URBAN WATER SECURITY: CLIMATE CHANGE ADAPTATION STRATEGIES IN CHENNAI, INDIA

By

SHARANYA SETHURAM

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ABSTRACT

Chennai, a typically large city in south India, with a growing population faces climate change related serious threats to the already growing water scarcity. The aims of this study were: to describe climatic variations, to analyze the supply- and demand-side policies and adaptation strategies and to provide recommendations based on this analysis.

Mixed- method and accidental sampling method were used for data collection. The data show that, even with 700mm and 1100mm of annual rainfall, Chennai still has water shortages. The water demand is 900 ml/d for the urban domestic sector (households), while there is only 700 to 730 ml/d supplied. The survey results implied that an increase in water use efficiency is much needed. Although, Chennai has 100% pipe connections, water supply is intermittent. Eighty-seven percent (87%) of respondents reported concerns about sporadic supply, low quality and poor service. Respondents notified that purchase water for drinking and cooking adds to their household expense and is on average 2% of their salary. The water price is 6 to 10 paisa per litre (for usage over 10KL), at an incremental rate. This raises major concerns regarding the fair pricing of water, as 82l/d is the per capita use.

The study concludes that Chennai has a potential water crisis due to climatic extremes and persistent insecurities. Respondent households have reported quality and service-related issues. Demand management through conservation efficiency needs to be enhanced. There is need to enhance control of project management, with planning and implementations, as there are many project failures on record. The policies and programs need strengthening in order to manage supply.

The adaptation programs recommended for Chennai are the 3 R’s (reduce, reuse and recycle), training and workshops, inventory of resources, and surveys of actual use (households). The major policies include efforts to rework and renovate water tanks, ponds and traditional tanks, and improve quality through monitoring stations and simple measures for implementation of Rainwater harvesting (RWH), or Artificial Recharge (AR). In addition, the strategy of using closed conduits to convey water to households, the rehabilitation of traditional tanks, and selective supply hours on several days of the month will improve conservation and improve water security in Chennai.

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APF	Adaptation Policy Framework
CCU	Climate Change Unit
CDM	Clean Development Mechanism
CMA	Chennai Metropolitan Area
CMP	Chennai Master Plan
Cu ft	Cubic Foot
cm	Centimeters
EPA	Environmental Protection Agency
Ft	Feet
GDP	Gross Domestic Product
GEF	Global Environment Facility
GWP	Global Water Partnership
HH	Households
IWS	Institute for Water Studies
IMD	Indian Meteorological Department
IWP	India Water Portal
MLD	million litres per day
MDGs	Millennium Development Goals
Mm	Millimeters
IWRM	Integrated Water Resources Management
MNRP	Ministry of Natural Resources Planning and Development
MWR	Ministry of Water Resources
NAPA	National Adaptation Plan of Action
NCAP	Netherlands Climate Assistance Program
NGOs	Non-governmental Organizations
NWRA	National Water Resource Authority
NWSA	National Water and Sanitation Authority
TN	Tamil Nadu
TRWH	Tamil Nadu Rainwater Harvesting Department
TWAD	Tamil Nadu Water and Drainage Board
UN	United Nations
UNDP	United Nations Development Program

UNEP	United Nation Environmental Program
UNFCCC	United Nations Framework Convention on Climate Change
V&A	Vulnerability and Adaptation
WB	World Bank
WEAP	Water Evaluation and Planning software
WEC	Water and Environment Centre
WHO	World Health Organization

1. INTRODUCTION

1.1. Water: An Invaluable Source

The shortage of clean water is a threat to global water security and a cause for concern in many urban cities. Urban regions are likely to suffer shortage due to their geographical locations, growing population and conflicting water demands. Unmet expectations, poor policy management, increasing demands, migration and overexploitation are the major cause of water security concerns in urban communities (European Commission, 2013). To compound the effects, climate change related water crises impact the society, environment and economy. The impacts of climate change on water resources are more profoundly felt due to the vitality of these resources for human survival. Extreme climatic change renders water security concerns more complex and necessitates immediate actions to manage resources.

Actions required for urban cities need to focus upon resource scarcity and socioeconomic concerns along with steps to proactively manage and sustain water resources. Improved water management techniques and planning are required, now and in the future (European Commission, 2013). The Global Water Partnership (GWP), a major think tank for environmental issues, adaptation, mitigation and management, indicates the impacts of climate change. The focus of think tanks such as the UN, GWP, and IWA in drought prone regions is on mitigation. However, most urban regions must actively plan mitigation as well as adaptation simultaneously.

Ironically, while water resources are abundant, freshwater resources are inadequate to meet the demands of the 7.2 billion people on the earth. While seawater is abundantly available its saline content makes it impossible to use for drinking purposes, unless desalinated. Only about 2.5 percent of the 1.4 billion cu km of water available on the earth is fresh (2.5 % of the total available water resources) and fit for consumption.

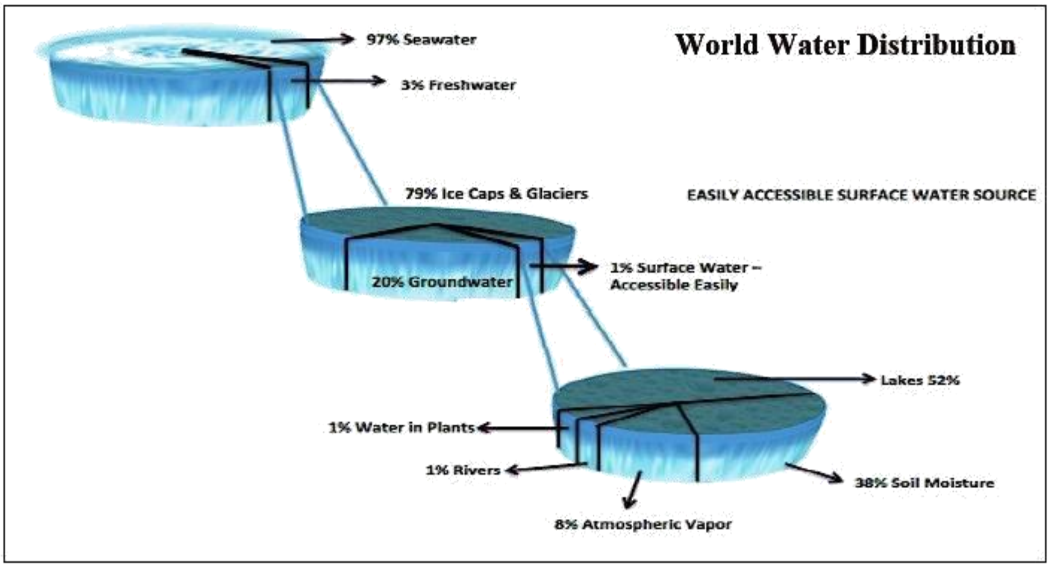

Figure 1 World Water Distribution

Source: Compiled from Literature (and Figures 1 and 2 Appendix)

Figure 1 shows the bigger picture of the total water content of the globe, the total freshwater content, and the percent of accessible freshwater. Surface water sources make up 0.4%, groundwater sources make up about 25.6%, and ice caps/ glaciers make up 74% of the total available freshwater content of 2.5%.

The total amount of water measured in 2003 was about 1.4 billion cu km, while the total content of renewable water is about 41,000 cu km every year (Kumar, 2003; Rola, 2004; Johnson, 2006; GWP, 2008; (Intergovernmental Panel on Climate Change (IPCC) 2008); GWP, 2009; Gleick, 2010) (See Appendix I for Charts). The global populace check indicates that the current population is 7.24 billion and increasing daily. This implies an increase in water demand. Water scarcity is often the consequence of increased population, over extraction, waste and high consumption.

Water Crisis: The water crisis can be looked at as water stress or shortage due to climate change, pollution, governance or population growth (Iglesias, 2010). The water crisis is also defined as a situation in which security of supply is compromised due to shortage, drought or flood events etc. (Mileham, 2010). The water resource crisis is then related to availability, affordability, allocation, and access. These factors are influenced by droughts, floods and supply- demand policies (IWA & WWC, 2012).

Furthermore, scarcity also indicates a gap in the supply and demand of water (World Water Council, 2005). Das (2007) concurs that stress and shortage can be measured by an increased dependence on alternative water sources of supply or through interstate water imports. Water stress indicators, as per the United Nations Assessment, are denoted as the ratio of withdrawal to the availability (World Water Council, 2006). Most countries have similar water stress levels, and the WWC signposts that a country with 40% use or withdrawal will be water stressed (World Water Council, 2005). The author however did not indicate if 40% use is cumulative or annual. Cumulative or otherwise, 40% remains a large amount that can potentially cause insecurity.

Despite technological and funding enhancements, the strategies to improve supply have not successfully helped in creating security. European countries, for example, with all their technologies and policy enhancements are still vulnerable and require new strategies to adapt to climate change (IWA and WWC, 2012). Successful adaptation methods require both supply enhancements and demand related conservation practices. A good example is droughts in Spain; the region needed further changes in use efficiency and conservation management, with household contributions to effect positive alterations. This reflected conservation during drought seasons [Mileham, 2010, Iglesias, 2010].

Another vulnerable region requiring proper adaptation strategies is California. California has several enhancements and many desalination and hydro projects in place. However, there is still discontent with regards to water. Droughts impact California in a major way. There are several policies (car wash, lawn watering and expending water for luxury purposes) that reflect water stress during drought seasons (EPA, 2012).

Similarly, China and India have also faced droughts and floods, respectively. Policy schemes for droughts and floods require vulnerability and adaptation action (V & A) (Mariappan, 2013; Mildhem, 2010; Nathan, 1998; Liu.L, 2007). Thus, these examples appropriately illustrate that the impact of climate change is felt everywhere, with no region being fully secure despite policy enhancements or technologies. The impact of reduced water availability is felt through stress and shortage that subtly alters the environment, social lifestyle, economical condition, entrenched poverty and ecological balance. Variations in climate can cause droughts and floods that in turn cause stress and scarcity or pollute water to reduce quality.

Over-extraction of water resources, especially, ground source creates water stress, and eventually the situation will demand more supply, with need for alternative source options. As ground and surface water resources are easily accessible either through wells and pumps or directly, contamination and consumption of unmetered amounts is convenient (Intergovernmental Panel on Climate Change (IPCC) 2008). This would mean scarcity and stress related demand would push over-extraction and the effects would be compounded by climate change. Thus, with the available sources, it is necessary to increase water security and to adapt to climate change extremes.

1.2. Water Security and Climate Change

The water supply system in any location is intricately linked to the water cycle, which is the balance of precipitation, temperatures and evaporation level (Iglesias, 2010). Iglesias, (2010) indicates that a water crisis arises due to major water insecurities. Water security is the availability, accessibility, affordability and allocation of enough good and clean water for people. Climate change causes acute imbalances in water resources both on land and at sea.

The temperatures on land and sea maintain the delicate balance of precipitation and evaporation of water. Often, stress and scarcity are by-products of floods and droughts. Property, environment and human lives are lost due to extreme flood events. According to the EPA (2012) warmer temperatures increase evaporation rates while drying certain parts and effecting increases in precipitation in other regions. This is also indicated in the report by IPCC (2008).

The global increase in temperature (this decade) is 0.5 degrees higher than the average warming between the years 1960 and 1990. The EPA (2012) marks a rapid increase in temperatures up until the year 2000, as established by the four major climate-change-monitoring institutions. The temperature records are based on the average spatial differences among stations. Temperature changes can impact rainfall and sea temperatures, effecting increase in droughts or floods.

Temperature rise also denotes an increase in surface or soil water evaporation (i.e. reducing surface resources). This increases demand for water to support population. Hence, temperature and precipitation changes increase rainwater during storms or cyclones. The evaporation may increase, but it does not denote surge in rains equally over all regions. Thus, this demonstrates that the water cycle is distorted and uneven to a certain extent (IPCC, 1997) (Intergovernmental Panel on Climate Change (IPCC), 2008). This is called climate related water crisis.

1.2.1. Understanding Climate Change and Adaptation

Change in climate is constant, and the intensity of impacts is measured depending upon the physical- geography and the topography of the region. The reason that climate needs to be studied is to identify alternations in the natural system and the alterations in the chemical compositions of atmosphere due to Greenhouse Gases (GHG). The influence of GHG, chemical factors etc., create uncertainties that show amplified effects on climate. These concepts led to the discovery of global warming.

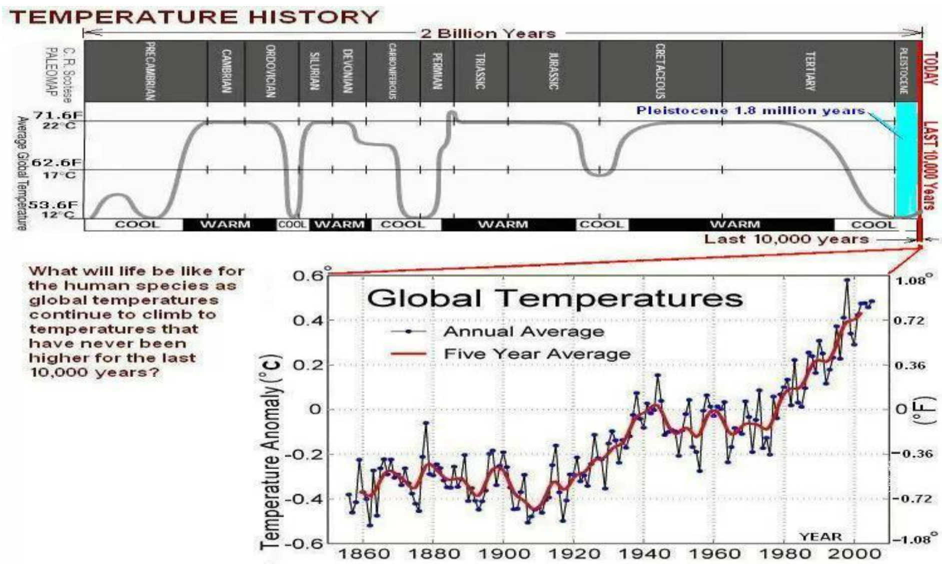

Figure 2 Global Temperature

Source: http://one-simple-idea.com/Environment1.htm

Figure 2 indicates the global temperatures for 2 billion years and up until 2000. The increase in temperature is not constant during Triassic or Jurassic periods and the highest is in the current period (the last 10,000 years). If there is further climb in temperatures there will be changes in the environment, especially the water resources. Hence, temperature change can play a large role in warming and reduction of water resources due to increased evaporation. Increase in evaporation does not denote equally distributed rains; it can rain in regions adjacent or the winds can carry it further away.

The temperature increase dictates an increase in the rate of evaporation, varying over time and physiography. The IPCC also predicts an increase in future temperatures of less than 3 degrees Celsius when compared to the 1990 levels, thereby increasing rains and runoffs. The runoffs increase due to precipitation and the infiltration decreases with the duration, intensity and frequency of rainfall (IPCC, 1997). The combination of rainfall and the evapotranspiration, i.e. the sum of evaporation and plant transpiration from surface, defines the level of water availability in the ground.

1.2.2. Defining Floods and Droughts

Droughts[1] are defined as the absence of precipitation over a period (IPCC, 2007). For example, Yemen has rainfall below 100 mm per year and NW Rajasthan rainfall is below 50 mm. But many regions also face droughts due to overuse, uneven distribution and excessive demand increase, while having a good level of rainfall and reasonable temperatures (IPCC, 2007). Onsets of droughts are often very slow and, it is hard to understand the cycle.

Droughts are otherwise called scarcity of water supply. It is a complex physical and social spread of water shortage. Drought has no perfect definition, it can be defined as a shortage of water due to various factors affecting the supply system, i.e., atmospheric, meteorological, social etc. It is a differential phenomenon often affecting areas of one state differently. They do occur with prior warnings or signs, as it is slow but intensifies with time, unlike floods. Drought is often a product of mass events within the environment, without a defined start or an end.

Floods are defined as the overflow of local water bodies or increased water flow on a large scale during heavy rains, usually damaging the locality and the environment in the process. A good example is the NE Kolkata floods that happen due to overflowing river tributaries. Different reactions to climate change all amount to a crisis and impact water security (Treut & Somerville, 2007). Likewise, several regions of South East Asia and South Asia have experienced dreadful floods.

[1] (See Appendix I for types of droughts and floods).

1.2.3. Impacts of Extreme Climate

South Asia is endowed with vast amounts of water resources, but due to the changes in spatial and temporal factors this is gradually dwindling. In South Asia, about 60% of the land area is used for agriculture and over 50% of these areas are irrigated; water resources are drawn in high amounts (Anand, 2007). At present, there are countries in South Asian that face water scarcities (with 200mm of rain), amplifying water insecurity. This signifies future water shortages at an acute level. Hence, climate change can produce a cascade of problems at multiple segments of the environment, society or economy of a country (Anand, 2007).

The impacts in some regions are harmful and others beneficial. According to the UNICEF report the temporal variability is high and this is well debated, discussed and proven by the GWP, IPCC and UN. For example, Assam in India receives 450 inches of annual rainfall, if all the rains were divided equally then there would be well over 5000 m3 of water available sources to meet demands per capita (UN, 2009). However, the spread of precipitation is differential and spatial, often uneven.

Sea level rise is often the case where water flooding and heavy rainfall occurs. The increased mean sea level by about 1.75mm each year between the years 1950 and 2000 induces the retreat of glaciers, reduction of water flows during dry seasons, decreases in rainfall, and increases in oceanic temperatures (NASA, 2000). Trapped solar energy drives the hydrological cycle; hence, it intensifies the cycle, the rainfall and the extreme events. Sea level rise is widely discussed, and is a concern for many coastal cities and islands such as San Francisco, Manila, Chennai, Pondicherry, Taiwan, Islands of Indonesia etc.

A range of published evidence indicates that the damage caused by droughts and floods is likely to take a negative turn over time, and being prepared is imperative for sustaining resources and human survival (BBC Network Report, 2011/ 2010; Asian Development Bank, 2003; Balgis, 2010; IPCC, 1997).

Table 1 Impacts of Climate Change Worldwide

North America	Reduced snow in the West
	Increased frequency and intensity of heat waves in cities
	Reduced yield of rain fed crops - only up to 20% yield
Latin America	Replacement of tropical forest by Savannah in Eastern Amazonia
	Significant biodiversity loss through extinction
	Changes in water availability for utilization - low availability
Europe	Frequent flooding of inland and coastal regions - Increase in flash floods
	Sea level rise
	Glacial melts in mountainous regions
	Reduced snow cover
	Loss of biodiversity
Africa	Water stress will impact 75 to 250 million by 2020
	Reduced yield of rain fed crops/ agricultural produce by up to 50%
	Overall reduction of agricultural production and access to food
Asia	Major reduction in freshwater availability - projected to decline all over Asia by 2050
	Increased coastal flooding - during monsoons and storms
	Increased death and disease - related to droughts and floods
	Increase in drying / droughts - increase in drying index percent

Source: Compiled from IPCC, 2009

Table 1 indicates that Africa and Asia are the Regions most likely affected by droughts. Researches indicate that there may be 50 million refugees by 2020, hit and affected by severe droughts in South Africa (IPCC, 2009). On the other hand, socio economic droughts are on the rise in both regions, adding to the pre-existent stress.

On the other hand, floods are predicted to worsen. For example, Bangladesh may experience 5 % increase in floods by the next decade. Table 1 indicates that Asia and Africa may experience increase in coastal flooding during cyclones, storms or monsoons.

Droughts, floods, and sea level rise are the major outcomes relevant to this study. These are major outcomes of extreme climate that most often result in loss of property, death, insecurity and environmental degradation. The only means to combat this is adaptation and mitigation. Adaptation is the key to being prepared for climatic extremes.

1.2.4. Overview of Adaptation

Adaptation planning have been achieved in water system planning and management, and yet there are many cases where water management for flood and drought, protection of drinking water and sanitation are inadequate to meet demand (IWA & WWC, 2012). According to the World Water Congress the only solution to water management is quick and proactive action that can secure sources and sustain them. To secure sources, policy interventions must handle pollution, increased population, climate change and misgoverned systems (IWA & WWC, 2012). A good approach to manage resources will enable security and efficiently administer policy responses to future climatic extremes.

According to the EPA, (2012) each region must have a strategic plan in order to implement mitigation and adaptation programs. A variety of adaptation strategies were used to control water stress and manage water in Europe, the US and other regions of the globe. Demand, through conservation, management, and utility, and service management are the major strategies used by several researchers as examples of successful adaptation strategies. The corresponding list of researches include: Amell, (2004); Bakker & Allen, (2012); Balgis, (2010); Iglesias, (2010); Cook C. B., (2012); EPA- SDWA, (2012); European Commission, (2013); GWP, (2008); Government of South Africa, (2013). These studies signify that the demand management requires efficient supply for regions without supply source. The technology has improved the level of supply, alternate source and quality of water.

The major approach in recent implementations across US, EU, Asia etc., that is gaining force is the IWRM approach. While there is no specific definition for IWRM, the approach is self-explanatory, as it integrates the policy interventions for security, governance and inter-sectoral benefits to mainly improve supply and demand (IWA & WWC, 2012). Water management in Asia is political and sensitive and requires institution specific outreach. Communication, knowledge spread, and specific media are important and relevant at various spatial scales of the policy process.

Current GWP research indicates that multiple sectors and multilateral approaches are integrated for attaining success in development and implementation of policies for the water environment (GWP, 2011), (IWA & WWC, 2012). The major problems affecting Asia are water shortages, inefficient use, inadequate quality and sanitation, waterlogging, saline intrusions, lack of use- efficiency, inadequate maintenance, lack of zoning, lack of training and pollution through waste, chemicals etc., (Iglesias, 2010). Hence, in order to manage water during and after floods or droughts and improve water security, adaptation and mitigation are vital.

Policy Adaptation: Given these problems, water policy changes are essential for management and enforcements, they act like a buffer system, maintaining a balance and managing resources while aiming to cause positive changes towards security. A policy implemented will have varied responses according to the level of enforcement or the level of commitment to find solutions. The solutions must include societal participation and adaptation of policy.

Adaptation is a slow process. The strength of the policy depends on enforcements and local acceptability, and level of adaptation. The government can enforce policy but in a democratic country, with corruption it becomes harder to understand if policy acceptance will be successful. In a country like India, the water use policy has drawn more attention, but the policies are weakened due to low positive response (Lakshmi & Ramalingam, 2012) (Srinivasan V., 2008). The society's response is crucial for a policy decision towards a goal for it to achieve success. Hence, social acceptance, awareness and education are elements that are vital for the study of community response. For example, in California when there is drought, watering lawns is prohibited unless they have sprinkler systems in place, and the timings for use are also specified (EPA, 2012) (CA. Gov, 2008). The "polluter pays" policy makes for an effective reinforcement, in this case. Not everyone adopted the policy instantly, but it is re-enforced several times with fines, so that most communities have sprinkler systems installed in California. Hence, re-enforcement of policy will enable policy success. Every policy change affects positive changes within the community and the environment depending on how well it is accepted and re-enforced by the administrative bodies.

Mainstreaming adaptation incorporates calculated adaptation planning, institutional change, investment in data collection, newer technologies and modifications of present infrastructures, and more consideration to disaster preparedness and hazard management.

Water Management: There are three sides to water management, water administration and utility management, and supply and demand side management.

Certain administrative programs for adaptation include upgrading customer advisories (for the user), improving utility measures, reducing water loss, surveying and provisioning effectual informatics, practical approach and goal setting for future management, enhancing education and creating awareness, improving local participation and managing grievances and feedback (GWP, 2011). Ground water extraction, pricing, fines within the regulatory system, staff regulations, and code of conduct for the public and administrative boards make up the major policies within the administrative system for utility management.

The supply side policies, programs, and projects incorporate enhancement and renovation of supply infrastructures, maintenance of quality and amendment of policies to include strategies i.e., allocation, zoning, source maintenance, quality control etc. Major distribution related adaptation strategies are to inspect and renovate pipelines, maintain valves and sumps, improve service for setup of RWH and AR equipment, renovate supply infrastructures (including dams and canals), install and maintain transfer conduits and increase supply through desalination plants.

The demand side includes all the policies, programs, and projects to improve the demand related technologies and policies, i.e., conservation, pricing, pipelines and metering etc. (SOPAC, 2013).

The water resource management is like any other management system; it is often flawed and failing. A few of the above-mentioned studies indicate that water management systems in the respective countries require change and re-enforcement. Likewise, India, China and South Africa are amid introducing new technologies, administrative measures and conservation techniques in order to improve their adaptability. Administrators use strategies to create and implement policies to manage water to create security and adapt to stress factors.

Although, there is need to meet the requirements of demand on the water table, it is equally essential to consider the overall aspect, people, environment, economic conditions and climate. Consideration given to the impacts of climate on water security and on the environmental sustainability is vital while planning for adaptation (GWP, 2011), (UN-Water, 2006). Thus, the overall supply-demand management establish foundation for adaptation societal response. It depends on the strength of supply demand policies and how they are enforced. Hence, supply-demand management does have a great impact on adaptation policy success.

1.3. Water Supply and Demand System and Management

Supply System and Management: Water supply network is a system of planned hydrologic and hydraulic components providing supply to users. Water supply network consists of raw water, purification, pressurizing elements, storage, distribution networks, sewer mains, drainage system and other infrastructures (UNEP, 2012). Water abstraction and raw water transportation is done from surface sources or ground water sources. The water is transferred from lakes to storage facilities (reservoirs, dams, water towers, tanks, pressure vessels, residential water storage) and then purified to remove pollutants.

The WHO or EPA standards are the main measure against which water is treated and measured. Usual components of water treatment consist of physical, bacteriological and inorganic material i.e., clarification, percolation, disinfection/ cleansing of organic matter. Water treatment is maintenance of a level of quality good for human consumption. Pressure system is used to transfer water up a pump for treatment or distribution.

Most distribution systems are zoned for management purposes. The major factors determining the zones are hydraulics, water purification and measurement of quality upstream, population density and historical divisions. Pipe networks distribute water to houses, commercial establishments and institutions. Most Asian communities now operate a stand–alone distribution system (UNEP, 2012). Policies, programs and projects are used to manage and maintain the supply system, including abstraction, treatment, and distribution networks.

Quality Management: Quality management is vital to prevent disease and chemical poisoning in humans. The WHO is an agency of the UN that works to provide medical assistance and improve environmental heath (specifically relevant to this research: quality of water resources) (UNEP, 2012). The main function in water quality management is the setting of standards, which will be made by the government. The quality standards of an abstracted source are with respect to local needs, international standards and the potential use (Further details are provided in Literature Review - Chapter 3).

Distribution Management: The United Nations Report on Integrated Approach for Water Resource Management (2012) indicates that efficient distribution management includes quality, distribution and usage management. Monitoring solutions to manage water quality is through monitoring turbidity, pH, electrical conductance, dissolved O_2 and other measures (UNEP, 2012). Quality monitoring requires evaluation of properties and infrastructures such as dams, rivers, lakes etc. Metering, chemical and bacteriological quality monitoring, GIS and remote sensing are major devices used. Monitoring distribution system includes flow, pressure, leakage detection, and water levels. Usage monitoring includes meter reading, control of gardens and pressure. Household and residential complexes have individual meters, quality testing, and control of valves and pipelines.

Major aspects of supply, quality and distribution management relevant to this research, are pipelines, metering and pressure gauge assessments, quality testing (physical, chemical and bacteriological), use monitoring, and evaluation of distribution networks.

Demand System and Management: Demand management is management of total abstracted water from source using measures to reduce waste and improve efficient use. Elements of demand management include tariffs, retrofitting, awareness and education, consumption and extraction, reuse, local and national policy change, infrastructures, conservation and pricing, technologies, and customer advisory.

Consumption and Extraction: The UN-Water, (2006) projects lower availability of renewable sources for urban populations around the world. Demand for water is an important factor that is influenced by the increased population growth.

Population growth is the major source of concern, as it brings about increase in water withdrawal and consumption. The global water demand differs for each region and by sectoral usage, scale of usage and population (Norman et. al., 2010). The current global population stands at 7,101,636,805 and the total amount of water consumed this year is 836,680 billion litres as on March 3rd, 2013 (Worldometer, 2013). The world population increased to 2.8 billion in 1955, then to 5.3 in 1990, today it is at 7.1 billion and the future projection is set to be about 9.1 billion (Kumar, 2003, Worldometer, 2013). The global population growth is 80 million per year. The level of water consumption varies every year due to changes in lifestyle, production of biofuel, energy demands, increasing population demand, sanitary and health requirements. The demand for water, according to Worldometer (2013) is estimated to be about 64 billion cu meters every year

(1 cu m = 1,000l). This increase in water demand is attributed to the increasing population across the globe, especially in urban centres of the world (Norman et. al., 2010). Thus, an increase in population and lifestyle change equals the increase in demand. Water consumption is influenced by water availability, which in turn depends on climate change.

Demand is measured by the total consumption. Both extraction and consumption are not the same, extraction is the total water abstracted from source and consumption is the actual use. The actual use does not include water losses or evaporation. For example: India, MENA, Middle East, South America, Mexico etc., all have less than 1000 cu.m (m3) per person per year (pp. p.yr), which means that the average each person can consume 1000 cu m (m3) per year, while withdrawals are much more than 1000 cu m per year per person.

Relevant to this research, India has net groundwater level of about 396 b cm and development is about 61%. India uses less than 500 cu m (pp. p. yr.) while abstracting more than 600 to 700 cu m (UN Water, 2006). This goes to show that the actual use is not equal to actual withdrawal, either the extracted water is in storage or contaminated or lost during transport. Within household's withdrawal is in excess. The exact amount consumed by households is always a little more than they require. There is also a certain percentage of wastage during water extraction. A certain percentage of the wastewater returns to the source or soil through natural or manmade mechanisms such as pipes and drains. The extra water is not always wasted, households store water for the rest of the week.

1.3.1. Rainwater Harvesting

The rainwater harvesting (RWH) technique is an old form of water harvesting and storing for immediate requirements of a household. The Figure 3 indicates how a rainwater harvesting installation is done for a single unit. The same can be modified for more than one unit of houses in a row or as an apartment block.

Figure 3 Simple Rainwater Harvesting Structures

Source: http://www.medindia.net/news/Interviews/Rain-Water-Harvesting-35311-1.htm

This is the simplest form of RWH used in many Asian countries at present, as shown in Figure 3. RWH allows conservation, storage of water while reducing water runoffs into the sea. Most Asian countries have a problem of extensive run off while the population is thirsty for water resources. RWH effectively provides a solution for this problem. Rainwater is the vital supply of water and, hence harvesting rainwater is a very effective supply-demand strategy.

1.3.2. Desalination Technology

Desalination is becoming one of *the* major options to resolving water scarcity in coastal cities with severe water stress. Desalination is the process of extracting potable water from existing seawater or from brackish water (James, 1974). There are currently 13869 desalination plants around the globe (UN 2009). Of those, about 59% are run on ‘Reverse Osmosis’ (RO) process, which is said to provide about 9790 MG/D of water. Other technologies used include MSF, MED, ED, and other (Hybrids), which respectively supply 27%, 9%, 4% and 1% of global water (Krishna, 1989). It is now the most efficient and effective method of providing water to cities that lack resources or cannot rely on the existent ones.

Urban cities require an alternate source due to increased dependence on ground water and imported sources. Cities that have experienced aquifer drops between 10 to 50 meters include Mexico City, Bangkok, Manila, Beijing, Shanghai and Chennai (UN, 2009). This indicates that alternate sources are necessary for urban cities to quench their thirst. The major drawback in implementing desalination is cost; for example, a 485 million-litre plant and equipment will cost between USD 1.5 and 1.8 billion. However, overlooking costs, a 100mld plant can provide minimal amounts of water to over 1 million households. Thus, desalination is a possible infrastructural improvement to the supply-demand management strategies.

1.3.3. Conservation: Pricing and practices

Water suppliers have many options for pricing supply allocation. Consumption can be metered or unmetered; especially in Asia unmetered, non-revenue water consumption is high. Most suppliers use a flat rate, often monthly, for piped water supply. Generally, flat rates are zero marginal pricing. This happens when monthly charges for consumption are not linked to actual consumption; households can use resources until their own fringe benefits of consumption become zero. However flat rates do not provide incentives for conservation. Subsidizing prices for water also do not help in water saving. Water savings improve with metered consumption. Regions like Washington D.C. have reported saving with metered billing. If use is metered, suppliers can charge differently based on revenue and water saving options. Under constant pricing all levels of consumption are charged the same unit price.

Sophisticated pricing structures include seasonal and block pricing. Increasing block pricing usually is related to the quantity consumed. When higher quantities are consumed the marginal price increases, and this results in lower consumption (and more water conservation). Decreasing block pricing (opposite of increasing block pricing) does not generate a positive trade-off but is used for industrial bulk supply. Decreasing block pricing usually has negative consequences in the long run as use will drive prices lower while increasing water use. The economic cost of block pricing can be severe. Seasonal pricing is used as an economic instrument to generate revenue and improve savings. In the summer months water demand peaks and hence prices are higher, and in the winter months the demand is at the lowest and so are the prices. The opportunity cost of water consumption is higher. With metering the prices produce effective saving and efficiently collect revenue for actual consumption based on demand.

Price structures also affect a household's ability to gain access to water. If prices are high, chances are that people under the poverty line do not get access to clean water. The UN and FAO, (2007) indicated that "one in three people face water shortage". To conserve water and improve water saving, GWP (2009) research indicates that water security can be achieved through provision of water at an affordable cost. Households at every economic level need to be able to access water and pricing structures can assist in that. Most Asian countries do not charge an incremental rate per consumption, they subsidize costs and charge an incremental rate only after a certain level of consumption is achieved. This pricing system makes water affordable (basic requirements about 15KL of water per household per every billing cycle as in Indian water pricing), but for aesthetics and luxury, the charge is higher.

1.3.4. Education and Policy Goal Setting

Setting national and state level goals for water security is an important feature that can be a guideline for water users, policy makers and other stakeholders.

The Millennium Development Goals address several water scarcity problems, and have set standards for achievement to increase accessibility, equitability, increase quality etc., which are yet to be achieved (UNICEF & WHO, 2000). The MDG's list and priority indicates that there are several levels of droughts, as some societies face more stress due to scarcity than do others.

In the report by UN (2007), the author suggests that education is a major issue that today's communities face. Many do not understand the seriousness of the need for conservation and the consequence of over abstraction. Likewise, they do not understand the impacts of climate change and the required actions from every household needed amplify the positive effects of adaptation strategies (IWA and WWC, 2012) (Olmos, 2001). Several studies by the SOPAC and the UN have stressed the fact that education will allow easier policy goal setting and smoother adaptation for a community (SOPAC, 2013) (UN - Water Final Report, n.d) (United Nations - Special Summit on Water, 2012).

The UN (2007) describes several levels of scarcity that are absolute, life threatening, seasonal, on- going, cyclical and temporary. The causal effect that these have on the society and environment is very apparent and can be addressed by carefully planning adaptation. Organizations such as WHO, UN or GWP have come up with adaptation strategies while conventions such as RIO or Rio + 20, or the Copenhagen conventions, have also contributed by creating a focus path by setting specific goals for various countries to follow. This has helped countries work towards a goal without deviations, but the outcome is related to the like-mindedness of political and policy leaders in acting towards these goals. Governance is therefore an equally important aspect in driving climate change adaptation efficiently.

1.4. Urban Water Governance and Leadership

Urban water governance in Asian cities such as Manila, Yangon, Colombo, or Chennai, is becoming tougher due to increasing insecurity of supply. Governance is the process and the institutions through which decisions are made (Heiland, 2009). These processes include the range of political, organizational and administrative functions used to implement decisions, and the fact that decision makers are held accountable. The elements of water governance approach for example in the Fiji Islands is based on a building block concept, which includes consultation, policy, legislation, awareness, planning, expertise, information, organization, and responsibility. As governance is complex and customized for various regions, each of the elements requires proper understanding to make good decisions based on the political and institutional footing of policy options, for these to benefit the economy, environment and society.

Altering policies and managing the structure of an organization is time consuming and dependent on political power and leadership, opportunities and in this case capacity to govern water. The capacity to govern reflects the level of competence within the society and the ability to implement effective water policies, laws, institutions, regulations and compliance. Without good and clear policy, it is difficult to develop coherent rules and regulations. Without a clear legal structure, it is difficult to operate institutions on compliance and enforcement.

Good governance provides effective water management strategies. Governance does not have a set pattern of a guidebook to follow, it is about achieving a balance within the system with both strengths and weaknesses are looked at and reformed, where necessary (Heiland, 2009).

The scope of governance includes the five elements of policy, legislation, coordination, organization and information (Heiland, 2009). These key elements identify developments in other elements such as planning, expertise, awareness and responsibility. A coordination committee reviews and advises the government on managing water resources and policy to improve or develop new water policies in most cases (IWA and WWC, 2012). The water policies include the ownership and water rights, which will improve management and organization efficiency. Clearly defined ownership allows pricing, distribution, information sharing and training, in an efficient manner. The organization indicates the structure of management and the role of government in managing and allocating resources (Heiland, 2009). To manage and allocate resources, supply, demand and quality management are very important as they incorporate the majority of the water insecurities.

1.5. Threats to Water Management

Political power play, leadership and conflicts affect human lives through influences they have on water decisions. This impacts the strength of adaptation. It is vital for developing countries to understand the political threats to water security and adaptation. This makes it easy for policy decision makers to overcome and work on fitting policies within a region.

Political Influence and Conflicts: There are political influences and conflicts that impact policy adaptation. The water stress areas on earth have widened and the localities facing stress also feel the need to compete for water access and inevitably face conflict. Conflicts over water resources can have effects on the hydrosphere, economy, and political and social sectors. Population growth has come close to exploding and has outstripped capacity to hold and mange resources. The environmental needs and the economic needs are at odds due to the needs for economic growth, especially in the political power spheres. This suggests an inequality between the poor and rich people and the knowledgeable and the illiterate consumers. To initiate good management strategy for water stress, UN investigated the efficient management of resources, timely and appropriate decisions by policymakers and participation of local individuals, created programs to manage watersheds to preserve and conserve for the future generations (UN, 2012).

Syria/ Jordan /Israel have conflict over the Jordan River and Egypt/ Sudan/ Ethiopia have conflict over River Nile (Postel, 1992). Water politics coupled with climate change makes it hard to plan for water needs and security. Water scheduling and rationing affects human lives and needs, it would be surprising if this did not lead to conflict. Politics is an essential part of policy making in many countries and focusing on water alone is not productive in policy decisions, leadership plays an important role in governance of water and every decision/ implementation made (Warner and Wegerich, 2009). Managing water includes all actors and representatives in an active rally for cause.

Table 2 Water and Political Problems Conceptualized

Facts & Values on Water	**Agreement over values**	**Disagreement over values**
Agreement over facts	Tamed problem securitization	Political problem politicization
Disagreement over facts	Technical problem Manageralization	Intractable problem; Debates and security dialogues; Joint learning with stakeholders

Source: Compiled from Warner and Wegerich, 2010

The author identifies three threats to water: the lack of water, excess water and water pollution. These threats place water security in the realm of politics and water risk. However, Warner and Wegerich (2009) identify that water by itself or the risk of scarcity itself is not political or politicized but the need to assert identities and preserve a certain ideology makes it political. The security with leadership concepts (from Table 2) indicates that water risks play on the social fears and highlights the underlying issues that supposedly play on bringing out more problems within the communities. Challengers indicate problems as values, while political entities are looking at it as management issues. Overall, the experts and managers are making decisions, which is the "hydrocracy" within the system. In the case where inhabitants conquer one area their view would be that they have a right to inhibit, while the people conquered are of two types: those who accept their fate and allow other leadership, and the others who believe that they have a right to participate in decisions and live the way they want to. Many political wars are of a similar kind.

A political power that allows or restricts people from gaining access is also part of policy decision and planning (Warner and Wegerich, 2009). The completeness of policy is achieved when participation is high, and the implementations are relevant and of use to the community.

The political structure influences decisions based on which all communities respond, i.e., the political structure followed by communities, the right kind of influence can positively impact decision. Hence, it is important that the political structure is not completely disrupted; otherwise the community will not have any structure to preserve itself. Political power cannot be disrupted but needs proper influence to enhance the decision making to cooperate and create effective policy responses, satisfying all entities, including leaders and society. For example, technology is utilized to solve droughts and floods around the world, connecting the hydrocracy and technocracy while policy planning makes the whole thing possible.

Societal pressure and political power plays are very important in policy decisions. This is one reason why for example, societies' imperative is to follow the political leaders' edicts. Decisions taken are invariably based on the pressures at any time to avoid reducing voter's support, such as environmental protests in China during December 2012 where China's leaders are increasingly willing to act based on public demands (Ide, 2012). The concept of satisfying the political structure has been consistent over the years from 1900's to the present, noted from the concepts it is also clear political power also bows to the public demand.

Public demand and environmental protests can be achieved when there is awareness and knowledge to act upon an issue. It is essential that the protesters need to know the solution, the methods to solve the issues. Political leaders on the other hand are responsible for the decisions as they need to sanction funds and parameters for an environmental project. Ultimately, if a dam is constructed, the political leader is responsible for it, not the policy maker, governing bodies or the environmental activists.

The major concerns highlighted so far in this chapter are water security, climate change, supply-demand management and adaptation. Concerns for Chennai are supply demand elements, threats to water security, water demand and consumption, leadership and political conflicts, inadequate participation levels among community. This indicates weak leadership effects bad decisions and, policy change and smooth adaptation requires planning, cooperation, coordination, local participation and planning.

1.6. Methods of Study

Context: This study focused on understanding the current supply-demand situation, policies and programs to evaluate if Chennai is currently water secure and climate ready. This will add value to the already existent research and provide policy makers with the unique views of the residents within water stressed regions for future policy implementation.

This research identifies climatic variations in Chennai (past and present), while examining the local supply and demand status to understand if Chennai can adapt smoothly and handle water crisis through implementation of new policies, enforcements of existing policies, management of supply and demand, satisfaction among people and good governance. The research encompasses investigation of stress, security and potential changes in population, climate, governance and quality of sources.

1.6.1. Research Problem

Is Chennai's water management climate ready? More specifically, are water policy, programs and projects able to promote water security in Chennai given the threats of climate change?

The following questions help answer the above research problem:

1. What are the climatic variations found in Chennai (within the last century)?

2. What are the major water supply and demand policies and adaptation strategies that aim to promote water security?

1.6.2. Objectives of the Study

Key objectives: The following are the list of objectives that are required to complete the study:

1) Identify and describe the climatic trends (for the last century, as decadal climate change indicates a general trend of droughts and floods) and identify any future projections.
2) Analyze the policy interventions and adaptation strategies within a supply- demand continuum to promote water security in the light of climatic variations.
3) Describe the level of water security and the overall readiness for climate change impacts.
4) Provide policy recommendation and adaptation strategies to promote water security given the threats of climate change.

1.6.3. Phases of the Study

This dissertation studies the water stress and security of Chennai in various phases. Phase one is to understand the climatic conditions and variations. Phase two is to examine water supply and demand levels and water policy interventions. Phase three is to survey and analyze with phase one and two to understand the regions' ability to adapt to climate change.

To complete these phases, an investigation of water systems and management, programs and projects, and IWRM tool is required. The research literature allows comprehensive understanding of supply and demand factors, water security, quality, quantity, people's participation, projects, policies and programs for supply and demand, management, different approaches to management and governance and the adaptation strategies that could be potentially used for urban water management.

1.6.4. Data Collection

This study uses interview and questionnaire style collection, with a mixed approach and stratified accidental sampling to obtain data. Data through surveys of households were collected first through stratifying accidental samples in an orderly manner to create a sample frame, and then sampling 10% to identify ideal locality based on response frequency, income levels and water issues. Then data was collected using the accidental sampling method to identify the actual sample households (100 per region). By factoring- in the local population and individual communities within the populated areas, one to two communities from five key regions were selected for the interviews of households in Chennai. The focus was on fast urbanizing regions of Chennai, where there is development and large masses of poor people. The information collected comprises of key-informant interviews, household surveys and open-ended interviews within local communities and the fishermen communities in the coastal sides.

Observation involved taking extensive notes during interviews and moving around town taking photographs of local water stress issues, rains, roads, pavements, water tanks, homes in the locality where interviews were conducted. The Minjur plant site, reservoirs and water issues of communities within Chennai were also observed and photographed. Secondary data included official documents collected during interviews with the analyst, management staff and desalination project head, other electronic journals and literatures relating to this study.

1.6.5. Research Significance

The current state of water supply-demand policies and management needs improvement. A potential drought can cause chaos in Chennai such as decreased demand satisfaction, reduced water quality and increased water-poor within the city. This research allows the potential threats to be recognized and the survey results aid in the analysis, encompassing all current policy interventions and suggest changes for the future.

This study will contribute to the growing knowledge and information network thereby enhancing policy studies. The significant approaches will also stem other new innovative studies on Chennai water resources. Similar to all developing nations, this research is fairly unique and socially innovative will add value to the current policy makers' reads in terms of household perspectives, local participation level assessments and major policy changes required to keep scarcity in check and mitigate climate change adaptation smoothly.

1.7. Area of Study: Chennai

Chennai is a region in Tamil Nadu. The State, Tamil Nadu, has 30 Revenue Districts with: 73 Revenue Divisions, 206 Taluks and 17371 Revenue Villages. There are 6 Municipal Corporations, 102 Municipalities, 611 town Panchayat's and 6486 habitations. The entire state has 39 Parliamentary Constituencies and 234 State Legislative Assembly Constituencies.

Chennai is both a district and a metropolitan city in the Southern Indian state of Tamil Nadu. Chennai metropolitan city is part of the Chennai district, which occupies about 40% of the city by land area. Chennai's sectoral division is shown in Table 7. Among the sectors listed here, sectors that are majorly water starved include some regions of North Chennai, and some regions of Southwest Chennai (based on pilot household interviews and surveys conducted in Chennai in January 2010). The metropolitan city of Chennai is itself part of a larger Chennai Metropolitan Area, which includes some urban areas and villages outside of the city. In addition to Chennai metropolitan city, the jurisdiction of the Chennai Metropolitan Water Supply and Sewage Board (CMWSSB) extends to urban outlying regions of about 164.6 sq. km, and rural regions covering about 142 sq. km. The urban outlying areas are called Adjacent Urban Areas (AUA), and the rural regions are called Distant Urban Areas (DUA) (CMWSSB n.d.).

Chennai is surrounded inland by Kanchipuram and Thiruvalluvar districts. Chennai's sectoral division is shown in Table 3 and Figure 4, indicating regions of North Chennai and some of South West, which are majorly water starved (pilot surveys conducted in Chennai in Jan 2010). Chennai is considered as the metropolitan area, which comprises of the city and its urban outlying regions of about 164.6 Sq. m and the rural regions covering about 142 Sq. m. The urban outlying areas are the Adjacent Urban Area (AUA) and the rural regions are the Distant Urban Area (DUA).

Table 3 Chennai Sectoral Division

North Chennai and Northwest
Ennore, Perambur, Purasavakkam, Ambattur, Aynavaram, Vadapalani, Thiruvottiyur, Tondoapet etc.
South Chennai and Southwest
Adayar, K. K. Nagar, Meenambakkam, Mylapore, Anna Nagar, Kilpauk, Porur, Tambaram, Saidapet, Tyagaraya Nagar, Thiruvanmyur Velachery, Kotturpuram etc.
Central Chennai and East
Egmore, George Town, Numgambakkam, Royapettah, Triplicane etc.

Source: Data collection, 2011

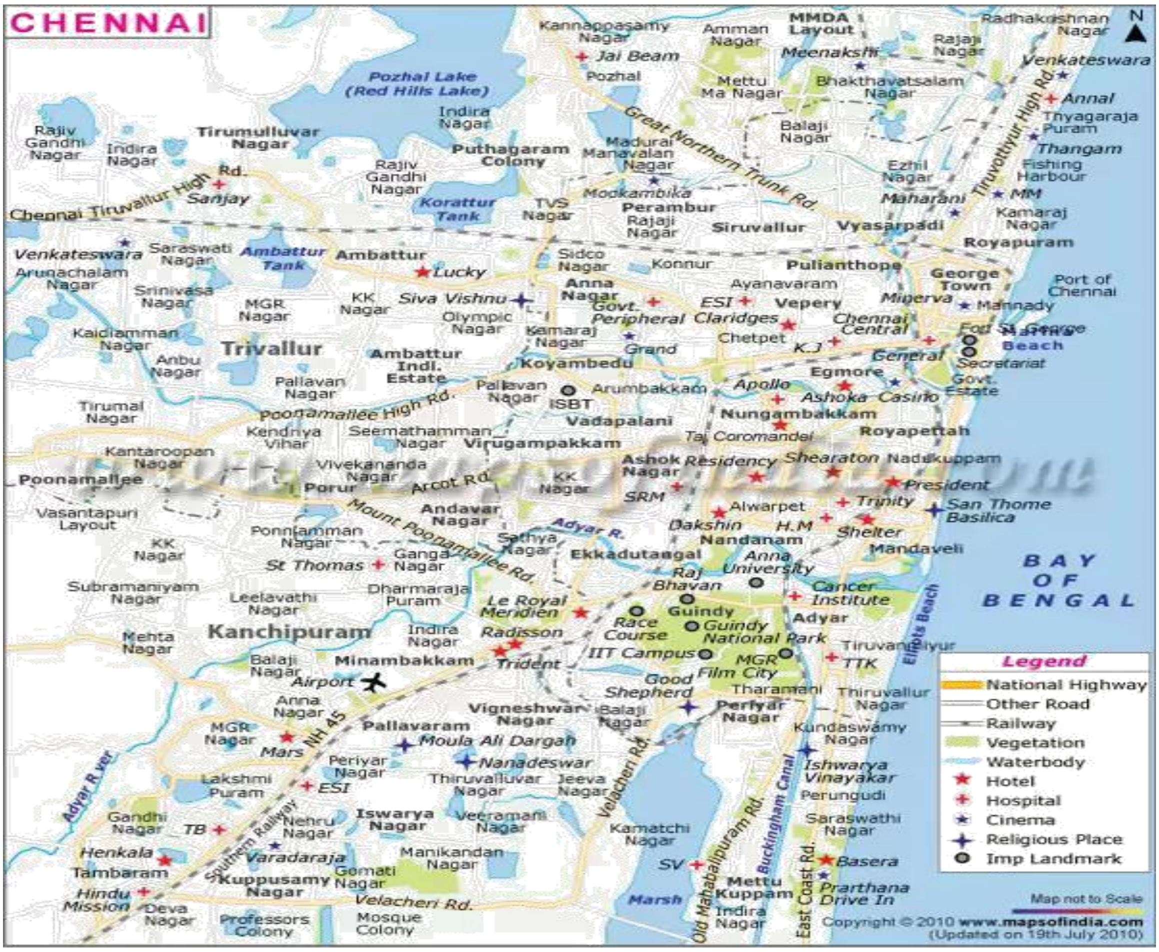

Figure 4 Chennai Metropolitan and City Map

Source: Maps of India 2011

The Chennai Metropolitan Area is the fourth most populous metropolitan area in India, after Mumbai, Kolkata and Delhi. 45% of the population is urban. The population growth of Chennai and adjacent regions is rapid. The population was about 7.5 million (in the Metropolitan Area; approximately 5.5 million in the city area) as of 2010. Chennai district is the 27th most populated of the 640 districts of India. The population density of the district is about 27,000 inhabitants per sq. km, and the growth was measured at about 7.8% over a decade (measured between 2001 and 2011) (TWAD 2010 – 2011). Other districts in Tamil Nadu state, like Madurai and Coimbatore, have populations only one fifth the size of Chennai's.

1.8. Organization of this Thesis

The thesis is arranged as follows: The focus of the current chapter (1) was on introducing the issues studied, the background and the basic research focus. Chapter two

(2) focuses on the background research and literature on water security, urban water issues, impacts of climate on water resources, supply – demand systems, climate change adaptation and derivation of the methodology and framework (see Appendix for Conceptual Framework) for this study. Methods include the elements and procedures used for research, the functional points and the idiosyncrasies in conveying the research and the methods of analysis. Chapter three (3) is on methodology and research design. Chapter four (4) focuses on an in-depth study of supply, distribution and institutional management, and demand and demand management for Chennai. This chapter includes the study of sources, supply modes and methods, points of access and policy management. Chapter five (5) concentrates on the water administration and policies. Chapter six (6) focuses on current and future climatic variations and the water security of Chennai. Chapter seven (7) consists of recommendations and conclusions based on the literature and the results of this study.

2. CLIMATE CHANGE AND WATER SECURITY: REVIEW OF LITERATURES

2.1. Introduction

Managing water crises such as droughts, floods, water poverty, scarcity etc., has become a global challenge for humankind (further explained in 2.3). Water security is the integration of water resources and management (among all sectors) to make clean water available, accessible and affordable in supply, for present and future generations. Thus, reducing water poverty, fragmenting water management, spreading knowledge and information, thereby increasing standards of living, represents water security (GWP, 2009). The major factors that sway water security are population, pollution, governance and climate change (Iglesias, 2010).

Climate change amplifies scarcity and stress, insecurities, making it hard for policy makers and administrators to manage supply and demand (GWP, 2011). Droughts and floods intensify these difficulties and the impact it has on society, the economy and environment. Hence, achieving water security and adapting to climate change is important, as it impacts lives, and major activities such as production and manufacturing within a community and environment.

Statistics indicate that Asian countries have a combination of water scarcity and droughts that impact humankind. Nearly one billion people face water shortage and lack access to safe drinking water; the worst areas are MENA, South France, Spain, Middle East and Asia (except Siberia) (Cook C. B., 2012). Aquifer reduction is seen, several meters every year. Mexico City, Bangkok city and Lima are showing a 10m-drop in aquifers. Megacities across the world are experiencing fresh surface and ground water depletion (Back & King, 2009). Countries depend on ground water for agricultural irrigation; 10 % of the globe depends on ground water for food production and the rate at which the extraction happens. It is suggested that many countries will not have ground water for food production. China, USA, Yemen, Middle East, Sub Saharan Africa and India are some regions where ground water is heavily utilized and often times over-abstracted (UN, 2009).

About 3 billion people lack access to sanitation (Bakker & Allen, 2012) (Cook C. B., 2012). 7 million die of water related ailments worldwide and one third of all deaths are related to water borne diseases or contaminants in developing countries. In 1999

UNEP suggested water related deaths are high, a child dies every 8 seconds around the globe (UNICEF & WHO, 2012) (UNDESA, 2005 - 2010) (UN - Water Final Report, n.d), (World Health Organization (WHO), 2007) (Magturo, Rosete, & Relox, 2006).

Transportation of water from one region to another cause's contamination and waste. European cities lose up to 40% of the water during transport due to pipe damage or leaks. New York City also has loss due to the old system of supply and population expulsion in the city hindering the policy makers from managing supply ((WWF), 2011). Regions in Bangladesh, Philippines and Thailand have 50% water loss due to an overall water distribution issue. Middle Eastern regions like Jordan and Yemen have water scarcity so high that they do not have much water to lose (WWF, 2011).

Many surface water sources are polluted, and it is through serious initiatives that some of them are restored / still preserved (The World Bank, 2013; Liu.L, 2007). Cities also face salt-water intrusion and contamination of freshwater resources (UNEP, 2000). Some cities like New York or London have an old sewer and waste system that impacts the clean water supply due to sewer mixing.

Major rivers from the Yellow river to the Colorado River are drying up. Several Asian rivers have dried up and this has caused water imports and immigration to other regions. Lakes/ rivers/ ponds are vulnerable as they are on the surface and are susceptible to climate and contamination. 20% of European lakes are wasted and dry (Global Monitoring for Environment and Security (GMES), 2013). Europe has 71 river basins and 16000 lakes. 20 % or more of these sources are vulnerable. For example, the Volga River that is drying is a major concern to communities and ecologists. The current prediction is that these lakes will be in a poor state by 2015. GMES indicates that a drop of contaminant can pollute the waters for years. It is common knowledge that some of the pollutants have a half-life of 10,000 years (GMES, 2013).

Urban waters diverted into agriculture and industries have a big impact on the population as they affect the quality and quantity of supply (EPA, 2012; EPA - SDWA, 2012). The Aral Sea is a good example of the water distribution and allocation issue, which led to contamination of sources, thereby creating problems for the locals (Owen, 2000). Aral Sea has suffered decrease in water level from the 1960's onwards for 60 plus years. The diversion of the river caused loss of balance in evaporation and inflow into the sea, which led to reduction of water levels.

The MENA region faces geographic and climatic related influences on water resources and holds less than 1% of freshwater reserve and, hence, there is scarcity (Nimah, 2008). Currently, all countries in MENA are considered water scarce with less than the standard (WHO level), less than 1000 cu m per capita of supply. 1000 cu m per capita is the amount declared by the UN and WHO as the basic requirement for drinking and cooking per person. Urban centres of MENA are impacted less than the rural centres, due to urban dependence on rural regions for extra supply to support the growing population, and this decreases supply. World Bank supports the fact that countries that have excess water currently will eventually face drought or flood related water insecurity (World Bank, 2013). For example, Latin America holds 31% of the world's freshwater resources, and has an exceptional governance management system (World Bank, 2013). Currently, climate change is considered to be the biggest threat to this available water resource. From the Amazon basin to the Andes glaciers, the region is rich in water resources and plays an extensive role in the region's development. Around 70 million people in urban centres have set a good example of good governance and management, quoted in many journals and articles or research (World Bank, 2013). The World Bank, (2013) article indicates that there are arid and semi-arid regions in South America that face the threat of severe drought and thereby face water scarcity. The wastewater treatment is at 20% in Latin America, and the rest of it is allowed to runoff into the river and sea, increasing pollution in the process. Latin America depends on improving governance practices, increasing stakeholder inputs and preparing adaptation strategies for potential climate change.

The IPCC (2007) report indicated that the monsoons in Asia and South East Asia bring lower and lower rains to the region due to changes in rainfall patterns due to weakening of the monsoons. It predicts a change in the glacial melt during the dry season and in-turn change in the level of river flows. Rivers like Ganges, Cauvery etc., which are already seasonal will become even more so due to increase in the demands. The UN projections for 2030 are that the population in India is likely to rise to by 4.6 million. This will increase the food requirements, industrial production requirements and the domestic water requirements (UN, 2009). It is indicated in WRG, (2009) that the demand will exceed supply by about 50% by the year 2030.

Floods also impact regions severely. A few flood events that stand out are Bangladesh, Indonesia, East coast of India etc., causing damage to health and property. A qualitative study in Bangladesh indicated that there were 918 flood related deaths in 1998 (Rashid, 2000). Siddique, (1991), indicated that 6% of all deaths recorded in 1998 were due to floods directly. This report indicated that community health and water quality were affected due to direct impact from unclean water. Similarly, several deaths were also recorded in the period between 1988 and 1994 in Georgia, Missouri and Puerto Rico in the US. The studies indicated that the number of deaths due to low water quality was more than 25. Additional Sources: (GWP, 2008; Gleick, 2010; Groisman, Pavel Ya, 2010; IWA and WWC, 2012; Loftus, 2011; GWP, 2009; GWP, 2008; GWP and INBO, 2009).

2.2. Understanding Integrated Water Resources Management

IWRM is the participatory and planning tool that promotes coordinated development and management of water resources. This framework is used for managing resources and developing water facilities. It can be also called as the process to ensure sustainable development, equal allocation and monitoring of resource use in order to balance social, environmental and economic needs, while ensuring political equilibrium and water security for the present day and future generations (GWP, 2011; GWP, 2009). IWRM aims to maximize economic and social welfare without compromising sustainability, i.e., the viable management of resources that leads to water security (GWP, 2009).

2.2.1. IWRM: A Tool for Adaptation

As established by literatures, water sources are of vital to humans and these resources are scarce or on the verge of becoming scarce in most regions of the globe. Managing resources to create security, the safe keep of water, is essential in driving the sustainability lever. Managing water requires cooperation, time, efforts, knowledge and expertise. According to literatures by UN, GWP etc., tutorials and educative materials are provided to expand the international knowledge base (UN Cap-Net, 2011). The vastness and knowledge of water security leaves researchers focusing on isolated concepts (in depth) or viewing horizontal macro expanse with less depth to it. A holistic approach is required to maintain allocation, sustainable development, availability, affordability and efficient monitoring for water uses within the social, environmental and economic goals. IWRM is widely celebrated for its success in efficiently managing water resources at all levels (GWP, 2011).

2.2.1.1. IWRM: A Tool for Management

Water resource administrators have been used to dealing with monthly and annual alterations in weather patterns. In regions where the climatic events are likely to get aggressive, a new and socially innovative approach is required. To initiate a proactive adaptation policy, it is necessary to look at the building blocks for a sound water management system to manage resources.

The climatic extremes and the future threats need a strong adaptation technique that allows multi-sectoral consideration in response to the water security problems. The appropriate response is to understand the productive and non-productive uses of water. All industries, agricultural activities, domestic uses, ecosystem uses need to be in the list of consideration given (UN Cap-Net, 2011). A good management approach, in this case would, for example, look at water for domestic purposes and other use opportunity values, while taking into consideration the wastewater reuse and the prevention of pollution of local water sources. Since, issues such as droughts, floods, saline intrusions and sea level increase are visible in many countries, it is necessary to adapt and manage available resources.

The agricultural, hydropower, industry, domestic and ecosystem use guide policies in response to severity of climatic events. Policies also guide selection of appropriate responses and interventions, set goals, examine implementation options and accomplish the set responses in an efficient manner. The policy will enable adaptation and "no regret" policy interventions will be useful due to the ambiguities involved with climatic conditions.

A "no regret policy" also called as adaptive response, otherwise referred to as the interventions that facilitate change, can be altered slightly to be in step with the changes in climate and is dynamic to the requirements of the situation. Hence, this dynamic response is a win-win policy, which contributes towards benefits regardless of the changes in climate (UN Cap-Net, 2011).

A policy response also needs to prioritize and balance the technical and non-technical interventions. Technical interventions include infrastructures such as dams, floodwalls and desalination etc. Non-technical interventions include improvement of institutions, facilitating knowledge spread, human resources to build capacity in order to research and adapt to the impacts of climate change. Good examples of non-technical interventions include emergency preparedness, knowledge spreading through tutorials and workshops etc. The go-between for the technical and non-technical response is the financial information of the project. The response is selected based on the financial availability and support.

IWRM, hence, is a holistic and conceptual framework to secure equitable allocation, sustainable development and monitoring water use efficiently for the social, economic and environmental goals. This conceptual framework guides the goals towards sustainable management and development. It facilitates people to be able to look at practices in a macro level rather than independent micro level actions. It makes people change their attitudes and practices toward a macro level concern. This approach introduces a decentralized democracy within the management system, besides implementing low-level decision making to include stakeholders.

The IWRM approach incorporates all water sources, all interests, all stakeholders, all administrative levels, all disciplines and sustainability of sources. This approach also allows multiple goal setting and not just sectoral-based approach. This approach also does not focus only on a single water body or source; instead it focuses on a wide span of watercourses. The UN Cap-Net (2011) notifies that IWRM widens the scope of traditional perspectives to integrate the “participatory multi stake holder decision making” identified from the GWP tutorials on IWRM and Climate Change adaptation.

The Dublin Management Principles (1992) is the principle behind the GWP’s IWRM approach.

Box 1: Dublin Principles and Water Management

Ideologies

Water is finite, susceptible to reduction and vital for all biota, requires management through integrated method.

Water resources development and administration should use the participatory approach, involving stakeholders.

Women play a large role in the provision, management and conservation of water.

Water has a monetary value and needs recognition, relative to the affordability and equity criteria.

Key Concepts: *Integrated water resources management, suggesting an inter-sectoral approach, including of all stakeholders, all physical aspects of water resources and sustainability and environmental considerations*

Sustainable development, is the sound socioeconomic development that safeguards the supply base for future generations

Importance for demand-driven and demand-oriented approaches

Decision making at the lowest possible level

Source: GWP, 2011; UN Cap-Net, (2011).

1) Principle 1 indicates that fresh water is finite and vulnerable resource, essential to sustain life, development and the environment. 2) Principle 2 indicates that water development and management should be based on participatory approach, involving users, planners and policy makers at all levels. 3) Principle 3 indicates that women play a central part in the provision, management and safeguarding of water. The women in the household run many families in Asia and the problems faced by the household are better understood by the women in-charge of the management of water resources (UN Cap-Net,

2011). Women collect water, cook, clean up and manage the rationing of water resource within the house efficiently. 4) Principle 4 indicates that water has an economic value in all its competing uses and should be recognized as an economic good as well as a social good (GWP, 2009; UN Cap-Net, 2011). The idea and concepts behind the principle can be used as a guide while applying the Integrated Water Resource Management approach within any area.

The policies for IWRM within the supply- demand context properly will require a national level reinforcement. Some of the major issues recognized are:

1. Environmental policy to include IWRM within a supply and demand context properly will require a national level commitment and reinforcement.

2. Clean water is not just a resource, but also a requirement for human existence, and hence a human right. It is also needed for the survival of economy and ecology.

3. National development requires proper planning along with long- term goals. Setting goals help policy makers look at possible issues and research solutions to secure water resources in a more sustainable manner.

4. Policy and research need to be made transparent for people to increase awareness and participation.

5. Projects and programs should be based on knowledge and awareness, i.e., policy, hydrology and technology.

6. The consequences and results need to be measured accurately and there should be room for improvements in the system.

7. Public participation is important and should be made mandatory for policy adaptation.

8. The costs, expenses and fund use and availability should be made available for public and accounted for in full.

9. Environmental decisions should not be made based on political necessity.

10. Inspection for all reports and project sites needs to be recorded and submitted to authorities and made available to the public.

11. Training sessions and community meetings need to be made mandatory for the whole community.

(UN Cap-Net, 2011; GWP, 2011; GWP, 2008; GWP and INBO, 2009; Norman, Bakker, Cook, Dunn, & Allen, 2010; UN and FAO, 2007; WHO (Quality Guidelines), 2006)

Water security measures in Indian water management systems are very complex and hard to decipher given the lack of complete data sources, lack of accuracy in collected data sources and other political contextual understanding behind the system. Can IWRM help address climate change in Chennai? The query can be answered after a set of theory to practice is available. The wide span of IWRM approaches are available with various tools and instruments used to deal with access to water, allocation and protecting the ecosystem and, thereby preserving a healthy watershed for generations to come. This is the one solution to adapt to the changing climate and water crisis situations.

2.2.1.2. Implementation of IWRM

According to the GWP, IWRM focus is on enabling environment through suitable policies, regulation and involvement of people, institutional framework for implementation of policies, practices and legislative changes, and management instruments that are usually required by the institutions to make decisions and implement policies. The general framework for IWRM by the GWP is as shown in the figure 5.

Figure 5 Framework for IWRM

Source: http://www.gwp.org/en/The-Challenge/What-is-IWRM/IWRM-pillars/

The implementation of IWRM is a one-shot approach, which relies on participatory approach. Most regions have sectoral divisions within governments and international institutions or agencies that do not allow cross cutting, holistic and resource management approaches to be implemented efficiently due to lack of participation, lack of integration of issues, stock take of resources and efficient management and good governance.

IWRM should be a process that needs to be referred to as a long-term approach rather than a one-shot approach for it to be dynamic in providing solutions for future and fast-moving changes. A change is constant and shifts the water development and the system of management to be unsustainable, and this necessitates IWRM. This approach does not have a start or a finish, it is a continuous approach that allows acceptance of changes and provides alterations to fit with the changes.

Capacity building is very important for the IWRM and integrating programs and organization of governance and government structures is a challenge. The other challenges are poverty, environmental management planning is difficult, considering the old-school way of finding solutions when presented with problems in most developing countries.

The talks during the fourth national policy indicated the nations' water status. The US faces several challenges and potentially several more in the decades to come. Future holds several floods, droughts and other threats to water quality and quantity along with loss of wetlands and flood plains.

The water resource infrastructure in the US is aging and requires restoration and renewal. There would be large financial losses if the infrastructures fall apart and collapse. The future drought and flood severity and frequency may increase and weaken the health and stability of the ecosystems within the country.

Within the research context the AWRA 4th National Policy discourse indicates that the water quality cannot be managed differently to the quantity, integrated management is required. Similarly, water resource management cannot be divorced from land management. Resources need to be safeguarded and protected to manage inflow, outflow and run- offs and quality. According to the AWRA sponsored policy discourse, water resource cannot be managed and secured if there is no understanding of the water system. In conclusion the report suggests that a holistic approach is required to water and the implementation of IWRM, as the resources need dynamic management and countries with potential climatic threats require efficient and quick action.

Since the 1992 RIO International conference on water and environment and the Dublin Principles, all governments were called to assess their capacity to implement the IWRM. The only problem is that it needs to be more dynamic and on hands in most countries as the water resources, community, and changes in climate are active and interconnected. Similarly, in 2002, the World Summit on Sustainable Development in Johannesburg called for all countries to implement the IWRM and assess their carrying capacity. The 2010 initiative identified the IWRM, as the vital part of sustainable water resource management, should be so for most other countries trying to secure their water resources. In addition, the national collaboration for U.S.A. identifies the IWRM as the way to plan and manage public water for the community. The major things suggested by this collaboration are 1) the need for appropriate federal support to help states handle the water problems through collaborative planning, creating bolstered support using tools and the IWRM framework; 2) the region needs to take initiative to make IWRM more understandable to plan and manage water resources within a community, and 3) all levels of government need to improve water resource management by reshaping and restructuring and in addition, need to increase public participation for IWRM.

From all the viewpoints assimilated the IWRM lacks a proper definition and the measures to monitor regional implementations. There is clear lack of guidance for those projects' planning and implementation. The 2010 National collaboration in the US recognizes all the issues and is committed to improving the status of IWRM.

The GWP indicates that the IWRM can be improved and managed using the internal and integral components such as management techniques i.e., the management of water at a basin or watershed level. This includes integrated land, upstream, downstream, ground, surface and coastal waters. The technique is to maintain a balance in supply while conducting assessments on surface, ground water supplies, assessing the balances, introducing, reinforcing or altering the wastewater reuse and understanding the impacts of distribution and use.

Demand management is a critical issue, as the pricing, utility value, technologies and management are affected. A key part is to strategically plan the cost recovery, implement policies for water efficient technologies and to decentralize management.

Equitable access is a major issue within water communities as the water wars are usually associated with securing sources for all. The effective support for water users is through associations, improving access for minority groups and consideration given to the third Dublin Principle – gender issue.

Quality norms are equally vital for IWRM. The system needs to have policies related to quality norms and standards and market regulations. A good example for this implementation is the "polluter- pays" policy, which literally means that the polluter such as they may be, industry, should pay a price for polluting the water resources. This policy is very good to keep pollution to a minimal level, as most people in developing countries do not wish to pay.

Asian countries do not have strong regulations attached to policies and have increased corruption; hence the policy implementation may or may not function well. Political contexts also play a very big role in Asian countries unlike the U.S.A. where management may be decentralized but the issue comes first and does not use political interests as a major deciding factor. There is also the concept of political leadership and interests, every party has its own ideals and goals and if the natural resources are not a priority, the ecosystem will suffer. The socialists, the republicans, the communist or the democrats need to realize that natural resource management is something that cannot be ignored, regardless of war or other security issues at hand. The GWP recommends the cross-sectoral integration, which is used as an administration tool for people, food, nature, and industry using environmental, institutional and management.

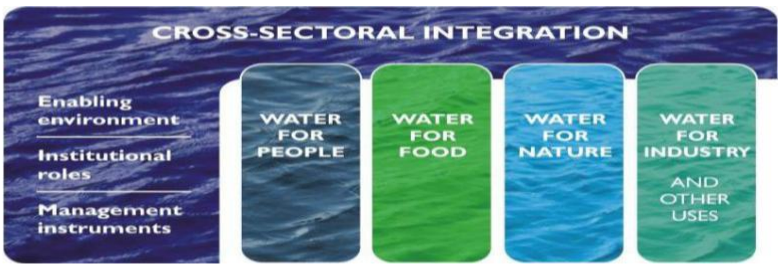

Figure 6 IWRM Cross- Sectoral Integration

Source: http://www.gwp.org/Global/The%20Challenge/IWRM%20and%20sub-sectors.jpg

The GWP recommends the IWRM to be as shown in the figure 6. The inter-sectoral approach to making decisions will allow smooth water management for all sectors. It is where authority for managing resources becomes responsible for the resource and user requirement. It employs users and the participation of locals in this process of decision-making.

The successful policies will have:

Table 4 Major Successful Policies

1) Consolidation of institutes that collect information improves forecast capacity, plan projects and adapts to current and projected future climate changes and improves long-term pliability.
2) Improve integration of land and water resource administration interventions and actions that allow multi-sectoral view of water use, conservation and securing resources. Interventions also consider adaptation capacity and securing water resources with a "no regret" approach of action.
3) Frameworks for climate change adaptation at all levels from projects to communities and river basins to nations.

Source: GWP, 2009

There is need for sound science and best practices as foundation for adaptation decisions; also, for improving and sharing knowledge and building comprehensive and sustainable data collection and monitoring systems.

The key aspects that are needed for IWRM management are prioritization and balancing between "soft" interventions and "hard" interventions, balancing the social equity, the economic efficiency and the environmental sustainability, preference given for marginal changes rather than fundamental changes in development paths, and drought and flood zoning and planning.

These aspects provide more flexibility for policy makers, locals and other stakeholders in managing water resources appropriately. Hard and soft interventions basically, are policy and technological interventions, respectively. Setting priorities for hard interventions and soft interventions are very important as the required funding, strategies, and approaches are striated within the community. The second aspect involves managing society, economy and environment in a sustainable manner. Essentially, this would mean integrating the interests of the environment, the society and the economy, while making policy decisions and management choices. The third aspect is to opt for smaller alterations instead of larger and more complex changes. This aspect is preferred, as the society functions in a certain way and fundamental changes may not be easily adopted in an efficient manner. The last aspect looked at is the flood and drought zoning and planning. Climate change impacts on water and other related sectors are synchronously analyzed to achieve the policy and strategy goals. Efforts achieved based on this will be an integrated solution for water security.

2.2.1.3. Significance of IWRM for Chennai

To redefine IWRM for Chennai, it is a participatory and planning tool, used for managing resources and developing water facilities. This tool is used to balance social, environmental and economic needs, while ensuring security for both present day and future generations (GWP 2009, 2011). The IWRM approach is significant for the water-poor or water stressed regions of Chennai due to the segments examined: access, availability, affordability, efficient allocation, and water policies. Given the current status of the supply system, this study identifies the climatic influences and the potential changes in future and signifies the current insecurity and inability to cope with future climatic variations in Chennai. The study looks at the climatic trends and threats, potential flood and drought proneness, policy responses and recommendations for the future of Chennai.

2.3. Climate Change: Causes and Impacts of Droughts and Floods

The arid and semiarid regions around the world face drought related water security problems, such as exploitation, misuse, lack of coordinated management etc. Floods may also severely impact, causing damage to health and property (See Appendix I for Types of Droughts and Floods).

IPCC (2009), denoted the global warming with anthropogenic events to induced droughts in the Arid and Semiarid regions of the Middle East and UAE. It is not possible to pinpoint the relationship, anthropogenic climate change to the drought events. A report by the National Oceanic and Atmospheric Administration indicated that the droughts are not all climate change related (Shahrzad, 2012). Between 1902 and 2010, a study by Martin Hoerling (2006, 2009) signified only half the droughts can be directly attributed to GHG or climatic conditions as the intensity of droughts in different regions is affected by natural variability.

Major causes of droughts are supply and climate related (Dey, 2011). The supply related causes are physical distance and non-availability of surface water, decrease in storage levels due to lack/reduction of rains, and inaccessibility of resource due to contamination (intentional and unintentional). The climate related causes are mainly due to the link between rainfall and surface temperatures, oceanic and atmospheric circulation and soil moisture retention.

Dey (2011) and Ramasy (2007) indicated the patterns of droughts in Bangladesh and the causes of increased risk. Climatic extremes and their impacts include: Higher maximum temperatures (heat waves and hot days) causing increase in illness, crop disease and failure, energy demand and heat stress. Increase in summer drying causes decrease in water resources quality and quantity, for ground water sources (due to over abstraction), surface water (due to reduced rains), crop harvest etc. Increased minumum temperatures (cold waves and fewer cold days) causes an increase in disease vectors and some crop damage. High precipitation increases soil erosion, flood events, loss of nutrients and property damage. Monsoon variability, higher variability in precipitation, can cause extended dry spells throughout the season (Dey, 2011; Ramasy, 2007).

The impacts of droughts vary with region and resources and the intensity of the impact depends on response and adaptation success. For example, drought in Syria is blamed on climate change and manmade desertification. Syrian drought in 2001 was intensified due to lack of proper policy management and mismanaged water practices. World Bank warned the government to secure food supply and to reduce ground water use for cotton production. This message was received but not acted upon. With energy and water subsidized by the state, the production was increased. This resulted in heavy drought and large movement of people to outskirts, signifying a protest. This mitigation aggravated the pecuniary due to inflow of people from Iraq and Palestine.

Drought hit Syria again from 2006 to 2010, harming the soil/ land, food and water security, and people. This led to the migration of 1 million people, mainly farmers. The country’s regime again overlooked the possible water scarcity in the event of drought. The management largely focused on economic and technology related development policies. Further drought induced migration instigated volatility within the region (Shahrzad, 2012).

The frequency of droughts has increased in Syria in the last decade, whereas only six droughts were recorded there between 1990 and 2005. The precipitation levels during this period were sized down to one third of the norm. The communities were satisfied with secondary water resources and subsidiaries. The most recent drought was a true anomaly and the average precipitation was lower than any of the other drought seasons. These are lessons and warnings for the grander catalyst that climate change will become a disaster in a region already under the strains of cultural polarity, political repression, and economic inequity, if signs and warnings go unheeded.

Droughts affect several countries in the MENA region, Middle East and South Asia. The hardest hit areas were India, Afghanistan, Iran and Pakistan (Shahrzad, 2012). But the drought situation was more critical in Afghanistan and Pakistan, where millions of people were/ are still at risk but fewer resources are available (Shahrzad, 2012). These regions requested for aid from large organizations during the time of drought. According to Shahrzad, (2012), requests for aid and funds are the initial signs of weak management. This is a clear indicator that the country is unable to handle crisis in a self-sufficient manner.

As explained by Sowers and Weinthal (2010), based on the climate index between 1950 and 2003, there are more and more dust storms, increasing summer temperatures and decreasing winter temperatures, varied rainfall with severe flash floods and landslides and an increase in the frequency of drought years. All this has amounted to empty dams, dry catchments and an overall decrease in the water table.

Historically, India has had agricultural famines brought on by drought. The first recorded drought was in 976 AD where agricultural crops failed heavily and thousands of people died. Similarly, in 1876 to 77 about 5- 6 million died in India, mainly in South India and in 1942 about 2 million died in Bengal. More recently, in 1965 and 1970 many crop failures caused 3 million or more deaths. In the year 1970 many organizations and local governments felt the need for external aid as crop failures were large and the general feeling was that India would not be able to produce enough to support the population. In 2009, there were small drought like symptoms in various regions coupled with 23% shortfall in rain (Indian Institute of Tropical Meteorology, 2011).

Table 5 History of Drought in India (1800 – 2010)

Period	Drought Years	No. of Droughts
1801 – 1830	1801, 1804, 1806, 1812, 1819, 1825	6
1831 – 1860	1832, 1833,1837,1853, 1860	5
1861 – 1890	1862, 1866, 1868, 1873, 1877, 1883	6
1891 – 1920	1891, 1897, 1899, 1901, 1904, 1905, 1907, 1911, 1918, 1920	10
1921 – 1950	1939, 1941	2
1951 – 1980	1951, 1965, 1966, 1971, 1972, 1974, 1979	7
1981 – 2010	1982, 1987, 2002, 2004, 2009	5

Source: Indian Institute of Tropical Meteorology, (2011) Compiled from www.editoria.u-tokyo.ac.jp.

The Government of India mobilized aid in relief efforts to several regions during the years between 2000 and 2004, as a way of managing the droughts. This was the worst drought in a century in India, which affected 130 - 200 million people, nearly 15 percent of its entire population in 1987 (Shahrzad, 2012). Monsoon failure and reduced rainfall affected 12 states in India, mainly Tamil Nadu, West Bengal, Kerala, Rajasthan, Karnataka, Bihar, Orissa, Madhya Pradesh (Indian Institute of Tropical Meteorology, 2011).

The highest number of droughts recorded was in the years between 1891 and 1920. The frequency of droughts in the last 2 to 3 decades is the second lowest (see Table 5). But even though the statistics read that there has actually been a decrease in drought years in India, it is not safe to assume that there are no possibilities of future droughts that hit the high mark beyond the numbers shown in the years 1891 – 1920 (Indian Institute of Tropical Meteorology, 2011).

Floods are often related to tropical storm, rains and tsunami that bring in excessive amounts of water flooding the land areas, causing damage to agricultural land, property and human lives. The causes of floods are due to heavy rains. However, inundation may also be due to water surge linked with a cyclone, a Tsunami or a high tide. Non-climate related direct causes are dam failure, leaks in storage facilities etc., which can be indirectly related to earthquakes. Flood events depend on spatial distribution, intensity and frequency of rains over a region. The intensity of flooding also depends on the capacity of the watercourse to allow runoff. The condition of storage facilities or dams also affects the intensity (Kelman, 2001).

Flooding events is the number two factor causing global deaths; especially in the US flooding is the number one cause of property damage. Great floods in U.S.A. occurred in 1993 along the Mississippi River. This flood caused damage of 20 million acres of land area in nine states. This was the greatest flood in North America, caused by slow storm surge and thunderstorms (Weiner, 1996). Similarly, several deaths were also recorded in the period between 1988 and 1994 in Georgia, Missouri and Puerto Rico in the US.

The floods events in Bangladesh in 1988 caused 6% deaths in the year (directly impacts individual lives) (Siddique, 1991). The records indicated that the health of people was affected due to direct impact from unclean water. The studies showed that the number of deaths due to quality and drowning was over 25 people, headcount. A qualitative study in Bangladesh indicated that there were 918 flood related deaths in 1998 (Rashid, 2000). Likewise, in Netherlands, 1863 deaths were reported without any analysis. These incidents show that the floods impact health, water quality and environment (Centres for Disease control and Prevention (CDC), 1993; Propin-Ferjomil & Crispin, 2002; Yale, et al., 2003; Spencer & Myer, 2007; Duke, et al., 1994). They also impact people and their lives. The instances where drowning was reported as well as ailments due to the impacts on water quality are also significant in many regions, especially Bangladesh. The impact may be slight, mild or severe but the effect on even a single person needs to be acted upon, so it does not grow to be uncontrolled the next time.

Combined with global warming and the unpredictable weather patterns being forecasted, the stress on water resources is amplified. Today, several countries have recognized this and are taking initiatives to adapt to the situations in an efficient manner. Many institutions such as the Global Water Partnerships, World Water Council, United Nations, International Water Congress, World Resources Institute (WRI) and IWMI have commenced works to implement Integrated Water Resource Management (IWRM). The chief concerns for integrated water management are securing and sustaining water resources. To sustain resources, it is imperative to secure them. Sustainable development is the viable management of resources including, access, availability, affordability and allocation- efficiency (key water security elements) (GWP, 2009). Urban governance, supply-demand management and adaptation planning are major aspects indicated by the GWP, as the major methods to achieving smoother adaptation.

2.4. Need for Good Water Governance

Good governance and careful planning for policy measures is required to handle this crisis. Governance for water includes proper access to available resources, equal allocation and affordability (Anand, 2007).

Globally, multilateral frameworks have been used to manage and create strategies so far. These strategies have been unsuccessful in South Asian countries. For example, the first instance of aquifer management through a ground water Act for agricultural production in India failed (Anand, 2007). On the other hand, in those unilateral strategies that have shared treaties, water initiatives function well, within limitations. The issues with unilateral strategies focus on regional tensions and political influences (Sowers and Weinthal, 2010). In addition, the Global Water Partnership (GWP) insinuates that the chances of other strategies becoming successful are slim due to issues relating to the multitudes of approaches within the state and sectors (GWP, 2011). A nexus is required for various sectors for the strategies to function well and provide benefits. The IWRM adaptation tool is used to manage resources without involving conflicts of any kind.

The IWRM is a significant approach for the water-poor regions of Chennai. Background information on the climate change impacts on water resources, flood or drought proneness, security issues and adaptation strategies.

2.4.1. Urban Governance for Water Security

Scarcity is a pressing issue in Asia that is compounded by the change in climate. “Water is unclean or dirty and mixed with sewerage or muddy” (Janardhanan, 2011) Water for Asian society is so scarce that many indicate “It is quite normal to get 3 hours of water in the morning, which we need to go out and collect from a lorry”. These are different voices from the group of people interviewed for investigations conducted in 2011/12 (Janardhanan, 2011; Siddhanti, 2011). Good governance aids in securing and sustaining water resources within a region, to be precise it pilots ‘the boat’ in a particular direction.

Urban water governance is defined by the political, social, economic and administrative system that are in place. It directly or indirectly influences use, development, management and conveyance of water services. This system is also influenced by decisions from other sectors. For example, the Canadian water policy report written by Norman et. al., (2010) advocates water governance for water management. This study defines the term "water governance" as the decision-making process through which water is managed. This covers an entire range of processes involved with the water supply system.

In Canada the changes came about due to events such as water contamination in Walkerton (Ontario) and North Battleford (Saskatchewan) that increased the need to secure water sources. Similarly, compounded impacts of climate change and scarcity influence water policy and practices. A new governance framework was developed to address these issues (Norman et. al., 2010). The new watershed legislation, regulatory frameworks and water assessment practices are a part of the changes in practices and approaches. The report by Normal et. al. (2010) uses water security as an overall term that emerges from various concepts such as quality maintenance and access to quantity. Similarly, many other developed nations improved their practices and approaches. The developing nations, on the other hand have a tough time altering their schemes due to political pressures, unavailability of resources and poor governance.

The last 20 years has brought radical changes to the water system across the world. Asian countries are just realizing a subtle change in climate causing catastrophic results (World Ecology Report, 2008). China and South Asia are among the more affected regions due to population growth and pollution of sources (UNICEF & WHO, 2000). In places like America, Japan, Paris etc., drinking from the tap is an indication of how clean the water is, while in Asian and African countries, drinking out of the tap provides surety of water borne diseases. Hence, developing clean water, 24 * 7, supply and separating sewerage from water denotes progress in quality and quantity of supply and success of achieving goals set out by the national policy makers. Moreover, progress will be a catalyst for improvement of public health (UNICEF & WHO, 2000; GWP, 2012; IWA, 2012). Good governance and adaptive strategies are the key to handling water resources for the future of uncertain climatic variations. Additionally, the state and the players involved in decision making contribute to the large slice of the water governance and management issues, and in some cases also induce insecurity.

To govern is to allow policy, actions and legislatures of the state, organization and citizens, i.e. how the society organizes itself and its implementation to find solutions to current problems related to environment, society and economy. The major idea that good governance promotes is the stability of society, operating at a household, village, province, and state, national and international level, where target actions are implemented. However, what is needed is simple focus on achievable goals, and efficient fund management with coherent communication to the public so as to enhance public involvement to induce smooth adaptation to crisis situation.

The indicators of water governance are public sector management, efficiency and effectiveness, participation, consensus orientation, law, development framework, accountability, transparency and information, responsiveness, and equity and strategic vision (UN Water, 2006; Dunn & Bakker, 2009) Among all the indicators of good water governance are the key aspects to look at are accountability, transparency, participation, information, effectiveness, and the policy and rule of law. Good governance is the rule of law, which encompasses political freedom and stability, judicial effectiveness, media independence, bureaucratic efficiency, economic management etc., to enhance the capacity to achieve goals.

Furthermore, Water governance is the collection of institutional controls that allow smooth plug-ins and set tenures for policies in place. Each policy can last only until its usefulness wears off. When policy hinders development, there is change to best suit the situation at that point. Allocating, developing and managing are the three elements of resource management that occur in cycle. Governance incorporates management to help maintain stability of the system, water system in this case. Governance and Management help maintain the quality and quantity of the water resources. The scope of management includes mapping, directing and the official use of funds. The intrinsic vulnerability of an aquifer can be mapped using information on soil, geology, water table depth etc.

Management of water most often involves risk assessment, examining costs, and stakeholder knowledge sharing, understanding social water use, behavior and adaptation levels and implementing appropriate policies.

1. To assess the risk factor for contamination such as application of fertilizer and sudden release via spills or other risks;

2. Cost to replace water supply or the public health care system for sick people.

The progress of the implementations can be monitored though analysis of process indicators, outcomes and then impacts to check the path of governance and the targets to be achieved.

Water security plays a prominent role in the balance between the social, economic and ecological system. It also demands maintenance of the water system within the climate change context and integrates it to other systems, so as to avoid friction between targets and its pro- active implementations (Dunn & Bakker, 2009). GWP identified five (5) elements of water security. 1) The overall security indicating the **sustainable access** to water resources for households; 2) The **extent of availability** of sources for all purposes, especially agriculture as it is the major activity in Asia; 3) The **percentage of renewable water resources** available in excess of environmental water requirement; 4) The extent to which countries **cushion water stress** due to climatic variations and the storage capacity to support the buffer system; and 5) The independence of the system, i.e. **the capacity to handle crisis** despite the changing environment, climate, economy and society (Lautze & Manthrithilake, 2012).

Insecurity condition is an issue widely debated without outcomes or achievable solutions for urban developing nations. The major actions required for management and policy decisions are:

1. Monitor and identify issues within supply, demand or distribution. Quality control every week, supply status and source extraction and distribution and demand management issues within the current water system;

2. Implement proper pricing, price conservation and tariffs for household (HH) usage. Balanced pricing and proper tariffs for usage is required;

3. Implement new technologies, development facilities and services. Desalination, RWH and artificial and other such technologies are vital for management of water resources;

4. Implement conservation techniques to improve water saving. Control of extraction and usage is needed as the water saving improves with it;

5. Improve training and education of locals and staff. Workshops and training camps are much needed for urban poor to understand circumstances and issues;

6. Build networks to improve staff skills and competencies for repair and maintenance. Improving competency of staff will prevent extensive leakage in pipes, tanks, and other water storage structures;

7. Improve existing conservation and structures. Rainwater harvesting, water saving HH techniques are needed to improve security and reduce stress;

8. Manage and prioritize fund allocations. Fund allocations for specific problems and infrastructures will improve efficiency and help policy makers prioritize decisions;

9. Enforce policies and fines extensively. Fine should be increased to make people more responsible about usage of water;

10. Promote water security through media. Involve TV, pamphlets and advertisements through magazines and newspapers to make people aware of issues and potential solutions;

11. Improve or implement good feedback mechanisms; and

12. Customize all policy, plans and projects in a region, geography, culture and environment specific manner. Micro-manage issues within each zone to decentralized management. For example, Japan has decentralized the management system, with pilot testing and the EU has centralized large land area management system. Each physiography responds differently to certain interventions. The advantages of having decentralized management is that, it can be customized to fit the geography, culture and water body within the region, while the centralized management allows for the actions to be uniform and therefore, easily implementable into the water system.

Sources: (Back & King, 2009; EPA, 2012; Fernandez, 2012; GWP, 2008; GWP, 2009; GWP and INBO, 2009; IWA and WWC, 2012; Mildhem, 2010; Shamir & Howard, 2012)

Water management requires proper understanding of the water system and the fit between goals should be friction free (the goals should not counter act against each other), have reliable indicators that consider current and past trends and have good feedback mechanisms within the system.

The challenges of water security are predominantly clear, especially in Asia, Africa and China, in both urban cities and islands. The activism of social and environmental institutions do not focus on poverty differences, climate and water use but look at the impact of water risks through climatic variations alone. The status quo is debated and, both supported and rejected by the political power and policy makers.

Societies in Asia take clean water for granted and users do not understand the intrinsic value of water. With urbanization of large cities, the environmental management suffers a block, due to changes in the consumption pattern, the quantity of consumption, the funding requirements to produce more or implement new infrastructures and the maintenance of quality. In urban areas, households with high income possess the ability to obtain access to a satisfactory amount of water. Some enjoy bulk deliveries at reasonable prices. Meanwhile, within the same region, low-income households have less than 20 litres of water or no access to water for primary necessities. These issues can be addressed only by good policies, institutional approaches and infrastructures.

2.5. Approaches for Adaptation and Policy Implementation

2.5.1. Land, Water and Climate Approach

Land, water and climate approach to 'manage land use and water resources for societal needs' was first raised in a study by United Nations, in the year 2000. This study assessed the water for society and ecosystem for the 21st century. The main approach used (by the UN, 2000), was to understand the kind of social institutional arrangements needed for the future of water and the management of potential crisis by looking at trade-offs between water and land use. The major idea conveyed (UN, 2000) is the introduction of institutional changes that allow good and swift policy decisions and treat social, economic and environmental purposes in an orderly manner within the regulatory framework.

The array of problems faced by households and other users have grown and doubled within a space of ten years. Water withdrawals from nature are due to climate change and increased population requirements that change the level of water flow into lakes, rivers or inland water bodies, changes ground water recharge levels, increase water availability for the society and reduce the biotic existence of soil and water ecosystems (if freshwater is withdrawn at an alarming rate).

Very often the relationship between land use and water resource use is overlooked. This leads to a plethora of issues; research indicates that land use has impacts on the flow strictures (UN, 2000). Increase in demand on the source makes the resource vulnerable to changes and, hence it is imperative to use it in the best possible, efficient and satisfying way. The trade-off made to the use pattern and the withdrawal will indicate changes in large scale.

The purpose of the research conducted on water resource management by GWP and UN is to understand how to secure water resources while getting good policy responses; i.e. being prepared to handle any kind of potential water crisis. Management under stress needs a strong institution that can cope with an array of problems with multilateral management. The UN (2000) study identifies three types of water scarcity: climate related, soil water, demographic and use related scarcity. Demographic and use related scarcity is the blue water scarcity, while the societal scarcity is the green water scarcity. The compromises made between blue and green waters flow denotes unavoidable impacts.

2.5.2. Water Supply and Demand Management

Many challenges to water security and management of supply have appeared in the last few decades, a few over centuries. The techniques used to adapt to water resources, globally, at the advent of approaching extreme shifts in climate, can be an interesting story to tell and know. The recent development of urban facilities and the increase in demand for water create stress, which undermines the equitable management of water. However, new techniques show ways to draw water out of aquifers without depleting existing resources. Water supply and demand side tools discussed in this section are to enhance the research on Chennai and provide valid and successful adaptation techniques.

Supply-side management includes status of source, estimation of demand, source extraction, wastewater and sanitation measures, quality control, community participation, maintenance and operation, training and education, supply methods, technological implementations, transportation of water, partnership and networks, water-aid for supply and supply policy implementations.

The demand side management includes consumption patterns, per capita use and use efficiency, efficiency and cost effectiveness, non-price and price conservation, tariffs, pipelines and metering, leak detection, repairs and maintenance, development of demand networks (to build skills and spread knowledge), dependence on alternative sources and policy implementations. Supply and demand side elements were compiled from (GWP, 2009, 2011 & 2012; IWA, 2010, 2011 & 2012; UN, 2009 & 2012; UN Cap-Net, 2011/ 2012). The distribution management includes large scale piping, metering, valve monitoring, flow and direction of supply, infrastructures, corrosion, leaks, repairs and maintenance, awareness, communication, training, education and pressure monitoring.

2.5.2.1. Supply-side Adaptation Strategies and Issues

To combat floods and desertification it is essential that the supply related policies are made with proper information regarding climatic conditions, facilities, alternative sources, and pollution. A water body inventory is required initially, while also collecting information on the security, conditions, occurrences of droughts or floods, habitants and activities, industries/ agricultural activities in order to improve water security (GWP, 2009).

Desertification has affected 250 million people directly and over 1 billion people are potentially at risk due to crisis that could ensue from droughts or lack of rain (Mileham, 2010). The example of drought in China shows the required adaptation measures relating to supply side management (Shilong, 2010). The demand for water in urban cities in China is expected to cross over 400 % by 2030 compared to the demand in 2000’s, and population growth and adverse climate change will also add to this issue (Shilong, 2010). Water resources will reduce in quantity, freshwater will be contaminated due to floodwater and resources in general will be overexploited due to increase in population. Climate change in China has also caused changes in the water table of the region. Over the past decade the water levels in the Yellow, Huajhe and Liaohe Rivers of N China have been visibly reduced. On the other hand, rivers in S china are flooded and water body content has increased considerably (Shilong, 2010). The occurrences of intense climate change, influences scientific reasoning through opposite responses to events i.e., cooling instead of warming or floods instead of drying or reduced snowmelts in S China.

Water facility developments in urban cities have allowed wells and tubes to access ground water sources to sustain populations. The wells got dry very soon due to overuse. A good example is the investigation conducted as part of this study on Vellore in Tamil Nadu, where development in the semi urban Vellore city and other urbanized centres within the district was supported by 150,000 wells that are now dry due to overexploitation. About 20 percent of these wells were constructed within the last decade. The ground water reserves are dry, the urban centres in Vellore are dying, and the populations are moving out of these cities to seek homes in other regions. To improve conditions the Vellore Water Board introduced schemes to reduce facilities development and acquire water from adjacent districts.

Pollution will destroy ground and surface waters in the coastal cities that are highly populated. Water pollution affects health of the communities and the livelihood of fishermen. Local pollution is due to domestic use and industrial pollutions. The discourse by UN ESCAP, (2010), indicates that most developing and developed countries will adopt the Polluter Pays Policy. This is because the costs are internalized and privatized. Technology and management with low cost centralized and decentralized treatment will benefit the urban regions. Polluted and wasted water needs to be centrally treated and the costs of treatment can be recovered by selling water from treated sources (UN ESCAP, 2010). UN, (2009), indicates that the water treatment facilities can cost a lot to implement.

2.5.2.2. Quality of Sources

A watershed can be contaminated through intentional actions or by accident. Intentional contamination is one of the most serious problems that can cause ill health. It is important to act rapidly and efficiently to protect public health. Literature suggests that the current death rates caused due to water related contamination issues are as high as 304,047 globally (Worldometer, 2013). According to geoscience information from F.A.O. and the WHO, there are deaths happening every 8 seconds around the globe due to water related disorders.

Evidence suggests that over five million children die every year due to illness caused by environmental dilapidation. To a large extent the water they drink, where they live, learn and play also plays a large role in how this affects the health of a child. The second most common cause, Diarrhoea accounts for 12 % of global deaths (about 1.3 million deaths) per year. Diarrhoea is a result of consuming dirty water or food. Besides this, malaria kills more than a million children each year, Dengue Hemorrhage kills about ten thousand every year and Japanese encephalitis kills about 8000 per year. When a threat is perceived, it is critical to act instantly and efficiently or grave impacts bring calamitous results, especially for the poor. WHO (2007) indicates that time and again water has a direct or indirect relationship with poverty, governance, climate, power, agriculture, education and society (culture) etc., and this equals the sustainability of life.

Hence, efficient water management is crucial, and to realize that, understanding the water systems is vital.

The WHO prescribes basic practices for administrative systems to maintain and improve quality of their water bodies: 1) Training of staff on water health; 2) Maintenance of clean water body by removal of TSD and solid wastes; 3) Communicating information to users and holding workshops; and 4) Testing water bodies and aquifers for pollutants (chemical and bacterial kind).

The WHO water analysts indicate that chemically it is impossible to find absolute purity in water. It is also considered good to have some minerals in drinking water. Purification is very expensive, and it is not often economically practicable. Hence, many countries only purify water to the basic level required by the WHO (WHO (quality guidelines), (2006).

Water in any form needs purification as: 1) Rainwater picks up gases from the atmosphere while falling through to land. Rainwater absorbs nitrogen, carbon-di-oxide, and rare gases, sweep particles, salt and radioactive fall outs etc.; 2) River and Surface runoff water flows through land, and hence picks up minerals, bacteria, salt and natural and synthetic fertilizers; 3) Lake and pond water contain low dissolved oxygen, iron and manganese, H2S, increase in Carbon-di-oxide and also has a reduced pH; and 4) Ground water absorbs decomposed and degradable organic matter, oxygen and carbon-di-oxide, with lowered pH, soil minerals and iron and manganese. It is important to improve quality of water through a 3- day quality filtration according to the Japanese water management board (interview with Japanese water officials) (WHO, 2006).

The quality standards of WHO in 1983 – 1984 and in 1993 – 1997, were published in the first and second editions of the Guidelines for Drinking Water Quality. Further development was seen though a revision of the version of International Standards (WHO, 2006), replacing the old series with new series, taking into account the important events of the past two decades. The recent editions further develop approaches and information from earlier versions on bacterial, chemical and other water pollutants. These are quality standards that need to be maintained. The major quality concerns are waste disposal, brine disposal or chemical disposal into water resources. This may create major environmental crisis.

Global water quality is not standardized as many regions still have high levels of contamination and pollution, including communities within developed nations. A good example for this is the Walkertown issue in Canada. There is clarity in many regions that water stress is due to poorer water quality and unavailable affordable and accessible supplies. These issues are compounded by climate change impacts on water resources. These are factors that result in water insecurities. Many water management approaches do not link water quality and quantity, for human and ecosystem stability.

The quality of water from underground sources is very good in general. Ground sources do not require extensive treatment and are often used as drinking water sources after treatment. On the other hand, surface sources need 3-day treatment and open access to offset increases in domestic and animal waste in the water body.

India travel health identifies that water quality in India is severely lacking (Cook, 2013). While external opinions remain skeptical, the BIS indicated that in 1983 there were 1230 million people without safe drinking water in India and now this number has reduced due to revision of water supply to specific areas. The revisions were formulated with help from International Standard for Drinking Water by WHO, 1984 Geneva; Manual of standards, Indian Council of Medial Research 1971, Delhi and Manual (third revision), Ministry of Urban Development, 1989, Delhi. Now the tenth five- year plan is documented. The plan includes IWRM with solid and liquid waste management ((UN - Water Final Report, n.d), (BIS - Indian Water Quality, 2009)). Thus, improvement in water quality requires active decisions and adaptive measures in India, especially with regard to the future uncertain conditions.

2.5.2.3. Dependence on Desalination

IWA's director Paul Reiter predicts a population increase by 1 million every week and that water professionals need to reconsider water sourcing and management. A Water Congress in Korea - stress the need for research and development and uptake of new water management options. The need to change the traditional approach to supply and distribution method is increasing. Global water's stable supply, quality, drainage, wastewater, recycle, reuse, and other facets of water management are concerns dealt with on a daily basis by various countries (IWA Water Congress Korea, 2012).

The speaker for the World Water Congress (WWC) and Exhibition illustrates that the population increase, globally, will be phenomenal. The projected numbers indicate that in the next 40 years, the population in urban centres alone will increase from 2.9 billion to 6.3 billion.

This is equivalent of creating a new city every week similar to that of Beirut, Kuala Lumpur or Prague. This is stressed on as increase in water demand goes hand-in-hand with population increase.

In short, the WWC wants the world to change its approaches to provide sustainable water supply. The WWC advocates the use of new technologies to improve supply. The major impact of increased population presents a problem for people under the poverty line and on top provide access to increasing number of people who come into cities. Hence, sustainable options need to be adopted.

Desalination is one of the most sustainable options for large urban cities located on the coasts. Busan is a city in Korea that is set to launch the world’s largest desalination project reverse osmosis plant. The water produced by this plant will be double the standards of all the other plants, for water treatment and quality. The benefits of saltwater reverse osmosis include treatment, renewable water resources and can be used in regions where long-term water stress due to climate change can be dealt with efficiently. Although the RO requires multiple steps to produce water it is considered safe and efficient.

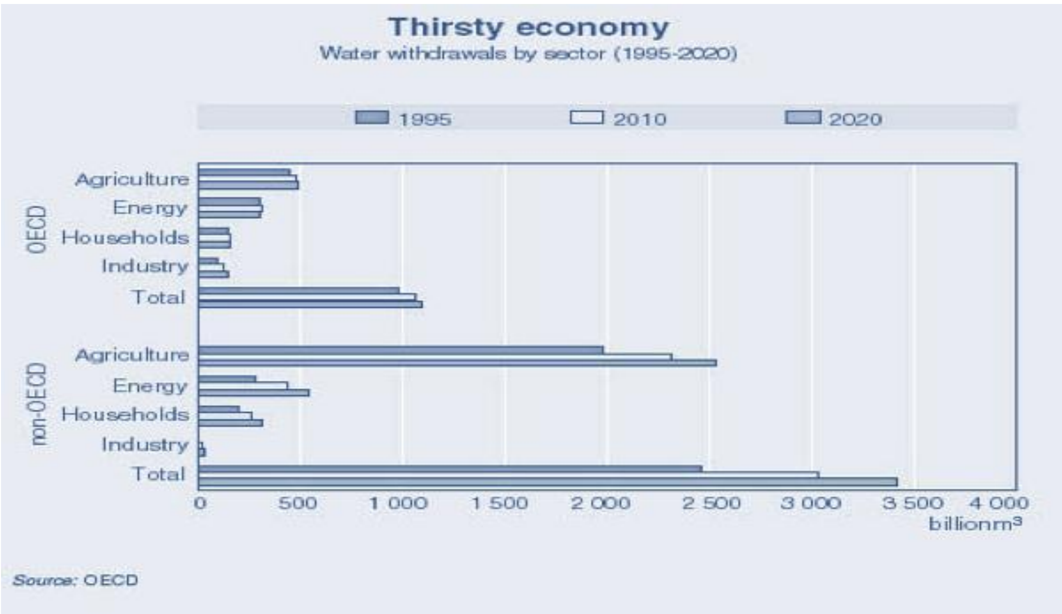

Figure 7 Global Water Demand

Source: Compiled from OECD

Figure 7 shows multiple uses for various years and indicates that the water demand has increased over the years. The future water solutions of arid environments may lie in the desalination of sea or brackish water, rainwater harvesting or the recycling of wastewater. In short, in urban areas including China and India, the demand for water has reached an unprecedented level where the urban populations are not supported by the natural reserves and the countries are seeking alternative means to attain security (WHO (Quality Guidelines), 2006).

2.5.3. Distribution Management

Water supply through various mediums is an integral part of the distribution system. The major elements defining the distribution system fall under institutions, organizational structures and project operations management of the water supply. The distribution system itself consists of pipes, valves, service lines, meters, pumping stations, storage, pressure tanks and fire hydrants. Efficient operation in order to supply water via the distribution network is known as the distribution system function.

The major functions of distribution involve: excavation of trenches to install shoring, maintenance of pipes, valves, pumps and equipment, installation of tap and connections to mains, meter reading, detection and repair, identification of hazards to the environment, along with records and maps, and control of cross connection/ illegal withdrawal or Non-Revenue Water (NRW) etc. One properly allows for easy provision of information, enhanced complaint handling and progression of rules for safety and management. Consequently, the supply of water will be smooth if the distribution units are handled in an efficient manner. Added to the focal issues is Climate Change. Climate change may induce reductions or increases in water flow through the distribution channels, it may also cause damage to the system during extreme events such as tsunami and hurricanes/ cyclones and it induces water insecurities and management issues (EPA - SDWA, 2012) (IPCC, 1997) (Heiland, 2009) (Mildhem, 2010) (Anand P. B., Right to water and access to water: an assessment, 2007).

2.5.4. Demand-side Tools for Adaptation

Demand increase in all sectors is expected, yet many policies are skewed towards increasing supply rather than managing demand or conserving water. This is achieved by increases in infrastructure, developing national and international transfers, and increased use of groundwater. The quantity supplied needs to remain at a constant level while demand needs to be managed to suit existent supply. This was strongly supported by GWP in their water demand management research, the Mediterranean Experience, in the year 2012 (Thivet & Fernandez, 2012). This research indicates that the major aims of IWRM for water demand management should stabilize water demand, reduce losses, misuse, increase value added per cu m of consumption, endorse IWRM for surface and ground water resources, achieve MDG's, promote education, cooperation, sustainability and participation (Thivet & Fernandez, 2012).

The demand side management for the present study looks at elements such as quantity, circulation of resources for activities, consumption, water use practices, water loss and wastage (Thivet & Fernandez, 2012). The other issues include leak, water-waste, runoff and pollution. Leaks in pipes and tubes occur while extracting and after extraction. GWP (2012) indicates that management of water waste during supply is a much-needed aspect of demand management. Leaks, pressure, repairs and enforcement of policies are vital aspects of technical demand management. Water is wasted washing, car cleaning, running water tap while doing laundry or washing dishes is also part of water use and conservation.

2.5.4.1. Quantity of Supply

Quantity is always measured and found to be deficient in most Asian, African and Oceania regions. The ground water requires development of water facilities such as: bore wells, tubes and sumps to extract water out while surface water resources can be directly extracted with vessels.

Water quantity refers to the total amount of water resources available and ready for supply. Some important facts about water supply and demand extricated from the World Resource Institute, WHO and United Nations (UNICEF & WHO, 2012) are the significance of the source of water supply, which comes from circulated water and used by humans, but there is no fresh source added or created. About 35% of the agricultural withdrawals are unsustainable. Water production loss is high and mainly due to leakage, theft and inadequate billing practices up to 50% in developing countries and 30% in developed nations (UNICEF & WHO, 2012). Similarly, Krishna (1989) indicates that developing countries keenly feel the lack of water resources and will be soon be unable to meet industrial, urban and rural water requirements. Eventually all countries will need to face water scarcity issues such as lack of water to help meet demands of population growth and, the water scheduling and rationing or restrictions on water supply during the day. Water policy and politics require change to bring control, balance the imbalanced in its efforts to achieve water security and climate change adaptation to handle crisis. Industrial withdrawals are expected to increase as well. Hence, the demand for water is increasing. The source is the constant that has been iterative and unchanged from the natural reserves. Since the 20th century, the global population has tripled, and the water use has also become six-fold higher comparatively. Tools of water demand management are technical, economic, regulation, planning and training and awareness.

2.5.4.2. Planning, Training and Awareness Tools

Coordination and planning are major tools that are used to enable all stakeholders. These are the vital aspects that drive water demand to be more stable and secure, and work locally and nationally. Local planning is vital within a centralized or de-centralized frame, depending on the area of interest being a catchment, aquifer, basin or a sub basin urban ward. The following are important aspects that are necessary for any water management unit to understand: 1) Appropriate boundaries are needed with stakeholders to monitor, mediate and plan the usage, policy and status of resources; and 2) Water agencies need to understand that their ability to know user behavior, to be aware of user needs, to maintain a level of transparency, and to control and be the regulatory experts, establishes their cogency in management of water.

Planning also requires knowledge about water resource and availability. This is an essential tool to assess the water balance. To manage urban waters, researches indicate that the more people get involved personally, the more effective and collective management becomes. Two good examples of planning and coordination for basin or urban water management are Morocco and France. Both countries have adapted a coordinated participatory approach with user involvement in the decision. Evidence shows that this has helped adaptation and demand management. Water saving and water pricing tools have become very effective in this region due to extensive public involvement (Thivet & Fernandez, 2012). However, urban regions like Algeria and Tunisia have issues related to the effective establishment of planning tools and participatory approaches. The asynchronous political drive to improve the decision makers makes it harder for this region to enable effective use of planning tools. The difficulties that these regions experience are based on ineffective integration, decentralization and coordination. Thus, each region requires careful planning and communication in an effective manner to successfully implement planning and coordination as a tool.

2.5.4.3. Economic Evaluations and Tools

Economic evaluations, according to GWP, suggest that water demand management is more viable and cost effective in urban centres. GWP research conducted a cross comparison of cost effectiveness among ten countries. The results of the study indicated that when yield is low the effective demand management strategy that was viable was leak reduction within the distribution units. Furthermore, demand is a constantly increasing factor and the solution to control overuse is to provide less water at a higher price. This effectively controls the users and reduces overuse. The cost effectiveness of water demand management includes direct and indirect costs. This roughly includes water saving from distribution equipment (households), leak repairs within drinking water mains, pricing water, restoration of groundwater, pumped supply, desalination plants (if any), general reduction of leaks (residential), and rainwater harvest. Thus, the SWP study indicates that the cost effectiveness ratios measures contribute to water saving and help secure water for future users.

The developing nations often face water shortage without resources to handle crisis. The developed countries, on the other hand, are able to pull in funds to research water technologies and reinstate new policies for water management to overcome stress or scarcity related problems. However, unlike the developed countries the underdeveloped countries have issues besides the scarcity, which impact on the local policies, water research and technology use (Das, 2007). Costs for infrastructural implementations are high, for example a desalination plant can cost 9 billion (Tamim, 2006). The price of water supplied from a desalination plant will be very high. The urban poor may not be able to afford an increase in water prices.

The major economic tools used in urban water management are pricing, quotas, subsidies and taxes. These tools effectively help reduce water loss or water-waste. They create incentive and prompt positive consumption related actions. Price structures are not being modified to create water saving. Morocco for example has a progressive charge or incremental block pricing that is based on volume. This reduces water waste compared to their special rate where annual rate was MAD 30/ year. The new rates charged were a little more than double MAD 30 to MAD 72/ year (Thivet and Fernandez, 2012). There was also a 3.5% increase in price rates for industrial use. Researchers used pricing to determine scarcity in Morocco. If water resources are scarce, raised prices will not help conserve or save water, but will be an indicator of water scarcity. Demand is vulnerable to price increase, as drinking water is essential. This is when alternative resources such as underground water use, network distribution of untreated water for domestic activities and rainwater harvest become more viable to households/ consumers.

There are millions, as UN and WHO suggests, without access to clean water resources. The public supplies in most countries range between USD 0.15 cents to USD 5 dollars for 1-meter cube of water. Increasing prices of public supply is considered an issue as many more water poor HH will be created due to affordability. If water were priced as a commodity and an economic resource (for which demand is high), then most people would not be able to afford even 40 litres of water (Butler & Ali Memon, 2006). Author indicates that US pricing structures are decreasing block, increasing block, uniform, flat fee and seasonal. The water suppliers have many structures of pricing (Tortajada & Joshi, 2007). A variety of issues affect the price. The underlying issues such as: corruption, lack of information, illiteracy, lack of awareness, avoidable social stigma etc., also need to be addressed in order to price resource correctly. Authors, Tortajada & Joshi, (2007) indicate that water consumption is priced in an incremental manner, a usage of 180 lpcd per capita consumption is billed high. While US and other Asian states also price in an incremental manner, the billing and billing cycle is different. US uses price conservation methods as well as increased tariffs for public sources. But sources indicate that out of 230 countries, only 116 have changed prices of public sources. Hence, indicating that most countries are aware but are not ready to increase price of sources. To manage water prices and infrastructure costs, the governments have hence introduced the public private partnerships (PPP).

Thus, economic tools play an important role and can be catastrophic, if national interests, policies and user incomes/ poverty levels are not considered.

2.5.4.4. Public Private Partnerships for Projects

The PPP concept has not functioned well in various countries. Several instances of improperly implemented PPP serve as a guide for future implementations. The Dar es Salaam water system in Tanzania, Stockton Municipal Water Utilities in California and the Hamilton Wentworth water system also were well-known PPP disasters [Canadian Dimension Magazine, 2006, Eurodad, 2008, Global Water Intelligence (GWI), 2003), GWI, 2003]. According to the Canadian Dimension Magazine, citizens suffered through disastrous privatization of water and wastewater treatment. The issues started when

Phillips in 1994 took up a contract to complete a wastewater treatment plant (The Hamilton Wentworth Water and Wastewater Treatment Plant). There was waste and sewerage flowing into the harbor. The environment was affected due sewer mixing with sea and flooding. Similarly, the Tanzanian water privatization project was a disastrous proceeding. The deal increased prices with little improvement to the supply and allocation. This made accessibility harder and the poor suffered though lack of water. The struggle increased as the poverty-ridden region needed to rapidly improve water allocation, in order to provide for the poor.

Thus, this indicates that PPP needs to be implemented with all care. The environmental impact and the social benefits need to be completely considered and, not just from a fully investment point of view.

2.5.4.5. Per capita Use and Domestic Conservation Practices

Domestic demand is estimated from just the residential use per capita. The residential needs as shown in the table require at least a minimum of 40 – 60 litres (in rural India) and 70 to 90 (in urban India). The use includes washing, bathing, flushing, washing / cleaning the house, washing utensils, cooking and drinking. Most important are the cooking, drinking, showering and washing utensils (WHO, 2006).

Table 6 Household Water Requirements in India

	Description	**Amount in Litres/ day**
1	Drinking	5
2	Cooking	5
3	Washing Utensils	10
4	Cleaning the house	10
5	Flush	20
6	Laundry	20
7	Shower	55

Source: Compiled from Punmia, 2011

Domestic activities including the domestic animal water need are accounted for in the structure, but the Table 6 only indicates the households with 5 members or less per day. The numbers in the table 6 denote the requirement per head per day. This breakup may reflect the maximum water requirement for an individual.

Most affected are urban Asia and Africa, as the sustainable development in these regions is lagging and large amounts of natural resources are misused and over 5 million die due to water related illnesses (UNDESA, 2005 - 2010) (UNICEF & WHO, 2012). Quality of water is as important as the quantity supplied. The wastewater, if not disposed in a proper manner, will contaminate one third of the global freshwater reserves by the year 2050. Industrial waste and contamination within urban populations can also degrade the quality of water. The paper "The top 10 of the dirty thirty", indicates the state of urban populations that have dirty water running through the cities and the worst pollution levels (gathered from the interview). Urban populations living below poverty line suffer the most as they are not able to access water resources at an affordable price and the government allocated water does not necessarily "reach" them. Chennai is considered to be one of the 10 dirty thirty cities with highly polluted river, Coovum that runs through the heart of the city. Many low-income workers of Chennai live along the edges of the river accessing the dirty river's water for domestic use. The supply of water for the demand needs to be clean. Contaminated drinking water systems can cause ailments or even death.

2.5.4.6. Use Efficiency: Supply and Use Efficiency

The UN (2000) indicates that the administrators and control actors need to be aware of the trade-offs and the resulting impacts. The study clearly states that the end-use needs to be efficient. However, the end- use efficiency is relative to the person utilizing water, the quantity and the purpose i.e., is societally related.

Changes in land use pattern are a functional aspect, whereby the source use and value is looked at while integrating use restrictions to influence water saving. The major aspect that stands out is the "more use per drop" concept, which tightens water use, and the initiation of it in the society will mean that water use efficiency increases. For example, when a 25 litre bucket of water is withdrawn through a pipe (connected to the source), there is the necessity to know how the water is going to be used and how much of it can be saved for other use. If plates need to be washed then HH need to identify the best possible method, with 30% or more water left in the bucket from bathing. Hence, efficiency is relative to use, and this can be determined by a trial and error method. The remedy is "to get more" through technology. The "to get more" notion induced a wave of engineering efforts to bring in the necessary technology, as the main way of adapting to scarcity (UN, 2000).

The other argument the author makes is to point out that water use is subject to climate and population expansion, which cannot be controlled. The other issue signified is the accumulation of overall ecosystem degradation and global warming effecting low supply. Within a conventional approach, the concepts looked at mainly relate to agricultural use and the food production area, within the conventional approach. Whereas, UN, 2000, gave water security a new approach for the 21st century. The new approach looks at and discusses all aspects of conventional approaches that could potentially be useful in solving the issue. Handling crisis situations can be hard but integrating all the approaches may still be a solution towards water security.

2.5.4.7. Consumption Patterns

The use or consumption pattern is based on social and economic factors including population, physiographic and climatic features. Asian communities have class- based, political and uneven distribution management that influences the ability to get easy access to water in a certain area.

The figures and facts show that, access to water resources is subject to various factors, the development level, the income level or the GNP, the population, the environmental reserves, the climatic extremes and the social pressures (UN Water, 2006), (United Nations - Special Summit on Water, 2012). In developing countries, the low-income users get less than 10 – 40 litres per day, while the per capita daily use in high-income areas is 100 to 400 litres per day per household (UN Water, 2006). Income levels often add discrimination to depravation; the physical availability and climatic extremes play a vital role in enabling access to people. Affordability is important because it enables access to water resources, despite the climate, social lifestyle or physical availability. For example, in Asia, many communities buy water in bulk and share it. People who do not pay do not receive water and hence, affordability plays a large role in water security.

The amount withdrawn is not the same as the amount consumed. The global annual withdrawal of fresh water in 1995 was 3790 Km3 and in the year 2000 it was 4430 km3 (Grid-ARENDAL, 2008). On the other hand, the consumption levels varied from 2,070 Km3 in 1995 to 2,304 Km3 in 2000, 61 percent and 52 percent respectively

(Grid-ARENDAL, 2008). The future global water withdrawal is expected to be higher than the consumption rate, which in turn will increase with global development and growth (GWP, 2011; UNEP, 2009; GRID – ARENDAL, 2008). The annual growth is projected to be about 12% while total withdrawal is expected to be about 5240 Km3. In 2007, the global freshwater withdrawal was at 57%, while the Asian water withdrawal was 70% of capacity. In future, a growth in the annual global water withdrawal is predicted to be about 10 to 12% per decade (GWP, 2011; UNEP, 2009; GRID – ARENDAL, 2008). Consumption is expected to growth at a slower rate than indicated in the past. The consumption rates between 1995 and 2000 have not increased very much and this is due to the reduction of rainfall, increase in population and mismanagement of resources. Consumption and withdrawal rates are as shown in Figure 2 (GRID - ARENDAL, 2008). The overall global consumption rates will increase 1.33 times a year by 2025 (GRID - ARENDAL, 2008). Future decades indicate that African and Asian withdrawal rates are intensive, and the increase is expected to be about 1.5 times. While an increase in withdrawals and consumption according to (GRID - ARENDAL, 2008), is about 1.2 times.

Although, there is a huge demand on the water table, it is necessary to consider the overall aspect and include the usage behavior of people, the climatic conditions and the physical availability of renewable resources.

2.5.4.8. Supply Demand Deficit

Supply and demand gaps and consumption levels make up most of the factors influencing the security of a region. The figures GWP, (2011) & GRID - ARENDAL, (2008) indicate the changes in supply for different river basins. The projections indicate values for 1995 and 2025 where the absolute value is just the same, while distribution and allocation is rearranged (GRID - ARENDAL, 2008). The uneven distribution of water and human settlement continues to create problems due to development and increased use of freshwater resources. The freshwater availability and accessibility reduce by the day due to the growing uses. The denser the population the harder it will get to supply the required amount. The increases in population also may indicate that the amount of water requirement doubles or triples every few decades, in effect due to changing technology, climate and requirements of daily life. The GWP (2011) and GRID – ARENDAL (2008) indicate that below 1700 m3 per capita is understood as stress and anything below 1000 m3 per capita is considered as scarcity.

Countries like Somalia or Rwanda face water stress but they are not water scarce. Kenya is a country also on the other hand that has been declared water scarce absolutely. Shortage of water is the absolute level where the available water does not meet the basic requirements (African Water, 2010). The factors affecting scarcity are different per country and thus, minimum requirements are different. A country like Somalia faces stress; this is not scarcity. On the other hand, parts of Asia have plenty of rain, yet do not have enough water to satisfy demand. This scarcity is based on supply-demand management. Countries like Kenya, Saudi Arabia etc., have been declared water scarce due to physical lack of availability and extreme climatic conditions. Thus, the difference in categorizing scarcity is based on climate change and trends in a particular locality and availability of water (Groisman, 2010; Gleick, 2010).

Multi sectoral demand further reduces the water available for human consumption. In addition, GRID – ARENDAL (2008) indicates that South India, Middle East, South Africa, East Africa, North Africa, Australia, West and Central America, and a portion of South America (Western region) are water scarce in the year 1995 and the illustration indicates that the stress is going to increase by the year 2025 (GWP, 2011; UNEP, 2009; GRID – ARENDAL, 2008). Stress and scarcity drives extraction levels.

The consumption and extraction levels of water per sector signify that the agricultural sector uses much more than Industrial or domestic sectors (GRID – ARENDAL, 2008). The interesting fact is that water withdrawal i.e. the extraction of water resources from source to supply to consumers, is not always the same as consumption.

The increase in consumption is known, but the concern is on the difference between amounts extracted and actual usage. With an increase in withdrawals/ consumption, comes an increase in water stress. The amount of water that is extracted can be used, recycled, reused and returned to source. The extraction level indicates the amount of water that can be drawn, with excess recycled or drained into the sea. Arguably most findings indicate not all of the excess / surplus water goes back to the source (GWP, 2011; UNEP, 2009). It is disposed into the sea or stored at the reservoir. Water loss after extraction is often attributed to exploitation, loss of water through evaporation (negligible amount), runoff into the sea or loss due to contamination after extraction. Hence, water use management is needed to channel as much of the water extracted back to the source.

The global water withdrawal to consumption levels indicates that the domestic sectoral water extraction was on par with the consumption level in 1900’s, while in 1950 the extraction and consumption gap increased where the consumption became less than 50% of the extraction. Furthermore, consumption levels in 1975 and 2000 implied while the extraction was very high consumption was still very low. There was only about 10 to 20 percent consumption of the extracted sources. According to the SWP, the predictions for 2025 indicates a very high level of extraction, while consumption does increase but will still be about 10 percent of the extraction level (GWP, 2011; UNEP, 2009; GRID – ARENDAL, 2008) only.

Extraction level is based on water demand and it is very different per region. Consequently, water needs, and availability are different per region, topography, population and sectoral requirement is variable rendering sectoral usage, scale of usage and population. It is possible that water resources will become non-renewable in future with the extent of use or abuse (Johnson, 2006; UNDESA, 2005; Groisman, 2010; Gleick, 2010). The need for luxuries has also increased over the years i.e. computers, water recreations, sports etc., also require enormous amounts of water. Hence, changes in lifestyle have tremendous effects in the way water is consumed. The way water is consumed also influences the water loss.

2.5.4.9. Water loss and Wastage

Water loss, waste and inefficient use of water is one of the major problems faced by countries. Water loss for households is related to inefficient supply, bad governance, distribution system, unfitting policy, lack of investment into water infrastructures, building institutions and supply and demand management (UN ESCAP, 2010).

In Asian countries 30 to 70 % of the drinking water is unaccounted for. Much of the water accounted for is wasted by inefficient water use by households, industries and agriculture. This is due to unenforced policy and uncorrected wastage and inefficient use also creates issues that can impair the water system in an unreversable manner (UN ESCAP, 2010).

The poor pricing policies, which is considered unnecessary for the elite and middle class, as they are able to spend money on water resource without any issues also influences and aids the inefficient water use. The poor people need subsidized water resources. They do not have access to piped water resources and end up paying twice or thrice more to buy water for drinking and cooking (UN ESCAP, 2010).

To minimize wastage of water and increase efficiency in water use pricing needs to be done properly. The real cost of providing water includes service and the actual production. To introduce pricing policies for water, the system needs to recognize the basic needs for human existence and on the other hand, waste and inefficient use needs to be charged individually and increasingly. This would be more ecofriendly and enforce use efficiency among households in a community.

Progressive pricing policies would increase funding for the system. Financial resources available can be invested rehabilitating and modernizing water infrastructures. Moreover, funds secured through policies for pricing, allows room for investments on water development and infrastructure. The government must in this case make efforts to improve the water loss situation and lessen wastage, infrastructures and management. Pricing for public and private society will reduce unaccounted water (unmetered water supply) and wastage of resources, increase security and conservation and promote reuse.

The global utilities of water and the mismanagement list can be very long. A balance can be maintained only through efficient use and bringing improvements to the water management systems (van Hofwegen and Svendsen, 2000). Most available fresh water sources are directed towards agriculture and food production processes and hence, reduced water availability for other sectors will cause nexus of problems within various sectors. The agriculture sector consumes more than 70% of the water supply, at a global scale, while Industry consumes about 20 percent or more, leaving about 5 to 10 percent for domestic use and other uses. Water shortage is always felt in many ways. Thus, countries cannot claim that everybody has enough water supplied to them.

The demand for global agricultural needs will be doubled in the next 30 years, while it is easier to realize water through ground water resources; it is becoming harder to maintain recharge levels. Moreover, a vast quantity of water is used in making silicon chips for computers and cell phones. A large amount of water goes towards power plants and running the economy of the country. Today, there are factories, food-manufacturing industries, and human domestic activities that require copious amounts of water. Books, encyclopedias, magazines, newspapers and public remain constant in noting an increase in population versus an increase in demand for natural resources regardless of the carrying capacities of the regions or the agro-climatic statuses. Multiple researches have attempted to create models that increase water use efficiency and help the water poor as an attempt to increase water security (EPA. 2012, GWP, 2011). With increasing demands, the probability is that any attempt to improve use would be futile. Future requirements will include research on water security, identification of source, system, and several small-scale pilot studies to determine need for centralized management and accelerated enquiry on the system-based issues. Water supply and demand balance is not optimal for most regions in Asia. The research inadequacy lies in the comprehension of major issues impeding proper policy interventions, to undesired policy responses. Integrated water management in Asia is a requirement, which can induce proper policy interventions to secure and sustain water resources.

Table 7 Factors Affecting Demand Rate

Factors affecting Rate of Demand	**Use and consumption level**
Size and Type	Smaller communities – smaller rate of use due to limited consumption
Standard of living	Higher standard – higher demand and variation in use
Climate	Hotter Climate – more water use for bathing Colder climate – increased toilet flush use to prevent freezing of pipes
Quality of water	Poor quality – lower amounts use
Pressure in supply	Higher pressure – increased use
System of Supply	24-hour supply – more consumption
Sewerage	Installation of sewerage – increases the water use
Metering	Metered supplies – decrease the use
Water rates	Increase in rate – decrease consumption
Age of community	Older – decreased use as the communities are more stable
Pools	Pools – increase use – improve conservation through storage
Lawn sprinkling	Enforcement of sprinkler – decreases water use

Source: Punmia, 2011

Table 7 indicates certain factors that impact the water requirement. As the average water consumption varies from one city to another, certain activities requiring water needs to be planned properly. The figures vary between 50 to 150 litres per head in a family for personal and drinking purposes while, cleaning, lawn watering, pools etc., entail new items on the list for water demand.

Pricing natural resources is a tricky if not impossible concept in developing nations, due to the heavy subsidization of costs for the locals. Generally, the water poor and people below the poverty line are affected more than others. UN indicated that before creating access it is necessary to understand affordability. For a community to be able to afford the water service or resource, it is necessary to see if the unmetered water loss is high. When unmetered water losses are high then a portion of the community is not able to buy water through metered source. The UN indicates that about 5% of monthly income is a high amount to be spending on water resources, for a family living under the poverty line.

The US Environmental Protection Agency identified median income for households and measured the level of compliance to water regulation. The weak correlation to the income and the expense on water can only be detected when the water costs are increased. Hence, this system of monitoring may not function well for a society with subsidized water costs. If the US EPA measures the increase in non-metered water use level against the percentage of income used for water expense, within the low income a waste may be easier to detect.

This study suggests that the median income household measure indicates if the households are at a risk of being unable to afford water. Income, poverty areas, poverty are the three indicators of affordability. On the other hand, the study does not consider the non-metered use of water resources. The argument is that, it could mean people with high income use wells and other unmetered access points. A further survey must indicate the point of access, use level, whether metered or not; it must also indicate household income level and what percentage of the income is used on water.

The EPA compared the regions for water use and urban areas at economic risk where the income level may not be a strict issue. The low-income areas that are highly populated are at risk due to the percentage of the HH income spent on water being higher than 5% of the total (EPA, 2012)**.** The affordability analysis needs focus on the local level water systems that are at risk. This means the urban poor must also be considered. For example, when there is economic crisis, like say inflation by 8%, the rich will not be impacted so much as the poor, who find that drinking water prices are now

$10 USD rather than $9 USD, where their income ranges between $110 to $200 USD and then must spend the extra $0.8 USD to get water. Inflation and the increase in demand increases the water stress to feed population and this is felt keenly in urban regions. The costs of receiving services are also an important factor in affordability analysis. In addition, the analysis should rely on specific data for water systems, costs involved, and compliance costs, while also looking at issues such as poverty, water poor and the availability (EPA, 2012).

Interventions in water system are needed to meet demands. The environment too needs to be altered to fit the demands of locals. In order to be able to face challenges and changes i.e. climate change, land use pattern change, deforestation, contamination of water, endemic/ epidemic etc., policy is altered in such a way that the after effects of interventions are minimal. The negative effects may be environmental, social or economic or all three; the major impact is on the downstream water users.

2.6. Achieving Water Security Through Governance

Various civilizations right from the 4th century BC have been managing resources with techniques that were prudent to the changes happening during the time period and when needed. Water resources have always been managed rather than just used and hence, the globe is essentially just facing a turn of events in terms of availability of water resources due to climate change rather than facing something new and unknown (Huitema, et. al., 2009). A disciplined manner to approach water security would mean gaining control of the anthropogenic activities that cause scarcity. UNEP, (2012), indicates that the measures to improve security lay in the way anthropogenic interventions are managed within the water system, to meet some or all of the social, environmental and economic goals. Too many of the developed and developing countries' major interventions denote a societal change that may or may not be enforced by the local authorities or policy makers.

The Urban Environmental Management approach deals with large cities' management of water, waste, air quality, etc., to maintain a sustainable level of resources within the system[2]. Poverty is one of the causes of major environmental problems and 'water poor' among them will increase drastically due to their income levels, affordability to pay for resources etc. Water poor generate allocation issues with the poor

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[2] System here refers to the management body, ecosystem, actors and stakeholders good

versus rich dilemma within a large city. Although this approach contributes to the generally water poor, it does not integrate other sectoral issues, decisions and changes, which may lead to probable unrest in the system. Major complaints for lack of water come from the poor and the main causes are attributed to the poor governance, poor management, poor enforcement, bribery, social stigmas, participation and manner of adaptation (Huitema, et. al., 2009).

Elements of adaptive governance include: Accountability, Reliability, Consistency, Legislation, Awareness, Information, Institution, Policy, Organization, Expertise and Planning ((Huitema, et. al., 2009); (SOPAC, 2013)). Policy, awareness, reliability and planning tools play a significant role in aiding adaptation and security. Policy is defined as the proposed course of action. It can also be termed as the basic principle that guides the governance and government. It is often formulated and enforced by the same organization based on social, economic and environmental needs. The policy making process is iterative or cyclical in nature with analysis of proposed action, review of inclusions, impacts review, alternative options, feasibility of the project, approvals, implementation and further analysis for improvement (SOPAC, 2013).

Policy proposals cannot be acted upon without proper thought or processing of information. This phase is called the planning phase, which is very vital as it necessitates careful thought, input, reliable sources, and accountability of managers, consistent information, and expert handling (SOPAC, 2013).

Accountability reflects the answerability, or the responsibility taken up by the organization or the person in charge. The organization or the individual needs to show the significance of the policy statements and the ability to take responsibility to complete the task without a problem. In the event of crisis, this person or organization is able to take a stand and lead. Leadership and political power use are also part of accountability. A working definition of Accountability is the ability of the organization to lead and handle problems in a responsible manner that is beneficial to the community, the economy and the environment (SOPAC, 2013).

Expertise is defined as “the knowledge-ability” of the organization, the decision makers, or the stakeholders. The availability of information, access to information also plays a vital role in expertise (SOPAC, 2013).

Consistency is when there is consistent progress in management. The decision makers need to have consistent information and need to make consistent progress with every change in policy. Reliability is the ability of a community to relay dependable information, decisions, expertise etc. For example, the decision maker needs to be relied on for information, good decisions, and trustworthy evidence (SOPAC, 2013).

Awareness and Information: Awareness and information are entwined, as awareness is created with information provided to the public. The RTI for Chennai, for example is an excellent instance of providing information to the public. The RTI essentially influences the authorities, the policymakers and the organization to post relevant and vital information on the bulletin for perusal. Hence, it hopes to create responsiveness, understanding and "knowledge-ability" within the society (SOPAC, 2013).

Legislation is the process of law making based on the proposed policy and plan of action. Legislation is the process of enacting edicts by the legislative body. These edicts are passed as bills within the legislative assembly. For example, the EPA's Safe Drinking Water Act (SDWA) ensures the quality of water. This law was passed in 1974 by the congress to protect public health (EPA - SDWA, 2012). The American drinking water SDWA sets the standards. The state, the localities, the communities and the suppliers follow these standards as law (EPA - SDWA, 2012). These are regulated and managed by the public health management bodies within the legislative system. The amended law (amended in 1986) regulates the sources and the supplies. Rivers, lakes, etc., are all managed under the same rule or institution.

Institution or organization refers to the body or establishing within the legislature, the information, the communications, the bills, the proposals, the funding and the development plans for policy. There are national, state and international organizations within a country.

Governance is rather vague as it can be defined based on functional needs and the considerable sources. The concept is defined for this research as the process through which the actions are taken, monitored and changed within a system of interaction between organization and legislature with an ability to create and implement policies for the communities' interests (Huitema, et. al., 2009).

There are several frameworks and approaches to achieve adaptive governance. Within the IWRM an integration of the key approaches and frameworks will benefit all the sectors and community.

2.6.1. Integrated Management Approaches

Integrated management approach is integrating different approaches to customize the solutions for each region. It is important to understand that not all sectors face the same issue, albeit it may relate to one impacting factor, but the results may vary. An integrated approach combines conventional ways to create a better solution.

There are three ideas conveyed by UN (2000), relating to the conventional approach. 1) The first is the domestic regulation of and withdrawal of water from source and more intensive use of that water. Use needs to be restricted as the amount of use required for industry, agriculture and domestic purposes can well mean that there is less for nature and the ecosystem. This resulted in the improved access functionally within the society. The develop-supply-use paradigm denotes that the quality and quantity of water was fast degrading. 2) Land use, management and climate change determines the water in-flow. Intensified production implies increase in consumption of natural resources. Hence, less water is required to recharge aquifers. This means that there is specific divide of the rainwater. 3) The societal efforts and the user are needed to manage water intensively and also to manage facilities and service development. The major difficulties of coping with the available quantity, quality and vulnerability add to the cost of building structures and the management of water conflicts between "end users". The vulnerabilities are yet to be addressed by implementing policies that allow management of foundations.

2.6.2. Domestic water management

Domestic Water Management is a good approach for water security at a household, community, national and environmental level to create reliability of source, resilience to disasters, and improvement of environment to enjoy healthy water sources (GWP, 2011). Hence, the goal here is to achieve security within water scarce or stressed regions, efficiently. The reduction of economic vulnerability also needs to be considered as infrastructures and interventions are managed through the economic management method to manage flow against time, where reliable flow of floods indicates a threshold of permissible water level and maximum flow is the quantity that is surplus to the allowed amount of water. Economic vulnerability will also impact society in the event of droughts. Water shortage is experienced by all regions including Asia or the US, depending on the drought management for availability, funding etc., (Stedman, 2012). The US has faced water shortage since the mid 1990's and the report indicates that about 1000 rural communities are impacted and in some cases security issues became worse than in developing communities. The report, by UN (2007), describes several levels of scarcity, namely: absolute, life threatening, seasonal, ongoing, cyclical and temporary. To overcome these threats, the Millennium Development Goals address several water scarcity problems and have set standards of achievement to increase accessibility, equitability, quality etc., (Cook C. B., 2012; (UN - Water Final Report, n.d).

The domestic water management will also include plans for reduction of degradation due to use of surface and ground water for human activities and domestic wastes such as building, infrastructure etc. The conventional way of approaching water resource focuses more on the amount and the flow towards water bodies in a centralized manner. The problem with this approach is that no one community has the same water issue as another, unless they share a river basin.

Surface and ground water are the direct access points for use. Ground water is more easily accessed, as it is a point access rather than transportation from source through pipes, which is the major means of water conveyance for urban societies. This implies that ground water is more likely to be illegally exploited and freely available at any location, as long as there is water available underground. It is very hard to meter or charge ground water sources unless all the wells and tubes are accounted for.

Understanding threats to water resource that may be due to climate change or via anthropogenic activities is vital, as these threats may impact the quality and accessible quantity for the community. A good governance lesson from the US water policy is the SECURE Act. The SECURE Water Act in the US includes a report prepared by the reclamation fulfilments that address the elements of 9503, part (c), indicating that the success to water management would require assessment of threats to the supply system, improving knowledge level and mitigating adaptation for security (SECURE Water Act Report to Congress, 2011). The short report includes the global change effects with respect to the quality of the water located in the river basin reclamation area; the impact of global climate change; mitigations and adaptation strategies implemented with close examination of each of the impacts; and survey and date assimilation by U.S Geological

Survey (USGS), National Oceanic and Atmospheric Administration (NOAA), U.S Department of Agriculture (USDA), and/ or any of the state water resource agencies (SECURE Water Act Report to Congress, 2011). The key issues as mentioned above are brought out or highlighted by the population growth, unsustainable consumption patterns and uncontrolled use and waste of water.

The water management included in this act reports on population, pollution, governance and climatic variations. Most studies including carbon emission and water security risks of extreme climatic events include regions that may potentially become water stressed and eventually resource scarce. The Secure Act uses the governance approach to understand issues and manage variations through adaptation strategies or technological advancement.

2.7. Adaptation to Climate Change

Adaptation includes methods and indicators that help deduce the best techniques to handle climate change impacts and patterns of vulnerability, and how to build adaptive capacity. The next step includes an improved system for mitigation of risks and then mechanisms that are specific to the communities, including the poor. The adaptation also involves looking into the finances of the state to handle risks specifically to manage climate change related risks. A key to adapting includes systems of data sharing and warning. The system of disaster reduction or prevention or fast recovery includes programs and projects to educate, to increase technology and to manage schemes efficiently. Especially, the risk management in water sector, particularly resilient management approaches and adapted design and management for every focal point within a region are vital. Focal points within every sector need to be understood and managed. Some focal points are economic systems, diversification and local community acceptance, appropriate levels of communication through experience sharing, policies and migration levels. Finally, two important aspects include professionalism and networks needed to hold the government, NGO's and private sectors to use existing knowledge and to devise good plans to implement to reduce risks or prevent further impacts. The second would be activities that could promote practical and simple actions such as shared perspectives in global issues, actions for a particular country and climate of the region in response to the climate change with consensus.

Adaptation to climate change is often strained among the developed and developing regions. Developing regions are stretched for resources and the growing population in the countries disallows the poor access and are left helpless and hapless. The hurricane Katrina produced a lot of difficulties in the year 2005. From the years 1963 to 1992 there have been various impacts in different regions in Asia. There have been 130 floods and 6 droughts. The Americas had 35 floods and no droughts, Europe 10 floods and no droughts, Africa 19 floods and 15 droughts, the Caribbean 2 floods and no droughts, and the Pacific had 6 floods and no droughts. Due to these floods and droughts there have been famines in Asia and Africa alone while the rest of the world provided aid to support them. Besides floods and droughts there are tropical cyclones, rainstorms, earthquakes and landslides seen in the continents.

The issues including some that have historically been applied to developing regions have been taken for granted and the scale now has been underestimated. For example, the intensity of typhoons may not be the same as it was in the past. Of course, there are a few regions that can claim climate change has always been impacting the region with similar intensity every year or once in five years. This entirely depends on the region being considered.

The poor are unable to respond to the climate change in anyway. They do not have the power and neither do they have a voice. The poor do not have the privilege to use natural resources or other resources, yet in turn they are blamed for all the issues around the world. While the poor do contribute to the population growth, they are not the sole cause.

Unexpected events such as earthquakes or tsunami give less time to prepare. Responses to events have to be prearranged and are hence difficult if states just start to recognize the importance of crisis management.

2.7.1. Case Studies and Major Strategies for Adaptation

The major adaptation strategies considered while combating climate change related impacts are to increase income, education and technical skills, the public availability of food, preparedness for disasters, and health and sustainable development.

Adaptation involves change is policy for certain aspects of water management: public- private participation (PPP), quality, zoning, conservation, flood control and management, land erosion, drought prone area development, monitoring projects, distribution (inclusive of state and local), ground water development, drinking water supply, irrigation (integration of water use and land use policies), resettlement and rehabilitation, financial and physical sustainability, participatory approach, information system, resource planning, institutional mechanism, allocation priorities, and project planning.

Cases of Climatic Extremes and Successful Strategies:

According to Liu, (2007) analysis suggests that drought is related to the large-scale changes in climate across the Indian and Pacific Oceans, including the recent La Niña, a weather phenomenon in the Eastern Pacific. Furthermore, a 2006 drought in Southern China left about 520,000 people in water scarcity and caused a large amount of crop spoilage. Liu (2007) states that drought affected the areas in mountainous Guangxi region on China's southern coast and nearly 102,000 hectares (254,000 acres) of crops were damaged, causing a loss of more than 400 million RMB Yuan (US$50 million). The worst drought hit China's South- western city of Chongqing, situated along the upper reaches of the Yangtze River. In 2006, between June 1st and August 14th, the whole province had a rainfall level of about 287.1 mm, about 103 mm less than the median rate. Within the 35 days from July 10th to August 13th the temperature rose to about 40 degrees, 13 degrees above normal, setting a modern temperature record (Liu, 2007). The financial losses were huge, reaching to above 8 billion RMB Yuan (US$1.04 billion). Apart from the financial losses, there were about 8 million locals without continuous access to water resources and 2 million hectares of farmland damaged. 18 million people felt the lack of drinking water (Liu, 2007). This is a good example showing increase in temperature, where management of water is a little skewed and requires a strong administration/ enforcement of policies. The solutions to such problems are yet to be simplified and implemented in a successful manner. There were a number of sophisticated monitoring of droughts and quality checks conducted in this region.

The drought in the Chongqing region raised climate change worries. Since then stronger warming in the North is seen. China has measured and monitored this warming through setup of 412 stations, and it is seen that the temperature has increased by about 1.2 mu degree C since the 1960's (Liu, 2007). The last decade has had the seven warmest years. The south of China is also warming, but at a slower rate. The winter warming as indicated by the journal article is four times that of the summer warming. The Author indicates IPCC projection that warming trends will continue, and will increase further up to 5 mu Degree C. There will be impacts on the water and agricultural production (food security) within populated cities in China. The contrast in increase of rainfall between N and S China and E china indicates variation that is brought about by the East and Indian Monsoons. Future projections, through a model, indicate that summer precipitation will increase in certain regions up to 767% above the mm of rain noted in 2000 – 2006. This model may not be accurate as to synoptic (cyclonic scale of rain and relative to high- and low-pressure rains) and orographic rain, i.e. in relation to the position of the mountains. This model may not be accurate in predicting the total rainfall itself that could possibly be triggered by pollutants. China initiated the setup of 355 stations, which are to gauge rainfall levels and also predict long-term trends. There is an overall decline in rain by about 12 percent. This is due to the weakening of the Indian Monsoons signifying lower rains also to the East Coast of India.

China faces major scientific problems and trends. Projections indicate that climate change may cause havoc in the N and S regions of heavily populated cities of China. China proposes to address this change through models that study the aerosol and chemical effects on climate change, complete stock taking of land and atmosphere processes, monitoring of water body conditions, enabling impact study on water resources and designing and implementing cost effective adaptations that can be enforced in an event of crisis, efficiently. The major concern is floods, as the rainfall level is expected to supersede all other years' rainfall measures. The risk increases due to the population density of certain cities. China intends to monitor and measure levels continuously, implement flood event planning and programs to help people during the time, provide aid for flood and drought events (Liu 2007) (Shilong, 2010). The reduction of rainfall and heat waves are seen in all part of China, except for Central China.

The Yangtze River basin that goes all the way to Vietnam has been researched and recently the UN has indicated that there is a general increase in the number of rainy days in the Southern region while the North and Northeast have low rains. The entire country will experience severe oscillation of climate with drought/ scarcity, heat waves and floods. Drought can be most severe in China as the source of water is reducing in quantity; there is 3,000,000 km2 of dry regions in China, approximately. In the past, severe drought hit china in the 1960's, late 1970's, early 80's, and the late 90's (Liu 2007) (Shilong, 2010). The NW part of China is dry and arid. In the past these regions have suffered lack of water and vegetation and surprisingly enough, the regions' rainfall level has improved and there is also increased vegetation as indicated by the author (Shilong, 2010). The main investigation that China is undertaking is to understand the trends and predict if there will be future droughts in this region. The results from the climatic models denote that the future predictions are not clear, and unpredictable extremes may surface. The IPCC climatic model indicated that the NE will dry up and the NW will have more rains, and this will continue in the near future for China (Shilong, 2010). On the other hand, Scenario B of the IPCC model indicates that the NE will not face drought for very long (Shilong, 2010). This could be due to the extreme heating cooling events bringing floods and droughts to parts of China, creating confusion in the minds of scientists.

China needs a new adaptation strategy, which requires information and knowledge spread and policy responses. The region also requires a study of past extreme events and the pattern of these events over the last century. The research needs to analyze the traits of events and impact and effect must be documented to plan for future, soil moisture level measure, the regional responses to adverse climate change must be understood and the extent and intensity of the hydrologic process impacting water bodies must also be considered (Liu 2007). The major adaptation strategies that have proven successful in other regions include the interception of rivers with dams and harvesting synoptic scale water for direct access for domestic activities. The river basin is large, and this means it can be channeled to create more water for the people in other parts of China with tubes, pipes and trench channels during floods or heavy rainfalls. The actual run off percentage may be higher than 80 and hence, there may be a threat of sea level rise for the highly populated coastal cities of China. As the author (Liu 2007) denotes, the runoff at Datong station measure indicates that is it is clearly induced by climate change and action must be taken if the intensity of this rainfall may increase in the future.

The country description of an island is a place having no land boundaries, only water. These characteristics are depicted in all of the Philippines, Japan, Malaysia and Indonesia. The Philippines has three major islands Luzon, Visayas and Mindano, with a population of 85.2 million in 2005. The Philippines climate would be termed as tropical marine with dry seasons from December to May and wet seasons from June to December. The annual temperatures range from 25 to 27 degrees Celsius and the regions suffer a minimum of 20 tropical cyclones every year. The observed increase in annual maximum temperatures is about 0.3 degree C between 1951 and 2006. The mean minimum temperatures increased to about 0.8 degree C and this is between 1951 and 2006 as well. This data depicts three times increase compared to the annual maximum temperatures. The Philippines faces flash floods, which occur in mountainous regions, typhoons across the country, storms in coastal regions and volcanoes active in 17 regions and erupted five times in the last 25 years in Kanlaon, Bulusan, Mayon, and Pinatubo. This region also faces Tsunamis in coastal parts, 4 mts above sea level. The regions of Mindanao are vulnerable in terms of going under the sea. Given that this region is volcanic it has also has at least 5 earthquakes daily and there was one recorded in 1990 as the strongest in the region. Besides these issues the region is prone to droughts, El Nino in 1982 and 1989, 1990 and 1993 and 1994. To sum up the changes, there is natural resource degradation, damage to urban environment such as water pollution and scarcity. There is also an insufficient institutional capacity found in the region. Thus, water pollution may be due to weak enforcements, increase in domestic activities, agricultural land use patterns and industrial activities. Hence, the issues come down to managing resources to last longer and also to make it available and accessible to people during calamities. Climate can also increase or initiate the spread of water borne diseases such as cholera, Diarrhoea, typhoid etc.

Methods and strategies used here are: Clean development projects by the UN reduction in emissions of Carbon dioxide. Emission reduction is shown to be about 253919 tons of CO_2. These are some of the current mechanisms that are used to handle climate change. Upon a close look at the mitigation section of the paper by the Department of Environment and Natural Resources (DENR) of the Philippines, the programs used for adaptation include the empowerment of people towards human development with key stress on sustainable development, the sustainable management of resources to alleviate poverty and pressures on the environment and the international activities with less degradation of environmental resources. The projects on water include management and control of tides, monitoring and advising people on high tides. Besides, there are also several river rehabilitations projects to bring in enough pure water to the regions. The health programs include information and production of safe water through sanitation programs to local people. The metropolitan environmental improvement program, the clean and green programs, ecological solid waste program, the environmental management and pollution control and the safe water and sanitation program comprise of the programs referred to above. The challenges observed for the future of water and other resources include health problems, human resources allotment, environmental degradation at a higher intensity, disparity in information access within the population and finally knowledge gaps when compared to other countries Magturo, (2006).

Spain is considered to be the most arid country in the EU, and water resource management is an issue that is most contemplated for this area. The drought impacts on water resources directly influence distributed. Spain's problem is with the governance of water resources rather than the physical drought itself. Similarly, the MENA region of the Middle East faces drought, reduction of water resources on a large scale. Yemen and Sudan are on the receiving-end of scarcity with projections of increased rainfall with predicted uncertainty. The resulting impacts are food insecurity, increased poverty, under development, reduced water sanitation and supply etc. Under a sea level rise the areas of Kuwait; Qatar, Libya, Tunisia, United Arab Emirates and Egypt are at risk of losing their coastal regions to sea. The storm surges are the main threat to the regions that impact the water systems, transport facilities, energy sector, tourism industry, beach facilities and the waste network. The higher intensity and frequency of hot days will increase the demand for energy and impact the power production.

A severe drought affected much of Southwest Asia between 1999 and 2003, including Afghanistan, Pakistan, Kyrgyzstan, Iran, Iraq, Turkmenistan, Uzbekistan and some of Kazakhstan (Liu 2007). A persistent drought in Central and South West Asia has affected close to 60 million people due to its multiple occurrences. Particularly impacted sectors are agriculture, water resources and public health. In arid climates such as Oman, for example, there is low rainfall and high temperatures and it has come to a point that underground water sources are not enough. There is rapid development of cities, agriculture, and industries. In general, coastal cities in the semi-arid tropic regions have varied climatic conditions and related mechanisms for climate change adaptation. Water in these regions has low quality due to salt intrusion into the local surface and ground water sources.

As the conditions worsen, setting water policies and political play, the policymaking becomes harder and more complicated. Hence, at various levels: the national, state and local levels the different management styles do indicate what the micro level effect would be on the water policy and implementations (Wagner et. al., 2010). An integral part of water security is the human security and environmental balance that brings about stability in handling climate change. Observations and the projections for water resource and security often relate to climate change and its adaptations. Water resources management and security will always involve politics, as the local and inter-state wars on water resources, involvement of power when dealing with water policies and the inclusion of economic benefits when it comes to highly corrupted societies and highly developed societies (Wester, 2009). The foundations of water policy change and managing climate change for water security depend on good governance. Governance essentially includes politics, policy planning and implementations, institutional level changes and social and cultural aspects. The complexity of the governance is clear when looking at the policies, politics, diplomacy, the role of religions and the water resource management within the policy expedient and technical frames.

Sirwaniya, a village in Surendranagar of Saurashtra, Gujarat, India a dry arid region without water resources to extract, fights every morning for water. Every day at dawn, there is a fight to obtain brackish water (Banerjee, 2012). This case is a good example for lack of water due to less monsoon rains and, hence the drought. Gujarat’s cotton growing district is now (2011) caught off guard, as the monsoons did not deliver the rains it did in the last ten years. Gujarat’s well-wetted region is now in trouble due to lack of monsoons. Since, cotton cannot be grown in the region; it is hard for locals to survive. The desalination plant provides water to people. Despite the water sanitation and management organization, the region does not get water from Narmada River. Sirwaniya, gains from Vatavatchh an acutely water deprived region that converted scarcity into a business by allowing those with storage tanks to get water for the poor and waterless at a low cost of Rs. 100 or close to 1.80 dollars. Now Vatavatchh supplies water to regions that do not have any water source. They use motored rickshaws to bring water to arid regions of Gujarat. Rajkot’s water shortage also worries its residents due to water crisis; they need water for processing livestock and milk supplies, which is the main revenue source. Water source is still less due to the failure of adaptation steps (Banarjee, 2012).

Bangladesh is a low-lying country with 70% of its land surface 1 m above sea level and most of the land is a flood plain (Ousmane, 2008). Monsoon climate brings excess rain, which results in rivers flooding. During seasonal change snow melts from the mountains increases the flood in the region. Some reasons for this are lack of money and depletion of resources. The tropical cyclones and hurricanes are common in the regions close to the Bay of Bengal. This creates issues with growing floods and causes sea level rise. Floods during 1998 in Bangladesh killed many and made many homeless. Besides this, many died due to lack of clean water supply (Ousmane, 2008), which resulted in spread of diseases such as cholera and typhoid. The good thing about flood is that when floods occur the water loses its energy when it strikes land and deposits nutrients on land. The soil becomes fertile and rich allowing growth of crops. The silt deposited on land increases the land space. Bangladesh has responded to floods through aid programs and workers for repair of damage. There are artificial embankments created so that the flow capacity of rivers increases (Ousmane, 2008). Water and food protection within shelters, emergency flood warning systems and dam constructions are the aid provided by the national and local government.

On examining the current status of water in Karnataka, author Siddhanti (2011) indicated that there was a very low level of access to water sources, 52% to be exact, in the year 2009. This coupled with low storage levels and dependency on ground water sources created a crisis. The solution proposed by the author is to look back in the history of water management and gain vital knowledge on implementations and ideas for future security of water. The system of water management according to Siddhanti in 2011 was good centuries ago. Some of these practices are still existent in several parts of India.

Table 8 Common Urban Adaptation Techniques

Assessing water security and water systems within a region Assessing
the climatic variations and checking models for responses
Monitoring stations for floods and droughts and compare
data Initial assessment of current status of water within cities
Long term assessment through repeated evaluation – for risk of water quality and quantity becoming degraded in the foreseeable future
Inspection and testing of water quality with WHO standards as a guide
Planning programs and projects to inform public and train them to handle extreme droughts
Equip governing bodies with people's participation and research findings to make an informed decision
Predict demand requirements and introduce efficient use of water within communities
Noting uncertain stress factors such as development and climate change
Examine cost effectiveness of programs
Properly allocate funds and account for it

Source: Compiled from Literatures

Siddhanti (2011) also feels that some of the practices, if adopted, would improve the current system and allow efficient management to sustain for the future. The Adil Shah and the other sultans were very efficient managers of resources (Siddhanti, 2011). The excellent water management systems and the conservation techniques adopted during that time may be the key to the future management in India, especially for many parts of South India (See Table 8).

2.8. Relevant Technologies and Policies for Supply

Asian countries have limited funding, resource and management power. Based on the current status and works adapted from Europe, United Arab Emirates (U.A.E.), and America, there are several recurring implementations for alternative supply sources. According to the UN, besides household and commercial practices and regulatory control on supply and demand, the most efficient alternative supply strategies that improve water security and help smooth adaptations to climatic impacts are: 1) rainwater harvest, 2) restoration of existent or ancient implementations, 3) ground water recharge, and 4) desalination.

2.8.1. Rainwater Harvesting

RWH is a very old technology that has been implemented both in ancient Rome, Palestine and Greece, with special apparatus built. The extensive apparatus is to capture rain for use in domestic household works. Most residences were built with cisterns that allow conservation of water (TN RWH, 2011). This age-old technique is implemented in today's world to bring about water security. Water harvesting reduces river overflows as well as flooding within the city. If there are heavy rains close to 600 mm, residences can capture a good chunk of the rainfall within the city. Besides extra water, there will be less stagnant water on the roads, runoff will be smooth, and the local government need not seek to install technological facilities to improve water supply. The technological installations usually bring social and environmental issues, besides the huge start up and maintenances.

2.8.2. Restoration of Existent or Ancient Implementations

A case of management that was successful, as per the views of all key administrators at TWAD, is the reconstruction and maintenance of the small areas of stagnant water structures, called *Ooranis* (TWAD interviews, 2012). These traditional ponds have proven to be a good water management system. The current project includes the restoration of the ancient *Ooranis*, and supply systems followed during ancient times. These ponds were the main supply system in Tamil Nadu many centuries ago. The constructions of these ponds were through the efforts of people over several phases to maintain a steady flow of water runoffs. All these ponds were well connected through irrigation tanks: the *kanmoi*. In recent years, these ponds, due to neglect and dilapidation, have collapsed and became functionally redundant, and reconstruction has proved to be the best solution to provide water and improve water management in TN (TWAD interviews, 2012). There have been various initiatives to improve the ponds under Rajiv Gandhi's National Drinking Water Mission (RGNDWM) by the Ministry of Rural Development, Pradan Mantri Grameen Yojana (PMGY) and Accelerated Rural Water Supply Programs (ARWSP). The schemes include the desalting of ponds, treatment of catchment zones, clearing of the supply channel, endowment of filter media and providing draw well arrangements and fencing of ponds.[3]This scheme, ARWSP, coupled with the rainwater-harvesting scheme has increased the surplus water levels in the water table of several regions of Tamil Nadu, yet the water supply demand gap is increasing. A pre-existent water scarcity issue coupled with climate change can further worsen conditions within highly populated regions. Unfortunately, they do not have the mechanism to install these structures due to the physiographic differences and the approvals to undertake such implementations within urban or semi urban regions.

2.8.3. Ground Water Recharge

The recharge of groundwater is a concept that is now given importance due to the effects of reduction of water levels in the aquifers and the decrease in the soil moisture. Some of the ancient water recharge systems used in various parts of the world such as recharge pits, trenches, dug wells, hand pumps, recharge wells, recharge shafts etc., indicate the success stories of the past water harvest systems (UN, 2009; Chennai Metropolitan Water Supply and Sewage Board, 2008; Weinthal, 2010). This indicates that maintenance of currently available recharge, harvest and storage areas along with

[3] Data through informal brief of water resources and initiatives, while collecting information through interviews

renovation of past structures will increase the water available and make it easily accessible for people.

Reclamation of water can be done by recovery and retrieval through two means: desalination and reuse of treated waste. Reuse of wastewater can be done by treating water suitable to an extent that it is as good as or better than the naturally occurring water used after treatment. This method can be used to artificially recharge the ground water. It can also provide water for faucets, showers, cleaning, agricultural and industrial purposes, in an efficient manner reducing the strain on the naturally available resources. Chennai Metro Water defines desalination as the process through which saline or brackish water may be rendered useful for drinking. Desalination is also otherwise referred to as "Desalting", as it was first named after the process. The common methods for desalination are distillation, reverse osmosis, electro-dialysis, freezing and solar evaporation.

2.9. Chapter Summary

Among all the approaches that the literature suggests, IWRM is the best due to flexibility and framework adaptability to a region's requirement. IWRM allows assessment and policy analysis and adaptation planning for a region in an efficient manner. Water governance literatures indicate that good governance shows the ability of the region to manage resources and cope with climate change. The leadership abilities of a region are reflected in policies that the system has implemented. Water security is a significant concept, which is used to understand the availability, accessibility, affordability and allocation of clean water equitably to all. Most countries have not achieved perfect level of security. The aim of most regions is to adapt to climate change and other problems through security of resources. Resource management within a supply and demand continuum signifies that every element of supply and demand side management carries weight in achieving water security. Supply side management includes the source (status and quality) and distribution management. The demand side management includes quantity of supply, dependence on desalination, tariffs and costs, PPP's, per capita use, use efficiency, consumption patterns, deficits, storm water drains, water loss and wastage management. The local and national drought and flood control policies that directly affect changes in the supply and demand side elements are major adaptation strategies. Some of the most talked of adaptation strategies are RWH, restoration of tanks and ancient structures, ground water recharge mechanisms and desalination. The other strategies in consideration are pipeline management, alternative supplies and adaptation planning and management. Literatures suggest that a community is climate ready when awareness is high, adaptation is smooth, mitigation is good, policy efforts, community efforts and participation and partnerships for projects.

3. RESEARCH DESIGN AND METHODOLOGY

3.1. Introduction to Methodology and Research Design

This study is descriptive and exploratory research that includes qualitative and quantitative data. Briefly, the exploratory research encompasses investigating the awareness and opinions of the selected respondents on water availability and access, affordability, quality, conservation techniques, water governance and policy awareness. The data obtained from qualitative interviews, targeting environmental management personnel and the local community is used to gauge their standpoints on the policy formulation and water supply system improvement and issues. Secondary data and quantitative data are used for descriptive analysis. The combination of both analyses will be used to identify past, present and future water management, security measures and climate change adaptation strategies.

This chapter discusses the research methods and research design used the research methods were derived from various studies from GWP, the framework that was established in relation to Chennai's community, and responses from pilot study. IWRM is the chosen as the conceptual framework, based on the GWP and UN research on river basin or ecological approaches. It is clear from the literature that the IWRM framework is flexible enough to fit in with various studies such as demand management or water flow study or integrated river basin management. It is also ideal for a region with problems related to the implementation of adaptation strategies, and hence is relevant for Chennai (UN - Water Final Report, n.d) (GWP and INBO, 2009).

3.2. Research Design and Methods

An exploratory study with mixed methods and qualitative design, this research, made use of a descriptive analytical framework to investigate water security and climate change adaptation for Chennai. The study utilizes both qualitative and quantitative data to convey the climatic variations over the last ten decades, showing: the policy changes, the temperature variations, the wet day frequencies and the precipitation levels in this region.

The key area of focus was the need to achieve water security and smooth adaptation in urban Chennai. Prior to identifying and analyzing the local climate change and strategies to adapt, the current water security and the local participation levels were recognized, as it was imperative for this study.

The research made use of both primary and secondary data for analysis. The primary data was collected through (1) observation, (2) survey/ questionnaires of local communities, (3) open-ended interviews with ten households per region local fishermen, and (4) interviews with the RWH management team, water analysts of TWAD, verification calls to CMWBSS and interview with the environmental engineer of the Minjur desalination project.

The secondary data included literatures from CMWSSB, TWAD, Internet and news articles. The main literature on water security includes work on water and how various cities secure water, the policy effectiveness and the current state of drought and flood management in different regions.

The research involves three steps to understand and successfully complete the study. The primary step is review of literature and other documents related to the impacts of climate change on water resources. The second step is to complete surveys and interviews that are focused on water security, policy effectiveness, conservation techniques, quality issues, policy awareness, transparency of policy decision making and climate change impacts on water management.

Interviews with two key informants served as a guide to study issues faced by the region and to analyze past and current water policies. The major data acquired were: (1) the state, level and geography of the water resource, (2) programs and conservation schemes, (3) climate data for over ten decades and (4) information on the policies that are implemented recently. All documents and information collected were from the TWAD e-documents, the Chennai Metro Water Board e-resources/ documents, the India Water Portal and few preliminary household interviews.

Key elements for data collection: The key elements for data collection are based on the major objectives of this study.

Table 9 Key Elements for Data Collection

Trends of climate change in Chennai, India
Water supply and demand in Chennai, India
Water quality and quantity supplied
The Policies, the projects and the implementations on Chennai's a
Difficulties and problems identified related to adaptation in the water sector
The methods or measures that consumers take in response to climate change – conservation/ recycle/ reuse

Source: Compiled from Research Aim and Focus

Table 9 indicates the major data required for analytical purposes. It indicates the elements for data collection for this investigation.

3.3. Background on Meteorological Data Set

Meteorological data is essential for water resource planning and research and it is an arduous task for Indians to obtain this data. The whole data set is from 1901 to 2002 for any part of India is available for public access. The database used is the Climate Research Unit (CRU) TS2.1 and is part of the Tyndall Centre for Climate Change Research, School of Environmental Sciences of University of East Anglia in Norwich, UK. The data has intercalated global monthly rain, temperatures, humidity, cloud cover, etc. (on a 0.5-degree latitude-longitude grid).

3.3.1. Selection of the Study Area

According to administrative conditions there are about ten areas in Chennai Metro-water regions and the TWAD has control of 5 taluks and 55 revenue villages. The five taluks include Purashawakam – Perambur; Fort – Tondiarpet; Egmore – Nungambakkam; Mambalam – Guindy and Mylapore – Triplicane. To achieve the objective of the study, five areas have been selected as the study area for this research. Considering the population density, time availability and funds for research, it is impossible to survey all regions extensively.

3.3.2. Sampling Method

The study used accidental and purposive sampling methods to get the required information from government officials and water user - households, in two parts. The first part includes surveys conducted on a sample basis and covered 10 to 12% of the households in the study area with accidental sampling method. Based on the responses of the first set, the rest of the 90 % were covered, based on middle class to low-income regions. This was done to understand the local issues, to identify local views on water security, to create profile for the middle class and poor water struggles. A good reason for doing this was to help people who suffer water shortage on a day- to- day basis, they need to observe their conservation methods, create policy awareness and most importantly require water that is available, accessible, affordable and allocated properly, while on the flip side, the rich community does not require the extra leverage.

The design of the sample is compiled in three stages. The first stage involved the selection of sample blocks. The second stage focused on the selection of sample sections within each block and the third stage is sample household selection from the section within each block. The frame used in the sample selection process was based on population density of each block/ region within Chennai. In line with questionnaires survey, sample households were picked up through literature review on the water issues within the study area.

3.3.2.1. Sample Groups and Sample Size

The selected groups were water user household and key-informants (Water Officials). Water user groups included water users in Chennai (metered and non-metered customers) and DUA (Chennai).

As a result of stratified sampling method, the following sample frame was used. The two communities within each block were selected with an area section of at least 75 homes (a good number of households) are used as a sample for this study. Two blocks from Chennai, falling within each of the five regions of Chennai regions are used as sample households for surveys. After the initial set of surveys are done. One of the two blocks is extensively, further, researched

The population density of each selected community within the study area is a sum of 16,000 households per block (see Table 10 and Figure 8). The total spans of surveyed households were 80,000 within Chennai, which were used as the “sample frame” for this study. The initial sample indicated the level of poverty within the region and based on that, either a section both the blocks or one or the other were selected for further surveying. A total of 500 surveys were collected in Chennai.

Figure 8 Regions Selected for Sample Frame and Groups

Table 10 Required Sample Groups and Size in Chennai (ref. Figure 8)

Name of Block (Shown in the map 2.1 a.)	**Total Community Population (~)**	**Total Respondents (Absolute number)**
Initial Region I Sample I – Block 1	100	11
Initial Region I Sample I – Block 2	80	15
Initial Region II Sample I – Block 1	120	14
Initial Region II Sample I – Block 2	180	20
Initial Region III Sample I – Block 1	140	12
Initial Region III Sample I – Block 2	16,000	110
Initial Region IV Sample I – Block 1	15,100	100
Initial Region IV Sample I – Block 2	16,200	110
Initial Region V Sample I – Block 1	17,100	118
Initial Region V Sample I – Block 2	15,800	110

Source: Field survey 2011 and 2012

Table 11 List of Key Informants

Department /Office	Position	#
TWAD Water Resource Data Centre	Access to e-documents	
Desalination IVRCL Office	Chief Engineer	1
TWAD Office and RWH	Engineer	2
Water quality division	Water Analyst	2
Water Distribution Division	Head	1
Disaster management	Section head	1
Total		7

Source: Field survey 2011 and 2012

A Total number of households, five hundred (548) were selected (accidental sampling) for survey for Chennai. An initial survey of 10 to 15 households within each block of the regions were conducted and used as the initial selection basis for conducting survey on a larger scale. After selection, the initially surveyed (72) household respondents were approached per region through accidental sampling method for discussion and questionnaires. However, after inspection the data and discussion information from these questionnaires, five hundred (500) surveys could be utilized for this study. The residual 120 surveys were vetoed, as most of them were unfinished and inapposite.

3.3.3. Questionnaire Survey Process

Questionnaire included three parts. The first part asked about background information. The second part was their water sources, water consumption, expenditures, and quality of current water supply, RWH and awareness of water conservation. The third part assessed the water expenses on extra requirements, RWH and billing.

The questionnaire interviews were carried out with several interviewers for different regions and the help of TWAD office staff. Interviews were mostly conducted on weekdays to increase the likelihood that officials would be available. Household interviews were conducted on weekdays as well as weekends. When the head of household could not be interviewed, one person who is over eighteen years old was interviewed instead, to get the most accurate information for the household. If, for any reason, a household could not provide information, the nearest house was chosen as substitute.

Interviews with government officials water supply issues, water loss, drought impacts, preparedness for future, the supply demand statistics, the information on lakes, reservoirs and water catchment and the implementations and policy details were obtained (See Table 11).

3.3.4. Research Phases

The research design adapted for this study includes four phases. 1) Phase one started with identification of research questions. The research questions were transformed into objectives, i.e., phase one is chapter I. 2) Phase two is the literature review, data collection (primary and secondary information) i.e., chapters 2 and 3. 3) Phase three, the final step, included a selection of analytical methods, which were employed to come up with the discussion and conclusion of the results, as shown in chapters 4, 5 and 6. 4) Finally, the findings from the analyses were translated into recommendations (in chapter 7 and 8 of this thesis) of water security policies for climate change adaptation in urban areas.

3.4. Data Processing and Analysis

All collected data were screened for accuracy. The primary data compiled from the questionnaire was formatted using spreadsheets (Microsoft Excel). Simple statistics like relative frequency mean and percentage were presented in tabular and graphical forms through Microsoft Excel.

4. URBAN WATER SUPPLY DEMAND MANAGEMENT

4.1. Introduction

Urban water security is the reliable supply of good quality water that is available and accessible to all at an affordable price (Mileham, 2010; Norman, et. al., 2010). Urban water security is affected by the projected growth in population, lifestyle changes and demographic structures (Gleick, 2010; Mildhem, 2010). Population growth translates into growth in demand. Increase in demand and low water availability increases insecurity. The insecurity is further compounded by climate change (CC) impact on water resources.

Mileham, (2010) denotes that above and beyond the acceptability, availability and reliability, the capability of the governing body to ensure the access to affordable good water resources is vital (Huitema, 2009; Cook, 2012).

IWRM is defined as the organized, purpose-oriented process for regulating the development and use of water resources (Smits et. al., 2005; Huitema, 2009; Lautze, (2012). IWRM approach involves applying knowledge from various disciplines along with feedback from stakeholders to frame and implement efficient, effective equitable and environmentally sustainable solutions to water security issues. Shamir and Howard (2012) signify that the major outcome of efficient management encompass economic good, social acceptance and environmental protection, social equity, sustainability of supply and political appropriateness. These aspects produce a sound and balanced policy solution. IWRM approach helps decision makers improve water security for the domestic sector, through both supply and demand management.

Supply Management: Supply management is defined by the IWA as the process of identifying sources, acquiring rights to supply, creating access points, positioning the supply distribution centres in order to induce fair supply and uniform allocation, managing resources through schemes and maintain capacities and organizational attributes in order to attain major strategic supply related goals (IWA and WWC, 2012). Water supply management can otherwise be defined as the administration of supply schemes to make clean water available, accessible, and affordable in a reliable manner for the present and the future in adequate quantities (GWP, 2011), (Bakker & Allen, 2012). The supply management is a major aspect of water system that allows management, updating, coordination, administration and organization of sources, status, supply options, water-waste management, quality and treatment, policy, participation of stakeholders, capital, operation, funds and capital, operation, funds and costs (if any) (Balgis, 2010). The quality, safety, and reliability of supply, mode of transportation, improvements are important aspects that enhance smooth climate change adaptation. Likewise, supply – demand management for Chennai is vital for adaptation to climate change in future.

Demand Management: Water demand management is defined as the policy responses, the initiatives to regulate use efficiency and conservation, by the governing body to effect changes in demand and usage (UN-HABITAT, 2006; Joshi, 2007). This is needed to meet economic growth, social advancement and equity, environmental security, resource security and sustainability and political acceptance (Shamir & Howard, 2012; Olmstead, & Stavins, 2007). The policy response, specified here, is the implementations, plans and programs initiated in order to find solutions for water related issues.

The demand management strategies are also referred to as the demand-side management. The demand side management appropriates the technical and non-technical aspects of water. The technical elements of demand management include metering, zoning of the district (metered areas), energy audit, active and passive leak control, asset management, repair and planned maintenance, alternative delivery options, consumer–end conservation, pressure management and pipeline management (UN-HABITAT, 2006). The major non-technical aspects are the conservation techniques that includes pricing, water restrictions, low use fixtures, education, training, advisory, information communication and awareness i.e., the tools of conservation (Joshi, 2007; Olmstead, & Stavins, 2007). Water uses are many for each sector of the economy. The domestic sector uses water for household consumption and commercial use.

Water conservation is approached as a non-price conservation technique in most countries (Olmsted & Stavins, 2007). The preference for non-price conservation is high compared to price conservation management. Demand management through pricing is defined by Olmsted & Stavins (2007), as the conservation technique to aid water saving in a more efficient manner. Similar to the preferences mentioned above, evidence suggests that water managers in Asia too prefer non-price demand management to conserve water. Since, significant sections of the population exist below poverty line and increased prices will impede water accessibility. The water managers in Asia instead use price increment technique (TWAD, 2011). For example, In Tamil Nadu and Kerala up to

10 Kilo Litres (KL) costs about less than 0.5 US cents per litre and increases steeply for use over 10 KL charged 1 US cent or more per litre. Increasing prices through this manner is efficient and will improve water use efficiency. There may be evidence to suggest that use efficiency can be achieved through increase in pricing. But price conservation may not be achieved in Asia as the consumers depend on low prices. The non-price technique includes restrictions on particular extractions and use, low flow fixtures and water supply restrictions (Olmstead, & Stavins, 2007).

Water demand management also requires implementation of strategies for pricing, conservation and the programs for engaging the public private sector. In Singapore water is considered in terms of its economic value, in other words, it is an economic good. The prices reflect the cost of production and reflect shortage (Joshi, 2007). The study in Singapore by Joshi, (2007), examines the demand management within a conservation framework, using public education, information and awareness and alternative supply. The emphasis is on the non- price conservation techniques such as education and information and awareness.

Similarly, Bakker & Allen, (2012) signify that public sector demand management is highly reliant on the government, the feedback mechanism and the authorities in charge. Furthermore, an active participatory approach is required for good governance (Ahmad, 2008). While, Ahmad (2008) indicates that water governance quality is influenced by the transparency, the responsiveness, the reliability, the accountability and the competence. It also is dependent on the local response and feedback. It is clear that the elements of governance can be categorized into three main dimensions viz. leadership, accountability and competence (Bakker & Allen, 2012). The governing bodies help strengthen the elements of water security via policy adaptation and leadership capabilities. The progress of water management depends on the quality of governance, i.e., resources management, leadership ability and political regime (Heiland, 2009). In addition, the demand management depends on the leadership abilities and adaptation capacities of an urban region (UN ESCAP, 2010).

Based on the local acceptance and participation, the policy responses reflect a region's ability to adapt to climate change. The leadership capability is a major aspect of water governance. For water governance to be effective the public agencies need to be open to new innovative responses in crisis situations (Bates, Kundzewicz, Wu, & Palutikof, 2008). Author states that responsiveness improves when the public is well informed and a feedback approach can be adopted within the decision- making process. Demand satisfaction is achieved when good feedback mechanisms such as complaint boxes or facilities such as training and workshops are in place. As the public feedback notifies the decision makers of the current status and requirements, the decision makers need only verify the shortcomings and long-term impacts of a technical or non-technical policy decision. Besides this, the public awareness is improved with feedback and training system. This increases awareness of issues strengthening the policy decisions.

Major demand policy decisions are made for issues such as faulty metering, low conservation, low pressure in supply, damaged pipelines etc. The key decisions leading towards proper water use efficiency and consumption, better conservation, subsidized pricing and alternative delivery system are the major elements of demand management. Thus, is the definition of concepts and elements for governance leading to good demand management to improve water security within the urban cities.

Chennai has intermittent water supply with a large supply – demand gap in the domestic sector. Chennai's major sources of water are external surface, well field and rainwater. The current deficit in supply demand is around 200 MLD. Optimizing water supply is vital for urban Chennai, as the supply is diminishing, and demand is increasing. Results indicate that the supply policies and schemes (technical and non-technical) are unstable, unreliable and unaccountable in terms of making water resources available, accessible, affordable and fairly allotted for the people of Chennai.

Chennai's focus until last decade was on supplies side management and, is shifting to include demand side management. A section of this chapter looks at the sources, status and major concerns for Chennai and supply policy response for future climate change adaptation. The other section looks at demand side elements such as pricing, conservation, leak detection, pressure, pipelines, programs for engaging the public private sector, and policies for adaptation.

4.1. Overview of Water Sources

The Surface Water Bodies:

The main surface sources are lakes/ reservoirs of Chennai are Cholavaram, Poondi and Redhills. These three interconnected reservoirs are used to collect, store and supply water to the Chennai region via the Kortalayar Nagari and Nandi rivers. The fourth lake is the

Chembarambakkam Lake, which is also a reservoir used to supply water to the city, but only during drought years. The lakes supply a total of about 7412 Mcft of water.

The three rivers that flow through Chennai are

(1) The Coovum River (through the center);

(2) Adayar River (to the south) and

(3) Kotalaiyar River (draining at Ennore shore).

The Buckingham canal is 4 km long links the two rivers within the city. The Otteri Nullah is an east-west stream that runs through North Chennai and merges with the Buckingham canal, a point called the Basin Bridge.

The Veeranam Project: The Veeranam Lake is located at 230 Km from Chennai. This lake draws water from the Cauvery River (through tributaries: Bhavani and Amaravathi) and provides drinking water to Chennai. The earlier version of the Veeranam Lake project (1965- 1967) was a failure, as it did not produce the necessary amount of water required. The current Veeranam Lake project in 2004 has managed to reduce the level of interstate water purchase in Chennai. The lake can store about 1,465 M. Cft of water, but only stores about 320 M Cft of water (180 MLD) currently. The total capacity is 1465 Mcu ft, with raw water pumped out at 20 Km distance and then treated and pumped out at 8 km and then transported 200 Km.

The Krishna River Project: The Krishna River is located in Andhra Pradesh, India North of Tamil Nadu State. Under an agreement with the neighboring states, the Telugu Ganga Project is to supply 1100 TMC per year from the Krishna River to meet Chennai’s agricultural, industrial and domestic needs. The water received under the Krishna Water Supply Scheme is in two stages, stage I and II conveying 400 and 530 MLD to Chembarambakkam Lake, respectively.

Ground Water Sources: The CMA, DUA and AUA regions get groundwater from two main, sources the Araniyar- Koratalaiyar Basin (A-K Basin) and the South Coastal Aquifer (SCA), as illustrated in Figure 9.

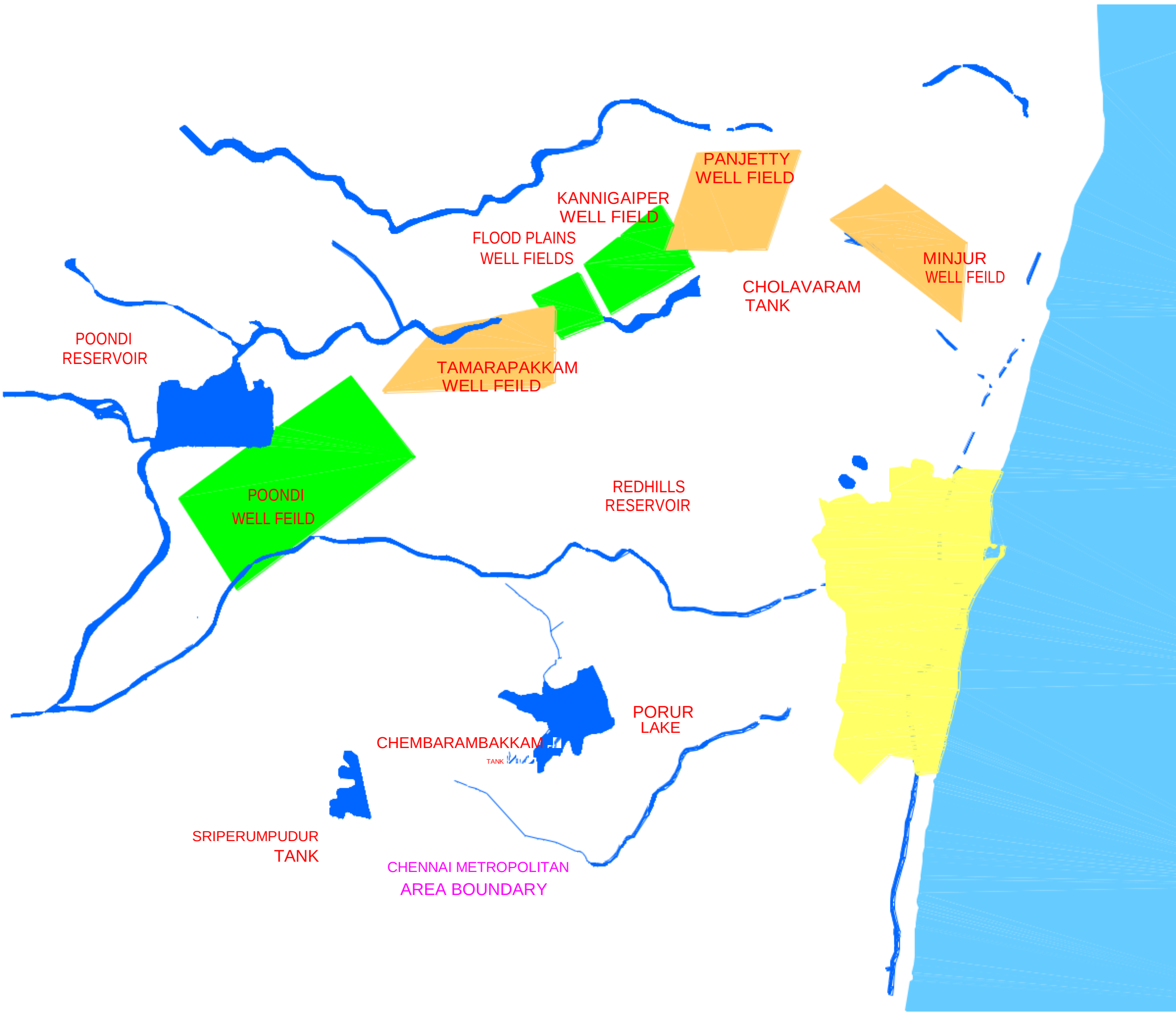

Figure 9 Water Resources for Chennai

Source: CMWSSB

Figure 9 illustrated all ground and surface water sources available for Chennai. The A-K Basin consists of well- fields and the SCA between Thiruvanmyur and Muttukadu through to Mahabalipuram region on the outskirts of Chennai.

Desalination: Desalination technology is fast becoming an option for urban cities in TN and other states; Chennai already has two plants with 100 MLD each. The CMWSS and TWAD boards are also planning another plant of 150 MLD to be initiated in 2014. With the increase in industrial usage, the water supply for the domestic sector is reduced in Chennai.

Chennai also has 5 other small-scale desalination plants with capacities of less than 15 MLD.

4.1.1. Water Supply Status

The supply status indicates that the total amount of supply is 730 million liters per day MLD approximately (2011/12) and the total required is about 900 MLD. The development of water supplies in Chennai evolved over the last 100 years, sharply modernizing over the last two decades. The chief improvements were supplementing the delivery system with increased quality control, piping and renovations of structures. The source of water for Chennai is from Veeranam, Krishna, desalination and well fields approximately totaling 1100 TMC. In addition, a recent request was made by Government of Tamil Nadu (TN) to increase supply by 200 – 300 TMC’s (Lakshmi & Ramalingam, 2012).

Observations of normal conditions in Chennai indicate that the current supply is not enough; more water is required to satisfy HH requirements of Chennai. A walk thought the streets of Chennai enables observation of various problems such as leaks, sewer pipe leaks, tankers with people fighting over who gets water first, and few places with ladies using hand pumps to draw water from bore wells. The demand for water is very high and in general, water related conflicts among people do not happen unless water shortage is acutely felt. Chennai’s problem is simple. There is lack of water to meet demand and the demand management needs fine-tuning of policy.

The source of water can be private or public. Chennai metro water is the main source of public water supply. However, there are other sources such as the private dug wells and bore wells, private tankers and canned water. The private canned water supplies are from intra and inter-state resources. The public well fields provide water through main supply lines such as pipes and tankers within the city. Currently around 70 percent of the water provided to Chennai is now from the reservoirs and lakes. It is estimated that most of the remaining 30 percent of the consumption is from water derived from ground sources.

Table 12 Water Profile of Chennai (1978 & 2010)

DETAILS	1978	2010
OPERATIONAL AREA	**176 SQ.KM.**	**176 + 7.88 SQ.KM. Outskirts**
Population	3 million (City)	5.5 million (City)
Water produced (Normal years)	240 MLD	760 MLD
Water Requirements	~300 MLD	831 MLD (~100 lpcd)
Area covered with piped supply	80%	100%
Treatment capacity	182 MLD	1,398 MLD
Length of water mains	1,250 km.	2,930 km.
No. Of consumers (Recorded)	1,16,000	4,97,811
Distribution Stations	3 No.	16 Nos.

Source: CMWSSB, TWAD. (2011).

Chennai cannot meet demand from existing supply as: 1) the existing supply is inadequate and significant portion of supply is from sources outside the city, 2) it is not equally accessible to all, as the various regions have limited public supply and HH's buy water from private sources to meet demand, 3) the quality is questionable as surveys report impurities and, 4) the allocation of supply is not equal among urban and semi urban areas (See Table 18).

The last decade supply and shortage indicated that in 2004 the supply was measured to be 550 MLD and in 2011 the supply increased to 730 MLD.

The average supply per capita indicated by the HH surveys is 82 lpcd and the actual measure across the city was slightly over 90 lpcd. While HH surveys indicated that the slum areas receive only 30 lpcd and the actual measure by CMWSSB and TWAD is 25 lpcd, the slum areas in Chennai only receive so much.

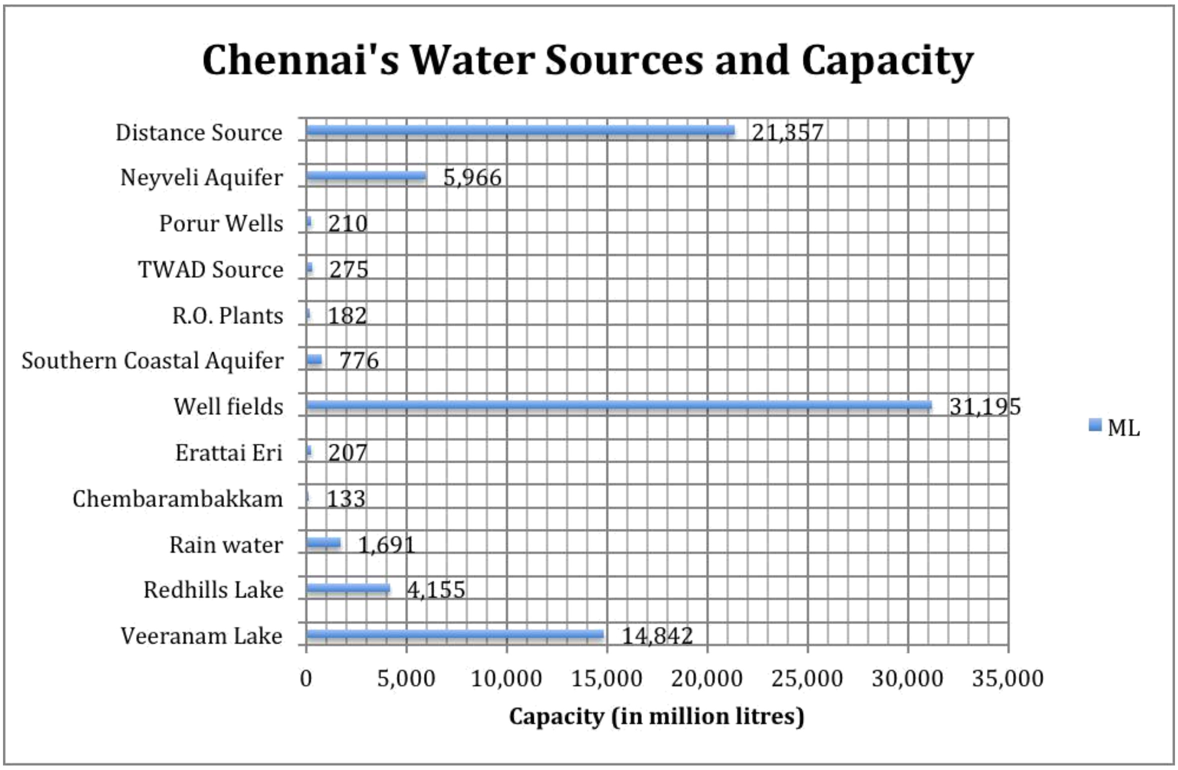

Figure 10 Water Supply Source and Capacity

Source: CMWSSB

The Figure 10 clearly indicates that the well fields, Veeranam, distant sources, the Redhills make up the majority of the supply. The sources are available for all purposes, and the domestic sector only consumes 5 to 10 percent of the total available. The 10 percent of the total is still inadequate for the domestic sector while 90 percent of the total available source is inadequate for agriculture, commercial and industrial purposes.

The following are some of the major changes to the supply system in Chennai:

1. Currently, the CMWSSB and TWAD supply 831 MLD's (as of 2013) and the 100 MLD from the new Nemelli desalination Project will be added to this supply.

2. The CMWSSB is now in the process of acquiring water from Poondi, Tamaraipakkam (155 MLD), and Neyveli aquifer (75 MLD).

3. The Chennai Metro Water Supply Board is digging 100 more wells to expand the existing wellfields and develop water facilities for semi urban regions.

4. In response to drought, the TWAD contracted 9000 or more lorries for meeting domestic supply (currently on standby).

5. To repair and restore existing tanks and *Ooranis*, TWAD's works (within and outside) are in progress. The RWH department indicated that about 9000 tanks are under scrutiny. Right now, about 5000 of them are in use and the rest of them are not in use. It is indicated by (Sivakumar, 2013), that these tanks would be reconstructed, and 1400 new ones will be constructed all over the city.

4.1.1. Mode of Conveyance

The conveyance modes involve transferring water from one region to another. Trucks, aqueducts, pipelines and water cans are commonly used modes of conveyance and distribution. Trucks are vehicles fitted with cisterns that are filled and moved from one region to another within Chennai suburbs and rural areas not supplied by central treatment facilities.

The Metropolitan Area government-initiated pipe borne water supply to Chennai's residents 100 years ago. The city has 100% piping in Chennai and about 40 to 60% of the rural pipelines are being used to support supply. Where the pipelines remain inadequate, tankers are used to fill residential tanks. Over 1300 tanker trips are made per day throughout Chennai.

Figure 11 depicts the type of *lorry*,[4] which delivers water to the city outskirts and to the city. People use *Kodams*[5] to collect water and store it for the week, as supply is not continuous, it is sporadic or weekly twice.

[4] Lorry is a term used in India for large tankers delivering goods, in this case water.
[5] *Kodams* are vessels used to carry and store water – as depicted in the photograph.

Figure 11 Chennai Water Supply via Tanker Lorries

Source: Photographed by the author during data collection, 2011

The region has 15,460 streets within the CMWSSB administration board; there are 130 or more streets, which are not reached by the pipelines. To increase water availability for such streets, improvements to channels of distribution are underway in Chennai. Although, most streets relate to pipelines, the mains do not get a 24 X 7 supply of water. For domestic purposes, TWAD has installed new India Mark-II pipes in the city to meet the water requirements. This installation is important for increasing the durability and the efficiency of the flow of water through the pipelines.

People below the poverty line use water supplied through tankers after. Several high-income residents indicated that the tap or tanker water is bought for domestic purposes (other than for drinking), whereas drinking water is bought every week separately from a canned potable water supplier. Interviews indicate that the water used for drinking is usually bought from mineral water companies. Water in cans used for drinking is supplied entirely by private potable mineral water companies.

4.2. Water Supply Status

The current supply is not enough to support the population and it is unreliable due to restricted availability, poor allocation, meagre accessibility, un-reasonable supply hours, lack of customer advisory, communication and awareness, and education and training etc.

4.2.1. Availability

The population of Chennai has tripled over the last four decades. Chennai urban area has a population close to 8.7 million in 2011 and this has been steady growing. With an increase in population, the number of settlements also has increased. Hence, the supply requirements for Chennai are higher and further increasing the water requirements for the domestic sector (as indicated by Table 13).

Table 13 Urban Populations in Chennai

	2011	2001
Requirements for Domestic Sector	Over 800 MLD	650 - 700 MLD
Urban Populations	8,696,010 (8.7 million)	6,560,242 (6.6 million)

Source: TWAD, Interview

Officials indicate that the ground sources are fast depleting and Chennai's rain retention is very low, about 80 percent of it drains into the sea. This indicates that the water retention is low ground water table has reduced in Chennai. This is because not all residences have RWH installed due to unfavorable housing conditions. Besides, the scheme to implement roadside RWH and AR was only partly successful, as the installations were not uniformly adopted throughout Chennai. Observation suggests that the roadside pits for AR are not installed nor are proper drains to collect rain in an efficient manner.

4.2.2. Accessibility and Allocation

The access to water for Chennai is mainly through direct in-house, outside tap, storage tanks, metro water tank, common/ independent wells, community wells, and private tankers. Chennai's water board claims to have 100% city pipelines, yet many streets have no piping and some that do, have no supply.

According to the Tamil Nadu Water Supply and Drainage Board (TWAD) there are 130 or more streets without supply. The government provides residents the choice of tank water, 300 trucks that make 13000 trips twice per week bearing water. This option is available to all residents who have trouble gaining access to water. Thus, there is some amount of inaccessibility in Chennai, clearly requiring attention.

Table 14 Number of households and means of access to water supply

Sources	Sample Households
Public	
Direct in-house	83
Outside tap	102
Storage tank	37
Metro tanker	128
Private	
Own well	4
Others well	5
Community well	9
Private tanker	132
Total	500

Source: Survey Results

Municipality abstracts about 20% of the total water for domestic purposes. Of the 20% certain zones get higher quantities compare to others. About 2 -5% percent of this is lost either during transport or misuse. In the zones surveyed, many residents fight for daily water needs. This is because water is not allocated evenly, some regions get 6 hours and others get it once every two days via tankers.

When availability and access are poor it is a clear indication that the allocation is uneven. Table 14 indicates the total available access points. The public supply is low in direct house when compare to the tankers and outside taps. Hence, the foray into Chennai's supply system indicates that the supply is poorly allocated.

4.2.3. Quality of Water Bodies

It is impossible to find absolute purity in tap water resources, especially in India. A recent study, (Janardhanan, 2011), indicates that the groundwater sources have not improved within the city. The surroundings of the reservoir are not kept clean. The domestic, industrial or construction, residential, commercial and other activities and subsequent wastes pollute the lakes and rivers. The water in Adayar and Coovum Rivers is highly contaminated and is, at present unsafe to use for all domestic purposes. The quality issues are yet unresolved. The Coovum and Adayar Rivers are highly contaminated with domestic waste, very saline due to saltwater intrusion from the Bay of Bengal. Although the Coovam River can be desalinated, this river will continue to remain saline, as there are sea inlets that allow saline intrusion. Observation indicated that the smell of Coovum River is so revolting that people cover their noses before they reach the River. This is partly due to regulation issues and due to the location of the slum regions, where people do not have toilets or cloth washing facilities at home.

Several water qualities reports in India have identified the presence of water bugs effecting spread of disease. A good example is 'The Super Bug Effect' that is, at present, an issue still being researched in New Delhi. Cases of New Delhi mettallo-beta-lactamase-1 (NDM-1) have been reported found in 51 out of 151 sewage samples and two water samples (The Hindu 2011b). This bug is transmitted easily among water bodies and is also drug resistant. The transfer of plasmids is optimal at temperatures above 30 degrees, temperatures reached during the peak of summer in most parts of India. Several news clips in India suggest that an increase in temperature increases the potential spread of disease. There is a potential that such bugs could be transmitted into Chennai's water sources. Through exploration of the literature and TWAD documents it is clear that there are at least three divisions of water management bodies that are working to improve these rivers. Typical management entails disease control, water treatment, removing metals and unwanted minerals from water making it safe for all purposes. An interview with a Japanese local management team, conducted during the research, suggested that there is a treatment method through which all regions of the world could maintain a high quality of drinking water.[6]

The evidence presented in this study indicates that samples from Besant Nagar and Santhome show that the Total Dissolved Solids have increase in groundwater sources (within the last two years). Similarly, RA Puram and Mylapore are affected by the pollution (See Appendix I for comparison Charts, WHO standards). Hence, the sources remain highly polluted and unregulated and, this is partly due to corroded pipelines.

Rainwater is acidic and comprises of gases from the atmosphere while falling through to land in Chennai. Rainwater absorbs nitrogen, carbon-di-oxide, rare gases, sweep particles, salt and radioactive fall outs etc. River and surface runoff water flows through land to the sea. Water flowing into lakes and rivers contains minerals, bacteria, salt and natural and synthetic fertilizers. In general, lake water contains low dissolved oxygen, iron and manganese, H2S, increases in Carbon-di-oxide and has a reduced pH. Rainwater in Chennai collected in ponds and lakes are highly acidic with a low pH. Seawater intrusion into these waters is also a common problem.

Groundwater also absorbs the decomposed and degradable organic matter, oxygen and carbon-di-oxide, with lowered pH, soil minerals, iron and manganese.

A watershed can be contaminated through, intentional actions or by accident by domestic or industrial means. It is common knowledge that the contaminated drinking water systems can cause ailments or even death. Intentional contamination is one of the most serious problems that can cause ill health. Acting rapidly and efficiently is important to protect public health in Chennai, as it reduces the intensity of impact and enhances the adaptability of a region to face quality issues in the future.

Tamil Nadu State Government report indicates that 5,574 water quality affected habitations in the year 2004. During the year 2005 – 2006, a target of 7500 habitations the Tamil Nadu State Government selected these habitations for survey and improvement. Chennai City and out skirts is one among many to receive assistance and support for water resource quality monitoring. About 500 habitations were affected areas where Fluoride, Salinity, Nitrate, Iron were noted to be on the higher level of the scale. Thiruvanmayur is among the 140 Iron affected area during the years 2010/ 2011. The

[6] In an interview with the Beppu Water management team, the team manager described this treatment method as a three-day process, wherein water is collected upstream (as it is purer) and treated on the first day for large impurities. Then, on the second and third days, it is treated extensively for chemical and biological impurities.

government aims to tackle all the quality related issues by the year 2012. The TWAD officials indicated that the quality of water is fair, but they do not recommend drinking water directly from the tap without treating or boiling it.

The most common water borne diseases mentioned were Diarrhoea, Typhoid, Paratyphoid, Cholera, Dysentery, Protozoal, viral infections and Helminthic (worm) ailment. These diseases are pathogenic and contaminate water through sewerage or unsanitary toilets. All respondents have had water borne diseases at some point in their life and, 70% (384 out of 548 respondents) of them indicated that they spend money on water borne diseases in the last ten years, also indicated that they had sanitation issues and store water for over 3 days.

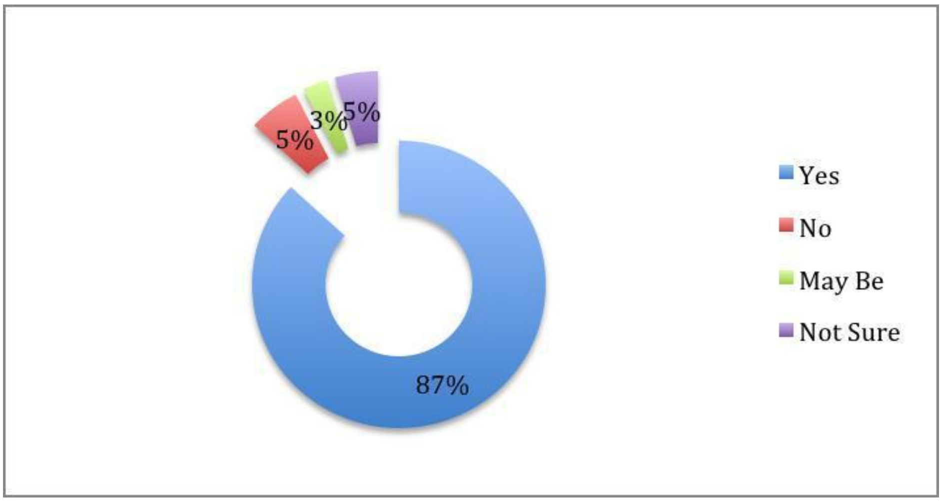

Figure 12 HH Facing Water Sanitation and Quality Issues

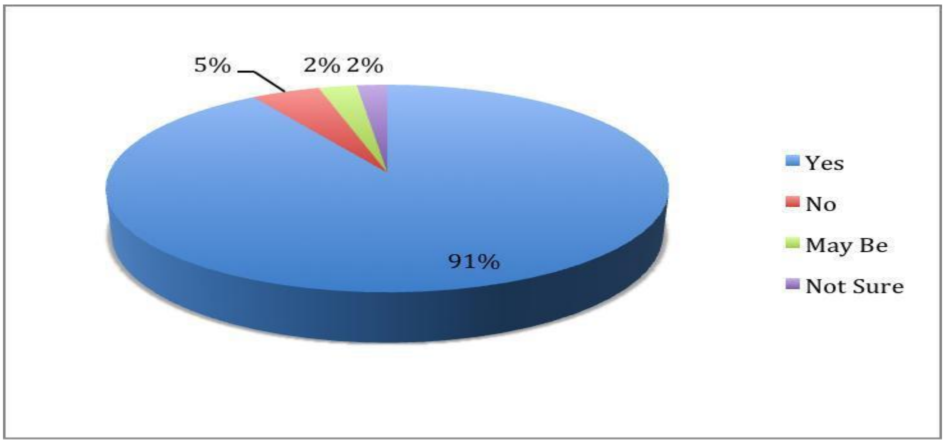

Figure 13 Requiring Further Improvements on Water

Figure 12 and 13 indicate that about 87% of the respondents have faced water quality related problems at least once during the last 10 years and 91% feel the need for improvement, respectively. This proves that Chennai has serious water quality issue.

4.2.4. Open Sewer Drains

One in 4 drains examined outside HH's were open and the sewer water flows out in the open. This indicates that the sewer mains are not managed well, and quality of the existent water resources may be poor. The poor sanitation is also indicated by the responses. About 140 of the 500 said they were slightly affected and 200 of the 500 indicated that they were affected badly due to open sewer systems. The government officials indicated that the sewer mains were well maintained, while the opposite was observed during survey. Observation identified that sewer drain lids were left open or half open in all the regions surveyed and hence, it is clear that maintenance is much required. This issue requires attention in order to manage quality of water sources in Chennai.

4.2.5. Ground Water Abstraction

Interviews with the TWAD officials indicate that Chennai's groundwater sources have improved, and the policy implementations are all successful. A closer look into the situation through interviews and discussions with local residents in T Nagar, Minjur, Purashawakkam Anna Nagar, Mylapore and Besant Nagar indicates that groundwater extraction is high. The Poonamalle freshwater source in Chennai is largely exploited. Janardhanan (2011) study indicates that there is illegal pumping and sales of freshwater sources. The Joint Director of the Centre for Groundwater Sources, Sudhakar indicates that: "In this area, large numbers of illegal groundwater pumping stations have sprung up where, every day, about 30-35 tanker loads are filled and sold in the city for Rs 750-Rs 1000 per tanker. Besant Nagar too has many water pumping stations besides hundreds of bore wells in apartment complexes," (Janardhanan, 2011).

The major well fields are highly exploited and these well fields are also used for sectors other than domestic. Besides keeping track of the number of wells, it is also very hard to maintain record of how much well water is extracted, consumed or wasted in these cases. "Currently, 40 million litres of water is drawn from Metro-water's wells in Neyveli, Poondi, Thamaraipakkam and Minjur to augment the supply from reservoirs" (Mariappan, 2013). Observation reveals that the wells were dug up between the years

2003 to 2005 to support extra sources, when Chennai faced drought and started relying on well and tankers for supply.

4.2.6. Awareness, Information and Communication

Awareness of quality is low. This is because the government does not provide information and test results with the locals.

The documents available currently only indicate the quality measures and the available standards, while most regional chemical, bacteriological and physical tests are not available. However, the fact remains that most people are not well informed. Out of 500 survey respondents only 150 were aware of the local water quality and the issues that are present and could appear in the future. Out of 500, 100 HH were not aware of policy and about 400 HH were aware of the policy.

The water quality awareness surveyed indicated that 150 HH were not sure of the quality of the currently supplied sources. About 200 HH respondents were not aware of the water research aspects and the new innovations found by TWAD, while 100 people were not aware of technological changes and new infrastructures implemented in Chennai. The respondents were not aware of the research and development but were more aware of the new technologies implemented due to newspapers and other media such as the television, flyers and posters.

Hence, the overall awareness is low in the surveyed HH, but since this survey was not concentrated in the slum regions it is hard to make out the awareness as per their income levels. However, a mixed survey, it is hard to tell if everyone is equally aware of the policy and other aspects examined. Hence, it is assumed that the higher the awareness of an aspect such as policy within the mixed surveys the more people in all classes are aware of it.

4.2.7. Customer Advisory, Feedback and Response Mechanism

The customer advisory is the efficiency with which the personnel solve the problems of local residents and give advice on installation, setup and other aspects (GWP, 2011). The current status indicates that among the survey respondents only 10 percent knew customer advisory means and were aware that Chennai needed to enhance it.

Many (50%) among the survey respondents believe that Chennai’s advisory system has been the same for years and that no change is possible anytime soon. Among the rest, 30 percent believe that they do not know if there is any customer advisory as it is was unavailable when they sought it for installation of the RWH. This is not entirely true as the CMWSSB and TWAD have pamphlets and information sheets as evidence for RWH customer advisory, available on request. They also have personnel on call for repair works. However, with respect to quality and other aspects there is no evidence of good customer advisory, as there was no mention made of any media.

The response facility in Chennai's supply system is slow and very unreliable. This is understood because the TWAD board and the CMWSSB records a complaint about the service or the source provision every day from at least a million people in Chennai. This could mean that the feedback mechanism is every efficient, but the response is very slow, and the quality of the service provided is very bad.

All 500 of the survey takers indicate that they do not believe that the service and response mechanism is any faster than before. They in fact believe that a private plumber or water installation service is more trustworthy than the government agent. This is simply due to inefficiency and poor training. For example, if a HH wants to repair their drain and they complain today, the response is two weeks later and after the initial repairs it still gives trouble. Surveys indicate that on average HH complain more than once in six months and more frequently, if they have a major problem.

4.3. Findings: Supply Policy Responses

The major findings reflect the opinions of HH, Water authority offices and water board staff.

Major policy responses by the TWAD and the CMWSSB are very vital as they effect changes in the way people rate reliability of the board, adapt and respond to these changes and the efficiency with which issues for the HH are resolved.

With 2013 summer reaching its peak, the media was full of new water management strategies that are being implemented within Chennai. The CMWBSSB and the TWAD aim to improve and increase quality of source, quantity of water supply and improve the efficiency with which water is allocated.

1. The Act 37 of 2002, with supply amendments including ground water extraction use, enforcement of fines, connection and installation charges and installation of meters.

    a) The law suggests that ground water should be for domestic purposes.

b) All water extracted from the wells for industrial purposes should be accounted for and specified if it is for private or public use. "…b) the use of groundwater in the schedule are for agricultural purposes immediately before the date of commencement of this Act; (c) the number of wells for which water is extracted for domestic purposes; (d) the number of wells from which water is extracted for industrial, automobile service centres, multipurpose halls and other commercial centres; (e) the number of water resources for both public and private…" (TWAD, 2012).

c) The quality of supply will be monitored every few weeks in order to test and analyze the microbial, chemical and physical status of water resources. These amendments made are good examples of ground water protection and to help the domestic life with more resources to use and to provide for all other purposes.

4.3.1. Policies to Manage Quality

The boards are currently strengthening Chennai's quality standards. The state guidelines for quality are based on national and international standards by the W.H.O.

Table 15 Indian Standard for Water Quality

Physical	Required	Permissible Limit	Value and Details
Color	5	25	Hazen units, Max
Odor	Unobjectionable	Unobjectionable	
Taste	Agreeable	Agreeable	
Turbidity	5	10	NTU, Max
pH Value	6.5 to 8.5	6.5 to 8.5	Above 6, Nonacidic
Total Hardness	300	600	As CaCO3 Mg/lit., Max
Iron	0.3	1	As Fe, mg/ lit, Max
Chlorides	250	1000	As Cl, mg/ lit, Max
Residual Free CL	0.2	0.2	Free Cl, mg/lit., Max
Other Characteristics	Required	Permissible Limit	Value and Details
Dissolved Solids	500	2000	mg/lit., Max
Calcium	75	200	(Ca) mg/lit., Max
Copper	0.05	1.5	(Cu) mg/lit., Max
Manganese	0.1	0.3	(Mn) mg/lit., Max
Sulfate	200	400	(SO4) mg/lit., Max
Nitrate	45	100	(NO3) mg/lit., Max
Fluoride	1.9	1.5	(F) mg/lit., Max
Phenolic Compounds	0.001	0.002	(C6 H5OH) mg/lit., Max
Mercury	0.001	0.001	(Hg) mg/lit., Max
Cadmium	0.01	0.01	(Cd) mg/lit., Max
Selenium	0.01		(Se) mg/lit., Max
Arsenic	0.05		(As) mg/lit., Max
Cyanide	0.05		(CN) mg/lit., Max
Lead	0.05		(Pb) mg/lit., Max
Zinc	5	15	(Zn) mg/lit., Max
Anionic Detergents	0.2	1	(MBAS) mg/lit., Max
Chromium	0.05		(Cr6+) mg/lit., Max
Polynuclear aromatic hydrocarbons	0	0	(PAH) mg/lit., Max
Mineral Oil	0.01	0.03	mg/lit., Max
Pesticides	Absent	0.001	mg/l., Max
Radioactive			mg/lit., Max
Alpha emitters	0	0.1	mg/lit., Max
Beta Emitters	0	1	mg/lit., Max
Alkalinity	200	600	mg/lit., Max
Aluminum	0.03	0.2	mg/lit., Max
Boron	1	5	mg/lit., Max

Sources: WHO (TWAD/CMWSSB, 2011)

The TWAD and the CMWSSB conduct a series of tests are not exactly based on the Table 15, values such as Phosphate, Nitrite and Ammonia are not provided with required and permissible values. The TWAD officials indicated that these values are not supposed to be present and if present it indicates a high pollution state industrial pollution.

Table 16 TWAD and Local Respondents on Quality Tests

Physical	TWAD response	Respondents	Responses Key
Color	1	1	
Odor	2	2	YES=1
Taste	3	3	NO=2
Turbidity	1	0	Sometimes = 3
pH Value	1	4	No response = 4
Total Hardness	4	4	N/A=0
Iron	1	0	
Chlorides	1	0	
Residual Free CL	0	0	
Desirable Characteristics			
Dissolved Solids	2	0	
Calcium	1	0	
Copper	3	0	
Manganese	2	0	
Sulfate	2	0	
Nitrate	0	0	
Fluoride	1	1	
Phenolic Compounds	0	0	
Mercury	0	0	
Cadmium	0	0	
Selenium	0	0	
Arsenic	0	0	
Cyanide	0	0	
Lead	0	0	
Zinc	1	0	
Anionic Detergents	0	0	
Chromium		0	
Polynuclear aromatic hydrocarbons	0	0	
Mineral Oil	0	0	
Pesticides	0	0	
Radioactive	0	0	
Alpha emitters	0	0	
Beta Emitters	0	0	
Alkalinity	0	0	
Aluminum	0	0	
Boron	0	0	

Source: (CMWSSB, 2012; Pilot Study, 2010)

The major quality tests were:

Source Based Tests conducted by the labs indicated that the water was generally of good quality.

The professional water testers provided analytical and periodical sampling reports, sponsored by the Analytical Section and Sampling Programme.

There are new water guidelines that will need to take into account the important events of the past two decades. The recent standards are further developed by the TWAD with approaches and information from earlier versions of the quality control document on sampling and testing for bacterial, chemical and other water pollutants.

1. The water samples are collected treated once- a- month from the three lakes. The lakes are the main sources of water supply to the Chennai city.
2. The treated water is collected from "test tap's" and samples are then checked. Within Chennai about 100 samples are collected every day from the WDS for physical, chemical and bacteriological analysis. Water is checked for minimum level of residual chlorine to ensure quality. Quality Assurance Department engineers monitor the level of residual level of water distribution networks and units.
3. Water supply to locals is assured as per norms in the BIS, Indian Standards. The physical, chemical and bacteriological quality of water may not exceed the limits set out in the Indian Standards for Water Quality shown in the Table 15 (CMWSSB, 2012).
4. Monitoring the Quality, the C.M.W.S.S.B. facilitates the public with access to water quality testing (their own sources such as: Well / Bore Well water), mainly physical and chemical parameters for a nominal charge as indicated by Table 16 (CMWSSB, 2012).
5. The coliform count in any sample of 100 ml must be 0 – 10 for any sample. Any sample collected for investigation needs to conform to standards, if not the efficacy of purification process and method of sample, needs to be questioned and investigated. Coliform organisms should not be present in 100 ml, any two samples of more than 5% of the sample collected for the year. The E. coli count in 100 ml of water should be 0 (CMWSSB, 2012).

Table 17 Individual Water Quality Tests

Test for	**Previous Charges (Per Sample) (Charges levied in Rs/-)**
Public (Individual houses-Drinking)	75
Private Institute (Drinking)	200
Private Institute (Construction)	200
Test for	Current Charges (2012) (Charges Rs/-)
Resident drinking water	500
Specific tests	300
Bacteriological	500

Source: TWAD/ CMWSSB, 2012

Hence, it is important to understand the level of total dissolved solids and the other elements to help safeguard water.

Issues such as penetration of saline water into fresh water and ground water sources are becoming frequently common in Chennai. When that occurs, the water becomes of zero utility value within households. The salinity can be managed if the floods are channeled in a proper fashion into drains that channel water to central purification facilities. The local drains are uncovered, and many potholes can be seen along the roadsides.

Hence, government has launched studies in collaboration with the UN and WHO to help improve quality and safeguard existing sources. It was found that the average yield is 370.34 MLD and the safe yield is 900 MLD. The scarcity in Chennai is due to monsoons and the supply operations and distribution. Until 2004 June the CMWSSB needed to supply water through lorries, pipes and wells. In response to this several projects have been launched. The government has come up with plans for channeling floods in Chennai, and they have also installed monitoring systems to identify floods and plan (see section on Policies for Flood Management).

4.3.2. Other Major Projects and Policies

4.3.2.1. Krishna Water Supply Scheme

The three governments, Maharashtra, Karnataka and Andhra Pradesh signed an agreement in 1976 to provide 15 TMC of Krishna River Water to Chennai city. Following this, a treaty was signed between Andhra Pradesh and Tamil Nadu Government in 1983. This accord allowed Chennai city access to 15 TMC of Water from the Krishna River. Water from Srisailam Reservoir on the Krishna River via Somaseela and Kandaleru Reservoirs is supplied to Chennai city. The total loss measured in transport is 3 TMC and only ~ 12 TMC was extended to Chennai, ultimately.

In 1996 the initial setup for this scheme was complete and towards end of 1996 water supply was initiated. Supply is delivered to Poondi Reservoir from Kandaleru Reservoir at a distance of 152 km and a long open canal up to Uthukottai close to TN border. This water is then routed 25 km. to Pondi Reservoir. From Poondi Reservoir, water is then delivered to Redhills and Chembarambakkam Lakes en route to the treatment facilities. The water delivery to these lakes is via the Link/Feeder canals.

Newer water supply schemes have been introduced to support Chennai’s water demand. The major water supply scheme is the Krishna Water Scheme. This source supports more than half of Chennai’s demand at present. Recently, the city and outer regions have higher demands and requires more water from Krishna. Water from Poondi is sent to Red Hills and Chembarambakkam reservoirs and then transported to pipelines into the city. Only 60 percent of the rural regions are connected through pipeline, while the city has 100 percent connection. The city depends partially on villages and rural water on the outskirts and improving supply through external source will ease up the stress.

The Government of Tamil Nadu requested the Government of Andhra Pradesh, in August 2012, to increase the water supply from Krishna. Chennai city until this point has received sufficient water resources 1100 TMC of water and this has reduced in the last few months to about 960 TMC, due to damage in the canal and hence the outskirts receive less water than usual (Ramalingam, 2012). Kandaleru reservoir has 26 TMC storage capacities that maintain the drinking water supply to the city, at the moment. The Krishna water scheme is to augment supply in two stages based on future estimates up until 2021. The numerical values are based on the carrying capacity of water resource and the demand requirements of Chennai but the numerical values are not essentially the actual amounts in storage.

4.3.2.2. The Updated Chennai Master Plan

The Master Plan for Water Supply to Chennai was formulated first in 1978 and was updated in 1991. The new features of the Master Plan are:

Water augmented from Krishna River is 930 MLD for supply to Chennai. The augmented water is apportioned among the beneficiaries, with respect to the projected population for the year 2021.

The system components are to be designed and installed progressively, with augmentable quantities so that the water allocated could be delivered with provision to reinforce the system to dispense 2021 water demand provided alternate source is identified.

The Master Plan can be implemented in two stages. The first stage will create the required infrastructures for Krishna water supply of 400 MLD. The second stage will strengthen and expand infrastructures to capacitate an additional 530 MLD supply of water resources from Krishna.

4.3.2.3. Master Plan Implementations

The Stage I was initiated in phases using the funds from central and state government along with World Bank Aided First Chennai Water Supply and Sanitation Project. Between 1987 and 1996, the New Well Field (Poondi, Kosathalaiyar Floor Plains and Kannigaiper) project was implemented to extract an additional 55 MLD of water from the AK Basin, 1987 (Chennai Metropolitan Development Authority, 2007).

A 300 MLD water treatment plant was completed in 1996 at Redhills. The transmission mains from the treatment facilities to North, Central and South of Chennai were installed (Chennai Metropolitan Development Authority, 2007. The treated water was transported to the distribution units where it was diverted to different regions of the city. All old distribution mains were renewed or repaired with unit metering facilities.

4.3.2.4. Veeranam Water Supply Project

The Veeranam Water Supply Project was initiated and executed as a supplementary source. The CMWSSB authorized this project in 2004 to supply, **180 MLD** drawn from the lake, water to the city. The lake gets water from Cauvery River through Kollidam, Lower Anicut and Vadavar Canal. The capacity of the lake is 1465 mcft and the water is treated through Vadakuthu Plant. Raw water is pumped to Vadakuthu from Sethiathope (20 Km). The treated water is pumped 8 km to Kadampuliyur. Kadampuliyur is a Break Pressure Tank. The water is then conveyed 200 km through mild steel pipes to Porur Water Distribution Station near Chennai. The distribution station then pumps water 1.2 km to the distribution units to the city.

4.3.2.5. Private Wells

The CMWSSB supplies water purchased from private wells (used for agriculture) in A-K Basin to supplement the current source. This increase concerns within food security sector as the water for food production decrease during drought years.

The wells are well maintained and up until 2008, water from these well are transported to the city through pipelines. Water abstracted from these wells help during drought years and provide a good backup to meet the city’s demand requirements. It is at the discretion of the CMWSSB board that this supply is utilized for domestic or other sectors. Presently this capacity is increased, and the water transported is also via tankers.

4.3.2.6. Groundwater Regulations

The extraction use and conveyance of ground sources need to be regulated and conserved, as the ground water table is fast reducing due to over exploitation. The Chennai Metropolitan Area Groundwater Regulations ACT (CMAGR) was enacted 1987. Chennai faces acute scarcity of water due to monsoon failures and reduction in the available resources at a very fast rate. Moreover, the other sources are inadequate to meet the domestic and drinking water purposes of people in Chennai.

The UN mission tried to research the possibility of supplementing water to Chennai. The investigation of the well fields suggested that Minjur, Duranallur-Kortaliyar basin, the Poondi, Kortaliyar Flood Plains and Kannigaipper aquifers and Poonamallee-Porur aquifer in Coovum-Adayar basin all have groundwater sources that are available for supply (Chennai Metropolitan Development Authority, 2007). The status of groundwater in certain wards of Chennai is indicated in the Table 18.

Table 18 Groundwater Utilization Table

	Ground Water Utilization	**Blocks**
Over exploited	More than 100%	138
Critical	90% to 100%	33
Semi Critical	70 to 90%	67
Safe		136
Poor Quality		11
Total		385

Source: CMWSSB and UNDP Groundwater Study

Due to failed monsoons, the recharge of ground water is also lesser, and more and more extractions further reduce the groundwater table. Chennai has many groundwater facilities developed, and many well fields and water service developments have been too many in efforts to supply a little extra.

According to the geologists in UNDP, groundwater in Chennai can be extracted between Kovalam and Madras. The CMWSSB indicated that all the possibilities of extractions have been explored and exhausted. Acts prohibiting use of ground water are for industrial use beyond a certain level when alternate sources are earmarked or available. The ground water for swimming pool is not to be used as it drains the water source. Users ignoring the laws will be fined an amount of Rs. 500 and now recently amended as Rs. 2000. This policy is not implemented strictly. It is important to regulate extraction and use of ground water in Chennai.

The steps taken to conserve and add to the water table are:

Based on the UN mission and UNDP studies on Chennai (according to the TWAD) the artificial recharge can be easily implemented with the excess water from the floods (Arni-Korteliyar Basin). The excess floodwater can be intercepted instead of letting it flow into the sea.

According to the TWAD and CMWSSB, a number of check dams are also considered. Recharge will become more balanced if 50 percent of the rainwater runoff is intercepted and directed towards supply. This will also stop seawater intrusions.

The boards and government has restricted the shallow and deep open wells and tube wells in efforts to reduce extractions. The groundwater sources are still unprotected in Chennai.

4.3.2.7. Restoration of Ancient Structures

The Ooranis are an example of storage mediums. Restoration project was successful (see section on Managing Crisis Situations). Since then, TWAD and Chennai Metro Water have both implemented a policy for improving and increasing the capacity of storage mediums for supply sources in Chennai. In the Rural and outskirts, the implementation of this program is easy as there are large tanks, ponds and other large - scale storage mediums in villages that are not maintained. While in urban regions there are large tanks within HH or large pond sized tanks within temples that could be used as community storage mediums. If the Chennai region is scanned there are small temples that have dry sacred ponds close by. This pond can be made into a water storage medium with artificial aquifer recharge, from the surface of the pond, to increase water level of that particular region. If the temple water ponds are converted into proper water storage and natural recharge of aquifers from below the ground, then it can provide the different regions with extra water. Chennai can implement Ooranis across the urban and rural regions with less material and low cost.

4.3.3. Treatment Facilities

There are several treatment plants in Chennai, supporting the quality of water supply. The initial capacity of treatment was 180MLD in the year 1978 and this has been progressively increased to 1398 MLD currently. The breakup of the total treatment capacity for Chennai indicates that Chembarambakkam has 530 MLD, Kilpauk has 270 MLD, Puzhal has 300 MLD, Veeranam Lake Treatment Facility has 180 MLD, K.K. Nagar has 4 MLD, Surapet has 14 MLD, Desalination Plant Minjur 100 MLD. The major treatment facilities that significantly impact urban Chennai are the Kilpauk, Chembarambakkam, Veeranam and the desalination plant at Minjur.

4.3.3.1. Kilpauk Treatment Facility

In addition to the mechanical treatment plant at Kilpauk (Kilpauk Water Works), a 90 MLD treatment plant was added to the upcoming projects' list. The government earmarked about Rs. 295 crores for this project in 1983. Further, the filter house, clarifiers, chemical house and 9 filtered water underground tanks were completed by 1990. The total treatment of this plant capacity reached **270 MLD**, this helps treat water homogeneously and to allocate via distribution units.

While other treatment plants also impact the water quality of urban Chennai, the Kilpauk facility is at the heart of urban Chennai. Kilpauk treatment plant has all major water services facilities installed and, plays a major role in equal distribution of good quality water to major sections of urban Chennai.

4.3.3.2. Chembarambakkam Treatment Facility

In 1996, to treat the water supply from the Krishna Water Supply Scheme, the TN Government sanctioned a **530 MLD** water treatment plant in Chembarambakkam for 206 crores (Telugu Ganga Project). The work was completed towards the end of 2007 and operations were started.

5.3.5.3 Surapet WTP

The CMWSSB took over the **14 MLD** treatment plant from the TWAD board as it supplied treated water to distribution units within the urban parts of Chennai. CMWSSB took over this plant in the year 2009 to improve operation and maintenance of water distributed within Chennai. Although, 14MLD may supply to a smaller community when compared to other plants, it becomes significant at a micro level for fast urbanizing Chennai.

4.3.4. Improvements to Zones and Water Distribution System

The Revised Master Plan Proposals indicate the Chennai City water distribution system is divided into 16 Zones. In addition to the 12 new water distribution stations constructed, 11 water distribution stations are rechecked and improved.

The 16 distribution mains have individual distribution units, which have separate transmission mains to supply water. It helps maintain water supply to a unit and micromanage the quantity and quality of supply from leaks and actual losses during transmission (for further details see sections on Distribution).

4.4. Findings & Analysis: Consumer Opinions, Adaptation Strategies & Policies

4.4.1. Water Supply Status

The supply status indicates that the total amount of supply is 730 million liters per day MLD approximately (2011/12) and the total required is about 900 MLD. The development of water supplies in Chennai evolved over the last 100 years, sharply modernizing over the last two decades. The chief improvements were supplementing the delivery system with increased quality control, piping and renovations of structures. The source of water for Chennai is from Veeranam, Krishna, desalination and well fields approximately totaling 1100 TMC. In addition, a recent request was made by Government of Tamil Nadu (TN) to increase supply by 200 – 300 TMC's (Lakshmi & Ramalingam, 2012).

Observations of normal conditions in Chennai indicate that the current supply is not enough; more water is required to satisfy HH requirements of Chennai. A walk thought the streets of Chennai enables observation of various problems such as leaks, sewer pipe leaks, tankers with people fighting over who gets water first, and few places with ladies using hand pumps to draw water from bore wells. The demand for water is very high and in general, water related conflicts among people do not happen unless water shortage is acutely felt. Chennai's problem is simple. There is lack of water to meet demand and the demand management needs fine-tuning of policy.

The source of water can be private or public. Chennai metro water is the main source of public water supply. However, there are other sources such as the private dug wells and bore wells, private tankers and canned water. The private canned water supplies are from intra and inter-state resources. The public well fields provide water through main supply lines such as pipes and tankers within the city. Currently around 70 percent of the water provided to Chennai is now from the reservoirs and lakes. It is estimated that most of the remaining 30 percent of the consumption is from water derived from ground sources.

Table 19 Water Profile of Chennai (1978 & 2010)

DETAILS	**1978**	**2010**
OPERATIONAL AREA	**176 SQ.KM.**	**176 + 7.88 SQ.KM. Outskirts**
Population	3 million (City)	5.5 million (City)
Water produced (Normal years)	240 MLD	760 MLD
Water Requirements	~300 MLD	831 MLD (~100 lpcd)
Area covered with piped supply	80%	100%
Treatment capacity	182 MLD	1,398 MLD
Length of water mains	1,250 km.	2,930 km.
No. Of consumers (Recorded)	1,16,000	4,97,811
Distribution Stations	3 No.	16 Nos.

Source: CMWSSB, TWAD. (2011).

Chennai cannot meet demand from existing supply as: 1) the existing supply is inadequate and significant portion of supply is from sources outside the city, 2) it is not equally accessible to all, as the various regions have limited public supply and HH's buy water from private sources to meet demand, 3) the quality is questionable as surveys report impurities and, 4) the allocation of supply is not equal among urban and semi urban areas (See Table 19).

4.4.2. *Water Demand Status: Consumer End*

Demand management in Chennai requires study of the consumption and satisfaction levels in order to better understand the policy, projects and programs.

4.4.2.1. Consumption and Per capita Usage

Consumption pattern includes the various uses for water along with the per capita usage. The per capita use refers to use in litres per person per day to complete a particular domestic activity. For example, the per capita use for drinking per day per person is 2 litres. The consumption pattern also includes study on source and extraction for use. The extraction methods may be within the house or outside the house for all domestic purposes. The consumption pattern also includes satisfaction of supply and water expenses for HH. In General, water expenses along with the amount of water supplied indicates the general satisfaction among residents.

The following features are significant in analyzing consumption patterns:

The public supply from tap inside and outside the house is used for all purposes with equal frequency due to supply times (6 AM to 10 AM and 4 PM to 6 AM). The water connections depend on the area and the systems' ability to pump out water to all regions.

The survey data indicates that HH with income range of 5,000 to 10,000 Rs. per month depend on public supply both inside the house through pipes and from outside from tankers and community pumps and storage tanks. About 10 percent of the residents indicate that in-house water pipes exist, but the water is supplied only on two or three days in a week. Supplies from overhead (independent and community) tanks and mobile tankers are also used for drinking and cooking purposes after filtration.

The dependence on canned water is medium to high (about 85 percent of the respondents indicated that they use water in cans) within the group of respondents. This pattern is noticed in the middle-income range groups. A large proportion of the total respondents depend on canned water for drinking and cooking. The higher income respondents (roughly 40 percent of the respondents) depend on public supply to a smaller extent in comparison with the other income groups. This group depends on private tankers for all uses except for drinking and cooking. The dependence on canned water is quite high for drinking and cooking within Chennai. Based on this, it is clear that canned water use involving higher cost is quite extensive.

Supply from community pumps and storage tanks are used for drinking and cooking purposes within low income HH (40 percent of the total respondents). The five regions selected for study use private tanker supply. A sizeable number of households, 80 percent of the survey respondents, utilize it for all domestic purposes.

A section of Chennai's population utilizes purified mineral water in 25 litre plastic cans for drinking and cooking, with established brands like Kinley and Bisleri. Overall in Chennai about one fourth of the HH use canned water for drinking and cooking. More than 85% of the surveyed respondents use 25 litre cans for cooking and drinking purposes.

About 10 of the 500 respondents have wells but cannot actually draw water from it due to dry conditions. Dug wells and deep bore wells are used both in rural and urban Chennai and there are HH's with wells that have dried up due to depletion in the ground water levels. There are also well fields, which are clusters of wells in Chennai used for public supply.

Saltwater is also used for cleaning floors and washing toilets by 5 percent of the respondents these respondents earn between Rs. 1000 and Rs. 5000 per month. Since, they cannot afford to use water extensively.

4.4.2.2. Satisfaction Levels in Chennai

Adequacy is measured through the available water and supply capacity satisfying the requirements of the HH within a region (Huitema, 2009). The satisfaction of water supply depends on the source quantity and the quality requirements. The overall water supply to HH constitutes only around 5% of the total supply, while the other sectors consume around 95% of the total supply in Chennai. Reportedly, the potential supply capacity is high for Chennai due to adequate rains, which averages 1100 mm as denoted by the officials, 100 percent piping, subsidized price and moderate level local participation. However, the actual supply is 100 to 170 MLD's lower than the required amount, there is inadequate piping and metering within the urban far reaches of the city and low local participation. The total demand is 900 MLD's while the supply is close to 730 MLD, as mentioned above. The surveyed regions showed signs of stress and shortage due to low quality and quantity of the water supplied.

Water supply in Chennai is unreliable. During discussion all residents expressed a level of dissatisfaction in the supplied sources. Among the respondents close to 50 percent indicated that public water through pipes is not supplied for 24 hours of the day. In addition, the survey reported that 75 percent of the respondents were not satisfied with the water supply hours and quantity and about 80 percent of the residents were not happy with the quality of sources. Due to the unreliable water supply, the HH dependence on private tanker supplies has increased. It is clear that among the surveyed HH water quantity and supply hours is unreliable.

The quality of the water supplied is also poor. Irrespective of the income levels about 85 percent of respondents still bought water cans for meeting requirements for drinking and cooking, due to low quality of the public water supply. A 25-liter can is bought from a private vendor for 0.50 US dollars to 1.25 US dollar per can. For a family of five, 25-liter cans last only for around 2 days and, hence they use 3 cans per week. In addition, the surveys indicate that a family of four consumes about 8 to 12 litres on average for drinking per day, which means approximately 2 to 3 litres per person per day.

Lifestyle changes have also contributed to this shift in consumption patterns. Thus, regardless of the income levels the private water supply consumption is increasing and the satisfaction level is low among the surveyed group.

4.4.2.3. Per capita Use

The consumption pattern indicates the purpose of use, the amount used per capita and the overall efficiency of use. Most respondents reported that they use public and private water supply for activities that are mandatory for HH such as laundry, cleaning, bathing and watering plants.

The residents of Chennai believe that each person requires varied amounts of water every day and on average a HH of 4 to 5 members requires 100 to 150 litres solely based on: 40 to 50 litres for showers, 5 to 10 litres for cooking, 10 to 20 litres for washing dishes, 8 to 10 litres for drinking (per HH of 4 to 5 members), 30 to 40 litres for laundry and the rest for miscellaneous tasks. Not many of the respondents understand the concept of basic water requirements of 40 litres per day per person, as this quantity is considered inadequate.

The chart Figure 14 indicates that there are more than 400 respondents that use 30 to 50 litres of water on average just on laundry every day. During discussion of the usage, respondents indicated that they wash clothes almost every day. They try to conserve by doing laundry once in three days, but they end up washing some clothes like hand towels, wipe rags etc., every day. They also clean their houses every day; the house is mopped and swept every single day.

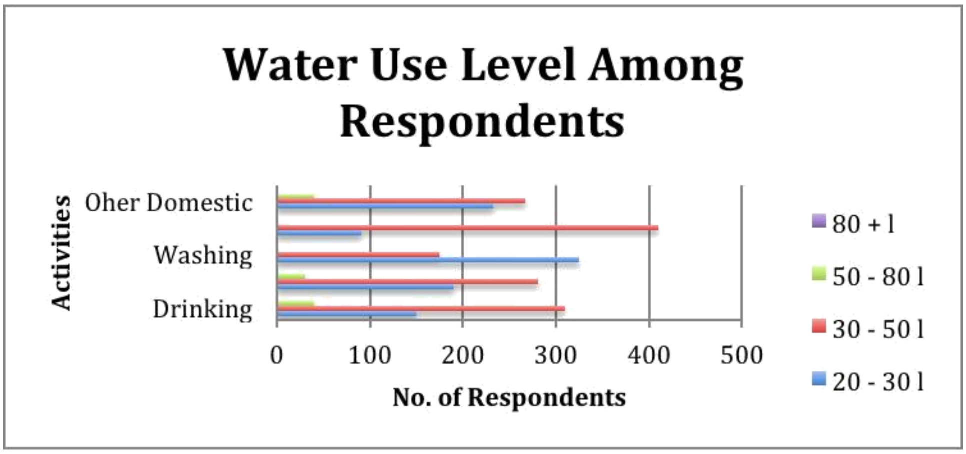

Figure 14 Water Use Pattern

Source: Data collection, 2012

The interviews suggest that the variation in water use, for Chennai's select wards, is about 35 percent of the total usage. The average use is high for cleaning the house and washing, 50 to 80 lpcd. The total use is 82.32 lpcd in Chennai, within the wards (CMWSSB, 2012). The average use in Chennai is recorded as 70 lpcd for 8 million residents and the difference is due to the smaller size in population. However, it is indicated that the per capita usage was at 120 lpcd before 2008 (CMWSSB, 2012).

A small quantity of the water supply is used for cooking and drinking, while large amounts are used for washing, laundry and other purposes. Water use for cooking and drinking per household per day is very little, 3 to 4 lpcd and hence, it falls within the allotted 60 - 70 litres of drinking water per week per person by WHO (calculated with respect to the breakup of 40 lpcd requirements per day).

The survey response also reported that 20 percent have pools or tanks, 45 percent of respondents indicated that they have vehicles and about 35 percent have a garden. Most people use water hoses to wash cars, water plants or to fill their pools.

Most respondents, 70 percent of them indicated that they store water for about 2 to 4 days to manage water efficiently. One 20- 30-liter bucket to shower per person is used by 30 percent of the respondents. The middle class and high-income respondents use showerheads and henceforth, measure their shower time rather than buckets. The residents also timed their showers as water cuts make it hard to shower longer as every family member need to finish with all water uses by 9:30 AM in the morning. Water is available between 5 and 10 PM but with weak pressure, that is not good enough to take showers, wash dishes or laundry. Respondents tend to have a schedule for showers, cooking, cleaning etc.; this cuts water-waste, thereby enabling efficient use. Besides, this also forces people to look at other options to obtain water. The alternatives to public supply include unmetered ground water usage and increase in water expenses for private sources, which could otherwise be utilized for other purposes.

Most HH respondents use extra water to maintain hygiene and sanitation at home. Among the respondent’s 90 percent indicated that hygiene is the foremost priority, as they cannot afford the expenses related to health problems. The general idea is that hygiene and sanitation will help upkeep the quality of water that is stored at home and help prevent diseases, keeping expenses on water ailments at bay.

Although, the litres per capita is high in Chennai the source is variant, most HH’s have saltwater taps along with the public in house taps or outside taps and a third tap to access water from tanks or storage facility. HH interviews indicated that the low-income residences use saltwater for cleaning the floor and toilets, while public source is used for baths, cooking and cans for drinking. The tank water is used during the day when there is no public water supply in taps. Households in Ennore (25 respondents) indicated that they use slightly salty water to clean homes and toilets while public supply is used for cooking, drinking and washing. On the other hand, respondents from Nungambakkam, Purushawakkam, and Adayar reported use of public tanks, community tanks and private supply.

The consumption may be irregular with respect to use, income and sources (private, public and groundwater resources). The average per capita daily domestic consumption within the HH indicates that Chennai on average uses more water than the WHO prescribed level, 40 lpcd (bare minimum). The per capita range is between 25 to 100 lpcd, about one third of the respondents use between 40 to 50 lpcd and the rest use about 50 – 85 lpcd. On average the low-income group use between 40 and 50 litres per day per person, while their salary is about Rs. 10,000 per month. The high-income groups earn between Rs. 30,000 and Rs. 50,000, and use about 60 to 85 litres per day per person denoting a higher per capita use. This indicates that the per capita use is proportionally linked to the income levels of the respondents.

Table 20 Average Per capita consumption

	Drinking	Cooking	Washing	Bathing	Others	Total
Average						
(In lpcd)	3.98	4.36	26.81	16.32	38.82	82.32

Source: Data collection, 2012

The Table 20 reports the statistics on the consumption of public supply use is high compared to the private community and privately shared supply. The consumption of public water is high in the wards with clean water supply and good quantity within low-income groups.

The measure of good, medium and poor level of water supply or quality in table 20 is based on the consumer feedback and the quality checks conducted by the water analysis team. Similarly, the spatial variation in public supply use is due to use of cans despite having public supply in most households. The public supply consumption for drinking and cooking is low as major sanitary issues prevent users from consuming it for drinking and cooking, most residents do not believe that it is safe to cook with the public supply unless it is treated and boiled extensively first. They believe most of the illness they face range from common stomach problems to typhoid and are related to the unclean water used for cooking. The wards with poor supply also have higher dependence on ground supply. The reported statistics from TWAD and CMWSSB reports that it is unclear if HH consider the public supply to be unclean and poor within Chennai. However, most respondents within the surveyed region feel that it is unclean as they spend money mostly on water related ailments every few months.

Table 21 Water Consumption and Public Supply Contribution (within select wards)

State of Public supply in Wards	Clean Water Supply	Good Quantity supply	Per capita use of Supply	No. Of wards with dependence on public water
Good	3	3	4	4
Medium	5	4	3	3
Poor	4	5	5	5

Source: Data collection, 2012

Table 21 indicates the consumption of clean and good quantity of water among 12 wards in Chennai. Within the surveyed regions there are 12 wards. There are 3 wards with good quantity and quality of water supply while, the rest of the wards have medium to poor water supply and quality. The per capita use of supply is poor in 5 wards with low water supply and low quality. From table it is clear that among 12 wards only 4 depend on public water sources, and the rest of them depend on both public and private sources. The major water security issues range from poor quality and quantity. The poor pressure, a smaller number of hours of supply and unclean water etc. are the major issues faced by Chennai.

4.4.2.4. Costs and Expenses at Consumer End

As per the HH income and expenditure survey, the estimated average monthly water expenditure is over Rs. 1500 (US dollars 25) per household. This denotes that this survey selected a large portion of low and middle-income respondents, while the lowest income groups and the very high-income groups constitute a small portion only.

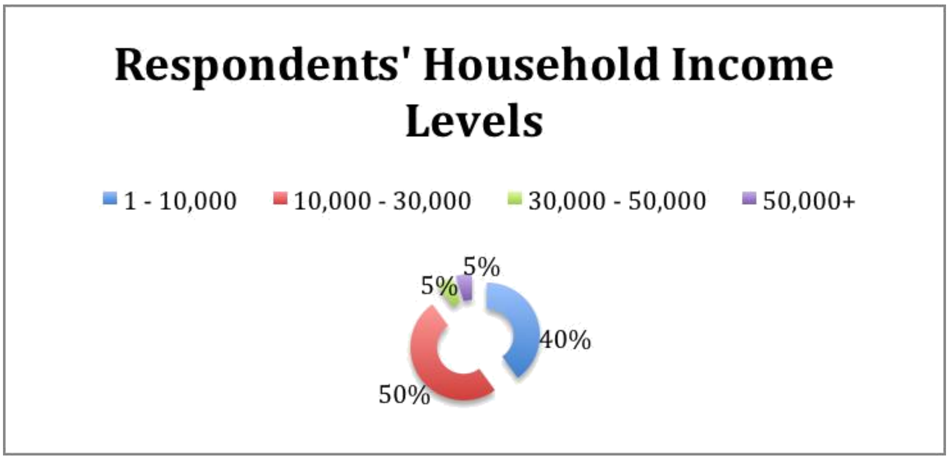

Figure 15 Pie chart of household income among respondents

Source: Data collection, 2012

Figure 15 & 16 show the histograms of household incomes and HH overall expenditures. The highest frequent range of the income is 10,000- 30,000 Rupees per month. As per the frequency curve of household income, the curve is inverted 'U' shape clearly showing the income range. It clearly shows that majority of respondents spend heavily on water requirements.

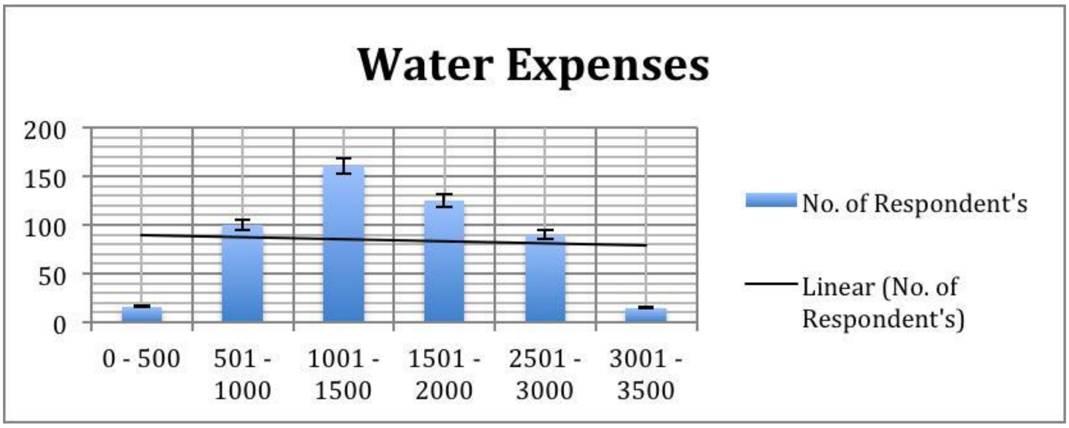

Figure 16 Histogram of Household Expenses on Water

Source: Data collection, 2012

The average HH utilities expenditure is about Rs. 6000 to 8000, which included gas for cooking, electricity, electricity, telephone and water cost etc. Electricity is the highest one for all households. The average expenditure for water cans is 7.75 cans per month, roughly about 503.75 Rupees per month. The average water bill for 500 households is about Rs. 1500, which indicates that about one fourth of the total expenses for utilities go towards water for low- income groups. Public supply of 157 litres costs only Rs. 10, yet most respondents buy water from private sources, making it more expensive.

Private companies supplying drinking water cans cannot alter the pricing according to government rules, as they need to recover costs. Hence, the prices are higher than public supply. The costs for treating and packaging are very high for private companies. Household income and water expenses indicate that the current level of water expense for Chennai residents is 2 to 3 percent of their income for residents earning below 20,000 and about 0.5 % of the income for higher income level HH (see Figure 15).

Affordability depends on a variety of aspects in Chennai such as the level of public supply, the accessibility of resources for all and the cost of drinking water. Chennai has generally high affordability of public sources. The cost of buying a good brand of drinking water is high, around US dollars 1.50 for 25-liter cans and it may increase over a period due to scarcity.

4.4.2.5. Projects Pipelines

Piping helps deliver the water supply to consumers. Lack of proper piping can restrict access to public water resources that is their right as residents of the region. The Metropolitan area-initiated pipe borne water supply 100 years ago. There have been several improvements to the past schemes in the present decade. Interview with officials suggests that Chennai has 100% city pipelines and about 40 to 60% rural pipelines supporting supply. All main roads and residential areas have connections to supply mains (authority views). There are regions however, with shared connections or community pipes. There are many HH in the interiors do not have independent pipes, they share it with multiple HH's. Restricted access to water implies dependence on other sources, as households require 90 lpcds. In Chennai, the problem with pipelines range from lack of supply, sewer mixing with water and sharing pipelines.

The district has 15460 streets within the CMWSS Board Water supply pipeline area. According to the Tami Nadu Water Supply and Drainage Board (TWAD) there are 130 or more streets where water is not reached through pipelines. To increase water availability for the streets there are improvements to channels of distribution, which are underway in Chennai. Although, most streets are now connected with pipelines the street mains still do not have 24-hour water supply. Hence, the number of pipelines is inadequate, and the hours of water supply are restricted.

The piping and connection do not imply water availability. Survey results do not show 100 percent piping, this may be due to shared pipelines and common pipe access for a community in certain regions such as Neelankarai. According to interviews with officials, the central regions of Chennai have 100 percent pipeline connections whereas the rural and the outskirts of the metropolitan boundary have only 40 to 60 percent pipeline connections to receive water. In some of the urban areas falling close to the outskirts of Chennai, no pipes are connected.

Municipal supply of potable water is provided in pipes during the day for a few hours and HH are asked to fill up vessels to meet requirements for the rest of the day or hire tankers to serve as an alternative source. Chennai's HH use pre-existing wells to extract water and a flat rate is levied for such sources. The metering is necessary to control misuse, extraction without permit or overuse of water for luxury or other purposes during drought periods. Besides these consumers are informed about their use level and the charges.

Maintenance of full piping does not indicate adequate or continuous supply in pipes. If there was 100 percent piping, flow and metering, the scenario would be ideal, but it is not the case for Chennai. Evidence shows that, most surveyed residents get tanker water supply within the surveyed group. Although the respondents that indicated that they do have pipeline they still depend on private sources and tanker supplies. The Figure 18 shows that the availability of water in pipes is not proportionally related to piping facility between surveyed HH's. Further investigation confirmed that many homes have water connection but no water. Although 5% error is taken into consideration, the percentage of piping and metering levels within the surveyed regions do not match. This is due to some miscommunicated responses. A large percent of the total HH's surveyed especially in Purushavalkam, Anna Nagar, Parts of Adayar, still depend on tankers for supply for domestic purposes due to lack of water in pipes. HH members usually bring vessels to carry water from the pumps or tankers. Furthermore, supply hours are restricted. The figures 18 and 19 indicate that piping facility is high and partially connected, within Chennai. Thus, the major issues with pipe connections are inadequacy of the number of connections and the unavailability of water from the connected mains for HH.

4.4.2.6. Metering and Non-revenue Uses

Metering is required for monitoring and controlling water use among residents and commercial users. Consumption patterns indicate that HH do not have a clear estimate of the amount of water they use. Chennai does not have universal metering. The meters installed are in apartment blocks and independent houses. Chennai city has installed one kind of meter for various housing facilities (Ref. Figure 17). Pumps and bore well access are measured with a meter during supply through pipes. It is very hard to measure water use for tanks, tankers and unmetered ground water resource use.

All regions need meter for pipelines to realize the exact amount of water supplied, the consumption, to improve techniques for use efficiency or improve conditions of supply. Around 80 percent of the total respondents with proper piping and metering indicated that they buy tanker supply on an emergency basis. They also buy private cans for drinking and cooking purposes. Hence not all houses with meters get access to only public supply. Significant amounts of people buy extra water and tanker supply to share within their community.

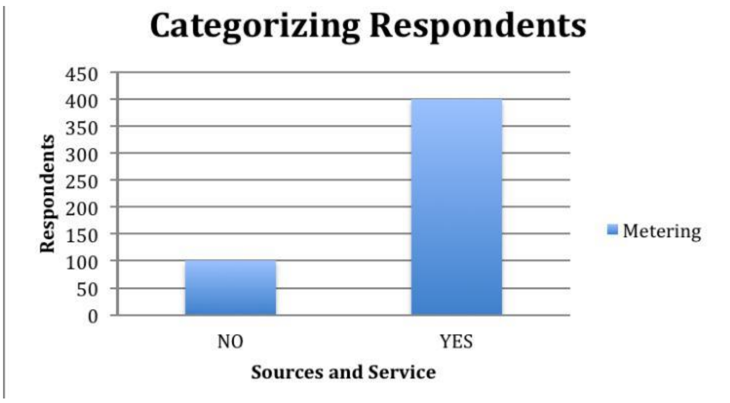

Figure 17 Water Supplies for Metered and Un-metered Household

Source: Data collection, 2012

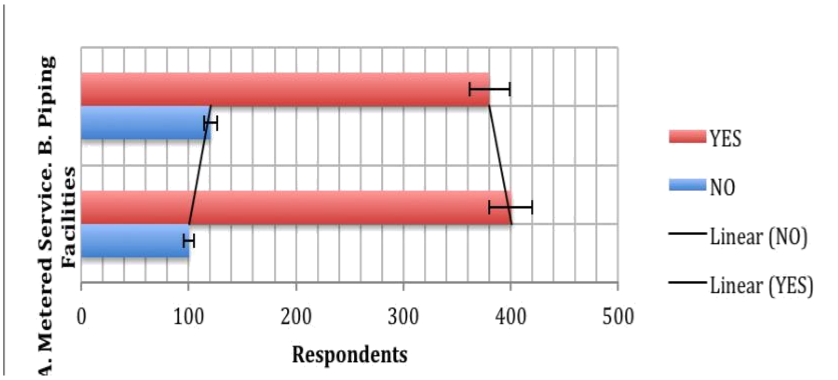

Figure 18 Households with Piping and Metering

Source: Data collection, 2012

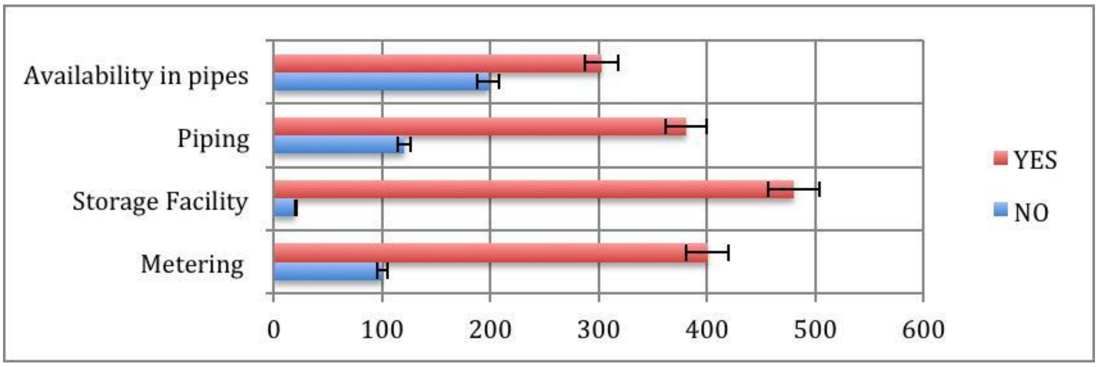

Figure 19 Responses for Metering, Piping and Storage

Source: Data collection, 2012

The Figure 17 specifies that the percentage of metered and unmetered, is 80 percent (Metered) and 20 percent (unmetered), among the surveyed respondents. There are specific unmetered areas which are charged Rs. 50 per month per HH for water usage, see Table 21 (CMWSSB). The billing is done every 6 months. The non-metered consumption within Chennai is about 26% of the total supply and it translates into 1200 to 1400MLD, approximately. The total unmetered supply 1200MLD for all sectors such agriculture, industrial and household commercial uses supply a large amount for unmetered water resources.

Lack of metering also hinders inventory of HH connections and use. The number of HH (as per Figure 18 and 19) has no metering services, as no pipelines are possible in hutments and slum areas. Some respondents did mention that they have pipelines but upon observation it is clear that they share a community pipe to access water.

Furthermore, water metering is not possible for wells and tankers as the supply is collected in vessels, storage tanks etc., for use. Hence, for inventory purposes it is only possible to get an overall estimate of water consumed and supplied.

Faulty or damaged meters are also major reasons for unmetered use between HH. The faulty meter is reported in some areas and mostly identified by staff recording water use. Many areas in Chennai do not report faulty or damaged meters unless detected by staff.

Thus, overall the inconsistent supply and metering indicates low accountability, reliability and maintenance.

4.4.2.7. Alternative Supply

Tankers are required to transport water to each region of Chennai. Most tankers are hired by contract and a fee is levied on HH. The water derived from various sources are collected and transported via tankers. 300 tankers move through the city delivering water supply. These tankers make 1300 trips throughout the day, but it is not feasible to provide water through tankers to all of Chennai. Energy and financial costs will be high apart from the vast area to be covered. A large number of people depend on the tankers due to lack of water in pipelines.

The CMWSSB decides the various methods of supply available for users, the quality control (treatment), metering and the various charges. The tanker supply is generally considered reliable. Tanker supply is for one hour per location, as they need to move through a select number of streets, to fill up private storage, shared storage and community tanks. Respondents in 3 out of 5 regions indicated that they need tankers, as public supply is insufficient. There are mini tankers used for extreme north and south of Chennai where there are small communities. Moreover, HH fill up storage tanks that store supply, with a capacity of 400 litres of water (400 litres of water can be used for 4 to 5 days depending on purpose of use and the total use). The tankers are accountable to the CMWSSB, but they make trips to as many regions as possible in one day. Since the number of tanks have been increased in the year 2011, it is now possible to cover more than 90 percent of the city with just tank water supply.

4.4.2.8. Leakage Control and Maintenance

Leakage control, repairs and maintenance are handled by TWAD and CMWSSB. The interviews and surveys indicate that there are many complaints registered every day in addition to the residents seeking help to fix leaks, repairs and maintenance. There are two types of leaks observed the active and the passive. Active leak control is the process where unreported leaks are identified and acted upon. The passive leaks are those, which are reported and repaired, mostly within HH's and commercial blocks. The interview with the TWAD reported an unreported leak account for about 70 to 80 percent of the total water loss in Chennai. Small hidden leaks can go undetected for days and requires special control measures. Chennai's piping has visible leaks, despite underground pipelines. These visible leaks are acted up on as soon as the government staff is available to work on it. The major problem in leak detection is that it consumes time and the time consumed for initiating and completing repairs takes longer.

The HH report leaks on a monthly basis within the house or outside the house. These HH complain at least once in a month or two. Discussion suggests that these leaks were only attended after 24 hours of complaint. Once the leaks are repaired the leaks constantly re-appear, indicating that the staff attending to leaks are either not trained or the repair action required is adequate. About 60 percent of the HH's indicated they face leakage multiple times over a period of 6 to 8 months. More leaks develop due to lack of attention or proper maintenance facility.

In Chennai the leaks are majorly due to 1) faulty distribution units, water development facilities or HH pipelines and, 2) faulty pipes in conveyance mode. Most connected pipes have leaks and a large quantity of water is lost due to leaks in Chennai.

The government of Tamil Nadu is undertaking leak repair work in Chennai. As per survey results, piping is unreliable, and repair of leaks are not done promptly or adequately. Water lost during transport is not measured accurately. The difference in total water source and actual supply to HH's indicates the total water lost. But the total water available is stored in reservoirs and transported, sources are divided among 300 tankers and the distribution units; hence, it is not possible to accurately estimate the water loss. Although the city office has made plans to ensure that water loss is under control. Observation of a tanker indicated that a significant amount of water was lost. A trip across Adyar to Mylapore, while following a tanker showed a wet trail. The water loss may be coincidental, yet most residents feel that there is a significant amount of water lost during transport. The measured water loss is unknown, as they are not disclosed. Leak detection at residence level and leak detection at community level is much needed in Chennai.

The repair and maintenance facilities are provided by the CMWSSB for effective conservation and efficiency of use. When there is an issue consumer must request for help and the board determines the required course of action, if the situation warrants immediate action. The actions by staff or private professional repairs in Chennai need to be improved based on the intensity of issues. The major issues are large undetected leaks, RWH installation repairs and maintenance of other infrastructure. The conservation technologies such as the RWH and artificial recharge (AR) are properly maintained throughout the year and the maintenance is very easy and simple. Only about 20 percent of the surveyed HH were aware of the required maintenance for RWH and leak maintenance. About 60 percent did not respond to the query on awareness of RWH maintenance and the rest were not aware of the kind of maintenance required. Managing pipelines is equally important for leak and repair management.

4.4.2.9. Household Conservation Practices

The major conservation techniques required from the consumer end is RWH installation, artificial recharge units and programs for efficient use. Among the respondents surveyed the 80 percent indicated that they do take water shortage seriously and would like to know more about it. The rest of the respondents included 5 percent without any response and 15 percent indicated that they do conserve on a daily basis. Most households in low-income sector within the surveyed group do not use water for recreational purposes as they spend about 2 to 3 percent of their salary for water. It is not viable for them to wash their homes with excessive amounts of water. Similarly, the middle-class group do use water but with limitations. For example, observation suggested that the HH's did not have cars or pools to maintain. But they still had house cleaning and washing requirements. The high income HH's however, do use water for gardening, pools, and car wash and for fountains or water bowls in their homes.

The government has hence introduced water cuts and RWH to help people conserve water as much as they can. The water cuts, however only induced people to seek water resources from an alternative source. RWH is an old technology using precipitation from a catchment surface to collect water. Chennai metro water has implemented this policy for communities to improve their water supply. With 1100 mm of rain annually, TWAD indicates that they will harvest about 2,67,000 litres per ground plot of land (223 sq. m.) per year. The cost of implementing RWH structure is anywhere between Rs. 800 – Rs. 4100 (USD 13.28 to USD 68.00) Per unit depending on the house design and structure. Whereas the cost of buying as much water as harvested would be much higher for a HH with average income. Installations are one time and quick, but many surveyed households indicated that they were not given the installation of RWH and training as they had to self-install. According to official's 80 percent of the rainwater that can be captured is allowed back into the sea. Similarly, the volume of recharge up to 60 percent effectiveness (predicted) adds about 160,000 litres of water per year for a plot of one ground (223 sq. m.) to replenish groundwater sources. The need for RWH is to meet demand, reduce dependence on ground sources and to artificially recharge underground sources. Tapping into the existing 80 percent rainwater that runoff into the sea conserves lot of water for local and HH use.

There are various methods of conservation. There are three kinds: the roof top harvest, wells recharge and the open spaces recharge. Techniques to harvest in Chennai include:

Table 22 Conservation Techniques

Pits for recharge,
Trenches (2 m wide and 3m deep),
Dug wells (water passes through existing water filter before reaching dug wells),
Recharge wells
Recharge shafts (for recharging aquifer or underground tanks),
Lateral shafts with bore wells include 2m wide to 20 m depth, and
Spreading techniques (consists of water permeation into soil and spread in-stream to dams, gabion structures or ponds etc.)

Source: Data Collection, 2012

Not every region can conserve rainwater resources; the regions where there is heavy rain, can implement structures like small tanks or Ooranis, which can act as storage tanks for households (Table 22 and 23). This works effectively as there is a lot of rain. On the other hand, areas with low rain occurring over 2 months can only collect in large storage facilities that can also treat water for use as and when required. This is due to the fact that rainfall is between long spells of time. HH indicate that the RWH installations are now becoming the best way to conserve. Many of the respondents implied that they have small storage containers besides the RWH structures at home for immediate use in case of water cuts.

Chennai now has consistently showed less rain in the two years (2011 and 2012), while the dependence on ground water has increased so much such that the ground is drying, even with increased inflow from intra and interstate imported water.

Table 23 Rainwater Harvesting Type and Percentage of Households

Type	**Households**	**Percentage of HH**
Roof Top	400	80%
Surface	15	3%
Combined	50	10%
No Response	35	7%

Source: Data collection, 2012

A fairly large number of people more than 70 percent of the HH have indicated that they have RWH (Table 23), but they require some assistance with the leak and implementation itself. Many RWH structures, as ascertained from the discussions, have self-installed or sought help from the private water service, plumber etc., for help due to non-availability of help from TWAD and CMWSSB water services.

Majority of the HH interviewed reported that they use roof top RWH installations. About 5 to 12 percent indicated that they have other RWH installations or do not have any installed. The no response category on the table below indicates that the HH do not have RWH structures, observations indicate that rainwater is harvested but not for recharging, but for domestic use. 25 litres cans are filled up with rainwater during heavy rains thus, improving the water supply levels.

According to officials, RWH staff members are under training for proper installations and repairs and monitoring residences. Chennai residents further, implement tanks and structures for water collection, use or recharge. All residents indicated that they like RWH, several people among the 5 percent without RWH installations indicated that they are willing to spend and install it. In addition, respondents feel that RWH will improve Chennai's conditions during drought situations.

For the current situation in Chennai the RWH staff and the administrative offices need improvements to enhance awareness, conservation and inventory. The lack of workers to install RWH units is due to lack of training and manuals etc. To improve such deficiencies the TWAD and CMWSSB has introduced training for RWH implementations. In addition, the TWAD has introduced a manual that indicates the significance of RWH within the city. The importance of harvesting more importantly "the ability to harvest" and cost of installations are important aspects requiring attention.

4.4.2.10. Education and Training: Awareness

Customer Advisory Services basically imparts knowledge on installation and use of efficient and effective equipment. The customers are advised on the new pipe sets, the use of RWH installations and the major quality control measures to be implemented within the HH. Customer advisory is not prominent in Chennai, 80 percent of the HH respondents are not aware of the existence and significance of such programs. Survey results indicate that only 10 percent of the residents within the surveyed group were aware of customary advisory. RWH has customer advisory program where HH are advised on installations and maintenance is made easy.

Awareness and inventory are important aspects of maintaining water quality, supply and demand. If the boards are not aware of the water conditions, it is important at least locals are aware of it and can report it to the boards to allow testing and monitoring. Water testing and monitoring is done once a month and only 500 samples are collected. This does mean that certain elements or contaminants cannot be confirmed with just a few runs of tests. About more than 300 respondents out of 500 indicated that they were unaware of quality and related policies in Chennai. They also do not have any community meetings or training sessions available with their neighborhood. None of the respondents indicated going to meetings or training. Officials indicated that there is low awareness, but recent training programs and information provided on the bulletins have increased the number of people aware of what their water quality is like and what are the likely problems they could face. From the bulletin print topics covered, it is clear that the public require more climate change and quality related information. Droughts and floods can impact water resources in different ways. Increased temperatures can cause already infected water bodies to breed and spread diseases. Floods can spread salinity and contaminate water bodies with mud, dirt, and minerals from the sea, salinity and slime.

The level of awareness is low in relation to quality, quantity and policy. 100 out of 500 people surveyed are unaware of information (see Figure 20).

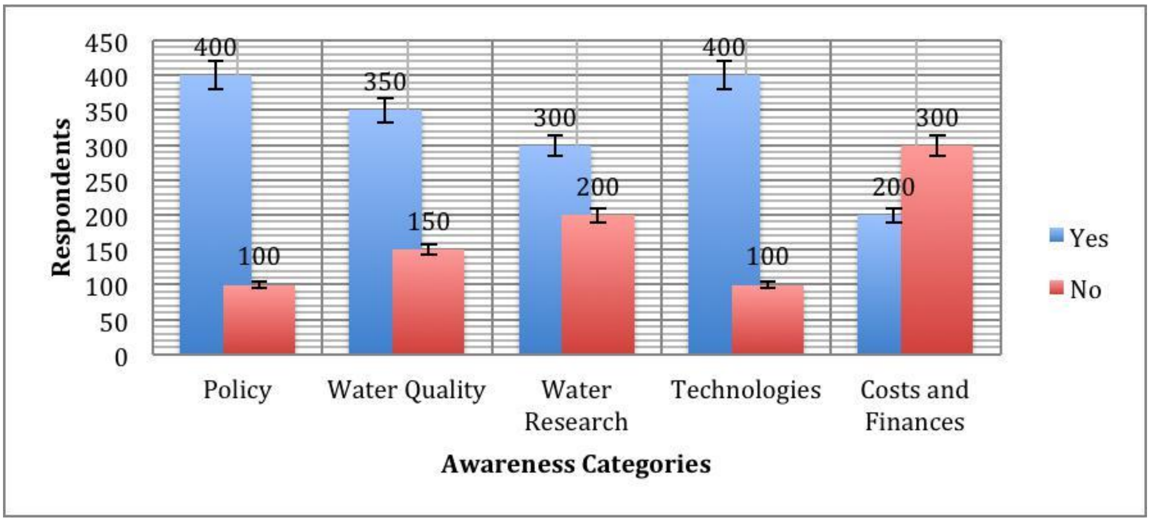

Figure 20 Awareness Level in Chennai

Source: Data collection, 2012

The survey results indicate that HH is less aware about water policy and quality issues than the water board claim. Officials indicated that people in Chennai are fully aware of policies, water researches, quality, technologies, costs and finances. However, as the chart above indicates the level of awareness within the surveyed regions of Chennai, over 20 percent of respondents within all categories are unaware of most aspects. All 500 respondents felt the inadequacy of water supply and the information available to them. Approximately 70% of respondents indicated that water is inefficiently used, and among these respondents only 50% have indicated that they are aware of the quality and policies. Thus, most HH are aware of the need for efficient use but are unable to successfully implement efficiency due to lack of awareness of water policies, quality and other aspects. Hence, policy changes should include training on water conservation and efficient use for the local residents.

To widen the knowledge base, the Tamil Nadu State Government has created workshops and training units that propose to educate people from the basics. People are often not aware of the training and programs available, and the significance of such programs. This presents a problem for administrators, and they first need to advertise and setup training camps or workshops in the city in order to improve awareness. Thus, the CMWSSB and the TWAD are required to respond to these issues.

4.5. Adaptation Strategies by Administrative Bodies

Demand related policies considered are based on the need to: 1) improve use regulation, 2) implement RWH in low income regions with community tanks, 3) improve training and education for HH, 4) improve communication and awareness and enforcing them in a dedicated manner and 5) steps to ensure organized and reliable service for all of the above. The policy response is to respond to calamities or crisis situations with efficiency, transparency, reliability, accountability and precision. Policy responses play an important role in adaptation to climate change.

The NIOT and other Climatological Institutions do not consider Chennai as a severely drought prone region. Nevertheless, the outskirts of the city face mild to severe droughts due to poor water supply, rains and management of water resources. The supply and RWH teams indicate that there is an increasing possibility of worsening climatic conditions, and that Chennai district is adequately prepared and will survive. The information provided by the TWAD through interviews and documents indicate that extreme cases of water droughts were recorded in the years 2003 and 2004. After the 1980's drought periods, it is estimated that severe droughts occur in a cycle roughly every 12 - 18 years, and they often last for more than two years. The cycles of drought occurrence have now become more intense in Chennai with droughts occurring every 3 to 4 years. The more erratic the occurrence of drought-like symptoms, the harder it is to manage droughts. Drought management requires more planning, efficiency and a regular inventory of available resources.

Policies for piping, metering and leak control, conservation, restricted use, RWH and AR, scheduling supply, short- and long-term planning, education and training, drought prone areas and goal setting play an important role in efficient demand management. The following sections indicate the vitality of organizing, managing and maintaining the technical and non-technical aspects of demand management.

4.5.1. Supply Piping, Metering and Leak Control

Chennai's water management and administration has decided to revamp the current water supply by introducing 13 new projects. The supply improvement will improve the current situations in the specified areas (as shown in Table 23). However, the current projects do not address the issues and state of water supply within all regions of the city. The regions studied in this paper are urban centres of Chennai, while the projects are more oriented towards rural and semi urban regions.

Table 24 Current Policy Responses

No.	Project type	Cost in Rupees (millions)
1	Tambaram Supply Scheme	326.2 (USD 5.26 Million)
2	Tambaram Under Ground Sewerage Scheme	1609.7 (USD 25.96 Million)
3	Avadi Supply	1038.4 (USD 16.75 Million)
4	Avadi Under Ground Sewerage Scheme	1580.5 (USD 25.49 Million)
5	Maduravoyal Supply Scheme	233.0 (USD 3.76 Million)
6	Maduravoyal Under Ground Sewerage Scheme	574.6 (USD 9.27 Million)
7	Ullagramam- Puzhuthivakkam Water Supply	242.4 (USD 3.91 Million)
8	Ullagramam- Puzhuthivakkam Sewerage	280.8 (USD 4.51 Million)
9	Ambattur Water Supply Scheme	2670.8 (USD 43.08 Million)
10	Ambattur Sewerage Scheme	1309.1 (USD 21.11 Million)
11	Alandur Supply Scheme	643.9 (USD 10.38 Million)
12	Thiruvottiyur Water Supply	851.2 (USD 13.73 Million)
13	Integrated Venkadamangalam Solid Water Projects (for all regions mentioned above)	442.1 (USD 7.13 Million)

Source: Data collection, 2012

The state level reforms for water management include implementation of regulations as presented in Table 24. The state level reforms are submitted for policy consideration or implementations in the year 2012. The plans do not include changes in funding availability and the transfer of schemes.

The JnNURM, the state government and urban bodies implemented a set of vital reforms for proper supply and demand management. The Tables 24 and 25 indicates acts that are mandatory reforms and plans for urban bodies in Chennai and project costs. Programmes for water demand management includes projects for urban planning within city development. The major noteworthy point indicates in table 28 is 25% increase in funds for urban poor. This will in effect induce better HH management of water and efficient consumption within low-income groups. The HH management will also aid poor people in maintaining better living conditions within urban societies.

Table 25 Urban Local Level Reforms

No	Reform	Status
1	Improving property tax collection and efficiency	Targets Achieved
2	Introducing Double Entry Accounting System	Targets Achieved – Accrual Based Accounting System has been introduced in the local bodies
3	Introduction of Computerized process of registration of land and property	Achieved.
4	Introducing e-governance activities in Urban local bodies.	Achieved. 16 different e governance modules are in operation
5	Internal – 25% funds of the Urban poor	Achieved. G.O.No. 167, Municipal Administration and Water Supply Department, dated 15/04/2008 direction has given to Urban local bodies for 25% of own source of revenue for urban poor.

Source: Policy Notes, 2012

The supply-based improvements include: the external stand posts replaced by household piped supply. A detailed plan for covering entire city may be developed by the water management team. The Table 26 indicates improvement to control leaks and maintenance of quality. The policy note suggests that the leak control and maintenance works are performed by the water board staff while the piping and in-house plumbing are handled by private plumbers.

Table 26 Short-term Actions for Improvement

1.	Improvement of conditions of tankers to avoid spills and leaks
2.	Improvement via modernization of the tanks to reduce wastage
3.	Regular cleaning and maintenance of tankers
4.	Inspection to ensure safety
5.	Metering of water supplied through tankers

Source: Data collection, 2012

Installation and advisory for RWH is extensive, pamphlets and booklets are provided for local users in order to improve knowledge of installation procedures and repairs. The RWH team undertakes repairs and maintenance. Many residents complain about the recurring issues after repairs (as indicated by interviews), it is clear that the RWH team is making efforts to reach out to customers and keep them informed. The repairs and maintenance staff according to surveys are very inefficient as the problems keep recurring.

4.5.2. Water Conservation

The government among other policies has taken initiatives to improve conservation and efficiency of use. Some initiatives are: 1) scheduling water use/ restricted water use, 2) water cuts, 3) RWH, and 4) Tariffs (Pipe and Tankers).

The optional reforms for water management in Chennai include 1) provision of RWH in city buildings. This policy has been implemented in 2003 and the provision for the installation has been made mandatory as per 1972 rules 3A of the TN District Municipalities Building rules, 2) Reuse of recycled water within Chennai and other regions. This policy has been revamped recently based on provision made for recycling the water from bathroom and washbasins. The 1972 Act as per section 17A of the TN District Municipalities Buildings Rules, 3) State has indicated that the Administrative reforms were introduced and implemented successfully. 5) Policy for earmarking 20 percent of developed land in all housing projects (public and private) for the poor (i.e., Economically Weaker Section and Low-Income Groups). The Tamil Nadu housing board sets aside about 40 percent of the developed plots for this purpose where the LIG and EWS are given preference. Although this is true, the key initiatives only have cleared measures rules to provide 10 percent of the developed plot mandatorily and 5) Initiation of Public Private Partnerships for urban projects in Chennai and other parts of TN (Table 7). The key initiatives of PPP are to outsource projects and minimizing cost by contract.

All buildings would require RWH in Chennai. In a talk on replenishing the water table, the governor of Tamil Nadu, Ramamohan Rao, indicated that "… the status of ground water sources necessitates recharge and the only simple technique to do it is rainwater harvest within the community". The law imposed in the year 2003 states that every building will have a structure installed or must have it installed to amplify water supplies. The law states that if any entity fails to implement the rainwater harvest system, water supply to that facility will be terminated. The installation must be complete before the monsoon season starts. The owner will be charged against incidental expenses as part of the property tax.

[(1) In every building owned or occupied by Government or a statutory body or company or an institution owned or controlled by the Government, rainwater harvesting structure shall be provided by the Government or by such statutory body or company or other institution, as the case may be, in such manner and within such time as may be prescribed. (2) Subject to the provisions of sub section (1), every owner or occupier of a building shall provide rainwater-harvesting structure in the building in such manner and within such period as may be prescribed. TWAD 2003]

This indicates that the rules are mandatory for all offices, private as well as government occupied buildings. It does not mention clearly if households should be included in this act. In recent changes to the law, RWH for HH have also been made mandatory.

Many countries have adopted the RWH structures as a measure for drought proofing. Furthermore, the policy on wells and ground water use are to protect sources of water and increase water saving, i.e., water conservation. The law introduced prohibits the extraction of ground water for industrial use when alternate sources are available.

4.5.2.1. Restricted Water Use

Ground Water Act is to improve efficiency of water use, through restricted use policy. The Chennai Ground water Act, 1987 was introduced to reduce commercial over use of water within the city. After the year 2000 the RWH was strongly enforced and made mandatory within apartment blocks. During the years 2000 to 2003 all buildings were asked to install Artificial Recharge and the RWH and a fine of Rs. 2000 was levied on the buildings with no RWH structure. The implementation is successful, requiring reinforcement of rules and regulations.

The huts and slum areas have no RWH structures. The structures are not properly designed to suit every building; some buildings do not accommodate chutes for drain unless they have a big terrace. The design fault is also due to lack of trained and skilled individuals to handle implementations within the city. Hence, the government asked all households to give feedback about implementations, costs and maintenance.

The old set of acts and ordinance created in 1919, were altered to fit the growing population and the development trends. Tamil Nadu acts and ordinances are explained in the following section. Many of these policies apply to most places in Tamil Nadu, particularly Chennai. Furthermore, the watershed development works under the drought prone area Programmes need to be improved. To do this the government of India brought in a few changes in the Drought Management Policies. The government wants to reduce engineering activities while increasing simple activities to increase water levels and conserving it. This is however not stressed in the policy that is implemented to gain participatory views of the local people.

The Act 37 of 2002, with amendments include list of attributes to comply with ground water uses. The law suggests the use of ground water should be for ground water recharge purposes or for domestic purposes. All water extracted from the wells for industrial purposes should be accounted for and specified if it is for private or public use. But the use of wells cannot be monitored

["…(b) the use of groundwater in the scheduled are for agricultural purposes immediately before the date of commencement of this Act; (c) the number of wells for which water is extracted for domestic purposes; (d) the number of wells from which water is extracted for industrial, automobile service centres, multipurpose halls and other commercial centres; (e) the number of water resources for both public and private…"] (TWAD, 2012).

Acts prohibiting use of ground water are for industrial use beyond a certain level when alternate sources are earmarked or available for consumption. The ground water use for pools is restricted as it drains the available water source. However, it acts as a storage facility during times of drought. The Act is enforced by increase in fines levied on users ignoring rules of ground water use (Rs. 500) that is now recently amended as 2000 Rs. as a first-time offense. The fine amounts are not levied if the bills are paid on time.

4.5.2.2. Scheduling Water Supply

Water use restrictions in Chennai are based on the rule of law for use of groundwater, public water, water supply timings and illegal extractions. Chennai has implemented water supply cuts for a few hours every day to conserve water use. The water cuts are announced within the city whereby residents are kept posted about the hours of water cuts via newspapers. Observation indicates that between 10 AM and 3 PM supply is terminated temporarily, every day. Although, the regions selected are pre-announced, the residents also reported unannounced water cuts. Among the interviewed residents all of them indicated that of Chennai has unreliable supply that can stop anytime during the day after 9 or 9:30AM.

Every day after 9 or 9:30 AM the water starts dwindling and the pressure starts reducing. The evidence from observation indicates that the water completely stops by the time it is 10 AM and supply starts again at around 3 or 4 PM. Thus, indicating that Chennai HH's do not get 24-hour supply. Hence, the reliability and continuous supply is questionable.

Chennai administration intendeds for this policy to become a conservation method that is easy to implement. The temporary termination of water in Chennai will force HH to use water efficiently, as suggested in pervious sections. The preciseness of water use for specific purposes will improve source security. However, Chennai's present water cuts have increased dependence on alternatives sources.

4.5.2.3. Rainwater Harvesting and Ground Water Recharge

Chennai's ground water is on a decline. The over dependence on ground water is increasing. The surface and ground sources do not support the whole population of Chennai. Hence, the administrators in Chennai water boards initiated RWH. Rains in Chennai are higher compared to regions in Saudi Arabia and Middle East etc., and it can tap into the rainfall to conserve and recharge the groundwater sources.

Table 27 Improvements to Rainwater Harvesting

1. The main long- term improvement includes creation of awareness on the importance of rainwater harvesting, to coordinate with various agencies to promote this concept, to initiate training to individuals, organization and government agencies.
2. RWH installation needs inspection and stock -take of the number of households with installations and the number without.

Source: Summary of Findings

The reliability of RWH depends on the rain and the ability of users to tap into it, as the users need to take initiative to improve their water quantity (see table 27). The issues with the management indicate that about 5 percent of the survey respondents do not have RWH structures within the city. Among the total HH surveyed all of them were willing to implement RWH structures as they feel that they do need extra water.

The CMWSSB and TWAD need to take charge as they accountable for the installations, fitting and repair works etc. The users need to be very responsible by actively participating in decision-making processes for water management in Chennai.

4.5.2.4. Current Tariffs, Tax and Surcharge

Investigation revealed that water resources are affordable in Chennai. The major issues considered are expenses for drinking and cooking and purchases from private tankers. The water bought for drinking and cooking is completely used up without room for conservation.

The metro supply prices in Chennai are heavily subsidized at 6 paisa (1 US Cent) per liter (as of 2009) due to state and central government support in order to provide easy access to water for the common people. Public water resources are not equally accessible to everyone, and hence, to avoid further problems the water prices are subsidized. Certain survey respondents who reside in huts share water supplied through thankers. This is a community effort by TWAD and CMWAAB to provide access for the LIG and the urban poor. Water prices in Chennai have been summarized in the tables 28 and 29.

Table 28 Metered Consumer Tariffs

Category	Qty of water	Rate/KL Rs.	Rate / KL in USD	Minimum Rate Chargeable (including sew charges) Rs.	Frequency of billing
	Domestic				
Residential (i) Domestic Residential premises (Other than Flats or Block or line of Houses)	Up to 10 KL	2.50	0.04	Rs.50/- per month per dwelling unit (USD 0.83)	Monthly
	11 to 15KL	10.00	0.16		
	16 to 25 KL	15.00	0.25		
	Above 25 KL	25.00	0.42		
(ii) Flats or houses in a Block of flats or line of houses respectively used wholly for residential purposes. Total consumption divided by no. of flats.	Up to 10 KL	2.50	0.04	Rs.50/- per month per flat	Monthly
	11 to 15KL	10.00	0.16		
	16 to 25 KL	15.00	0.25		
	Above 25 KL	25.00	0.42		

Source: Data collection, CMWSSB (2012)

The charts indicate the amount residents pay for water and water services. Most respondents indicated that they pay between 6 paisa (USD 0.01) and 10 paisa (USD 0.02) overall per liter of water consumed. The values indicated as well as tariffs are surveyed by the local government and are flat rates which are heavily subsidized. The charts indicate that HHs are charged Rs. 2.50 for consumption up to 10 KL of water per month, with the charges going up steeply for higher consumption, apart from a flat charge of Rs. 50 per HH per month (see Table 28). The charges are the same for independent houses and apartments. The Tables 28 and 29 indicate the costs of supply, including the cost for water connections, other charges and the sewer connections with respect to the water mains. Therefore, the current prices of water supply and connections in Chennai do not impact society. On the other hand, it impacts the environment due to low cost of natural resources. This allows misuse and exploitation at a faster rate. Over-use and exploitation are kept in check through reduced hours of supply. This helps improve efficiency of use.

Table 29 Unmetered Customer Tariffs

Category	**Water charges / Month (including sewerage charges)**	**Sewer charges / Month**	**Frequency of Billing**
A. Domestic			
Residential (i) Domestic Residential premises (Other than Flats or Block or line of Houses)	Rs.50/- per month per dwelling unit (USD 0.83)		Half yearly
(ii) Flats or houses in a Block of flats or line of houses respectively used wholly for residential purposes	Rs.50/- per month per flat (USD 0.83)		Half yearly
(iii) Individual flats or Houses in a Block of Flats or line of houses respectively used for other than residential purposes	Part- Commercial. Rs.150/- p.m. per flat (USD 2.50) Non-Water Intensive Rs.400/- p.m. per flat (USD 6.67) Water Intensive (All others) Rs.650/- p.m. per flat (USD 10.83) Pvt. Hospital Rs.800/- p.m. per flat (USD 13.33) Institutional Rs.300/- p.m. per flat (USD 5.00) Pvt. Educational Institution. Rs. 400/- p.m. per flat (USD 6.66)		Half yearly
B. Commercial	Water Intensive Private Hospitals Rs.800/ p.m. (USD 13.33) All othersRs.650/- p.m. (USD 10.83) Non-Water Intensive All Others Rs.400/- p.m. (USD 6.67)		Half yearly
C. Partly Commercial	Rs.150/- p.m. (USD 2.50)		Half yearly
D. Institutional	i) Pvt. Educational Institution - Rs.400/- p.m. (USD 6.67) ii) Govt. Hospitals - Rs.200/- p.m. (USD 3.33) iii) All others - Rs.300/- p.m. (USD 5.00)		Half yearly
E. Public supply - Tube Well Pumps or Mark II pumps.	Rs.40/- (USD 0.67)	Rs.10/-	Half yearly

Source: Data collection, 2012

The table 29 indicates the tariffs for various water uses within the domestic, commercial and institutional sectors. The water taxes levied on residents are at 1.5 percent on assessed values annually. The sewerage maintenance taxes are at 5.5 percent of the assessed annual value. The significance is that the charges are not high, and hence many residents (including the low-income groups) can survive using public water sources. Tax and other tariffs including meter charges were further reduced for all consumers after 2003 from 1.5 to 1.25 percent per month. The government cannot easily change these prices, as the natural resources are not accounted for and allotted equally in Chennai.

For all TWAD and CMWSSB services, a fine of approximately 2 percent per household per month is levied on a recurring basis for any late payments of charges for supply and sewerage. The board can levy surcharges towards late payments as per Section 81(2) J of the CMWSSB Act 1978 and Demand 32 of the TWAD Water Act as of 2002.

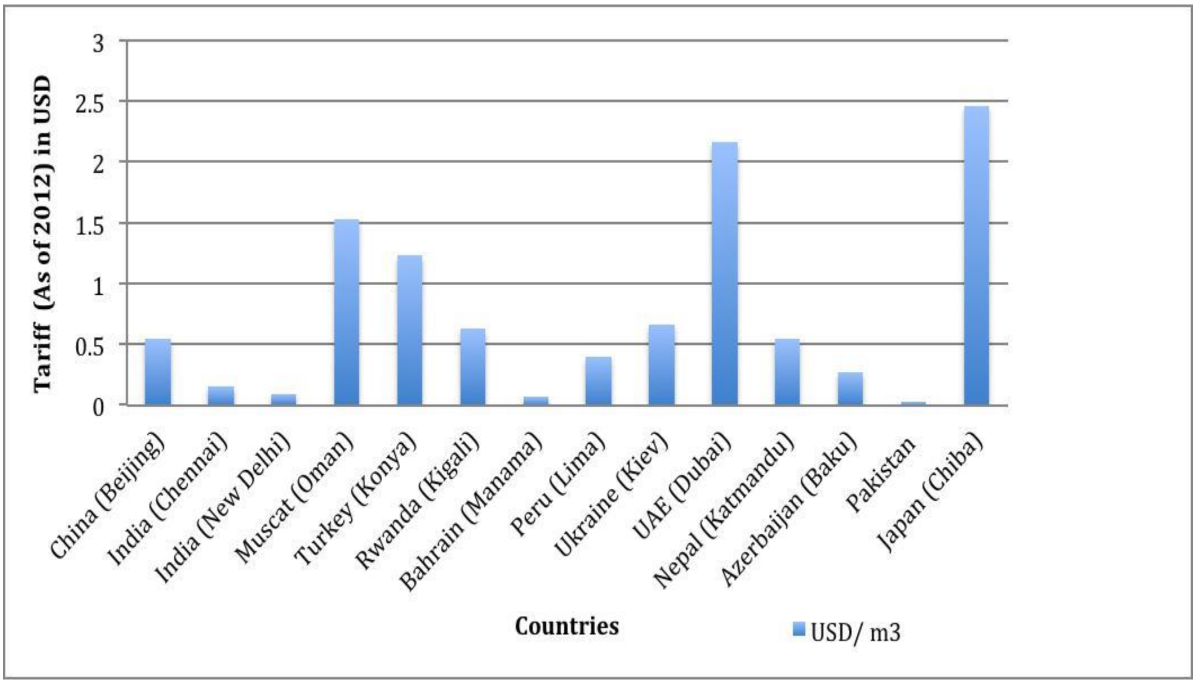

Figure 21 Water Tariff Comparisons – 2012

Source: Compiled from various sources

Comparisons of tariffs of various countries are indicated in the Figure 21. This figure indicates that prices in Chennai are slightly higher compared to Bahrain, Pakistan and New Delhi, India. Comparatively, the prices in desert regions (UAE) are very high. For example, the chart shows that Japan, Chiba has the highest price. The price in Muscat and Turkey are also high due to low rains and high demand.

4.5.2.5. Tanker Supply Charges

Tankers are the alternative source of supply; as they are more reliable, provide adequate supply and easy access. The Table 30 indicates the amount to be paid for tank supply to household tanks or overhead tanks. Based on the information given, the domestic sector is charged about Rs 600 (USD 10.00) for 9KL.

Table 30 Tanker Supply (Within 24 Hours)

Category	**Amount/Per load of 9 KL**	**Amount/Per load of 10**
Domestic (including Hostels of Colleges and Schools Recognized by State / Central Govt. / Govt.	Rs 600/- (USD 10.00)	Rs 670/- (USD 11.17)
Partly Commercial Domestic purpose Other than Domestic purpose **Commercial** (including private Hospitals)	Rs.600/- (USD 10.00) Rs 765/- (USD 12.75) Rs.765/- (USD 12.75)	Rs.670/- (USD 11.17) Rs 850/- (USD 14.17) Rs.850/- (USD 14.17)
Institutional Private Educational Institution Incl. Hostels. Govt. Offices / Schools / Colleges / Hospitals etc.	Rs 765/- (USD 12.75) Rs.600/- (USD 10.00)	Rs 850/- (USD 14.17) Rs.670/- (USD 11.17)

Source: Data collection, CMWSSB (2012)

As buildings and properties provided with proper mains are eligible to get more fresh water, supply for urban poor cannot be compared. People have common mains, shared mains and individual mains. The regions surveyed do not get water through connected mains. Specific regions such as Minjur, Purasavakkam, Neelankarai and T. Nagar do not have proper piping and availability of water. Therefore, these areas in comparison with such as: Kodambakkam, Kilpauk etc., are much worse in terms of gaining access to water supply.

The method of dividing the total consumption by number of flats is not applicable to the multistoried buildings, special buildings / multi assessed buildings where supply is through reliable mains. Thus, the charges at applicable rates need to be claimed for total quantity of supply to premises with proper and reliable mains.

4.5.2.6. Integrated Short-term and Long-term Plans

The action-plan for Chennai by the CMWSSB in managing water demand is based on short-term and long-terms recognition of water management and demand related issues. 1) Food security is necessary and remains priority and hence, conservation in food sector will improve water transfers to domestic sector. The direction of climate-smart agriculture will improve small-scale farming that will enhance the sustainable productivity of land, water, energy etc., and the local economic, social and environmental will be enhanced. This can be achieved through inserting social, economic and environmental concerns into the agricultural policies, practices and climate change adaptation and technological changes. A program was started for supply and demand management where emphasis is placed on augmentation and conservation of resources through agriculture and indigenous community-based practices and policies. Community based management practices to conserve water include rainwater harvesting, artificial recharge, community participation and conservation feedback are the major projects by the CMWSSB and TWAD.

4.5.2.7. Education and Training

When there is less awareness of policies, quality etc., it does not impede water users; they only require household level improvements. Hence, most users utilize all resources available and further access the ground water resources.

In response to lack of awareness the TWAD board intends to manage information in a more efficient manner by posting notices more often and providing booklets for educating local residents. The water board indicates that water crisis, is it climate or exploitation related, and needs a solution. The board realizes that the people are the key to water security and adaptation. Participation is considered important; the major improvements in education and training are feedbacks via complaint boxes. TWAD and

CMWSSB have initiated a complaint box system where local residents are asked to write their grievances about water security.

A major initiative in the past decade was to successfully implement the ‘Right to Information Act’ as part of knowledge spread and data available for research. Hence, education is as important in maintaining water security and adaptation as treating or protecting water supply. As of 2011 all projects and details, except for the cost details, are put up on the notice board for public perusal.

4.5.2.8. Policies under Drought Prone Expanses

Potential threats due to climate change are expected by the CMWSSB and they indicated that they are very prepared for it. In the view of the findings of this research Chennai must take more steps in order to be able to handle crisis situations. Watersheds need improvement due to the weak sources and low quality of water resources. The system to transport water through pipelines needs monitoring to estimate lack of connection, the HH requirements and the faults in installations. Installation of saltwater pipes in Chennai has improved freshwater conservation to a certain extent as the respondents do cleaning jobs with this water. Furthermore, the drought policy identifies a need for increase in quantity of water resources development in Tamil Nadu.

The water use for industries and farming is reduced with planning and efficient use and this benefits the local populations. The method used to control water use is the national policy implemented on dry land farming. This has, to a certain extent, proven beneficial for households in the urban and rural regions.

The government has taken initiatives to take inventory of wells to protect the ground water resources. The extracted water is accounted for and categorized according to the purpose of use. The policies signify that detailed reports on quality and quantity, and RWH, are required. Some other rules include water conservation through rainwater harvest. There is need for support from rainwater in order to supply the population’s domestic, agricultural, industrial use.

The efficiency with which these policies are accomplished is yet to be proven. There is a tough layer of resistance to this program due to lack of knowledge, increasing necessity to over-use, decrease in conservation and a stagnation of policy success in, Ambattur, Valasaravakkam, Porur and in another few regions of Chennai. This requires a suitable construction and installation of water harvesting methods to help households adapt and afford water supply that is naturally found.

The optimum level of supply and demand can be wrought through conservation methods that allow efficient use and recharge of aquifers in the process. The RWH policy on harvesting water for conservation needs to be expanded to local households, agrarian and industrial levels. This will bring out the best results within Chennai city and semi-rural regions of the district.

Further, the use of water in swimming pools and gardens can provide additional storage as well as ground water recharge. It has been easily overlooked, but water stored in swimming pools can easily serve as additional contingency supply to allow households extra sources during times of less rain or supply cuts etc. Water for swimming pools can be maintained efficiently and harvested through rainwater easily. This could mean that a lot of the misuse of water would be set right.

Misuse and overuse of water is strictly discouraged by the National Drought Control Program applicable to all states. In properties without rainwater harvesting systems, water connections are restricted and or fined heavily. These policies self-explain their purposes, and they were implemented in the years 2003, 2004 and 2005. They indicate a specific purpose to recharge the aquifers and to raise the level of the water table by about 2m at least within a year.

However, policies implemented in this regard are weaker, and are not enforced as diligently as policies for energy use (such as fines for late payments of electricity). The misuse and overuse are slightly under-rated compared to the actual values or the actual amount of water used is unknown. There are accurate estimates for this, but none of them are absolutely conclusive, as spatial differences exist within use patterns, availability, and accessibility.

That said, they are increasing the amount of fines and penalties for people who do not follow rules and they have these rules and regulations put up in the form of notices and also in the local language so as to enable the local people to read with comfort. Further, if default payments are not made, supply connections are cancelled, and fines are levied on HHs.

The water table can be increased only by rain harvesting (mentioned in several sections of the paper), but this needs to be implemented in a safe and secure manner. This requires some efforts from TWAD and CMWSSB to spread knowledge about climate and availability of water through rain.

Officials are required to check residential complexes for installations of rainwater harvest. The government provides the installations and hence the government officials need to take responsibility to ensure every residence, be it an apartment or an independent house, has the RWH systems installed. The government and the Tamil Nadu Water Board terminate supply connection for residential blocks without rainwater harvesting installations. This ensures proper installations and conservation techniques. Harvesting water from now will save Chennai a lot of trouble in the future management of droughts.

4.5.2.9. Goal Setting for the Future

Some goals set out by TWAD board, consistent with the TN government, are (1) to create a complete and understandable water database that will include the assessment of impacts of climatic on the water table; (2) to improve water conservation; (3) to improve inventory of resources, focusing on over-exploited regions of Tamil Nadu (including Chennai); (4) to educate and train through workshops and information provision to public; (5) to improve water use efficiency by 20% and, (6) to stimulate a basin level integrated water resources management (TWAD interviews).

Literatures signify that the policy changes are responses to the crisis situations based on specific goals (UN, 2009), (UN HABITAT, 2006). The situation and the society need to be fully understood before the plan and the projects are implemented (GWP, 2011; GWP, 2012). Policy failures in Chennai are generally related to people’s willingness to participate and appreciate the consequences of the policy. Thus, water security in Chennai requires policy responses that will drive adaptation changes; just as the RWH implementations in Chennai expand the water table and improve conditions. Despite the deficits in water supply - demand, it is understood that changes in policy will happen slowly.

4.6. Chapter Summary and Analysis

Based on investigation, the following conclusions are drawn about water demand management: Results suggest that water supply is irregular, unreliable and inadequate. This is due to lack of availability and accessibility.

Chennai's water availability is moderate due to rains and the sources, but access is low and, while affordability is high, the allocation is unstable. The quality of water is generally low, as the water cannot be consumed directly from the tap due to bad quality. The current policy implementations have not resulted in creating water security within Chennai.

In addition, a noteworthy point is that the water related data in Chennai is generally inaccurate and unreliable, even though the data is collected from the administrative authority in the region, there were discrepancies in data. Hence, accountability and reliability are low. When data is inaccurate it leads to an assumption that the stock of water resources and regional supply level is also skewed.

Due to the prevailing water shortage and poor management conditions in regions like Purashawakkam, T. Nagar, Anna Nagar, Ennore, Tambaram and Ambattur, Chennai is forced to make do with available data and create plans such as the 1997 Master Plan which was on the basis of 2001 population, created recently, and responses were based on 2021 projection of the population that requires major alteration as the values projected for 2021. Hence, the poor planning and management hinder reduction of supply- demand gap.

Availability needs to improve in order to improve access, to make water available it needs to be of good quality and distributed equitably. The interview responses and survey results were contradictory; however, there are water scarcity issues and security concerns perceived through many voices from the communities. Evidence indicates that the Chennai water boards are trying their best to reduce the issues and improve water supply, there are certain obstacles that affect this, including policy strengths, schemes, distribution issues, quality issues, customer advisory, awareness etc., as mentioned within the supply concerns and policy response sections of this chapter.

The training and workshops and awareness, feedback and response are vital for water supply management within Chennai. Moreover, policies are neither understood nor conveyed by administrators to residents. About 30 % of the respondents required detailed information to comprehend the situation to answer the survey sheet properly. This indicated that the people do require workshops and training to understand water system, supply, uses, conservation techniques and also quality to make an informed decision and useful feedback. The awareness is low and hence the information and communication section of the governance does not function well.

As of now the climate related water shortage occurs every 4 years due to lapse in monsoons, this is strengthening by the year due to increased frequency of sudden extremes climate change. There was a four-year period of frequent floods in Chennai and the coastal sides of Tamil Nadu. The floods in East coast also affected millions of people due to contamination of water. This is due to changing extremes of Climate. The increase in floods creates penetration of saline water into the fresh sources and ground water sources. This creates issues for people due to the zero-utility value within households. The salinity can be managed if the floods are channeled in a proper fashion. Road water reuse after treatment is also an option for policy makers to consider. Managing floods require proper quality control, which is not looked at in detail in this paper due to the vastness of the topic.

Recently, Chennai temperatures indicate an increase in the maximum temperatures to about 42 degrees centigrade and this is one sign that should be enough for Chennai to take steps to prevent severe droughts, going to the extent of transporting existing and available sources in closed conduits to distribution units or for storage in Redhills. This increase poses quality problems. There are several bacterial infections that make water un-usable and this creates more water waste and reduces water security (see section on water security).

The TWAD information through the interview, documents indicate that Chennai is prepared to tackle the upcoming water security issues that may rise. The supply and demand management investigation indicate otherwise. The supply and demand management indicate issues and concerns that could intensify with worsening climate change. While climate change may not look like a pressing issue, it is impossible to ignore the signs as droughts occur every 4 years and floods approximately every other year (mild intensities). In addition, drought in Chennai is mostly source supply and demand related, at present, rather than purely climate related, but it is not possible to ignore the signs of water scarcity and insecurity (indicated in supply-demand management chapter).

4.6.1. Adaptation Strategies: Projects

Accessibility is one of the major causes of Chennai's discontent. The connected pipe mains do not supply water on a regular basis. This requires attention, as the public water supply is needed in order to prevent usage of cans or tankers for mundane activities within the HH.

New connections and main appropriations are required to manage water flow through pipelines. Pressure of water is low in the surveyed regions, especially during the day when HHs in second or third floors does not receive any water supply. Low pressure just increases the time consumed for a particular activity that utilizes water resources. If the pressure is low HH take longer to shower. Hence, decreasing water pressure is ineffective in controlling consumption.

Pipelines from reservoirs, mainly Redhills, are thick and made of steel. Hence, leaks should not be as common in Chennai, as indicated by available data. Upon further investigation, the pipes laid look proper but there are leaks occurring due to roadwork, digging, adjustment of pipes etc. The major changes can be brought through locating pipes so as to prevent sewer mixing and leaks.

4.6.2. Plans and Programs

The price of water is low for HH's (with 4 members) and varies with consumption. The estimates for consumption vary, a very rough estimate based is on 4-day requirements of users. The per capita use is 83 lpcd whereas Chennai had close to 120 lpcd two to three years back. This could be due to change in availability and restricted hours of use (water cuts).

The method of recording the flow, the connections and the use are highly irregular, as each department of the CMWSSB and TWAD states a slightly different total amount of water supplied. Hence, the information is ambiguous and makes policy maker's decisions and the water balance analysis inaccurate for Chennai.

The information on the infrastructure and Programmes is not complete. The version the required information varies from one person to another.

Information on crisis management is only available for public use via the main office of water research. The officials' interviews do not give details in depth unless the recipient is privy to sensitive information in the first place. The information is balanced by secondary information. Information provided is based on 2006 or 2007 and, the only policy outcomes available for public perusal. This impedes complete analysis of the water supply and demand.

The resource availability, newly implemented infrastructures and improved measures for waters supply aid in managing demand within Chennai. Piping, awareness, metering and leak control needs improvement in Chennai. Partial metering in Chennai does not help in inventory of water use and the supply. Thus, Chennai requires refining of the existent policy responses to improve water demand management.

4.7. Recommendations

Supply: The mismanagement of the water supply, lack of availability, accessibility and low quality impede Chennai's efforts to adapt to climate change. The fact remains that supply policies are not enforced properly, like with random checks or inspections of premises. Improve information availability and communication to locals especially the local HH.

1. A participatory approach is required and HH in general do not tend to pay attention to issues unless it directly impacts them, so people. It is also second nature to ignore or push aside policies to reach goals E.g. builders or local individuals;

2. Simple structures can help enhance supply. Ponds and tanks at home or old wells can be used as a recharge or harvest mechanism. This could mean that a lot of the misuse of water would be set right. This requires more planning, efficiency and a regular stock-take of available resources;

3. The adaptation strategies needed are the 3 R's, training and workshops, stock-take of resources, household surveying, reworking and renovating water tanks, ponds and *Kollam's* and improving quality through simple measures. The 3 R's are reduce, reuse and recycle adapted from the waste management technique;

a. Reducing water use will increase efficiency of water as it allots water or most important necessities and dis-allows wastage of resources;

b. The reuse suggests use of water for multiple purposes, usually recreational such as pools or fountains etc., can be used in flushes;

c. While the recycling water may have social stigma attached, it still does not imply use of dirty water, it is fully treated and clean water that can be used for domestic purposes;

4. Several households on the outskirts of Chennai have maintained wells but have ended up needing to close the wells due to lack of water; This can be used for rainwater collection or storage of water.

5. A column needs to be constructed to intercept rainwater and prevent it from draining out. Three major advantages to this would be less runoff, more water harvesting and prevention of saline intrusion; and

6. The quality of water needs to be maintained and scientific evidence collected.

There may be initial setup costs for all recommended implementations but eventually, it will be easy to create surplus water for Tamil Nadu. Hence, the water scarcity in Chennai can be attributed to the lack of innovation, worsening monsoons, in equitability, supply cuts, RWH installation challenges, and lack of information sharing.

Demand: Recommendations are based on results and the policies implemented by the GWP and the UN-HABITAT. The major recommendations include:

4.7.1. Piping and Metering

Major recommendations to improve the current state of metering and piping are seen in Chennai.

1) Increase in the number of checks on existing pipes, enhance street installations with new pipes and improve existing pipes (that are connected but without water supply).

2) The water scheduling will not help in the long run as it allows dependence on alternative sources.

3) The metering should be made mandatory for all new and existing connections.

4) The metering of RWH structures will allow water managers to better understand use of RWH within HH.

5) The faulty pipelines and leaks need to be checked promptly within 24 hours.

4.7.2. Leak Control and Maintenance

Leak control and maintenance need to step up their inspections. The customer advisory needs to be setup for leak control. HH in Chennai need information on the need for managing leaks and the impacts of leaks.

Improving tanker facilities and upgrading the features to modern tap like features with sealed top to prevent water spills and leaks.

4.7.3. Education and Training

Overcoming obstacles in implementation of community water initiatives are important. The changes should include improvements to awareness, stakeholder participation, and consumer end initiatives that are already in place.

4.7.4. Alternative sources

Tanks and wells need to be well maintained in order to avoid water borne diseases. Japanese management system allows 3-day water treatment and clean supply conduits to convey water to residents. The supply route, the number of trips and the scheduled supply to a particular area need to be fixed.

Chennai's management team needs to strengthen the short-term goals such as to improve alternative supply, in case of extreme changes in rainfall and temperatures.

4.7.5. Conservation Techniques

Chennai also need to regularize and enforce inspections and fines applied. Fines should be mandated to allow no loopholes when the required conditions are not met with. Singapore management system absolutely enforces the fining system within so as to disallow any water misuse or unclean facilities.

Increasing RWH through filters and direct inlets for artificial recharge instead of pits built over tank systems will not only improve the AR, it will intercept the run-off towards the sea. The system needs to be built in such a way that the land from the house towards the filters on the pavement should gently slope like a catchment in order to capture run-off. A simple pipe system can be utilized along with a water hose to serve as an artificial filter inlet.

The authorities need to enforce of rules and regulations in a strict manner. Chennai’s water resources are unreliable and of low quality. The improvement should be supported by the TWAD and CMWSSB in terms of strict rules to improve conditions in Chennai. To increase water supply individuals and HH members should willingly acquire knowledge about the status of water and quality.

4.7.5.1. Pricing

Charging water per peak and non-peak hours will improve water conservation through pricing. Chennai has incremental use policy where usage over 10 KL is charged higher. The Oita water and energy conservation team has a system where prices and charges vary according to the peak and non-peak hours. The non-peak hours after 11PM are charged lower compared to peak hours. For example, doing laundry after 11PM can save energy as well as save water. This system can be easily adapted into Chennai’s pricing system.

4.7.5.2. Restricting Use

Special water uses related initiatives include low flow toilets. Reduce toilet flush requirements by one seventh of the usual use. Since the flow is restricted the number of minutes of shower may increase or the number of flushes may increase depending on the use.

4.7.5.3. Actions to Minimize Water Requirement at HH: Drought Scenario

i. The water requirement per day per person may be reduced to 42 - 45 l/d (Drinking 7 litre's, bathing 15 litres, washing clothes and toilets use 15 litres). This can be exercised till water situation in Chennai improves. The water cans for drinking purposes can be used for more than 2 days according to the WHO requirement standards i.e. 2 lpcd pp. drinking; 3-4 lpcd pp. cooking, 20 lpcd pp. wash and shower; 20 lpcd pp. for other domestic use. Since water cans are only used for drinking and cooking, it is easier to manage water and conserve the can for as long as possible.

ii. Replacing worn-out pipes, taps and sealing leaks in all water pipes across Chennai City, DUA and other AO regions. This option was considered by Chennai but dropped, as changes to pipes will imply need for new roads and the new roads mean more funding used up.

iii. Clean the cars and two wheelers with wetted cloth. This is an option for people willing to conserve water resources.

iv. Practicing sprinkler irrigation to home garden in the evening hours rather than a hose. This will conserve a lot of water as the sprinklers only allow a certain amount of water to be poured over a large area.

v. Using showerheads for bath rather than water from the buckets will improve water conservation, use up less water.

vi. Taking shorter showers helps conservation; 5-minute reduction would save about 5 liters of water provided the inflow pressure in high enough to fill a 1-liter container in 60 seconds.

vii. Reducing laundry will reduce large amounts of water resources in Chennai. Using washing machine with full load once in a week.

viii. Reusing the used water for cloth washing to clean the houses and toilets.

ix. Reducing the flush-out tank capacity from 10 liters' to 5 liter's in the toilets.

x. Recycling water from pools, tanks, flushes, tanks and RWH, helps conserve, bring 80% conservation efficiency within HH's.

xi. Leaks and overflows need to be attended to as soon as possible because it will help conserve water.

xii. Restriction of well use within the city to reduce non- metered use. Local sumps and public spot sources should be metered. Well use also depletes ground water use and also stock take of water use becomes very easy.

xiii. Improving local conveyance can reduce water loss such as tankers. The water hose connected to the tank pipe always leaks and as per results water loss is high.

xiv. The pipes should be of steel and these should have taps that are locked to allow flow of water, thereby reducing the amount of water loss.

Although, Chennai's water security is poor, fine- tuning the above-mentioned aspects would improve water security and adaptation to potential climate change. Thus, based on the respondents and responses, Chennai requires extensive conservation within HH's.

5. WATER ADMINISTRATION

5.1. Introduction

Cities concentrate efforts on economic activity, population, infrastructure development and the supply and therefore, these cities face a level of discrepancy in the intensity of impact. Administration plays a major role in balancing the discrepancy. Proper allocation of tasks and defining elements of allocation, distribution, use efficiency, transfers, zoning and tariff will ensure a fair chance at bringing in smooth adaptation within the city (Loftus, 2011). According to Loftus, (2011) the major uncertainties that are faced during research of climatic systems and water resource management are the data gaps, deficiency in understanding the system, projections without considering all linkages to climatic systems and limitation within the system of management.

While decision makers are now more aware of climate change and impacts, they tend to underestimate its dominance on water stress and insecurity. Likewise, human activities and actions can have a very big impact on the water resource system. Supply distribution and demand can be affected by the actions or infrastructure policy changes. Water sources for example may be affected by the temperature and rainfall at the same time the level of water in the water body is influenced by the use, activities, the level of dams, pollution and over abstractions (Loftus, 2011). Human actions can have a negative impact on climate change, thereby increasing vulnerability of the region to floods and droughts. Author Loftus, (2011) indicates that while the research focus should be on adaptation it is essential that planners should take driving forces into account along with a flexible framework. Some cases focus on climate and miss the obvious issues such as cost-effective, utility efficiency and management for greater benefit. Acknowledgment of compelling forces should then be a key practice within a city's assessment of its baseline situation.

5.2. Water Utility and Administration

Water administration includes correct utility management for all water users to improve water savings ((WWF), 2011). Utilities are generally known as services and facilities that are provided to the user and administration of these services are the tasks of policy makers and local municipal staff.

The water administration handles information such as:

1. Address information.
2. Scheduled areas and zones.
3. Water quota allocations per sector per area.
4. Water delivered through pressure-regulated conduit, measuring units and meters.
5. Water distribution sheets.
6. Water use efficiency reports.
7. Water transfers between users.
8. Water use calculations per sector.
9. Date and time related flow data collected.
10. Discharge tables (DT)
11. List of Rateable areas (LRA)/ Zoning information.
12. Calculation of water balances.
13. Dam information.
14. Water releases for water distribution
15. Billing system
16. Flexible tariff, use based and a flat rate zone.
17. Bulk water purchase and community tanks (European Commission, 2013) (CA. Gov, 2008) ((WWF), 2011).

This information allows administrators to gauge water balance based on available and usage. The level of dams, rivers and rainfall also allows administrators to understand the level of inflow of water.

5.3. Climate Change and Water Administration

Climate change presents several challenges to drinking water and waste services. The frequency and duration of droughts and floods, intense precipitation, storms, degradation of quality, contamination and ever-rising demand for water facilities present challenges to the water administration and utility management. The need for changes is based on the type of utility required and the regional situation at a point. Several publications document the guidelines for utilities and management for climate change adaptation. The major guidelines are to provide drinking water and waste- water services with consideration of climate change and impacts on utility administration and to provide different actions and possible adaptation options in order to be prepared for the impacts.

5.4. Adaptation Strategies and Recommendations

Cities require an administrative setup to reduce consumption, recycle and reuse water, restore waterbodies, improve infrastructures to engineer solutions to manage water supply. This in turn will improve security and sustainability of resources as all water resources administration will be efficient and, the adaptation to climate change smooth (European Commission, 2013).

The WWF projects in Kenya and Brazil indicate that successful management strategies will adopt multi-sectoral approach with ecosystem-based management principles. This paper however focuses on the agricultural and ecosystem, yet the management approach fit in with the IWRM and Multi-sectoral approach that make it simple to adapt to. The simple fact indicated in this paper is that the instruments to control demand will improve water balance, while supply management also improves security, but demand management is more effective ((WWF), 2011). This is because conservation and recycling can improve the level of water bodies and secure it. Demand management not only includes conservation, it also includes services that aid administration of water facilities and amenities (Back & King, 2009) (Huhne & Slingo, 2009) (Loftus, 2011).

The major adaptation strategies discussed in published papers are given below.
These strategies are based on supply and demand management.

The adaptation strategies discussed in the papers are as follows:

1. Raising awareness
2. RWH
3. Treatment of Water
4. Reduce, recycle and reuse

5. Understanding the water footprint
6. Economic and legal incentives and instruments
7. Cost recovery and innovative financing
8. Integrated River Basin Management
9. Payment for Environmental Services
10. Inventory of services and infrastructures
11. Emission reduction (Back & King, 2009) (Huhne & Slingo, 2009) (Loftus, 2011).

The major queries raised are the need for adaptation strategies for utility administration. There are complex issues within the utilities are expected to face many more challenges. The concerns faced are consumer acceptance, awareness, management related aspects such as budget, infrastructure, cost saving, maintenance etc. The major strategies for adaptation include:

1. Sustainable and efficient service and operation
2. Cost savings
3. Maintenance of adequate supply and of good quality ((WWF), 2011) (CA. Gov, 2008)

Every region has its utility goals and mission and climate change will impact this differently. Thus, it is necessary for the utility manager to consider various options and the consequences of actions in order to develop an adaptation plan or strategy.

The major administration level strategies include:

1. Recognition of staff, their operative functions and approaches for policy decisions (top – down approach etc.)
2. Personnel training
3. Climate impact assessment and adaptation planning (WWF), 2011) (European Commission, 2013) (CA. Gov, 2008)

Adaptation planning for utilities comprise of impact and uncertainties and mitigation options. To better adapt, it is important to understand organizational positioning, operational (supply and demand activities), services administered, capital options and financial budgeting to improve the low-cost options, no regret policy and supply and demand operation actions. Among these options the best fit is picked for different regions to enhance adaptation. This will magnify efforts towards climate change adaptation practices (CA. Gov, 2008).

The state of California uses IWRM strategic plan and hints that for the success of IWRM:

1. The past and current success efforts need to be built upon
2. Enable, empower and support regional management efforts
3. Align state and national programs to suit the IWRM framework (i.e., work towards no regret policies and with integrated multi- sectoral efforts focusing on adaptation and mitigation).
4. Develop funding priorities
5. Inform and influence policies, plans and manage investments (CA. Gov, 2008)

Likewise, Arab counties also have adapted similar strategies but with more severe options as the MENA region has extreme droughts and high population. The MENA Development report indicates that taking the integrated approach requires leadership and administration and that adaptation is an integral part of public sector for security and sustenance (The World Bank, 2012). The report denotes that assessing climatic risks and impacts, setting priorities and goal options and implementing response within a sector with consideration for other sector, monitoring outcomes.

From the reports and publications, the policy options available for climate change adaptation are based on aims. The major aim in this section is

1. To facilitate development to make resources accessible, to provide reliable information and to report adaptation options.
2. To provision development of human, infrastructure and facilities to support adaptation
3. To provide security and ensure accessibility to all

4. To enhance policies and plans for adaptation; and
5. To improve budgeting and financial management required for adaptation strategies to function well.

The figure 3 (in Appendix I Data needs for effective decision making) indicates that the current data needs based on challenges and key options improve policy decisions that are important for water management and adaptation. The key policy option is to promote cooperation, data sharing, share good practices in data collection, economic and policy analysis that will improve the efficiency of reports that will allow water administration (for efficient supply and demand management and adaptation to climate change). The World Bank (2012) report indicates that the solutions to water policy administration are in fact derived from the challenges. All water managers need is a guide to manage water resources and administer services to the users in an efficient manner. The efficiency with which administration and utility managers prevent water loss, promote conservation and equitable distribution denotes the level of sustainability and security of water resources in the region.

The IWA journal indicates that water loss prevention can improve the availability by a lot. Many urban cities in the coast experience 40 to 80 percent loss due to damaged pipes and transportation losses (see Literature review: Adaptation Strategies and Case Studies for details). This means that monitoring pipelines and transport systems as part of water administration will save a lot of water that will otherwise be wasted.

Water loss is an essential part of water management includes water loss monitoring through infrastructure maintenance and renovation. The supply system needs work, as water loss can be devastating in regions with little funding and poor governance. Water loss needs to be dealt with through a holistic approach. The focus of the approach needs to be capacity building through business coaching. The author, Kovac & Charalambous, (2012), indicates that everything can be handled through commercial dealings such as the requirements, the method to obtain, the suppliers of such services and the efficient way to sustain it. The publications indicate that strategic management of supply and demand affects water utilities. Utilities include benchmarking, billing, tariff, IT and services for maintenance. The major aspects looked at in most publications are related to financing, regulation, investments, private sector involvements, participation, personnel, sector reforms or plans and customer service.

This section focuses on the Chennai's water organization, structure, personnel, projects and investments, regulations and sector reforms and customer services.

5.5. Chennai: Protected Water System

The secure water system was developed in 1914 in Chennai. This system improved the filtration, pumping and intake. The intake tower called as the Jones tower, also referred to as the Red Hills was built in 1881. The intake tower was improved (in 1914), with an underground conduit to convey water from Redhills to Kilpauk, the epicenter of the water distribution networks. Today, the distribution system takes into account the availability of water, status of supply and regulation and policies.

Current water supply is drawn from the three lakes. The Redhills Lake receives water supply from the Kosathalaiyar River that has a dam to separate it from Poondi. The flow of water is diverted at Tamaraipakkam from Poondi, through to Cholavaram Lake. From Cholavaram it flows into Redhills Lake. From Poondi reservoir, a lined channel (the upper supply channel) passes through dry beds of river and the water flows to these rivers is seasonal. Water from lakes around the northwester catchment also flows into the Redhills Lake (Chennai Metro Water, 2011). Water from Redhills Lake is filtered and conveyed through closed conduits to Kilpauk water works. At Kilpauk the water is treated and sent to distribution units for supply.

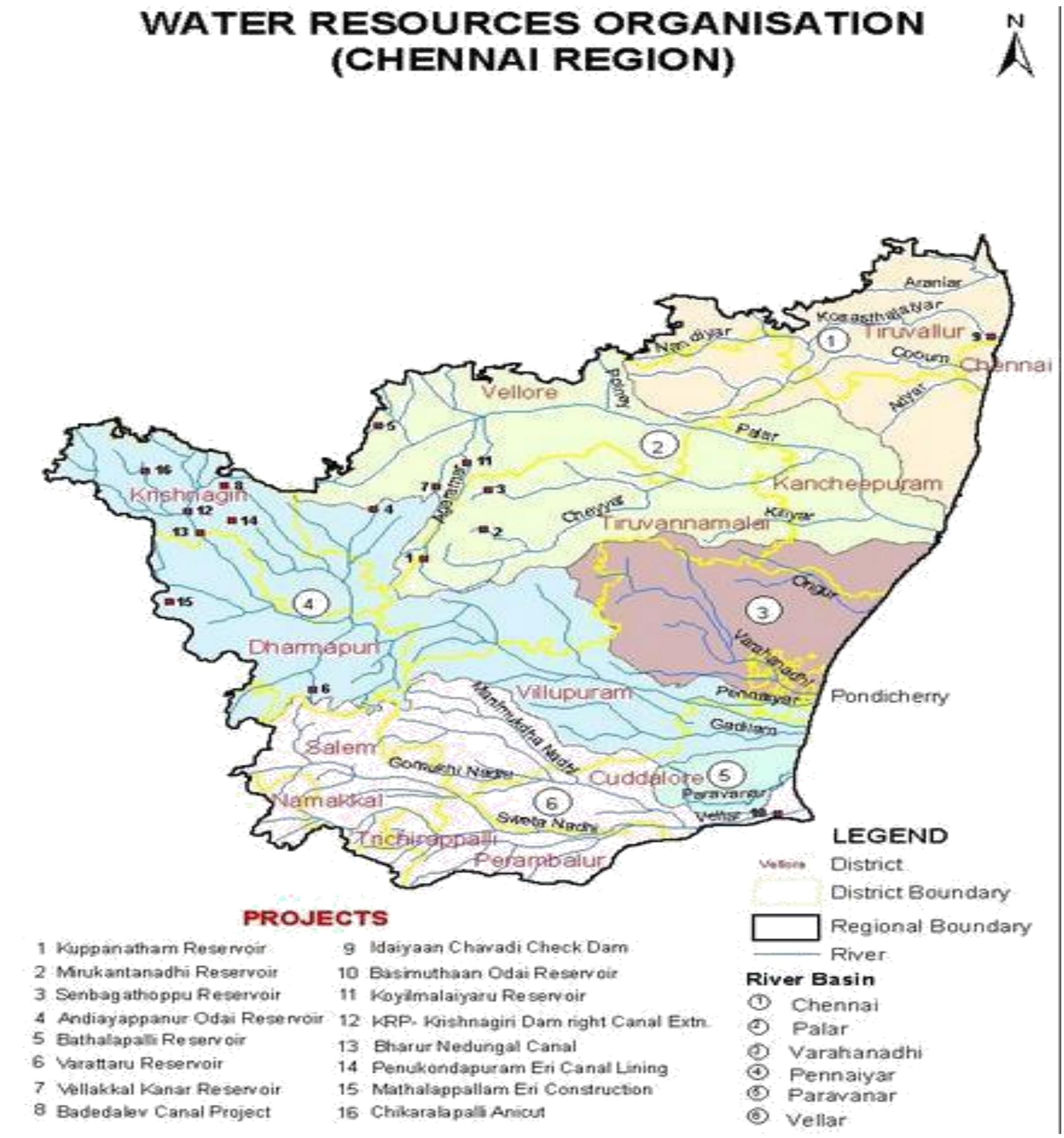

Figure 22 Organization of Water Source

Source: TWAD

The water organization Figure 22 indicates the 16 projects that have already been implemented in Chennai, Palar, Varahanadhi, Pennaiyar, Paravanar and Vellar River Basins. Chennai region has three rivers that have been used to supply water to the city and other greater Chennai regions. The organization of supply and source show in the Figure indicates that the recent projects to the six regions in TN. Region one is the study areas which comprises of the city and greater Chennai.

Furthermore, supply through distribution channels includes distribution to suppliers, public use, domestic use, retail, industrial, agricultural and non-revenue or unaccounted for water consumers. The channels through which the regional expanses of Chennai are reached are made efficient by the modes of supply.

The accessibility and allocation is managed by the distribution system. Hence, the water security is impeded if the distribution system becomes inefficient, unreliable, and unaccountable and has poor policy and regulation (Kovac & Charalambous, 2012.

5.6. Chennai Water Administration

The Chennai Metro Water (CMWSSB) and the Tamil Nadu Water Board (TWAD) manage the administration, finance, service and operation and institutional operation. The CMWSS Act, Regulations, Ground Water Act, Power Delegation, Management of Services, Policies and Public and Employee welfare and relations are a part of the water governance in Chennai.

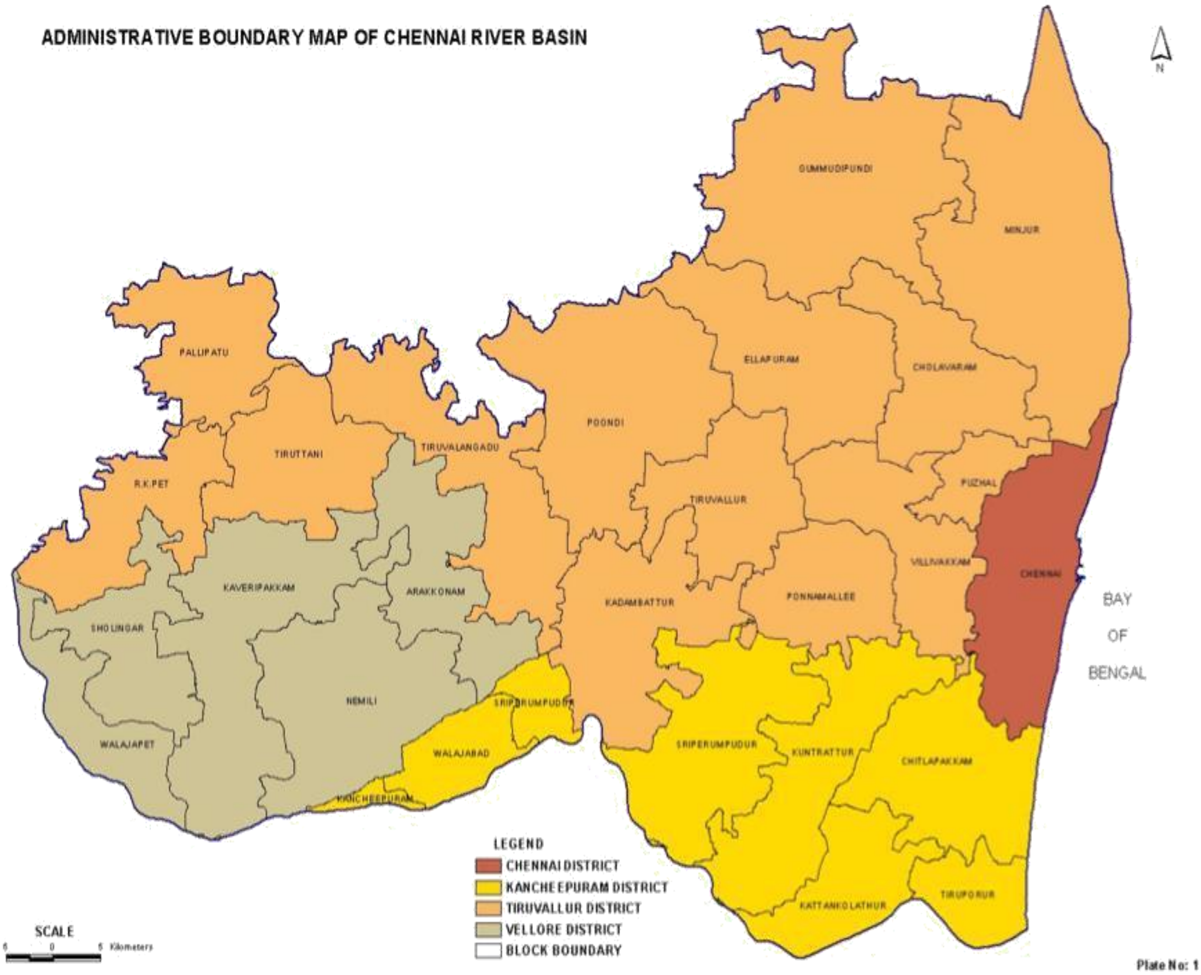

Figure 23 Administrative Boundaries

Source: TWAD

The administrative boundaries indicate that the major administrative bodies lie in the red portions, the Chennai district Figure 23. The other regions are still part of Chennai river basin where the localities are urban and semi-rural. Some regions fall under the Kanchi Puram district, which is adjacent to Chennai, but are still managed by Chennai district administrators. Thus, it is clear that Chennai’s resource administration is very vast and the regions in focus are the central district areas (in red).

5.7. Structure of the CMWSSB

The Chairman heads the CMWSS board. Next in the hierarchical order comes the

Managing Director, who is responsible for the operations of the Metro Water Board. The Managing Director warrants the operation and delivery of water within the supply system. Beneath the Managing Director are the General Manager, Financial Director, Executive Director, Engineering Director and the Chief Engineers. The CMWSSB has a Financial Director, Executive Director, Engineering Director, and the four Co-Chief Engineers. Each person controls a section of the boards' office. The area of expertise is considered while designating a position. There are more than 87 categories of staff with 4196 employees in the CMWSSB, of which 2442 are major laborer's and 1754 of them are office staff within 16 branches and 2 main offices in Chennai. The CMWSS board requires modification in terms of defining the duties, the specific office that they serve and the dedication to allow information and communication to be imparted to the local citizens. This clearly indicates that there is some change required to organize and manage water administration properly.

To improve efficiency in the CMWSSB, several changes need to be implemented in the structure of the Metro Water Administration. First, the offices of the four Chief Engineers should be consolidated into one single office. The duty of one Chief Engineer is to oversee only the Second Chennai Project (New Veeranam Project), which certainly appears a superfluous department now that the project has been completed for over a year. Another official controls the Chennai City River conservation project, which has been abandoned. Under the engineering department, the administrator would oversee operation and maintenance of groundwork and new project construction works. Since the water board's departments have no internal interactions, rearrangement is required whereby, instead of sourcing information for each department for every project, a consolidate report for all departments would be more effective. All engineering officials should be knowledgeable regarding all aspects of the infrastructure and management.

5.8. State and Local: Ordinance and Policy

The policy changes are the technical policy changes allowing technological implementation to the distribution system and the non-technical policy changes include fines, charges and other administrative works within the distribution system.

The changes to the distribution system include the change in the capacity, coverage, repairs and renovations, master plan and associated schemes, the schemes under the second master plan, slum coverage and the additional improvements seen.

The present CMWSSB and TWAD policy targets include:

1. To increase supply coverage to all towns to achieve the norms for per capita supply;
2. To guarantee that the water supply is of good quality by increasing the frequency of monitoring;
3. To ensure reliability of supply for 24 hours;
4. To install a newer desalination plant;
5. To increase the normal supply levels with respect to the JNNURM standards and maintain the WHO standards for quality;
6. To create small water supply undertaking to concentrate on specific zones that are weak at present;
7. To create supply actions similar to the electrical undertaking under the management of urban local bodies and entrust tasks to professionally qualified personnel;
8. To implement schemes for capacity building;
9. To avoid physical losses, zoning of distribution system and leak detection should be a periodic measure to control non-metered water resources; and
10. To develop training and workshops in order to upsurge information uptake, water standards maintenance and improve water related information to encourage PPP and proactive participation.

Several things can be inferred from the target policy response goals. The goals indicate that within the current policy structure there is no training and workshops but for the RWH team workshops and that it neither adapts a participatory approach nor is it transparent. In addition, the supply action is not efficient as the supply schemes are weak and there are huge physical losses during transportation in Chennai.

Chennai per capita average supply is 82 lpcd when compared to the other cities in India, at 70 lpcd. The average per capita supply is not achieved in Chennai, not everyone has equal access to water. This made the authorities to bring in desalination as an alternate source of water supply. The Minjur desalination plant percolated the public taps with salty water in Kattupalli village in Chennai.

Furthermore, some parts of Chennai have poor quality water supply. The consumption of tap water creates illnesses and many HH complain regarding the low quality of tap water. In Chennai, one cannot drink water directly from the tap. There are policies and projects in place to deal with water supply, treatment and distribution issues.

5.8.1. Schemes under the Master Plan

The master plan for supply management for the city was revisited in the year 1991 and then in 1997 to strengthen the Telugu Ganga Project from Andhra. The master plan planned an additional WTP, WDS, new transmission mains and repairs to the distribution system. The projects under the master plan is implemented to re-organize the networks, repair stations, restructure and isolate the 16 zones and to ensure equitable distribution of water. The master plan was implemented in two stages Krishna I and Krishna II.

The major installations include contributions via the installation of 100mm to 1500mm pipes to cover the entire distribution system. These piping system covers about 2,582 km, in total. The current supply pipes are C.I. pipes which according to the TWAD are more than 50 years old.

According to local authorities' pipelines are aged and there are incrustations due to sporadic supply. The capacity of Chennai's distribution system has reduced significantly due to old pipelines. This reduction in the capacity of the distribution system is causing low pressure in the distribution system. "More than 50% of the total system is estimated to have zero residual head. Chennai City has been expanding at a fast rate and because of this; it is found difficult to meet the demand, especially at the tail end areas" (Chennai Metro Water, 2011). The 300 MLD Water Treatment Plant was constructed at Red hills with World Bank assistance under the first Chennai Water Supply Project and 3 Nos. of transmission mains were also laid to facilitate the treated water to different water distribution stations located in the City. Thus, there is also need for improvement of existing distribution lines.

5.8.2. Slum Coverage

Chennai has 3.5-lakhs (0.35 million) people living in the slum areas. Interviews and observation indicate that a lot of the slums are only partially supplied to. There are about 60,000 HH according to the CMWSSB and they are covered through tankers and few supply mains. About 3,542 mini tanks are used to supplement the piped supply and about 2/3rd of these facilities cater to the low-income group. Groundwater for supplementation purposes is also drawn through 7,726 pumps.

5.8.3. Second Chennai Projects and Partners

The Second Chennai Water Supply Project was taken up by CMWSS with the World Bank Assistance at a cost of approximately Rs.778 crores (in 1996). Most of the works contemplated under this project has now been completed. Some of the major works such as construction of Water Distribution stations (7 nos.), Laying of Clear Water Transmission mains (36 km.), and Strengthening of Water Distribution system in 11 zones (660 km.) out of 16 zones were taken up, including leak detection rectification works covering about 70% of Chennai City Area (Janakarajan, 2007 - 2008).

Table 31 Responses for Implementation of Distribution Projects

(a) Piping prompted an increase in source availability and in turn improved the road conditions. This improved service level and pressure in supply pipes.
(b) The reduction in area of WDS increased the piped supply availability with reduction in the actual supply.
(c) The non-revenue water or the non-metered water is reducing considerably in Chennai and in turn results in supplementary water supply for HH's.

Source: CMWSSB, 2011

The construction of WTP of 300 MLD in capacity, at Redhills in 1996, the restoration works at Kilpauk WTP of 270 MLD in capacity were the major distribution unit projects taken up by CMWSSB and TWAD. The project costs were 24.6 crores for all the works completed. The status of the distribution projects is functional at present i.e., completed and launched (Table 31).

5.8.4. The Updated Chennai Master Plan

The Master Plan for Water Supply to Chennai was formulated first in 1978 and was updated in 1991. The new features of the Master Plan are:

Water augmented from Krishna River is 930 MLD for supply to Chennai.

The augmented water is apportioned among the beneficiaries, with respect to the projected population for the year 2021.

The system components is to be designed and installed progressively, with augmentable quantities so that the water allocated could be delivered with provision to reinforce the system to dispense 2021 water demand, provided alternate source is identified.

The Master Plan can be implemented in two stages. The first stage will create the required infrastructures for Krishna water supply of 400 MLD. The second stage will strengthen and expand infrastructures to capacitate an additional 530 MLD supply of water resources from Krishna.

5.8.4.1. Implementation of the Master Plan

The Stage I was initiated in phases using the funds from central and state government along with World Bank Aided First Chennai Water Supply and Sanitation Project. Between 1987 and 1996, the New Well Field (Poondi, Kosathalaiyar Floor Plains and Kannigaiper) project was implemented to extract an additional 55 MLD of water from the AK Basin, 1987.

A 300 MLD water treatment plant was completed in 1996 at Redhills. The transmission mains from the treatment facilities to North, Central and South of Chennai were installed. The treated water was transported to the distribution units where it was diverted to different regions of the city. All old distribution mains were renewed or repaired with unit metering facilities.

5.8.5. Improved Plans

Rather than focusing on the economic or financial goals, the projects consider significant aspects of water and wastewater utility management for Chennai.

The three primary components considered are:

1. The attributes to an effectively managed water sector utility. They provide problem areas and goals to achieve.
2. Key issues to manage to bring about success
3. Assessment of the current and potential management methods

The attributes comprise of the frameworks related to operation, infrastructures, customer satisfaction, community welfare, and natural resources stewardship.

The costs of projects and expenses dispensed for a project should be divulged to the public. Project related sensitive issues needs to be reread and reworked as the local, central and state governments manage the finances. As a government agency, it is the responsibility of the CMWSSB to withhold any information from the stakeholders. Stakeholders for Chennai water supply are the users, the domestic workers, the staff and the investors in projects and infrastructures. The CMWSSB currently, manages its own funds for training and paying workers. Rather than manage its own finances the Board should contract financial work to a water auditor or a large financial investment company. This ensures efficiency, accuracy and transparency of financial management in Chennai's water administration system.

5.8.6. Supply Project Failures

One of the most prominent failures in water provision is the Veeranam project commenced in the year 1968. The project was initiated with the intention of extracting water from the Veeranam tank, located 225 km (south of Chennai). The purpose of this effort was to supply 40 MLD of water to Chennai. As problems mounted one after another the government decided to stop funding and abandon the project. The project had construction troubles and the pipe leaks became more and more conspicuous. By the mid

1970's the project was a dead project. The expenses mounted so high due to the pre–laid pipelines within the project areas, 100 pipes (unused). Only in 2003, did the TN government bring out these pipes for sale. It is assumed that the government changed tactics due to political repercussions. The taxpayer's money was wasted on the dead project. This was not the last project that the government wasted money on.

The World Bank funded the TN government's new Veeranam Project in 1993 and by the time construction began, the political party changed, and the new party had other plans to execute and this project was temporarily shelved. Thus, the water scarcity in Chennai prolonged into the 2000's.

The Krishna River project was also a partial failure. This water project was initiated in the year 1976 with the Andhra Pradesh, Maharashtra and Karnataka governments. These three states decided to provide water for Chennai. After a few years Karnataka and Maharashtra backed out of the agreement to provide water for Chennai and Andhra Pradesh was left to honor their agreement. The total cost for this project to be paid to AP was Rs. 2180 crores, of which the TN government paid about Rs. 500 Crores.

As part of this project, TN increased capacity and constructed 700 km long channels to convey the river water into the city. It was agreed that the AP government would provide Chennai 12 TMC, which was more than the initial 5 TMC's agreed upon. By 1996 the government had spent another 180 crores, while only very little of the promised 12 TMC was seen. According to: The Hindu, Article in 2001 it is clear that this far 1.583 TMC in 2005 and the highest in 2000, 3.591 TMC [7] has been supplied to Chennai.

Knowing that each year from 1996 to 2004, the city of Chennai should have received 12 TMC, and assuming that since half the year in 2005 has passed the city should have received at least six TMC, we take the sum to determine that the city of Chennai should have received 114 TMC of water in total. We find, however, that Chennai has only received a total of 20.30 TMC since 1996. This means that over the course of almost one decade, Andhra Pradesh has gone back on its agreement and left

[7] Mcft = Million cubic feet; TMC = Thousand million cubic feet. From the June 2, 2001 issue of The Hindu, published in Chennai

Tamil Nadu with a water deficit to the effect of 93.69 TMC of water. Because of incredibly poor water management in Andhra Pradesh, the city of Chennai has not received anywhere near the quantity of water owed to it, and yet nothing is done by the government of Tamil Nadu to force Andhra Pradesh to fulfil its end of the agreement.

5.9. Findings: Policy and Analysis

5.9.1. Adaptation Practices in Chennai

The current technical distribution works executed by the Government of Tamil Nadu are an indication that the distribution network was not previously well managed. The important works executed are:

1. The Water Board Chennai completed construction of the 8^{th} underground clear water storage tank (at Kilpauk) of 10 ML capacity.

2. The 43 km of the old and chocked pipes are replaced and renewed.

3. New water distribution zone for Chennai has been planned. Chennai now has 12 Zones and the planned 13^{th} Zone is 34km long with steel pipes.

4. The TN constructed K.K Nagar Water Treatment Plant during 1970 with a treatment capacity of 4.5MLD. The source of supply was 4 of infiltration wells at Porur Lake and 5 infiltration wells at the Virugambakkam Lake. Water from these wells are conveyed through pipes through gravity and supplied to K.K. Nagar after treatment. In 1978 this came under the CMWSSB. After 1992, the infiltration wells failed at Porur and Virugambakkam. Roughly, about 2.7 MLD of water is extracted from the Porur Lake, after the failure of wells at Porur and Virugambakkam. This water is treated at K.K. Nagar Water Treatment Plant and is distributed to regions such as K.K. Nagar, Ashok Nagar and MGR Nagar. The current distribution system does not cover all regions; there are certain un-connected areas that are being supplied to. The unserved area cover is of 70 km across the outskirts.

5. Certain fast urbanizing regions of Chennai are still considered as Panchayats around the outskirts. The main regions are Velachery, K.K. Nagar, Thiruvanmiyur, and Virugambakkam. The CMWSSB initiated an action plan to supply water and manage sewerage in these regions.

6. The Artificial Recharge studies were initiated during the years between 1982 and 1985; UNDO/ UNTACD aided the Hydrogeological and AR program. Three sites Poondi, Kosathalaiyar Flood Plains and Kannigaiper were identified. The project would allow extraction of 55 MLD of groundwater from the A.K Basin and if the new flood water interception plan comes into effect, the floodwaters are also transferred to this basin. The total floodwaters would translate into 27- 30 MLD of water per season. The three surface source Lakes and six groundwater well-fields (Minjur, Panjetty, Tamaraipakkam, Poondi, Flood Plains and Kannigaiper), supply about 273 MLD to Chennai on average that translates into 70 lpcd and about 45 MLD supplied to Industries.

The water distribution happens from four head works viz. Kilpauk, Anna Poonga, Southern Head Works and K.K. Nagar (CMWSSB, 2012). Distributions to the city from these main heads were continuous but needed improvement. Hence, the distribution Zonal packages were introduced.

5.9.1.1. Rateable Areas and Zonal Allocation Packages

There are many improvements to the distribution of Chennai. There are now 16 zones in the distribution network of Chennai, each with a package of improvements and costs. Some of these projects have been completed and installed, while others referred to as work in progress.

Package I Kilpauk

The distribution station at Kilpauk has been improved multiple times. Actions include installation of underground tank (35.9 ML capacity), overhead tank (9 ML capacity), installation of pump house (six pump sets) with motors covering civil, mechanical and instrumentation works (CMWSSB, 2012).

Package II Anna Poonga

The package II included improvements and renovations to the Anna Poonga Water Distribution Station (WDS) (region. 1). The package allowed acquisition of an overhead tank (2.8 ML in capacity) and 6 pump sets.

Package – III Southern Head Works

The Southern Head Works has two projects. The project fund for this project was approved by PWD and CMWSSB in 2009. The PWD and the CMWSSB provided approx. 300 crores improve the distribution system. The improvements include mechanical, electrical and instrumentation works.

Package - IV K.K. Nagar

The CMWSSB has initiated projects to improve the K.K Nagar WDS. The major aspects considered are construction of a WDS at the supply zone (2.4 ML capacity) and also installation of an underground tank (14 ML capacity) (CMWSSB, 2012). In the process, the project will include installation of pump sets, improvements to the pump house (with 590 lps 30 m head 250 KW motors) and installation of overhead tanks.

Package - V Kilpauk Zone

The WDS and the system were the first to be established at Kilpauk. All stations were launched after Kilpauk, and it is now considered the central supply distribution system. The works related to Kilpauk Zones involved renovation and examination of the existing pipes and installation of new pipes and water lines to improve some regions without water mains. The total length of mains in consideration is 167 km.

Package – VI Anna Poonga Zone

The second project to improve the Anna Poonga Zone involves constructing new mains and examining the existing mains to see if the pipes need replacement. This project also improves distribution by adding additional lines to support the current ones. The length of piping to be altered is 30 km across the Anna Poonga Region.

Package - VII Southern Head Works Zone

This section of the project is to strengthen the WDS and to improve pipelines. The Southern Head Works project team have identified pipelines that need replacement and the lines that are in reasonable shape but require additional support. They have initiated the project and the pipelines are considered for streets without mains. Sections of this region has no piping system and the CMWSSB has proposed new mains (24 km into the region) (CMWSSB, 2012).

Package – VIII K.K. Nagar Zone

The new package is similar to the Southern Head Works Zone, it involves inventory of the mains and pipelines so as to decide on the pipelines to retain and re-lay. This project also involved construction of lines where the main is not appropriated or installed. There are certain sections of this region without any piping. Hence, the CMWSSB initiated this project to examine 61 km of K.K Nagar water lines to identify and relay pipes, where required (CMWSSB).

Package – IX Triplicane Zone

The project works for Triplicane also involves retaining pipes, laying additional support lines and relaying/ laying pipes in regions without mains. The length of the proposed project is 24 km across Triplicane (CMWSSB).

Package – X All Zones

This package provides valves to all 16 zones to separate all zones, to easily identify zones with weak mains and to project the required issues with piping. "As identified by the CMWSSB, there are 15460 streets in Chennai (2581.95 km of land area). As indicated in Supply Management the entire city is supplied by pipes and tanks from 16 zones. All 16 zones need to be segregated by installing valves to cover the boundaries of each zone in feeder and distribution mains, so as to cover the entire city distribution network. The CMWSSB indicates that the packages from I to X will remove defective pipelines, alter existing ones, relay fresh ones and isolate one zone from another" (CMWSSB). The idea behind isolation is to prevent water to converge to prevent spread of contamination, provide exact inventory of the precise amount supplied to each section of the city and to separate the source point of supply. Unless the zones share the same source, in which case the distribution mains have inlets to allow source in flow into the systems where raw water is accumulated. The shared raw water is then treated and supplied to the distribution pipes for supply to various entities.

Package – XI Leak Detection and Rectification Programme under Phase VI

The major aim of this project is to assess the entire distribution system for leaks at both the mains and HH service lines. This project has been initiated and is nearing the end. The major changes initiated towards these mains are: 1) All HH service pipes will be replaced and the service connection will be replaced by pipes of varying sizes such as mentioned by CMWSSB (MDPE pipe - 100/150/200 mm diameter) and DI pipes are used to replace lines at the isolation point, the zone end points. The speculative prearrangement of pipelines and DI and CI pipes (50 km) and in package VI there are 42,000 pipes that need renewal and they have found all the CI pipes, completely, corroded and replacements are being considered (CMWSSB).

Pressurization is a technique to estimate the pressure of the flow into HH service or other service lines. If leaks are noticed, according to this package, the authorities must be notified and re-pressurization to identify and manage leaks will be considered. The distribution staffs perform all pipeline repairs and changing lines with leaks, faults and corrosion.

Package - XII Provision of Basic Amenities (to Unserved and Un-skewered areas)

Out of the 15460 streets in Chennai, 732 streets require street coverage (94.78 Kms in area). About 270 streets require water supply (48 Kms) and sewer lines. A proposal has been made to provide water supply & sewerage amenities to these un-served streets.

Package – XIII: Reconstruction, Repairs and Changes (to Treatment Plants):

The project involves reconstruction of raw water conduits I and III, repairs and rehabilitation of conduits from Redhills to Kilpauk WTP. There are three masonry conduits. Raw water is drawn from Redhills via three conduits that were built in 1914, 1955 and 1986. These conduits are damaged and leaking, a proposal has been drawn to reconstruct and relay conduits I and III. There are also a list of repairs and rehabilitation considered for the Conduit II[8]. Conduit II transfers about 360 MLD of water to the

[8] The conduit construction specifics are as follows: A) 1300mm x 1300mm RCC - Conduit-I and B) 1700 mm x 1400 mm RCC - Conduit-III.

Kilpauk WTP. Since it is in the main distribution system, the conduit construction needs to be planned carefully. Hence, the proposal envisions new conduits I and II with different dimensions (CMWSSB).

5.9.1.2. Funding and Project Costs

The proposals for enhancement to water system in the city was considered before the JNNURM commission under Ministry of Urban Development, Government of India in 2006 and the committee accepted proposals for Rs 322.00 Crores (CMWSSB).

Table 32 Cost of Distribution Projects

#	**Project (WD St)**	**Cost Under JNNURM**	**Revised Estimate**
1	Kilpauk	44.63	49.71
2	Anna Poonga	10.73	11.00
3	Southern Head	1.63	1.65
4	K.K. Nagar	22.48	23.80
5	Strengthening Kilpauk	73.86	76.72
6	Strengthening Anna Poonga	11.24	11.33
7	Strengthening of Southern Head	8.75	8.77
8	Strengthening of K.K. Nagar	21.66	22.02
9	Strengthening of Triplicane Zone	11.27	12.56
10	Valves in all 16 zones	15.12	15.62
11	Leak detection & Rectification	28.54	30.12
12	Proposal to extend basic Amenities to the Urban Poor	21.34	21.34
13	Reconstruction of raw water transfer conduits I & III, repairs and rehabilitation of conduit II from Redhills to Kilpauk WTP	41.38	43.01
14	TOTAL	312.63	327.65
	Miscellaneous	9.37	9.83
	Total Estimate	322.00	337.48

Source: CMWSSB Policy Notes, 2011 – 2012 (Data Collection, 2012)

Table 32 shows the cost of various components of works envisaged in the present proposal.

5.9.1.3. Project Implementation Arrangements

The projects will be executed by the CMWSSB, as shown in Figure 24. Since its formation the CMWSSB has implemented programs to enhance the current system.

Work has started only for four packages out of 13 and four packages are completed. (Package 1, 2, 3 & 12) The rest are in consideration or under progress. In view of high value of bids, the contract for the balance one package viz., Reconstruction of raw water transfer conduits I & III and repairs and rehabilitation of conduit II from Red hills to Kilpauk WTP has been cancelled and proposals are under revision (Figure 24).

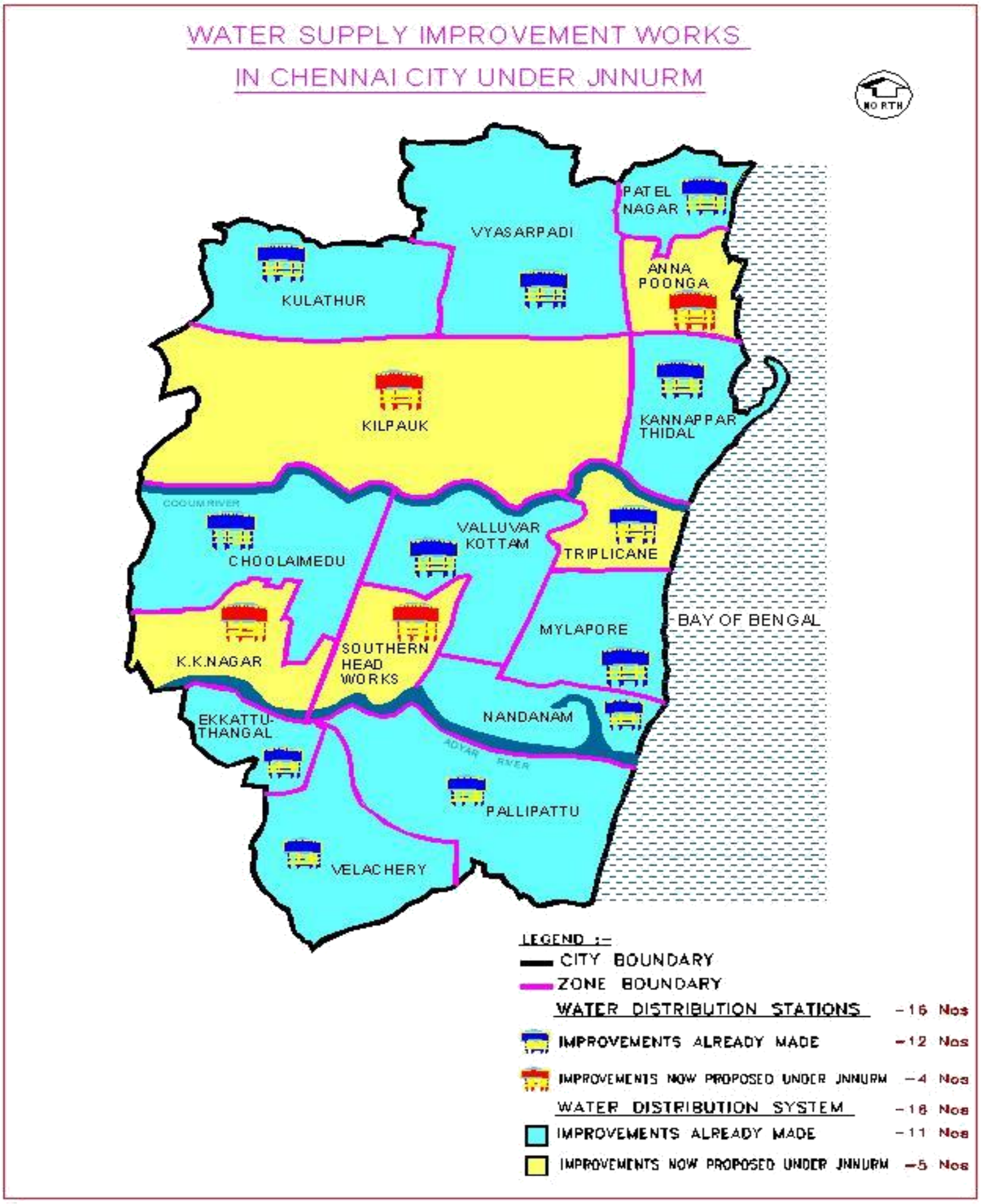

Figure 24 Water Supply Improvements Work Supported by JNNURM

Source: Data Collection 2012

5.9.1.4. Remote Monitoring

In order to transfer the data on water flow, the CMWSSB monitors pumps, motors, quality and supply. The provision of supply schemes has been completed in most parts. To enhance the distribution system in order to have clear and accurate data, the distribution and supply system will be monitored. A set of supply schemes failed due to both management, logistics and distribution related issues.

5.9.1.5. Revamping Supply System

Government of TN commenced an all-inclusive plan to rebuild the present supply distribution network in urban local bodies. Project heads, consultants and urban local bodies are involved in the initial phase. There are several schemes such as urban roads, ground sewerage schemes, Solid waste management, urban women's self-help, urban community development network, etc., that are funded by Tamil Nadu Urban Development Project (TNUDP III), Urban Infrastructure and Governance (UIG) under Jawaharlal Nehru National Urban Renewal Mission (JnNURM), Urban Infrastructure Development Scheme for Small and Medium Towns (UIDSSMT) under JnNURM, Japan International Cooperation Agency (JICA) and Kreditanstalt Fur Wiederaufbau (Kfw).

Table 33 Water Supply Schemes

No	Scheme	CMWSSB	PWD	Cost (in Crores)
1	Northern Basin	277.17	82.69	359.86
2	Central Basin	261.11	83.89	345.00
3	Eastern Basin	140.40	303.67	444.07
4	Southern Basin	136.20	162.78	298.98
	Total	814.88	633.03	1447.91

Source: (Tamil Nadu Water Board (Government of India Ministry of Water Resources, 2012))

Mainly the JnNURM sanctions funds for projects and CMWSSB is responsible for creating and maintaining the infrastructures (Table 33 and 34). The major tasks are to dispose flood / storm water and to overcome floods.

Table 34 Distribution Schemes and Projects

No.	PROJECT	ESTIMATE (In Crores)	STATUS	YEAR SANCTIONED
Kolathur	Storm Water Drain (SWD)	25.53	Work in Progress	2011
Velachery	SWD	47.52	Work in Progress	2012
North Buckingham	SWD	20.5	Work in Progress	2012
Central Buckingham	SWD	47.17	Work in Progress	2012
Mambalam and Nandhanam	SWD and Canal Works	121.53	Work in Progress	2013
Royapuram	SWD	30	Work in Progress	2012
South Buckingham	SWD	39.96	Work in Progress	2012
Captain Cotton Canal	SWD	40.5	Work in Progress	2013
Captain Cotton Canal	Canal Works	67.68	Work in Progress	2012
Coovum	SWD	82.17	Work in Progress	2013
Coovum	Canal Works	5.4	Work in Progress	2012
Virugambakkam	SWD	53.85	Work in Progress	2013
Virugambakkam	Canal Works	6.47	Work in Progress	2012
Otteri Nullah	SWD	92.15	Work in Progress	2013
Otteri Nullah	Canal Works	14.49	Work in Progress	2012
Adayar	SWD	60.74	Work in Progress	2013
Adayar	Canal Works	22.63	Work in Progress	2013
Total		**778.29**		

Source: Compiled and Modified from Data CMWSSB, 2012

The Ministry of UD sanctioned the project, as detailed in Table 34. The grants for this project totals: 1447.91 crores. The government shares 35 percent of the total while TN shares 15 percent and CMWSSB puts in 50 percent. The 50 percent is meet with by through loans from Tamil Nadu Urban Infrastructures Development Corporation Ltd. (TUFIDCO) 203.72 crores, Tamil Nadu Infrastructure Financial Services Ltd. (TNUIFSL) 150 crores and CMWSSB 53.72 crores. The project envisages construction of 290 Kms of drains, remodeling of 183 Kms of existing drains and renovating 16 canals for a length of 29 Kms at 815 crores. The regions in table 34 were further split into 12 watersheds and 17 packages (Tamil Nadu Water Supply and Drainage Board, 2011).

5.9.2. Current Programs and Projects

The major programs are attempts at PPP, communication and staff training, handling complaints and issues, approvals, service and management of hazards and cross connection monitoring.

5.9.2.1. Approvals, Services and Management of Hazards

To handle distribution management in a secure manner, the TWAD and CMWSSB have come up with a safety monitoring and hazard assessment plan. All projects, plans and distribution operations undergo checks once in 3 to 6 months. In the event of typhoons, cyclones or equipment failure as set of procedures are adopted to avoid environmental hazard and injury to person.

Projects are usually monitored and assessed before implementation, during launch and during operation. A good example is the desalination plant at Nemelli which has a monitoring system established for hazards and malfunction of equipment.

Approvals for projects are from the EIA and the central board of environmental resource management in India. Most approvals take more than a year to complete and they are often not smoothly and efficiently achieved.

Out of 500 about 300 HH's indicate that approvals for all services or implementations are long procedures with time consuming practices and in the end, there is no guaranty that it will help in an all-round manner. This is to a certain extent true. The complaint box installed in Chennai allows HH to report a matter or issue. But the service to act on the complaint takes a long time. HH indicated that they hire private companies to handle tasks, which the CMWSSB and TWAD need to be efficient at. 100 HH indicated that they hire people to fix and maintain their pipes, meters, pumps or valves. This indicates that there is a small percentage of distrust among residents with regard to services offered by the distribution system within Chennai.

All 500 residents indicated that the service provided by the two boards is very unreliable, inefficient and untimely. Out of these, 200 of them indicate that they have requested more service after a repair. This means the staffs handling repairs to the pipes, meters or pumps do not efficiently solve the issues. Nearly, 300 HH's indicate that the help arrives two to three weeks after a complaint is launched. This indicates that the service is not timely and residents of Chennai, hence, have a general feeling of distrust.

5.9.2.2. Communication and Staff Training

Chennai's staff training and communication system is currently being updated. There is a Metro Water Training Centre in place to train all engineering staff. The present functions include: Operation and Maintenance, quality module, sewerage disposal, human resources development, project management, financial management and demonstration of utilization of safety equipment's. The special training programs according to the TWAD are available throughout the year for enrolment. There is training for every member of various levels from junior to senior. That being said the complaints and service-related issues can be solved if the programs are strengthened. Making service reliable, accountable, efficient and timely will help improve security.

5.9.2.3. Cross Connection

Monitoring cross connections is a big problem in Chennai, one of the major water loss aspects. Residents of Chennai indicated, in the survey, that they are aware of such happenings and feel that the government is not taking enough steps to plug the water withdrawals.

TWAD interviews provided evidence that the system is under scrutiny and will be updated in the following years, 2014 and 2015. Currently, the cross connections are investigated via regional expanse monitoring, observation during meter reading and by looking at the water charts for HH's to understand the average amount use versus the current amount. This prevents faulty meter reading and also monitors the expanses within Chennai.

5.9.2.4. Issues and Complaints Handling

The issues and complaints are multiple in Chennai. HH surveys indicate that there are at least two to three complaints related to water metering, piping and the technical aspects of the distribution management. About 100 out of 500 people have issues with meter readings on a regular basis and the rest have issues once in six months. It is evident that many HH in the urban reaches of Chennai do not get meter readings or false meter reading is accepted, in the process destroying the accountability and reliability of the distribution system. The TWAD records officially thousands of HH related complaints regarding service, information and pipe leaks.

5.10. Further Analysis

The major conclusions drawn from looking at the distribution system are that the approvals, services and management of hazards require attention. Since the staff training still requires fine-tuning, the services and management of hazards and safety procedures will be majorly affected. Survey results indicated that HH's do not find services satisfactory or efficient.

In addition, the communication and transparency of the distribution implementations and the policies are poor. The boards indicated that they have programs and training, but the surveys indicate that the communication, transparency and staff training are very low due to the fact that the services and complaint handling are poor and the residents are unaware of the on goings within the distribution system.

The details of the costs provided are generally vague and the actual expenditures are not provided in the policy notes. CMWSSB and TWAD do agree that the cost information provided is inadequate for the public to make a good decision and participate in policymaking process.

5.10.1. Policy Changes Required for Business

1. To increase supply coverage to all towns to achieve the norms for per capita supply.
2. To guarantee that the water supply is of good quality by increasing the frequency of monitoring.
3. To ensure reliability of supply for 24 hours
4. To install a newer desalination plant
5. To increase the normal supply levels with respect to the JNNURM standards and maintain the WHO standards for quality.
6. To create small water supply undertaking to concentrate on specific zones that are weak at present.
7. To create supply actions similar to the electrical undertaking under the management of urban local bodies and entrust tasks to professionally qualified personnel

8. To implement schemes for capacity building
9. To avoid physical losses, zoning of distribution system and leak detection should be a periodic measure to control non-metered water resources.
10. To develop training and workshops in order to upsurge information uptake, water standards maintenance and improve water related information to encourage PPP and proactive participation.

5.10.2. Policy Changes Required for Distribution System

To increase supply coverage to the urban poor it is necessary to achieve the norms for per capita supply. The norms can be achieved when the distribution unit and network is managed well. Chennai's distribution units repair and maintenance will not stop supply, as there are alternative supply means. The following are actions required to have good distribution of supply in Chennai.

1. Rust and incrustations to be identified and the pipes to be changed.
2. To increase reliability, the distribution networks will always need to function during the day.
3. To install a new desalination plant in order to improve supply to the unserved regions.
4. To create a small water supply undertaking to concentrate on specific zones that are weak at present.
5. To distribute water under the management of urban local bodies, in collaboration with the sewer management and entrust tasks to professionally qualified personnel.
6. To implement schemes for capacity building.
7. To improve equitability via the distribution networks.
8. To avoid physical losses, zoning of distribution system and leak detection should be frequently performed and considered a measure to control non-metered water resources.
9. To develop training and workshops in order to upsurge information uptake, water standards maintenance and improve water related information to encourage PPP and proactive participation.

6. CLIMATIC TRENDS, PRACTICES AND POLICY RESPONSES

6.1. Introduction to Climate Change and Water Security

Natural resources are finite. Notable among these is water, and more particularly freshwater. Oftentimes a lack of water security can cause a crisis. Regions of the world have become more volatile and vulnerable due to the combined effects of human actions and unpredictable weather, hence creating a potential threat to sustainability of water resources.

To preserve water resources for the future, it is imperative to secure resources in a sustainable manner and adapt to climate change. Part of sustainable development entails the security of resources, which, in the case of water security, includes access, availability, affordability, and allocation efficiency (Mitchell 2005; GWP 2005). Water security can be defined as the integration of water resources and management among all sectors to provide good and affordable water through which poverty reduction, decrease in fragmented management, spread of education and increased standards of living for now and for the future can be achieved (GWP 2011).

Potential implications of climate change on water resources are: melting snow, floods, drought-like conditions (a reduced number of wet days and drying of resources), flood events (increased rainfall), lower ground water quality[9]- saltwater intrusions, sea-level rise and impact on ground water recharge due to vicissitudes in rainfall (Indian Ministry of Water Resources 2009; Olmos 2001; Potter et al. 2005). Changes in temperatures and rainfall can cause variations in water table of a region. The IPCC (1997, 2008) note that extremes in climate change manifests itself in the form of droughts or floods, which are now a common phenomenon. Intergovernmental Panel on Climate Change (IPCC) that a two-degree centigrade increase in temperature would bring about catastrophic flooding and droughts in most areas of the world, while rainfall below 500mm per year can cause severe droughts, and above 1800mm may cause floods (Groisman 2010; IPCC 2008). These impacts play a large role in water security and resource management, and in order to maintain sustainability, adaptation is the key.

Water-related security issues are common in arid to semi-arid regions of India. The non-equitable distribution of water is a problem in certain parts of the world, notably

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[9] Floods cause salt, un-dissolved solid and dissolved solid intrusions into alluvial aquifers.

India. The literature suggests that water-related deaths are greater in number than warfare-related deaths (WHO 2011). One billion people fall short of having access to a level of 1000m3 per person per year of water for drinking, domestic or other purposes (WHO 2011). In addition, other issues such as pollution, drought, flooding, salt intrusion and over-extraction add to the shortage. These issues further reduce opportunities for the poor to gain access to water resources.

6.2. Chennai's Water Supply and Current Situation

The current supply (2012) is approximately 730 MLD, which is insufficient. The total requirement is increasing every day, and presently the total need is at 900 MLD (approximately). Chennai Metro Water delivers about 575 MLD throughout the city to domestic consumers (2009) and over 70 MLD to the industries and a large amount to agriculture use (CMWSSB/ TWAD).

The Veeranam Lake receives water from Cauvery River and Chembarambakkam receives water from the Krishna River Project. The other reservoirs include Cholavaram, Poondi, Redhills, Puzhal and Vadakuthu. Besides these sources two desalination plants were installed in the last decade. Chennai also has ground water sources such as dug wells in major urban areas of Chennai and metro water wells in areas such as Neyveli, Poondi, Tamaraipakkam and Minjur (for further details see Water Supply and Status).

6.2.1. Water Supply and History

The Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB) and the Tamil Nadu Water Supply and Drainage Board (TWAD) handle water supply to the two sections of rural and urban Chennai. The TWAD manages supply to rural Chennai while the CMWSSB (also referred to as "Chennai Metro Water") supplies to the city. This difference is due to the access to water and certain political divisions.

Major expansion of water resources occurred between 1960 and 1980. Table 34 shows expansions and improvements to the water system in Tamil Nadu, affecting Chennai, between 1872 and 2011 (Table 35). The development of water supply, storage and transport mediums evolved over the last 100 years, sharply modernizing over the last two decades with inclusion of modern infrastructures and management strategies such as

RWH. Additionally, the capacities of the three water reservoirs [10] were updated and improved to 7412 M cft (million cubic feet) in the year 1980. This improvement was only about 1% of the total supply requirement, though, and may well be considered a very minor change. This effort to slowly drag up the storage limit over the years was not as successful as anticipated, in part because the water need requirements increased from 600tmcft (thousand million cubic feet) to 1500 tmcft between the years 1980 and 2010.

Table 35 Historic Timeline of Water Supply in Chennai

Date(s)	Item
1872	- Start of water supply (for all of Tamil Nadu)
1881	- Completed construction of Redhills
1910	- Start of protected pump and pipe supply
1914	- Dam constructions - Installation of protected pumps (large scale) and filtration technology
1916 ~	- Construction of storage tanks, dug wells, tube wells, sumps, etc.
1947 ~	- Treatment, conveyance, and distribution of water for Tamil Nadu - Steam engine drive pumps (SEDP), Elevated overhead tanks, & protected long distance supply - Rapid gravity sand filter treatment facilities installed (45 MLD)
1959 ~	- Second underground masonry conduit installed (146 MLD of raw water) – Redhills to Kilpauk - Storage tanks and combined water supply (0.66 million population and 115 LPCD)
1966 – 1972	- Electrical plumbing for Chennai (Kilpauk), replacing the SEFP - Two underground water filter tanks (18 MLD) at Kilpauk - Poondi line canal to transport water to Cholavaram - Interception of surplus water at Tamaraipakkam and Anicut
1980 ~	- Krishna River Project I and II - Reservoirs updated 7412 Mcft
2003 – 2004	- Artificial recharge; rainwater harvest
2004	- Veeranam Project
2005	- Reinforcement of Right to Information Act (RTI)
2006	- Desalination Project (100 MLD)
2008 – 2011	- Purchase of agricultural wells - Monitoring progress of dam maintenance and renovations - Nemelli Desalination Project (100 MLD)

Sources: CMWSSB and TWAD 2011/ 2010

[10] The three water reservoirs in Chennai are Poondi, Cholavaram and Redhills.

Other measures designed to increase water supply included interstate agreements such as the Krishna River Stages II and I scheme for Chennai. This scheme increased supply capacity for the city up to 1100 Tmcft. Chennai now has approximately 1100 Tmcft of water supply (for industry, agriculture and domestic use), supplied from the Krishna River, and 7412 Tmcft of it is stored in the three reservoirs. However, the 1100 Tmcft of water supply is still less than the actual required supply for Chennai: about 1400 to 1600 Tmcft.

The timeline from 2001 up until 2011 shows policy and technological imports from various regions of the world implemented with the goal of increasing supply.[11] Only a few of the projects indicated in Table 34 are located on the outskirts, the DUA, adjacent districts and the AUA regions. A large-scale desalination project, also referred to as the Minjur Project, is similarly located on the outskirts, and is currently dormant. Subsequent to the Minjur Project, new projects for desalination have been initiated to increase supply. The Minjur Project was considered to be unsuccessful,[12] and hence a new project with100 MLD (million liters per day) capacity in Nemelli, close to Chennai district, was initiated in 2010. The fact however remains that the existing Minjur large-scale desalination plant does not function to produce water and transmit it to the adjacent areas of Chennai (based on a 2010 household survey).

6.3. Common Climate Change Threats to Water Resources

6.3.1. Drought, Deficit and Depletion

The TWAD indicates that the water supply level in Chennai is at a deficit in relation to overall demand, with many minor and a few major issues faced by the domestic, industrial and agricultural sectors. The water deficit in Chennai is over 100 MLD's, yet this not considered as significant as that of other drought-declared regions.

Flood and drought cause variations in the water table. In the early 2000's, Chennai suffered an acute water deficit of more than 200 MLD's for the domestic sector, as the monsoons brought less rain than usual. Hence a water-rationing scheme was introduced to conserve water resources through "water scheduling". The scheme limited supply to two hours per week, creating the need to seek supply from other sources. Hence,

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[11] Technological imports include equipment, technology such as desalting, and policy changes that can be adopted out.

[12] The desalination portion of the Minjur project took a long time to complete (2006 to 2011) and the local interviews, conducted as part of this study, indicate that the project does not, currently, produce water for HHs.

the dependence on desalination and tankers increased. This led to joint ventures such as the Desalt and Max Joint Agreement, and the Krishna River and Veeranam Lake Projects.

According to sources, the water supply to Chennai is to be cut by 20 to 25% in 2013, due to the drying reservoirs and the thirsting lakes. The per capita water supplied used to be about 130 lpcd (liters per capita per day) on average for most areas. It has now sunk to 70 lpcd (approximately) in some areas. This is primarily due to the deficient NE monsoon in 2012. All the reservoirs currently have 3.6 tmcft of water, while the total storage capacity is 11 tmcft. A declaration of inadequate water supply was also made in 2011 when the rains did not bring up the storage level.

Data provided by TWAD (2011) enhances clarity on the water levels, showing them to be lower than usual every five to seven years. Furthermore, the western part of the city (including water-starved regions like Tambaram and Velachery) has issues due to intense overuse and lack of means to replenish. The rural outskirts of Chennai have similar issues as Northern Chennai. Among other problems are dry wells and overuse of ponds. There are severe shortages in regions close to Perambur, Ambattur and Minjur.[13] Several other well-connected regions also have tank supply and collection by *Kodams* due to water scheduling.

6.3.2. Sea Level Rise and Saline Intrusion

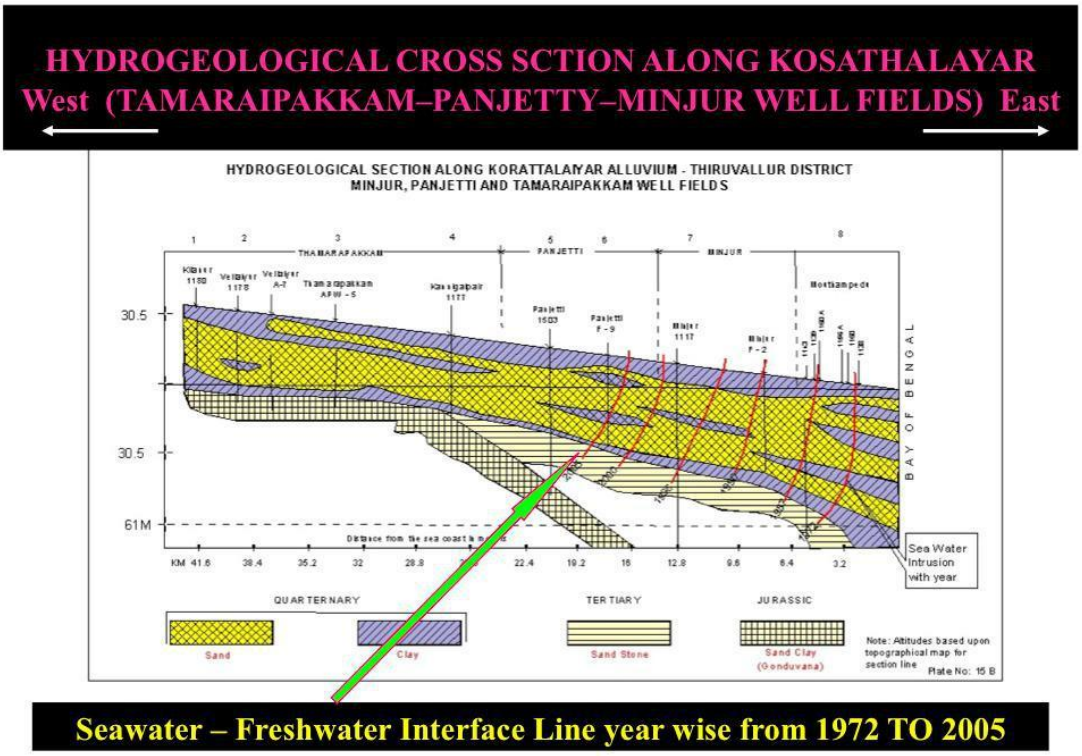
The rainy season [14] brings new changes in the coastlines, where flooding is common. Coastal areas of Chennai such as Velacheri, Madipakkam, Minjur and Kotturpuram have been declared as the most vulnerable to impacts of sea level rise. Flooding of regions close to the coastline has become a pressing issue in recent years.

Nine out of ten HH interviewed in Velacheri specified that water flooding is common and has become a frequent event, with water sometimes completely clogging the region. This foreshadows a future threat of sea level rising over the land area close to the coast. TWAD during the inspection and projection of groundwater resources found that there are in fact substantial amounts of seawater intrusion in the main water aquifer supplying water to Chennai and greater Chennai. Figure 25 indicates evidence for

[13] Interviews were conducted where ten fishermen were asked questions about the shortage and the climatic conditions in the region. All of them indicated that they had problems, and the desalination plant did not provide much improvement to the conditions.

[14] The precipitation characteristics of this region are as follows: summer rains last from January to February, transition rains from March to May, southwest monsoons from June to September, and northwest monsoons from October to November.

seawater intrusions in Chennai, to be expected, as it is a coastal city with major sections at sea level. Water from the sea constantly permeates the freshwater inlets.



Source: TWAD

Figure 25 Seawater Intrusions

Furthermore, flooding also causes saline intrusion into the ground water source. Coastal Chennai experiences saline intrusion, as its elevation is close to sea level, elevating gradually up to only two meters above sea level toward the inland. Saline intrusions reach inland and seep into the rechargeable aquifers. Hence, coastal aquifer recharge is not very successful. In flooding seasons, the situation is worse due to the mixture of salt, dirt and mud slouching into the coastal land area and penetrating the ground. Thus, the ground water resources are unusable in their present state.

Groundwater levels in Chennai have recently fallen to low levels. In many places saline intrusion has been reported. The Central Groundwater Boards indicate that Chennai’s saline intrusion is still at a lower level compared to Pondicherry, Daman etc. Saline intrusion coupled with over extraction effect stress. Surveys indicated that the wells in the coastal regions have a slightly saline taste to the water extracted. The

TWAD indicated that there is a low-level TDS in the well water and there are certain other elements in the region's quality tests were conducted. The CMWSSB confirms that saltwater intrusion is steadily increasing in Chennai. The South, Central and North of Chennai are the main regions that CMWSSB, Ground Water Board and TWAD found majority of the saline water intrusions. In Mylapore, and adjacent regions surveys and the official interviews suggest that the TDS have constantly increased. TWAD confirms that Chennai has 60 to 70 percent increases in TDS in all water services that are tested. Heavy withdrawal increases in buildings, domestic waste dumped into rivers, the general unavailability of potable water in the urban metropolitan areas and the lack of proper management has decreased the potential capacity to improve resources and adapt to climate change.

6.4. Climatic Trends

To indicate the extent to which climate change can impact Chennai's water, selected literature, the locally collected data from TWAD and a few household interviews were used.

Rainfall in Tamil Nadu varies in different regions. For example, Coimbatore gets 800 mm of annual rainfall, Chennai gets 1000 to 1400 mm, and Nilgiris gets 1400 to 1800 mm on average per annum. Droughts and floods are the main conditions that affect water quantity and quality. In the year 2010, Tamil Nadu declared all districts except Chennai, Nilgiris and a few others as drought prone (data from TWAD – Water Development Chennai, 2011). However, although drought conditions may not be explicit in Chennai, the region still suffers from water scarcity, coastal flooding, an outsized population and reduction of water sources for the future. The TWAD has created a map, shown as Figure 11 and Table 13, of all areas within Tamil Nadu, identifying whether they are over exploited, critical or safe, based on the status of the area's ground water development.[15] The map indicates that all of Tamil Nadu except Chennai city and six other regions are water starved. On the map, white regions, according to interviews with the TWAD board, are regions with low-level scarcity. Regions and districts adjacent to Chennai (and part of the Chennai Metropolitan Area), shown in blue and green on the

[15] TWAD 2011, which includes the map shown in Figure 3, is a document created from online resources, which enables locals to access information on surface and ground water resources. This document has different sections within sectoral analysis of water planning, all compiled between 2010 and 2011. The RIT has posted information on the website, including the government policy acts and water resource management plans. The Chennai Master Plan indicates the changes in acts and ordinances for the state that have been amended for the district.

map face moderate scarcity, but in comparison many other regions of Tamil Nadu, shown in red on the map, face more severe scarcity. The districts toward the southwest, southeast and north are severely impacted, with reducing water resources due to the drying of wells and rivers, the lack of access to water resources, the lack of sanitation or quality in the rivers, reservoirs, etc.

Figure 26 Ground Water Development Status throughout Tamil Nadu

Table 36 Ground water Development Status throughout Tamil Nadu

Condition	Regions	Water Facilities Development	Areas in TN
Undecided	2	Variable	White
Safe	145	< 70	Green
Semi Critical	57	70 - 90	Teal Green
Critical	33	90 - 100	Pink
Over Exploited	142	>100	Red
Saline	8		Magenta

Source: TWAD 2011.

Among the flood prone regions of India, Tamil Nadu, at a level of 0.045 in a flood liability range of 0.01 to 8.00, falls in the lower half (Table 36). In contrast, Uttar Pradesh, a state where floods occur often, is on the higher end of the scale at 7.34. Even if Chennai is not flood prone today, it may well in the future have extreme climatic events that may increase the threats to people and water resources. As coastal regions suffer small- level of floods, based on interviews Neelankarai is one such region where floods were mild but common.

Although Tamil Nadu and Madhya Pradesh have the largest land areas that are declared drought prone among Indian states, Chennai is still not considered drought prone, simply due to the fact that the annual rainfall level has exceeded 1000mm during most years in the last few decades. The fact is that many countries did not at first understand the consequence of climate related water issues (GWP 2011). The increased understanding that today's inefficiently managed water resources may well end in physical scarcity due to increased temperatures and lack of rainfall, if left unmanaged, will be helpful (GWP 2011). There are more than eight million people in Chennai and its AUA and DUA regions; more than three million of these people will be affected due to possible drought and flood vulnerabilities. Already, the regions of Valsarvakkam, Porur, and Tambaram are drought prone, as shown in the household interviews conducted for this study, due to experiencing some amount of water shortage and stress.[16] The droughts

[16] Ten HHs were interviewed (not as part of the survey, but separately, with open ended questions). These interviews helped to disclose the exact extent of the water scarcity problems within Chennai. Part of the interviews also solicited local opinions on finding solutions to the water problems.

in Chennai are classified as non-hydrological, that is, not completely associated with the climate. Chennai is more aligned toward droughts with causes that are socio-economic (supply, distribution and demand related) as much as meteorological (the climatic conditions that vary from one region to another). Administration-related droughts also play a role and are in direct relation to the available and accessible water quantity, and lack of equitability plays a major role in the water management for Chennai (as observed from interviews).

The values in Figure 26 indicate that a large number of the outer city and districts of Chennai are affected by semi critical to critical droughts. Based on the reducing level of water in the reservoirs and the water requirement predictions for the year 2021 (interviews conducted as part of this study), the variability of climate may not allow efficient policy implementations. There will likely be further water scarcity surfacing in regions that are currently satisfying the supply requirements for Kilpauk, Adayar, Saidapet and other regions of South and South West Chennai.

6.4.1. Trends and Vulnerability to Climate Change

Chennai faces potential drought with a fewer number of wet days from the northeast monsoon and very low precipitation from the southwest monsoons. The western part of Chennai, a dry zone, is where shortage is felt acutely, partially due to climate and over exploitation of resources.

Major measures for managing floods were brought out by the central government of India (CMWSSB 2007; TWAD 2010). Governor P. S. Ramamohan Rao stated that the state would seek a relief scheme through which drought can be handled. This statement set off several alarms in terms of drought and flood mitigation in Tamil Nadu. Besides this, five regions of Tamil Nadu were also declared flood prone and they were also expecting large amounts of floods in the future.

Dryness impacts Chennai through drying of wells, uneven distribution, and shortages related to reduction of water supply. Chennai and adjacent regions have seen an increase in temperatures (the maximum values). There is also an increase in floods in some parts of Chennai due to cyclones. The earlier Figures 27 and 28 provides an indicator of dryness level. Figure 27 provides a color-coded measure of climate change vulnerability. When juxtaposed with each other, it can be seen that the dryness levels indicated in Figure 27 do not precisely match the vulnerability levels indicated on Figure

28. Specifically, Figure 28 identifies Chennai as a low vulnerability level region whereas Figure 27 identifies Chennai almost as a neutral zone with a very low level of scarcity. This variation may be due to the fact that Figure 28 looks at the climate change vulnerability, and the parameters to assess it may be slightly different from Figure 27.

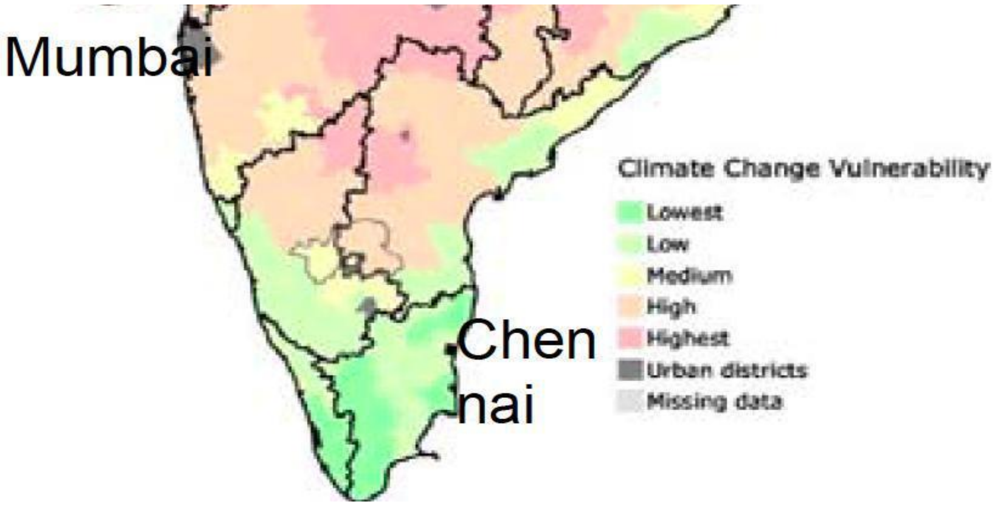


Figure 27 Climate Change Vulnerability in Southern India

Source: O'Brien et al. 2004

Figures 28 and 29 indicate a marginal increase in rainfall and increase in temperatures over the coastal regions of Chennai. The increase is due to the change in overall rains during 2004 and 2005.

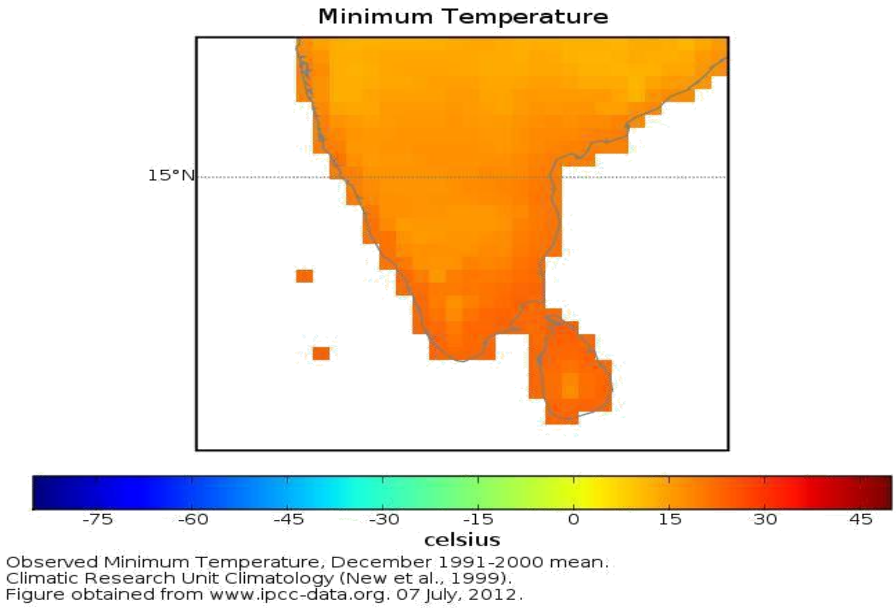


Figure 28 30-Year Minimum Temperature Values

Source: Intergovernmental Panel on Climate Change (2012)

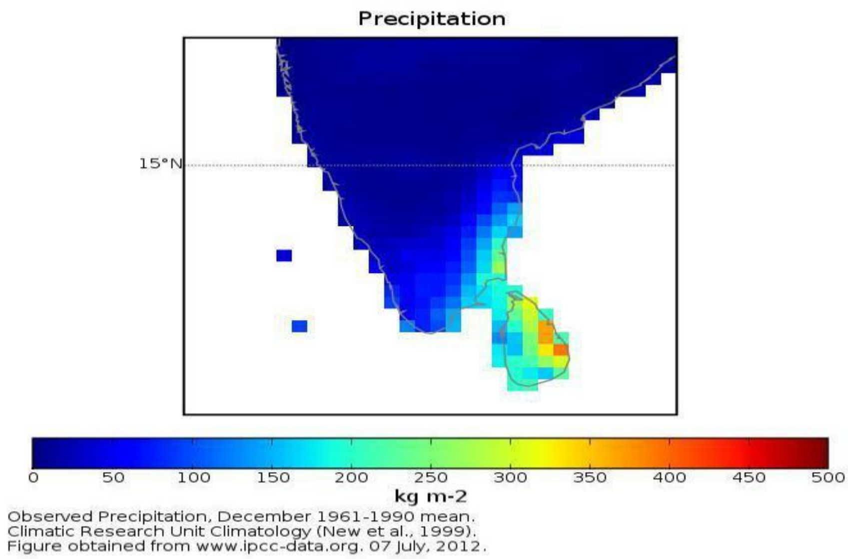


Figure 29 30-Year Average Precipitation Values

Source: Intergovernmental Panel on Climate Change (2012)

Data from the India Water Portal indicated that the decrease in rainfall during the last four decades is minor when compared to the changes over the last century. These conclusions were drawn through minor adjustments to data, due to lack of availability from more than one station and the error corrections for values that were unavailable for rainfall and temperatures levels over the last 100 years (data adjusted in comparison to

Nair 2009). The areas within Chennai fall between the lowest and medium level of vulnerability.

Through these data, it is clear that Tamil Nadu is drought prone at a moderate level (1% to 25%), and Chennai also falls within this range, as shown in the figures. On the dryness indicator scale, Chennai falls between 1% and 25% dryness, as compared to regions further to the north that are between 45% and 65%. Figure 16 showing average annual temperatures were derived from the raw data collection, [17] and indicate an increasing trend in temperature. Although not steep, it is an enormous increase by about 0.5 to about 1 degree over the last 100 years. The increase shows a numerical value range between 27.6 in 1901 and 28.6 in 2001, showing a 0.5 to 1 degree increase within a 100-year period, and a 0.8-degree actual increase within the last four decades. Nair (2009) indicates that there was a massive increase in temperatures in South India up until the year 2000. The climate data shows an increase in temperatures by ~0.5 to 1 degree, shown in Figure 30, and a decrease in wet day frequency, shown in Figure 32, indicating that there could be a severe impact on water resources in the future. A decrease in rain and increase in temperatures does not signify shortage but could lead to a crisis situation through water stress.

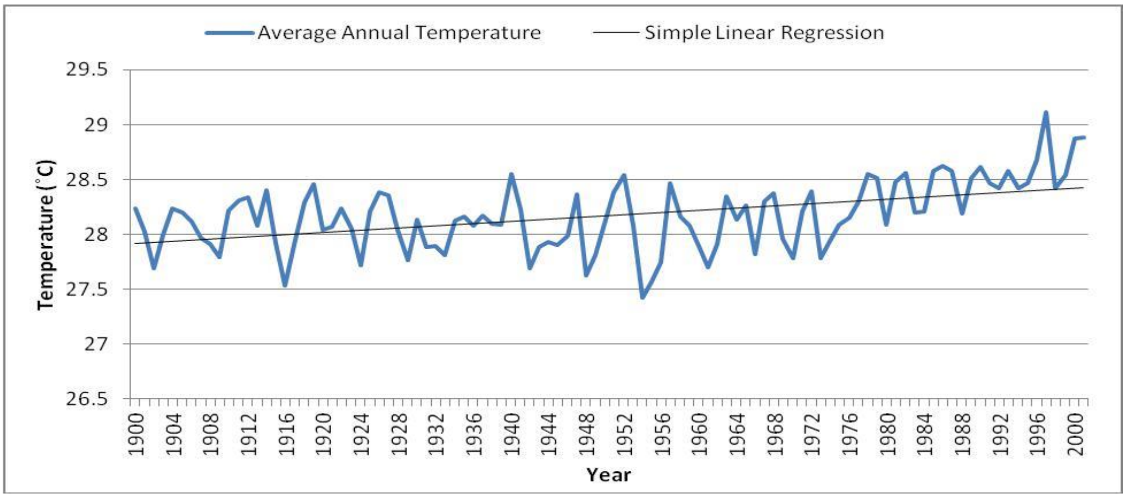


Figure 30 Chennai Average Temperatures, 1901 to 2002[18]

Source: Data compiled from secondary data sources on the India Water Portal

[17] http://www.ipcc-data.org/maps/

[18] From the station where this data was obtained, only data up to 2002 is available.

Despite a general lack of water and the resulting stress for locals, and the increasing need for more water for agriculture, the TWAD board has not yet declared Chennai a drought prone region. This could be due to several factors, including sufficient rainfall (more than 1000 mm, as compared to other regions which see only 300mm of rainfall) and the potential ability to meet water requirements for the current time period. Over time, however, the level of rainfall is clearly expected to drop further, as evidenced by past trends (IWP 2009, 2011 and 2012). This reduction in rainfall and the failing monsoons of 2012 should caution the water authority of Chennai to prepare for a future drought.

The data for precipitation levels in Chennai from 1901 to recent times (2002) is shown in Figure 31. On average, Chennai has had a precipitation level of about 1100 to 1300 mm per year, with tiny spells of great intensity. Although there has been at least 1100 mm of annual rainfall in recent years between 2004 and 2008, the rain runoff is 65% or more. Rainfall levels from 2004 to 2008 were collected from various sources including the Indian Ministry of Water Resources. This data indicates an increase in rainfall levels, and partial flooding in Chennai. The examination of monthly rainfall data indicates a decrease in rainfall or the intensity during the rainy seasons, over time, in Chennai. The extraordinary level of rains seen in 2005 is unexplained by officials. The rainfall generally is concentrated during the monsoon season and beyond that there are no rains in Chennai. The rainfall above 2000mm in (see Table 36) 2005 may be due to an error in recording or due to the typhoons and flooding that constantly wreaked havoc in 2005, Chennai. The rainfall levels recorded for 2004 to 2008 are generally higher than that of 2003. The TWAD documents (TWAD 2011) suggest that the rainfall levels may actually be higher than most arid regions across the world, and yet the district faces a lack of water resources.

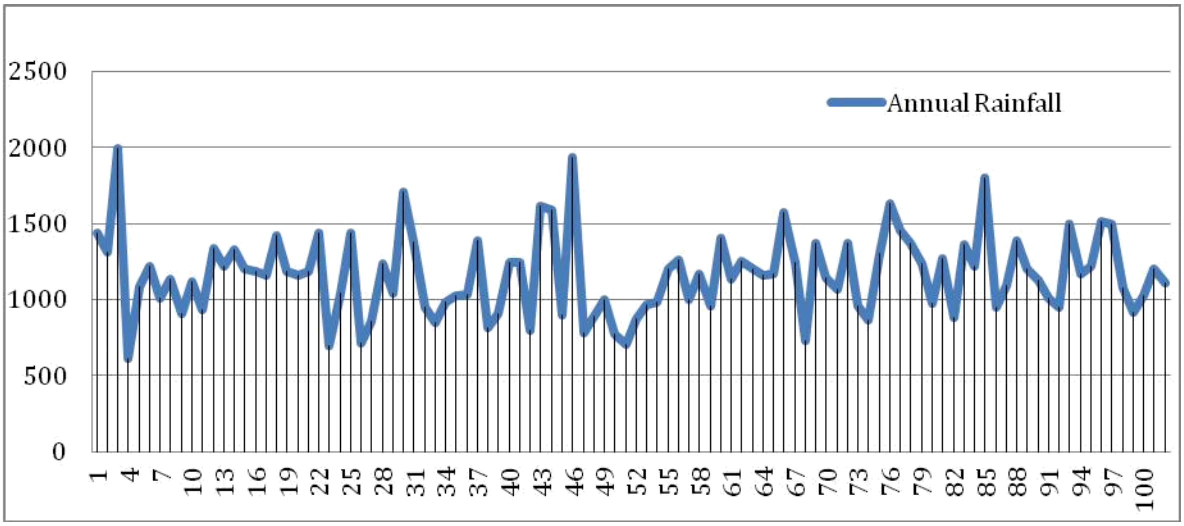


Figure 31 Chennai Average Precipitation Levels (in mm), 1901 to 2002 Table 37 Annual Rainfall Amounts (in mm), 2004 to 2008[19]

2004	2005	2006	2007	2008
1298.7	2481.6	1405.6	1294.1	1391.9

Source: Data compiled from the India Water Portal (2009); TWAD 2011

Wet day frequency refers to the number of days in a year that an area stays wet due to rainfall (Nathan 1998). Wet day frequency data for Chennai was gathered from the India Water Portal for the years from 1900 to 2002. The wet day and rainfall pattern indicate a change in the rainfall level, a decrease of about 200 mm when compared to the last two decades (as indicated by interviews). Water availability data, used to generate Figure 19, also reflects a change in wet day frequency.[20] The linear regression in Figure 20 indicates that the increase in wet day frequency is minor, from about 46 days to about 49, over 100 years. The level of precipitation for Chennai was close to 1500mm to 2000mm during peak seasons between the years 1900 to 1945, where the wet days were uneven, ranging anywhere from 38 to 60 days. The current level of rainfall during peak season is between 900 mm to 1400 mm or below (see Figure 31 and Table 37). The rainfall is heavy, but the total rainfall is concentrated over 40 to 50 days in a year and the rest of the year does not get any rains. There is a pattern shown in the level of rainfall

[19] The data in this table comes from a different source than that of Figure 8. Therefore, the data is shown separately, rather than combined into the same figure.

[20] In addition to amount of water supplied by rain, water availability can be used as another measure of wet day frequency.

ever four to six years in Chennai. A dryer than normal season followed by a wetter than normal season. The temperatures vary between one to two degrees, which may not be significant compared to the changes seen in South China, 2006, during the time of severe droughts. Observation suggests that Chennai's temperatures have hit 40 to 42 degrees in the last two years (2010 to 2012). Thus, this indicates that a further increase in temperatures is a possibility for Chennai.

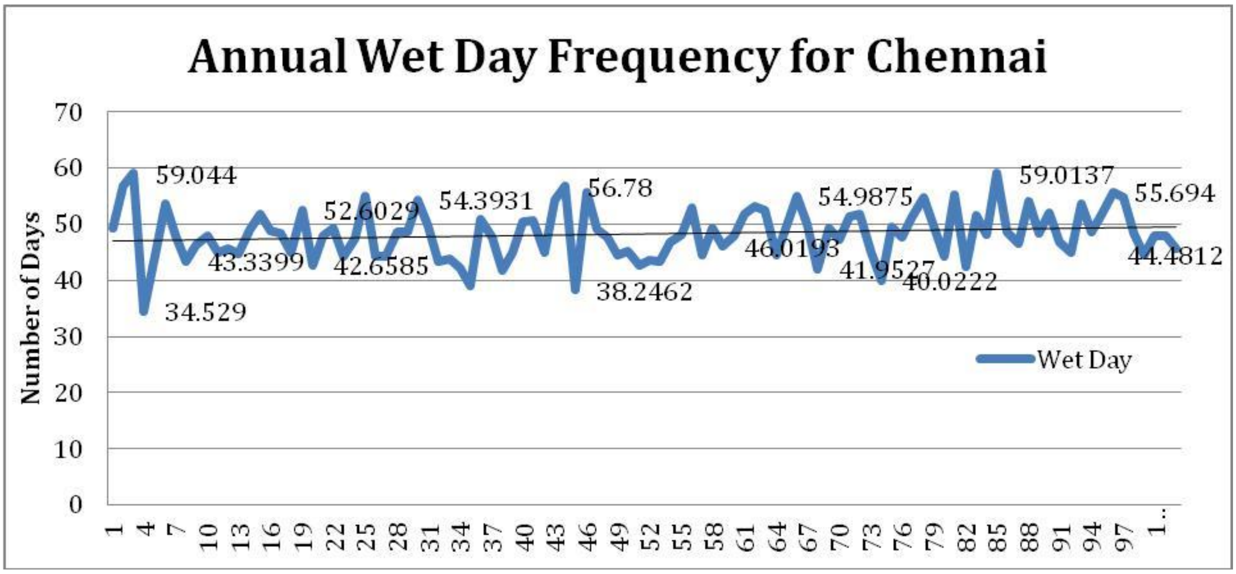


Figure 32 Chennai Average Wet- Day Frequency, 1901 to 2002

Source: Data compiled from secondary data sources on the India Water Portal

So, Chennai is not drought prone and neither has it been declared flood prone. A flood prone region would, in fact, see a greater number of wet days with water logging. And the present condition of wet day frequency, according to the TWAD staff, does not denote a drought condition. However, the future predictions within the RWH office indicates that the drought may occur, and it may well become more intensive if the monsoon rains keep being insufficient. The wet day frequency is higher from September to mid-February than during the rest of the year, and the data indicates that there has been a very slight increase in the annual number of wet days (see Figure 32). This increase may be due to correction error and due to consideration of annual rains instead of the seasonal number of rainy days where approximation is also present within the data, due to the fact that the last decade has known more droughts than periods of rainy days.

Four regions in the outskirts of Chennai: Maduravoyal, Valasaravakkam, three wards of Ambattur and another nearby region, have floods in some parts, while other parts are dry and parched. This is mainly interpreted in news reports as a management issue due to the absence of storm water drains and good roads to manage and secure water supply (The Hindu 2011a). This issue could soon affect central Chennai, as the signs of bad roads and improper maintenance of storm water drains are clearer. The flood prone regions of the four local bodies each support 50,000 or more people, while Chennai city alone supports 4 million or more people. Hence, the issue needs to be tackled efficiently and promptly due to its scale and predictable intensity of impact.

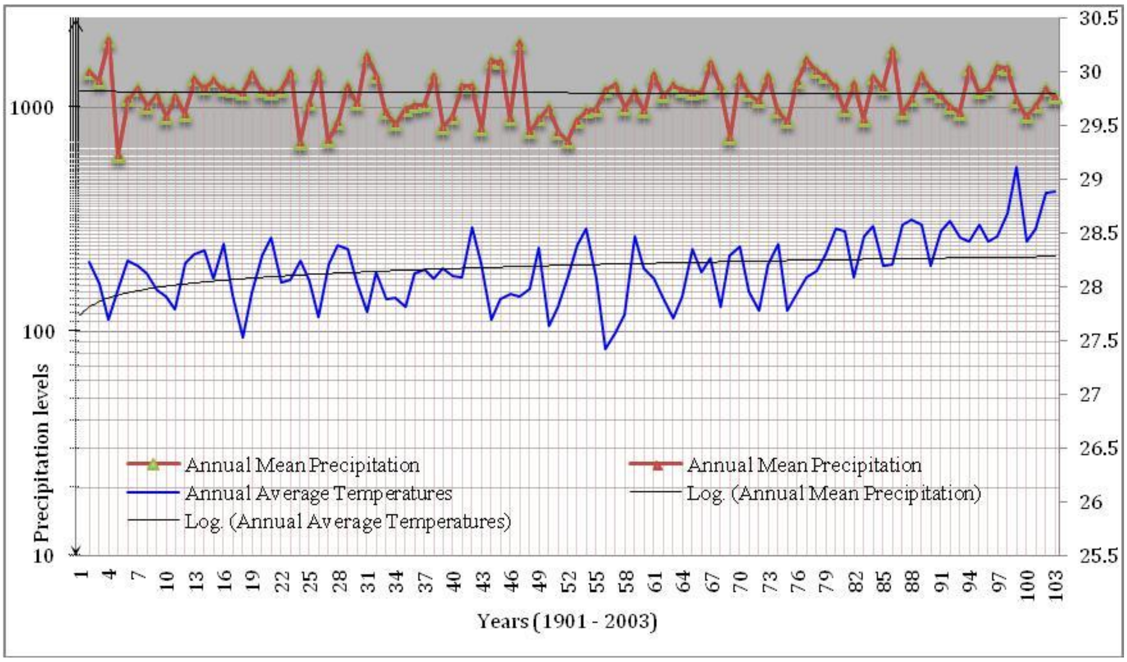


Figure 33 Precipitation Levels Relative to Temperatures

Source: Data compiled from secondary data sources on the India Water Portal

Figure 33 shows the annual mean precipitation and the annual mean temperature correlated. Comparing these graphs clearly shows an increase in temperatures while the precipitation levels are relatively flat. The gap between months with heavy rains and months with sparse rains has lessened in the last few years when compared to the years between the 1900s and 1950s. This is due to heavy evaporation due to high temperatures and increasing rains during the rainy seasons. The rest of the months get little rain.

6.4.2. Correlating Water Levels, Rainfall Patterns and Temperatures

Rains are essential for ground water resources to recharge. The evaporation process reduces surface and the ground water levels. East coast rains fall frequently in the sea, reducing the inflow of fresh water inland. Surface water levels also depend on good rains. Chennai's rain level is higher than most but is lost due to 80% runoff to the sea, as measured in the current year, as the interviews signify. Thus, overall retained water level is low, and the ground water sources dry up as the years pass.

The gap between heavy and light rain is reflected in the measure of rainfall captured in the dams and storage facilities in Chennai. The storage capacity for Chennai's reservoirs is large, and only a quarter of the storage facility is in use at the moment. Hence, when there is rainfall it is reflected in the level of water stored, and so the reduction of rainwater is easily observed. The results of the interviews with members of the Tamil Nadu Water Board indicate that there has been a shortage of water due to shortfalls in supply and poor management, especially of trucks and hand pumps, since the year 2004.

Table 38 Rainfall Measures in Storage Mediums (in mm) in Chennai

	Rainfall in 2008	**Rainfall in 2011**	**Rainfall in 2012**
Cholavaram	1678	1086.2	902
Poondi	1523	1333.4	1094.8
Chembarambakkam	1578	1967	700.3
Redhills	1751	1472.4	935.5
Anicut	1223	1694	922
Tamaraipakkam	1683	1497	1173

Source: Compiled from data collected, secondary source CMWSSB, (2012)

The level of rain brought by the southwest and northeast monsoons has been at a stagnant level. Table 38 indicates the measure of rainfall as determined from storage mediums such as reservoirs and overhead tanks. Between the years 2008 and 2011, the reservoir water level decreased as rainfall was drastically reduced. The reason for this could be the fact that there were heavy rains and flooding up until the end of 2008, while there was a brief decline and then a reducing rainfall level after 2008. The rainfall levels in 2011 and in 2008 measured (mentioned in the TWAD website) is slightly higher (1200mm), compared to the absolute values represented in the India Water Portal data (IWP 2009). However, during this time peak temperatures shot up to 41 degree Celsius, which intensified evaporation. The change in temperature was very significant in Chennai during this period. In 2011 and 2012, the temperatures were measured between 35 and 41 degrees Celsius, whereas the temperatures were slightly lower in 2003, when they were measured between 34 and 38 degrees (Collected during interview with TWAD). Thus, a higher temperature and lower rainfall condition has resulted in a decrease in the reservoir water levels in Chennai, and an increase in rain does not imply successful ground water recharge or increased RWH, because of runoff. (As mentioned earlier, an estimated 80% of precipitation is lost to the sea as runoff.)

6.5. Adaptation Measures in Chennai

Although Chennai has not yet been declared drought prone, the outskirts of the city face mild to severe drought due to lack of supply, and poor management. The region has less than twenty percent of water available for household use due to various industries and farmlands situated nearby. Initiatives are being undertaken to improve and adapt to the current and there is focus on improving the future management for potential climate change issues. Some of the policies that are implemented are renovation and restoration of old water storage structures, improving management of floods in urban regions, and strengthening policies and reinforcing them, RWH and refocusing goals.

6.5.1. Rainwater Harvesting

One important way by which water levels can be increased is through rainwater harvesting. This needs to be implemented uniformly everywhere and further education is required to be successful in making people install RWH systems. Furthermore, the current level of rain could continue to decrease. The 2004 rains were erratic in nature and only stabilized after a period of four-year floods and a tsunami occurrence in Chennai. Thus, harvesting water will save Chennai a lot of trouble in the future management of droughts.

Chennai faced a four-year period of frequent floods along the coasts in the 2000, due to extreme climates. Managing floods requires some amount of quality control, which is not looked at in detail in this paper due to the vastness of the topic. Issues such as penetration of saline water into fresh water and ground water sources are becoming common in Chennai. When that occurs, the water becomes of zero utility value within households. The salinity can be managed if the floods are channeled in a proper fashion into drains that channel water to central purification facilities. However, the local drains are uncovered, and many potholes can be seen along the roadsides.

The rainwater harvest system implemented in Chennai is becoming popular at present and will in fact increase the water table by several 100 MLDs and is the only practical way to facilitate ground water recharge. The ancient technology is being noticed as the simplest way to handle supply-related drought. About 4000 years ago the Palestinian and Greek people had the concept of collecting rainwater through an apparatus. This is similar to the modern tanks for collection of rainwater. The RWH structures are easy to install. The form of policy intervention that is most likely to work is the cancellation of the water supply connection and the levying of a fine on entities without RWH installations. This policy implementation would require official checks on residential RWH installations to ensure every residence, including both apartments and independent houses, has installed RWH system. The government and the local authorities should not allow occupation for new buildings without RWH equipment. Reduction of rainfall due to climatic conditions is a possibility that can be adapted to with proper management of current issues. Thus, water scarcity in Chennai can be attributed to a lack of innovation, in-equitable distribution, supply cuts, RWH installation challenges, and lack of information sharing.

6.5.2. National Drought Measures

The National Drought Policies under the Drought Prone Area Program include a large thrust for watershed development. Watersheds need improvement due to the weak sources and low quality of water resources.

Water use for industries and farming can be reduced with planning and efficient use, benefitting the local citizens. The dry land farming, i.e., converting dry lands to agricultural areas, is the method used to control water use. This has to a certain extent proven beneficial for households in the rural DUA regions. Dry land farming along with sprinkler systems is beneficial for controlling water use, and eventually benefits households by providing them with more water for domestic use. Although sprinkler systems may be useful, not all crops can benefit from them due to the varying levels of water required. Yet, this method can be efficient if implemented selectively, and will not impact other crop productions. The Tamil Nadu government has already, to a large extent, implemented this policy for conservation of water through irrigation methods, control of ground water use, and controlled measures of pasture development and afforestation. Yet this policy implementation has a downside to it due to the ineffective uptake by the people. In addition to these implementations, traditional methods of farming will prove effective along with use of sprinkler systems. Efficient farming may ensure improved water use and surplus for households.

Drought is always an issue that relates to climatological patterns. The problem is interconnected to water availability to maintain food security. Dry lands can be converted into farmlands on a large scale; this is true for the Chennai outskirts and on the coast, as there are large areas of dry and barren land where construction is not possible or profitable. A sprinkler system in these places used with crops that require considerably less water compared to rice will allow some use of barren land. The texture of soil on this land can be improved with fertilizer and compost. These methods can reduce waste or improve the efficiency with which waste is disposed.

Furthermore, the government wants to reduce activity involving high technology and instead depend on simple processes to increase water levels and conservation. In addition, the locals have lot of skills that have been acquired from farming and irrigation techniques, hence it would be better if they were able to understand and devise new methods to conserve soil moisture. There are many well fields within Chennai as well as outside of the district.

The Dryness Index indicates that Chennai has over 2.7 % dryness, and the Exposure Dryness Index indicates that the region is between 2.5 and 14 % dry (TWAD 2011). This indicates that the soil moisture and the level of dryness are toward the lower to medium level of dryness. Future changes in temperature can have a bigger impact on the soil and surface moisture, which in turn can cause increased ground water exploitation. However, this has not been stressed in policies, which have been implemented to improve local participation of the public.

Policies to control misuse and overuse of water are implemented by the national Drought Prone Area Program, applicable to all states. A good example is to reduce use of swimming pools. The efficiency, with which this has been accomplished, though, is yet to be established. There is a tough layer of resistance to this program due to lack of knowledge among the people and the increasing tendency to overuse water resources (ground water), and there is a general reduction in conservation of water. Increased need to overuse / exploit stems from the lack of availability of the resource and, affordability also plays a significant role in allowing metered or unmetered use of water. This policy adaptation has been unsuccessful in Ambattur, Valasaravakkam, Porur, T Nagar and Anna Nagar.

Suitable construction and installation of water harvesting methods to help households adapt water supply that is naturally found is required to successfully implement this policy. The optimum of supply and demand is wrought through conservation methods that allow efficient use and recharge of aquifers in the process. The RWH policy that harvests water for conservation needs to be expanded to local households and to the agrarian and industrial level. This will bring out the best results within Chennai city and semi-rural regions of the district due to its varied water consumption interests just like it did for other countries like China and Spain.

Policies and Programs: Chennai's drought cycle occurs once with an interval of 4 to 6 years. This affects the supply, demand and distribution management. All policies in supply management are part of drought proofing plans for Chennai.

Major policies for drought response include:

1. Conversion of dry lands into farmlands on a large scale. As there are large areas of dry and barren land where construction is not possible or profitable.

2. Water use for industries and farming can be reduced with planning and efficient use. Farming along with sprinkler systems is beneficial for controlling water use, and eventually benefits households by providing them with more water for domestic use.

3. Preventing further development of well fields. Furthermore, the government wants to reduce engineering activities while increasing simple activities to increase HH water conservation.

4. Policies to control misuse and overuse of water are in place: a) reduced use of swimming pools, b) fining overuse and c) fine wells without permit

5. RWH installation throughout the city to improve water harvest. RWH can trap close 50 percent of the available rainwater that otherwise runs off into the sea.

6. Implementation of desalting technology called desalination. Chennai now has two 100 MLD plants installed in the far North close to Minjur, although only one plant is operating.

7. Improving transparency through communication, awareness and feedback mechanisms.

8. Improving fund management of projects and bringing in public private partnerships (PPP).

The efficiency with which the policy implementations have been accomplished is yet to be established. There is a tough layer of resistance to these programs due to lack of knowledge among the people and the increasing tendency to overuse water resources (ground water), and there is a general reduction in conservation of water. Increased need to overuse / exploit stems from the lack of availability of the resource and, affordability also plays a significant role in allowing metered or unmetered use of water. A stagnation of this policy adaptation has been seen in Ambattur, Valasaravakkam, Porur, T Nagar and Anna Nagar. Suitable construction and installation of water harvesting methods to help households adapt water supply that is naturally found is required to successfully implement this policy. The optimum of supply and demand is wrought through conservation methods that allow efficient use and recharge of aquifers in the process. The RWH conservation needs to be expanded to local HH and to agricultural and industrial sectors.

6.5.3. Restorations of Water Conservation Structures

Ooranis are examples of successful water storage mediums. [21] TWAD and Chennai Metro Water have both implemented a policy for improving structure and increasing capacity of storage mediums for supply. The rural areas and outskirts benefit from the implementation of this program. Executing the program is easy as there are large tanks, ponds and other large-scale storage facilities in the villages that are not maintained properly. Chennai can implement *Ooranis* across the rural regions with less material and low cost. If the area of Chennai is carefully examined, it can be seen that there are small temples that have dry ponds that can serve as closed storage mediums with artificial recharge mechanisms installed, from the surface of the pond, to increase

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[21] *Ooranis* are age-old water recharge and storage systems that allow storage and management of water, while allowing recharge through small insertions.

the water table of the locality. If ten temple water ponds were converted into proper storage mediums with recharge of aquifers, this would benefit ten different regions with extra water.

6.5.4. Flood Management Measures

The flood control policies implemented for both the local government and the central government of Tamil Nadu oversee the disaster management unit in Chennai. The main implementations based on several national policies are as shown in Table 39.

Table 39 National Flood Control Policies

Structural Implementations	**Non-Structural Implementations**
Reservoir construction	Food plain zoning
Channel improvement	Flood forecasting
Marginal embankment construction	Warning
Construction of raised platforms	
Raising of villages	
Mitigation	
Nationwide flood forecasting	Warning system
Structural Measures	
Central Water Commission – Flood Control Stations (175)	
Other Stations	3
River Stations	145
Inflow Stations	27

Source: Compiled from data collected, secondary source CMWSSB, (2012)

The flood control policies implemented for disaster management unit in Chennai are by the State Government of Tamil Nadu and the Central Government (Table 39).

1. A number of reservoirs constructed that have the capacity to store water directed from the flood plains. This will improve supply as the government has made plans to improve channeling of floodwaters from the flood plains to the reservoirs or tanks.

2. Warning systems for these floods are also in place where the dam is being constructed across the flood plains.

3. There are 27 different stations newly implemented and are useful in giving information on climate change.

4. The forecast of floods is through 173 stations and the majority is for the river stage. Government is also exploring the options of construction of raised platforms in semi urban and rural regions where floods are uncontrolled.

The improvements to the flood management system include both structural and non-structural policies that allow efficient water drainage and channeling water into collection tanks. Nationwide forecasting of floods has been implemented. The 27 newly implemented stations are useful in giving information on floods and droughts for Chennai and adjacent districts such as Vellore, etc., allowing local management bodies to understand interventions required.

The National Water Mission submitted a report that includes information on the structural management, the new stations in and around rivers, and the inflow stations designed to manage floods. To manage droughts and floods the government launched new technological installations ordained by the Central Water Commission. The 175 stations and new observatories are for forecast and management of floods and droughts, and the majority is for the river stage. The National Action Plan on Climate Change (NAPCC) report in 2008 identifies the approaches and adoption techniques to manage the climate change crisis on water supply and other resources. This encompasses the National Missions such as the National Solar Mission, the National Water Mission, the National Mission on Sustainable Habitat, the National Mission for Sustaining the Himalayan Ecosystem, and the National Mission for Green India. The NAPCC report also indicates ways to achieve goals such as to prepare a detailed water database, to spread knowledge and to establish a detailed research unit on assessment of impacts of climatic variations on water resources and to improve efficient public and household use.

6.5.5. Measures to Refocus Goals and Strategies

The TWAD board indicates that the situation of water crisis, whether it is caused by climate or exploitation, needs a solution. In addition, the interviewed households consider the water resource as a public good that is now becoming scarce. Hence, it is imperative that the boards taken an active role in refocusing goals and strategies.

Information spread, improve access to information, educating public and staff, effective communication, research focus, policy focus for climate change and future research goals.

To protect water from being exploited TWAD and CMWSSB have taken measures to publish information and provide data through the institute of water studies (IWS) for research and education of the local population. Effective communication according to the boards is to hear what people have to say regarding water use, conservation, conservation and administration. Hence, a complaint box is the initial step that CMWSSB adapted to improve feedback mechanisms. The other initiatives suggested by several researches are periodic local surveying and public participation through information sessions before a program is implemented within the region.

A major initiative in the past decade to improve the access to information was the ‘Right to Information Act 2003’ as part of knowledge spread. As part of the initiative data is made available for research online. Some goals set out by the TWAD board for water management, consistent with the Tamil Nadu government, are to create a complete and understandable water database that will include the assessment of impacts of climate on the water table.

To improve focus on goals for climate change the boards indicated the need (1) to provide easy access to information; (2) to improve water conservation, amplification and increasing continuance of the resources; (3) to improve stock take of resources, ground water availability, identification and focus on over-exploited regions; (4) to improve education by holding workshops, and lastly (5) to stimulate a basin level integrated water resources management (Government of India Ministry of Water Resources 2009). By doing all this, the TWAD and CMWSSB boards aim to improve water use efficiency by 20%. These goals are consistent with the state and national goals for water resource management.

Spread of information is as important for water resources as treating or protecting water supply or adapting to climate change. Spread of information is vital for Chennai, as much of the literature (see the section Climate and Water: In Literature) states that most policy changes are in response to crisis situations. Moreover, the situational changes and the level of adoption within the society need to be fully understood before the plan and projects are implemented. The projects in Chennai take into account the needs of local residents, but it is also clear that the decisions being made are not seen through to completion (desalination projects exemplifying the project failures). This could be due to changes in political parties that bring in changes in management focus or the priority of actions and resource management approaches.

The policy changes to accommodate climate change and its extremes are beginning to improve the water status of Chennai. Despite the deficit in water supply demand, it is understood that changes in policy will happen slowly. Policy failures in Chennai are generally related to a lack of people's willingness to participate and appreciate the consequences of the policy implemented.

6.5.6. Combining Resource Projects

Combining water projects such as construction, energy production and distribution, RWH constructed within premises, etc., and reducing ground water resource use or increasing ground water recharge is an important part of the national water policies to handle droughts and floods. This policy needs to be properly enforced, as the current situation is not being efficiently managed. The policy section in TWAD 2011 indicates that all projects related to soil, farming or construction should support conservation and harvest options, to reduce water use for agriculture. Construction should include rainwater harvesting (RWH) and water conservation techniques, and projects should abide by policies such as limited irrigation and reducing overuse of ground water.

6.6. Chapter Summary

The TWAD teams (such as Supply and RWH) feel that despite the worsening climate the district will survive as it is prepared to tackle issues that may rise. Although shortage of water in Chennai is mostly source supply and demand related, at present, rather than purely climate related, it is not possible to ignore the drought-like symptoms. The evidence for this is the fact that Chennai has requested more supply water from the Krishna Project, and that the current reservoir storage levels are low due to drying, monsoon failure and increased availability. Added to this is the stagnant precipitation level with a noted decrease every few years, and a continuous increase in temperatures, denoting potential climatic drought. An efficient harvest system set up in regions with more rain is required to uphold the current lifestyle in Chennai.

Furthermore, recent temperature records suggest a future increase in the maximum temperatures to about 42 degrees centigrade, a possible warning bell for

Chennai to take steps to prevent severe droughts. In addition, the temperature increase can pose quality problems due to spread of health issues. Several types of infections, bacterial, etc., make water unsafe, creating more wastewater in addition to drastically reducing water health due to pollution. This directly impacts households and animals consuming this water on a daily basis. The city has seen some stomach ailments as well as typhoid cases that have been caused by reduction in water quality. High temperatures make it optimal for diseases to breed and contaminate water resources.

The policies do deal with drought proofing and flood proofing, yet the management does not consider raising low lying areas or coastal regions or deepening the Coovum region as a solution. Deepening the Coovum River would decrease flooding and create a way to purify the river by constant of water and run off or overflow of water into the sea. However, this could mean coastal pollution.

7. Conclusions and Recommendations

7.1. Conclusions

This study aimed to answer this question: Is Chennai climate ready? i.e., Are water policy, programs and projects able to promote water security in the face of climate change in Chennai? The 2011 and 2012 water policies, programs and projects point towards poor water security in the face of climate change. The field study revealed that the supply demand gap is large within the domestic sector of Chennai. The supply-demand deficit adds up to 250 MLD within the city and surrounding regions (Chennai city and greater Chennai) making it about 15 percent in total. Overall water deficit is about 300 TMC, which is close to a 20 percent shortfall. Furthermore, even with spurts of sporadic good rains, Chennai has experienced steadily reducing rain frequency and number of wet days (over the last decade), the actual reduction is very gradual and seen via the total rainwater harvest in the reservoirs. Rainfall frequency is not at a stable level. This is indicated by the total rain concentrations in certain periods of the monsoon season. Four out of ten monsoons have failed to produce the average amount of water for Chennai, in the last decade.

The available resources are fast depleting in Chennai, reservoirs are drying, and water is now being safeguarded in closed storage in response to excessive evaporation due to increase in temperatures. Failed monsoons indicate drought like symptoms that are becoming common in Chennai. It is clear that a drought cycle is expected every three to four years. The water shortage is inevitable and a conclusion for Chennai.

The modes of transport covered are tankers, lorry, and direct-in- house, bore well and dug wells. All regions of urban Chennai are provided with water through these means. The conveyance of water is not 24 hours 7 days a week, normal in- house –direct supplies water for three to four hours in a day. The Lorries are in convenient modes of water conveyance as they supply to households.

The overall result indicates that, although, officials at the water boards disclosed that Chennai is prepared for a potential water crisis. But the fact remains that in terms of supply management Chennai requires several policy changes and the drought measures.

7.1.1. Scope and Limitations of the Study

Water security issues can occur at different spatial levels, ranging from the local community and workplace to the global scale. This research dealt with those issues that are of relevance to and are concerned with city community water supplies. It deals with urban water policies within water systems of Chennai. This includes technical and non-technical policies, plans and project implementation, variations in climate (average temperatures and rainfall) in relation to water security, and policies for adaptation and effective management.

Surveys occasionally tend to have minor errors such as translational errors, when conducted in regional language rather than English, or human errors while transcribing it into the sheet, for people who could not read or write. The human errors were found to be slightly high, 40 surveys had errors in the number recording. The qualitative feedback was detailed and accurate, as the surveys were entrusted to certain other individuals in order to get responses from respondents faster and more efficiently. Recording, taping or capturing the interviews was not permitted. All information was provided only on documents and through interview notes (upon validation of student credentials).

Furthermore, multiple ambiguities affect the precision of information gathered on water supply – demand, water table, cost figures, temperature and precipitation levels between 2002 and 2010 and the adaptation levels within society. While the figures may not be exact, the fact remains that there is demand supply gap and it is assumed to be substantial enough to cause future impact.

In addition, this study relied on the accuracy of the responses received from water resource professionals and water users. The responses were required to be a fair representation of how the water management system in Chennai is structured and performs. One hopes that, for the benefit of research, the respondents to this study felt the need to portray accurate and unbiased accounts of their views on water supply management

7.2. Climate Change Variations

Climatic variations are measured by the temperature, rainfall, drying of land and concerns for reservoir levels. The spatial variation in rains and temperatures as recorded by the India Water Portal indicates low rains and high temperatures and relatively higher drying of land and water (Ref. Climatic Trends, Practices and Policy Responses). The droughts in 2003 and 2004 created heavy deficits in supply as the supply levels reduced by more than 300 MLD. Generally, within the domestic sector, the level of deficit is about 200 to 250 MLD. The total deficit is due to less rain when compared to 1900's and poor quality. 1100 mm is considered a good amount for most urban cities in India, while not being extreme. However, rainfall recorded by the CMWSSB in the final months of 2004 indicated that Chennai had 2400mm of rains. This number verified by sources, was found to be inaccurate. The actual rainfall level in 2004 is still unknown; the India water portal indicates rainfall levels only up until 2003.

The fluctuation in precipitation occurs every 5 to 7 years in Chennai. Droughts, such as the one in 2004, hit Chennai every decade (once or twice). Data collected from the India water portal indicated that precipitation more or less averaged to 1000 mm in the years between 1990 and 2000. The temperatures are steadily increasing causing much concern to the local authorities. Temperatures have increased from 34 to 42 in the last two decades. Hence, drying of land is more intense and evaporation of sources is also high. Recently, Cholavaram Lake water shifted was to Redhills in closed conduits in fear of further evaporation. Evaporation had caused the total water reserve to go down to 35 percent of capacity.

Out of the total rains only 20 percent is tapped into reservoirs and lakes, the rest flows into the sea. About half of the 80 percent of water that drains into the sea can be intercepted to create more water for supply. The issues found when there were floods are: damage to pipelines that are exposed, mixing of good water with sewerage and most important of all saline water intrusion into freshwater sources. The floods run-off into the sea taking with them silt and debris/ garbage. Chennai has high amount of saline intrusion that is reflected in many of the studies conducted by the board. TWAD and CMWSSB have indicated that the Adayar and Coovum Rivers have saline water intrusions to the point where now they have become sea inlets. This impacts the quality and accessibility of water resources there by affecting water security.

TWAD indicated that the climatic variations will intensify and will become harder to conserve water resources in future. Hence, the board has drawn up plans and schemes to allow smoother adaptation to climate change.

7.3. Policy Interventions and Regulation within a Supply-Demand Continuum

Rainwater Harvesting

RWH is the process through which rain is harvested and used as supplementary source for HH and community. This implementation improves the overall supply. As rainwater is easy to procure if there is good amount of rain, the accessibility of rainwater during monsoons is very good. Rainfall for Chennai is uniform as there is no spatial geographic distance or difference. This means that allocation of rainfall is even, and everyone has equal opportunity to harvest rains.

Artificial Recharge

This research identified that RWH and Artificial recharge and rainwater structures are successful implementations and are the key to successful adaptation, in so far as to provide extra water and recharge the underground aquifers. Besides this are the training, customer advisory, education and communication to improve awareness. Desalination and Interstate treaties are part of the technological implementations that help adapt to climate change.

Awareness, Training and Workshops

The training and workshops are implemented by the TWAD, as they are vital for conservation, use efficiency and rainwater harvesting within Chennai. Results indicated that about 30 % of the respondents had just completed middle school to high school level and required detailed information to comprehend the situation to answer the survey sheet properly. This indicated that the people do require workshops and training for water system, uses, conservation techniques and also quality to make an informed decision and useful feedback. Awareness within the surveyed group is very low; one in two people are not aware of some aspect of water management according to the surveys. Over all the training, workshops, communication of material and customer advisory on various water service and supply related aspects improved security. Ever three months there are workshops for locals, farmers and investors to inform them about the status of supply, the sources and the policy decisions to enhance supply and manage demand.

Desalination

Desalination policy was implemented in order to allow smooth adaptation because it does not strain the environmental resources, neither does it draw on the ground water resources. This technology uses seawater to create fresh water. Albeit, it is not the most economical of the policies, but has meant the water supply capacity increased by 100 MLD and this improved the lives of 2 million people. Water availability increases, accessibility is still under question but it is allocated equally and is very safe to directly drink from the tap. The quality and quantity of supply greatly improve with desalination.

Restoration Works

Dams and tank restorations allow for an increase in availability as, the dams trap more of the rainwater. The dams intercept at least 40 to 50 percent of the water, which could easily create supply for over a million people in Chennai. Dam structures also to a certain extent prevent saltwater intrusion into the freshwaters. Thus, the dam construction improves security by creating more water, making is safe and securing it from salt contamination and making it easily available to people for use.

The tank reconstruction acts as a water harvest tank for use at home. This improves storage, artificial recharge and improves quality due to filtration through the ground. In some ways the tanks and dams allows for equitable supply within a community and the city. Community tanks allow equal access to people and it also enables more and more water harvesting so as to improve future availability.

Supply and Demand Policies

Some of the supply demand related policies include:

TWAD will in effect promote reduction of dependence on external sources and to allow environmentally safe installations to be adapted. To improve self-sufficiency, TWAD has implemented restoration of old tanks, desalination, the RWH, the AR, new ground water use and extraction rules and quality control.

1. Ground water extraction rules are such that HH are unable to withdraw water from a well unless it is registered. If they do withdraw without permission, it is

found out during ground water inspection and they are either heavily fined and the well is closed. The well water is easy to access and HH and rainwater can be easily harvested through wells. Thus, it improves security and the groundwater health within Chennai.

2. TWAD has implemented workshops and testing centers to improve upon the current low quality of source by testing and monitoring each area. This improves quality and also the general well-being of the population of Chennai. To a certain extent it has helped Chennai initiate the process of participatory approach. Evidence indicates that
there are at least 600 HH's that request testing of their resources once every six months.

3. The officials need to seek approvals and plans six months in advance in Chennai. This denotes that if there were a delay in project it will not be due to planning or management, it would be external pressures or political roadblocks. Gaining approvals and doing things properly helps promote sustainability and security of water facility implementations for Chennai's water supply. The more efficiently it is done the more benefits the people of Chennai can reap. In the present times, this policy is not enforced properly and this is evidenced by the series of project failures. Krishna, Veeranam, Minjur Desalination and tank reconstructions.

4. The water boards are required to efficiently repair leaks and damaged pipelines. They also should replace old pipelines if they are very old and rusted. This will help water circulate better within the distribution system. The quality of water will be greatly improved due to the healthy conditions of the pipelines. At the moment policies to replace old and faulty pipes have been initiated. This induced identification of hundreds of old pipelines that needs replacement. Thus, improving the overall water security within the distribution network.

5. TWAD is contemplating implementing a new policy to improve upon the poor service, efficiency and timely response. Evidence indicates that the services are fairly poor in Chennai, most residents relay on the private services to fix their pipes, meter and RWH installations. The policy to provide instant and timely services. The staffs are supposed to improve the speed with which they respond to issues and also finish the job so that it does not give trouble.

6. TWAD has set out to examine all sewers and isolate them from water supply mains to prevent mixing of sewer water. This policy will improve the general quality of water, lifestyle and prevent diseases.

7. The distribution management team has started to isolate the distribution branch. The isolation will allow control of water allocation, prevent complete contamination (if at all) and also improve accessibility to each region. The total water allocated will be micro managed in each unit so that the work is more concentrated. The faulty lines and issues will be managed efficiently and service will be timely and efficient.

8. TWAD is currently introducing a 24- hour supply scheme (pipes), this will allow supply all time and also improve the accessibility. The overall water security in Chennai will drastically improve.

9. TWAD by increasing RWH and AR facilities ensures an increase in supply. Rainwater is intercepted and harvested with residential and commercial equipment's. While dams and drains intercept water resources and prevent saline intrusion they also stop floods and conserve water resources. This policy will help control at least 40 of the 80 percent runoff to supplement existing supply,

10. Pricing of water is incremental, where after 10KL use the water is priced higher. Most households with four (4) members consume about 12 to 14 KL every month. With a per capita use of approximately 82 (as per surveys) or 90 (as per the information provided by the boards). Low pricing implies high affordability and thereby, improving security of the existing water resources.

11. Educate public and private stakeholders on policies to improve awareness through training, workshops and information sessions. Once every two months the board organizes a workshop/ training in order to improve HH, farming and industrial use of water resources. This training will allow communication of important information, promote awareness and to educate and inform public and private stakeholders. This will improve use efficiency, thereby promoting water conservation and security. HH will realize the importance of drinking good quality water or boil water before drinking or the importance of RWH.

The current status of supply indicates that changes are required within supply systems to manage and adapt to natural circumstances. Chennai's water system is insecure the supply, demand and distribution management is unreliable, in efficient and unaccountable. Hence Chennai is not fully prepared in terms of managing crisis and successfully adapting to climate change smoothly.

Future survival of water system in Chennai many depends on stronger policy enforcement, smart implementation of technological infrastructures, adaptation and climate change action for public and HH in order to conserve and harvest water.

7.4. Specific Adaptation Policies and Practices to Promote Water Security

Improve coastline management for saline intrusions by blocking off the seawater from entering ground sources or rivers through dam constructions and concrete separators.

Sea level rise is managed by emergency land raising policy where sand bags, soil and stones are used to increase the land so that seawater does not threaten the population.

Flood control policies and drought measures include monitoring stations, drought and flood analysis team, disaster management ideals and the general policies to move in case of crisis, are all in place for Chennai. Monitoring stations and climate analysis centres to improve the overall security and adaptability to climate change.

RWH and AR are adaptation mechanisms to improve on supply and tap water when rainfall is high. AR is a tool to improve the groundwater reserves, by increasing the aquifer capacity. RWH improves social water stress and also improves availability and accessibility of water resources.

The HH in Chennai are implementing the HH RO plant to filter water. Many experts in Chennai, with all the rivers polluted, saline intrusion and metal contamination, have debated the quality of water. Chennai water quality is low and hence, the TWAD and CMWSSB have introduced options for HH such as boiling water resources, the RO filters and also testing their supply every once in a while.

Some HH are taking heed and initiating activities to conserve and use water more efficiently. Residents are paying attention and following the policy changes and the government's initiatives to improve water security. The current HH practices that help water security include:

1. More and more HH are paying bills on time. Many customers have a lot of outstanding bills and some have illegal connection from the distribution unit directly. The boards are considering policy solutions to this issue;

2. HH are implementing RWH connections without fail. There is a fine levied on them if they don't have RWH equipment installed. But this fine is not enforced properly as there are many survey taker who do not have RWH installed in their residences;

3. HH bring out large vessels and store water to use for washing and cleaning. Policy suggestion for HH indicates that HH should make efforts to store water and use it more efficiently without causing quality concerns. They boil water and use it as per the instruction manual from the TWAD. This will help improve water security of the region by improving quality within HH, which will spread community wide and then state wide; and

4. Many HH are minimizing baths, shower and car cleaning times so as to conserve further. This in itself will improve the amount of water used and use efficiency thereby, improving security.

7.5. Level of Water Security and Overall Readiness

Chennai's supply sources are mainly ground water or well fields, the Krishna, local rivers, Veeranam, rains and distance sources. The status of supply security is measures by its availability, accessibility, affordability, quality and allocation. The supply and RWH team feel that there is an increasing possibility that the climate will worsen and Chennai district will survive. Based on surveys, TWAD interviews, CMWSSB documents, and literature, the major national drought policy deals with dry land farming, RWH, AR and transparency. Since, dry land is increasing and there are options for sprinkler systems. The sprinkler system that the government is proposing is small and consumes half the amount of water poured by other mechanisms. But it needs to deal with insecurity issues discussed within the supply demand management such as poor quality, meagre quantity and poor allocation.

Although drought in Chennai is mostly source supply and demand related, at present, rather than purely climate related it is not possible to ignore the signs of water scarcity. The fact remains that water supply is insufficient, the interviews clearly state that the supply is not enough (within different regions North to South). All the rainfall is approximately enough to provide for close to one million people who do not receive even a minimum of 20 litres of water per day. As of now the climate related water shortage is relatively low, varying every 4 years due to lapses in monsoons, this is strengthening by the year due to increased frequency of sudden extremes climate change. The TWAD information through the interview, documents indicate that Chennai is prepared to tackle the upcoming water scarcity issues that may rise.

Major concerns that contradict the water administrator's views are:

The accessibility of the supply is very low as the piping is not 100 percent as the TWAD and CMWSSB claims. There are regions in the surveyed expanse, where piping is not present, not connected or connected but does not provide water. Instead, cumbersome methods of supply are adopted to supply water to Chennai. The current situation indicates that the water sources supplied are low but due to increase in demand cannot be supplied to certain regions. Hence, there is a deficit of about 200 to 250 MLD. Chennai Domestic sector alone requires 200 MLD more, while other sectors require much more. Transport of water from one region to another via tankers indicates that the supply status is very bad. Chennai engages about 9000 Lorries but only 300 of them make 13000 trips.

Recently, Chennai temperatures indicate an increase in the maximum temperatures to about 42 degrees centigrade and this is one sign that should be enough for Chennai to take steps to prevent severe droughts, going to the extent of transporting existing and available sources in closed conduits to distribution units or for storage in Redhills. This increase poses quality problems as well as extreme climatic conditions. There are several bacterial infections that make water un-usable and this creates more water waste and reduces water security for households (see section on water security). The increase in floods creates penetration of saline water into the fresh sources and ground water sources. This creates issues for people due to the zero utility value within households. The salinity can be managed if the floods are channeled in a proper fashion. Road water reuse after treatment is also an option for policy makers to consider.

A number of HH have issues with quality of water and 87 percent of the respondents indicated that they have quality issues while 90 percent of the HH indicated that changes to the water quality in Chennai are necessary. There are many HH that buy mineral water and this indicates the low quality of the direct tap water supply. Policy responses to this issue was in the form of The quality control department in response has undertaken monitoring works at all lakes and tests both for lake level and HH level samples. The tests include physical, chemical and bacteriological standards. Among all the wards, TWAD feels that there are 3 to 4 problematic ones, where water has fluoride or iron content. The issue is not reported to the public and the general concern is that people are unaware of the issues caused by fluorosis or by iron in the water that they shower, drink or cook with. The current condition and policy responses indicate that the water treatment in Chennai and the quality control measures are in adequate.

The current situation indicates that the organization of supply sources is however generally considered satisfactory, while the institutional and project management are a little imbalanced. The policy and reform reinstatement is very weak. Policies are not enforced in a timely and proper manner in Chennai. Survey suggested that people of Chennai want lawmakers to strengthen their policies, programs and regulations. In addition the project costs are unclear and the partnerships that exist are very good but do not help Chennai achieve the distribution target. The distribution target for Chennai is to supply clean and good quantity supply that will lead to a healthy lifestyle and equitable supply. Operation and maintenance of the distribution pipes, valves and pumps is a major issue as the TWAD and CMWSSB team found year old pipes that were corroded and leaking.

The management of equipment in terms of safety hazards needs to be addressed in-depth as the board staff do not have complete knowledge on operation and management as yet. The TWAD has initiated training and workshops to enhance the knowledge level. The staff training for service and operation management is a little weak, as the HH surveyed indicated that the service is poor (200 out of 500 had similar opinions),

Pipelines are old and also have leaks, the major connections are found to have leaks. TWAD and CMWSSB have initiated a program in response to detect and replace pipelines within Chennai. In one such sites, the pipes were found incrusted and had leaks. This was due to the fact that they were 50 years old.

The meters in Chennai are unreliable as they have faulty meters and either the staff or a member of the HH does the meter reading manually and, the reading is not always accurate, proper or honest. Chennai TWAD and CMWSSB have initiated a program to identify and repair meters so at to function well. Hence forth, the meter reading will be through a staff member to make is more accurate.

The demand management also included the conservation and consumption pattern/ use. Chennai people consume about 82 lpcd per capita, and this is within a survey of 500. The major issue is that the per capita consumption that was close 85 lpcd, it is now recorded at 105 to 110 lpcd.

The stock-take of water resources and regional supply level is low due to the prevailing water shortage conditions in regions like Purushavalkam, T. Nagar, Anna Nagar, Ennore, Tambaram and Ambattur. Supply modes and policy enforcement is low as there are illegal connections as there were days when water was unavailable, repairs are untimely, households getaway without being fined for lack of RWH structures. In addition most HH relay on the arrival of tanks very early in the morning. Since, water lorry only comes once a day, it causes conflicts among residents while collecting. Policies indicate that pipe supply simply cannot be improved as they have been laid.

Policy structures are fragmented and they do not unify all components of the water system. For example, findings indicated that the supply demand policies are clearly defined while the distribution aspects are not clear. The distribution management needs to be considered as an integral part of the supply system, it is rather isolated and the projects are very unclear.

Documents and policy notes do not identify projects and describe details of each project in depth. While the policy change adoption in Chennai happens in an efficient pattern, it dies down soon due to inefficiency, unreliability, inaccurate, lack of transparency and participation and untimely services. There are still aberrations in the policy model that falter the smooth management.

7.6. Recommendations

7.6.1. Policy Recommendations

Problems in Chennai can be managed with efficient water harvest systems set up in regions where there is more rain. The results indicated that water supply availability is low; with more and more people migrating to Chennai, more and more water is consumed. The availability is low because of rains and monsoon failures and low reservoir levels.

Recommendations for Management, the following are brought to the attention of the authorities to consider practical and potential actions for government and HH to act upon in a fit manner:

1. Regularizing supply schedule and the mode of supply to fit for every region zone wise;
2. Improve awareness through programs right from junior high school;
3. Take steps to follow the national drought and flood policies in a more serious and efficient manner;
4. Install more climate change stations to receive information for water and climate change and then plan projects;
5. Complete and launch a participatory research for every project;
6. Conduct satisfaction surveys across Chennai to understand issues and the level of satisfaction of water supply and services;
7. Consider every point published by the environmental assessments for projects by experts before input of funds to start up a project;
8. Sell the failed projects or repair the failed projects so as to put it to use;
9. The Minjur desalination plant is shut down but could be used as an education facility to inform kids and adults about the process, the hazards and the issues relating to this;
10. Improved quality methods like three- day treatment can be implemented as a project or HH level quality control can be communicated to people;
11. Funding newer pipes or utilizing old pipes that are unused from another project can enhance the pipeline project;
12. Pipes need to be 1 meter away from the sewers so as to control sewer mixing; and

All these practices will eventually reduce dependence on inter or intra state supply.

The reuse suggests use of water for multiple purposes, usually recreational such as pools or fountains etc. While the recycling water may have social stigma attached, it still does not imply use of dirty water, it is fully treated and clean water that can be used for domestic purposes.

Floods in Chennai can be intercepted efficiently to provide supplementary sources for the city. With 80 percent run off, harvesting water should provide a good amount for the public use. Public structures can be made into AR system where funnel shaped structures used as sunshades or tents can have chutes that allow recharge in the event of rainfall.

Several public and HH methods can make water consumption more efficient:

- Reduce, reuse and recycle water at a HH level when possible;
- Promote the participatory approach;
- Improve training and workshops;
- Enhance the stock-take of resources;
- Chennai requires major rework and renovation of water tanks, ponds and *Kolams;*
- Reuse wastewater for cleaning or recharge ground water by letting it permeate in to the ground.

While Chennai has an annual rainfall of over 1000mm, the fact remains that water supply is insufficient, and the interviews clearly state that the supply is not enough (within different regions North to South). All the rainfall is approximately enough to provide for close to one million people who do not receive even a minimum of 20 litres of water per day. The mismanagement of the water resource is indicated in the method of policy implementation in Chennai. It is second nature to ignore or push aside policies to reach goals E.g. builders or local individuals. A good example would be the water use act relating to swimming pools, ground water or other sources, stipulating permission restrictions.

7.6.2. Practical Approach

The only way to improve water saving and conservation is through rainwater harvesting, but this needs uniform implementations everywhere and further education is required to be successful in making people install RWH systems. Furthermore, the current level of rain could continue to decrease. The 2004 rains were erratic in nature and stabilized after a period of four-year floods and a tsunami occurrence in Chennai. The year 2010/ 2011 also had a mild drought in the adjacent areas and some central regions of Chennai due to monsoons. Thus, harvesting water will save Chennai a lot of trouble in the future management. Chennai faced a four-year period of frequent floods along the coasts, due to extreme climates. Managing floods requires some amount of quality control, which is not looked at in detail in this paper due to the vastness of the topic. Issues such as penetration of saline water into fresh water and ground water sources are becoming frequently common in Chennai. When that occurs, the water becomes of zero utility value within households. The salinity can be managed if the floods are channeled properly into drains that lead to central purification facilities. The local drains are uncovered and many potholes can be seen along the roadsides.

7.6.2.1. Demand Management

Chennai does not have proper metering and, hence inventory of water use is incomplete. Unmetered use is rising. Since zone management is effective, managing demand becomes easy.

Long distance transport of water has leaks, which can be handled with care if the transportation vehicles are inspected and monitored for leaks. Structures and washers to enclose the containers are important.

Water pressure can be managed if instead of direct pipe supply HH receive overhead tank supply so as to improve pressure of supply. Chennai manages water pressure, repairs and maintenance in a mediocre manner and many households complain on a daily basis. Chennai requires introduction of staff training and service response protocols that can take effect in Chennai so as to improve the quality of service can avoid this.

The pipelines are laid closer to the sewer pipelines and the sewerage mixes with fresh water resources and overflows, creating health issues for residents. Pipelines need to be checked and replaced if there are incrustations or corrosions.

The water management for Chennai found solutions through conservation techniques, price management, managing consumption and use-efficiency. So far the issues have not been amplified but existent, nonetheless. Hence, the demand management is mediocre and Chennai's ability to adapt to climate change is not a 100 percent.

7.6.3. Other Recommendations for the Future

Future recommendations include making small adjustments within households, improving Rainwater Harvesting (RWH) by mesh nets so as to enable direct use of rainwater for household activities during times of drought, improving the hours of water supply by reducing supply during nights or during non-peak hours in the day time. Japanese buildings style such as shared water tanks between adjacent buildings will allow constant collection and supply to HH directly.

The problems faced and solutions sought for Chennai's zones are different and need to be customized.

The recommendations for managing demand and distribution are:

1. Increase monitoring of pipes, meters etc.;
2. Increase the number of streets with piped water supply;
3. Metering and meter reading by staff should be made mandatory with penalties;
4. All new and existing connections require metering;
5. Improve participator approach by promoting it competently;
6. Improve competency and skills of maintenance staff;
7. Metering of RWH structures will allow water managers to better understand use of RWH within HHs;
8. Faulty pipelines and leaks need to be checked promptly within 24 hours.

9. A participatory approach is stressed upon; transparency of policy is also desired in Chennai.

10. A participatory approach is required to understand problems and HH in general do not tend to pay attention to issues unless it directly impacts them. It is also second nature to ignore or push aside policies to reach goals E.g. builders or local individuals.

11. The fact remains that policies are not enforced properly, like with random checks or inspections of premises. Improve information availability and communication to locals especially the local HH. For example meetings about water to their community or workshops related to safeguarding water resources are a must.

12. Simple structures can help enhance supply. Ponds and tanks at home or old wells can be used as a recharge or harvest mechanism. A swimming pool can easily provide more during times of drought or supply cuts etc. A good example would be the act that specifies that swimming pools should not use ground water or other sources of water unless permission is granted. This could mean that a lot of the misuse of water would be set right. This requires more planning, efficiency and a regular stock-take of available resources.

13. The adaptation strategies are lacking and recommended for Chennai's water balance. The main strategies recommended are the 3 R's, training and workshops, stock-take of resources, household surveying, reworking and renovating water tanks, ponds and *Kollam's*, and improving quality through simple measures. The 3 R's are reducing, reuse and recycle adapted from the waste management technique. The R's will ensure conservation and saving.

a. Reducing water use will increase efficiency of water saving as it allocates water for vital activities and shrinks wastage.

b. The reuse suggests use of water for multiple purposes, usually recreational such as pools or fountains etc., can be used in flushes.

c. While the recycling water may have social stigma attached, it still does not imply use of dirty water, it is fully treated and clean water that can be used for domestic purposes.

7. Chennai’s management is yet to increase quality of water that will allow users to drink water from the tap directly. A three-day treatment is required for this process. Research & development and extensive surveying will help enhance the process;

8. Water requirements are projected to be higher every year and increasing supply means to initiate political conflict as the Krishna water supply costs a lot to transport and maintain. Hence, if water becomes very expensive for Andhra Pradesh Government to supply there will be political repercussions. It is better to manage demand rather than increasing supply. The solution to avoid conflict is to reduce the Krishna requirement by generating means of excess water through artificial recharge and rainwater harvest. Thus, dependence on water resources from interstate needs to be reduced;

9. Low comprehension levels, overuse and unawareness of policies cause users to opt for household-level improvement and use based on the availability. The simple method would be to improve HH activities and water use efficiency;

10. Several households on the outskirts of Chennai have maintained wells but have ended up needing to close the wells due to lack of water;

11. Deepening the Coovum would decrease flooding and create a way to purify the river by constant dilatation of water and run off or overflow of water into the sea;

12. A column needs to be constructed to intercept rainwater and prevent it from draining out. Three major advantages to this would be less runoff, more water harvesting and prevention of saline intrusion. The three rivers need to be saline proofed, in order to make them independent, as they are considered as extended sea in lets. Another consideration that could be useful is desalination to remove impurities;

13. Groundwater use now is very high compared to the use in the last few decades. According to the Tamil Nadu Water Board policies are not completely transparent, and steps to undertake this is under discourse. All details of ground water resource use and adaptation needed to be presented and communicated between the people and the boards; and

14. The reports on quality of water need to be maintained and scientific evidence collected.

Discourse: The government, to protect the surface source and groundwater, wants to keep track of wells. The extracted water is accounted and categorized according to the purpose of use and the amount drawn out. This is done to measure available sources, understand issues and methods in order to extrapolate new methods of rainwater harvesting. The policies underline that detailed reports are to be submitted regarding quality of water, rainwater harvesting and other projects as required. Some other rules include water conservation through rainwater harvest, the necessity of rainwater to maintain population's domestic, agricultural, industrial requirements.

CMWSSB should consider charging water per peak and non-peak hours to improve water conservation through pricing.

Chennai, now, has incremental pricing where usage over 10 kl is charged higher. While in comparison the Oita, Japan water and energy conservation team has a system where prices and charges vary according to the peak and non-peak hours. Use pricing of water and electricity are twined. The non-peak hours after 11PM are charged lower compared to peak hours that are very high so people do not consume water for dishwashing or machine-washes as often. The HH plan for activities to save money. It is easier to get people to save money rather than save water or electricity.

Exceptional water saving initiatives include low flow toilets and low-pressure showerheads. Reduce toilet flush requirements by one seventh of the usual use. It could help water saving; yet, as the flow is restricted the number of minutes of shower may increase or the number of flushes may increase (depending on the use).

The government should improve capacities and take up responsibility in order to protect the surface and groundwater. Once extracted water is fast utilized and the wastewater flow is not properly managed in Chennai, hence, the extraction for various purposes and fines need to be clarified and posted in the public notice board. Monitoring wells will ensure accountability of extracted water. Furthermore will allow efficient categorization of extracted water based on purpose of use and amount withdrawn.

The TWAD teams (such as Supply and RWH) feel that there is an increasing possibility that the climate will worsen, and yet the district will survive as it is prepared to tackle issues that may rise. More than floods that are channeled towards the sea it is droughts that worry authorities in Chennai. Added to this, the precipitation levels with a noted decrease every few years, and a continuous increase in temperatures denotes potential climatic drought. An efficient water harvest system is required to uphold the current lifestyle in Chennai.

Contrary to the feeling that the district will survive the future crisis, it is clear that certain changes in policy are required to maintain a level of HH and public conservation via RWH or simple HH practices, response, service, approval system, and participatory approach is necessary. There may be initial setup costs for all recommended implementations but eventually, it will be easy to create surplus water for Tamil Nadu. Hence, the water scarcity in Chennai can be attributed to the lack of innovation, worsening monsoons, in equitability, supply cuts, RWH installation challenges, and lack of information sharing.

Climate change may not impact Chennai as much as mismanagement does; yet it is not possible to ignore the failed monsoons or frequent drought-like symptoms. The evidence for this is the fact that Chennai has requested more supply water from the Krishna Project, and that the current reservoir storage levels are low due to drying supplement the evidence that Chennai’s governance need to step up its approach and policies.

7.6.3.1. Future Studies

The focus for the future water management in Chennai would be climate change related. The climatic variation within Chennai may or may not become very extreme, but most experts believe it is better to have a plan in place and test it out for capacity to endure crisis. The future options for policy makers in Chennai would be to customize adaptation policies per area and micromanage it. This means each section of Chennai that have different policies, endure stress differently.

7.7. Final Comments

Overview of the research indicates that both droughts and floods plague Chennai in mild intensities. Given the mild intensities of floods and droughts, it is probable that the frequencies may increase, and the level of adaptation needs to be upgraded in order to manage water for the future.

Several strategies are in place but require more research in order to bring in an adaptation strategy for climate change related water management. The data collected for this region adds to the research completed in the past. Many studies in the past have focused on the development and economic stability of the region. Hence, the implementation of five test plants and the Minjur and Nemelli desalination plants.

Administrative bodies indicate that they are decentralized, they neither have cooperation among the existing department nor do the departments have any collaboration with the people during decision making.

The dams across the Krishna River were constructed to transport water to the reservoir and routed into the city and this causes water losses. When transporting water over 100 km, water loss is inevitable. Water loss can be monitored and maintained with proper planning.

Aid and funding for the region are plenty; this indicates that if there is proper adaptation planning along with local participation will improve the situation. The public private partnerships have not been successful, while projects with new focus have been initiated in Chennai this year (2013).

Assessing Climate Readiness: Overall Adaptability

Becoming climate ready is a recurring concept with specific objectives within framework components marking improvement to readiness. The major aspects looked at in this research are community awareness, adaptation, some mitigation, partnerships, policies and community. Chennai, in general, is not yet completely climate ready as there are some inefficiency in governance of resources, people, and policies.

Chennai’s problems in relation to climate readiness are information exchange, assessment of assets vulnerable to climate change, personnel and community training and workshops, integration of climate changes into utility and policy decisions and general awareness. Including documents can raise awareness and notices within the offices where people go in to enquire or give feedback. The major improvement areas in Chennai are the training sessions for personnel and the workshops that aim to improve knowledge among people about water quality, impacts on water resources, and installations such as

RWH. There are some documents shared on the Internet (research and board findings and policy options specific to climate change and water resources) but by and large Chennai's awareness of water and climate change needs improvement. There is evidence through this study that people are more than willing to learn new aspects of water and climate.

Conducting community workshops will improve local participation and stakeholder awareness. That in turn will improve the overall awareness and prepare people for future droughts and floods.

Adaptation is critical for long term planning and management of water resources. Utility planning needs to take into to account the ambiguity in the exact climatic projections. Hence, constantly evaluating and monitoring projections will allow for proper utility planning and incorporate climate change related aspects.

The major areas that need work are the current awareness to climate change and assessments of climate related risks for utility management, participation of stakeholders in decision-making and periodic monitoring of services.

There are adaptation strategies that are used for conservation, utility management and distribution management in Chennai. The major improvements that are initiated under the new political rule include periodic checks on all services and evaluation to reduce vulnerability of the system to climate change. This process is not successfully implemented, as there are political, practical and policy changes that are required.

Various policy changes include pricing, billing, feedback, scheduling supply and distribution and lorry supply etc. Chennai requires actions that will maintain awareness, improve local and national regulations, enforcement of regulation is lacking in general. Enforcing policies is a major disadvantage as the rules are waived and not adopted by people. Fines and fees for not enforcing policies are not really a solution, as the authorities do not really know if the policies are not monitored in the first place.

Mitigation can reduce emission from utility and reduce costs, increase resilience and improve public health. Energy requirements for utility implementations are high but there are some renewable sources that reduce the energy requirements for services provided. Distribution services take up most of the energy requirements; pressured pumping within each household requires energy. Chennai uses the overhead tank system to reduce the pressured pumping related energy consumption, where possible. Energy management in Chennai also more recently enhanced, as the policy makers are well aware of the pollution, energy savings cost saving. More research into energy savings will allow for a complete assessment on climate readiness.

Major water utility implementations affect the community; therefore partnerships with community will result in good management and public support for policies, adaptation planning and enhancement of community. Outreach tools in Chennai needs a boost. To ensure community support and resiliency water management should include community related aspects in adaptation planning in Chennai. As of now, there is little community involvement and Chennai requires government survey on public requirements and the level of support to improve participation.

Partnerships with community will enhance public support, while partnerships with other sectors will enhance integrated management. Chennai's management is not interdependent and has very few partnerships with other sectors. The water shed management; environmental organizations and building construction planners are improving their collaboration with Chennai's water utility management. Chennai requires further work on utility and land use planners in order to best manage services.

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APPENDICES

Appendix I

Figures and tables compiled from the data collected, 2012.

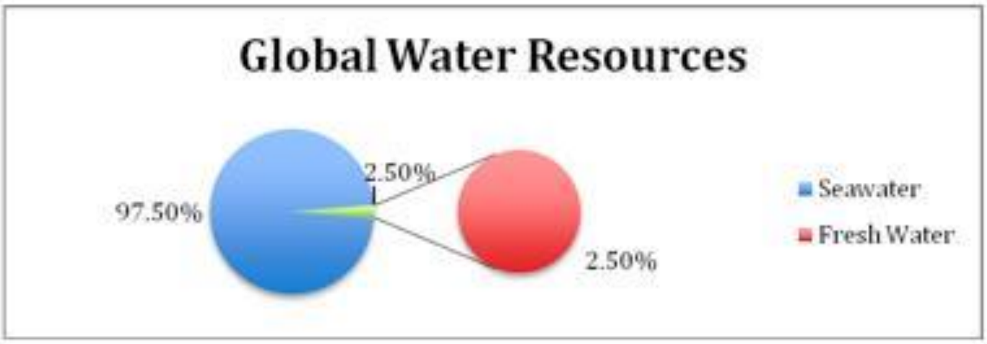


Figure 1 Global Fresh Water Content

Source: (Kumar, 2003; Rola., 2004; Johnson, 2006; GWP, 2009; Gleick, 2010).

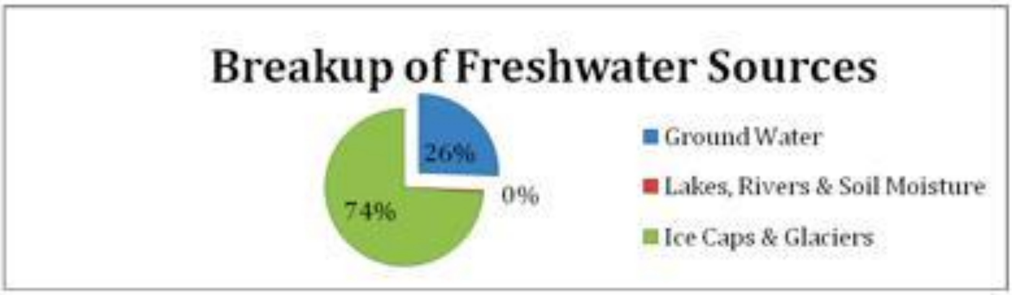


Figure 2 Fresh Water

Sources: (Johnson, 2006; Rola., 2004; GWP, 2009; Gleick, 2010).

Pages 1 and 2 of thesis

Illustrates the total resources and the resources available for consumption. This figure also aided in compiling the figure 1 on page 3 of thesis, "**World Water Distribution".**

Types of Droughts

The major droughts are of four kinds: Meteorological, Agricultural, Hydrological and Socioeconomic.

Table 40 Types of Drought

Meteorological drought signifies a land area and the dryness for a prolonged period where the atmospheric conditions that result in paucities of rain.
Agricultural drought results in shortage in food production and farming. This type of drought ties both meteorological issues such as rainfall deficits and the soil water or the ground water deficits.
Hydrological drought occurs when precipitation shortages creates a deficiency in water supply or the resources. The water hydrologic storage such as reserves, rivers etc. are used for multiple purposes such as floods, irrigation, hydropower and general habitat. The demand and race to get water in these storage system increases during drought and there are often conflicts that recur.
Socioeconomic drought indicates a demand for an economic good exceeds supply due to weather pattern and shortfall in water supply. Supply of water, forage, food grains, fish and hydroelectric power (economic goods) depend on the weather. Hence, the variability of climate implies a change in water supply, insufficient food, and reduction of hydroelectric power. The demand for these goods is increasing with the increase in population and so far, the water supply has risen due to the efficiency and technology usage.

Source: Compiled from GWP, 2011

Types of Floods

The first category is the type of floods differentiated according to their duration: (1) Slow-Onset (2) Rapid-Onset and (3) Flash are the types categorized according to the duration. Slow onset floods last for a long weeks or even months. This kind of floods can create damage to stock, agricultural products, roads and railway lines. Rapid onset occurs in days and lasts for one or two days at the most. Rapid onset floods may not last longer, but can cause more damage to properties, environment and lives. The reason is that there is no time for preventive measures to be implemented or act on. Lastly, flash floods are faster and cause the most damage to society. These floods occur in minutes and last for hours, a few hours of heavy rains, storms etc., causing havoc to society (GWP, 2011).

The second category of floods is divided according to the location are coastal, arroyos, river and urban floods. The coastal floods occur in the coastal regions where normally typhoons, storms, hurricanes and cyclones bring rains. Large waves, earthquakes and tsunamis also bring coastal floods. Arroyos floods are normally common in dry river regions where storms occur bringing in sudden rapids that flood and damage the region. The common type of floods are river floods that occurs when there is an increase in the amount of water flowing in the river, causing floods in the banks and regions surrounding it. Lastly, urban floods are usually flooding along the roads due to heavy rains or water flooded in through typhoons and this water is not absorbed into the ground or the aquifers (GWP, 2011, UN, 2009). The types of floods and droughts can be estimated with the intensity and type in a V&A action-requiring region. Hence, as floods and droughts cannot be prevented, can be adapted based on available resources, management and services.

Conceptual Framework

The conceptual framework make-up factors that influence the water system and the issues that require attention in order to achieve water security for Chennai can be managed properly. Source, Supply, policies practices, organization, institutions, public participation and Stakeholders are part of the governing body of a water system. The framework includes the major aspects used to understand the impacts of climate change on the system: supply, distribution and demand and to analyze responses and adaptation strategies to gauge the ability of Chennai 's water management to handle crisis.

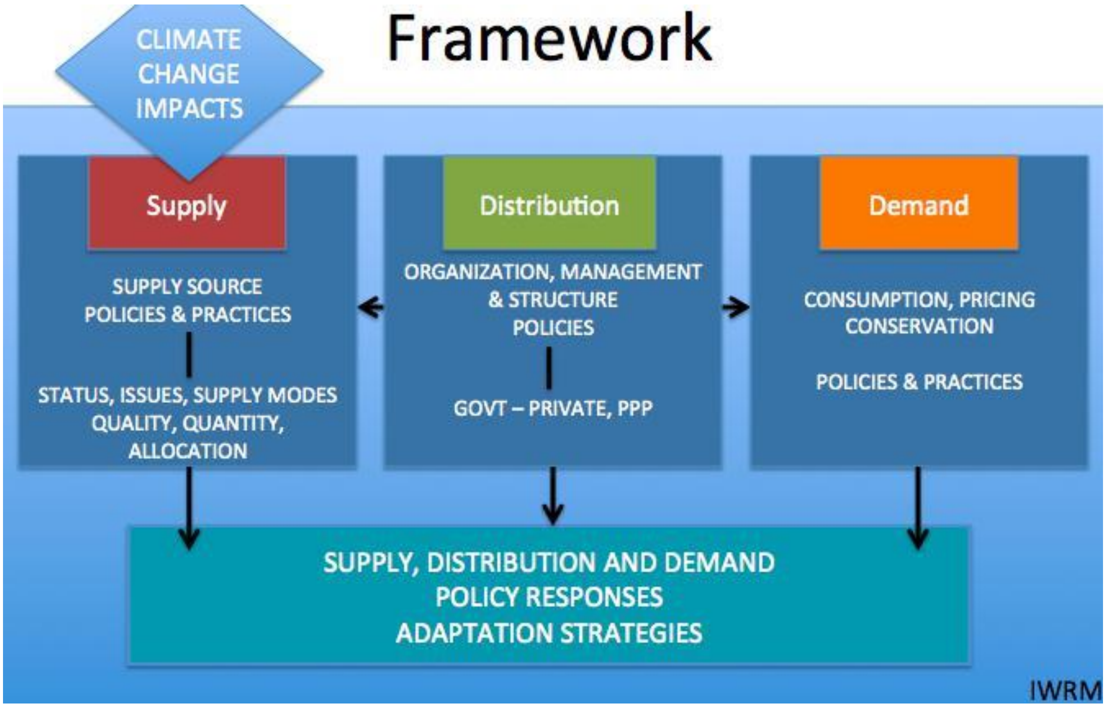


Figure 34 Frameworks for Investigation

The conceptual framework is based on Figure 11. The governance for urban water security is understood such that the supply management, distribution management, demand management and the policy responses and adaptation strategies. Chennai's water supply status, sources, issues, quantity, quality and allocation are looked synchronously looking at the distribution and demand management. The distribution management includes public – private partnerships, role of government and organization and institutions. The demand management looks at the consumption, pricing and conservation where policies and practices are vital to manage use. The policy responses are based on the current status, new projects, issues and opinions collected as part of the survey.

Sources: The major aspects considered under sources are the amount of available resources that is also accessible and is equally allocated. Furthermore, if the **available** water is monitored and protected to **maintain quantity and quality**, in accordance with the current practices, it becomes safe to use. The sources are an important aspect as it allows insight into raw water available to a region (via an inter-state treaty), if is in **cooperation** with the state, district and local officials and whether the source condition and extraction methods are **standardized and monitored** frequently. All supply conditions are examined through policy responses that are supply related.

Demand: Demand in the framework looks at the supplied water, available, affordable, equally allocated and accessible water supply is on par with the demand requirements. Such being the case, the current and future requirements is considered and strategies to meet requirements are then analyzed, to understand the need for water suppliers to ensure **equitabl**y shared water is enough to meet the needs of the community.

Policy Practices: the policy responses in Chennai mainly looked at the implementation of policies, programs and projects for demand management and if it is sustainable and makes use of sustainability concepts such as the Net Zero Use efficiency, the sustainable practices and the integrated implementation. Water **use efficiency** will enhance the implementation of **conservation, recycling, reuse programs** etc., within households. The programs are customized to specific drought or flood conditions, the carrying capacity and the capabilities of local communities **to adapt** and **adopt** practices for their households.

Adaptation and Responses: The adaptation and quick responses **ensures survivability and,** within practices to prevent further degradation and recover disruption or contamination of the water supply. The major analysis is coned to understand policies and plans and to check if they are in accordance with contingency planning for droughts or floods to increase survivability in future. Similarly, the analysis also indicates if Chennai has established workshops for local knowledge sharing to help transition and **adapt** to future crisis in a smooth manner within Chennai. To further enhance Chennai's water system, sourcing alternate water supply and backup agreements and budget system and 'fund seek' to help timely planning and implementation are looked at in depth.

Operational Definitions

Water System, Supply and Demand: Water system is defined as the process through, which water is withdrawn, treated, tested, distributed to units for allocation and transmitted to households, industries or farms through the mode of conveyance (Planning Commission, 2007). Water supply is the quantity of water drawn out for use within a region. Water demand is the requirement of water by people, industry or agricultural productivity in general.

Water security: The Canadian water policy report indicates water security as the sustainable access, to adequate quantities of acceptable quality to safeguard environmental, human and ecosystem health (Norman et al 2010). The concept is also, otherwise defined, in broad terms as the security through which the population has reliable access, appropriate facilities to deliver water equally at an affordable cost, now and for the future (Allen, 1998). UNEP defines water security as "…water security represents a unifying element supplying humanity with drinking water, hygiene and sanitation, food, industrial resources, energy, transportation and natural amenities, all dependent upon maintaining ecosystem health and productivity" (UNEP, 2012). Some of the other known scientists and water specialist such as Dr. Michael Campana described water security as the capacity of the population to have access and to meet requirements at an affordable cost, while balancing productivity and degradation of the environment (President of AWRA). Dr. Campana is also an advocate of hydro-philanthropy, which is defined as the altruistic concern for water related needs through money, information, education and training. Although, this sums up most think tanks' definition, it does not delineate good conservation or efficient use or proper governance.

Water Scarcity: GWP, (2011) defines scarcity as a situation when there is inadequate water resource available to meet basic requirements of families (GWP, 2011). The 'measure of scarcity' is the policy inputs, whereby the policies within a country measure the disparity between the amounts of water availability and level of requirement (Johnson, 2006). Water scarcity is recognized when there are supply and demand gaps, if more than 5 percent of the total income is spent on water (by a household) and unsafe water causes diseases or death (Johnson, 2006, GWP, 2011). The year 2012, water availability portrays a reduction of resources with an increase in demand, worldwide (UNICEF and WHO, 2012).

Stress and Shortage of Water: Stress and shortage are terms related to the vulnerability that society faces when there is impending lack or current lack of water supply to meet the basic needs of the residents. This definition identifies how stress is identified differently to shortage. Shortage is the actual deficiency of water, identified within the society. Stress is the implied factor, where water shortage is impending while it is clear not everyone is satisfied with what they have.

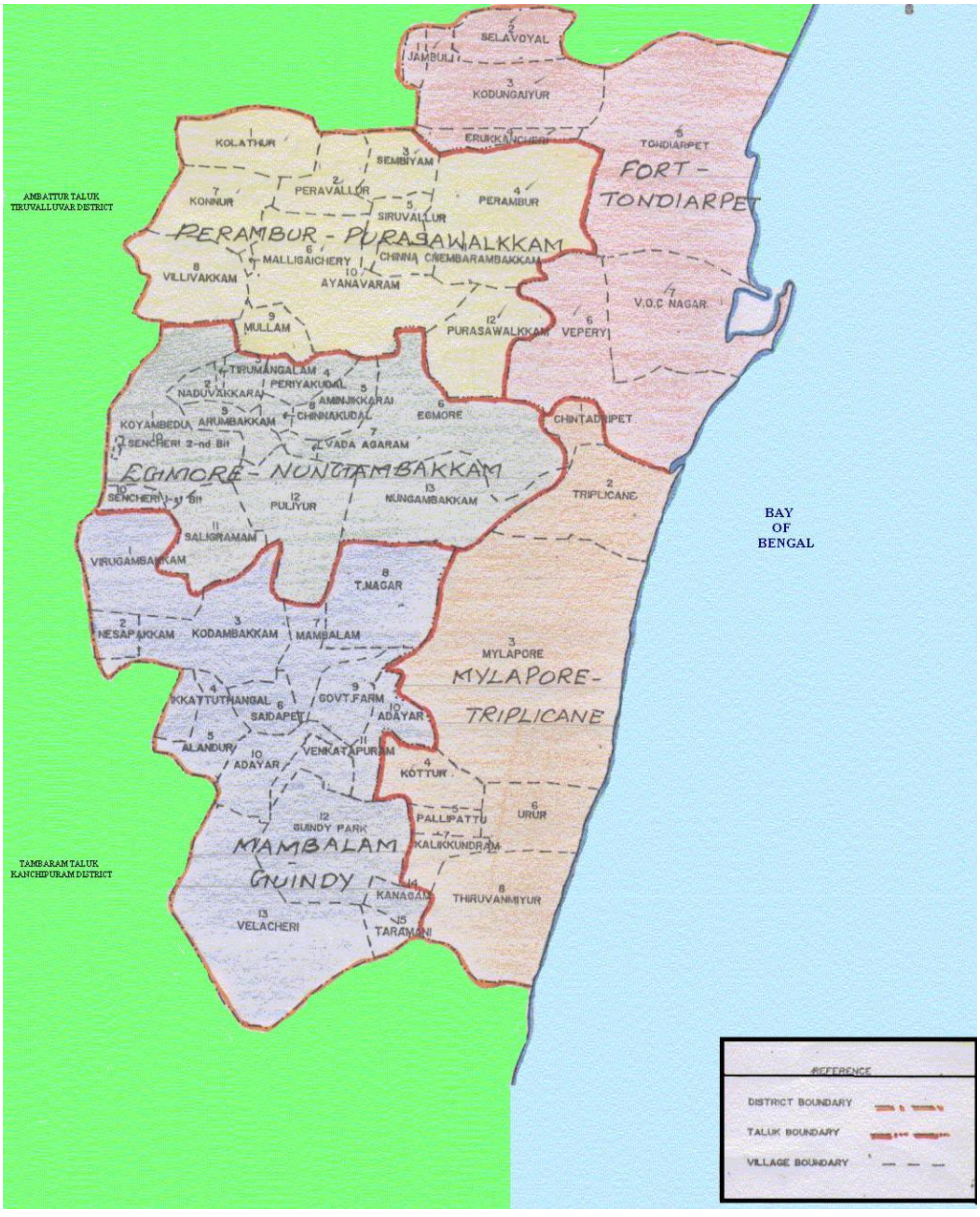
Climate Change: NASA defines climate as a long-term average behavior of daily weather, which is a short-term change in temperatures and rainfall. This distinguishes the climate and the weather. Day to day temperatures may not seem significant and hence, the long-term patterns such as yearly or decadal patterns are often observed to look at the changing climate. The changing climate is affected by the changes in factors such as the El Nino, La Nina, seismic activities such as volcanic eruptions, tsunami's etc. The measure of atmospheric behavior over a long-term basis includes temperatures, humidity, precipitation, wind, atmospheric pressure etc., is considered as climatic variation. Things that make up climate include rain, flooding, snow, wind, cloud cover, flooding, blizzards, ice storms, thunderstorms, heat waves etc. The weather stations predict changes like typhoons, snow, thunderstorms, extensive periods of dryness, fogs etc. The significance of this change could impact the forest cover, crops and water supplies is a very direct way (Treut & Somerville, 2007).

IWRM: IWRM is a logical tool and is based on the interdependency of water use for various sectors. A good example is that water is required for tanneries, while it is also used for agriculture or for making computer processor chips. Now the idea behind integrated management is to provide enough for all purposes while protecting water resources. For instances, irrigation practices demand water for crops and the waste and pesticides are the by-products that pollute the region. The main policy approach found in such framework, seeks to indicate the management approaches and goals that include environmental security, economic viability and social equity.

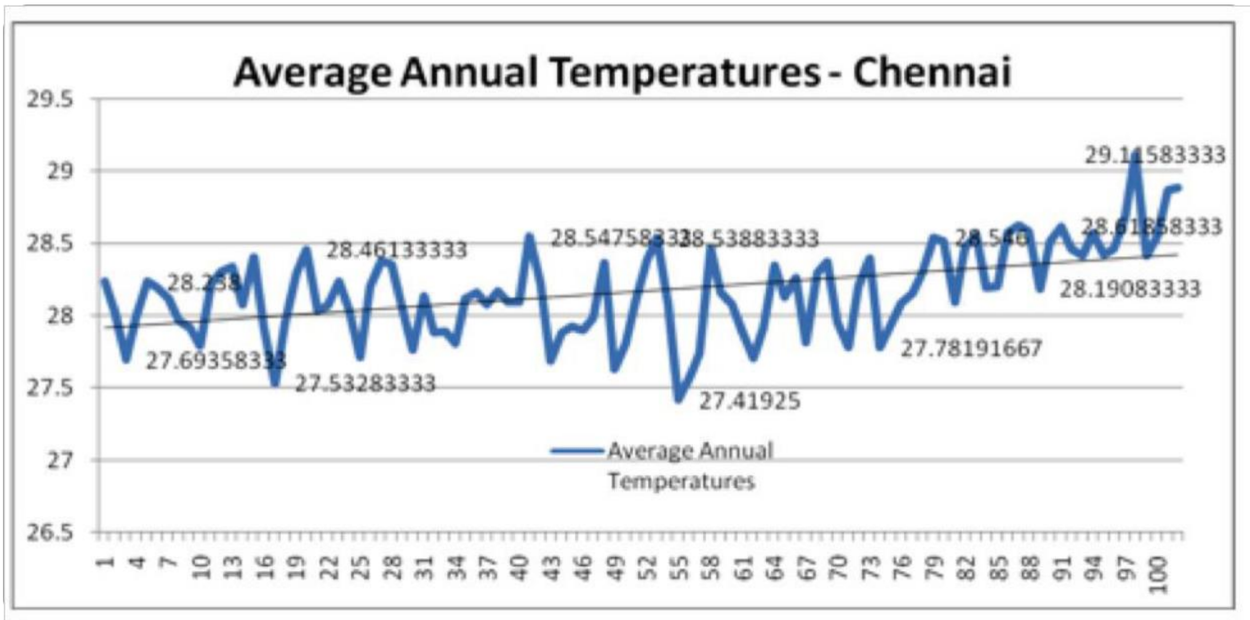
Water Security within IWRM: One of the best water management approaches is the Integrated Water Resource Management implemented by the Global Water Partnership for water security. Water security is the management of water within the IWRM components to achieve sustainability and stability within an ecosystem. The major approaches for IWRM are the accessibility, availability, allocation efficiency and affordability. Availability is the available sources, which provide water sources. Accessibility is the ease of access to draw resources for various purposes. Access is important due to the fact that sources available do not necessarily mean it is easy to supply or allocate that is region specific. Successful management of resources includes a stock take on the sources and the division of problems within the supply system.

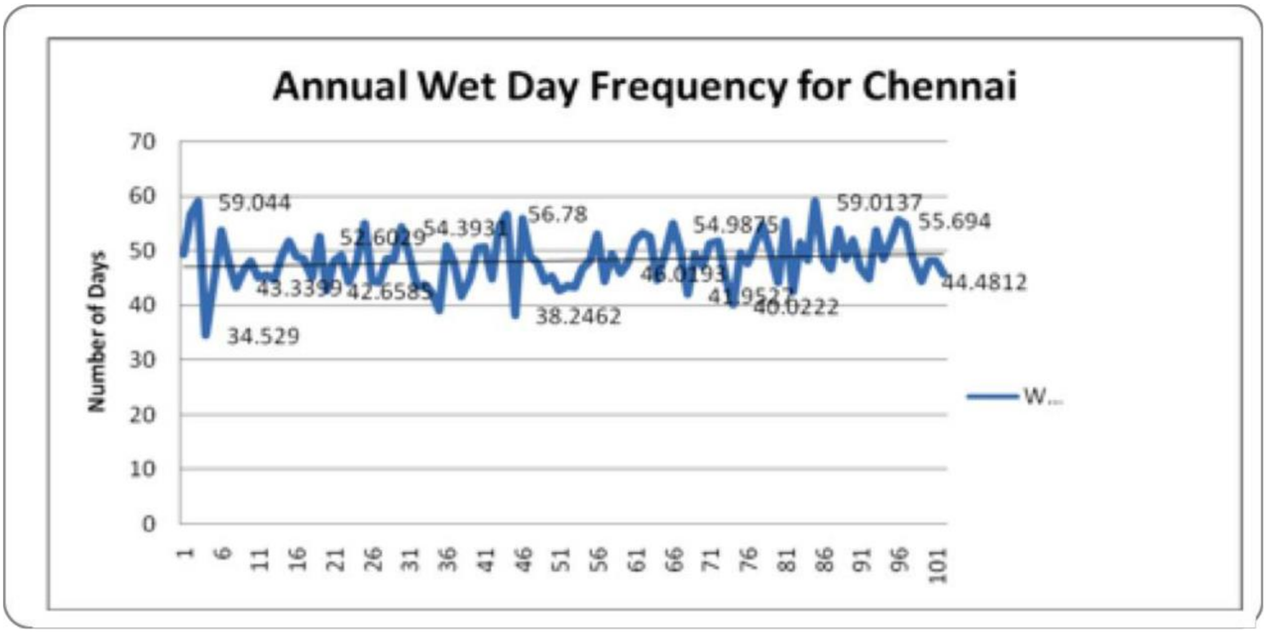
Adaptation: Adaptation is a process through, which the society, the economy and the environment, together is able to withstand the pressures of resource shortage and is able to supply resources in a sustainable manner. There are several methods to adapting to climate change. The major approaches include coordinated facility operation, integrating ground and surface water operations, improving water allocation and markets, setting national and stage goals, urban conservation, improving use efficiency, agricultural efficiency and fallowing, environmental water use efficiency and use of new technologies to reuse and desalt.

Chennai Division and Zones



Chennai Climatic Variations





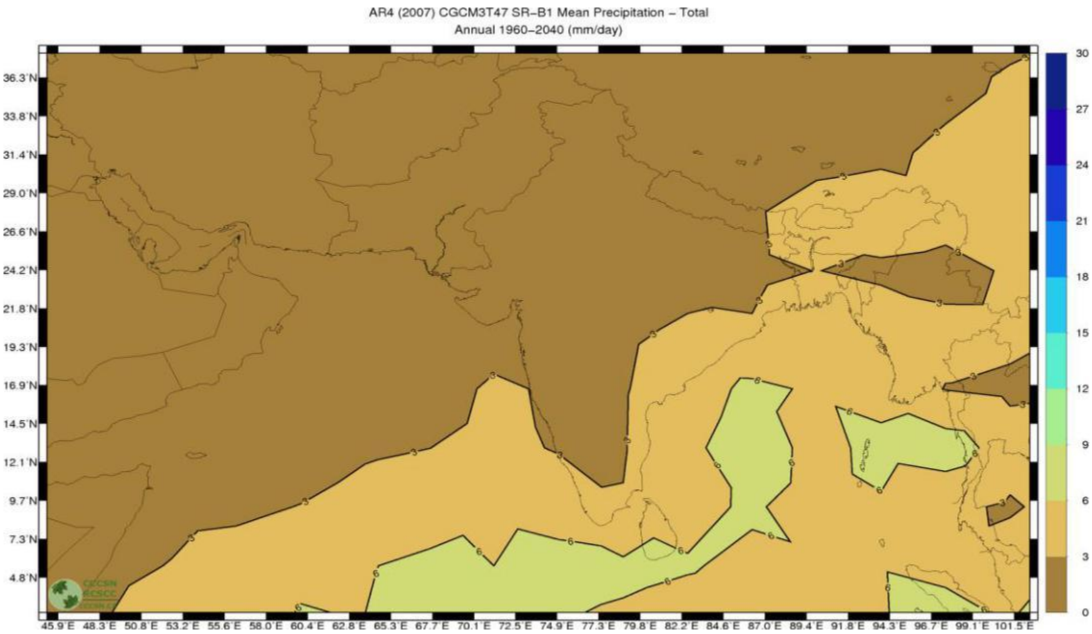
Source: Data collection, 2012 (1 – 101; Where 1 = the year 1901)

Projections from 1950 - 2010

Water Potential

Ground Water Potential	Water Capacity (MCM)
Utilizable Ground Water Recharge	984.8
Net Ground Water draft	1376
Balance	-391.2
Total No. of Rural Habitations:	5797
Not covered	0 (0 - 9 lpcd)
Partially covered	171 (10-39 lpcd)
Fully covered	5626 (40 lpcd and above)

India’s Mean Precipitation Projections from 1960 to 2040



Source: Meteorological Data, 2012

Conversion Chart

1 Ha.M = 10,000 Cum=0.01 Mcum= 0.00001 BCM
100 Ha.M = 1 Mcum
100000 HaM = 1 BCM
1 Cum = 35.31814156 cft. = 35.32 cft.
1 cft. = 28.31406 Litre
1 Gallon = 4.541 Litre
1Cusecday = (24x60x60)/(4840x9) = 1.983471 Acre feet = 0.0000019 MAF Say .000002 MAF
500000 Cusecdays = 1 MAF (0.9917355)
28.31406 MLD = 1 Million Cubic feet (1 MCft)
28.314 x 500000 LD = 1 MAF (0.992 MAF)
1 MLD = 1000 Cum = 35318.14 Cft.
100 MLD = 100000 Cum = 3531814 Cft. = 3.53 Mcft.
100000 MLD = 3503 Mcft. = 3.503 TMC = 3.503 / 43.56 = 0.0804178MAF = 0.0651338BCM.

Sector	Types of data needed	Key challenges	Policy options
Water	- Water availability, salinity, and quality o River runoff o Groundwater levels o Current and future water consumption - Impacts of various policy measures on water supply and demand	- Limited capacity to monitor long-term trends in hydrometeo-rological data and regional climate change modeling capacity - Limited understanding of the impacts of policy responses on human behaviors	- Promote regional cooperation and sharing of data and good practices in data collection and dissemination, long-term monitoring, regional water modeling, and economic and policy analysis
Climatological	- Temperature - Precipitation - Air pressure - Humidity - Wind - Radiation	- Data often under governance of the Ministry of Defense, etc., limiting data - Insufficient data - Not linked to impact analysis	- Charge the civil authority with making climate data available - Expand data rescue and the number of weather stations - Ensure that data are readily available to policy makers and researchers for analysis

Data Needs for Effective Adaptation Decision Making

Source: (The World Bank, 2012)

Appendix II

Select Photographs Supply and Collection – South and Central Chennai

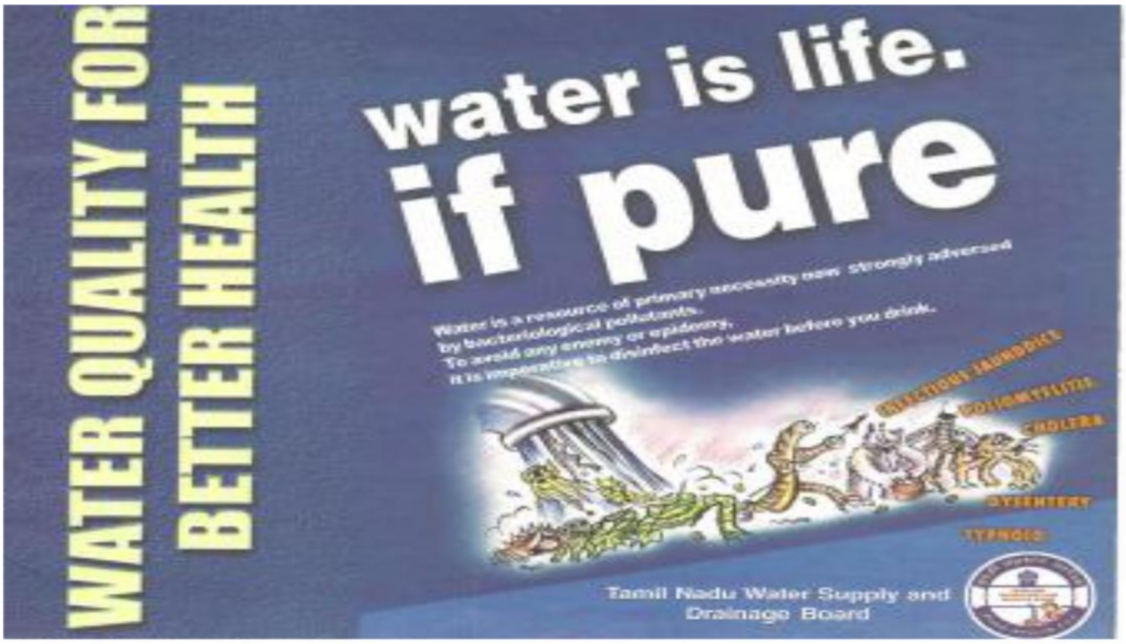
Desalination Plant

Water supply to North-east coastal regions of Chennai

Appendix III

Documents from TWAD and CMWSSB

Consolidated Water Quality Booklets



Life depends on water, water depends on purity.

Total Dissolved Solids (TDS)

- About 97-99% of TDS in natural water is contributed only by six major ions i.e., calcium, magnesium, sodium, bicarbonate, chloride and sulfate.
- The balance TDS is contributed by a number of contaminants like iron, manganese, potassium, ammonia, nitrite, nitrate, fluoride, phosphate, trace metals and organic substances.
- The permissible limit for TDS is 500 mg/L. However, in the absence of better alternative source, it may be relaxed upto 2000 mg/L.

Total Dissolved Solids in some waters

- Rain water - 1-50 mg/L
- Surface water in hills - 10-100 mg/L
- Surface water in plains - 100-1000 mg/L
- Ground water - 500-5000 mg/L
- Ground water polluted by tannery - 10000-20000 mg/L
- Sea water - 35000 mg/L
- Bottled (mineral) water - 100-300 mg/L
- Permissible limit - 500 mg/L
- Maximum allowable limit - 2000 mg/L

Water Quality in Water Sources

1. Ground water has :
   - high TDS
   - low turbidity
   - less bacteria.
2. Surface water has :
   - low TDS
   - high turbidity
   - more bacteria.

High fluoride in water causes dental and skeletal fluorosis.

Infectious diseases caused by water

The infectious diseases are frequently classified, not according to the causitive organism, but to the water-related mechanism whereby they are spread among communities.

1) **Water borne diseases (fecal-oral)**

(a) by Bacterial organisms

Cholera, Typhoid, Paratyphoid, Dysentery, Diarrhoea, Weil's disease (Leptospirosis), Tuberculosis.

(b) by phage virus or Bacteriophages

Infectious hepatitis, Jaundice, Poliomyelitis.

(c) by Protozoan

Amoebic dysentery, Ascaris, Amoebic meningo-cephalitis (fatal encephalitis usually acquired while swimming in ponds).

Preventive measures : Improve quality of drinking water, prevent causal use of the unhygienic sources.

Filaria

2) **Water washed diseases**

Scabies, Skin diseases, Typhus fever, Leprosy, Trachoma, Conjunctivitis, Bacillary dysentery.

Preventive measures : Increase water quantity for (washing / cleaning) use. Improve accessibility and reliability of domestic water supply.

Nitrate causes blue baby disease - mother's feeding prevents it.

3) **Water based diseases**

Schistosomiasis (liver fluke), Dracunculosis (Guinea worm disease).

Preventive measures : Control snail populations; filter the water through a fine mesh cloth to remove larvae / cyclops / snail. Disinfect contaminated water.

4) **Water related diseases (by vector organisms)**

Malaria, Filaria, Dengue Fever, Sleeping sickness (African sleeping sickness).

Preventive measures : Destroy breeding sites of insects. Decrease need to visit breeding sites. Use mosquito nets.

By boiling or addition of bleaching powder, the disease causing bacteria and other organisms can be killed and the water could be made safe.

Doubts on Water Quality

- **Water is saltish :** Chlorides give water a salty taste, but the intensity of the taste depends upon the ionic composition. Thus in some waters the salty taste is detected at about 200 mg cl/L, but if the water contains high concentrations of calcium and magnesium, the salty taste is not noticed even at 1000 mg/L.
- **Water on standing becomes turbid and brownish yellow :** Normally some ground water may contain ferrous iron in the form of its bicarbonate, which is in dissolved condition. On exposure to air, ferrous iron is oxidized to insoluble ferric iron hydroxide and is seen in the form of brownish yellow precipitate.

Right dose of a substance differentiates it from a poison and remedy.

- **Soap is not lathering :** This is due to the property of excessive hardness in water. Hardness is mainly contributed by calcium and magnesium.
- **Boiled rice is hard and yellow in colour :** This is due to the property of high alkalinity in water. Alkalinity is mainly contributed by bicarbonate.
- **Dhal becomes hard on cooking :** This is due to high alkalinity of water.
- **Boiled meat / food becomes poor in quality :** This may be due to the high hardness of water.
- **Nuisance of algae :** Trace levels of phosphorous and nitrogen aid for algae growth. Sunlight or stray light can help this process.
- **White deposits in vessels (when water is stored / boiled) :** The scales are due to precipitation of calcium carbonate from water. Scale formation is notable when the water has temporary hardness. The water after filtration can be used without any harm.
- **Oily suspensions noted on the surface of water in wells :** This is also due to precipitation of calcium carbonate in water.
- **White deposits blocking the PVC pipes :** This is due to deposition of calcium carbonate scales. This is found particularly when compressor pumps are used.
- **Horizontal brownish or brownish-black streaks in teeth :** This is caused in children due to excess fluoride in water. The horizontal streaks formed are permanent and cannot be treated or removed.
- **Rotten egg smell from water :** In the absence of sufficient air and under anaerobic conditions, hydrogen sulfide is formed due to putrefaction of organic matter in water. This causes rotten egg smell in water.

For healthy and happy life ensure water quality.

- **Brownish or brownish-black slimes in water conveying pipes :** May be due to growth of iron bacteria in water.
- **Death of infants due to blue baby disease :** High nitrate in water causes blue baby disease. The blood of the children affected by the disease turns blue and the children die of asphyxiation. The disease affects only infants below six months age. Adults are not affected. Breast fed children are not affected by this disease.
- **Clothes loose their shining and become dirty after some washings :** This is due to presence of high hardness and iron in water used for washing. Good lathering can occur with detergents but the cleaning action in hard water will not be always satisfactory.
- **Slime formation in classet in toilets and in the floors of bathroom :** This happens due to microbial growth or scale deposition.
- **Diseases like cholera, jaundice, diarrhoea, dysentery etc. :** These are caused due to presence of disease causing micro-organisms (called pathogens) in water.

Frequently asked questions

- **Can we use alum or permanganate for water purification ? :** Except bleaching powder, no other chemical is recommended for use by the public at houehold level.
- **Can we use 'nellikattai *(emblica species)*' for reduction of salt and improvement of taste of water ?** 'Nellikattai' may improve the taste but cannot reduce the salt content or other harmful effects of water.
- **Can we use 'thethankottai *(strychnous potatorum)*' for water purification ? :** 'Thethankottai' is a natural coagulant and removes only turbidity and can be used for removal of turbidity.

Life depends on water; water depends on purity.

- **Whether the presence of septic tank may affect the quality of water in nearby wells? :** If the seepage from septic tank mixes with well water, it can definitely affect the quality of water and can cause water borne diseases. Mixing of septic tank waste or sewage in drinking water can be easily identified by testing for ammonia, phosphate and fecal coliform. There should be sufficient distance (at least 20-50') between the septic tank and a well.

Testing facilities in TWAD Board Laboratories

1) **Physical Examinations :** Colour, odour, turbidity, electrical conductivity, total dissolved solids, suspended solids.
2) **Chemical Examinations :** pH, alkalinity, hardness, sodium, potassium, iron, manganese, ammonia, nitrite, nitrate, chloride, fluoride, sulfate, phosphate, Bio-chemical oxygen demand (BOD), Chemical oxygen demand (COD), Total Kjeldahl nitrogen (TKN), oil & grease, aluminium, chromium, arsenic, residual chlorine.
3) **Bacteriological Examination :** Standard plate count, total coliform, fecal coliform, fecal streptococci.
4) **Water for construction purpose :** Fitness.
5) **Bleaching Powder and Alum :** Quality analysis.

Water Testing in a Lab.

Testing Charges

1) Physical and Chemical Examination of water (for domestic / other use) : Rs. 250/- (Single Test Rs. 25/-).
2) Bacteriological Examination : Rs. 250/- (Single Test Rs. 100/-).

Good sanitation is the first measure to protect the water.

3)	Sewage / Waste water testing	: Rs. 600/- (Single Test Rs. 100/-).
4)	Water for Construction purpose	: Rs. 300/-
5)	Alum Testing	: Rs. 500/-
6)	Bleaching Powder	: Rs. 10/-
7)	Fluoride Testing alone	: Rs. 5/-

** Payment should be made along with samples.*

Microscopical Examination

Sampling Procedures

Sampling for Chemical Examination

- Water for chemical examination should be collected in a clean, white 2 litre polythene container.
- The source from where water is collected should be in regular use. Before sampling, the source should be adequately flushed. For hand pump sources, the water should be pumped and wasted for at least three to five minutes to clear all dirt, slime and turbidity. Water from wells should be taken in the middle at mid depth. For lakes, rivers and dams, the water should be collected near the off-take point.
- Before collection of sample, the container should be washed with the water to be sampled for at least two or three times.
- The water should then be filled completely in the container without leaving any air space.
- Place the inner cap. Place a polythene sheet (10 x 10 cm.) in between the inner and outer caps. Screw the outer cap. Place another polythene sheet of same size over the outer cap and tie the neck with a rubber band or twine thread.

Protection of water sources prevents you from diseases.

- Label the container with all required source particulars.
- The sample collected for physical and chemical examination should be delivered to the lab within 24 hours from the time of collection.

Sampling for Bacteriological Examination

- For bacteriological examination, the water should be collected only in a pre-sterilized 250 ml. glass bottle which has to be received from any of the TWAD Board laboratories.
- The sample collection procedures for bacteriological samples will be explained in the laboratory when the sample bottles are delivered to the customer.
- The sample should reach the laboratory within 6 hours from the time of collection. However, when preserved in ice box, the sample can be delivered within 24 hours.
- The sample collected for bacteriological examination should be labelled properly furnishing the source particulars before it is despatched.

Source particulars for samples

The following source particulars should be furnished for each sample :
Location & address of sampling, locations of source (if it is away from the sampling point), type of source, date of collection, pollution to source if any, tests to be conducted, purpose of testing etc.

Clean water is our friend; impure water is our enemy.

Public water treatment systems

The water supplied to big cities is usually derived from surface water sources like lakes, rivers, dams, reservoirs etc. or from ground water (bore well) sources.

The water from surface water sources may be turbid and will have high bacterial contamination. The turbidity is removed by coagulation with alum. This is done in a mechanical unit called clariflocculator. The water is then filtered through filter beds; it is disinfected with chlorine or bleaching powder and then supplied to the public.

The water from ground water sources may have high salinity and in such cases desalination may be followed. For removal of specific salts like fluoride or iron, defluoridation or iron removal plants may be used.

Simple treatment for water containing turbidity and iron

Water containing iron will be turbid and brownish. On standing, the turbidity settles within 2 to 12 hrs. depending on the form in which iron is present (inorganic or organic iron). The water after settling can be filtered and directly used. Addition of bleaching powder and alum (at a dosage level of 10-20 g. and 30-50 g. respectively per 1000 litres) can quicken the settling of iron and the water can become clear within 1 to 2 hours. The correct dosing level may be determined in a laboratory.

Protection of Public Drinking Water Systems

- Drinking water sources should be fenced and well protected.
- No defecation should be permitted near these sources.
- Pollution from domestic, industrial and agricultural wastes should not find access to these sources.

Test water at least twice a year.

Protected Borewell

- Drainage carrying sewage and other wastewater should be diverted away from drinking water sources.
- Solid wastes should not be dumped near these sources.
- Formation of cesspools, allowing the cattle to graze near the drinking water source, tying cattle around the water structures etc. should be prevented.
- Bathing, washing etc. should not be practiced near wells, hand pumps and other drinking water sources.
- Ponds and lakes used as drinking water sources should not be used for bathing or washing of cattle and vehicles.
- Open wells and hand pumps should have platforms. The waste water should be drained out into soak pits located at some distance from the source.
- Leakage and bursts in pipelines should be attended to immediately.
- Pit taps should not be permitted in the distribution.
- Sand quarrying in riverbeds near the infiltration / collector wells can affect the water source.

It is the duty of every citizen to extend necessary help for the protection of public drinking water systems in their neighbourhood.

Protection of Domestic Water Sources

- Open wells and storage tanks in the houses should be provided with cover slabs and kept in closed condition.
- Overhead tanks and sumps should be periodically cleaned. After cleaning, the inner walls may be coated with lime to prevent algal growth.

'TDS' is an indicator to judge the basic quality of water.

- Periodical desilting may be required for open wells.
- Culturing some local varieties of fish (like Katla Katla) in wells can avoid breeding of insects and larvae.
- Bleaching powder at a dosage level of 2.0 g / 1000 litres of water may be added daily to overhead tanks. When fish is not cultured, the same dosage level may be applied to wells once in a week in normal seasons and daily during rainy seasons.
- The best method of disinfection is to boil, cool and filter the water. This has to be followed particularly during rainy seasons. Addition of bleaching powder is not necessary if the water is boiled and used.
- Water filters (reliable brands) available in the market may be used; however, proper maintenance and cleaning is necessary. The filters will be useful for removal of turbidity and suspended matter. The units available in the filter have the following functions :

  Silver / Iodine / UV light - disinfection.

  Micro filters / candles - removal of suspended matter.

  Activated Carbon - removal of odour and taste.

Above all, good hygienic practice should be followed by every individual.

Abstraction Rate and Water Quality

- Water quality can be improved by reduced rate of pumping even though the pumping period is increased. Smaller capacity pump, which is operated more continuously rather than a larger pump operated at infrequent intervals, can help for improvement of water quality. By this practice, incrustation in pipes can also be minimized.

Certain chemicals in water are carcinogenic.

Rain Water Harvesting and Quality Improvement

Due to over abstraction of water, water quality deteriorates and the quantity also depletes. It is necessary that all private and public buildings including individual houses should be provided with rainwater harvesting structures.

Rainwater harvesting can be done either by roof water harvesting or harvesting of surface run-off. The roof harvested rainwater may be directly collected or may be used to recharge the wells / bore wells.

- Recharging of water source by rainwater harvesting can improve the quality of water.
- Quality of rainwater will not deteriorate on standing.
- Rain water may be blended with ordinary water (4 parts rain water +1 part ordinary water) and can be used for drinking after disinfection.

Water may cause corrosion, scaling and slime formation.

Behaviours for Better Hygiene

Water Source

- Water sources should be protected from contamination from nearby latrines, wastewater drainage, cattle wastes or agricultural run-off.
- For drinking and cooking only safe water sources should be used.
- Use of adequate water for latrine, bathing, household cleaning and clothe washing can ensure better hygiene
- Waste water should be disposed off safely.

Water Treatment

- Disinfection should be invariably included as one of the processes in treatment.
- A filter system will always be useful for removal of suspended material, worms and other micro organisms.

Water Collection and Storage

- Water for drinking should be collected and stored in clean vessels without getting into contact with hands and other materials.
- Water should be stored in vessels that are covered and regularly cleaned.
- Drinking water should be stored in separate containers and water for other uses should be stored separately.

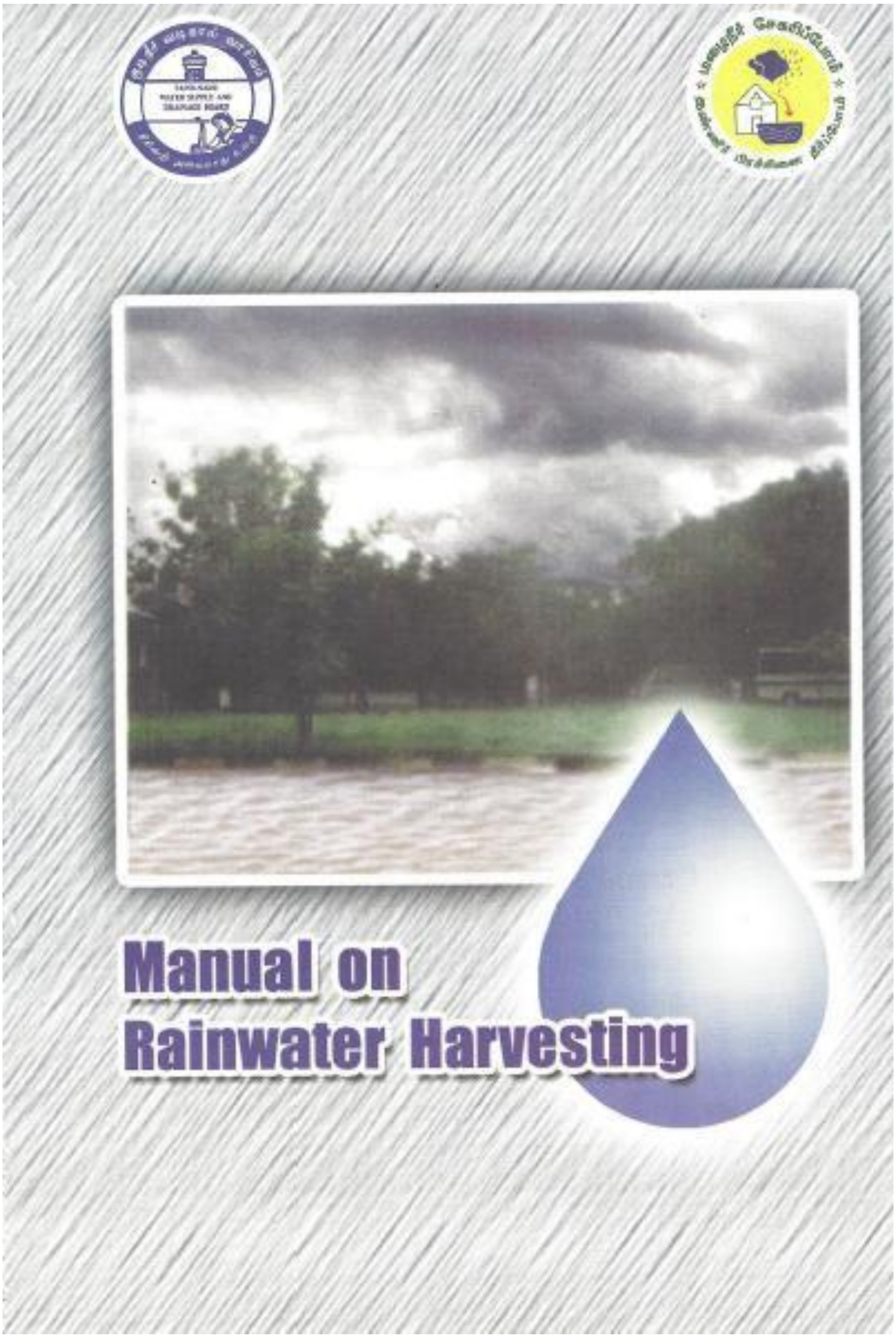
Water drinking

- Drinking water should be taken from the storage vessel without touching by hands or contaminated vessels or objects.

Water Use

- Better water quality and sanitation facilities can have positive impact on health only when there is appropriate behaviour for use of water.
- Adequate amounts of water should be available and used for personal and domestic hygiene (it is estimated that a minimum of 30 to 40 litres per person per day are needed for personal and domestic hygiene).

Rainwater Harvesting



Water Crisis - Why ?

- Fresh water sources are being heavily exploited to meet the ever-increasing demand of urban populance.
- Fast rate of urbanisation reduce the availability of open surfaces for natural recharge of rainwater.
- Failure of monsoon makes the situation worse.
- Dependence on ground water increase during low rainfall.
- Large scale extraction results in depletion of water table and finally the wells become dry.

What is the solution ?

- Rainwater is the ultimate source of fresh water.
- Potential of rain to meet water demand is tremendous.
- Rainwater harvesting helps to overcome water scarcity.
- To conserve ground water, the aquifers must be recharged with rainwater.
- Rainwater Harvesting is the ultimate answer.

Why Rainwater be harvested ?

- To conserve and augment the storage of ground water.
- To reduce water table depletion.
- To improve the quality of ground water.
- To arrest sea water intrusion in coastal areas.
- To avoid flood and water stagnation in urban areas.
- To control formation of cracks on walls.

What is Rainwater Harvesting ?

- It is the activity of direct collection of rainwater.
- Rainwater can be stored for direct use or can be recharged into the ground water aquifer in use.

How Rainwater can be harvested ?

Broadly rainwater can be harvested in two ways :

1. Collected and stored for ready use in containers.
2. Recharged into the ground for withdrawal later.

Methods of Rainwater Harvesting

- Rainwater can be harvested from roof tops and also from open spaces.
- Wherever open wells / bore wells are available, roof top water can be used for direct recharging of these wells.
- Rainwater available in the open spaces can be recharged into the ground using other recharge structures.

Rainwater may be collected and recharged into the ground water aquifers through the following simple and cost-effective methods :

1. Roof-top Harvesting

a) Open well method.

b) Bore well method.

2. Roof-top / Open space Harvesting

a) Percolation / Recharge pit.

b) Percolation / Recharge pit with bore.

c) Recharge Trench.

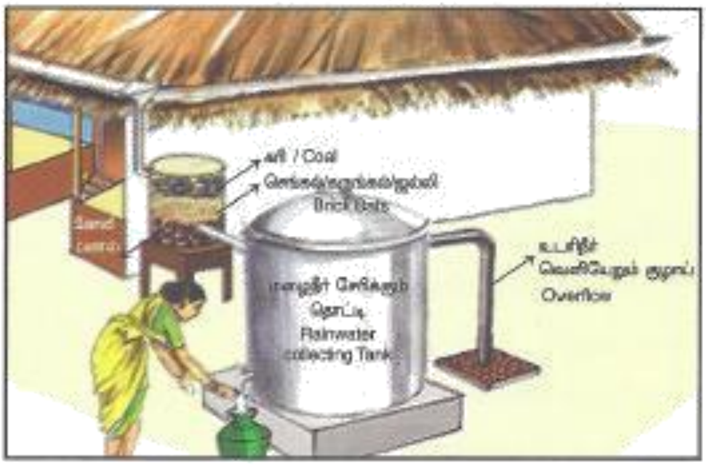
d) Recharge Trench with bore.

e) Recharge well (Small diameter).

f) Recharge well (Large diameter).

Note : Basically, these are simple and common methods from which any combinations can be selected based on the site conditions such as the extent of the building and sub-soil conditions. For example, in large apartments / commercial complexes, No. of units of RWH structures may be increased since the volume of the rainwater collected is more.

Rainwater collection from thatched & tiled roof

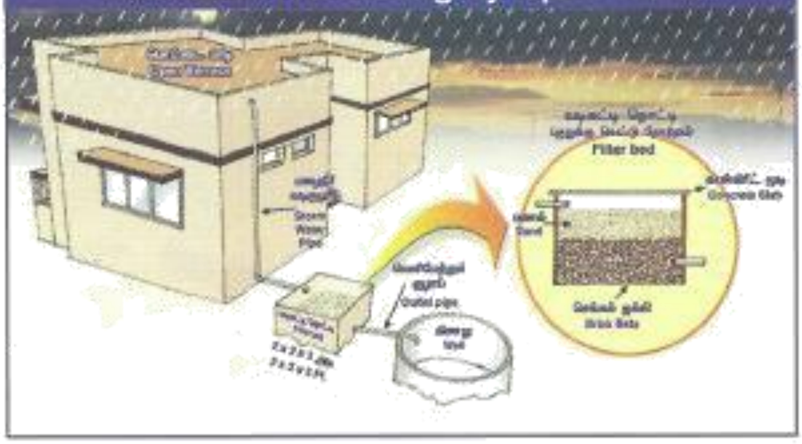


- In the thatched house, polythene sheets can be used for collecting the rainwater.
- Rainwater from the roof is collected through the gutters in the roof.
- The collected water is filtered through a filter.
- The filtered water is collected either in a storage tank or existing sump.
- Approximate cost : Rs. 800/- - 1,000/- (excluding storage tank).

Rainwater collection from a roof

- Rainwater from the roof is collected through the gutters in the roof.
- The collected water is filtered through a filter.
- The filtered water is collected either in a storage tank or existing sump.
- If it is a thatched house, polythene sheets can be used for collecting the rainwater.
- Approximate cost : Rs. 800 - 1,000/- (excluding storage tank).

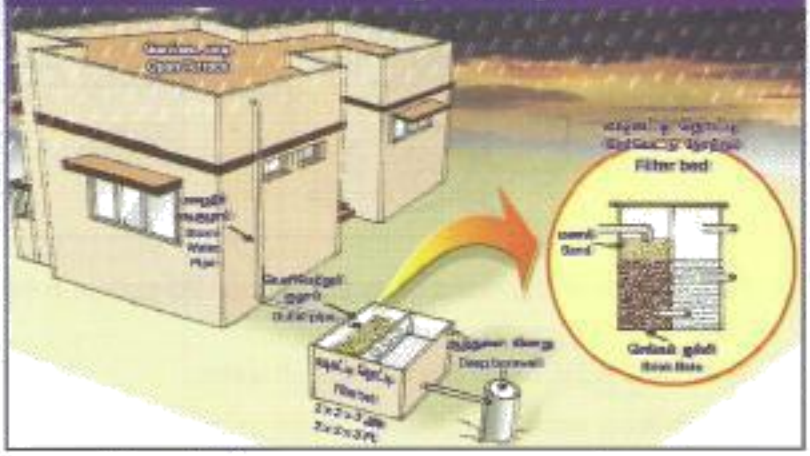
Rainwater Harvesting by Open Wells



- Rainwater collected from the terrace is diverted to the existing open well using PVC pipes through a filter chamber/sump.

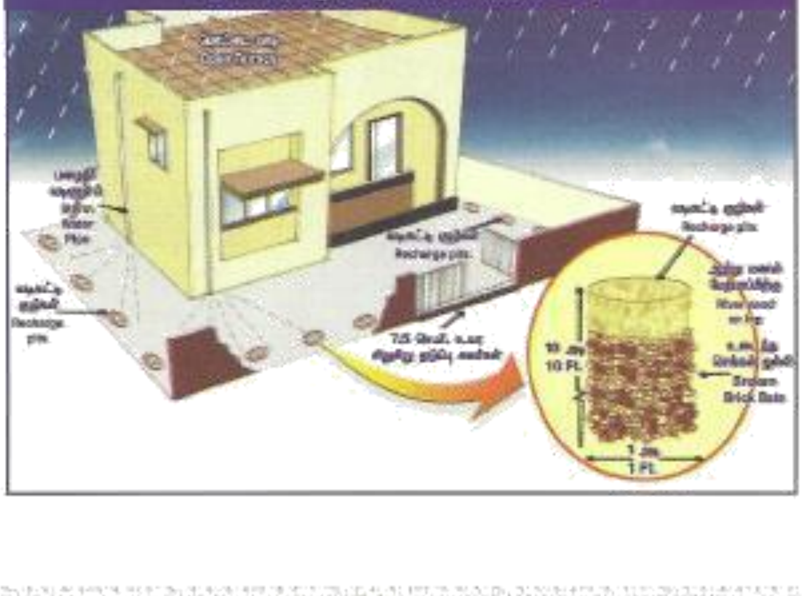
- The size of the filter chamber may be 2' x 2' x 3' filled by brick bats/pebbles in the bottom and coarse sand on the top.
- The chamber may be covered with RCC slab.
- Approx. cost : Rs. 1,350/- (for chamber only).

Rainwater Harvesting through Borewell



- Roof top rainwater may also be diverted to an existing borewell also.
- A settlement / filter tank of required size has to be provided.
- Overflow water may be diverted to a percolation pit nearby.
- Approximate cost : Rs. 1,000 - 1,200/-

Recharge/Percolation Pit



- Recharge pits are constructed in the open space at required intervals around the building.
- Size : 3' x 3' x 4.5' (depth).
- They may be square/rectangular/circular in shape.
- Filled with brickbats/pebbles.
- Suitable for sandy sub-soil area.
- One unit for 250 sq. ft. area (approx.).
- Approx. cost : Rs. 650/- per unit.

Recharge Pit with Bore

- In addition to recharge pit, a borehole is to be drilled at the centre.
- Suitable for clay sub-soil area where deep percolation is needed.
- Bore hole size : 150-300 mm. dia with 10-15 ft. depth (approx.).
- Filled with brickbats/pebbles.
- 1 unit for 250 sq. ft. area (approx.).
- Approx. cost : Rs. 1,200/- per unit.

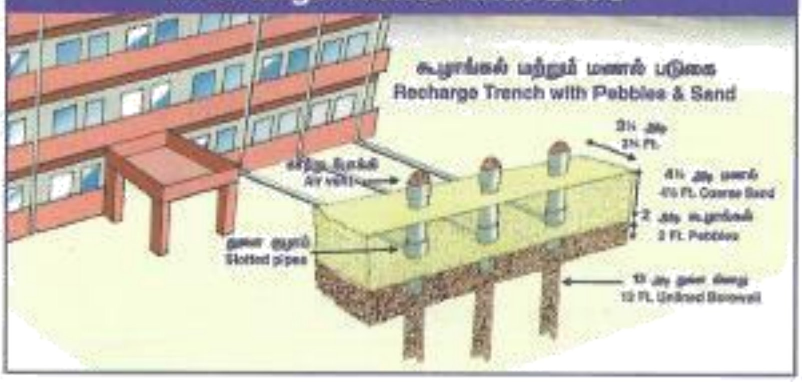
Note :

1. Above structures are meant for area with small catchment like individual houses.
2. RCC slab cover is optional.
3. Top (1') portion may be filled with coarse sand.

Recharge Trench

- Similar to Recharge Pit but constructed longitudinal in shape.
- Size : 1' - 3' wide/3' - 4.5' depth, length may vary from 3'-15'.
- Filled with brickbats/pebbles.
- Suitable for sandy sub-soil area.
- One or two units required based on the catchment / run-off.
- Approx. cost : Rs. 650/- per unit with 3' x 3' x 4.5'.

Recharge Trench with Bore



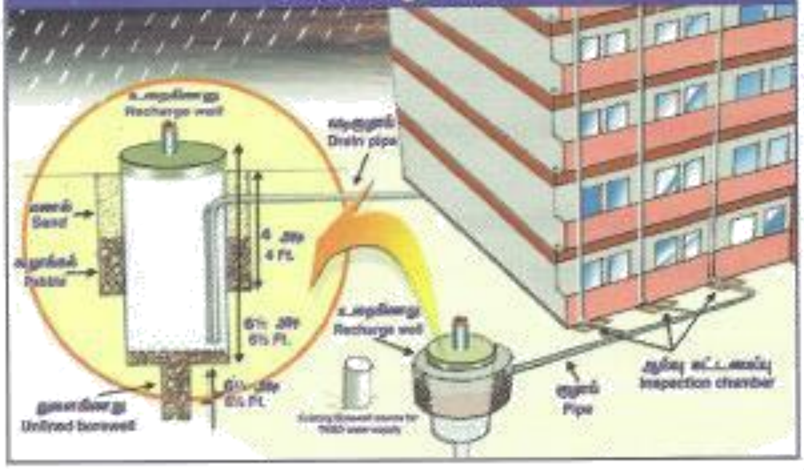
- Along the recharge trench, boreholes has to be drilled.
- Bore hole size : 150-300 mm. dia with 10'-15' depth.
- Filled with brickbats/pebbles.

- Borehole interval : 10'-15'.
- Suitable for clay sub-soil area.
- Approx. cost : Rs. 900/- per metre.

Note :

1. Above structures are meant for area with large catchment like apartments / big complexes.
2. RCC slab cover is optional.
3. Top (1') portion may be filled with coarse sand.

Recharge Well



- Small diameter wells.
- Size : 3' dia with 5' - 10' depth.
- Constructed with brick/concrete rings.
- Side walls must be perforated.
- Bottom (1') is filled with brickbats.
- Covered with RCC slab/manhole.
- Suitable for sandy sub-soil area.
- Approx. cost : Rs. 4,100/- per unit.

Note :

1. Above structures are meant for large areas with heavy run-off.
2. Run-off water diverted through a filter media preferably.
3. One well is sufficient for areas with more than one ground extent.
4. Rainwater may be diverted through small trenches (if necessary).

Rainwater Harvesting Structures :

Sandy Sub-soil areas :

1. Percolation Pit.
2. Recharge Trench.
3. Recharge Well (Small Diameter/Shallow).

Clay Sub-soil areas :

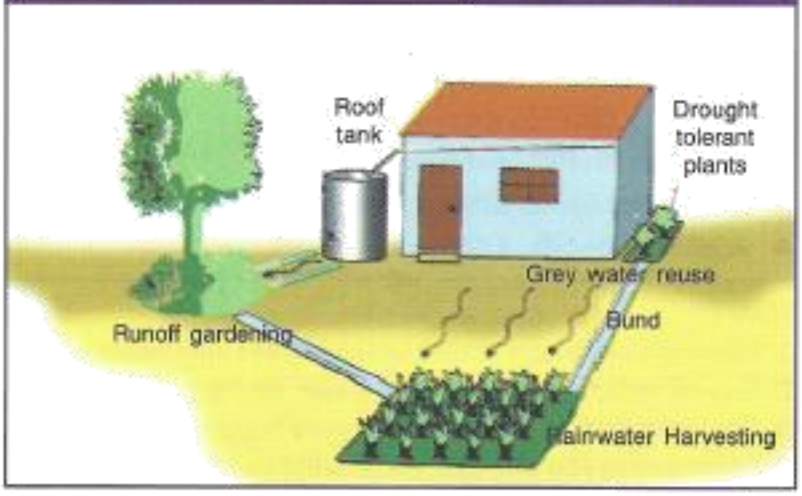
1. Percolation Pit with Bore.
2. Recharge Trench with Bore.
3. Recharge Well (Large Diameter/Deep).

Hard Rock areas (Weathered) :

Recharge Well (Large Diameter / Deep).

Note : Open Well (existing), Bore Well and Defunct / Bore Well methods are common for all areas.

Kitchen & bathroom water reuse



Things to be remembered

1. The nature of Rain Water Harvesting (RWH) structures and their design parameters remain the same for any building except the physical scale (size) and No. of structures which may increase corresponding to the size of the catchment.

2. For harvesting rainwater in open space around the building, a dwarf wall of required height (approx. 7.5 cm.) should be constructed at the entrance (gate) to avoid surface run-off and to make rainwater available to recharge.

3. If manholes (waste water line) are present in the open space, the height of which have to be raised a little to avoid draining of rainwater along with waste water.

4. The cost of RWH structures may vary depending on the availability of existing structures like wells/tanks which may be modified to be used, thereby reduce the cost.

5. Grill/mesh has to be fixed at the entrance / mouth of the rainwater pipe in the terrace to filter large particles such as leaves etc.

6. Avoid pavements since unpaved surfaces have more percolation rate. If paving of open space is unavoidable, use perforated pavement blocks to allow percolation of rainwater.

7. For effective recharge of rainwater, combination of different structures may be used as per the site requirement viz. area of the building and soil conditions.

8. All recharge structures must be properly maintained for effective recharge throughout the year. Maintenance is very easy and simple.

Notification has been issued by Tamilnadu Government with amendments to Tamilnadu District Municipalities Buildings Rule 1972 & Multistoried & Public Buildings Rules 1973 with provision for conservation of rainwater by implementation of RWH in all the existing and new buildings.

Existing Buildings should have Rainwater Harvesting Structures before 11-10-2003 as per the above notification.

Considering the importance of Rain Water Harvesting (RWH) in conserving the precious ground water resources, Metrowater Board has already taken up consumer education programmes on RWH, besides making it a compulsoy in cases of new property development. However, in order to strengthen this activity, Metrowater Board and TWAD Board have constituted exclusively RWH units. The main objectives of the RWH units are as follows :

i) To create public awareness on the importance of RWH.

ii) To co-ordinate with various agencies for promoting the RWH concept in a large scale.

iii) To impart training to individuals/organisations/Govt. Agencies in RWH methods.

iv) To provide demonstrative RWH facilities in selected public places to popularise among the public.

v) To offer technical guidance and assistance based on the geological formations.

vi) To monitor the water table and water quality in the rainwater harvested areas and wells.

vii) To assure proper maintenance of the harvesting structures after installation.

viii) To do and undertake anything which would promote RWH both in individual and in public places.

INCOME AND EXPENDITURE FOR REVISED ESTIMATE 2012 - 2013 & BUDGET ESTIMATE 2013 - 2014

Description	Rs. in Crore			
	Actual	B.E	R.E	B.E
	11-12	12-13	12-13	13-14
INCOME				
Sale of Water				
Existing Areas		269.93	253.72	260.49
Added Areas		5.54	11.44	12.09
Total	235.62	275.47	265.16	272.58
Water & Sewerage Tax				
Existing Areas		109.77	105.22	108.33
Added Areas		0.00	0.00	0.00
Total	103.69	109.77	105.22	108.33
Grants from Government				
Existing Areas		237.68	178.00	311.50
Added Areas		55.00	24.68	26.50
Total	173.67	292.68	202.68	338.00
Other Income				
Existing Areas		41.74	41.03	41.62
Added Areas		0.00	0.01	0.01
Total	66.22	41.74	41.03	41.63
Total Income	579.20	719.66	614.09	760.54
Deficit	107.40	142.38	141.40	130.35
TOTAL	**686.60**	**862.04**	**755.49**	**890.89**

Description	Rs in crore			
	Actual	B.E	R.E	B.E
	11-12	12-13	12-13	13-14
EXPENDITURE				
Power				
Existing Areas		101.78	76.98	77.63
Added Areas		13.19	7.17	7.75
Total	63.03	114.97	84.15	85.38
Chemicals				
Existing Areas		6.66	8.66	8.87
Added Areas		0.80	0.23	0.26
Total	5.53	7.46	8.89	9.13
Operation & Maintenance				
Existing Areas		65.69	82.07	79.75
Added Areas		23.14	16.53	18.03
Total	70.38	88.83	98.60	97.78
Purchase of Desal Water				
Existing Areas		176.00	167.51	301.01
Added Areas		54.00	0.00	0.00
Total	125.73	230.00	167.51	301.01
Hiring of Water lorry				
Existing Areas		13.40	21.29	20.67
Added Areas		5.56	3.91	4.00
Total	19.49	18.96	25.20	24.67
Office & Administration				
Existing Areas		6.37	9.05	8.52
Added Areas		0.40	0.29	0.32
Total	7.06	6.77	9.34	8.84
Payment & Provision to Employees				
Existing Areas		158.29	141.65	148.22
Added Areas		14.03	8.00	8.25
Total	148.56	172.32	149.65	156.47
Debt Service Charges	89.15	95.23	84.66	80.11
Depreciation	119.79	120.00	120.00	120.00
Provision for Doubtful Debts	2.50	2.50	2.50	2.50
Deferred Drought Expenditure	5.00	5.00	5.00	5.00
Prior Period Expenditure	30.38			
TOTAL	**686.60**	**862.04**	**755.49**	**890.89**

Income and Expenditure – Water Budget and Estimates (2012)

Chennai water policy documents collected during data collection, 2011 to 2013.

Relevant information is provided from the document. For ease of understanding, several pages of the documents provided in this section are compiled into charts and graphs.

THE CHENNAI METROPOLITAN WATER SUPPLY AND SEWERAGE ACT, 1978.

(TAMIL NADU ACT 28 OF 1978)

(As Amended upto 30th November 1998)
(The Chennai Metropolitan Water Supply and Sewerage (Second Amendment) Act, 1997)

(For Statement of Objects and Reasons see Part IV - Section 1 of the Tamil Nadu Government Gazette Extraordinary, dated the 10th January 1978, page 196; For Act see Part IV – Section 2 of the Tamil Nadu Government Gazette Extraordinary, dated the 14th June 1978 pages 269-341).

(Received the assent of the President on the 8th June 1978, first published in the Tamil Nadu Government Gazette Extra-ordinary on the 14th June 1978).

RWH Information booklets currently in circulation within Chennai, it is provided for users, upon request. Relevant pages of the booklet are scanned and tabulated below.

Location	Rs. in Lakhs Total Demand
Area 1	1,409.83
Area 2	3,094.60
Area 3	2,580.54
Area 4	2,569.28
Area 5	4,886.69
A.U.A (DEPOTS)	787.62
Area 6	2,420.48
Area 7	5,087.29
Area 8	4,470.49
Area 9	3,072.70
Area 10A	1,538.72
Area 10B	2,468.27
R.O.II	5,330.13
S.T.P	689.95
A.U.A (BULK)	950.85
Total	**41,357.44**

Table Showing Demand Value for Water in Each region

INDIAN STANDARD DRINKING WATER - SPECIFICATION (BIS 10500 : 1991)

Sl. No.	Substance or Characteristic	Requirement (Desirable Limit)	Permissible Limit in the absence of Alternate source
Essential characteristics			
1.	Colour, (Hazen units, Max)	5	25
2.	Odour	Unobjectonable	Unobjectionable
3.	Taste	Agreeable	Agreeable
4.	Turbidity (NTU, Max)	5	10
5.	pH Value	6.5 to 8.5	No Relaxsation
6.	Total Hardness (as $CaCo_3$) mg/lit.,Max	300	600
7.	Iron (as Fe) mg/lit,Max	0.3	1.0
8.	Chlorides (as Cl) mg/lit,Max.	250	1000
9.	Residual,free chlorine,mg/lit,Min	0.2	--
Desirable Characteristics			
10.	Dissolved solids mg/lit,Max	500	2000
11.	Calcium (as Ca) mg/lit,Max	75	200
12.	Copper (as Cu) mg/lit,Max	0.05	1.5
13	Manganese (as Mn)mg/lit,Max	0.10	0.3
14	Sulfate (as SO_4) mg/lit,Max	200	400
15	Nitrate (as NO_3) mg/lit,Max	45	100
16	Fluoride (as F) mg/lit,Max	1.9	1.5
17	Phenolic Compounds (as C_6H_5OH)mg/lit, Max.	0.001	0.002
18	Mercury (as Hg)mg/lit,Max	0.001	No relaxation
19	Cadmiun (as Cd)mg/lit,Max	0.01	No relaxation
20	Selenium (as Se)mg/lit,Max	0.01	No relaxation
21	Arsenic (as As) mg/lit,Max	0.05	No relaxation
22	Cyanide (as CN) mg/lit,Max	0.05	No relaxation
23	Lead (as Pb) mg/lit,Max	0.05	No relaxation
24	Zinc (as Zn) mg/lit,Max	5	15
25	Anionic detergents (as MBAS) mg/lit,Max	0.2	1.0
26	Chromium (as Cr^{6+})mg/lit,Max	0.05	No relaxation
27	Polynuclear aromatic hydro carbons (as PAH) g/lit,Max	--	--
28	Mineral Oil mg/lit,Max	0.01	0.03
29	Pesticides mg/l, Max	Absent	0.001
30	Radioactive Materials		
	i. Alpha emitters Bq/l,Max	--	0.1
	ii. Beta emitters pci/l,Max	--	1.0
31	Alkalinity mg/lit.Max	200	600
32	Aluminium (as Al) mg/l,Max	0.03	0.2
33	Boron mg/lit,Max	1	5

Water Quality - Documents provided by Water Research Analysts, 2012.

Water Testing Kit Sample Document

The local water quality testing procedures and fees explained within the document.

Relevant pages are attached.

TAMILNADU WATER SUPPLY AND DRAINAGE BOARD
FIELD WATER TESTING KIT - PROCEDURE

USE OF FIELD WATER TESTING KIT

About 80% of diseases are caused by poor quality of water. Water may become poor in quality due to presence of some chemicals or microbial contamination. Many salts/chemicals are normally dissolved in water and WHO and BIS have prescribed guideline values for various water quality parameters. When these guideline values are exceeded some diseases may be caused and may also affect the aquatic life and crops. In order to lead a healthy life, it is necessary to test the water in a laboratory or in the field. The Field Water Testing Kit developed by **Tamilnadu Water Supply and Drainage Board (*TWAD Board*)** is a simple device, which can be used for testing some critical water quality parameters in the field. By testing in the field, the general quality of water can be easily assessed and this can give first hand information on the quality of water. This Water Testing Kit can be used for regular Water Quality Monitoring Programs to be conducted at Village level. Panchayat level functionaries, NGOs and students of even 7th and 8th standards can easily do the experiments using this kit. The details of water sources and the quality of water in many villages can be collected and the data computerized at Panchayat level. The data will be much useful in planning and formulating various water supply schemes and will be useful for proper maintenance of water supply schemes. The kits can be used in Schools to promote the knowledge on 'Water quality' and help to develop a good practice and scientific culture among the students.

WATER TESTING - METHODOLOGY

For testing the water in the field, the following aspects have to be clearly understood:

1) *Sampling procedures*
2) *Testing procedures*
3) *Reporting*

I. SAMPLING PROCEDURE:

- The source from where water is collected should be in regular use. Before sampling, the source should be adequately flushed. For Hand pump sources, before collecting the water, the water should be pumped and wasted for at least three to five minutes to clear all dirt, turbidity and slime. Water from wells should be taken in the middle at mid depth. For lakes, rivers and dams, the water should be collected near the off-take point. The water should be collected after clearing the suspended and floating matter.
- Water for chemical examination should be collected in a clean **white 250 mL capacity leak proof pet bottle or polythene container**.
- Before collection of sample, the container should be washed/rinsed with the water to be sampled for at least two to three times.
- The water should be then filled completely in the container without leaving any air space.
- Place a polythene sheet (10 x 10 cm.) over the cap and tie it with a rubber band or twine thread to avoid any leak.
- Write the 'field code number (*sample ID*)' on the container. The 'field code number' and the source details should be separately recorded in a notebook.
- The testing of sample should be completed within 12 Hrs. from the time of collection.

II. WATER TESTING PROCEDURE:

Using the measuring jar, measure 10 ml water and pour it into the 100 mL polypropylene/titration cup. By observing the water in the cup, record qualitatively the appearance, odor and turbidity. Using the pH paper, measure the pH.

1. **Appearance**: Record appearance as follows:
   Colorless & clear/ Brownish/ Slightly brownish/ Greenish/ Slightly greenish/ Blackish/ Slightly blackish/ Slightly whitish/ Turbid etc.

2. **Odor**: Record odor as follows:
   None/ Soil smell/ Algal smell/ Objectionable odor/ Slightly objectionable odor/ Rotten egg smell etc.,

3. **Turbidity**: Record Turbidity as follows:
   No turbidity/Slightly turbid/Moderately turbid/Highly turbid

4. **pH**: pH booklets have been provided to measure pH value of water. Tear a portion of the pH paper and hold it by your fingers. Using the ink filler add 1 drop of water sample on the paper. Wait for 10 seconds. The colour change taking place on the wet portion of the pH paper is observed and compared with the pH chart provided in the cover page of pH booklet. Record the pH value.

5. **Alkalinity**: Using the 10 mL measuring cylinder, measure 20 ml of water sample (2 x 10 mL) and pour it into the clean titration cup. Add 5 drops of '**A1**' liquid. The water turns ***bluish green***. Using the '1 mL syringe' provided in the kit, add '**A2**' liquid (starting from the 40th division). At the end point, the color of water changes into ***Orange/ yellow***. Record the number of divisions of '**A2**' added to reach the end point.
   Calculation: Alkalinity mg/L = No. of Divisions of 'A2' added x 10.

6. **Hardness**: Using the 10 mL measuring cylinder, measure 20 ml of water sample (2 x 10 mL) and pour it into the clean titration cup. Add 5 drops of '**H1**' and then 5 drops of '**H2**' liquids. The water in the titration cup turns ***Pink*** in colour. Using the '1 mL syringe' add **'H3'** liquid in drops (starting from the 40th division). At the end point, the colour of water changes into ***Bluish color***. Record the number of divisions of '**H3**' liquid added to reach the end point.
   Calculation: Hardness mg/L = No. of Divisions of 'H3' added x 10.

7. **Chloride**: Using the 10 mL measuring cylinder, measure 20 ml of water sample (2 x 10 mL) and pour it into the clean titration cup. Add 5 drops of '**C1**' liquid. The water turns ***yellowish*** in colour. Using the '1 mL syringe' add '**C2**' liquid in drops (starting from the 40th division). At the end point, the color of water changes to ***slight reddish*** in colour. Record the number of divisions of '**C2**' liquid added to reach the end point.
   Calculation: Chloride mg/L = No. of Divisions of 'C2' liquid x 10.

8. **Total Dissolved Solids (TDS)**: The approximate value of TDS can be arrived at by the following calculation:
   Calculation: TDS mg/L = (Alkalinity + Hardness + Chloride) x 1.2.

9. **Fluoride**: Take 5 mL of water sample in the 10 mL glass bottle. Add 5 drops of '**F**' liquid. Mix. Compare the color with "**Fluoride chart**" provided and record the Fluoride value.

10. **Iron**: Using the measuring cylinder, take 10 mL of water sample in the 10 mL glass bottle. Add 5 drops of '**Fe1**' liquid and 1 drop of '**Fe2**' liquid. Mix. Then add 5 drops of '**Fe3**' liquid. Mix well. For colorless samples wait for 2 minutes. For turbid samples wait for 5-10 minutes till a persistent color develops. If there is no Iron, the color will not change. If Iron is present, the color of water will change into red. Compare the 'red' color with the '**Iron chart**' provided and record the Iron value.

11. **Ammonia**: Using the measuring cylinder, take 10 mL of water sample in the 10 mL glass bottle. Add 5 drops of '**AM**' liquid. Gently shake the bottle. If there is no Ammonia, the color will not change. If Ammonia is present, the water turns ***yellow***. Compare the ***'yellow'*** color developed with the '**Ammonia chart**' provided and record the Ammonia value.

12. **Nitrite**: Using the measuring cylinder, take 10 mL of water sample in the 10 mL glass bottle. Add 2 drops of '**N2**' and 2 drops of '**N3**' liquids. Gently shake the bottle. If there is no Nitrite, the color will not change. If Nitrite is present, the color of water will change into pink. Compare the 'pink' color with the '**Nitrite color chart**' provided and record the Nitrite value.

13. **Nitrate**: Using the 1 mL syringe take 1 mL water sample in the 10 mL glass bottle. Using the measuring cylinder add 9 mL bottled/distilled water to the same glass bottle. Using a mini spatula add a small pinch (one mustard size only) of metal powder (**N1**). Add 2 drops of '**N2**' and 2 drops of '**N3**' liquids. Shake continuously and vigorously for 1 minute. Wait for 5 minutes and immediately compare the color developed with the '**Nitrate color chart'**. If there is no Nitrate, the color will not change. If Nitrate is present, the color of water will change into pink. Record the Nitrate value.

14. **Phosphate**: Using the measuring cylinder, take 10 mL of water sample in the 10 mL glass bottle. Add 5 drops of '**P1**' liquid. Gently shake the bottle. Then add 1 drop of '**P2**' liquid. Again gently shake. If there is no Phosphate, the color will not change. If Phosphate is present, the color of water will change into blue. Compare the '**blue**' color with the '**Phosphate chart**' provided and record the Phosphate value.

15. **Residual Chlorine**: Using the measuring cylinder, take 10 mL of water sample in the 10 mL glass bottle. Add 5 drops of '**RC**' liquid. Slightly shake the bottle. If there is no Residual Chlorine, the colour will not change. If Residual Chlorine is present, the colour of water will change into ***yellow***. Compare the ***'yellow'*** color with the '**Chlorine chart**' provided and record the Residual Chlorine value.

Note: In the above tests for rinsing use Distilled water or Bottled/mineral water

16. **E.Coli/Fecal Coliform**: The test is conducted using H_2S vials (H_2S vials have to be procured separately from the market). The water should be added up to the mark in the H_2S vial. After screwing the cap, keep the vial for 24 hours. After 24 hours observe any one of the following changes.

i) Black color	= High level of contamination
ii) Turbid & brownish	= Moderate level of contamination
iii) No change in the honey brown color	= Absence of E.Coli/Fecal coliform

Reporting Test Results – Water Quality Report Sample, 2012

III. REPORTING:

The test results should be compiled in the following report form:

Test Report

Sample ID: **Date:**

Source Details:

SlNo	Details	
1.	Location and address of the source	
2.	Location and address of sampling point	
3.	Name of Village/Habitation	
4.	Name of Panchayat	
5.	Name of Block	
6.	Name of District	
7.	Type of source	Open well/ Bore well/ Infiltration well/ Lake/ Dam/ Surface water etc.
8.	Type of scheme	Hand pump/Power pump
9.	Collected by (Name, designation & Office)	

Water Quality Results:

Sl. No.	Water Quality Parameter	BIS Guidelines Allowable limit	Value mg/L
1	Appearance	Colorless	
2	Odor	None	
3	Turbidity	No turbidity	
4	pH	*6.5 – 9.2*	
5	Alkalinity (maximum)	*600 mg/L*	
6	Hardness (maximum)	*600 mg/L*	
7	Chloride (maximum)	*1000 mg/L*	
8	Fluoride (maximum)	*1.5 mg/L*	
9	Iron (maximum)	*1.0 mg/L*	
10	Ammonia*	-	
11	Nitrite*	-	
12	Nitrate (maximum)	*45 mg/L*	
13	Phosphate*	-	
14	Residual chlorine (minimum)**	*0.2 mg/L*	
15	Total dissolved solids (maximum)	*2000 mg/L*	

* No guideline value prescribed; however if ammonia, nitrite and phosphate (any one or more) are present at more than 1.0 mg/L, it indicates pollution (mainly due to domestic liquid wastes and leachates from solid wastes).

** To ensure effective disinfection, minimum residual chlorine of 0.2 mg/L should be present.

Report: The water is **POTABLE / NON POTABLE**

SIGNATURE

The details of Field kit can be obtained from:

The Deputy Chief Engineer © or The Chief Water Analyst,
TWAD Board, 31 Kamarajar Salai, Chepauk, Chennai 600 005.
Ph: 28412098; E.Mail: twadboard@dataone.in Fax: 28548623

Note: The cost of Field Kit is Rs. 2,500/= each. The reagents for the Field kit can be replenished from the above address at a cost of Rs. 1,750/= per set (to test 100 samples).
Packing, forwarding and taxes inclusive.
The payment can be made either by cash or D.D drawn in favor of "The Deputy Chief Engineer (C.M), TWAD Board, Chennai-600005".

HANDLING OF FIELD KIT AND PRECAUTIONS TO BE FOLLOWED

(1) The liquids provided in the Field kit for water testing are chemicals, which are corrosive and toxic. These liquids (reagents) should not be split on the skin. When split on the skin, immediately blot out the liquid using tissue paper and then wash with ordinary water.
(2) Under no circumstance, the chemicals/liquids in the Field kit should be inhaled or consumed.
(3) Misuse of these chemicals/liquids in any way should be prevented.
(4) When the Field kit is used, avoid spillage of chemicals on the floor or within the box. If the spillage is within the box, wipe out with tissue paper. If the spillage is on the floor, wash it with water.
(5) When not in use, the Field kit should be kept safely away from the reach of children and mentally retarded.
(6) In Gram Panchayats, the Panchayat President will be the custodian of the Field kit. In Schools, the Head master or the Science teacher can be the custodian of the kit.
(7) When you go out for sampling and testing, it is not necessary to test each sample at the site of sampling itself. A set of samples can be collected and tested at a common place. This can avoid repeated packing, unpacking and washing processes and the resulting wastage of time. However, each sample container should be properly codified before you leave the sampling site.
(8) After sampling, the source details as required should be collected in full and recorded in a notebook. While noting down the source details the corresponding code number for each sample should be also recorded in the notebook.
(9) When testing is carried out for a set of water samples, in order to save time, each test can be carried out on all samples and then proceed with the next test. This can avoid repeated washings.
(10) While going for sampling, you can purchase a **bottled water** and **tissue paper** from the local shop and these items will be useful while conducting the tests.
(11) For rinsing of kit wares, use distilled water or mineral/bottled water.
(12) While taking the readings in the syringe for titrimetric tests, the initial reading will be at '40'. Note down the final reading (say 14). Then the calculation is → (40-14 = 26). Then the value of the parameter is = 26 x 10 = 260 mg/L.
(13) When testing chlorinated sample, first test residual chlorine. Before conducting the other tests, keep the sample exposed to air for 30 minutes to allow the chlorine to escape. Then start analysis for other parameters.
(14) After completing the tests, the items like syringe, measuring cylinder, cups, ink filler, bottles etc. should be washed thoroughly with distilled water or mineral/bottled water. Water from these items should be drained out or even dried before packing.
(15) After completing the tests the containers containing the liquids should be stopper tightly and the outer cap should also be screwed tightly to avoid leakages. This can help to prolong the shelf life of the reagents used. Any leakages over the bottle should be wiped out with the tissue paper before stoppering the container.
(16) The Field kit can be used to test totally 8 parameters – pH, Turbidity, hardness, chloride, fluoride, iron, nitrate, residual chlorine:

Tests	Significance
pH	All chemical reactions depend on pH of water, which is nothing but the concentration of hydrogen ions. A low pH can affect the mucous membrane. A high pH can upset stomach pH so that the digestion capacity is lost.
Alkalinity, hardness and chloride	These are the major nonmetallic constituents in water.
Fluoride and iron	Present due to the nature of soil and rocks.
Nitrate	Indicates pollution due to agricultural activities
Residual chlorine	Residual chlorine ensures proper disinfection of water. It can protect from water borne diseases.

(17) The chemicals in the Field kit can be used to test about 100 water samples. However the number of samples that can be tested shall depend on the salts present in water.
(18) The reagents in the field kit have a shelf life of one year.
(19) The TWAD Kit weighs only 1.5 kg and can be easily handled by school children, SHGs and Panchayat level functionaries.
(20) Keep the Test procedure, Checklist, Quality check certificate and precautions in a separate folder and preserve for reference. Avoid wetting or damage of these printed items.

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Documents from Indian Water Studies - Network of Climatic Stations in Tamil Nadu, 2012 Sample

District :	Thiruvallur	THIRUTHANI	Latitude :	13°09' 00"
Taluk :	Thiruthani	YEAR : 2005	Longitude :	78°33' 00"
Basin :	Nandhi River		Altitude :	86.590 m

Particulars	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall in mm	0.60	Nil	24.00	107.00	20.00	27.00	131.00	96.50	260.00	446.00	291.00	249.00
Maximum	0.60	-	24.00	65.00	18.00	12.00	70.00	23.00	69.00	63.00	45.00	127.00
Date	22	-	3	8	12	14	14	31	7	27	24	22
Minimum	-	-	-	10.00	2.00	7.00	1.00	2.00	3.00	2.00	1.00	2.00
Date	-	-	-	29	26	21	15	16	8	31	10	2
Evaporation in mm	124.20	73.00	104.50	95.50	104.00	98.00	101.50	81.00	85.50	78.00	59.00	71.00
Maximum	5.40	3.00	3.50	3.50	4.00	4.00	4.00	4.00	3.50	4.00	3.00	3.00
Date	1	2	12	1	7	13	23	15	3	12	24	22
Minimum	2.00	0.50	2.50	1.50	2.00	2.50	2.00	1.50	1.50	1.50	1.00	1.50
Date	22	1	23	6	26	9	15	17	11	7	10	25
Average Max. Temp in °C	30.44	34.52	37.27	36.56	41.35	40.20	37.50	37.52	35.17	34.37	32.34	29.94
Maximum	34.00	38.00	40.00	41.00	44.00	43.00	41.00	40.00	37.00	40.00	37.00	33.00
Date	2	14	29	28	11	2	4	22	1	30	31	24
Minimum	28.00	32.00	35.60	26.60	36.60	35.60	32.00	34.00	28.60	28.30	26.60	25.60
Date	21	2	14	5	2	29	23	9	7	27	11	18
Average Min. Temp in °C	22.10	29.86	28.07	25.97	29.76	32.74	29.37	27.53	27.35	25.80	20.82	21.03
Maximum	24.00	34.60	28.00	31.50	35.00	38.60	33.00	37.60	29.00	29.50	22.50	24.00
Date	21	19	24	13	29	6	14	20	28	31	4	2
Minimum	16.00	27.00	23.00	19.00	26.00	26.60	24.00	22.60	24.00	18.30	15.00	15.60
Date	12	1	3	6	3	30	16	27	5	28	17	27
Average Mean. Temp in °C	25.47	32.40	31.69	30.59	35.23	36.15	33.17	32.57	30.50	29.82	25.96	24.83
Ave. Relative Humidity in %	67.40	68.05	69.31	73.65	65.68	63.02	65.27	63.21	75.75	84.69	84.72	86.60
Maximum	96.00	88.00	89.00	92.00	85.00	96.00	85.00	85.00	97.00	99.00	98.00	96.00
Date	19	20	14	8	31	11	15	31	14	27	5	26
Minimum	32.00	41.00	42.00	31.00	38.00	36.00	41.00	38.00	58.00	62.00	69.00	63.00
Date	10	12	12	29	18	18	2	17	24	4	16	10
Ave. Wind Velocity in KMPH	2.64	2.71	3.66	3.27	4.02	6.01	5.44	5.25	3.02	1.57	1.06	1.84
Maximum	7.58	4.12	6.56	4.99	6.66	9.97	10.50	8.73	6.05	7.68	2.54	4.26
Date	16	19	13	1	28	18	28	1	20	28	21	19
Minimum	1.28	1.50	2.45	0.66	1.72	3.14	1.74	1.91	1.24	0.14	0.23	0.17
Date	11	1	19	6	31	8	18	29	4	25	12	5
Ave. Sunshine hours / Day	7.07	8.34	8.29	5.83	8.00	5.25	4.82	3.86	3.70	2.55	0.43	1.58
Maximum	10.00	10.00	10.00	10.00	10.00	11.00	9.50	9.50	9.50	8.50	4.00	4.50
Date	5	7	3	14	17	1	3	28	21	5	1	24
Minimum	0.10	0.00	1.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Date	21	20	13	4	9	8	10	5	1	10	5	3
Evapotranspiration in mm/day	4.68	5.44	6.30	5.52	6.77	6.04	5.64	5.17	4.17	3.21	2.38	2.42

RATES OF TAXATION

7.

0. The rate of tax shall be as below on each premise per annum :-
   i. Water tax 1.5% of assessed annual value
   ii. Sewerage tax 5.5.% of assessed annual value.

1. In the case of any land which is not appurtenant to any building or which is occupied by or appurtenant to huts the authorised authority may assess the land or premises, as the case may be, with reference to extent in lieu of annual value and at such rates as he may himself determine subject always to the following maximum per ground of land measuring 220 square metres.
   . Water Tax : Rs.1/-
   a. Sewerage tax : Rs.2/-

8. The authorized authority shall determine water tax and sewerage tax to which each premises or portion is liable per annum.

RAISING OF WATER AND SEWERAGE TAX DEMANDS AND PAYMENT CONDITIONS

9. The amount of tax determined under regulation 8 of these regulations shall be divided into two equal half yearly demands and levied each half year commencing on the 1st day of April and 1st day of October and ending on the 30th day of September and 31st day of March respectively. Save, as otherwise, expressly provided in these regulations the half yearly demand for water and sewerage tax is arisen within fifteen days of the commencement of the half year, which is payable as prescribed by the competent authority. The Board may also notify executive order for further extension of time for payment from time to time as it may consider appropriate.

10. The payment of water and sewerage tax shall be made as specified in the demand notice, water and sewerage tax card or as intimated by the Board from time to time.

10 (i) The Board shall levy surcharge at the rates specified from time to time for the belated payment of water and sewerage tax. Surcharge is being levied at 2% per month on recurring basis w.e.f. 1.10.1997 upto 31.3.2003 and 1.25% p.m. from 1.4.2003 onwards. In respect of appeal preferred by the assessees for revision of Annual Value, the allowable time for payment at revised rate would be 30 days from the date of receipt of order or from the date of intimation from the Board whichever is earlier.

ANNUAL VALUE

11. As long as the Board adopts the annual value specified in sub-section (3) of section 35 of the Act, it need not maintain separate assessment books and instead record in its tax ledgers, the annual value and tax payable in respect of each premises.

12. The Board shall enter in the assessment books the annual value of assessed premises and the tax payable thereon such assessment books shall also record the following particulars with regard to each assessable item.

DISCONNECTION AND RESTORATION OF WATER / SEWER CONNECTIONS

24. If any amount due on account of water tax and sewerage tax as determined under the Act and the regulations is not paid before the due date prescribed by the authorised authority, the Board shall issue a notice for cutting off water or sewer connection or both between any water or sewer works main or pipe line of the Board and the premises to which water is supplied or sewerage is provided giving a further grace time as decided by the competent authority.

25. If the taxes due to the Board are not paid even after the grace time as specified in the notices issued under Regulation 24, the authorised authority shall proceed to cut off water supply or sewerage connection.

26. Restoration of water supply or sewerage cut off under regulation 25 shall be done only after payment of the entire charges due together with a penalty of Rs.50/- (Rupees fifty only) and payment of all disconnection and reconnection expenses incurred by the Board. The authorised authority shall order reconnection after satisfying himself that all payments due have been made. The Board may at its discretion grant time for payment in exceptional cases.

27. Request by tenants that the owners are liable to pay the tax dues and hence disconnection of water supply need not be given effect to shall not be considered. Requests that water supply should not be cut off for non-payment on the plea that such arrears are due by previous owners shall not be considered.