WATER MANAGEMENT IN URBAN RESIDENTIAL DEVELOPMENT

A THESIS

Submitted in partial fulfilment of the requirements for the award of the degree

of

DOCTOR OF PHILOSOPHY

in

ARCHITECTURE AND PLANNING

by

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DECEMBER, 2009

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
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CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the thesis entitled **WATER MANAGEMENT IN URBAN RESIDENTIAL DEVELOPMENT** in partial fulfillment of the requirements for the award of the degree of Doctor of Philosophy and submitted in the Department of Architecture and Planning of the Indian Institute of Technology Roorkee, Roorkee, is an authentic record of my own work carried out during the period from July 2006 to December 2009 under the supervision of Professor R. Shankar, Department of Architecture and Planning and Dr. Deepak Khare, Professor, Department of Water Resources Development & Management, Indian Institute of Technology Roorkee, Roorkee.

The matter presented in this thesis has not been submitted by me for the award of any other degree of this or any other Institute.

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ABSTRACT

India's water crisis in urban areas is predominantly due to poor management of water. The growth of urban population is responsible for decreasing per capita availability of water, as the supply cannot be increased due to scarce raw water resources. On the other hand the per capita demand of water is increasing in urban area due to higher standards of living and lifestyle changes.

India's urban population is increasing at a faster rate. According to the 2001 census, about 28 % of Indian populations (about 300 million) live in urban areas. This figure expected to become double to 634 million or 46 % of the total population by 2030. The water requirements in urban area are expected to double by 2025-30. This is going to put immense pressure on the already strained centralized water supply systems of urban areas. A study by the Asian Development Bank (2007) showed that in 20 cities in India the average duration of supply was only 4.3 hours per day. No city had continuous supply. The situation will deteriorate if innovative water management is not adopted.

In an effort to tackle this situation, the government and NGOs have initiated various programmes, policies and projects. However, these efforts are not comprehensive. Proper utilization of site-specific contributions of different parameters of water resources management and planning are not practiced in India. It is observed that no statutory body has prepared a comprehensive urban water management plan comprising of all aspects of conservation of water and rain water harvesting along with reuse of treated waste water. It is also seen that appropriate approaches for urban water management are not considered and tested in India. The residential water requirement in urban area comprises more than 75 % of the total water demand but this sector is grossly subsidized and mismanaged. Therefore, there is an urgent need to investigate the possibility of urban management approaches and techniques to find out suitable options to solve residential urban water problems.

The design for the urban water infrastructure services is mainly driven by public health considerations, rather than environmental sustainability. The urban water management remains a complex and fragmented area relying on traditional, technical, linear management approach. Traditional approaches to urban water management provide little

emphasis on water efficiency, recycling, energy efficiency and protection of environment. The task of urban water management is not simply a water-engineering problem, but it is more a question of the integration of land and water planning, and management under new set of objectives for provision of water. The reorientation of urban water policy towards more sustainable directions with the use of different management practices and their wise combinations based on the local situation is necessary.

There are many significant research works done in the field of urban water system, urban water supply distribution and management, forecasting of daily water demand, urban runoff modeling, urban imperviousness runoff estimation, storm water and drainage network and management analysis and optimization of waste water systems, urban waste water management and treatment technology, water conservation, ground water recharge in urban areas, evaluation of residential water demand, decision support system for urban water management etc. But such research work in Indian context is limited due to the non-availability of relevant data on urban water provision. The comprehensive water management, low impact development approach and water sensitive design have been discussed and successes of such approaches are documented by several researchers in urban water management. But such approaches are rarely tried in India.

In urban area the centralized system of water supply doesn't consider different management approaches for different types of residential development for variable water requirements, technological options for water recycle and reuse, water harvesting and conservation potentials etc. Individual aspects of water supply, water demand, water conservation, water recycling are researched but comprehensive approach with integration of these elements to make the system sustainable are not considered in India. There is basically no policy guideline or institutional arrangement to achieve integrated approach of water management in different types of residential development in urban areas in India.

Therefore, study has been done to arrive at urban residential water management options with suggestion of suitable strategies and policy guidelines for efficient urban residential water management.

Reviews of different types of water management approaches and techniques have been done in general and urban water management in particular. The problems and prospects of Delhi's water situation have been studied through field survey with a view to evaluate the applicability of the urban management approaches and techniques as reviewed.

Primary field surveys were conducted in selected residential areas of Delhi to study the residential water use patterns and potential for sustainable water management in residential development. It includes three types of residential development like Plotted development, Cooperative Group Housing and DDA Group Housing development which have been selected from four sectors of Dwarka, a planned urban extension of Delhi. Primary sample survey has been conducted and results analyzed. Results of findings are appropriately used to formulate sustainable management options and measures for efficient water management in the three types of residential development. The findings also helped to estimate the water saving potentials for these developments. Water saving, space requirement and cost implications of the application of various management techniques on these residential developments are also evaluated.

It has been found that there is a substantial amount of water saving if techniques like rainwater harvesting, greywater recycling, water saving devices and metering is implemented in these residential developments. Techniques like water harvesting, implementation of water saving devices and metering is possible for all types of development with marginal cost implications. But the implementation of grey water system in plotted development is restricted due to space constrain and maintenance of such systems.

Finally policy guidelines are recommended for the efficient water management in these residential developments to address future water management in a sustainable manner and to overcome water scarcity and further deterioration ground water quality and quantity.

ACKNOWLEDGEMENTS

I express my immense sense of gratitude to my supervisors Prof. R. Shankar, Professor, Department of Architecture and Planning and Dr. Deepak Khare, Professor, Department of Water Resources Development and Management, Indian Institute of Technology Roorkee, Roorkee, for their invaluable guidance, thought provoking discussions and constant encouragement for the completion of my work.

The cooperation and help extended by the Head and all faculty members, Department of Architecture and Planning, Indian Institute of Technology Roorkee, Roorkee is gratefully acknowledged. I also want to thank my research committee members for providing me insight and constructive comments. I am highly obliged to the Director, School of Planning and Architecture, New Delhi for allowing me to peruse this research work. I also thankful to all my colleagues of Department of Physical Planning, School of Planning and Architecture, New Delhi for their constant support during my study.

I thankfully acknowledge the financial assistance provided by the All India Council of Technical Education (AICTE) under QIP for the present study. I specially convey my thanks to all the office bearers of the QIP Office in IIT Roorkee for their constant help and support.

I am highly grateful to the Director, Delhi Development Authority, Dwarka Project for providing me relevant information, maps and also his valuable discussing on the issues and problems of water management in Dwarka. I am also grateful to all office staffs in Dwarka Project Office. I am specially thankful to Mr. Sabayasachi Dass, Deputy Director, DDA; Mr Lalit Mohon, Executive Engineer, Engineering Wing, DDA, Dwarka for providing guidance and information about the water supply status in Dwarka.

I express my gratitude to all residents of Dwarka who provided me necessary information during my primary survey in Dwarka. Special thanks to Mr. B. B. Mandal, Mr. S.K. Bharadwaj, Mr. S.R. Halder and all other Secretaries and Members of Executive Committees of Residential Welfare Associations, Cooperative Group Housing Societies in Sector 6, 8, 9 and 19 of Dwarka. Besides providing necessary information for primary survey, they took their own time to introduce me with different people and groups. It was their help for which I could complete my primary survey within time.

I express my deep sense of gratitude to my wife Suchismita and daughter Prashita for their constant support and encouragement. Finally I express my gratitude to all my friends here in IIT Roorkee for help and encouragement.

(Rabidyuti Biswas)

TABLE OF CONTENTS

CHAPTER 4

URBAN WASTEWATER MANAGMENT AND TECHNQUES

CHAPTER 5

EXISTING WATER MANAGEMENT SCENARIO IN DELHI

CHAPTER 7

QUANTIFICATION AND ESTIMATION

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS AND ACRONYMS USED

BEE: Bureau of Energy Efficiency

BIS: Bureau of Indian Standard

CGHS: Cooperative Group Housing Society

CPCB: Central Pollution Control Board,

DCB: Delhi Cantonment Board

DDAGH: Delhi Development Authority Group Housing

DJB: Delhi Jal Board

GWR: Greywater recycling,

IWRM: Integrated Water Resources Management,

Lpcd: litres per capita per day.

MCD: Municipal Corporation of Delhi

MLD or mld: million litres per day

NBC: National Building Code

NDMC: New Delhi Municipal Corporation

NGO: Nongovernmental organisation

RWA: Residential Welfare Association

RWH: Rainwater Harvesting,

J.J. CLUSTERS: *Juggi jupri clusters,* basically slum clusters

CPHEEO: Central Public Health and Environmental Engineering Organization

BCM: Billion Cubic Mitres

PIB: Press Information Bureau

CHAPTER 1
INTRODUCTION

1.1 PRELUDE

The present world population is estimated around 6.5 billion and it is projected to increase to over 8 billion by 2025 (IPCC, 2000). It is also projected that by the year 2050 about one-third of the population in the developing world will face severe shortage of water. The water scarcity situation will get worse in the urban areas. It is projected that over 50% of the world's population will live in urban areas by 2015 (United Nations, 2004). The alarming rate of water scarcity coupled with widespread environmental degradation has brought into focus the need for planned action to manage water resources in a more effective way. Water has increasingly been recognized as (Bakir, 2004) (1) a valuable resource, for health and well-being of the society and its sustainable development to be ensured, (2) a finite resource, which must be used efficiently and wisely, (3) a renewable resource, which must be kept clean and its quality protected, and (4) a shared resource, which must meet the needs of competing users and future generations.

Parallel with this growth of population, the demand for drinking water is also increasing rapidly in urban areas of developing countries. The number of viable water resources is limited and has to serve competing requirements such as domestic, industrial, irrigation, fishing, navigation, tourism, recreational, ecological and waste disposal and assimilation. Therefore, in the macro environment, water planners, policy makers and managers face challenges of ensuring the optimal utilisation of available water resources in a sustainable manner (Kayaga & Smout, 2006). Water is a multiple-use resource and a key factor of development. Widespread mismanagement of water resources, growing use of fresh water, increased generation of waste water, uncontrolled pollution of sources and reduced recharge of ground water have increased the acuteness of the problems in urban areas. Moreover, urban development alters all aspects of water cycle i.e., the climate, the quantity, quality and regime of surface and ground water. Especially, the problems are acute in India, where the traditional water supply is not supported by innovative approaches and policy of urban water management.

According to the 2001 census of India, about 28 percent of Indian population (about 300 million) lives in urban areas. This figure is expected to become more than double to 634 million or 46 percent of the total national population by 2030. Urban areas are growing rapidly and require potable water. The government estimates that 80 per cent of urban Indians have access to safe drinking water this number hide more than it tells (Narain, 2007). According to the National Sample Survey Organization (NSSO) around 50 per cent of urban households do not have access to safe water. All urban local bodies responsible for water supply are facing challenges in providing adequate supply of water. The situation will deteriorate if innovative water management is not encouraged in urban areas of India.

India's water crisis is predominantly due to extremely poor management. The growth of urban population is responsible for decreasing per capita availability of water, as the supply cannot be increased due to scarce raw water resources. On the other hand the per capita demand of water is increasing in urban areas due to higher standard of living. The densification of population living in urban areas and associated construction of buildings results in increase in impermeable areas due to paving and roofs. These changes result in changes to runoff patterns, frequency of flooding and drainage problems in many urban areas. A large amount of wastewater is also being generated within the urban area of which only a small part is being treated and rarely the treated water is reused. Many Indian cities see no option except to find water from sources further and further away from urban area. This increases the cost of treatment and delivery of water and also leads to inefficiencies in supply, with distribution losses estimated to be in the order of 30-50 percent in almost all cities of the country. So there is less water to supply and less water for which full costs can be recovered (Narain, 2007).

In an effort to tackle this situation, the Government and Non Governmental Organisations (NGOs) have initiated programmes, policies and projects. These efforts are not comprehensive. Proper utilization of site-specific contributions of different parameters of water resources management and planning are not practiced in India. It is observed that no statutory body has prepared a comprehensive urban water management plan comprising of all aspects of conservation of water, rainwater harvesting along with reuse of treated waste water (Paul, 2002).

1.2 WATER SUPPLY SCENARIO IN INDIA

India occupies around 2.45 per cent of the world's land area, shares about 16% of the global population but it has only 4% of the world's total fresh water resource (Government of India, Planning Commission, 2001). The average annual rainfall in the country is about 1170 mm with an equivalent volume of rainwater of about 4000 billion cubic meters (BCM). After accounting for the losses for evaporation and evapo-transpiration, the average annual water availability has been estimated to be about 1869 BCM. However, there is a very high degree of variability both in space and time. Owing to the topographical constraints and hydrological features, only about 1123 BCM has been assessed as utilizable which comprises 690 BCM of surface water and about 423 BCM of ground water (PIB Press release, 2007).

Due to population growth, industrialization, urbanization and improvement in the living standards, the water requirement for various purposes is increasing year after year. As per the assessment made by the Standing Sub-Committee of the Ministry of Water Resources, Government of India, the water requirement could be in the order of 1447 BCM by the year 2050, which is much more than the available utilizable water 1123 BCM of India. The National Commission for Integrated Water Resources Development in India has assessed that even with the introduction of better management practice the ultimate water requirement would be in the order of 1180 BCM by the year 2050 (PIB Press release, 2007), which is still higher than available water. Therefore there should be alternative approaches to be adapted to reduce the gap.

India is one among the top 12 water poor countries with percapita availability of 1850 m^3 per person per year as against the world average of 7690 m^3 per person per year (Shah *et al.*, 2009). In 1947, percapita available water was measured at 5,150 m^3. By the year 2000, it was around 2,200 m^3. It has been recently estimated that by 2017 India will be water stressed and per capita availability will decline to 1600 m^3. As per the international standards, if the per capita water availability is less than 1700 m^3 per year then the country is categorized as water stressed. In India even per capita projected availability of water will further reduce to 1401 m^3 by the year 2025 and 1191 m^3 by the year 2050 (Bharadwaj, 2008). It is a matter of serious concern that water availability is dropping very sharply in India.

India has not been able to provide safe and adequate water supply for all. Around 20% of populations of India have no access to drinking water (that is about 230 million people) (USAID analysis based on 2001 National Census). Access to improved drinking water is only around 80 % (Census of India 2001) with urban 93% and rural 78% in India. Between 69 to 74 percent of India's rural population take their drinking water from protected sources, leaving an un-served population to 26 to 31 percent (Planning Commission, 2002). The quality of water is poor and most users that are counted as having access receive water of dubious quality and only on an intermittent basis. Water supply in India continues to be inadequate, despite longstanding efforts by the government and communities for improving coverage. The local government institutions in charge of provision of water are weak and lack the financial resources to carry out their functions, partly due to very low water tariff levels. The World Health Organization (WHO) estimates that diarrheal diseases, frequently associated with contaminated water, account for five percent of India's disease burden and 11 percent of its communicable disease burden.

In India, the water scarcity is also due to unregulated land cover and land use changes, unregulated urbanizations without proper understanding of geology and hydrology of the region, nil or partial solid waste management and waste water management, reduction of availability of fresh surface and ground water due to pollution and reduced recharge, absence of proper policies and water resource management system. About 85 % of rural population in India is solely depended on ground water, which is depleting at a fast rate. Depleting ground water table and deteriorating ground water quality are threatening the sustainability of both urban and rural water supply in many parts of India. It was even admitted in the 4th Five Year Plan (1969-74) that water related disease constitute nearly 80% of the public health problems in India. Every fifth Indian child under the age of five dies due to diarrhoea (Rao, 2007). Water related diseases are claiming the lives of about 1.5 million children below 5 years of age (Ramachandraiah, 2004).

Surface water development requires comparatively higher investment and long planning and construction period, on the other hand due to relatively low cost and generally high quality, groundwater has often been the preferred source for public water supplies and is widely exploited for private, domestic and industrial uses. Therefore, problems pertaining to groundwater over-abstraction have taken place in many cities. Groundwater plays a fundamental role in supporting the economic and social wealth of many urban areas, but the comprehensive statistics on the proportion of urban water supply derived from groundwater is not available. Intensive groundwater exploitation and massive effluent and waste water disposal from urban areas deteriorate the urban groundwater, including the local groundwater recharge areas and the groundwater quality.

1.3 URBAN WATER SCENARIO IN INDIA

It is reported that 93 percent of urban India now has access to safe sources of water (Census, 2001) but only 74 percent is covered by piped water network. However much of urban area is perennially short of water, especially in summer. Millions of households struggle on a daily basis to cope with problems that include inadequate and interrupted supply and poor water quality (Water and Sanitation Programme, May, 2007). In the urban areas though about 60% of the population is dependent on surface water sources but the availability and quality are questionable (Planning Commission of India, 2002). Unless drastic steps are taken water scarcity will become acute in near future in these urban areas.

The Central Public Health and Environmental Engineering Organization (CPHEEO) also estimated (2000) around 88 percent of urban population has access to a potable water supply. Even this supply is highly erratic and unreliable. The transmission and distribution network is old and poorly maintained. Consequently physical losses are high ranging from 25 to 50 percent. Lower pressures and intermittent supplies allow back siphoning which result contamination of water in the distribution network. Water is typically available for only 2 to 8 hrs a day in most of the Indian cities. The situation is even worse in summer when water is available only for few minutes in a day or not at al. A study of 20 cities in India by the Asian Development Bank in 2007 showed that the average duration of supply was only 4.3 hours per day. No city had continuous supply. The longest duration of supply was 12 hours per day in Chandigarh and the lowest was 0.3 hours per day in Rajkot (Figure 1.1).

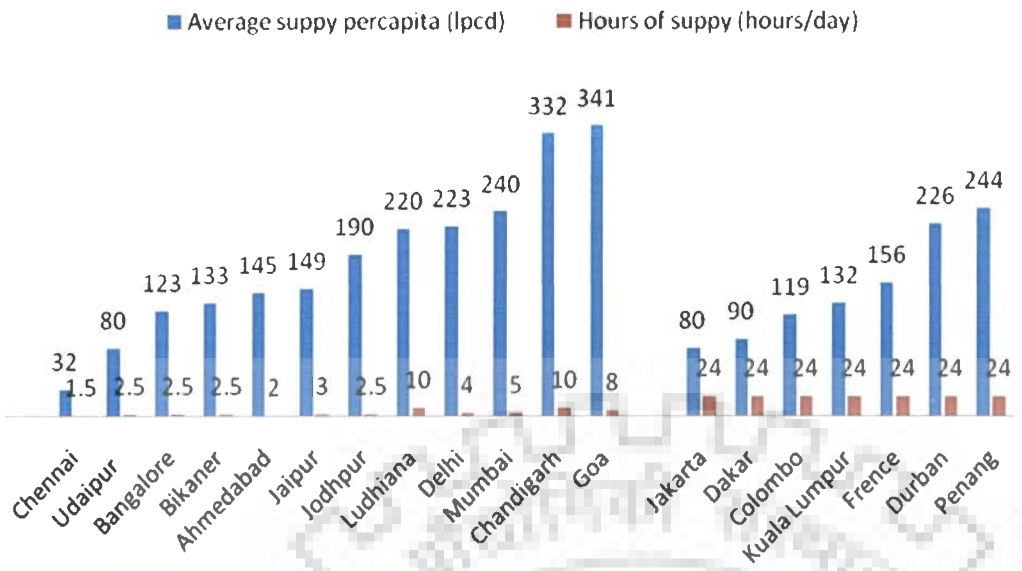


Figure 1.1 Comparison of water supply quantity and frequency in few cities.

Source: Ministry of Urban Development and Water and Sanitation Programme - South Asia, May, 2007.

1.4 WASTEWATER SCENARIO IN INDIA

Out of total about 5,161 cities and towns in India (Census, 2001), a mere 232 (only about five percent) have something resembling a sewerage network (Rao, 2007). India is literally drowning in its sewage. Indian cities generated 33,212 MLD of sewage in 2006, but had an installed capacity to treat only 6,190 MLD (CSE, 2008) which is around 18.6% only. According to the Central Pollution Control Board (CPCB) survey, (2006), the actual capacity utilization of the built STPs is only 72.2%. So while there is build capacity of 18.6% of the sewage generated, the actual treatment done is 13.5%. Around 86.5% of the sewage generated in India is not treated (CSE, 2008). Disposal of sewage from the rapidly growing cities of India have become a nightmare for civic authorities and planners. Untreated domestic wastewater has become the major pollutant of receiving water in urban area and reason for the spread of water-borne diseases.

Out of 300 Class I cities of India about 70 (23 percent) have partial sewerage system and sewage treatment facilities. The untreated wastewater pollutes rivers, lakes, streams, ground water coastal waters. The rivers thus can no longer serve as fresh water source to these urban areas as their self-assimilative capacities are exhausted. The coverage in terms of organized sewerage systems range from 35 percent in class IV cities to 75 percent in Class I cities. Total wastewater generated in 300 class I cities is around 15800 million litres a day (MLD), while treatment capacity is hardly 3,750 million litres per day, i.e. only 24 percent. Twenty three metro cities generate over 9000 MLD of sewage of which about 60 percent is generated in four metros (Mumbai, Delhi, Kolkata and Chennai). Of the total waste water generated in these four metros, barely 30 percent is treated before disposal (Planning Commissions, 2002).

In Mumbai, 90 per cent of sewage generated within the municipal council area and over 50 per cent in the municipal corporation area goes untreated and flows into the Arabian Sea and creeks. In Chennai, rivers Adyar and Cooum run polluted. In Delhi, river Yamuna is almost dead because of untreated sewage flowing into the river (Chauhan, 2006). India may not be able to afford the huge cost of treating all sewage, which is estimated to be Rs 76.55 billion, the actual requirement of funds may be higher as data on actual generation of sewage is not available for urban areas. In many cities people depend on private ground water for their needs. This is not accounted in the estimated total waste water. Delhi is an example where the city generates 3,864 MLD of sewage against Delhi Jal Board's claim of 2,940 MLD (Chauhan, 2006).

Sunita Narain of the Centre for Science and Environment argues that a water based disposal system with centralized sewage treatment facilities is neither environmentally nor economically viable for India (Brown, 2007). There is a need for some alternative to the present system of wastewater management and treatment. A decentralized approach must be encouraged with proper technical and economical feasibility.

1.5 URBAN DRAINAGE SCENARIO IN INDIA

The densification of population living in urban areas and associated constructions results in increase of impermeable areas such as paving and roofs. These permanent physical changes resulted in the changes to runoff patterns, frequency of flooding and created drainage problems in some locations (Jounathan *et al.*, 2005). In Mumbai, Kolkata, Hyderabad and Delhi, 70 year old storm water drainage systems are fighting pressures of urbanization. Most large cities in India are prone to flash floods. Mumbai alone has over a hundred flood prone areas. Even in the country's driest district, Jaisalmer, and in adjoining Barmer, floods killed over 150 people due to haphazard construction and choked natural runoffs (Mudgal, 2007).

Urban drainage is more about town planning and water management. Urbanization disrupts traditional watercourses and sewage and solid waste are dumped in natural drains, already burdened by erosion and silting. Typically, the flash floods kill and displace slum dwellers, disrupting livelihoods of the poorest (Mudgal, 2007). The creation of recharge zone, construction of storages can increase the replenishment of ground water which can be used for domestic purposes at the same time can reduce the problems of flooding. Urban drainage problems are never looked as the potential water sources for future.

1.6 REVIW OF URBAN WATER MANAGEMENT

The urban water management remains a complex and fragmented area relying on traditional, technical and linear management approach (Brown *et al.*, 2009). There is a growing awareness that conventional approaches to urban water management provide little emphasis on water efficiency, recycling, energy efficiency and protection of environmental values and are no longer sustainable (Wong, 2006). The task of urban water management is not simply a water-engineering problem, but it is more a question of the integration of land and water planning and management under new set of objectives for provision of water. As explained by Mouritz, *et al.*, (1999), the integrated urban water resource management implies the following:

- Planning with the total water cycle.
- Use of storage or retention approaches rather than a conveyance approach to storm water.
- Provide multiple uses of water facilities.
- Apply water-conserving strategies in the built form as well as landscape techniques.
- Seek to shift from centralized water and waste water system to decentralized system that provide enhanced opportunities for reuse and recycling options to be incorporated.

The reorientation of urban water policy towards more sustainable directions is closely connected with the use of demand management practices. This shift requires integration of engineering, environmental, as well as, social and economic aspects of water supply planning and management (Kolokytha *et al*., 2002). Brown *et al.,* (2009) analyzed the types of barriers in the implementation of the concepts of sustainable urban water management approaches. The analysis revealed that the barriers are largely socio-institutional rather than technical, reflecting issues related to community, resources, responsibility, knowledge, vision, commitment and coordination and paucity of targeted strategies for overcoming these barriers. Integration of technical and social viewpoints has received increasing attention in recent years but is rarely applied to the field of urban water management in general and water supply systems in particular. Mitchell (2006) suggests that 'new' forms of management emphasize 'demand management and supply, using non-traditional water resources and the concept of fit-for-purpose and decentralization'.

Some positive advances have been made in working towards sustainable urban water management, particularly in regard to technological advancement, Mitchell (2006) points out that sustainable urban water management (SUWM) could be considered as mainstream practice in the water and development industries. Wong (2006) suggested that to advance SUWM technologies, an understanding of the socio-institutional aspects of governance is required. It is within an environment of numerous socio-institutional barriers that emergent leaders known as 'champions' sometimes emerge to act as change agents (White, 2006) and work with others to promote the SUWM paradigm. It is also acknowledged fact that the leaders play a critical role in the delivery of sustainable urban water management. Taylor (2009), identified attributes of these leaders who were typically strong and/or distinguishing compared to relevant control groups, as well as influential contextual factors. He highlighted evidence-based strategies to build leadership capacity throughout water agencies. Such capacity is one of the elements needed to drive the transition to more 'water sensitive cities'.

In urban areas, the runoff is increased by impermeable urban surfaces and due to inadequate development control mechanisms and their incompetent enforcement, settlements are constructed with little consideration for stormwater drainage (Parkinson, 2003). The management of urban groundwater resources is directly linked to urban water supply and drainage concepts. A proper integration of groundwater into urban water management plans is recommended for long-term planning (Wolf *et al*., 2006). The management of urban groundwater resources is often neglected as they are frequently presumed to be polluted and not usable for drinking water purposes owing to quality restrictions. However, the quantitative aspects of urban groundwater management can also be of significance to the urban community (Wolf *et al.*, 2006). Lee *et al.*, (2003) had estimated urban imperviousness and its impact on storm water management. This study only depicts the accuracy aspect of runoff estimation using different level of detailed investigation and data collection. The issues of management of excess runoff with in the catchment area are not considered.

Imperviousness is one of the critical parameters for analyzing the impact of urbanization on the water resources in urban areas. To minimise the impact of urbanisation on water resources, it is necessary to reduce the impervious areas in the urban context. Lee *et al.*, (2003) estimated urban imperviousness and its impact on storm water management. This study only depicts the accuracy aspect of runoff estimation using different levels of detailed investigation and data collection. The issues of management of excess runoff within the catchment area are not considered.

It is a fact that many activities in our daily life do not require water as per drinking water quality standards. Even for these activities in urban areas drinking quality of water is used which is a wastage. Excess amount of water is being spent in many activities without proper consideration of water conservation. The water conservation implies the judicious use of water. Good housekeeping and maintenance of equipment play a major role in conserving water. Perkins (1989) discussed different aspects of water conservation in urban context. According to him the first step in conserving water use is to eliminate leaking plumbing system. To enhance conservation many devices are commercially available – like low flow shower, dual flush system used for flushing liquid and solid waste in the toilet, pressure reducing valves etc. Proper policies and incentives should be there to adopt such practices.

The recent advancement in computer technology and water resource modelling has led to significant growth in the development and application of Decision Support System (DSS) for water resource system. Westphal, *et al.*, (2003) developed a real time DSS for adaptive water supply management for a seven-day planning period and output based input of current weather forecast. It allows the planners to maximize or minimize as applicable to achieve objectives like 1) minimization of total organic carbon (TOC), 2) minimization of deviation from target elevation, 3) balancing the two reservoirs and 4) the maximization of revenues from three hydropower facilities, depending on the circumstances. Makropouls *et al.*, (2003) developed a Spatial Decision Support System (SDSS) for Urban Water Management (UWM) supporting strategic planning for a particular application in Water Demand Management (WDM) like leakage reduction, greywater recycling and compulsory metering. Alaa *et al.*, (2004) developed short time forecasting for municipal water use that utilizes a deterministic smoothing algorithms to predict monthly and daily use of water. To contribute to better knowledge and understanding of consumption pattern in urban water supply network, a stochastic model for residential water demand simulation is developed by Garcia *et al.,* (2004). Levite *et al.*, (2002), used the Water Evaluation and Planning Model (WEAP) for water demand management scenarios in a water stressed basin in South Africa. This model allows the simulation and analysis of users' behaviour and water demand management is one of the options discussed. Tong *et al.*, (2002), used a comprehensive approach involving statistical, GIS, as well as hydrologic modelling, to examine the hydrologic effects of land use at both regional and local scale. The objective of this study was to use a watershed-based approach to examine the plausible statistical and spatial relationships of land use on the quantity and quality of the surface water under a broad regional scale in the state of Ohio, and to model the relative impacts of different types of the land use in local watershed. Yang *et al.*, (1999), developed a multi-plan management of urban ground water with two optimization scenarios in order to alleviate and improve the environment, social and economic situation caused by over exploitation of ground water. Artificial recharge management, with conjunctive use of surface water and ground water, provide a practical solution to the overall groundwater exhaustion and led to a solution for water table recovery, aquifer protection and sustainable water management. A comprehensive water management strategy for decision making was developed to reduce the negative impacts of urban growth on water use.

Tony (1998) has done comparison of site yield, construction cost, maintenance cost and environmental implications of a 'conventional' and 'water sensitive' design layout for a parcel of land of approximately 3.3 hectares. This study does not cover the aspects of water reuse, waste water recycling etc. Escudero (2000) presented a solution procedure for multi-period water resources system planning, where the aim was to obtain the optimal policy for water resources utilization under uncertainty. The major parameters considered are related to reservoir capacity, hydropower demand and other demand for urban, irrigation, ecological and other purposes. It is an approach of conjunctive use of surface and ground water. A scheme is prepared to model the constraints to preserve the reserved stored water in upstream reservoir to satisfy potential future needs in demand at given time periods. There is a need to incorporate wastewater management systems within an integrated framework of water resource management (Parkinson *et al.,* 2003). Roach *et al.,* (2004) documented effective treatment trains using pre-filtering and other good design practices for water sensitive urban design in Australia.

The present dominance of centralized concepts for urban drainage and water supply in developed countries unquestionably does not comply with sustainable requirements (Kaufmann *et al.,* 2007). Alternative concepts of sustainable drainage (Sustainable Urban Drainage Systems - SUDS) and Decentralized Sanitation and Reuse (DESAR) have become more and more significant in recent years (Lens *et al.*, 2001). Decentralized and localized management of water is an innovative strategy (Kim *et al.*, 2008). During recent years, decentralized and integrated water management has developed into a remarkable strategy for sustainable and safe urban infrastructure (Kim *et al.*, 2008). Decentralized approaches also offer increased opportunities for local stakeholder participation in planning and decision-making. Parkinson *et al.*, 2003 emphasized the importance of building the capacity of local organizations in all aspects of decentralized wastewater management. Alternative approaches include decentralized rainwater infiltration, on-site treatment and wastewater reuse. All of these techniques also influence the urban groundwater resource in terms of quality and quantity and need to be assessed in a common framework (Wolf *et al.*, 2006). Present government approaches are not framed in a way that supports the development of decentralized systems in developing countries. Therefore there is a need to develop appropriate standards to be utilized for the design and construction of decentralized wastewater systems and also to promote realistic and acceptable standards for treatment where wastewater is reused. It also requires that these institutions develop capacities for monitoring and regulation and effective systems for enforcing appropriate policies.

Brown *et al.*, (2009) presented a typology of six city states, namely the Water Supply City, Sewered City, Drained City, Waterways City, Water Cycle City, and Water Sensitive City. This framework recognizes the temporal, ideological and technological contexts that cities change through when moving towards sustainable urban water conditions. The aim of this research was to assist urban water managers with understanding the scope of the hydro-social contracts currently operating across cities in order to determine the capacity development and cultural reform initiatives needed to effectively expedite the transition to more sustainable water management and ultimately to 'Water Sensitive Cities'.

Appropriate technology is being developed that helps us for better water management, but it appears that the real constraints for more effective management are institutional and social. It is recognized that the different aspects of urban water systems should be viewed in relation to each other, which requires the adoption of an integrated approach to urban water system planning, provision and management. The Integrated Urban Water Management (IUWM) takes a comprehensive approach to urban water services, viewing water supply, drainage and sanitation as components of an integrated physical system and recognizes that the physical system sits within an organizational framework and a broader natural landscape (Mitchell, 2006).

Mitchell (2006) reviewed case studies from Australia and found that it is certainly possible to successfully implement IUWM approaches, in a manner that is both technically sound and acceptable to stakeholders but still there is room for greater integration of the water supply, stormwater and wastewater components of the urban water cycle. Many steps along this path are available, including water recycling, water efficiency programs and water sensitive stormwater management and progressively these individual IUWM tools are being combined to create the integrated total system solutions that urban communities require.

There are also many research works done in the field of urban water system, urban water supply distribution and management, urban runoff modelling, storm water or drainage network and management, analysis and optimization of waste water systems, urban waste water treatment technology, ground water recharge in urban areas, evaluation of residential water demand, forecasting of urban water consumptions etc. But such research works in Indian context are limited due to the non-availability of relevant data on urban water provision in India. Though comprehensive water management, low impact development approach and water sensitive design have been discussed and successes of such approaches are documented by several researchers in urban water management, but such approaches are rarely tried and implemented in India.

1.7 STATUS OF URBAN WATER MANAGEMENT IN INDIA

In India development and management of water resources have been undertaken for specific purposes, like irrigation, flood control, hydropower generation and drinking water supply. There are highly centralized decision making and approval which affect the management of water supply and sanitation services. A majority of decisions are made in a very centralized manner at the headquarter level. The responsibility for water supply and sanitation at the central and state level is shared by various Ministries. Unlike in many other countries, there are no autonomous regulatory agencies for water supply and sanitation in India at the state or national level. In urban areas, municipalities, called Urban Local Bodies (ULBs) are in charge of operation and maintenance. Some of the largest cities have created separate water and sanitation boards. However, these institutions remain weak in terms of financial viability. The ULBs remain dependent on capital subsidies from state governments and tariffs are also set by state governments, which often subsidize even operating costs. There is no separation of accounts for different activities within a municipality, which can lead to the limited tariff revenues to be diverted for uses other than the operation and maintenance of the water and sewerage system.

The National Water policy, 2002 emphasizes integrated water resources development and management for optimal and sustainable utilization of the available surface and ground water, creation of well-developed information system, use of traditional methods of water conservation and non-conventional methods for water utilization and demand management. It also stresses on adequate institutional arrangement and involvement of people in project planning and participatory approach in water resource management. These policies are, to some extent, followed in context of regional water management or state level watershed management. But none of these policies are considered for urban water management.

As per the assessment made by the Standing Sub-Committee of the Ministry of Water Resources, Government of India, the water annual requirement could be in the order of 1447 billion cubic meters (BCM) by the year 2050. The requirement can be reduced with adoption of better management practices through improvement in efficiency. The National Commission for Integrated Water Resources Development has assessed that with the introduction of better management practices the ultimate water requirement would be in the order of 1180 BCM by the year 2050 (PIB Press release, 2007). The Standing Sub-Committee suggested the states to take some immediate necessary actions in respect of improving the efficiency of created facilities for water utilization for various purposes by adopting better management practices; planning and implementation of various projects/ schemes for conservation of water resources to meet the future requirements and augmenting the utilizable water (PIB Press release, 2007). These actions are basically for the agriculture, irrigation and industrial water use. No innovative approaches are considered for urban water management. Government has not taken any comprehensive policy decision to solve the urban water problems except increasing the supply to augment demand. Policy reforms are also needed in urban areas to provide secured water rights vested in individuals or groups of water users that increase incentives for investment, improve water efficiency, reduce the degradation of the environment and encourage flexibility in resources allocation (Basil, 2004).

Indian cities are fragmented and heterogeneous and it would be more adequate to consider water supply in terms of service available according to the areas to be provided services with decentralized solution (Llorente *et al.*, 2003). The solution lies in evolving a decentralized operational structure, with clearly defined service standard and accountability at each operational level monitored by a new regulatory setup on the lines of the power regulations. The municipalities are still giving priority to increase supply rather than to rational approaches towards demand management.

The total water requirement for a city based on an average per capita demand may not be realistic assessment when the different type of demand may require different quality of water. Bhave *et al.*, (2004) has shown in a study that it is economically feasible to construct dual purpose water supply system with advanced water treatment plant for achieving high quality water for drinking and cooking purposes leading to saving of capital and annual maintenance and repair cost of water treatment plant. Natesan (2004) used the capabilities of GIS in ground water targeting in Pernampet Block of Tamil Nadu. The parameters considered for assessing ground water potential were rainfall, soil, geology, geomorphology, land use, slope, drainage density and ground water level. To identify ground water potential zone, thematic map for each parameter was generated and overlayed with appropriate weightages. Both the studies do not cover the other aspects of the water management. Kaur *et al.*, (2004) developed a DSS to estimate sediment yields under prevailing resource management system and also proposed a linear programming based optimized land use plan for soil loss reduction from a test watershed in India. In this research other parameters of water management has not been discussed. The study also does not consider the issues of urban water management.

Many appropriate technologies of sewage treatment like the Up-flow Anaerobic Sludge Blanket Clarifier (UASB), *Lemna* System, Wetland System and *Karnal* Technology, in the context of Delhi have been discussed by Rohilla *et al.*, (2001). But the benefit, capacity, area requirement and location of these technologies have not been established and elaborated. Shah *et al.*, (2009) discussed the water use pattern in residential development in Mumbai. The findings from their analysis reveals that saving of 47% is possible if the water saving measures are adapted in such development. The analysis does not include the other management approaches like water reuse, dual supply systems, metering etc. in a comprehensive manner. Soni (2003) has estimated the population carrying capacity of Delhi based on the total water available. As per his estimation the maximum carrying capacity of Delhi is about 7.8 million people. To find out the figure he estimated the water availability basically based on existing river water, rain water harvesting potentials and ground water recharge potential and availability. His concept is an aggregated condition applicable to entire city and not considered any decentralised water management concept or any demand management situation which may further enhance the carrying capacity.

Asadi *et al.*, (2005) have done a study using Remote Sensing and GIS application along with the field study for evaluation of the impact of land use changes on the ground water quality on a part of the Hyderabad city. It is concluded that intensely developed residential and built up areas are experiencing deteriorating ground water quality compared to other land use classes of the study area, where the ground water quality is good and the main cause for deterioration is the improper handling and disposal of untreated or partially treated residential and industrial waste into open drains and surface water bodies. However this study doesn't suggest any measure to protect the ground water quality.

Master Plan for Delhi - 2021 (MPD - 2021) focuses on perspective plans for water along with other infrastructures. The emphasis has been given for new technology and a realistic standard of water supply for equitable distribution. But no management approaches and policies to solve the water problem of Delhi are discussed. However one of the published research papers (Khare *et al.*, 2006) has been included in MPD -2021 in the Annexure – A, page 148-149 as an example for water management by recycled waste water.

1.8 PROBLEM IDENTIFICATION

The world is not facing a water crisis because of actual physical scarcities of water. However, the world may face a water crisis in future because of wide spread and continuous mismanagement of water (Biswas, 2007). The world has enough water for current and foreseeable needs, if demand and supply is managed properly. Even though there is knowledge, experience and technology to manage water efficiently, these are widely ignored.

As a consequence of urbanization and associated environmental impacts, the issue of providing water services to the growing urban population is becoming critical in India. The challenges are more due to the urbanization associated with higher standards of living, which lead to increased per capita demand of water, depletion of conventional sources like surface and groundwater due to unregulated extraction of water and reduced replenishment of the groundwater. The quality of existing sources is also deteriorating due to pollution. In the absence of the policies and strategies for efficient water management at the demand and supply ends the country is expected to undergo transition from the present state of water stress to that of scarcity. To augment the increasing demand of water in urban areas today, there is no option except to search water source from further and further away from city, which would then increases the cost of treatment and delivery of water. It also leads to inefficiencies in supply, with high distribution losses estimated to be in the order of 30 to 50 per cent in almost all cities of the country.

The cost of supply and delivery is high due to procurement of water from long distance to supply water to urban areas. It is important to understand that if public agencies were to do full cost pricing and charge users the cost of water supply and waste disposal even then the rich may not be able to pay for the costs. This is because the current capital-intensive technological model adopted by our cities which requires huge investment in supply and treatment of water and waste.

The quality of life of a settlement can be judged by the conditions of the water supply and sanitation in the settlement. The growth of towns and cities of India in terms of population and area is rapid and the water demand in urban areas continues to increase but provision of water and sanitation facilities to these areas is difficult. Water distribution system in most of the urban areas in India is partly developed, poorly maintained and often operated under weak governance. Even if there is sufficient water, people face water scarcity due to misuse, wastage and mismanagement of water. The predominant solution for the scarcity is searching new sources away from the city without having any holistic approaches to solve the problem locally.

In urban areas of India almost 80 to 85 percent of water used for domestic consumption comes back as wastewater, proper handling of which is emerging as big challenge. Untreated waste water pollutes streams and become source of contamination of good quality water and creates health hazards. In addition to that precious and scarce water is lost that could be put to reuse of water in other activity where the requirement of quality of water may not be of potable quality. It has been observed that most of the water bodies which were earlier the sources of clean water for human consumption are transformed to polluted water bodies and not able to sustain even aquatic life, thus becoming major threat to the environment. Poor sanitation and poor wastewater management is the most common reason for environmental and public health problems in India. Unsanitary excreta disposal contaminate water resources by pathogens which are associated with diarrheal diseases causing deaths to many children in India. Last few years it became a real problem of managing storm water in urban areas and many cities are facing flood problems. This is due to increased in paved area leading to increase in storm water flow, reduction of ground water recharge and blockage of natural streams or surface flows and reduction of natural water bodies due to encroachments or construction activities. For efficient water management in the urban areas the ground water recharge and use should be balanced. Therefore for urban water management approach it is always necessary to include wastewater management and surface drainage management within the purview of the water management to ensure the sustainable approach to urban water management.

The city will have to learn to minimize its water use and work on conservation and reuse. It needs to plan carefully and reduce the water need in homes. There should be a bill that mandates household equipment to be water efficient. Though required nothing has been done in this respect in India, even the flush toilets still use more water than anywhere else in the world. The water utilities are to be improved; distribution losses should be plugged by reducing the length of the pipeline itself. A city will be much more efficient if it can adopt strategies to locally collect water, supply it locally and take back the waste locally.

Centralized wastewater management practices are based on the assumptions there are plenty of water which can be used by residents to ensure sewer flushing and self cleansing, water body receives the treated effluent and the effluent quality standards do not exceed the self purifying capacity of the water bodies and there is enough money to build these costly systems. These assumptions are not suitable for India. The high costs of centralized systems are unaffordable and dependence on treated water as a transportation medium is a wastage of resources and inappropriate. Moreover the sewer networks are overloaded and often suffer from siltation and blockages due to the long pipe network, low water consumption where water supplies are intermittent. The treatment plants are often added years after the construction of the sewer networks which also responsible for pollution of receiving water. The quality of their outputs falls short of expectations for the intended pollution control and recycling. Therefore Indian cities must look into the alternative innovative approaches for water management in total with integration of water, wastewater and surface water management.

During the twentieth century, the world's urban population increased more than tenfold, while rural population increased only twofold (United Nations, 2004). Water use in urban areas is directly related to economic development, social progress, and environmental conservation. The urban population growth, the water use in such urban areas has also increased rapidly. For developed countries, the technology and infrastructure are relatively well developed to handle the intensive water requirements of urban areas. However, in the developing world, the urban population growth rate always exceeds the growth rate of investments for water infrastructure. An integrated approach for better water management, including appropriate technology and legislation, is urgently needed for the urban areas in the developing countries.

The World Water Vision in its report also has accepted that there is a water crisis situation persisting in the world water scenario. But the crisis in not about having too little water to satisfy our needs, it is a crisis of managing water so badly that billions of people and the environment suffer badly (Bharadwaj, 2008). So a comprehensive water management approach should be developed and its validity for implementation should be demonstrated.

The United Nations estimate says that by 2025 A.D two third of humanity will face a shortage of freshwater. One of the millennium goals of the United Nations states that every person should have access to clean water by 2015. This goal is unlikely to be reached unless there is a considerable acceleration in the cumulative effort to improve situation. Today, population growth, depletion and contamination of ground water, scarcity of new water sources, competitive use of water and the increasing frequency of droughts are bringing about the intensive need to develop alternative schemes to manage water resources in an integrated manner (Kolokytha *et al.*, 2002). New approaches, even new mentalities are required with a sense of urgency to successfully face current urban water challenges – especially in developing countries (www.unesco.org/water).

The issue of proper management of wastewater also has not received adequate attention in India. As mentioned by World Commission on Water, less than 10% of wastewater is only properly treated. The lack of proper water and wastewater management in urban area has caused many rivers, which are in or near urban settlements to transform in to open sewers. The ground water is also becoming increasingly polluted due to inadequate wastewater treatment. The discharge of untreated domestic wastewater is the single major cause of water pollution in India. It is imperative to discontinue discharge of wastewater into such dwindling water resource and water management in urban area in India should properly integrate the aspect of wastewater management as a part of comprehensive approach.

There is a drastic imbalance between rate of extraction of ground water and its recharge in almost all urban areas. This has led to severe depletion of ground water and resulted in water scarcity in urban areas. The present pattern of extraction is unregulated and with no concern of sustainability of the resources. There are no monitoring systems or institutions to see that the rainwater harvesting is properly implemented and maintained to its fullest capacity. There is a water harvesting byelaw in many urban areas but implementation is not up to the mark. Reasons of non-implementation of such provisions need to be investigated and incorporated in urban water management.

Present planning process of urban water supply consists mainly of engineering solutions with only crude and elementary economic demographic and social analysis (Holtz *et al.*, 1978). The traditional paradigm of centralized urban water supply, sanitation and drainage systems dates back to the mid to late 19th century. The technical literature produced many examples of adverse economic and environmental impacts associated with this traditional approach to water service provision (Mitchell, 2006). Traditionally water supply technologies and system in urban areas have offered linear solution, drawing increasing volumes of water in to cities and discharging waste at ever increasing levels, thereby causing escalating stress on receiving environment (Mouritz *et al.*, 1999). The development of traditional water sources is also becoming more difficult. The past and present solution of the urban water problem will gradually become unable to solve similar problems of future and therefore innovative approach and solution are urgently needed which are environmentally desirable.

The provisions of water, wastewater and storm water services are linked to the land use planning and development control (Mouritz *et al.*, 1999). The urban runoff presents significant localized flooding problems. Management of runoff at community level should be given priority. It is necessary to investigate scientific and technical information on urban water management issues of a selected case study area and formulate sound policies leading to sustainable and integrated urban water management.

The traditional response to water demand has been the development of additional water supply. Little attention has been given to the objective of water conservation through the options that control and modify water demand (Kolokytha *et al.*, 2002). Water conservation can be achieved with proper policy for better water management and by offering cost effective technical options to consumers for reduced water use. The water users, as well as, the general public, who may affect and be affected by water management decisions, should be a part of the decision making process. Public preferences and trends should be included and taken into account in analyzing alternatives and their economic effect (Kolokytha *et al.*, 2002). It has been observed that no single initiative is enough to solve the problem of water in urban areas. Water technologies do not operate in isolation. The diverse approaches and plurality of programmes are needed to achieve the objective. Instead of a large water supply system, there are opportunities to decentralize the water management for smaller areas with the active involvement of the communities. A more integrated approach is needed with greater weight to the interaction among water provider and other policy areas. It is also felt that sustainability of water would depend on the interdependence on the measure or process that complement each other.

The important issues related to water resources in India is in the form of declining per capita availability of water, deterioration in quality, over-exploitation of ground water resources leading to lowering of water table in some areas, cost and time overruns in completion of projects and poor maintenance of the existing system. Further, natural disasters related to water i.e. floods and drought are also required to be addressed in proper perspective. Moreover the practice of sustainable urban water management and planning in India requires serious attention to (1) the access and use of analytical tools and adequate information for solving the problems, (2) the level of commitment of utilities and regulatory authority for considering and pursuing new water management options and stakeholders involvement and (3) the implementation of these approaches and methods within the real-world context by changing byelaws and regulatory practices. In the case of India though all these issues are important but use of analytical tools and models to solve the actual urban water management problems are restricted due to inadequacy of relevant data or information. Therefore, initially, there should be more demonstrations of application oriented approach for sustainable urban water management.

The comprehensive urban water resource planning should encompass the detailed study of effects and interrelations of parameters of urban water management, available technical, planning and policy options at different levels along with detailed study of available water resources, water distribution, consumption patterns, water pricing, management of storm water and flooding, rainwater harvesting possibilities, ground water recharge and exploitation, water conservation for future use, wastewater recycling and reuse and use of appropriate technology.

Therefore, this research will be dealing with the aspects and issues of the present approaches of water resource management in general and urban water management in particular and technological options available for water management in urban residential development. Selected residential development will be studied through primary survey and applicability of few water management techniques will be investigated. On the basis of the findings policy proposals for selected residential development will be given.

1.9 RESEARCH GAP

Urban water supply planning has changed greatly in recent decades, and has generally become a much more technically serious endeavour. Yet for all the serious and fine technical work and research on urban water supply engineering and economics, it often seems that such work has not provided a clear unified approach for combining the many technical measures available for water supply system planning and management (Lund *et al.*, 1998). The quantitative engineering methodology has improved the quality and cost-effectiveness of contemporary urban water supplies. However, new models for urban water supply engineering have not always been integrated in a way which expeditiously identifies highly promising combinations of diverse water supply management measures (Lund *et al.*, 1998). This observation is especially relevant in Indian context. Individual aspects of water supply, water demand, water conservations, water recycling etc. are researched but comprehensive approach with a combination of these elements to make the system sustainable is not considered in India.

In urban area the centralized system of water supply does not consider different management approaches for variable water requirements, technological options for water recycle and reuse, water harvesting and conservation potentials for different types of residential development. There is basically no policy guideline or institutional arrangement to achieve integrated approach of water management in different types of residential development in urban areas in India.

1.10 OBJECTIVES OF THE RESEARCH

In view of the above research needs, following objectives are outlined for the present study;

i. To study different approaches and technological options of water management in urban area.
ii. To study existing water provision and management in Delhi to understand the issues related to urban water management.
iii. To make analytical study of the present water use pattern of selected residential development of Delhi and assess the existing water management approaches.
iv. To evolve alternative water management approaches and asses their implications when implemented in the selected residential development.
v. To arrive at appropriate water management options along with suitable planning guidelines for efficient urban residential water management.

1.11 SCOPE

1. Different types of urban residential development will be analyzed to understand the approaches and technology options for water management. Different types of residential development include group housing and plotted development at individual or community level.
2. Sample study is done for different types of residential development in Dwarka, a sub-city of Delhi as a case study. Sample household questionnaire survey has been done to understand water related issues and options for the selected residential developments.
3. Some major water management techniques are investigated for efficient water management in urban residential development.

1.12 METHODOLOGY

The methodology followed in the present study is presented in Figure 1.2 as methodology flow chart.

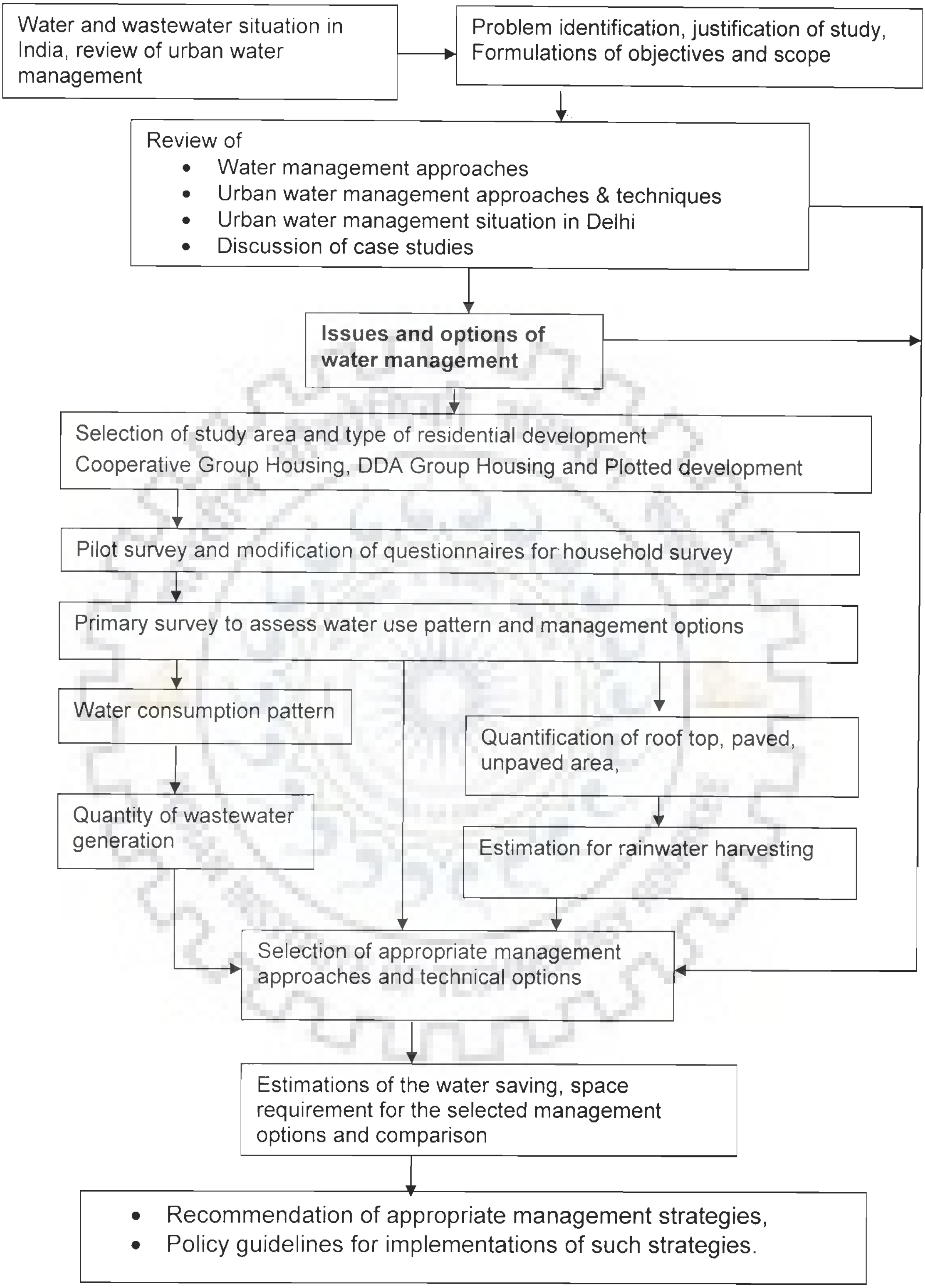


Figure 1.2 Flow chart of the proposed methodology

1.13 ORGANIZATION OF THESIS

Chapter 1:

This chapter is the introduction of the thesis. To understand the problems associated with water management situation in India a brief description of the water supply, waste water management and drainage scenarios are discussed in this chapter. Review of urban water management and status of management in India is briefly described to identify the problems on urban water managements and research gaps which have lead to the objectives formulation and scope of the research work. To achieve the formulated objectives a methodology flow chart is also proposed. This chapter is followed by extensive literature review in chapters 2, 3, 4 and 5 covering different aspects relevant to the thesis objectives.

Chapter 2:

This chapter discusses major water management approaches and urban water management approaches as practised in different situations and contexts based on available literature.

Chapter 3:

Urban water managements are associated with techniques and measures which are needed to be studied and understood for implementation any such management techniques. In this chapter few major techniques from literature and also from case studies are presented. The advantages and applicability of such techniques are investigated. Water savings, cost of the systems and space requirement associated with such techniques are also studied and presented.

Chapter 4:

Waste water management is an important part of integrated water management in urban areas. Therefore in this chapter the waste water management techniques and their advantages have been discussed.

Chapter 5:

With fair understating of urban water management approaches, techniques and measures form the previous chapters; the present water management situation in Delhi is discussed in this chapter. The problems, challenges and opportunities of water management in Delhi are discussed.

Chapter 6:

To understand the existing residential water management scenario in planned residential development and evolve approaches for efficient and sustainable water management in such residential developments four different types of residential development are selected as case study from Dwarka, a sub-city of Delhi. In this chapter the typology of residential development in Delhi, selection criteria and methodology of primary survey and analysis of data are explained.

Chapter 7:

In this chapter estimations for water saving, space requirements and cost associated with the different management options on the different types of residential development are presented.

Chapter 8:

On the basis of the findings of primary survey analysis and findings of estimated water saving, space requirement and cost implications due to the proposed management options water management strategies are formulated for selected residential development. Based on these strategies urban residential water management policies are also recommended followed by over all conclusions of the research work.

CHAPTER 2
WATER MANAGEMENT APPROACHES

2.1 PRELUDE

There may be two basic solutions to water problems (1) develop additional sources to increase the supplies through more dams and additional intake points, treatment plants etc. and (2) stretch existing supplies by reducing demand through water conservation and other water use efficiency measures. Traditionally, water management is focused on expanding or manipulating the country's supplies of fresh water to meet the needs of users. A number of large dams were built to increase the supply of fresh water for any given time and place. Water supply engineering was based on requirement approach. The water needs of any area were estimated based on per-capita requirements or demand and this was multiplied by estimated or projected service area population. This total water demand was then sought from a supply system. Other aspects of water demand management were not considered for future water requirement.

The fresh water supplies are scarce, over extracted and becoming unfit for use due to pollution. Water must be considered as a finite resource that has limits and boundaries to its availability and suitability for use. The finite water supply and existing infrastructure requires the demand to be managed more effectively within the available supply. Water must be planned, developed, conserved and managed on an integrated and environment friendly manner. Demand for fresh water is increasing as a consequence of a growing population and increasing demand in developing countries. By 2025 around 3 billion people are expected to live in places where fresh water is in short supply. The United Nations General Assembly and the World Summit on Sustainable Development, 2002 both highlighted fresh water as one of the key global issues of this century. They stressed the need for more effective water management around the world. To evolve efficient water resources management many approaches and policies on water management have been given priorities by different countries and world forums. Among these relevant major approaches of water management are discussed in this chapter.

2.2 INTEGRATED WATER RESOURCE MANAGEMENT (IWRM)

Integrated Water Resources Management (IWRM) has become the new paradigm for fresh water policy. The Global Water Partnership defines IWRM as a process that promotes the coordinated development and management of water, land and related resources in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems (IRC, 2004). It integrates land use and water management at a watershed level, to optimize economic, social and environmental outcomes simultaneously. The IWRM is approach towards a more comprehensive planning and management of water supplies. It also emphasizes the importance of establishing a more open and participatory decision making process and coordinating the water institutions that govern water resources. Thus, IWRM encourages the development of new institutional roles in addition to new analytical, technical and management tools.

Integrated water resources management is the practice of making decisions and taking actions with multiple viewpoints of how water should be managed. These decisions and actions relate to situations such as river basin planning, organization of task forces, planning of new capital facilities, controlling reservoir releases, regulating floodplains and developing new laws and regulations. It can be of structural measures and non-structural measures to control natural and human-made water resources systems for beneficial uses. IWRM needs the comprehensive consideration of aspects like technical, social, environmental, institutional, political and financial. Structural components used in human-made systems control water flow and quality and include conveyance systems (channels, canals and pipes), diversion structures, dams and storage facilities, treatment plants, pumping stations and hydroelectric plants, wells and appurtenances. The major elements of natural water resources systems of IWRM include the atmosphere, watersheds (drainage basins), stream channels, wetlands, floodplains, aquifers, lakes, estuaries, seas and ocean. Examples of elements of non-structural measures, which do not require constructed facilities, are pricing schedules, zoning, incentives, public relations, regulatory programs and insurance. However the integrated water resource management and planning is basically a regional approach of water management. The approach can be modified to the context of urban water management.

2.3 SUSTAINABLE WATER MANAGEMENT (SWM)

Sustainable development emerged during the late 1980s as a unifying approach which concerns about the environment, economic development and quality of life. The World Commission on Environment and Development (1987) defined sustainable development as the development that meets the needs of the present without compromising the ability of future generations to meet their own needs. This intergenerational perspective implies that we must use the water resources in ways that are compatible with maintaining them for future generations. Sustainable water management is an important element of sustainable urban development. In 2002, the World Summit on Sustainable Development, focused on five key areas: water and sanitation, energy, health, agriculture and biodiversity. The action plan included reducing by half the proportion of people without access to clean drinking water by 2015 (www.waterdome.net).

Regarding water management, sustainable development has generated attention on few principles. First, fresh water should be regarded as a finite and vulnerable resource. Effective management links both land and water across the whole of a catchment or groundwater aquifer and therefore effective management requires a holistic approach in which social and economic development is linked to the protection of natural ecosystems. Second, water development and management should be based on a participatory approach, involving users, planners, and policymakers at all levels. This also means that decisions should be taken at the lowest (most basic) appropriate level via open public consultation with and involvement of, users. Third, women play a central role globally in the provision, management, and safeguarding of water, therefore, women should have more opportunity to participate in planning and managing of water resources. Fourth, water has significant economic value and thus should be recognized as an economic good. However, it is also essential to recognize the basic right of all humans to have access to safe, drinkable water and sanitation. Yet current policies and practices often do not reflect these principles of sustainable water management. The basic human needs for drinking water and sanitation are not met for many people in various countries. Moreover, most countries do not treat water as an economic good. In many countries, water management is fragmented among many sectors and institutions, making it difficult to manage water holistically. Fragmentation also makes it difficult to integrate environmental, economic and social considerations, or to link water quality to health, the environment, and economic development. Water management often over-relies on centralized administration, with rare opportunities for local people to participate in planning, management and implementation.

The World Water Council, with headquarters in Marseille, France, was established in 1996 to provide global leadership for sustainable water management. The council promotes a holistic and participatory approach, combining development of new sources of water supply with economic incentives, especially pricing to encourage water conservation and to discourage wasteful water use practices. The council had led preparation of global and regional "visions" related to water use, development and management, as a first step toward ensuring water is managed systematically in the twenty-first century.

2.4 TOTAL WATER MANAGEMENT (TWM)

In the 1990s, total water management emerged as a potentially salient concept for water and wastewater utilities. Total water management reflects the philosophy that water resources should be managed for the greatest good of people and the environment with opportunities for participation in water policy by all segments of society.

While not strictly a planning model, total water management seems to encompass the basic principles of Integrated Resources Planning (IRP). According to a white paper by the American Water Works Association, total water management recognizes the paradigm shift from considering water available in unlimited quantities to a limited resource. Total water management seeks to inspire the water industry to embrace such ideas as sustainability, stewardship, unified water resource policies, watershed and ecosystem management, water conservation and the importance of public and political support for water management decisions.

Total water management recognizes that water resources are a part of numerous complex systems, both natural and social. These perspectives, present numerous intellectual, analytical and evaluative challenges. The term 'total water management' and its manifestations are more normative and prescriptive. There is also a concept of Total Water Cycle Management, which includes water supply (potable and non potable), storm water, groundwater and sewage services are interrelated components of catchment systems and therefore must be dealt with a holistic water management approach that reflects the principles of ecological sustainability. Water efficiency, re-use and recycling are also integral components of total water cycle management. The idea of managing urban water as a 'total water cycle' is confronting for it challenges traditional and technical management practices (Brown *et al.*, 2009).

2.5 WATER DEMAND MANAGEMENT (WDM)

Water Demand Management (WDM) may be defined as the policies, measures or other initiatives which serve to control or restrict the demand of water for use or waste of water supplies or other water services (Herrington, 2006). WDM is a practical response to the realisation that no supply strategies can cope with the present growth and demand even in the water-rich or the developed countries (Bakir, 2004). It is the implementation of policies or measures which serve to control or influence the amount of water used. It aims to conserve water by controlling demand, which involves the application of selective incentives and penalties to promote the efficient and equitable use of water.

Traditional supply oriented approaches proved to be insufficient to deal with strong competition for available water, growing per capita water use, increasing population, urbanization, pollution and shortages of funds. Water demand management is a new approach suggesting a fairly wide range of measures to cope with these problems (Kolokytha *et al.*, 2004). The demand management approach, successfully tried in many countries worldwide, focuses on manipulating the demands on water in a serious attempt to match them with the available water resources. Each nation's water resources must be protected, conserved, developed, managed, used, and controlled in ways which ensure efficient, sustainable and beneficial use of water in the public interest. In addition to developing and diversifying water resources, water conservation is also a key to ensure sustainable water supply.

Water demand management is often perceived as water conservation drives with efficient allocation of water amongst the competing groups of users to ensure that water supplies are used wisely and optimally in the public interest, increasing the efficiency of water use to eliminate wasteful consumption and reduce consumptive use of water while maintaining its social benefits, strengthening environmental protection policies and pollution control to safeguard the quality of the scarce freshwater and safely reintegrate wastewater into the water cycle as a component of the water budget of agriculture, industries, communities and households.

Water demand management aims to conserve water and as a result improves quality and quantity. This involves the application of policies like selected incentives to promote the efficient and equitable use and allocation of water. Measures of water demand management and conservation are technological, behavioural, economic and institutional. Selected measures should address a broader water management strategy that clearly defines the human and financial costs, capacity of the institutions responsible and the resulting benefits of implementation. Demand Management appears to be one of the main alternatives to control high increase in the demand.

Taking into account the political, environmental and economic changes that are happening throughout the world, towards the implementation of the main principles of sustainable water management, demand management is considered to be the best potential solution to meet future needs. The concept of demand management can improve the efficient and effective use of water supply resources (Kolokytha *et al.*, 2004).

The demand management approach calls for institutionalizing comprehensive, sustained and long-term water efficiency measures within the management practices of the water suppliers. It requires the water suppliers to play a proactive role and invest not only in improving the efficiency of the water supply systems but also in extending their responsibility to include efficient water use by the water consumers. The demand management is a more holistic approach in which several sectors of the society cooperate and where the water requirement is not viewed as technological approach to increase supply.

Water Demand Management (WDM), being a component of integrated water resources management (IWRM), promotes and balances efficiency, equity and sustainability objectives for the management and allocation of water resources. WDM covers a wide range of technical, economic, educational, capacity building and policy measures that need to be applied by water resource planners, water supply agencies and end-users. The economic, social and environmental reasons for WDM vary from country to country in terms of meeting basic human needs and providing affordable access to minimum supplies of water for that purpose (GWP-TEC8, 2003). So WDM is normally viewed as a useful tool in achieving IWRM (Goldblatt *et al.*, 2000).

2.6 LEAST COST PLANNING (LCP)

Least cost planning emphasizes a balanced consideration of supply management and demand management options in identifying feasible least-cost alternatives for meeting future water needs. Different definitions emphasize the minimization of rates, customer bills, utility revenue requirements and production (both capacity and operating) costs. The variety of available perspectives leaves open the question of whose costs are supposed to be least: existing customers, future customers, utility shareholders, or society at large. One of the implications of the concept of least cost is that it suggests a single, optimal solution. Regulators and utility managers do not necessarily have identical views about the meaning of least-cost planning. The regulators tend to view least-cost planning with an emphasis on conservation, whereas utilities tend to regard least-cost planning as an integrated supply-and-demand analysis.

In contrast to traditional supply planning, least cost planning gives much weight to the distinction between demand management and supply management activities, both of which can be used to achieve reliable goals. Least-cost planning recognizes that demand is flexible rather than simply a fixed input to planning models. The demand side involves any strategy to eliminate or defer the need for an investment in new capacity by the utility, including load management, conservation and pricing strategies. The supply side involves determining the most efficient method of meeting growing demand, including investments in new capacity. Integrated resource planning is a somewhat more encompassing term than least-cost utility planning, although the two are consistent and can be used interchangeably for many analytical purposes. In fact, the term 'least-cost integrated resource planning' sometimes is used. The concept of integrated planning evolved in part to address the potential misconceptions and complexities arising from use of the term 'least cost' as well as any unjustified bias against supply-side solutions.

2.7 CONJUNCTIVE USE OF SURFACE AND GROUND WATER

Both the surface and ground water are components of a single continuum of water sources. Excessive exploitation of aquifer can and often does cause the reduction of flow in adjacent stream. The full development of water resources in a region often requires the operation of surface reservoirs in a conjunction with ground water aquifers. Studies of basins illustrate the potential gains available from conjunctive use and management of ground and surface water. Ground water can be used to supplement surface flows when the flow is seasonally low. In the wet season, when the surface flows recover, surplus water can be released into the aquifer to recharge it. The conjunctive uses require the ability to transfer water between various parties, which may require the definition of rights and calls for an active management role for public authorities. The conjunctive use approach is basically regional approach of water management.

2.8 URBAN WATER MANAGEMENT (UWM)

The design for the urban water infrastructure services was mainly driven by public health considerations, rather than environmental sustainability and understandably, did not take due consideration of high population growth rates, high levels of urbanisation, industrial growth and climatic change or variability that are currently experienced. There are several major limitations with the conventional urban water management concept as identified by Kayaga and Smout (2006):

1. The traditional response to the ever increasing water demand is development of new water sources. This is not sustainable, as the number of viable sources in any country is limited and has to satisfy competing demands in other sectors. Furthermore, the costs of development of new sources and treatment of raw water are increasing.
2. Large quantities of water treated to high drinking standards are used for all household purposes in the urban areas. Yet, there are substantial differences in water quality and

quantities demanded for different uses in the household. Only drinking and cooking, which consume a small proportion of the total household demand, require high quality treated water. The other uses can be satisfied with poorer quality water, which could permit re-use of water from one application to another.

3. The use of large quantities of water for transportation of wastes results into massive wastewater flows, which makes the wastewater management not only difficult but also costly. This situation is aggravated by use of centralised wastewater treatment plants.
4. Many managers of urban water utilities do not fully appreciate the impact of their operations on the environment and do not recognise that every little in mitigating against environmental degradation helps. Put differently, environmental sustainability is not mainstreamed in the operational management of urban water utilities.
5. Where there are efforts to mitigate against environmental degradation, the efforts are mostly ad-hoc and often fragmented.

Today planning of urban water supply is a different challenge as compared to the past. The reliance on traditional approaches is not adequate. The challenges are due to rapid growth of urbanization, higher standards of living leading to increased per capita demand of water, new sources and reservoir are scarce, ground water sources are depleting in quantity due to unregulated extraction of water and reduced replenishment of the ground water, quality of existing sources also deteriorating due to surface water pollution and ground water pollution, and technological, economic and political problems of water procurement from other states.

Though there are many approaches for water management advocated in different parts but there is a distinct context for all these approaches. In the context of provision of urban water different approaches are available a few of which are discussed.

2.8.1 Integrated Urban Water Management (IUWM)

Integrated Urban Water Management (IUWM) takes a comprehensive approach to urban water services, viewing water supply, drainage and sanitation as components of an integrated physical system and recognizes that the physical system sits within an organizational framework and a broader natural landscape (Mitchell, 3006). IUWM places emphasis on demand side management as well as supply side management, utilization of non-traditional water resources and the concept of fit-for-purpose and decentralization, which appears in much of the literature discussing urban water and sustainability. It is also observed that the urban water management is becoming integrated with land use policy, town and landscape planning, the development approvals process, building construction, economics, regulation and legislation, education and social acceptance and community involvement (Mitchell, 2006).

Principles of IUWM are (as Mitchell, 2006): (1) Consideration of all parts of the water cycle, natural and constructed, surface and subsurface, recognizing them as an integrated system. (2) Consideration of all requirements for water, both anthropogenic and ecological. (3) Consideration of the local context, accounting for environmental, social, cultural, and economic perspectives. (4) Including all stakeholders in planning and decision making processes. (5) Ensuring sustainability, aiming to balance environmental, social and economic needs in short, medium and long term.

The key to IUWM is that individual processes should be planned and managed in such a way that the collective impact is minimized, and the collective system efficiency is maximized, as much as practically possible. There is a board range of tools that are employed within IUWM, which are not limited to water conservation and efficiency, water sensitive planning and design, but also include urban layout and landscaping; utilization of nonconventional water sources including roof runoff, storm water, grey water and waste water; the application of fit-to-purpose principles; storm water and waste water source control and pollution prevention; storm water flow and quality and management; the use of mixtures of soft (ecological) and hard (infrastructure) technologies and non-structural tools such as education, pricing incentives, regulations and restriction regimes (Mitchell, 2006).

Successes of IUWM include the translation of its concepts into well-functioning operational urban developments, significant reductions in the impact of the urban developments on the total water cycle, and the increasing acceptance of the concept within the water and land development. IUWM places an emphasis on demand-side management as well as supply-side management, utilization of non-traditional water resources, and the concept of fit-for-purpose and decentralization. This appears in much of the literature, discussing urban water and sustainability observed that urban water management was also becoming integrated with land use policy, town and landscape planning, the development approvals process, building construction, economics, regulation and legislation, education and social acceptance and community involvement (Mitchell, 2006).

2.8.2 Sustainable Urban Water Management (SUWM)

The sustainable urban water management (SUWM) is a shift to an adaptive, participatory and integrated approach. The SUWM can be considered both a philosophical and technical approach that can be incorporated in all forms of urban development. Internationally a growing body of urban water professionals is focused on transitioning to more SUWM as they respond to the challenges associated with environmental degradation, rapidly growing urban populations and the impacts from climate change (Brown *et al*., 2009).

2.8.3 Low Impact Development (LID)

Imperviousness is one of the critical parameters for the impact of urbanization on the water resources in urban areas. The current development practices tend to increase runoff, speeding the water into our storm drains, picking up automotive, fertilizer and pesticide pollutants along the way. It is necessary to reduce the impervious areas in the urban context. In urban areas with impervious surfaces everywhere, there are green methods of slowing and controlling runoff, allowing pollutants to be cleaned by the soil and limiting the amount of water that enters the combined sewer system during peak events. The low impact development is basically an approach of urban development sensible to water. The Low Impact Development (LID) can be used for any development site to manage and control storm water with simple process of allowing water to infiltrate the ground as much as possible or sit long enough to evaporate back into the atmosphere.

Low impact development strategies were introduced in a manual by the county of Prince George County in 1999 (Prince George's County, 1999). In LID urban stormwater can be controlled through a variety of methods of detention and retention instead of the conventional end-of-pipe or in-the-pipe strategies. The techniques used as LID are like (1) Green roofs or living roofs planted with vegetation that captures rainwater, (2) Pervious pavement, which is a surface interlocking pavers or porous cement that allows water to infiltrate, rather than quickly runoff, (3) Rain garden is a vegetated area engineered to capture as much as possible of the excess rainwater runoff from a house or other building, etc. and also (4) Implementing policies and regulations and doing things to get the development and engineering community to embrace the technology. The government can rewrite regulations and mandate certain things. Chicago, which leads in green-roof space, gives away green-roof kits to residents who are thinking about installing one. Seattle's department of public utilities has implemented many of the above practices in successful pilot programs (Thompson, 2007).

2.8.4 Water Sensitive Urban Design (WSUD)

Water Sensitive Urban Design (WSUD) is a new philosophy of water management being developed during the early 1990s within Australia that embraces sustainability principles to reduce the impacts of development on the total water cycle (Roach *et al.*, 2004). WSUD embraces the concept of integrated land and water management and in particular integrated urban water cycle management. It is about the integration of urban planning and development with management, protection and conservation of the water cycle as a whole. It is a balanced approach depends on site conditions and constraints to achieve sustainability through conservation, protection and recharge for whole water cycle management.

The water sensitive urban design is the application of a wide range of measures to manage the impacts of urban developments on the total water cycle (WBM Oceanics Australia, 1999). Any proposed development may have the impacts like increased stormwater runoff, which could impact downstream sensitive habitats in terms of flushing regimes (frequency, volume and rate), increased flood peaks, decreased water quality and wetting cycles; reduction in rainfall infiltration and decreased groundwater recharge; and disturbance of groundwater flow due to site compaction, fill, landform reshaping and underground structures. WSUD provides solutions to the negative impacts of any proposed development. Retardation of storm water discharge provides a store of water that could be used for toilet flushing or wash down water, where potable quality water is not required. Reduction of potable demand reduces dependence on remote water sources, possibly allowing more water to be made available locally and reduces the need for new dams to be constructed. Water sensitive urban design encompasses many different measures that have a range of suitable applications, resulting in many different realizations of this concept, depending on the site-specific conditions.

WSUD is the term used to describe a new approach to urban planning and design that offers sustainable solutions for integrating land development and the natural water cycle. It addresses a series of simple control measures such as land cover control, rainwater retention and conveyance control of storm water through infiltration and ultimately discharge controls through proper drainage systems for a sustainable catchment development right from residential cluster level (Sen, 2005).

Water sensitive urban design incorporates a chain of treatment elements to be undertaken in all catchment basins. When applied to the design and operation of urban layout at the site level, these ideas have been referred to as 'Water Sensitive Urban Development' or 'Water Smart Development'. Application of such models would also help reducing potable water demand, bringing down negative impact on environment and curtailing considerably the capital requirements for new infrastructure. Essentially, this alternative approach to resource sensitive site planning, forms a part of a broader framework of 'Ecologically sustainable development' (Sen, 2009). WSUD generally covers the following:

- ***Protect natural systems*** – protect and enhance natural water systems within urban development;
- ***Integrate storm water treatment into the landscape*** – use storm water in the landscape by incorporating multiple use corridors that maximize the visual and recreational amenity of developments;
- ***Protect water quality*** – improve the quality of water draining from urban development into receiving environment;

- ***Reduce runoff and peak flows*** – reduce peak flows from urban development by local detention measures and minimizing impervious areas;
- ***Add value while minimizing development costs*** – minimize the drainage infrastructure cost of the development.

In some cases the WSUD also maximize water use efficiency, reduce potable water demand, maximize reuse of wastewater and maximize the use of harvested water, minimized pollutant inputs through implementation of appropriate non-structural source controls.

A range of applications are available for the integration of WSUD concepts and technologies into urban developments. Types of WSUD techniques include (but are not limited to):

- Grassed or vegetated swales – primary treatment and conveyance function,
- Filtration trenches – primary treatment and conveyance and detention options,
- Bio-retention systems – secondary treatment, conveyance, detention and retention functions (through infiltration),
- Wetlands – tertiary treatment system, storage, detention, possible reuse options,
- Rainwater tanks – using storm water as a resource not a nuisance – detention, retention, a substitute for potable supply in garden irrigation, car washing, toilet flushing, etc,
- grey water reuse – collect from households, primary treatment on site, reuse for external irrigation or internal toilet flushing options,
- Rain gardens, rooftop greening, urban forests – provide natural vegetated features of aesthetic value and provide treatment function by filtering storm water or any combination of these and other techniques for the best possible outcome.

WSUD encompasses all aspects of urban water cycle management, including water supply, wastewater and stormwater management. WSUD is a multi-disciplinary approach that promotes opportunities for linking water infrastructure, landscape design and the urban built form, to minimize the impacts of development upon the water cycle and achieve more sustainable forms of urban development.

It depends upon a number of factors, including climate and rainfall, site topography, geology and available land. Steeper slopes make construction and sitting of larger wetlands and detention basins more difficult, particularly when located offline. WSUD measures such as swales, bio-swales along with smaller wetlands and detention basins are often considered more suitable for flatter environments, provided adequate attention is given to minimize erosion risk.

In general, the principles for WSUD aim to retain as much stormwater as possible on site, transport as little stormwater pollutants as possible to receiving waters, 'lose' an appropriate amount of stormwater as along the treatment train and slow the transmission of stormwater to receiving environments. The city of Canberra utilizes stormwater from detention basins for non-potable uses, reported as providing 6% of its total water needs in the mid 1990's (Anderson, 1996).

WSUD emphasizes a more decentralized approach of water management that is more in tune with natural environmental processes and the restoration of the natural water cycle in terms of surface runoff, groundwater and evapo-transpiration. WSUD emphasizes the near-source collection, treatment and use of water as part of an integrated management system.

2.8.5 Urban Water Supply Management (UWSM)

The water management approaches in the context of urban areas are supply side management approaches and demand side management approaches. The supply side management approaches include increasing the quantity of supply from existing sources – large projects (dams, reservoirs, long distance water transfers etc.), additional sources (rainwater harvesting for a larger context) or alternative sources like extraction of groundwater. The supply can be increased if we are able to increase the quantity of raw water, which can be done through increasing the quantity from existing sources or additional sources or alternative sources are searched like use of rainwater or extraction of ground water etc. The consequences of large projects are not always positive, especially when urban centres are far from the water sources. The unregulated extraction of groundwater in urban areas with rapid depletion and pollution of groundwater levels is a serious concern. Water harvesting is also not gaining proper momentum in most of the urban areas as an alternative source of water because of limited rainy days. The traditional supply-oriented approaches have proved to be insufficient to deal with strong competition for available water, growing per capita water use, increasing population, urbanization, pollution and shortages of funds (Kolokytha and Mylopoulos, 1999).

In the past, water planners commonly estimated growth in their regions over some time horizon (often a single forecast) and then recommended that the calculated demands based on this growth be met by developing new water sources. Water demands are met by a combination of practices, one of which is to develop new water supplies. Groundwater sources are tapped by wells and surface waters are pumped directly from rivers, streams and lakes. Other techniques for storing waters, such as aquifer storage and recovery, are available and they are becoming more popular. These systems operate on the premise of capturing excess waters and pumping them into underground reservoirs for recovery and use during times of need. The goal of water supply management is to meet the target demand. This may be achieved by making additional water sources available. The water supply management approaches are the processes by which the world's water sources are engineered to deliver adequate quantities of high-quality water to serve the forecasted needs of society.

Traditional supply management activities have focused on providing new sources of supply to meet future water demands. Dam-building has been an important component of traditional water-supply planning, and civil engineers have played a major role in the construction and maintenance of these dams. Forecast demand is taken as a given and virtually no attempt is made to integrate supply management and demand management options. The public-at-large, outside experts and government regulators generally have little or no involvement in traditional utility planning. Demand analysis and the assessment of supply alternatives take place within the utility (or a single planning unit within the utility); only the final product is made available for review or regulatory approval. The prevailing planning processes undertaken by water utilities have been internally driven and dominated by supply considerations. The result has been an emphasis on increasing water to be supplied and accordingly the engineering of facilities increased for source development, treatment and storage, transmission and distribution of water. Water planning generally takes the form of forecasting future demand and developing and analyzing supply options to meet the projected demand level, plus a comfortable margin. The result is a disaggregated planning approach focusing only on new supply alternatives.

2.8.6 Urban Water Demand Management (UWDM)

The urban water demand side management reduces misuse and increases efficiency by introducing pricing policies, compulsory installation of water meters, water conservation, water harvesting and its direct use to reduce the potable water demand, increase wastewater recycling and reuse, reduce leakages, increase the installation of water saving devices, maintaining pressures, maintaining 24X7 supply systems and by supplying the renovated water through dual pipe system where potable water will be supplied for drinking and cooking and non-potable water will be supplied for other uses. By limiting demand, resources are conserved and environmental impacts can be reduced.

The reorientation of urban water policy towards more sustainable directions is closely connected with the use of demand management practices. This shift requires integration of engineering, environmental, as well as social and economic aspects of water supply planning and management (Kolokytha *et al.*, 2002).The urban water demand management approach is to explore alternative patterns of growth and to make detailed estimates of the water needs associated with them. Rather than recommending new source development as the only way to deal with anticipated growth, analysis is made for the potential demand reduction in residential water use, reduction of wastage of water, recirculation of commercial and industrial water supplies, modification of industrial processes, upgrading inefficient agricultural irrigation systems, and developing landscapes that require less water to maintain.

Urban water demand management starts from a recognition of water as an economic resource and aims to optimize the use of existing supplies. It is any practice or policy implemented which results in water being used in a more efficient, equitable and sustainable manner. It ensures positive shift in water use behaviour and saves fresh water for other uses. The water demand management is difficult to practice because of the traditional approach of centralized and top-down management and difficulty to change people's attitude and behaviour in water use practice. These actions can be carried out either by water suppliers (water companies) or by customers themselves. The most commonly used measures, which have significant potential in reducing domestic demand or at least slowing the rate of increase in water demand, include water metering, water pricing and billing reforms, water saving devices, waste water reuse, household leakage-control, pressure reduction, water use restrictions, water rationing, water byelaws, standards, efficiency ratings of water use equipments, education programmes, training and advisory services which assist customers to take action to reduce their water use, financial incentives for installation of water efficient equipments.

Urban water demand management aims at achieving desirable demands and desirable uses. It influences demand in order to use a scarce resource efficiently and in a sustainable manner. The water demand management approach (also referred as soft path water management) refers to the use of improved techniques rather than large physical investment, in new water infrastructure such as dams, canals and well fields (Agthe *et al.*, 2003). The examples of soft path management in residential cluster may include: raising price of water to reduce the quantity of water demand; offering water bill rebates to encourage *xeriscaping* in new and existing houses and updating building codes for new construction and resale properties to force installation of low flow toilets, shower heads and faucets.

To follow the approaches to prepare a holistic plan for any municipalities the entire management should be vested with one single organization. The scientific and technological knowhow can be borrowed from other agencies. We need to evaluate the benefits of proposed alternatives, both structural and non-structural as well as to identify the optimal combinations of these alternatives (Holtz *et al.*, 1978).

2.9 URBAN WATER DEMAND MANAGEMENT IN INDIA

As a consequence of urbanization and associated environmental impacts, the issue of providing water to the growing urban population of India is becoming critical. Traditionally the solution is to draw increasing volumes of water into cities and discharge waste at ever increasing levels to the receiving environment. This approach has been found inadequate for water deficient urban environments in India, so there is urgent need to change from the existing supply side approach to an alternative water demand management approach.

Water supply systems in urban areas of India have offered linear solutions, drawing increasing volumes of water into cities and discharging waste at ever increasing levels, thereby causing stress on the receiving environment. The conventional supply management options for India's urban areas have been found to be inadequate. Water demand management techniques have been experimented within various situations, with positive results along with increase in supply in various parts of the world, but such techniques have not been applied in India to augment the demand supply gap of the urban water supply.

The studies related to the concept of water demand management are qualitative in India. Detailed investigations related to practical implementation, feasibility, economic analysis, water saving efficiency etc. are very few. The water conservation and demand management options include the use of low flow toilet fixtures, recycling of rainwater, and reuse of greywater for toilet flushing. (Suryawanshi, 2006; Gautam, 2006; Chakrabarti *et al.*, 2006; Jain, 2006; Khare *et al.*, 2006; Kapila, 2006). Khare *et al.*, (2006) demonstrated the feasibility of greywater recycling for a group housing apartment in Dwarka. They found that about 35% of the domestic water supply can be saved by using recycled greywater.

Kapila (2006) presented different type of treatment processes suitable for the wastewater recycling for industrial use. According to him the use of membrane technology, in particular using a membrane bioreactor in addition to tertiary treatment has been found to be suitable and economical for reuse of wastewater for non-potable uses. Further, with reverse osmosis treatment this can be used for potable purposes.

Gupta and Gupta, (2006) presented some of the successful examples of water conservation and recycling of treated wastewater achieved in commercial and official buildings across India. The ITC Green Centre, Gurgaon, has achieved a 40% saving of water through wastewater recycling. The office complex of Grundfos Pumps Private Ltd, Chenni, has also achieved about 40% saving in potable water use through recycling of wastewater. Detail studies of wastewater reuse and its integration with other water supply sources have not been reported.

In India, water management approaches are more traditional, supply oriented, centralized. Dam-building and sourcing water from a long distance for major cities are still considered the solution of adequate water provision. The crisis of water is viewed as a crisis of availability of water. Thus the solution is prescribed as increasing the availability of water for use i.e. in bringing more of the finite quantum of water available in nature into the usable category through supply side solutions in the form of big projects (Iyer, 2007).

2.10 CONCLUDING REMARKS

There are many water management approaches exists. These are applicable in different context and situations. Integrated Water Resource Management, Sustainable Water Management, Total Water Management, Least Cost Planning and Demand Management are basically regional concept; where as Integrated Urban Water Resource Management, Sustainable Urban Water Management, Low impact Development, Water Sensitive Urban Design, Urban Water Supply Management, Urban Water Demand Management are for urban area. Integrated Water Resource Management is a comprehensive approach includes environmental sustainability, economic and social welfare along with application of analytical, technical and management tools and institutional role. Urban water management approaches have given emphasis on the integration of water supply, drainage and sanitation component in sustainable water management in urban context. Aspects of decentralisation of water supply and wastewater treatment system, stakeholder involvements, water conservation, water use efficiencies, institutional involvement, awareness and education also have been given priorities. So there are both structural and non-structural approaches for water management in general and urban water management in specific.

There is a need to evaluate the benefits of proposed alternatives, both structural and non-structural as well as to identify the optimal combinations of these alternatives (Holtz *et* *al.,* 1978). The optimum integration of these techniques within conventional water supply systems in order to form a coherent water management strategy is necessary. The concept of demand management is widely gaining recognition worldwide. In many water-using sectors there is enough scope for water demand management, especially in India. In the context of urban water management it is well accepted that unless new technologies are socially embedded into the local institution, their development in isolation is insufficient to ensure successful implementation these techniques in practice (Brown, 2004; Elzen and Wieczorek, 2005). Therefore to address urban water sustainability issues, current research must consider both the technical and social dimensions of systems and understand that these are co-dependent, which is encapsulated by the term 'socio-technical systems' (Geels, 2004).

Water management institutions must also recognize that investment in water demand management is an effective investment in the country's water resources which can lead to better returns than investment in new water supplies. Water suppliers must play a proactive role not only investing in improving their efficiency in producing, delivering and distributing water, but also investing in ensuring that their customers use water efficiently. Many demand management approaches have been applied with positive results and the results of such approaches have been documented in many countries of the world. The integration of these techniques within conventional water supply system in order to form a coherent water management strategy is not being considered in any Indian cities. The studies related to the concept of water demand management are also qualitative in India. Detailed investigations related to practical implementation, feasibility, economic analysis, water saving efficiency etc. are very few.

CHAPTER 3

URBAN WATER DEMAND MANAGEMENT MEASURES AND TECHNIQUES

3.1 PRELUDE

Urban water demand management aims at achieving desirable demands and desirable uses. It influences demand in order to use a scarce resource efficiently and in a sustainable manner. The water demand management approach refers to the use of improved techniques rather than large physical investment in new water infrastructure such as dams, canals etc. (Agthe *et al.*, 2003). There is a need to evaluate the benefits of demand side management alternatives, both structural and non-structural as well as to identify the optimal combinations of these alternatives. The optimum integration of these techniques within conventional water supply system in order to form a coherent water management strategy is necessary. The concept of demand management is widely gaining recognition worldwide and its effectiveness in practice depends on the political will to implement the available possible measures. In many water-using sectors there is scope for water demand management especially in India.

3.2 REVIEW OF URBAN WATER DEMAND MANAGEMENT

The major water demand management techniques as implemented in different cities are as (Biswas, 2009) (a) **Economic techniques**: water pricing and tariff structure; tax benefit; and rebate (incentives) etc. (b) **Structural and operational techniques**: water metering; in-house retrofitting with water saving, flow controlling devices and fixtures; recycling and reuse of wastewater and rainwater harvesting; leakage reduction and dual supply systems etc. (c) **Socio-political techniques**: encouragement of water conservation; education and training, public awareness, in-school education, promotion of the advantages of all demand management practices, training and education of the staff in water related agencies; partial privatization of system; restrictions; rationing; affidavit requirement etc.; reduction of illegal connections; institutional measurements and effective legislation, regulations for water demand management and water reuse.

Economic techniques rely upon a range of incentives and disincentives (taxes, rebates, subsidies) to promote water conservation and demand reduction, aiming to change the behaviour of water users. Water pricing is a fundamental economic tool to influence water demand. The rebate programmes are used to promote water conservation and demand reduction and include water bill rebates, distribution of free toilet retrofit kits and council tax rebates. Structural and operational techniques used in different cities for water conservation and demand management are metering, toilet retrofitting with water saving devices, controlling flow, pressure reduction, leakage detection and repair, rainwater harvesting and wastewater recycling and reuse. Socio-political techniques refer to policy options to encourage water conservation and demand reduction, the creation of the institutional and policy environment that enables the reduction of water demand by the user. The commonly used socio-political measures are public awareness, information and education. Socio-political techniques also include the promotion of the advantages of all demand management practices and partial privatization of some parts of the water system.

The relative benefits of some of these techniques of water demand management in urban areas from different case studies from the literature are compiled and presented in subsequent sections.

3.2.1 Economic techniques

Pricing water as an economic good will discourage wasteful and environmentally damaging uses of water by encouraging conservation and protection of water. Water conservation is a key to enhance water use efficiency. The core of water conservation is rate structure that communicates the full cost of supplies of water, thereby encouraging water users to use less water in light of the cost of the water supplies.

Maddaus (1984), Renwick and Green (2000), Campbell and Johnson (1999) and Maddaus (2001) have assessed the outcomes of different demand management programmes and their implementation. Maddaus (2001) analyzed the effect of metering and variable charges of water. White and Howe (1998) and White and Fane (2002) evaluated the potential cost effectiveness of a range of demand management policies such as price increases, outdoor water use restrictions, shower head rebate, washing machine rebate, etc. considered for implementation at two locations in Australia.

Campbell and Johnson (1999) investigated the impact of various conservation measures on the water prices for the residential users in Phoenix, Arizona, during 1990 to 1996. The study shows that water price can be an effective conservation method. Another study shows that a 10% price increase reduces demand by 3.4% and increases revenue by 6.6% (Agthe *et al.*, 2003). The rate structure in Colorado reduced the residential water consumption by 19% during its first two years of implementation (Driver, 2002).

As per the study by Maddaus (2001) the water consumption declined by 13% in the year 1999, compared to what it was before the rate change in Davis, California. The studies by Maddaus (1984), Renwick and Green (2000), Campbell and Johnson (1999) and Maddaus (2001) were ex-post in the sense that they measured consequences of demand management policies after those policies were implemented. However, planning studies can be ex-ante in the sense that they analyze expected consequences before policies are implemented.

3.2.2. Structural and operational techniques

Metering, retrofitting and using dual systems are among the most popular structural and operational methods used to reduce water demand in the urban water sector. Leidal (1983), Barclay (1984) and Gumbo (1998) presented the results of using metering and other water saving devices, whilst Haney and Hagar (1985) indicated the water savings achieved by using dual supply and greywater systems. Greywater reuse systems have been investigated by Dixon *et al.,* (1999), Sayers (1998) and Nolde (1995), and the benefit of the system for water management are discussed. Water meter can be a useful tool in the effort to increase water efficiency in residence. Water meter is used to determine how much water is being used on a daily basis and to detect slow leaks. Domestic water metering and pricing are effective tools for reducing wasteful use of water and increasing water use efficiency. Water metering increases people's awareness of their water consumption and encourages consciousness. The rising block tariff structures have been used widely as disincentives for wasteful water use and incentive for efficient water use and have proven their effectiveness as water conservation tools especially when coupled with consumer education exercises. Metering and accurate volumetric measurement enables the service provider to monitor the water demand for various end-uses and take appropriate measures for managing the demand. When used with an effective tariff structure, metering has been found to be a powerful incentive to reduce water consumption. For instance in 2001 Canadian residential water consumers whose house connections were not metered and who paid a fixed or flat rate used an average of 474 litres/person/day, which was 74% more water used, compared to Canadians charged on volume-based water rates (Environment Canada, 2004). Maddaus (2001) analyzed the effect of metering and variable charges of water based on its use in Davis, California. Maddaus's review of the literature indicated that the installation of water meters typically reduced the water demand in the range of 10 to 30% and sometimes as high as 50%. Studies for metering cities in British Columbia, Canada present evidence for a 15-20% reduction in residential water use (Leidal, 1983). Preliminary results from analysis of metering programmes in New York City report 12 to 25% savings (New York City, 1997). Washington experienced a 43% reduction in water consumption during peak summer months as a result of a metering programme and an aggressive pricing structure (Water Conservation Guidelines, 1993).

Retrofitting plumbing fittings, such as installing low volume water closets and low volume shower roses, reduce overall water use by 25% of domestic water consumption (Gleick, 2001). Residential retrofitting resulted in a 20% drop in water use in Ontario, Canada by using water saving devices (Barclay, 1984). Dual systems or 'greywater systems' can save up to 39% of water for indoor uses (Haney and Hagar, 1985).

Gumbo (1998) estimated the quantity of water used for flushing, which constitutes about 30% of total domestic water use. Adjusting floats in existing installations or simply putting one or two standard bricks in the cistern would reduce cistern capacity by 10% or more. Federal law in the US prohibits the sale of toilets that exceed a maximum water flow capacity of 1.5 gallons (5.7 litres) (Agthe *et al.*, 2003), but in urban areas of India the majority of people use toilet cisterns with a capacity of 10 to12 litres, which uses water of drinking water quality for flushing.

Maddaus (1984) presented many studies comparing water conservation programmes. Results of the several (water conservation) demonstration projects have been presented, which include the effects of water-saving fixtures, water pressure and water metering on household water use. The principal quantitative results presented by Maddaus (1984) have been summarized in Table 3.1.

Table 3.1 Results of water conservation measures (Maddaus, 1984)

Water conservation measure	Observed water savings
Installation of water meters	20%
Fix toilet leaks	36.34 litres per capita per day (lpcd)
Shower head @ 0.5 gallon (1.9 litre) per minute	52.23 lpcd
Shower head @Three gallon (11.35 litre) per minute	27.25 lpcd
Retrofit kits	15.1 to 26.5 lpcd
Water efficient washing machine	6.43 lpcd
Water efficient dishwasher	3.78 lpcd

Renwick and Green (2000) presented the results of various California water conservation programmes and the effects of each (restrictions, rationing, retrofit kits, a public information campaign, rebates and affidavit requirement) on residential water consumption. Retrofit kits were distributed for free, which included low-flow showerheads, tank displacement devices and dye tablets for leak detection. This measure resulted in a 9% reduction in residential consumption.

Greywater is normally collected from hand washbasins, bathtubs/bathrooms, washing machines and dishwashers (Khare *et al.*, 2006). Several filtering methods are available to treat the greywater before it is collected in a storage tank. The water is pumped into storage at a higher elevation and then distributed by gravity. Greywater contains less organic matter and pathogens than wastewater from a mixture of sink and toilet waste residue. Thus greywater can be reused for domestic purposes such as toilet flushing and irrigation. Greywater reuse systems have been investigated (Dixon *et al.,* 1999; Sayers,

1998) in several countries and there are also systems in the market that allow houses to be retrofitted with greywater recycling systems. The technology used varies among different countries. Greywater is treated to higher levels and applied to larger housing estates in Germany and the UK (Nolde, 1996; Dixon *et al.*, 1999; Sayers, 1998).

Various qualitative and monitoring studies conducted by Haney and Hagar (1985), Nolde (1996), Naisby (1997) and Khare *et al.*, (2006) have demonstrated the various aspects (efficiency, treatment required, type of treatment) of greywater reuse. Theoretically, greywater can replace the water required for toilet flushing. This can constitute up to 34% of a household's total water consumption (Haney and Hagar, 1985). Haney and Hagar (1985) reported a reduction of 39% in main water supply through indoor uses of greywater, while Khare *et al.*, (2006) estimated 35% reduction for a group-housing residential development in Dwarka, India. Sayers (1998) claimed that domestic main water supply demand could be reduced by 30.6% through the reuse of greywater and Karpiscak *et al.*, (1990) claimed that about 31% of the total water budget can be recycled as greywater, representing the largest source of water savings. Smerdon *et al.*, (1997) estimated that about 30% of water usage could be saved if a greywater system was installed. Karpiscak *et al.*, (1991) described a desert house in the US where water-conserving fixtures, greywater recycling and water harvesting reduced potable drinking water use by up to 50% without major expense or change in lifestyle.

Dube and Zaag (2003) shed light on some of the possibilities and constraints of both choices, whether to go the demand management route or to continue constructing new infrastructure through a case study of the city of Masvingo in Zimbabwe. The paper first looks at the long-term water use pattern of the city as a whole and the factors which have caused the observed pattern using multiple linear regressions. In projecting future demand, the paper then considers a number of interventions that could influence demand, which include leakage control, pressure management, awareness campaigns, free technical advice to water users and a new tariff structure. Water losses in the city are around 15%. Some of these losses are the result of high static pressures, pipe bursts, leaking valves and reservoirs and water treatment processes. It was necessary to reduce pressures to between 30 and 60 m in order to reduce water losses by at least 7%. Using the flow balancing and pressure reduction techniques, combined with separate grey water and black water systems (which increases the efficiency of operations of sewage treatment facilities and avoids dilution of nutrients) recycling can be achieved at a cost comparable to conventional systems despite the additional infrastructure required (Speers *et al.*, 2000).

Burn *et al.*, (2002) analyzed the effect of employing demand and pressure management techniques on the cost of a water supply system. The analysis was based on the cost of supplying a cluster of 4000 households serving a range of hourly demands using pipes of various pressure classes. Demand management reduces costs by 25-40% and pressure management increases the savings further to 55%.

Water conservation can increase water use efficiency and the core of water conservation is rate structures. Cyprus has taken conservation measures at household level by encouraging the reuse of greywater for watering gardens and flushing toilets, reducing per capita water consumption by up to 40%. In 2007, government subsidies covered 75% of the cost of the system (Commission of the European Communities, 2007).

Growth in freshwater demand in urban areas can sometimes be met by rainwater reuse. Rainwater harvesting as a source of potable water is common in many parts of the world since ancient times (UNEP, 1998a). It is particularly suitable to locations where the average rainfall exceeds 400 mm/year and other sources of water are scarce and or of poor quality (Lye, 2002). This source of water is currently widely utilized in both developing and developed nations. Rainwater harvesting is common in many countries throughout Asia and Africa (UNEP, 1998a, b). Currently in China and Brazil, rooftop rainwater harvesting is being practiced. Gansu province in China and semi-arid north east Brazil have largest rooftop rainwater harvesting projects ongoing. It has been estimated that approximately 40% of households in South Australia use rainwater harvesting as their principal supply of drinking water (Heyworth *et al.*, 2006) and also in the USA (Olem & Berthouex, 1989). In Toronto and Canada some residents use treated harvested rainwater for drinking and reuse water (treated wastewater) for all other household water applications including toilet flushing, bathing, showers, laundry and gardening (Toronto Healthy House). In New Zealand, many houses away from the larger towns and cities routinely rely on rainwater collected from roofs as the only source of water for all household activities and rainwater is also an important source of drinking water in some regions of New Zealand (Simmons *et al.*, 2001).

Rainwater harvesting or storm water harvesting from streetscapes has also been considered as viable, cost effective form of water recycling for small to medium developments. Rainwater tanks can be a sustainable solution for the control of heavy runoff (Kim and Han, 2008). So it is observed that rainwater harvesting is appropriate in many parts of the world, such as China, Brazil, Thailand, Sri Lanka, Germany, Australia and India, where there is enough rain for collection and conventional water resources either do not exist or are at risk of being over used to supply a large population. Rainwater harvesting can provide lifeline water for human consumption, reduce water bills. Walavalkar *et al.*, (2008) have found that the rainwater if stored properly and away from the sunlight does not get contaminated even by the microbes. Despins *et al.*, (2009) studied about the quality aspects of rainwater harvesting in seven sites located in Ontario, Canada. The results indicate that, while quality can be expected to vary with environmental conditions; the harvested rainwater can be maintained at consistently high quality through the selection of appropriate catchment and storage materials and the application of post-cistern treatment.

Rainwater harvesting is certainly a viable option when it comes to watering gardens and the techniques can range from simple to sophisticated technical solutions. For example, rainwater harvesting is used in a housing project in Nottingham, UK where some of it is treated to a potable standard. In a similar analysis, reusing harvested roof water for toilet flushing and cold-water laundry washing was also found to be viable. In Germany, one fifth of the biggest cities have been supporting rainwater harvesting for more than 10 years with the objective of equipping 15% of buildings by 2010 (Commission of the European Communities, 2007).

Outdoor water uses account for about 54% of total residential water use in the Denver area, most of which goes toward turf irrigation. Xeriscaping offers a much lower water using alternative, which incorporates principles to promote quality landscapes, water conservation, and environmental protection. Xeriscaping saved over 20 gallons per square foot during each watering season as observed in El Paso, Texas (Driver, 2002). Drip irrigation, which usefully applies 30 to 50% less water than sprinkler irrigation and still meets the requirements of most plants (Driver, 2002).

3.2.3 Socio-political techniques

During 1976-77 in California, restriction on selected uses of water and rationing plans were reported to reduce water use by up to 65% (Dziegielwski, 2003). Restrictions were also covered as part of Renwick and Green's (2002) analysis of California water conservation programmes which include the prohibition of certain water uses, such as washing down sidewalks or driveways and banning landscape irrigation during peak evapo-transpiration hours, which achieved a 29% reduction in consumption. In rationing, a fixed quantity of water was allocated to each household and severe marginal price penalties were imposed for exceeding the allotment. This measure reduced the residential consumption by 19%. The public information campaign helped in alerting households to shortages, attempted to motivate more water efficient behaviour and provided information on ways to reduce the usage. A reduction of 8% residential consumption was observed from this measure. Various demand management methods and corresponding savings in water demand have been compiled in the present study and given in the Table 3.2.

Table 3.2 Relative benefits of water demand management techniques on water saving.

	Demand management measures/ techniques	Saving in water demand	Author/references
A	Economic techniques		
1	10% price increase	Reduced demand by 3.4% and increased revenue by 6.6%	Agthe *et al.*, 2003
2	Increase in price	13%	Maddaus, 2001
B	Structural and operational techniques		
3	Residential retrofitting	20%	Barclay, 1984
4	Dual systems or greywater systems	39%, Indoor uses	Haney and Hagar, 1985
5	Greywater system installed	30%, 35%	Smerdon *et al.* 1997, Khare *et al.* 2006

6	Fix toilet leaks	36.34 lpcd	Maddaus, 1984
7	0.5 gallon (1.9 litre) per minute shower head	52.23 lpcd	Maddaus, 1984
8	Three gallon (11.35 litre) per minute shower head	27.25 lpcd	Maddaus, 1984
9	Water efficient washing machine	6.43 lpcd	Maddaus, 1984
10	Water efficient dishwasher	3.78 lpcd	Maddaus, 1984
11	Installation of water meters	10-30% Sometimes as high as 50%, 15-20%, 43%, 20%	Maddaus , 2001; Leidal, 1983; Water Conservation Guidelines, 1993; Maddaus, 1984
12	Putting one or two standard bricks in the cistern	3%	Gumbo, 1998
13	Water saving fixture, greywater recycling	Up to 50%	Foster, 1991
14	Recycling of wastewater	40%	Gupta and Gupta, 2006
15	Reduction of supply pressure	7%	Dube and Zaag, 2003
16	Pressure management	25-40% cost reduction	Burn *et al.*, 2002
C	Socio-political techniques		
17	Restriction on selected water use and rationing plan	65%, 48%	Dziegielwski, 2003; Renwick and Green, 2000
18	Public Information Campaign (PIC)	8%	Renwick and Green, 2000

Source: Compiled by author from various sources

3.3 RAINWATER HARVESTING

The capture and storage of rainwater for subsequent utilization is called rainwater harvesting. It is the collection and storage of rainwater from roofs or from a surface catchment for future use. The water is generally stored in rainwater tanks or directed into mechanisms which recharge groundwater. Rainwater harvesting in urban areas can supplement water for city's water requirements, increase soil moisture levels for urban greenery, increase ground water table through artificial recharge, mitigate urban flooding and also improve ground water quality by dilutions. Rainwater is directly harvested for domestic (household) consumption in more than one hundred countries, both in arid regions where water is scarce and in humid regions where precipitation is easily captured. Traditional rainwater harvesting systems include a rooftop and storage tank (Figure 3.1). Improved systems include water harvesting from all paved surfaces like road, parking and even unpaved area, paved hillsides, airport runways etc. Then water is filtered, disinfected and reused. Automated monitoring and computer controlled systems are also used in some parts of Japan and Scandinavia for rainwater harvesting and use.

In urban areas of developing countries at house level harvested water can be used for flushing toilets and washing laundry. Where ground water is hard the rainwater is much better option for washing and other nondrinking water use. The treated rainwater can be supplement to drinking water. If the harvested water is used for toilet flushing and other non-potable applications substantial amounts of fresh drinking water can be saved which need not be produced and remain in reserve for use in the dry summers. Utilizing rainwater as it comes during the rainy season will eliminate the need of costly large rainwater storage cisterns and make it appealing to the householders.

3.3.1 Components of urban rainwater harvesting system

There are two main techniques of rainwater harvesting in urban areas: a) Storage of rain water for future use, b) Recharge to ground water.

A typical rooftop rainwater harvesting system (Figure 3.1) comprises of a) Roof catchment, b) Gutters, c) Downpipes, d) Filter, e) Storage, f) Rainwater/Storm water drains, g) Ground water recharge structures like pit, trench, tube well or combination of above structures.

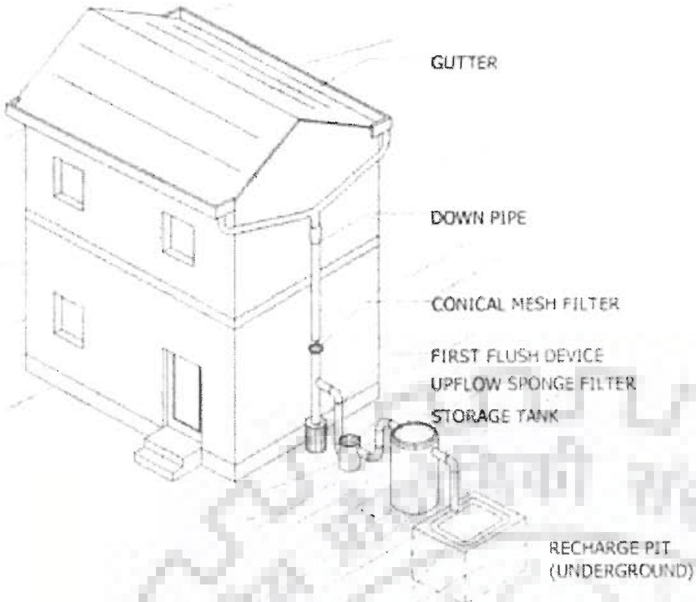


Figure 3.1 Typical rooftop rainwater harvesting

1) **Storage tanks:** Storage of rain water is a traditional techniques and the structure used are on ground, underground tanks, ponds, check dams, weirs etc. For harvesting the roof top rainwater, the storage tanks may be used. These tanks may be constructed on the surface as well as underground by utilizing local material. The size of tank depends upon availability of runoff and water demand. After proper disinfection the stored water may be used for drinking purpose.

2) **Ground water recharge structure:** Recharge of ground water is relatively new concept of rainwater harvesting and the structures generally used are discussed below

   i. **Pits:** Recharge pits are constructed for recharging the shallow aquifers. These are constructed normally square sections of 1 to 2 m side and 2 to 3 m deep which are back filled with boulders, gravels and course sand.

   ii. **Trenches:** These are constructed when the permeable strata is available at shallow depths. Trench may be 0.5 to 1m wide, 1 to 1.5m deep and 10 to 12 m long depending upon availability of water. These are back filled with filter materials.

   iii. **Dug wells**: Existing dug wells may be utilized as recharge structure and water should pass through filter media before putting into dug well.

   iv. **Tube well:** Abandoned tube well may be used for recharging the shallow or deep aquifers. These tube wells should be redeveloped before use as recharge structure. Water should pass through filter media before diverting it into recharge tube well.

v. **Hand pumps:** The existing hand pumps may be used for recharging the shallow or deep aquifers, if the availability of water is limited. Water should pass through filter media before diverting to hand pumps.

vi. **Recharge well:** Recharge wells of 100 to 300 mm diameter are generally constructed for recharging the deeper aquifers and water is passed through filter media to avoid chocking of recharge wells.

vii. **Recharge shafts:** For recharging the shallow aquifers which are located below clayey surface at a depth of about 10 to 15 m, recharge shafts of 0.5 to 3 m diameter and 10 to 15 m deep are constructed depending upon the availability of runoff and back filled with boulders, gravels and coarse sands.

viii. **Lateral shafts with bore wells:** For recharging the upper as well as deeper aquifers lateral shafts of 1.5 to 2m wide and 10 to 30 m long depending on availability of water with one or two bore wells are constructed. The lateral shafts are back filled with boulders, gravels and coarse sand.

ix. **Shaft with recharge well:** If the aquifer is available at greater depth say 20 or 30 m, in that case a shallow shaft of 2 to 5 m diameter and 5 to 6 m deep may be constructed depending upon availability of runoff. Inside the shaft, a recharge well of 100 to 300 mm diameter is constructed for recharging the available water to deeper aquifer. At the bottom of the shaft, a filter media is provided to avoid choking of the recharge well.

x. **Spreading techniques:** When permeable strata stats from top then this techniques is used. Spreading the water in streams by making check dams, bunds, cement plugs, Gabion structures or percolation pond may be constructed.

1. Filters for rainwater

Usually the filter is placed below the vertical down pipe. It can also be placed adjacent to the sump tank. A drum of 90 litres can filter the water of a roof area up to 100 m^2. Filter is designed to keep organic material such as leaves and twigs out of the stored rainwater. Filters are of many kinds. The filter is essentially a drum (Figure 3.2) or a ferro-cement box (Figure 3.3) of about 90 litres capacity. The inlet rainwater comes in through the top from the down pipe. Inside the drum gravel or charcoal can be filled to varying depths but usually 9 to 12 inches of it is sufficient. A 'netlon'-type mesh is then kept on the top preferably in three layers. To prevent the gravel or charcoal from slipping out a similar nylon mesh is tied to the outlet pipe from the inside of the filter. A good filter will also have a simple bye-pass mechanism at the top. This will take the rainwater in case of a heavy downpour and allow it to go straight into the sump. A filter needs regular inspection and cleaning.

Rainwater collected from rooftops is free of mineral pollutants like fluoride and calcium salts that are generally found in groundwater. But, it is likely to be contaminated with air pollutants and surface contamination (e.g., silts, dust). Such contaminations can be prevented to a large extent by flushing off the first rainfall. A grill at the terrace outlet for rainwater can arrest leaves, plastic bags and paper pieces carried by water. Other

Figure 3.2 PVC Drum filters

Figure 3.3 Ferro cement filter

contamination can be removed by sedimentation and filtration. Disinfectants can remove biological contamination.

4. Rainwater collection sump

Even a small storage system can generate large collection provided the rainwater is used every time it rains. In Bangalore, for example, with it's evenly spread rains; a 500-litre sump tank can generate 25,000 litres of rainwater in a year. An ideal size is 2,000 litres of sump storage for 100 m^2 of roof area. This is as per the building bye-law for Bangalore. A total of 6,000 litres of storage for 100 m^2 roof areas should give around 70,000 litres of water in a well-distributed rainfall year. The excess water from the sump during heavy rains should go out through an outlet pipe and fall into a recharge well or a bore well (www.rainwaterclub.org). A typical rainwater harvesting tank in an apartment is shown in Figure 3.4.

Figure 3.4 Simple rainwater harvesting tank in apartment, (Source: www.rainwaterclub.org)

3.3.2 Rainwater harvesting system costs

Cost of a rainwater harvesting system designed as an integrated component of a new construction project is generally low. Designing a system on an existing building is costlier. With careful planning and design, the cost of a rainwater system can be reduced considerably. Water harvesting system costs are subject to local variations in different parts of India. Actual costs will depend upon specific design, size of the facility / house and percent of rainwater harvested and stored. The unit costs of rainwater harvesting system components are given below (Source: www.indiawaterportal.org):

- Sump: 10,000 to 12,000 litre sumps will cost about Rs 50,000 or about Rs 3.50 to Rs.5.00 per litre for large sumps.
- Drain pipes cost around Rs 50 to Rs 100 per running metre.
- Bends and elbows around Rs 20 to Rs 75 per piece.
- Filter chamber 0.6m x 0.6m x 0.6m with pebbles and sand is Rs 1,500.
- One metre deep percolation pit with sand, pebbles, air vent and a perforated slab on the top is Rs 2,500.
- For old style well 1.8 m to 2.5 m diameter and about 18 m deep, it will cost about Rs 5,000.
- labour costs, transportation and supervision is 5%
- To construct a baby well, it may cost around Rs 2,500.

Estimated average cost of installing a Water Harvesting System for various types of buildings (Bhattacharya *et al.*, 2003):

1. **Construction and installation cost**

i. **For an individual house** of an average plot area of 300-500 m^2, the average cost will be around Rs. 20,000- 25,000. A recharge well will be constructed near the existing bore well. The roof water through PVC pipe will be diverted to recharge well. For a single dwelling house in Chennai, it would cost about Rs 6,000 to install. The typical house will have an existing sump designed to get and store municipal supply water. It will also have an electric motor to pump this water from the sump to an overhead storage tank on the rooftop and distribute water through existing plumbing. The only addition to this existing setup is the PVC pipes to collect the roof water during rain then filter it through a brick-sand filter and put the water into the sump. Excess water from the sump during the rain could be put into an existing well, or a baby well or a percolation pit based on the type of location.

ii. **For an apartment building** per unit cost will be less since the many people will share the cost. More over in apartments there are separate storm water drains, which join the MCD drains in the main road. Here along with recharge well, recharge trench and percolation pits can be constructed. The cost will be around Rs. 60000 to 70000/-. For an apartment building with 25 tenants, a similar system will cost about Rs 60,000. (www.lokvani.org).

iii. **For a residential colony** the cost will be much less. For instance, in Panchsheel Park colony, around 36 recharge wells were installed at the cost of Rs. 0.8 million, which is around Rs 500-600 per house. In many colonies in Delhi, storm water drains are present but it is difficult to isolate them from sewage drains because there has been violation of the drainage master plan. Also, these drains are not properly maintained. Hence, care needs to be taken while using storm water for water harvesting. Rooftop harvesting is preferred because the silt load is less. In storm water drain the silt load is high and generally the municipality does not maintain the storm drains properly.

iv. **For an institutional** campus, the cost are around Rs. 0.4 million. This cost is for two recharge wells and three trenches cum percolation pits.

2. **Maintenance cost**

Average annual maintenance cost would be around Rs 200-300 for two labourers once in a year to remove the pebbles and replace the sand from trenches.

Indian Institute of Technology Madras (IITMadras) also adopted rainwater harvesting in the campus. There are 12 boys' hostels in IIT Madras. Each hostel has around 300 students. With a daily demand per student of 45 litres, all the 12 hostels need 48,600,000 litres of water per year (300 usage days in a year). Prior to RWH, the water needs were met with 2 water tankers (12,000 litres per tanker) everyday for each hostel at a cost of about Rs 900 per tanker. Annual cost of purchased water is Rs 3645000. The RWH installation at each hostel has cost about Rs 0.3 million for a total of Rs 3.6 million. Water from the 12 hostels is diverted into 4 existing large agricultural wells 12 m diameter and 12 m depth. After RWH installation, about 40-50% of the drinking water requirements have been met. Additional wells can help meet 100% of the water requirements (http://akash-ganga-rwh.com/RWH/IITM-RWH.html).

In Delhi few rainwater harvesting projects have been implemented and the cost and other particulars of different projects are given in the Table 3.3. The Central Ground Water Board (CGWB) has also given estimates of different rainwater harvesting structure which are given in the Table 3.4.

3.4 WATER CONSERVATION AND WATER USE EFFICIENCY

Water use efficiency refers to technical and economic approaches to reduce the quantity of water used to achieve a given task. Water conservation refers to reductions in net water use at watershed or basin level, this water can be made available for other use, such as ensuring in-stream flows. Water conservation implies the judicious use of water. It is a fact that many activities in our daily life do not require drinking quality of water. Excess amount of water is used for many activities without proper knowledge of water conservation.

Table 3.3 Project cost of rainwater harvesting in Delhi

Projects	Techniques	Runoff quantity	Cost	Per unit cost
		in cu. m	Rs. in million	Rs. / cu. m.
Shram Shakti Bhawan	Trench and recharge wells	3325	0.41	123
Sultan Garhi Tomb	Bund, diversion channel, three recharge ponds	6500	0.60	92
a)Deen Dayal Upadhyaya Hospital, b)Abhiyan CGHS, Sector-12, Dwarka	Recharge	8270	0.5535	67
a) Vayusenabad - residential area, b)Meerabai Poly-techniques, c)Central Park, D-Block Vasant Vihar, d)DTC Workshop-II, Okhla,	Recharge shaft, recharge trenches with tube wells, lateral shafts with tube wells	42410	1.711	40
JNU IIT - Sanjay Van Project	Check dams and recharge structure like injection wells and abandoned dug well	49048	4.358	89
A groups of projects: a) Banglow-5, Janpath Road, b) Sena Bhawan, c) Kaushak Nala	Recharge by abandoned dug wells, recharge wells, recharge shafts, trenches with bore wells, gabion bunds, nala bunds	225670	6.012	27
		225,670	6.012	41
Source: Compiled by author from CGWB, 2008				

Table 3.4 Approximate cost of recharge structure (CGWB, 2000)

Sl. No	Recharge structure	Approximate cost (Rs.)
1	Recharge pit	2500- 5000
2	Recharge trench	5000- 10000
3	Recharge through hand pump	1500- 2500
4	Recharge through dug well	5000 – 8000
5	Recharge well	50000 – 80000
6	Recharge shaft	60000 – 85000
7	Lateral shaft with bore well	Shaft per m 2000 – 3000 Bore well 25000 - 35000

Good housekeeping and maintenance of equipment play a major role in conserving water. There are several water conservation techniques and one of them is reducing the amount of unaccounted-for-water (UAW) by fixing supply system leaks. The University of California, Santa Barbara campus provides an institutional example of a comprehensive water-efficiency program leading to significant water and cost savings. Through a wide variety of cost-effective indoor and outdoor conservation efforts, total campus water use was reduced by nearly 50 percent between 1987 and 1994, even as the campus population increased (Gleik *et al.,* 1999).

Perkins (1989) discussed different aspects of water conservation in urban context. According to him the first step in conserving water use is to eliminate leaking plumbing system. A faucet that drips two drops every second, wastes more than 200 gallon of water each month. To enhance conservation many devices are commercially available like low flow shower, dual flush system used for flushing liquid and solid waste in the toilet, pressure reducing valves etc. Conservation measures also includes efficient irrigation, xeriscaping, plumbing code modifications, water fixture retrofits, low flush toilet replacements, efficient washing machines, plumbing fixtures, conservation rate structures and education programs. The rebate provided by water providers to customers to buy the new appliances are successful way of achieving the savings of indoor water use. Many of the conservation measures are relatively less expensive compared to the construction of new large infrastructure to increase the supply.

3.5 WATER SAVING DEVICES

There is numerous water saving devices which can be used to save water for residential development, starting from installing a low-flow showerhead to sweeping the driveway instead of hosing it off. There's practically no limit to the number of water saving devices that can be used to reduce water consumption. The initial higher cost of installing such devices is returned within a year due to a good amount of saving of water and energy. Decreased water consumption means lower water bills, saving water also mean saving energy, as extracting, transporting and treating water comes at a high energy cost. In addition to that this would lower environmental impact by reducing the need to dam rivers.

If demand is reduced less waste water is produced and treated at sewage plants. The demand or water use reduction measures conserve the existing limited water supply through the practices which require less water and reduce wastage and misuse of water. A wide range of policy options are needed to be considered for the same. Indoor water efficiency can be boosted through the use of improved water saving fixtures and appliances such as low volume flush toilets, dual flush toilets, high performance shower heads, showers and faucet aerators, and front loading washing machines without causing inconvenience to water users.

In residential building water conservation can be achieved through efficient toilets, washing machines, plumbing fixtures etc. The major water saving technologies are (1) Taps and tap controls, (2) Flow Restrictors, (3) low flow showerheads, (4) Low flush/ no flush toilets, (5) Urinals and urinal controls, (6) washing machines, dishwashers.

Typical conventional water use devices use much higher quantity of water for same residential water use as compare to the water used by any water efficient or water saving devices (Table 3.5). Some of these devices and the quantity of water use from such devices are discussed.

Table 3.5 Typical water use for different water use devices

Device or appliance	Quantity of water use
Conventional taps	10-20 litres/ minute
Low flow / aerating taps	2 litres/ minute
Conventional shower heads	15 – 25 litres/ minute
Water efficient shower heads	<9 litres/ minute
Top loading cloth washing machine	130-216 litres/load
Front loading cloth washing machine	45-60 litres/load
Automatic home-type dishwasher	36-60 litres/load
Bathtub	114 litres/use
Toilet, tank, standard type	15-23 litres /use
Toilet, tank, conservation type	6-13 litres/use

Source: Compiled by author from Government of South Australia, fact sheet: ESO10, http://www.capitalprograms.sa.edu.au.

3.5.1 Water saving taps

In general if a tap in the house is fully turned on it will use up 20 litres of water one minute. At residential level the water use through taps is about 8%. A conventional tap, running continuously for one hour, discharges about 1000 litres of water per hour (Memon and Butler, 2003). The use of low flow taps can substantially reduce the domestic water use. The types of water saving taps are (1) Spray taps; (2) Battery operated taps, (3) Infra-red taps, (4) Push top taps, (5) Single lever mixer taps and (6) Tap magic insert etc. Spray Taps contain small holes near mouth, which forces water come out in mist or spray form. Water savings from such taps are about 60-70%. Battery operated taps have small solenoid valve fitted in pipes going to taps (Figure 3.5). The valve operates with battery and water flows by pressing the button to open valve. The duration of flow can be adjusted using the valve by user. So the tap left open will switch off automatically. Water saving from such taps is around 60%. Battery in the valve lasts for about 2 years (hence minimal operating cost). Valves may be cleaned after 2 years (Memon and Butler, 2003). Infra-red taps are touch free taps which contain infra-red sensor which switches on/off the tap automatically. Duration of flow is pre-determined. This type of sensor based taps (Figure 3.6) saves 50 to 60 % of water for every use. Push top taps (Figure 3.7) operate by creating pressure inside the tap (by pressing the tap top downwards). Once pressed down the tap top starts moving upwards, flow stops when the pressure is fully released. Duration of flow can be adjusted at the time of installation (1 to 20 seconds). It is hygienic because it doesn't require retouching the tap to stop. In Single Lever Mixer Tap flow rate increases when lever is lifted up. When the lever is half way up, resistance is felt. This is due to ceramic cartridge. Flow can be increased beyond this point to full flow by lifting the lever up with additional force. Tap magic inserts are small inserts that can be fitted on taps with round mouth. At low flow they work as spray taps. At high flow the insert opens fully. All these are suitable for domestic use (Memon and Butler, 2003) and can save a large quantity of water. There are also slow close valves and sensor activated taps which eliminate the possibility of tapes being left open for longer

Figure 3.5 Electronic tap (Battery operated), Water saving 60%.

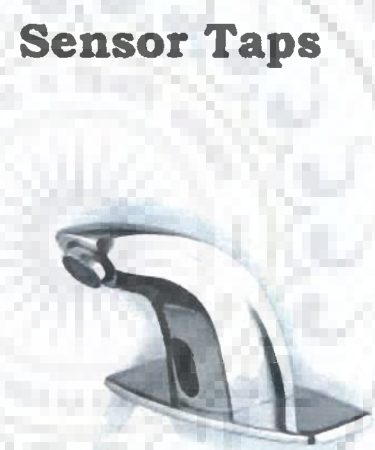


Figure 3.6 Sensor taps, saves 50-60% of water, Source: Insha Exports Pvt. Ltd.

time. Slow close valves are less expensive than sensor fitted taps.

In India also Roca produces water and energy saving cartridges which feature a specific saving mechanism, reducing the consumption of water down to 50%. Roca also has a water saving device known as Flow Regulators, limiting the maximum flow from the tap. But these are not being used in middle income residential houses because of higher cost. A standard faucet will use 8.3 litres per minute (lpm), but aerators that add air to the stream for a softer feel and reduced splashing can bring that down to 5.68 lpm. Some aerators reduce water flow to as little as 1.89 lpm. Aerators are great for bathroom faucets, but not as practical in the kitchen where faucets are used for filling pots and other containers. Aerating taps have flows up to 50% less the conventional ones. Taps with 8-10 l/min of flow are available to use for domestic use. A dripping tap looses 25-50 l/d of water (Memon and Butler, 2003).

3.5.2 Flow restrictor valves

Flow Restrictor (Figure 4.8) is valve fitted upstream of the consumption point (tap/shower) in supply pipe. It reduces the flow by means of reducing the orifice size when incoming water has high flow which can offer considerable water saving. It is an easy and fool-proof solution to reduce this water wastage by installing water flow restrictor valves in the taps. This can give water savings up to 70% of water use. A simpler and more effective way to restrict the amount of water used in kitchen is to install

Figure 3.7 Push tap, it saves 50% of water for normal use. Cost per unit is Rs. 4480/-

a water saving nozzle on kitchen tap. This nozzle cuts the water used by kitchen tap in half by restricting the flow rate to 10 litres per minute (www.ecologicalhomes.com.au). Using the flow balancing and pressure reduction techniques, combined with separate grey water and black water systems (which increases the efficiency of operations of sewage treatment facilities and avoids dilution of nutrients) recycling can be achieved at a cost comparable to conventional systems despite the additional infrastructure required (Speers *et al.*, 2000).

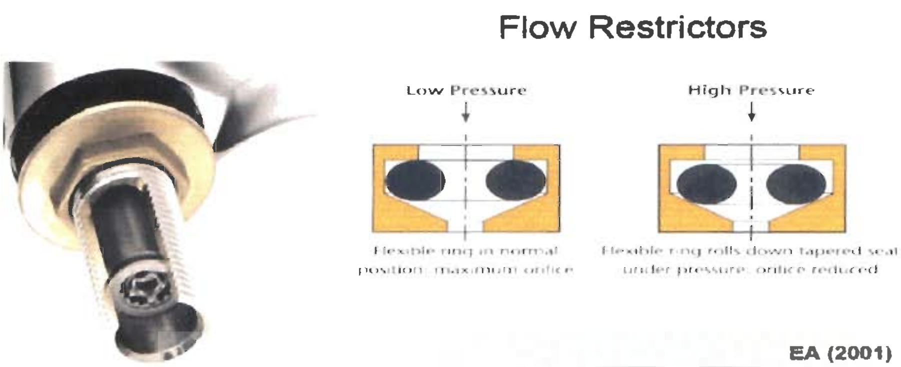


Figure 3.8 Flow restrictor fitted to a pillar tap inlet.

3.5.3 Low flow showerheads

The shower is one of the easiest and most cost effective places to decrease water use. The use of low flow taps and showerheads can substantially reduce the domestic water use. Low flow showerheads works in two ways (1) Lower water use, (2) Decreased wastewater volume. An inefficient or conventional showerhead can use 20 to 30 litres of water every minute while an efficient one will give a high quality shower using only nine litres of water every minute. The new water saving showerhead has an average flow rate even of 2.0 GPM, and provides the same enjoyable showering. It saves up to 25% more than 2.5 GPM showerheads (http://amconservationgroup.com/Profile.aspx). The Springking Industry Co. Ltd, China is marketing water saving shower (Figure 3.9) which saves 84% of water. There are low flow shower heads with maximum flow 2.5 to 2.25 gallons per minutes (GPM) (Figure 3.10). This type of shower heads cuts water use by 50 to 70%. (www.gaiam.com/product/eco-home-outdoor/bathroom/).

Figure 3.9 EZ Faucet, Water Saving 84% (Springking Industry Co. Ltd, China)

Aerating showerheads have flows up to 50% less the conventional ones. Showers with low-flow have 12 litres /min flow rate. It is estimated that, the use of water saving shower heads for 4 persons having 10 minute showers each per day, the water savings/ per year is around 182.5 kilolitre and sewer saved/year is around 91.25 kilolitres (www.ecologicalhomes.com.au/water_saving_devices.htm). Shifting from a showerhead flowing at 19 litres per minute to a 9.4 litres-per-minute model cuts water use nearly in half (Brown, 2007).

Figure 3.10 Water saving shower heads.
Source:www.chinatraderonline.com/Files/Household/Bathroom-Toilet-Accessories/

3.5.4 Low flush toilets

The flushing toilet is responsible for about one third of all water used by the average household and the environmental cost of treating this huge amount of wastewater is also enormous in terms of pollution of our waterways and oceans. Two household appliances, toilets and showers, together account for over half of indoor water use. Whereas traditional flush toilets used 22.7 litres per flush, the legal U.S. maximum for new toilets is 6 litres. An Australian-produced toilet with a dual-flush two-button technology uses only 3.7 litres for a liquid waste flush and 6 litres for a solid waste flush (Brown, 2007). The old toilets use 5 gallons of water per flush where as new ultra low flow flush uses maximum 1.6 gallons per flush (Driver, 2002).

Toilets has mainly two components (1) Flush tank, (2) Bowl. The efforts have been focused on reducing flush volumes and optimize the bowl size. Water saving toilets may be installed with displacement devices, flush tanks with siphon mechanism, flush tanks with valves; dual flush toilets etc. There may be also compressed air or vacuum toilets, waterless toilets.

Toilet flushes with just 6 litres against 10 litres saves approximately 12 litres per capita per day. Low flush toilet uses 1.6 gallons per flush instead of as many as 7 gallons. In India dual flush 6/3 toilet cisterns (Figure 3.11) can reduce the water used per flush from approximately 11 litres for older style single flush cisterns to an average of 4 litres per flush with 67% reduction of water usage for the same purpose.

Figure 3.11 Dual flush cisterns

Dual flush designed to discharge 6 litres for the full flush and 3 litres for the short flush saves approx 42 litres per day for a family of four persons. Power flush Closets which can flush with just 4 / 2 litres. Some dual flush toilets are designed to release water depending on the nature of use, less water (half flush, 0.8 gallon) for liquids and more water (full flush, 1.6 gallon) (Figure 3.12) for solids (www.insidestore.com/shopping/product/). It is evident in CSIRO's analysis of domestic water use patterns that the impact of the introduction of 6/3 litre dual flush toilets has been significant (ARCWIS, 1999) and 65% of homes in the survey undertaken have at least one dual flush toilet installed. This has led to toilet water use falling from the 2nd largest indoor use of water behind bathroom use (MWA, 1985) to 3rd position behind both bathroom and laundry use (ARCWIS, 2000). The uptake of dual flush appliances has led to a decline in the potential market for reclaimed water for toilet flushing of almost 30% (Speers *et al.*, 2000).

Low flush toilets use a maximum of 6 litres of water per flush compared with about 13 litres of water used by a standard toilet. These could save up to 22000 gallons (83.279 litres) of water per year for a family of four. New air-displacement flush toilets, using 1.6 litters per flush, are under development (Moore, 2000). Federal law in United States prohibits sale of toilets that exceed a maximum water flow capacity of 1.5 gallons (5.7 litres) (Agthe *et al.*, 2003).

Figure 3.12 Dual flush toilets (1.6 GPF / 0.9 GPF)

Source: www.insidestore.com/shopping/product/

3.5.5 Waterless Urinals

A single waterless urinal saves up to 60 m^3 of water per year (Figure 3.13). Around 20% of drinking water produced throughout the world is used for urinal flushing. There are also Low water urinals which use a retrofit cartridge lined with bacteria and enzymes that deal with odours between flushes and can reduce the number of flushes in a day. Cartridge cost between Rs.3000 and Rs.5000 and needs quarterly replacement.

Figure 3.13 Waterless urinals

3.5.6 Water saving washing machines and dishwashers

Water consumption in washing machines is about 14% of domestic consumption. Clothes washing are typically the second largest user of indoor water use after toilet flushing. Washing machines are large consumers of water, which is in the order of 28 to 55 litres per person per day. High efficiency clothes washers can reduce about 40% of average volume water per load. Top loading washing machines require water about 40 gallons/ wash but front loading washing machine requires water about 18 to 25 gallons/wash (http://www.mchenrycountyblog.com/uploaded_images/). Many of these machines will also reduce energy consumption by using less hot water and because of higher spin speeds and hence the clothes come out of the washer with a lower moisture content and require less drying time. The typical residential washing machine uses 50 gallons per load. Models exist that use between 16-27 gallons per load (Driver, 2002). These machines are costlier than the conventional but saves water and electricity. Rebate by water providers have been useful in encouraging customers to purchase water efficient machine. With washing machines, horizontal axis design developed in Europe uses 40 percent less than the traditional top-loading models. In addition, this European model now being marketed internationally also uses less energy (Brown, 2007).

Dishwashers account for about 7% of consumption. Use of fuzzy logic based electronic controls, ultrasonic agitation, reuse of rinse water saves water substantially and further water savings would be possible by inventing new detergents, by reducing/optimizing consumption when machines are partly loaded. Water use efficiencies of water saving devices are given in Table 3.6.

Many countries are adopting water efficiency standards and labelling for appliances. Based on the study the use of water saving technologies and its efficiencies for water saving in urban residential water uses are given in the Table 3.7.

Table 3.6 Water use efficiency of water saving devices

Devices	Standard model	Improved efficiency model
Cistern	5-7 gallons (19-26 litres)/ flush	1.6 gallons/flush
Shower	Up to 12 gallons (45 litres) / minute	2.5 gallons (11 litres)/ minute
Kitchen and lavatory faucets	Up to 5 gallons (20 litres)/ minute	1.5 gallons (5.7 litres)/ minute
Automatic clothes washer	27 – 54 gallons (100-200 litres)/ load	16 – 20 gallons (60-75 litres)/ load
Automatic dish washer	7.5 – 16 gallons (28-60 litres) / load	7.5 gallons (28 litres)/ load

Source: Washington State University, Report number. EB0732

Table 3.7 Water saving due to the application of water saving equipments.

Sl. No.	Use of water saving equipments	% saving of water use
1	Water efficient/ saving taps	50-70
2	Flow restriction valves	50
3	Low flow shower heads	50-70
4	Dual flush toilets	60
5.	Water efficient washing machine	40

Source: Compiled by author from different literature based case studies.

3.6 WATER SAVING EFFORTS IN INDIA

Efforts have been made in India to make commercially available power saving equipments. But there are no efforts from the government side as well the manufacturer of plumbing equipment to make available water saving and water efficient plumbing fixtures and equipments. The market offers a variety of water supply fixtures, plumbing equipments and water use equipments for domestic use. Many of these are available without IS (Indian Standard) mark. People purchase them without any doubt in mind because these equipments are cheaper in cost and people do not know any negative effect for purchasing these equipments. Low quality equipments require frequent repair and lead to water loss and associated recurring costs. Life cost of any inferior equipment is more than good quality certified IS mark equipments. In Indian context there is no research information available on life cycle cost and efficiency of plumbing fixtures. No agency takes it seriously to enforce the IS mark plumbing fixtures in domestic use. People also do not consider these compromises in quality as they do in case of electrical equipment for safety.

Moreover the Bureau of Indian Standard (BIS) codes also do not provide specification of water saving equipments or recommend their mandatory use. This shows how the responsible government agencies not very serious about water conservation. IS codes or standards should be changed to include the water saving equipments and their specifications for ready reference and use. Similarly changes in building byelaws are required to make it compulsory to use water saving plumbing fixture in all residential building.

The water supply requirements for residences and for buildings other than residences have been specified in IS: 1172-1983. Indian Standard code of practice for water supply in buildings (IS: 2065-1983, revised) has attempted to provide the minimum standards for design, layout and workmanship governing water supply in buildings and helped in bringing about desired uniformity in the byelaws and regulations framed by different water supply authorities in the country. This code deals with water supply in the buildings and covers general requirements, regulations for water supply and plumbing, licensing of plumbers, design of water supply systems, principles of conveyance and distribution of water within the premises, storage, water fittings and appliances and inspection and maintenance. But these codes do not deal with water conserving fixtures or water saving alternatives. Moreover the application (as in IS:2065-1983) for new water supply connection and the licensed plumber certificate form does not have any entry provisions for compulsory use of water saving equipments in domestic water supply connection.

IS code on taps in residential building is discussed in the IS: 781-1977, IS: 1701-1960 and in IS: 1711-1970 and revised IS: 1711-1984 which provides specification for self-closing taps for water supply purposes. The self-closing tap to be designed to close by itself even without the release of the button or handle, after discharging not less than 5 litres or more than 10 litres of water at a time by providing a capillary groove in the valve, which shall slide in the bottom hollow chamber of the spindle or by any other equally suitable device. But these specifications or code do not suggest water saving efficiency.

The code for water closet flushing cisterns are detailed out in IS: 2556-1981(Part-I and III) for 10 litres discharges capacity and modern water saving cisterns and their efficiency has not been considered. The IS: 2326-1970 prescribes the 5 litres urinal flushing cistern but it is not used for domestic purpose.

The IS: 774-2004 also provides the specification for Flushing Cistern for Water Closets and Urinals (Other than Plastic Cistern). This standard covers requirements for manually operated high-level and low-level flushing cisterns of capacities, 5 litres and 10 litres, both single-flush and dual-flush types and 6/3 litres capacity dual-flush cisterns, for water-closets, squatting pans and urinals, together with flush pipe details. This code provides some information about specifications of water saving equipments. But still the equipments are not marked with any water rating.

The water supply provisions covered in National Building Code of India 2005 (Part 9, Section 1), encompass the requirements of water supply, plumbing connected to public water supply, design of water supply systems, principles of conveyance and distribution of water within the premises, hot water supply system, inspection and maintenance of water supply systems. It also covers design of water supply systems in high altitudes and/or sub-zero temperature regions. This section has been based largely on the following Indian Standards IS:1172-1983 Code of basic requirements for water supply, drainage and sanitation, IS: 1742-1983 Code of practice for building drainage (second revision), IS: 2065-1983 Code of practice for water supply in buildings (second revision), IS:4111 (Part 1)-1986 Code of practice for ancillary structures in sewage system: Part 1, IS:5329-1983 Code of practice for sanitary pipe work above ground for buildings (first revision), IS:6295-1986 Code of practice for water supply and drainage in high altitudes and or sub-zero temperature regions (first revision), IS:7558-1974 Code of practice for domestic hot water installations, IS:12183 (Part 1)-1987 Code of practice for plumbing in multi-storied buildings: Part 1, SP:35-1987 Handbook on water supply and drainage. These codes and NBC-2005 which is based on these codes do not provide specifications for water saving fixture or equipments. Therefore, it is necessary to change these codes or include new codes for water saving fixtures and equipments with proper water rating marks. Governments should make policy to implement these codes for all construction and renovation of buildings in urban areas.

3.7 WATER EFFICIENT URBAN LANDSCAPING

Private and public landscaping in urban areas are major outdoor water users. Solutions for water efficient landscaping include the use of low quality water and recycled wastewater or greywater in landscaping. Water efficient landscaping is generally based on selection of plant types requiring less water and efficient lawn watering methods. A promising technique is drip irrigation, which usefully applies 30 – 50% less water than sprinkler irrigation and still meets the requirements of most plants (Driver, 2002).

Technologies are also available for using low quality water for landscaping. Separation and recovery of greywater for landscaping can readily be done with small investment. Brackish or lower quality water can be used for landscaping and toilet flushing. Small wastewater recycling systems at the scale of the household, residential building or neighbourhood offer a cost effective and robust means of closing the water loop.

Outdoor water uses accounts for about 54% of total residential water use in the Denver area, most of which goes toward turf irrigation. Xeriscaping offers a much lower water using alternative. Xeriscaping promote quality landscapes, water conservation and environmental protection. Xeriscaping programmes in El Paso, Texas, led to save water over 20 gallons per square foot during each watering seasons (Driver, 2002).

3.8 SUSTAINABLE URBAN DRAINAGE SYSTEMS (SUDS)

Sustainable urban drainage systems are designed to reduce the potential of flooding on new and existing urban developments. Unlike traditional urban stormwater drainage systems, it also helps to protect and enhance ground water quality. Originally the terms SUDS used in UK as the approach to sustainable urban drainage systems. Similar approaches were termed as "Best Management Practice" (BMP) in the United States. SUDS use the techniques like source control, permeable paving, storm water detention, storm water infiltration, evapo-transpiration (e.g., from green roof).

The results show that utilization of stormwater and wastewater at a local scale is able to significantly decrease the nutrient (nitrogen and phosphorus) loads discharged to external water courses (Mitchell *et al.,* 2000). The increased load of nutrients returned to the garden as a result of water reuse, is lower than that estimated from fertilizer addition. Thus reduced fertilizer addition is able to compensate for the extra load of nutrients supplied to the garden in the recycled water.

The objectives of storm water management have broadened over the last decade from purely flood protection, to encompass pollution control, ecological regeneration and enhancement of storm water amenity value (Thomas *et al.*, 1997). Water can provide other values in our urban landscape apart from a supply source. Water bodies such as ponds and wetlands as well as creeks, streams and rivers can add significantly to the aesthetic and recreational amenity of an urban area.

In addition to this broader view of storm water management, storm water is increasingly being seen as a resource that have undervalued so far. Storm water utilization is likely to be of significant environmental benefit through the reduction of non-point source pollution and minimization of the requirement to augment traditional water supply (WBM Oceanics Australia, 1999). Options for storm water use within an urban catchment include approaches that substitute storm water for potable water supplies, such as on-site rainwater tanks, community collection and storage for irrigation, aquifer storage and recovery.

The main problem with the reliance on urban storm water as the sole water source is the reliability of supply through extended dry periods. As a result, the best approach to storm water utilization can be in conjunction with other water resources such as currently developed potable water supplies and wastewater, to overcome need for large carryover storage.

3.9 PUBLIC EDUCATION

Public education and awareness is of paramount importance. Water utilities often target the wrong audience with their across the board public awareness exercises and water education campaigns. Water awareness campaigns will have little credibility with people who barely have enough water for their basic needs while the big consumers continue to wastefully use water. Water efficiency campaigns must be targeted at the right audience and must be closely coordinated with other demand management measures in order to ensure long-term behavioural change.

3.10 CASE STUDIES OF SUCCESSFUL URBAN WATER MANAGEMENT

Singapore has made remarkable progress in terms of total catchment management, provision high quality water supply, waste water management, water conservation and public participation. Singapore provides sustainable supply of safe drinking water and sanitation to 100% of its population with 100% metered water supply. Singapore achieved recycled water use up to 50%. The consumption of water is reduced by 11% by proper metering and block tariff system.

Through various water conservation initiatives such as promoting water-efficiency households fittings and appliances, working with non-domestic sectors and community-driven public education programmes, Singapore has managed to reduce domestic water consumption from 172 litres per capita per day in 1995 to 157 litres in 2007. The Singapore government aims at reducing domestic water consumption to 155 litres per capita per day by 2012 (Marie, 2008).

Singapore has many measures to save water. To overcome Singapore's scarce water resources, water conservation is a national policy. A conservation plan was put into place since 1981 and is still very active in saving water. The Public Utilities Board (PUB) has held many educational and publicity activities to raise the awareness of the dire need to conserve water. Mailers are sent, pamphlets are given out and talks are organized. Save Water Campaigns that lasted for a month were held for various industries. Citizens were also encouraged to check their water meters and monitor their own water usage regularly. Water-saving devices were compulsory at all non-domestic places. Since 1997, low capacity flushing cisterns were mandatory and all new buildings had to have them installed. These cisterns save about 1 to 5 litres of water per flush. Incentives were given to industries to encourage them to reuse and recycle their process water through methods like cascading systems, counter flow systems and reverse osmosis treatment. The Water Efficiency Fund (WEF) was introduced to help factories purchase equipments to reduce usage of drinking water for industrial purposes.

India has not been able to provide safe and adequate water supply for all. Even the national capital New Delhi has very few pockets where 24x7 water supplies are present. Compare this with Singapore which has constant water supply despite the fact that it does not have any ground water and has seen a drop in per capita water consumption due to the government's proactive approach in demand management (Chadha, 2007).

Phnom Penh has made absolutely remarkable progress in terms of urban water management since 1993, when unaccounted-for-water (UAF) losses were at 75 percent. By 2006, these losses have been reduced to only about nine percent, which is better than many European cities. Phnom Penh in Cambodia manages to deliver 100% coverage on supplying water 24X7 to all its residents (Biswas, 2007).

Greater Sydney is using the same amount of water now as in 1970, even though the population has grown by an extra one million people. Water consumption in greater Sydney has reduced from 500 litres per capita a day in 1991 to around 315 litres per capita a day, which is around 37% reduction in the per capita consumption. Total 4,65,200 households have installed water efficient taps and fittings, 47,600 households have received rainwater tank rebates, 1,17,200 households received washing machine rebates, 224 schools have completed the Every Drop Counts in schools education program, business is also playing its part. Over 390 of the biggest water users are in Sydney Water's Every Drop Counts Business Program. Together they are saving more than 37.2 million litres of water every day (www.sydneywater.com.au/savingwater/).

In Spain, proactive water saving programmes have been launched in several towns and have produced significant results. In 1997 Zaragoza launched a comprehensive programme based on updated water devices and equipment, introduction of metering and raising public awareness. Its implementation resulted in the saving of 1.2 billion litres of water per year and the lowest water consumption per inhabitant per day in Spain (96 litres/ person/ day) (Commission of the European Communities, 2007).

France in 2006 launched a national campaign based on television and radio which encouraged individual efforts at water saving. The public considered the messages were convincing and 88% said that they made efforts to save water (Commission of the European Communities, 2007).

The use of water conserving equipments to be facilitated by rebate programme can save millions of gallons of water per day as have successful programs done in Tampa, Florida, Austin, Texas, New York City and Los Angeles. In Seattle, Washington, over 3,30,000 low flow showerheads were distributed to residential customers door-to-door, saving close to 6 million gallons of water per day (Driver, 2002).

Namibia, a country of Africa was facing water shortage 20 years ago but today even as the population doubled, the same amount of water is found to be sufficient and serving the whole population. The leakage in the distribution system has been reduced, 20% of the waste water is reused and full cost pricing of water led to water efficient industry (Eriksson, 2006). The cost of implementing these approaches (demand management) through the policy and incentives for water conservation was only a fraction of what the infrastructure for new sources would have cost (Eriksson, 2006). Investment in municipal water efficiency not only saves the best quality and scarcest water from wastage but also spares the expenditure to produce it.

In India also, successful water management has been demonstrated at some places, as experienced in a training centre project, Panchgani, Maharashtra, (Mungekar, 2003). This project is basically a holiday home and training centre with a capacity to accommodate nearly thirty persons in eight suits. This training centre is located in Bhose village near Panchgani on the peak of Sahyadri ranges in Western Maharashtra. It gets an annual rainfall of 6223 mm but because it is in the hilltop there is virtually no catchment and this area had been facing recurring water shortage after monsoon. The buildings are designed to collect the rainwater. Considering the occupancy and water requirement, the size of underground water tank was quite large. Hence it was proposed to reuse the wastewater again and again for various purposes after filtration and purification, which reduced the requirement of fresh water by nearly 60% and also reduced the size of the water tank.

Some important examples of effective water managements in India at building levels and community level are listed below:

1) Godrej-CII building in Hyderabad: This building discharges zero water as all of its used water is recycled. It has a huge capacity for the collection of rain water.
2) TERI Environmental Awareness and Training complex at Gurgaon, Himachal Pradesh: The root zone treatment system is implemented to treat $5m^3$/day waste water from toilets and kitchen. The treated waste water is used for irrigation.
3) ITC Green Centre, Gurgaon – The rainwater recharge pits are made to ensure zero discharge into municipal drainage. Water efficient landscaping with native plants and high efficiency irrigation. 100% recycled water is used for irrigation. Fluidized Aerobic Bio reactors (FAB) sewage treatment plant has been provided to treat gray water to tertiary standards. There ensures 40% reduction in water usage over base case.
4) WIPRO Technologies' Gurgaon Development Centre: Total plot size of the centre is 4533 m^2 with built up area of 1626 m^2 for 1,305 residents. A sewage treatment plant operating on Extended Aeration process treats the entire wastewater discharged from buildings.
5) Grundfos Pumps India Pvt. Ltd, Chennai: The plot size of the building is 8094 m^2 with total built up area of 3252 m^2. With efficient fittings and management in the

building there is 40% reduction of potable water use. Zero water discharge and water recycling are adopted and 100% recycled water is used for irrigation.

6) NEG Micon Building, Chennai: the building is with total built-up area of 1672 m^2 for 125 occupants. The building has used low flush water closets, sensor based urinals and low flow faucets in the toilet to reduce water consumption. The greywater is treated and used for irrigation instead of being released to the municipal drainage.

3.11 URBAN WATER DEMAND AND USE PATTERN

Even though there is a plenty of fresh water on the earth, but in reality water is not always available when and where it is needed, nor is it always of suitable quality for all uses. The availability and quality of water determines where people can live and their quality of life. Water must be considered as a finite resource that has limits and boundaries to its availability and suitability for use. People use water for drinking, bathing, cooking, washing clothes and maintaining lawns and gardens. Water also is used by the manufacturing sector to make products, by the agricultural industry to provide food, and by the energy industry to provide illumination, heat, and air conditioning. The residential water demand varies according to the location, the climate, and socio-economic variables. The amount of water used directly by individuals is related to various human attributes such as age, education, cultural background, religious beliefs, and financial status. The water demand may vary considerably among different countries and different regions. A city with higher standard of living will need more water for its domestic use than cities with lower standard of living but in similar climatic conditions. Water-use information can be used to evaluate the impacts of population growth and the effectiveness of alternative water management policies, regulations, and conservation activities. The availability and quality of water determines where people can live and their quality of life. To adopt the water management approaches in any residential area it is essential to know the domestic water demand and water use pattern of the area.

The relationship between rainfall and water consumption is significant issue in managing the water resources effectively. The demand for water increases during period of low rainfall and the main reason for this is that the majority of water is going to garden usage (Nagarajan, 2006). Urban parks and gardens essentially need water to meet their irrigation needs in urban areas. In addition to drinking requirements, water is traditionally used for sanitation purposes for the disposal of human waste. Humans also have basic hygiene needs for personal washing and bathing, and for food preparation. These hygiene-related uses of water also have many health benefits.

As per the National Building Code 2005 (NBC-2005) minimum of 70 to 100 litres per head per day may be considered adequate for domestic water needs of urban communities, apart from non-domestic needs. The IS: 2065-1983, revised 1990 also considered maximum demand load for 200 litres per capita per day. As a general rule the following rates per capita per day may be considered minimum for domestic and non-domestic needs: (a) For communities with population up to 20000 and without flushing system: 1) Water supply through stand post 40 lpcd, 2) Water supply through house service connection 70 to 100 lpcd, (b) For communities with population 20000 to 100000 together with full flushing system 100 to 150 lpcd, (c) For communities with population above 100000 together with full flushing system 150 to 200 lpcd. The value of water supply given as 150 to 200 litres per head per day may be reduced to 135 litres per head per day for houses for Lower Income Groups (LIG) and Economically Weaker Section of Society (EWS), depending upon prevailing conditions. Out of the 150 to 200 litres per head per day, 45 litres per head per day may be taken for flushing requirements and the remaining quantity for other domestic purposes. On average, people in Europe use more than 200 litres, United States more than 400 litres (HDR 2006), but in India, average city water demand is around 135 litres per capita per day. The average domestic water consumption in different countries has been listed in the Table 3.8.

3.11.1 Absolute minimum water requirement

Researchers have investigated the absolute minimum amount of water required for human survival. Regular intake of water is needed to maintain a person's water balance as water lost through normal activities must be restored. For an average person the minimum water requirement for replacement purpose has been estimated to be approximately 3 litres per day, given average temperate climate conditions. Although in hot climates it could be about 20 litres per capita per day for those involved in labour intensive activities. In simple living pattern, water consumption of around 10 litres per person per day is fairly typical to include all cooking and drinking requirement (Kumar *et al.*, 2006).

Table 3.8 Average domestic water consumption different countries.

Location	Litres/capita/day
Belgium	145
Denmark	190
Hungary	205
Italy	220
The Netherlands	167
Spain	126
Sweden	194
Switzerland	264
United Kingdom	136
USA	300
India	80-100

Source: Kumar *et al.*, 2006.

International organizations such as the U.S. Agency for International Development, World Bank and World Health Organization recommend between 20 and 40 litres of water per capita daily (lpcd) for the average human being. The clean water is part of the social minimum, with 20 litres per person each day as the minimum threshold requirement (HDR 2006). Table 3.9 gives the basic human needs for various purposes (Gleick, 2000).

Table 3.9 Basic water requirements for human domestic needs

Purpose	LPCD
Drinking Water	5
Sanitation Services	20
Bathing	15
Food Preparation	10

Source: Gleik, 2000.

Water for drinking, sanitation and hygiene needs and food preparation constitute the basic human survival needs for water (Table 3.9). These minimum needs total about 50 litres (13.2 gallons) per person per day. Fifty litres per person per day maintains a person's water balance and provides benefits vital for human health. The supply norms adopted by different municipalities in India vary as recommended by the CPHEEO (Table 3.10). However the domestic demand of water in a city also depends upon the size of the city (Table 3.11).

Table 3.10 Water demand for urban areas in India

Sl. No.	Classification of towns/ cities	Recommended maximum water supply levels (lpcd)
1	Towns provided with piped water supply but without sewerage system	70
2	Cities provided with piped water supply where sewerage system exists	135
3	Metropolitan and Mega cities provided with piped water supply and sewerage system exists.	150

Source: CPHEEO, 1999, Manual on Water supply and treatment,

Table 3.11 Water demand based on the size of the cities.

Size of Town	Domestic Demand(lpcd)	
	Absolute minimum	Desirable
Small <50,000	70	100
Medium >50,000	70 -100 upper limit above 100000	135-150
Large city and metro >10,00,000	135 but it can be reduced up to 70	150-200 upper limits for metro cities, high income areas.

Source: UDPFI Guidelines, 1996.

However for hot areas in India larger amounts are required both for cleaning (better hygiene) and for consumption. The manual on water supply and treatment produced by the Central Public Health Engineering and Environmental Organization's (CPHEEO) recommends 60 gpcd (247 lpcd) as a minimum (Table 3.12).

Even countries with a similar climate and per capita incomes as India such as Senegal and Ivory Coast supply around 70 to 110 lpcd (Kumar *et al.*, 2005). Different organizations and individuals have given different norms for water supply in cities. Majority of the cities base their supplies on unrealistic norms which results in lot of water getting wasted. India's urban water delivery infrastructure is built to supply legally connected households with at least 130-150 litres per capita per day (lpcd).

Table 3.12 Per capita demand for Delhi as per CPHEEO norms

Sl. No.	Purpose/ use	Quantity in lpcd
1	Domestic	172
2	Industrial, Commercial and Community requirement based on 45000 litres/hector/day	47
3	Fire protection based on 1% of the total demand	3
4	Floating population and special uses like hotels and embassies	52
	Total	(60gpcd) 274

The Central Public Health and Environmental Engineering Organization (CPHEEO), Government of India, has set a domestic water demand standard of 70 lpcd in urban areas without piped sewerage, 130 lpcd in areas with sewerage, 150 lpcd for cities with over one million population and 40 lpcd for areas with public stand post. The National Commission of Urbanization considered 70 litres per capita per day as the absolute minimum and 90 lpcd as desirable level (with 110-120 lpcd as a more desirable scenario) to carry out life at a minimum standard of hygiene (NCU, 1988 p.293-301). Gleick (2000) estimated 50 lpcd as true minimum to sustain life in moderate climatic conditions and average activity levels (Table 3.9). The minimum required quantity of water is put at 40 lpcd by the National Drinking Water Mission (Government of India) and 50 lpcd by United Nations Economic and Social Council, General Comment no. 15. But which are mostly for rural areas percapita drinking water need.

3.12 CONCLUDING REMARKS

Water demand management techniques are not considered in India in a comprehensive and integrated manner. The applications of many of these techniques are feasible in urban areas of India and proper application of these techniques can reduce water demand substantially. One of the major water management techniques is rainwater harvesting. This can be implemented to reduce the dependency on utility providers for water. The cost of implementation can be shared among many families if implemented collectively. The space required for the systems can be worked out depending on types of the system selected and the storage capacity and treatment capacities.

It has also been observed from the successful case studies that there is substantial quantity of water saving possible in urban residential water use with the implementation of water saving technologies. Water saving technologies are proven techniques for water demand management and must be made widely used. Water utilities must encourage wider application of these technologies and invest in retrofitting programmers or provide financial incentives. Legislation, revised building codes and manufacturing restrictions and tax incentives are all necessary measures for ensuring and encouraging wider use of domestic water efficiency solutions. The rebate provided by water providers to customers to buy the new appliances are successful way of achieving the savings of indoor water use. Many of the conservation measures are relatively less expensive compared to the construction of new large infrastructure to increase the supply. At the household level, water can be saved by using showerheads, flush toilets, dishwashers, clothes washers, and other appliances that are more water efficient. Only few countries are adopting water efficiency standards and labelling for appliances but much has been done for energy efficiency.

There are higher chances of success of the use of water efficient devices in middle and high income groups. Involvement of local appliance manufacturers is imperative and may require incentives and subsidies. Besides developing standards for water using devices for water efficiency it is necessary to ensure water use and water efficiency technical specifications are enforced for all water using products. Technical specifications for all plumbing products such as pipes, tools and other materials shall be adopted because it will save large quantities of water by ensuring use of only high quality products, thereby minimizing water leakage in households. It is necessary to introduce water efficiency labelling schemes which should involve the introduction of national mandatory water efficiency labelling for all domestic plumbing equipments and water use devices. Especially the labelling should be available for shower heads, tap equipments, flow controllers, toilet fixtures, urinal equipments, washing machines and dishwashers. It is necessary for developing a new directive for water performance of buildings similar to the Energy Performance of Building Directive. Ensure manufacturers to develop more water efficient products for buildings.

CHAPTER 4

URBAN WASTEWATER MANAGEMENT AND TECHNIQUES

4.1 PRELUDE

In India some of the water management techniques are applied with successful results. But waste water reuses for landscaping and grey water recycling have been done in limited cases. In this chapter aspect of waste water treatment and management including greywater recycling and waste water reuses have been discussed to understand the major components of these systems, space requirements and cost associated with such system. Detailed study of decentralised waste water treatment and greywater treatment and other options are necessary to select appropriate waste water treatment system for different residential developments as a part of integrated water management system. However some cases are available where innovative technologies are tested and found successful. To understand the applicability of wastewater treatment options in the residential development initially basic treatment stages of wastewater are discussed and then some successful case studies of innovative wastewater treatment system adapted in India is discussed.

4.2 WASTEWATER TREATMENT SYSTEM

Residential waste water generates from indoor activities like flushing toilets contains human body wastes (faeces and urine) and the waste water resulting from personal washing, laundry, food preparation and the cleaning of kitchen utensils, floor washing, etc. In higher income group residential areas the waste water also generate from the cleaning of personal vehicles, lawns, parking areas etc. The process of waste water treatment includes preliminary treatment, secondary treatment and tertiary or final treatment and disposal or reuse. The preliminary treatment of wastewater treatment comprises of screening and grit removal. The first stage of wastewater treatment is the removal of large floating objects and heavy mineral particles like sand and grit. This is done to prevent floating particle or materials to accumulate on the surface of waste stabilization pond and heavy particle entering into the pond sludge layer and protect the damages of equipments used in subsequent stages of treatment. There are lots of technologies and options available for the treatment of municipal wastewater, but Indian context, only centralized conventional technologies are considered for municipal wastewater management. Centralized wastewater systems have been the preferred choice of technical service providers, consultants, planners and decision makers and are seen as the ultimate solution for the wastewater problem. The standard large, water dependant and capital intensive sewer networks are built to transport domestic wastewater to central treatment from which the treated effluent is disposed on land, rivers, or sea.

In conventional centralized sewage treatment system about 80% of the cost is accounted for the collection alone. The cost of collection of sewage and its conveyance to one terminal point in the larger cities is very high and this also requires high energy consumption and high cost for maintenances. Further, the depth of sewer goes on increasing with the increase in length of sewer line and pumping of the sewage at intermediate and terminal points requires a lot of energy. Further centralized treatment systems or conventional systems aggravate the environmental problem, as large volume of the wastewater of the entire city is discharged at one place.

The current engineering concept for dealing with human waste is to use vast quantities of water to wash it away, preferably into a sewer system where it will be treated before being discharged into the local river. This system is expensive, water-intensive, disrupts the nutrient cycle and is a major source of disease in developing countries (Brown, 2007). Water based sewage systems take nutrients originating in the soil and typically dump them into rivers, lakes or the sea. There is nutrients loss from agriculture but nutrient overload in receiving water. This has led to the death of many rivers and formation of around 200 dead zones in ocean coastal regions. Sewer systems that dump untreated sewage into rivers and streams are a major source of disease and death (Brown, 2007).

On the other hand the decentralized waste water treatment system is a cheaper alternative. It minimizes the cost of trunk sewerage and avoids expenditure on pumping. Each decentralized plant serves as a single drainage basin or a small number of drainage sub-basins (Mara, 2003). Increasing attention has been paid to decentralized wastewater management by wastewater professionals because of its potential for reducing environmental hazards in case of accidents and increasing reuse opportunities, cost effectiveness and reuse efficiency (Butler and McCormick, 1996; Venhuizen, 1997a, b; Otterpohl *et al.*, 1997; Widerrer and Schreff, 1999; Hedberg, 1999). The use of treated wastewater in landscape and recreation is common in many areas, including Beijing (Wang *et al.*, 1999).

4.3 WASTEWATER RECYCLING AND REUSE

The generated wastewater from homes, buildings, industry, and agriculture end up consuming the scarce freshwater resources if poorly managed or can be brought back into the water budget as a non-conventional water source. Water recycling is reusing treated wastewater for beneficial purposes such as agricultural and landscape irrigation, industrial processes, toilet flushing and replenishing a ground water basin (ground water recharge). Reused water can function as a new source of water or can function for pollution control. Water recycling refers to using water more than once by the same user for different purpose to a new use. Water reuse often requires some level of treatment but not necessarily to the highest standards for drinking water. The level of treatment required depends on the potential level of human contact and purpose of reuse. Pollution control through effective wastewater management is the tool available to water resource managers to protect the scarce water resources and recover water. Necessity and promotional efforts over the past two decades led to wide recognition of the importance of wastewater as a potential water source. This potential water source is not fully utilized and it continues to pollute the scarce water resources.

Disposal and not reuse is the primary objective of conventional centralized wastewater management. The effluent quality standards expressed in BOD, COD and SS terms and the treatment processes designed to achieve them are not always compatible with reuse quality requirements. The physical configuration of a centralized wastewater system is also not always compatible with the location of wastewater reuse opportunities. Consequently, wastewater reuse is often concentrated in agriculture at distant locations from the generating communities.

For reasons of the economy of scale large systems are promoted. But there is growing evidence that while large sewerage treatment plants gain some economies of scale the entire wastewater management system gains bigger diseconomies because of the cost of the sewers networks to collect waste from greater areas. A study in Adelaide, Australia, found that the conventional centralized design was at least ten fold larger than an economic optimum (Clark and Tomlinson, 1995). The centralized systems place lesser investment in the treatment plants and greater investment in the non value adding sewer networks which account for even about 90% of the entire wastewater management systems.

There is a growing debate (Bakir, 2001; Hedberg,1999; Widerer & Schreff, 1999; Otterpohl *et al.*, 1997 ; Butler & McCormick, 1996) that small decentralized wastewater systems at the scale of a household or neighbourhood can efficiently deliver at much lower cost the intended benefits of wastewater management like the protection of public health, stopping pollution of the community environment and water resources and maximizing the recovery of water for beneficial use. Small decentralized systems facilitate accelerated and environmentally responsible extension of wastewater services which are robust and efficient. However research is suggesting that the optimum scale of integrated waste water recycling systems is in the range of 1000 to 10000 connections (Mitchell, 2006).

For decentralized system water conservation efforts can be accommodated and the water inputs in wastewater transportation can be reduced, eliminating the non-productive and unnecessary consumption of freshwater in waste transportation. The pollution control can be made more efficient and site specific. By managing wastewater closer to the source, greater investment in reliable treatment works can be ensured than in non value adding sewer networks. The environmental risks associated with large schemes are reduced by isolating the problem rather than centralizing it. Wastewater reuse opportunities can be increased within and closer to the source in the household, neighbourhood and community where the value of water is highest. The community needs can also be met for better surrounding environment, habitat, trees and economic productivity.

The reclamation and reuse of municipal wastewater is a well-established practice in many areas of the world and these activities will continue to increase. Total onsite wastewater management and recycling systems may include a septic tank followed by further treatment in intermittent sand filters, subsurface constructed wetlands or reed beds. Highly efficient and compact aerobic treatment plants are also available. When total onsite management becomes not possible due to prevailing site conditions or increased development density, onsite systems can be upgraded. Modular wastewater systems can be built using the lower cost and less water intensive settled sewers to collect the partially treated wastewater effluent from septic tanks to neighbourhood or community treatment facility after which the effluent can be brought back for beneficial reuse.

Using reused water for landscaping application generally requires only secondary treatment and disinfection while potable reuse requires much more extensive treatment. Potable reuse requires in addition to primary and secondary treatment, treatment processes such as re-carbonation, multimedia filtration, selective ion-exchange, carbon adsorption, reverse osmosis and disinfection. In general, water reuse for non-potable purposes is more feasible and cost effective than for potable uses (Asano and Madancy, 1984).

In the United States, cities located in water-stressed regions are on the cutting edge of water-reuse activities. For example, Los Angeles has set the goal of reusing 40 percent of its municipal wastewaters within 20 years. This goal is an important component of plans to recharge underlying aquifers and combat seawater intrusion into their coastal groundwater reserves. Arizona also has ambitious water reuse plans calling for 19 percent of all water needs to be met through reclaimed wastewater. Retrofitting systems to individual houses requires a double collection and distribution pipe network (Kaufmann *et al.*, 2007).

St. Petersburg, Florida, completely reuses all of its wastewater and discharges none to its surrounding lakes and rivers. The city has developed dual water distribution systems, one for delivering drinking-quality water and one for delivering treated wastewater. The treated water costs about one-third less than the drinking quality water. Windhoek, Namibia was the first to reclaim wastewater for their public supply. Studies are being conducted on the feasibility of reclaiming wastewater to drinking quality.

A range of technologies for different stages of waste water treatment exist and are also used in India. These technologies are not always sustainable or sensible. Professionals need to understand these technologies to take informed decisions about which are really the best technologies or combination of technologies to implement in any given situation and also to avoid particular technology. For the sustainability of the treatment of domestic waste water issues that are relevant for the urban areas in Indian context (Mara, 2003) are low cost system in terms of capital and maintenance, simplicity in operation and can be maintained by low skill personals, low or zero energy usage, low or zero use of chemicals, low land requirement, low sludge production and high performance. Some of these technologies applicable in residential development are discussed in brief below:

Septic tanks (Primary and decentralized treatment): The septic tanks only provide primary treatment. But in improved septic tank two treatment process i.e., mechanical and biological is applied. Most of the treatment in septic tank takes place in anaerobic conditions. Hence by adding a polishing pond the treated water is exposed to sunlight which helps in reducing the pathogen count. Finally this treated water is used for irrigation. For waste water generation between 600 to 700 litres per day is treated in improved septic tank in farmhouse in Delhi with a capital cost of Rs. 35,000/- (CSE, 2008).

Waste stabilization ponds (WSP): It is a large shallow basins enclosed with earthen embankments where raw waste water is treated by natural processes in presence of algae and bacteria. As the oxidation of the waste in this types ponds are slow it require a longer hydraulic retention time than in conventional waste water treatment plant. Therefore WSP require large area. There are three major components of WSP: anaerobic, facultative and maturation ponds. Anaerobic and facultative ponds are designed for BOD removal and maturation ponds are designed for faecal bacteria removal. However macrophyte ponds and advanced pond systems are also other types of WSP. The WSP is simple, low cost, efficient and robust. Simple construction, simple operation and maintenance therefore cost is also less. The system is based on gravity flow and power requirement is nil. WSP is extremely efficient because it can be designed to remove BOD and suspended solids and ammonia more than 90 percent. It is also efficient in removing excreta pathogens (Mara, 2003).

Constructed wetlands (Reed bed system): The constructed wetlands are secondary treatment units. Therefore these are to be preceded by a septic tank or an anaerobic pond to remove the solids that would otherwise clog the gravel bed of the wetlands. Constructed wetlands are also called reed beds as the aquatic macrophytes are grown in them. The constructed wetlands are long narrow shallow reactors in which the partially treated wastewater is treated further by natural wetland processes. The constructed wetlands generally require more land than a secondary facultative pond.

Root zone treatment: It is a decentralized wastewater treatment and recycling system, consists of sealed filter beds made up of sand, gravel or soil planted with vegetation which can grow in wet systems. After removal of coarse and floating material, wastewater passes through the filter bed where its biodegradation takes place. The process is a natural way of treating domestic wastes. It has three integrated compartments the reeds, reed bed and microbial organism. In this system, contaminated water is allowed to flow underground through the root zones of especially designed reed beds. The reeds and the reed beds on the soil surface provide an efficient treatment system. It can be built for effluent ranging from one kilo-litres per day to 10, 000 kilo-litres per day. For domestic wastewater the land requirement is around $0.2m^2$/ person. The treated water can be used for irrigation.

Up flow anaerobic sludge blanket reactors (UASBs): The UASBs are reinforced concrete structures. The UASBs are very efficient anaerobic reactors with short retention times (6-12 hours). But these are not significantly more efficient than anaerobic ponds, especially high rate anaerobic ponds but they are much more expensive to construct and overall land area savings are small (Mara, 2003).

Aerated lagoons: Aerated lagoons are activated sludge units operated without sludge return. It can treat raw waste water or settled waste water. BOD removal > 90 percent are achieved at a short retention time of 2-6 days, with 4 days a typical value. In common with all activated sludge systems, aerated lagoons are not particularly effective in removing faecal bacteria and reductions are only 90-95 percent (Mara, 2003).

Activated sludge system: The conventional activated sludge system can be used for very large population with extreme caution as they consume considerable quantities of electrical energy, very complicated to operate and maintenance (highly skilled operators are needed).

In the conventional and highly engineered wastewater management technologies and strategies often focus on electro-mechanical solutions that are capital intensive and require ongoing capital investments for effective operation. Additionally, these systems have shorter life-cycles compared to many alternative and naturally-based technologies which also offer opportunities for resource recovery. The development of zero-discharge urban wastewater management strategies will contribute to a reduction in the pathogenic contamination of surface and groundwater and aid in protecting the vitality of urban dwellers. Organic waste recovery can result in production inputs for urban agriculture, enhance food security and link different sectors of local economies. Decentralized, organic waste recovery systems that integrate the best available low-technology in the recovery of urban domestic wastewater flows are essential and appropriate components in the promotion of a comprehensive urban ecosystem health strategy.

In the decentralized treatment system, a balance between the advantages of large scale treatment in terms of economics of scale and individual responsibility for domestic wastewater treatment can be obtained by providing colony wise or sector wise treatment system. It does not necessarily mean the low cost treatment systems like root zone treatment, stabilization ponds, septic tanks and imhoff tanks, wherein installation cost, operation and maintenance cost of such treatment system are low in comparison with conventional energy intensive treatment system. Sometimes high-tech systems are also required for such projects. Each treatment technology has got its advantages and disadvantages and any technology for treatment should be selected after taking all necessary considerations.

In many situations, onsite treatment and storage systems (e.g. anaerobic treatment technologies and septic tanks) can be effectively used for the management of wastewater. The increased understanding of the role of organisms in waste water purification process is providing both economic and environmental benefits. In these systems, enclosed greenhouses enhanced the growth of algae, plants & bacteria which in turn, act to degrade the biological and pathogenic components of waste water effluent. Mechanized or conventional treatment systems are efficient, in terms of their spatial requirements (0.5-1 m^2 /person compared to natural treatment systems at 5-10 m^2/ person), but depend on economies of scale to make them economically feasible. Conventional, aerobic treatment results in maximum reductions in BOD and nutrients while it is desirable to retain biomass BOD and nutrients for agricultural production. Often, the removal of pathogens requires chemical inputs to meet disinfection guidelines which increase the operation cost and complexity of the system. Dependence on chemical disinfection also complicates effluent reuse in non-restricted irrigation schemes when compared to low-cost solutions such as wastewater stabilization ponds (WSP), which are economical, produce similar reductions in BOD, nutrients, and greater pathogen reduction but at a fraction of the cost. Natural treatment technologies are considered viable because of their low capital costs, their cost of maintenance, their potentially long life cycle compared to electro-mechanical solution and their ability to recover a variety of resources.

4.4 GREYWATER REUSES

Greywater is defined as the residential waste water without any input from toilets which means that it corresponds to waste water produced from bathroom, showers, hand basin, laundry water, and kitchen water. Dishwashers, showers and bathtubs, bathroom and kitchen sinks and washing machines are common sources that produce greywater, which comprises 50 to 80% of residential waste water. Greywater can be treated with relatively low effort to render the recycled water fit for the specific reuse purpose. As greywater production is constant and exceeds the demand of water for non-potable applications (flushing water, garden watering or washing clothes) greywater recycling is adequate for all kinds of settlements (Kaufmann *et al.,* 2007). However, greywater from the kitchen contains additional oils and fats so in many situations the kitchen waste water in not combined with greywater to make the treatment system more efficient.

Greywater can be separated and used for household landscaping with minimum treatment and possibly for other non-potable application, such as toilet flushing but with more investment in treatment. The technologies are well developed and tested. Domestic greywater recycling reduces the need for potable water (up to 50%) and thus relieves the demand on public water supplies and wastewater collection and treatment facilities (Kaufmann *et. al.,* 2007). Use of greywater for urinal and toilet flushing is one of the possibilities as good quality water is used for toilet flushing in many countries. In St. Petersburg, Florida, USA treated grey water is supplied to over 7000 establishment for flushing and gardening.

Greywater can replace fresh water in many instances, saving money and increasing the effective water supply in regions where irrigation is needed. Greywater use greatly extends the useful life and capacity of septic systems. For municipal treatment systems, decreased wastewater flow means higher treatment effectiveness and lower costs. Greywater is purified to a spectacularly high degree in the upper, most biologically active region of the soil. This protects the quality of natural surface and ground waters. Less energy and chemicals are used due to the reduced amount of both freshwater and wastewater that needs pumping and treatment. Greywater application in excess of plant needs recharges groundwater. Greywater enables a landscape to flourish where water may not otherwise be available to support much plant growth. Reclaiming nutrients in greywater helps to maintain the fertility of the land.

4.4.1 Components of greywater treatment system

Greywater treatment system generally includes primary, secondary and tertiary treatment systems. In primary treatment system, a sedimentation tank is used to screen out oils and greases and solid particles. In secondary treatment system, chemical and biological treatment processes are used to remove most of the organic matter. This reduces health risk at end use with human contact and provides additional safety for reuse. Tertiary treatment processes further improves the quality of greywater or polish it for reuse applications. Fixed film biological rotating drums, membrane bioreactors, biologically aerated filters, activated sludge and membrane treatment systems are all included in this category.

4.4.2 Pre-treatment of greywater

If any significant quantity of food waste enters the system from dishwashers and kitchen sinks receiving cooking grease and a fair amount of food residue, this option is recommended. A typical installation is not very different from a traditional system; but the treated effluent is of much better quality and does not pollute nearly as much. Ideally, it should consist of a three-stage septic tank for sludge and grease separation (Figure 4.1and 4.2). The separated sludge can thus be removed less frequently (every fourth year instead of bi-yearly as is standard practice with many conventional systems). The outgoing effluent in the septic system is anaerobic. Following the septic tank is a sand filter (Figure 4.3) designed for restoration of aerobic conditions. The final treatment stage leading to purified water of near potable-quality (Figure 4.4) is treatment in a planter bed.

This is not the most inexpensive solution. It is, however, one of the most effective, simple-to-maintain on-site treatment techniques available today (http://www.greywater.com/treatment.htm).

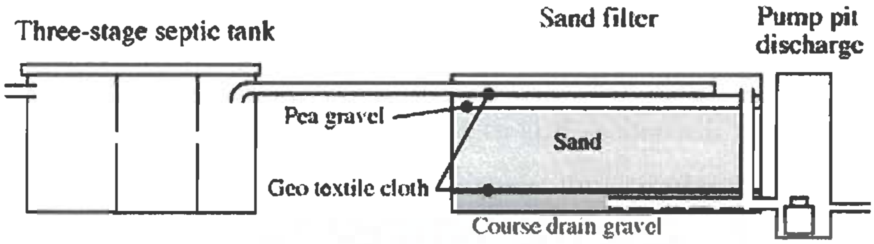


Figure 4.1 Septic tank, sand filter and pump pit (http://www.greywater.com/treatment.htm).

Figure 4.2 Three-chamber septic tank (http://www.greywater.com/treatment.htm)

Figure 4.3 Sand filter with a geo-textile cloth (http://www.greywater.com/treatment.htm)

Figure 4.4 Final result from the sand filter (swimming-quality water) (http://www.greywater.com/treatment.htm)

4.4.3 New technology for residential reuse of treated greywater

Nubian Water Systems introduces the latest OASIS GT600 greywater treatment system with its new age slim line treatment unit (Figure 4.5). The system can be installed beside house, requiring no excavation or disruption. It is as easy to install like other household appliances. It has no unpleasant odours, self cleaning, low maintenance, low power consumption, no harmful chemicals, no pump outs, automatic, continuous process; chemical free and can process up to 1500 litres per day.

Figure 4.5 Domestic greywater systems by Nubian Water Systems (Oasis GT600)
Source: http://www.spec-net.com.au/press/0609/nws_100609.htm

4.4.4 Case studies of greywater use in India

The greywater recycling and reuse in the India is rare. More over there are companies provide solutions for waste water treatment as a whole but not greywater treatment plant separately for residential development. The author has personal interactions with few companies like ITT India, Decan Waters Pvt. Ltd etc, who are providing the waste water treatment solution in India. Engineers of ITT India (Mr. S. Naik and R. Sonawane, June, 2009) informed that they have systems like Sequential Batch Reactors (SBR) and

Membrane Bioreactor for residential or hotel waste water treatment for low end recycle applications. Initial cost, maintenance and space requirement information have not been provided as it is project specific information. However it has been informed that greywater treatment system for residential can be simple clarifier with disinfection system and for reuse application further sand filter and ultra-filtration is required. Mr. A. Sarkar, Managing Director, Decan Water Treatment Pvt. Ltd. informed the author through personal email that the company is providing greywater treatment plant (Figure 5.6, DECPAC- GWTS). The cost of 50 m^3/ day treatment capacity greywater treatment plant cost approximately Rs. 0.55 million (ex-factory price) and space required for the same is about 3mX3m. However the system depends on continuous power supply.

Figure 4.6 DECPAC- GWTS (Grey Water Treatment System)
(Source: www.decanaqua.com)

In residential schools in Jhabua (Madhya Pradesh, India), the UNICEF along with NEERI designed and implemented the rain water harvesting system and grey water recycling system for reuse of water. One of the schools has over 500 students, 175 of whom live in the girls' hostel. The rainwater from this hostel roof is collected in a covered brick masonry tank through a PVC pipeline and is chlorinated every 15 days. An overflow pipe for recharge connects the collection tank to the tube-well which is the only permanent source of water in the school. The water used in kitchens and bathrooms is treated and reused for bathing, washing, cleaning toilets, mopping and flushing. Treatment includes an equalization-cum-settling tank and filtration units comprising locally available filtering material and storage tanks with baffles for aeration. An average of 2,000 litres of grey water is treated every day per project. The low-cost system comes for about Rs 22,000 (http://www.unicef.org/india/resources_2537.htm).

A number of technologies have been applied for greywater treatment worldwide varying in both complexity and performance. Greywater treatment process varies from simple devices that divert greywater for direct application such as irrigation to complex systems involving sedimentation tanks, filters, bioreactors, pumps and disinfection systems.

Design components of greywater treatment system: The design components of treatment system based on the application in schools in Dhar and Jhabua districts by NEERI is discussed below.

Primary treatment (Figure 4.7) is composed of (1) Screening, (2) Equalization, **Secondary treatment** (1) Gravel filtration, (2) Sand filtration and disinfection by Chlorination.

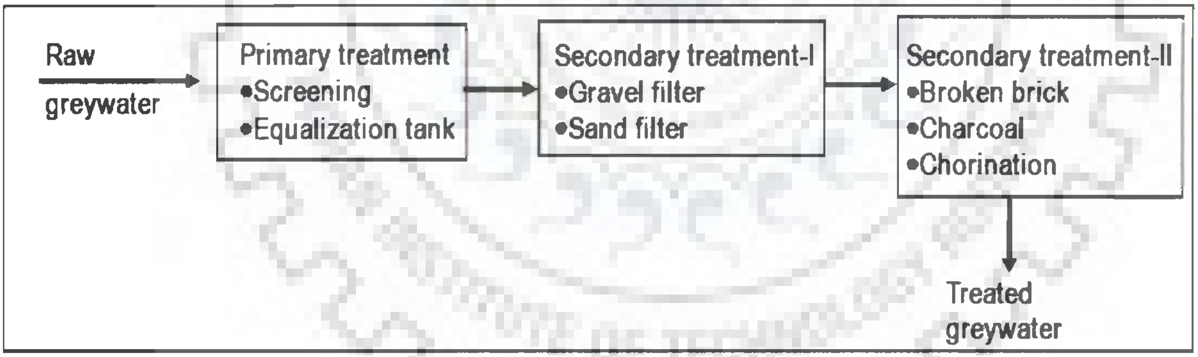


Figure 4.7 Grey water treatment schemes as used by NEERI in schools.

Screen: Screen is kept at the outlet of pipes collecting greywater from different sources. Screen can be a mesh with less than 10 mm size to remove coarse particles. The load to common screen can be reduced if mesh is kept at the inlet to the piping system of sources such as bathroom, kitchen etc. The functions of greywater treatment units are given in the Table 4.1.

Table 4.1 Greywater treatment units and functions

Unit of treatment system	Removal
1. Screen	Floating matter, suspended matter
2. Junction chamber	Odour, some of settleable solids
3. Equalization Tank (Holding)	Settleable solids
4. Horizontal Roughing Filter	Turbidity, suspended solids, some amount of BOD
5. Slow Sand Filter	Colour, bacteria, suspended solids and some amount of BOD
6. Disinfection	Bacteria, odour

Junction Chamber: Junction chamber is provided to facilitate draining out greywater from different sources. The dimension of junction chamber is kept about 0.3 m x 0.3 m x 0.5 m for a hostel having greywater generation of 2000-3000 l/day. The dimension of junction chamber is determined based on providing sufficient storage to handle peak hourly volume. A small rack containing sponge or foam can be provided close to the top of junction chamber (or equalization tank) for removal of froth generated from bathroom and washing place due to use of soap.

Equalization or Settling Tank: Equalization or settling tank (Figure 5.8) is an important component of greywater treatment system. It is required to balance flow to take into account maximum flow of greywater generated during morning hours due to bathroom use. Adequate aeration by providing baffles and mixing must be provided to prevent odors and solids deposition in equalization tank. Baffles can also be provided in equalization tank though it may restrict settling of particles. Greywater is continuously collected in the tank and flows to filters for treatment. In addition to providing constant load to the filter system it facilitates settling of coarse particles (>10mm size).

Figure 4.8 Settling tank for primary treatment of grey water in school in MP (NEERI, 2007)

Filter: The type of filter required for a greywater system depends largely upon the amount of greywater to be filtered, the type of contaminants present and end use. A drain filter is an easy and inexpensive way to filter lint and hair out of bath or laundry water. A simple cloth bag tied over the end of a bathroom pipe may be sufficient for irrigating outdoors or similar applications. Filtration is one of the most important operations in the greywater purification process. Though screening and sedimentation process remove a large proportion of suspended matter, they do not effectively remove fine flock particles, colour, dissolved minerals and microorganisms. In filtration, water is passed through a filter medium in order to remove the particulate matter not previously removed by sedimentation. During filtration, the turbidity and colloidal matter of non-settleable type protozoan cysts and helminthes eggs are also removed. It is to be mentioned that protozoa are stopped in the gravels, the bacteria by the medium gravel and the viruses by the sand. The filter types are 1) Up flow –down flow filter, 2) Multi Media Filter, 3) Slow Sand Filter (Figure 4.9), 4) Horizontal Roughing Filter.

Figure 4.9 Sand filers are accommodated within small area in the plot (NEERI, 2007)

Up flow-down flow filter: As the name suggests, raw greywater is put into the bottom of first column of filter and collected at the top of second column. This water is again fed to the third column of filter from the bottom and is collected at the top of fourth column. The number of columns depends on quality of greywater and expected use of greywater and optimally upflow-downflow filter contains four columns. The filter media varies with the column and may contain gravel, coarse sand, fine sand and other material such as wooden chips, charcoal etc (Figure 4.10).

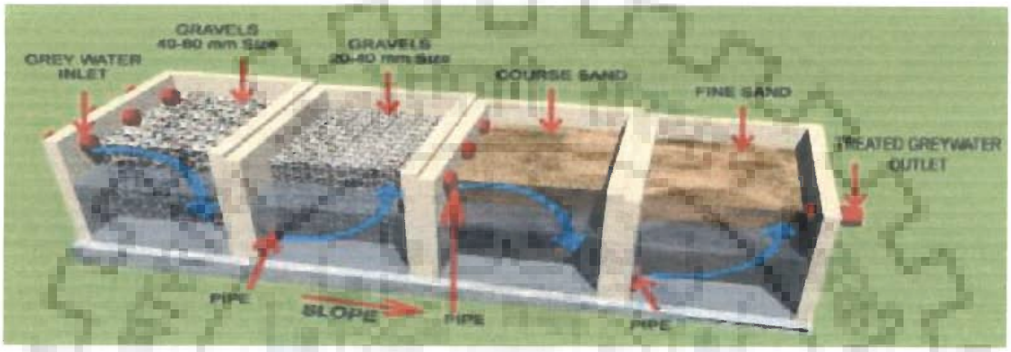


Figure 4.10 Up flow-down flow greywater filter developed by NEERI, 07

Multi-media filter: Multi-media filters are filled with a variety of media in order of increasing size, for example, fine sand, coarse sand, gravel, stone and wood chips to a total depth of 0.75 m to 1 m. The inlet is provided at the top so that the filtered water is collected through outlet in the bottom. A vent is provided at the top for letting out odorous emissions if generated in the filter. Media can be taken out for washing periodically depending on the greywater characteristics and quantity. Replacement of local filter media is also a feasible alternative.

Slow sand filter: Slow sand filters are shallow layers of stone, medium gravel and pea gravel beneath a deep layer of sand (Figure 4.11). A slow sand filter will have greywater load of 0.1 to 0.2 $m^3/m^2/hr$. These gravity filters may be constructed in a 200 liter drum or similar container that is of suitable size. Features that should be part of a filter include a perforated plate or some other device to distribute water evenly over the top, a concrete funnel in the bottom to help water drain to the perforated drain pipe, and a cover and vent to prevent odors. The bottom of the filter should be filled with stones that are too large to enter the drain pipe. Slow sand filters require regular cleaning and replacement of the top layer of media. Multi-media filters require less frequent cleaning, but all layers must be cleaned or replaced when maintenance is required. Routing greywater through a settling tank before filtering reduces contaminant load and can lengthen the interval between cleanings.

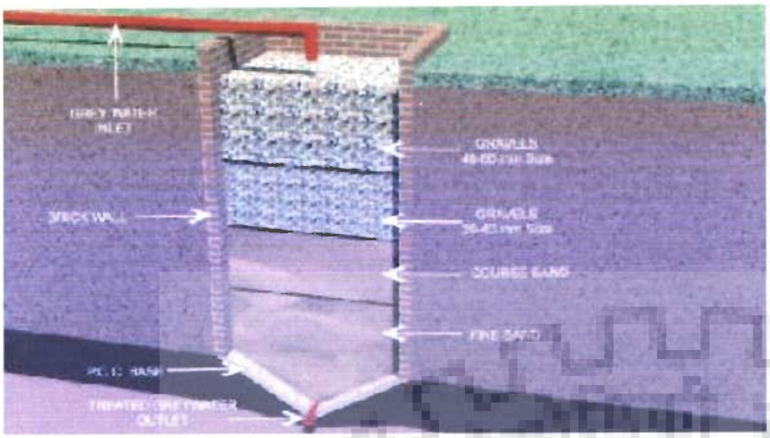


Figure 4.11 Slow sand filters for greywater treatment in Madhya Pradesh (NEERI, 2007)

Horizontal roughing filter: The horizontal flow pre-filtration technique using coarse gravel or crushed stone as a filter media is also a sound alternative in handling turbid waters. The main advantage of the horizontal flow pre-filter is that when the raw water flows through it, a combination of filtration and gravity settling takes place which invariably reduces the concentration of suspended solids. The effluent from the pre-filter, being less turbid, can be further easily treated with slow sand filter. Horizontal flow pre-filtration may be carried out in a rectangular box similar to a basin used for plain sedimentation filled with various filter media. The raw water inlet is situated at one side of the box and the outlet at the opposite side. In the main direction of flow the water passes through various layers of graded course materials in the sequence coarse-medium-fine.

Collection sump: A collection sump of an appropriate capacity to handle the average daily generation of treated greywater is required along with greywater treatment plant. In case the greywater generation is large (more than 4000 liter/day), collection sump may have capacity to handle half of the quantity of greywater generated per day. It should be ensured that greywater reuse should also continue along with greywater generation and treatment to avoid accumulation and facilitate overflow of treated greywater from collection sump. Freeboard of 0.2-0.3 m should be provided in collection sump.

Pump: Various types of pumping mechanisms can be employed in greywater reuse systems. The pump should have a minimal yield (Q) of 1000 liter per hour and should be a high head or low discharge pump.

Wetland treatment: Experience has shown that especially constructed wetlands are suitable for greywater treatment including disinfection of the treated greywater when reuse is considered. The constructed wetlands are artificial greywater treatment system consisting of shallow (usually less than 0.6 m deep), ponds or channel or tanks planted with aquatic plants and relying upon natural microbial, biological, physical and chemical processes are used as wetland treatment system. Submerged type of wetland treatment minimum can treat up to 4000 litre per day of greywater. The flow diagram of greywater treatment system incorporating wetland treatment is shown in Figure 5.12.

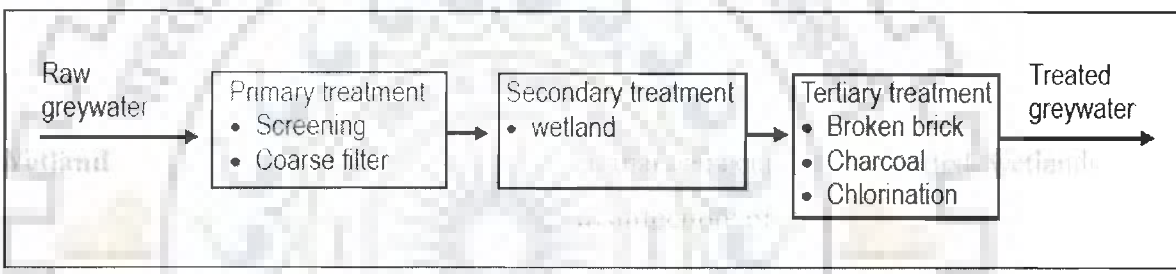


Figure 4.12 Greywater Treatment Systems with Wetland Treatment (NEERI, 2007).

4.4.5 Standard design of greywater treatment system

It has been seen that greywater treatment plants mainly consist of sedimentation or settling unit and filters. Removal efficiency of suspended solids in sedimentation tanks depends on surface area and depth of tank. Surface loading rate is the basic guidance parameter for determining size of tank. The design criteria for sedimentation or settling tank presented in Table 4.2 can be considered.

Table 4.2 Design Criteria for Sedimentation Tank (NEERI, 2007)

S.No	Parameter	Range
1.	Detention time (hours)	1-2
2.	Surface loading rate ($l/hr/m^2$)	500-750
3.	Depth of tank (m)	0.6-1.0
4.	Length to width ratio	3:1 to 4:1

The major processes in filtration are sedimentation in the pore spaces, adhesion to the media particles, and bio-chemical degradation of captured particles in slow-sand filter. The design features of upflow-downflow and horizontal roughing filters in greywater treatment system are provided in Table 5.3. Standard design for greywater treatment systems have been worked out for different quantities of greywater generation based on the design criteria described above. Various treatment options, possible greywater reuse, construction and maintenance costs and associated health risks are presented in Table 4.4.

Table 4.3 Design Criteria for Roughing Filters (NEERI 2007)

Sr. No.	Parameter	Roughing filter	
		Upflow - downflow	Horizontal
1.	Number of compartments	3-4	3-4
2.	Media and size (mm)	Gravel (20-40) Gravel (5-20) Coarse sand (1-5) Fine sand (0.1-1)	Gravel (20-40) Gravel (5-20) Coarse sand (1-5) Fine sand (0.1-1)
3.	Hydraulic loading (m^3/m^2-hr)	0.1-0.3	0.1-0.2
4.	Depth of media (m)	0.4-0.6	0.5-0.7

4.4.6 Greywater treatment in Kokawad Ashram School in MP

Total grey water generated 1500 - 1750 litres / day. The detail of the area requirement of designed treatment plant in the school is given in the Table 5.5. The UNICEF and NEERI along with Government and Non-government partners have constructed six greywater treatment plants in Dhar and Jhabua districts. The details of the grey water recycle system along with the cost of these systems are presented in Table 5.6. On the basis of these case studies the capital cost and area requirement can be estimated for other grey water reuse systems.

Table 4.4 Details of greywater treatment system

Parameter	500 to 2000 l/day	> 2000 l/day
Treatment	➢ Sedimentation ➢ Horizontal filter ➢ Slow sand filter ➢ Disinfection	➢ Sedimentation ➢ Horizontal filter ➢ Slow sand filter ➢ Disinfection OR ➢ Sedimentation ➢ Wetland
Uses	➢ Toilet flushing ➢ Irrigation ➢ Floor washing ➢ Construction	➢ Toilet flushing ➢ Irrigation ➢ Floor washing ➢ Construction
Construction Cost	USD 250-600 based on flow*	USD 500 1000 based on flow*
Maintenance Cost per year	USD 12-25*	USD 25-50*
Water saving per year	200,000 to 400,000 litre	More than 400,000 litre
Monitoring/ Maintenance	High	High
Health risk	Low	Low

Table 4.5 Design details of greywater treatment system in Kokawad Ashram School

Sr.No.	Specification	Size of tank in cm	Filter material
1.	Equalization tank	75 x 75 x 60	
2.	Filter I	75 x 75 x 60 40 x 75 x 60	Gravels (40 to 50 mm)
3.	Filter II	35 x 75 x 60	Gravels (10 to 30 mm)
4.	Filter III	50 x 75 x 60	Coarse sand (1 to 1.4 mm)
5	Filter IV	35 x 75 x 60	Burnt bricks (15 to 30 mm)
6	Filter V	35 x 75 x 60	Fine sand (1 to 0.07 mm)
7	Collection tank	100 x 100 x 100	
8	Greywater storage tank	200 x 100 x 100	
9	Overhead tank	100 x 100 x 100	

Table 4.6 System details and cost of the greywater reuse system in Madhya Pradesh

Ashram School	Greywater generation (l/d)	Treatment units	Size L x B x H (m)	Slope (%)	Collection Tank (liter)	Cost (USD)
Kalidevi (50 Students)	1000	1) Equalization 2) Gravel (30-50 mm) 3) Gravel (10-30 mm) 4) Coarse sand (1-2 mm) 5) Fine sand (0.5-0.8 mm) 6) Broken Brick (20-40 mm)	3x2x0.5 0.4x2x0.5 0.35x2x0.5 0.5x2x0.5 0.35x2x0.5 0.35x2x0.5	2	2000	600
Kokavad (50 Students)	1000	1) Equalization 2) Gravel (30-50 mm) 3) Gravel (10-30 mm) 4) Coarse sand (1-1.4 mm) 5) Broken Brick (20-40 mm) 6) Fine sand (0.5-0.8 mm)	3x2x0.5 0.4x2x0.5 0.35x2x0.5 0.5x2x0.5 0.35x2x0.5 0.35x2x0.5	2	2000	650
Mandu (135 Students)	2500	1) Equalization 2) Gravel (15-25 mm) 3) Gravel (8-15 mm) 4) Coarse sand (1-1.4 mm) 5) Fine sand (0.5-0.8 mm) 6) Charcoal 7) Chlorination	1.7x1.2x0.6 0.5x2.3x0.6 0.5x1.5x0.6 0.7x1.2x0.6 0.3x1.2.x0.6 0.25x1.2x0.6 -	2	2500	870
Nalchha (65 Students)	1825	1) Equalization 2) Gravel (15-25 mm) 3) Gravel (8-15 mm) 4) Coarse sand (1-1.4 mm) 5) Broken Brick (20-40 mm) 6) Fine sand (0.5-0.8 mm) 7) Charcoal 8) Chlorination	3.0x0.7x0.5 0.5x0.7x0.5 0.5x0.7x0.5 0.6x0.7x0.5 0.4x0.7x0.5 0.35x0.7x0.5 0.35x0.7x0.5 0.3x0.7x0.5	2.5	2000	$610

4.5 DEWAT SYSTEMS

Decentralized Wastewater Treatment Systems (DEWATS) is a system where the waste water is not transported over long distances and is a compact system with low foot prints. It is practically useful for small and medium community. It mostly uses anaerobic treatment, multiple baffle tank, root zone aeration system and sand bed/ gravel filters and solution which use biotechnology that subsidizes effluents with respect to pathogens and dissolved solids – bio-converting them into a safe mode.

It can be implemented various capacities at various levels. It is also reliable and long lasting. Due to the use of biotechnology effluent get stabilized in respect of pathogens and dissolved solids, including brackishness, heavy metals and other toxic which get bio converted into a safe mode. The treated waste water gets stabilized with lower BOD and COD. The dissolved solids don't pollute the ground water. Experience suggests that the use of pollutant actually seem to help plant life to flourish, without contamination of such residual.

DEWAT is based on different natural treatment techniques put together in different conditions according to need. It is based on the four basic treatment modules which are 1) Primary treatment, which includes pre-treatment and sedimentation in settlement tank or septic tank. 2) Secondary anaerobic treatment in baffled reactors. 3) Tertiary aerobic or anaerobic treatment in reed bed system. 4) Aerobic treatment in ponds.

Primary treatment: Pre-treatment is used for screening and sedimentation process, in which the liquid part is separated from solid matter. A unit called a septic tank is used for this. It is a sedimentation tank in which settled sludge is stabilized by anaerobic digestion. The treatment efficiency of a septic tank is in the range of 30% of BOD removal. Space requirement is 0.5 square metres per cubic metre of daily flow.

Secondary treatment: In this stage biological and natural chemical processes are used to digest and remove most of the organic matter. A device called an anaerobic baffled tank reactor is used for this phase. Several chambers are built in a series to digest degradable substances. At the end of the treatment device, a chamber can be set aside as an anaerobic filter in order to improve the treatment efficiency. Nearly 90% of the original load is removed at this stage. Space requirement is one sq. m. per cu. m. of daily flow.

Tertiary treatment: A horizontal planted gravel filter acts through the combined effect of the filter material and plants growing on the filter media. The effluent is odour free. Space requirement is 5 sq. m. per cu. m. of daily flow.

Aerobic pond or polishing pond: The final treated water will be exposed to atmosphere through the polishing ponds. Here both aerobic degradation and pathogen removal takes place. It require large permanent place and if these are too small mosquitoes and odour can be a problem and algae can raise the BOD of the effluent. Space requirement is 1.2 sq m. per cu m. of daily flow.

Reuse options: Reuse of treated water for gardening and horticulture, biogas for lighting and heating purpose, sludge can be transformed into good manure through composting, re-use of construction areas as play grounds and parks chatting place etc.

O &M : Operation and maintenance can do by trained persons of local community, periodical maintenance can do once in 3years or 5 years, cost inculcated for operation and maintenances per annum is approximately Rs. 5000/-.

Brar *et al.*, 2005, reviewed the water supply and sewage disposal system in small and medium towns with viable technological options and cost related to implement these technologies. The comparison of Centralized Wastewater Treatment System (CTS) with Decentralized Wastewater Treatment System (DTS) have been discussed in terms of it technology, applicably, cost and area required for the system for a particular size of population. It is concluded that for a community size of 5000 to 10,000 population the combination of non-conventional methods of decentralized wastewater treatment (DTS) like baffled septic tanks, anaerobic filters, root zone planted filters and duck weed pond can be adopted which will also reduce the overall water demand of the community from 270 lpcd to 185 lpcd reducing demand by 31.5 percent. It will also conserve the quality of existing water sources and improve environmental quality.

4.6 CASE STUDIES OF WASTEWATER MANAGEMENT

Centre for Scientific Research (CSR), Auroville, Tamil Nadu has using DEWAT methods since 1984. At present, CSR operates more than 50 DEWATS plants for recycling both grey and black domestic waste water.

In Delhi, the Vigyan Vijay Foundation constructed a waste water treatment system in Vasant Vihar with active coordination with Vasant Vihar Residential Welfare Associations (RWA), MCD and Horticulture Department in 2005. The decentralized waste water treatment system (DEWATS) were used to treat the waste water from nearby stream and used to irrigate parks. The overall cost of the plant came out to be around 0.7 million with plant capacity of 35kl/day. After stabilization for 3 months the result of BOD reduction was up to 90% and the total area was irrigated is 45,000 sq. m. (www.vigyanvijay.org). The cost implication of such DEWAT plant as estimated by the Vigyan Vijay Foundation is described as below:

An apartment of say 100 houses discharges a quantity of waste water; say about 300litres per day per house, i.e., 30,000 litres in total. A DEWATS plant having a capacity of 10kilo-litres per day costs Rs. 0.25 million hence this will be 3 times for this case i.e. Rs. 0.75 million. The monthly cost of 3000/- on electricity and 2000/- for 1 or 2 *mali* (gardeners) to work regularly on the plant is needed.

Including the depreciation cost of Rs.0.75 million for 10 years works out to Rs.6250/- month, Rs.5000/- pm for the monthly cost of operation and 5% per year for maintenance after 3 years works to Rs.3125/-, the total cost of maintenance per month works out to Rs.14375/- per month. Therefore, for the 900kilo-litres of water processed every month, the cost of treating one kilo-litre of waste water works out to Rs.16/- (www.vigyanvijay.org).

Chandigarh has received the distinction of being at the top in the areas of water supply and waste water management through effective sewerage drainage system. Chandigarh has the highest per capita quantum of water supplied in the country at 332 litres per capita per day. Water is supplied to households from 16 to 19 hours daily in urban sectors and 8 to 10 hours in colonies and villages. The city has 100 per cent coverage with direct water supply connections of which 78 per cent are metered. The award for best sewerage and drainage services has been given to Chandigarh for being the only city in India which has prepared a concrete action plan to treat its sewage effluent as per the Central Water Pollution Control Board standards before its disposal into natural streams. The coverage of waste water network is 100 per cent. Around 59 per cent of the waste water is treated for secondary treatment and 14.25 per cent of waste water is recycled which is used for irrigation purposes in green belts, parks etc. The cost recovery in waste management is 80 per cent.

In the Xavier Institute of Management in collaboration with Central Institute of Freshwater Aquaculture (CIFA), Bhubaneswar implemented community based water resource management with emphasis on natural water quality improvement and resource recovery. In this system the sewage is made to undergo natural rejuvenation process through engineered wetland system before disposal. An over flow weir is constructed on the drains which act as the first siltation pond or tanks followed by a series of 3 more pond or tanks namely aeration pond, duck weed pond and fishery pond. Water quality is monitored regularly for BOD load etc. before the disposal (http: // www.icefindia.org/sp xim.htm).

Two villages in Punjab have developed community based waste water treatment projects on constructed wetlands. The wetland reduced BOD up to 85 percent and coli form 90 percent. In Kharoudi village, (Punjab) an efficient sewage treatment system is developed. The entire sewage of the village is made to flow into a large septic tank outside the village with in anaerobic bacteria are produced and thrive on sewerage. This bacterium does not need oxygen but feeds only on solids thus cleaning the water up to 85 percent. From this tank water flows into a smaller tank laid with perforated pipes, covered with nylon filters and three feet of rubble and further covered with three inches of sand and three inches of mud, finally taken into a pond for UV treatment of pathogens. A fountain is placed in the middle of the pond provides aeration. Water is finally used for fisheries and irrigation of field (Saxena, 2005).

Saraf, 2008, reported that the result on studies of kitchen waste water treatment as:

- A family of four persons generate 25 to 40 litres of highly biodegradable kitchen wash water.
- The COD of wash water varies from 625 – 5000 mg/l
- Hydraulic loading rate of waste water for treatment is $0.2m^3/m^2$/day.
- The treated water is almost clear, colourless and odourless. Turbidity never exceeds 10 NTU. pH value varies from 7 to 8.34.
- The COD of treated water varies 63 to 375 mg/l. The reduction of COD varies from 72.2 to 96.66 percent. The average value of COD reduction is 84.43 percent.
- No mosquitoes breeding are observed during experiment. The loss of water by trans-evaporation is 25 percent in month of December and 40 percent in month of April.
- The treated water can be recycled for the activities like watering plant and flushing of toilets.

The East Devadhanam is a peri-urban area slum, located in Trichi with a population of 2000. The DEWATS has been successfully implemented in the area. In this project waste water is collected from 20 toilets with approximate number of user is 450. The waste water streams are channelled from all the sources and collected in a common place near treatment system which consists of four modules: Biogas settler, Baffled reactor, Planted gravel filter and Collection tank. The design capacity of the system is $9m^3$/day.

1) Biogas settler is a sedimentation tank. Biogas is formed due to digestion of settled organic particles under anaerobic condition.
2) The baffle reactor ensures anaerobic degradation of suspended and dissolved solids by mixing.
3) Planted gravel filter is used as tertiary treatment unit where aerobic and facultative degradation of dissolved organic and pathogen removal occurs.
4) The collection tank in used to store treated water.

The details of the area requirement are given in the Table 4.7

Table 4.7 Details of area requirement of the DEWATS:

Components		area requirement in m^2
Biogas settler	Digester volume -15.2 m^3	
	Gas volume-2.5 m^3	
	Area of construction	19
Extension Chamber	Volume - 2.5 m^3	
	Area of construction	7
Baffled reactor	Volume – 36.3m^3	
	Number of chambers – 16	
	Area of construction	36
Planted gravel filter	Volume – 19m^3	
	Filter material – gravel	
	Plant used – Reed juncas, Colacasia,	
	Area of construction	57
Total built up area		126

Source: Fact sheet (2006), on CBS-DEWATS in East Devadhanam, Exnora International, Chennai.

The waste water treatment plant is operated and maintained by the trained members of the self help groups. A regular schedule is followed for maintenance like periodical checks of sewer line systems, removal of sludge in settler and in baffled reactor. In the planted gravel filter regular harvesting of plants is done and the filter media is washed once in five years. The Influent Quality: BOD – 300, COD – 600, Effluent Quality: BOD – 45, TS – 68, Efficiency: BOD – 89%, TS – 92%, Biogas production: 2 to 3 m^3 /day, Cost: Rs. 0.5 million. Cost incurred for operation and maintenance per annum is approximately Rs. 5000/-. The treated waste water is reused for gardening and horticulture of the nearby area, biogas is used for lighting and heating purpose and sludge is transformed into good manure through composting. The monitoring result of the system shows the reduction of BOD by 83% and TS by 68% (Table 4.8).

Table 4.8 Monitoring result of the system implemented in East Devadhanam.

Location	BOD in mg/litre	TS in mg/litre
Inlet point	181	198
Inlet of baffle reactor	55	100
Inlet planted gravel filter	50	70
Outlet drain	30	64
% reduction	83	68

4.7 OTHER OPTIONS OF WASTEWATER TREATMENT IN INDIA

The M/s Simplex Envirosciences & Infradevelopment (P) Ltd has developed package sewage and effluent treatment system in collaboration with US based firm. These package sewage and effluent treatment plants known as AEROFLOW system are prebuilt at factory and can be installed directly with minimum of supervision. The benefits of packaged Aeroflow Sewage and Effluent Treatment have the advantages like compact footprint, easy installation, low maintenance cost, ease of operation , long life, above all saving of valuable land space (almost 40 to 50 % reduction in space over conventional system). These compact package sewage and effluent treatment systems are suitable and beneficial to hotels, hospitals, resorts and housing colonies, multi-storeyed apartments, school and college buildings, small and medium size industries and other similar institutions (http://www.geomiller.com).

The selection of any of the option totally depends upon the raw water quality available and the final application of treated water. For wastewater treatment for residential buildings or apartments, there are certain issues to be addressed while designing a system as under:

1. The system must be compact so that it occupies minimal area. This is because apartments have hardly any area to spare for STP.
2. The system must be such that there is no odour around it. This is because it may be located in the car park (underground) or in the garden area where kids play.
3. The system must be closed so that there is no open sewage that is bad to look at and there are no germs flying around the open system.

4. The system must be aesthetic in appearance like a silent DG set versus a normal DG set which invariably looks like a monster ready to eat.
5. The system must be such that it could be shifted or relocated as and when required. The system must have minimal power consumption.
6. The system must be able to run at less than 24 hours operation unlike most systems which run round the clock and cannot be shut.

4.8 CONCLUDING REMARKS

The decentralized wastewater treatment and recovery technologies that are linked with urban agriculture systems, at the neighbourhood level; appear to be a rational approach of solving the human and environmental health dilemmas that result from under-managed wastewater. Decentralized small scale systems must be considered in planning and upgrading urban environments. Gravity flow, small bore sewage and water borne conveyance systems offer the potential to decentralize urban environments into catchment systems, each with their own integrated treatment plants and at low costs. These systems would be based on the topography of the local water shed and would result in small-scale facilities equally dispersed through environment. Pathogenic reduction and nutrient recovery would occur through the use of integrated biological processes. This approach would allow for independent, self maintained and self sustained facilities that are capable of recovering wastewater resources and immediately reusing them in decentralized urban farms.

Urban waste management must be transformed from a disposal-based linear system to a recovery-based closed-loop system that promotes the conservation of water and nutrient resources and contributes to public health. Moreover it is apparent that both the knowledge and the technology exist can enable this transformation. There is a gap between the current availability of innovative technology and the promotion and financing of demonstration level projects as well as the development of complementary socioeconomic methodologies to facilitate their implementation.

The development of zero-discharge urban wastewater management strategies will contribute to a reduction in the pathogenic contamination of surface and groundwater and aid in protecting the vitality of urban dwellers. Organic waste recovery can result in production inputs for urban agriculture, enhance food security and link different sectors of local economies. Decentralized, organic waste recovery systems that integrate the best available low-technology in the recovery of urban domestic wastewater flows are essential and appropriate components in the promotion of a comprehensive urban ecosystem health strategy.

In the decentralized treatment system, a balance between the advantages of large scale treatment in terms of economics of scale and individual responsibility for domestic wastewater treatment can be obtained by providing colony wise or sector wise treatment system. It does not necessarily mean the low cost treatment systems like root zone treatment, stabilization ponds, septic tanks and imhoff tanks, wherein installation cost and operation and maintenance cost of such treatment system are low in comparison with conventional energy intensive treatment system. Sometimes high-tech systems are also required for such projects. Each treatment technology has got its advantages and disadvantages and any technology for treatment should be selected after taking all necessary considerations.

CHAPTER 5
EXISTING WATER MANAGEMENT SCENARIO IN DELHI

5.1 PRELUDE

Delhi is situated on the banks of river Yamuna, Delhi is located at 28.38° N and 77.13° E on the northern part of India (Figure 5.1) and stretched over an area of 1483 sq km. Major part of Delhi is a plain area. The other parts of Delhi are the Yamuna flood plains and the ridge which is the most dominating feature surrounded by the Aravallis Range. Delhi has semi arid type of climate with well-defined three seasons namely summer, winter and rainy. About 80% of the annual rainfall received during southwest monsoon period between July and September (27 days). The average rainfall of the state is around 611mm.

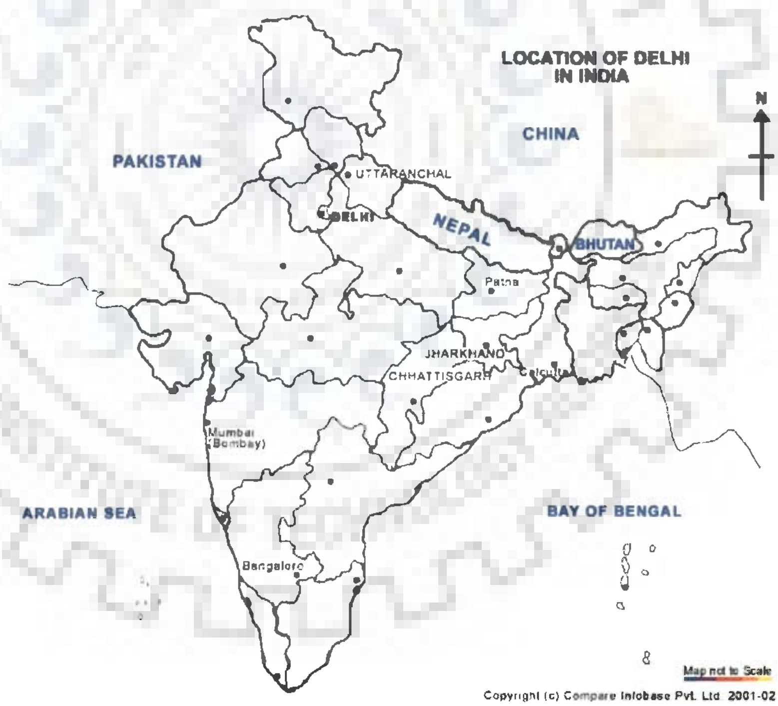


Figure 5.1 Location Delhi, Source: www.mapsofindia.com

Delhi is experiencing population increase from 0.4 million in 1911 to 13.8 million in 2001 (Table 5.1) and the population is expected to become 23 million by 2021 (Table 5.1). The growth of population exerts severe stress on the water supply system in Delhi. Delhi urban area has highest per capita supply of water in India at a rate of 60 gallons per capita per day (gpcd) or around 273 litres per capita per day (lpcd). The demand of water was 3810 million litres per day (MLD) in 2004 where as the supply has been only 2868 MLD. The present demand of water is 3864 MLD, whereas the supply is around 3082 MLD. There is a large demand supply gap of water. There is also an alarming transmission loss of 48 percent (Basil, 2004), which reduces the actual treated water available to consumer. Delhi faces acute shortage of water, especially during summer months. In a recent survey of 27 Asian Cities having million plus population, Delhi was ranked as one of the worst performing metropolis in terms of hours of water availability per day. Around 10 percent of the population of Delhi has no piped water supply and around 30 percent of population has grossly inadequate water supply (Daga, 2003). Two thirds of the population in the city receives less than 37 litres (2-3 buckets) of water daily (http://www.hazardscentre.org/water.html). The residents of *J.J.* clusters (JJCs), resettlement colonies and unauthorized colonies fulfil their requirements with water from hand pumps, bore wells of Delhi Jal Board or Slum Wing of Delhi Government and a few from treated surface water supply. People living in resettlement colonies like Madanpur Khadar have their own hand pumps and JJCs like Tigri have private bore well to meet the need of water (http://www.hazardscentre.org/water.html).

Table 5.1 Population growth and estimated population of Delhi

Year	Population in millions	Decadal growth (%)
1951	1.74	90.00
1961	2.65	52.40
1971	4.06	52.90
1981	6.22	53.00
1991	9.42	51.50
2001	13.80	46.40
2006	16.2	
2011	18.2	
2016	19.9	
2021	23.0	

Source: www.delhiplanning.nic.in and Mater Plan of Delhi – 2021 (MPD-2021)

The access of safe drinking water in Delhi is 96.24% but in terms of hour of supply it ranked as worst city in Asia (Basil, 2004). Delhi faces water shortage as well as low pressure and high leakage. It has less than 15% of its own water to meet the needs, bulk of the water come from neighbouring states. This along with inadequate and intermittent supply of water has led to unchecked over exploitation of ground water and nearly drying up the river and shallow wells of the city. Delhi has very few pockets where 24x7 water supplies are present (Chadha, 2007). Improvement in living standards and access to sanitation facilities has also increased the per capita demand of water. On the other hand new water sources are scarce, existing surface and ground water sources are deteriorating due to pollution and ground water quantity is reducing due to over extraction and reduced replenishment. About 40 percent of the water supplied by DJB daily is never used for drinking, cooking or bathing. Instead, it is used for other domestic use including flushing of toilets (Table 5.2). It is an international practice to use recycled or less-treated water for the purpose other than drinking. But which is not done in Delhi. Even about 80 percent of the treated water is released into river though Delhi requires large amount of water for gardening and the treated waste water can be used for this purpose. The overall production of water in Delhi is better than any other cities in India but around 10 percent of the population of Delhi has no piped water supply and around 30 percent of population has grossly inadequate water supply. This demands serious overhaul of the supply management. Even planned areas of Municipal Corporation of Delhi (MCD) with house connections have a shortfall of 42 percent (Daga, 2003).

Table 5.2 Estimated break up of domestic water demand in Delhi

	Purpose	Potable @30 gpcd (135lpcd)	Non-potable @20 gpcd (90 lpcd)
1	Drinking	05	
2	Cooking	10	
3	Washing cloths	30	
4	Washing utensil	20	
5	Washing hand and faces	10	
6	Bathing	60	
7	Floor washing		30
8	Flushing of toilets		60
	Total @225lpcd	135lpcd	90lpcd

Source: Khare *et al.*, 2006

5.2 ORGANIZATIONS

The Delhi Jal Board (DJB) is responsible for the production and distribution of potable water after treating raw water from various sources and also provides treatment and disposal of wastewater. The Municipal Corporation of Delhi (MCD) areas are supplied directly from the DJB to the households while water is provided in bulk to the New Delhi Municipal Corporation (NDMC) and the Delhi Cantonment Board (DCB) areas. There are several authorities engaged in the provision, development and maintenance of water supply in Delhi. The Delhi Development Authority (DDA), MCD, DCB) and NDMC are directly responsible for provision of water and plan for new development activities. Besides these, Central Ground Water Authority (CGWA), Central Ground Water Board (CGWB), Central Public Works Department (CPWD), and other Government and non-governmental organizations are engaged in preparations of policy and technological innovations and other aspects of water management in Delhi. Conflicting priorities among these organizations and lack of common action plan affects the delivery of services. One such example is that the CGWA has notified seven districts of Delhi (notified in 1999 for regulation of ground water extraction) but people continue to extract ground water without permission and none of the organization takes responsibility to stop such practices. Similarly there is a bye-law to enforce Rainwater harvesting in all new residential development on 100 m^2 plot size or more. But it is observed that a large percentage of new development does not follow this bye law and no government authority takes responsibility to panelise such development for not following bye-law. There are many such examples in Delhi. The implementation of policies on the issues of water is not clearly defined and not vested on one organization in Delhi. DJB supplies treated water in bulk to the NDMC and to the DCB both are responsible for the distribution of this water within their own territories. The water supply infrastructure in these territories is owned by them and, consequently, is not the responsibility of the DJB.

5.3 SOURCES AND QUANTITY OF WATER SUPPLY

Delhi gets 83% of its raw water from surface water sources and 17% from ground water sources. The surface water sources in Delhi basically comprise of the river Yamuna, canals, drains and the lakes or ponds. There are two main river intake points at Wazirabad and Haiderpur (Figure 6.2). Other sources are the sub-surface sources like Ranney wells and tube wells. 60% of the rainwater goes down the drain as surface runoff (http://www.wwfenvis.org/pdf/rain.pdf). Though average per capita availability of water in Delhi is 232 litres, some parts get 30 litres per capita, whereas, 5% of the population gets even more than 450 litres per capita per day (http://www.wwfenvis.org/pdf/rain.pdf).

Delhi receives 2300 million litres of water from the Yamuna, the Western Yamuna Canal, and the Ganga (Figure 5.2). These sources of water supply of Delhi are through different interstate arrangement. The main source of water in Delhi is the river Yamuna on which a dam was constructed in Wazirabad to supply water to the entire city. Delhi is presently sourcing part of its water supply from a distance of 500 kilometres. This also adds in the cost of transport, treatment and delivery of water to the consumer (http://www.hazardscentre.org/water.html).

The existing water works at Bhagirathi, Wazirabad, Chandrawal, Haiderpur, Nangloi and the ground water sources have a total capacity of 678 mgd. There is a requirement to increase the treatment capacity as well as raw water supply through additional infrastructure and proper legislative arrangement. The DJB is only able to treat and supply about 60% of the raw water which it receives (international standard are ranging between 80 to 90%). Substantial investment is required to increase the treatment capacity and efficiency.

To reduce the demand supply gap new raw water sources have been identified in Delhi (Table 5.3). These sources aim to provide supplies to treatment plants at Sonia Vihar, Nangloi, Bawana, Okhla and Dwarka. All planning for future water supply in Delhi is based on anticipated raw water inflow from three large dams under construction in the Himalayas, which may not be able to supply water for near future due to environmental controversies. The DJB's approach is basically a supply side approach by exploiting additional water resources to meet the increasing water demand of Delhi. The Central Ground Water Board also has provided details of fresh water sources in the city to the Delhi Jal Board but they have not exploited the potentials of those sources. The Central Ground Water Board also assessed 215 billion cubic meters surplus monsoon runoff that can be stored and utilized for future but DJB has not utilized the potential yet and DJB did not consider it as an alternative source. This shows that there is no coordination among the organizations for implementation of research findings on water management in Delhi.

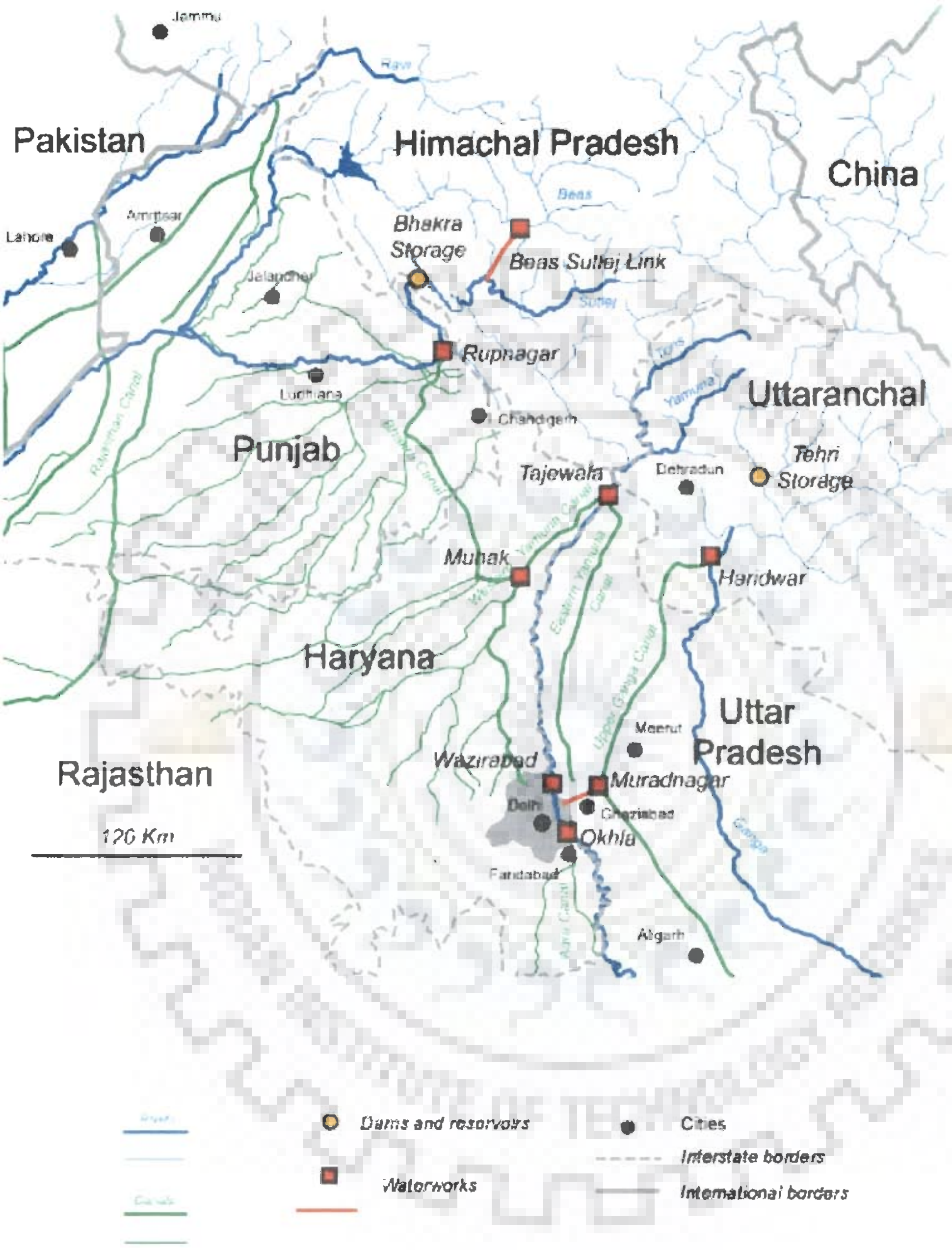


Figure 5.2 Location major sources of water for Delhi
Source:www.iddri.org

The total number of private tube wells (domestic, commercial and industrial) in Delhi is estimated at around 200,000. In addition to private tube wells, there are supplies of bottled water as well as numerous hand pumps. No consumption figures are available for hand pump and bottled water supplies. The willingness-to-pay survey carried out under a study project estimates that 23% of the households use such sources for some part of their water requirement (Economic Survey of Delhi 2003-2004).

Table 5.3 Status of new raw water sources and expected supplies

Identified source	Expected quantity of supplies	Current status
Tehri dam	300 cusec	Availability expected
Channel from Munak to Haiderpur	Loss of 720 mld owing to leakage and seepage expected	Construction delayed due to disputes over the cost estimates
Additional water from BBMB*	180mld	Delays in construction of the Yamuna-Satluj link canal
Renuka Dam on the Giri River	500 cusec	Long-term proposal
Kishau Dam on the Tons River	500cusec	Long-term proposal
Lakhawar Dam on the Tons river	500 cusec	Long-term proposal

Source: TERI; *BBMB: Bhakra Beas Management Board,

Water supply and treatment capacity is being increased in Delhi, almost in each five year plan taking into account the requirement of drinking water for the population increasing at a very high rate, almost more than double to the rate of increase at national level. In spite of best efforts made by the Government, water supply front remained a matter of concern due to various reasons like raw water scarcity and related problems, transmission and distribution losses, supply with less pressure, uneven distribution, depleting ground water level, reduction in ground water recharge due to rapid urbanization, increasing cost of water treatment and increasing gap between water supply cost & tariff, etc. (Economic Survey of Delhi 2005-2006).

The water treatment and supply capacity was 66 MGD in 1956 raised to 650 MGD in 2002 and about 75.33% households met their water requirement through piped water supply system and about 21.91% household through tube wells or deep bore hand pumps or public hydrants. Remaining 2.76% households depended on other sources like wells, river, tanks, canal, ponds etc (Economic Survey of Delhi 2005-2006).

The report of Asian Development Bank (2002) mentioned that the domestic consumption of water in Delhi is 37%; nondomestic consumption 10% and non revenue water 53% with service coverage of 69%. The water production during 2001-2002 by DJB was 2911 MLD (640 mgd) with authorized consumption 58% and water losses 42% (Economic Survey of Delhi, 2003-04).

5.4 GROUND WATER SITUATION

The ground water also contributes a substantial quantity of raw water for Delhi. As per the report released by Central Ground Water Board, the dynamic ground water resources in Delhi have been assessed as 292 MCM in 2003 (withdrawal equals to 312 MCM) as compared to 428.07 MCM in 1983 showing an overdraft and reduction of around 130 MCM over past 20 years . The high population growth and high level of urbanization in Delhi has resulted in over-development of ground water. And in about 75% of area of Delhi ground water levels are declining at an alarming rate of 0.20 m per annum (CGWB, 2008).

Underground water is fast depleting in quantity and quality. Percolation is less as the earth surface is covered with buildings, roads, pavements etc. The intermittent supply and the gap between demand and supply, which is partially met by extractions of ground water through wells; tube wells and deep bore wells has led to the over exploitation of ground water and nearly drying up the river and ground water. In Delhi, as per the report presented to the Union Ministry of Water Resource by the Central Ground Water Board (CGWB), six districts – Central, New Delhi, North, West, South, and South West – have been listed for registering a negative trend of ground water levels. A comparison of the existing groundwater levels in the different administrative blocks with levels in 1960 shows a decline of 2 to 30 m (Figure 5.3 and 5.4). The ground water levels in Alipur and Kanjhawala blocks have declined by 2 to 6 m, in the Najafgarh block by 8-20 m and in Mehrauli by 8-35 m (Economic Survey of Delhi 2003-2004). The situation has not been changed even after the amendment of building byelaws to make water-harvesting mandatory for all new building of plot area of 100 m^2 or more. Even freshwater tube wells are yielding brackish water (Basil, 2004).

The rapid urbanization resulted in reduction of the recharge of aquifer where as the increasing demand has increased the unplanned withdrawals. The Central Ground Water Board carried out isotopic investigations to assess the natural recharge in Delhi and found levels of recharge lower than 5% in most of the area. In the urban centre, recharge was lower than 3%. A sustainable use of ground water means withdrawal of ground water at a rate at which it is replenished through recharge but which is not in the case for Delhi. The ground water abstraction is regulated in many parts of Delhi (Vasant Kunj and Vasant Vihar areas of Mehrauli Block has been notified in 1999 for regulation of ground water extraction) but the authorities have no practical means of controlling it and abstraction is tolerated as a compensation for the failure of the reliable water supply. The ground water recharge areas need to be identified so that maximum recharge can be achieved and these recharge areas should be conserved and preserved.

The (hydro) geological situation of Delhi is characterized by the occurrence of alluvial and hard rock formations and controls the groundwater availability in the territory. The quality of the groundwater in the hard rock formation in Delhi is generally potable, whereas in the alluvial formation groundwater, the water quality deteriorates with depth. The decreasing ground water level in Delhi has become a matter of serious concern. Large-scale groundwater withdrawal for domestic, irrigation, and industrial purposes has resulted in a widespread decline of ground water table. Moderate to highly saline-water suggests that the amount of rainfall recharge is very limited and that groundwater flushing is incomplete. The ground water levels have declined with the additional problems of brackishness and pollution due to the tremendous abstraction. Brackish ground water is found in Kanjhawala, Najafgarh and Bhalaswa, Burari and Dheerpur at shallow depths. Minor patches of brackish water are found in Alipore and City Blocks. The quality of underground water is deteriorating and in several places it has been found to be unfit for human consumption. The salinity of ground water is increasing in south-west and north-west Delhi. In some areas of Shahdara and Kanjhawala, nitrate content has been found to be more than 1000 mg/litre. Fluoride and chemical concentrations, more than prescribed limits, have also been found in ground water at various locations in Delhi (Economic Survey of Delhi 2003-2004). Approximately 65% of ground water in Delhi required purification and 33% need constant monitoring. There has been an increase of fluoride and nitrate contents beyond permissible limits. In areas like IIT, NCERT campus, Naraina and part of Shahadra, nitrate content in more than the permitted 10mg per litre. Other parts of the city like Najafgarh and Kanjhawala have more than the permitted 1.55 mg per litre of fluoride (Basil, 2004).

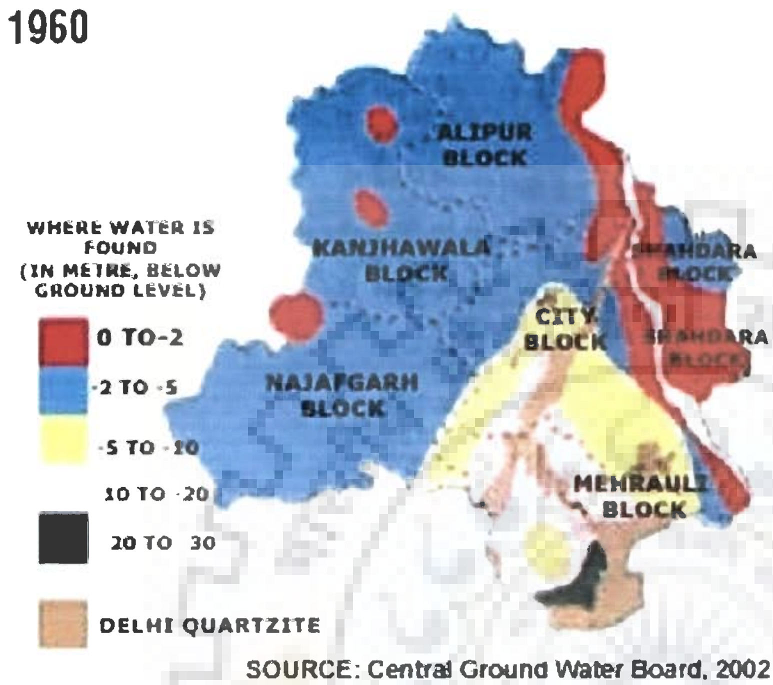


Figure 5.3 Ground water levels in Delhi in 1960

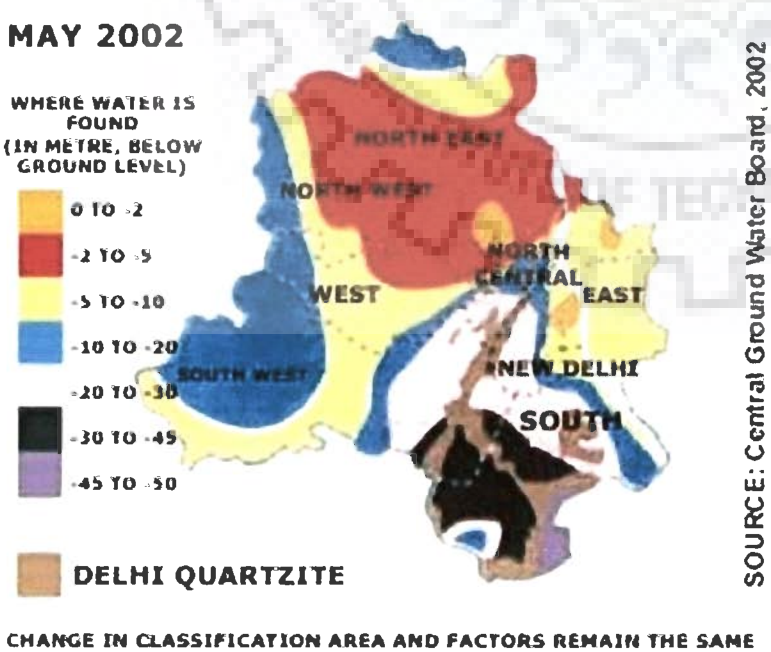


Figure 5.4 Ground water levels in Delhi in 2002

5.5 WATER QUALITY

In Delhi residents receive water only a few hours per day because of inadequate management of the distribution system. This results in contaminated water and forces households to complement a deficient public water service at prohibitive coping costs; the poor suffer most from this situation. With the increasing complains related to quality of water supplied and cases of water borne diseases, Hazards Centre collaborated with other organizations of *Sajha Manch* has been conducting a study on the water quality of *Juggi Jupri Cluster (JJC)* and resettlement colonies in Delhi in three phases; pre-monsoon, monsoon and post-monsoon. Water quality testing was done for different parameters like-nitrate, fluoride, chloride, residual chlorine, total iron and faecal coliform in 11 different *JJCs* and resettlement colonies. The pre-monsoon study included 27 water samples from DJB boring, private boring, hand pump, surface water supply through pipe and tanker and the results of analysis revealed only one sample as potable. The second phase study incorporated 53 water samples, of which only 5 samples meet the standards for drinking water quality (http://www.hazardscentre.org/water.html). This has lead to the use of individual water purifying devices by the residents who can afford it.

5.6 WATER DEMAND

The Master Plan of Delhi-2021 has given the water requirement 80 gpcd (360 lpcd) with breakup of domestic and non-domestic as 50 gpcd (225 lpcd) and 30 gpcd (135 lpcd) respectively. The Master Plan of Delhi 2021 (MPD-2021) projected a water supply requirement of 1150 MGD for 2021 and as per the estimate by DJB in all possible way it can supply around 919 MGD only by 2021 after implementation of augmentation plan though the projected demand by DJB for 2021 is around 1380 MGD (Table 5.4). Therefore the supply and demand gap will continue to increase and people will depend more to the unsustainable arrangement to reduce the gap. Delhi is facing serious water shortage due to increase in demand of water. The demand supply gap of water is more than 20%, as estimated from the present demand supply status of Delhi Jal Board (DJB). The present water demand for potable water in Delhi has been assessed as 990 MGD (@ 60 gpcd for all uses) (MPD-2021). Whereas, the DJB's actual production of water is around 678 MGD. There is around 32% shortage of potable water in Delhi.

Table 5.4 Estimated water demand in Delhi

Year	Populations in million	DJB estimation(MGD) (@60 gpcd)	DDA estimation(MGD) (@80 gpcd)
2006	16.5	990	
2007	17.5	1050	
2011	19	1140	1520
2021	23	1380	1840

Source: DJB and MPD 2021

The estimated water demand for Delhi (Table 5.4) as per DJB estimation is around 1140 mgd for 2011 and about 1380 mgd for 2021 where as the maximum water augmentation capacity by DJB is around 940 mgd 2021. The proposed steps to meet the shortfall as per MPD 2021 is to expedite the construction of more dams and increase the height of dam and transfer of large volume of water through interstate agreement but there is no proposal for reducing the water demand through demand management.

The standards on which the DJB as well as DDA is working are very high as compared to other Indian Cities (Mumbai 135 lpcd, Chennai 80 lpcd). Moreover standards set by two organizations are different show the lack of understanding among the two organizations for water provision in Delhi. The DJB is unable to provide continuous supply of water which leads to water wastage, water contamination and responsible for reducing the life of the system. Most of the European, Asian and African cities able to manage 24-hour supplies with much less water than Delhi (Lal, 2005). The present water supply standard appears to be unrealistic, which also need to be reconsidered.

The estimated breakup of the per capita demand as given in Table 6.2 (Khare *et al*, 2006) clearly shows that the other demand except domestic demand need not to be the potable water, recycled water or water from other sources can be used for the same. It is necessary to classify the quality of water required for different activity in our day-to-day life, like for drinking and cooking, for washing, for toilet flushing, for industries, for recreation, for maintaining garden and urban green etc. The dual supply (water for drinking and cooking and water for other uses) needs to be seriously considered for Delhi.

The per capita demand can be reduced through policy measures and with appropriate technology. DJB has initiated water saving programme through media to educate people, but these efforts are not sufficient. More over DJB or any other organizations in this context are not encouraging the use of water saving devices in the system. Presently the market don't provides water appliances and water use devices with information on water saving.

The per capita distribution differs even for different areas within Delhi e.g. the MCD area receives 29 lpcd to 337 lpcd, the Cantonment Board 509 lpcd, the NDMC areas 462 lpcd (Table 5.5) and some core areas like the Golf links etc. receive greater than 450 lpcd in contrast with slums that barely receive 30 lpcd. The emphasis should be given on equitable distribution or the pricing should be sensitive to this differences. It is absurd that the potable water demand is different for different area in the same city. A clear policy should be initiated to check the discrepancy.

Table 5.5 Quantity of water supply in various zones of Delhi (1997)

Sl. No.	Name of Zones/ locality	Per capita supply (lpcd)
1	Cantonment	509
2	NDMC	462
3	Karol Bagh	337
4	Paharganj	201
5	City	277
6	Civil lines and Rohini	274
7	West Delhi	202
8	New Delhi and South Delhi	148
9	West Delhi	202
10	Narela	31
11	Shahadra	130
12	Najafgarh and Dwarka	74
13	Mehrauli	29

Source: Rohilla *et al.*, 1999.

The experience of the past two Master Plans shows that the projections regarding various basic infrastructure services have been made with reference to the population growth projections and the increased urbanization requirement. However, the infrastructure provisions especially those related to water and power have not matched the pace of development (MPD-2021). Per capita water demand for Delhi as per the CPHEEO guidelines are given in the Table 5.6.

Table 5.6 Per capita per day water requirement for Delhi as per CPHEEO norms

1	Domestic	172 lpcd
2	Industrial, Commercial and Community requirement based on 45000 litres per hector per day	47 lpcd
3	Fire protection based on 1% of the total demand	3 lpcd
4	Floating population and special uses like hotels and Embassies	52 lpcd
5	Total	274 lpcd (60gpcd)

Source: Master Plan of Delhi - 2001

The Master Plan of Delhi 2021 (MPD-2021) projected a water supply requirement of 1150 MGD for 2021 but Delhi Jal Board (DJB) in all possible way maximum can supply around 919 MGD by 2021 after implementation of their augmentation plan. There will be around 20 percent gap between supply and demand. However to improve the situation the MPD-2021 has given emphasis on the following issues

- Promote water conservation through an integrated and community driven model.
- Recycling of treated wastewater with separate lines for potable water and recycled water.
- Groundwater recharging through rain water harvesting, conserving water bodies and controlling encroachments.
- Focused planning and action to be taken to prepare and implement rain water as roof water harvesting schemes both with the aim of optimizing water use and ground water recharge.

The issues have been addressed in the overall vision to the improvement of the system but this should be backed by action plan with proper technical and institutional and policy guideline. There is a need for proper technical, physical and economical investigation to offer consumers the appropriate options for efficient water management. The benefit and options should be demonstrated and proper policy and institutional arrangement should be made for implementation. There is no consideration for water use efficiencies and use of water saving devices to reduce the demand.

5.7 LOSSES IN THE SYSTEM

The infrastructure of basic water supply services is marked with resource losses caused by leakage in water conveyance from the raw source to treatment plants and within the consumer distribution networks. The percentage of unaccounted-for-water (UFW) calculated from the deference between water produced and pumped is about 40%, reflecting problems in management of available resources. As per calculations by DJB, the UFW losses in Delhi are 1082 mld. It is estimated that non-revenue water in Delhi is close to 50%, including physical and commercial losses of 40% and 15% respectively, where 15% of the water is lost during distribution and about 40% is stolen (http://www.wwfenvis.org/pdf/rain.pdf). These are due to old supply lines and leakages, non-metered connection and water pilferages. Further, this leaves the service provider with inadequate funds and insufficient resource for efficient operation and upkeep of the system. Use of modern technology to detect the leakage and the use of GIS for locating and monitoring the same is must. For reduction of UFW the approaches may be adapted are the leak prevention surveys, use of leak detectors for early discovery of leaks followed by rapid repair, maintenance and replacement of pipes, water distribution regulation and reduction of loss by pressure regulation. It is necessary to put bulk as well as individual meter to keep track of water use and wastage through leakage.

5.8 WATER METERING

Water meter can be a useful tool in the effort to increase water efficiency in home. It can be used to determine how much water is being used on a daily basis and to detect leaks. The billed metered connections in Delhi are only 13 percent (Table 5.8). Most of the cases the water bill is charged based on bulk average consumptions. All the consumers in an area/ group housing/ community share equally the total water bill. Therefore individual does not care for water saving (Figure 5.5) and none of the housing is equipped with water saving fixtures. Individual water metering and tariff based on the actual consumption is to be implemented to ensure the reduction on water wastage.

Figure 5.5 Drinking quality water is wasted to wash car in Delhi

Table 5.8 Water supply distribution in Delhi 2005

System input volume	Authorized consumption 58%	Billed authorized consumption	Billed metered consumption (including water exported in bulk)	13%	Revenue water 50%
			Billed unmetered consumption	37%	
		Unbilled authorized consumptions	Unbilled unmetered consumptions	8%	Non-revenue water (NRW) 50%
	Water losses 42%	Apparent losses 2%	Unauthorized consumptions	2%	
		Real loss 40%	Leakage on transmission mains	16%	
			Leakage on distribution mains and service and connection up to point of customer metering	24%	

Source: Prepared by author based on Economic Survey of Delhi 2005-2006 and Delhi Water Supply and Sewerage project preparation study report.

If all water connections are metered and water is charged on the basis of actual consumption the saving can be considered more than 20 % of the demand (Maddaus, 2001 estimated 10 to 30 %, Leidal, 1983 estimated as 15-20 %).

5.9 WATER PRICING

Pricing of water will discourage wasteful and environmentally damaging uses of water and therefore encourage conservation and protection of water. While developing water rates, planners must ensure that water is always available for meeting the basic human needs at a reasonable and affordable cost. Water pricing must permit sufficient supply of water for the basic human needs, at an affordable cost to the low income groups within the society and ensure that water efficiency measures never harm public health.

The conservative pricing of treated water discourages a wise use of the water. There are three categories of consumers of water for DJB, the domestic, commercial and industrial consumer. The domestic consumers are the largest consumers (about 86% whereas commercial is about 11% and industrial is about 3%) of treated water and are in subsidized category. This has led to the indiscriminate use of water and wastage. Pricing is considered as tool which automatically guides the consumer and the producer to appropriate level of use and supply. The water supply department or the government has also not attempted to highlight the process and cost involved in the delivery of the potable water to the consumer. The people also do not realize their responsibility towards conserving the water.

Inadequate billing and collection system don't facilitate 100% billing collection. The water charges in Delhi are very low (Table 5.8). The National Water Policy advocates the water rates should be such as to convey the scarcity value of the resources to the user but which is not the case of Delhi. People wash their car, floor and water the plants with highly precious drinking quality water. In absence of proper systems of water charge collection and the billing which is not based on actual water consumptions, encourage the misuse and wastage precious treated water. In Delhi the revenue generation was only about 43 percent in 1999-2000 (Planning Commission, 2002).

5.10 WASTEWATER TREATMENT

As per the DJB around 55% of the population is served by sewerage system. Sewage generated from remaining 45% of the population is eventually drained to the Yamuna River through various open drains. Among the metro-cities in India, Delhi has the maximum gross installation capacity of sewage treatment plant and also has the highest coverage of sewerage network (Paul, 2005). But the sewerage network has lacked maintenance over the years and overflow of raw sewage in open drains is common, due to blockage, settlements and inadequate pumping capacities. Yamuna has been acting as a waste pipe for Delhi by draining out all the wastewater from the city. The area of Yamuna catchments in National Capital Territory (NCT) of Delhi is 1,485 km^2. This area is responsible for 80% of its total pollution load in the river whereas this segment of the catchments constitutes only 2% of the entire catchments (http://www.hazardscentre.org/water.html). The stretch of Yamuna in Delhi is perhaps the most threatened river ecosystem in the world. The river gets more than 3000 million litres of untreated waste water per day from all the 17 main drains which carry both industrial as well as domestic waste water (http://www.hazardscentre.org/water.html).

Table 5.8 Water Charges of the Delhi Jal Board (Applicable From 1.4.2005)

Category	Quantity in litres	Charges Rs. /1000litres
Category I **Domestic**	Till 6,000	00
	7,000 - 20,000	2.00
	21,000 - 30,000	7.00
	More than 30,000	10.00
Category II **Commercial**	≤ 25,000	10.00
	25,000-- 50,000	20.00
	Above 50,000	30.00
Category III **Industrial**	Up to 25,000	15.00
	25,000 – 50,000	25.00
	50,000 – 1,00,000	35.00
	Above 1,00,000	50.00

Source: Delhi Jal Board, 2005

According to DJB, total sewage generated in Delhi in 2005 was 2,948 MLD. This is based on the quantum of water DJB supplied to the people of Delhi. But when the CPCB measured waste flowing in to river Yamuna through the drains, it found that the discharge was 3,684 MLD and 736 MLD higher than the DJB estimation. The total sewage treatment capacity in Delhi is 2,330 MLD. Assuming 80% of the water is converted into wastewater, the treatment capacity to treat wastewater is inadequate which is about 63% only. Delhi has waste water installed treatment capacity of 2330 MLD against the estimated generation is about 3684 MLD (CSE, 2007). The actual quantity of wastewater treated is much below the installed capacity due to incomplete sewer connectivity and chocking of sewer lines. A proper inventory of existing sewer system and network plan is necessary to find out actual area coverage and missing link. The treated waste water is hardly being used. On the other hand, the horticulture water needs are not met. The result is all the public parks and their lawns and gardens are not maintained and remain parched (www.vigyanvijay.org).

Each large building (group housing, apartments etc.) should be constructed with individual water circulation system where grey water can be treated and used for flushing of the toilets. This system can reduce water demand as high as 36% (Khare *et al.*, 2006). As per the new building byelaw in Delhi any building having a minimum discharge of 10,000 litres and above per day shall incorporate wastewater-recycling system. The recycled water would be used for horticulture purpose (GOI Notification, 28th July 2001). Delhi Development Authority (DDA) has prepared guidelines on dual piping system of water supply for supplying the water for drinking and cooking and other pipe system for supplying water for other domestic use to newly developed residential areas to reduce the demand of water. Though the approach is good for reduction of water demand but people are not clear about the benefit of the system and technicalities involved. The implementation of the same is not visible in any part of Delhi. A clear method and technical input are required for the resident to implement the same. The wastewater recycle techniques are not properly experimented in Delhi. A comprehensive plan should be prepared in area level or sector level with the participation of community to reduce the piped municipal water demand. The treated wastewater also can be provided as a dual source of supply for bulk users. However this requires identification of users for pilot implementation and conducting studies to find the potential cost of such provisions, cost/benefit ratio and user acceptability.

Authors' discussion with residents in group housing apartments reveals that people do not even know that the waste water recycling is mandatory for almost all group housing developments because the waste water generation from such development is always more than 10,000 litres per day. Delhi Development Authority in their own group housing schemes also has not considered implementing waste water recycling systems.

A Central Pollution Control Board (CPCB) funded study indicated that only 950 MLD (60% of the installed capacity of STPs) reach the various Sewage Treatment Plants (STPs).

The exiting capacity and utilization of STPs in Delhi are as under:

Total sewage generated	:	3259 MLD (719MGD)
Planned capacity	:	2258 MLD
Installed capacity	:	1573 MLD
Current level of utilization of STPs	:	1332 MLD
CPCB assessed performance level	:	950 MLD

The untreated sewage is released directly into the 14 open drains in Delhi, which finally discharge in to Yamuna. Delhi alone contributes around 3296 MLD of sewage in Yamuna (The Times of India, 2007). Also the treated effluent-meeting all pollution parameters and costing money and electricity to clean is discharged into drains, which are already putrid and full of sewage. The treated effluent does little to dilute the floating filth. The officials have never considered how the treated effluent would be disposed and if indeed it could be reused. The decentralised waste water treatment has not been tried in Delhi. A city will be more efficient if it collects water locally, supplies it locally and disposes waste locally (Narayan, 2006).

5.11 WATER CONSERVATION

The traditional water bodies like ponds in Delhi are either defunct or encroached upon. There is a need to revive the water bodies in the urban area on priority basis. The surface runoff management is the starting point of water resource management. The excess water, causing flooding in some areas, can be used as the potential recharge water to reduce the flooding. The High Court of Delhi has ordered to revive the water bodies in Delhi comprising a network of wells and *baolis*. There are 508 water bodies with wet surface area 4000 m^2 in Delhi (Sinha, 2002). But no comprehensive effort has been shown by MCD, DDA or any other agency to protect these water bodies in Delhi. In the year 2008 again there are some effort to enlist 629 water bodies for revival and maintenance. This list again is not comprehensive. Several water bodies which are struggling to survive due to urbanisation do not figure in this list. The 36000 sq. ft. Mayapuri Lake is one such example. This water body is partially filled up for a common effluent plant (CEPT). A park has come up on the 31000 m^2 water body in Vinod Nagar. A hospital is to come up on an 8400 m^2 water body in Jilmil Tahirpur (Lalchandani, 2008). However several discrepancies are there for about the number and sizes of the water bodies in Delhi. An independent body set up by the court has identified 794 water bodies, out of which 629 water bodies exist officially in Delhi (Lalchandani, 2008). Sincere efforts are required to maintain, preserve and use the existing water bodies. The abandoned quarries with modification of their depth, catchments area and linkage with other nearby channels can be used as storage to reduce runoff and increase groundwater recharge. There are number of micro watersheds present in Delhi which prove excellent topographical formation to conserve monsoon runoff through simple recharge structure. New tanks, reservoir can be created in low-lying areas where there is a natural slope in the terrain and runoff water can be harnessed managed and administered. The Yamuna flood plain (area 97 km^2) in Delhi offers a good scope for development of groundwater resources for storage monsoon water. Out of 580 MCM of monsoon flow allocated to Delhi about 280 MCM goes unutilized due to lack of storages. There is a need to prepare a plan to conserve the resources.

5.12 WATER SAVING DEVICES

Promoting the water saving equipment like water saving plug in the kitchen/hand washbasin, water-saving or waterless toilets, technologically enhanced flushes and showerheads are urgently required. The rating systems of water appliances like washing machine, dish washer etc. to be implemented and customer should be informed about the water requirement of these appliances. The governments needs to push such appliances through incentives and rebates. Efforts have been given to make commercially available power saving equipments in India. But there are no efforts from the government side as well the manufacturers of plumbing equipment to make available water saving and water efficient plumbing fixtures and equipments. The market offers a variety of water supply fixtures, plumbing equipments and water use equipments for domestic use. Many of these are available without ISI mark. People purchase them without any doubt in mind because these equipments are cheaper in cost and people do not know any negative effect for purchasing these equipments. Low quality equipment require frequent repair and associated recurring cost. Life cost of any inferior equipment is more than good quality ISI mark equipment. These issues are not properly explained by any agency and the research in these fields has not been done as these can be documented for awareness of the people. Low quality plumbing and water use equipments leads to a large quantity of water loss. In Indian context there is no research information for quantity of loss in domestic level for such situation. No agency takes it seriously to enforce the ISI mark plumbing fixtures in domestic use. People also do not consider these compromises in quality as a safety consideration for the resident as in the case of electrical equipment.

No effort has been made by the authority to educate people about easy and inexpensive technologies for conservations of treated water. Promoting the water conserving equipment like water conserving plug in the kitchen/hand washbasin, water-conserving toilets, technologically enhanced flushes, showerheads, water thimbles use only half of the volume of water as normal appliances. The rating of water-dependent appliances like washing machine etc needs to be done in the market and customer should be informed about rates of water usage by these appliances. The government needs to push such appliances thorough incentives and rebates. This is high time to introduce water efficiency labelling schemes, which should involve the introduction of national mandatory Water Efficiency Labelling for all domestic plumbing equipments and water use devices. Especially the labelling should be available for shower heads, tap equipment, flow controllers, toilet fixtures, urinal equipment, flushing cisterns, washing machines and dishwashers.

5.13 RAINWATER HARVESTING

Rainwater harvesting is an important technique for increasing the supply. The amount of runoff generated from 910 million cubic meters (MCM) of precipitation in Delhi is 193 MCM. The enormous amount of rainfall is available for which efforts can be made to tap and store the rainfall in both surface and subsurface reservoirs for use. The harvested rainwater can also be used to recharge the groundwater through injection wells, recharge pits, shafts and trenches.

The Central Ground Water Authority recently made it mandatory for big buildings (for an area 100 m^2 or more) situated in place where the ground water level is low in Delhi to make provision of rainwater harvesting and the target date for its implementation was March 31, 2002. But the implementation of the same is not encouraging and satisfactory, as in general people are not aware who to approach for the right harvesting plan or who will execute the plan and above all how to finance the project (The times of India, 8th Feb, 2002; p2). Table 5.9 gives the details of the status of water harvesting works in Delhi implemented by various agencies. The implementation of the rain water harvesting in Delhi is not being monitored by concerned government agencies. Newly developed areas of Delhi show that the group housing societies have made some provisions of rainwater harvesting but its technological appropriateness and maintenance is doubtful. On the other hand most of the plotted developments do not have the provision of rain water harvesting.

The government of National Capital Territory (NCT) Delhi entrusted INTACH, an NGO, for preparing `Blueprint for Water Augmentation' in Delhi. According to the INTACH study, rainwater runoff and flood discharges constitute a major resource to be conserved. It has been proposed to harvest the water through storage and recharge of storm water channels, off-channel storage for floodwaters, storage in lakes and depressions, flood reservoirs, quarries, historical water bodies, check dams, channels, village ponds, rooftop water harvesting and eco-parks. It is estimated that water harvesting and recycling within Delhi can help in reducing the demand supply gap by the year 2021 (Rajput, 2000). This plan is also not been considered for implementation.

It is clear that the issue of water harvesting may be recognized to some extent but because of the involvement of many organizations it is confusing for preparation of proper strategy for implementation. The related issues of ground water pollution due to the recharge of polluted water, quality of water from roof, evaluation of recharging rate and consideration of giving benefit to the person implemented water harvesting scheme are not addressed. The ground water should be treated as national property and therefore, there is a need for a strong institutional and legal framework for its usage, conservation and maintenance of quality (Basil, 2004). There are no policies or programme for road, open space, recreational area, water bodies to adopt rain water harvesting which actually share the major part of urban land use.

The water supply authority needs to install large rainwater storage tank for collection of rainwater from rooftops of building as well as from the other surfaces (paved, unpaved) of the catchment area and distribute the processed water for drinking and non-drinking purpose.

Table 5.9 List of water harvesting works implemented till 2004 in Delhi (By different organizations).

Sl. No.	Organizations	Number of building/ works completed
1	PWD	288 building out of the 430 it own.
2	NDMC	22 out of 107 buildings
3	MCD	257 out of 360
		Sanctioned 2800 for the city
4	DJB	190
		128 schemes for RWAs
5	CGWB:	Approved 1700 designs, in city

Source: compiled by author

In 2001, the Delhi High Court asked the government to make rainwater harvesting compulsory in the city. Eight years on, the situation remains alarming, the ground water level is dropping day by day. According to the 2001 order and a subsequent Central Ground Water Board (CGWB) notification, all government buildings, new structures with a plot area of 100 m^2, all farmhouses, flyovers, hotels, hospitals and cooperative group housing societies were supposed to implement rainwater harvesting. A status report on rainwater harvesting was supposed to have been submitted in court every six months. However, the last time any figures were made available was in December 2007. According to the report submitted to the court, New Delhi Municipal Council (NDMC) had finished work on only 18 of its 125 projects. Municipal Corporation of Delhi (MCD) had identified 365 sites of which work on 297 had been completed. However, about 52 of these were not functional. Several government buildings did not have rainwater harvesting facilities. NDMC also identified 90 roads but no status report was available on them. Delhi Jal Board (DJB), which had taken up the project and provides financial assistance up to a maximum of Rs 0.1 million for approved plans, was also indicted by the CAG report of 2008 for not taking sufficient measures to monitor progress. Those agencies or individuals to whom it provided financial assistance were required to submit six monthly reports on the working of the system. The report stated that between 2002 and 2007, no maintenance report was filed for 97 out of the 108 cases. Only seven random checks were carried out by the utility in this time. Till March 2009, around 279 group housing societies had water harvesting units while 623 had expressed an interest in installing them. Government agencies outlined the problems simply. It is difficult to make people understand that it does not benefit individually but is good for the city. Investment is another problem. Even though the government is aiding financially, not too many people are coming forth. Lack of technical assistance also hindered implementation of the concept. CGWB is the nodal agency in monitoring the project, but, alleged NGOs, other than issuing pre-prepared plans, it has not done much. CGWB has to assist on a case to case basis but it has released several plans which might not be appropriate for each case. CGWB has also been hugely understaffed and not too many designs are being issued. CGWB officials, however, said they were only a technical body and it was up to the Delhi government to take more pro-active steps (Lalchandani, 2009).

5.14 AWARENESS PROGRAMME

Extensive efforts are required to educate people about easy and inexpensive ways for wise use of treated water. It is observed that people of Delhi have little idea about water saving equipments and water saving measures and techniques. Also the market does not sell water use equipments and fixtures with water saving rating as now available for electrical equipments and appliances. Therefore public information campaign can make people aware of such techniques.

Substantial amount of water saving can be done by adopting such techniques and approaches. The government of Delhi through Bhagidhari schemes started awareness campaign to encourage water saving by changing the water use behaviour but does not talk about the technological alterative and use of such water saving devices. Just telling about how to save water may not attribute to water saving unless it is linked to the reduction of water bill.

5.15 ALTERNATIVE WATER PROVISIONS IN DELHI

Delhi Jal Board (DJB) is the sole government agency responsible for meeting water demands of the city. As per the DJB report the present demand for water in Delhi is around 850 million gallon per day (MGD) whereas the supply is about 650 MGD. The DJB in its report also informed that the gap between demand and supply is partly being met by extraction of ground water through wells, tube wells, deep bore wells, hand pumps etc., which is around 20 percent of the total demand. Other estimation also revealed the gap is between 20 to 30 % (Tewari, 2007). Out of total 2.55 million households in Delhi in 2001, about 1.92 million households were provided piped water supply system. About 0.63 million households were dependent on water from other sources like tube wells, deep bore well, hand pumps, public hydrants. Thus about 75% households met their water requirements through piped water supply system and rest 25% household depended on tube wells, deep bore wells, hand pumps, public hydrants and other sources (Economic Survey of Delhi 2005-06, and Table 5.10), which are basically private and informal in nature.

Table 5.10 Sources of water in Delhi (Census 2001).

Sl. No.	Sources	No. of household	(%)
1	All sources	2554149	100.00
2	Tap	1924140	75.33
3	Hand pump / tube wells	559518	21.91
4	Well	1019	0.04
5	Others (river / canal/ tank etc)	69472	2.72

Source: Delhi Statistical Handbook, 2004.

Because of demand supply gap, incomplete coverage, unreliable supply, the residents of Delhi make their own private provision for water by digging tube wells, adding storage tanks and infrastructure for pumping and purifying water in their homes, as well as buying bottled drinking water and water from tanker trucks. A willingness-to-pay survey carried out under a study project estimates that around 23% of the households use such sources for at least part of their water requirement (Economic Survey of Delhi 2005-06). The residents are paying a high price to augment water and the poorer suffer most from such state of affairs. These informal and alternative arrangements of water in Delhi are

(1) private owned bore wells and tube wells, (2) private small scale piped water provision, (3) private water tanker, (4) private packaged water / bottled water, (5) informal reselling of water through push-cart and bicycle operations, (6) DJBs' water tanker, (7) DJBs' packaged water. Most of these alternatives are grossly unsustainable and available to people with high environmental, economical and health cost.

The key reasons for growth and dependency on such alternative water provisions in Delhi are (1) the failure of the public utility provider to provide clean drinking water to the people, (2) the increase in demand for clean water, (3) decrease of water sources due to pollution, (4) increased awareness about drinking water quality and health among the rich and higher middle class and middle class population with increased the dependency on bottled water. Therefore insufficient and inefficient supply of water has increased dependency on bore well or tube wells and private water tanker, again dominated among the people who can afford higher cost for constructing and maintaining the bore well or pay a high cost to procure water from private water tanker. The poor coverage of many areas and unreliable supply by public authority has also increased dependency on public water tanker, informal private piped water supply and pushcart water provider and these areas are dominated by lower middle class and poor people.

5.15.1 Private owned bore wells and tube wells

Almost all colonies in Delhi have private tube wells or bore wells as substitute to the public supply at an individual level. Although the number of private tube wells legally registered to the authority in charge is around 100 000, other sources estimate the actual number of private tube wells between 200 000 and 360 000 (Maria, 2006). Total number of private tube wells (domestic, commercial and industrial) in Delhi is also estimated at around 200000 (Economic Survey of Delhi, 2005-06). Another report informed that there are about 300000 bore wells in Delhi of which 200000 are illegal (Raghupathi, 2003). The phenomenon is more prominent in South Delhi, which has acute shortage of water.

The ground water abstraction is regulated (in notified areas) in many parts of Delhi (Vasant Kunj and Vasant Vihar areas of Mehrauli Block has been notified in 1999 for regulation of ground water extraction) but the authorities have no practical means of controlling it and abstraction is tolerated as a compensation for the failure of the reliable public supply. Legally the bore wells have to be registered with Central Ground Water Authority (CGWA), but these are seldom registered, people continue to drill bore wells and tube wells illegally.

5.15.2 Small scale private pipe water supply

The small scale private piped water providers mostly operate in the areas inhabited by the poor population in the unauthorized colonies where the water utility does not supply water through house connections or stand posts. These operators usually use low technology and charge rates which are much higher than that of charged by the water utility provider. They operate informally. These private operators lay down pipes and provide household connections to residents. They draw underground water and supply it to resident without treating it. These operators take a connection deposit for each connection and charge Rs. 200 per month for 500 litres of water per day (Raghupathi, 2003). The residents use the water for all their needs even for drinking and cooking. As these systems are informal therefore there is no data available with government about the area coverage and quantum of operation of the system.

5.15.3 Private water tanker

There are approximately 250 private suppliers who supply water through water tankers in Delhi (Daga, 2003). There are almost 1200 private tankers (Figure 5.6) operating in Delhi and charging Rs.89 – Rs. 100 or more for per 1000 litres of water (Raghupathi, 2003, Water and Sanitation Program, 2007). The supply of water to areas like Vasant Vihar, Vasant Kunj, Greater Kailash, Dwarka and other areas rely on such water tanker.

Most of these water suppliers operate from Delhi, Noida, Gurgaon and other adjacent areas. These tankers don't take the responsibility of water quality. These suppliers get water by drilling bore well or tube wells and heavily rely on the ground water for their business. It does not take much to venture into this business. Cost of installing a simple bore well varies from Rs. 30000/-to Rs. 40000/- to maximum Rs. 0.25 million. One can dig such well in any part of Delhi without much hassle (Daga, 2003).

Tanker operator began as landowners with access to underground water or transport operators. The water tanker suppliers deliver water at the cost about Rs.500 to Rs.600 for 8000 to 10000 litres of water. The private water operators extract ground water and supply without treating. Though it is mandatory for private water provider to display a sign stating that the water is 'not fit for drinking', in a scarcity situation this sign is not taken seriously and people use this for even drinking and cooking.

5.15.4 Public water tanker

DJB owns and operates about 585 water tankers (Figure 5.7) and hires 375 tankers from private operators to supply water to problems areas. In rural areas from Narela belt to Kapashera belt the ground water is brackish and not fit for drinking, rely on DJB tankers or private takers. Private tankers also supply water on behalf of DJB to several places like slum areas, rural areas, upcoming societies, Delhi Development Authority (DDA) colonies etc. and also to government hospitals, central jail, congested colonies and heavy construction sites like metro project. During period of shortage DJB hires 200-400 water tankers from private operators (Daga, 2003). The DJB supplies tanker free of cost to the connected or eligible households.

Figure 5.6 Hired private water tanker by DDA   Figure 5.7 DJB water tanker in Delhi

5.15.5 Packaged water and bottled water

Bottled water (Figure 5.8) or packed water (Figure 5.9) sector in India is considered to be one of the fastest growing business sectors in India. It is growing at the rate of 75-80%

and a large number of reverse osmosis plants have come up in the last two years (Bhatt, 2005). There are as many as 180 players in the market selling as much as 1000 million litres of water each year (Ramachandraiah, 2004).

People depend on bottled water due to the doubtful quality of water supplied by water utility. Most bottled water companies in Delhi use bore wells and tube wells to pump out ground water and purify to sell it in the market. The brands like Bisleri and Paras have their bore wells in and around Delhi. Under the existing legal framework, companies can simply drill a hole in the ground and extract water to make profit. Though there are regulations concerning the issuance of permits for drawing groundwater, the laws at present have no provision to set a limit on the quantum of water that could be exploited by the permit holders. Independent observers say that the permit system for licensing commercial activities involving extraction of water is fundamentally flawed because no means exist to independently verify the quantity of water drawn by companies. Even worse, in the absence of accurate data, like who is drawing how much, it is virtually impossible to ensure efficient usage of water and minimize wastage.

Delhi Jal Board also supplies bottled water under the brand name of JAL and priced at Rs. 15 per 20 litres. Private bottled water provider charges around Rs. 40 per 20 litre

Figure 5.8 Bottled water

Figure 5.9 Packaged water

containers. The rates of bottled water vary though a typical charge would be Rs. 10 for one litre bottle. This could come down to Rs. 35 - 40 for 20 litres bottle.

5.15.6 Water supplied by pushcarts and bicycles

These are also small scale water provider operates in areas of acute water shortage where the water utility is not operating or during summer. These operators fetch water in 10-20 litre plastic canisters from public hydrant and deliver it to houses. Bicycles (Figure 5.10) or Carts (Figure 5.11) are used for delivering the water. They charge nominal, basically for transportation. The charge for getting water delivered at door step ranges from Rs. 6 to Rs. 8 for 25 litres can (Raghupathi, 2003). As the water is collected from public stand post so this system is not responsible for additional environmental cost, though there is still risk of public health due to use of inferior quality of plastic or dirty container to collect and store the water.

Figure 5.10 Bicycle used for water supply Figure 5.11 Push-cart used for water supply.

5.15.7 Effects of present alternative water provision

The details of the characteristic, cost and effect of private water provisions in Delhi are compiled in the Table 5.12. Zerah (2000) investigated the development of private strategies for coping with the unreliability of the public supply, and found that the total annual cost of these strategies represented twice the annual public expenditure in water in Delhi. Another study informed that the financial cost borne by Delhi households on account of strategies devised to compensate for water shortages such as pumps, tankers, storage etc. is estimated to be 6.5 times higher than what they pay to DJB. The full cost will be even higher when we count the cost of all the water purification systems like Aqua guard, R.O systems and filters that have been purchased. People of Sainik farm spend around Rs. 20,000/ every year to deepen bore wells (Daga, 2003). So the residents are paying a high price to augment water and the poorer suffer most.

Table 5.12 Characteristics of alternative water supply in Delhi.

Sources and types	Reliability and quality	Uses	Avg. cost in Rs.	Effects and remarks
Private bore wells depend on ground water,	Unreliable over long period, quality is doubtful,	Drinking, and all domestic purposes,	Coping cost is much higher than public utility supply,	Quality degradation, health risks, depletion of ground water, power cost and maintenance cost goes higher and higher every year.
Private small scale piped water supply, uses ground water,	Unreliable over long period, doubtful of quality,	Drinking and all domestic purposes,	Installation cost + Rs. 200 per month for 500 litre per day,	High cost, depletion of ground water, quality deteriorates and public health risk.
Public, DJB Tanker uses DJB treated water,	Availability is not assured, quality is also doubtful,	Drinking and all domestic uses,	Free,	Water may be contaminated during transportation and storage.
Private Tanker uses ground water without treatment,	Available with high price, quality is doubtful,	Not for drinking, but used for all domestic purpose,	Rs. 500-600 for 8000-10000liter tanker,	Dangerous for domestic use, depletion groundwater, not affordable by poor people.
Private packaged water uses ground water	Reliable but quality is doubtful,	Drinking purpose only,	Rs. 35 - 40 for 20 litres can,	Ground water depletion, high environmental cost, not affordable by poor people.
Private Bottled water uses ground water,	Reliable but quality is doubtful,	Drinking purpose only,	Rs. 10-12 per litre,	Ground water depletion, high environmental cost, not affordable by poor.

Source: Compiled by author.

Total volumes of ground water extraction by private tube wells are very high. Some estimates give a total abstraction around 1300 MLD or the private extraction of groundwater represents around 50% of the total supply (Maria, 2006), which seems to be a serious concerned for sustenance of such alternatives, where the natural recharge of ground water in the Delhi found to be lower than 5% in most of the area (Dutta, *et al.*, 1996). According to a study done by the Central Ground Water Board, it will take just 2,600 additional tube wells running at an average of ten hours per day to exhaust the entire reserve of underground water in Delhi (Jha, 2006). The net results are the alarming depletion of ground water and deterioration of ground water quality. A comparison of the existing groundwater levels in the different administrative blocks with the levels in 1960 shows a decline of 2m to 30m. The ground water levels in Alipur and Kanjhawala blocks have declined by 2 to 6m, in the Najafgarh block by 10m and in Mehrauli block by 20m (Figure 5.3 and Figure 5.4). In Delhi the tube wells have been dug up without any proper technical advice. On many occasions ground water contamination has been due to the carelessness of the people and industries. Residues of pesticides were detected from samples drawn from places near agricultural areas like Alipur, Kanjhawala, Najafgarh and Mehrauli. The samples from the tube wells of bottling units located in places like Okhla, Shivaji Marg and Burari shown the presence of pesticide as per the Centre for Environment and Science (CES) study. As the artificial recharge can ease the ground water crisis a scientific and cost effective recharging techniques should be considered.

The chemical quality of the ground water of Delhi is also varies with depth and space. Brackish water at shallow depths exists in Kanjhawla and Najafgarh blocks and in some minor patches of Alipur and city blocks. In the flood plains of Yamuna, freshwater generally exists at a depth of 35-45m. The quality of ground water in Delhi is alkaline with pH ranging from 7.1 to 9.2, chloride content ranges between 21 and 1380 ppm. South of Delhi average chloride content is 250 ppm while in Najafgarh area it is around 1000 ppm rendering the water saline covering the area of 32 km^2 and marginally saline over the area of 129 km^2. The ground water study of Delhi revealed high nitrate and fluoride concentrations (Table 5.12).

Fluoride concentration is more than permissible limits in around 30 percent of the Delhi (Table 5.13). The ground water survey in summer, 2000 revealed that fluoride content of Rithala village is as high as 6.39 mg/l, old Hanuman Mandir area 3.2 mg/l and Motibagh around 2.6 mg/l. Prolonged ingestion of high quantities of fluoride can lead to dental or skeletal fluorosis. Ground water quality survey in monsoon 2001 reveals bacterial contamination in almost 90% of ground water sample in the areas like Azadpur, Wazirpur, Mandir Marg, Vasant Kunj and villages in Cantonment areas (Jharera, Mehram Nagar), Prahaladpur. High metallic content, particularly manganese and iron have also been observed in the samples collected. High values of nitrate are found at many locations i.e. at Gadaipur, Rajokri, Jaunapur, Ghitorni and Andheri More. Using Iron contaminated water, which is over the permissible limit (Table 5.12) can cause constipation accompanied by other physiological disorders (Table 5.14).

Table 5.12 Ground water quality in Delhi.

Parameters	Permissible limits (IS-10500:1991)	Existing situation in Delhi
pH value	6.5-8.5	As high as 9.2
Fluoride mg/l	1.5	2.6 – 6.39
Nitrate mg/l	45	100
Iron mg/l	0.3	4.05
Coliform	Nil	90% samples have bacterial contamination

Source: Compiled by author from reports of NEERI, CGWB, www.rainwaterharvesting.org.

Table 5.13 Fluoride content of water in different parts of Delhi (Source: Economic Survey of Delhi, 2005-2006)

Sl. No.	Name of areas	Fluoride contents mg/litre
1	Mahammadpur	2.50
2	Shahbad	7.36
3	J.J. Colony	6.67
4	Narela	4.87
5	Okhla village	3.00
6	Rohini	4.35
7	Najafgarh	8.70
8	Suraj Park	4.23
9	Green Park	19.33
10	Jangpura	2.44
11	Lodhi Road	4.00

Groundwater of Delhi shows wide range in nitrate (10-1600 mg/l) content. In 2003, the Nitrate levels in groundwater ranges from 1-135 mg/l in Alipur Block; 1-159 mg/l in Kanjhawala Block; 2-716 mg/l in Najafgarh Block; 19-303 mg/l in Mehrauli Block and 1-69 mg/l in Shahdara Block (Datta, 2004). Large part of the area to the west, having very little recharge from rainfall, is severely affected by nitrate pollution of groundwater (Datta, 2004), exceeding the WHO and IS-10500:1991 prescribed minimum permissible limit (45 mg/l). Therefore, the untreated ground water supplied by private operators through private piped supply and private tankers which generally use low technology and do not go for proper treatment to maintain any quality standards, is a high health and environmental risk for the poor people of Delhi.

Table 5.14 Effect of health hazards due to chemical pollution in water

Access chemical present	Associate health problems
Arsenic	Nervous system disorder, cardiovascular effects, carcinogenicity, cancer in skin, lungs, urinary bladder, and kidney.
Cadmium	Nervous system disorder, hypertension, kidney disorder, Itai-itai diseases, cancer
Chromium	Ulceration.
Copper	Hepatic and Nervous system disorder.
Fluorides	Fluorosis, skeletal damage
Iron	Hemosiderosis, hemachromatosis, skin pigmentation, hepatic disorder.
Lead	Abdominal colic, anaemia, Nervous system disorder, teratogenic and fetotoxic effects.
Manganese	Nervous system disorder,
Mercury	Nervous system disorder, kidney damage, mutagenicity and teratogenicity.
Nitrates	Cause gastric disorder or cancer, mathaemoglobinaemia.

Source: Compiled by author from various sources, The low quality and poor standards in the bottled water market is a serious matter of concern to the public health. The bottled water companies have little regards for public health standards. The Centre for Science and Environment, New Delhi (CSE) conducted laboratory tests on 34 samples from 17 different brands of bottled water that are commonly sold in the Delhi and surroundings. The samples include five top brands of big companies (like Bisleri, Pure Life, Aquafina and Kinley). The pesticide residues were found in almost all samples (except one) in order of 36.4 times higher than the European Economic Commission (EEC) stipulated levels. Even in some samples of bottled water in California, the volatile organic compounds (VOCs) including toluene and benzene were identified. This contamination, most likely introduced during processing, was attributed to inadequate process control. For instance, operation and maintenance of equipment (e.g., ozonators, pumps, deionizers, and bottle fillers) requires the use of lubricants and cleaning solvents which, if not adequately controlled, will contaminate the water (Allen, 1994). Most bottlers use processing methods like reverse osmosis, filtration, ultraviolet light and treatment with ozone gas. Although ozone creates far fewer by products than chlorine, but one of these by products is bromate, which has been shown in EPA studies to cause cancer in rats (Bogo, 2001). Even though bottled water is disinfected, the microbes, nitrogen, pesticides, solvents and arsenic can still be found in bottled water (Bogo, 2001). It is also unrealistic to think that water can be bottled in plastic containers, produced at a bottling factory, transported and stored at high temperatures for months at a time and be pure. Water is the universal solvent; it will dissolve some part of everything it contacts. When water is stored in plastic containers, it takes on some of the chemicals that the plastic is made from. It is impossible to get chemical free water from a plastic bottle. There is no way of knowing the actual quality of bottled water. So the bottled water also may be cause of health risk. The tap water is actually held to more stringent quality standards than bottled water. According to a four-year scientific study by the Natural Resources Defence Council, over one third (33%) of the tested brands contains contaminants such as arsenic and carcinogenic compounds. Arsenic contamination through drinking water may be responsible for cancer of skin, lungs, urinary bladder, and kidney, as well as other skin infections (Table 5.14). Another study by Martin Wagner and Jorg Oehlmann from Goethe University, in Frankfurt detected estrogens (female sex hormone) contamination in 66% of bottled water samples in Germany. The estrogens contamination in water can impair reproduction and reduce flow of breast milk (The times of India, 2009).

Bottled water can cost around 2000 times more than tap water. Approximately 1.5 million barrels of oil, enough to run 100,000 cars for a whole year are used to make plastic water bottles, while transporting these bottles burns even more oil. The growth in bottled water production has increased water extraction in areas near bottling plants, leading to water shortages that affect nearby consumers and farmers. In addition to the millions of gallons of water used in the plastic making process, two gallons of water are wasted in the purification process for every gallon that goes into the bottles. Nearly 90 percent of water bottles are not recycled and wind up in landfills where it takes thousands of years to decompose (Union of Concerned Scientists, 2007). It is all piling up in landfills, depressions, water bodies, drains, rivers, oceans and agricultural fields and the harm to our planet is devastating. Over 90% of the cost of bottled water is in the bottle, lid and label (www.bottledwaterblues.com).

With the increase of the water demand in Delhi and due to prevalent supply gap, the dependency of such alternative will multiply with the cost of health, economy and environment of the people of Delhi if there is no alternative approach to the existing water supply in Delhi.

5.16 CONCLUDING REMARKS

In current planning process of water supply for Delhi, engineering solutions are provided with only elementary socio-economic analysis and a supply oriented approach of increasing supply to meet demand. The past and present efforts to tackle the situation in Delhi are focused on those alternatives that increase supply. The reliance on such traditional approaches has not improved the water situation in Delhi. Even these approaches are not clearly focused and not vested to one organization to implement. This has led to more confusion and is responsible for present water crisis in Delhi. The organization responsible for planning and distribution of water is not able to coordinate with the other planning organizations which are responsible for water management, preparation of water policies and the development plans. Different organizations are also working independently for the augmentation of the water needs in the city. The other approach of the demand side management like restriction of misuse, pricing policies, compulsory installation of water meter, water conservation, waste water reuse, use of water saving gadgets to reduce water demand etc. has not been considered at all. It is now high time to follow innovative management approaches to prepare a comprehensive water management plan for Delhi. There should be one management unit for all aspect of water management in a city. The scientific and technological knowhow can be borrowed from other agencies.

There are research needs to identify the priority of action and formulate a methodology and policy change to address the haphazard, piecemeal and unconvincing progress in water management in Delhi. The water management is fragmented among sectors and institutions. It is necessary for planning and management of water in urban area on the basis of some comprehensive approaches and also there should be appropriate action to implement it.

Policy reforms are needed to provide secured water rights vested in individuals or groups of water users that increase incentives for investment, improve water efficiency, reduce the degradation of the environment, and encourage flexibility in resources allocation (Basil, 2004).

To augment the gap between demand and supply in Delhi the residents depend on the private provisions of water. Most of these services are unsustainable. These situations compel to think for other sustainable alternatives of water management strategies with the involvement of people. Delhi government should start encouraging new approaches and strategies by policy and incentives, which are environmentally sound. All over the world, many models have been demonstrated as successful alternatives. There are wide ranges of best management and water conservation practices that can be used to maximize the use of existing water supplies. There should be policies to encourage the use of water saving devices. All water use devices should be marked with Water Saving Rating like power saving rating. A research programme should be initiated to investigate the appropriateness of these devices and quantify the benefit of it to motivate consumer to use these innovation.

Water Conservation needs to be encouraged at user levels. The aspects like metering, pricing, waste water recycling, use of water saving devices etc., which relate to wiser use available water should be given more importance. Adequate systems and proper monitoring protocol for surveillance of water quality within the distribution network are required.

Institutional and legal changes need to be brought for management of water. Water should be considered an economic good with the tariff structure of the resource and related services designed so as to encourage a conservative approach. Recycling of treated wastewater and auditing water consumption needs to be made mandatory. Regulatory provisions related to groundwater use and its implementation needs to be reinforced to avoid over-exploitation.

CHAPTER 6

SURVEY OF RESIDENTIAL DEVELOPMENT IN DWARKA

6.1 PRELUDE

It has been observed that the water management in Delhi is basically city level centralise supply system. Supply has been increased to meet the impending demand even then demand supply gap still exist. The options of demand management approaches are not tried. The different residential developments have potential for application of management techniques to reduce demand or reuse treated waste water for further use. To find out the applicability of such alternative approaches Dwarka a sub-city of Delhi has been considered as case study area and different residential typologies are selected to evaluate water management strategies.

6.2 RESIDENTIAL TYPOLOGY IN DELHI

The residential development in Delhi is characterized by a large variety of typology and characteristics. Broadly on the basis of its origin basically the residential developments are (1) Planned residential development and (2) Unplanned residential development.

The planned residential development can again be sub-classified as (1) Bungalows – characterized by large plot size with low-rise and low-density development. This type of residential development is predominant in Lutyen's Bungalow zone, Chanakya Puri and Civil lines areas of Delhi. (2) Plotted development – a large variety of different plot sizes of development is all over the city to accommodate different income group people. Depending on the plot size the development is classified as Economically Weaker Section (EWS), Lower Income Group (LIG), Middle Income Group (MIG) and Higher Income Group (HIG), (3) Group housing (a) Cooperative Society Group Housing with LIG, MIG and HIG dwelling units, (b) Institutional/employers group housing, (c) Delhi Development Authority (DDA) housing and self finance schemes, etc. (4) Public / Private Apartments – Developed by DDA as its housing schemes and also converted into plotted housing by the private developer and individuals as apartments, (5) Government accommodation for employee – low density development offered to government employees as rented residential quarters.

On the other hand the unplanned residential developments are located in (1) Villages: mixed use premises, compact and continuous built form along narrow road, low-rise high-density development. (2) Unauthorized colonies and (3) Slum and *Juggi Jupri Clusters* (JJC), resettlement of squatter, (4) Resettlement colonies, etc.

Besides these some residential areas are of ancient origin and fast changing residential character. These are designated by Master Plan for Delhi – 2021 (MPD-2021) as Special Areas, which comprises of (1) Walled City, (2) Walled City Extensions: Paharhganj, Sadar Bazar, Roshanara Road and their adjoining areas, and (3) Karol Bagh, which is just adjacent to walled city. These residential areas are characterized by mixed use premises, compact built form, narrow roads, low-rise high density development, coexisting with commercial – retail or whole sale and industrial uses.

6.3 CRITERIA FOR SELECTION OF DWARKA

To understand existing water management options in the different types of residential development, newly developed planned area has been selected for primary survey. The criteria for selection are as follows

1. The areas should be water stressed so that the feasible water management options can be considered for implementation.
2. The areas are to be selected from a planned new residential development having a range of plot sizes and residential development typologies, which can be compared with regards to water management options.
3. Areas where some water management approaches like the new byelaws on water harvesting and water recycling are in enforcement.
4. The areas should have selected typology of residential development for which water management options can be evaluated.
5. The area is selected also due to availability of sector level maps and accessibility to the information and familiarity of the area to the author to do the necessary survey and data collection.

As per the MPD-2021 the population holding capacity of Dwarka, Rohini, and Narela is proposed to be enhanced (Table 6.1). There is more emphasis for the development of these areas. Providing water to these new developments is real challenge for utility provider. Therefore positive action to face the challenges is very much necessary. Moreover future urban extensions will have 4.8 million populations with a land area around 20,000 to 22,000 ha within a time frame of 15-16 years and will have to be assembled for planned development. The water management to these areas also will become a matter of prime importance and critical issue. Therefore Dwarka as a part of such development has been considered for case study and water management in the residential developments in Dwarka has been critically investigated.

Table 6.1 Estimated holding capacity of urban extensions of Delhi 2021 (Population in millions)

Zone	Existing population 2001	Holding capacity 2021	Increase %
Dwarka	0.597	1.3	54.08
Rohini III	0.096	0.16	40.00
Rohini IV & V	0.198	0.82	75.85
Narela	0.179	1.62	88.95
Sub total	1.07	3.9	72.56
Future urban extension		4.8	

Source: Based on MPD-2021

6.4 DWARKA SUB-CITY

Dwarka is located in the western part of the NCT Delhi, on older alluvial plains. Dwarka's hydrology is characterized by the proximity of the Najafgarh drain which forms the western limit of the sub-city, and constitutes an important source of groundwater recharge. The thickness of the alluvium is about 300 m in the area and potential aquifers can be found at depths up to 240 meters below ground level.

Dwarka is a recent urban extension located at the periphery of the current urban centre of Delhi. The Dwarka sub-city is a part of the urban extension of Delhi in the Planning Zone K (Nazafgarh District) with a total area of 5648 hectares (Figure 6.1). Dwarka is planned for a population of around 1.1 million. Dwarka enjoys a semi arid climate with about 80% of the annual rainfall received during the south-west monsoon period between July and September (27 rainy days). The average rainfall is around 611mm. About 70% of the housing in Dwarka is group housing of multi-storeyed development with minimum plot size of 4000 m^2 and with 48.54 % residential, 7.05% commercial, 14.33% transport, 19.94% recreational, 3% public semi-public and 0.94% government land uses. Dwarka has over 450 housing societies in 29 sectors.

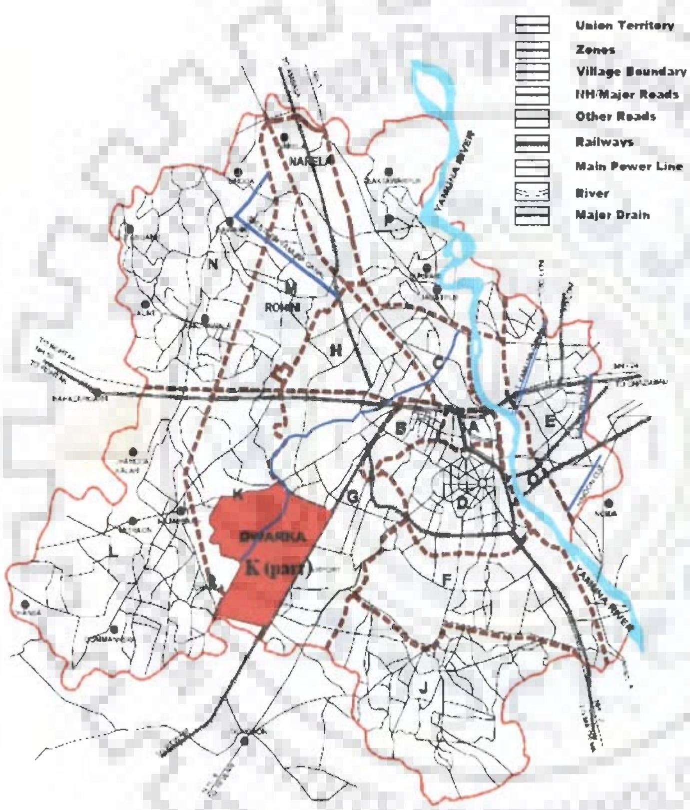


Figure 6.1 Location of Dwarka in Delhi

The Master Plan for Delhi 2021 has considered the water requirement 360 lpcd (litres per capita per day) with a breakup of domestic and non-domestic of 225 lpcd and 135 lpcd respectively. Therefore the total domestic water demand of Dwarka for the project population of one million is 225mld (million litres per day). Dwarka is getting around 25-30% of their demand from the Delhi Development Authority (DDA) (bulk received from Delhi Jal Board and from bore wells). The residents manage the rest of their demand by procuring water from government tankers or purchasing water from private tankers or groundwater extraction within their plots. Almost all group housing societies and plotted housings have their own private bore wells, leading to the over-exploitation of groundwater and the amount of freshwater is decreasing at a rate of 0.5 m per annum.

According to DDA officials, DDA is sourcing about 2.8 MGD (12.73 million litres per day) from Delhi Jal Board (DJB) and getting an additional 1 MGD (4.55 million litres per day) from 53 authorized tube wells. During summer the situation is worse and Dwarka gets only between 1 and 1.5 MGD from DJB. However DJB claims that it supplies 2.5-3 MGD of water even during summers (authors personal discussions with Executive Engineer, Dwarka project). Their supply comes from the Nangloi plant. Officials say only 25% of the current demand is being met and there are no chances of respite in the near future (Lalchandani, 2008).

DDA has 500 tankers to service the area; most of these are used to fill up main feeder tanks. When there is acute shortage, private group housing societies are charged Rs 300 per tanker while the service for DDA colonies is free. However, at times, residents have to wait for as long as three days for tankers.

However, the water requirement for Dwarka if calculated on the basis of the standards proposed in MPD -2021 or even DJB standard is much higher. The standards used by the DDA for the water requirements of an urban population are worked out at a rate of 225 lpcd (50gpcd) which has 75 lpcd for potable uses (drinking, cooking, washing of utensils), and 150 lpcd for other domestic uses (washing of clothes, bathing, flushing). The estimated breakup of the per capita water demand (Khare, *et al.*, 2006) clearly shows that 40% of the domestic demands in Delhi need not to be potable water and recycled greywater can be used instead. With the urban development and the increasing standards of living, the future water requirement is projected as 363 lpcd (80gpcd). The future daily requirements for the population of 1.1 million, based on the MPD-2021 standard, would be 248 MLD (54 MGD) where 83 MLD (18 MGD) for potable purposes and 165 MLD (36MGD) for other domestic purposes. Taking the norm of 363 lpcd, the requirements would be 399 MLD or 88 MGD.

Dwarka shows a rapid decline in ground water levels due to over exploitation of groundwater for domestic and other uses. The other problem in Dwarka, as far as groundwater resources are concerned is the occurrence of brackish and saline water in the deeper aquifers. High concentrations of fluoride have also been found in samples collected by the Central Ground Water Board (CGWB). According to the calculation of the CGWB, the total reserve of potable water is limited to 16 million cubic meters (MCM) (CGWB, 2003).

One of the major reasons for the shortfall is the gradual decline in the level of groundwater, which has fallen to 20-25 m, a drop of 8-10 m in the past three years. Central Ground Water Authority (CGWA) officials say the area never really had the kind of resources that could warrant development of an entire township. Dwarka falls in the southwest zone where withdrawal is more than 200%. The area has been notified which means no groundwater extraction is permitted unless approved by the CWGA. However, it is a known fact that there is rampant illegal boring in the area (Lalchandani, 2008).

6.5 WATER MANAGEMENT MEASURES FOR DWARKA

6.5.1 Rainwater harvesting

The Central Groundwater Authority made it mandatory for buildings (for plot area 100 m^2 or more) in Delhi to make provision for rainwater harvesting. The byelaw is applicable for Dwarka also; however the implementation of the same is not being monitored by the government concerned agencies.

6.5.2 Wastewater recycling

The Delhi Government has modified the building byelaws (GOI notification 28 July 2001) to promote reuse of wastewater in buildings where daily wastewater generation is 10,000 litres or more. DDA initiated use of dual water supply systems in Dwarka in 2002-03 to promote the reuse of rainwater and recycled wastewater. The Master Plan for Delhi 2021 has also emphasized the recycling of treated wastewater through dual supply systems, however, these concepts have not been implemented in Dwarka until today.

Besides these two measures there were no initiatives for promotions of water saving devices, universal metering and public awareness campaign.

6.6 SURVEY METHODOLOGY

The case study residential developments were chosen from the planned development in the urban extensions of Delhi in its sub-city Dwarka. Primary house hold questionnaire survey has been done by the author. Additional information is drawn from the informal discussion with members of Residential Welfare Associations, Secretaries of Cooperative Group Housing Societies, planners and engineers of DDA, and other professionals and individuals. However before the primary survey conducted in the selected sectors, pilot survey is being conducted by the author to test the relevance of specific questions and questions are modified as per the experience and availability of information in the field. Pilot survey has been done for three deferent types of residential development with ten samples each category in the month of April 2008. After refining the questionnaire the actual primary survey is being done in the month of May – June 2008. The months between May and June has been selected for survey because these are the months when there is more water scarcity and author wants to know how people manage water during such situation.

The case study residential areas are chosen from four residential sectors in Dwarka. Two sectors are predominantly Cooperative Group Housing Societies developments (CGHS) (Figure 6.2) and two sectors are predominantly Plotted (Figure 6.3 and 6.4) residential development and DDA Group Housing (DDAGH) (Figure 6.5) has been selected from these four sectors. The details of the sample collected are given in the Table 6.2. The total sample size is 145, CGHS Plot size surveyed between 4000 to 8500 m^2, DDA GH Plot size between 10,000 to 40000 m2 and Plotted development plot sizes between 100 to 210 m^2.

Figure 6.2 CGHS development in sector 9

Table 6.2 Sample size of residential units surveyed

Types of development	CGHS	DDAGH	Plotted	Total
Estimated total DU's	6200	1936	2004	10140
Sample DU's	55	14	76	145
	0.80%	0.70%	3%	1%

Note: DU = dwelling units

Figure 6.3 Residential Plotted developments in Dwarka Sector 19

Figure 6.4 Plotted developments in sector 8 Dwarka

Figure 6.5 DDA Group Housing

The selected sectors which are considered for primary survey are Sector 6, Sector 9, Sector 8 and Sector 19. Location of sectors are given in Figure 6.6. Sector 6 is predominatly group housing with majority Cooperative Group Housing Societies (CGHS) and only one plot of Delhi Development Authority Group Housing (DDAGH). The details of the plots in the sector 6 is given in the Figure 6.7. Sector 9 is also CGHS plots and two plots are DDAGH (Figure 6.8). Sector 8 is predominantly plotted development of variable sizes (Figure 6.9), and sector 19 is also predominatly plotted development with two DDAGH plots (Figure 6.10).

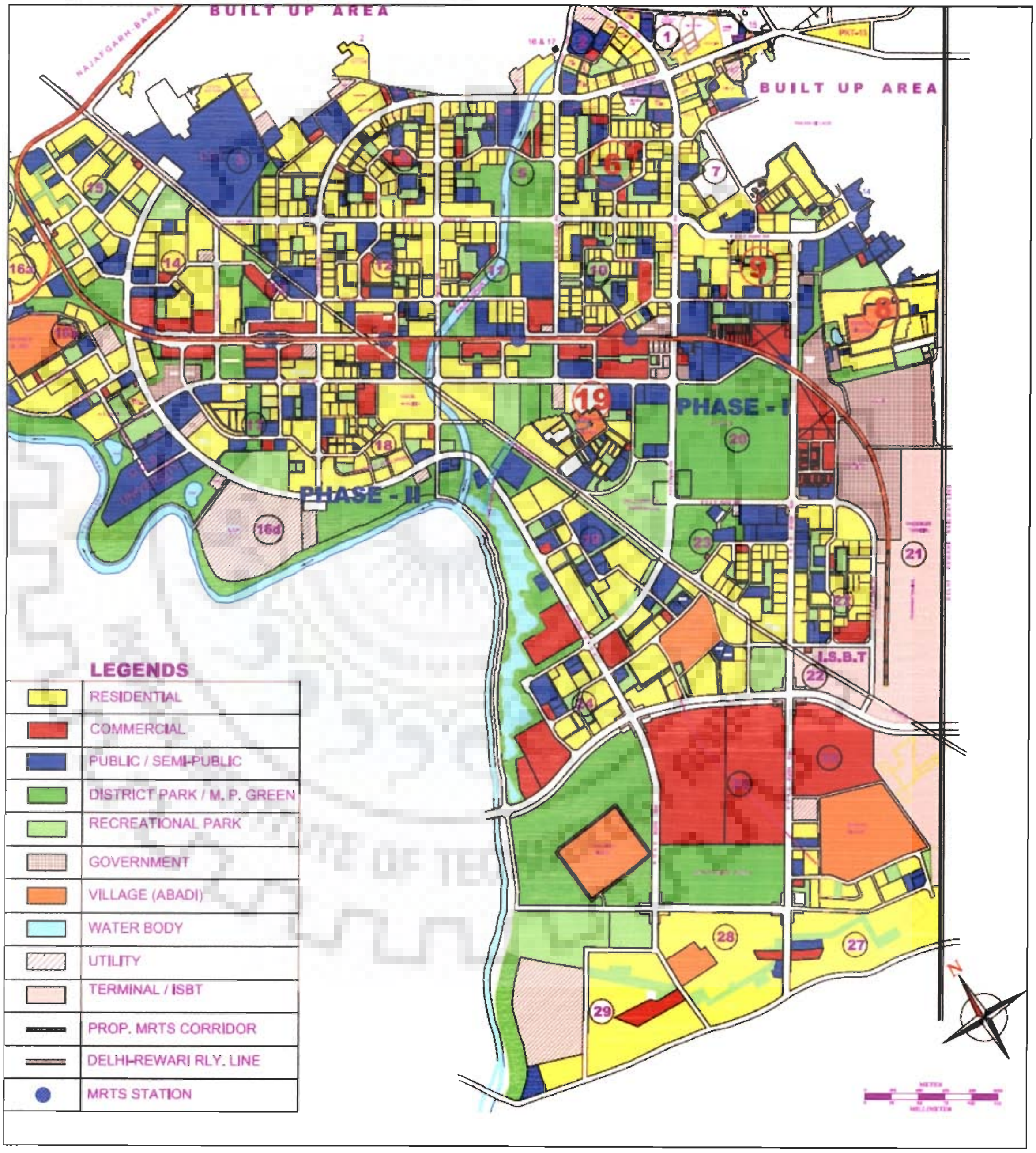


Figure 6.6 Location of selected sectors in Dwarka, Source: DDA

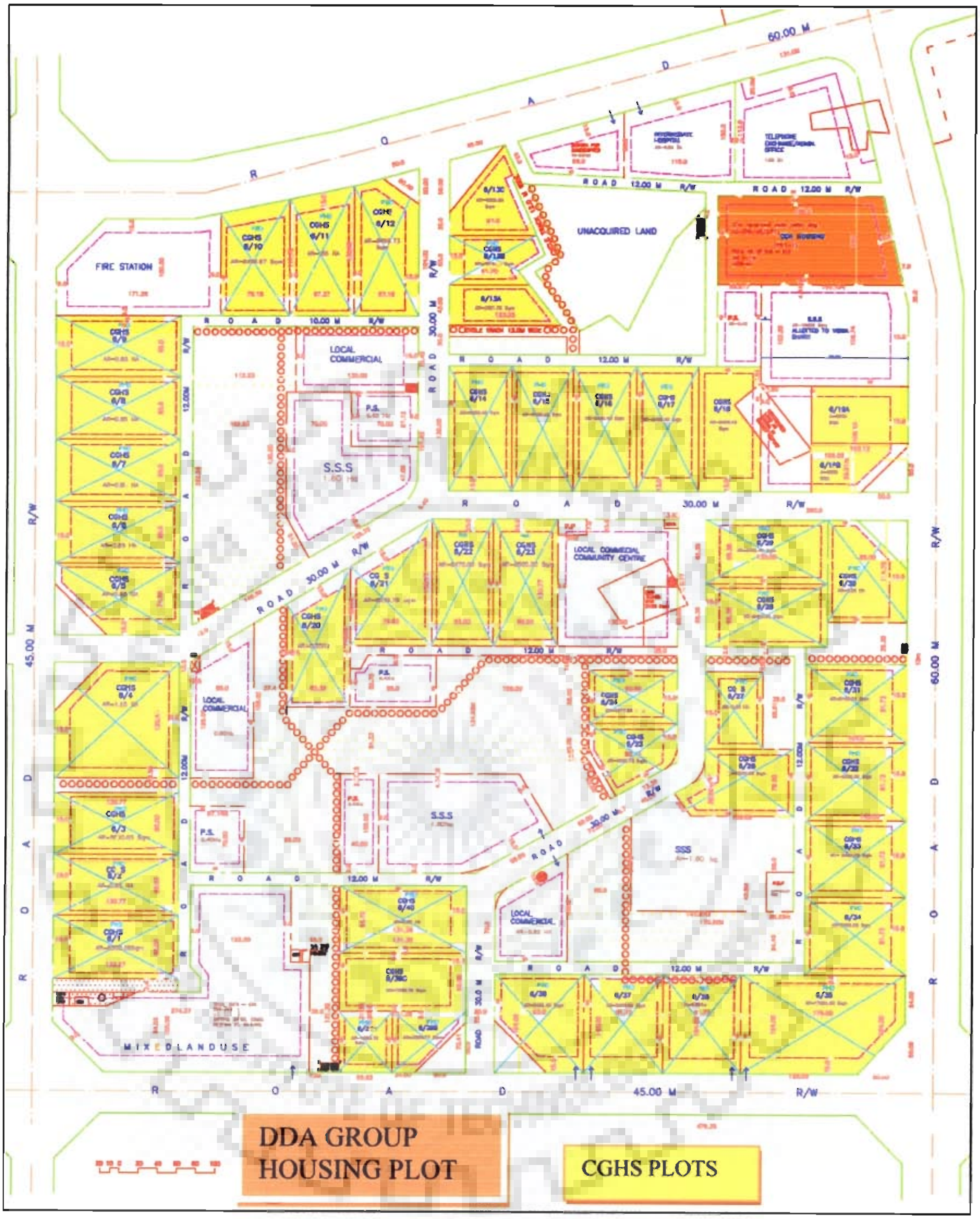


Figure 6.7 Details of residential plots in sector 6,

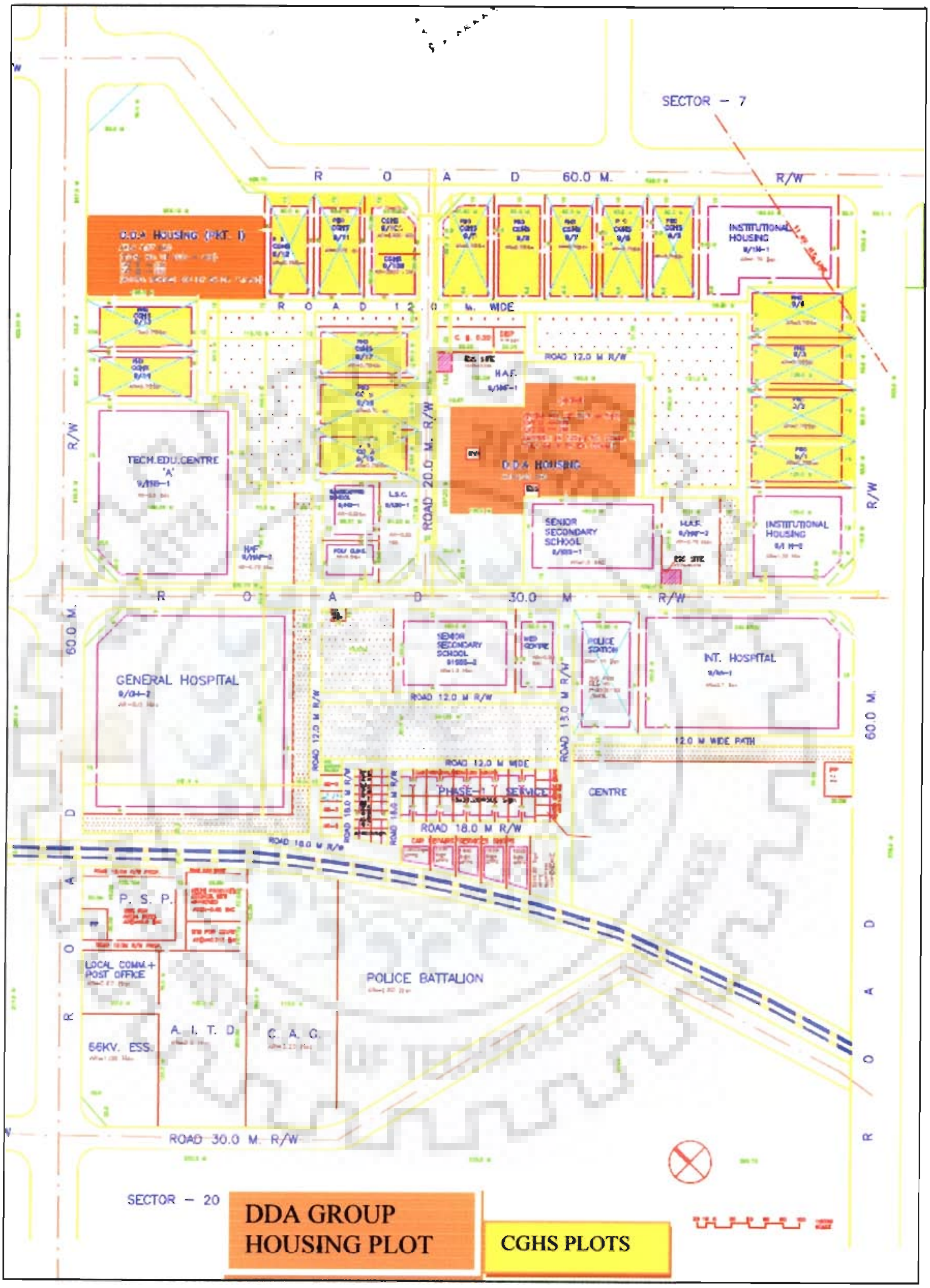


Figure 6.8 Details of residential plots in sector 9, Dwarka.

Figure 6.9 Details of residential plots in sector 8 Dwarka.

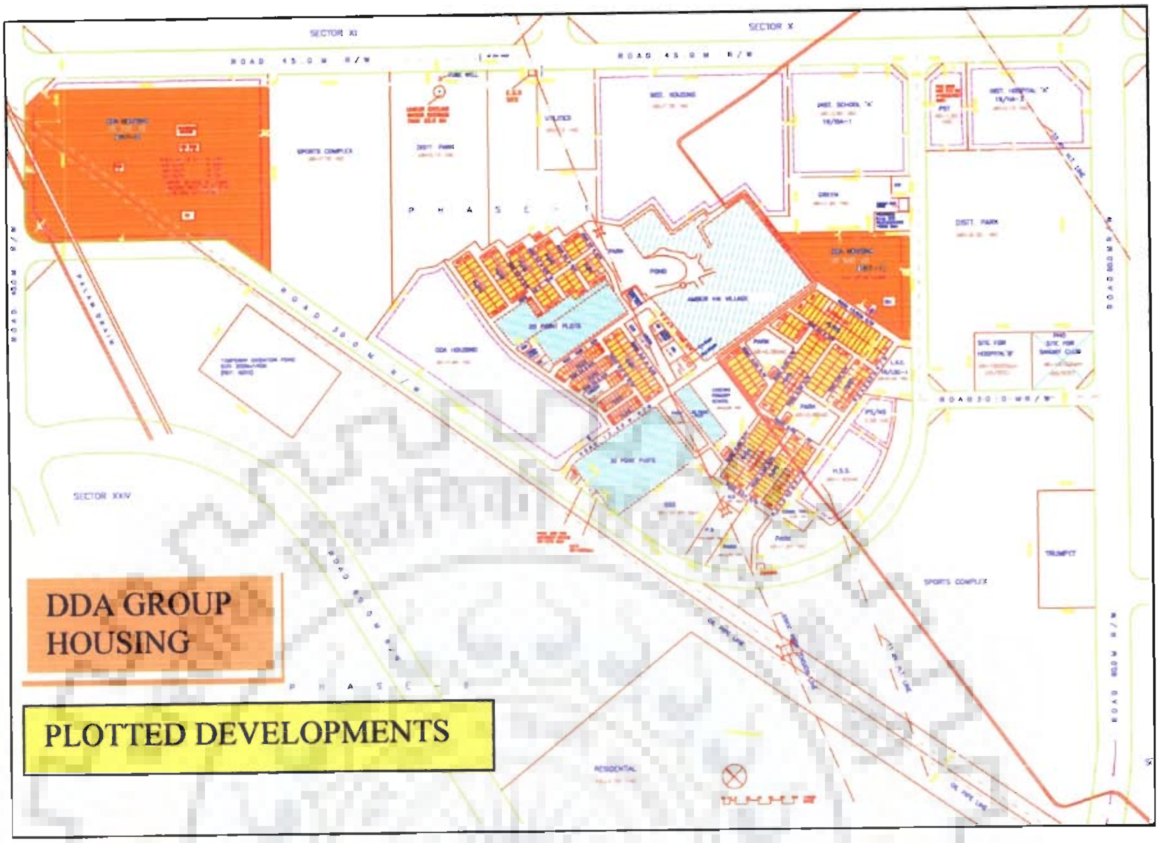


Figure 6.10 Details of residential plots in sector 19, Dwarka

6.7 SURVEY ANALYSIS

6.7.1 General information of residential development

It found that about 90% houses are owned by the occupant and average houses are occupied after the year 2004, so building byelaws on water harvesting and water recycling were applicable. The CGHS and DDAGH have less percentage of roof area (29% and 30%) but higher percentage of unpaved area (49% and 43%), so natural recharge in such development is expected to be high on the other hand, the Plotted housing has higher percentage (73%) of roof area but less (9%) unpaved area, almost nil natural recharge possible (Table 6.3). Figure 6.11 presents the details of different types of residential development surveyed.

Table 6.3 General information of different types of residential development

Residential types	Owned (%)	Avg. no of year living	Avg. roof area in a plot (%)	Avg. paved area (%)	Avg. unpaved area (%)
CGHS	89	4	29	22	49
DDAGH	93	3	30	27	43
PLOTTED	92	3	73	18	9

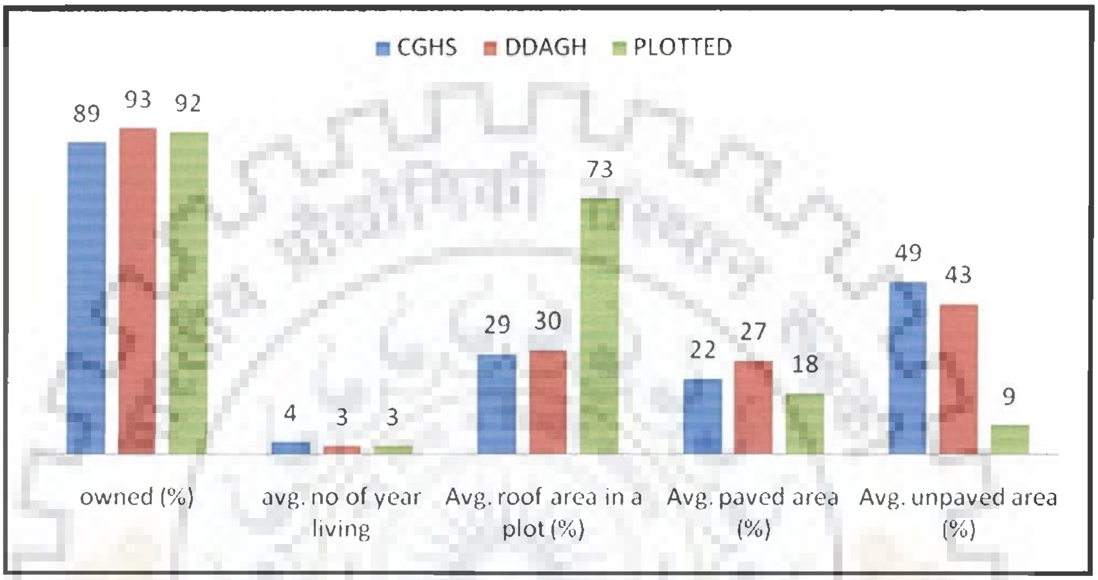


Figure 6.11 General information of the different types of residential development

6.7.2 Water supply status

The government water supply is insufficient for all types of residential developments. The average supply is four hours in a day for CGHS and DDAGH, whereas plotted housings get only one hour a day. The CGHS is bulked metered and resident don't know even how much they pay to government, therefore don't even serious about the water conservation. DDAGH is 100% individually metered but plotted housing is only 39% metered, grossly low and not ensures water conservation.

The plotted development should be 100% metered to ensure proper water conservation and reduction of wastage. Residents of DDAGH and Plotted development pay average bill of Rs. 157, fixed irrespective of quantity used. Therefore people are also not interested for judicious water use. However on an average CGHS resident pay Rs. 516/- , DDAGH area pay Rs. 375/- and Plotted housing pay Rs. 250 per month for procurement of water other than the government provision. The details of supply hours, status of meters, water bills etc for each category of the houses are given in Table 6.4.

Table 6.4 Water supply status in different types of residential development

Residential types	Hours of supply (hrs)	Frequency per day	Metered (%)	Meter types	Water bill per month (Rs)	Extra cost for water procurement (Rs)
CGHS	2	2	100	bulk	Not known	516
DDAGH	2	2	100	individual	157	375
PLOTTED	1	1	39	individual	157	250

6.7.3 Use of water purifying devices

People are doubtful about the quality of water supplied by the government. There is high dependency on the water purifying devices. Highest dependency (91%) on water purifiers have been observed in the CGHS development and plotted development showed the least (66%). Average initial cost and maintenance cost is also is higher in CGHS development (Table 6.5, Figure 6.12).

Table 6.5 Use of water purifier in residences.

Residential types	Purifying devices (%)	Avg. initial cost (Rs)	Avg. maintenance Cost (Rs)
CGHS	91	9388	1057
DDAGH	86	9375	963
PLOTTED	66	8038	640

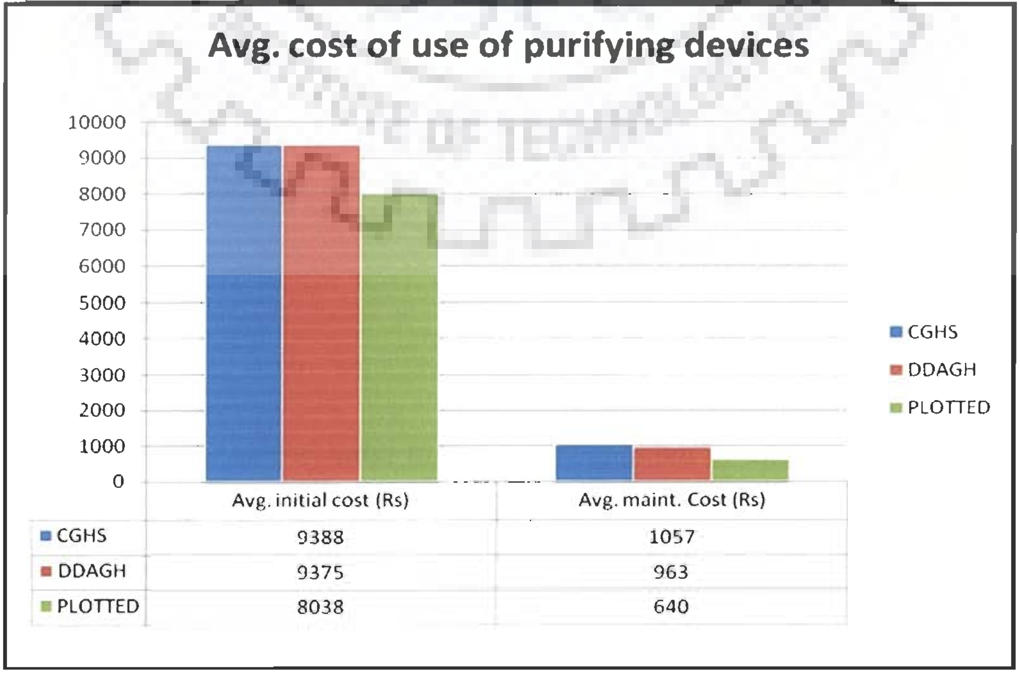


Figure 6.12 Average cost of purifying devices.

6.7.4 Dependence on alternative sources of water

To augment the water supply, so as to meet the demand supply gap and to assure good quality of water people go for alternative provisions of water. Dependency on ground water is extremely high for CGHS and also plotted housing. Dependency on tanker is high for CGHS and DDAGH and the dependency on packaged water is high for plotted housing (Table 6.6). Dependency on ground water is unsustainable and quality is doubtful. Tanker and packaged water is costly and quality is not assured. For each category the use of alternative sources are presented in Figure 6.13.

Table 6.6 Dependency on alternative sources of water

Residential types	Ground water (%)	Tanker (%)	Packaged Water (%)
CGHS	89	58	9
DDAGH	14	36	7
PLOTTED	55	17	14

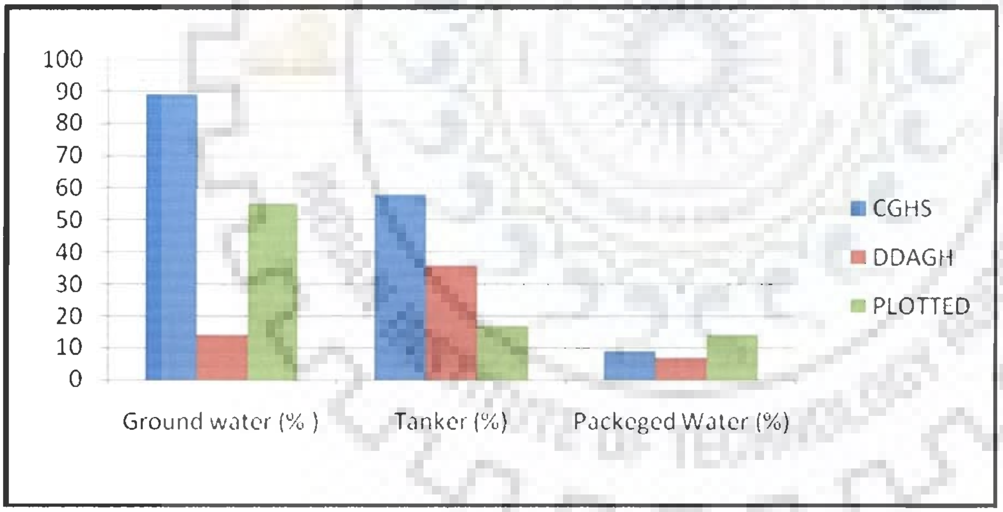


Figure 6.13 Dependency on alternative sources of water

6.7.5 Rainwater Harvesting and Water Recycling

Though it is mandatory, the status of the implementation of rainwater harvesting (RWH) systems in the case study residential development is not satisfactory. In the study area 78% of CGHS have RWH where as 21% DDAGH and only 5% plotted housing have RWH. There is no storage of rainwater in the harvesting systems only recharge is considered so there is no direct visible benefit; therefore people are least interested for

RWH. Maintenance of the RWH system is also not done. Though mandatory, water recycling has not been done anywhere. People are ignorant about the byelaw and also do not know the benefit and technology of waste water recycling systems. The status of RWH and water recycling in the study area is given in the Table 6.7 and presented in the Figure 6.14.

Table 6.7 Implementation status of RWH and Wastewater Recycling

Residential types	RWH % coverage	Types	Initial cost (Rs)	Maintenance Cost (Rs)	Water Recycling % coverage
CGHS	78	Recharge	220500	not known	0
DDAGH	29	Recharge	not known	not known	0
PLOTTED	5	Recharge	7000	0	0

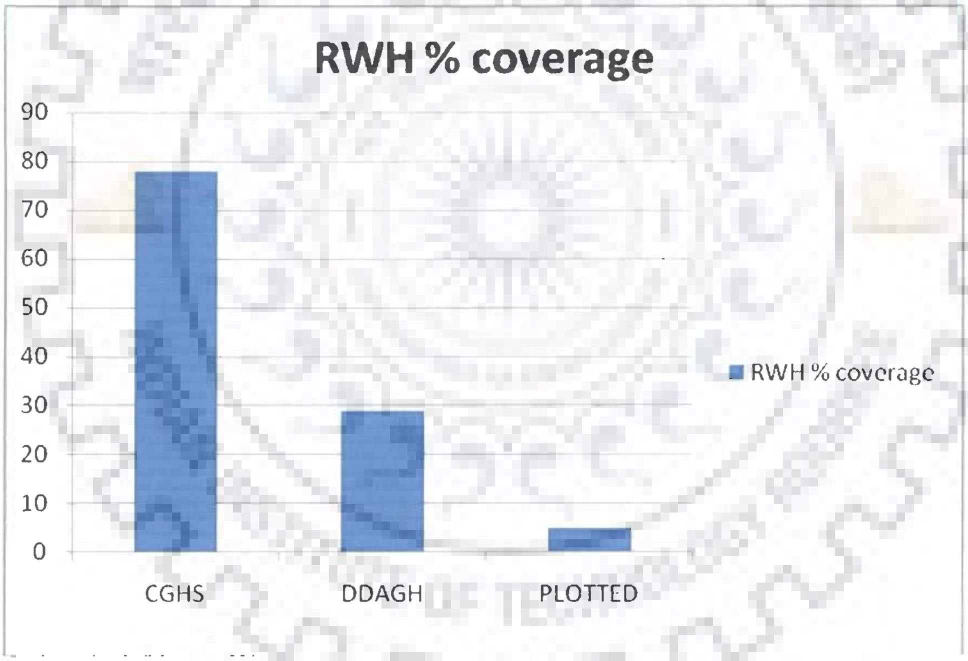


Figure 6.14 Implementation of rainwater harvesting

6.7.6 Use of water saving devices

The uses of water saving devices in selected residential developments are negligible. There are higher percentages of use of water saving cisterns (26%) in plotted developments, and use of all other water saving devices is negligible. There is scope of introducing water saving measures in all types of developments. Table 6.8 gives the details of use of water saving devices in each category of residential development and the same are presented in Figure 6.15.

Table 6.8 Use of water saving devices in different residential development

Residential types	Water saving cistern (%)	Water saving shower (%)	Water saving taps (%)	Water saving washing machine (%)
CGHS	4	4	0	13
DDAGH	21	0	0	14
PLOTTED	26	1	0	4

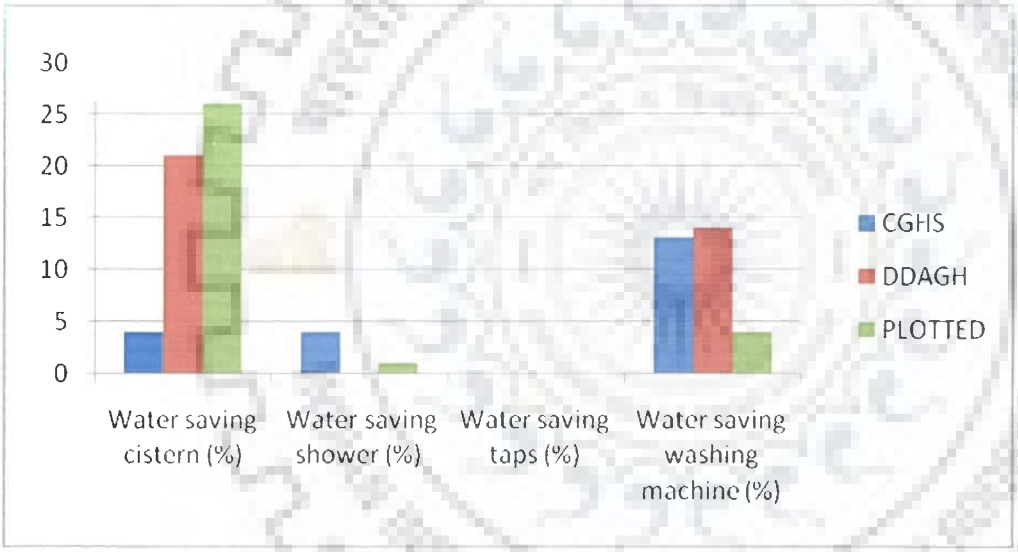


Figure 6.15 Use of water saving devices

6.7.7 Water requirements for different residential activity

The water use pattern in different types of residential development is given in the Table 6.9, which follows the similar pattern proposed by IS code for residential water use (IS 1172: 1983). The comparison of water use pattern for each residential category is shown in Figure 6.16.

Table 6.9 Daily water requirement in percentage for different activities

Residenti -al types	Drink- ing	Cook- ing	Bath- ing	Uten Wash	H/F wash	Cloth wash	Floor wash	Toilet flush	Garden -ing	Car wash
CGHS	3	2	25	6	4	14	5	38	1	2
DDAG H	3	2	24	5	3	17	6	36	2	2
Plotted	3	2	22	5	3	19	5	38	1	2

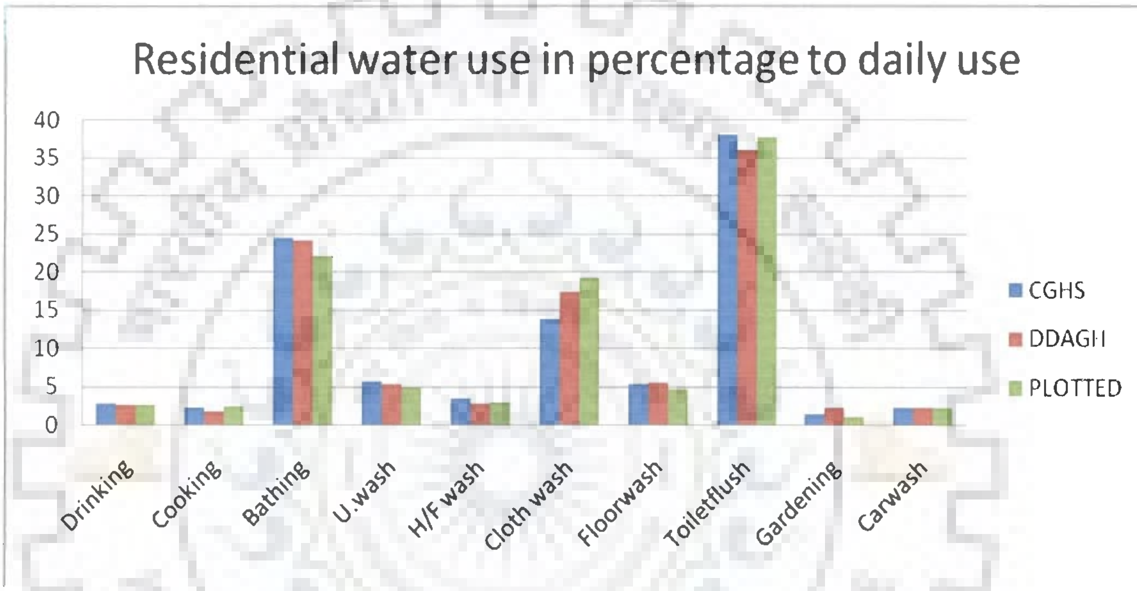


Figure 6.16 Daily water uses in different types of residential development

6.7.8 Awareness of water management aspects

It has been observed that the awareness about the water management aspects among the residents is poor. Because of government initiatives on rainwater harvesting reasonable number of the residents know about it. Plotted development shows the highest percentage of people who know about rainwater harvesting (72%, Table 6.10), but implementation percentage is very low (5%, Table 6.7). Awareness for water saving devices and greywater recycling is low and almost nil. Figure 6.17 shows the status of the awareness of water management aspects in the study area for each category of houses.

Table 6.10 Awareness of water management aspects (% know about it)

Residential types	Water harvesting (WH)	Water saving devices (WSD)	Water recycling (WR)	Dual supply (DS)	Grey water recycling (GWR)
CGHS	53	15	27	18	4
DDAGH	57	7	43	29	0
PLOTTED	72	7	21	14	0

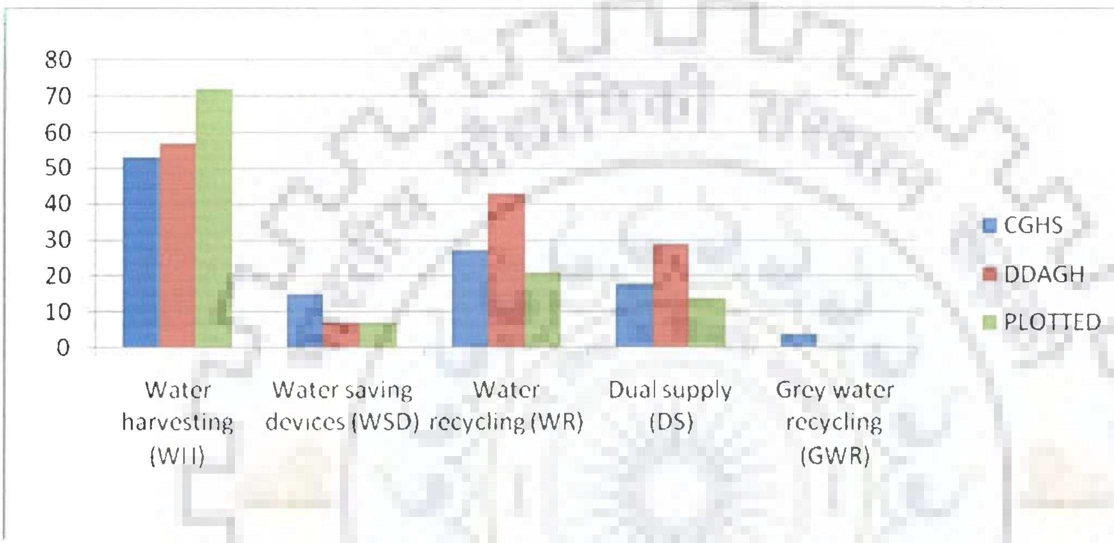


Figure 6.17 Awareness of water management aspects (% know about it)

6.8 MAJOR FINDINGS FROM PRIMARY SURVEY

The major findings of primary survey results are compiled here, which can be used to decide the residential water management options and policy considered for the case study area.

- CGHS development has highest (49) percent of unpaved area; plotted development has minimum 9% of unpaved area.
- DDAGH is 100% individually metered but pay fixed tariff whereas plotted development is only 39% metered.
- Average extra cost of procuring water is Rs.516/ month are the highest for CGHS development and even 91% resident has purifiers and dependency on GW is highest (89%).
- CGHS residents adopted RWH (78%), where as resident of plotted development adopted only 5% RWH. Waste water recycling or greywater recycling has not adopted.

- Plotted developments resident use highest % of water saving devices (26%) where as in CGHS it is only 4%. Selected management measures for CGHS can contribute to a substantial quantity of water saving (71-74%).
- Application of water saving devices contribute to maximum saving (40-47%) followed by grey water recycling (35-38%).
- Both the rainwater harvesting and greywater recycling systems can be easily accommodated in CGHS and DDAGH development.
- The percentage space required for both the systems against available space is least for both CGHS and DDAGH, (4% only) but is highest for plot size of 100 sq. m (28%).
- Per dwelling unit cost of RWH is lowest for CGHS and highest for 200 sq. m plot.
- Per dwelling unit cost of GWR is lowest for CGHS (Rs.1240) followed by DDAGH and plotted.
- The applications of selected water management techniques are easy possible in group housing (CGHS and DDAGH) development.

6.9 CONCLUDING REMARKS

Dwarka is facing water scarcity. The concerned authority is not able to provide required quantity of water but not come up with proper strategies or policies to ensure the demand can be reduced and additional water can be made available through water harvesting and wastewater recycling. Though the residential development came after 2003 i.e. after the rainwater harvesting and wastewater recycling made mandatory for most of these developments. Government has not taken measures to implement these as approaches are not accepted by the resident due to limited understandings of benefits. As there is partial metering and water billing is not based on the actual consumption there is least consideration of water saving. Based on the survey findings it is clear that the group housing development have more unpaved areas and ensure natural recharge. Recharge from roof top and paved areas are not significant (5%) in plotted residential development though the percentage of roof top (73%) and paved area (18%) is high in this development. People are not assured about the quality of water supplied and depend on the individual water purifying devices (66 to 91%) with additional costs. Due to insufficient water supply dependency on ground water is high (55 to 89%) but there are insignificant use of water saving devices and no use of recycled greywater to reduce water demand. Type of water harvesting systems being implemented is only for recharging and not for storage to direct use. There are no differences in the water use pattern in different residential development as the income status and standard of living of the selected residential development is same. It is observed that highest percentages of water is being used for toilet flush (36 to 38%) which does not require drinking quality water followed by bathing (22 to 25%) and washing clothes (14 to 19%) respectively. The wastewater from bathing, clothes washing and hand and face washing can be considered as sources of greywater together constitutes around 44% of total water use and is higher than the maximum demand for toilet flush and household gardening. It is evident from the survey analysis that the water management measures like rainwater harvesting, greywater recycling, use water saving devices, metering can be given priority and their applicability can be found out based on the space requirement and benefit of these techniques.

CHAPTER 7
QUANTIFICATION AND ESTIMATION

7.1 PRELUDE

To understand the applicability of selected water management techniques in different residential development the water saving, space requirements are estimated for the case study residential development of Dwarka. Based on the primary survey analysis and the personal interaction with the secretaries of the Cooperative Group Housing Societies (CGHS) and secretaries of Residential Welfare Associations (RWA) of DDA Group Housing (DDAGH) and plotted developments the estimation for water demand, rainwater harvesting potentials, ground water recharge potential, grey water reuse potentials, water saving potentials due to water saving devices and metering have been done. The detailed estimations are presented in this chapter.

7.2 WATER REQUIREMENT AND MANAGEMENT OPTIONS IN CGHS

The selected Cooperative Group Housing Scheme (CGHS) is in Sector 6, Plot number 7 of Dwarka sub-city. The size of the plot is 8500 m^2. Total Dwelling Units (DUs) are 121 but only 80 DUs are occupied presently with around 66% occupancy rate.

7.2.1 Existing water requirement and expenditure

As per the government prescribed standard @225 lpcd, the water requirement for the total population 320 (80 DUs x 4 persons) is 72000 litres per day. A family size of four is considered based on the primary survey. However it is found that only around 10,000 to 12,000 litres (17% of the total demand) are available from piped supply, around 20,000 liters (28% of the total demand) from Government tankers (2 tankers per day) and rest 30,000 to 40,000 liters (55% of the total demand) (2 to 4 tankers per day, average 3 tankers per day) are being purchased from private water tanker at a rate of Rs. 500 per tanker. As the ground water quality is saline ground water is not being used for drinking purpose it is only used for gardening occasionally and no data is available about the amount of extraction.

The society is paying an average amount of Rs. 45000 per month for procuring water from the private tanker with an average extra expenditure of Rs. 562 per month per family approximately. For 100% occupancy (i.e., for the population of 121 x 4 = 484) the total water requirement will be 484x225 = 1,08,900 litres per day.

As the Delhi Development Authority (DDA) cannot increase the supply beyond 32,000 litres per day (with both piped and tanker supply) of water in near future the residents have to purchase the remaining 76900 litres from private tanker which will cost around Rs.500x8 = Rs. 4000 per day and monthly around Rs. 1,20,000/- .

7.2.2 Water harvesting potentials

The existing rainwater harvesting system was implemented in the society in the year 2007 with approximate expenditure of Rs. 200000/- and an approximate cost of Rs.1653/- per family. The system does not have any rainwater storage systems the entire water collected from roof top is recharged to the ground. The society is not utilizing the water from water harvesting.

The total area of roof top is 2465 m^2. (29% of the plot size primary survey findings), accordingly the potential of rainwater harvesting would be;

1. The rainwater harvesting potentials from the roof top of 2465 m^2 as estimated = 1183 m^3 (IS 15797:2008). = 11, 83,000 litres. (for 600 mm average annual rainfall)

2. The rainwater harvesting potentials from other paved surface of 1870 m^2 (22% of plot size) = 1870x0.6(annual rainfall in m)x0.8(runoff coefficient #)x0.8 (coefficient of evaporation and spillage etc) = 1197 m^3= 1197000 litres

3. The rainwater harvesting potentials from unpaved surface (49%) of 4165 m^2 = 4165x0.6x0.1 (runoff coefficient for lawns #) x0.8 = 200 m^3 = 200000 litres.

the value is from Table 2 of CPWD Manual on rainwater harvesting and conservation.

The total annual water harvesting potentials = 11,83,000+11,97,000+2,00,000 = 25,70,000 litres. Therefore per day availability is 7068 litres which is only 06% of the total water requirement.

7.2.3 Greywater recycling potentials

The waste water (greywater) generated from bathing, hand and face washing and clothes washing in CGHS development is = (56+9+32) = 97 litres per person per day (Table 7.1).

The waste water from utensil washing, floor washing and car washing is also constitute a part of greywater but as these contains more solid particles, grease, oil etc and difficult to treat is not considered here as greywater for recycling.

Table 7.1 Per capita water uses in CGHS development in Dwarka

Water use	in %	in litres
Drinking	3	6
Cooking	2	5
Bathing	25	56
Utensil washing	6	14
Hand / face washing	4	9
Cloth wash	14	32
Floor wash	5	11
Toilet flush	38	85
Gardening	1	2
Carwash	2	5
Total	100	225

Source: Primary survey 2008.

The total grey water generation for total population = 97x484 = 46948 liters.

If only 85% of the total grey water is reused after treatment the total grey water potential would be 39905 litres water which is around 36% of the total demand and are available for reuse for flushing of toilets and gardening.

7.2.4 Water saving potentials with metering

Water metering is an important tool for reduction of water demand in addition metering also ensures detection of leakage in the system. There is no individual metering system in CGHS development in Dwarka. The bulk water is metered in the group housing level. All the members in a group housing society equally share the total water bill. So people do not care for water saving. The review of the literature indicated that installation of water meters typically reduced consumption in the range of 10 to 30% and sometimes as high as 50% (Maddaus, 1996, 2001; Leidal, 1983). As there is no literature available for water saving from the metering in Indian context. Therefore the saving due to metering is considered as 20 percent (a moderate approach) for the group housing development in Dwarka.

7.2.5 Water saving potentials from water saving devices

Primary survey analysis reveals that there is a tremendous potential for implementation of water saving devices in the CGHS development. In the existing situation water saving cisterns and water saving showers are used by only 4% households and top loading washing machines are used by 13% households but none uses water saving taps in their apartments.

Primary survey results also show that almost 85 litres water is used for toilet flushing (Table 7.1) per person per day. The average cistern capacity used in CGHS is 10 litres and average flushing of toilet is 8.5 times per day leading as average consumptions of 85 liters per persons per day for toilet flushing. If dual flush system 6/3 is used per person water requirement for flushing will be reduced to only 31.5 litres per day (2x6+6.5x3). Therefore a saving of 53.5 lpcd (63% of total demand for toilet flush) is possible if only the toilet cistern is changed to dual flush water saving cistern. Considering 4% of these households are already having dual flush system the affective saving from remaining 96% household will be around 60% saving for toilet flush if all change to water saving cisterns systems.

There will be 40% saving of water if people use front loading washing machine instead of top loading or semiautomatic washing machine. Every house hold of CGHS development of Dwarka does own a washing machine. Only 13 percent of them own top loading washing machine and if rest 87% is encouraged to change to top loading washing machine (or any other water saving machines) the water saving from washing clothes will be around 35%.

The use of water saving shower or low flow shower reduces 50 to 70% (Table 3.7). In existing CGHS development only 4% households are using water saving shower. Therefore remaining 96% even if 50% saving is considered the estimated saving in bathing will be 48%. No household in CGHS uses water saving taps therefore there is a possibility of encouraging the use of water saving taps. Water saving taps ensures a saving of at least 50% (Table 3.7) of water used from taps.

Table 7.2 Estimated water saving due to the use of water saving devices in CGHS

	Residential water use	Water use (%)	Estimated use litres/capita/day (lpcd)	Saving with water saving measures (%)	Estimated water requirements (lpcd)
1	Drinking	3	6		6
2	Cooking	2	5		5
3	Bathing	25	56	48	27
4	Utensil wash	6	14	50	7
5	Hand and face wash	4	9	50	5
6	Cloth wash	14	32	35	21
7	Floor wash	5	11		11
8	Toilet flush	38	85	63	54
9	Gardening	1	2		2
10	Car wash	2	5		5
	Total	100	225		138(39% saving)

Source: Estimated by author based on the primary survey, 2008.

From the Table 7.2, it is clear that if the water saving devices used in CGHS households the water demand can be reduced to 138 lpcd instead of 225 lpcd leading to around 39% saving on total water demand per person.

As in the above estimate there is water saving individually due to the implementation of rainwater harvesting (rwh), greywater recycling (gwr), metering (m) and water saving devices (wsd) and it is necessary to estimate the cumulative water saving due to the implementation of all four management techniques for CGHS development. It is found that the cumulative application of these techniques reduce the water demand from existing 108900 litres per day to 32311 liters per day (Table 7.3).

7.3 WATER REQUIREMENT AND MANAGEMENT OPTIONS IN A DDA GROUP HOUSING

DDA Group Housing is of larger plot sizes. One of the surveyed DDA Group Housing developments is selected for the estimation of water requirement and water saving due to the application of the selected water management techniques. The selected DDA Group

Housing development is in Sector 6 Pocket 1 of plot size of 17860 m^2 and accommodates total 212 DU's.

Table 7.3 Estimated cumulative water saving in CGHS development in Dwarka

Management measures	Existing demand (litres per day)	Saving per day (%)	Saving (litres/ day)	Reduced demand (litres per day)
Existing	1,08,900			1,08,900
Rainwater harvesting (rwh)	1,08,900	05	5445	103455
rwh + grey water recycling (gwr)	103455	36	37244	66211
rwh+ gwr + metering (m)	66211	20	13242	52969
rwh+gwr+m+water saving devices (wsd)	52969	39	20658	32311

Source: Estimated by author

The water requirements for the occupants are given below.

Estimated population in the group housing is = 212x4 = 848.

Estimated water requirement for 848 persons is 848x225 = 190800 litres per day.

The water from the piped supply is insufficient and residents pay Rs. 157/- per family per month for piped water and also spend extra Rs. 375 per family per month to procure water from tanker and packaged water.

7.3.1 Water harvesting potentials

Around 50% of the DDA Group Housing is having rainwater harvesting system. However it is observed that the residents do not have the knowledge about the initial cost or technical aspects and maintenance of the system.

As the survey results shows that the average roof area of such development is 30%, paved area 27% and unpaved area 43% of the plot size 17869 m^2.

Area under roof top is 5458 m^2, Area under paved surface = 4822 m^2, Area under unpaved surface = 7679 m^2. Therefore,

1. Rain water harvesting potentials from roof top of 5458 m^2 = 2620 m^3 = 2620000 litres

2. Rain water harvesting potentials from paved areas of 4822 m^2 = 4822x0.6x0.8x0.8 = 1852 m^3 = 1852000 litres

3. Rain water harvesting potentials from unpaved areas of 7679 m^2 = 7679x0.6x0.1x0.8 = 369 m^3= 369000 litres

4. Total annual water harvesting potential = 2620000+1852000+369000 = 4841000 litres. Therefore, per day availability is 13263 litres which only 07% of the total water requirement

7.3.2 Greywater recycling potentials

The greywater from bathing, hand and face washing and cloth washing in DDAGHS development is 54+7+38 = 99 litres per person per day (Table 7.4.) The total grey water generation for total population = 99x848 = 83952 liters. If only 85% of the total grey water is reused after treatment the total grey water potential would be 67162 litres water which is around 35% of the total demand and are available for reuse as flushing of toilets and gardening.

Table 7.4 Per Capita Water uses in DDAGHS development in Dwarka

Water use	in %	in litres
Drinking	3	7
Cooking	2	5
Bathing	24	54
Utensil washing	5	11
Hand / face washing	3	7
Cloth wash	17	38
Floor wash	6	14
Toilet flush	36	81
Gardening	2	5
Carwash	2	5
Total	100	227

Source: Primary survey 2008.

7.3.3 Water saving potentials with metering:

Water metering is an important tool for reduction of water; in addition to that the metering also ensures the detection of leakage in the system. There is individual metering in DDAGH development in Dwarka. But billing is never done on the basis of actual consumption. An amount of Rs.157 per month is charged to each house irrespective of the total water used. This system never encourage water saving or economical use of water rather encourage wastage of water. As discussed in the 8.2.4 the saving with metering can also be considered as 20 percent for the DDA group housing development in Dwarka.

7.3.4 Water saving potentials from water saving devices

Primary survey analysis reveals that there is good potential for implementations of water saving devices in the DDA Group Housing development. In the existing situation water saving cisterns is used by 21% of household and top loading washing machines are used by 14 % household but none uses water saving shower and water saving taps in their apartments.

Existing survey results show that almost 81 litres water is used for toilet flushing (Table 7.4) per person per day. The average cistern capacity used in CGHS is 10 litres so average flushing of toilet is 8 times per day. If dual flush system 6/3 is used per persons water requirement for flushing will reduced to only 30 litres per day (2x6+6x3). Therefore a saving of 51 lpcd (63% of total demand for toilet flush) is possible if only the toilet cistern is change to dual flush water saving cistern. Considering 21% of these households are already having dual flush system the affective saving from remaining 79% household will be around 50% saving for toilet flush if all retrofit their cisterns.

There are 40% saving of water use if people use front loading washing machine instead of top loading or semiautomatic washing machine. Every house hold of DDAGH development of Dwarka does own a washing machine. Only 14 percent of them own top loading washing machine if rest 86% are encouraged to change to top loading washing machine (or any other water saving machines) the water saving from washing clothes will be around 34%.

The use of water saving shower or low flow shower reduces 50 to 70% (Table 3.7). In existing DDAGH development no household is using water saving shower. Therefore 50% saving can be considered saving in bathing. There is no use of water saving taps in DDAGH development therefore there is enough scope for use of water saving taps. Water saving taps ensures a saving of at least 50% (Table 3.7) of water used from taps.

From the Table 7.5 it is clear that if the water saving devices used in DDAGH households the water demand can be reduced to 133 lpcd instead of 227 lpcd leading to around 41% saving on total water demand per person.

Table 7.5 Estimated water saving due to the use of water saving devices in DDAGH

	Residential water use	Water use (%)	Estimated use litres/capita/ day (lpcd)	Saving with water saving measures (%)	Estimated water requirements (lpcd)
1	Drinking	3	7		7
2	Cooking	2	5		5
3	Bathing	24	54	50	27
4	Utensil wash	5	11	50	6
5	Hand and face wash	3	7	50	4
6	Cloth wash	17	38	34	25
7	Floor wash	6	14		11
8	Toilet flush	36	81	50	41
9	Gardening	2	5		2
10	Car wash	2	5		5
	Total	100	227		133 (41% saving)

Source: Estimated by author based on the primary survey.

In the above estimate, there is water saving individually due to the implementation of rainwater harvesting (rwh), greywater recycling (gwr), metering (m) and water saving devices (wsd) and it is necessary to estimate the cumulative water saving due to the implementation of all four management techniques for DDAGHS development. It is found that the cumulative application of these techniques reduce the water demand from existing 190800 litres per day to 54440 liters per day (Table 7.6).

7.4 WATER REQUIREMENT AND MANAGEMENT OPTIONS PLOT - I

The plotted residential development of plot size 200 m^2 is the largest plotted residential development in Dwarka sector 8 and 19. The average height of these plotted developments is two storey's with average two DUs. The average family size is four.

Therefore the number of people living in one plot is around 8 and water requirement for them is 8x225 = 1800 litres.

Table 7.6 Estimated cumulative water saving in DDAGH development in Dwarka

Management measures	Existing demand (litres per day)	Saving per day (%)	Saving (litres/ day)	Reduced demand (litres per day)
Existing	190800			190800
Rainwater harvesting (rwh)	190800	07	13356	177444
rwh + grey water recycling (gwr)	177444	35	62105	115339
rwh+ gwr + metering (m)	115339	20	23068	92271
rwh+gwr+m+water saving devices (wsd)	92271	41	37831	54440

Source: Estimated by author

7.4.1 Water harvesting potentials

Around 5% of the plotted housing is having rain water harvesting system. However it is observed that the residents do not have the knowledge about the initial cost or technical aspects and maintenances of the system.

As the survey results show that the average roof area of such development is 73%, paved area 18 % and unpaved area 9% of the plot size of 200 m^2, therefore areas under each category of the surfaces would be as estimated below:

Area under roof top is = 146 m^2, Area under paved surface = 36 m^2, Area under unpaved surface = 18 m^2. Therefore,

1. Rain water harvesting potentials from roof top of 146 m^2 = 72 m^3 = 72000 litres
2. Rain water harvesting potentials from paved areas of 36 m^2 = 36*0.6*0.8*0.8 = 14 m^3 = 14000 litres

3. Rain water harvesting potentials from unpaved areas of 18 m^2 = 18*0.6*0.1*0.8 = 0.86 m^3= 860 litres

The total annual water harvesting potentials = 72000+14000+860 = 86860 litres. Therefore, per day availability is 238 litres which only 13% of the total water requirement

7.4.2 Greywater recycling potential

The waste water (grey water) from bathing, hand and face washing and cloth washing in Plotted development is 50+7+43 = 100 litres per person per day (Table 7.7)

The total grey water generation for total population = 100x8 = 800 liters.

If only 85% of the total grey water is reused after treatment the total grey water potential would be 680 litres water which is around 38% of the total demand and are available for reuse as flushing of toilets and gardening.

Table 7.7 Per capita water uses in Plot-I in Dwarka

Water use	in %	in litres
Drinking	3	7
Cooking	2	5
Bathing	22	50
Utensil washing	5	11
Hand / face washing	3	7
Cloth wash	19	43
Floor wash	5	11
Toilet flush	38	86
Gardening	1	2
Carwash	2	5
Total	100	227

Source: Primary survey 2008.

7.4.3 Water saving potentials with metering

Water metering is an important tool for reduction of water; in addition to that the metering also ensures the detection of leakage in the system. There is individual metering in plotted development in Dwarka. But billing is never done on the basis of actual consumption. An amount of Rs.157 per month is charged to each house irrespective of the total water used. This system never encourage water saving or economical use of water rather encourage wastage of water. As already discussed in previous section 8.2.4 water saving due to metering can also be considered as 20 percent for the plotted housing development in Dwarka.

7.4.4 Water saving potentials from water saving devices

Primary survey analysis reveals that there is good potential for implementations of water saving devices in the plotted development in Dwarka. In the existing situation water saving cistern is used by 26% of household and top loading washing machine is used by 4% household, only 1% uses water saving shower and water saving taps in their apartments.

Existing survey results shows that almost 86 litres water is used for toilet flushing (Table 7.7) per person per day. The average cistern capacity used in plotted development is 10 litres so average flushing of toilet is 8 times per day. If dual flush system 6/3 is used per persons water requirement for flushing will reduced to only 30 litres per day (2x6+6x3). Therefore a saving of 56 lpcd (65% of total demand for toilet flush) is possible if only the toilet cistern is change to dual flush water saving cistern. Considering 26% of these households are already having dual flush system the affective saving from remaining 74% household will be around 48% saving for toilet flush if all retrofit their cisterns.

There are 40% saving of water use if people use front loading washing machine instead of top loading or semiautomatic washing machine. Every house hold of plotted development of Dwarka does own a washing machine. Only 4 percent of them own top loading washing machine if rest 96% is encouraged to change to top loading washing machine (or any other water saving machines) the water saving from washing clothes will be around 38%.

The use of water saving shower or low flow shower reduces 50 to 70% (Table 7.7). In existing plotted development only one percent household is using water saving shower. Therefore around 50% saving can be considered in bathing.

There are only one percent uses water saving taps in plotted development therefore there is a possibility encouraging the use of water saving taps. Water saving taps ensures a saving of at least 50% of water used from taps.

Table 7.8 Estimated water saving due to water saving devices in Plot-I

	Residential water use	Water use (%)	Estimated use litres/capita/day (lpcd)	Saving with water saving measures (%)	Estimated water requirements (lpcd)
1	Drinking	3	7		7
2	Cooking	2	5		5
3	Bathing	22	50	50	25
4	Utensil wash	5	11	50	6
5	Hand and face wash	3	7	50	4
6	Cloth wash	19	43	38	27
7	Floor wash	5	11		11
8	Toilet flush	38	86	48	45
9	Gardening	1	2		2
10	Car wash	2	5		5
	Total	100	227		137 (40% saving)

Source: Estimated by author based on the primary survey.

From the Table 7.8 it is clear that if the water saving devices used in plotted deployment of size 200 m^2, the water demand can be reduced to 137 lpcd instead of 227 lpcd leading to around 40% saving on total water demand per person.

In the above estimate there is water saving individually due to the implementation of rainwater harvesting (rwh), greywater recycling (gwr), metering (m) and water saving devices (wsd) and it is necessary to estimate the cumulative water saving due to the implementation of all four management techniques for plotted development of plot size 200 m^2. It is found that the cumulative application of these techniques reduce the water demand from existing 1800 litres per day to 466 liters per day (Table 7.9).

7.5 WATER REQUIREMENT AND MANAGEMENT OPTIONS IN PLOT- II

The 100 m^2 plot is the minimum plot size where the rain water harvesting is compulsory by the building byelaws in Dwarka. The average number of DUs in such plots is two. Average number people are living in such plotted development is 8. The water requirement for the population is 1800 litres per day.

Table 7.9 Estimated cumulative water saving in Plot -I

Management measures	Existing demand (litres per day)	Saving per day (%)	Saving (litres/ day)	Reduced demand (litres per day)
Existing	1800			1800
Rainwater harvesting (rwh)	1800	13	234	1566
rwh + grey water recycling (gwr)	1566	38	595	971
rwh+ gwr + metering (m)	971	20	194	777
rwh+gwr+m+water saving devices (wsd)	777	40	311	466

7.5.1 Water harvesting potentials

As the survey results shows that the average roof area of such development is 73%, paved area 18% and unpaved area 9% of the plot size, thus the respective areas would be ;

Area under roof top is 73 m^2, Area under paved surface = 18 m^2, Area under unpaved surface = 9 m^2. Therefore,

1. Rain water harvesting potentials from roof top of 73 m^2 = 34 m^3 = 34000 litres
2. Rain water harvesting potentials from paved areas of 18 m^2 = 18x0.6x0.8x0.8 = 7 m^3 = 7000 litres
3. Rain water harvesting potentials from unpaved areas of 9 m^2 = 9x0.6x0.1x0.8 = 0.43m^3= 430 litres

The total annual water harvesting potentials = 34000+7000+430 = 41430 litres. Therefore, per day availability is 114 litres which only 6 % of the total water requirement.

7.5.2 Greywater recycling potential

The waste water (grey water) from bathing, hand and face washing and cloth washing in Plotted development is 50+7+43 = 100 litres per person per day (Table 7.10)

The total grey water generation for total population = 100x8 = 800 liters.

If only 85% of the total grey water is reused after treatment the total grey water potential would be 680 litres water which is around 38% of the total demand and are available for reuse as flushing of toilets and gardening.

Table 7.10 Per capita water uses in Plot-II in Dwarka

Water use	in %	in litres
Drinking	3	7
Cooking	2	5
Bathing	22	50
Utensil washing	5	11
Hand / face washing	3	7
Cloth wash	19	43
Floor wash	5	11
Toilet flush	38	86
Gardening	1	2
Carwash	2	5
Total	100	227

Source: Primary survey 2008.

7.5.3 Water saving potentials with metering

Water metering is an important tool for reduction of water in addition to that the metering also ensures the detection of leakage in the system. There is individual metering in plotted development in Dwarka. But billing is never done on the basis of actual consumption. An amount of Rs.157 per month is charged to each house irrespective of the total water used. This system never encourage water saving or economical use of water rather encourage wastage of water. As already discussed in previous section 7.2.3 water saving due to metering can also be considered as 20 percent for the plotted housing development in Dwarka.

7.5.4 Water saving potentials from water saving devices

The analysis of primary survey reveals that there is good potential for implementations of water saving devices in the plotted development in Dwarka. In the existing situation water saving cisterns is used by 26% of household and top loading washing machines are used by 4% household, only one percent uses water saving showers and water saving taps in their apartments.

Existing survey results shows that almost 86 litres water is used for toilet flushing (Table 7.11) per person per day. The average cistern capacity used in plotted development is 10 litres so average flushing of toilet is 8 times per day. If dual flush system 6/3 is used per persons water requirement for flushing will reduced to only 30 litres per day (2x6+6x3). Therefore a saving of 56 lpcd (65% of total demand for toilet flush) is possible if only the toilet cistern is change to dual flush water saving cistern. Considering 26% of these households are already having dual flush system the affective saving from remaining 74 % household will be around 48 % saving for toilet flush if all retrofit their cisterns.

There are 40% saving of water use if people use front loading washing machine instead of top loading or semiautomatic washing machine. Every house hold of plotted development of Dwarka does own a washing machine. Only 4 percent of them own top loading washing machine if rest 96% is encouraged to change to top loading washing machine (or any other water saving machines) the water saving from washing clothes will be around 38 %.

The use of water saving shower or low flow shower reduces 50 to 70%. In existing plotted development only one percent household is using water saving shower. Therefore around 50% saving can be considered in bathing.

There are only one percent uses water saving taps in plotted development therefore there is a possibility of encouraging the use of water saving taps. Water saving taps ensures a saving of at least 50% (Table 7.11) of water used from taps.

From the Table 7.11 it is clear that if the water saving devices used in plotted development of plot size 100 m^2, the water demand can be reduced to 137 lpcd instead of 227 lpcd leading to around 40% saving on total water demand per person.

Table 7.11 Estimated water saving due to the use of water saving devices in plot-II

	Residential water use	Water use (%)	Estimated use litres/capita/day (lpcd)	Saving with water saving measures (%)	Estimated water requirements (lpcd)
1	Drinking	3	7		7
2	Cooking	2	5		5
3	Bathing	22	50	50	25
4	Utensil wash	5	11	50	6
5	Hand and face wash	3	7	50	4
6	Cloth wash	19	43	38	27
7	Floor wash	5	11		11
8	Toilet flush	38	86	48	45
9	Gardening	1	2		2
10	Car wash	2	5		5
	Total	100	227		137 (40% saving)

Source: Estimated by author based on the primary survey.

In the above estimate there is water saving individually due to the implementation of rainwater harvesting (rwh), greywater recycling (gwr), metering (m) and water saving devices (wsd) and it is necessary to estimate the cumulative water saving due to the implementation of all four management techniques for plotted development of plot size 100 m^2.

It is found that the cumulative application of these techniques reduce the water demand from existing 1800 litres per day to 503 liters per day (Table 7.12).

Table 7.13 shows the comparison of the water saving due to the application of water management options in different types of residential development in Dwarka. It is observed that there is a substantial reduction of water demand (more than 70%) due to the applications of the selected water management techniques in all types of residential development.

Table 7.12 Estimated cumulative water saving in plot-II

Management measures	Existing demand (litres per day)	Saving per day (%)	Saving (litres/ day)	Reduced demand (litres per day)
Existing	1800			1800
Rainwater harvesting (rwh)	1800	06	108	1692
rwh + grey water recycling (gwr)	1692	38	643	1094
rwh+ gwr + metering (m)	1049	20	210	839
rwh+gwr+m+water saving devices (wsd)	839	40	336	503

Table 7.13 Comparison of the water saving due to the application of water management options in different types of development in Dwarka.

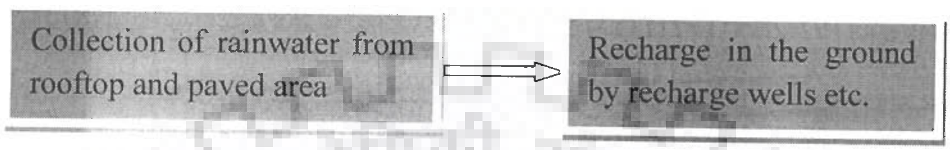
Management options	Water demand reduction			
	GHS		PLOTTED	
	CGHS 8500 m^2	DDA 17860 m^2	200 m^2	100 m^2
Rainwater harvesting	06%	07 %	13%	06%
Grey water reuse	36%	35 %	38%	38%
Water saving devices	39%	41%	40%	40%
Metering	20%	20 %	20%	20%
Combined measures	70%	71%	74%	72%

7.6 SPACE REQUIREMENT FOR MANAGEMENT OPTIONS IN CGHS

7.6.1 Existing rainwater harvesting system in Dwarka

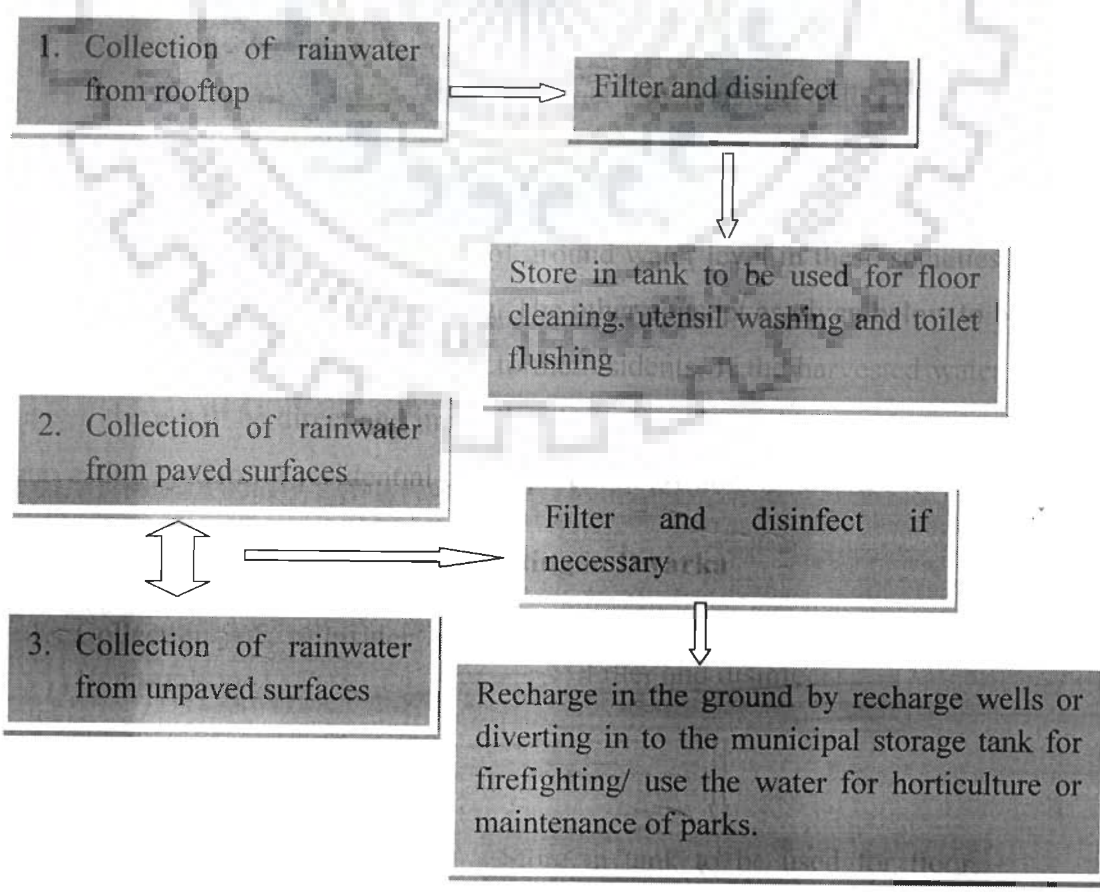
The existing rainwater harvesting system in all residential developments in Dwarka is only recharging of harvested water.

There is no provision of water storage in existing. This can be represented as



But as the residents do not get direct benefit from the recharge and there is no investigation to show the behaviors of ground water level in these societies, residents are not interested in rainwater harvesting. The other concept as given below to be tried as this system can give some direct benefit to the residents. If the harvested water is stored and reused there will be direct and immediate benefit to the residents. The proposed rainwater harvesting system for residential development in Dwarka is shown below

Proposed system of rainwater harvesting in Dwarka



7.6.2 Space requirement for rainwater harvesting systems

Use of rainwater for floor washing, utensil washing and toilet flushing reduces the water demand and reduction on dependency on the tanker during rainy days. The quantity requirement for floor washing, utensil washing and toilet flushing is 14+11+85=110 lpcd which is 49% of the per capita demand. The total demand for such use for the entire society of 484 residents is 53240 litres. If this amount is to be stored for one day, the tank size can be designed as 5x5.5x2 which can accommodate 55000 litres.

1 The rain water harvesting potentials from the roof top of 2550 m^2 as estimated 11,24,000 litres. But this amount is not coming in one day. As per rainfall data analysis it is found that the maximum rainfall of 212.53 mm (34% of total rainfall) is expected for 7.9 days in August (Table 7.14). If the entire amount is stored at a time, the storage requirement is 48375 litres, which is less than the one day requirement of resident for floor washing, utensil washing and toilet flushing (53240litres).

Table 7.14 Average rainfall data of Delhi from 1950-1999,

Month	Average across years in mm	Number of rainy days in a month
Jan	15.13	1.2
Feb	11.32	1
Mar	10.18	0.8
Apr	6.83	0.5
May	15.4	0.8
Jun	43.62	2.1
Jul	195.91	7.4
Aug	212.53	7.9
Sep	92.97	4
Oct	10.32	0.8
Nov	6.06	0.1
Dec	5.01	0.4
	625.28	27
source : www.indiawaterportal.org		

Therefore the designed storage tank of size 5 m x5.5 m x2 m is sufficient to store entire 11,24,000 liters for the above mentioned use and can easily be accommodated within the paved area or unpaved area in the group housing societies.

2 The rain water harvesting potentials from other paved surface = 685000 litres and

3 The rain water harvesting potentials from unpaved surface would be = 200000 litres, i.e., total 885000 litres or 885 m^3 can either be recharged to underground or collected and discharged to a storage tank outside the group housing societies conveniently designed by utility provider for collecting the water in a community tank to be used for firefighting, horticulture road swiping purposes.

7.6.3 Space requirement for greywater recycling system

The grey water generated from bathing, hand and face washing and cloth washing in CGHS development is 56+9+32 = 97 litres per person per day (Table 7.1.)

So total grey water potential would be 39905 litres water which is around 36% of the total demand and are available for reuse as flushing of toilets and gardening.

The major component of such recycle system is equalization tank, filter, collection tank (Table 7.15) disinfections chamber and pump sets and pipe systems.

Table 7.15 Area requirement for grey water system in CGHS development

Components	Size required	Area required
Equalization tank	10mX10mX.8m	100 m^2
Filter		100 m^2
Collection tank	5m X5.5mX3	27.5 m^2
Total area		227.5 m^2

The total area required for all components will be around 227.5 m^2 (Table 7.15). This can be located within the plot without losing much area. The recycled water can be pumped to the tank over the apartment blocks and connected to the toilet flush with totally separate plumbing system.

7.7 SPACE REQUIREMENT FOR MANAGEMENT OPTIONS IN DDAGH

7.7.1 Space requirement for rainwater harvesting systems

Use of rainwater for floor washing, utensil washing and toilet flushing reduces the water demand and reduction on dependency on the tanker during rainy days. The quantity requirement for floor washing, utensil washing and toilet flushing is 106 lpcd (14+11+81) which is 47% of the per capita demand. The total demand for such use for the entire society of 848 residents is 89888 litres. Potential of rainwater harvesting from different catchments for plot size 1.7 ha would be:

1. The rainwater harvesting potentials from the roof top of 5458 m^2 as estimated 2616000 litres. But this amount is not coming in one day. As per rainfall data analysis it is found that the maximum rainfall of 212.53 mm (34% of total rainfall) is expected for 7.9 days in August. If the entire amount is stored at a time, the storage requirement is 112587 litres, which is more than the one day requirement of resident for floor washing, utensil washing and toilet flushing (89888litres). Therefore the storage tank should be designed for accommodating 112587 litres and the size should be 7.5x8x2=120 m^3

2. Rainwater harvesting potentials from paved areas of 5179 m^2 is 1989 m^3 or 1989000 litres

3. Rainwater harvesting potentials from unpaved areas of 7323 m^2 is 352 m^3 or 352000 litres

The total annual water harvesting potentials would be 2341000 litres which can be recharged to underground or collected to a storage tank outside the group housing societies conveniently designed by utility provider for collecting the water in a community tank to be used for firefighting, horticulture and road swiping purposes.

7.7.2 Space requirement for greywater recycling system

The greywater from bathing, hand and face washing and cloth washing in DDAGHS development is 99 litres (54+7+38) per person per day (Table 7.4.)

The total greywater generation for total population = 99x848 = 83952 liters

The major component of such recycle system is equalization tank, filter, collection tank, (Table 7.16) disinfections chamber and pump sets and pipe systems.

The total area required for all components is around 448.00 m^2 (Table 7.16). This can be located within the plot without losing much area. The recycled water can be pumped to the tank over the apartment blocks and connected to the toilet flush with totally separate plumbing system.

Table 7.16 Area requirement for greywater system in DDAGH development

Component	Volume in cu. m	Area in m^2
Equalization tank	14X15X.8	210
Filter		210
Collection tank	5.3X5.3X3	28.09
Total		448.00 (say)

7.8 SPACE REQUIREMENT FOR MANAGEMENT OPTIONS IN PLOT -I

7.8.1 Space requirement for rainwater harvesting system

Use of rainwater for floor washing, utensil washing and toilet flushing reduces the water demand and reduction on dependency on the tanker/ ground water during rainy days. The quantity requirement for floor washing, utensil washing and toilet flushing is 106 lpcd (11+11+86). The total corresponding demand for the 8 residents in such plot is 848 litres. The salient features for rainwater harvesting are given below:

1. Rainwater harvesting potentials from roof top of 146 m^2 = 72 m^3 = 72000 litres
2. But this amount is not coming in one day. As per rainfall data analysis it is found that the maximum rainfall of 212.53 mm (34% of total rainfall) is expected for 7.9 days in August. If the entire amount is stored at a time, the storage requirement is 3099 litres, which is more than the one day requirement of resident for floor washing, utensil washing and toilet flushing (848 litres).

Therefore the designed storage tank of size 1.5 m x1 m x2 m (3 m^3) is sufficient to store entire 72000 liters for the above mentioned use and can easily be accommodated within the paved area in the plot.

3. Rain water harvesting potentials from paved areas of 36 m^2 = 14 m^3 = 14000 litres

4. Rain water harvesting potentials from unpaved areas of 18 m^2 = 0.86 m^3= 860 litres

The total annual water harvesting potentials from paved and unpaved surface would be 14860 litres (14000+860) can either be recharged to underground or collected and discharged to a storage tank outside the plot conveniently designed by utility provider for collecting the water in a community tank to be used for firefighting, horticulture road swiping purposes.

7.8.2 Space requirement for greywater recycling system

The greywater from bathing, hand and face washing and cloth washing in Plotted development is 100 litres per person per day (50+7+43) (Table 7.7).

The total grey water generation for total population = 100x8 = 800 liters.

The major component of such recycle system is equalization tank, filter, collection tank, disinfections chamber, pump sets and pipe systems (Table 7.17).

Table 7.17 Area requirement for grey water system in Plot-I (200 sq. m.)

Component	Size in cu. m	Area in m^2
Equalization tank	1.8X1.6X.6	2.88
Filter		2.88
Collection tank	1X.8X1	.8
Total		6.56

The total area required for grey water system is around 6.65 m^2 (Table 7.17) which can be accommodated within the plot. The recycled water can be pumped to the tank over the apartment blocks and connected to the toilet flush with totally separate plumbing system.

7.9 SPACE REQUIREMENT FOR MANAGEMENT OPTIONS IN PLOT -II

7.9.1 Space requirement for rainwater harvesting systems

Use of rainwater for floor washing, utensil washing and toilet flushing reduces the water demand and reduction on dependency on the tanker/ ground water during rainy days. The quantity requirement for floor washing, utensil washing and toilet flushing is 106 lpcd (11+11+86). The total demand for such use for the 8 residents in such plot is 848 litres. The rainwater harvesting and space requirement is estimated below:

1 Rain water harvesting potentials from roof top of 73 m^2 = 34000 litres

2 But this amount is not coming in one day. As per rainfall data analysis it is found that the maximum rainfall of 212.53 mm (34% of total rainfall) is expected for 7.9 days in August. If the entire amount is stored at a time, the storage requirement is 1463 litres, which is more than the one day requirement of resident for floor washing, utensil washing and toilet flushing (848 litres).

Therefore the designed storage tank of size 1mx1mx1.5m (1.5 m^3) is sufficient to store entire 34000 liters for the above mentioned use and can easily be accommodated within the paved area in the plot.

3 Rain water harvesting potentials from paved areas of 18 m^2 = 7 m^3 = 7000 litres

4 Rain water harvesting potentials from unpaved areas of 9 m^2 = 0.43m^3= 430 litres

The total annual water harvesting potentials would be 7430 litres (7000+430) can either be recharged to underground or collected and discharged to a storage tank outside the plot conveniently designed by utility provider for collecting the water in a community tank to be used for firefighting, horticulture road swiping purposes.

7.9.2 Space requirement for greywater recycling system

The greywater from bathing, hand and face washing and cloth washing in Plotted development is 100 litres per person per day (50+7+43).

The total grey water generation for total population = 100x8 = 800 liters.

The major component of such recycle system is equalization tank, filter, collection tank, disinfections chamber, pump sets and pipe systems (Table 7.18).

Table 7.18 Area requirement for greywater system in Plot-II (100 m^2)

Component	Size in cu. m	Area in m^2
Equalization tank	1.8X1.6X.6	2.88
Filter		2.88
Collection tank	1X.8X1	.8
Total		6.56

The total area required for all other components is 6.56 m^2 (Table 7.18) which can be located within the plot without losing much area. The recycled water can be pumped to the tank over the apartment blocks and connected to the toilet flush with totally separate plumbing system.

7.10 COMPARISON OF SPACE REQUIREMENT

The comparison of space requirement due to the water harvesting, greywater recycling and reuse in selected four types of development is given in the Table 7.19. It is observed that the rainwater harvesting tank is the major component of rainwater harvesting system. The area requirement for the same is depended on the rainfall intensity, number of rainy days in a year and the probable use of the harvested water. It has been seen that the percentage of area requirement within the plot area for rainwater harvesting tank for selected residential development is between highest four percent for 100 m^2 plot to even less than one percent in the case of group housing development. Figure 7.1, 7.2 and 7.3 clearly shows that the rainwater harvesting tank can be accommodated within the plot of all selected residential development. The components of conventional greywater recycling system take large percentage of area within the plot. For group housing developments the area requirement for greywater recycling system is around four percent of the plot area (Table 7.19) but for plotted development the percentage is high between 12 to 24%. So it difficult to accommodate in the smaller plots (Figure 7.3). In the case of plotted development of plot size 100 m^2 the greywater recycling system cannot be accommodated within the available spaces and setback area can be used for the same (Figure 7.3) but this is not allowed under existing building byelaw. Therefore it is seen that group housing residential development are more suitable for greywater recycling due to the availability of large percentage of area.

7.19 Comparison of the space requirement for different water management options in residential development

Management options	Group housing development		Plotted development	
	CGHS (m^2)	DDAGH (m^2)	200 m^2	100 m^2
Water harvesting tank (% to total available area)	27.5 <1%)	60(<1%)	1.5(2%)	1(4%)
Greywater system	227.5 (4%)	448 (4%)	6.65(12%)	6.65 (24%)
Total area requirement	255 (4%)	506 (4%)	8.15(15%)	7.65 (28%)
Total paved area	1785 (14%)	5179(10%)	36(23%)	18 (43%)
Total unpaved area	4165 (6%)	7323(7%)	18(45%)	9 (85%)

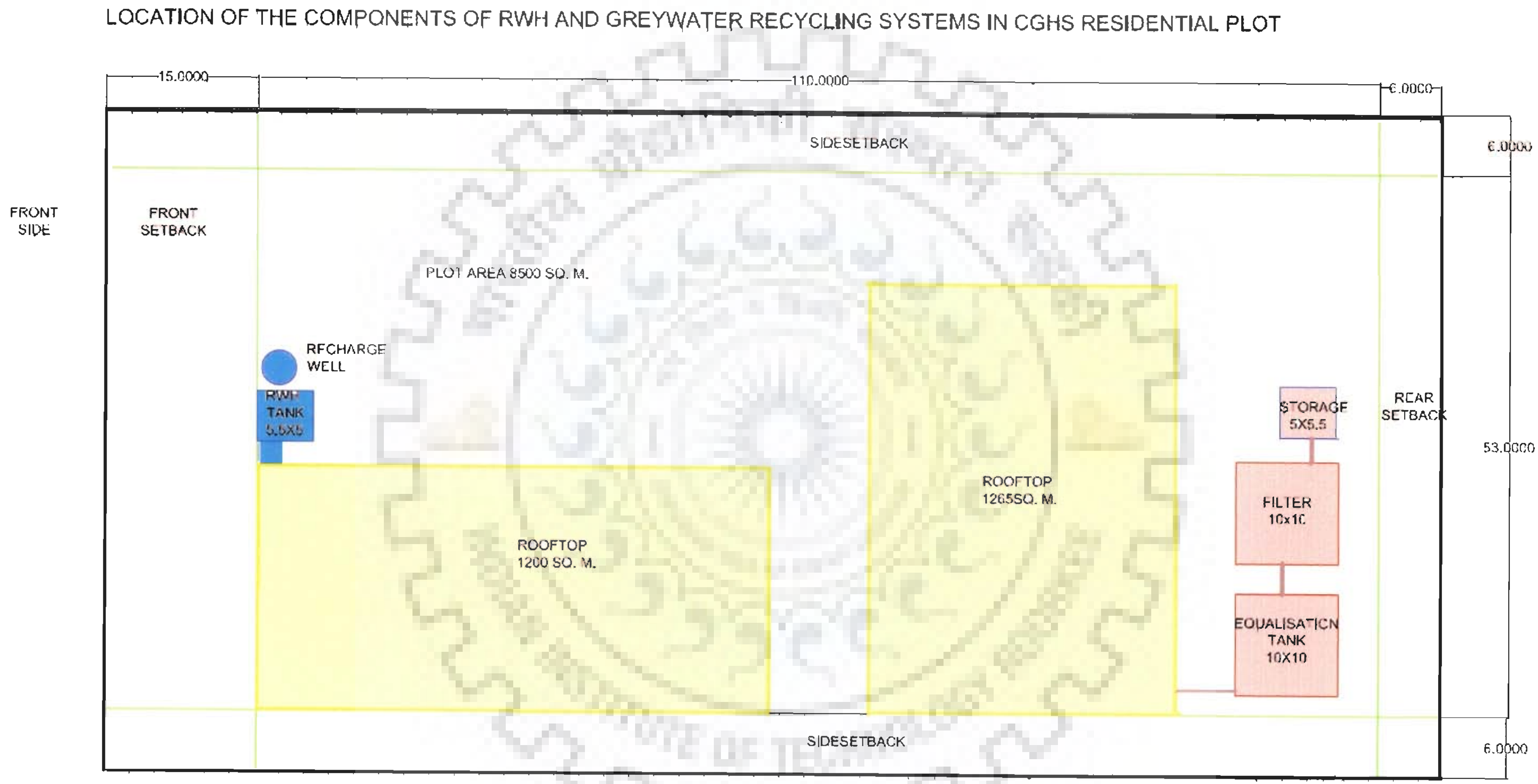


Figure 7.1 Components of rainwater harvesting and greywater recycling in CGGH plot

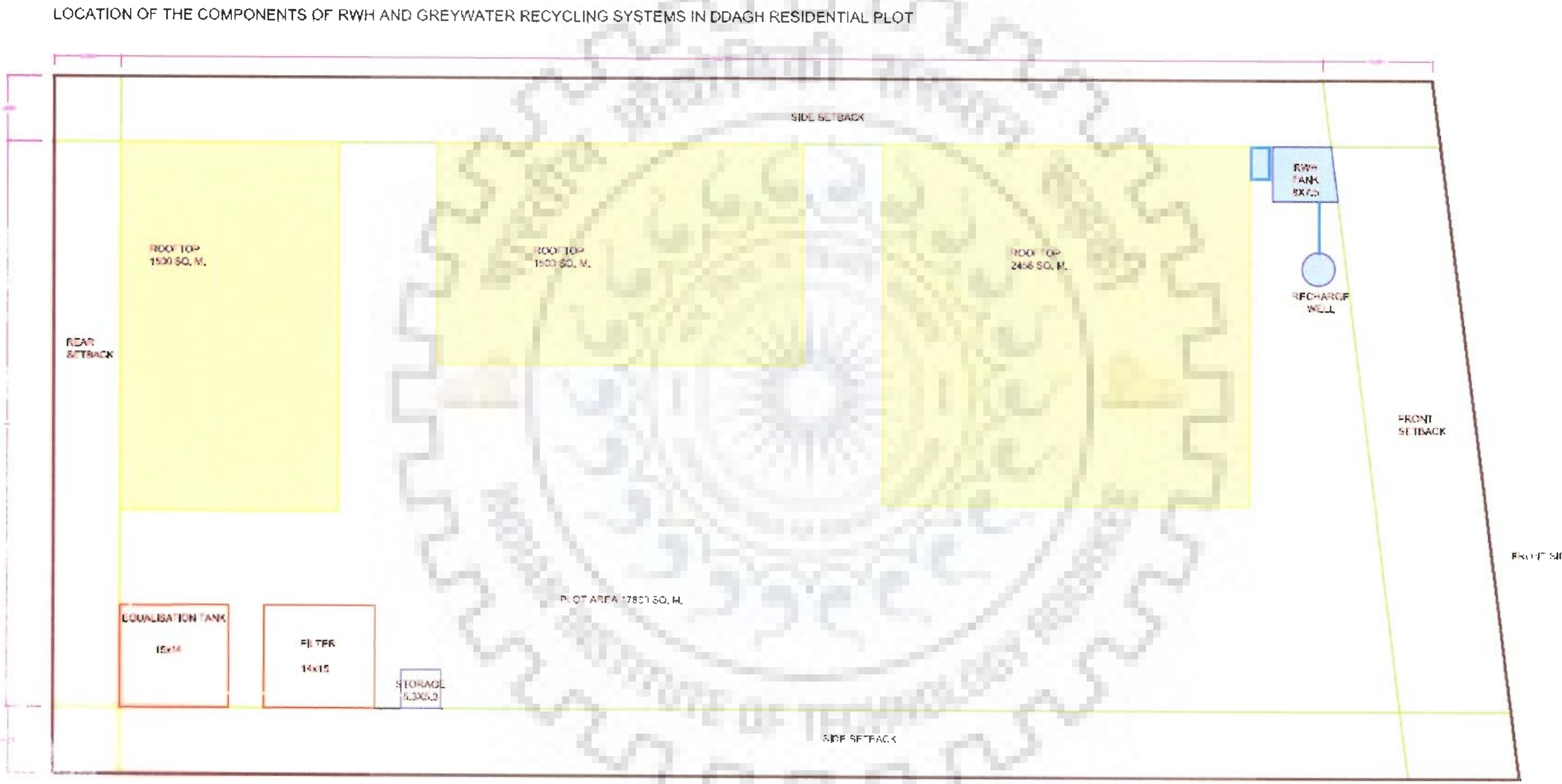
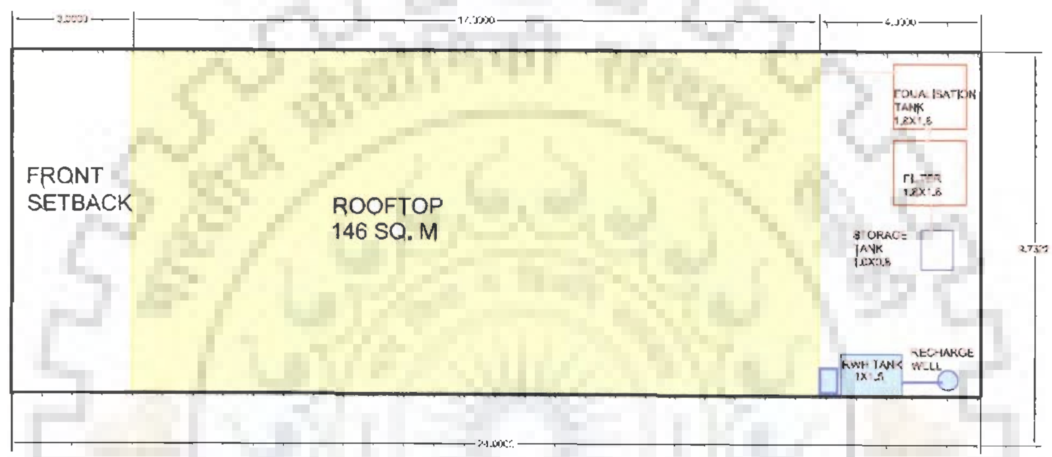


Figure 7.2 Components of rainwater harvesting and greywater recycling in DDAGH plot

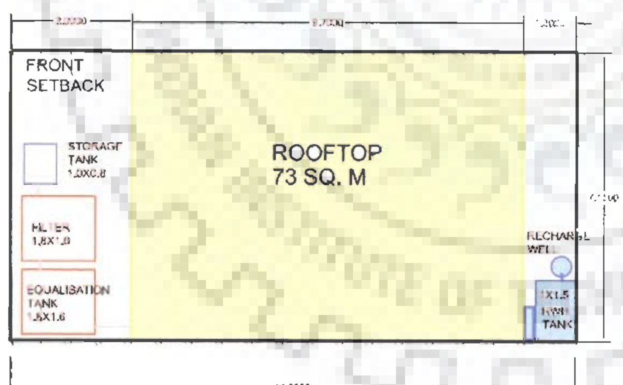
LOCATION OF THE COMPONENTS OF RWH AND GREYWATER RECYCLING SYSTEMS IN RESIDENTIAL PLOT OF 200 SQ.M.

FRONT SIDE



LOCATION OF THE COMPONENTS OF RWH AND GREYWATER RECYCLING SYSTEMS IN RESIDENTIAL PLOT OF 100 SQ.M.

FRONT SIDE



INFERENCES:

It is observed that both the rainwater harvesting and greywater recycling system can be accommodate within the plot of 200 sq. m. In the space available in the rear side of the plot.

But in the plot size 100 sq. m. it is not possible to accommodate greywater system in rear open space and front setback area is used for the same which is presently not permitted under building byelaw.

Figure 7.3 Components of rainwater harvesting and greywater recycling in plotted development

7.11 CONCLUDING REMARKS

It has been observed that there are immense potentials for implementation of water harvesting, greywater recycling and reuse, water saving devices and metering in the selected residential development in Dwarka. If these techniques are implemented there will be substantial water saving. The authors discussion with planners and engineers of the implementing agencies revealed that they have an impression that storage for rainwater harvesting and implementation of greywater recycling is not possible in the plotted development due to space constrain but which is not true for higher plot sizes. For lower plot size only rainwater harvesting system with storage can be accommodated within available area but conventional greywater recycling system is difficult to accommodate. To accommodate conventional greywater system use of setback areas are to be permitted which require the change of existing building byelaws. The group housing developments are more suitable for implementation of selected water management measures in terms of space availability and cost because of more dwelling units are served by the system if implemented and cost can be shared amongst them. The recurring maintenances of rainwater harvesting and greywater system can be ensured due to presence of Cooperative Societies or Welfare Association within the individual plot, which is not in the case of plotted development. As estimated for all types of residential development the water saving from greywater recycling and implementation of water saving devices ensure highest reduction on water demand followed by metering. But government policy has never given any importance to these measures for water management in urban residential development in Dwarka and also in Delhi.

CHAPTER 8
CONCLUSIONS AND RECOMENDATIONS

8.1 PRELUDE

Based on the review of water management approaches, evaluation of case studies, primary survey and analysis on selected residential developments, evaluation of the selected water management techniques for water saving and space requirements in these development, it is found that there is enough scope for the application of water management techniques in the residential development in the urban areas which would result in reduction in water demand. There is also substantial benefit in terms of water saving, reduction of generation of waste water and reduction of surface runoff. Therefore there should be strategies and specific policies to implement such water management techniques in residential development in Dwarka, sub-city of Delhi. To ensure this there should be comprehensive policy reforms and initiatives by the government which have not been done so far. In the present study various strategies for urban water management are suggested, which are presented in subsequent section.

8.2 STRTEGIES FOR URBAN WATER MANAGEMENT

The analysis and findings from the study lead to the development of water management strategies for urban residential areas specifically for Dwarka a sub-city of Delhi. The major strategies can be considered for water metering, water saving devices, greywater recycling and rainwater harvesting. The strategies for these management measures are given below.

8.2.1 Water metering

Metering is partial and the billing for water is not based on the actual consumption leading to misuse and wastage of treated water. Therefore metering and billing based on the actual consumption is the preconditions for efficient water use.

- Ensure 100% metering in all residential development and water charges should be on the basis of actual consumption.
- Resident Welfare Associations (RWAs) are to be given responsibility to install individual water meters for all dwelling units.
- Privatisation of collection of water charges to be implemented.

8.2.2 Water saving devices

Implementation of water saving devices ensure highest quantity of water saving. In order to strengthen water saving and make efficient use of water resources, appropriate policy should be pursued to take water-saving measures, spread new technology and new techniques to save water and encourage manufacturing of water saving equipments by industries. Major strategies to ensure efficient use of water include:

- National Performance Standards or Water Saving Rating for water fittings, appliances and devices should be prepared,
- All new buildings should be fitted with water saving devices,
- Water consumption or water use rating of building should be implemented.
- Rebate and incentives or loan should be provided for purchasing / installing water saving devices.
- Appropriate building byelaws should be developed to incorporate water saving measure in building.
- National Building Code (NBC) should incorporate a section for water saving devices and its standards.

8.2.3 Greywater recycling

Recycling of greywater ensures the availability of large quantity of water back in the system for toilet flushing and gardening. There space requirement of greywater recycling system can be accommodated within group housing residential development. Therefore strategies to encourage greywater recycling would include:

- All the new group housing should be provided with the system of supplying potable and non potable water as well as a system of collection of black water and greywater.
- Greywater treatment manual should be prepared by Bureau of Indian Standard and training for installation and maintenance of greywater treatment system should be provided to the staff of implementing agencies.

8.2.4 Rainwater harvesting

Though the rainwater harvesting do not ensure significant quantity of water availability but storage and direct use of water can reduce dependency on utility provider and recharge of harvested rainwater will reduce the pressure on ground water. The major strategies for encouraging rainwater harvesting are given below.

- Storage of rooftop rainwater harvesting should be encouraged for non-potable use.
- Rainwater harvesting manual should incorporate the methods of design of optimum size of storage tank for different plot sizes and for different urban areas.

8.3 CONCLUSIONS

Based on the literature review, primary survey and analysis in the present study the following salient features and conclusions can be outlined;

World population is increasing at a high rate, especially in urban areas, but the water resources have not only remained constant, these are being polluted at a high rate, which inevitably results in water scarcity. Therefore, there is a need for water sector policy makers and professionals to have a shift in the way they manage water resources in urban areas. Instead of focusing on supply-side options, it is necessary to apply water demand management approach both on the utility and end-user sides. The goal is to trigger a shift in current urban water management practices by developing, applying and demonstrating a range of tested scientific, technological and socio-economic solutions and approaches that contribute to the achievement of sustainable and effective urban water management for city of tomorrow.

It is seen that the group housing development has more unpaved area (43 to 49%) which ensures natural recharge. The higher percentage of roof area (73%) for the plotted development is an opportunity to rainwater harvesting for direct use. The government supply of water is insufficient. Water bill is not as per actual consumption and metering in plotted development is only 39%. Therefore residents do not go for water conservation or water saving. The use of water saving devices are less and awareness about water saving measures also very low (maximum 15% in case of CGHS resident). The people are also not sure about the water quality of supplied water and go for individual water purifiers (66 to 91%).

Though the ground water quantity is decreasing which is obvious from the depletion rate of 0.5 m per year but the dependency on the ground water is still high i.e. 55% for plotted development and as high as 89 % for CGSH. Water harvesting is not significant, only five percent in the case of plotted development. There is a need to make the rainwater harvesting more popular. The present process of only rainwater harvesting through recharging is not accepted by people as they do not get direct benefit out of that.

Highest percentage of treated water supplied to the people is used for toilet flushing (36-38%). The greywater generated from bathing, cloth washing and hand or face washing is around 40% which can be used by implementing greywater recycling system.

It has been found that rainwater harvesting ensure only 6% in the case of CGHS residential development, 7% percent for DDAGH, around 13% for residential development of plot size 200 m^2 and 6% for residential development of plot size 100 m^2. However there is a substantial reduction of water demand due to the implementation of greywater recycling (36 to 38%) and water saving devices (39 to 41%). The water saving due to the implementation of all four measure i.e., rainwater harvesting, greywater recycling, water saving devices and metering together can lead to a saving up-to 70%. Therefore these measures needs to be given highest priority for the implementation in the study area i.e. Dwarka.

The space requirement for rainwater harvesting is less. The only component which takes substantial space is the rainwater storage tank. Depending on the potential use of stored water, number of rainy days in a year and intensity of rainfall the size of the tank can be adjusted. The estimated percentage of area required by the rainwater harvesting tank against the plot area in the case of group housing society is negligible (< 1%) but increases with the reduction of plot size. The area requirement of rainwater harvesting tank for plotted development of plot size 200 m^2 is two percent and for plot size 100 m^2 is around four percent. However in all the cases the rainwater harvesting tank can be accommodated within available spaces in the plot.

The space requirement of conventional greywater recycling system takes substantial space in residential developments. However the estimated percentage of area requirement against the plot area in case of group housing is less around only four percent but in the case of plot size 200 m^2 is 12% and for plot size 100 m^2 is around 24%. It is difficult to accommodate the greywater system in the available space in smaller plot size.

To ensure a sustainable water management in urban areas group housing development should be encouraged, individual metering should be made compulsory for all types of residential development and tariff should be based on the actual consumption, implementation of use of water saving devices should be encouraged on a priority basis, greywater recycling should be encouraged and implemented in all group housing developments and new development, and storage of roof top rainwater should be encouraged for non-potable use of water.

8.4 POLICY RECOMMENDATIONS

Based on the primary survey of different categories of urban residential development, literature reviews on the relevant aspects of water management and case studies of different urban water management and analysis following recommendations can be made for immediate attention by the government:

1. Government should consider seriously the demand water management approaches rather than focusing on increasing supply i.e., supply side management.
2. A comprehensive plan should be prepared for each water division, subdivision, zone or sector along with urban water policy or municipal water policy to ensure wise use of water and which should incorporate principles of water demand management. The policy must also state the strategies for implementation and monitoring of water demand management. Appropriate government policies must ensure changes of development control, building byelaws and changes in Bureau of Indian Standard (BIS) codes. Policies must also aim at reducing misuse and encroachment of water bodies, ponds, lakes, and flood plain zone in and around urban areas.
3. Appropriate byelaws should be developed to incorporate water saving measure within the buildings to limit the inefficient and wasteful use of water. National Performance Standards or Water Saving Rating for water fittings, appliances and devices should be prepared. Government must seriously consider introducing appropriate technology that does not use more water than required, such as automatic or push taps, automatic or waterless urinals, water saving dual flush cisterns, low flow shower, water saving washing machines and introduction of appropriate fiscal incentives for water harvesting, water recycling and use of water saving equipment. Policy on water saving standards and water saving rating to be developed by Bureau of Indian Standard (BIS) or Bureau of Energy Efficiency (BEE) and should be implemented.
4. Water metering is to be installed for all consumers, and billing should be based on the actual consumption of water by the consumer.
5. Stakeholders involvement and raising awareness of water saving and use of appropriate equipments is urgently required. Public awareness campaigns on water conservation must be encouraged through the print and electronic media. Awareness must particularly be targeted at consumers at the household level and at public institutions.
6. Efforts must be made to train staff in the water supplying institutions for approaches and aspects of water demand management. Such education must emphasize the significance of water demand management and must also promote a change in peoples' attitudes towards efficient use of water

resources. The role of service providing authorities, Resident Welfare Associations (RWAs), Non-Governmental Organizations (NGOs) and politicians for promoting water demand management approaches should be defined.

7. Integrated water management plan including the demand management approach like water pricing, water metering, water reuse, use of water saving equipments and appliances, water conservation and water harvesting should be prepared for Delhi at different levels i.e. city level, community level and individual building level.
8. Wastewater recycling and reuse plan for different scales of residential development is required to be prepared. Waste water treatment should be carried out at micro level for use in household, group housing and small community level as well as in large scale for city level for different parts of the city and emphasis should be given on the supply of recycled water through separate pipeline to people for use other than drinking and cooking.
9. Tax rebate and rebate in water bill should be considered for those household implement water harvesting and waste water recycling system in their premises. Incentives also should be given for use of water saving equipments for domestic and industrial water use in Delhi. A separate urban water policy is necessary to address these issues particularly for Delhi.
10. Water demand management training and capacity building programs shall be implemented for stakeholders in the water sector as an integral part of a water demand management strategy
11. The location and operation of private water tanker, small scale private pipe water supplier should be properly documented, and regulated to ensure adherence to environmental and public health norms and water quality standards. Periodic water sample testing to be carried out.
12. Stakeholders involvement and raising awareness of water saving and use of appropriate equipments is urgently required.

8.5 SCOPE FOR FUTURE RESEARCH

Though there is a component of cost in literature review but detailed study and cost analysis of different water management options are not estimated in this study.

Therefore this study can be further extended to estimate cost and its implications in the policy recommendation. The suitability of greywater system in terms of its quality and maintenance aspect also needs to be investigated to make the system sustainable. Pilot projects can be taken to test the success of the proposed options.

The sample size was restricted as it was difficult for the author as an individual to go door-to-door to conduct primary survey in an urban situation where people are not ready to entertain any unknown individual and share the required information. Therefore lower income group residential development and higher income group residential development could not be included in the sample. A better understanding of the situation can be done if sample is from entire urban area with all typology of residential development.

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LIST OF PUBLICATIONS

PAPER PRESENTED IN SEMINARS AND PUBLICATIONS OUT OF THE RESEARCH WORK

Paper selected for presentation in Seminars to be held

1. Paper titled 'Efficient Urban Residential Water Use: An Approach for Sustainable Water Management' has been selected for presentation in the *Aquatech Conference on Innovative Technologies in Water Sustainability* to be held in Delhi during 3 to 5, February, 2010.
2. Paper titled 'Water management for group housing development' has been selected for presentation on *National Seminar on Water Resources Management* to be held in Delhi, organized by Bureau of Indian Standards.
3. Paper titled, 'Sustainable water management approaches for Delhi' in *3rd International Perspective on Current and Future State of Water Resource Management and the Environment*, to be held in IIT Madras with collaboration with EWRI of ASCE, India 2010.

Paper presented in national conferences/ workshop

4. Titled 'Alternative water provisions in Delhi: present status and sustainability' in *40th Annual Convention, Indian Water Works Association on Wise Water Management* held at Indore, from 7th to 9th Feb, 2008.
5. Titled 'Water Supply in New Regional Growth Centre – Case Study Greater Noida' in the National seminar on *Integrated development of towns as new growth centre,* organized by Indian Building Congress, at Vigyan Bhawan, New Delhi, held during May 17-19, 2007.

Paper presented in international conferences

6. Paper titled 'Unsustainable alternative water provisions in Delhi', in Global Summit on *Sustainable Development and Biodiversity (GLOSS-08)* held on Raipur, during 7th to 9th Feb, 09 organized by VRM Foundation, Raipur.
7. *International Congress of Environmental Research 2008*, held at BITS Pilani – Goa Campus, Zuari Nagar, Goa, from 18th to 20th Dec, 08.
8. Paper titled, 'Residential water management for urban area, in 2nd *World Aqua Congress on Global Climate Change and Water Resources, Current Practices and Planning for the Future* held in New Delhi during 26th to 28th Nov, 2008.
9. Paper titled 'Alternative approaches for urban water management' in International Convention on *Water Resources Management 2008 (ICWRDM-08)* held at BITS, Pilani from 23rd Oct to 26th Oct, 08.

List of publications:

Published in international journal

10. Biswas R., Khare D., and Shankar R., 2009, Water demand management for an urban area: the cases study of Dwarka, a sub-city of Delhi, *Water Utility Management International,* Vol.4, Issue 2, p10-17.

Published in journals and proceedings

11. Biswas R, Khare D, Shankar R, 2008, Residential Water Management for Urban Area, in Sinha P. and Rana S. (Ed), 2008, *Global Climate Change and Water Resources, Current Practices and Planning for Future,* the proceedings of 2nd World Aqua Congress, Volume I, p102-114.
12. Biswas R, Khare D, Shankar R, 2008, Alternative Approaches to Urban Water Management, in *SPACE, the SPA Journal of Planning and Architecture*, Vol. 13, No. 2, April-June 2008, p 65-97.

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15. Biswas R., Brar T.S., Khare D. and Shankar R., 2007, Water Supply in New Regional Growth Centre – Case Study Greater Noida, *Journal of Indian Building Congress*, Vol.XIV, No. 1, p180 -186, May 2007.

16. Khare D., Biswas R., and Shankar R., 2006, Waste Water Management in Green Building, *Journal of Indian Building Congress,* Vol. XIII, No. 3, p99-108, Dec 2006. ***Major part of this paper has been published as an example of Water management by use of recycled waste water in Delhi, in the Gazette notification Government of India 7th Feb, 2007, for Master plan for Delhi 2021, Annexure B, page 148 and 149.***

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE, ROORKEE
(Department of Architecture and Planning)

Research study on Water Management in Urban Residential Development

1. Address: (i) House Number. (ii) Apartment
   (iii) Sector (iv) Plot number
2. Ownership: (i) Ground floor/ F.F. / S.F. / ---th floor. (ii) Owned/ rented
   (iii) No. years living in this house:
3. Type of residential development:
   (i) Plotted: Detached/ Semi detached / Row housing / Flat / Duplex / Single floor/ Personally built/ DDA/ private developer/ any other
   (ii)Group Housing: CGHS/ DDA
4. (a) Plot size (sq. m) (b)Covered area (sq. m)
   (c) Total paved area (sq. m) (d) No. of floors
5. Family details

Members	Age	Sex	Education	Employment if any
1				
2				
3				
4				
5				
6				

6. Building details: (1) Plinth area (sq.m). (2) No. of rooms:
   (3) No. of Bath rooms/ toilets:
7. Public water supply status: (i) Hours of supply (ii) Frequency
8. Is the supply metered? Yes/ no. (i) Individual (ii) Bulk
9. Average water bill per month? Rs.
10. Capacity of storage tank (i) Individual (ii)Bulk
11. (i) Do you have water purifying devices? Yes / no (ii) Type
    (iii) Year of purchase (iv) Purchase cost Rs.
    (v) Maintenance cost Rs. Per year
12. Other sources of water:

Type	Quantity(Litres)	Requirement /week or/month	Cost (Rs)
Ground water			
Package water/ bottled water			
Water tanker			
Any other source			

13. Do you have water harvesting system in your building? Yes/no.

14. If yes, what type of harvesting system you have? (i) Storage system (ii) Recharge system, (iii) Both (iv) Year of installation (v) Initial cost of the system Rs. (vi)Maintenance cost Rs.
15. Do you have water recycling system? Yes / no.
16. Water use equipments used in the house:

Equipments	Types	Numbers	Capacity/water use
Cistern/ flush	Single/ dual flush/		
Showerheads	Low flow/ high flow		
Tap			
Washing machine	Semi automatic/ automatic: top loading/ front loading		
Dishwashers			
Desert cooler	Indoor/ window		
Bath tubs/ shower stall			

17. Please give the details of water use in your daily life

Type use	Quantities (litres per head)	Quantities (litres per family)
Drinking		
Cooking		
Bathing		
Utensil washing		
Hand and face washing		
Cloth washing		
Floor washing / wipe		
Toilet flushing		
Gardening/ horticulture		
Car /vehicle washing		
Any other		

18. Awareness of water management aspects

Aspects	Awareness		
Water harvesting	Known	Somewhat known	Not known
Water saving devices			
Water recycling			
Dual supply			
Grey water recycling			

19. Are you satisfied with the quantity of supply? Yes/ no.
20. Are you satisfied with the quality of supply? Yes / no.
21. Water stressed months (a) April- July, (b) August- Nov, (c) Dec- March,
22. Do you have any suggestion for upgrading water situation in your house:

DETAILED PHYSICAL INFORMATION REQUIRED TO BE COLLECTED FROM PLOTTED/ GROUP HOUSING RESIDENTIAL DEVELOPMENT

1. Address:
2. Plot and building details:

Total plot area (sq.m)	Covered area (sq.m)	Paved area (sq.m)	Total Dwelling units (nos)	Family residing (nos)	D.Us Sizes	Height of building/ Storey

3. Total quantity of water required per day (litres)
4. Sources of water:

Source	Quantity/day	Cost/day or /month
Public piped connection		
Ground water (bore well)		
Water tanker		
Bottled water/ packaged water		
Any other		

5. Water storage (a)Number (b) type (c) capacity
6. (a) Bore well number (b)Depth (c) yield (d) quality
7. Water management measures

Types	Year of installation	Initial cost Rs.	Maintenance cost Rs.
Water harvesting			
Water Recycling			

8. Water stressed months (a) April- July, (b) August- Nov, (c) Dec- March,
9. Site plan/ sketch with dimensions: