STUDY OF NON-REVENUE WATER WITH SPECIAL REFERENCE TO JAIPUR CITY

Submitted by

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CERTIFICATE

This is to certify that the thesis report entitled “**STUDY OF NON-REVENUE WATER WITH SPECIAL REFERENCE TO JAIPUR CITY**” which is being submitted by **ARVIND VIJAY**, **Institute ID No 2009 RCE 104** for the fulfillment of the requirements for the degree of **Doctor of Philosophy** in Civil Engineering to the **MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY, JAIPUR** is a record of the student’s own work carried out by him under my direct supervision and guidance.

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STUDY OF NON-REVENUE WATER WITH SPECIAL REFERENCE TO JAIPUR CITY

ABSTRACT

Water is the most precious natural resource which is always in delicate equilibrium. Water use has increased at over twice the population growth rate in the last century. An increasing number of regions are now chronically short of water. Managing and ensuring sustainable use of scarce water resources is one of the major development challenges to countries, states and water utilities around the world.

High levels of Non-Revenue Water (NRW) reflect huge volumes of water being lost through leakages and theft. It becomes a burden to those consumers who are billed. It also affects the financial viability of water utilities / projects through lost revenues and increased operational costs. Knowing the sources where NRW generates and reducing it is of great help in improving water supply status of the area and economic viability of water supply system.

Jaipur, the capital city of Rajasthan is growing rapidly as regards to both urban area and population. A detailed study of NRW has been carried out for the Jaipur city. The feedback on NRW and 24x7 continuous water supply has been collected from consumers, PHED officers and Public representatives.

The results indicate that reduction of NRW is key to 24x7 continuous water supply and enhanced consumer satisfaction. This also reveals that there is less water consumption or wastage, negligible pressure and quality problems, leakages are easily detected as lines are continuously charged and rectified promptly in 24x7 water supply system. In order to get full revenue of water poured into distribution

system it is necessary to reduce leakages, consumers are billed accurately for their water consumption, illegal connection are removed and thefts are checked. It is required to have good quality functional water meters to reduce NRW substantially. In present scenario Jaipur water supply lacks proper water metering.

Water tariff also plays its role on water consumption pattern. Rajasthan has very low water tariff hence consumers are not much cautious to make optimum use of water. Water tariff needs urgent upward revision to reduce tendency of misuse of water and also help make water supply projects financially viable.

As per consumer feedback surveys, majority of consumers prefer 24x7 water supply system and are ready to pay more for better services. Majority of PHED Engineers are also in favour of 24x7 supply system alongwith proper metering and tariff hike. This also helps in reducing maintenance requirements. Majority of Public Representatives also favour 24x7 water supplies and hike in water tariff.

The present study shows, it is possible to reduce NRW to targeted level and achieve 24x7 water supply in the city.

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LIST OF ABBREVIATIONS USED IN THE THESIS

ADB	:	Asian Development Bank
AE	:	Assistant Engineer
ALC	:	Awareness Location Repair
ALI	:	Apparent Loss Index
ALR	:	Active Leakage Control
AWWA	:	American Water Works Association
BCM	:	Billion Cubic Metre
CAPL	:	Current Annual Volume of Physical losses
CWC	:	Central Water Commission
CWR	:	Clear Water Reservoir
DMA	:	District Metered Area
EE	:	Executive Engineer
EPA	:	Environmental Protection Agency
GDP	:	Gross Domestic Product
HDPE	:	High Density Polyethylene
IEC	:	Information, Education and Communication
IFC	:	International Finance Corporation
ILI	:	Infrastructure Leakage Index
IWA	:	International Water Association
JDA	:	Jaipur Development Agency
JMC	:	Jaipur Municipal Corporation
PHED	:	Public Health Engineering Department
PI	:	Performance Indicator
PPP	:	Purchasing Power Parity
PRC	:	People's Republic of China

PRV	:	Pressure Release Valve
PSI	:	Pounds per Square Inch
PSP	:	Public Stand Post
MCM	:	Million Cubic Meter
MAAPL	:	Minimum Achievable annual Physical Losses
MJP	:	Maharashtra Jeevan Pradhikaran
MPLAD	:	Member of Parliament Local Area Development
NGO	:	Non Government Organisation
NRW	:	Non-Revenue water
SCADA	:	Supervisory Control and Data Acquisition
SE	:	Superintending Engineer
SIV	:	System Input Volume
SP	:	Single Phase
SWAN	:	Smart Water Network Forum
TMC	:	Thousand Million Cubic feet
UFW	:	Unaccounted for Water
UNICEF	:	United Nations International Children's Emergency Fund
WTP	:	Water Treatment Plant
WHO	:	World Health Organisation

CHAPTER 1
INTRODUCTION

1.1 General

Water is vital for the sustenance of life and development in all parts of world. The 20th century has seen the world's population triple whereas the utilization of water recourses has increased by six times during the same period. In the next half century, the world population would grow by 35 to 40 percent [WHO, 2004]. The stress on water resources is due to the imbalance between the consumption of water and the availability of water resources. The water supply – demand gap is likely to grow wider and is threatening economic and social development and also environmental sustainability. The stress on water resources poses the major challenge to researchers, engineers and water professionals [Klein, 2004].

The earth has finite supply of fresh water stored as groundwater, surface water and the atmospheric moisture. Water demand is increasing day by day due to increase in population, urbanization, agriculture, industrialization etc. This scarcity of water worldwide has compelled the people to use unsafe drinking water, inadequate sanitation resulting in poor hygiene [WHO, 2004].

Non-Revenue water (NRW) is the water which is not counted in the consumers bills. In water distribution system leakages and theft of water are the problems associated in every nation even when water is scare. This give rise to high levels of Non-Revenue Water and seriously affects the financial viability of water utilities through lost revenue, quality of water and increased operational cost.

1.2 Water Scenario in the World

The total quantity of water in the world is estimated as 1357.5 million cubic kilometres (Mkm^3) and 97% of this water is contained in the oceans as saline water. As such, only 37.5 Mkm^3 is fresh water. Out of this fresh water 8.5 Mkm^3 is available as fresh water and the remaining is contained in frozen state as ice in the polar regions, on mountain tops and in glaciers. The distribution of fresh water on the earth is as given in Table 1.1 [Subramanya, 1982].

Table 1.1: Distribution of Fresh Water on Earth

Description	Quantity	Percentage
In polar ice caps and in glaciers	29.00 Mkm^3	77.33%
as ground water at depth < 800m below ground level	4.15 Mkm^3	11.07%
as ground water at depth > 800m below ground level	4.15 Mkm^3	11.07%
in lakes, rivers and streams	0.120 Mkm^3	0.32%
as soil moisture and seepage	0.067 Mkm^3	0.18%
in atmosphere as water vapour	0.013 Mkm^3	0.035%
Total Fresh Water	**37.5 Mkm^3**	

1.3 Scarcity of Water

World is facing 'Silent Emergency' as billions struggle for safe drinking water and basic sanitation as per reports of WHO [2004] and UNICEF [2004]. More than 2.6 billion people i.e. over 40% of the world's population do not have access to basic sanitation. More than one billion people still use unsafe sources of drinking water [WHO, 2004; WHO, 2009; Tiwari, 2009]. There are two types of scarcity namely, Physical Scarcity and Economic Scarcity, which are defined as below:

1.3.1 Physical Scarcity

Physical scarcity is the condition when physical access to water is limited i.e. when the demand outstrips the land's or nature's ability to provide the needed quantity of water.

1.3.2 Economic Scarcity

Economic scarcity is when the population does not have the necessary monetary means to utilize an adequate source of water. It is due to lack of compassion and good governance that allows the condition to persist [http://thewaterproject.org/water_scarcity_2.asp].

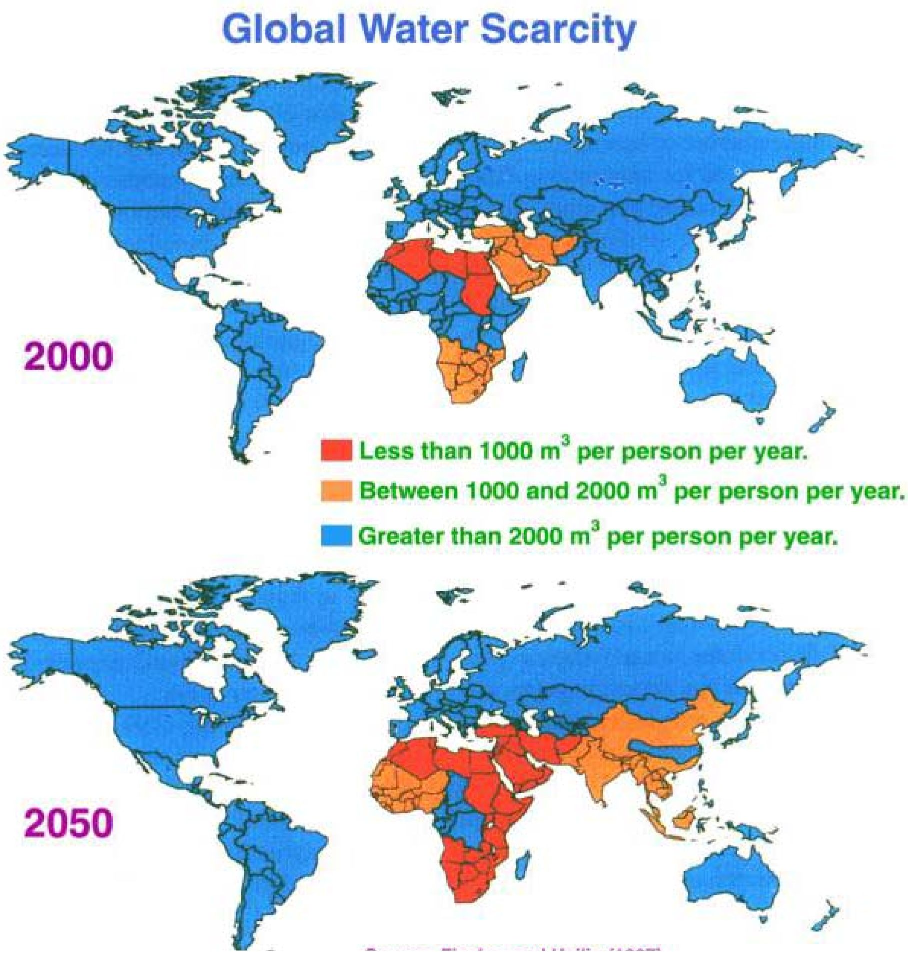


Figure 1.1: Global Water Scarcity [Fischer, 1997]

1.4 Indian Water Scenario

1.4.1 General

India is a land of many rivers and mountains. Its geographical area of about 329 MHa is criss-crossed by the large number of small and big rivers. Some of them are amongst the mighty rivers of the world. The rivers and mountains have a greater significance in the history of Indian cultural development, religious and spiritual life. It may not be an exaggeration to say that the rivers are the heart and soul of Indian life [www.wrmin.nic.in; Kumar et al. 2005].

India is a union of States with a federal set up. Politically, India comprises of 29 States and 7 Union Territories. A major part of India's population of 1,210,726,932 (2011 census) is rural and agriculturally oriented for whom the rivers are the source of their prosperity [Census, 2011; www.wrmin.nic.in].

India is in the early stage of the urbanisation process and will be witnessing exponential growth in many cities in the next few decades. By 2030, the urban population is expected to reach more than 590 million. This will put very heavy pressure on all existing natural resources, especially water. Despite sufficient availability of raw water, many cities struggle to provide more than a few hours of water supply [PWC, 2011, Padode et al, 2011]. Agriculture is expected to account for the majority of growth in water withdrawal in India; the challenges posed by growing urbanisation on water requirement also calls for a monumental shift in response from all stakeholders [Garg and Hassan, 2007].

The Central Water Commission (CWC, 2009) has assessed the total utilisable water resources of the country as 1108.849 Billion Cubic Metres (BCM) which include

690.309 BCM of surface water and 418.54 BCM of groundwater. While the rising population continues to put pressure on per capita water availability, another area of concern is the depleting ground water table. The annual extraction of groundwater in India is over 150 BCM [Shah, 2000]. Moreover, issues like saline water intrusion in coastal areas and further deteriorating water quality curtail the potable water availability in the country [Garg, 2007, PWC, 2011].

Table 1.2: Per Capita Water Availability in India

Year	Population (Million)	Per capita Water Availability (m^3/ year)
1951	361	5177
1955	395	4732
1991	486	2209
2001	1027	1820
2025	1394	1341
2050	1640	1140

[Source: www.wrmin.nic.in]

Besides, global climate change is adding to the resource availability crisis by distorting the hydrological cycle. The impact would be visible both in terms of quantity viz. melting of glaciers and polar ice caps as well as in terms of quality through increased salinity and pronounced water pollution. India's per capita water availability is expected to witness a 26% decline by 2025 and 36% decline by 2050 as compared to 2001 levels [www.wrmin.nic.in].

1.4.2 Rivers

India is blessed with many rivers. Twelve of them are classifled as major rivers whose total catchment area is 252.8 million heactare (MHa). Of the major rivers, the Ganga

– Brahmaputra-Meghana system is the biggest with catchment area of about 110 MHa The other major rivers with catchment area more than 10 MHa are Indus (32.1 MHa), Godavari (31.3 MHa), Krishna, (25.9 MHa) and Mahanadi (14.2 MHa). The catchment area of medium rivers is about 25 MHa and Subernarekha with 1.9 MHa catchment area is the largest river among the medium rivers in the country. Basin-wise water availability is given in Table 1.4 [www.wrmin.nic.in].

Table 1.3: Basin-Wise Water Availability in India

Name of the River Basin	Average annual water availability (in km^3/ year)
Indus (upto Border) a) Ganga b) Brahmaputra, Barak and Others	73.31 525.02 585.60
Godavari	110.54
Krishna	78.12
Cauvery	21.36
Pennar	6.32
East Flowing Rivers between Mahanadi and Pennar	22.52
East Flowing Rivers between Pennar and Kanyakumari	16.46
Mahanadi	66.88
Brahmani and Baitarni	28.48
Subernarekha	12.37
Sabarmati	3.81
Mahi	11.02
West Flowing Rivers of Kutch, Sabarmati including Luni	15.10
Narmada	45.64

Name of the River Basin	Average annual water availability (in km^3/ year)
Tapi	14.88
West Flowing Rivers from Tapi to Tadri	87.41
West Flowing Rivers from Tadri to Kanyakumari	113.53
Area of Inland drainage in Rajasthan desert	NEG.
Minor River Basins Draining into Bangladesh & Myanmar (Burma)	31.00
Total	**1869.35**

Figure 1.2: Major River Basins of India [Source: imd.gov.in]

1.4.3 Rainfall

Rainfall in India is dependent on the South-West and North-East Monsoon, on shallow cyclonic depressions and disturbances, and on violent local storms. Most of the rainfall in India takes place under the influence of South-West monsoon between June to September except in Tamil Nadu where it is under the influence of North-East monsoon during October and November. The rainfall in India has great variations, unequal seasonal distribution, unequal geographical distribution and the frequent departures from the normal. It generally exceeds 1000 mm in areas east of 78^{O} E longitude and it is upto 2500 mm along almost the entire West Coast and Western Ghats and over most of Assam and Sub-Himalayan West Bengal. On the West of the line joining Porbandar (Gujarat) to Delhi and to Ferozpur the rainfall diminishes rapidly from 500 mm to less than 150 mm in the extreme west. The Peninsula has large areas of rainfall less than 600 mm [www.wrmin.nic.in].

Table 1.4: India's Water Budget

Description	**Analysis based on MoWR (Values in BCM)**	**Percentage of annual rainfall**
Annual rainfall	3,840	
Surface runoff	1,869	48.7 %
Groundwater recharge	432	11.3 %
Evapotranspiration	3,840-(1,869+432)=1539	40 %
Available water	2,301	59.9 %
Utilisable water	1,123	29.2 %
Current water use	634	16.5 %
Remarks	Current use (634) well below 1,123	

[Source: unicef.org/india/Final_Report, 2013]

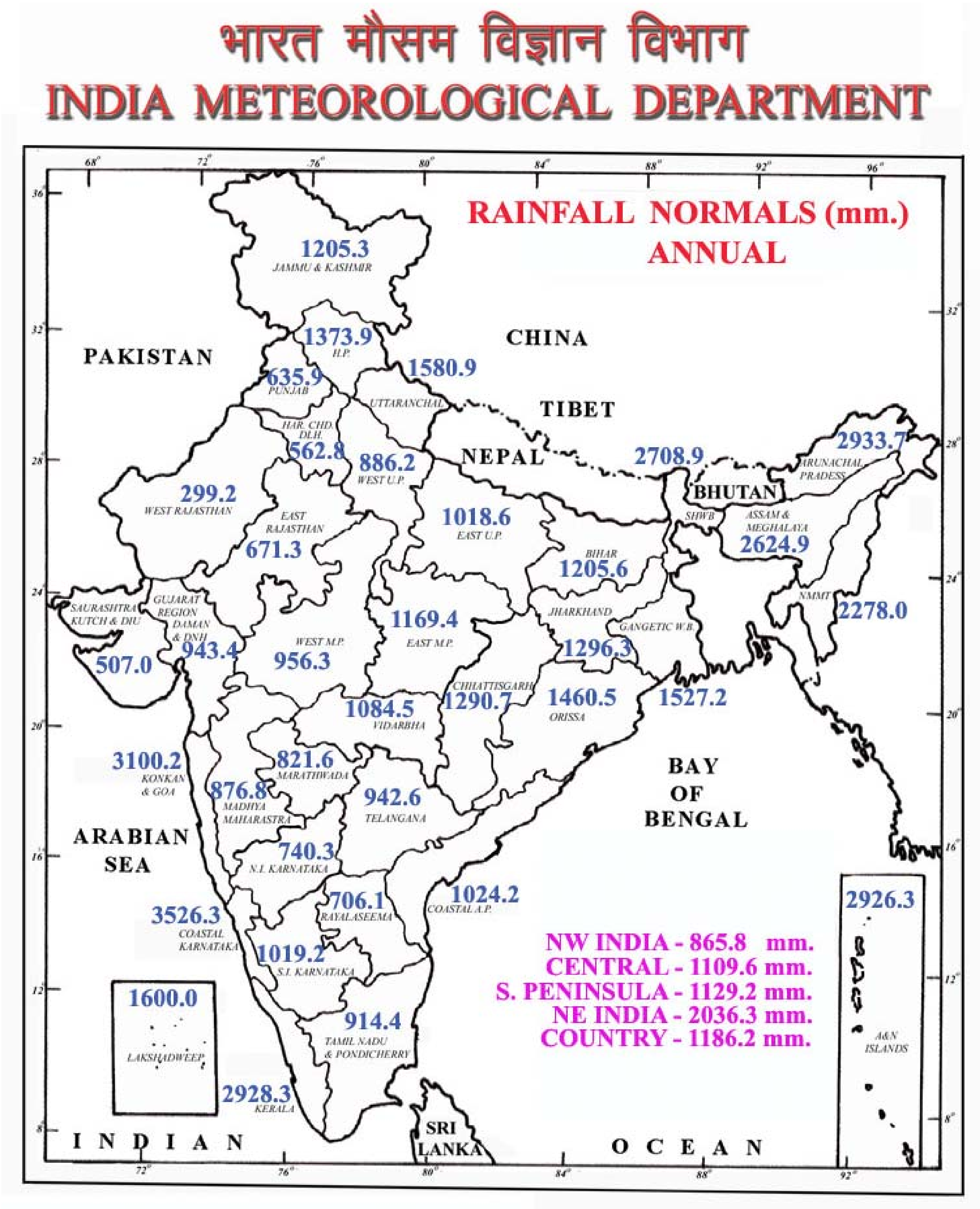


Figure 1.3: Normal Rainfall in India [Source: imd.gov.in]

1.5 Rajasthan Water Scenario

Rajasthan is one of the most water deprived State with respect to rainfall and per capita water availability. The State faces severe water scarcity challenges as rainfall patterns are impacted by climate change. Increasing agricultural and industrial demand is placing additional pressure on the State’s dwindling water resources. Rajasthan has some of the lowest supplies of drinking water in India with only 162 of

222 towns in the State receiving regular supply of drinking water [Mirdha, 2013]. Rajasthan has only 1.16% of the country's total surface water resources (21.71BCM) and out of which only 16.05 BCM is economically usable. The State has created capacity to harness and store 11.29 BCM. Rajasthan has 1.72% of the country's groundwater resources (11.36 BCM). The State also receives 17.88 BCM water per year through inter-state agreements [Mirdha, 2013].

1.5.1 Rainfall

The State has the highest incidence of drought in the country. Between 1901 and 2002 there have been 48 drought years of varied intensity. The average rainfall data of Rajasthan is given in Table 1.6 below.

Table 1.5: Average Rainfall (in mm/year) of Rajasthan

Particulars	Average Rainfall in mm/year		
	Rajasthan State	**Eastern Districts 23 nos.**	**Western Districts 10 nos.**
Average of 100 year (1901 to 2000)	531.00	688.68	318.68
Monsoon Normal Rainfall (1941 to 1990)	539.80	655.1	288.2
Maximum Yearly Rainfall (year)	1079.49 (1917)	1226.54 (1917)	785.39 (1917)
Minimum Yearly Rainfall (year)	197.00 (1918)	266.165 (1905)	55.94 (1918)
Annual Yearly Rainfall in 2003	560.30	612.00	402.30
Annual Yearly Rainfall in 2004	493.47	586.17	211.51
Annual Yearly Rainfall in 2005	526.70	608.45	283.66
Annual Yearly Rainfall in 2006	670.30	737.99	469.03
Annual Yearly Rainfall in 2007	504.30	575.06	327.55
Annual Yearly Rainfall in 2008	549.90	631.75	306.68
Annual Yearly Rainfall in 2009	378.80	436.82	194.73
Annual Yearly Rainfall in 2010	606.30	641.20	494.80
Annual Yearly Rainfall in 2011	737.60	812.20	498.50
Annual Yearly Rainfall in 2012	617.90	687.40	392.20

[Source: waterresources.rajasthan.gov.in]

1.5.2 Groundwater

In Rajasthan, the ground water table goes down by 1 to 3 metres per year. The gross annual draft of groundwater in the State is 13 BCM whereas the annual recharge is estimated as 10.4 BCM. About 90% of drinking water and 73% of water for irrigation is met by groundwater. Exploitation of groundwater has shot up from 35% in 1984 to 138% of annual groundwater recharge in 2008. It is estimated to reach 189.1, 221.4 and 259.1 percent in 2015, 2020 and 2025 respectively. Of the 249 blocks in the State about 80% are either over-exploited or critical [Mirdha, 2013].

1.5.3 Surface Water Resources and River Basins

Rajasthan State comprises of fourteen river basins and an outside basin. The surface water available from all the basins is 25,931 million cubic metres (MCM), of this only 60% (16,054 MCM) is considered economically usable. Surface water resources are scarce and confined to the south and southeast part of the state [Mirdha, 2013].

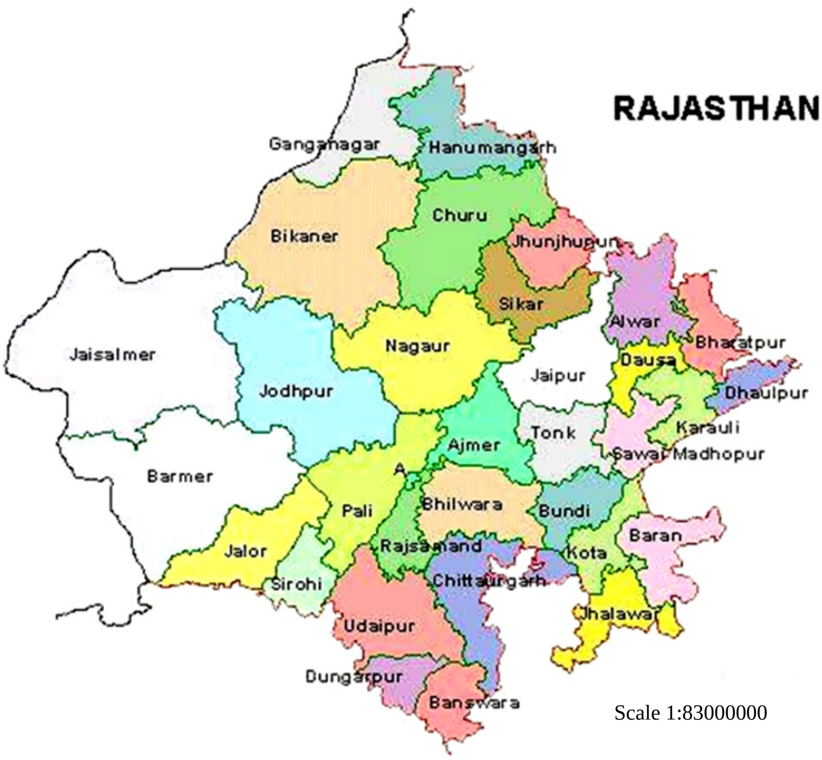


Figure 1.4: Map of Rajasthan

1.6 Drivers of Water Uses in India

Water use in India is rapidly increasing due to following reasons:

(i) Population: Expected to increase from 1.21 billion in the year 2011 to 1.66 billion by the year 2050.

(ii) Urbanisation: Urban population is expected to grow from 377 million in year 2011 to 916 million by the year 2050 i.e. 31.16% of total population in 2011 to 55.2% by 2050.

(iii) Percapita Income: Expected to increase from $ 1219 (₹ 60972) in 2011 to $ 17366 (₹ 868241) by 2050.

(iv) Industrialisation: Industrial contribution to the GDP is expected to increase from ~78% in 2000 to ~92% by 2015.

(v) Agriculture: Production of water intensive crops is expected to grow by 80% between 2000 and 2050.

[Census, 2011; GRAIL, 2009]

1.7 Financial Status of Organisations Providing Water Supply

Water Scarcity has resulted in increased use of groundwater and depletion of groundwater table. Water quality degradation due to pollution has further enhanced the cost of potable water production due to increased treatment cost. The diminishing local surface water source has forced to transport water from far off places, which has increased the production cost. In Jaipur, Jodhpur and other cities where water is being transported from distant surface water sources the production cost has increased enormously. However, water tariff has not been increased for a long in Rajasthan. The details of water tariff in Rajasthan and some other cities of India are given in Table 1.6 to 1.11 [PHED Rajasthan Notifications].

The Tariff Rate for water in Rajasthan is as given in Table 1.7

Table 1.6: Water Tariff in Rajasthan

Consumption m^3 / month per connection	Tariff Rate (₹/ m^3)		
	Domestic	Commercial	Industry
<15	1.25	3.75	8.80
15-40	2.40	6.60	11.0
>40	3.20	8.80	13.2

[Source: PHED Rajasthan Notifications] (1₹ = 0.0167$ as on 29.4.14)
PPP conversion factor – 15.91 (2009-13)
[data.worldbank.org/indicator/PA.NUS.PPP]
PPP - Purchasing Power Parity

Table 1.7: Chronology of Water Tariff Revisions

PHED Rajasthan Notification Date	Consumption m^3/ month	Domestic Tariff (Rupees per 1000 litres)	Minimum Tariff (₹)	Meter Rent (₹)	Service Maintenance (₹)
31.10.74	0-15	0.52 to 0.60	12.50	1.25	-
	15-100				
	>100				
08.08.87	0-15	1.00	15.40	2.00	10.00
	15-100	1.20			
	>100	1.60			
03.05.98	0-15	1.25	16.00	5.00	10.00
	15-40	2.40			
	>40	3.20			

[Source: PHED Rajasthan Notifications]

Water Tariffs in some other cities of India are given in Annexure I

Operation & maintenance cost, and, revenue received from water supply scheme of Jaipur city is given in Table 1.8

Table 1.8: O&M Expenditure and Revenue Generated from Jaipur Water Supply Scheme

YEAR	Expenditure on Operation & Maintenance (In ₹ million)	Revenue Generated from Consumers (In ₹ million)	Revenue Deficit (In ₹ million)	Percentage Recovery of Expenditure
2011-2012	₹ 1337.773	₹ 384.098	₹ 953.675	28.71%
2012-2013	₹ 1577.572	₹ 429.828	₹ 1147.744	27.25%

[Source: PHED Rajasthan]

As per International Standard Revenue generated by Tariff shall be more than 100% of production cost [JBIC, 2004]). In Rajasthan, there is vast difference between production cost and revenue generated from consumers. The availability of water to the consumers at cheaper rates promote the wastage of water. People give little or no attention towards conservation of water.

The organisations providing water supply services are generally local bodies (Municipal corporations, Panchayats etc.) and government departments/ organizations. Their finances are constitutionally the domain of the State Government and/ or Central Government. All expenditure, revenue collection and tariff are decided by the government. Revenue collections by organizations are not sufficient to meet the expenditures of the organization. The financial structure of local bodies in India primarily consists of tax and non-tax sources of revenue. They also receive funds from the State Government in the form of grants-in-aid as also share in taxes collected by the State Government.

Now, in some cities like Bangalore, Hyderabad, Chennai etc. efforts are being made to step up the quantum of funds through institutional financing, foreign direct investment, assistance from bilateral, multi-lateral agencies, newly launched Pooled Finance Development Scheme, tax-free municipal bonds, Member of Parliament Local Area Development (MPLAD) fund etc. apart from involving private entrepreneurs.

1.8 Motivation for the Present Study

Today the world is suffering from many problems associated with water. These problems are very common in every nation. High levels of Non-Revenue water (NRW) reflect huge volumes of water being lost through water theft and leakages. It seriously affects the financial viability of water utilities through lost revenues and increased operational costs. The water which is lost through leakages, theft etc. and not billed is a burden to the consumers whose water is being billed. Knowing the sources where NRW generates and reducing its component will be of great help to improve water supply status of the area and thereby meeting water supply economically viable.

1.9 Objectives of the Research Work

The present study of Non-Revenue Water in Jaipur is aimed at evaluating the NRW of Jaipur water supply scheme with following objectives:

1. Study the water supply system of Jaipur city and assess the NRW of water supply system of Jaipur.
2. Study the effect of NRW reduction in water supply systems.
3. Study the feasibility of 24x7 water supply with NRW reduction.
4. Study the outcome of 24x7 water supply.

1.10 Prologue

The Thesis has been organized as below:

Chapter 2: Description of Non-Revenue Water and its terminology and methods of reduction of NRW are given in this chapter.

Chapter 3: Presents the detailed review of literature on Non-Revenue water reduction of different cities.

Chapter 4: This chapter describes present status of Jaipur water supply.

Chapter 5: This chapter presents study of Non-Revenue Water, 24x7 water supply and feedback on 24x7 water supply in Jaipur.

Chapter 6: This chapter deals with result and discussion on study of Non-Revenue Water, 24x7 water supply and various feedbacks from consumers, public representatives and government officials.

Chapter 7: Conclusions of the study and suggestions for future work are presented in this chapter.

References

Annexure I : Water tariffs in some cities of India

Annexure II : Salient features of the Jaipur water supply scheme

Annexure III: Salient features of Ramgarh dam

Annexure IV: Salient features of Bisalpur dam

Annexure V : Monthly average of daily production & supply of drinking water

Annexure VI: Sample feedback form on 24x7 water supply from consumers.

Annexure VII: Sample feedback form on 24x7 water supply from PHED officials.

AnnexureVIII: Sample feedback form on 24x7 water supply from public representatives

CHAPTER 2
NON-REVENUE WATER: TERMINOLOGY AND REDUCTION

2.1 Introduction

Non-Revenue Water (NRW) refers to the difference between the amount of water put into the distribution system and the amount of water billed to the consumers. As per the International Water Association (IWA), NRW is the difference between system input volume and billed authorized consumption. As suggested by International Water Association (IWA) [Farley et.al., 2007], and recommended by both American Water Work Association (AWWA) and United States Environmental Protection Agency [USEPA, 2009] the term Non-Revenue Water should substitute the term Unaccounted for Water (UFW)

The recommendation has been made because of widely varying interpretations of the term UFW worldwide and all components of the water balance should be accounted for in a water balance study [Alegre et al., 2000, Lambert, 2003 and Farley et.al., 2007].

An annual water balance is normally used to assess NRW and its components. Unfortunately, because of the wide diversity of formats and definitions used for such calculations, earlier attempts made at national and international levels to compare performance in NRW management and performance have left considerable doubts [Lambert, 2003].

International Water Association (IWA) Task Forces produced an international 'best practice' standard approach for water balance calculations (Table 2.1), with definitions of all terms involved, as the essential first step in practical management of water losses [Hirner et al., 2000; Alegre et al., 2000].

Table 2.1: International Water Association (IWA) Standard Water Balance

<table>
<tr><td rowspan="9">System Input Volume (corrected for known errors)</td><td rowspan="4">Authorised consumption</td><td rowspan="2">Billed Authorised Consumption</td><td>Billed Metered Consumption (including water exported)</td><td rowspan="2">Revenue Water</td></tr>
<tr><td>Billed Unmetered Consumption</td></tr>
<tr><td rowspan="2">Unbilled authorised Consumption</td><td>Unbilled Metered Consumption</td><td rowspan="7">Non-Revenue Water (NRW)</td></tr>
<tr><td>Unbilled Unmetered Consumption</td></tr>
<tr><td rowspan="5">Water Losses</td><td rowspan="2">Apparent Losses</td><td>Unauthorised Consumption</td></tr>
<tr><td>Customer Metering Inaccuracies</td></tr>
<tr><td rowspan="3">Real Losses</td><td>Leakage in Transmission and/ or Distribution Mains</td></tr>
<tr><td>Leakage and Overflow at Utility's Storage Tanks</td></tr>
<tr><td>Leakage in Service Connections upto the point of Customer metering</td></tr>
</table>

[Source: IWA, Aug 2003]

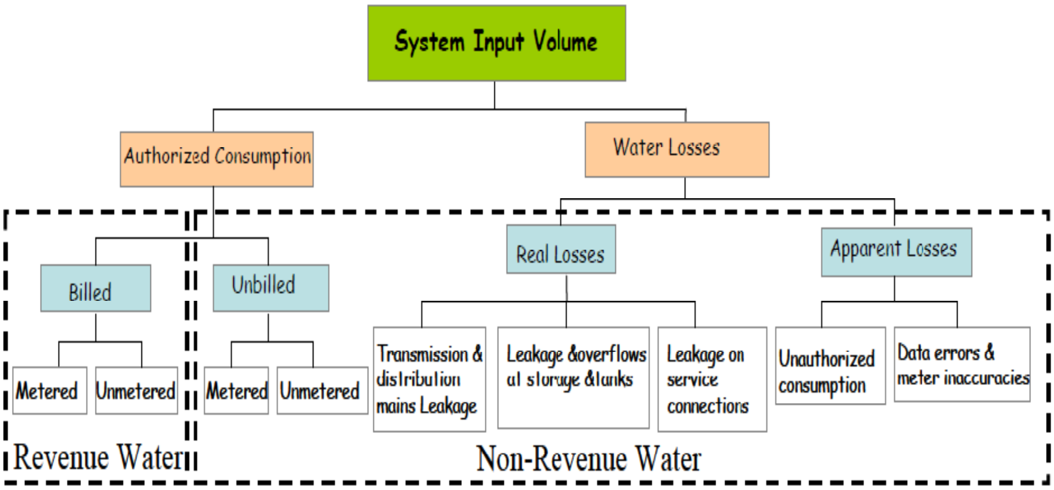


Figure 2.1: Standard IWA Water Balance for NRW

Abbreviated definitions of the principal components of Table 2.1 are given in 2.2.

2.2 Terminology of Water Balance Components

- **System Input Volume** is the annual water volume input to the water supply system.
- **Authorised Consumption** is the annual water volume of metered and non-metered water taken by registered customers, the water supplier, and others who are implicitly or explicitly authorized to do so (e.g. water used in government offices or fire hydrants). It includes exported water, leaks and overflows after the point of customer metering.
- **Non-Revenue Water** is the difference between System Input Volume and Billed Authorised Consumption. NRW consists of Unbilled Authorised Consumption (usually a minor component of the water balance) and Water Losses.
- **Water Losses** is the difference between System Input Volume and Authorised Consumption. It consists of Commercial Losses and Physical Losses.

- **Commercial Losses** are referred to as 'apparent losses', consist of Unauthorised Consumption and all types of metering inaccuracies.
- **Physical Losses** are referred to as 'real losses', and are the annual water volumes lost through all types of leaks, bursts and overflows on mains, service reservoirs and service connections, upto the point of customer metering.

Figure 2.2: Leakages in Distribution Network [Farley, 2008]

2.3 NRW Levels: A Global View

The global volume of Non-Revenue water is staggering. Every year more than 32 billion cubic metre treated water is lost through leakages from distribution networks. An additional 16 billion cubic metre water per year is delivered to customers but not billed because of theft, poor metering or corruption. An estimate of the total annual cost of NRW to water utilities worldwide is US$14 billion. In some low-income countries water loss is upto 50-60% of water supplied, with a global average estimated at 35% [Ranhill and USAID, 2008]. Saving just half of this amount would supply water to an additional 100 million people without further investment.

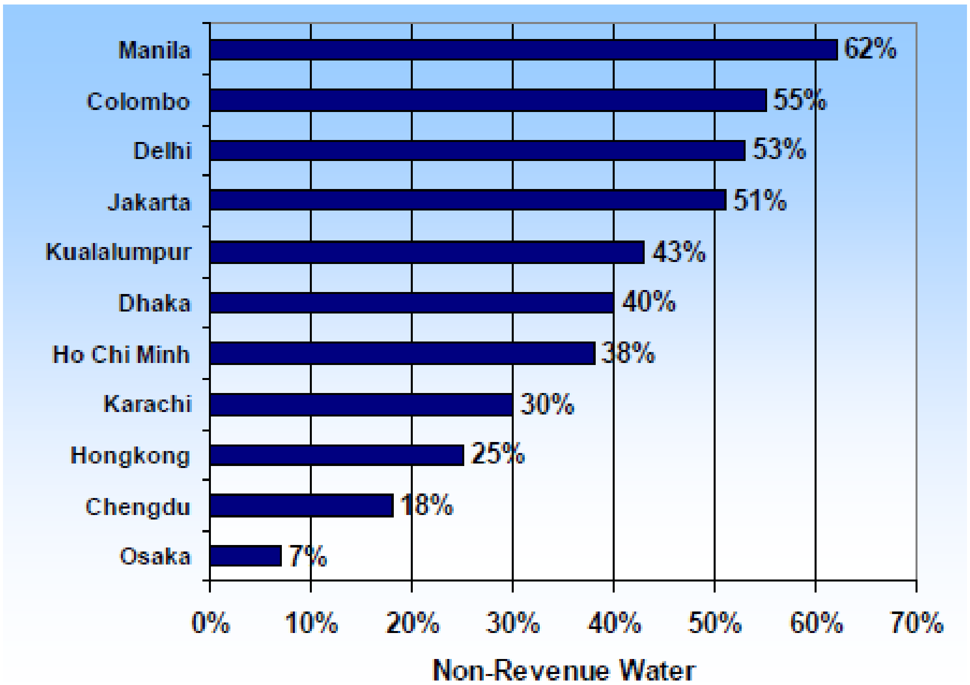


Figure 2.3: Non-Revenue Water in Asian Cities (ADB, 2004)

Table 2.2 : The Stated NRW Rates in Various Cities Worldwide.

City	Country	Stated NRW	Continent
Nairobi	Kenya	34.00%	Africa
Windhoek	Namibia	14.00%	Africa
Adana	Turkey	69.00%	Asia
Bacolod	Philippines	37.00%	Asia
Baliuag	Philippines	21.00%	Asia
Bangalore	India	36.00%	Asia
Bangkok*	Thailand	34.00%	Asia
Cabanatuan	Thailand	25.50%	Asia
Chengdu	China	18.00%	Asia
Chennai	India	12.00%	Asia
Delhi	India	53.00%	Asia

City	Country	Stated NRW	Continent
Dhaka	Bangladesh	40.00%	Asia
Diyarbakir	Turkey	51.00%	Asia
Hai Phong	Vietnam	18.00%	Asia
Hanoi	Vietnam	44.00%	Asia
Ho Chi Minh City	Vietnam	40.00%	Asia
Hong Kong	Hong Kong	25.00%	Asia
Hyderabad	India	50.0%	Asia
Istanbul	Turkey	30.00%	Asia
Jamshedpur	India	9.9%	Asia
Jakarta	Indonesia	51.00%	Asia
Jakarta	Indonesia	51.00%	Asia
Jerusalem	Israel	10.50%	Asia
Katmandu	Nepal	37.00%	Asia
Kayseri	Turkey	45.00%	Asia
Manila East	Philippines	13.50%	Asia
Manila West	Philippines	53.00%	Asia
Osaska	Japan	7.00%	Asia
Phnom Penh	Cambodia	6.19%	Asia
Rawalpindi	Pakistan	46.00%	Asia
Seoul	Korea	25.00%	Asia
Shanghai	China	17.00%	Asia
Singapore	Singapore	4.00%	Asia
Tokyo	Japan	8.00%	Asia
Melbourne	Australia	3.00%	Australia
Amsterdam	Netherlands	6.00%	Europe
Athens*	Greece	20.0%	Europe
Barcelona	Spain	19.00%	Europe
Birmingham*	UK	26.00%	Europe
Bristol*	UK	16.80%	Europe
Brno	Czech Republic	13.00%	Europe
Bucharest	Romania	46.00%	Europe
Budapest*	Hungary	16.50%	Europe
Caserta	Italy	38.60%	Europe
Copenhagen	Denmark	4.00%	Europe
Cork	Ireland	45.00%	Europe
Dublin	Ireland	40.0%	Europe
Glasgow*	UK	44.00%	Europe
Geneva	Switzerland	13.70%	Europe
Genova	Italy	29.50%	Europe

City	Country	Stated NRW	Continent
Helsinki	Finland	17.00%	Europe
Katowice	Poland	9.00%	Europe
Krakow	Poland	14.00%	Europe
Larnaca	Cyprus	23.00%	Europe
Limassol	Cyprus	14.80%	Europe
Lódz	Poland	14.00%	Europe
London	UK	28.00%	Europe
Lublin	Poland	10.00%	Europe
Madrid	Spain	12.00%	Europe
Milan*	Italy	10.40%	Europe
Naples	Italy	35.00%	Europe
Norwich*	UK	18.20%	Europe
Nymburk	Czech Republic	13.20%	Europe
Oslo	Norway	22.00%	Europe
Ostrava	Czech Republic	21.10%	Europe
Rome	Italy	37.80%	Europe
Sofia	Bulgaria	62.00%	Europe
Stockholm	Sweden	15.00%	Europe
Vienna	Austria	8.50%	Europe
Warsaw*	Poland	20.00%	Europe
Chicago	USA	24.00%	North America
Guadalajara	Mexico	33.70%	North America
Hermosillo	Mexico	35.00%	North America
Memphis	USA	16.70%	North America
Mexico City	Mexico	37.00%	North America
Monterrey	Mexico	31.40%	North America
Montreal	Canada	40.00%	North America
New York	USA	10.00%	North America
San Diego	USA	8.00%	North America
San Jose	USA	5.00%	North America
Toronto	Canada	10.00%	North America
Bogota	Colombia	41.00%	South America
Guayaquil	Ecuador	73.00%	South America
Lima	Peru	37.00%	South America
Santiago	Argentina	15.00%	South America
Santiago*	Chile	25.00%	South America
Sao Paulo	Brazil	38.00%	South America

* refers to the entire network operated by the water utility serving the city's network.
[Source: Smart Water Network (SWAN) Forum, 2011]

2.4 The Vicious and Virtuous Circles

The 'Vicious Circle' of NRW (Figure 2.4) is one of the key factor for poor performance of organisation and result in both physical and commercial losses. Physical losses or leakages, divert limited costly water from reaching customers and increase the operating cost. They also result in larger investments than necessary to augment network capacity to fill the gap created by NRW. Commercial losses, caused by customer meter inaccuracies, illegal connections and poor data handling, reduce financial resource generation.

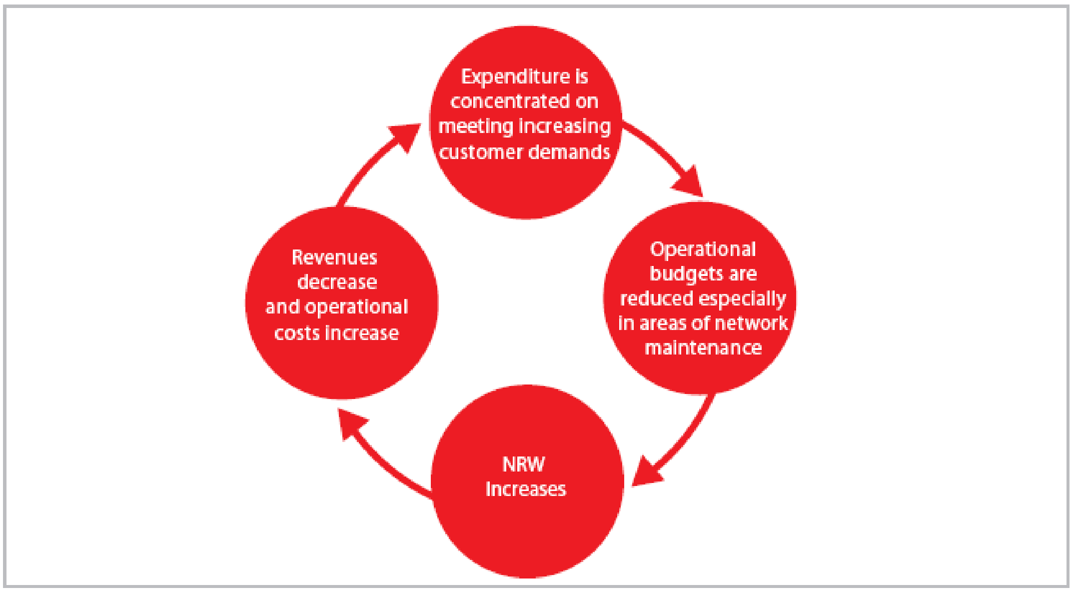


Figure 2.4 : The Vicious Circle of NRW

[Source: Farley et al., 2008]

The challenge for water utility managers is to transform the Vicious Circle into the 'Virtuous Circle' (Figure 2.5). In effect, reducing NRW creates new sources of both water and finances. Reducing physical losses result in a greater amount of water available for consumption and postpones the need for investing in developing new sources. It also lowers operating costs. Similarly, reducing commercial losses generates more revenue.

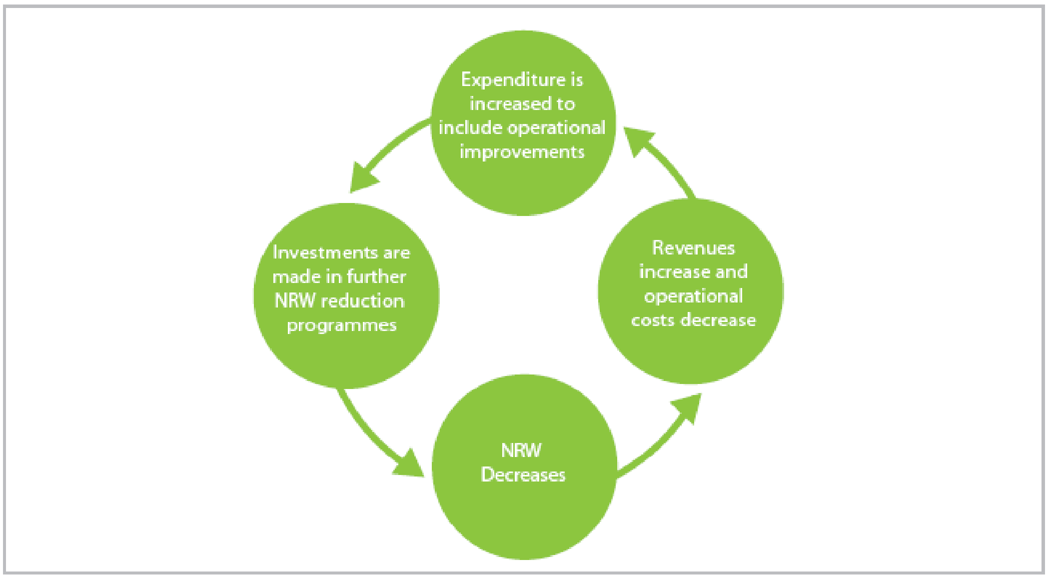


Figure 2.5 : The Virtuous Circle of NRW

[Source: Farley et al., 2008]

To most water utilities, the level of NRW is a key performance indicator of efficiency. However, most utilities tend to underestimate NRW because of institutional and political pressures, as well as a lack of knowledge to properly determine the NRW level. Reports of low levels of NRW put senior managers in comfortable situation. However, reported low levels of NRW are either due to deliberate misinformation or more likely, due to lack of accurate information. This does not help the water utility to reduce its costs and increase revenue, rather it only masks the real problems affecting the water utility's operating efficiency.

NRW situation can be properly understood by

(a) Quantifying NRW and its components.

(b) Calculating appropriate performance indicators and turning volumes of lost water into monetary values.

2.5 Key Steps for Conducting a Water Balance

To conduct a water balance following information is required about the network:

- System input volume
- Billed consumption
- Unbilled consumption
- Unauthorised consumption
- Consumer metering inaccuracies and data handling errors
- Network data
- Length of transmission mains, distribution mains and service connections
- Number of registered connections
- Estimated number of illegal connections
- Average pressure
- Historic burst data
- Level of supply service (24 hour, intermittent etc.)

The basic steps to conduct a water balance are as below:

- Step 1. Determine system input volume
- Step 2. Determine authorised consumption
  - -- Billed - total volume of water billed by the water utility
  - -- Unbilled - total volume of water provided at no charge
- Step 3. Estimate commercial losses
  - -- Theft of water and fraud
  - -- Meter under-registration
  - -- Data handling errors
- Step 4. Calculate physical losses
  - -- Leakage on transmission mains

-- Leakage on distribution mains

-- Leakage from reservoirs and overflows

-- Leakage on consumer service connections

Water balance is an important tool for understanding inflows, consumption and losses but the general lack of data leads to problems. This data gap makes it difficult to quantify commercial losses and to pinpoint the nature and location of physical losses.

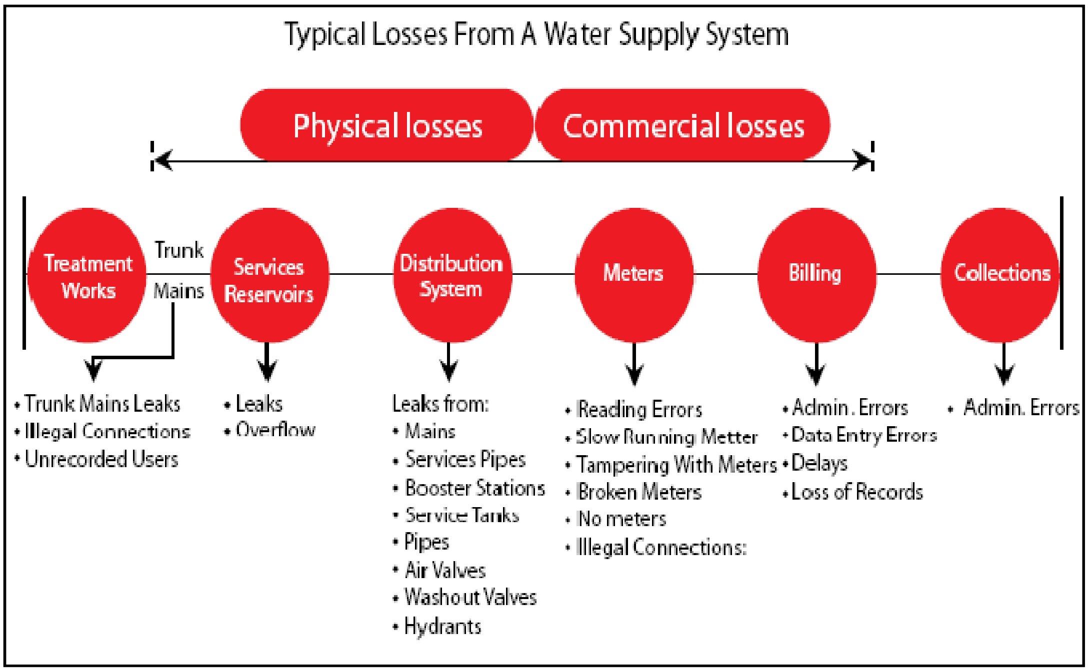


Figure 2.6: Typical Losses from a Water Supply System

[Source: Farley et al., 2008]

2.6 NRW Reduction and Management Strategies

The first step in developing a NRW management strategy is setting its long and short term targets alongwith the utility’s other goals and policies. In the next step NRW assessment and its various components assessment is made. The key to progress of NRW strategy is to get a better understanding of the reasons for NRW and the factors that influence its components [Kingdom et al., 2006 and Farley et al., 2005]. The initial steps make up the main part of a suggested diagnostic approach for developing NRW reduction strategy [Farley and Trow, 2003] which include the following typical questions:

- How much water is being lost?
- Where is it being lost from?
- Why is it being lost?
- What strategies can be introduced to reduce losses and improve performance?
- How can the strategy be maintained and the achievements sustained?

Details on how to answer the above questions is given in Table 2.3 in which tasks and action plans are presented. Additional issues to be considered while developing the strategy are:

- To estimate the potential saved water by the target period for the various NRW components.
- To carry out a prioritizing analysis according to how the required total reduction can be most cost-effectively achieved and which component to be targeted first.
- To include the other factors into the strategy; which are usually the political role and environmental factors [Farley et al., 2008].

Table 2.3:Task and Tools for Developing a NRW Reduction Strategy

QUESTIONS	TASKS
1 How much water is being lost? • Measure components	Water Balance • Improved estimation / measurement techniques • Meter calibration policy • Meter checks • Identify improvements to recording procedures
2 Where is it being lost from? • Quality leakages • Quantities apparent losses	Network audit • Leakage studies (reservoirs, transmission mains, distribution networks) • Operational / customer investigations
3 Why is it being lost? • Conduct network and operational audit	Review of network operating practices • Investigate: historical reason, quality management procedures, poor materials /infrastructure, local/ political influence, cultural / social/ financial factors
4 How to improve performance? • Design a strategy and action plan	Upgrading and strategy development • Update records systems • Introduce zoning • Introduce leakage monitoring • Address cause of apparent losses • Initiate leak detection / repair policy • Design short, medium, long term action plans
5 How to maintain strategy?	Policy change, O&M and training • Training: improve awareness, increase motivation, transfer skill, introduce best practice / technology • O&M: Community development, water conservation and demand management programmes, action plan recommendations, O&M procedures

[Source: Farley, 2004]

The NRW problem can be better appreciated and managed after NRW and its components are quantified, relevant performance indicators calculated and the volume of lost water is translated into its corresponding economic value. The water balance study reveals the magnitude of each NRW component.

2.6.1 Strategy Development Team

The NRW reduction strategy team ensures that all components of NRW are covered and that the proposed strategy is feasible in terms of physical application and financial requirements. The team should include members from each operational department, including production, distribution, customer service, finance, procurement, and human resource departments. Choosing the right members to NRW reduction strategy team enhance outcome of various departments involved in the strategy’s implementation and also ensures consensus by senior management.

2.6.2 Setting NRW Reduction Targets

The strategy development team should first set a target for NRW reduction based on the utility’s other goals or policies that will either complement or conflict with NRW reduction. An active regulator may set performance indicators for NRW and other targets. Many times NRW target is chosen arbitrarily. NRW targets should be set by real consideration of cost implications and should be achievable. Identifying the economic level of NRW is essential for setting the initial NRW target. It requires a comparison of the cost of water being lost versus the cost of undertaking NRW reduction activities.

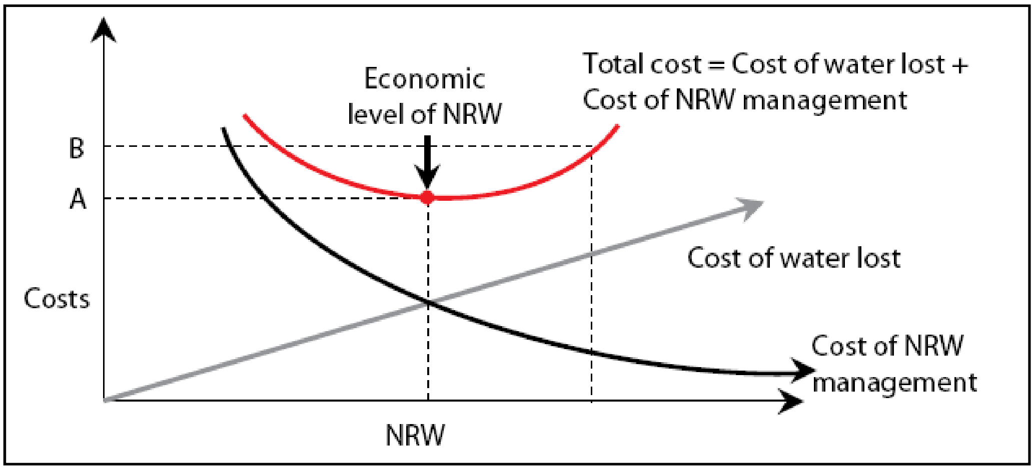


Figure 2.7: Identifying the Economic Level of NRW

[Source: Farley et al., 2008]

Figure 2.7 shows, how the economic level of NRW is determined. The two components that must be determined are the cost of water lost and the cost of NRW management:

- The cost of water lost is the value of the water lost through both commercial and physical losses. The volume of physical losses should be multiplied by the variable operational costs including manpower, electricity and chemicals used. The volume of commercial losses should be multiplied by the average consumer water tariff. As NRW increases, proportionally the cost of water lost increases.
- The cost of NRW management is the cost of reducing NRW, including staff costs, equipment, transportation etc. As NRW decreases, the cost of NRW management increases.

Adding the two cost components together gives the total cost. In Figure 2.7, the minimum total cost (cost A), which is the economic level of NRW. It is clear from Figure 2.7 that letting NRW increase past the economic level reduces the cost of NRW management, but the total cost for the utility (cost B) will rise. Similarly, reducing NRW lower than the economic level of NRW will cost more than the potential savings. However, utility managers may sometimes decide to push NRW below the economic level, for example in areas where raw water is scarce.

The economic level of NRW is not fixed but constantly changes with changes in water tariffs, the cost of chemicals and electricity, staff salaries and equipments costs. Managers should assess the economic level of NRW on a yearly basis and adjust the NRW target accordingly to ensure the efficient use of resources.

2.6.3 Prioritising NRW Reduction Components

After setting NRW reducing targets, prioritisation is to be done among various NRW reduction components in such a way that the target level of NRW can be achieved at minimum cost. For this, a component whose marginal cost of reduction of NRW is the least should be selected first. In general, if a physical loss is detected and repaired then the savings will be in terms of a reduction in variable operational costs. When a commercial loss is detected and resolved, then the saving will be an immediate revenue increase and this is also based on the water sales tariff. A smaller volume of commercial loss may have a higher financial value. If increasing financial resources is the objective, then commercial losses should be prioritised. Here, customer meter accuracies is just as important as sealing pipe leakages.

Where the water utility has a shortage of treated water resulting some customers receiving less than a 24-hour supply or designed supply or the supply coverage is less than 100%, then the reduction in physical losses would effectively create additional water supply. If increasing water supply is the objective, then prioritising physical losses could enable consumers to receive designed water supply or for new consumers to be connected to the supply system.

Table 2.4 shows an analysis of NRW actions according to volume and cost, and enables decision-makers to logically proceed with NRW planning.

Table 2.4: Volume and Cost Analysis for NRW Management Activities

		Cost		
		High	**Medium**	**Low**
Volume	**High**	Leakage in mains (P) Leakage in service connections (P)	Unauthorised consumption (C)	Unbilled metered consumption (U)
	Medium	Customer meter replacement (C)	Customer metering inaccuracies and data handling errors (C)	Pressure management (P)
	Low	Reservoir leakage (P)	Unbilled unmetered consumption (U)	Reservoir overflows (P)

NRW Type: U=Unbilled authorised consumption, P=Physical losses, C=Commercial losses
[Source: Farley et al., 2008]

2.7 NRW Reduction Strategy: Awareness, Location, And Repair (ALR)

The development of the NRW development strategy should be based on the concept of Awareness, Location, and Repair (ALR).

- Awareness time—time taken by the utility to become aware of the leak
- Location time—time taken to locate the leak
- Repair time—time taken to repair the leak

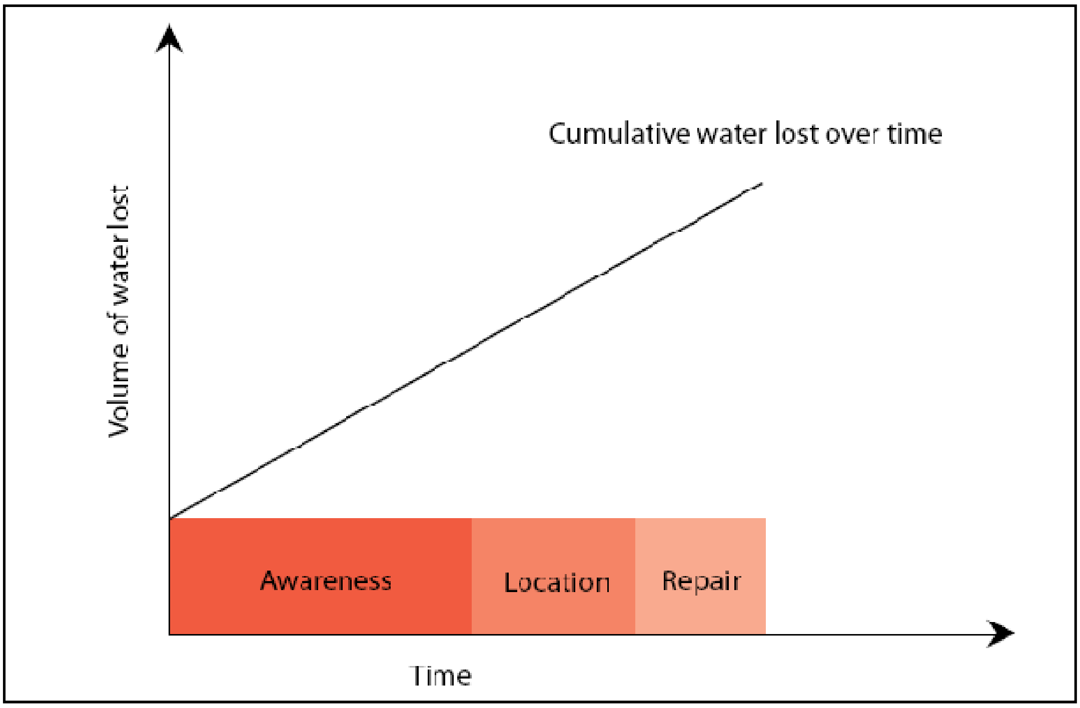


Figure 2.8: The Effect of Time on the Total Volume Lost

[Source: Malcom Farley, 2004]

Therefore, the NRW strategy is to reduce awareness, location, and repair times for all NRW components.

Many losses occur because of poor or limited maintenance, so in addition to reducing ALR, a fourth element of the NRW strategy should be system maintenance. This is critical and would help maintain good condition of assets and thereby reducing the incidence of leaks, meter failures, reservoir leaks etc.

Reducing NRW is not a short-term process, especially in large, open, aging or high pressure systems. The time frame for implementing each NRW strategy component should be outlined. Some activities may be possibly spanning over years rather than months. NRW strategies spanning between four and seven years are reasonable. Any less time frame is ambitious and any more time will not be cost-effective [Farley, 2004].

Figure 2.9: Leakages Visible During Supply Hours

[Source: Ardakanian et al., 2010]

Figure 2.9: Leakages Visible During Supply Hours

[Source: Ardakanian et al., 2010]

2.8 Budget Considerations for NRW Reduction Strategy

The development and implementation of activities to achieve the targeted level of NRW requires financial support for a substantial period. A long-term budget will ensure the financial viability of strategy. Many NRW strategies start off at full swing but often fail due to budget cuts over time.

Undertaking pilot projects to demonstrate the effectiveness of the NRW strategy is useful. The pilot study should cover a smaller area but substantial enough to ensure that all components of the NRW strategy are tested, and operate under financial conditions that can be replicated when activities are implemented for the entire network. The analysis of the pilot results should be used in the development of the economic level of NRW for the entire system [Laville, 2004].

In preparing a budget, the utility manager needs to identify the following costs:

- Staffing—Include staff for both direct NRW works (e.g. leakage technicians) and indirect support (e.g. procurement staff).
- Equipment—Include equipment installed permanently [e.g. District Metered Area (DMA) meters, valves] and those used on a day-to-day basis (e.g. leakage detection equipment etc.).
- Vehicles—Include transportation costs, which can become an important issue in maximizing the work rate of all staff. Small teams generally cover the entire supply system for undertaking NRW works.
- Works—Include the costs for installing all equipment, such as meters, pressure reducing valves, and also detecting and repairing all leaks.
- Office expenses.

2.9 Commercial Losses

In many cases, water has passed through the meters but is not recorded accurately. In contrast to reservoir overflows or leaks, this lost water is not visible and as such many water utilities overlook commercial losses and concentrate instead on physical losses.

Commercial losses can amount to a higher volume of water than physical losses and often have a greater value. Reducing commercial losses increases revenue, whereas reductions of physical losses reduce production cost. For any utility to be profitable, the water tariff should be higher than the variable production cost, sometimes upto four times higher. Therefore, even a small volume of commercial loss will have a large financial impact. An additional benefit in reducing commercial losses is that it can be accomplished quickly and effectively [Rizzo, 2004].

2.9.1 Commercial Loss Elements and Management Strategies

Commercial losses can be divided into four fundamental elements as below:

- Customer meter inaccuracy
- Unauthorised consumption
- Meter reading errors
- Data handling and accounting errors

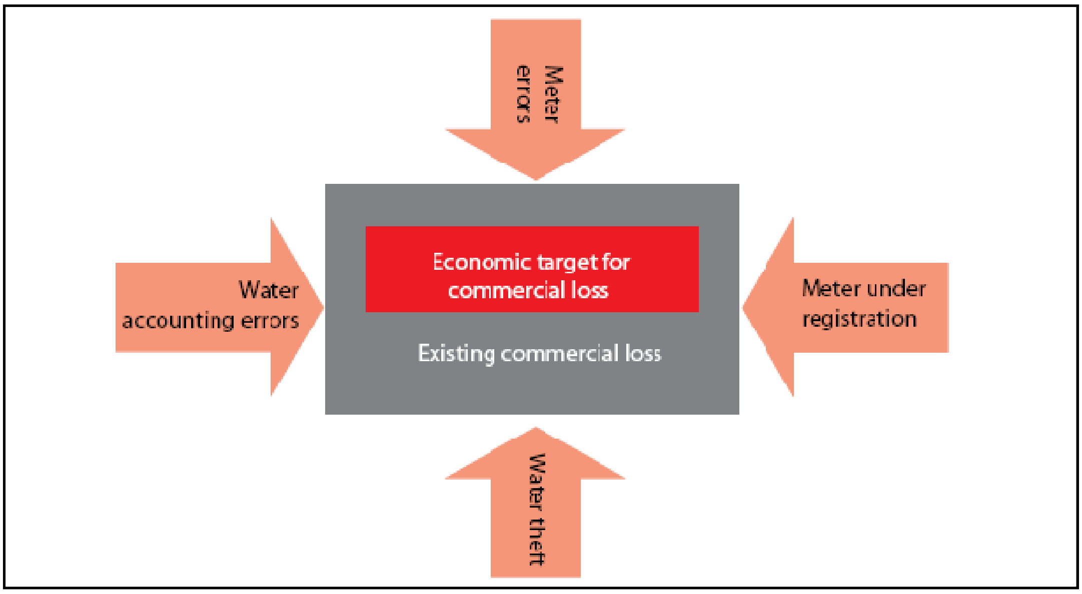


Figure 2.10: Four Pillars of Commercial Losses

[Source: Farley, 2004; Pilcher, 2003]

Reducing commercial losses requires a low level of investment with a short payback period, but it needs sustained management commitment, political will and community support. Utilities should focus on commercial losses in the beginning of an NRW reduction program since the activities can be undertaken in-house with little effort and the payback is immediate.

Figure 2.11: Non Working Water Meters

2.10 Physical Losses

The main components of physical losses include:

- Leakage from distribution and transmission mains
- Leakage and overflows from the storage tanks and utility's reservoirs
- Leakage on service connections up to the consumer's meter

The first and second types of leakage are usually quite visible to either the public or utility staff, so they are easy to detect and are repaired relatively quickly. The third type of leakage is more difficult to detect and can therefore lead to a greater volume of physical losses.

Figure 2.12 : Major Leakages (Bursts)

Figure 2.13 : Leakages on Service Connection

2.11 Characteristics of Leakages

The type and location (e.g. main or service connection) of a burst influences the total leak run time.

- **Reported bursts—**Visible and usually quickly reported by the public or observed by water utility staff. They have a short awareness time.
- **Unreported bursts—**commonly occur underground and are not visible at the surface. They are usually discovered during leak detection surveys and they often have a long awareness time.
- **Background leakage—**An accumulation of very small leaks that are difficult and not cost-effective to detect and repair individually.

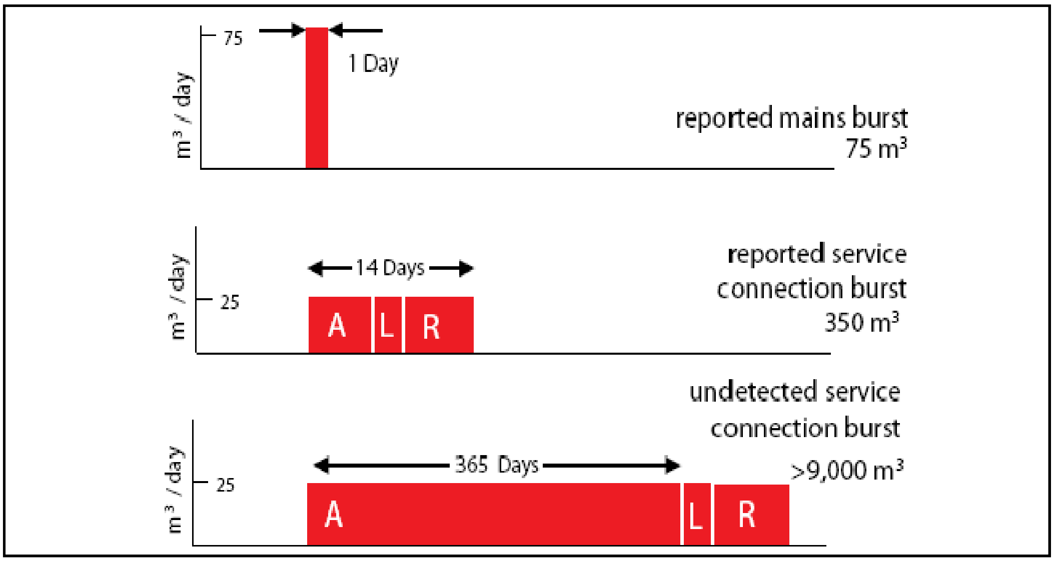


Figure 2.14: Leak Run Time and Volume of Water Loss

[Source: Pilcher, 2007]

General conclusions concerning leakages are:

- Most leaks are invisible
- The majority of leaks do not come to the surface
- Managers need to be aware that most leaks are on service connections
- The absence of an active programme to detect invisible leaks is an indication of high levels of leakage [Pilcher, 2007].

2.12 Providing Continuous (24x7) Water Supply

In some systems, the water supply is not continuously available to customers during all the 24 hours a day. Therefore, consumers develop a tendency to store water whenever it is available in case of delays in getting reconnected water supply. As a result, consumer often stores more water than is required for the period of non-supply. When the water supply is reconnected, they then discard the stored water and hoard fresh water again.

Water consumption per capita per day is therefore often much higher in intermittent supply systems compared to continuous supply systems. Converting to a 24-hour supply will result in lower water consumption and lower demand from the water production and treatment plant. However, turning the entire water network into 24-hour continuous supply remains challenging since the process normally requires 5 to 7 days for the water consumption to decrease to normal levels (actual use levels). During this period, the demand would be too high that the system pressure would be reduced significantly and causing people to continue hoarding water.

The additional benefit of having 24-hour supply is that the pipe will be constantly pressurised, benefiting that infiltration from outside the pipe is minimal. This ensures that the quality of the water is not deteriorated and the consumer receives water of an acceptable quality.

This chapter explains NRW, its components, various losses, methods and strategies of reducing NRW. Next chapter gives the brief of work done to reduce the leakages and NRW and their outcome in some of the cities abroad and in India.

CHAPTER 3
LITERATURE REVIEW

3.1 Introduction

Every year more than 32 billion m^3 of treated water is lost through distribution system and 16 billion m^3 of water is distributed to consumers without invoice due to poor metering, theft or corruption. Therefore there is a need to reduce leakages, non-revenue water and losses in the distribution system. The reduction of water loss by NRW is vital worldwide and many water utilities have developed the strategies to reduce water loss to an acceptable or economic level. But still more research and work is required in this area. Findings of studies done in some of the cities are briefed below.

3.2 Asian Cities

Utilities (Government departments, water supply companies/ corporations/ organizations etc. dealing with production and distribution of water) in Asia particularly lose upto 65% of their daily production, with most utilities averaging a 30% water loss [www.adb.org]. Governments and utilities mistakenly try to cover the losses by increasing production, developing new freshwater sources, building treatment plants, and even constructing dams. None of these investments solve the problem but make the problem worse by feeding more water into a wasteful system. Those investments could have been put to better use rehabilitating the faulty piped system, constructing new systems, or addressing inadequate maintenance, metering or collection processes [World Bank, 2006].

3.3 Studies by Asian Development Bank

Impact of evaluation study on water supply and sanitation projects in some countries were conducted by Asian Development Bank. Based on evidence and experiences from case studies on water supply and sanitation projects in People's Republic of China (PRC), Malaysia, Philippines, and Sri Lanka, Asian Development Bank examined the key result and indentified lessons and good practices for addressing common problems in designing, implementing, operating, maintaining water supply and sanitation project in future [Asian Development Bank Report, 2002].

3.3.1 Summary Findings of Case Studies

Summary findings based on evidence and experiences from case studies on water supply and sanitation projects in selected countries by Asian Development Bank are as under:

- In all the case studies, it was observed that there is a significant increase in water consumption by households.
- Household connected to piped system were paying on average, 1% to 2% of their household income for water, and their willingness to pay was well established. However, the willingness to pay of household in villages still using hand pumps and stand posts differed in each section of society. In some projects in the Philippines less than 50% of households were willing to pay for connecting to a piped supply system. In Public Republic of China (PRC) accepted increase in water tariff and affordability did not appear to be an issue.
- None of the water utilities reviewed had achieved full cost recovery at the time of the study. However, two water supply companies in PRC were most likely to achieve full cost recovery in the near future.

- Utilities meeting cost recovery targets increase the likelihood of long-term sustainability of water supply project.
- Success stories in PRC and Malaysia show that it is possible to reduce non-revenue water to low levels. Leak detection is one of the available options and a caretaker approach coupled with benchmarking of water utilities performances has proven useful.
- Demand side management has proven to be efficient in PRC where political support and awareness campaign are aimed at conservation by the users.

3.3.2 Recommendations

Non-Revenue water can be reduced by caretaker approach, promoting tariff reform, encouraging demand side management for sustainable 24 hour piped water supply and promoting initiatives for financially sustainable water supply utilities/ companies.

3.4 Case Study – Manila (Philippines)

Manila Water Company, Inc., a concessionaire that took over an inefficient water network system in 1997, faced deteriorated pipes lines, widespread illegal connections and a 63% NRW. With a multi-pronged strategy that involved strategic zoning, gaining the public’s trust and technological innovations, Manila Water Company not only reduced NRW to 15% by 2009, but has also increased its customer base, including 148,000 urban poor households. Population served increased from 3 million(1997) to 6 million (2009), Staff per 1000 connection reduced from 6.3(1997) to 1.5(2009) [IBRD, 2010; World Bank, 2010].

3.5 Case Study - Ho Chi Minh City (Vietnam)

In Ho Chi Minh, a pilot study in two districts that lose massive amounts of water and revenues found 126 leaks in just a 10 kilometre stretch of pipes and uncovered metering and connection anomalies. By readjusting water pressure to minimize the leaks and updating its customer database to identify thieves, the city's water utility reduced NRW from 42% to 31% in less than a year, saving $1.4 million in annual losses [Sharma et al., 2006; VMI-water.com].

3.6 Case Study – Sandakan (Malaysia)

The Sandakan situation is a very good example of a transmission and distribution system that was under great stress because of the combination of the shortage of water, high incidence of bursts and leaks on mains and service pipes and further exacerbated by theft of water and tampering with the pipes and fittings. The operational staff had a very difficult task trying to provide the customers with a reasonable water supply. The object of this project was to try and alleviate the problem by the reduction of physical losses by almost 18Mld through enhanced leakage reduction techniques and replacement of approximately 20% of the infrastructure that was in a very poor condition. [Pilcher, 2007; Jokinol, 2009]

Good results have been achieved on this project by application of:

- International best practice in the assessment of losses and development of a tailor made strategy for NRW reduction.
- Active leakage control using the latest techniques and practices
- Appropriate training of local staff

3.7 Badlapur (India) Experience

Maharashtra Jeevan Pradhikaran (MJP) is the principal water service provider in Maharashtra (India). Badlapur had intermittent supply with approximately four hours duration. During the non-supply, there was risk on intrusion on contamination through leaks. In this system of supply there are cases of ‘no supply’ to poor hamlets. MJP is responsible for technical support on water supply and sewerage services for urban and rural local bodies through 25 water works throughout the Maharashtra, carried out extensive capital works to successfully transform from intermittent to continuous 24x7 water supply in Badlapur.

Table 3.1: Pre and Post Project Situation at Badlapur, Maharashtra.

PARAMETERS	PRE-PROJECT STATUS	POST-PROJECT STATUS
Revenue	91%	96%
NRW	29%	23%
Satff/1000 connections	13.72	10
Complaints/1000 connections	55	5
Annual O&M expense/1000 connections	Rs 34.55 Lacs	Rs 29 Lacs
LPCD (litres per capita per day)	171	135
Energy charges to consumers	Quite high due to storage in sump and pumping to overhead tank.	Saving in energy charges is observed at as residual pressure are now enough to supply water even to the second story of buildings.
Awareness about conservation of water	Tendency of storing excess water and later on throwing the stored water when fresh water is supplied.	Reduction in consumption/ wastage of water due to change in habit of storing of water to non storing.
Invisible leak detection and removal	Nil	4 to 5 invisible leaks are detected per month with sounding rods and other

PARAMETERS	PRE-PROJECT STATUS	POST-PROJECT STATUS
		equipments and then the same are repaired.
Public stand post	In slum areas 3 group connections were given.	Individual connections are given. Hence, no stand posts exists in city.
Reliability and satisfaction of water supply system	In convenient supply hours affected poor people. Large size of storage was required and consumers had to pay for pumping. Results in poor sanitation leading to increase in health risks and mortality.	A better demand management is possible due to elaborate metering and effective leakage control. Reduction in consumption due to change in habit from storing of water to non-storing. Excellent consumer satisfaction. Enhanced willingness to pay even in slum pockets.
Housewives time for house hold activities.	Anchored to water supply schedule, i.e., 3.5 hour per day.	Since water is readily available housewives can effectively manage time for other productive activities and house responsibilities.

In the process, MJP partnered with Ranhill Utilities in 2008 to support the implementation and operation of the 24x7 supply scheme. MJP now provides continuous water supply to 16 out of 34 wards in Badlapur, benefiting 80,000 residents [Dahasahashra, 2008].

3.8 Bangalore (India) Experience

Unlike other cities Bangalore was also facing acute water crisis in terms in imbalance between supply and demand. the problem and constraints include increasing scarcity of water, low pricing, high subsidy, poor cost recovery, poor maintenance, rising NRW. Bangalore Water Supply and Sewerage Board (BWSSB) conducted a pilot project between 2003 to 2006 for mitigation of Unaccounted for Water (UFW) and has accrued the benefit by controlling distribution losses, improving reliability in supplies, increasing system pressure, improving water quality and thereby increasing water revenue collection.

The pilot study of Bangalore also demonstrated that urban poor are willing and able to pay for improved sanitation and water supply services, if procedural barriers and property taxation norms are simplified [Muniyappa, 2010; Raj, 2013].

3.9 Reduction of Non-Revenue Water in Kundapura Municipal Water Supply (Karnataka)

Kundapura is a prominent town in Udupi district of Karnataka State in India and developing along the western coastline of Karnataka. Water supply to town were from 11 open wells without treatment. These are maintained by Town Municipal Council (TMC). The water supply system had about 29 km PVC pipes distribution lines, diameter ranging from 50 mm to 200 mm. most of the pipes were leaking and damaged. Valves were not functioning properly.

In the year 2006, in order to have a sustainable water supply system for the entire town the TMC took various steps including estimation of future demand, new treatment facility, new raising mains, revised water tariff, reduction in leakages, compulsory metered connections etc.

3.9.1 Situation Prior to the Initiative

The source of water supply for Kundapura is groundwater. There were 11 open wells maintained by municipal council for supplying the water to entire town. Water was supplied without treatment and monitoring of water quality was not in practice. There used to be scarcity of water during summer due to inadequate water availability from existing open wells [TMC, 2010; Nayak and Swamy, 2010]. The demerits of water supply were identified as:

a) Inadequate water supply.

b) Untreated water supply.

c) More number of public stand posts, increased percentage of Non- Revenue Water.

d) Insufficient length of water supply lines.

e) Maximum amount of leakages due to old PVC pipe network.

f) Water scarcity during summer season.

g) Only two hours water supply per day.

h) Maintenance of open wells was very tedious and expensive.

i) Water storage facility was inadequate.

j) Water audit, Energy audit and Recovery audit were not carried out.

3.9.2 Aims and Objectives

The various aims and objectives set before implementation of corrective measures were as below:

a) To provide sustainable water supply system for entire town.

b) Identify permanent source of water.

c) Supply treated water with proper quality monitoring system.

d) Increase water storage capacity.

e) Increase supply level from 23 lpcd to 135 lpcd.

f) Increase supply duration to at least 8 hours.

g) Discouraging public stand posts and increasing individual house connections.

h) 100% metering and efficient revenue collection.

i) To have fully efficient distribution system including water and energy audit.

j) To reduce quantity of non-revenue water in the system.

3.9.3 Implementation Process

The various corrective measures, strategies and implementation technique adopted to strengthen the water supply were as below:

a) Estimated water demand projection up to 2029 AD.

b) Identified permanent source of water supply from nearby river 'Jambu' which is about12 km from the town.

c) Constructed required water supply structures and new pipe lines.

d) Implemented the water quality monitoring system.

e) Reduced the water supply connection deposit amount.

f) Revised water tariff with respect to kilolitre expenditure.

g) Encouraged public to have individual house connections allowed to pay water connection deposit in 3-4 instalments.

h) Reduced public stand post in phased manner.

i) Setting up 24/7 Public Grievance Redressal cell.

j) Attending water leakage complaints within 24 hours.

3.9.4 Situation after Implementation of Initiatives

Water supply situation achieved after these corrective measures is that Kundapura town is having sufficient quantity of water supply. Merits of town water supply are as listed below:

a) Sufficient water supply to town.

b) Sufficient length of distribution lines.

c) Because of less number of public stand posts there is reduction in NRW.

d) Since distribution lines are of High Density Polyethylene (HDPE), less number of leakage problem were registered and reduction in Non-revenue water.

e) Treated water supply for a minimum of 6 hrs in the town was ensured.

f) No drinking water scarcity during summer season was faced.

g) Water contamination level was reduced to zero.

h) Better demand management was achieved due to metering.

i) Excellent consumer satisfaction with willingness to pay the bills which motivated the Municipal Council to go for 24x7 water supply.

j) O & M cost was recovered.

3.10 Gaza (Palestine) Non-Revenue Water

A four year contract was awarded to a private contractor (Water and sanitation Services Improvement Project, WSSIP) in Gaza to improve the quality, quantity, management and revenue of water. With the multiple steps which included leak detection and repair, survey of malfunctioning meters, their repair and replacement, survey of illegal connections and regularization of them, laying of pipe lines wherever required, the non-revenue water in Gaza was reduced from 50% in 1996 to 30% by the year 2000. It set up a clear policy regarding metering and illegal connections. The success of such program needed the public participation to discard vandalism to meters, illegal connections and to build confidence between water utility and customers [Jmean and Al-Jamal, 2004].

3.11 Tanzhou (China)

A joint venture company viz. Tanzhou Water and Sino French Water took the task in 1995, to reduce the NRW and to optimize the revenue. The various key processes were taken viz. rationalized meter replacement, inspection and leak repair, leak report system, leak detection methods by check meters, proper documentations, standardization of the processes, formation of NRW teams and the use of GIS system. In different phase over 15 years, the NRW was reduced from 35% to 6.7% [Tong, 2012].

3.12 Phnom Penh (Cambodia)

Phnom Penh Water Supply Authority (PPWSA) has showed an example of good governance. In the 1980s PPWSA was in bad shape- institutionally, financially, technically and in management. NRW was over 70%. In 1990s PPWSA initiated various measures to improve the water supply and its income which include:

- Significant reduction in NRW so that the water produced be sold to consumers.
- Fixing tariff structure and implementing it fully with a social conscience.
- Preparing and continually updating a roaster of consumers on a regular basis.
- Transparent and timely billing system was structured. Bill collection ratio improved with appropriate incentives for timely payment and disincentives for late or nonpayment.

These steps reduced NRW from 72% in year 1993 to 6.19% in year 2008. In this time frame, PPWSA increased its water production by 437%, distribution network by 557%, Pressure in system by 1260% and consumer base by 662% [Biswas and Tortajada, 2010].

3.13 Jamshedpur (India)

Jamshedpur is located in the East Singhbhun district of Jharkhand. Jamshedpur Utility and Service Company Limited (JUSCO) is responsible for providing water and waste water services in Jamshedpur. JUSCO recognized the need to constantly reduce the NRW to cut wastage and increase revenue. It properly managed the water distribution networks through flow management, leakage detection and proactive network maintenance. The city is divided into 74 DMAs for effective management. To monitor flow in distribution system electromagnetic meters were installed. The JUSCO's NRW reduction program included installation of DMA meters and consumer meters, disconnecting illegal connections to convert them to authorised connections and monitoring number of leakages. NRW is calculated, monitored and reported on a monthly basis. The NRW reduction program's main focus was on addressing leakages and illegal connections, which are the two key areas of water losses. These steps reduced NRW from 36% in year 2005 to 9.9% in year 2009 [Madhvan and Sahai, 2010].

This chapter gives details of result obtained of various NRW reduction programmes/ activities in some of the cities of India and abroad. All the results strengthen the importance of NRW reduction for better water supplies to the cities. In the next chapter water sources of Jaipur, consumer connection and meter details, current situation of water supply, problems and other issues has been discussed.

CHAPTER 4
PRESENT STATUS OF JAIPUR WATER SUPPLY

4.1 Introduction

Jaipur is the largest city and the capital of Rajasthan State of India. It was founded on 18th November 1727 by Maharaja Sawai Jai Singh II, the ruler of Amber, after whom the city has been named.

The city was built on the principles of 'Shilpa Shastra', the science of Indian Architecture. It was divided into nine blocks, two of which contained the state buildings and palaces, while the remaining seven were allotted to the public. Huge fortification walls were built, alongwith seven strong gates. The Jaipur region/ Jaipur Development Authority (JDA) area has an extent of 1464 sq. km [jaipur.nic.in].

4.2 Population Projections

The population of Jaipur, as per the 2011 census was 3.07 million which is projected to be about 4.8 million in 2021.

Table 4.1 : Population Forecast of Jaipur City

YEAR	POPULATION
1991	15.81 Lacs
2001	23.22 Lacs
2011	30.73 Lacs
2021	47.99 Lacs Projected

Till 2008, almost 97% potable water supply was from groundwater resources. The current rate of groundwater abstraction is not sustainable. The water table throughout the city area has fallen considerably over the past four decades and continues to decline at an alarming rate. Average rate of water table decline in blocks Amer 2.20m/year, Jamwa Ramgarh 0.56 m/year, Jhotwara 2.49 m/year and Sanganer 1.72 m/year [cgwb.gov.in/District_Profile/Rajasthan/Jaipur.pdf]. The groundwater resources within many parts of Jaipur city will be substantially exhausted in the near future unless appropriate measures are taken to significantly reduce the rate of groundwater abstraction.

The problems of Jaipur water supply are well known, and the State Government has made long-term plans to augment the Jaipur water supplies by developing sustainable surface water resources in the region. The Bisalpur Dam, which is located on the Banas River about 120 km South-West of Jaipur City, was constructed in the mid-1990s for the purpose of providing potable water supplies to Ajmer city, Jaipur city and other towns in the region, and to provide supplemental irrigation for agricultural lands downstream of the dam site. Jaipur now has access to this surface water resource also.

Present population of Jaipur (2013) is approximately 32.61 Lacs. Out of this 29.70 Lac population is connected to the water supply network of PHED. Present water supply of the connected area is 396 million litres per day against the requirement of 465.5 million litres per day. The salient features of Jaipur water supply scheme are given at Annexure-II.

4.3 Sources Of Water:

4.3.1 Surface Water Sources

4.3.1.1 Ramgarh Lake

Ramgarh Lake is the only surface water source available for drinking water purpose. This lake is having depth upto 19.81 metre out of which 4.88 metre is non-usable because of silting. Due to scanty rainfall and construction activities taking place in catchment area during the last few years Ramgarh lake is not receiving sufficient surface water runoff and water storage is negligible [Dass et al., 2013].

The salient features of Ramgarh Dam are given in Annexure-III.

4.3.1.2 Bisalpur Dam

Jaipur city is getting water from Bisalpur dam since March 2009 in phased manner and presently 304 MLD of water per day is received.

The salient features of Bisalpur dam are given in Annexure-IV

4.3.2 Groundwater Sources

For the distribution of water supply in the city 1858 tube wells are operational, after receipt of water from Bisalpur dam since March 2009, 920 lacs litres water is produced per day from 1066 tube wells. Alongwith these tubewells 1073 Handpumps are also operational in Jaipur city [PHED City Circle, Jaipur report dated 15.5.2013].

4.4 Tankers Deployed

Areas not covered by PHED pipe network, slum areas, areas located at higher elevations and tail end points which are not getting proper pressure and quantity of water is further benefited with water supply from tankers. Presently average 787 tanker trips are pressed into service to augment water supply of Jaipur City. In addition to that tankers are also utilized to fill PVC tanks of capacity 4000, 3000, 2000 and 1000 litres placed at various locations for use of public by PHED, Nagar Nigam, and other government agencies. For the tail end areas, elevated areas and areas of insufficient distribution network 155 small tube wells of 125 mm diameter has also been constructed and developed.

4.5 Details of Water Connections

There are 3,96,620 total running water connections in Jaipur city as on 15.5.13, out of which 3,56,970 are metered connections. Total number of non-functional water meters are 1,40,231.

4.6 Study of Jaipur Water Supply

A study was done during 1988 to 2000 by Public Health Engineering Department (PHED) and Seureca Consulting Engineers with the following objective:

- To make overall water audit of the existing Jaipur water supply system and estimate losses in each major distribution zone and each major conveyance, treatment and storage system.
- To undertake leakage survey in selected areas of Jaipur water supply service area to determine UFW and identify the causes and contributory factors of UFW [Seureca, 2000].

During the study period the Jaipur water supply was from two main sources. One was groundwater with around 792 tube wells supplying 80% of the water and remaining 20% of the water was supplied from Ramgarh Lake. As this system was failing to cope with continuously increasing demand and the aquifer in and around Jaipur was being over exploited, Bisalpur dam on river Banas was added as a new surface water source of water supply to Jaipur. The pumping head involved is 322 m.

Due to pumping, energy cost is high and water supply from Bisalpur dam is very expensive. As such, the use of this costly water in city needs to be optimally used. In this regard evaluation of the water losses in the water supply and distribution system is necessary and that are required to be reduced to minimum.

The study was conducted in Mansarovar, Gangapole, Civil lines, Gandhi Nagar, AG Colony, VKI Area, Bais Godam and Brahampuri areas. The aim of the study was to determine the characteristic in terms of meter functionality, consumption, system conditions and the reduction of NRW.

4.6.1 Losses from Tubewells

After the study it was estimated that the level of losses from the tube well network is of the order of 20%, which amounts to total daily volume of water loss of 0.07 Mm^3. This high level of loss can be attributed to a number of reasons, the main ones of which are lack of non-return valves or non-operable non-return valves, leaking joints and valves passing water.

Average pumping rate of tube wells was found to be $21m^3$ / hr, with the tube wells operating for 21 hours a day. At the time of study 792 tube wells were operational against total installed 828 tubewells. The estimated total daily tube wells productions, volume lost and level of leakages were as given in Table 4.2

Table 4.2: Per day NRW from Tube wells

Total tubewell production (Mm^3/day)	Total Water inflow (Mm^3/day)	Total volume lost(Mm^3/day)	% Volume lost
0.35	0.28	0.07	20

The site visits showed following reasons for water loss:

(i) high number of tube wells have leaking joints.

(ii) number of tubewells do not have NRVs fitted / working.

(iii) high number of tubewells have a wash out valve fitted which is passing water.

4.6.2 Consumer Water Meters

In the study 2000 consumers of Jaipur selected on the basis of meter size and consumption. From the study status of consumer water meters is given in table 4.3

Table 4.3: Position of Consumer Water meters

PHED Information	Meters working	30%
	Meters not working	48%
	Disconnected	22%
Billing Record	Meters read	25%
	Meters not read	56%
	Disconnected	19%

It is also observed that 60% of nonfunctioning meters have been in this condition for more than one year.

Site examination results of Domestic Consumers connections is given in Table 4.4

Table 4.4: Details of Domestic Consumer connections

Metered connection	85%
Un-metered connection	9%
No connection	2%
Unknown	4%

Results of site examinations of bulk / major consumers are given in Table 4.5

Table 4.5: Details of Bulk / Major Consumer connections

A: Consumerwise Details

A	Domestic Consumers	45%
	Industrial consumers	15%
	Others	40%

B: Metered/ Non-Metered

B	Meter working	37%
	Meter not working	27%
	Unmetered	5%
	Information not available	31%

From the Table 4.5 it is seen that only 37% of the bulk/ major consumers have a working meters, with 27% having a non-functional meters. It was also observed that approximately 60% of the non-functional meters have been in this condition for the past one year or longer.

4.6.3 Public Stand Post

Water uses study was made at public stand posts. Investigation carried out at public stand posts are given in Table 4.6.

Table 4.6: Details from Public Stand Posts (PSP)

Average supply per day per PSP	1770 l
Total PSP supply per day	990 m^3
Average consumption per PSP per day	1240 l
Total PSP consumption per day	690 m^3
Level of wastage	30.3%

The losses through PSP can be attributed to number of reasons, some of which are as under:

(i) Not all PSPs have stop taps fitted.

(ii) Leak in stop taps

(iii) Stop taps frequently left running during supply hours.

Pilot area studies showed that:

The average consumption per property per week ranges from 3.6 m^3 for domestic properties to 8.6 m^3 for industrial properties.

The percentage disconnection ranges from 3.2% for domestic to 55% for industrial. NRW of Jaipur city is given in Table 4.7.

Table 4.7: NRW of Jaipur City

Component	Volume m^3/day	% of System Input Volume
System Input Value	4901.99	100
Metered consumption	2734.56	55.8
NRW	2167.43	44.2

NRW is further split as given in Table 4.8.

Table 4.8: Components of NRW of Jaipur City

<table>
<tr><th>NRW Component</th><th>% of NRW from Pilot area studies</th><th>% of NRW Expected range</th></tr>
<tr><td>Meter under registration</td><td>9.9</td><td>10-15</td></tr>
<tr><td>PSP use</td><td>0.5</td><td>1.5-3.5</td></tr>
<tr><td>Unmetered consumption</td><td>3.0</td><td rowspan="2">3.5-6.5</td></tr>
<tr><td>Illegal consumption</td><td>1.2</td></tr>
<tr><td>Balance to leakage</td><td>85.4</td><td>75-85</td></tr>
</table>

The levels of NRW calculated based on billing records and Piolt Area Studies are given in Table 4.9.

Table 4.9: NRW Based on Billing Record and Pilot Area Study

	Billing Records		**Pilot area study**	
Area	**Volume of NRW (m^3)**	**Percentage NRW**	**Volume of NRW (m^3)**	**Percentage NRW**
North	67649	47.3	66591	46.5
South	18723	19.1	12936	13.2
Overall	86317	35.8	79527	33.0

4.6.4 Assessment of NRW in Structures / Transmission

Assessment of NRW/ water lost was carried out in raw water transmission system, distribution centres, inter zone transfer mains and treatment plant. Assessment of NRW in Structures and transmission mains are given in Table 4.10.

Table 4.10: NRW in Structres / Transmission

UFW in raw water transmission system	16.9%
Distribution centres	4.2%
Inter zone transfer main	19.7%
Treatment Plant	16%

The average overall level of NRW was found to be 44.2% which comprises of 5.0% meter under-registration, 0.2% PSP use, 1.3% unmetered consumption, 0.5% illegal consumption and the remaining 37.2% being leakages.

The assessment of components of NRW based on billing records and pilot area study are given in Table 4.11.

Table 4.11: Assessment of Components of NRW

Leakages	75 to 85%
Meter Under Registration	10 to 15%
Illegal / unmetered connection	3.5 to 6.5%
Public Use	1.5 to 3.5%

4.7 Current Situation and Problem of Jaipur Water Supply System

Good water supply service calls for adequate quantity, good water pressure and potable water quality at required time. In terms of these criteria the current condition of Jaipur water supply is as below:

(i) Insufficient water quantity which causes short supply period of 60 minutes to 120 minutes per day.

(ii) Inadequate water with low pressure and no pressure at some places.

(iii) Poor water quality. Complaint of supply of polluted water from various places.

Water shortage causes intermittent water supply which results in low distribution pressure and water contamination. Leakages and illegal connections make the situation worse. The cause and effect linkage is shown in Figure 4.1

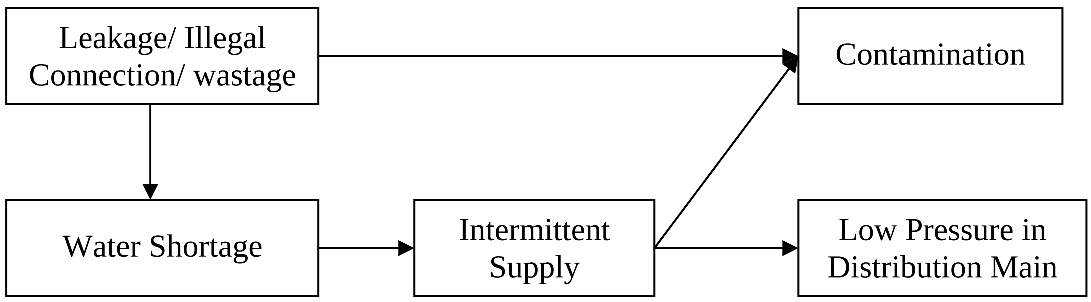


Figure 4.1: Cause and Effect Linkage

The most serious problem in water supply is low pressure and consumers do not get adequate quantity of water in several areas. The reasons of low pressure are as follows:

(i) Under-designed pipe diameter.

(ii) Increase of water flow due to short supply period.

(iii) Increase of water flow in pipes due to illegal connections.

(iv) Increase of water flow in pipes due to Leakages.

(v) Increase of water demand due to wastage of water.

Leakage, Illegal connection and wastage cause not only water loss but also contamination and reduction in water pressure.

4.8 Real Loss - Leakages

Leakage is largest component and has about 80% share of NRW in Jaipur city. Reasons of leakages and problems in repair of them are following:

4.8.1 Reasons of Leakages

Reasons of Leakages are following

Aged Pipe and Corroded Pipes.

Pipes in the walled city were installed more than 50 years ago and most of the pipes outside the walled city were installed 30 years ago. Galvanised iron pipes were used for house connections and are in corroded condition. This is one of the major cause of leakages.

Use of Improper Material for Pipes.

Asbestos cement pipes (ACP) were installed even in congested area where heavy traffic has increased. ACP is a not proper material specially in shallow depth and heavy traffic. These pipes get damaged during excavation work, improper house construction work or due to the heavy traffic plying in the city.

Improper Pipe Installation

There is insufficient earth cover at many locations. Further improper installation of pipes due to poor workmanship and inadequate tools causes leakages.

Poor Workmanship in Repair

Improper leak repair by using improper materials was observed and poor workmanship in leak repair is another reason for pipe leakages.

Accidents

Inadequate earth cover of pipes and lack of protection of water meters and air valves have caused accidents. Pipe bursts in rising main are also frequently observed.

Vandalism

House service connections are exposed or laid at very shallow depth and it is very easy for consumers to access the pipes. Meters are not covered in meter boxes hence easily tampered by consumers. In the areas of low water pressure consumers are accustomed to removing the meters or making collection facilities at levels below ground in order to get sufficient quantity of water. These activities cause leakages. Damage to the pipe by illegal connections also causes serious leakages (in the form of theft).

4.8.2 Problems in Repair of Leakages

Major problem in repair of leakages are as under

Insufficient Detection of Leakage

Linemen patrol the pipe routes to find out leakage in the distribution system. Water meter readers and valve operators also report leakages. These activities are very limited mainly for riser main and house connections only. The major information is obtained from consumer's claim for low pressure and contamination. It is found in the study that only 36% of leaks in quantity are located on service connections though large numbers of leakages were found at service connection in ordinary activities. It is also observed that about 70% of leakages are invisible.

Poor Repair of Leakage

PHED staff try to attend the major leakage in 24 hours, but small leakages are not repaired for a long time even if they are visible. By leaving leakage without repair, the NRW increases and situation become worse. Poor repair work is observed using improper material. There is much room to improve quality of repair. Repair is usually done to cope with complaints and PHED is not executing a planned repair work.

Leakage in House Connection

Installation and maintenance of house connections is the responsibility of consumers. Service pipes are frequently connected to distribution pipes without proper supervision by PHED. This causes damage to distribution network and result into un-noticed leaks.

Illegal Connections

The official procedure to detect illegal connection is to survey the area during service period and find illegal connection. After finding out an illegal connection, it is disconnected and then legalized.

The actual condition of illegal connections is as under:

(i) Illegal connections are causing lots of leakage and wastage.

(ii) Residents are accustomed to tampering the distribution pipes.

(iii) Penalty is not properly imposed on illegal connections.

(iv) In slums, PHED staff hesitate to take action due to fear of violence, insufficient support from police and interference from public representatives.

4.9 Operation and Maintenance

Problems of O&M aspect are low pressure, insufficient record keeping, lack of staff/ skilled staff, lack of motivation etc.

Low Water Pressure / Unplanned Pipe Installation

The most serious problem in the water supply system is low pressure and insufficient quantity. PHED installed several pipes to cope with low pressure and complaints from consumer. This activity make situation worse as follows:

(i) The present water distribution system becomes unclear and odd because the pipes are installed without proper planning, analysis and recording.

(ii) After a house connection shifted to new distribution pipe line, leakage occurs from abandoned branches of house connections.

Insufficient Record Keeping

It is difficult to study the current problems of PHED and prepare future plan because several important and/ or basic data are not available in the records. PHED staff is not keen on data collection and compilation as there are no strict rules and procedures to upkeep the data.

Organisation for NRW Reduction

There is no such separate division in PHED to prepare NRW reduction plan and to execute the work. The staff is generally busy in routine operations and usual maintenance works and cannot concentrate on NRW reduction. Separate divisions are needed to take up activities to find out weak points, prepare long-term plans and execute them.

Skill and Motivation of Staff

Skill and motivation of staff is not high. The staff does not have operation and maintenance manual. Training has not been given since long and the staff is working based on experience but no technical up-gradation has been done.

Frequent Moves of Staff

PHED staff is transferred frequently without rigid rules. The key staff do not stay in a position for sufficient period to prepare long-term plan and their execution. Frequent transfers also disturb proper data collection and up-keeping of records.

4.10 Other Issues

Other issues of Jaipur city water supply are as follows:

Wastage

There is water shortage and problems of water supply, but water conservation is not taken as a major issue. Due to intermittent supply and insufficient quantity of water, consumers generally are in habit of leaving all external taps open and wait for supply or create opening without the tap at its lower opening level. When supply period becomes longer, wastage also increases.

Slum Areas

There are 52 and 167 slum areas in Jaipur city under the jurisdiction of JDA and JMC respectively [SAPI, 2004]. There are number of illegal connections, leakage and huge wastage in these areas but PHED faces difficulty in taking action against them.

In this chapter water sources of Jaipur, consumer connection and meter details, current situation of water supply, problems, causes of current situation etc. has been discussed. This shows that water supply situation of Jaipur city is not so good. In the next chapter an attempt has been made to study the NRW of Jaipur city, 24x7 water supply in selected pilot area, study of water demand on different water pressure and feedback from consumers, PHED officials and public representatives.

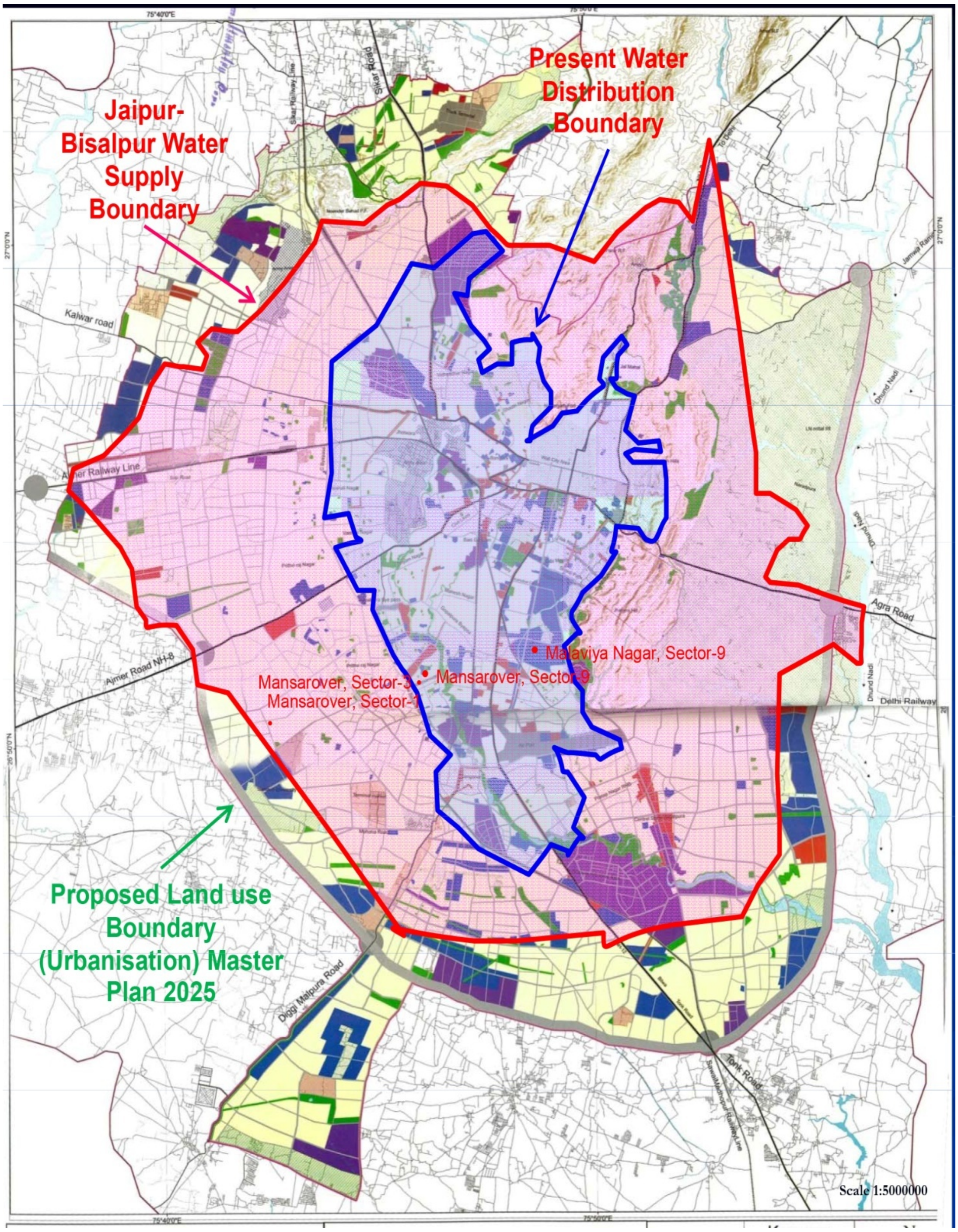


Figure 4.2: Water Supply Coverage of Jaipur City

CHAPTER 5
STUDY OF NRW AND 24x7 WATER SUPPLIES

5.1 Study of NRW

Additional Chief Engineer (ACE), Jaipur city is responsible for overall administrative control of Jaipur city water supply system. He is supported by Superintending Engineer (SE) specifically for operations in Jaipur. To make water supply of Jaipur city functional, at the time of study there exist four divisions namely North-1, North-2, South-1 and South-2 (i.e., Executive Engineers offices). The functions of these divisions include following:

- Operation and maintenance of all water works including water treatment plants, pumping stations, tubewells, transmission and distribution network.
- Surveillance of pipelines, detection of leaks and unauthorised water supply connections.
- Rehabilitation work, preventative and breakdown maintenance.
- Inspection of different works including projects in progress and checking water quality.
- Processing of application for new connections and installation of new connections.
- Meter reading and distribution of bills.
- Revenue collection.
- Disconnection.
- Attending to the complaints of the public.

Each Executive Engineer is supported by a Technical Assistant who is of the level of Assistant Engineer. Each division is further divided into Sub-divisions headed by Assistant Engineer (AEs) and each subdivision into several chowkies (Water distribution Zones) headed by Junior Engineers (JEs). The chowkies are responsible for water supply in their own area.

Water is supplied in each zone from different sources like Bisalpur dam, tube wells, water-transfer from other zones, hand pumps, PSP, Tankers, SPs. For the study of NRW total water supplied in each zone is compared with the quantity of water for which bills are raised to consumers.

Daily records of water supplied in each zone in the division are compiled in order to determine the NRW in each of the divisions on a daily basis. This daily record is further averaged monthly to study monthly NRW in each division and in the Jaipur city as a whole. This study was carried out for the period February 2012 to May 2013. Daily records compiled and monthly averages calculated for each division are given in Annexure V.

5.2 Study of 24x7 Water Supply

5.2.1 Study Area

Public Health Engineering Department (PHED), Government of Rajasthan has been entrusted with the responsibility of providing safe and potable drinking water to the people throughout the State of Rajasthan. It plans to supply continuous 24x7 water supply service to cities and towns of Rajasthan, starting from Jaipur through a pilot study in four service areas. Main objective of undertaking study is to build confidence among staff and decision makers that the conversion to 24x7 water supplies is feasible and realistic through application of mitigating water loss and its management techniques.

For this study pilot area feasible for 24x7 water supply was selected in Sector 1, 3 and 9 of Mansarovar and Sector 9 of Malaviya Nagar and maps are prepared for proposed DMAs. In each DMA necessary works required were identified. Consumer data were collected by door to door survey in selected DMAs. The details of study area selected are given in Table 5.1

Table 5.1 : Details of District Metered Areas (DMAs) Selected

DMA	No. of House hold	No of Consumers	Total Population	No of Disconnections	Number of No Connection	Category of Houses	Average Family Size
Malviya Nagar Sector-09	170	158	832	06	06	LIG	5.27
Mansarovar Sector-01	139	139	693	-	-	HIG & MIG	4.98
Mansarovar Sector-03	306	306	1480	-	-	LIG	4.84
Mansarovar Sector-09	128	128	730	-	-	HIG & MIG	5.70

In the present study the data is available from November 2010 to March 2011 for Mansarovar area and from November 2010 to May 2013 for Malaviya Nagar area.

5.2.2 Activities Done in Pilot Areas

a) Before final commencement of 24x7 water supply to the pilot study areas preparatory works were started in the month of August 2010.

b) Pilot study area (DMA) was surveyed and it was isolated by fixing sluice valves and flanges at appropriate places in the distribution system.

c) Survey of houses were conducted and information regarding number of connections, number of members in the family, details of water tank, number of stories, functioning of water meters etc. were gathered.

d) IEC material prepared and publicity of project was made through news papers.

e) Layout and depths of pipe lines were ascertained. Few extra pipe lines including pipeline from service reservoirs to DMA as per requirement were also laid. Bulk meters were installed at service reservoirs. Leaking valves were replaced or repaired. Leakages found in the distribution system were repaired.

f) Consumers whose meter coupling and service connections were leaking were issued notices to get them corrected. Consumers were also informed to see the condition of their underground water tanks regarding leakages, float valve etc.

g) 24x7 water supply to the pilot study areas of Mansarovar and Malaviya Nagar were started in November 2010.

h) Initially very high water consumption was found in the DMA and looking to it DMA was tested for leakages. Consumers were also informed personally to get leakages repaired, check their underground and over head tanks for leakages and were informed, explained and educated not to misuse the water as the water supply would be 24x7.

i) On receipt of higher consumption through bulk meter necessary steps were taken to sort out the problems which included DMA checking for leakages, survey of area, consumer connections educating people about optimum use of water, leakages repair etc.

j) It was also observed that bulk meters often stop due to some fault which requires prompt rectification of the meter.

5.2.3 Details of Water Meter Replaced

Details of meters replaced are given in Table 5.2

Table 5.2 : Details of Water Meter Replacement

Area → / **Consumer Meter ↓**	**Sector - 9 Malaviya Nagar**	**Sector - 1 Mansarovar**	**Sector - 3 Mansarovar**	**Sector - 9 Mansarovar**	**Total**
Total Consumers	158	139	306	128	731
No. of Non-Functional Meters Replaced	106	87	255	90	538

These DMAs were isolated from the rest of the supply area and 24x7 water supplies were started. Initially many problems were encountered in these areas viz. frequent leakages, leakages in consumer service connections, un-noticed water by passing from DMAs to other areas, frequent malfunctioning of bulk meter installed, faulty meters at consumer ends, unawareness of consumer regarding conservation of water etc.

During the study period continuous monitoring of Bulk meters was done in the study area. Simultaneously consumer water meters were also read daily. Difference between bulk meter reading and consumer meter readings is the actual NRW of DMA. Based on the onsite observations necessary steps were taken simultaneously to reduce the losses.

Consumer meter reading and bulk meter readings were averaged on a weekly basis viz. Dec I (1to 7 Dec), Dec II (8 to 15 Dec), Dec III (16to 22 Dec) and Dec IV (23 to 31 Dec). On these weekly average data total water consumption, per consumer water consumption and per capita water consumption as per consumer meter readings and as per bulk meter readings were calculated. From this data weekly value of NRW was calculated. The readings are given in Tables 5.3 to 5.6.

Table 5.3 : Weekly NRW Readings in Mansarovar Sector-1

Duration (week)	**Nov IV**	**Dec I**	**Dec II**	**Dec III**	**Dec IV**	**Jan I**	**Jan II**	**Jan III**	**Jan IV**	**Feb I**	**Feb II**	**Feb III**	**Feb IV**	**Mar I**	**Mar II**
Consumption as per consumer meter reading (litres)	137227.33	109096.14	93330.25	91905.36	76792.28	83776.43	93528.00	97314.43	88559.50	91761.71	95588.94	84586.14	89572.67	93106.50	96884.00
Average Consumption/ per consumer (lit)	1047.54	832.79	712.44	701.57	586.20	639.51	713.95	742.86	676.03	700.47	729.69	645.70	683.76	710.74	739.57
Per capita Consumption as per consumer meter readings	195.00	155.02	132.62	130.59	109.12	119.04	132.90	138.28	125.84	130.39	135.83	120.19	127.28	132.30	137.67
Consumption as per Bulk Meter (litres)	239500.00	244928.57	190750.00	184857.14	200000.00	186571.43	225875.00	222857.14	247888.89	227000.00	245500.00	149714.29	128750.00	149000.00	162333.33
Average Consumption per consumer	1828.24	1869.68	1456.11	1411.12	1526.72	1424.21	1724.24	1701.20	1892.28	1732.82	1874.05	1142.86	982.82	1137.40	1239.19
Per capita Consumption as per bulk meter readings	340.32	348.04	271.05	262.68	284.19	265.11	320.96	316.67	352.24	322.56	348.85	212.74	182.95	211.72	230.67
NRW (%)	42.70	55.46	51.07	50.28	61.60	55.10	58.59	56.33	64.27	59.58	61.06	43.50	30.43	37.51	40.32

Table 5.4 : Weekly NRW Readings in Mansarovar Sector-3

Duration (week)	**Dec I**	**Dec II**	**Dec III**	**Dec IV**	**Jan I**	**Jan II**	**Jan III**	**Jan IV**	**Feb I**	**Feb II**	**Feb III**	**Feb IV**	**Mar I**	**Mar II**
Consumption as per consumer meter reading (litres)	162939.86	164664.00	157039.79	143768.22	141530.36	142248.25	149634.43	142014.28	145877.93	143524.06	146538.43	140363.17	156193.43	143991.33
Average Consumption/ per consumer (lit)	588.23	594.45	566.93	519.02	510.94	513.53	540.20	512.69	526.64	518.14	529.02	506.73	563.88	519.82
Per capita Consumption as per consumer meter readings	110.09	111.26	106.11	97.14	95.63	96.11	101.10	95.96	98.57	96.98	99.01	94.84	105.54	97.29
Consumption as per Bulk Meter (litres)	200192.86	198000.00	182000.00	149111.11	150428.57	163375.00	151285.71	182722.22	186857.14	231250.00	196714.29	183000.00	186714.29	167000.00
Average Consumption per consumer	722.72	714.80	657.04	538.31	543.06	589.80	546.16	659.65	674.57	834.84	710.16	660.65	674.06	602.89
Per capita Consumption as per bulk meter readings	135.27	133.78	122.97	100.75	101.64	110.39	102.22	123.46	126.25	156.25	132.92	123.65	126.16	112.84
NRW (%)	18.61	16.84	13.71	3.58	5.92	12.93	1.09	22.28	21.93	37.94	25.51	23.30	16.35	13.78

Table 5.5 : Weekly NRW Readings in Mansarovar Sector-9

Duration (week)	Nov IV	Dec I	Dec II	Dec III	Dec IV	Jan I	Jan II	Jan III	Jan IV	Feb I	Feb II	Feb III	Feb IV	Mar I	Mar II
Consumption as per consumer meter reading (litres)	200123	130336.9	102180.9	107259.9	101389.9	102156	101702.4	103343.7	108210.7	116623.9	114899.1	108228.1	120740.5	126071.3	121954
Average Consumption/ per consumer (lit)	1563.46	1018.25	798.28	837.97	792.11	798.09	794.55	807.37	845.39	911.12	897.64	845.53	943.28	984.93	952.76
Per capita Consumption as per consumer meter readings	252.74	164.61	129.05	135.46	128.04	129.02	128.44	130.52	136.66	147.28	145.11	136.68	152.48	159.22	154.02
Consumption as per Bulk Meter (litres)	128250	119228.6	124000	126428.6	129888.9	153285.7	162750	118142.9	157111.1	175000	172375	185428.6	178333.3	173857.1	141000
Average Consumption per consumer	1001.95	931.47	968.75	987.72	1014.75	1197.55	1271.484	922.991	1227.43	1367.18	1346.68	1448.66	1393.22	1358.25	1101.56
Per capita Consumption as per bulk meter readings	161.97	150.58	156.60	159.67	164.04	193.58	205.54	149.21	198.42	221.01	217.69	234.18	225.22	219.56	178.07
NRW (%)	-56.04	-9.32	17.59	15.16	21.94	33.36	37.51	12.53	31.12	33.36	33.34	41.63	32.29	27.48	13.51

Table 5.6 : Weekly NRW Readings in Malaviya Nagar Sector-9

Duration (week)	Nov III	Nov IV	Dec I	Dec II	Dec III	Dec IV	Jan I	Jan II	Jan III	Jan IV	Feb I	Feb II	Feb III	Feb IV	Mar I	Mar II	Mar III
Consumption as per consumer meter reading (litres)	90757.60	39934.43	34147.57	31231.88	33725.57	33708.11	37951.00	42583.38	50818.71	50643.78	45672.50	45365.57	45613.00	45898.13	50740.00	50857.60	58189.25
Average Consumption / per consumer (lit)	574.42	252.75	216.12	197.67	213.45	213.34	240.20	269.52	321.64	320.53	289.07	287.12	288.69	290.49	321.14	321.88	368.29
Per capita Consumption as per consumer meter readings	109.08	48.00	41.04	37.54	40.54	40.51	45.61	51.18	61.08	60.87	54.89	54.53	54.82	55.17	60.99	61.13	69.94
Consumption as per Bulk Meter (litres)				235000.00	108000.00	99000.00	90000.00	73250.00	71285.71	71500.00	99047.25	100817.57	98641.14	106833.50	95691.67	97880.40	101304.00
Average Consumption per consumer				1487.34	683.54	626.58	569.62	463.61	451.18	452.53	626.88	638.09	624.31	676.16	605.64	619.50	641.16
Per capita Consumption as per bulk meter readings				282.45	129.81	118.99	108.17	88.04	85.68	85.94	119.05	121.17	118.56	128.41	115.01	117.64	121.76
NRW (%)				86.71	68.77	65.95	57.83	41.87	28.71	29.17	53.89	55.00	53.76	57.04	46.98	48.04	42.56

Study of NRW based on total monthly consumption as per bulk water meter and water consumption as per bills raised to consumers is presented in Table 5.7. In the Malaviya Nagar DMA night flow rate was checked after closing all consumer connection valves. This has shown zero flow through bulk meter. This gives an idea that NRW in DMA is due to faulty meters or meters under registration.

Table 5.7: Non-Revenue Water at Malaviya Nagar Sector-9

MONTH	Total Monthly Consumption as per Bulk Meter (KL)	Total Monthly Consumption as per Consumer Meters (KL)	NRW in KL	Daily Per Capita Consumption (LPCD)	% NRW
Jan'11	3210	2169	1041	124	32.44
Feb'11	2886	2205	681	124	23.58
March'11	2964	2314	650	115	21.91
April'11	3213	2475	738	129	22.98
May'11	3516	2703	813	136	23.11
June'11	3021	2601	420	121	13.90
July'11	3039	2507	532	118	17.51
AUG'11	3120	2616	504	121	16.15
Sep'11	3316	2845	471	133	14.21
Oct'11	3432	2848	584	133	17.02
Nov'11	3139	2651	488	126	15.56
Dec'11	3057	2686	371	119	12.15
Jan'12	2985	2640	345	116	11.56
Feb'12	3113	2609	504	129	16.20
March'12	3186	2671	515	124	16.17
April'12	3370	2727	643	135	19.08
May'12	3267	2805	462	124	14.13
June'12	3305	2867	438	129	13.26
July'12	3380	2905	475	128	14.05
Aug'12	3842	3192	650	146	16.92
Sep'12	3540	2933	607	139	17.16
Oct'12	3680	3021	659	140	17.91
Nov'12	3540	2952	588	139	16.61
Dec'12	3930	3137	793	149	20.18
Jan'13	4247	3448	799	161	18.81
Feb'13	3509	2902	607	147	17.31
March'13	3402	2799	603	129	17.73
April'13	3675	3060	615	144	16.73
May'13	3876	3221	655	152	16.90

5.3 Study of Water Consumption on Different Water Pressure in Malaviya Nagar DMA

In the Malaviya Nagar DMA water consumption has been observed at different pressures also. Details are given in Table 5.8 below:

Table 5.8 : Water Consumption at Different Pressure

PRESSURE psi (kg/cm^2)	Date	Bulk Meter Reading	Consumption (kl)	Average Daily Consumption over the week (kl)	Remark
34 (2.39)	11.09.12	127365.865	120.955		
34 (2.39)	12.09.12	127486.820	127.167	119.516	at 34 psi
34 (2.39)	13.09.12	127613.987	121.058		
34 (2.39)	14.09.12	127735.045	119.585		
34 (2.39)	15.09.12	127854.630	101.765		
34 (2.39)	16.09.12	127956.395	137.305		
34 (2.39)	17.09.12	128093.700	108.780		
30 (2.11)	18.09.12	128202.480	105.320	115.742	at 30 psi
30 (2.11)	19.09.12	128307.800	118.450		
30 (2.11)	20.09.12	128426.250	113.039		
30 (2.11)	21.09.12	128539.289	158.941		
30 (2.11)	22.09.12	128698.230	80.000		
30 (2.11)	23.09.12	128778.230	108.523		
30 (2.11)	24.09.12	128886.753	93.067		
30 (2.11)	25.09.12	128979.820	148.598		
25 (1.76)	26.09.12	129128.418	110.771	118.509	at 25 psi
25 (1.76)	27.09.12	129239.189	118.635		
25 (1.76)	28.09.12	129357.824	118.530		
25 (1.76)	29.09.12	129476.354	111.078		
25 (1.76)	30.09.12	129587.432	119.882		
25 (1.76)	01.10.12	129707.314	126.831		
25 (1.76)	02.10.12	129834.145	125.730		
25 (1.76)	03.10.12	129959.875	122.305		
25 (1.76)	04.10.12	130082.180	112.815		
25 (1.76)	05.10.12	130194.995			

From the above it is observed that average water consumption in DMA is not very much dependent on water pressure. This also suggests that there are negligible leakages in distribution system of DMA.

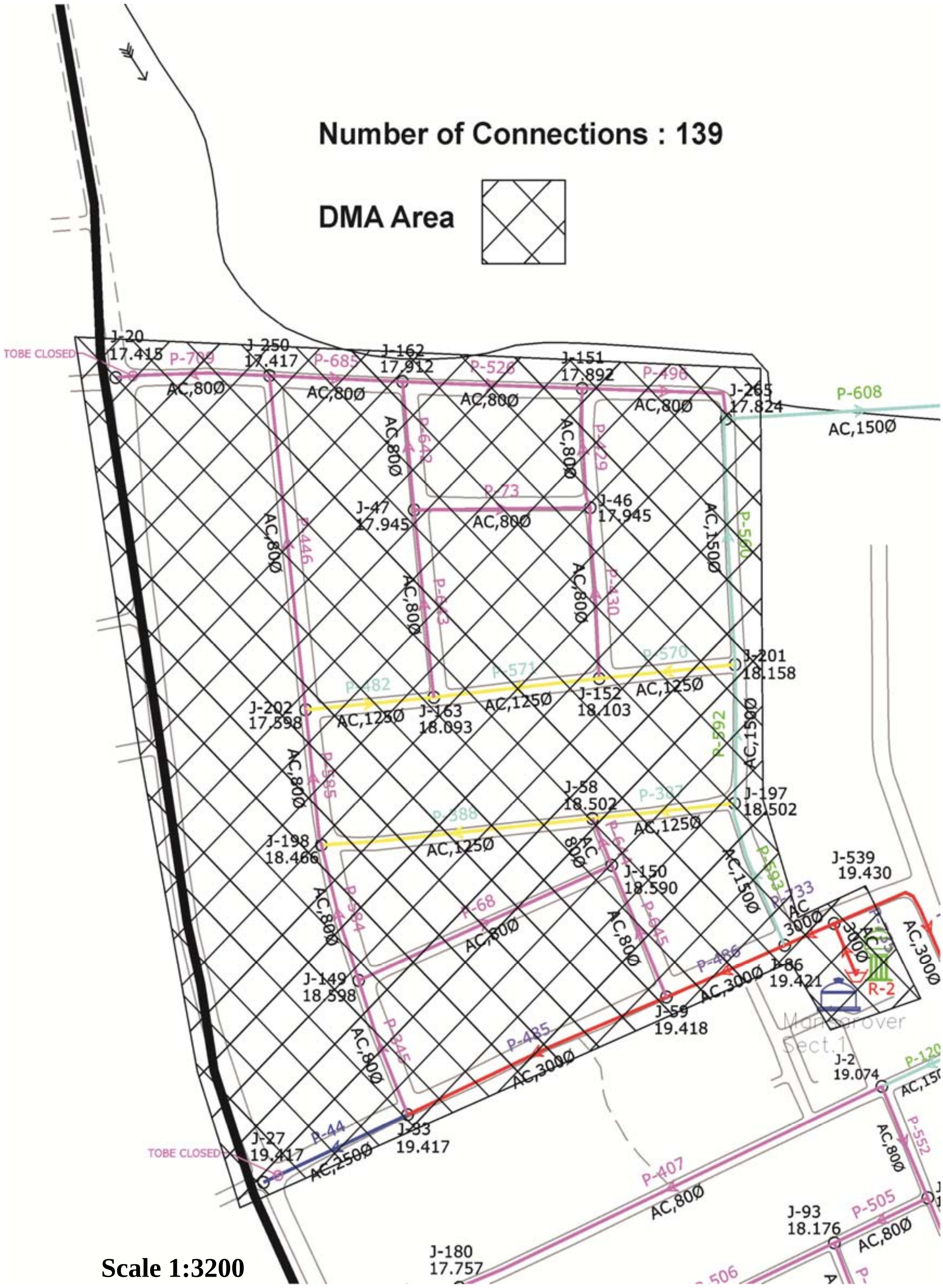


Figure 5.1: DMA of Mansarovar Sector-1

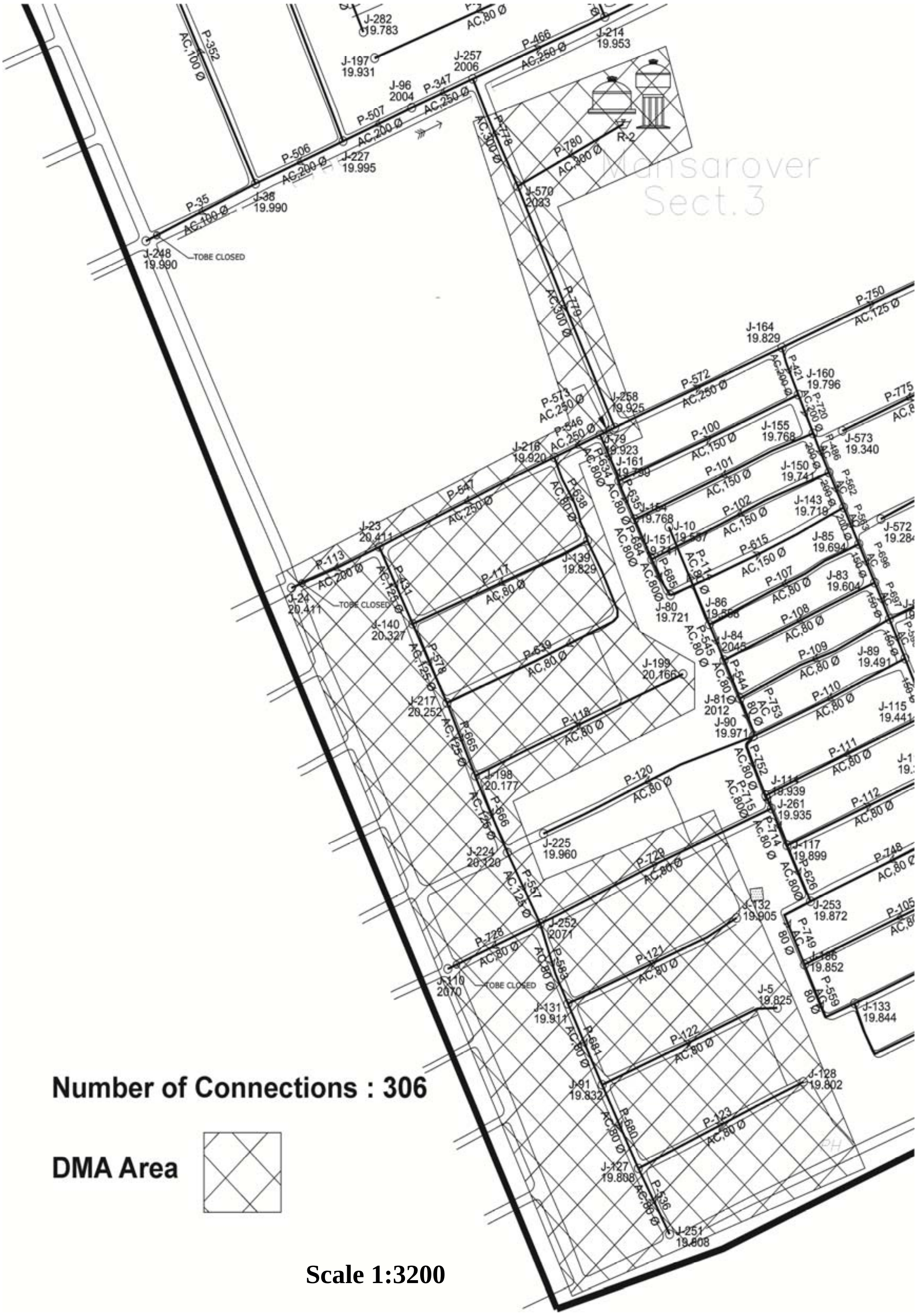


Figure 5.2: DMA of Mansarovar Sector-3

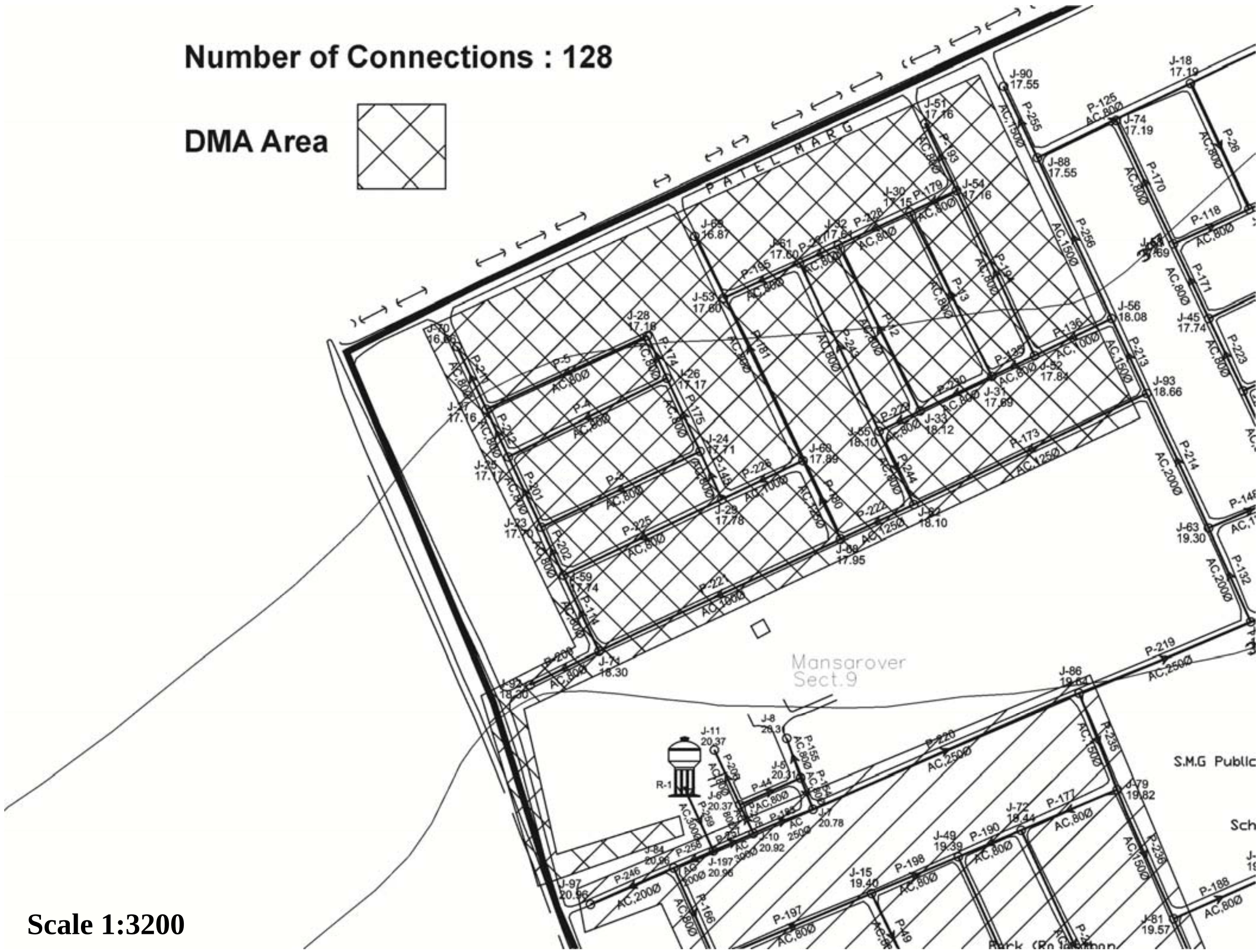


Figure 5.3: DMA of Mansarovar Sector-9

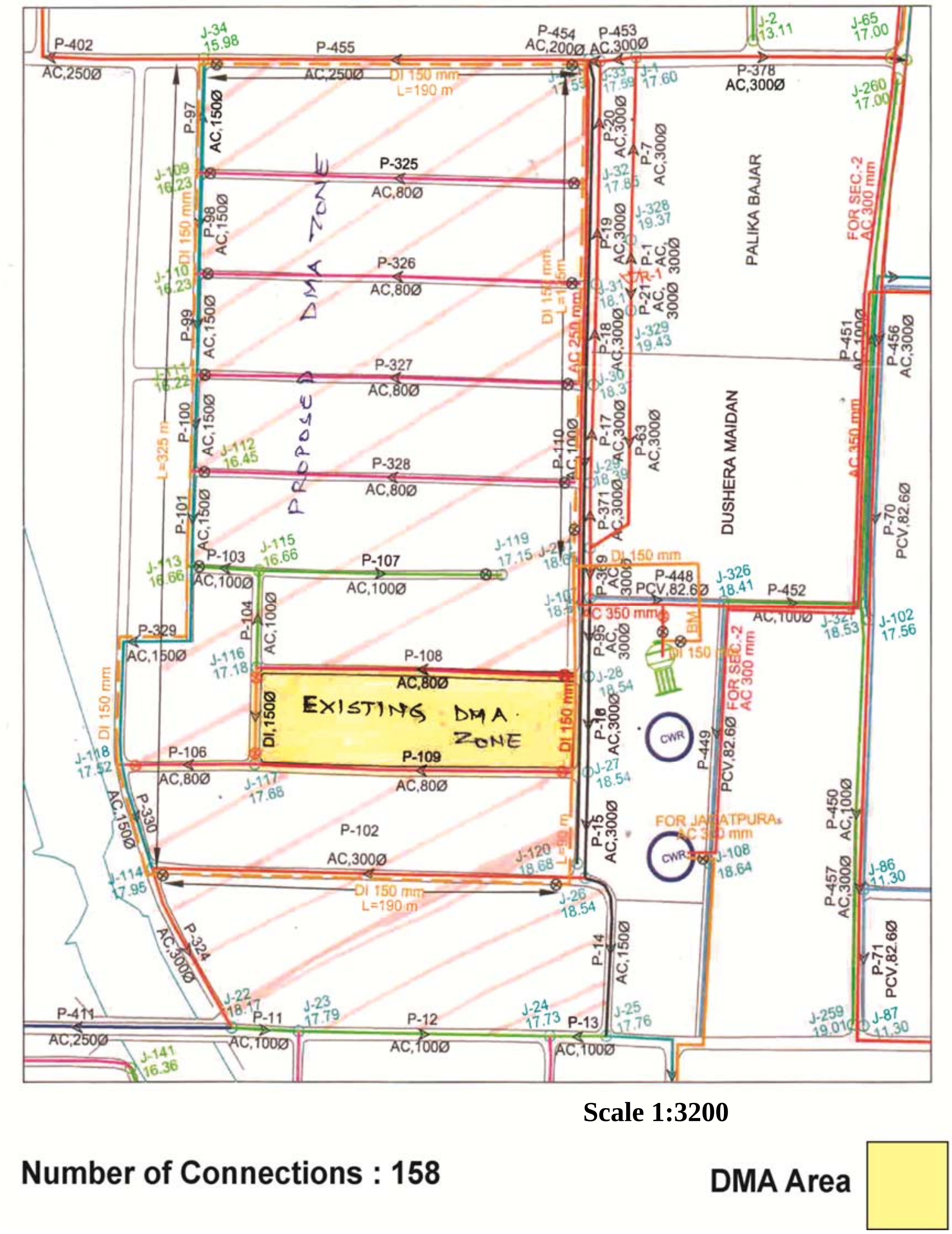


Figure 5.4: DMA of Malaviya Nagar Sector-9

5.4 Feedback on 24x7 Water Supply

Consumer survey has been conducted to know their feedback on 24x7 water supplies. Survey of departmental officials and public representatives have also been conducted on reduction of NRW and 24x7 water supply and water tariff. Sample feedback performa are enclosed at Annexure VI, VII & VIII. Feedback collected has been discussed in Chapter 6.

Photograph 5.1: Bulk Meter Reading at Malaviya Nagar Sector-9

Photograph 5.2: Pressure Gauge Reading at Malaviya Nagar Sector-9

Photograph 5.3: Distribution Area Map at Mansarovar Sector-3

Photograph 5.4: Soft Seated Valve and Pressure Gauge at Masarovar Sector-3

Photograph 5.5: Bulk Flow Meter

Photograph 5.6: Soft Seated Valve and Pressure Gauge at Malaviya Nagar Sector-9

Photograph 5.7: Observing Bulk Meter and Levels in CWR

This chapter describes the various activities undertaken in pilot areas selected and observations made to study the NRW of Jaipur city, 24x7 water supply in selected pilot area, study of water demand on different water pressure and feedback from consumers, PHED officials and public representatives for the thesis. In the next chapter results has been discussed in details.

CHAPTER 6
RESULTS AND DISCUSSIONS

6.1 Non-Revenue Water of Jaipur City

In each distribution zone of Jaipur, daily record of water supplied in different parts of zone from various sources- Bisalpur dam, Tube wells pumping, other Zones, hand pumps, PSPs, Tankers, SPs were studied from February 2012 to May 2013. Total water supplied in each zone is compared with quantity of water for which bills were issued to the consumers. Daily records of each zone in a division are compiled to determine the daily NRW in that division. These daily records are further averaged monthly to study monthly NRW in each division in the Jaipur city.

Daily records compiled and averaged on a monthly basis in each division are presented in previous Chapter from Table 5.1 to Table 5.16 and also in graphical form Figure 6.1 to Figure 6.6. Monthly NRW of each division is given in Table 6.1.

Table 6.1: Monthly NRW of PHED Divisions of Jaipur City

Month	NRW (%)				
	CITY Division North I	CITY Division North II	CITY Division South I	CITY Division South II	Entire City of Jaipur
Feb.12	38.65	44.04	31.59	31.84	36.05
Mar.12	39.99	42.59	32.01	33.69	36.59
Apr.12	42.04	44.61	33.12	34.35	38.04
May.12	43.09	39.88	36.64	32.50	37.51
Jun.12	46.37	41.70	39.34	34.85	40.09
Jul.12	45.42	43.56	37.82	35.51	40.03
Aug.12	40.28	40.99	34.82	28.41	35.43
Sep.12	38.93	40.06	32.81	29.30	34.70
Oct.12	36.62	37.08	31.76	31.38	33.78
Nov.12	35.73	36.79	32.19	32.41	33.96
Dec.12	33.31	36.51	30.90	27.86	31.66
Jan.13	30.83	36.32	30.32	28.09	31.00
Feb.13	31.19	37.47	30.10	37.18	34.21
Mar.13	33.70	33.49	30.42	31.03	31.96
Apr.13	33.06	35.00	30.97	25.56	30.49
May.13	35.57	37.46	32.83	28.86	33.08
Average	**37.80**	**39.22**	**32.98**	**31.43**	**34.91**

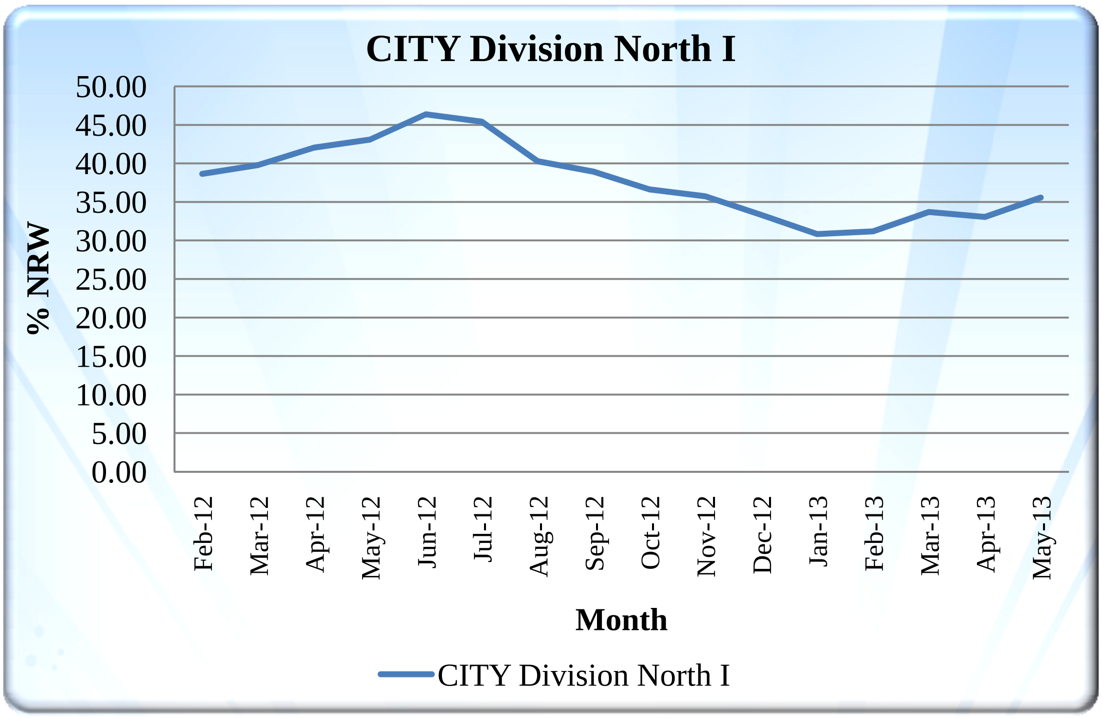


Figure 6.1: NRW in City Division North I

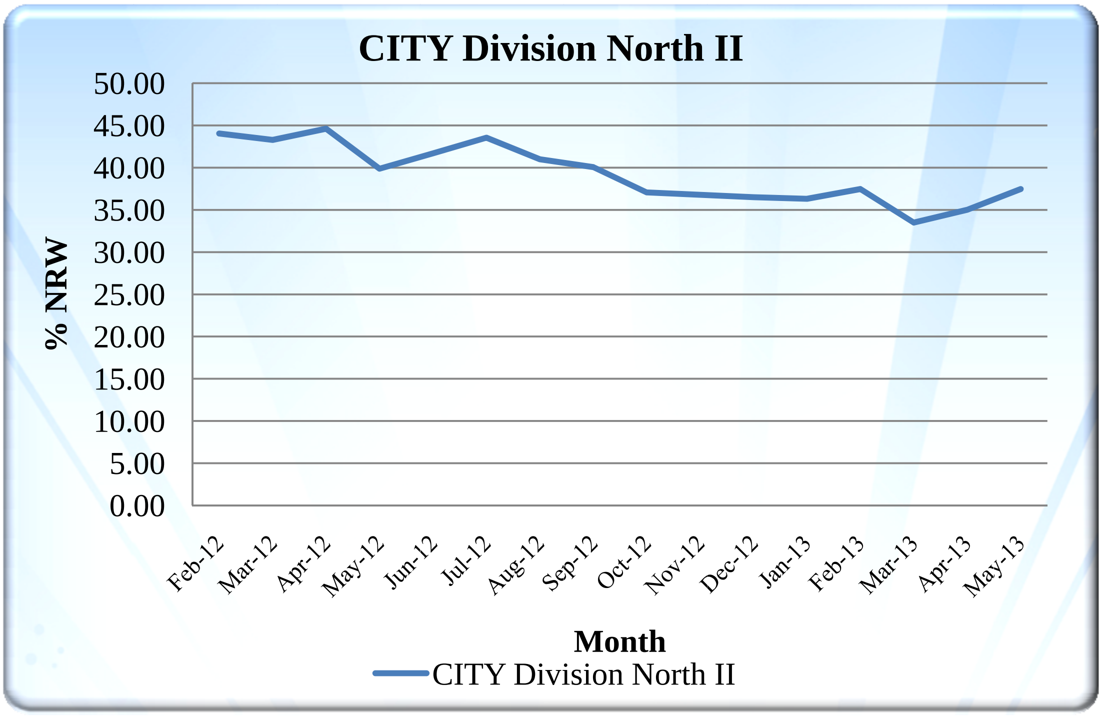


Figure 6.2: NRW in city Division North II

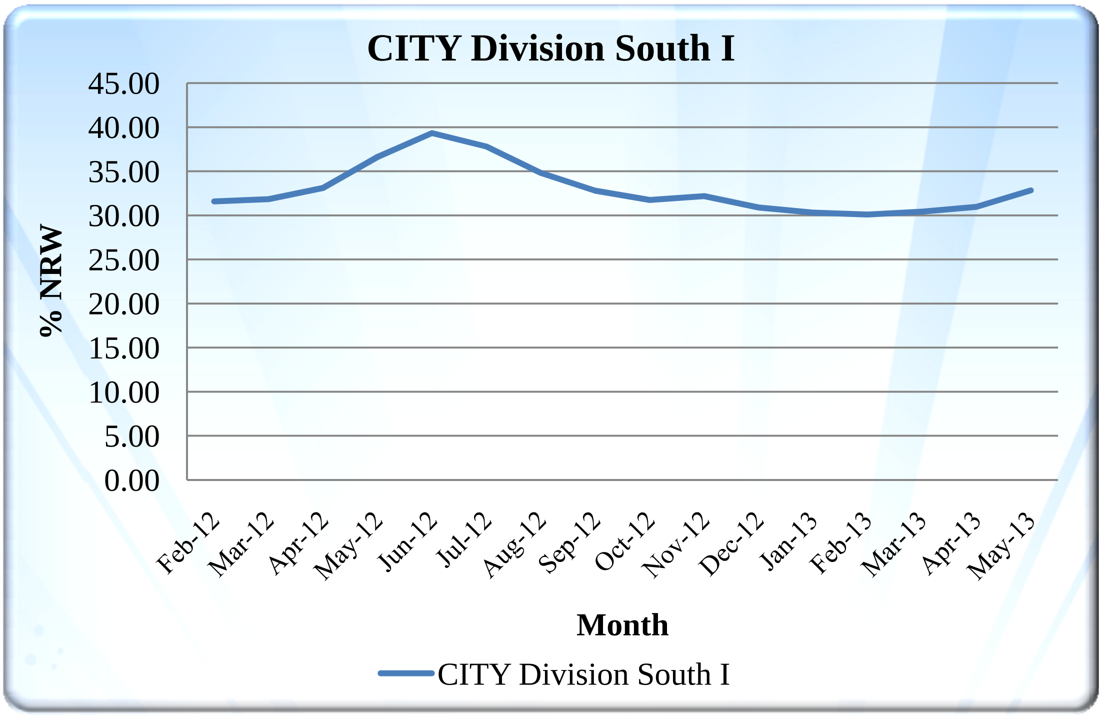


Figure 6.3: NRW in City Division South I

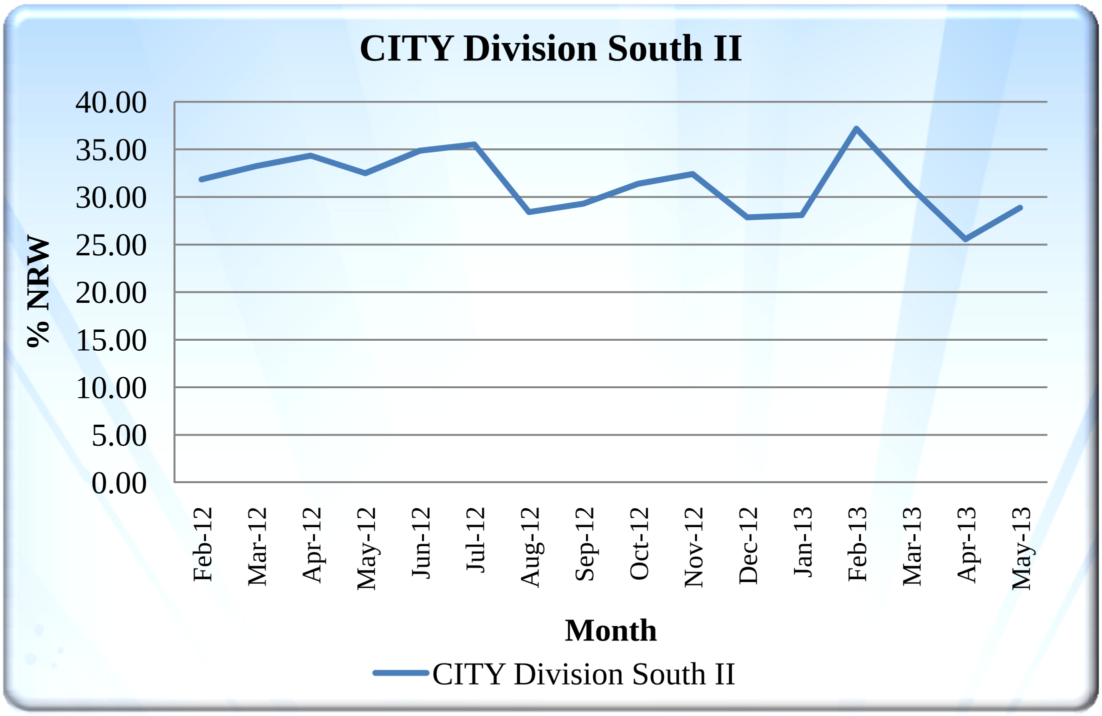


Figure 6.4: NRW in City Division South II

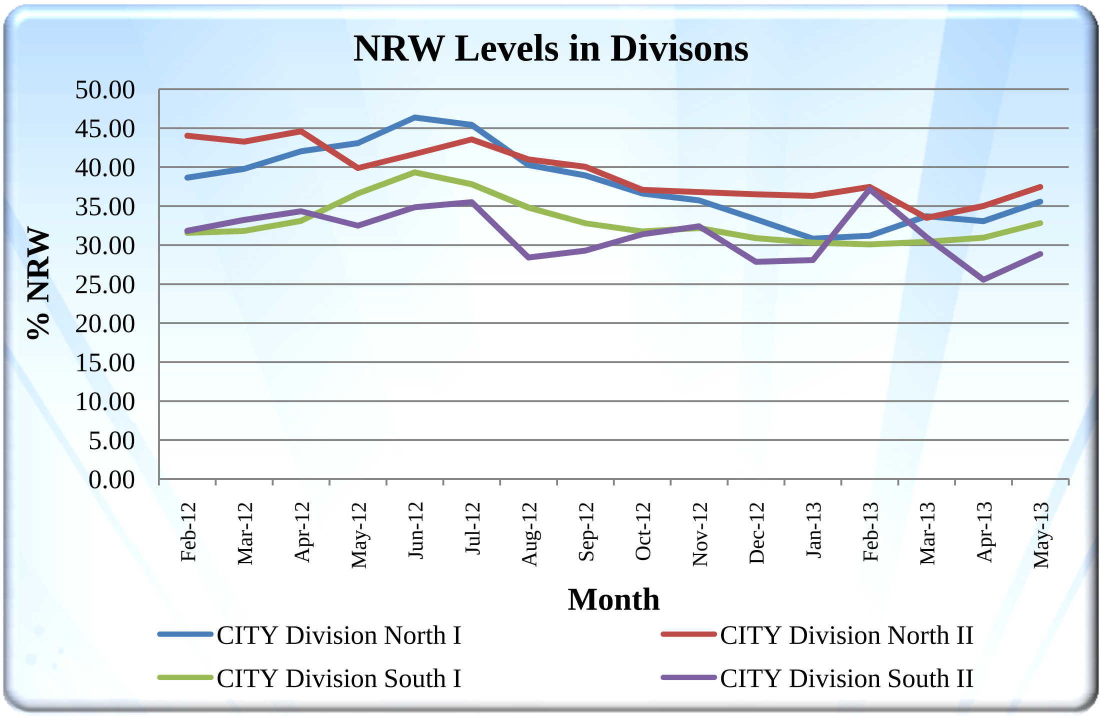
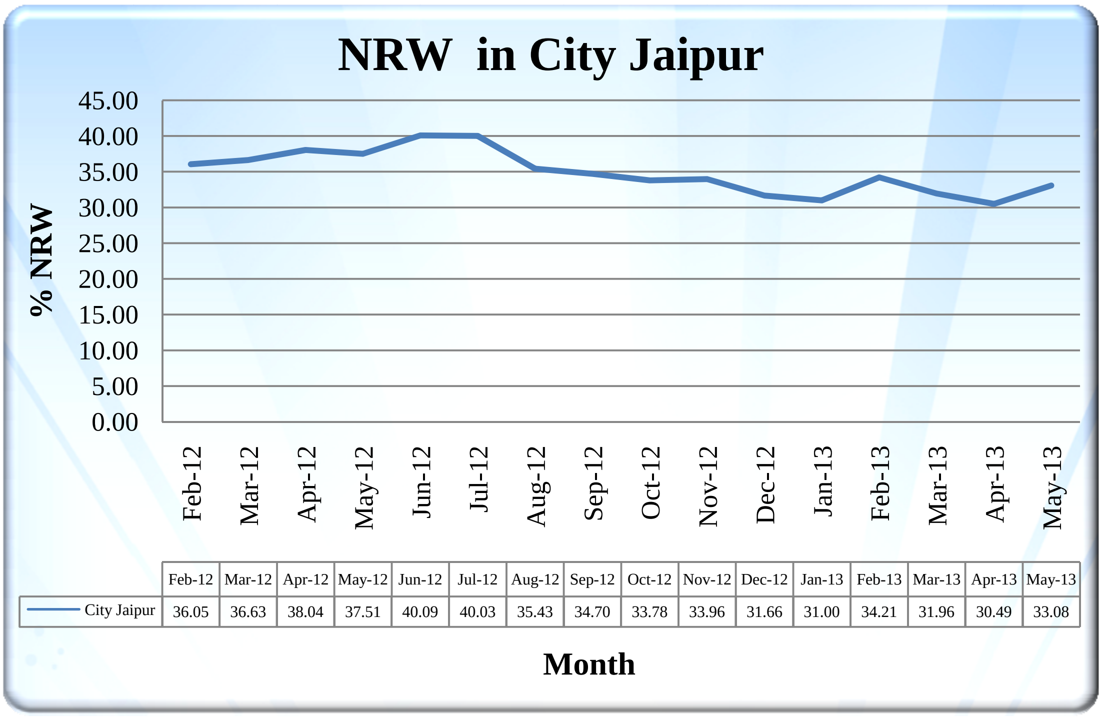


Figure 6.5: NRW in Divisions



	Feb-12	Mar-12	Apr-12	May-12	Jun-12	Jul-12	Aug-12	Sep-12	Oct-12	Nov-12	Dec-12	Jan-13	Feb-13	Mar-13	Apr-13	May-13
City Jaipur	36.05	36.63	38.04	37.51	40.09	40.03	35.43	34.70	33.78	33.96	31.66	31.00	34.21	31.96	30.49	33.08

Figure 6.6: NRW in the Entire Jaipur City

From the observation of NRW data of divisions it is revealed that NRW in North divisions are more than the NRW in South divisions. North division include walled city with old water supply distribution system and the leakages in old water supply system is the main cause for more leakages in this area. The problem of higher leakages in congested streets of walled city cause difficulty in proper repair and maintenance, which further deteriorate the quality of water supplied in the area.

6.2 Study of 24x7 Water Supplies

Study of 24x7 water supplies were conducted in four pilot study areas of Jaipur. In these areas actual NRW is determined by taking bulk water meter readings and individual consumer water meter readings.

Consumer meter reading and bulk meter readings were averaged weekly viz. Dec I (1to 7 Dec), Dec II (8 to 15 Dec), Dec III (16to 22 Dec) and Dec IV (23 to 31 Dec). On these weekly averaged data on total water consumption, per consumer water consumption and per capita water consumption based on consumer meter reading and bulk meter readings are calculated. The result and graphs for each pilot study area are given and discussed in following paragraphs.

Mansarovar Sector – 1

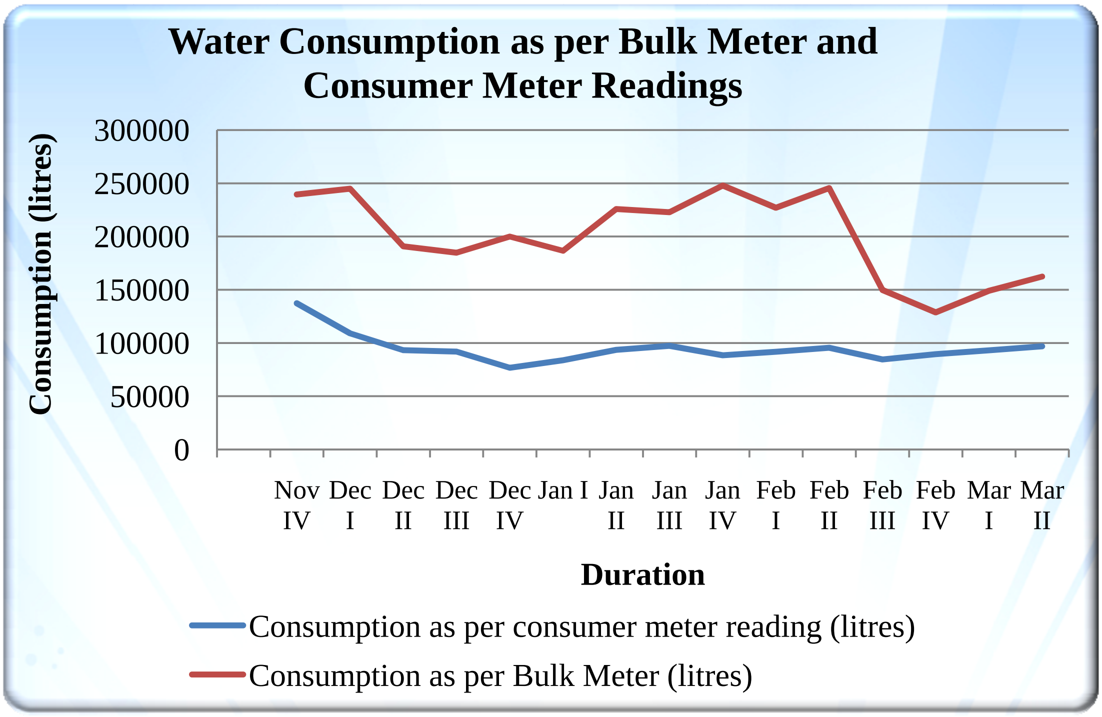


Figure 6.7: Water Consumption as per Bulk Meter and Consumer Meters in Mansarovar Sector-1 DMA

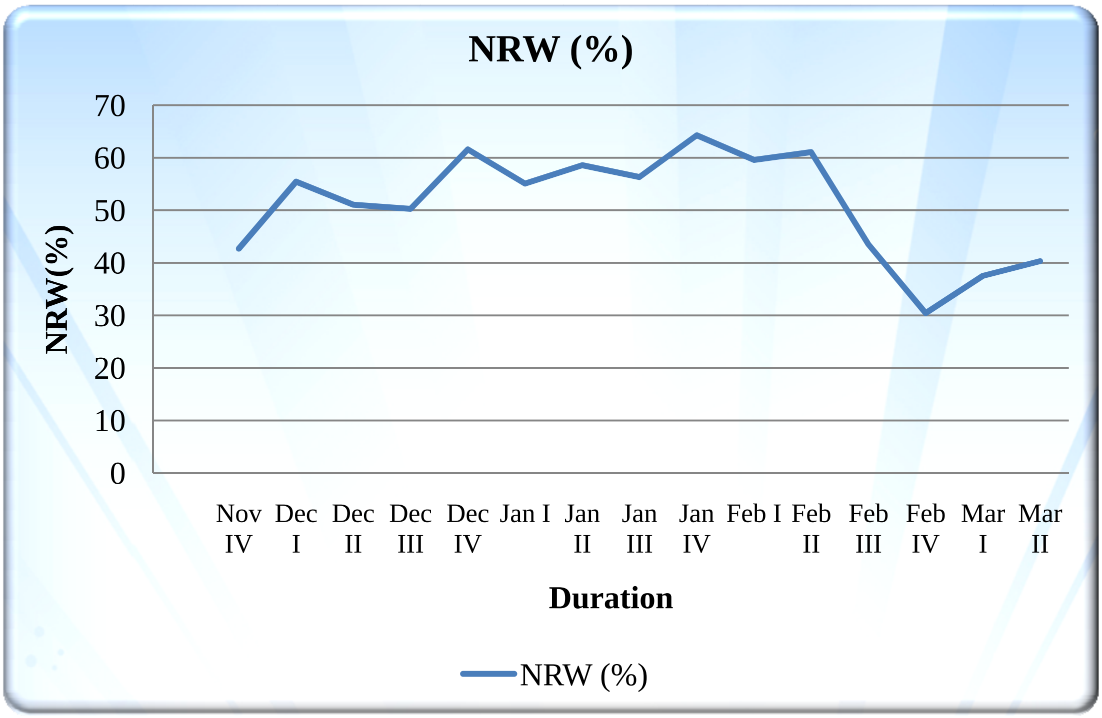


Figure 6.8: Non-Revenue Water in Mansarovar Sector-1 DMA

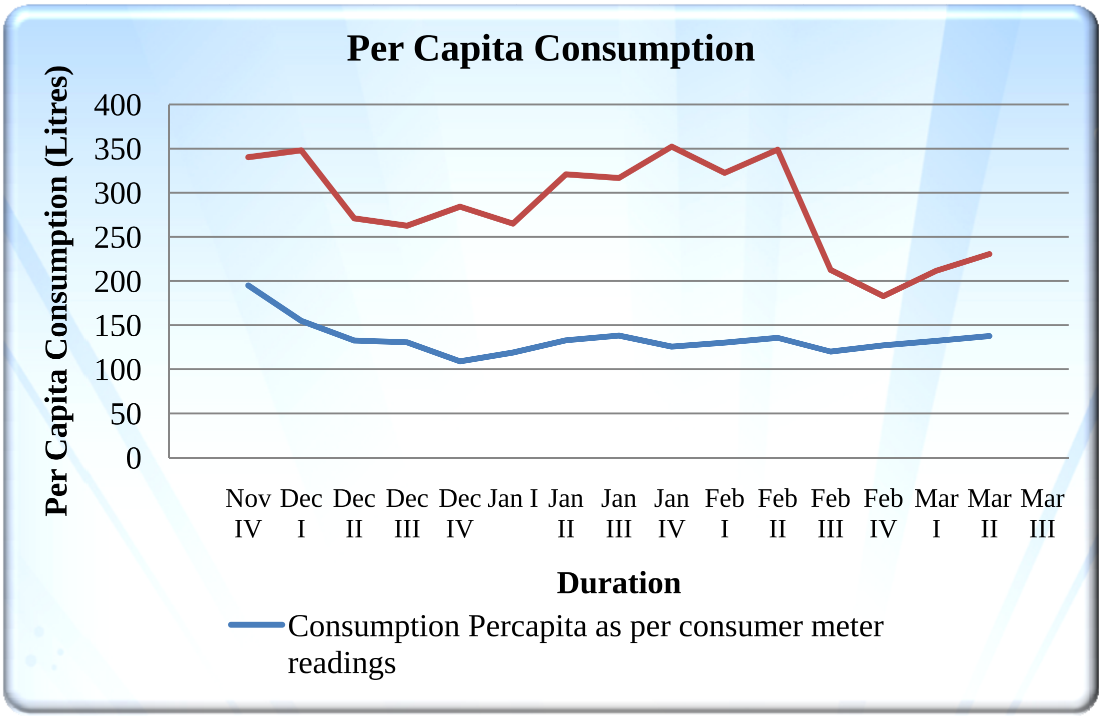


Figure 6.9: Per Capita Water Consumption as per Bulk Meter and Individual Consumer Meter Readings in Mansarovar Sector-1 DMA

Mansarovar Sector – 3

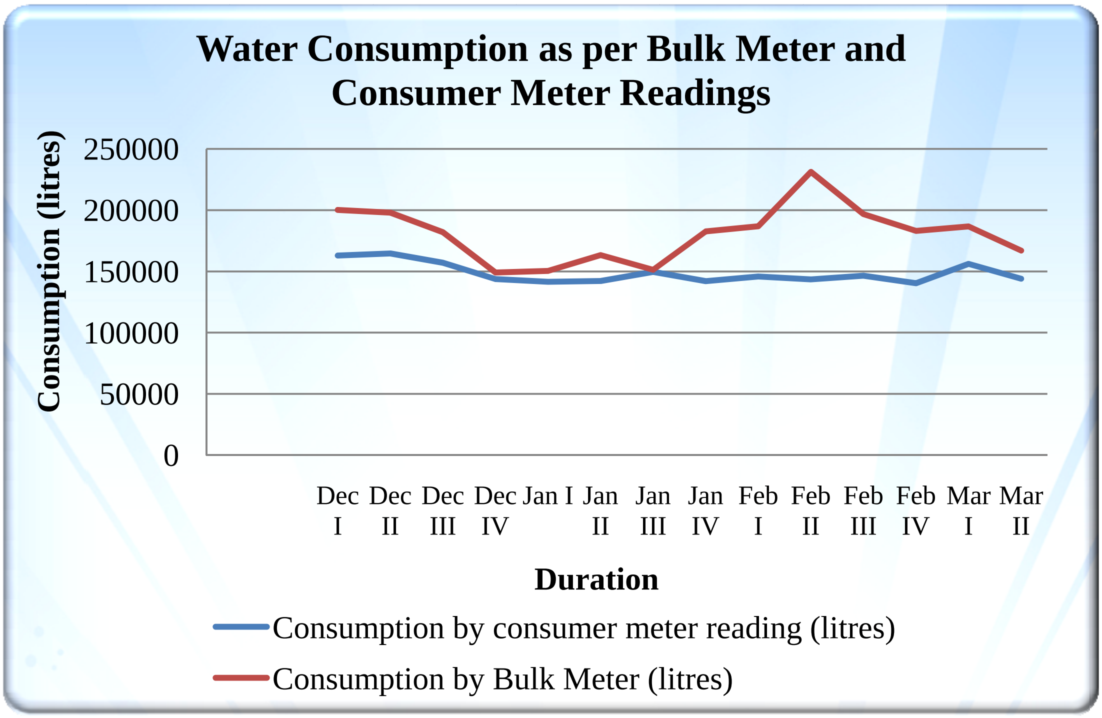


Figure 6.10: Water Consumption as per Bulk Meter and Consumer Meters in Mansarovar Sector-3 DMA

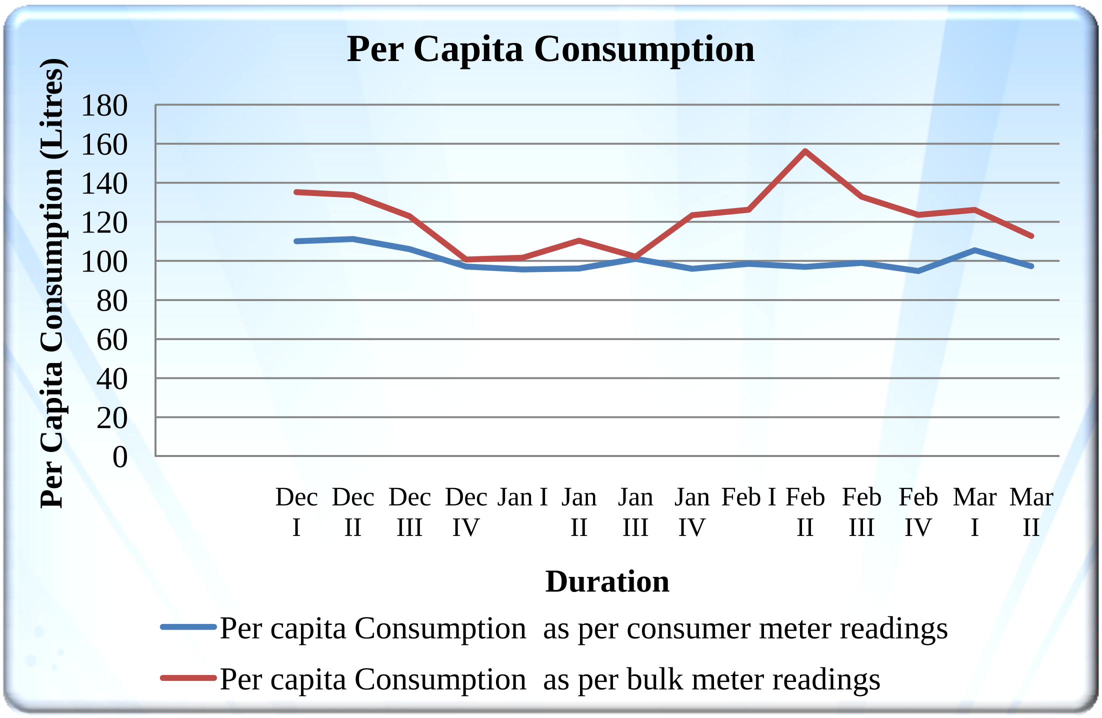


Figure 6.11: Per Capita Water Consumption as per Bulk Meter and Individual Consumer Meter Readings in Mansarovar Sector -3 DMA

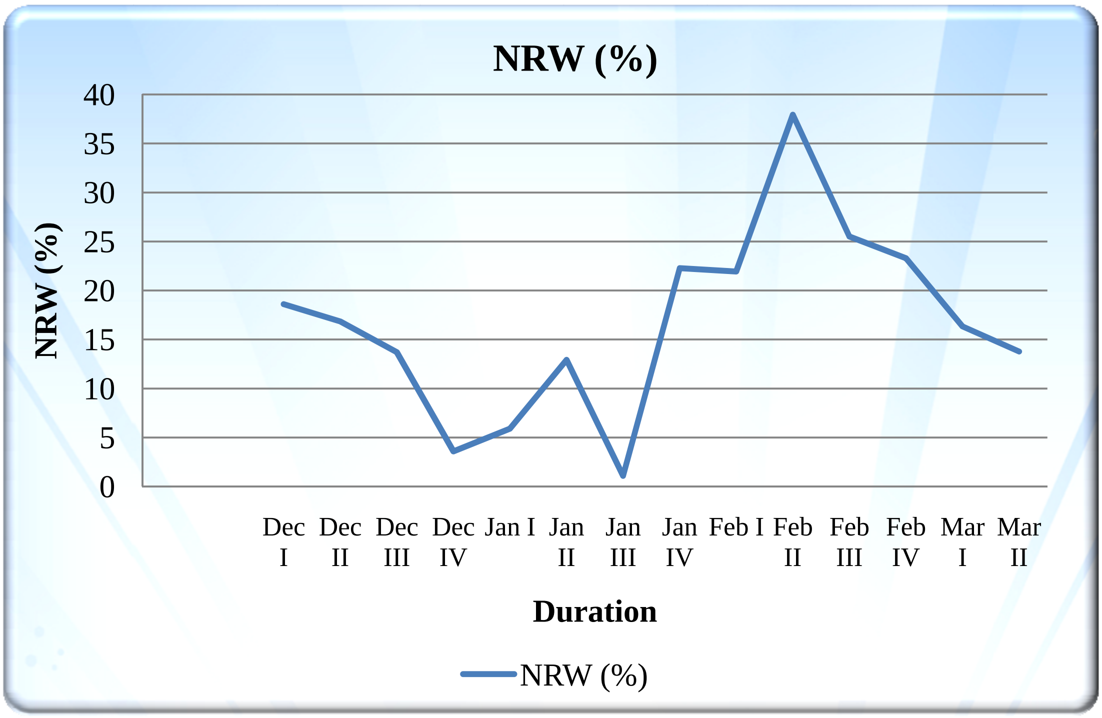


Figure 6.12: Non-Revenue Water in Mansarovar Sector-3 DMA

Mansarovar Sector - 9

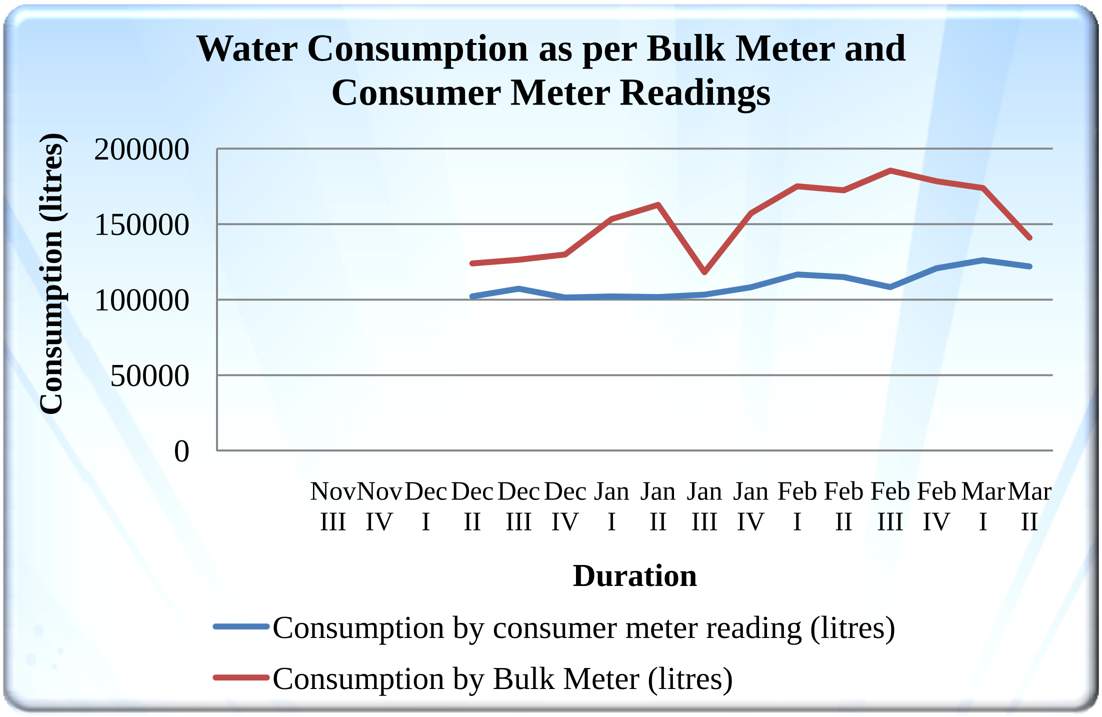


Figure 6.13: Water Consumption as per Bulk Meter and Individual Consumer Meter Readings in Mansarovar Sector-9 DMA

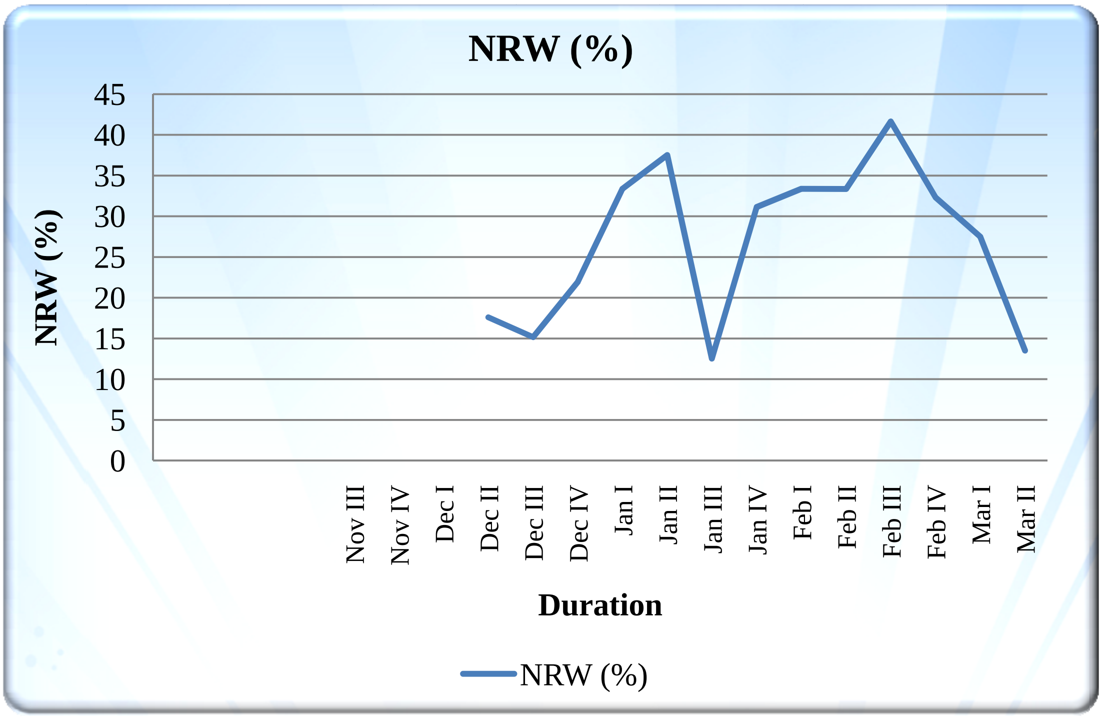


Figure 6.14: Non-Revenue Water in Mansarovar Sector-9 DMA

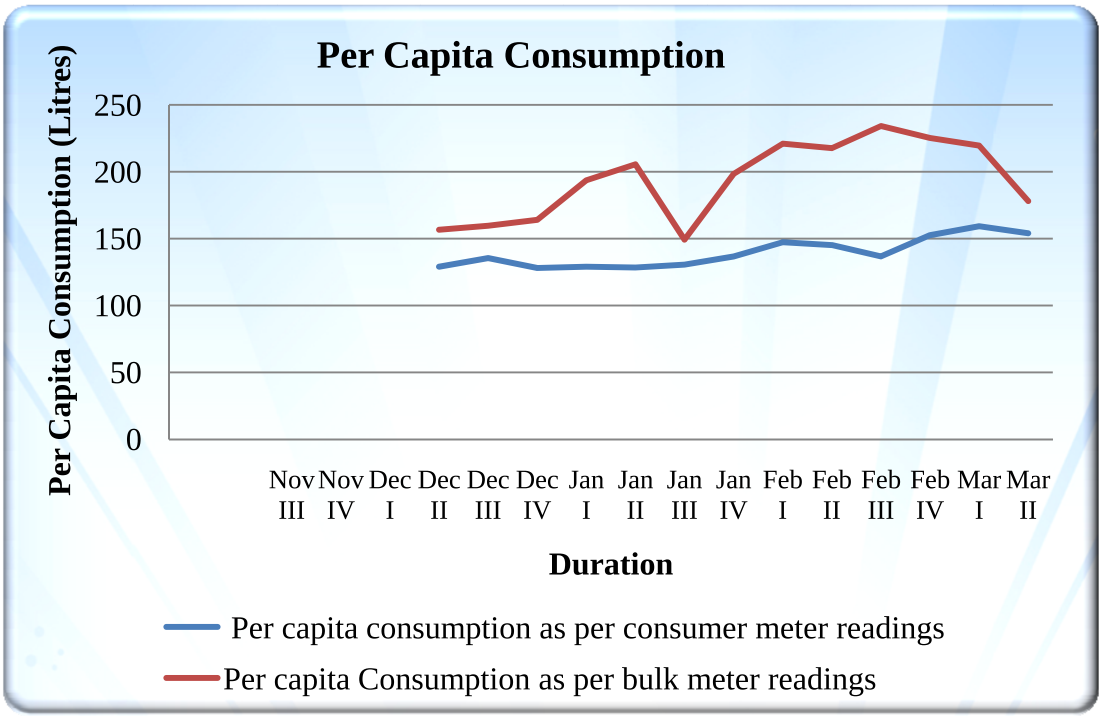


Figure 6.15: Per Capita Water Consumption as per Bulk Meter and Individual Consumer Meter Readings in Mansarovar Sector- 9 DMA

Malaviya Nagar Sector - 9

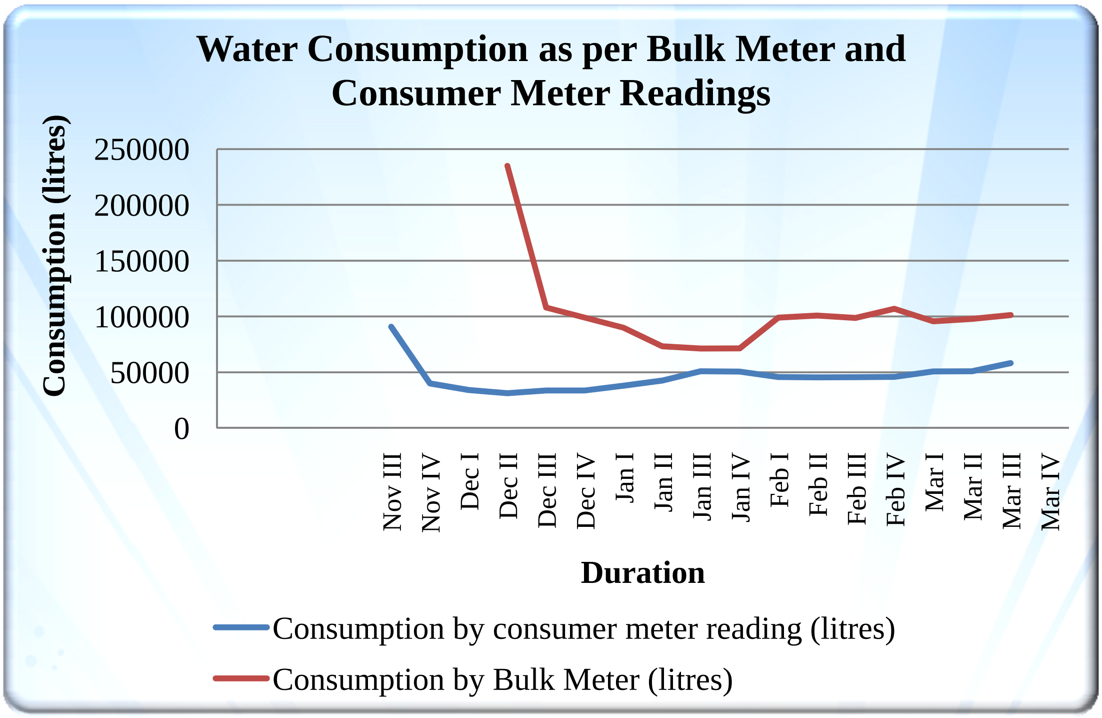


Figure 6.16: Water Consumption as per Bulk Meter and Individual Consumer Meters Readings in Malaviya Nagar Sector-9 DMA

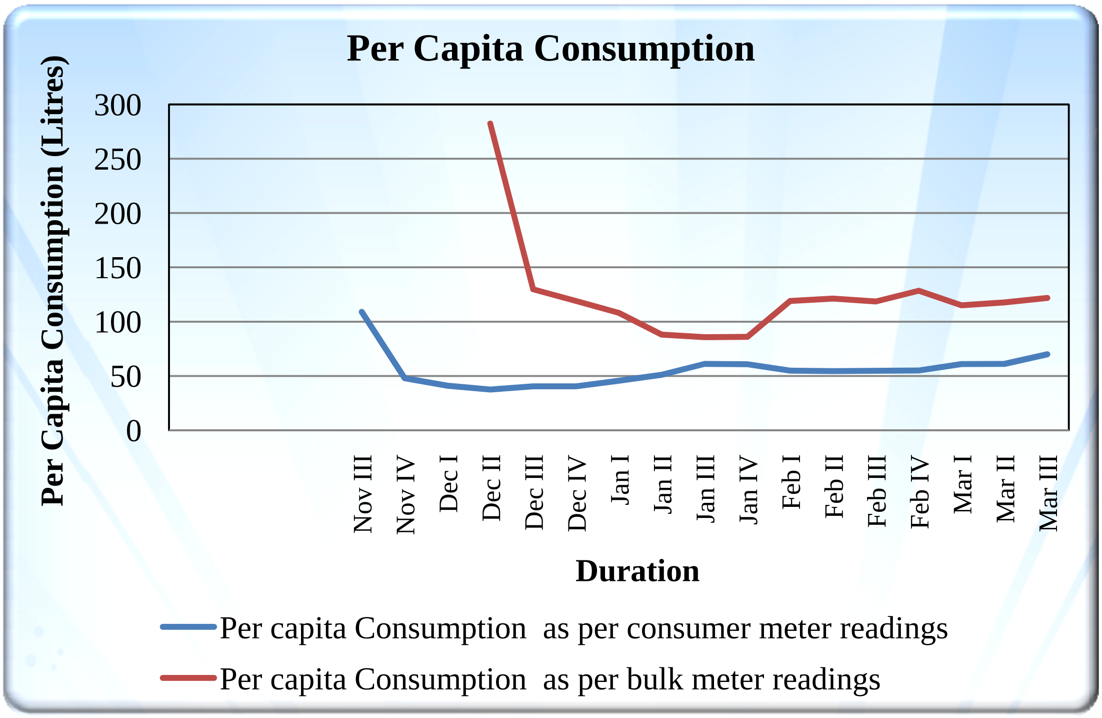


Figure 6.17: Per Capita Water Consumption as per Bulk Meter and Individual Consumer Meter Readings in Malaviya Nagar Sector-9 DMA

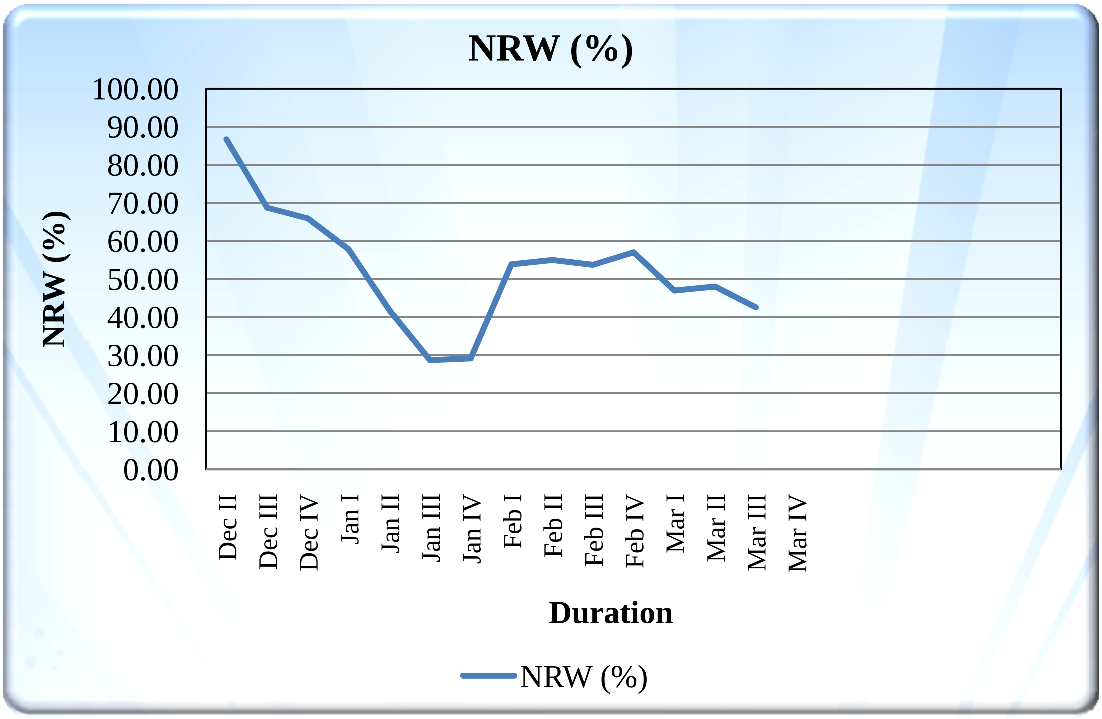


Figure 6.18: Non-Revenue Water in Malaviya Nagar Sector-9 DMA

In the Pilot study DMAs water consumption was very high at the beginning of study. After the implementaion of 24x7 water supply, all the leakages were taken care of, consumer meters were read daily and problems, if any were rectified/ corrected immediately. This consequently reduced the water consumption in the DMAs as indicated in Figure 6.7, 6.10 and 6.16. There were leakages and malfunctioning of fittings in the consumer premises downstream of the water meters. In case of intermittent water supply these leakages bother consumers only during supply hours and they never attend to them. After start of 24x7 water supply such leakages give continuous problem like dampness etc. to the consumers and they were forced to get them rectified. Working meters and continuous awareness and education from the water supply department further helped in reducing leakages within the consumers premises.

There were some cases of malfunctioning in Bulk meters, initially due to lack of maintenance from the supplier and also due to lack of knowledge of the new and technically advanced bulk meters. This was revealed from the relatively low consumption recorded in Bulk meters in the initial period.

After the middle of February 2011, a fall in the NRW and also in the water consumption has been observed.

This has broken the myth that more water is required for sustaining 24x7 water supply. In fact over all water consumption in maintaining 24x7 water supply is less as compared to the intermittent water supplies.

Occurrence of leakages reduce considerably in the areas where 24x7 supplies are there as compared to areas where water is supplied intermittently.

The water quality related problems in 24x7 water supply area are almost negligible as there are no complaints from consumers.

At the onset of the pilot study majority of consumers did not belive that 24x7 water supply is possible. Successful implementation of the scheme has brought confidence in this system and now more and more consumers demand 24x7 water supply.

In Malaviya Nagar Sector-9 DMA total monthly consumption of water as per bulk meter reading has been compared with total quantity of water for which bill was raised to the consumers in that month. This observation has been made from January 2011 to May 2013. It has been observed that during this period NRW has reduced from 32% to 17%. It has also been observed that after initial months NRW has remained almost constant(i.e., steady) and less than 20%. In this DMA there is almost no leakage. DMA has been tested for night flow or leakages after closing the stop valves of all the consumers. In this test zero flow was observed during test periods. This shows that there are negligible leakages in distribution system of this DMA. This also shows that faulty water meters and/ or meter under registration are major component of NRW in this DMA. It is observed that all the consumer meters were not functioning properly. There were frequent malfunctioning of meters and even replaced meters were not functioning properly. Which is one of the cause of fluctuation in readings. For non-functional meters bills were raised based on pervious months water consumption, average of three months consumption or of last year consumption in that month, whichever is higher.

However, there was no complaint from the consumers regarding water quality, water quantity and service in the 24x7 pilot study areas. Comparison of water consumption as per bulk meter and consumer meter readings for which bills were issued has been given in Figure 6.19. This shows almost steady NRW throughout the study period. Percentage of NRW in Malaviya Nagar Sector-9 DMA is given in Figure 6.20.

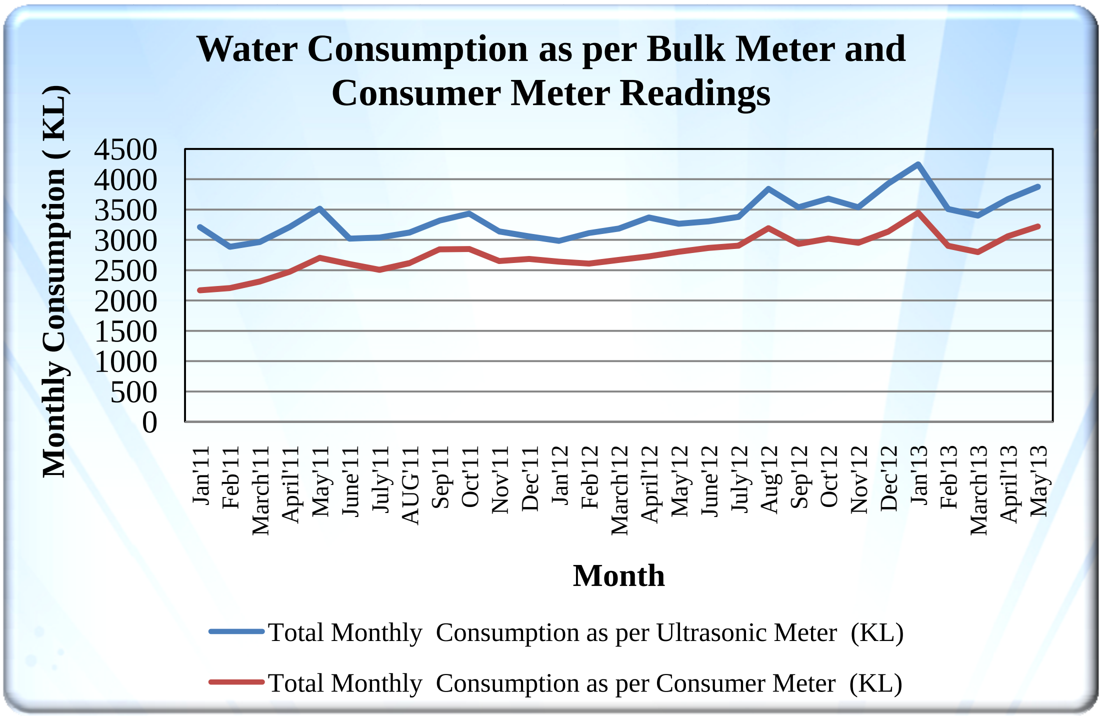


Figure 6.19: Water Consumption as per Bulk Meter and Consumer Meters in Malaviya Nagar Sector-9 DMA

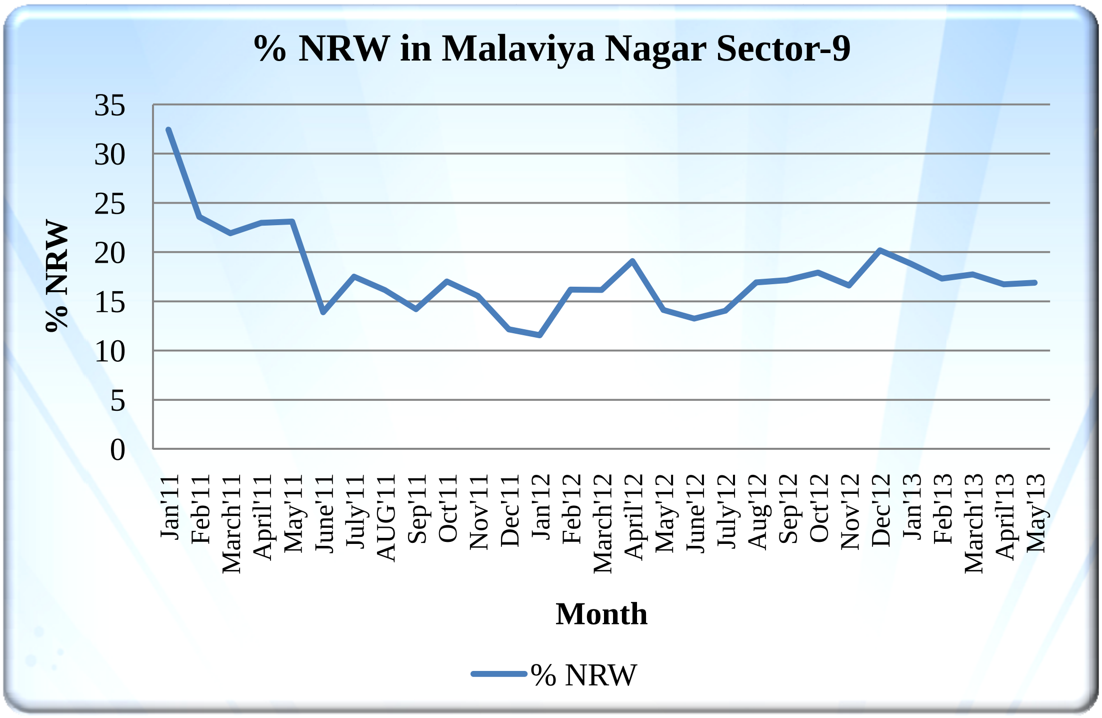


Figure 6.20: Percentage NRW in Malaviya Nagar Sector-9 DMA

6.3 Study of Water Consumption at Different Water Pressures in Malaviya Nagar DMA

In order to assess the effect of water pressure on water consumption and NRW a separate study was conducted in the pilot study area of Malaviya Nagar, Sector-9 DMA. In this area water is supplied at 34 psi, 30 psi and 25 psi. Pressure is measured through pressure guage fitted at inlet pipe of DMA, near soft seated valve to control the water pressure. DMA selected is on level ground. The height of houses varies from 3m to 7m. As per CPHEEO manual 7 m minimum head is required at consumer meter. Bulk meter redings were taken during the period 11.9.12 to 5.10.12. The observations made in this study are given in Table 5.24. In this study, the average water consumption for each pressure was determined. The average water consumption was almost constant for all the three pressures. The study suggests that in this DMA, water consumption is independent of pressure studied. This is very uncommon and can happen only if there are negligible leakages in the DMA. Night flow tests were also conducted in the study area. Bulk flow rate became zero on closing valves of all consumers in the DMA which indicates that there are negligible leakages in the study area. Major component of the NRW observed in the DMA is due to faulty meters, meters under registration and average/ flat rate billing made to consumers with nonfunctional meters.

Photograph 6.1 : Malaviya Nagar Sector-9 DMA

6.4 Feedback from Consumers

Feedback on 24x7 water supply and on other related issues were taken from the consumers of all the DMAs. A questionnaire was prepared and feedback was received from total 84 consumers. The sample feedback form for consumers is given at Annexure VI. Summary of feedback received is given as below:

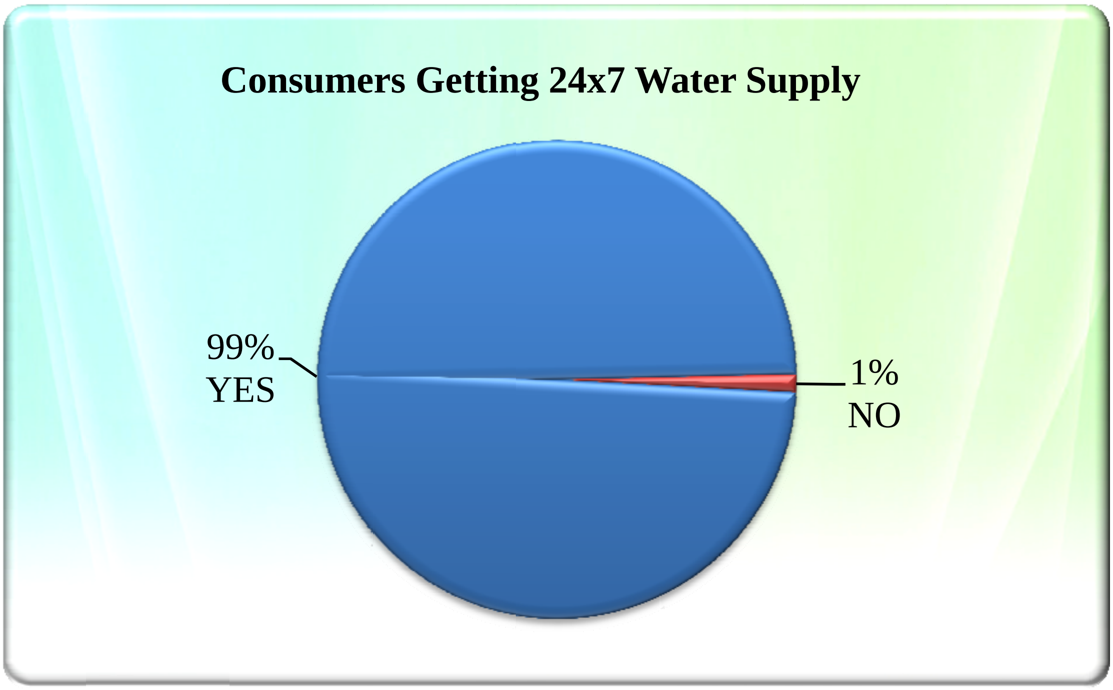


Figure 6.21: Consumers Getting 24x7 Water Supply

All the households surveyed informed that they were getting continuous 24x7 water supply except one who said that there was very low pressure for one to two hours in a day [Figure 6.21].

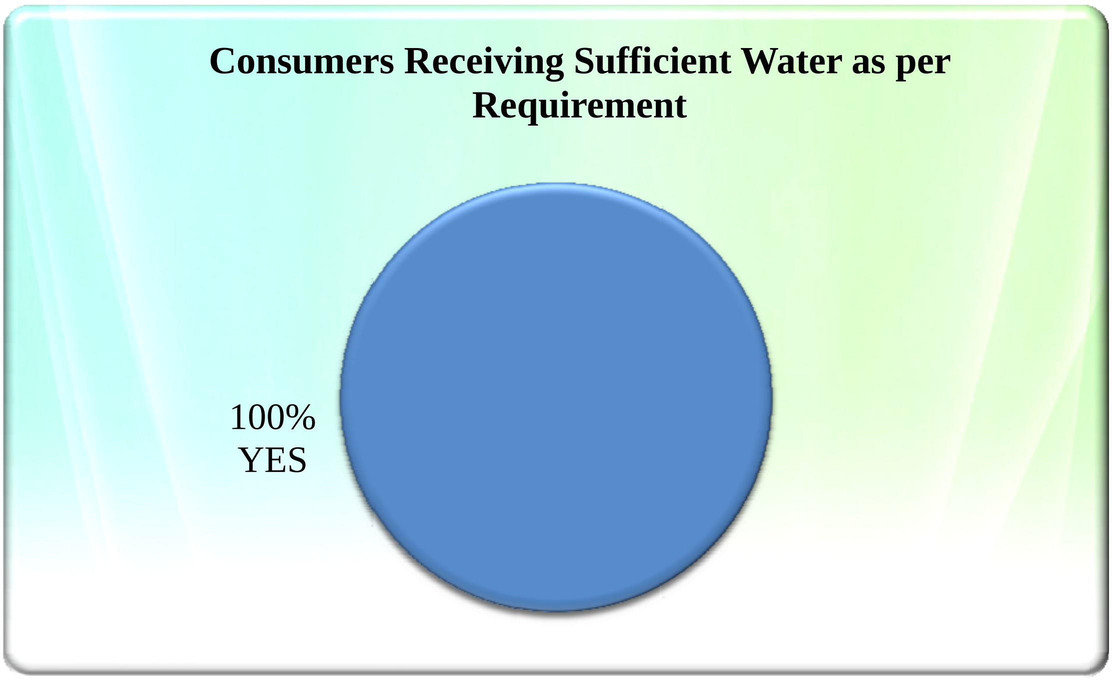


Figure 6.22: Consumers Receiving Sufficient Water as per Requirement

All the houses surveyed reported that they were getting sufficient quantity of water as per their requirement [Figure 6.22].

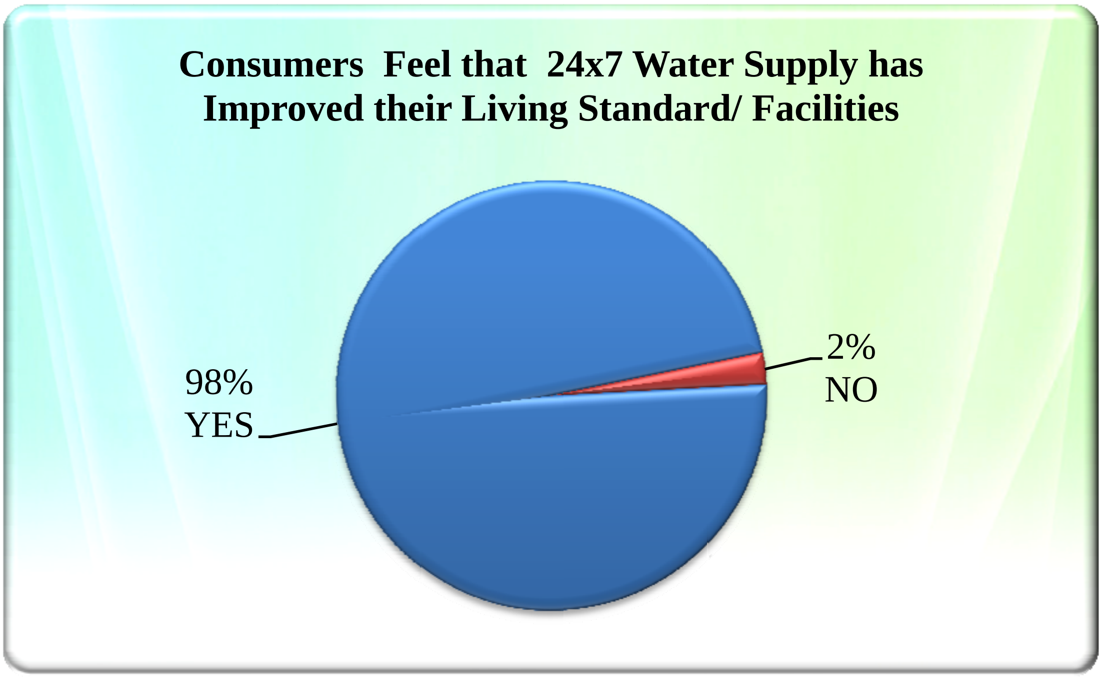


Figure 6.23: Consumers Feel that 24x7 Water Supply has Improved their Living Standard/ Facilities

98% of the consumers feel that their living standard and facilities have improved with the 24x7 water supply [Figure 6.23].

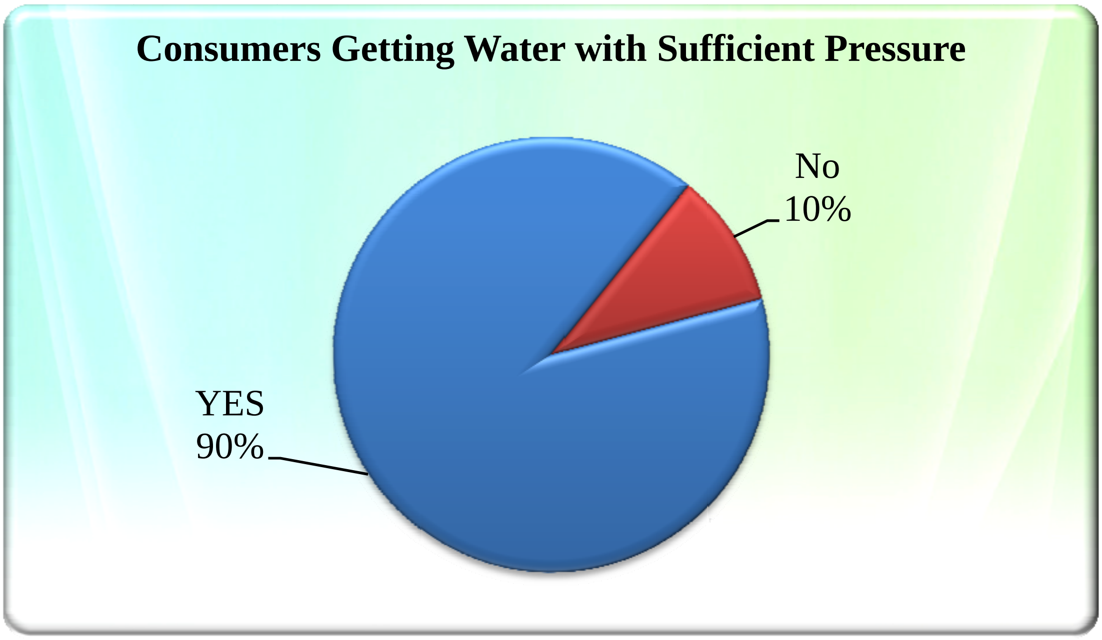


Figure 6.24: Consumers Getting Water with Sufficient Pressure

90% of the consumers mentioned that they were receiving water with adequate pressure. Some of them have even reported about excessive water pressure. As per the survey, 10% of the consumers reported about low water pressure [Figure 6.24].

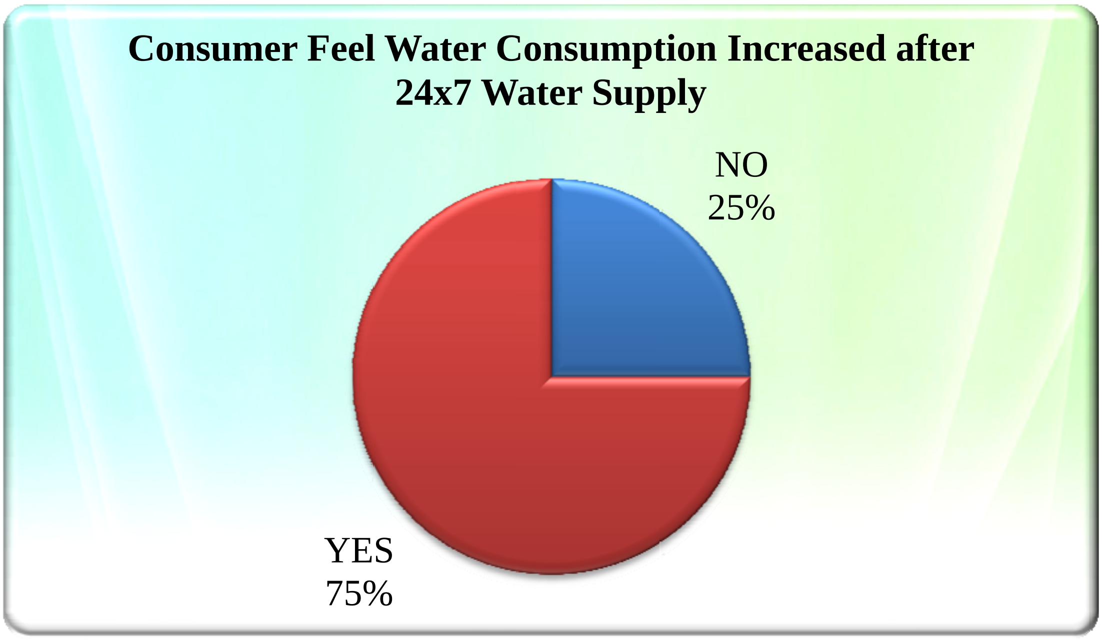


Figure 6.25: Consumer Feel Water Consumption Increased after 24x7 Water Supply

75% consumers felt that their water consumption had increased after 24x7 water supply whereas 25% mentioned that there is no change in their water consumption [Figure 6.25].

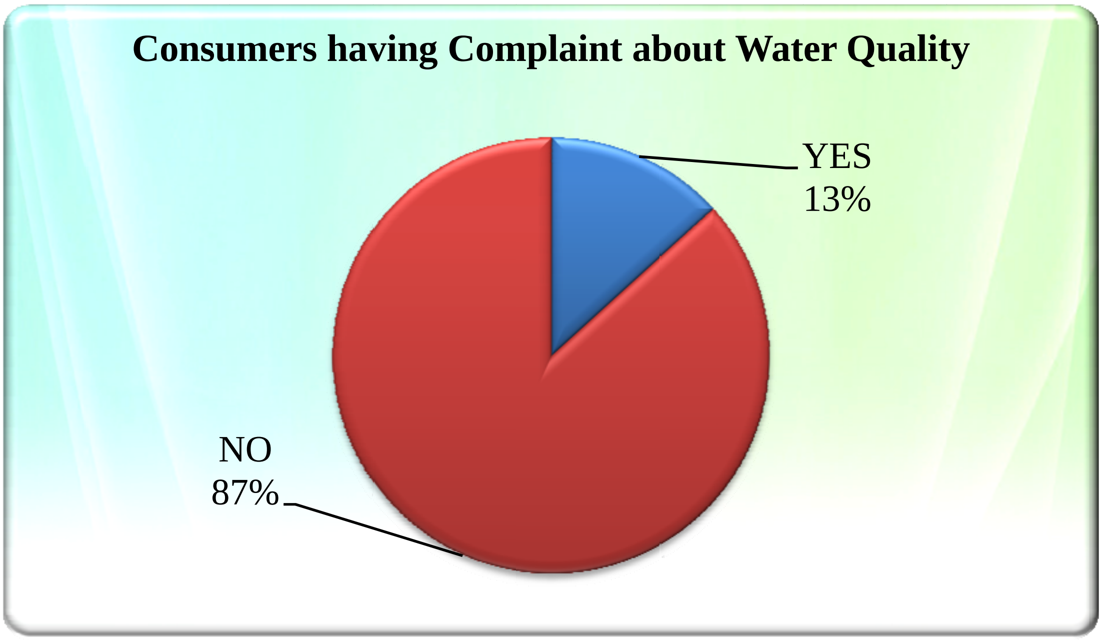


Figure 6.26: Consumers having Complaint about Water Quality

13% of the consumers complained about deterioration in water quality. As per the survey, there were 1-2 undesirable instances of water quality in a month. However, 87% of the consumers had no complaint with regard to water quality [Figure 6.26].

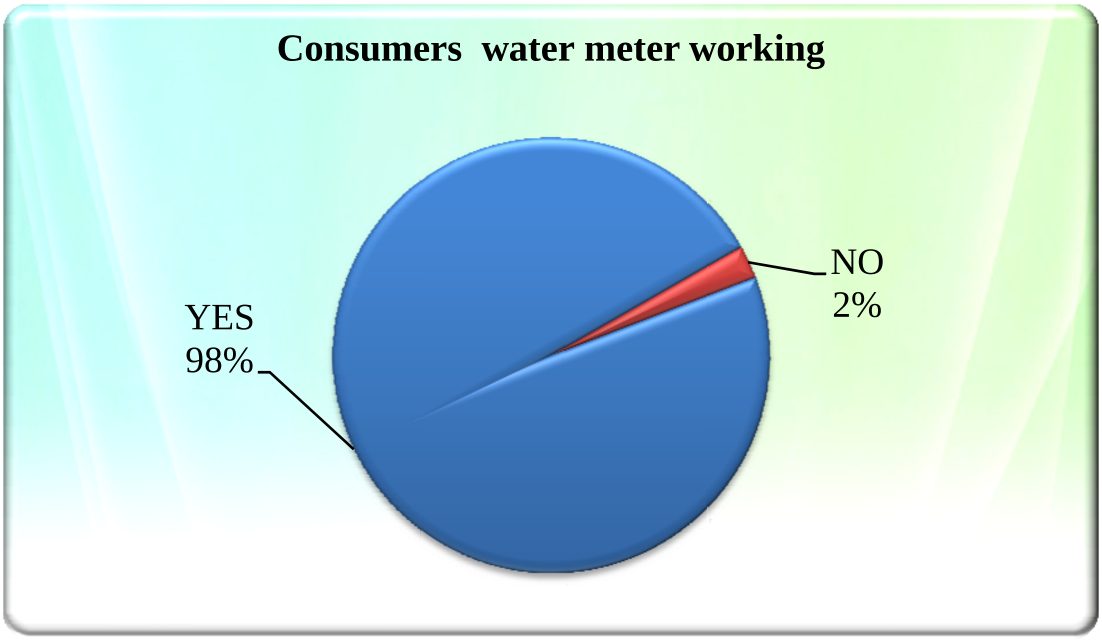


Figure 6.27: Consumers Water Meter Working

As per the consumer survey, 98% have reported about their working water meter. Only 2% have reported a non-working water meter [Figure 6.27].

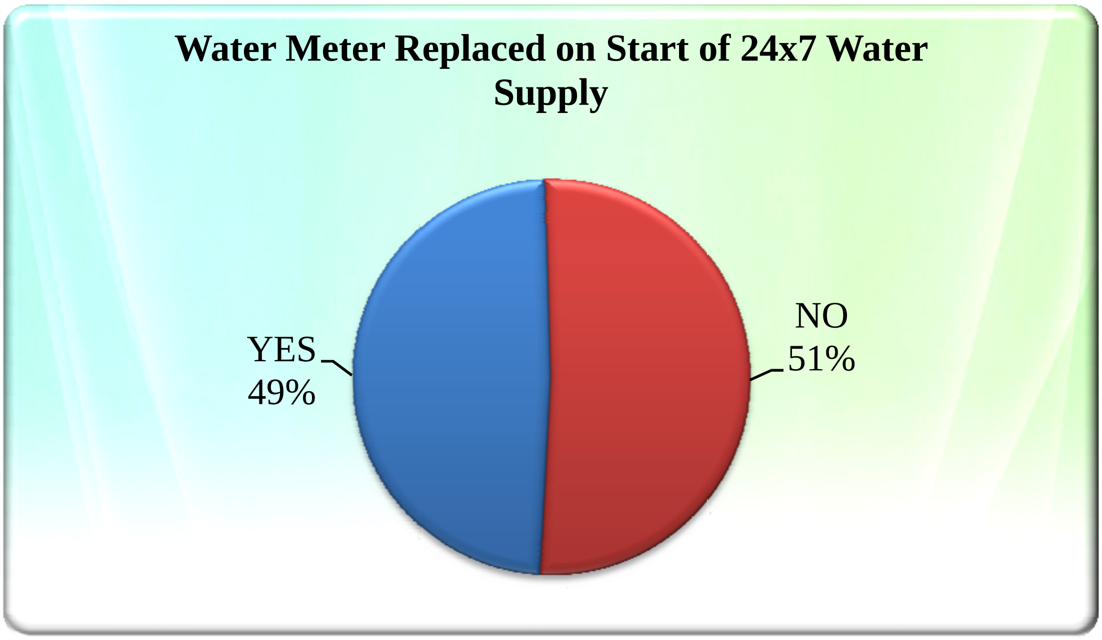


Figure 6.28: Water Meter Replaced on Start of 24x7 Water Supply

49% of the consumers have informed that their water meter was replaced at the start of the 24x7 water supply, whereas 51% says their water meters were not replaced [Figure 6.28].

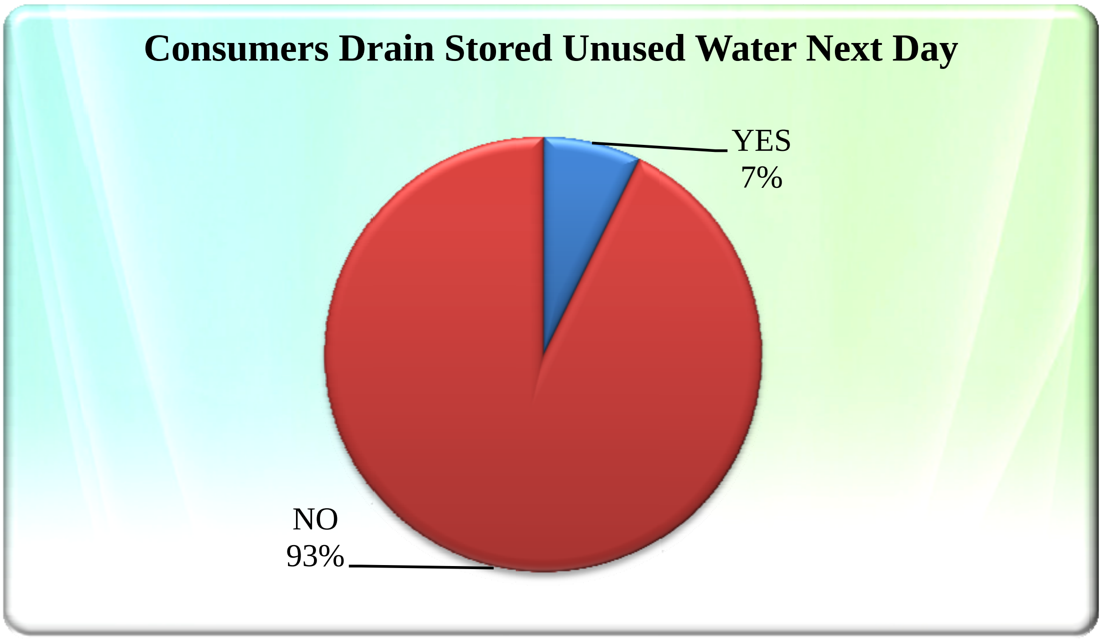


Figure 6.29: Consumers Drain Stored Unused Water Next Day

Only 7% of the consumers have reported a practice of draining out the stored and unused water the next day [Figure 6.29].

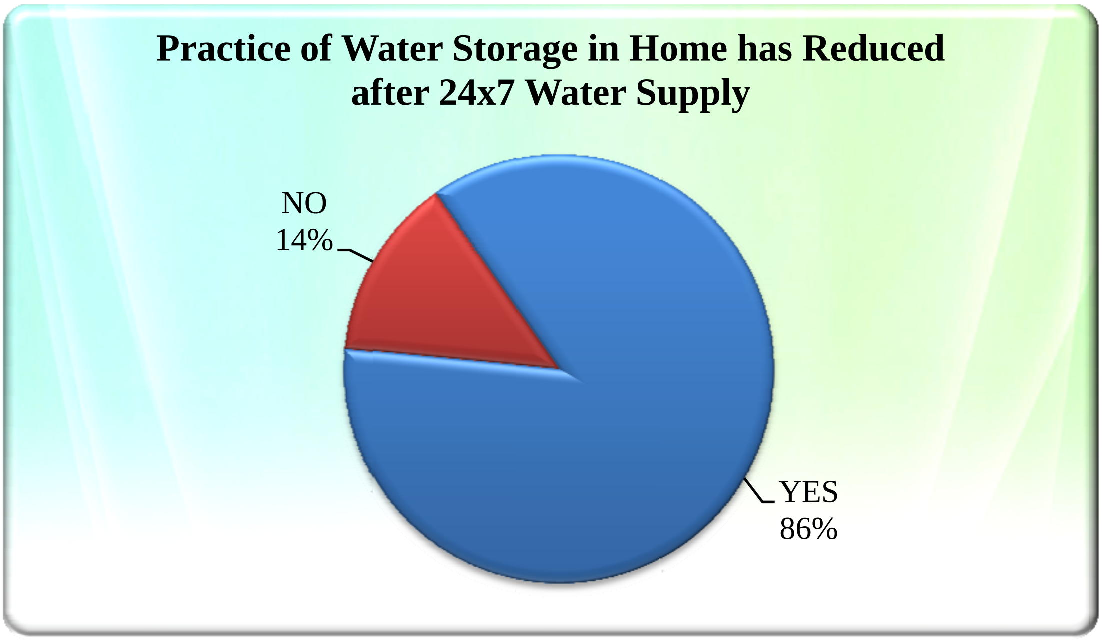


Figure 6.30: Practice of Water Storage in the Individual Homes had Reduced after the 24x7 Water Supply

86% of the consumers mentioned that the practice of storeing the water has reduced after 24x7 water supply was introduced [Figure 6.30].

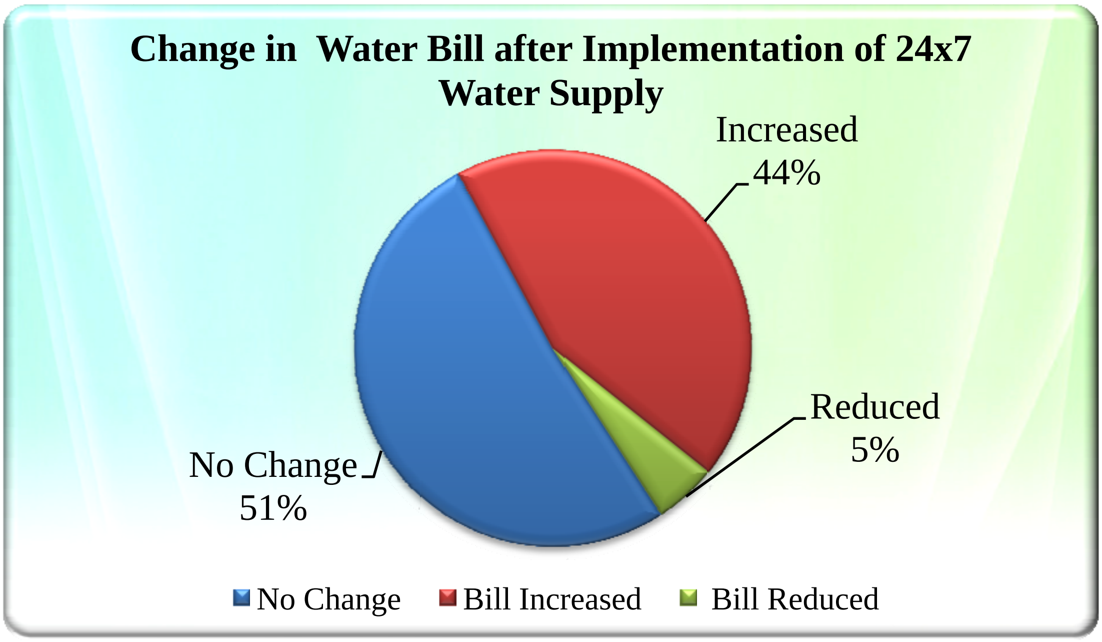


Figure 6.31: Change in Water Bill after Implementation of 24x7 Water Supply

51% of the consumers reported that there was no change in their water bills after the start of 24x7 water supply. However, 44% reported that their bills had increased and 5% said that there was a reduction in their water bills [Figure 6.31].

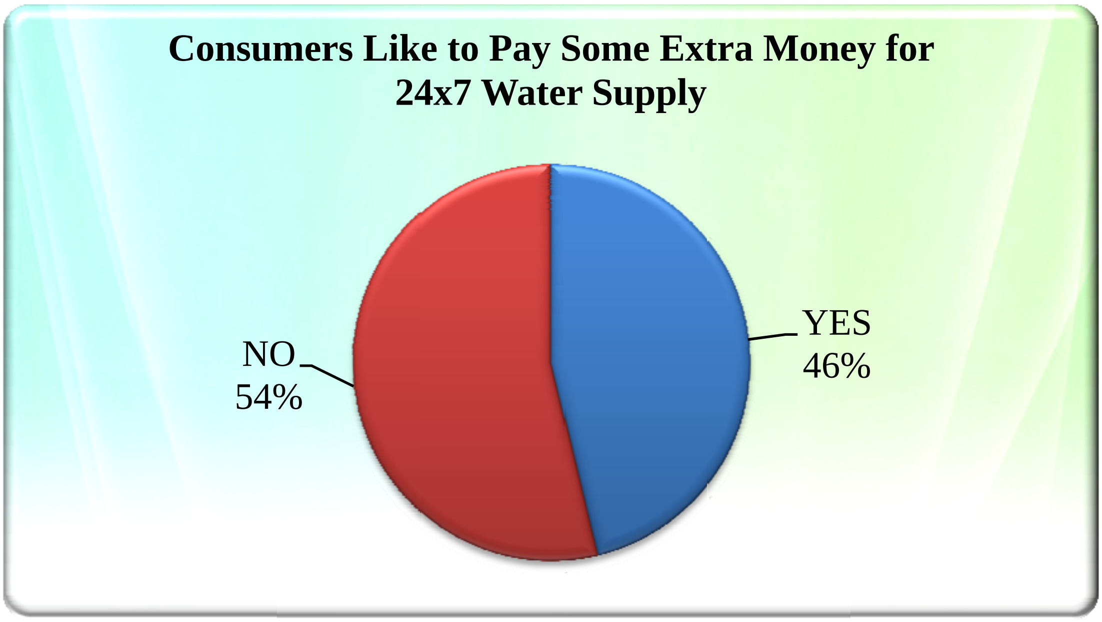


Figure 6.32: Consumers Like to Pay Some Extra Money for 24x7 Water Supply

54% of the consumers did not agree on the issue of paying some extra money for receiving 24x7 water supply. However, only the remaining 46% agreed to pay some extra money toward this [Figure 6.32].

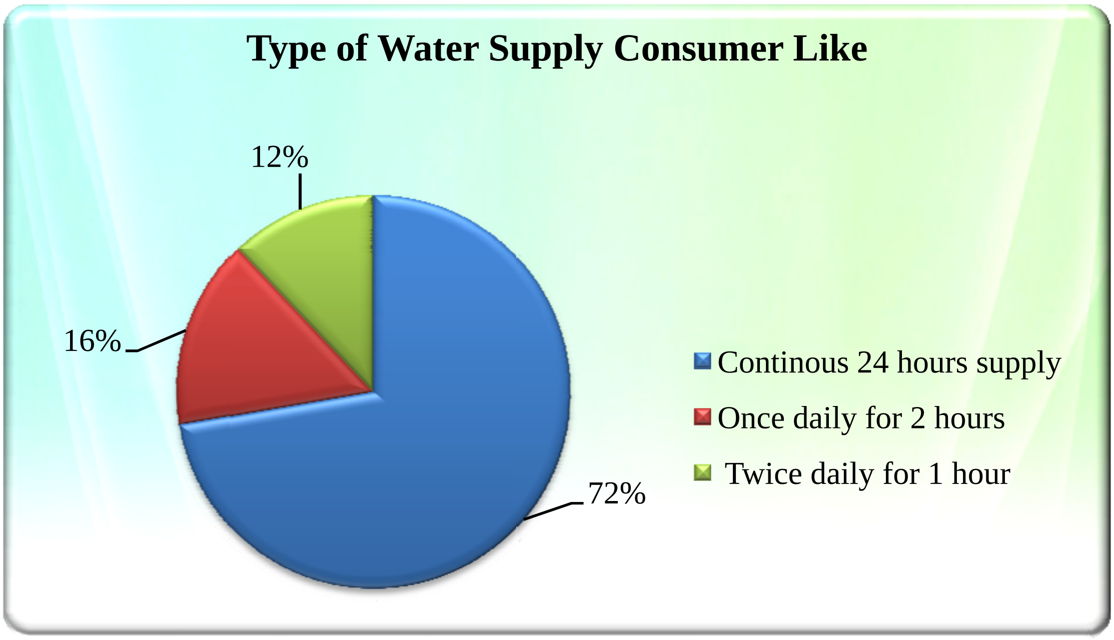


Figure 6.33: Type of Water Supply Consumers Like

72% of the consumers liked 24x7 water supply, 16% liked once daily for 2 hours and 12% indicated a preference for twice daily water supply for one hour each in the morning and evening [Figure 6.33].

It can be concluded from the feedback received from the consumers that a large majority of them were in favour of 24x7 water supply. Awareness campaign can very much reduce the wastage of water. For majority of the connections there was no change in water use and water bill. Public Health Engineering Department (PHED), Government of Rajasthan was able to provide better services with more or less the same quantity of water. Water tariff in Rajasthan is very low in comparison to other cities of India. Even non-functional meters and billing by average rate encourage wasteful use of water. To establish the importance of this scarce resource, accurate water measurement for billing is very much essential. Increased water tariff with accurate metering will force consumers from misusing water.

6.5 Feedback from PHED Officials

Feedback on the 24x7 water supply and on other related issues was also taken from the PHED Engineers. A questionnaire was prepared and feedback was requested from the PHED Engineers. The sample feedback form for PHED Engineers is given in Annexure-VII. Summary of this feedback received is given below:

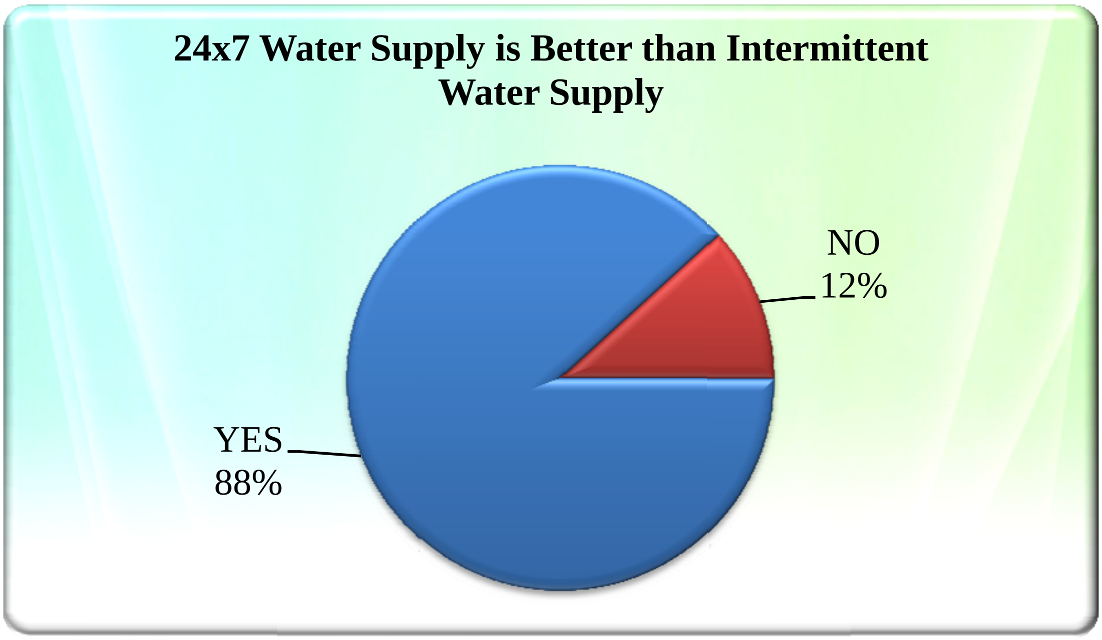


Figure 6.34: 24x7 Water Supply is Better than Intermittent Water Supply

88% of the PHED Engineers/ officials believed that 24x7 continuous water supply is a better option than intermittent water supply. However, 12% were in favour of intermittent supply [Figure 6.34].

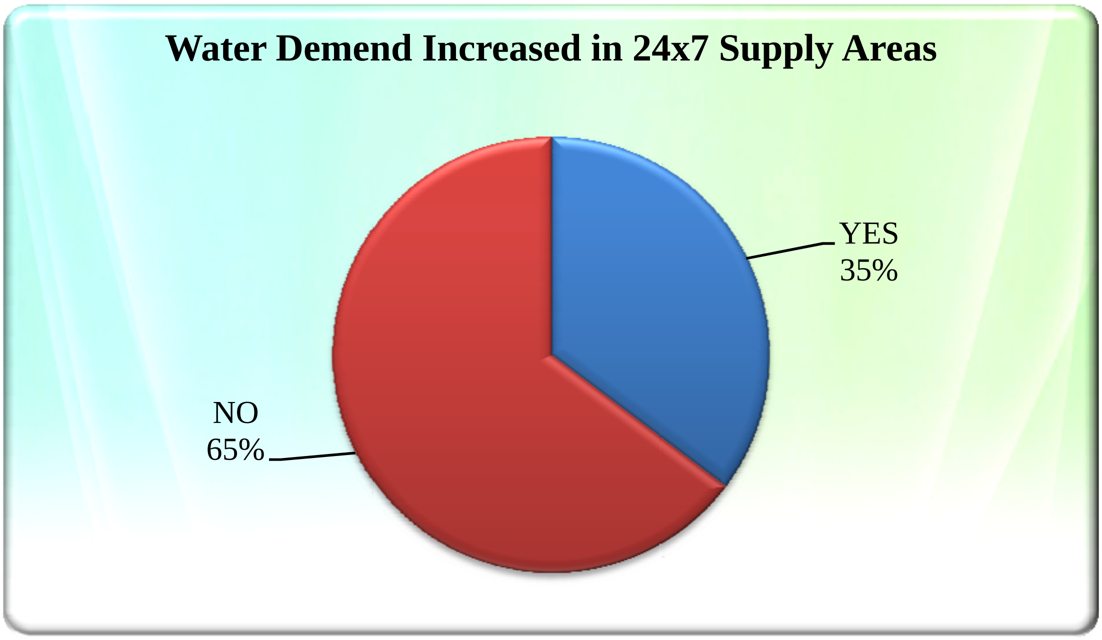


Figure 6.35: Water Demend Increase in 24x7 Supply Areas

35% of PHED Engineers believed that water demand increases with 24x7 continuous water supply whereas 65% mentioned that water demand is independent of the system of water supply [Figure 6.35].

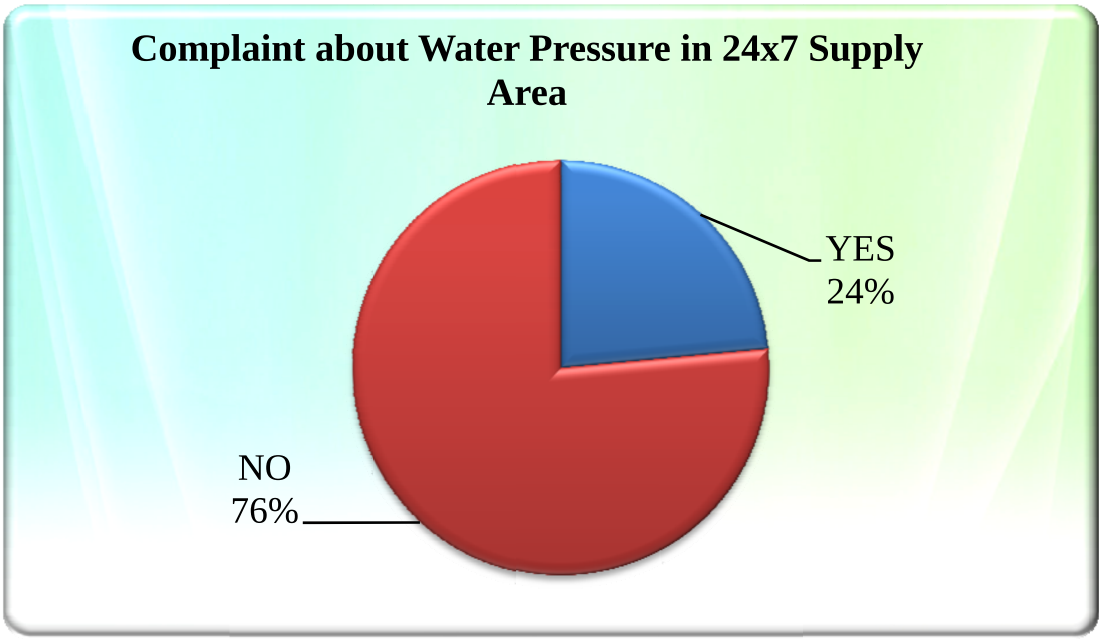


Figure 6.36: Complaint about Water Pressure in 24x7 Supply Area

As per the feedback received, 76% of the PHED Engineers there was no complaint about the water pressure in 24x7 supply area. However, 24% of the Engineers reported consumer complaints about water pressure [Figure 6.36].

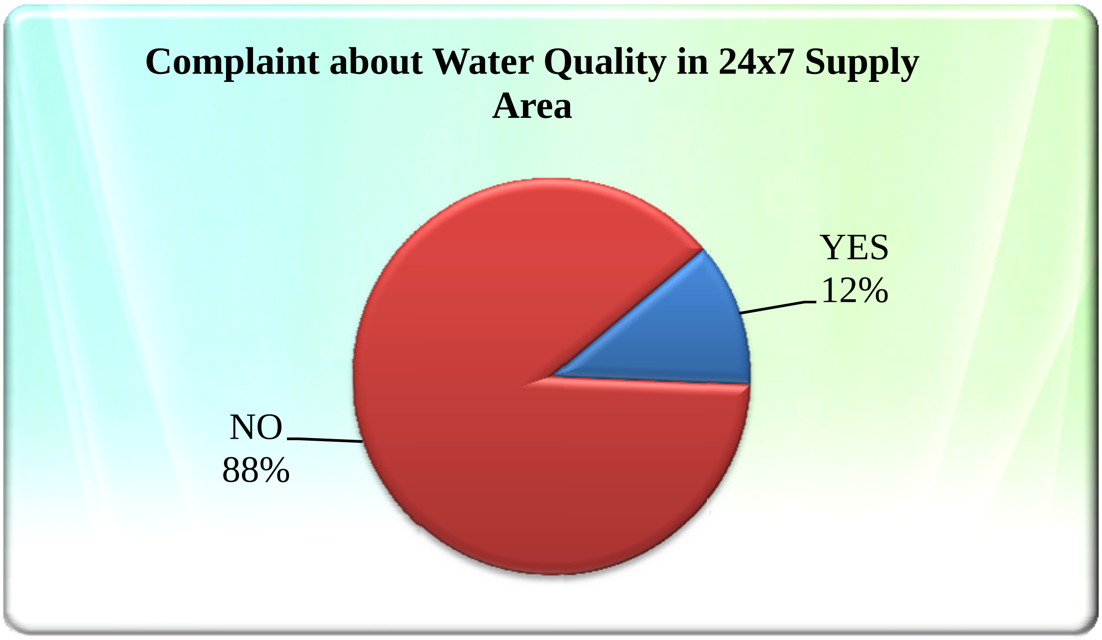


Figure 6.37: Complaint about Water Quality in 24x7 Supply Area

As per the feedback received, 88% of the PHED officials said that there was no complaint about water quality in the 24x7 water supply areas. However, 12% of them reported consumer complaints about the quality of water [Figure 6.37].

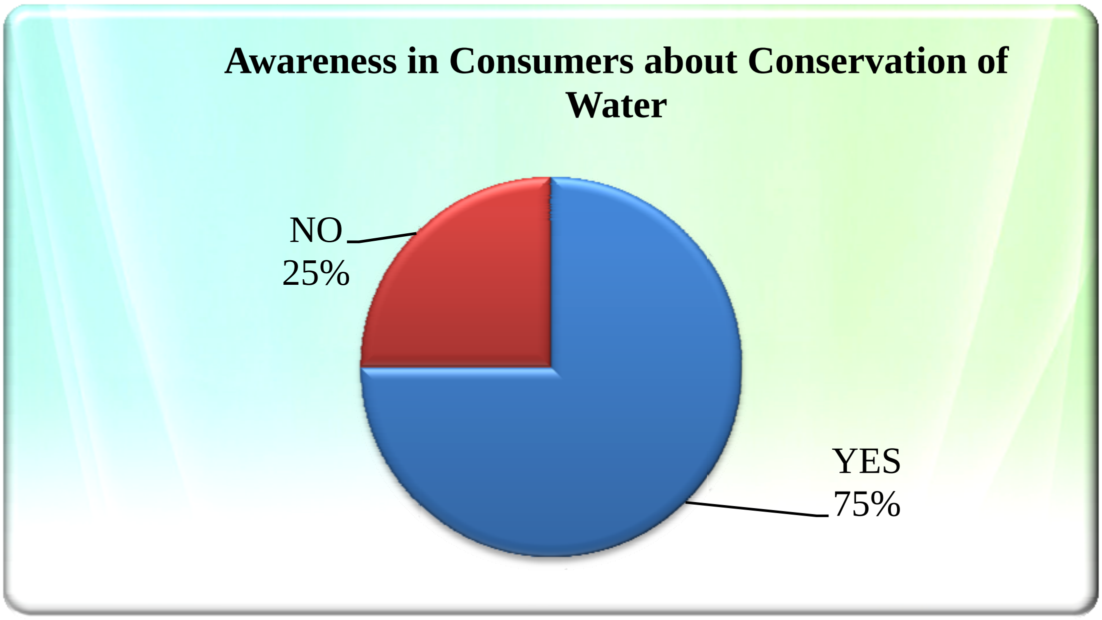


Figure 6.38: Awareness in Consumers about Conservation of Water

As per 75% of the PHED officers, there was an awareness among consumers about conservation of water, whereas 25% reported that there was not much awareness about water conservation. Officers also expressed that low water tariff and water billing on average consumption were the main causes for the consumer reluctance to conserve water [Figure 6.38].

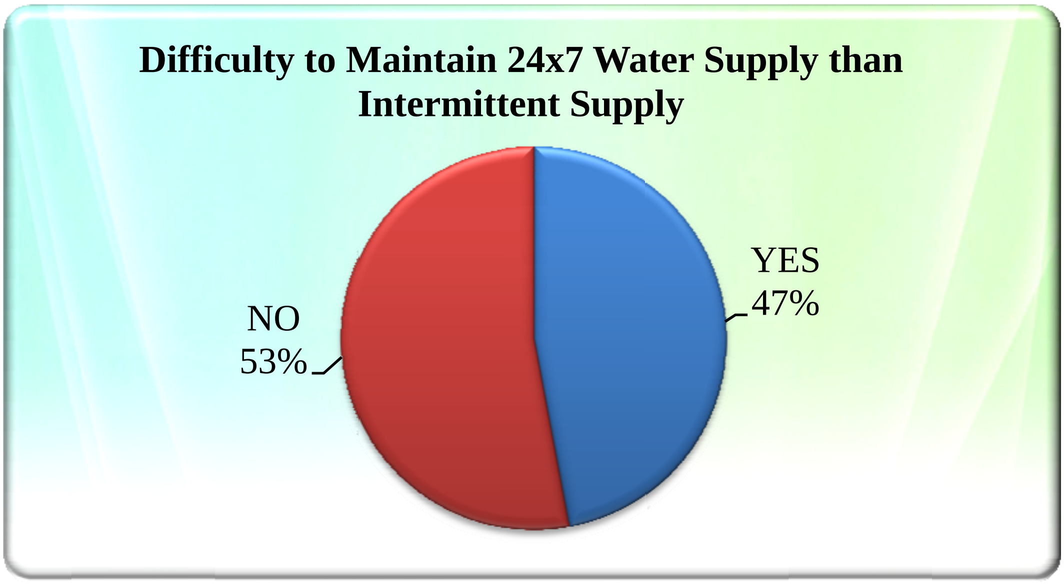


Figure 6.39: Difficulty to Maintain a 24x7 Water Supply than Intermittent Supply

Nearly 47% of the PHED officials felt that it was difficult to maintain 24x7 water supply whereas 53% mentioned that it was easier to maintain a 24x7 supply after its installation. There would be some difficulty initially but once system stabilises, it would be very convenient to maintain it [Figure 6.39].

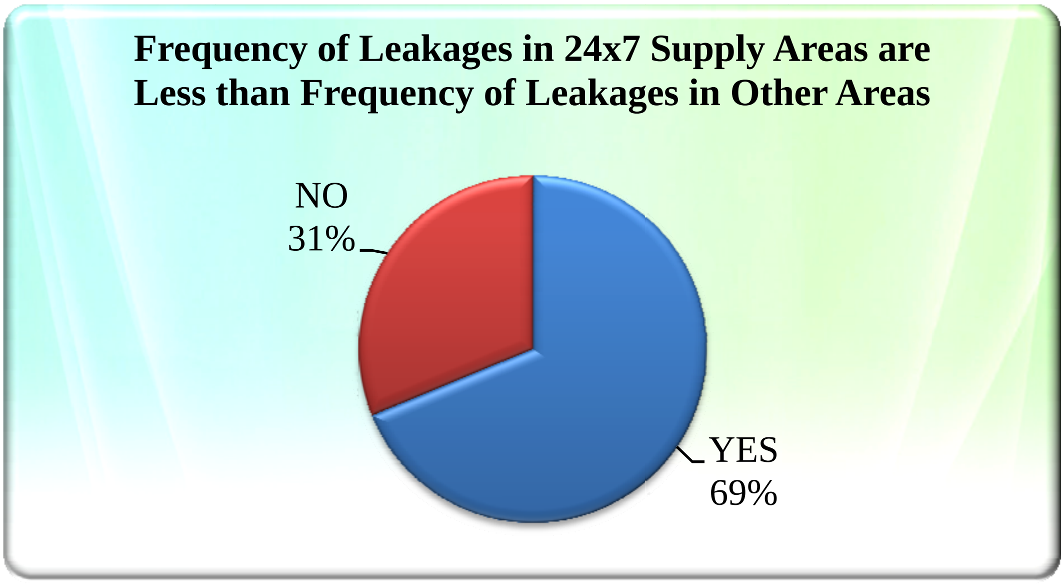


Figure 6.40: Frequency of Leakages in 24x7 Supply Areas are Less than Frequency of Leakages in Other Areas

Frequency of leakages in 24x7 areas were less in comparison to the other areas as opined by 69% the PHED officials. The officers who were in direct touch with 24x7 supply reported that there were very few leakage complaints from these areas [Figure 6.40].

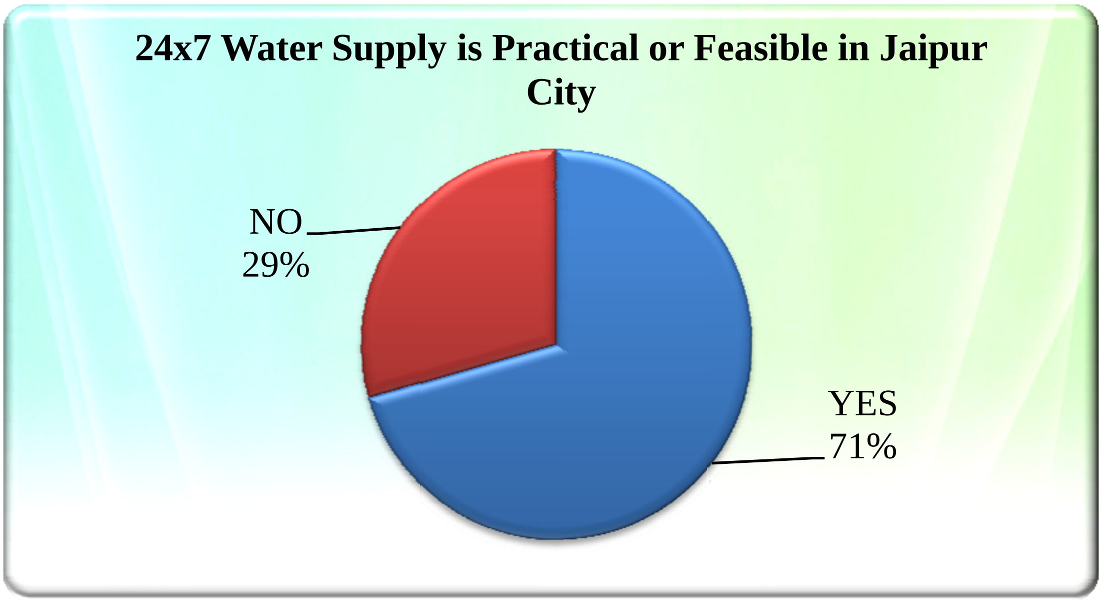


Figure 6.41: 24x7 Water Supply is Practical or Feasible in Jaipur City

71% of the PHED officials felt that 24x7 water supply was feasible in Jaipur city whereas 29% felt that 24x7 water supply was not practical or feasible. Officers also explained that before the implementation of the 24x7 continuous supply, the equipments, valves etc. are required to be installed in the system. Also, training of staff would be essentisl with respect to various aspects of the 24x7 water suppliy [Figure 6.41].

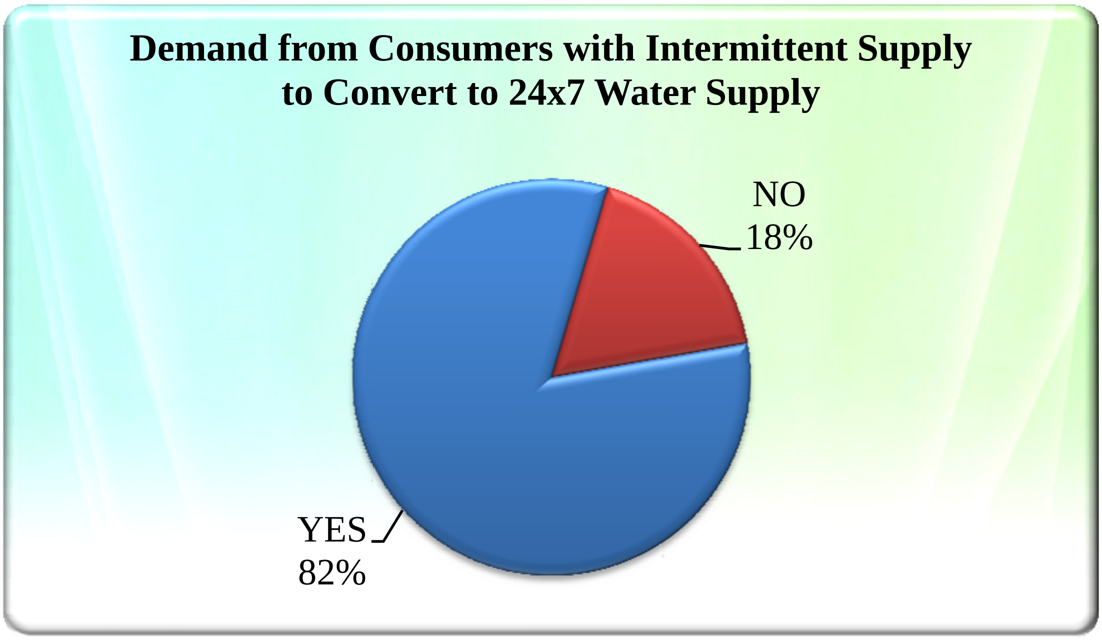


Figure 6.42: Demand from Consumers with Intermittent Supply to Convert to 24x7 Water Supply

82% of the PHED officials mentioned that there was a demand from the consumers for switchover to a 24x7 water supply; whereas, 18% of them felt that consumers were not in favour of a 24x7 water supply [Figure 6.42].

6.6 Feedback from Public Representatives

Feedback on 24x7 water supply and on other issues was also obtained from Public Representatives including Ward Parshads, representitives of Housing Societies, local political workers etc. They expressed that water supply situation was generally not very satisfactory. They reported problems related to water quality, pressure and supply duration. A questionnaire was prepared and feedback was requested from the general Public Representatives. The sample feedback form for Public Representatives is given in the Annexure VIII. Summary of feedback is given below:

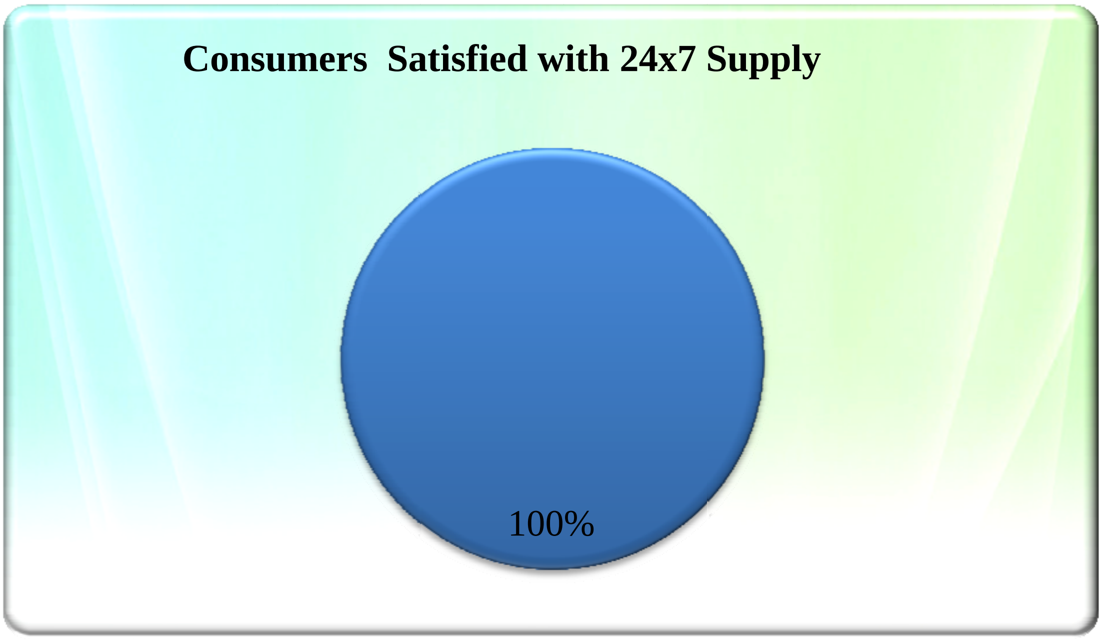


Figure 6.43: Consumers Satisfied with 24x7 Supply

All the representatives expressed that consumers would be fully satisfied with 24x7 water supply [Figure 6.43].

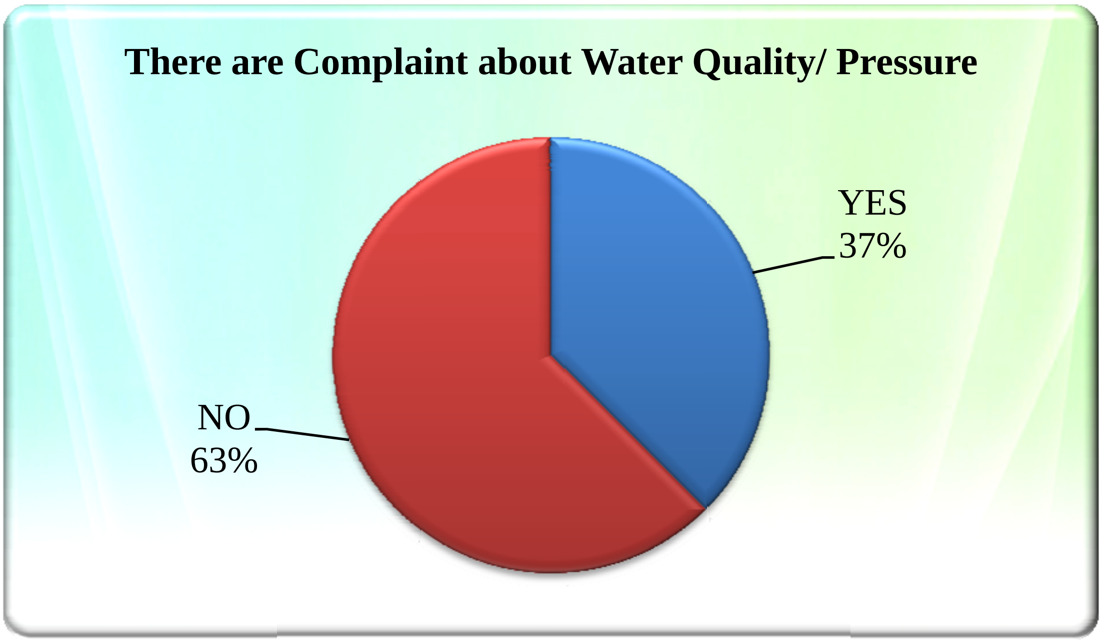


Figure 6.44: There are Complaint about Water Quality/ Pressure

37% Representatives mentioned that there were water quality and pressure problems with water supply whereas 67% reported no such problems [Figure 6.44].

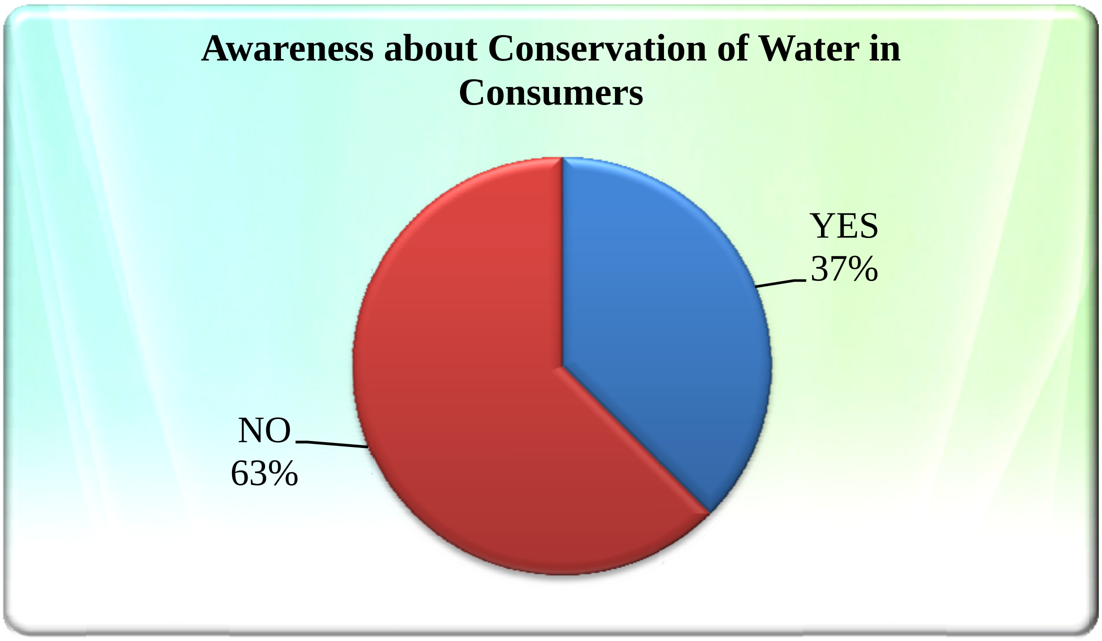


Figure 6.45: Awareness about Conservation of Water in Consumers

37% Representatives felt that the consumers are aware of water conservation whereas 67% felt that public is not very much aware of water conservation [Figure 6.45].

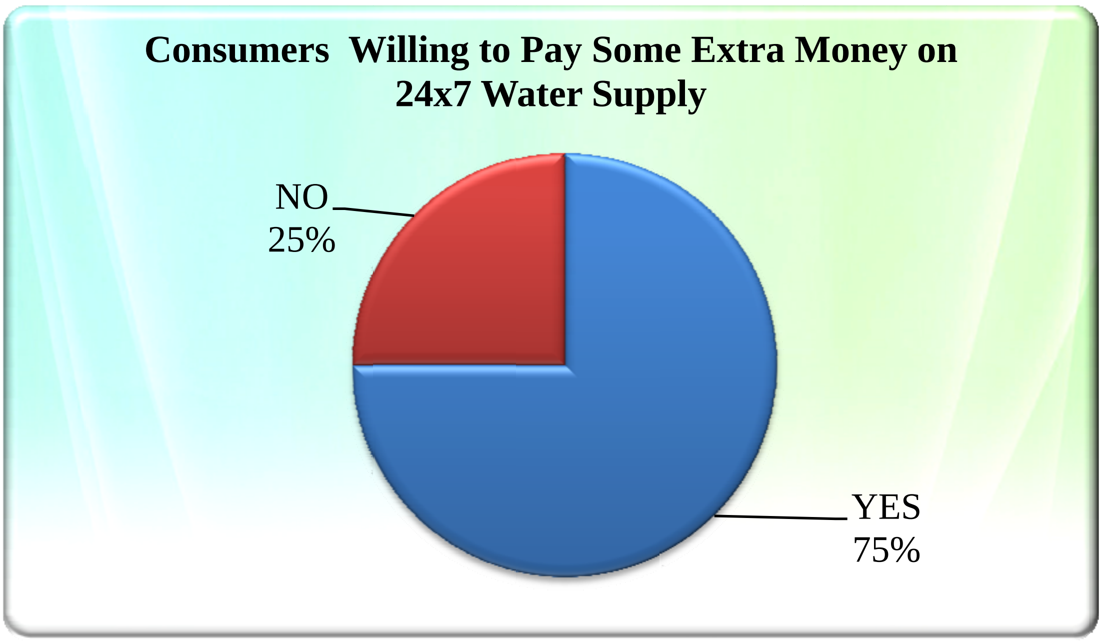


Figure 6.46: Consumers Willing to Pay Some Extra Money on 24x7 Water Supply

75% of the Representatives from the general public said consumers were willing to pay some extra money for receiving 24x7 water supply but 25% felt that consumers were not willing to pay extra money [Figure 6.46].

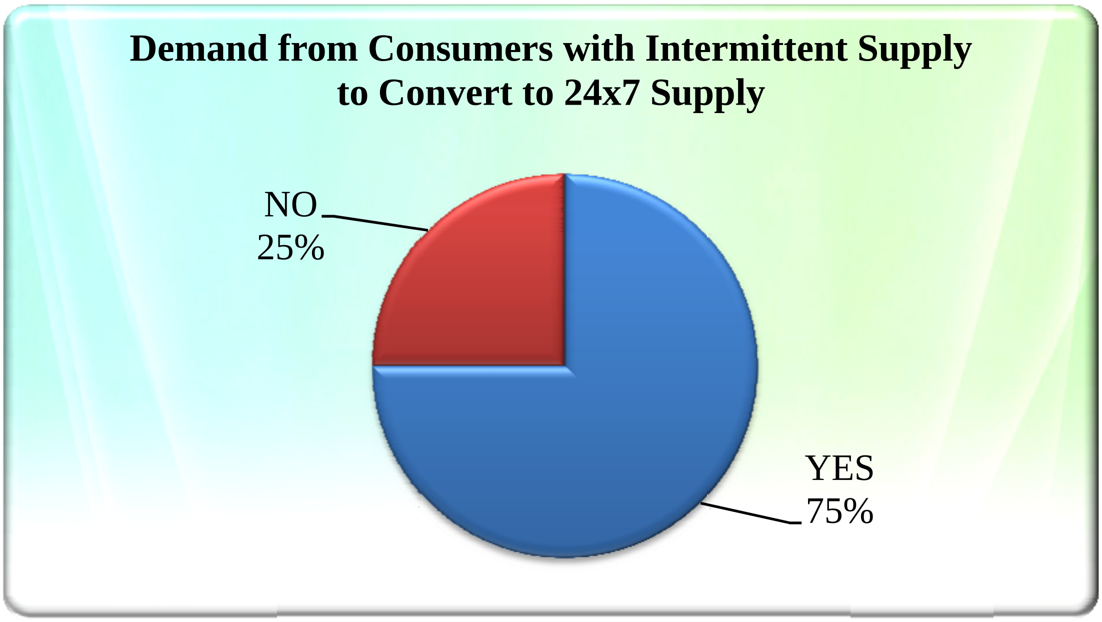


Figure 6.47: Demand from Consumers with Intermittent Supply to Convert to 24x7 Supply

75% of the Representatives from general public mentioned that consumers were favouring for 24x7 water supply but 25% felt that consumers were not willing to switchover to a continuous 24x7 water supply [Figure 6.47].

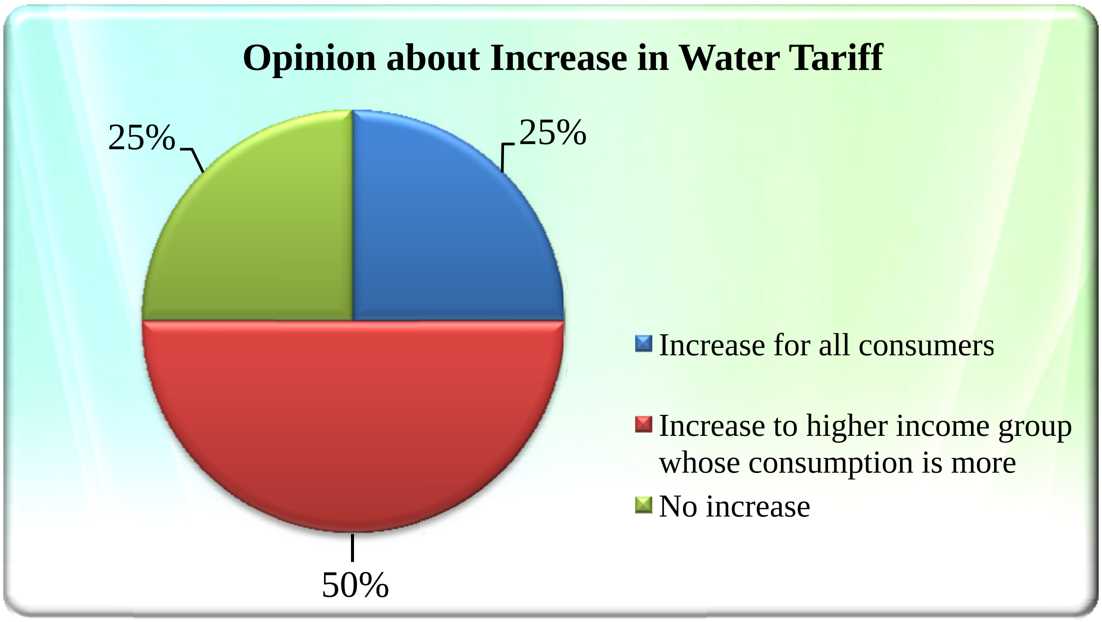


Figure 6.48: Opinion about Increase in Water Tariff

50% of the Public Representatives surveyed opined that water tariff should be increased only for higher income group consumers whose consumption is more. 25%

of the representatives opined that water tariff be increased for all the consumers while the remaining 25% were in favour of no water tariff increase of any sort [Figure 6.48].

6.7 Reducing Non-Revenue Water

24x7 water supply with other necessary steps like leakages removal, accurate metering, legalisation of illegal connections etc. help in reducing NRW.

Reduction of NRW means an opportunity for improving the overall sustainability of the city water supply scheme. Some of the direct benefits of NRW reduction achieved include following:

- It increases the water supply to legitimate consumers without going for an increase in either the resource availability or the treatment capacity.
- Cost involved in reducing leakage is likely to be lower than the significant cost involved in creating additional capacity.
- With more revenue water, the need for increasing water tariffs to meet costs would be reduced as greater volumes of water supplied will fetch more revenue.
- It has the potential to bring unconnected consumers into the formal distribution system.
- It can create a financial support plan for Water supply agencies (i.e.,PHED) to implement specific reduction measures. This programme should provide incrementally higher level of support for more and more challenging measures to be taken.
- It can Identify all un-connected consumers and illegal connections and it can have a policy of providing access to the formal network. It can also bring

about a legalization of illegal connections which should also have a liberal connection fee in order to encourage illegal consumers to come forward for legalization.

- It can provide for bulk level metering across the city to capture water availability in different zones and it can also introduce measures for water balancing and equitable distribution of water.
- It can lead to moving towards 100% consumer level metering and consumption based tariffs. If majority of the connections are metered, a volumetric tariff structure that reflects the true economic cost of water can be introduced.

Implementation of a NRW reduction programme requires a specialized strategy which would include proper leakage control programme, consumer meter changeover/ upgradation programme, NRW control unit, training of PHED staff, planned maintenance programme, consumer awareness, appropriate policy decisions by top administrators.

6.8 Consumer Meter Change-out Program

Accurate measurement of water and followed by accurate billing is the key to NRW reduction. The number of partially/ fully malfunctioning consumer meters also lead to a suspicion that revenue due to large amount of water might be lost due to inadequate metering. The programme of replacing such meters be implemented on a regular basis such that all meters get replaced over a specified time period and remain functional ever.

6.9 NRW Control Units

Regular PHED divisions and staff deployed cannot control NRW efficiently along with their regular work. Separate NRW reduction Circles / Divisions should be created which have full powers and budget to take necessary steps to achieve the targeted level of NRW.

6.10 Training of Public Health Engg. Dept. (PHED) Staff

It was also observed that there is a misconception among the majority of the PHED Engineers and other staff regarding the 24X7 water supply to public. They have misconceptions that in 24x7 water supply there is too much wastage of water. It is very necessary that more number of PHED engineers and other staff be given training and class room sessions on the usefulness of NRW reduction program.

Adequate exposure/ training and opportunities to the staff for implementing best practices available in day to day activities of NRW reduction are necessary. Based on the experience gained from the pilot projects, better water supply facilities may be extended to more areas.

The level of NRW is a key performance indicator of the efficiency of the water utility. However, many engineers tend to underestimate NRW because of departmental and political pressures, as well as due to lack of knowledge to properly estimate the NRW level.

6.11 Planned Maintenance Programme

In the present system there exists very little planned or routine maintenance procedure, which leads to an inefficient and inadequate service of water supply. It is further reinforced by the practices that are adopted by the approved plumbers who carry out the installation of service connections and other related works. This is a major contributing factor to the unacceptable increase in NRW. In order to curb this practice PHED/ Department should take responsibility of providing service connections from the ferrule to the consumer meter, its installation and maintenance.

Department should also take responsibility for providing water meters to consumers. Only then it will be possible to exert some control over the quality and standard of the meter and also to standardize on the type of meter to be used. This will also allow department to remove consumer meters as and when required for either maintenance or repair purposes.

A proper record should also be kept which include date of installation, repair, meter type, size, location etc. in a way that the year in which meter was installed becomes recognizable.

6.12 Policy Decisions

There is an urgent need for the policy maker along with top officials of the department to take major policy decisions in regard to carry out a planned and extensive leakage reduction programme, replacement of non-functional water meters, legalization of illegal connections by planning a suitable policy, to initiate 24x7 water supply in new areas and other appropriate measures in order to reduce NRW.

6.13 Tariff

One of the fundamental issues that give great trouble to urban water supply is the prevailing approach towards the setting and revision of water tariffs. National Water

Policy 2002 clearly states that water charges ought to be fixed in a way to cover the operation and maintenance costs for providing the service initially and a part of the capital cost subsequently. At present, water charges are not linked to inflation. This makes every rate revision difficult and conditional subject to government ratification and political interventions.

In Jaipur in the year 2012-13 difference between total expenditure made on Operation & Maintenance (O&M) and Revenue received from consumers was ₹1147.74 million which was about 73% of total expenditure made in O&M. As per the international standards revenue generated should be equal to or more than the expenditure made on O&M. To encourage public to use water judiciously it is very essential that the city should have totally functional consumer water meters and tariff should be increased suitably to recoup O&M expenses and eventually make water supply self sustainable.

6.14 Inefficient Public Delivery Imposes High Cost on Poor

Too much attention has been placed on increasing the resource base against ensuring efficient management of supply and distribution. Water tariffs have been kept low on the argument of making water affordable for the poor. But the present situation is such that most urban poor are not at all connected to the formal water supply network and hence do not benefit from low tariffs (Mathur and Thakur, 2006). While the burden of unreliable water supply is felt by all sections of the society, it is more pronounced in case of the urban poor households. The cost of coping with unreliable water supply is the highest on low income groups (LIGs) of the urban poor. An intermittent water supply forces the poor to forego work during the period of water supply. Alternatively, they are required to pay much higher cost for supply from illegal or informal networks. The impact on women and children is also higher as they are most likely to be involved in bringing water to home.

6.15 24x7 Water Supply is a Focus Area for Future

Introduction of continuous water supply (24x7) is one of the focus areas for urban water supply schemes. Many cities in India have sufficient water resources availability but could supply water for only a few hours a day. The key steps in moving towards continuous 24x7 water supply lie in NRW reduction coupled with wide-spread introduction of metering. Present study indicates that contrary to the general perception, the overall water demand has gone down after the introduction of continuous water supply.

Rajasthan which faces scarcity of potable water, requires more holistic and integrated water resources management strategies to be evolved and implemented. Collective action is necessary to bring together the public sector, the private sector, civil society and other stakeholders to work together towards integrated and participatory solutions for water resources planning and management.

Experiences on Indian cities (as explained in chapter 3) long duration studies are carried out on large area with extensive capital work. In these cities water supply situation were very poor when these projects started. There desired results had been obtained over a long period of time. The ultimate aim of any water supply utility to reduce NRW, provide 24x7 water to their consumers and recover its O&M costs. In the present study relatively small pilot areas with short duration had been selected, with the objective to study the feasibility of 24x7 water supply with NRW reduction and impart confidence among PHED officials and public toward 24x7 water supply.

In this chapter results/ findings of observations made to study the NRW of Jaipur city, 24x7 water supplies in selected pilot area, study of water demand on different water pressure and feedback from consumers, PHED officials and public representatives has been discussed in detail with graphical representations. Findings of the discussions has become part of next chapter i.e. conclusions.

CHAPTER 7
CONCLUSIONS

Water is a very precious natural resource of the earth and hence a unique feature of our planet earth. It is extremly essential for human beings, plants and animals. Due to the presence of water, earth is often called watery planet. However, this precious resource is in a delicate equilibrium.

India is at the early stage of the urbanisation process. Exponential growth is being witnessed in many cities. By the year 2030, the urban population is expected to reach more than 590 million. This will put enormous pressure on all the existing natural resources, especially water. Despite sufficient availability of raw water, many of our cities struggle to provide more than a few hours of water supply.

There are International Standards which state that the consumers should get continuous 24x7 potable water supply. Till now only few developed countries / cities have achieved this norm. The key to provide 24x7 water supplies is to reduce Non-Revenue Water.

7.1 Non-Revenue Water (NRW)

From the present study of NRW data pertaining to the Divisions of Jaiput City, it is revealed that NRW in the North Divisions are average 6.31% more than the NRW in the South Division. North Divisions include the walled city with old water supply distribution system which is the main reason of more leakages in that area. The problem of higher leakages in congested streets of walled city cause difficulty in proper repair and maintenance. This also gives rise to water quality problem in that area. There is an urgent need to give attention in that area to check leakages and solve water quality and pressure problems in that area. The water conserved through leak reduction will solve the water quantity and pressure problems along with creating the enhanced revenue out of water supply.

There is an average supply of 3960 lac litres of water in Jaipur city and as per the studies NRW is 34.91%. Even if the NRW achievable target be kept 20% then 590 lac litres of additional water and corresponding revenue can be generated. This will also ease the pressure of raising the water tariff.

7.2 Study of 24x7 Water Supply

From the study of 24x7 continuous water supplies it is concluded that it does not require more water. This can be very well achieved in same or even slightly less quantity of water required than that amount required for an intermittent supply. Due to continuous supply leaks be detected easily and rectified immediately. After attending to all the leakages, further leakages in distribution system can be brought to a very low level in comparison to intermittent supplies. Here, the water supply lines remain charged hence possibility of contamination is ruled out. As per survey 13% consumers have reported quality problem (1-2 instance of water quality in a month), needs further investigation by regular water quality test at consumer end. 24x7 water supplies also eliminate water quantity and pressure problems. Feedbacks from consumers also reveal that people store nil or less water hence water wastage in the form of emptying and draining out of unused stored water in the next day is almost negligible.

Study of Water Consumption at Different Water Pressures

Study of consumption in Malaviya Nagar DMA revealed that there is no effect of water pressure variation on water consumption, if there are no leakages in the distribution system. Leakages in continuous supplies are identified easily and hence can be repaired promptly.

Low water tariff with argument to keep water affordable to poor, do not benefit to the section which are not connected to the formal water supply network.

Implementation of NRW reduction programme requires specialized strategies which include establishment of proper leakage control programme, tariff revision, consumer meter change over programme, NRW control unit, training of PHED staff, planned maintenance programme as well as initiation or continuance of appropriate policy decisions by the top administrators or policy makers. Following steps are extremely necessary in order to reduce NRW:

(i) Planned Maintenance Programme

(ii) Tariff Revision

(iii) Need for Consumer Meter Change-over/ upgradation Programme

(iv) Establishment of NRW Control Unit(s)

(v) Training of PHED staff

(vi) Review of Existing Practices and Procedures

(vii) Prompt or timely policy decisions for water tariff revision, replacement of non-functional meters with quality water meters, implementation of planned leakage reduction programme, regularize illegal connections, taking all the necessary steps for implementation of 24x7 water supply in the new areas are required.

Improving water availability in cities requires addressing complex policy, funding and institutional challenges. Collective vision needed to provide good quality, reliable, affordable and continuous (24x7) water supply to the general public.

7.3 Specific Contribution of this Research Work

The following points have been clearly identified and listed as the contribution from this study:

- 24x7 water supply has increased the service reliability with respect to water availability among consumers in pilot study areas.
- Due to leakage removal, the loss of water (i.e., NRW) has been reduced to a great extent in the pilot study areas.
- Per capita consumption has also been reduced in the pilot study areas due to prevention of leakage.
- Greater satisfaction of consumers, with overall less supply of water to the pilot areas as compared to their earlier supplies has been achieved.
- Adequate water pressure has been created, which is even sufficient to fill overhead water storage tanks of consumers. Hence energy saving to lift the water to overhead storage has been achieved.
- Due to pressurized pipes and continuous supply, the risk of intrusion was reduced.
- Increased knowledgebase about the distribution system types of leakages / theft /losses / metering errors / condition of meters etc.
- NRW studies have broken several myths of the PHED and consumers regarding the 24x7 water supply.
- This study will be helpful to give confidence to the policy makers regarding introduction of 24x7 water supply to newer urban areas.

7.4 Recommendations for Future Work

(i) A study can be conducted to determine the various components of Non Revenue Water. Based on this study on NRW components, further NRW reduction strategy can be planned.

(ii) Further study can be initiated to determine the optimum level of NRW and the most cost effective method of leakage control.

(iii) Delay which can be attained in capacity enhancement i.e., capital expenditure due to increase in water availability with reduction in NRW can also be studied.

(iv) Effects of small efforts and small expenditure made on minor works like proper metering, leakage reduction, installation of bulk meters, valves, replacement of small lines, IEC activities etc. on NRW can as well be studied. Based on this study short term, medium term and long term plans can be prepared.

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ANNEXURE - I

WATER TARIFFS IN SOME CITIES OF INDIA

Water Tariff in Bangalore (Karnataka, India)

Water Consumption / month (in litres)	Water tariff per 1000 litres
(A) Domestic	
0 to 8000	₹ 6.00 (min. ₹ 48/ month)
8001 to 25000	₹ 9.00
25001 to 50000	₹ 15.00
50001 to 75000	₹ 30.00
75001 to 100000	₹ 36.00
100000 and above	₹ 36.00
(B) Non-Domestic	
0 to 10000	₹ 36.00 (min. ₹ 360/ month)
10001 to 20000	₹ 39.00
20001 to 40000	₹ 44.00
40001 to 60000	₹ 51.00
60001 to 100000	₹ 57.00
100000 and above	₹ 60.00

[Source: bwssb.org/water-tariff-prorata]

Water Tariff in Chennai (Tamilnadu, India)

Water Consumption / month (in litres)	Water tariff per 1000 litres
(A) Domestic	
0 to 10000	₹ 2.50 (min. ₹ 50/ month)
10001 to 15000	₹ 10.00
15001 to 25000	₹ 15.00
Above 25000	₹ 25.00
(B) Commercial	
Private Hospitals upto 500 kl	₹ 50.00 (min. ₹ 800/ month)
All Others upto 500 kl	₹ 35.00 (min. ₹ 400)
Private Hospitals above 500 kl	₹ 80.00 for entire quantity (min. ₹ 800)
All Others above 500 kl	₹ 60.00 for entire quantity (min. ₹ 650)
(C) Partially Commercial	
0 to 10000	₹ 5.00 (min. ₹ 150/ month)
10001 to 15000	₹ 15.00
Above 15000	₹ 25.00

[Source: Chennaimetrowater.nic.in]

Water Tariff in Kolkata (West Bengal, India)

Water Consumption / month (in litres)	Water tariff per 1000 litres
Domestic	₹ 7.00
Commercial	₹ 18.00
Domestic + Partially Commercial	₹ 15.00

[Source: kmcgov.in/KMCportal/jsp/water]

Water Tariff in Hyderabad(Andhra Pradesh/ Telangana, India)

Water Consumption / month (in litres)	Water tariff per 1000 litres
(A) Domestic	
Upto 15000 (Slums)	₹ 7.00 (min. ₹ 55/ month)
Upto 15000	₹ 10.00
15001-30000	₹ 12.00
30001-50000	₹ 22.00
50001-100000	₹ 27.00
100001-200000	₹ 35.00
Above 200000 (entire quantity)	₹ 40.00
(B) Non-Domestic	
Upto 15000	₹ 20.00 (min. ₹ 200/ month)
15001-100000	₹ 35.00
100001-200000	₹ 50.00
Above 200000 (entire quantity)	₹ 50.00
(C) Industrial	
Upto 15000	₹ 25.00
15001-100000	₹ 40.00
100001-200000	₹ 60.00
Above 200000 (entire quantity)	₹ 60.00
Water based units (entire quantity)	₹ 100.00

[Source: www.hyderabadwater.gov.in]

ANNEXURE - II

SALIENT FEATURES OF JAIPUR WATER SUPPLY SCHEME

S.No	PARTICULARS		
1.	Population Year 2011	**30.73**	Lacs
2.	Present Population 2013	**32.61**	Lacs
3.	Population Connected to Piped Scheme	**29.70**	Lacs
4.	Water Requirement	**4655**	Lac Litres
5.	Water Production	**3960**	Lac Litres
	(a) Tube Well	**920**	Lac Litres
	(b) Bisalpur system	**3040**	Lac Litres
	(c) Hand Pumps	**10**	Lac Litres
	(d) 125 mm Tubewell	**15**	Lac Litres
6.	Water Supplied per person per day	**133**	Litres
7.	Present Sources		
	(a) Tube Well	**1858**	
	(b) Hand Pumps (Working)	**1073**	
	(c) Tanker trips per day	**787**	
	(d) Water supplied through tankers	**31.48**	Lac Litres
	(e) Number of PVC tanks	**510**	
	(f) Total Supply Zones	**162**	
8.	Water Treatment		
	(a) Ramgarh Lake	Filtration & Chlorination through plant	
	(b) From Tube Wells	Chlorination	
9.	Clear Water Resorvoires	**78**	Nos.
10.	Service Resorvoires	**95**	Nos.
11.	Water Connection (As on April 13)		
	Total Connections	**396620**	
	(a) Running Connection	**356970**	
	(b) Metered Connection	**389796**	
	(c) Connections having flat rate	**6824**	
12.	Domestic Connection	**306368**	
13.	Non-Domistic Connection	**41860**	
14.	Industrial Connection	**2212**	
15.	PSP Connection	**1170**	
16.	Non-Functional Water Meters ½"	**140231**	

ANNEXURE - III

THE SALIENT FEATURES OF RAMGARH DAM

1	Gross Storage Capacity	74.80 Million Cubic Metre
2	FRL	404 metre
3	River	Ban Ganga
4	Completion year	1903
5	Length of Dam	1143 metre
6	Dam Height	26 metre

ANNEXURE - IV

THE SALIENT FEATURES OF BISALPUR DAM

1	Gross Storage Capacity	38.0 TMC
2	FRL	315.5 Metre
3	Designated yield at 75% dependability	32.2 TMC
4	Proposed Utilisation	
	(a) Drinking Water	Total Potential 16.2 TMC (a) For Jaipur 11.2 TMC (b) For Ajmer 5.0 TMC
	(b) Irrigation	8.0 TMC
	(c) Losses	8.0 TMC
	(d) Total	32.2 TMC

ANNEXURE - V

Monthly Average of Daily Production & Supply of Drinking water : Jaipur City for Feb 2012

S.No.	Name of the Division	Drinking water supply required as per the number of connections (MLD)	CWR (SCADA) /(MLD)		Direct pumping		Qty. of Water received from other zone (MLD)	Qty. of Water transferred to other zone (MLD)	No. of Other Public Sources			Estimated Production of other Sources (11+12+13) (MLD)	Total Supply (5+6+8+9-10+14) (MLD)	Qty. of water for which bills raised for the zone (MLD)	Diff between Column (4 -15) (MLD)	NRW (15-16) (MLD)	% NRW col 18*100/ (col 15)
			Bisalpur Dam	Tube Wells	No. of tube wells	Production in (MLD)			HP's	SP's	Tankers						
1	2	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	CITY Division North I	100.36	73.80	10.56	180	17.85	19.84	40.04	69	12	145	0.83	82.82	50.81	17.53	32.01	38.65
2	CITY Division North II	99.62	40.27	10.35	246	6.36	23.37	1.51	630	58	435	2.19	81.03	45.35	18.59	35.68	44.04
3	CITY Division South I	119.22	68.09	3.93	157	19.45	9.60	9.65	62	31	106	1.01	92.42	63.22	26.80	29.19	31.59
4	CITY Division South II	125.70	68.23	7.88	215	29.18	4.60	4.58	311	50	89	1.57	106.88	72.85	18.82	34.03	31.84
	Total	444.90	250.40	32.71	798	72.84	57.41	55.78	1072	151	774.92	5.59	363.16	232.24	81.74	130.92	36.05

Monthly Average of Daily Production & Supply of Drinking water : Jaipur City for Mar 2012

S.No.	Name of the Division	Drinking water supply required as per the number of connections (MLD)	CWR (SCADA) /(MLD)		Direct pumping		Qty. of Water received from other zone (MLD)	Qty. of Water transferred to other zone (MLD)	No. of Other Public Sources			Estimated Production of other Sources (11+12+13) (MLD)	Total Supply (5+6+8+9-10+14) (MLD)	Qty. of water for which bills raised for the zone (MLD)	Diff between Column (4 -15) (MLD)	NRW (15-16) (MLD)	% NRW col 18*100/ (col 15)
			Bisalpur Dam	Tube Wells	No. of tube wells	Production in (MLD)			HP's	SP's	Tankers						
1	2	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	CITY Division North I	100.36	75.63	10.79	180	17.70	20.63	41.23	69	12	156	0.87	84.39	50.81	15.97	33.58	39.79
2	CITY Division North II	98.94	39.11	10.35	246	6.27	23.57	1.54	630	58	435	2.19	79.94	45.35	18.99	34.60	43.28
3	CITY Division South I	119.22	64.32	3.28	163	20.82	8.02	8.02	62	25	115	0.94	89.36	60.91	29.86	28.45	31.83
4	CITY Division South II	125.70	69.75	8.78	213	29.06	4.60	4.60	311	50	80	1.53	109.11	72.85	16.59	36.26	33.23
	Total	444.22	248.82	33.19	802	73.84	56.82	55.39	1072	145	786	5.53	362.81	229.92	81.41	132.88	36.63

Monthly Average of Daily Production & Supply of Drinking water : Jaipur City for Apr 2012

S.No.	Name of the Division	Drinking water supply required as per the number of connections (MLD)	CWR (SCADA) /(MLD)		Direct pumping		Qty. of Water received from other zone (MLD)	Qty. of Water transferred to other zone (MLD)	No. of Other Public Sources			Estimated Production of other Sources (11+12+13) (MLD)	Total Supply (5+6+8+9-10+14) (MLD)	Qty. of water for which bills raised for the zone (MLD)	Diff between Column (4 -15) (MLD)	NRW (15-16) (MLD)	% NRW col 18*100/ (col 15)
			Bisalpur Dam	Tube Wells	No. of tube wells	Production in (MLD)			HP's	SP's	Tankers						
1	2	4	5	6	7	8	9	10	11	12	13	14	15	1	2	4	5
1	CITY Division North I	100.35	77.96	11.31	182	17.55	17.61	37.65	69	12	162	0.90	87.67	50.81	12.68	36.86	42.04
2	CITY Division North II	99.62	41.78	10.33	246	6.06	23.40	1.44	630	58	396	2.07	82.20	45.53	17.42	36.67	44.61
3	CITY Division South I	119.22	68.96	5.22	170	22.18	9.87	10.35	63	29	102	0.93	96.81	64.75	22.41	32.06	33.12
4	CITY Division South II	125.70	70.23	11.24	219	28.85	4.57	4.60	311	50	69	1.49	111.78	73.39	13.92	38.40	34.35
	Total	444.89	258.92	38.10	817	74.64	55.44	54.03	1073	149	729	5.39	378.46	234.48	66.43	143.98	38.04

Monthly Average of Daily Production & Supply of Drinking water : Jaipur City for May 2012

S.No.	Name of the Division	Drinking water supply required as per the number of connections (MLD)	CWR (SCADA) /(MLD)		Direct pumping		Qty. of Water received from other zone (MLD)	Qty. of Water transferred to other zone (MLD)	No. of Other Public Sources			Estimated Production of other Sources (11+12+13) (MLD)	Total Supply (5+6+8+9-10+14) (MLD)	Qty. of water for which bills raised for the zone (MLD)	Diff between Column (4 -15) (MLD)	NRW (15-16) (MLD)	% NRW col 18*100/ (col 15)
			Bisalpur Dam	Tube Wells	No. of tube wells	Production in (MLD)			HP's	SP's	Tankers						
1	2	4	5	6	7	8	9	10	11	12	13	14	15	1	2	4	5
1	CITY Division North I	100.35	79.44	10.88	183	16.26	16.63	34.96	69	12	195	1.03	89.28	50.81	11.07	38.47	43.09
2	CITY Division North II	99.63	44.21	10.05	246	3.13	20.99	0.00	630	58	317	1.69	80.07	48.14	19.56	31.93	39.88
3	CITY Division South I	119.22	74.59	5.17	174	22.37	10.19	11.68	63	30	96	0.92	101.58	64.36	17.64	37.21	36.64
4	CITY Division South II	125.70	73.15	15.35	231	30.26	4.10	4.60	311	50	81	1.53	119.80	80.86	5.90	38.94	32.50
	Total	444.90	271.40	41.46	835	72.02	51.91	51.24	1073	150	688	5.18	390.73	244.18	54.17	146.55	37.51

Monthly Average of Daily Production & Supply of Drinking water : Jaipur City for Jun 2012

S.No.	Name of the Division	Drinking water supply required as per the number of connections (MLD)	CWR (SCADA) /(MLD)		Direct pumping		Qty. of Water received from other zone (MLD)	Qty. of Water transferred to other zone (MLD)	No. of Other Public Sources			Estimated Production of other Sources (11+12+13) (MLD)	Total Supply (5+6+8+9-10+14) (MLD)	Qty. of water for which bills raised for the zone (MLD)	Diff between Column (4 -15) (MLD)	NRW (15-16) (MLD)	% NRW col 18*100/ (col 15)
			Bisalpur Dam	Tube Wells	No. of tube wells	Production in (MLD)			HP's	SP's	Tankers						
1	2	4	5	6	7	8	9	10	11	12	13	14	15	1	2	4	5
1	CITY Division North I	100.35	81.66	10.40	183	16.26	15.88	30.91	69	12	302	1.46	94.76	50.81	5.59	43.94	46.37
2	CITY Division North II	100.15	45.63	10.05	246	3.13	20.99	0.00	630	58	586	2.77	82.56	48.14	17.59	34.43	41.70
3	CITY Division South I	119.22	78.54	4.20	174	21.65	10.27	10.91	63	30	139	1.17	104.92	63.65	14.30	41.27	39.34
4	CITY Division South II	125.70	81.41	12.36	232	29.32	4.10	4.60	311	50	119	1.69	124.28	80.96	1.42	43.32	34.85
	Total	445.42	287.24	37.00	835	70.37	51.24	46.42	1073	150	1145	7.08	406.52	243.56	38.90	162.96	40.09

Monthly Average of Daily Production & Supply of Drinking water : Jaipur City for Jul 2012

S.No.	Name of the Division	Drinking water supply required as per the number of connections (MLD)	CWR (SCADA) /(MLD)		Direct pumping		Qty. of Water received from other zone (MLD)	Qty. of Water transferred to other zone (MLD)	No. of Other Public Sources			Estimated Production of other Sources (11+12+13) (MLD)	Total Supply (5+6+8+9-10+14) (MLD)	Qty. of water for which bills raised for the zone (MLD)	Diff between Column (4 -15) (MLD)	NRW (15-16) (MLD)	% NRW col 18*100/ (col 15)
			Bisalpur Dam	Tube Wells	No. of tube wells	Production in (MLD)			HP's	SP's	Tankers						
1	2	4	5	6	7	8	9	10	11	12	13	14	15	1	2	4	5
1	CITY Division North I	100.35	82.45	9.01	183	15.32	17.52	32.51	69	12	266	1.31	93.10	50.81	7.25	42.29	45.42
2	CITY Division North II	100.28	48.14	10.05	246	3.13	20.99	0.00	630	58	639	2.98	85.28	48.14	14.99	37.15	43.56
3	CITY Division South I	119.22	77.18	3.52	173	21.38	10.16	10.86	63	31	142	1.00	102.38	63.67	16.84	38.72	37.82
4	CITY Division South II	125.70	82.18	19.56	232	24.74	4.10	4.60	311	50	132	1.74	127.72	82.36	-2.02	45.36	35.51
	Total	445.55	289.94	42.14	834	64.58	52.76	47.97	1073	151	1179	7.03	408.49	244.98	37.06	163.51	40.03

Monthly Average of Daily Production & Supply of Drinking water : Jaipur City for Aug 2012

S.No.	Name of the Division	Drinking water supply required as per the number of connections (MLD)	CWR (SCADA) /(MLD)		Direct pumping		Qty. of Water received from other zone (MLD)	Qty. of Water transferred to other zone (MLD)	No. of Other Public Sources			Estimated Production of other Sources (11+12+13) (MLD)	Total Supply (5+6+8+9-10+14) (MLD)	Qty. of water for which bills raised for the zone (MLD)	Diff between Column (4 -15) (MLD)	NRW (15-16) (MLD)	% NRW col 18*100/ (col 15)
			Bisalpur Dam	Tube Wells	No. of tube wells	Production in (MLD)			HP's	SP's	Tankers						
1	2	4	5	6	7	8	9	10	11	12	13	14	15	1	2	4	5
1	CITY Division North I	101.49	81.41	6.65	179	15.27	11.20	29.75	69	12	181	0.97	85.76	51.21	15.73	34.55	40.28
2	CITY Division North II	99.82	45.00	10.05	246	3.13	20.99	0.00	630	58	492	2.40	81.57	48.14	18.25	33.43	40.99
3	CITY Division South I	119.22	71.75	4.12	173	22.35	10.21	10.94	63	33	130	1.00	98.49	64.20	20.73	34.29	34.82
4	CITY Division South II	126.09	75.50	13.70	233	24.73	4.09	4.57	311	50	100	1.61	115.06	82.38	11.03	32.68	28.41
	Total	446.61	273.67	34.51	830	65.48	46.50	45.26	1073	153	902	5.98	380.88	245.93	65.74	134.95	35.43

Monthly Average of Daily Production & Supply of Drinking water: Jaipur City for Sep 2012

S.No.	Name of the Division	Drinking water supply required as per the number of connections (MLD)	CWR (SCADA) /(MLD)		Direct pumping		Qty. of Water received from other zone (MLD)	Qty. of Water transferred to other zone (MLD)	No. of Other Public Sources			Estimated Production of other Sources (11+12+13) (MLD)	Total Supply (5+6+8+9-10+14) (MLD)	Qty. of water for which bills raised for the zone (MLD)	Diff between Column (4 -15) (MLD)	NRW (15-16) (MLD)	% NRW col 18*100/ (col 15)
			Bisalpur Dam	Tube Wells	No. of tube wells	Production in (MLD)			HP's	SP's	Tankers						
1	2	4	5	6	7	8	9	10	11	12	13	14	15	1	2	4	5
1	CITY Division North I	102.43	83.44	4.55	175	14.79	8.34	27.10	69	12	169	0.93	84.95	51.87	17.48	33.07	38.93
2	CITY Division North II	100.01	44.13	10.08	246	3.41	20.77	0.00	630	58	506	2.45	80.84	48.46	19.17	32.38	40.06
3	CITY Division South I	119.22	69.95	4.29	172	22.10	9.99	10.97	63	34	121	0.99	96.37	64.75	22.85	31.62	32.81
4	CITY Division South II	138.05	71.86	10.60	256	29.06	3.64	3.72	311	50	93	1.58	113.03	79.92	25.02	33.11	29.30
	Total	459.71	269.38	29.53	848	69.37	42.74	41.79	1073	154	890	5.95	375.18	245.00	84.53	130.18	34.70

Monthly Average of Daily Production & Supply of Drinking water : Jaipur City for Oct 2012

S.No.	Name of the Division	Drinking water supply required as per the number of connections (MLD)	CWR (SCADA) /(MLD)		Direct pumping		Qty. of Water received from other zone (MLD)	Qty. of Water transferred to other zone (MLD)	No. of Other Public Sources			Estimated Production of other Sources (11+12+13) (MLD)	Total Supply (5+6+8+9-10+14) (MLD)	Qty. of water for which bills raised for the zone (MLD)	Diff between Column (4 -15) (MLD)	NRW (15-16) (MLD)	% NRW col 18*100/ (col 15)
			Bisalpur Dam	Tube Wells	No. of tube wells	Production in (MLD)			HP's	SP's	Tankers						
1	2	4	5	6	7	8	9	10	11	12	13	14	15	1	2	4	5
1	CITY Division North I	102.43	83.43	4.11	171	13.41	10.25	29.70	69	12	153	0.86	82.36	52.20	20.07	30.16	36.62
2	CITY Division North II	101.25	41.97	10.20	244	4.32	20.05	0.00	630	58	433	2.16	78.69	49.51	22.56	29.18	37.08
3	CITY Division South I	119.22	73.73	4.17	169	21.86	9.81	11.36	63	34	117	0.91	99.11	67.64	20.11	31.47	31.76
4	CITY Division South II	138.60	75.52	11.54	262	32.91	3.00	3.00	311	50	86	1.55	121.53	83.39	17.07	38.14	31.38
	Total	461.51	274.65	30.01	846	72.50	43.11	44.06	1073	154	788	5.48	381.69	252.74	79.81	128.95	33.78

Monthly Average of Daily Production & Supply of Drinking water : Jaipur City for Nov 2012

S.No.	Name of the Division	Drinking water supply required as per the number of connections (MLD)	CWR (SCADA) /(MLD)		Direct pumping		Qty. of Water received from other zone (MLD)	Qty. of Water transferred to other zone (MLD)	No. of Other Public Sources			Estimated Production of other Sources (11+12+13) (MLD)	Total Supply (5+6+8+9-10+14) (MLD)	Qty. of water for which bills raised for the zone (MLD)	Diff between Column (4 -15) (MLD)	NRW (15-16) (MLD)	% NRW col 18*100/ (col 15)
			Bisalpur Dam	Tube Wells	No. of tube wells	Production in (MLD)			HP's	SP's	Tankers						
1	2	4	5	6	7	8	9	10	11	12	13	14	15	1	2	4	5
1	CITY Division North I	102.43	83.88	3.52	171	12.15	9.25	28.42	69	12	148	0.84	81.22	52.20	21.21	29.02	35.73
2	CITY Division North II	101.25	41.73	10.20	244	4.32	20.05	0.00	630	58	403	2.03	78.33	49.51	22.92	28.82	36.79
3	CITY Division South I	119.22	75.78	3.76	168	21.23	9.98	11.43	63	34	110	0.88	100.20	67.94	19.02	32.26	32.19
4	CITY Division South II	138.60	77.95	10.36	263	32.01	3.00	3.00	311	50	60	1.45	121.77	82.31	16.83	39.46	32.41
	Total	461.51	279.34	27.83	846	69.71	42.29	42.86	1073	154	721	5.21	381.52	251.96	79.99	129.56	33.96

Monthly Average of Daily Production & Supply of Drinking water : Jaipur City for Dec 2012

S.No.	Name of the Division	Drinking water supply required as per the number of connections (MLD)	CWR (SCADA) /(MLD)		Direct pumping		Qty. of Water received from other zone (MLD)	Qty. of Water transferred to other zone (MLD)	No. of Other Public Sources			Estimated Production of other Sources (11+12+13) (MLD)	Total Supply (5+6+8+9-10+14) (MLD)	Qty. of water for which bills raised for the zone (MLD)	Diff between Column (4 -15) (MLD)	NRW (15-16) (MLD)	% NRW col 18*100/ (col 15)
			Bisalpur Dam	Tube Wells	No. of tube wells	Production in (MLD)			HP's	SP's	Tankers						
1	2	4	5	6	7	8	9	10	11	12	13	14	15	1	2	4	5
1	CITY Division North I	102.43	81.34	3.78	171	12.30	8.73	27.83	69	12	129	0.77	79.08	52.74	23.35	26.34	33.31
2	CITY Division North II	101.25	41.38	10.20	244	4.32	20.05	0.00	630	58	411	2.04	77.98	49.51	23.27	28.47	36.51
3	CITY Division South I	119.22	74.24	3.70	170	22.15	9.85	11.45	63	35	107	0.89	99.38	68.67	19.84	30.71	30.90
4	CITY Division South II	141.88	74.39	9.78	267	28.87	3.00	3.00	311	50	45	1.39	114.43	82.55	27.45	31.89	27.86
	Total	464.78	271.34	27.45	852	67.64	41.63	42.28	1073	155	693	5.09	370.87	253.46	93.91	117.41	31.66

Monthly Average of Daily Production & Supply of Drinking water : Jaipur City for Jan 2013

S.No.	Name of the Division	Drinking water supply required as per the number of connections (MLD)	CWR (SCADA) /(MLD)		Direct pumping		Qty. of Water received from other zone (MLD)	Qty. of Water transferred to other zone (MLD)	No. of Other Public Sources			Estimated Production of other Sources (11+12+13) (MLD)	Total Supply (5+6+8+9-10+14) (MLD)	Qty. of water for which bills raised for the zone (MLD)	Diff between Column (4 -15) (MLD)	NRW (15-16) (MLD)	% NRW col 18*100/ (col 15)
			Bisalpur Dam	Tube Wells	No. of tube wells	Production in (MLD)			HP's	SP's	Tankers						
1	2	4	5	6	7	8	9	10	11	12	13	14	15	1	2	4	5
1	CITY Division North I	102.45	81.35	3.32	175	9.99	8.85	26.79	69	12	127	0.76	77.48	53.60	24.96	23.88	30.83
2	CITY Division North II	101.25	41.07	10.20	244	4.32	20.05	0.00	630	58	421	2.11	77.74	49.51	23.51	28.23	36.32
3	CITY Division South I	119.22	73.57	4.29	168	21.07	9.88	11.48	63	36	109	0.85	98.17	68.41	21.05	29.76	30.32
4	CITY Division South II	142.51	75.71	8.94	271	28.69	3.00	3.00	311	50	40	1.37	114.71	82.49	27.80	32.22	28.09
	Total	465.43	271.70	26.74	859	64.06	41.78	41.27	1073	156	698	5.09	368.11	254.01	97.32	114.10	31.00

Monthly Average of Daily Production & Supply of Drinking water : Jaipur City for Feb 2013

S.No.	Name of the Division	Drinking water supply required as per the number of connections (MLD)	CWR (SCADA) /(MLD)		Direct pumping		Qty. of Water received from other zone (MLD)	Qty. of Water transferred to other zone (MLD)	No. of Other Public Sources			Estimated Production of other Sources (11+12+13) (MLD)	Total Supply (5+6+8+9-10+14) (MLD)	Qty. of water for which bills raised for the zone (MLD)	Diff between Column (4 -15) (MLD)	NRW (15-16) (MLD)	% NRW col 18*100/ (col 15)
			Bisalpur Dam	Tube Wells	No. of tube wells	Production in (MLD)			HP's	SP's	Tankers						
1	2	4	5	6	7	8	9	10	11	12	13	14	15	1	2	4	5
1	CITY Division North I	102.47	82.02	3.46	176	9.54	8.31	26.23	69	12	132	0.78	77.88	53.59	24.59	24.29	31.19
2	CITY Division North II	101.25	42.27	10.20	244	4.32	20.05	0.00	630	58	480	2.35	79.18	49.51	22.08	29.66	37.47
3	CITY Division South I	119.22	75.40	3.35	170	20.14	10.18	11.52	63	37	122	0.84	98.39	68.77	20.83	29.62	30.10
4	CITY Division South II	142.51	89.71	8.31	272	28.80	3.00	3.00	311	50	48	1.40	128.23	80.55	14.28	47.67	37.18
	Total	465.45	289.40	25.31	862	62.80	41.54	40.74	1073	157	782	5.36	383.67	252.43	81.78	131.24	34.21

Monthly Average of Daily Production & Supply of Drinking water : Jaipur City for Mar 2013

S.No.	Name of the Division	Drinking water supply required as per the number of connections (MLD)	CWR (SCADA) /(MLD)		Direct pumping		Qty. of Water received from other zone (MLD)	Qty. of Water transferred to other zone (MLD)	No. of Other Public Sources			Estimated Production of other Sources (11+12+13) (MLD)	Total Supply (5+6+8+9-10+14) (MLD)	Qty. of water for which bills raised for the zone (MLD)	Diff between Column (4 -15) (MLD)	NRW (15-16) (MLD)	% NRW col 18*100/ (col 15)
			Bisalpur Dam	Tube Wells	No. of tube wells	Production in (MLD)			HP's	SP's	Tankers						
1	2	4	5	6	7	8	9	10	11	12	13	14	15	1	2	4	5
1	CITY Division North I	102.47	87.08	3.33	176	9.28	10.02	27.44	69	12	157	0.88	83.14	55.12	19.33	28.02	33.70
2	CITY Division North II	101.25	40.88	10.20	244	4.32	16.56	0.00	630	58	514	2.48	74.44	49.51	26.81	24.93	33.49
3	CITY Division South I	119.22	75.66	2.47	176	19.76	10.92	12.02	63	37	118	0.80	97.59	67.90	21.63	29.69	30.42
4	CITY Division South II	142.51	78.33	6.17	284	31.28	3.97	4.00	311	50	65	1.47	117.21	80.84	25.30	36.37	31.03
	Total	465.45	281.95	22.15	880	64.63	41.47	43.46	1073	157	854	5.63	372.38	253.37	93.07	119.01	31.96

Monthly Average of Daily Production & Supply of Drinking water : Jaipur City for Apr 2013

S.No.	Name of the Division	Drinking water supply required as per the number of connections (MLD)	CWR (SCADA) /(MLD)		Direct pumping		Qty. of Water received from other zone (MLD)	Qty. of Water transferred to other zone (MLD)	No. of Other Public Sources			Estimated Production of other Sources (11+12+13) (MLD)	Total Supply (5+6+8+9-10+14) (MLD)	Qty. of water for which bills raised for the zone (MLD)	Diff between Column (4 -15) (MLD)	NRW (15-16) (MLD)	% NRW col 18*100/ (col 15)
			Bisalpur Dam	Tube Wells	No. of tube wells	Production in (MLD)			HP's	SP's	Tankers						
1	2	4	5	6	7	8	9	10	11	12	13	14	15	1	2	4	5
1	CITY Division North I	102.47	89.63	3.73	163	8.52	9.30	26.70	69	12	191	1.01	85.49	57.23	16.98	28.26	33.06
2	CITY Division North II	101.25	42.20	10.20	244	4.32	17.05	0.00	630	58	495	2.41	76.18	49.51	25.08	26.66	35.00
3	CITY Division South I	119.22	77.85	2.98	174	19.04	10.70	12.03	63	35	112	0.79	99.33	68.57	19.89	30.76	30.97
4	CITY Division South II	142.51	79.54	8.89	284	33.62	4.00	4.00	311	50	79	1.53	123.58	92.00	18.93	31.58	25.56
	Total	465.45	289.22	25.79	865	65.51	41.05	42.73	1073	155	877	5.74	384.58	267.31	80.87	117.27	30.49

Monthly Average of Daily Production & Supply of Drinking water : Jaipur City for May 2013

S.No.	Name of the Division	Drinking water supply required as per the number of connections (MLD)	CWR (SCADA) /(MLD)		Direct pumping		Qty. of Water received from other zone (MLD)	Qty. of Water transferred to other zone (MLD)	No. of Other Public Sources			Estimated Production of other Sources (11+12+13) (MLD)	Total Supply (5+6+8+9-10+14) (MLD)	Qty. of water for which bills raised for the zone (MLD)	Diff between Column (4 -15) (MLD)	NRW (15-16) (MLD)	% NRW col 18*100/ (col 15)
			Bisalpur Dam	Tube Wells	No. of tube wells	Production in (MLD)			HP's	SP's	Tankers						
1	2	4	5	6	7	8	9	10	11	12	13	14	15	1	2	4	5
1	CITY Division North I	102.47	89.32	3.06	144	8.40	5.87	19.01	69	12	236	1.20	88.83	57.23	13.64	31.60	35.57
2	CITY Division North II	101.25	45.13	10.20	244	4.32	17.05	0.00	630	58	513	2.48	79.17	49.51	22.08	29.66	37.46
3	CITY Division South I	119.22	81.52	2.78	172	18.59	10.50	12.20	63	34	131	0.90	102.09	68.57	17.13	33.52	32.83
4	CITY Division South II	142.51	83.19	10.14	284	34.17	4.00	4.00	311	50	99	1.61	129.11	91.85	13.40	37.26	28.86
	Total	465.45	299.16	26.17	844	65.48	37.42	35.21	1073	154	980	6.19	399.21	267.16	66.24	132.04	33.08

ANNEXURE VI

FEEDBACK FORM ON 24x7 WATER SUPPLY (Consumers)

Area : Mansarovar/ Malviya Nagar Jaipur

Sector:…………………

Name: …………………………………. House No:………

Telephone No……………………………….

1.	Are you getting 24x7 water supply?	Yes	No
2.	Are you receiving sufficient water as per your requirement?	Yes	No
3.	Are you getting water with sufficient pressure?	Yes	No
4.	Has your water consumption increased after 24x7 water supply?	Yes	No
5.	Do you feel that 24x7 water supply has improved your living standard / facilities?	Yes	No
6.	Is there any complaint about water quality? If yes, then frequency in a month ………..	Yes	No
7.	Is your water meter working?	Yes	No
8.	Is your water meter replaced on start of 24x7 water supply?	Yes	No
9.	Do you drain stored unused water next day? If yes, then how much ……………….	Yes	No
10.	Is your practice of water storage in home has reduced after 24x7 water supply? If yes, then how much …………….	Yes	No
11.	Is there any change in your water bill after implementation 24x7 water supply? (tick one and give detail) (a) No change (b) Bill increased how much……………% (c) Bill reduced how much……………%	 [ ] [ ] [ ]	
12.	Time taken by PHED in rectification of leakages		
13.	Which type of water supply you like most (tick any one) (a) 24x7 water supply (b) Once in a day for two hours (c) Twice daily in morning and evening for one hour	 [ ] [ ] [ ]	
14.	Do you like to pay some extra money for 24x7 water supply If yes then how much (please tick one) 5% 10% 15% 20% 25% 30%	Yes	no
15.	Any other information		

Signature……………………..

ANNEXURE VII

FEEDBACK FORM ON 24x7 WATER SUPPLY (PHED Officials)

Area : Mansarovar/ Malviya Nagar Jaipur

Sector:…………………

Name: ………………………………….   Designation:…………

Telephone No……………………………….

1.	Do you feel that 24x7 water supply is better than intermittent water supply?	Yes	No
2.	Has water demand increased in 24x7 supply areas?	Yes	No
3.	Is there any complaint about water pressure? If yes, then frequency in a month ……….	Yes	No
4.	Is there any complaint about water quality? If yes, then frequency in a month ………..	Yes	No
5.	Do you feel that it is difficult to maintain 24x7 water supply than intermittent supply?	Yes	No
6.	Is there awareness about conservation of water in consumers ?	Yes	No
7.	Is there any demand from consumers with intermittent supply to convert to 24x7 supply ?	Yes	No
8.	Do you feel that 24x7 water supply is practical or feasible in Jaipur city?	Yes	No
9.	Is frequency of leakages in 24x7 supply area are less than frequency of leakages in other area?	Yes	No
10.	Present level of NRW in Jaipur city (%)		
11.	NRW in Jaipur should be reduced to (%)		
12.	Split of NRW Leakages………………………………. % Faulty Meters………………………..…% Theft……………………………………% Others………………………………..%		
13.	Your opinion about 24x7 water supply		

Signature……………………..

ANNEXURE VIII

FEEDBACK FORM on 24x7 WATER SUPPLY (Public Representative)

Area : Mansarovar/ Malviya Nagar Jaipur

Sector:…………………

Name:…………………………………… Designation:……………

Tel No …………………………

1.	Are consumers more satisfied with 24x7 supply?	Yes	No
2.	Is there any complaint about water quality/pressure If yes, then frequency in a month ………..	Yes	No
3.	Is there awareness about conservation of water in consumers ?	Yes	No
4.	Are consumers willing to pay some extra money on 24x7 water supply?	Yes	No
5.	Is there any demand from consumers with intermittent supply to convert to 24x7 supply ?	Yes	No
6.	What is your opinion about increase in water tariff (please tick one) • Tariff needs to be increased for all consumers • Tariff to be increased to higher income group only whose consumption is more. • Tariff should not be increased.	[ ] [ ] [ ]	
7.	Your opinion about 24x7 water supply		

Signature……………………..

Publications from this Thesis

1. Mathur Y.P. and Vijay, Arvind (2013), “Non Revenue Water Reduction : A Tool for Achiving 24X7 Water Supply ’’, IOSR Journal of Mechanical and Civil Engineering, Vol 7, Issue 3, Jul-Aug 2013.
2. Mathur Y.P. and Vijay, Arvind (2013), “Feasibility of 24x7 Continuous Water Supply in Jaipur city : through NRW Reduction” in International conference on Advanced Trends in Engineering and Technology –ICATET-2013, 19-20 Dec 2013, Jaipur India.

BIO - DATA

The author was born on 28.04.1965 at Hanumangarh (Rajasthan State, India). He graduated in Civil Engineering from M.B.M. Engineering College, Jai Narayan Vyas University, Jodhpur with Honours division in 1987. He did his Master's degree in Civil Engineering (Environmental Engineering) from M.B.M. Engineering College, Jai Narayan Vyas University, Jodhpur with Honours division in 1991. Author did his Post Graduate Diploma in "Project Planning and Infrastructure Management" from University of Rajasthan, Jaipur in 2006.

The author has worked in the Department of Technical Education, Government of Rajasthan for about 9 years in various capacities as Lecturer (Civil) in Govt. Polytechnic College, Jodhpur; Lecturer (Civil) in Learning Resources Development Centre, Jodhpur and as Academic Officer in Board of Technical Education, Rajasthan, Jodhpur.

The author is presently working as Executive Engineer in Public Health Engineering Department, Government of Rajasthan, Jaipur for the past 16 years. He has teaching, engineering and administrative experience of about 25 Years.