EFFECTS OF METERED WATER CONNECTIONS IN A RESIDENTIAL SOCIETY

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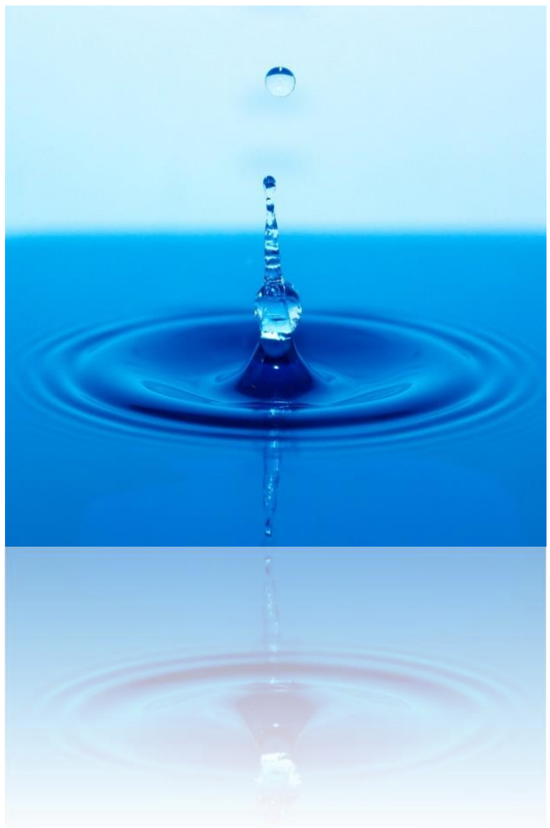
بسم الله الرحمن الرحيم

DEDICATED TO OUR BELOVED PARENTS, TEACHERS AND ALL THOSE WHO HAVE CONTRIBUTED IN THIS PROJECT



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It is to certify that the

Research and Development work titled

EFFECTS OF METERED WATER CONNECTIONS IN A RESIDENTIAL SOCIETY

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For

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ACKNOWLEDGEMENTS

All thanks and praises to Allah Almighty.

We bow our heads with all humility before God for giving us opportunity to complete our research work. Completion of this thesis is the result of cooperation of many dedicated and helpful people. It is difficult to gauge their contributions in helping us to complete this research work.

It is with great pleasure and profound feelings of obligation that we thank Major Dr. Irfan Abid (our syndicate DS), for his genuine concern, advice, invaluable guidance and enthusiastic encouragement throughout our research work. We are profoundly indebted to him.

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LIST OF ABBREVIATIONS

IMF – International Monetary Fund

UNDP-United Nations Development Programme

PCRWR-Pakistan Council of Research in Water Resources

NRW-Non- Revenue Water

MAF-Million Acre Feet

UMP-Universal Metering Programme

ADB-Asian Development Bank

IBNET- The International Bench- marking Network for Water and Sanitation Utilities

DDM-Domestic Demand Model

GPD-Gallons per day

LPCD-Liters per capita per day

ABSTRACT

Water has always been an indispensable resource and of utmost necessity to mankind, water resources have been a major cause of war and conflict. Discrepancies have been seen to be breaking out in many regions of the world as water scarcity progresses. Pakistan is likely to face acute shortage of water by 2025. To prevent such a situation to occur, immediate measures must be taken. Domestic water use conservation is a need of the time to control the ever-increasing use of water because of population increase and urbanization thrust. The installation of water metering systems in the commercial areas as well as the residential areas is a viable option for water conservation.

Water conservation measures primarily based on water metering are actively being taken by many developed countries like USA, France, Germany, UK etc. These methods have proved to be very successful towards the achievement of water conservation in these countries. However, Pakistan is not making use of the available methods amid already depleting ground water resources.

Nexus to above, this research was carried out to promote the concept of metering the domestic water connections to promote water conservation. The broad philosophical underpinning of the research method was largely quantitative. The analysis was based on the data collected, collated and processed after personal visits to Askari XIV. The complete research was conducted smoothly in which a major contribution was provided by the Askari XIV management by their timely responses and provision of relevant data whenever approached.

The water consumption requirement of the society was compared with the existing water supply capacity. The reduction was envisaged based on the results achieved by various countries towards reducing the domestic water demand. The reduction was also envisaged based on applying other NRW reduction techniques. The effects of the water conserved through metering and application of other NRW reduction technique were analyzed in detail. These effects included the effects towards water conservation, effects towards improving public awareness, economic aspects and the environmental aspects.

After the envisaged reduction was pictured, recommendations were made to enforce the effects achievable through the study by introducing bye laws and other regulatory procedures. These bye laws are suggested to applied at all residential societies across Pakistan. This study was conducted in the face of limitations and challenges, the most prominent being that the research related to this topic is almost non-existent in Pakistan. This would however provide some insight to future researchers who intend to continue the endeavor in this field since Pakistan’s literature related to water conservation in general and metering in specific is in its embryonic stages.

CHAPTER 1

INTRODUCTION

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INTRODUCTION

"Say: Have you thought: if (all) your water were to disappear into the earth, who then could bring you water gushing forth?" Al-Mulk [67:30]

"And We send down water from the sky according to measure, and We cause it to soak in the soil; and We certainly are able to drain it off (with ease)" Al-Mumenoon [23:18]

1.1 Overview

Water has always been an indispensable resource and of utmost necessity to mankind, water resources have been a major cause of war and conflict. Discrepancies have been seen to be breaking out in many regions of the world as water scarcity progresses. The countries that shared the same water resources, and the misuse of this shared water bodies lead to outrageous consequences. With the increase in the population, the fresh water available for daily use has been depleting day by day causing man to resort to violent methods to claim these resources.

Earth's surface has had approximately a volume of water equal to 1.4 billion km^3. From this the freshwater resources made up 35 million km^3 or 2.5 percent of the entire volume of water. From these freshwater reserves 24 million km^3 or 70 percent were in the form of ice and snow caps in the Arctic and the Antarctic regions. 30 percent of this freshwater has been found as groundwater (including basins up to 2000 meters), soil moisture, permafrost and water of swamps. These resources added up to 97 percent of the freshwater sources that had been harvested for usage. Approximately, 105,000 km^3 or 0.3 percent of the freshwater was found as water of lakes and rivers. 13,000 km^3 of water was found in the Earth's atmosphere. The total consumable freshwater has been about 200,000 km^3 in volume, which made up a percentage of 1% of the freshwater bodies on Earth. The further breakdown of freshwater resources breakdown is shown in fig – 1.1. It shows that 70% of the Earth's surface is water, 97.5% of which is covered by the oceans and the seas that is the salt water which unfortunately without treatment is not consumable. The rest of the 2.5% is in the various forms of freshwater including lakes, groundwater, waterbeds etc.

Despite the depletion of water resources at a startling rate, water conservation

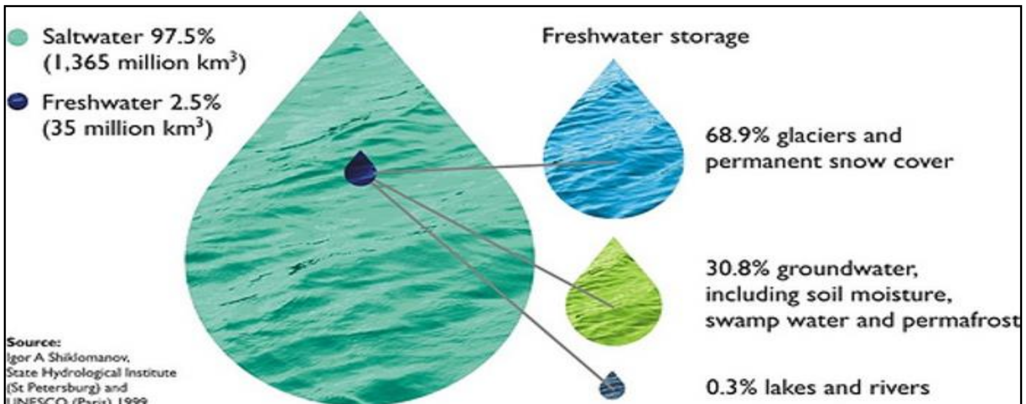

Fig – 1.1: Breakdown of freshwater Resources

awareness and practicing methods have not been up to the mark. Most of the people have been reluctant to change their water usage practices until the need arose for them to cut back on the consumption.

A UNDP report mentioned Pakistani authorities as negligent towards the imminent water crisis faced by the country, along with experts claiming the country to desiccate by 2025. The International Monetary Fund (IMF) claimed that Pakistan held a third place in the most water stressed countries list, with 1,017 cubic meters of per capita water availability with the threshold of scarcity being 1,000 cubic meters. Pakistan's availability for water was approximately 1,500 cubic meters in 2009. It has been declared by the Pakistan Council of Research in Water Resources (PCRWR) that the country would dry up by the year 2025 if no action is taken[1]. It stated that Pakistan grazed the "water stress line" in 1990 and crossed the "water scarcity line" in 2005. Perhaps it could be due to the lack of water storage facilities like dams. No new dams have been constructed in Pakistan since the 1960s. Michael Kugelman, (a Washington-based Woodrow Wilson Center expert), claimed that year after year Pakistan has been nearing the scarcity threshold, along with an excessive and rapid depletion of the groundwater resources. And worst of all is that the authorities failed to ensure substantial actions.

The major issue in Pakistan has not been the Islamic terrorism that makes headlines all around the world rather it was the alarming water scarcity situation that failed to make waves on the media as the former situation. (Shams, 2017)

Water metering has played an essential role in efficient water management, not only this but it has also enabled utilities to use pricing for water conservation and efficiency. As in the absence of water metering systems customers were charged at a flat rate i.e. the same amount irrespective of the consumption. Hence charging on the volume of water used inculcated a sense of conservation in the customers.(Renwick & Green 2000;beecher et al 1994). Metering could also aid in the prevention of leaks and loses therfore helping the utilities and the customers in reserving water and undesired payment for unused water.

[1] https://tribune.com.pk/story/1112704/pakistan-may-run-dry-2025-study/

Nexus to above, we selected Askari-XIV as our pilot study project to evaluate the reduction in water consumption because of water metering. Askari XIV is located in DHA phase IV Islamabad. It has three residential areas with around 600 houses in each sector. It also accommodates an Army Public School and College, mosques, shops in every sector and greenery. A management team of professionals runs its daily affairs in a systematic way and keeps the record up to date. Since the encompasses all the facilities ranging from residential complexes to commercial areas therefore it was a good option for our study.

The project data comprised of the water source input volume, average daily water requirement and calculation of reduction factor achieved through water metering and resultantly savings in carbon emissions. Lastly, the water conserved and the carbon credit saved will be calculated and extrapolated for annual result calculations. The study focused on the domestic water requirement of the society only. The water used for commercial and horticulture activities was not included in our analysis. At present, 88 percent of the total water consumption of Askari XIV is by domestic users, 5 percent by commercial users and 7% for horticulture.

1.2 Problem Statement

As it has been mentioned above, Pakistan is likely to face acute shortage of water by 2025. To prevent such a situation to occur, immediate measures must be taken. Domestic water use conservation is a need of the time to control the ever-increasing use of water because of population increase and urbanization thrust. The installation of water metering systems in the commercial areas as well as the residential areas is a viable option for water conservation**.**

1.3 Objectives

The major objectives of our study are:

- Study outcomes of water metering as a pilot project on a housing society.
- A comparative study of water usage prior to and after metering.
- Economic and water conservation and analysis for the metering system.
- Evaluation of carbon credit reduction via metering.
- Suggest bylaws for the water conservation measures.

1.4 Scope

The scope of our study was:

- To predict the reduction in water consumption based on previous studies carried out by various countries.
- Evaluation of predicted improvements in water availability to the residents after envisaged meter installation.
- Assessing the effects of reduced water consumption, related to public awareness enhancement, economic sustainability and environmental aspects.

1.5 Limitations

The limitations of this project were:

- The water metering technique was studied on the existing water supply system (without metering) as no metered water supply system data was available.

- The concept of metered water connection is in its embryonic stages in Pakistan, hence estimated reduction in water consumption could only be calculated based on results of previous studies carried out in other countries.
- The capital cost required for installation of the meters was neglected.
- The environmental aspects were studied by evaluating the pre- and post-metering carbon emissions.

CHAPTER 2

LITERATURE REVIEW

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Water conservation measures primarily based on water metering are actively being taken by many developed countries like USA, France, Germany, UK etc. These methods have proved to be very successful towards the achievement of water conservation in these countries. However, Pakistan is not making use of the available methods amid already depleting ground water resources. As already discussed in Chapter 1, the situation is heading towards drought in major cities of the country by 2025.

Nexus to above, this research was carried out to promote the concept of metering the water connections to promote water conservation. The broad philosophical underpinning of the research method was largely quantitative.

2.2 Definitions and Explanation of various terms

- **Fresh Water**

  The water having salt content less than 0.5 parts per thousand of dissolved salts.

- **Ground Water**

  The water existing under the surface that runs in the form of saturated soil, glacial deposits or deposits in between rocks and layers.

- **Hydrology**

The study dealing with properties of water, its distribution across the landscapes and its circulation through the ground and in the atmosphere.

- **Impervious surface**

  A surface impermeable to water that causes infiltration and generates run off. Such surfaces are pavement rocks, rooftops, etc.

- **Infiltration**

  The process of water percolation from land into the ground.

- **Outfall**

  The discharge point from a river, pipe or drain to a recipient body of water.

- **Runoff**

  The water flowing on the ground surface, which does not infiltrate into the ground.

- **Surface water**

  Water present on the land surface that flows in the form of channels, or the water contained in depressions such as ponds etc.

- **Water (hydrologic) Cycle**

  The cycle that represents the flow and distribution of water in nature i.e., from the sky onto the earth, into the ground (or runoff) and back to the atmosphere by evaporation. Precipitation, surface runoff, infiltration, channel or depression storage and ground water are the major components of the phenomena.

- **Water conservation**

  Using water in an efficient and wise manner for saving it through the water shortage periods.

- **Acre foot**

The volume of water up to a depth of one foot, present on the land of one acre ($43,560\ ft^3$ or 325851 gallons).

- **Flat Rate**

  Any assemblage of charges that do not depend on the amount of water consumed.

- **Commodity Charges**

  Charges depending and varying on the quantity used.

- **Non-Revenue Water (NRW)**

  Non-revenue water is the difference between the volume of water put into a water distribution system and the volume that is billed to the customers.

- **Carbon Credit**

  Carbon credit is a license or a permit allowing the person holding it to discard one ton of carbon dioxide or an equivalent amount of greenhouse gas with a mass corresponding to one ton of carbon dioxide into earth's atmosphere.

2.3 Water – Importance and Resources

Water has been crucial to sustaining life on Earth and has been deeply integrated into the daily life of man. Not only this but also the economies of the world depend heavily on water. In Pakistan water has been of immense importance due to Pakistan having an agricultural economy which contributes 24 percent of the GDP (Gross National Product). As agriculture requires a timely supply of water for proper crop generation, a major concern of water shortage may arise due to the increasing population and industrialization. Not only this but this rise in population and industrialization has increased the demand and disputes over the available water and its usage. Pakistan's high index of aridity has been playing a role in increasing the significance of water in the developmental activities. (Kahlown & Majeed, 2003)

As history indicates this area was once a water rich and well irrigated land supplied by the mighty Indus River, but now Pakistan is water deficient country barely surviving with its current resources. The per capita water available in Pakistan was approximately 1,100 cubic meters. It is below the level of 1,000 cubic meters when the countries start to experience chronic water stress (Population Action International, 1993). Table 2.1 indicates the per capita availability of water in regions of the world. As mentioned above Pakistan is critically close to a water stress meanwhile the gap between the demand and supply of water is on the rise. The drought conditions experienced in the recent years and the reduction of the fresh water supply has

	Per Capita Availability of Water (m^3 per year)		
Country	**1955**	**1990**	**2025**
China	4,597	2,427	1,818
Philippines	13,507	5,173	3,072
Mexico	11,396	4,226	2,597
USA	14,934	9,913	7,695
Iraq	18,441	6,029	2,356
Pakistan	2,490	1,672	837

Table – 2.1: Per capita availability of water for different regions of the world by 2025 (Population Action International, 1993)

enhanced the importance of unearthing new sources and adapting to water conservation techniques to reserve what little water we have got left.

2.4 Surface Water Resources

Surface water resources of Pakistan have been supplied by River Indus, 2900 kilometers with a drainage-area of 966,000 sq. Km, and the five tributaries. The major tributaries connecting to Indus at the east side are Chenab, Jhelum, Ravi, Sutlej and Beas and the minor ones are Siran, Harow and Soan, these drain the mountain region. Along with this a number of tributaries connect the Indus in the western side including Kabul River. Although the rivers in Pakistan have had discrete attributes, most of the rivers usually rise during springs or early summer due to monsoon rains and melting ice caps contributing water into them. The rivers have been at a low during winters usually from November to February; the water flow becomes one tenth of the quantity during summers. Along with the rivers various smaller rivers and streams flow during certain times of the year and depend on rainfall, running dry during the winters. Annually, the River Indus yields about 138.7 MAF water as indicated by its 77-year record (1922-23 to 1999-2000).

64 percent of total river flow has been contributed by the Indus River alone whereas Jhelum and Chenab contribute 17 % and 19 % respectively. The river flow becomes at its peak during the monsoon season i.e. from June to August. The flow for the Rabi and Kharif crops has been 16% and 84% respectively hence the importance of storing water during the high flow period to be used during the low flow duration has been immense. As a consequence of the Indus Basin signed by India and Pakistan (1960), only three western rivers i.e. Indus, Jhelum and Chenab are the source of water for Pakistan whereas Ravi, Beas and Sutlej supply India. The treaty also permitted constructions of barrages, canals and dams on the Jhelum, Chenab

and Indus for the irrigation of lands that were previously irrigated by Ravi, Sutlej and Beas, transferring about 20 MAF of water. (Kahlown & Majeed, 2003)

Currently the Indus Basin is the most extensive irrigation system in the world including its tributaries, reservoirs (Chashma, Tarbela and Mangla), barrages (19), canals (12), canal commands (45) and various watercourses (99,000). The canal system is 58,450 km in length and includes 88,600 water courses and 160,000 km of farm channels and field ditches.

Another source of surface water is the hill torrent in the hilly areas, although they have not been used to their full potential. 14 prominent hill torrents have been seen in four of Pakistan's provinces, with a potential for the provision of 19 MAF at about 12,000 locations. Table – 2.2 depicts the MAF potential of the provinces. 60% of this can be manipulated for the crop production especially in the wasteland hill torrent areas that have about 6 million acres of potential land. (Kahlown & Majeed, 2003)

Province	Water Development Potential (MAF)
Punjab	2.7
Sindh	0.78
Baluchistan	7.856
KPK	703

Table – 2.2: MAF for provinces of Pakistan. (Kahlown & Majeed, 2003)

2.5 Rainfall

70% of the annual rainfall in Pakistan is from June to September which causes a loss of runoff water from the lower Indus plain into the sea. The average rainfall distribution varies from region to region with 125mm in the South-East (Baluchistan) to 750mm in the North. As the weather can never be truly predicted, rainfall has not always been constant and its intensity and volume of down pour are always more than their utilization. Therefore, a large part of the rainwater causes a lot of damage than benefit to the cities and village near the rivers in the form of floods.

High intensity rainfall occurs in the Sindh plains from July to August, with a varying intensity from the coastal to the central areas i.e. high to low respectively. Southern Punjab and the northern areas of Sindh have been getting very low rainfall of less than 152mm. In contrast areas like Rawalpindi, Jhelum, Mianwali and Attock have been receiving a relatively high rainfall with an average of 635mm annually. During the winter season the rainfall is ubiquitous with Northern and North western NWFP and Northern Baluchistan receiving a large amount of rainfall. Annual rainfall that falls over about 21 million hectares of Peshawar and the Indus plains is about 26 MAF. At present about 6 MAF of rain pours over the irrigated areas. (Kahlown & Majeed, 2003)

2.6 Groundwater Resources

Various ground water resources of Pakistan have been found in the Indus Plain existing from the Himalayas to the Arabian Sea in the form alluvial deposits. Being about 1600km in length and covering 21 million hectares, the plain is also rich in unconfined aquifer. The aquifer forms due to the natural processes of precipitation flow of rivers and seepage from canals and watercourses over the course of years. The above-mentioned aquifer, having a potential of 50 MAF, has been employed and made use of to acquire 38 MAF using tube wells (562,000 private and 10,000 public). Fig – 2.1 depicts the growth in tube wells in the past years.

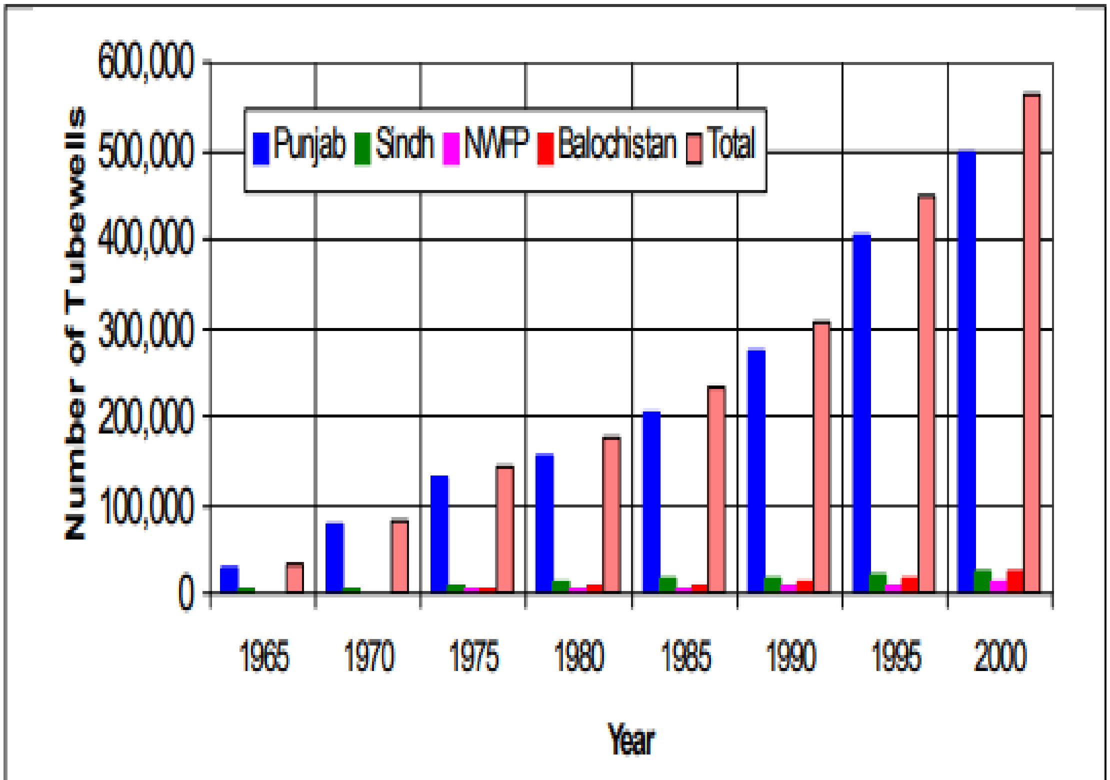

Fig – 2.1: Tube well development in provinces of Pakistan. (Kahlown & Majeed, 2003)

In Baluchistan the groundwater has been obtained through springs, dug wells, karezes and tube wells, with karezes being the most reliable source of irrigation of the orchids and other crop plants. The reason for this being that all the rivers and streams flow seasonally. Observations suggest that about 0.5 MAF of 0.9 was being utilized with a leftover potential to exploit 0.4 MAF. There can be a misconception that the aquifers are limited due to the geological conditions. In the basins of Pishin Lora and Nari, the over exploitation of the groundwater beyond the developmental potential could cause the aquifers to dry up over the years.

2.7 Industrial and Domestic requirements

Table – 2.3 depicts the water requirements for domestic use (during the past and in the future) depending on the demand per capita i.e. 46 cubic meters per annum. The subsequent requirements for industrial purposes have been negligible as compared to the domestic and agricultural needs.

Year	**1990**	**2000**	**2025**
Water Demand (MAF)	4.1	5.2	9.7
Population (million)	110	140	260

Table – 2.3: Demand of water for Domestic consumption. (Kahlown & Majeed, 2003)

2.8 Challenges

2.8.1 Water Scarcity

The average water supply by canals in the Indus basin canals has been about 104 MAF out of which 38 MAF availability has been during in the Rabi season. In 2000-2001, the water shortage during the Rabi season was 40% below the average which resulted in decreased productivity and affecting the cotton plantation in Sindh.

The major concerns about water availability are as follows:

- The impact of global warming and seasonal changes in the surface water availability.
- Ecosystem degradation in the Kotri due to the low flows as a consequence of seawater intrusion.
- Reduced water storage capacity of dams due to sedimentation.
- Increased domestic and industrial demand resulting in low irrigational supply.
- Poor delivery of irrigational systems and municipal supply.

- Decline in water quality due to untreated wastes and agricultural discharges.
- Reduction in water resources due to over-exploitation.
- Reduced performance of tube wells resulting in expense of pumps.
- Salt intrusion as a consequence of up welling of aquifers that are saline.

2.8.2 Inadequate Storage and Sedimentation

Reduction in the storage capacity in three of the major reservoirs (Tarbela, Mangala and Chashma) to 40% was attributed to the sedimentation over the course years (reported in 2010). Therefore, keeping this in mind their supply capacities must be re-evaluated and elucidated. Table – 2.4 shows the loss of storage capacity over the years till 2010.

Reservoir	Year Commissioned	Live Storage Capacity (MAF)			Decrease (%)	
		Starting	2000	2010	2000	2010
Mangala	1967	5.3	4.5	4.2	15	21
Tarbela	1974	9.7	8.8	7.3	9	25
Chashma	1970	0.7	0.3	0.2	57	71

Table – 2.4: loss of storage capacity over the years till 2010 (Kahlown & Majeed, 2003)

2.9 Water metering

It is the process of determining the consumption or usage of water. Water metering is employed by various countries to measure the water consumption, from the public supply system, by buildings in the domestic and commercial areas. Not only this but these metering systems can be used at the points of distribution to measure the amount of water flow to a specific point in the system. The units used for water metering in most countries are cubic meters (m3) or liters (l) whereas the USA employs measurement in cubic feet (ft3) or gallons. Some of the electrical water metering registers can show usage as well as flow rate.

Various studies have confirmed that the metering structures when combined with appropriate billing structures, 15-20 % of water reduction can be observed. Further reduction can be seen if the allocation of leaks and repair of the distribution system is kept in check.

Metering practices in California help the customers to efficiently use water. Metering with appropriate pricing structures helps the customers cut back on the consumption and waste. These systems help detect leakage which leads to timely repair hence less losses. Most Californians, being so vulnerable to drought, have metered water supply but more than 219,000 houses are still not installed with meters. (Beecher et al 1994)

2.10 Effective Water Management

Metering can play an essential role in managing water efficiently. If a customer doesn't have a meter installed, they are charged on a flat mode irrespective of the quantity of water used. With meters, effective payment and measurement ensures the water conservation. Volume based charges enable customers to effectively use their resources. (Renwick & Green, 2000)

2.11 The Universal Metering Program (UMP)

In the year 2010, the Southern Water initiated a program "The UMP" to meter the houses in the areas of South East England as it was stated as a water stress area by the government. The program had 500,000 meters installed by the year 2015, this included the metering of 90% of the houses in the area (only 40% of the houses were metered before the program). (Carmine & Micro, 2015). The methodology of this program was as follows:

- This was in the middle of meter installation and switching of contracts. After installation the meter charges were still on the basis of the last contract.
- During the contract switching and the 3-month letter, the water charges were made on the basis of consumption without the customers knowing about their consumption level.
- After the 3 months letter the customers received a letter regarding the usage information after the contract switch along with their first bill.
- Customers received bills every 6 months based on their consumption which was measured by using meters.

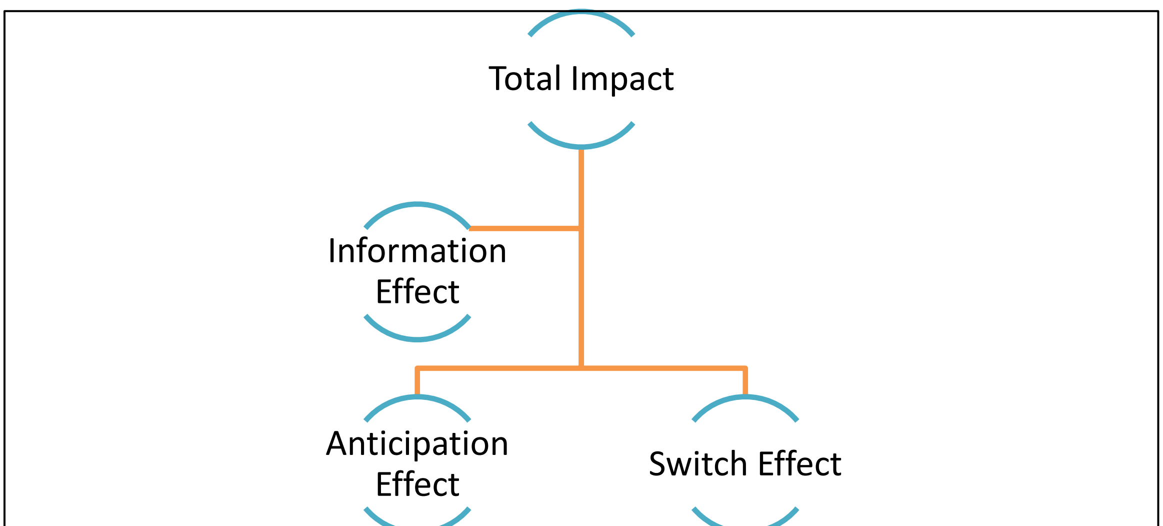

Fig – 2.2: The UMP impact and its components

The impact of the UMP could be analyzed on the basis of three components

- Information Effect
- Anticipation Effect

- Switch Effect

2.11.1 Information Effect

Along with the conduction of this program the Southern Water conducted a campaign to shed light on the importance of water conservation. This may have influenced the customers either because it attracts attention to the importance of saving water and means to do so or it makes the customers aware of the water consumption.

2.11.2 Anticipation Effect

This may have influenced the behavior of the customers such that they may have changed their consumption habits during the period of un-metered charged after meter installation. This may have been a consequence of the time it takes to change habits, and they must have had the need to do so before the actual practice had started.

2.11.3 Switch Effect

This component reflects the changes in water consumption as an outcome of the change in prices due to meter installation.

This program was done in such a way so that the results on the daily consumption and the changes made as part of UMP can be traced and compared to the already metered houses in the same area. The presence of the latter party made it possible to the draw the effect of UMP as it allowed to capture the variation in the average consumption of water based on factors like season or economic conditions like unemployment.

2.11.4 Outcomes

The data collected by UMP was during the span of January 2011-September 2014. The results depicted that the program played a significant part in the consumption of water starting from the installation of meters and even after the contract switching. Approximately 16.5% reductions in the water usage were seen due to the program (Carmine & Micro, 2015).

2.12 Metering and water efficiency

Various studies have shown a marked reduction in water consumption and pricing policies based on volume. Amongst these, the earliest studies on water metering impacts were conducted in Boulder, Colorado. The results displayed a 35% decrease in the domestic water use for the houses with meter installed. (Hanke, 1970). A recent study held in California showed a major decrease of 54 gallons per day in water consumption using metering and charging by volume. Similarly, a decrease of 37 gallons per day and 13 gallons per day was seen in Bakersfield and Chico respectively (Tanverakul & Lee, 2013).Likewise, in the city of Davis, 10,000 meters were installed which later when coupled with volumetric billing caused a reduction of 18% of per-capita water use (Maddaus, 2001). The same case was observed in Fresno with a decrease of 17% per capita water use (Haagenson, 2012). A study conducted in 2004 shows that the meters which use submeters in a multi-family house, cut back water consumption by 15% (Mayer, et al., 2004).

2.13 Metering as a Tariff Policy Tool

A stable tariff policy is an essential requirement for the development of a sound water supply and sanitation facility. However, this policy has been hindered by the unavailability of the data on total water consumption. In the absence of this data customers would have to pay the water costs regardless of the consumption.

This is where metering comes into play as it can provide the data on consumption along with the billing transparency. Not only this but it also ensures quality of service and regulation based on affordability and need.

2.14 Other Non-Revenue Water Reduction Techniques

Before discussing the potential of performance-based service contracting to reduce the significant levels of non-revenue water (NRW) in developing countries, it is important to broadly set NRW in context. There are three different categories that contribute towards NRW: -

- **Physical losses** contain spillage from all parts of the system and floods at the utility's storage tanks. They are caused by poor maintenance and operations, the absence of dynamic pilferage control, and low quality of underground resources.
- **Commercial losses** are caused by client meter under enlistment, information taking care of blunders, and theft of water in different structures.
- **Unbilled authorized consumption** incorporates water utilized by the utility for operational purposes, water utilized for firefighting, and water provided for free to certain consumer groups.

A recent report[2] by the Asian Development Bank (ADB) mentions a study performed by the South East Asian Water Utilities Network (SEAWUN) analyzing

[2] "Nonrevenue Water: A Governance Challenge," ADB, October 2006. http://www.adb.org/water/topics/non-revenue/default.asp

NRW levels of 47 water utilities across Indonesia, Malaysia, Thailand, the Philippines, and Vietnam, which concluded that the levels of NRW average 30 percent of the water produced, with wide variations among individual utilities ranging from 4 percent to 65 percent.

The World Bank database on water utility performance (IBNET, the International Bench- marking Network for Water and Sanitation Utilities, at www.ib-net.org) includes data from more than 900 utilities in 44 developing countries. The average figure for NRW levels in developing countries' utilities covered by IBNET is around 35 percent. Source: IBNET

The developing world lack the capacity to efficiently implement on their own an NRW reduction program. They operate under an inadequate incentive framework; they typically lack expertise, technology, and the practical experience of putting in place such programs; and they therefore need external assistance. An obvious source of assistance is the private sector, where involvement can take many forms, ranging from long-term PPP arrangements to service con- tracts or subcontracting of certain tasks. Depending on the option chosen, the private sector can bring the following (Kingdom, Liemberger, & Marin, 2006):

- New technology and the know-how to utilize it efficiently.
- Better incentives for project performance.
- Creative solutions for the design and implementation of the program.
- Qualified human resources.
- Flexibility for field work (for example, night crews).
- Investment, under certain conditions

- Several options for involvement of the private sector in NRW reduction are explained below.
- Delegated Management under a Public-Private Partnership (PPP) Contract.
- Outsourcing of NRW Reduction Activities.
- Technical Assistance Contracts.
- Performance-Based Service Contracting.

These other techniques are highly suited for the developing countries because NRW requires a range of skilled staff, including managers and professional engineers at one end of the spectrum right through to street crews, technicians, and plumbers at the other. “NRW reduction,” in its broadest sense, is not taught at universities or technical colleges nor in many of the water industry training institutions especially in the developing countries. Consequently, staff with necessary skills are not widely available. Addressing this issue will require both an acceptance of the widespread challenges and consequences associated with NRW and then the development of appropriate training materials, methods, and institutions.

Another reason for its complexity in developing countries is that the reduction is very unpopular among the following:

- **Politicians**: Because it would involve making unpopular decisions (disconnection of illegal consumers or customers who don’t pay) which might affect their vote bank. Also, that they are mostly interested in “ribbon cutting,” and so it is easier for them to install a new water treatment plant than for a leakage reduction program.

- **Meter readers**: Their fraudulent practices earn them a substantial additional income.
- **Field staff**: Because working on detecting illegal connections or on suspending service for those who don’t pay their bills is unpopular and can even be dangerous.
- **Managers**: Because It is easier to close any revenue gap by just spending less on asset rehabilitation (letting the system slowly deteriorate) or asking the government for more money.

The NRW reduction will only be popular for those customers who do pay their bills, however it might appear that there is no support from any party in their favour.

According to a recent study published in the water and sanitation sector board discussion paper series the other techniques of NRW reduction can be applied through public private partnership. The fact that in developing countries alone more than $2.9 billion of additional cash could be generated from reduced costs or increased revenues associated with a realistic 50 percent reduction of physical and commercial losses should capture the attention of donors and developing countries’ governments alike (Kingdom, Liemberger, & Marin, 2006).

The other methods of reduction of water consumption through the public private partnerships is beyond the scope of this study. This study will only analyze the effects achieved if those methods are applied through the public private partnerships. As already highlighted in the above paragraph, in the developing countries a reduction of 50% of the water losses can be easily achieved through these techniques.

2.15 Carbon Credit

Carbon credit is a permit to release one ton of carbon dioxide or an equivalent amount of greenhouse gases into the atmosphere. Carbon credit is bound to decrease with the decrease in water consumption. In the last decade, the carbon dioxide content has increased at an alarming rate of 2ppm/a (1ppm=$1x10^{-6}$). As a result of this increase the greenhouse effect produced has caused the temperature increase of 0.85^{o}C from 1880 to 2012. At present, 40% of total energy resources worldwide are being consumed by the construction industry and accounts for approximately 36% of the carbon dioxide released into the atmosphere. Therefore, energy conservation and carbon reduction measures could significantly reduce the greenhouse effect if these are implemented throughout the building life cycle.

2.15.1 Visualizing a ton of CO_2

But what is a ton of CO_2? To visualize, picture a football ground in your mind. Imagine a sphere balloon with one end lined up on goal line and other end lined up on 10 yards line. That makes it a balloon with a diameter of 10 yards. If the balloon is to be filled with CO2 it would weight around 1 ton. It is supposed to be a ton CO2 balloon.

2.15.2 Carbon Emission inventory

2.15.2.1 Material flow in buildings

Carbon emissions in a building life cycle have been mostly related to the material and energy flow within its boundaries. But it has been very hard to include all the building materials in this analysis due to the complex and diverse nature of their properties. Due to this, a conventional method has been applied which can cater to various primary materials where classification is a key point in their classification.

Table – 2.5 shows the classification of materials based on the material usage, data collection ease and results of previous studies. (Zhang & Wang, 2015)

2.15.2.2 Energy Flow in Buildings

Widely used materials in buildings are the non-renewable energy sources such as coal, oil and natural gas. However, explorations of the alternate energy resources have come into the limelight due to energy crisis. Consideration of the building life cycle is important for energy consumption of the buildings. The table – 2.6 suggests the energy flow categorization. (Zhang & Wang, 2015)

2.15.2.3 Carbon Emission Assessment of a building life cycle

A unified expression can be applied to the assessment of the calculation of the life cycle carbon emissions. (Zhang & Wang, 2015)

$$E = Q \times EF$$

Where,

E= carbon emissions

Q= engineering quantities

EF= emission factors of the assessed process

Class	Explanation	Examples
M_A	Load bearing structural materials constituting load bearing system	Steel products, concreate, bricks, wood
M_B	Non- load bearing structural materials constituting the building envelope	Masonry, gypsum, plywood
M_C	Auxiliary materials aiding on site construction but un involved in building themselves	Temples and scaffolds
M_D	Functional materials for the buildings sustenance	Insulation and water proofing, PVC pipes
M_E	Decorative materials for architectural aesthetic requirements	Wood, gypsum, coatings

Table – 2.5: Clarification of materials (Zhang & Wang, 2015)

Class	Explanation	Examples
E_A	Energy consumption for preparation of materials (embodied)	Steel making process, mining
E_B	Energy consumption for conveyance and construction machinery	Operation of concreate mixers, cranes and trucks
E_{C1}	Energy consumption for essential equipment for building	Heating, cooling, lighting, and ventilation
E_{C2}	Energy consumption for appliances	Refrigerators and water heater systems
E_D	Energy saved by using energy efficient equipment	Solar panels application

Table – 2.6: Energy classification in a building life cycle (Zhang & Wang, 2015)

2.15.3 Carbon emissions at materialization stage, E MAT

This stage, materialization, consists of three primary processes:

- Material preparation
- Transportation
- On-site construction

The carbon emissions at this stage can be found out by:

$$E_{MAT} = E_{PREP} + E_{TRANS} + E_{CONS}$$

Where,

E_{MAT}= emissions at materialization

E_{PREP}= material preparation

E_{TRANS}= Transportation

E_{CONS}= on-site construction

For the calculation of materials preparation, a notable method based on the carbon emission factor was applied. Therefore, according to the emission factors and material consumption E_{PREP} is determined as

$E_{PREP} = \sum_{i=1}^{n} mi \times (\frac{1+wi}{100}) \times EFmat, i$ Where,

n= total number of materials; mi= consumption type of i material

wi= loss rate of type i material; EF mat, i= Carbon dioxide factor of type i material

Construction material	**CO_2 emission factor**
Steel bar	3.15 tCO_2/t
Cement	0.86 tCO_2/t
Concrete	0.48 tCO_2/ m^3
Composite mortar	0.34 tCO_2/ m^3
Cement mortar	0.40 tCO_2/ m^3
Clay brick	0.20 tCO_2/t
Concrete block	0.12 tCO_2/ m^3
Plywood	0.27 tCO_2/ m^3
Glass	1.40 tCO_2/t
Gypsum	0.23 tCO_2/t
Architectural coating	2.60 tCO_2/t
Polystyrene board	3.10 t CO_2/t
Styrene butadiene styrene	0.77 tCO_2/m^2

Table – 2.7: reference value for emission factor of commonly used materials (Zhang & Wang, 2015)

2.15.4 Carbon emission during pumping

The consumption of electricity during pumping was calculated and the results are displayed in the Table – 2.8. (Zhang & Wang, 2015)

Energy	**CO_2 emission factor**
Raw coal	2060 gCO_2/kg
Electricity	970 gCO_2/kWh
Diesel	3180 gCO_2/kg
Natural gas	2700 gCO_2/kg
Solar photovoltaic system	50-250 gCO_2/kWh
Nuclear power	10-130 gCO_2/kWh
Wind turbines	15-25 gCO_2/kWh
Bio-diesel	1900 gCO_2/kg
Wood residues	1750 gCO_2/kg

Table – 2.8: reference values of emission factors of energy resources (Zhang & Wang, 2015)

2.16 Customer Insight

A customer interested in any item is always concerned with the price due to limited assets and income. Therefore, the change in price of any commodity can have the following effects on the customer: (Charles & F.P. Linaweaver, 1967)

- Income Effect

- Substitution Effect

The income effect may be generated due to the change in the price of an everyday item of need. Therefore, the income may seem to increase or decrease.

The substitution effect may arise by replacing the extra of the reduced valued item by a better one at the consequence of the savings that may have occurred due to the income effect. Both the effects are diagrammatically explained in Fig – 2.3.

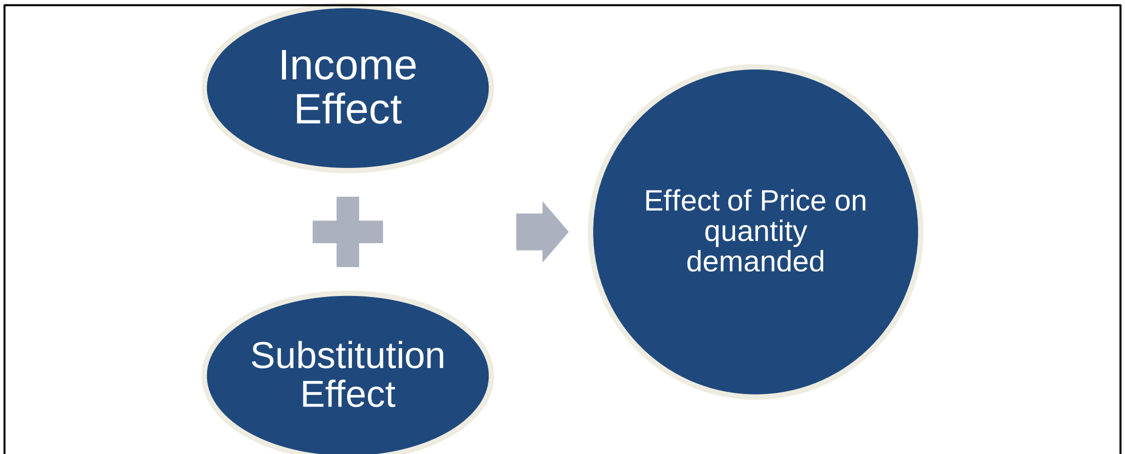

Fig – 2.3: Effects of price on a commodity demanded

Two propositions can be drawn as result of the above-mentioned effects:

- If a larger portion is kept for a commodity, larger will be income effect if changes in the price occur and the demand for change in that commodity will also be greater.
- If many commodities are considered as substitutes for a specific commodity, a larger substitution effect and change in its demand will be seen.

If we put all this in the context of domestic water consumption, the small expenditure of water results in a small income effect. Therefore, the change in the demand must be via the substation effect but water is essential and can't be substituted. Hence this brings us to a model that can help with the water cutbacks in a house hold like the proper use of sprinklers etc.

2.17 Domestic Demand Model

The formula for the DDM is as follows (Charles & F.P. Linaweaver, 1967)**:**

$$q_{ad} = f(v, a, d_p, k, p_w)$$

q_{ad} = average annual quantity for domestic purposes (gallons per dwelling unit per day)

v = market value of the dwelling unit (Dollars); dp = no of persons per dwelling

a = age of the dwelling unit in years; k = average water pressure (psi)

p_w = number of billing periods per year

The structure of the DDM equation depicts that the requirement for the domestic usage of water is influenced and depends market value of the dwelling and the number of persons using it. The age on the dwelling and pressure affect the flow and changes must be due to leaks which must be notified.

The domestic demand is represented at best in conjunction with the types of residential areas. The linear equations are as follows:

Metered with Public Sewer:

$$q_{,ad} = 206 + 3.47v - 1.30\ p_w$$

Metered with Septic Tanks:

$$q_{a,d} = 30.2 + 39.5\ d_p$$

CHAPTER 3

RESEARCH METHODOLOGY

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

Water conservation measures primarily based on water metering are actively being taken by many developed countries like USA, France, Germany, UK etc. These methods have proved to be very successful towards the achievement of water conservation in these countries. However, Pakistan is not making use of the available methods amid already depleting ground water resources. As already discussed in Chapter 1, the situation is heading towards drought in major cities of the country by 2025.

Nexus to above, this research was carried out to promote the concept of metering the water connections to promote water conservation. The broad philosophical underpinning of the research method was largely quantitative. The analysis was based on the data collected, collated and processed after personal visits to Askari XIV. The complete research was conducted smoothly in which a major contribution was provided by the Askari XIV management by their timely responses and provision of relevant data whenever approached. Throughout the process of the research there were many occasions where relevant data couldn’t be found for which technical assumptions and estimations were based on previously conducted studies related to the topic. The previously conducted studies mainly included the research conducted in various countries by different universities.

3.2 Research Methodology

As already mentioned in the Chapter 1, the main limitation of our project was absence of data comparison of pre- and post-metering for any society in Pakistan. The study started off with literature review of the foreign studies carried out in countries. The foreign studies clarified the effects of metering water connections because they were based on actual data of pre- and post-metering. The studies concluded with giving an exact quantity or percentage of water consumption reduced in the respective studies.

Based on the studies we could get a reduction factor of 15% which could be easily achieved by metering the water connections in Pakistan. This factor of 15% was calculated from studies conducted in places which resemble our area from climate and environmental point of view. A conservative factor was taken because of the low public awareness level in our case.

After selection of the reduction factor, site for the application of metering was selected. For the purpose, our interest was to apply the reduction factor on the data of a housing society which maintains its data in an amicable manner. Askari XIV was selected for the purpose because the society has a team of professional management team which maintains all the relevant record. Askari XIV had another advantage that it accommodates every facility including schools, commercial markets, offices, residential areas, parks, etc. The target area of our research was to analyse the reduction in only the domestic water consumption of the society. The commercial and horticulture water consumption was deliberately kept out of our analysis. This is done primarily because the domestic water users in Pakistan outnumber the industrial and commercial users.

After the Selection of Site for the application of our concept, the next step was collection of the relevant data from the concerned authorities. The population data of the society was collected from Pakistan Bureau of Statistics. The data for the number and type of housing units, their daily average water consumption and water supply capacity of the society was provided by Askari XIV management. The data collection of the study was smoothly conducted in which the Askari management played a key role because of their timely and effective responses to our queries.

The data was then collected, collated and then analysed under four different categories. This is shown in Fig – 3.1.

- Existing water consumption requirement.
- Existing water supply capacity.
- Reduction in water consumption after installation of meters.
- Reduction in water consumption after application of other NRW techniques.

The results of the analysis were then studied to see the effects that will be achieved because of the complete study. The effects were analysed under four different categories as also shown in Fig – 3.2. These categories were as follows:

- Effects achieved towards sustainable water use.
- Increased Public awareness.
- Economic sustainability.
- Environmental aspects.

The effects achievable, led us to the conclusions and the recommendations that are suggested for future endeavors' carried out in this regard. The aim of the complete study was to provide a benchmark for future research students who will then take the study a step further based on the recommendations. This would also help in defining the policy measures towards sustainable water use and promote a healthy culture which will benefit the country and its citizens. The overview of the complete study is shown is Fig – 3.3.

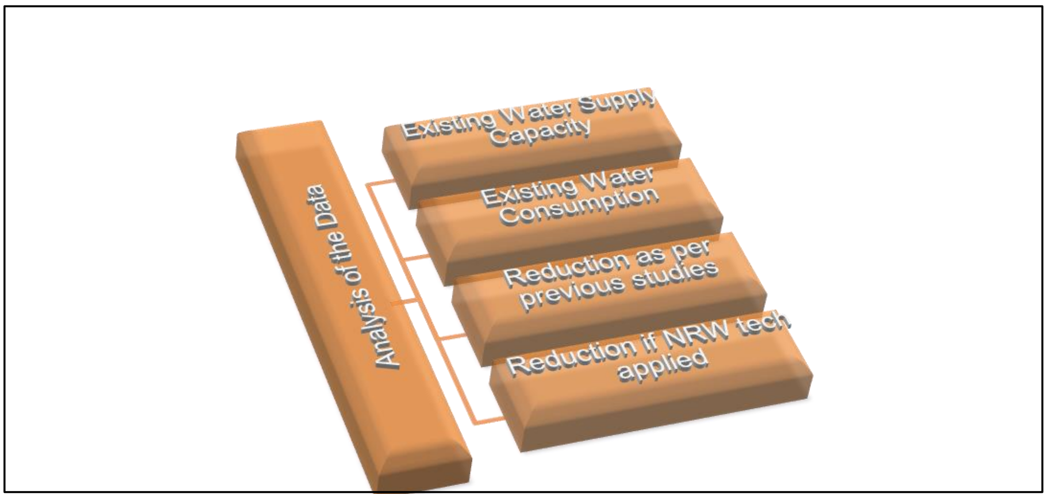

Fig – 3.1:

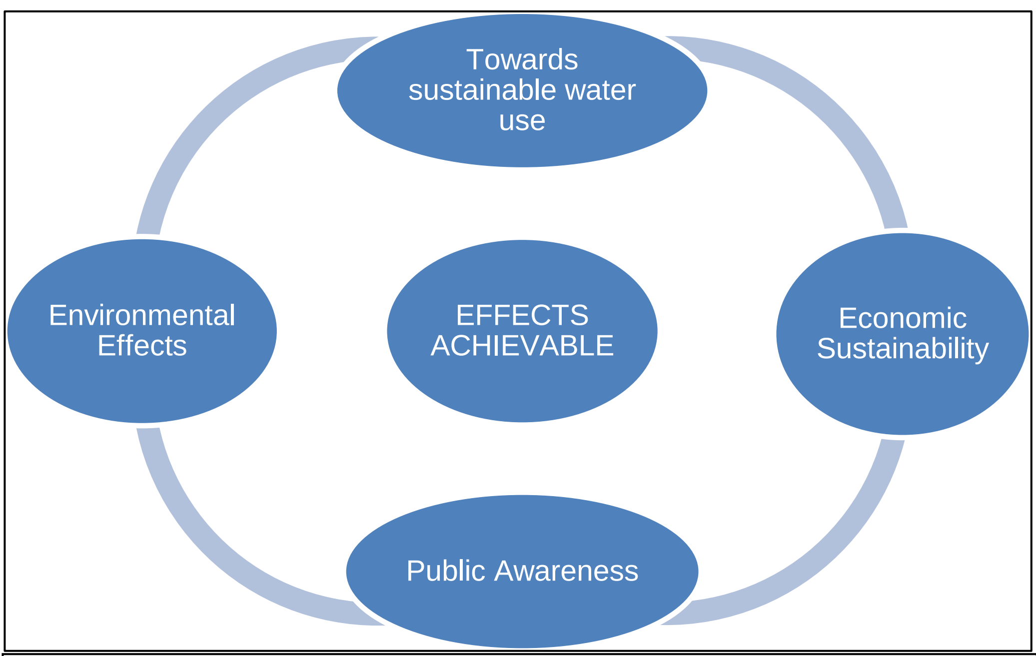

Fig – 3.2:

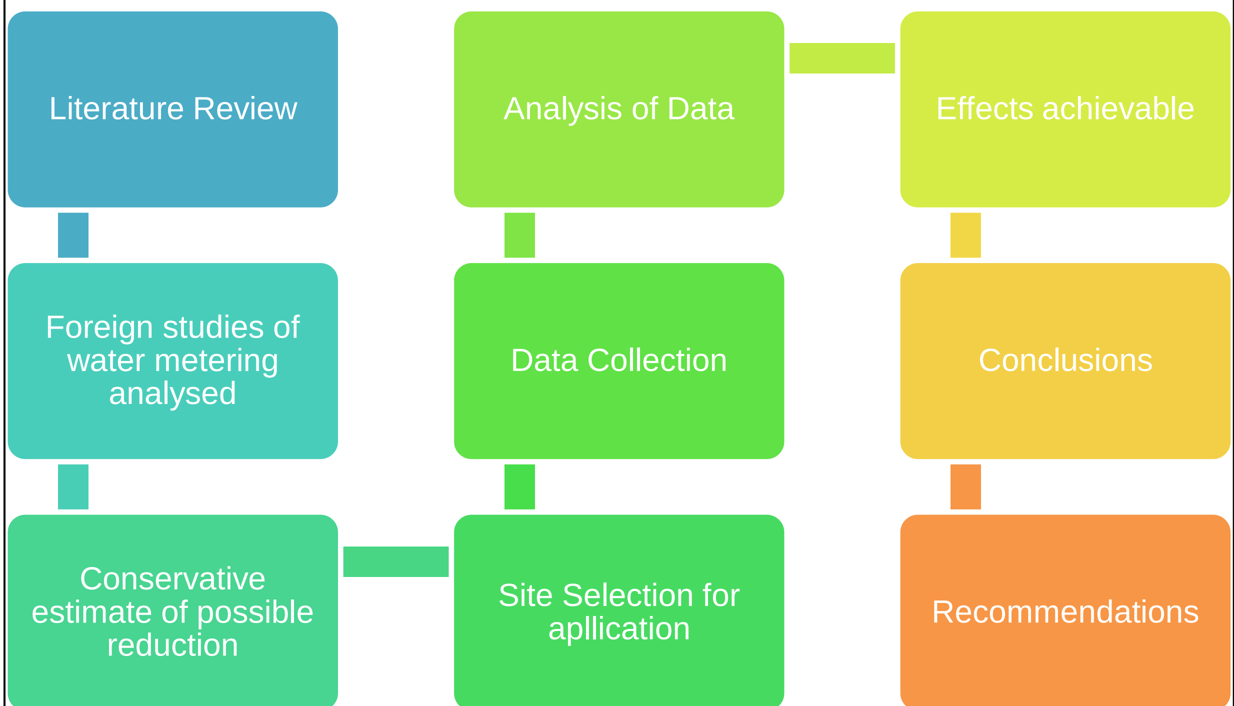

Fig – 3.3: Overview of Study Approach

CHAPTER 4

ANALYSIS

CHAPTER 4

ANALYSIS

4.1 General

Askari XIV located in DHA Phase IV, Islamabad was selected for the application of our pilot study. The society comprises of different category of houses ranging from single unit houses to flats. It also houses schools, commercial areas, mosques and green patches. It is being run in a systematic way by a professional management team which supervises its daily affairs including provision of all basic facilities. The dedicated administration maintains and keeps the data/record updated.

The study aimed at collecting, collating and analyzing the data related to the water supply and consumption of the society. As already highlighted in the above paragraph, the societies water requirement includes domestic, commercial and horticulture water. The breakdown of the water requirement is shown in fig – 4.1. About 88% of the total water supplied is consumed by the domestic user while the remaining 5% and 7% is utilized for commercial and horticulture activities respectively. This study focused on the reduction in water consumption and improvement in the water supply for the domestic user.

Since the domestic users outnumber the industrial and commercial users with regards to water usage, hence the focus on the domestic users' water consumption is more feasible. According to the figures available with the SECP, there are 5100 registered housing societies in Pakistan and another around 35000 unregistered / illegal housing societies. Therefore, while analyzing the results for Askari XIV, it was hoped that the same is achieved in every housing society for long term gains to Pakistan.

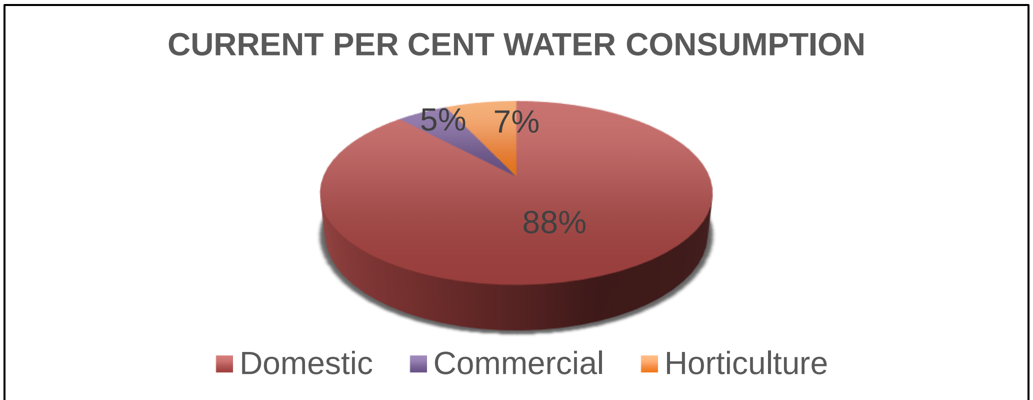

Fig – 4.1: Existing Water Consumption Distribution

The domestic users that add up to the 88% of the domestic water consumption are further divided into three categories namely, Single Unit / Brig House (SU), Single Detached / Col / Lt Col House (SD), and Flats / Apartments. The total number of houses including the ones that are under construction is around 1700. Currently around 1500 houses are being supplied with the water. The detailed distribution of the houses is shown in Table – 4.1. For our study the under-construction houses were neglected.

The water is supplied to these houses through underground water source by pumping through 8 tube wells installed at various locations within Askari XIV. The tube wells lift the ground water for further distribution to various underground water tanks dispersed throughout the area. The water from the underground water tanks is pumped up to Overhead water tanks of each sector for onward supply to the consumer through gravity flow. The detailed capacity and consumption of the society is discussed later in the Chapter.

Sec	Allotted/Occupied Houses			Under Construction		
	SU	SD	Flats	SD/SU	Flats	TOTAL
A	35	568	40	9	-	652
B	24	515	40	15	96	690
C	31	221	16	25	64	357
TOTAL	90	1304	96	49	160	1699

Table – 4.1 State of Accommodation

The population data for the society was taken from Pakistan Bureau of Statistics (PBS) calculated in the census 2018. The Askari XIV management does not collect the population data for the society rather only maintains the record of owners, and in case the house is further rented, then the record of the head of family living on rent basis. Therefore, PBS was approached for provision of data related to the population of the society.

According to the PBS, Askari XIV falls under the population circle no 110020622-26 Morgah Moza Rawalpindi. The total population of the society according to 2018 Census stands at 6985 persons. Compared with the total number of houses, the average occupancy per house stands at 4.7. This was particularly helpful in calculating the existing water consumption requirement for Askari XIV.

4.2 Analysis

The portion required thorough study of the complex network of water supply system and its distribution network. The task was to calculate the existing water demand on accurate basis vis-à-vis actual water consumption. The reduction factor was then to be applied to estimate actual water saving on realistic terms from an individual household already staggered in different categories. Not only that, results in case of other techniques of NRW reduction were also estimated for in the whole process. The analysis was divided into 4 x parts: -

- Existing water supply capacity.
- Existing water consumption.
- Reduction in water consumption after metering.
- Reduction in water consumption after application of other NRW reduction techniques.

4.2.1 Existing Water Supply Capacity

Askari XIV, Islamabad doesn't get its water from the usual supply source of Islamabad i.e., Khanpur and Rawal Dam. Rather, it relies on a network of integrated Tube Wells situated at different locations in Rawalpindi and supplying water for 20 to 24 hours to meet the colony requirement. The state of houses requiring the bulk demand is already mentioned in Table – 4.1.

The system is such that each sector is provided with underground water tanks of different capacity at different locations with total storage capacity of 12 lac gallons. Underground water tanks for sector A & B are interlinked with total capacity of 9 lac gallon and sector C is separate with capacity of 3 lac gallon. They are filled directly by tube wells with 4 x tube wells supplying water to sector A & B at the rate of 1143 gal/hr and four tube wells supply water to sector C at the rate of 5417 gal/hr. Each sector comprises of an overhead water tank of 1 lac gallon capacity. Water is pumped to these tanks from underground water tanks. Further, water is supplied to consumer to their respective house overhead water tank by gravity flow the tube wells provide a total of 370788 GPD as per 22 hours pumping. The complete water supply system is graphically shown in Fig – 4.2.

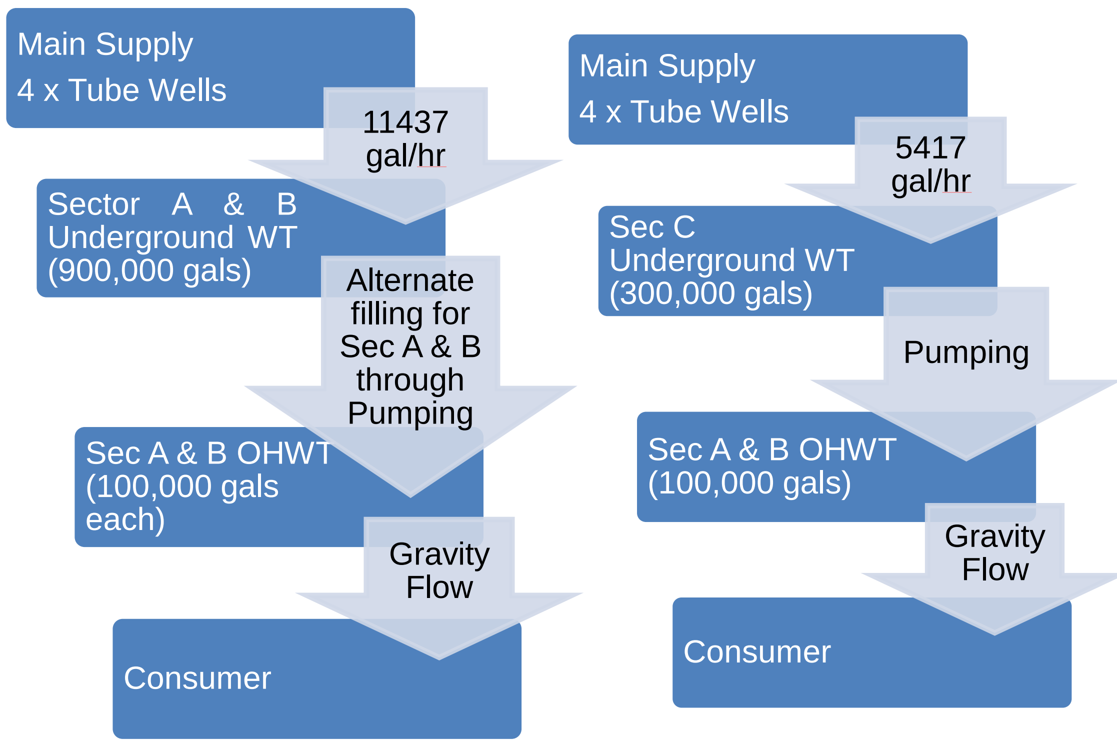

Fig – 4.2: Water Supply System and its Capacity

The important fact revealed from the tube wells' data was that only in the last 6 years, the ground water level went down by 100 feet in Rawalpindi/Islamabad which is an alarming situation as far as the current use of water is concerned and especially when the main source of water supply is ground water. The graph gives depleting output of discharge per hour through years as shown above in Fig – 4.3.

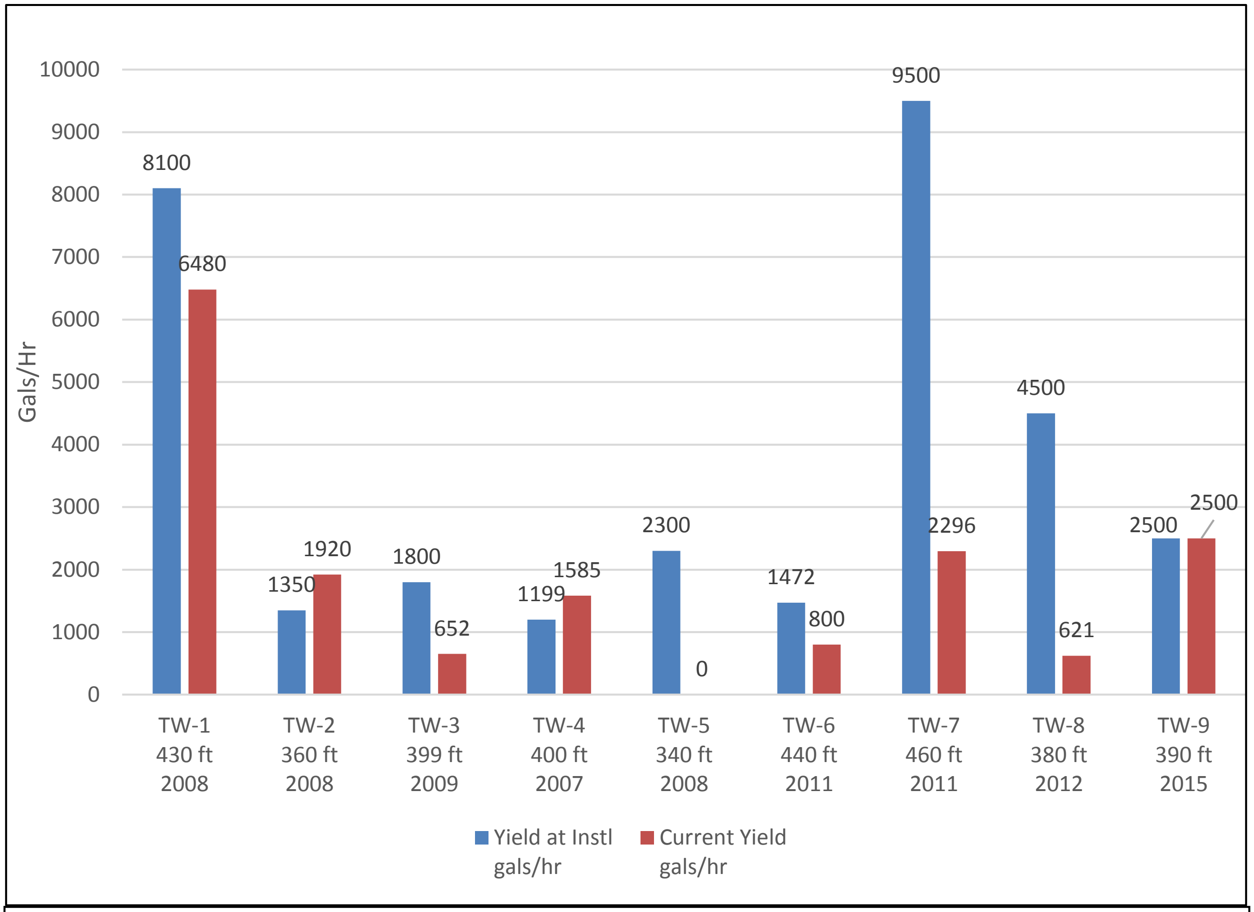

Fig – 4.3: Original vs Current Yield of Tube Wells

4.2.2 Existing Water Consumption

The water consumption is based on a number of society based factors from the general framework of consumer goods, the number of occupants of a house, their life style habits of utilizing water as a collective system. The Muslim society laid much emphasis on its inhabitants to use water with great care even when on the riverside, however, the people have resorted to certain careless measures leading to wastage of a lot of precious water and worst can be attributed to the wastage in flushing and sprinkling requirements.

According to data provided by the administration 88% of the total water provided was consumed by household, 7% by horticulture and 5% by commercial use as already highlighted in Chapter 4 Fig – 4.1. The first step was to calculate the existing population. Data of population per household was collected through PBS as already highlighted.

The query arouse here was that the practical occupancy of houses was different from the average because of the different size and category of houses. Moreover, many houses were occupied by tenants who chose houses with the priority of less rental payment instead of space required according to number of occupants. There were many houses which had a higher frequency of incoming guest/visitors. So, a consensus was developed on number of person per house i.e., 4 x persons per SU House and 5 x persons per SD House and Flat each. The water consumption per individual per household came out to be 200 LPCD (Indian Code of basic requirements for water supply, drainage and sanitation i.e., IS1172:1993, Revised 2002) which incorporated everything from cooking, drinking to even bathroom requirements. The total domestic water requirement came out to be 388861 GPD as mentioned in Table – 4.2, out of which 370788 was provided via tube wells and remaining was purchased and supplied through water bowsers. Extra ordinary water requirements were also monitored and catered for in case of a ceremony, event or deaths in a house, over and above of the routine consumption.

Type of House	Units	Per capita Consumption	Avg Person / Unit	Total (GPD)
SU	90	200 LPCD/52.8 GPCD	4	19020
SD	1304	200 LPCD/52.8 GPCD	5	344480
Flat	96	200 LPCD/52.8 GPCD	5	25360
Total				388861

Table – 4.2: Domestic Water Requirement

Having collected all the data, it is pertinent to mention that the water requirements were calculated according to international standards, however, it was noticed that even the international standards need to be revised as the water requirements per person being over and above the actual requirements were accompanied by a lot of wastage. There was no segmentation of scale for water utilization in summer as compared to winter. Lot of leakages were observed, people were seen washing their cars outside, no recycling process was there to utilize kitchen, laundry or bathing water, water could be seen flowing on the roads at places going unchecked, no arrangement for utilization of rain water and wastage of water for horticulture. The trend is against the customs which need to be followed by a country already far below the scarcity line, yet this wastage adds to the system burden.

4.2.3 Reduction after Metering

Pakistan on its creation was supposedly included in the blessed countries which were never supposed to face water crisis owing to its rivers, rainfall, climate and the resources this land possess. However, the quality of measures for planning of water saving and optimum utilization kept on deteriorating. As per Pakistani culture, people tend to waste utilities they get free of cost and start saving when the commodity faces intense price hike e.g., the use of electricity had seen a decline once the billing charges went sky high testifying above theory. Similarly, billing of water and consequently water metering is inevitable, so that people come to understand its value and start saving and utilizing it optimally.

After metering, societies are billed either according to a flat rate or as per different slab categories. Flat rate is normally successful in communities where socially aware people tend to utilize a resource optimally out of feeling of responsibility towards a natural resource and where the leakages and short comings of the supply system are well taken care by the administration as well. Flat rate does not suit Pakistan since people out of their habit, will get a license to exploit water availability, however, the slab system with increased prices upon increased usage will keep them restrained out of fear of huge billing.

Different foreign studies were analyzed to see the effects of water metering. The studies incorporated different countries with different weather and climatic conditions. The closest to Pakistan was California with reduction factor of 15% and hence selected for our study. The results are shown in Table – 4.3.

Country / Cities of Studies	Reduction Achieved
Carmine and Macro, 2015	16.5 %
Boulder Colorado	35 %
California	54 gal/day
Bakersfield	37 gal/day
Chico	13 gal/day
Fresno	17 %
Mayer et al, 2004	15%

Table – 4.3: Reduction achieved by metering in other parts of the world

Resultantly the consumption of Askari XIV was estimated to reduce from 388861 GPD to 330532 GPD as indicated in Fig – 4.4. This would be an important achievement resulting in saving of water and expenditure along with sparing water for the new under construction houses in the society. It is worthy to remind that Pakistan is at the verge of facing extreme water shortage and implementation of metering concept now will prove to be an asset.

4.2.4 Reduction after Application of other NRW Reduction Techniques

Non-Revenue water, as already explained in Chapter 2, is the amount of water that has some cost of supply which has not been recouped through consumer because of faulty meters, leakages, overflowing water tanks, water utilized in horticulture, firefighting etc. It influences operation of certain water utility or even setting up a new one. Moreover, it indicates lack of governance, management and accountability.

Pakistan is a poor country and unfortunately suffering from decades of poor governance and planning. The general household in Pakistan is supplied with free of cost water. Moreover, there are no laws to cater for utilization of underground water or pose some usage restriction, which is resulting in depletion of ground water source as well. If the same has had been imposed earlier, Pakistan would have had enough money to build several dams which would have solved the matter from the outset. Following table will help in understanding the volume of

NRW, resulting in the cost that could be saved and utilized for development of water resource projects and saving thousands and millions of lives.

The cost of supplying domestic water in Askari XIV was Rs 4224000 per month out of which Rs 1340400 were recouped from the consumers and rest borne by Army since it is a welfare housing society. The consumers' response on the other hand was not encouraging. If the legitimate amount would have been invoiced upon consumer through water metering, not only the usage of water would be curtailed but also the administration would also have found some money to spend on finding a new source of supply against the procurement of water bowser which it is already paying for.

Studies have shown that application of NRW techniques reduces water consumption from 4 – 65 % and the figure for developing countries like Pakistan is 50% (Kingdom, Liemberger, & Marin, 2006). The average NRW levels for developing countries stand at 35% as shown in Table – 4.4. Therefore, if the techniques are applied then a further reduction of 17.5% will be achieved.

	Supplied Population (Millions)	System Input LPCD	Level of NRW (%)	Estimates of NRW				
				Ratio		Volume (billions of m^3/year)		
				Physical Losses (%)	Commercial Losses (%)	Physical Losses	Commercial Losses	Total NRW
Developed Countries	744.8	300	15	80	20	9.8	2.4	12.2
Eurasia	178	500	30	70	30	6.8	2.9	9.7
Developing Countries	837.2	250	35	60	40	16.1	10.6	26.7
Total						32.7	15.9	48.6

Table – 4.4: Worldwide estimates of NRW Volumes (Kingdom, et al., 2006)

So once applied to our pilot project Askari 14, the water consumption after application of the NRW techniques would be reduced from 330532 GPD to 274342 GPD as shown in Fig – 4.4, which would be highly beneficial. Since application of these NRW techniques by involving the private sector is a complete project and beyond the scope of this project, it will not be deliberated upon here and is recommended to be pursued in further research studies.

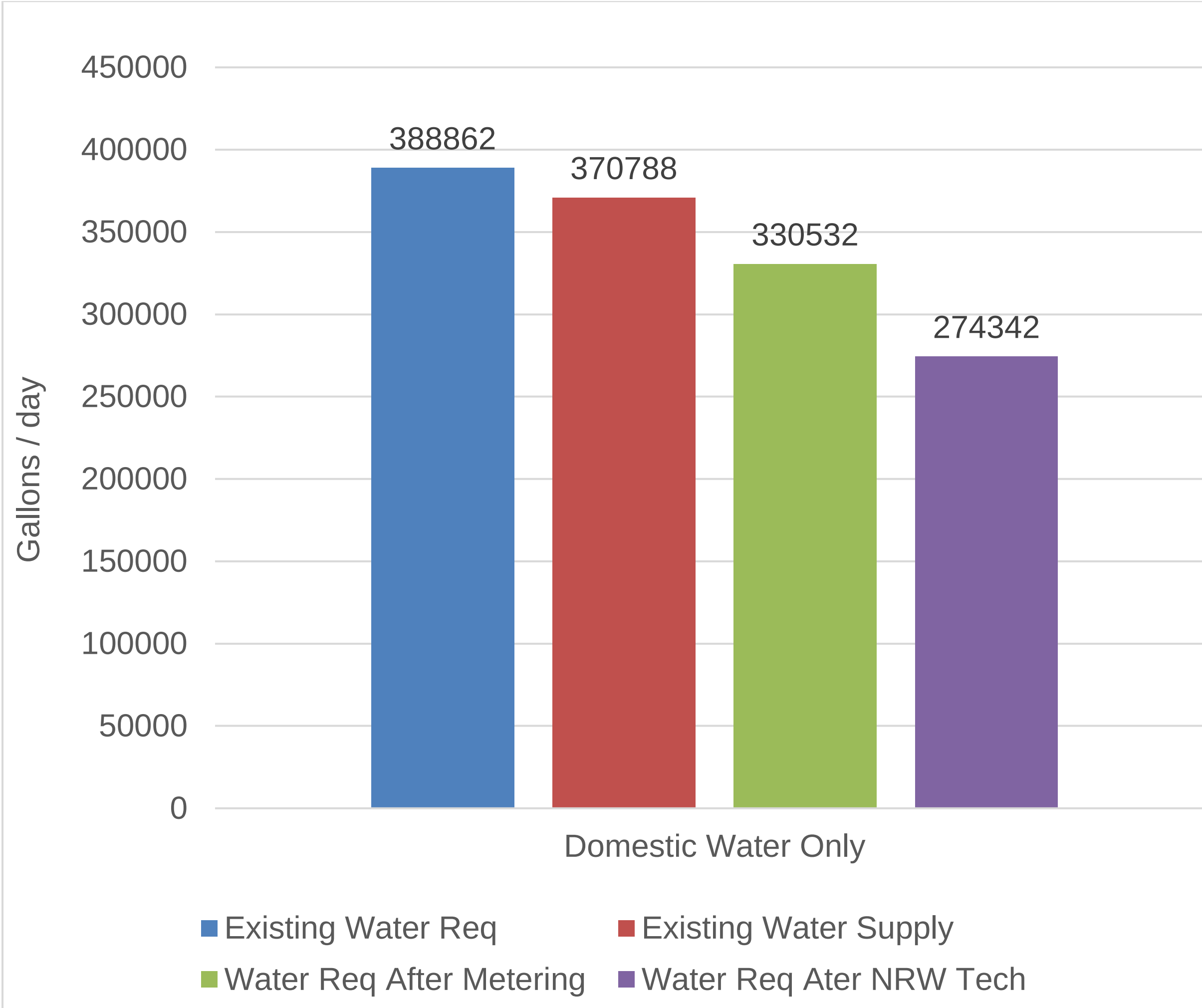

Fig – 4.4: Existing vs envisaged Domestic Water demand

4.3 Effects Achievable

The effects that can be achieved by the enforcement of water conservation through metering and in later stages by applying the other NRW reduction techniques can be studied in different categories. The results of the envisaged water reduction calculated in the analysis were then studied keeping in mind the effects that they'll be able to achieve. These categories can be classified as the effects achievable towards:

- Towards sustainable water use.
- Increased Public awareness.

- Economic aspects.
- Environmental aspects.

The results of the study are based on the data collected from Askari XIV. However, the same can be used to get a picture of what will be the situation if water metering and other NRW reduction techniques are applied to various housing societies in Pakistan. It must be noted that according to the SECP there are 5100 registered housing societies in Pakistan and another 35000 unregistered / illegal housing societies. Therefore, while the results of the study are for Askari XIV only, a picture however must be visualized if the same is done in all the other societies.

4.3.1 Effects achievable towards Sustainable Water Use

At present the domestic water consumption requirement for Askari XIV stand at around 388,861 GPD apart from the water required commercial and horticulture activities. The situation is alarming because the current water supply capacity of Askari XIV is only 370,788 GPD. The additional domestic demand of 18,073 GPD, commercial and the horticulture activities demand is met by providing the additional water to the system through purchase of water from other sources.

The fig – 4.4 shows that the water consumption requirement will be reduced to 330,532 GPD in case of water metering and 274341 GPD in case the other NRW reduction techniques are applied. This means a saving of a daily water 58329 GPD and 114520 GPD respectively. Now the question is how much is 58329 and 114520 GPD? It means 2.5 hours and additional 3.2 hours less pumping water by tube wells if meters are installed and when later other techniques of NRW reduction are applied.

As we already discussed in the previous chapter the capacity of the water supply system is decreasing due to the decrease in the Tube Wells' Yield. Therefore, this saving of water will contribute towards the sustainable water use. The saving of 50329 GPD equals to the water requirement for 221 Flats/SD units which is 17% of the total SD units in the society. Furthermore, if the other NRW reduction techniques are applied the water saving would jump to 114520 GPD which equals to the water requirement of 434 SD units i.e., 33 % of the total SD units.

The reduction of water consumption up to this level will allow the society administration to supply water to the consumers from own sources. The need to purchase water for supply to the consumers will be over. This would serve as an additional capacity available to the society which can be easily stored in the already available underground water tanks of the society. As already mentioned in the beginning of the study, Askari XIV is also planning an expansion and currently 160 flats and 49 SD houses are under construction. The additional capacity generated by the application of our concept would also cater for the water needs of these 209 units and still be able to conserve water in the underground tanks for emergency situations.

4.3.2 Effects achievable towards Increased Public awareness

We have already highlighted the current depleting state of the water resources of Pakistan. The situation, as already discussed in chapter 1, is hypercritical. However, the level of public awareness towards its realization is far from sight and measures to improve it are non-existent.

Our study aimed at not only reducing the water consumption requirement but also contribute towards increasing public awareness in this regard. This will be achieved by enforcing strict water usage regulations by introducing consumption based metering. The residents will be charged for every cubic meter of water which the consume.

The water consumption requirement for a unit has already been calculated in Table – 4.2 based on international standards commensurate with our environment. The consumers using water within 10% of this allowance will be based on No profit-No loss. The cubic meter rate of water on this basis is calculated out to be Rs 100.4 /m^3. The residents will be forced to conserve the water by charging them 200% rate if they exceed this allowance of 10% mentioned above.

The effect of the consumption based pricing on the monthly bill of a resident can be seen in Fig – 4.5. The figure explains how the monthly bill will contribute towards enforced water conservation and improving public awareness.

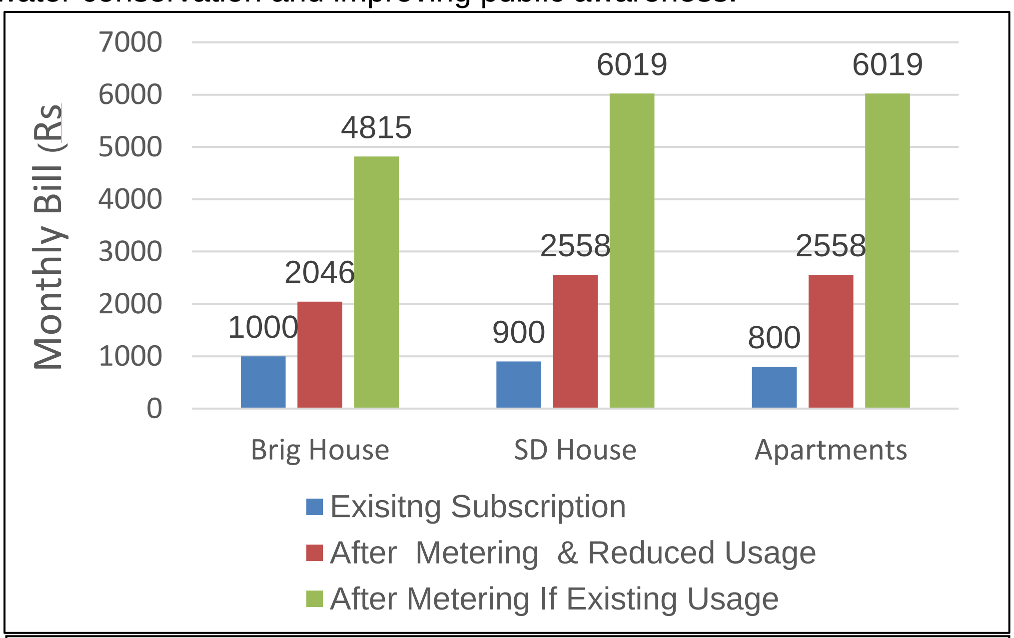

Fig – 4.5: Comparison of Monthly Bills before and after metering and application of NRW reduction

4.3.2 Economic Sustainability

At present the water supply system of Askari XIV is being run on subsidy provided by housing directorate on monthly basis. The residents are being charged on flat rate basis which vary based on the type of unit. The categories include SU, SD houses and flats. The occupants pay Rs 1000, 900 and 800 per month respectively. This amount caters for only Rs 1.34 Million per month. The actual monthly expenditure incurred in supply of water is around Rs 4.22 Million which includes the Tube Wells' electric bills, Diesel for generators installed with Tube Wells, Staff salary etc.

The monthly deficit of around Rs 2.88 Million is being provided by Housing directorate. As already discussed above, the public awareness towards water consumption is minimal. The low awareness level coupled with minimal flat rates for water consumption contribute towards over use of the water. The consumption based water pricing as discussed previously is based on No Profit-No Loss. This would allow the society administration to collect the amount incurred on expenditure from the residents.

This would result in a monthly saving of Rs 2.88 Million which amounts to Rs 34.6 Million. The same amount can be utilized initially in installation of water meters and later for the funds required for applying other NRW techniques in case it needs to be done from own sources. This model would ensure sustainability of the metering based system for a longer duration. The comparison between the amount collected before and after metering is shown in Fig – 4.6.

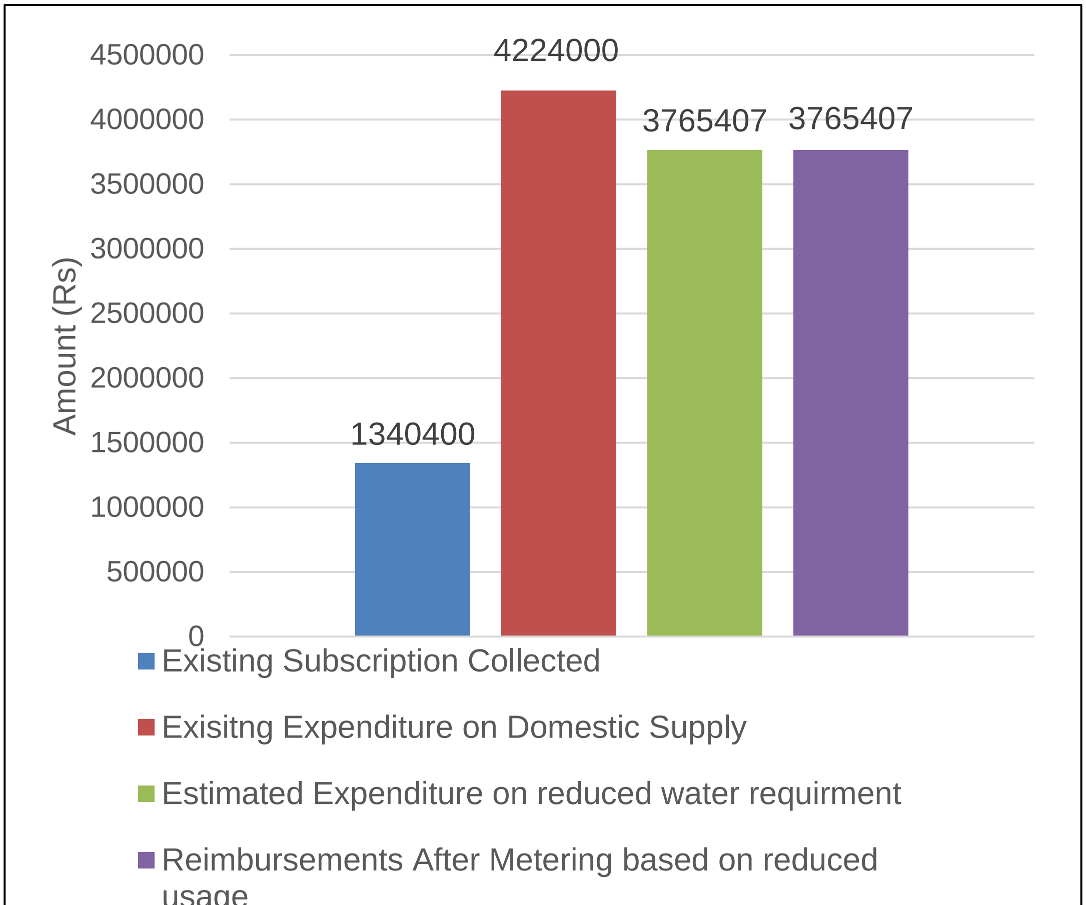

Fig - 4.6: Comparison of subscription based on flat rate and No Profit-No Loss

4.3.3 Environmental Aspects

4.3.3.1 Carbon Emission Calculations for UG water tank

Due to shortage of water the community has been instructed to construct UG water tank as per standards shown in Fig – 4.7 and Fig – 4.8.

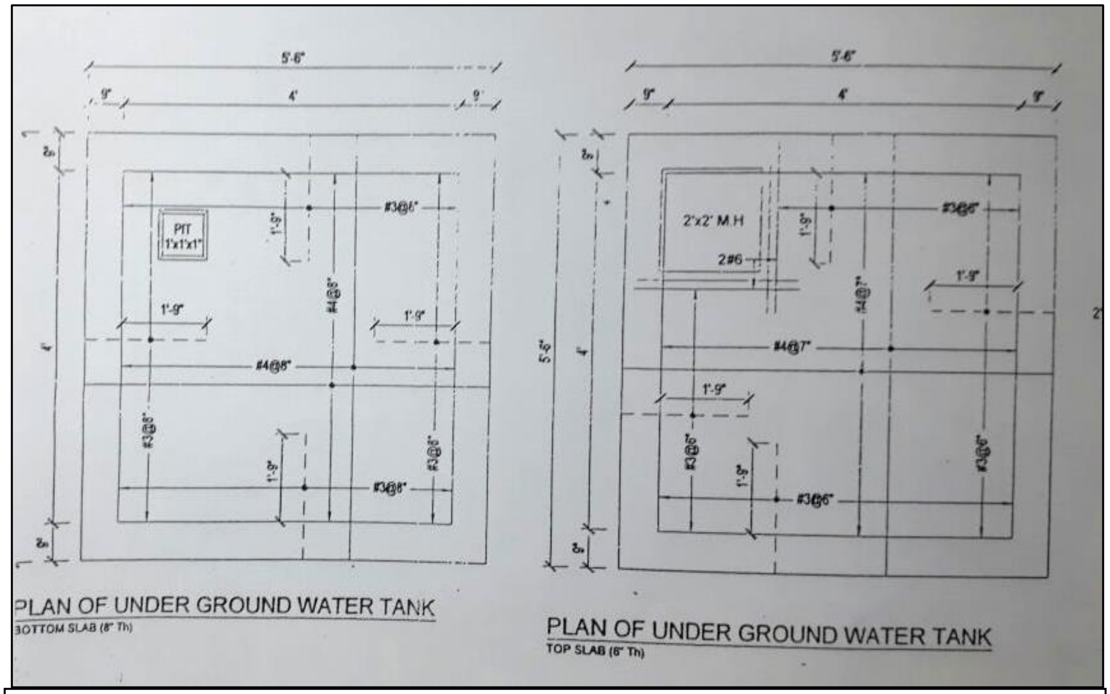

Fig – 4.7: Plan View of approved Underground water tank

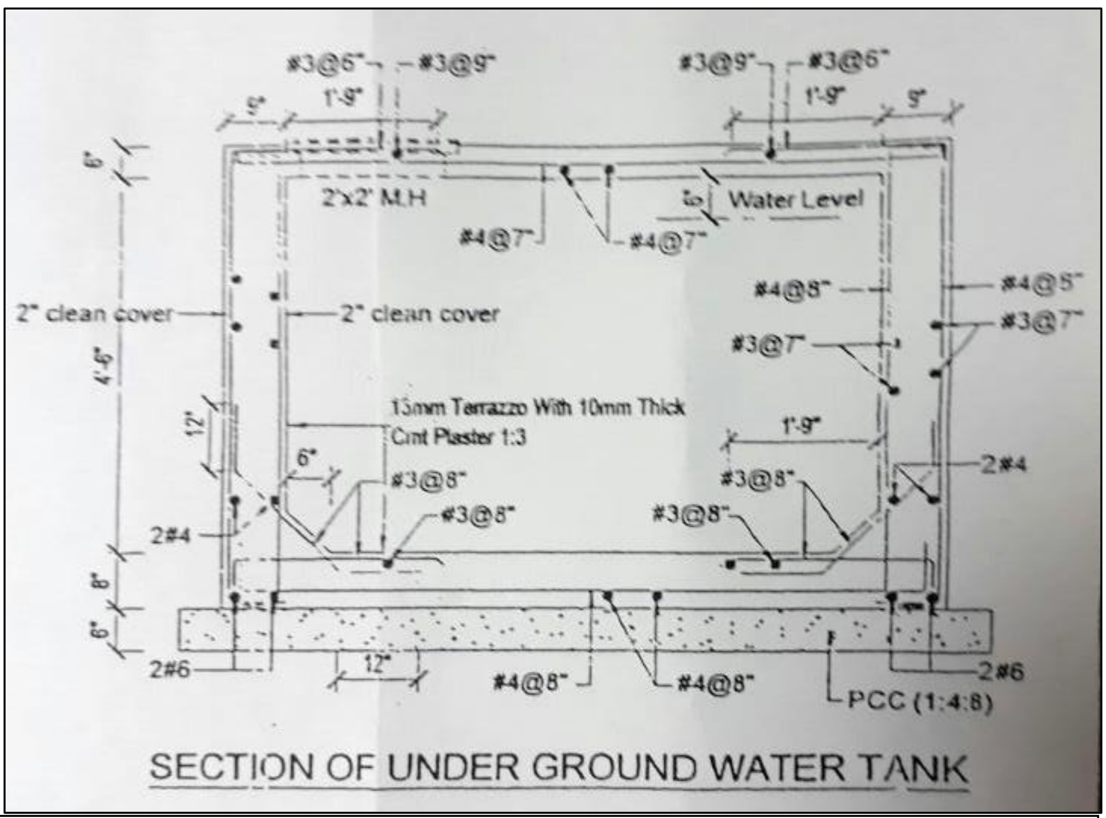

Fig – 4.8: Section of approved Underground water tank

Based upon above plan and cross section following calculations were done for the amount of CO_2 that will be emitted during the preparation phase as shown in table – 4.5.

Ser	**Material**	**Carbon Foot Print (Tons/ house)**	**Carbon Foot Print Total (Tons)**
1	Concrete	1.6264	2267.2
2	Steel	1.33	1857.2
	Grand Total	**2.96**	**4125**

Table – 4.5: Carbon emissions calculation for Underground water tank

4.3.3.2 Carbon Emission Calculations for Water Pumping

Two types of pumping operations were reduced: -

- Main pumping operation (done through 5x 15 HP pumps and 3x 25 HP pumps) reduced from 22 hrs. to 19.5 hrs. and if NRW is applied it is further reduced to 16.3 hrs.
- The pumping operation (done through 0.5 HP pump) for supply of water from UG to OHT. Since it value of carbon emission has no significant effect on results so it is neglected.

The calculation for pumping is shown in table – 4.6 & 4.7. As already mentioned in Chapter 3 there are a total of 8 Tube wells supplying water to the society. 5 out the 8 pumps are of 15 HP and rest 3 are 25 HP pumps. So, we calculated the Carbon emissions accordingly for each type of pump. From the tables the total carbon emission before applying any reduction factor turns out to be (1.2+1.12=2.32 tons).

Ser	Time(Hrs)	KW	KWH	CO_2 factor=970 g of CO_2/KWH	CO_2Emitted (Tons/Pump)	For 5x Pumps CO_2 (Tons)
1	22 (Actual)	11.20	246.4	239008	0.242	1.12
2	19.5 (After Metering)	11.20	218.4	211848	0.2118	1.059
3	16.5 (After other NRW reduction)	11.20	182.56	177083	0.1770	0.885

Table – 4.6: Carbon Emissions by a 15 HP Pump

And after applying the reduction factor of 15 % the total carbon emission is (1.059+1.05= 2.019 tons). Whereas if the other NRW reduction techniques are applied

Ser	Time(Hrs)	KW	KWH	CO_2 factor=970g CO_2/KWH	CO_2Emitted (Tons/Pump)	For 3x Pumps CO_2 (Tons)
1	22 (Actual)	18.64	410.08	397777	0.4	1.2
2	19.5(After Reduction)	18.64	363.48	352575	0.35	1.05
3	16.5 (After other NRW reduction)	18.64	303.83	294715	0.30	0.9

Table – 4.6: Carbon Emissions by a 25 HP Pump

the amount of carbon emissions is reduced to (0.885+0.9=1.785 tons). So, we can achieve 9% reduction of Carbon emission through metering and 23 % reduction through applying other NRW reduction techniques. As shown in Fig – 4.9.

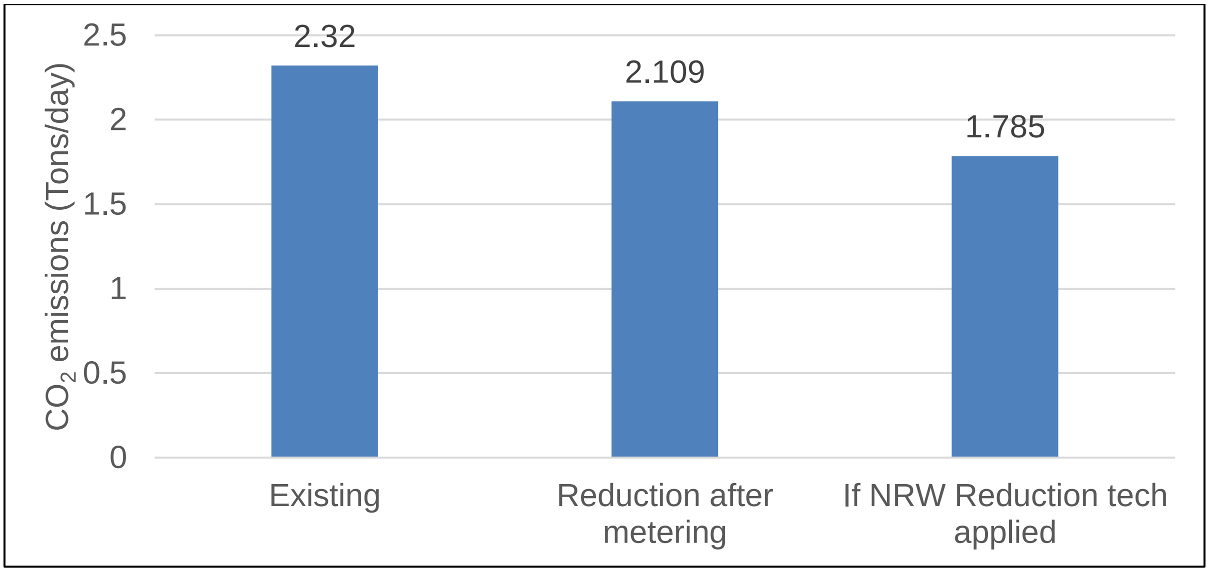

Fig – 4.9: Carbon Emissions before and after reductions

Thereafter the Impacts of Carbon emissions' reduction were computed under three categories:

- Economic impact
- Environmental impact
- Health impact

4.3.3.3 Economic Impact

First, we must understand the concept of Social Cost of Carbon (SCC). It is the price a society pays for the changes in

- The damages caused by flooding due to rise in temperature by carbon.
- Impact on human health due to increase emission of carbon.
- Agricultural production.

Researchers from Stanford university believe the economic damages of Carbon dioxide emission is roughly to be 220 $ / ton[3]. For first year we saved 4125 tons[4] of Carbon footprints by avoiding the construction of underground water tank. So, we saved 907500 $ on account of SCC.

And by reducing 2.5 pumping hours by installation of meters and later 3.2 hours by application of other NRW reduction techniques, we are saving 16945 $ / year in case of metering and 42960 $/ year in case of application of NRW techniques[5].

4.3.3.4 Environmental Impacts

For South Asian nations a trillion-ton discharge of Carbon dioxide causes one-degree centigrade rise in temperature, which comes about into an Earth-wide temperature boost, dissolving of icy masses, flooding, less yield of products, dry spell and so on (Leduc, 2016). Even though we are not making a major segment of diminishment in carbon dioxide simply by decreasing pumping hour yet at the same time we are attempting to make a sense among the general population about lessening in carbon discharge.

Some of the prominent environmental effects of carbon emission are

- Pollutants and loss of air quality
- Ozone depletion and Smog (A major problem for Pakistan during winters).
- Global warming.

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[3] https://www.forbes.com/sites/tomzeller/2015/01/13/economic-impacts-of-carbon-dioxide-emissions-are-grossly-underestimated-a-new-stanford-study-suggests/#7e591ec73da3

[4] Detailed Calculation in Annex A

[5] Detailed Calculation in Annex B

- Acid rain.
- Reduced visibility.

4.3.3.5 Health Impacts

Mark Jacobson a scientist from Stanford University has linked human mortality with the increase emission of Carbon dioxide. According to him one degree increases in the temp causes 30% of 1000 additional deaths. For South Asian countries 1 trillion-ton CO_2 will result into one-degree Celsius rise in temperature[6].The diseases that are common due to increased emission of Carbon dioxide are

- Asthma
- Respiratory allergies
- Airway diseases

The commonness of asthma in Pakistan is expanding step by step with a yearly increment of 5% of which 20% to 30% are youngsters near 13 and 15 years old (Mehdi, Arsalan, Khan, & Kazmi, 2012).Almost 20 million people — 12% of Pakistani grown-up populace are as of now experiencing the illness.

[6] https://news.stanford.edu/news/2010/march/urban-carbon-domes-031610.html

CHAPTER 5

CONCLUSIONS & RECOMMENDATIONS

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5.1 General

The research was conducted with the aim to act as a stepping stone for upcoming projects where the study should be taken a step further. This study was conducted in the face of limitations and challenges, the most prominent being that the research related to this topic is almost non-existent in Pakistan. This would however provide some insight to future researchers who intend to continue the endeavor in this field since Pakistan's literature related to water conservation in general and metering in specific is in its embryonic stages.

5.2 Conclusions

After the detailed analysis of the data and identification of the effects achievable, the following conclusions are drawn from the study.

5.2.1 Water conservation and public awareness

Considering the rate of depletion of the water sources in Pakistan, and the level of public awareness among the masses, Metering of the water connections is inevitable.

Even if the conservative reduction of 15% is achieved successfully by the installation of meters, its effects will be manifold towards conservation of water and improvement of the environment.

By providing water based on commodity charges instead of flat rate, the reduction of water can be enforced upon the consumers.

The metering would serve as a tool for educating the masses with regards to saving water by using it judiciously rather than extravagant usage.

As the population growth and the ever-increasing number of constructions taking place, metering would help to provide water to more users using existing resources.

5.2.2 Economic Advantages

Currently a deficit exists between the amount the consumers pay and the amount that is collected by the authorities. Metering would help eradicate that deficit which would help sustain the economy of the society. This would allow availability of funds for the maintenance of the supply system which would help in carrying out other NRW reduction practices like detection of leakages etc.

Commodity charges applied to affect the water conservation would allow generation of funds, which can be used to attract the private sector to invest in the other NRW reduction techniques mentioned in Chapter 2.

5.2.3 Environmental Advantages

As already mentioned in chapter 2, Pakistan increasingly relies on ground water to meet its water requirement. The metered water would help reduce that requirement. This would cause a decrease in the number of hours of pumping being done by the tube wells, hence causing a reduction in the emissions of carbon dioxide to the environment.

Once meters are installed, the probability of water provision to the customers also increased. Hence regulations need to be enforced which put a ban on construction of underground water tanks by residents. The underground water tanks cause huge amounts of carbon dioxide emissions to the environment, which is a cause of many diseases including asthma etc.

5.2.4 Other NRW Reduction techniques

The NRW reduction technique other than metering will prove to be very vital if achieved successfully. Although it would require detailed research studies at the beginning to examine the modalities which suit our environment. However, the benefits that it would accrue will be commensurate with the efforts induced.

Developing countries have large proportion of the NRW in the supply systems. The value averages at 35%. Even if 50% of reduction is achieved through the other NRW reduction techniques the water provision can be improved for the domestic consumer.

Although water metering does not enhance the overall water resources of the country but will slow down the depletion rate. Metering and other NRW reduction techniques can be utilized as an immediate and short-term measure to improve the declining water situation of the country. The long-term and permanent measures however would be to increase the storage capacity of the country and to shift the reliance from ground water to surface water. The ground water can then be kept as a reserve for such critical situations.

5.3 Recommendations

Metering all around the world is proving to be an important tool in conserving water. Therefore, future studies related to this topic must be pursued at all levels. Since this study was conducted with the aim to be a stepping stone for the next ones, hence following recommendations are suggested for those who intend carrying out research in this field.

Actual water metering should be done in some residential areas of Pakistan to confirm the actual percentage of reduction in water consumption can be calculated. This can be done by comparing the results of the pre- and post- metering water consumption.

Bye laws and regulations should be enforced which forbid the users to construct underground water tanks at their homes. This can be easily enforced once water provision is enhanced after installation of meters.

The other NRW techniques should be studied in detail and tailored according to our social and cultural environment. These techniques should then be put to test by application on ground through NGOs or public-private partnerships.

The amount of capital required for installation of metering was not catered for in our study. Detailed studies need to be carried out in this regard so as to calculate accurate rate of water once meters are installed.

The developed countries have already shifted focus to smart meters which give real time information about defects or leaks in the system. This helps the consumer to be in control of the water leakages and in turn helps in conserving water. This also benefits the user who does not get charged for the leaked water, since smart meters would allow the early rectification. Efforts should be made so that our country also shifts towards the smart meters in an earlier time frame.

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