# RAIN GARDENS: A WAY FORWARD TO DEALING WITH WATER SHORTAGE ISSUES IN BUILT UP AREAS OF RAWALPINDI

By


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# THESIS ACCEPTANCE CERTIFICATE

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# <u>Dedication</u>

*To my beloved Parents*

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*(Romesa Malik)*

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| | |
|---|---|
| BMP’s | Best Management Practices |
| LIDC | Low Impact Development Center |
| SUDS | Sustainable Urban Drainage System |
| LIUDD | Low Impact Urban Design and Development |
| WSUD | Water Sensitive Urban Design |
| ACT | Action on Climate Today |
| CRWM | Climate Resilient Water Management |
| CDA | Capital Development Authority |
| UNDP | United Nation Development Programme |
| PCRWR | Pakistan Council of Research in Water Resources |
| RDA | Rawalpindi Development Authority |
| WASA | Water and Sanitation Agency |
| PMD | Pakistan Meteorological Department |
| GWT | Ground Water Table |
| NGO’s | Non-Governmental Organizations |
| WT | Water Table |
| GWT | Ground Water Table |
| RG | Rain Gardens |

# Abstract

Pakistan is facing severe water crisis. It is suffering from worst climatic changes that has resulted in continuous decrease in underground water level. Water shortage problem has hit hard the big cities. As cities are growing and forests are being replaced rapidly due to urbanization, storm water run-off increment from impermeable surfaces, is becoming a problem. Rain gardens are simple, easy to implement, inexpensive and environmentally friendly solution to cater storm water problems in cities. Moreover, they conserve water hence increasing under-ground water level. Capturing rainwater by use of rain gardens and holding it until it is slowly absorbed by soil is quick and efficient way for increasing under-ground water table. This study helped to identify pattern of change in ground water table and rainfall pattern because of urbanization over a period in Rawalpindi region. The findings showed that ground water table has no link with increase or decrease in rainfall, however it is linked to consumption, as increased urbanization has increased water consumption resulting in lowering of water table. In such situation, rain garden is the best solution to store rain water and utilize it in the best possible way. Data collection comprised of a field survey through an especially formulated questionnaire. This survey helped in determining the perception of rain gardens among residents of water stressed communities, its benefits and prospects. Furthermore, the study was conducted in two water stressed societies of Rawalpindi city via an exploratory research design for which qualitative and quantitative data were collected and analyzed on perception, awareness and willingness to install rain gardens from residents, management of societies, experts and professionals. The residents

wanted incentives to install rain gardens initially and the management was of the view to embed rain gardens in housing design. Another part of this research was to determine the satisfaction of residents with already prevailing rain water management strategies. Majority of the residents were not satisfied as these strategies did not help in storing a lot of rain water for longer duration. Futuristic impact of the proposed rain water management strategy is discussed in this report along with recommendations for successful and continued implementation of rain gardens in the study area.

*Chapter 1*

# Introduction

Rain garden is a specially designed depression or shallow storage within a garden that receives water from hard surfaces like rooftops, patios and sidewalks. This water slowly seeps back in the ground. The main purpose of these rain gardens is to rise underground water level by soaking in the soil. As cities are growing and forests are being replaced rapidly due to urbanization, storm water run-off increments from impermeable surfaces becomes a problem. Rain gardens are simple, easy to implement, inexpensive and environmentally friendly solution to cater storm water problems in cities.

A rain garden conserves water and hence increases under-ground water level. It also helps in filtering pollutants from run-off storm water in urban areas (Dietz, 2005). Capturing rainwater by use of rain gardens and then holding it until it is slowly absorbed by soil is quick and efficient way for catering storm water problems and increasing under-ground water table. As land is converted into impervious surfaces, a lot of rain water is wasted while passing by areas including driveways, parking lots, homes, roofs, yards and paved walkways ( Engel et al., 2012). Rain gardens are basically scenic features that catches water runoff and direct it onsite before they enter our streets and waterways. These gardens are manmade, and they utilize natural components such as soil and plants to filter the storm water within them. They are made to work with nature, not against the nature.

Rain Gardens are made up of five components which are; an inlet, berm, slope, basin, and an outlet. Inlet is the location where the storm water is collected from a drainage pipe. Once the storm water enters in the inlet, it then allows the water to be passed over to the berm of the rain garden (Shokouhian et al., 2001).The plants that can bear dry soil conditions are planted in the berm because of its location at the top fringes of the rain garden. After passing through the berm water then enters the slope. The plants in the slope portion can tolerate both dry and wet soil conditions. Next area is the basin from where the storm water passes through. It is located at the bottom of the rain garden. The basin plants need to be tolerable of wet environments as this is where the storm water will stay for long (Anderson, 2011).

Rain gardens decreases the water amount which enters our sewer system and it is achieved by catching surplus water from our roof, yard, or parking lot and letting it to penetrate in the ground under natural conditions. Impermeable surfaces mostly allow water to pass through the surface speedily, without any treatment into the water channels which greatly affects our health. Native plants are planted in rain gardens that adjust to local conditions over many years ( Dick et al., 2013).

This research will assist us in the process of planting a rain garden, its benefits and water sustainability. Planting rain gardens in our lawns not only embellishes our property, but we are also doing our part to protect our community from deteriorated water quality and recharging water table (Endreny, 2009).

## 1.1 Problem Statement

The increase in urbanization exerts immense pressure on urban services and biggest one is water shortage. This problem is deepening in Rawalpindi city and Cantonments areas with each passing day. Increasing impermeable surface areas reduces water penetrating in the soil, resulting rainfall to convert into runoff (Endreny, 2009).

Due to storm water runoff, ground water recharge is not possible and water table is getting lower day by day. Consequently, water is being supplied to homes by the water tankers with a long waiting time span and that too after advance booking. The inhabitants of Rawalpindi and Chaklala cantonment boards are also living without water while the civic bodies have failed to supply the basic commodity to the residents, thus sparking protests and agitations (Qureshi, 2011). The areas where the citizens are facing acute water shortage include Morgah, Officers

Colony, Kotha Kallan, Jari, Jhamra, Dhoke Nawaz, Gulshanabad, Kalyal, Shahpur, Dehgal, Adiala, Landco, Rehman Markaz, Sanjoli State, Kehkashan Colony, Jarahi, Janjua Town, Khayaban-e-Jinnah, Ali Town, Munawar Colony, Hill View, Dhama Syedan, Sadiq Town, Kohsar Colony, Khatana, Sher Zaman Colony, Jorian, Dhamial, Hayyal, Bunda Nagyal, Chakri Road, Quaid-e-Azam Colony, Ahmedabad, Bakra Mandi, Dhoke Syedan, Baraf Khana Chowk, Misrial Road, IJP Road, Pirwadhai, Sadiqabad, Shakrial, Muslim Town, Chah Sultan, Waris Khan, Iqbal Road, Raja Bazaar and many other localities. Provision of water through water tankers on daily basis costs veryhigh for a household (Shabbir, 2016). All these issues result in water shortage in Rawalpindi areas.

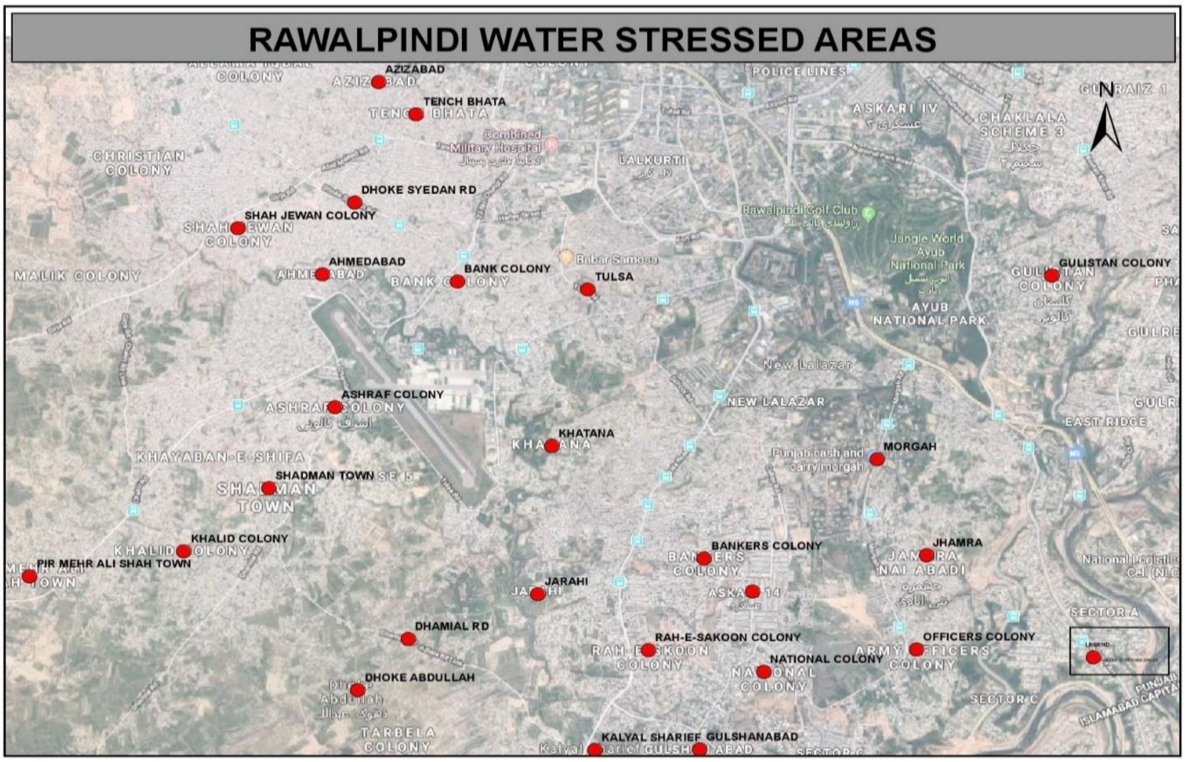


**Figure 1- 1: Rawalpindi Water Stressed Areas**
**(Source: ArcGIS Map)**

One solution which is proposed and that can benefit water quality and reduce runoff is implementing a storm water treatment such as rain gardens or permeable pavements. The success of rain gardens is basically because of the plants and soil that are the major ingredients of the rain garden. The soil captures the storm water and the plants absorb and filter it.

## 1.2 Justification to Research

The population of Pakistan keeps on rising every day. The increase in population causes an increase in urbanization.

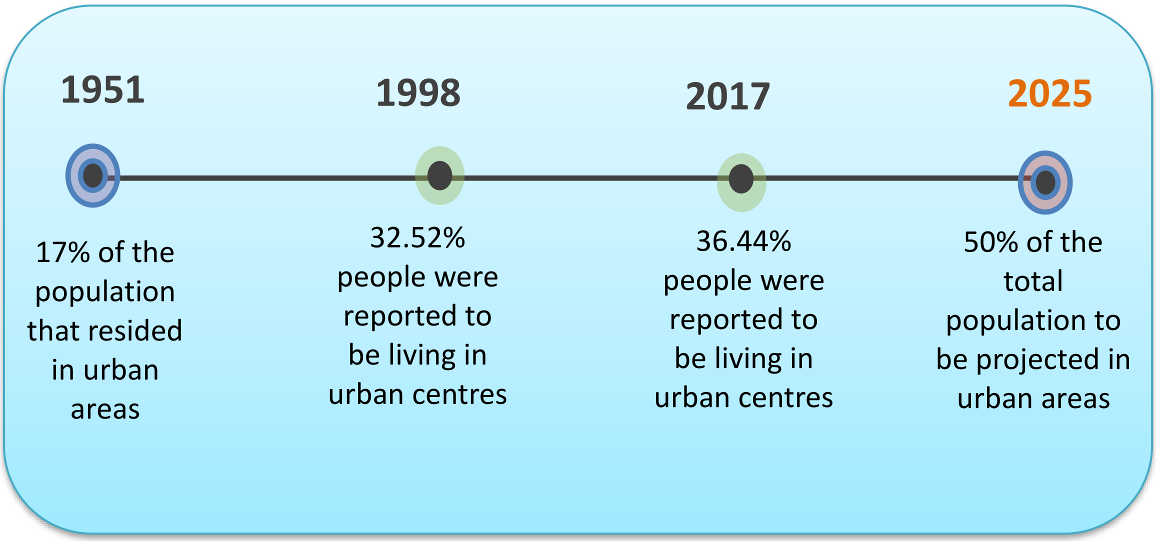


**Figure 1- 1: Urbanization Over a Period of Time**
**(Source: Internet)**

More houses are built, the more roads we need, and hence every need is increased. Urbanization leads to many problems. One of the biggest problems that relates with the increased urbanization is the increase in storm water runoff.

Impermeable surfaces are one of the key reasons for the increase in storm water runoff because of its lack of ability to filter water, which then gather pollutants from the surfaces and turns the storm water into pollution (Bengtsson et al., 2009). The increase in impermeable surfaces such as roads, parking lots, driveways, and buildings are the features that play major role in contributing to high storm water runoff. The high proportion of impermeable areas reduces the amount of water penetrating the soil and this causes the rainfall to be converted into runoff, carrying along with it the pollutants along the surface. These surfaces turn rainwater into a problem because of the amount of pollutants it collects and no place for the water to be filtered. Runoff has deep impact on both the water quality and quantity. Problems linked with storm water runoff are the increase in erosion, flooding, and the lowering groundwater infiltration.

Other problems associated with storm water runoff causes the increase in nutrients, sediments, pathogens, organic materials, toxic contaminants, debris, freshwater impacts, and thermal stress

(Aravena, 2009).

## 1.3 Research Questions

The research will be aimed at answering the following questions.

1. What is the rainfall pattern over 10 to 15 years in Rawalpindi Region and how does it affect groundwater table?
2. What is groundwater table situation in Potohar region over the past years?
3. What is the satisfaction level of people regarding their current rain water management practices?
4. How rain gardens are effective according to managements/expert's opinion?
5. What is the perception of residents about rain gardens and are they willing to adopt rain gardens as a water management strategy?
6. Will rain gardens be able to solve water scarcity issues in selected areas?

## 1.4 Objectives of Study

The research is guided by the following objectives:

1. To identify pattern of change in groundwater table and rainfall because of urbanization over a period of time in Rawalpindi region.
2. To identify current practices being used at household and other community levels for rain water usage in water stressed areas of Rawalpindi.
3. To investigate perception about rain gardens concept from residents of water stressed communities, management & professionals; its benefits and future prospects.
4. To suggest strategies for promotion of rain gardens installation in communities to address the issues of water shortage.

*Chapter 2*

# Literature Review

The increasing population requires increase in the resources, assets and facilities to cater that increase. The urban population is increasing at an alarming rate globally and resulting in an increased pressure on the environment and natural assets. Urbanization has also changed the way humans utilize natural resources. Moreover, the consumption of water, electricity and gas has increased due to the urban lifestyle. The increase in urbanization is directly related to the increase in developed land area and natural resources such as water, gas and electric power (Proctor et al., 2009). This increased population has led to the increase in the urbanization which resulted in development of more paved roads, more houses, more pesticides, more buildings etc. The advancement in technology and provision of benefits to humans is accompanied by certain problems. One of the most common problems associated with the increase in urbanization is the increase in stormwater runoff (Booth, 1997).

## 2.1 Storm Water Runoff

Storm water runoff is basically the rainfall that pours down on hard or paved surfaces such as rooftops, patios, sidewalks and roads. This water is unable to penetrate the ground and before entering the main water streams it becomes polluted to a higher degree and becomes a hazard for plants, fish, animals and people (Sample et al., 2017). One of the major reasons of stormwater runoff is the impermeable surfaces which do not allow penetration of water in the ground, leading to the collection of water and other pollutants from the surfaces thus turning the stormwater to pollution (Fraley-McNeal et al., 2009). The urbanized land leads to the increase in the impermeable surfaces which doesn't allow water infiltration and becomes overland run off (Novotny, 1994). The reduced infiltration of water in the ground is associated with the reduced groundwater recharge and reduced water flow in the streams base along with the higher overland flow proportion (Leopold, 1968).

The major problem occurring with the overland water is the amount of pollutants that it carries with it which cannot be filtered. The other major problem includes flooding and erosion. The runoff is the drainage of the freely flowing water of rain from surfaces including structures, buildings or lands (Gorman, 2014).

The runoff has an effect over the quality of water as well as its quantity. The quality of the rainwater falling on the impervious surface is reduced due to the pathogens, organic materials, sediments, toxic contaminants, freshwater impacts, debris and thermal stress. The increase in the chemicals is also observed more commonly. Ammonia and nitrogen are present in water which are more harmful for human health (Brattebo, 2003).

Increased impermeable surfaces leads to reduced water infiltration and thus the rainfall is converted into the runoff (Colandini et al., 1996).

## 2.2 Strategies to Prevent Storm-Water Runoff

A large number of strategies have been applied in order to prevent the stormwater runoff due to its harmful effects on human's health. The most common options to manage the stormwater runoff included underground water pipes, rain gardens, tree planting, urban forest buffers, stream restoration, nutrient management, wetland construction and erosion control (Hagan, 2011). Two of the above-mentioned efficient strategies are:

### 2.2.1 Underground Water Pipes

The underground water pipes are also used as the alternative strategy to redirect the runoff towards the nearest discharge area without affecting drinking water. This is how the pollutants will be discharged into the nearest water source but the major drawback associated with this approach is the pollutants increase within the nearest waters including lakes, rivers and ocean, affecting the water life (Urriola, 1998).

### 2.2.2 Rain Gardens

So, the other most adoptive and successful strategy is the rain gardens which are also known as the bio retention areas as they manage the discharge of stormwater and remediate the runoff.

It is the permeable surface which offers the reduction in the stormwater runoff and directs all the pollutants inside this water (Nestingen et al., 2009). These rain gardens can be easily installed on the residential property in order to improve the surface water runoff. The rain gardens are the manmade gardens which use natural components including plants and soil in order to filter the pollutants present within stormwater.

These rain gardens work with the mechanism of nature which makes it one of the best options to be used for the stormwater runoff control. The rain garden is the shallow depression which stores water and its porous soil mixture helps in the soaking of rain water gradually within ground (Mailhot et al., 2014).

The layered mixture of soil which is made up of sand, compost, mulch and hydrophilic plants remove the pollutants. The highly simple rain garden structure offers the management of the stormwater water with very effective rain and they have the ability to absorb more than 14 times of rainwater as compared to the lawns and it has the potential to replenish all the groundwater supply as well (Dietz, 2008).

Rain gardens not only serve the rainwater retention and pollutants of filtration, they also serve as the good habitat for the birds and small fauna. The engineered gardens, carrying stormwater, are available at the community level and they can also be used at the household or individual level in order to create the stormwater management strategy.

#### 2.2.2.1 Components of Rain Garden

There are basically five main components of the rain gardens including inlet, slope, berm, outlet and basin. The inlet of the rain garden is the position in which the stormwater enters and collects with help of drainage pipe. After the collection of water, it reaches the berm portion in which plants are placed. After passing berm, the stormwater hits slope which carries different plants and then after passing through basin portion, it passes through the outlet. The inlet of the rain garden offers the flow of the stormwater directly over the land and from the rooftop downspouts (Gorman, 2014). A study conducted by Pitt and Voorhees showed that the 90 percent reduction of the annual roof runoff can be easily achieved based on the total rain garden area with respect to the roof area (Burian et al., 2014). The slope bypasses the flow above the unit storage capacity on the surface and the under-drain system is common within bio retention cell which carries dry soil in order to retain water for long time.

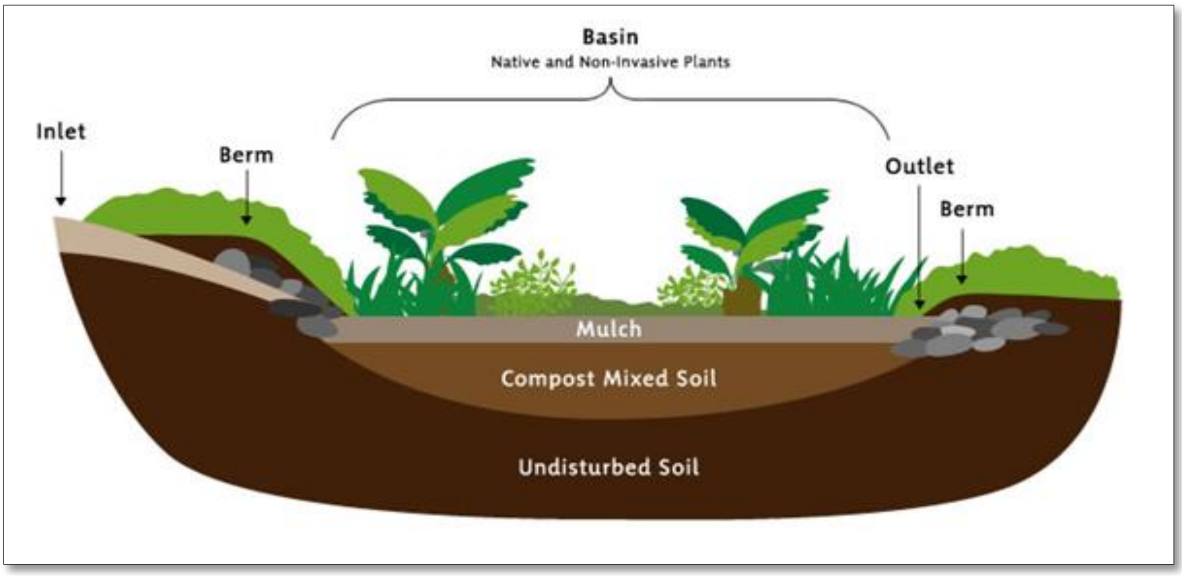


**Figure 2- 1: Components of Rain Garden**
**(Source: Internet)**

### 2.2.2.2 Functionality of Rain Gardens

The rain gardens offer some highly unique structural features and the plants which are selected based on their functional abilities in saturated conditions. A large variety of grasses, shrubs and perennials are used within different climatic regions but majority of the rain gardens carry dry plants in the berm portion, both dry and wet in slope portion and only wet plants in the basin portion (Anderson, 2011).

In order to increase the retention of soil, the mulch layer is added within the rain garden which serves to reduce the surface soil clogging and reduces soil erosion. The basic goal of the rain garden is to provide filtration as well as the storage zone for the rain water. This bio retention is one of the highly cost-effective processes to reduce the pollutants in the stormwater.

### 2.2.2.3 Advantages of Rain Garden

The advantages of implementing the rain gardens are that they can easily remove pollutants from rain water as the dry plants in rain gardens easily stores stormwater and absorb all the toxic nutrients present in it. Rain gardens also enable the recharge of the local groundwater by providing larger amount of cleaned and filtered water from the wet plants in basin portion that conserves large water amount. It also offers the betterment in water quality due to natural filtration by plants and thus it also prevents the harmful effects of the pollutants on water bodies. With the removal of standing water, the mosquito breeding is also reduced, and the home flooding is also prevented (Dietz, 2006).

All the above-mentioned benefits in the rain garden are due to the presence of the soil and plants present within it. The presence of bacteria on the roots of plants along with natural biological mechanism helps in the cleaning of water and reduction of pollutants inside stormwater. Soil in the rain garden also absorbs much water that allows the rain gardens to offer higher rates of infiltration. A study conducted by Alexandra has showed several benefits of rain gardens or green infrastructure to the residents of the area. It has been shown that the green infrastructure offers the highly economical as well as environmental opportunity for the natural resource protection as well as for water management within urban areas. This is not only going to improve the quality of life due to the pure water and reduced pollution, it is also going to reduce the pollution in air with improvement in the public health (Nestingen et al., 2009). It also offers the enhancement of the urban aesthetics and its safety with the generation of more jobs and facilitation of the food quality (Dunn, 2010).

#### 2.2.2.4 Rain Garden Implementation

Study revealed that if higher financial incentives are offered to the residents of Chesapeake Bay, they are more likely to support the installation of the rain gardens (Alberini, 2016). Many government policies have been made worldwide in order to create the rain gardens for the removal of pollutants. District of Colombia is offering services to install Best Management Practices (BMP's) at local and domestic levels to cater the storm water run-off and the pollution produced by the untreated rain water accumulation. All those methods and techniques that can be utilized to save rain water and avoid the merger of polluted storm water run-off within the main stream water are termed as the BMP's and must be employed on urgent basis to ensure conservation and purification of water. The rebate program includes installation of the rain gardens at their own full upfront cost whereas the government is going to pay some portion later. For the rain gardens, $75 is suggested to be given to the residents. The Anne Arundel County offers the property tax credit to the residents for the proper performance of BMP's at their home. This is one of the methods to convince the residents to install rain gardens as well (Wong, 2012).

#### 2.2.2.5 Cost and Size of Rain Garden

The size and cost of rain garden is highly variable and is dependent upon each other. This is obvious that a bigger rain garden costs much higher than a smaller rain garden. Moreover, the size of the rain garden isalso dependent upon the size of the house on which the rain garden is installed (Newburn, 2016). The estimated size of rain garden is measured on the basis of the house footprint and one-inch event of rainfall. The estimated cost of the rain garden is determined by considering the size of rain garden within square feet and the average cost of installation is $9/square foot. The average cost of rain garden is from $3 to the $15 for which the median cost is $9/square foot, which is considered as a reasonable cost for every study area (Clark, 2008).

For instance, if the size of the house is 2000 square feet and it carries two story houses then it means that the footprint of the house would be 1000 square feet. The expected size of rain garden is 200 square feet, considering the ratio of 5:1 which is the depth of rain garden to the footprint of house in order to accommodate one inch of the rainfall event. The cost of the rain garden is estimated to be $1800 if the installation is carried out without any rebate.

## 2.3 Pollution with Stormwater

A study was conducted by Michael on the nutrients amount within stormwater as the nitrate carried higher retention percentage in rain gardens (67 %), followed by ammonia (82%) and nitrogen (26%). The rain gardens offer the reduction in the pollutant's concentration inside stormwater. The system of bio retention or rain gardens is gaining importance due to the lower impact, high effectiveness and larger aesthetic value that it carries (Mailhot et al., 2014). The pollution treatment offered by rain gardens is considered as the best treatment because it includes all the essential filtration processes such as ion exchange, volatilization, adsorption and decomposition.

## 2.4 Practice of building Rain Gardens in Developed Countries

The establishment of rain gardens is of extreme importance in order to maintain the groundwater table. In today's world where infrastructure, buildings and hard construction has taken over a major part of our landscape, pollution is an inevitable consequence. In the given circumstances, water consumption and purification are one of the most crucial steps. Nature bestows a large quantity of water that can be saved in a constructive manner to aid human population, plants and animals. With the rapid increase in urbanization and utilization of natural assets, there is a dire need of initiatives to be taken around the world to conserve water and other natural resources. Rain gardens have numerous applications and can be established in home gardens and lawns, along motorways and highways, large scale parking lots and rooftops. A study carried out by (Davis, 2009) showed that in order to rise ground water table and to improve water standard that has suffered to a significant depth as a result of excessive urban development, rain gardens and other bio retention services must be studied, developed (with the most cost-effective and time-efficient designs) and deployed on a robust pace to improve water quality, conserve purified water and avert storm water run-off. They studied and composed results after monitoring two separate bio-retention plants in Maryland and concluded that reducing the storm-water runoff leads to the exclusion of pollutants and the outflow from the plants showed better water quality. Whereas, dissolved copper analysis showed that major changes in water composition occurs as a result of bio retention medium.

Scientists and managers of numerous nations have embraced a lot of research and practices to enhance urban stormwater overflow management. A portion of these activities incorporate the United Kingdom's Sustainable Urban Drainage System (SUDS), United States Best Management Practices (BMP) (2008) and Low Impact Development (LID) (Dietz, 2008), New Zealand's Low Impact Urban Design and Development (LIUDD) and Australia's Water Sensitive Urban Design (WSUD). To promote the improvement of these measures, the applicable government divisions have drawn up rules and set up research foundations, for instance, the United States set up the Low Impact Development Center (LIDC) in 1998. The LIDC demonstrates an extensive variety of stormwater administration applications and is used in many developed countries, including the United States, Canada, and Japan.

### 2.4.1 United Kingdom:

Rain gardens were first created in the United States during the 1990s, where they have turned out to be progressively mainstream. In the UK, the mirroring of common seepage in urban territories is formally energized and known as Sustainable Urban Drainage Systems (SUDS). This methodology is a piece of another reasoning to urban water administration, created in Australia, which is known as Water Sensitive Urban Design (WSUD). SUDS are a generally new idea in stormwater control in the United Kingdom (Lampe, 2004) and are getting expanding affirmation as a powerful option in contrast to customary seepage frameworks (PCTPR, 2002). The 'urban drainage triangle' (Fletcher, 2014) involving water amount, water quality and environment/convenience outlines the wide worries of manageable seepage choices and how they can speak to a profitable commitment toward practical advancement. The viability of practically identical rain patio nurseries would fluctuate from about (51.3-99.8) percent over the adjoining United States. Indistinguishable greenery enclosures would be slightest compelling in Atlantic and Gulf Coast states and best in northern Midwest and Mountain states. Results likewise show cultivate evapotranspiration and vanishing have an insignificant effect (<1 percent< 1percent) on spillover decreases.

### 2.4.2 United States

In USA, a simple numerical model for design and evaluation of rain gardens was developed. Water flow through the soil, modelled over three layers which are: a root zone; a middle storage layer; and the site subsoil. Green-Ampt equation coupled with a surface water balance was used to continuously simulate recharge, runoff and evapotranspiration. For the humid climate of Madison, Wisconsin, USA, results show very high recharge rates of ground water in the rainy season. A rain garden with an area of (10–20) percent of the impervious area maximizes recharge. For semiarid climate of Santiago, Chile, ratio was (10–20) percent. For the arid climate of Reno, Nevada, USA, it was closer to five percent (Dussaillant, 2005).

### 2.4.3 New Zealand

The LIUDD program is a six-year program inside the Sustainable Cities Portfolio, subsidized by the New Zealand Foundation for Research Science and Technology from 2003. The possibility of economical living developed emphatically in the late 1980s through worldwide activities. From that point forward it has turned out to be inserted in the enactment and way of life of New Zealanders, from the Resource Management Act 1991 directly through to network and social activities.

### 2.4.4 Australia:

WSUD is a land planning and building configuration approach which incorporates the urban water cycle, including storm water, groundwater and wastewater administration and water supply, into urban plan. WSUD is a term utilized in the Middle East and Australia and is like low-affect improvement LID in Australia, there are no quantitative execution focuses for water tanks. The different rules given by state governments, do prompt that rain water tanks be intended to give a solid wellspring of water to enhance mains water supply, and keep up proper water quality. The utilization of water tanks ought to consider issues like free market activity, water quality, storm water benefits, cost, accessible space, upkeep, size, shape and material of the tank. Water tanks should likewise be introduced as per pipes and waste guidelines. An exhorted reasonable setup may incorporate a water channel or first flush redirection, a mains water top-up supply (double supply framework), upkeep deplete, a siphon (weight framework), and an on-location maintenance arrangement.

## 2.5 Rain Gardens in Developing Countries

Rain gardens in developing countries ( South Africa, China, Singapore , Malaysia, Hong Kong and South Korea) covers an extensive variety of techniques and ways to improve the understanding and ability of local stakeholders to resolve rain gardens issue inside the system of coordinated urban water management, and additionally basic interventions with different non-structural methodologies for flood mitigation and pollution control. There are numerous difficulties to effectively implement a sustainable rain garden approach in developing countries. In developing countries, the climatic and socioeconomic conditions drive difficulties to the use of arrangements adopted in temperate areas. China has implemented numerous successful rain gardens especially in its tropical cities that receive the maximum rain fall and has witnessed a substantial increase in its underground water levels.

### 2.5.1 South Africa:

Storm water management in the urban territories of South Africa has and proceeds to dominatingly center on gathering spillover and directing it to the closest waterway. This implies storm water waste as of now organizes amount (stream) management with almost no accentuation on the protection of nature. The outcome has been a noteworthy effect on the earth through the subsequent disintegration, siltation and contamination. An elective methodology is to consider rain garden as a feature of the urban water cycle, a procedure which is by and large progressively known as Water Sensitive Urban Design (WSUD) with the rain garden management part being known as Sustainable Drainage Systems (SUDS). SUDS endeavor to oversee surface water waste frameworks comprehensively in accordance with the goals of maintainable advancement. It plans to structure for water amount management, water quality treatment, improved courtesy, and the support of biodiversity. In this manner many of the negative ecological effects of storm water are relieved and a few advantages may be figured it out.

### 2.5.2 China:

At present, the flow approach rain garden management in China principally centers on "utilization" as opposed to "usage". Albeit some huge urban communities, for example, Shanghai, Beijing and Shenzhen have started to embrace techniques considering the rain garden as an asset, it is still particularly in the primer stages. Utilizing urban rain garden for gainful intentions is a generally new idea for China and this is a multidisciplinary inquire about field. Analysts in China are yet assembling learning identifying with the maintainable administration of urban rain garden. All things considered, China is yet utilizing customary ways to deal with oversee storm water instead of the utilization of forefront methodologies to relieve storm water amount and quality effects because of urbanization. This is despite the way that these systems have been routinely connected for a long time in many created nations.

### 2.5.3 Malaysia:

As per an article published by (Muha et al., 2013), Malaysia has taken rain gardens as a permanent part of its urban development and water cycle management. Rain gardens have been proved to be extremely efficient in its first round of deployment and conserving water and reducing storm water pollutants.

## 2.6 Rain Gardens in South Asian Countries

Countries in South Asia already face considerable water management challenges. Water resources are overexploited and are draining quickly. Challenges faced by the South-Asian countries regarding the successful establishment of rain gardens are the lack of proper design and implementation strategy to ensure that the storm-water concentration is not located near the drinking water reservoirs. Michael Dietz’s in 2007 explained that it a widely accepted fact that rain gardens are very beneficial but, in some cases, they have been found to omit larger quantities of pollutants as compared to those absorbed. South Asian countries are lacking behind on the technical and development front and need proper guidance and research to cater such issues.

The biggest challenge is to reduce compost and yield water that is organic and safe enough to be consumed by plants and the soil. Pollutants such as phosphorus and copper, if not removed properly can be poisonous. The Action on Climate Today (ACT) program has been effectively working in five South Asian nations (Afghanistan, Bangladesh, India, Nepal, and Pakistan) to enable governments to get ready for, and deal with, the effects of environmental changes in the water area. The ACT has advocated a Climate-Resilient Water Management (CRWM) approach as a method for expanding the strength of water frameworks on which billions of individuals depend. In view of ACT's activities in South Asia, rain garden management interventions are arranged into three general classifications including rain garden resource management, management of extreme events (floods and droughts) and creating an empowering situation (through mainstreaming climate impacts in sectoral and cross-sectoral strategies, among other governance instruments)(Milfont et al., 2016).

### 2.6.1 India:

As reported by the Times of India in 2008, the new Hyderabad airport included rain gardens to avoid Storm-water run-off, flooding and saved water accumulating at roof-tops and other paved and hard surfaces.

## 2.7 Rain Gardens in Pakistan

0.3 sq. km area of Margalla hills near Faisal Mosque in E-7 is targeted by Capital Development Authority (CDA) for establishing a water collection system. The main purpose of this system is to use the storm water and saving it from getting wasted on roads. The existing system is already very helpful, but it may fail in some ways for depleting groundwater resources and ecosystem restoration. It was estimated that 0.6 million gallons of water can be generated in an hour just by 10mm per hour precipitation in this area. All the water from the above scenario goes to the main drain which gets connected to Lai Nullah system which thus results in wasting huge amount of water. It had been seen that almost 3 million liters of water is used to be run from the drainage system of pipes when heavy rain comes from the roof top of Faisal Mosque Islamabad. From last two decades, by doing monitoring all over the Islamabad, it was observed that the level of ground water is decreasing every year constantly by one or two meters. Hence government of Pakistan started a program with collaboration of United Nations Development to recharge ground water table. A pilot project was started at Faisal Mosque for harvesting the rain water by the help of UNDP. Two bore holes were installed. They were just acting like tube wells, but in these bore holes water flows through gravity. The immediate result that was noticed,14 feet rise in the local water table, after 3 days of rain. So that was a tremendous success. (Schwengsbier,2010).


**Figure 2- 2: Bore Holes near Faisal Mosque**
**(Source: Internet)**

### 2.7.1 Soak way for Ground Water Recharge:

Pakistan Council of Research in Water Resources (PCRWR) has also started a project in which they have made soak way (An Australian term for rain gardens) for ground water recharge. All the rain water from roof top of this building is collected and directed into the soak way. There is a flow meter which measures the amount of rain water directed towards the soak way.


**Figure 2- 3: Soak Way in PCRWR Islamabad**
**(Source: PCRWR)**

**Figure 2- 4: Flow Meter On top of Soak Way**
**(Source: PCRWR)**

Soak way has a rectangular pit of size (8' x 8' x 10') which is dug in the ground. There are basically, six layers of a soak way. The first layer which is the bottom most layer contains boulders; the second layer contains gravels. Third layer contains stones which are lesser in size than gravels. The fourth layer is the sand and the top most layer is the mud layer which maintains the green belt. When the rainfall occurs all the water from rooftop of PCRWR is directed into the soak way and is measured with flow meter. This soak way basically recharges groundwater table. It was installed in year 2017 when initial GWT was measured as 185ft. In year 2018, GWT was measured to be 215ft.

### 2.7.2 Inverted Well for Ground Water Recharge:

One other ground water recharge technique is inverted well. This concept is basically used in Baluchistan. It's a low cost, high efficiency system which diverts flood water into underground artesian basin, to make it safe from evaporation and other impurities present in the surrounding atmosphere. The Schematic diagram of an inverted well is as follows:

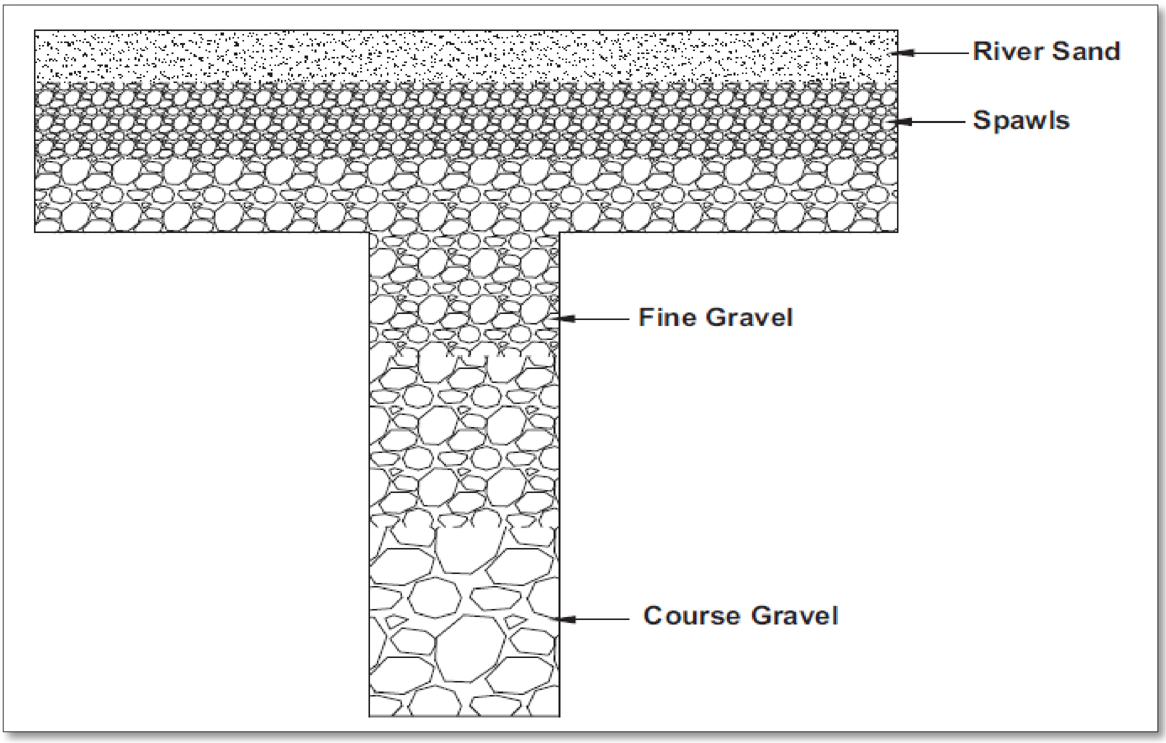


**Figure 2- 5: Schematic diagram of an Inverted well**
**(Source: Sustainable groundwater Management in Baluchistan)**

Inverted well structure and functionality is simple. A square pit of (1m x 1m) is dug, up to a depth of about 2m. It has basically four layers, bottom most layer contains course gravel followed by a layer of fine gravel. At the top most layer of the pit, fine sand is placed. This sand is placed purposefully to retain silt and other debris from entering the well. In this way groundwater is recharged quickly. The top fine sand is removed after some time and fresh sand is filled to avoid clogging of the (Ashraf, 2017).

**Figure 2- 6: An Inverted well on the upstream of a leaky dam**
**(Source: Sustainable groundwater Management in Baluchistan)**

For the purpose of rain gardens, the quality of water plays a significant role. An experimentation was conducted on groundwater quality in the sandy aquifer of Bass Endean (Australia) where they found that sand obviously fuses a higher ability to trap toxins than normally thought (Barber et al., 1988).

In Pakistan, a country that has suffered from economic, social and political instability the water distribution has always been unjust. Cities with a larger influence and political power get a large share of water while the rural areas and less developed cities suffer from acute water shortage. In addition, providing water in rocky territories is time overpowering, unsafe, and costly business with differed dangers associated with it (Loiskandl et al., 2010).

## 2.8 Rain Gardens Implementation: A Case study of New York

After the implementation of rain gardens for underground water table recharge, an extensive study was held in this regard. The recently constructed Wiebicke housing development site located along Hoffman Road in Milton, New York was chosen for the study site. It had almost 14 residential properties and some of which were not fully constructed by May 2010. The eight lots west of Hoffman Road, the adjacent detention pond, and the 550 feet of new proposed roadway, were the focus area for the study. The soil present in this area was in between class A and B type. It was moderately drained in the upper two feet and poorer drained silt below that depth. There were 4 catch basins through which storm water runoff happened to pass through 560 feet of underground piping.

Computer modeling was used to compare the results between rain gardens runoff and traditional out dated methods. An infiltration test was conducted. The infiltration data of the site illustrated that; the highest infiltration was estimated in 2010 during the study period as the maximum rainfall received during the year. Before the year 2010 the infiltration due some fluctuation and was average. The amount of infiltration was increased from 2010 to 2013 but did not reach the highest values obtained in 2011. The estimated highest infiltration was 3645 mm in 2011, and the lowest was 980 mm in 2001 (Company, 2006). Results showed 1.7 in/hr. this number was used to discharge water through both traditional and rain garden sites. The Hydro CAD results showed 43-80percent less runoff in the site having rain gardens. Study revealed that rain gardens work best in particular environment. It is very possible that type of rain garden working best in one area may fail on another site as soil composition infiltration rate etc. may differ. On soils that are comparatively more permeable like in our study area infiltration occur easily. In such areas rain gardens are implemented to treat the runoff from roads and other concrete surfaces that are impervious (Bedan, 2009).

Types of soils for example clay or silty soil where permeability rate is very low in rain gardens are used to absorb runoff even from houses. Since street runoff is not possible in this scenario due to the quality of soil one may hope we can achieve some results from residential area. Even on well-draining soil just like the one in our study, the Hydro CAD model shows that even rain gardens were not able to control and manipulates all the storm water runoff. Significant remedy was achieved through the rain gardens though (Carpenter, 2010). In non- storm situations results showed 100 percent effect. In our study site even, the soil was permeable still we managed to achieve up to 45 percent progress. Rain gardens in addition to their primary purpose of keeping underground water table balance also are aesthetically pleasing.

The results of the study showed that rain gardens can help keeping the water table to bear minimum level despite all this urbanization. In other words, rain forests are very helpful in capturing the runoff storm water which is totally wasted otherwise.

## 2.9 Rainwater Harvesting

The rain water harvesting is also one of the oldest traditions to cope up water scarcity or to reduce the water wastage and maximize the storage. Rain water harvesting strategy is used to collect the rainwater and store it from the top of the roofs, rocks and land surfaces using minimal and natural resources such as artificial or natural reservoirs and ponds. The amount of 1 mm rainwater harvested is equal to the 1 L of water/square meter (Ben-Asher, 1982). This stored rainwater become a source for the household use including sanitation, washing etc. moreover, it can also be used for agricultural purposes.

Rain water harvesting has three major forms:

- **External Water Harvesting**– water is collected from the rainfall somewhere else but is stored offside
- ***In-Situ*** **Water Harvesting**– water is collected from the rainfall on the surface over which it isfallen
- **Domestic Water Harvesting**– water is stored from streets, courtyards and roofs runoffs (Abdulla and Al-Shareef 2009)

## 2.10 Difference between Rainwater Harvesting and Rain Garden

There are some misconceptions that rain gardens and rain water harvesting are similar concepts. Here is the difference between both the concepts.

**Table 2- 1: Difference between rainwater harvesting and rain gardens**

| Rainwater Harvesting | | Rain Gardens |
|---|---|---|
| 1. | Collect and store water from one's property. | Rainwater is collected from stormwater runoff and can soak within soil. |
| 2. | Reduce portable water use and polluted runoff. | Naturally cleanses all pollutants with help of soil. |
| 3. | Stored in large containers or rain barrels. | Stored in the soil. |
| 4. | Aid portable water supply conservation.  | Increased ground water resources.  |

## 2.11 Geographical Rainfall Trend

There is a higher variation in the rainfall in all seasons as well as based on geography in the whole Asian region from past few years. This is the reason that a reduced trend has been observed in the coastal regions of Pakistan as well. The reports published by the Pakistan Meteorological Department has showed that the majority areas of Pakistan suffer from the dry climate (Rehman et al., 2012). The conditions of humidity have been restricted to the smaller areas of north. On the other side, the major part of Baluchistan, Punjab and Sindh receives lower than the 250 mm of rain every year.

### 2.11.1 Fluctuations in Rainfall Pattern in Pakistan

The fluctuations within rainfall causes an effect over the farming and water management. In

2010, a report published by Task force on Climate Change demonstrated that Pakistan has been exposed by various floods and extreme rainfall in past two decades (Rehman et al., 2012). Moreover, the majority areas of country have unpredictable and highly unreliable rainfall pattern which has made difficult for people to make safety measurements.

The country was exposed to a super flood on the 29 July 2010 as a result of dense monsoon in the region of Punjab, Khyber Pakhtunkhwa and Baluchistan. The heavy and record-breaking rainfall of 274 mm in one day was recorded in Peshawar against the previous 187 mm record in 2009 (McElhinney, 2016).

The rainfall variation has been raised around the Asian region in the last three decades, and so a reduction within the rainfall has been observed in the plains and coastal regions of Pakistan (Khan et al., 2013).

The key areas of Pakistan have a very dry climate and the average rainfall in the Baluchistan, Potohar and whole Sindh is lower than the 250 mm. The mean rainfall pattern is varied in every part of country as the Sindh province carries lower than the 100 mm of rain while northern region and foothills get above than 1500 mm. The monsoon period ranges from July to September in the whole country and a total of 60 percent of rainfall is observed in this time. Most rains of summer cannot be utilized for the crop production or other reservoirs as they rapidly runoff because of the torrential showers. In some other times, the rain water is so light that the time to reach the root is so long and the water is evaporated quickly. The total of 50 to 60 percent of rainfall water is wasted due to the runoff and reduced reservoir resources (Chaudhari, 1994).

### 2.11.2 Reasons for Higher Variability in Rainfall Pattern

The major reason behind the wider variability in the rainfall pattern is the presence of monsoon winds as well as western disturbances. The Baluchistan and Khyber Pakhtunkhwa provinces get maximum rainfall in winter season (Dec – Mar) while on the other side, Sindh province and Punjab earns more than 60 percent in the monsoon time. This is how, there are basically two precipitations including winter and summer precipitation (Khattak, 2015).

- The winter precipitation is received mainly from the western disturbances that is entered in Pakistan from Afghanistan and Iran. The entry of weather from the Afghanistan is known as the primary western disturbance whereas, the other one entering from Iran is known as the secondary western disturbance and the later one is responsible for major rainfall.
- On the other side, the monsoon weather in Pakistan is received from the north or south east and the rainfall of this time is prominent over the northeast and northern areas (Khan et al., 2013).

### 2.11.3 Potohar Region

The region of Potohar is lying between 72ºE to 74ºE Longitude and 32.5ºN to 34ºN Latitude. The major cities under Potohar region include Attock, Rawalpindi, Jhelum and Islamabad. The representative city of Potohar region is Rawalpindi that is also the fourth biggest city of Pakistan. The city is located at 517 meters above the sea level (Arshad et al., 2013).

### 2.11.4 Existing Rainfall Pattern in Potohar Region

The matter of climate change has been steadily rising on the global scale in terms of its effects over the environment. Increased temperatures and its effects over the atmosphere especially rainfall is very evident in the whole world. Just like other countries, Pakistan has also kept a share within the diverse climatic change observed within northwest India. The major fragment of the climatic change is the erratic or variable rainfall patterns, owing to the transformed atmospheric circulation (Rodó, 2003).

### 2.11.5 Rainfall pattern in Rawalpindi from 1991

The climatic conditions of the Rawalpindi city are topical and experience the moderate temperature throughout the year. There is fluctuation in the annual rainfall pattern of the city just like the other cities of Pakistan (Rashid, 2011). The conditions of drought were prevalent from the time period of 1999 to 2001 (Rehman et al., 2012). According to the results of the rainfall as shown in Figure below, the year 1994 suffered as the wettest year while the year 2000 was the driest year for the city. After one year, the total rainfall in the year 2001 was quite normal.

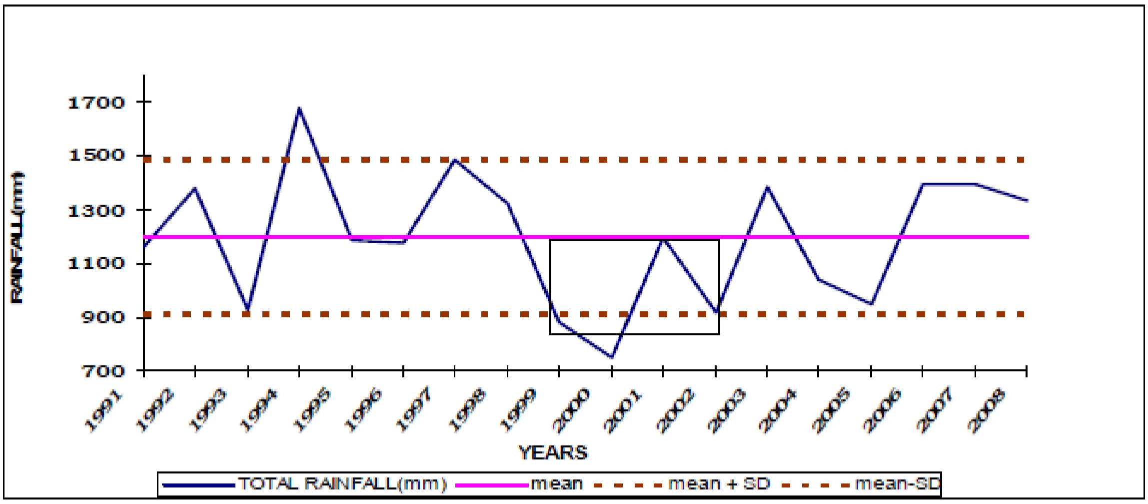


**Figure 2- 7: Annual Variation of rainfall in Rawalpindi (1991-2008)**
**(Source: Internet)**

The above figure shows the variation in the rainfall pattern observed in Rawalpindi from 1991 to 2008. It can be easily seen that the first two years including 1991 and 1992, received total rainfall of 1100-1400 mm. But in 1993 the city received less than 1000 mm of rainfall annually. From 1994 to 1998, the rainfall was either average or it was above average, but no reduction was observed. Year 1999 to 2002, severe drought conditions hit the city and the total rainfall was reduced to 750 mm in 2001. The conditions of drought were later suppressed due to the increased rainfall in 2003. The other years received a total rainfall of more than 1400 mm (Kahlown et al., 2007).

According to the rainfall pattern in Rawalpindi in 2009, most of the rainfall happened from the January to April while the monsoon period received lower rainfall of about 25-50 mm. On the contrary, in the rainfall pattern of 2010, a wide variation has been observed. the major part of rainfall happened in the monsoon period while the January to March period received 100-200 mm. The average rainfall in monsoon time of 2010 was record-breaking as 400 mm rain was received at that time.

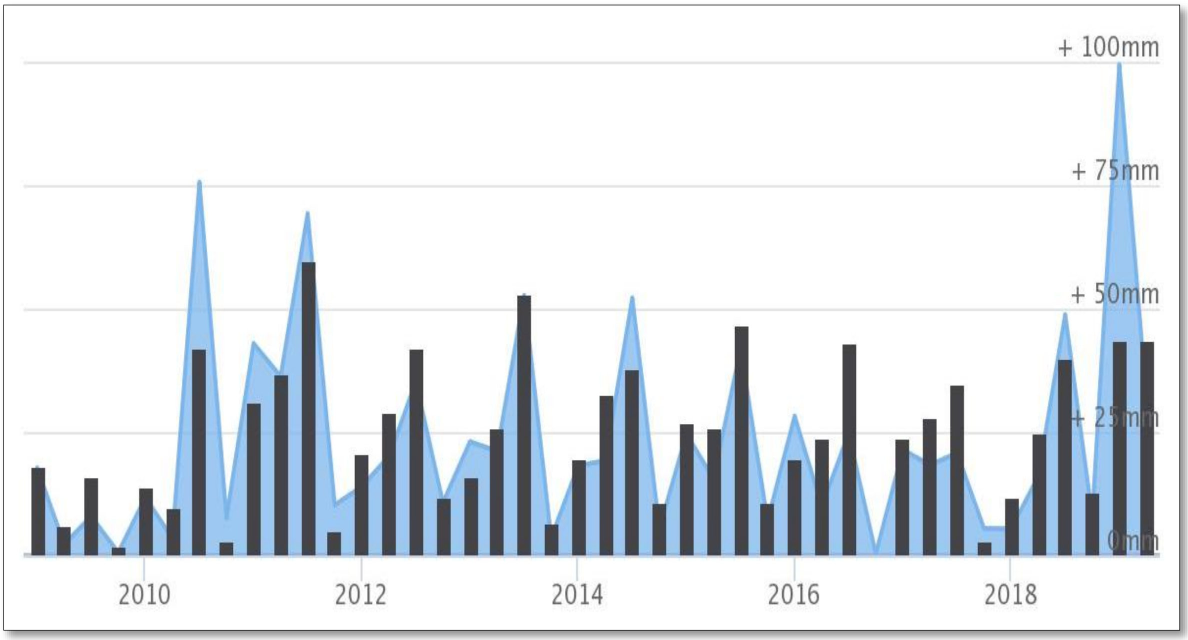


**Figure 2- 8: Annual Variation of rainfall in Rawalpindi (2009-2018)**
**(Source: Internet)**

Rainfall pattern of 2011 showed, the maximum rainfall happened from January to March period and then in the Monsoon time, but the whole year experienced better rain when compared with the previous years. The next year 2012 received similar pattern of rainfall but the only change was in the quantity of rain. January to March and monsoon time received more rainfall and average rainfall was from 50-100 mm. Year 2013 also experienced the similar behavior of rainfall but average rainfall 50-150 mm was higher than year 2012. All these three years 2011-2013, other months except winter and monsoon, also experienced rain. The trend remained stable till 2014 but after that, the rainfall remained restricted from January to March and then July to September. In 2015, the maximum rainfall in Rawalpindi was received from January to the start of May and then the trend reduced in June. But as the period of July started, the rainfall increased to 150 mm until the start of September. The rainfall pattern of 2016 showed little difference than the previous trends as the period of January to March received lesser rainfall, approximately 50 mm. On the contrary, 75 mm rainfall was recorded in the month of April, which was completely new trend. The monsoon season remained similar as it was in the previous years with the average rainfall of 100 mm. in 2017. The peak rainfall started in February instead of January and the average rainfall recorded in February was more than 150 mm. Only two seasons received maximum rainfall in 2017, being the winter and monsoon season and the later received only 100 mm of average rainfall. The rainfall pattern of 2018 till now is like the previous rainfall patterns with a little change. The heavy rainfall was observed in the monsoon season (June to Aug) which is quite normal. But the average rainfall in this season recorded was much higher than the previous ones as the maximum rainfall recorded was approximately 400 mm which is record breaking. Moreover, another important thing to notice is the absence of heavy rainfall in the period of January to March. There is only slight rainfall (<50 mm) recorded in the entire season which is much less as compared to the previous patterns. All the above-mentioned years have shown a variable pattern of rainfall from last two decades. There is no linear trend observed between these years. Some of them have received maximum rainfall as year 2010 got more than 300 mm of maximum rainfall while on the other side, year 2009 received less than 100 mm of maximum rainfall. On a general note, after the maximum recorded rain in 2010, all the years till 2017 have experienced lower rainfall that is only limited to 100 to 150 mm.

According to the Hydrological Studies report, Islamabad being the center of Potohar region, receives the average annual rainfall of 1248 mm. whereas, the maximum monthly rainfall accounts for 340 mm at the time of monsoon season from (July to September) and the minimum rainfall is recorded to be 14 mm in November. So, the maximum rainfall was nearly 60 percent recorded in the Monsoon season (Kahlown et al., 2007).

## 2.12 Ground Water Situation in Potohar Region

### 2.12.1 Hydrology and Geography of Potohar Plateau

The Potohar plateau is present in between the Indus and Jhelum River but parallel towards the outer Himalaya. It carried the districts of Rawalpindi and Attock along with the few parts of Murree, more than half of the Chakwal District and a small portion of Mianwali and Jhelum district. The Potohar region is 250 km long ,100 km wide and has elevation of 200 m alongside river Indus, 457 m being the average elevation. The southwest part of Potohar carries arid climate whereas the north east part has humidity in its environment. The two rivers including Soan and Haro flow in the region from east to west and fall in the Indus region. The River Kanshi is present in the east part of plateau and flows from north to the south to drain in river Jhelum (Ali et al., 2010).

### 2.12.2 Water table in Punjab Province

The water table overall in Punjab province has reduced by 3 feet each year. Twenty years ago, the water was extracted from 20-40 feet below the surface in the whole Punjab. But, because of the excessive drilling and reduced ground water availability, drilling is done below 800 feet to get the water in Punjab (Morris et al., 2001).

### 2.12.3 Water supply sources in Twin Cities

Around the globe, the major source of water is always the ground water and the surface water. In the twin cities of Pakistan, the major cities of Potohar region, these two resources are the major water supply systems. These dams are the resources of the surface water supply. Along with that, CDA has installed 180 tube wells in Islamabad to supply the ground water whereas the Rawalpindi Development Authority (RDA) has installed 260 tube wells to meet the demands of inhabitants' water supply. Moreover, many municipal and private wells are also under use in order to meet the requirements of water (Nabeela, 2014).

### 2.12.4 Groundwater situation in Rawalpindi

The groundwater is the major source of water for the inhabitants of Potohar region particularly Rawalpindi where water is obtained from 278 tube wells network. In 1998, there were only 39 wells in Rawalpindi region but due to increased demand, 41 more wells were installed till 2003 and a total of 80 wells were successfully operated to meet water demand. In 2007, an additional 198 tube wells were installed in a short period of 4 years. Because of higher number of wells, groundwater elevation was significantly reduced. In 1998, a maximum of 490 m was the elevation of groundwater. But after the addition of 41 tube wells in 2003, the uppermost level of drilling was significantly reduced to 480 m.

Due to the limited area of aquifer, groundwater is considered as an inconsistent or unsustainable water resource. Moreover, the water table is also depleting gradually due to the increased withdrawal situation in Rawalpindi. The water table was reduced to 14 m in five years, from 1998 to 2003 and 5 m was further depleted till 2007. The water table was significantly reduced from the 600 meters (at Margalla Hills) to the 450 meters around Soan River. The annual water table was reduced to 1.40 meters from 1988 to the 1995 and this gradual reduction is continued as a result of the increased urbanization and over pumping. Moreover, the ground water quality within the Potohar region is also low due to biological contamination (Cheema et al., 2008).

### 2.12.5 Vulnerability index for Groundwater in Potohar Region:

According to a study conducted by Rabia and Sheikh in 2010, the vulnerability evaluation index for the water resource has proved that the resources of water in the Potohar region, particularly Islamabad and Rawalpindi, have found to be highly vulnerable. The reason behind this higher vulnerability is not only the climatic change but there are also some other non-climatic factors responsible for this change including the socioeconomic variables (Nabeela, 2014).

The other common factors responsible for such lower levels of ground water in the Potohar region includes the shortage of water, increased growth of population, reduced water tables due to excess withdrawal and erratic rainfall pattern (Khan et al., 2016).

All these factors along with the underprivileged socio-economic conditions has resulted in the significant water resources vulnerability in the whole region. There are also some other common problems related to this higher vulnerability that are causing worsening of situation such as lack of infrastructure maintenance, reduced resources distribution, insufficient awareness, lack of policy measures for operation, confusion related to the legal framework for the environmental, political and social aims.

### 2.12.5 Urbanization and Groundwater

In Pakistan, especially Punjab, the total of 70 percent private tube wells is present within canal areas. In such areas the groundwater is utilized for the purposes of irrigation along with the canal water and separately (McCornick et al., 2010). Although, according to the research such method should not be carried out, but this strategy is widely used in Punjab. Therefore, the use of groundwater is very much prevalent among the farmers than it was thought. Most of the farmers use the groundwater only at the time when the surface water is unavailable(Asghar et al., 2004). Major part of Potohar region has come up with reduced groundwater table due to enhanced production of crops that are completely relying over the groundwater (McCornick et al., 2010). Urbanization has completely transferred the resources of water from surface to the groundwater. Every area of Potohar has become dependent over the use of groundwater as the resource. Such increased population using groundwater has come up with the dropping 3.5 m aquifers annually and they are liable to extinction in the next 15 years, creating an alarming situation of increased groundwater use due to urbanization (Malik et al., 2009).

*Chapter 3*

# Research Methodology

The aim of the study was to promote rain gardens as a water conservation strategy in water stressed communities of Rawalpindi. This was a hybrid research, the method used in this study was Mixed Research Method as this method is thought to be best suited for this research as it took into consideration both forms of data which proved helpful in answering the research questions regarding the existing situation and helped in explaining the causes of the present situation.

This study embodies an exploratory research design for which qualitative and quantitative data were collected for analysis of rain gardens perception from residents, management, experts and professionals. Data collection comprised a field survey of Askari 14 and Gulshan-e-Abad through questionnaire. This survey helped in determining the perception of rain gardens among residents of water stressed communities, its benefits and future prospects. As the variable selected for field survey was mainly water stressed residential areas of the city, the sample size was taken to be 200 by using Slovin’s formula. Population sample was selected randomly so the study would be free of any kind of bias.

## 3.1 Case Study Area

Rawalpindi is a city in the Punjab province of Pakistan. It is adjacent to country's capital Islamabad, and the two are jointly known as the twin cities on account of strong social and economic links between them. Rawalpindi is the fourth largest city in Pakistan with a population of 2.1 million, while the larger Islamabad Rawalpindi metropolitan area is the country's third-largest metropolitan area consisting of the twin cities along with Murree, Attock, and Wah. For this research two housing societies located in Rawalpindi, which were facing water shortage issues were selected.

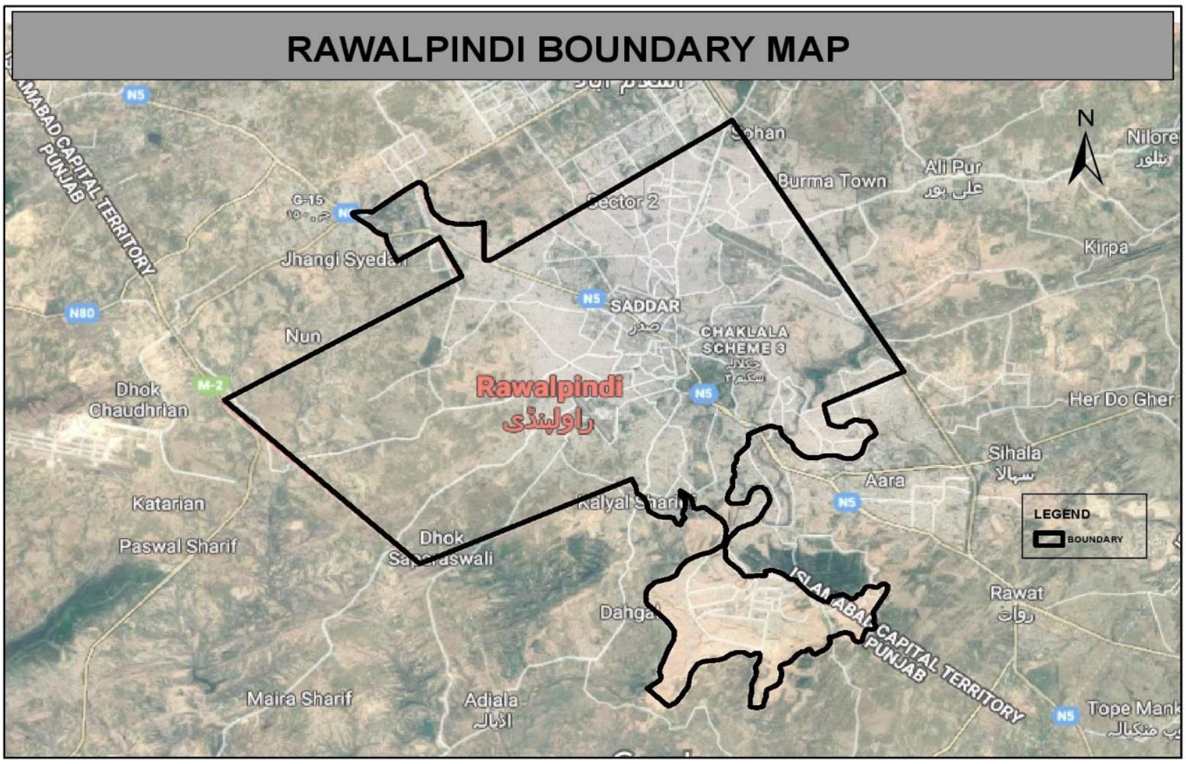


**Figure 3- 1**: **Rawalpindi Boundary Map**
**(Source: ArcGIS map)**

### 3.1.1 Askari 14

Askari 14 is a part of Askari Rawalpindi Properties located on Western side of G.T Road and is near Bahria Town Rawalpindi. Adiala Road is within a five minutes' distance just south to it, while Attock Refinery is yet another mega development located outside it. Askari 14 was established in 2006, presently well-developed comprising of 1689 houses. Houses/plots range from ten (10) marla to two (02) kanal, with 97 percent of plots already been constructed upon. Being former armed forces employees, most of the residents are of a middle to high class background, being supplied with all the basic amenities like gas, electricity and water. Water shortage is the major issue. For water supply, tube wells are sunk near Military College of signals.

### 3.1.2 Gulshan-e-Abad

ABAD Cooperative Housing Society Ltd Rawalpindi, more familiar with its project name

“Gulshan-e-Abad” is a housing society located on the suburbs of Rawalpindi. It is located at the center of Adiala Road and Morgah Road and was launched on 27th March 1983. It’s a very old housing society comprising of approximately 3000 houses and is divided into four sectors with plot sizes ranging from five (05) marla to one (01) kanal. All plots have been constructed on. The society harbors technical workers; thus, the socioeconomic backgrounds range from low to lower middle class. Since the society is old, it lacks availability of basic resources which diminish from time to time. Electricity, gas and water shortage are the major issues. The initial water scheme was commenced in year 1985 and it was completely functional up till the year 1990.

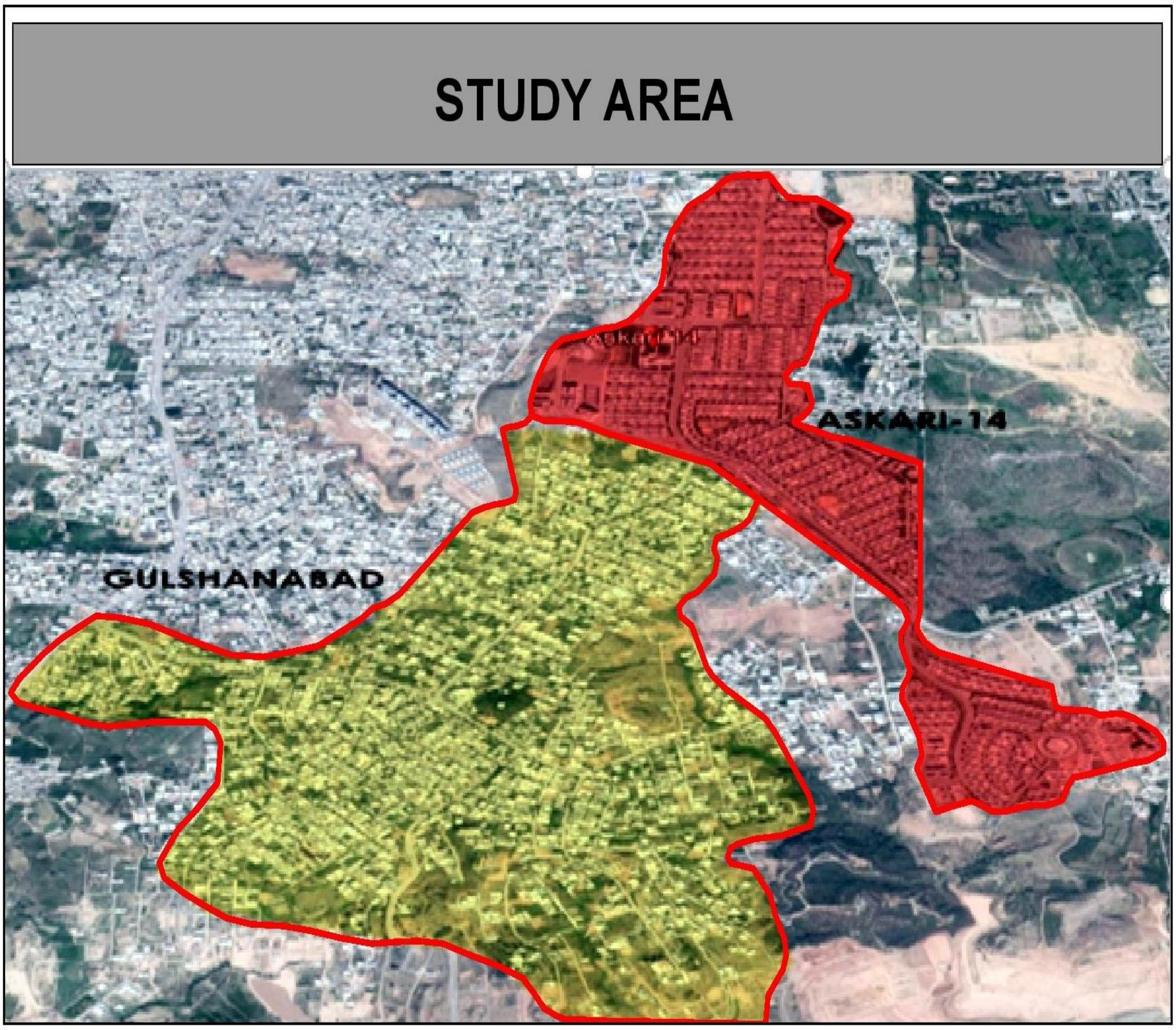


**Figure 3- 2: Askari 14 & Gulshan-e-Abad Boundary Map**
**(Source: ArcGIS map)**

## 3.2 Data Collection

The first step in the research was to review the current knowledge of the research topic and find gaps which are needed to be pushed towards research objectives. The secondary data collection from various national and international journals, human right reports, research studies, dissertations, reports and world reports were performed.

The primary data was collected with help of interviews and surveys by use of questionnaires in order to analyze data quantitatively. The data collection is one of the highly critical part of research as the analysis is performed on the data collected and this enables the researcher to draw final conclusions and make the recommendations. The data collection was the expensive and difficult task, and that is why, it is highly important to collect data that is accurate and reliable, and it must be connected with the research. Data accessed for this study was based on two different sources which are as follows:

1. Secondary sources of data
2. Primary sources of data

### 3.2.1 Secondary Data

Both primary and secondary resources were accessed for data collection. The first step of current research was to review some well-renowned literature related to the concept of rain gardens and its implementation. The secondary data collection is a cheap and easy process to collect data when compared with the primary data and so, firstly the secondary data was collected. The secondary sources that were accessed for data collection consisted of the following:

a. Relevant books
b. Articles
c. Published reports

d. Previous research articles

Peer reviewed research papers, reports published nationally and internationally, data provided by PMD, WASA and PCRWR were studied for understanding the concept of rainfall pattern, groundwater table situation, rain gardens and its application in different cities of the world. Study of literature also helped in understanding different ways through which research objectives can be achieved. Review of literature helped in identification of indicators that were used for developing questionnaires and observatory checklist. The review of literature also helped in enhancing the research objectives for this study and played a significant role in assessing the needs and requirements of the people in the study area.

### 3.2.2 Primary Data

Secondary data helped in understanding the existing situation of the city, but primary data covered a major part of this research. Primary data was collected through the following data collection techniques:

1. Field Survey
2. Interviews

#### 3.2.2.1 Field Survey

Field survey was conducted at 2 different housing societies so that basic characteristics of the study area can be identified and analyzed. This survey was carried out so that perception of the residents can be obtained and considered while deriving a strategy for implementing rain gardens for the study area while considering requirements and reservations of the residents of the study area. Questionnaires for residents was developed based on the indicators identified with the help of literature review.

##### 3.2.2.1.1 Sample size

The sample size has been calculated through Solvin's formula.

$n= N/ (1+Ne^2)$

Where;

n= Sample size

N= Population of the community

e= Margin of error

The projected population of both societies is 4394 houses. The margin of error was taken to be 7 percent. The reason for taking 7 percent as the margin of error was the present security situation of the city. People don't feel safe in sharing their personal information for studies.

**Table 3- 1: Sample Size Details**

| Housing units | Margin of Error | Sample size |
|---|---|---|
| 4394 | 7 % | 200 |

#### 3.2.2.2 Interviews

Interviews play a very important role in shaping the outcome of the entire research. Management of both societies, experts and professionals were approached for obtaining expert opinion about the concept of rain gardens and its implementation. Semi-structured interviews were conducted. Also, futuristic impacts of rain gardens were also discussed in the interviews and recommendations for continued implementation of the concept were discussed with the experts.

## 3.3 Data Analysis

This phase of research included compilation of data and its analysis using softwares like SPSS, ArcGIS, MS Office and so on. The data analysis included cleaning, inspection, modeling and transformation of data.

The data collected from the sources mentioned above was of two types:

1. Quantitative Data
2. Qualitative Data

### 3.3.1 Quantitative Analysis

#### 3.3.1.1 Descriptive Analysis

Descriptive analysis was done for results of field survey and helped in summarizing the raw form of data into meaningful information that can be used for assessing the present situation of the study area. For this purpose, that collected data was analyzed with the help of SPSS which gave results in the form of descriptive statistics. This meaningful data was then analyzed which gave clear picture of the existing conditions of the residents of study area and the issues that were faced by them.

The results of field survey were then used for determining awareness index , satisfaction index and willingness index variables for the rain gardens.

### 3.3.2 Qualitative Analysis

#### 3.3.2.1 Content Analysis

Content analysis was undertaken for selected literature related to rain gardens concept. Apart from this, content analysis was also undertaken after conducting semi-structured interviews with experts that were focused on implementation of rain gardens based on the requirements and reservations of the respondents of the field survey.

## 3.4 Strategic Recommendations

After analysis of results of the study area, recommendations were given. These recommendations were based on the results obtained through analysis of expert opinion and responses of the respondents of the field survey.

## 3.5 Work Flow Diagram

Research methodology framework is as follows:

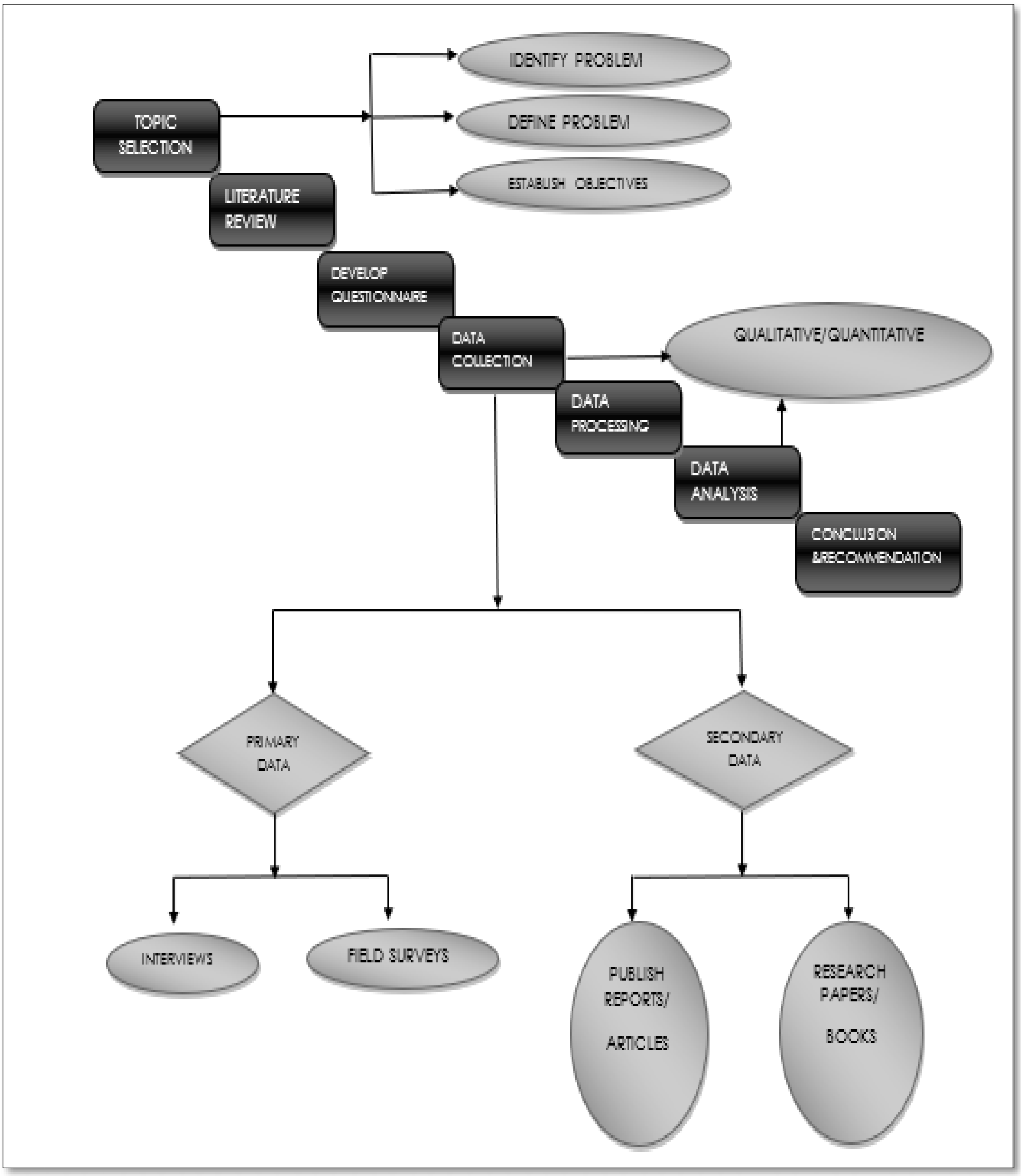


**Figure 3- 3: Research Methodology Framework**

### 3.5.1 Data Set

Data set required for the research is as follows:

**Table 3- 2: Data Set Details**

| Features | | Data Sources |
|---|---|---|
| Data (Obj-1) → | Analysis of rainfall, water table and population data to check pattern of change over a period of time. | Rainfall data was taken from Pakistan Meteorological Department.<br>Water table data was taken from Water and Sanitation Agency.<br>Population data was taken from Population Census Bureau. |
| Questionnaire Survey (Obj-2) → | To identify current rain water management strategies used by people of both societies. | Survey was conducted from residents of:<br>•Askari 14<br>•Gulshan-e-Abad |
| Questionnaire Survey + Interviews (Obj-3) → | To investigate perception of rain gardens from societies, management and experts. Its benefits and future prospects. | Survey was conducted from residents of Askari 14 and Gulshan-e-Abad. Interview was conducted from Management of Askari 14 and Gulshan-e-Abad. (2 interviewees each)<br>Interviews were conducted from Hydrologists for Expert Opinion. (7 Interviewees) |

*Chapter 4*

# Data Analysis

The objective of this research was basically to investigate the perception amongst the general masses regarding the adoption of rain gardens, to reduce water scarcity. The average annual rainfall and ground water table of last eighteen years along with population increase was also analyzed. The awareness index of rain gardens, and willingness index for installation of rain gardens among residents of both societies was measured. Subsequently the satisfaction index of already prevailing rain water management strategies in both societies was also measured.

## 4.1 Average Annual Rainfall and Ground Water Table from 2000-2018

This study helped to identify pattern of change in ground water table and rainfall pattern because of urbanization over a period in Rawalpindi region. The below graph shows the trend of average rainfall pattern from 2000 to 2018 in Rawalpindi region.

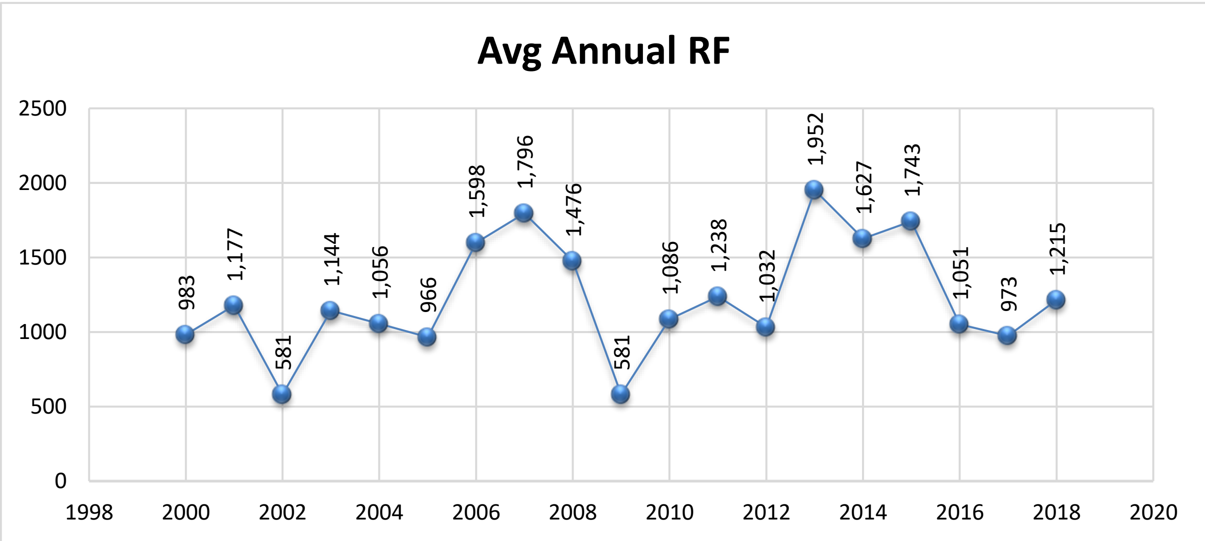


**Figure 4- 1: Average Annual Rainfall from 2000-2018**

The data, which was collected from PMD, after analysis depicts that, maximum average rainfall recorded was 1951.7 mm in the year of 2013 and minimum rainfall was observed in year 2002 which was 580.85 mm. 2006 to 2008 and 2013 to 2015 shows maximum average rainfall trend. The largest decrease of average rainfall was shown in the year 2002 which was up to 50 percent and the previous year declined up to 49 percent.

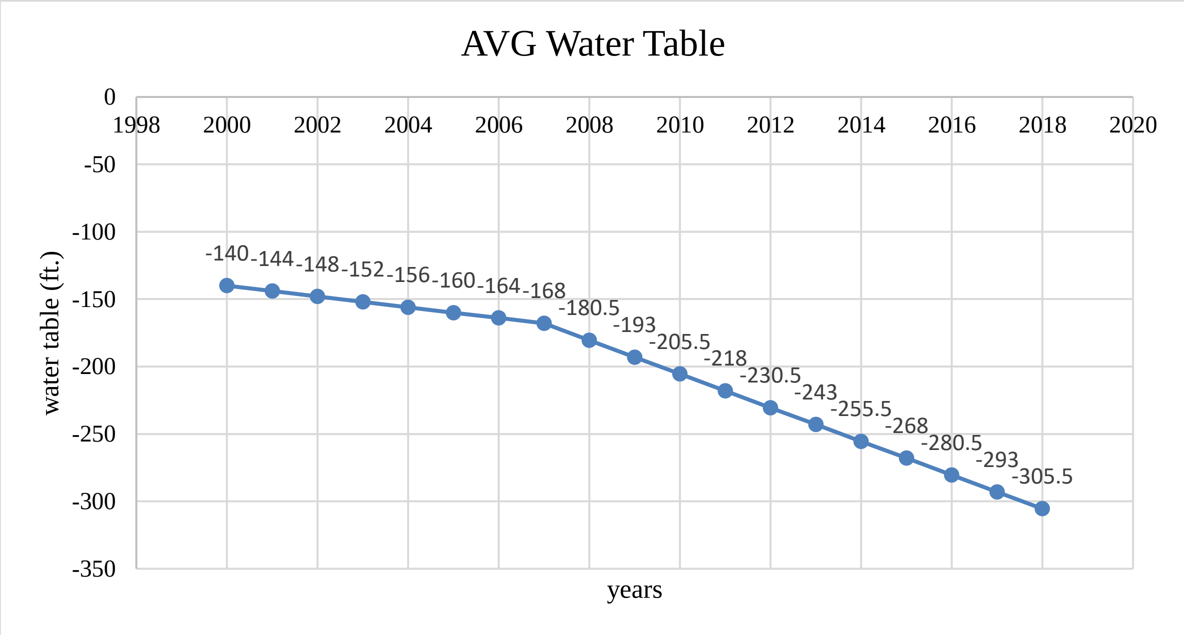


**Figure 4- 2: Average Annual Water Table from 2000-2018**

Water table data was collected from the Water and Sanitation Agency (WASA), which after analysis depicts, an average decrease in the water table each year. From 2000 to 2007 there is an average 4 feet drop in water table every year. From year 2008 till 2018 there is an average 12 to 13 feet drop in water table. Hence, increase or decrease of average rainfall does not affect the average water table because it shows continuously decreasing trend. But we can relate it with increasing population as due to increase in usage of water, even increase in rainfall did not help in rise of water table trend.

With the passage of time, water table shows continuously decreasing trend as number of wells is increasing due to increase in demand of water. The increase in population causes significant change in depleting water table at slow pace from 2000-2007, though the city is receiving good amount of rainfall yearly. After year 2008, the water table is constantly decreasing but yearly rain fall has shown fluctuation. Majority of the citizens use groundwater as a major source of water supply i.e. there is a drastic increase in number of wells resulting in depleting water table

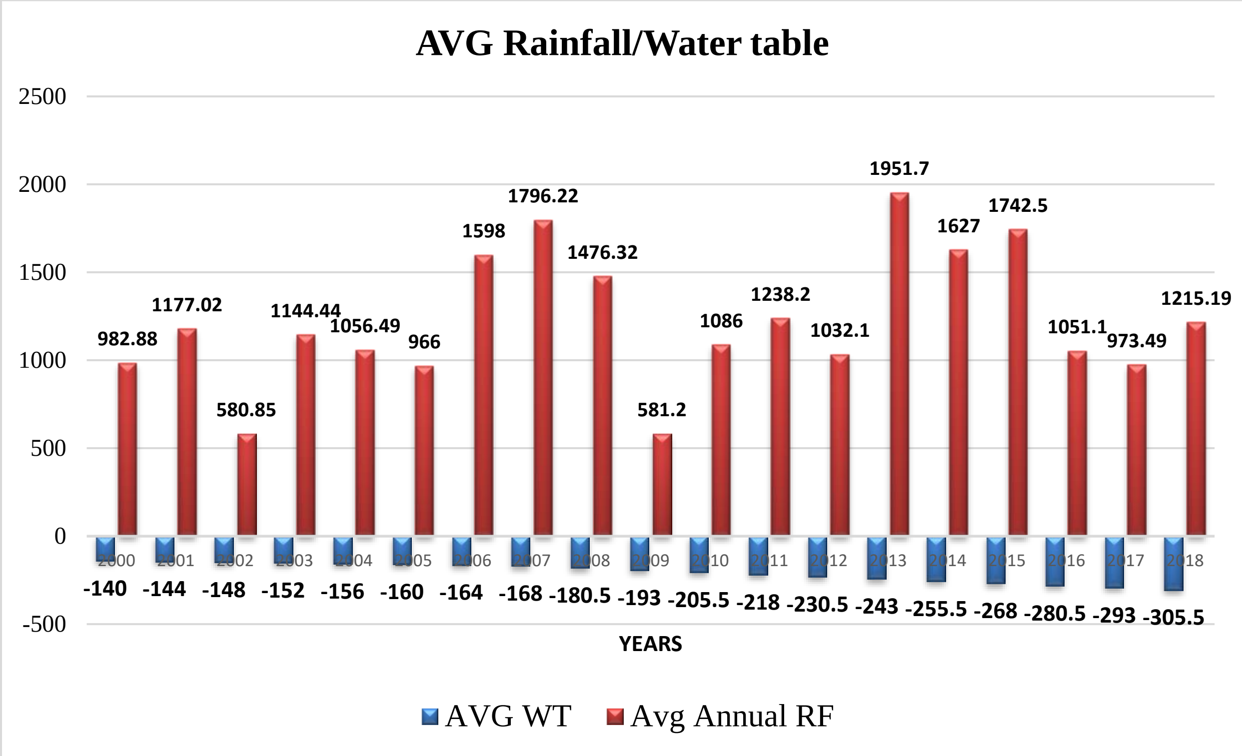


**Figure 4- 3: Average Annual Rainfall and Ground Water Table from 2000-2018**

## 4.2 Population Pattern over the Years

Figure 4-4 shows the total population of Rawalpindi District by dividing it into urban and rural population categories. The population is continuously increasing in both regions; however, it is increasing significantly in the urban areas.

| Year | Region | Population |
|---|---|---|
| 1981 | Rural | 1106595 |
| | Urban | 1014855 |
| 1998 | Rural | 1575638 |
| | Urban | 1788273 |
| 2017 | Rural | 2530117 |
| | Urban | 2875116 |

**Figure 4- 4: Population Pattern over the Years**
**(Source: Population Census Bureau)**

Coming to the Rawalpindi city which we focused upon in our study, data shows that the increase in population causes significant change in water table because the city is receiving good amount of rainfall yearly. The yearly rainfall is very fluctuating, but water table is decreasing at slow pace with almost constant decrement from year 2000-2007.

There is no proportional relation between yearly rainfall and water table. After year 2008, the water table is constantly decreasing but yearly rain fall has shown fluctuation. On other hand, the population is increasing at rapid pace from last 20 years due to urbanization. Urbanization decreases the underground water level due to increased consumption. So, due to rapid urbanization from last 20 years, there is no significant increment in water table level.

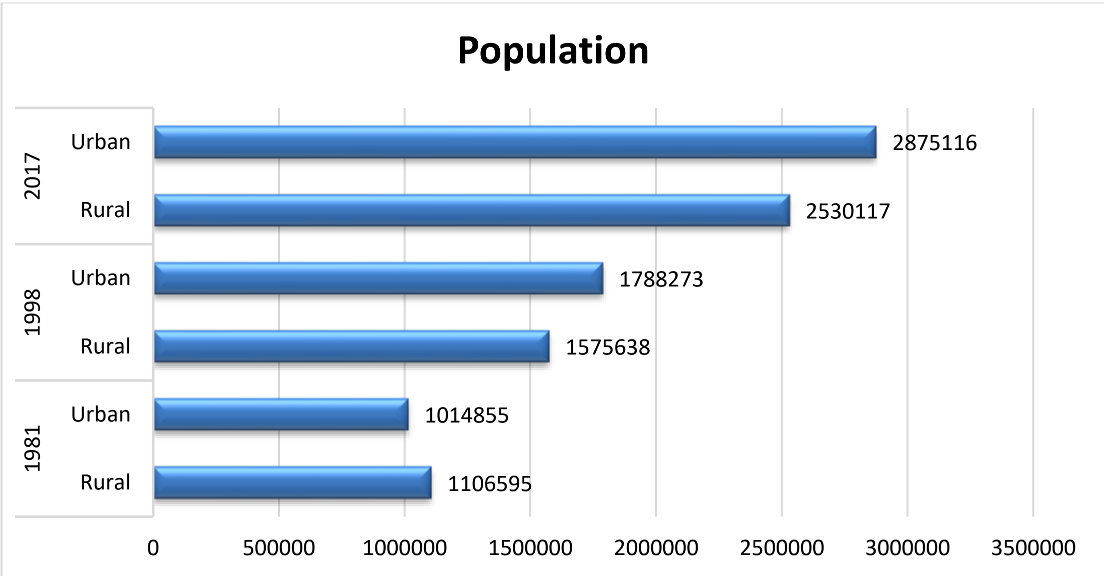


**Figure 4- 5: Graphical Presentation of Population Pattern over the Years**
**(Source: Population Census Bureau)**

## 4.3 Demographics Details of Residents with Respect to Place of Residence

The demographic data of both the societies shows that 54 percent respondents from Askari were male while 46 percent respondents were female. Whereas 78 percent respondents from Gulshan-e-Abad were male while 22 percent respondents were female. The females of Gulshan-e-Abad were reluctant to respond because majority of them were having lower literacy level, so male population responded there in larger number

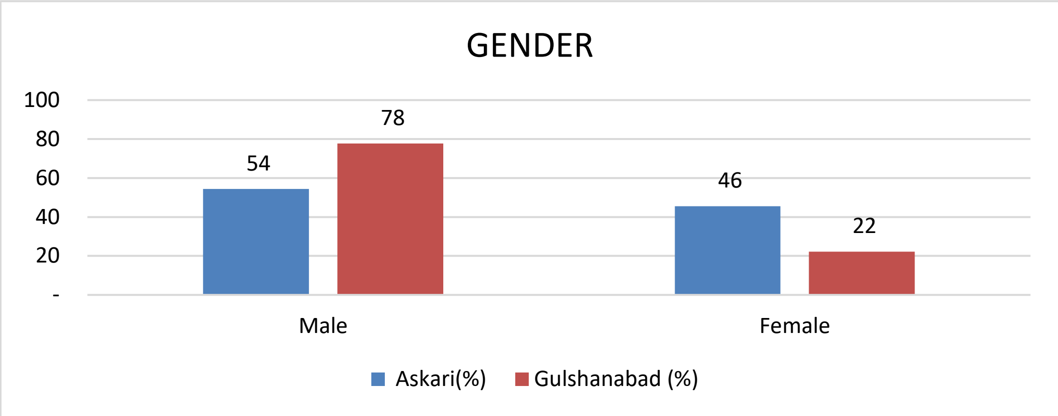


**Figure 4- 6: Gender percentages of respondents of Askari & Gulshan-e-Abad**

Eighty-seven (87) percent of the people responded in Gulshan-e-Abad were aged in-between 20-40 while 71 percent respondents of similar age group responded from Askari. Thirteen (13) percent respondents from Gulshan-e-Abad were aged in-between 41-60 where as 30 percent respondents of similar age group were from Askari. The majority number of old age respondents from Askari was because of many retired army personals living there.

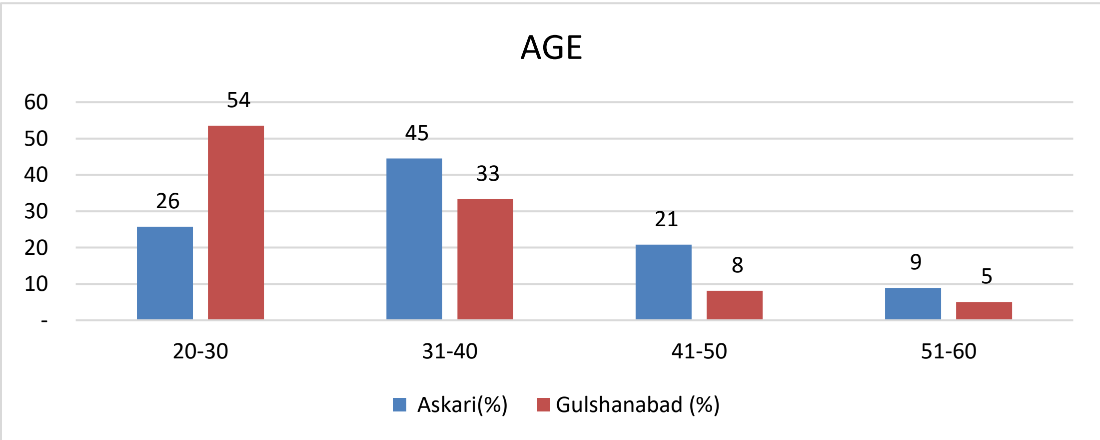


**Figure 4- 7: Age percentages of respondents of Askari & Gulshan-e-Abad**

The results show that about 20 percent respondents from both the societies were having intermediate level of education. The other 70 percent were having bachelor's degree and remaining 8-10 percent fall in post graduate level of education. This indicates that majority of the people living there are literate.

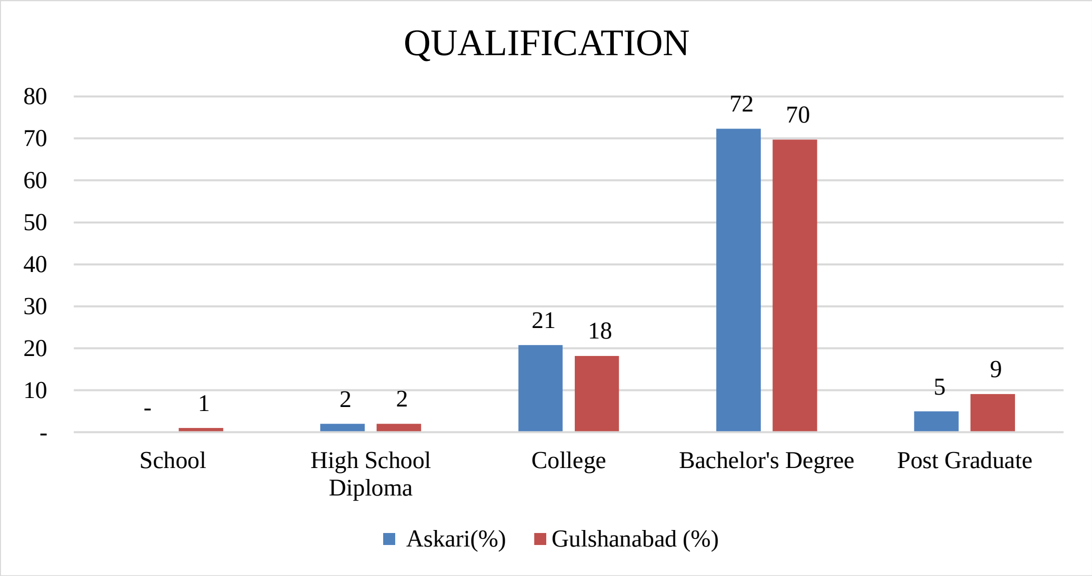


**Figure 4- 8: Qualification percentages of respondents of Askari & Gulshan-e-Abad**

Seventy-five (75) percent respondents from Askari were having income between 50,000 to 1,00,000 whereas 38 percent respondents from Gulshan-e-Abad were having income less than 50,000 and 34 percent respondents were having income between 50,000 to 1,00,000. Remaining 22 percent respondents from both societies were having income greater than 1, 00,000. As asking someone about their income is the most sensitive question so mostly people were reluctant in telling their original incomes.

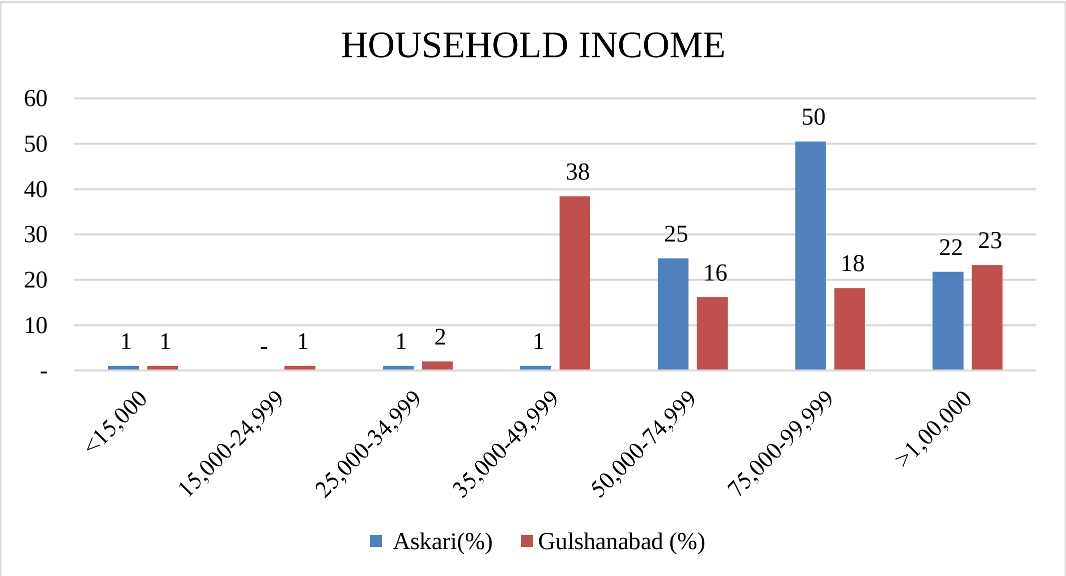


**Figure 4- 9: Household Income percentages of respondents of Askari & Gulshan-e-Abad**

Approximately 75 percent respondents were living from 1 to 4 years in both the societies. Twenty (20) percent to 25 percent of the respondents lived in their houses for more than five years. Fifteen (15) percent people of Gulshan-e-Abad had a long span of living which was 10 to 19 years.

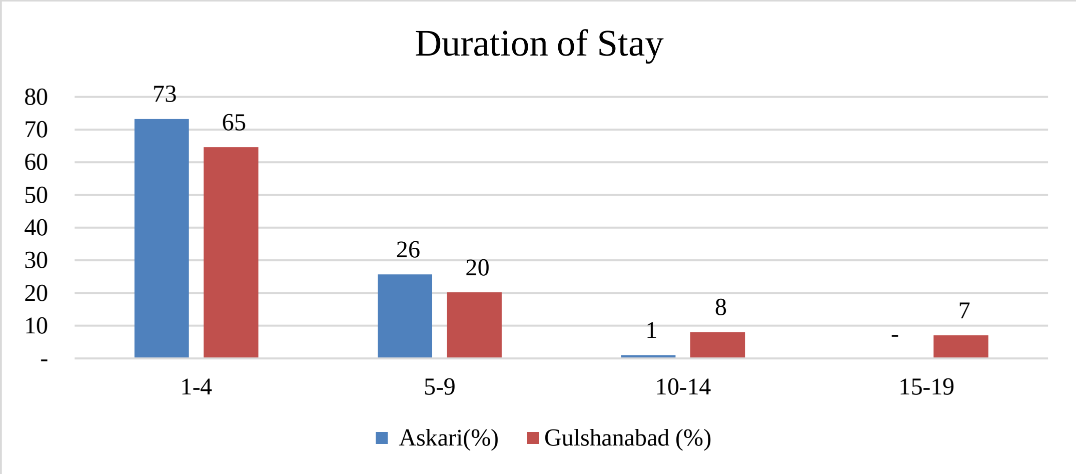


**Figure 4- 10: Duration of Stay percentages of respondents of Askari & Gulshan-e-Abad**

About 21 percent people of Askari and 26 percent people from Gulshan-e-Abad responded were students. The employed percentage of people was more in both the societies than the unemployed. Forty- one (41) percent people of Askari and 64 percent people of Gulshan-e-Abad were employed. Thirty-two (32) percent people of Askari and 8 percent people of Gulshan-e-Abad were unemployed. Rest of the 7 percent people of Askari and 2 percent people of Gulshan-e-Abad were retired personals.

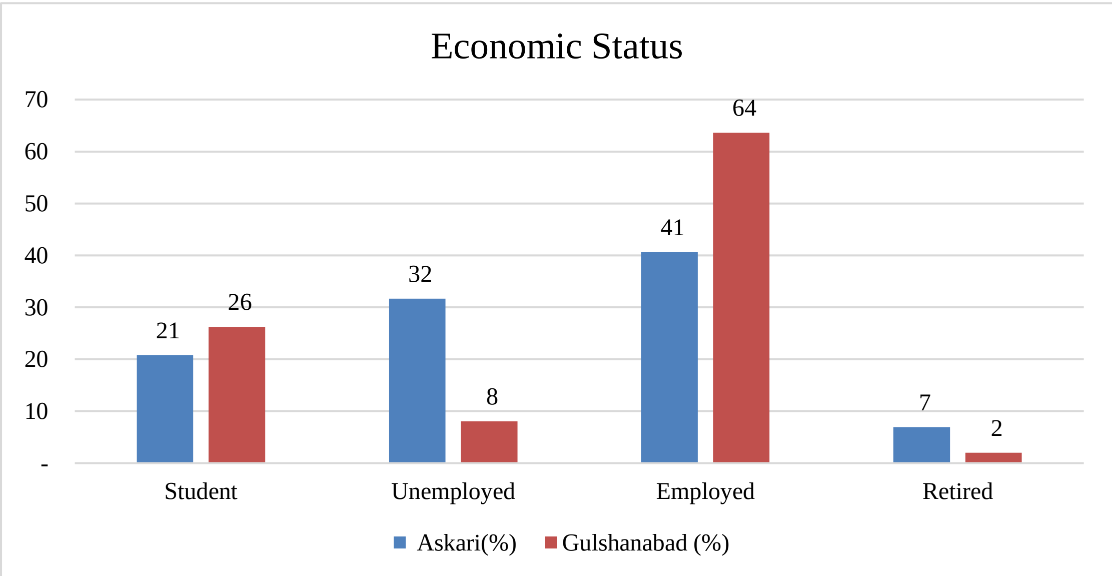


**Figure 4- 11: Economic Status percentages of respondents of Askari & Gulshan-e-Abad**

About 82 percent people of Askari and 73 percent people of Gulshan-e-Abad were having ownership of houses. Approximately 18 percent population of Askari and 27 percent population of Gulshan-e-Abad were living in houses on rent.

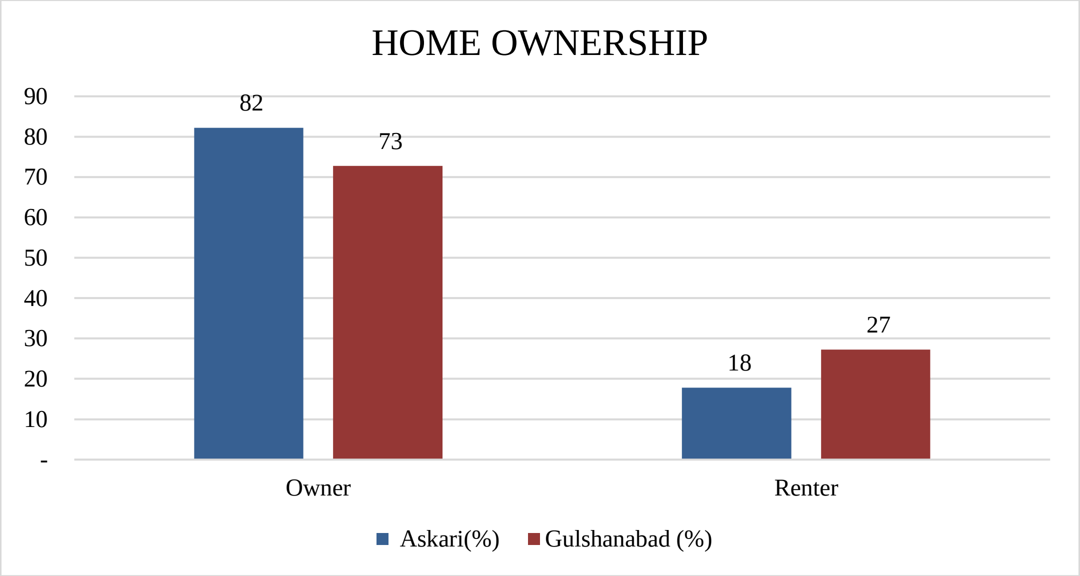


**Figure 4- 12: Home Ownership percentages of respondents of Askari & Gulshan-e-Abad**

## 4.4 Awareness of Residents about Rain Gardens

To evaluate the awareness level of the respondents of both societies about rain gardens, different questions were asked, and variable index was made in SPSS. The awareness index variables were divided into the higher, moderate and lower levels. Lower awareness meant that the individual had almost zero knowledge about concept of rain gardens, its benefits, and whether its installation would have any impact on their property. Moderate awareness meant that the individual gave a mild response, some of them may know about the rain gardens uses, others might know about how they can be implemented along with their benefits but were not fully aware about it. Some of them might think that the rain gardens installation will increase the value of property as well as its appearance and it will also improve wildlife habitat. High awareness meant a complete awareness. The awareness index variable chart is shown below.

1.01-2.61 shows low awareness index variable. Moderate range was from 2.62-3.68 and 3.69-5.0 Showed high awareness index variable range.

| Awareness Index variables | Range |
|---|---|
| Low | 1.01 – 2.61 |
| Moderate | 2.62 – 3.68 |
| High | 3.69 – 5.0 |

The respondents were asked hypothetical questions about their awareness of rain gardens and the awareness index was further classified based on their demographic details.

According to the demographic details of awareness chart with respect to gender, 84 percent females and 80 percent males were found to be moderately aware. Whereas, only 13 percent of females and 18 percent of males were highly aware about the concept of rain garden.

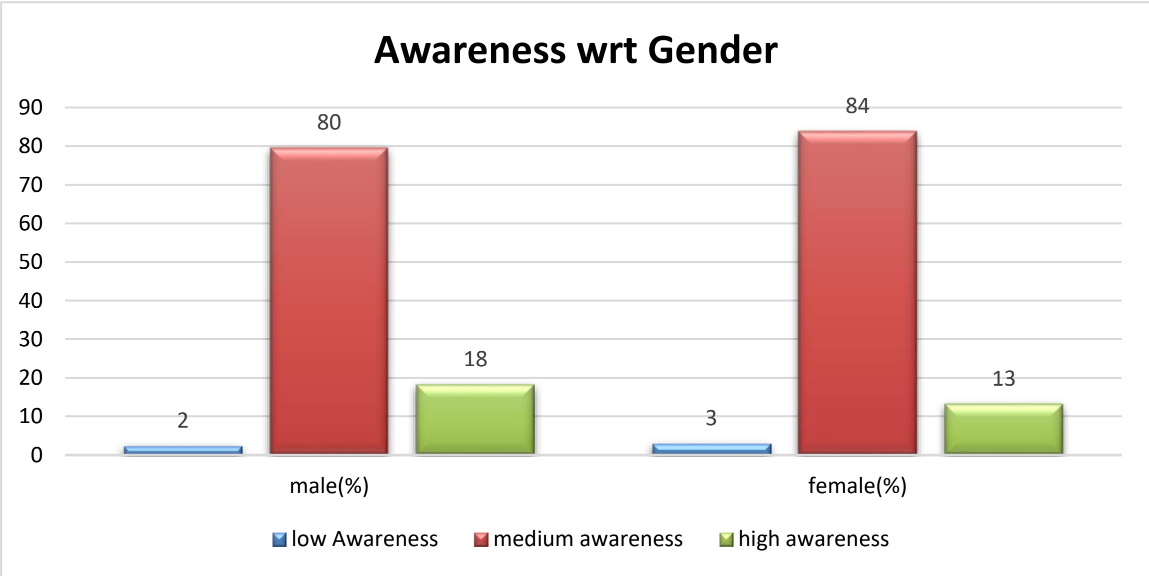


**Figure 4- 13: Awareness with respect to Gender**

When the awareness was assessed with respect to age, then there were 93 percent of people in the age group of 41-50, who were moderately aware, while only 6 percent of this age group were highly aware about the concept of rain gardens. All of them were moderately aware about the benefits of rain garden. The respondents from age group of 20-30 showed mixed results as 69 percent of them were moderately aware but 27 percent of the young generation were completely aware about the rain gardens and they showed higher interest in such water conservation practices. It shows that the younger population is highly aware about this concept of storing rain water in an efficient and cost-effective way.

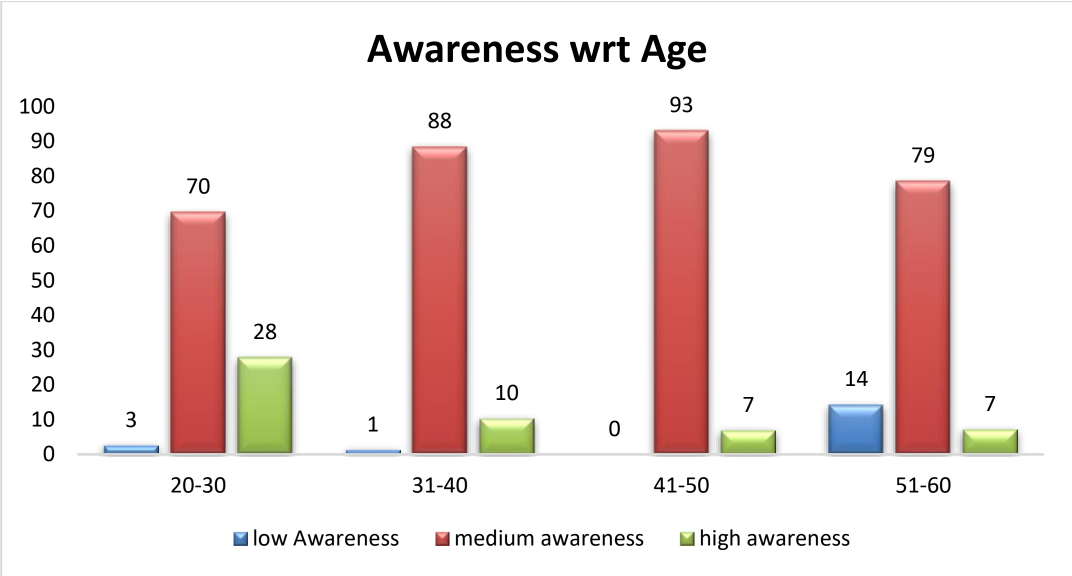


**Figure 4- 14: Awareness with respect to Age**

The respondents were further classified based on their qualification and awareness level about the rain gardens. It is a general assessment that highly qualified people are more aware about the new concepts as compared to the uneducated people. Qualification in the community leads to betterment of the community. So, our results correlated with the theory that the people having post graduate qualification were highly aware about 35 percent, about the rain gardens as compared to the other groups with lower qualification.

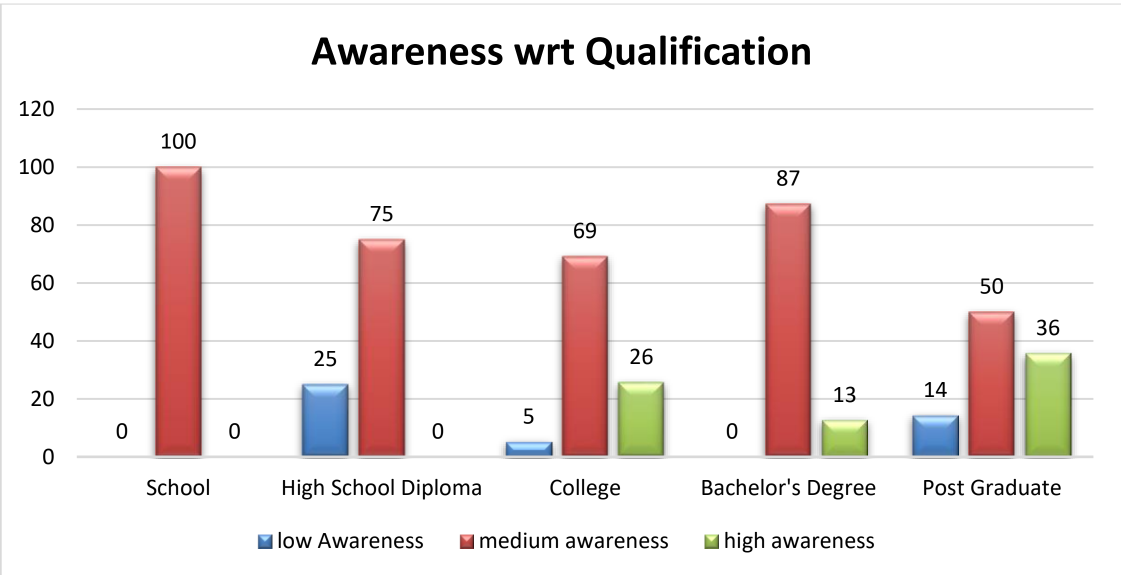


**Figure 4- 15: Awareness with respect to Qualification**

Whereas, the above graph shows that the respondents studying in college were also more aware

(25) percent as compared to the students of school zero percent and higher school also were zero percent. The students undergoing bachelor's degree were moderately aware (87) percent about the rain gardens, but they were highly interested in learning more about water management practices and rain gardens.

The respondents were classified further based on their place of residence. It is shown in the graph that the residents of Askari 14 are moderately aware (98) percent about the rain gardens while 32 percent of the respondents from Gulshan-e-Abad were highly aware. It is easy to analyze that residents of Gulshan-e-Abad were more aware as compared to the residents of Askari 14.

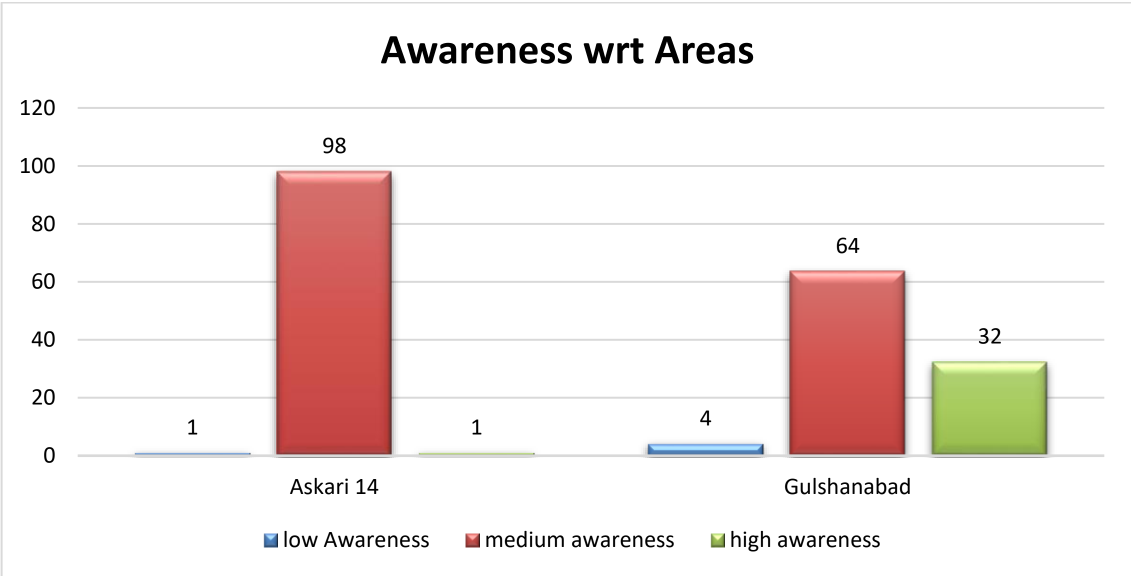


**Figure 4- 16: Awareness with respect to Areas**

Respondents were also evaluated based on their Home ownership. It is a usual concept that the home owners are usually less aware about the rain gardens when compared to the home rentals. It is because of the reason that the home renters are more likely to displace after few years to another place which provides them more awareness about different things as compared to the home owners living in their community for a longer time. In accordance with this theory, our results showed higher correlation as majority of the home renters' 24 percent were found to be fully aware about the rain gardens and their impact on environment as compared to the 14 percent of home owners. Whereas, the 75 percent of home rentals have some basic knowledge about the rain gardens which was nearly equivalent to the knowledge of the rain gardens in the home owners which were 82 percent.

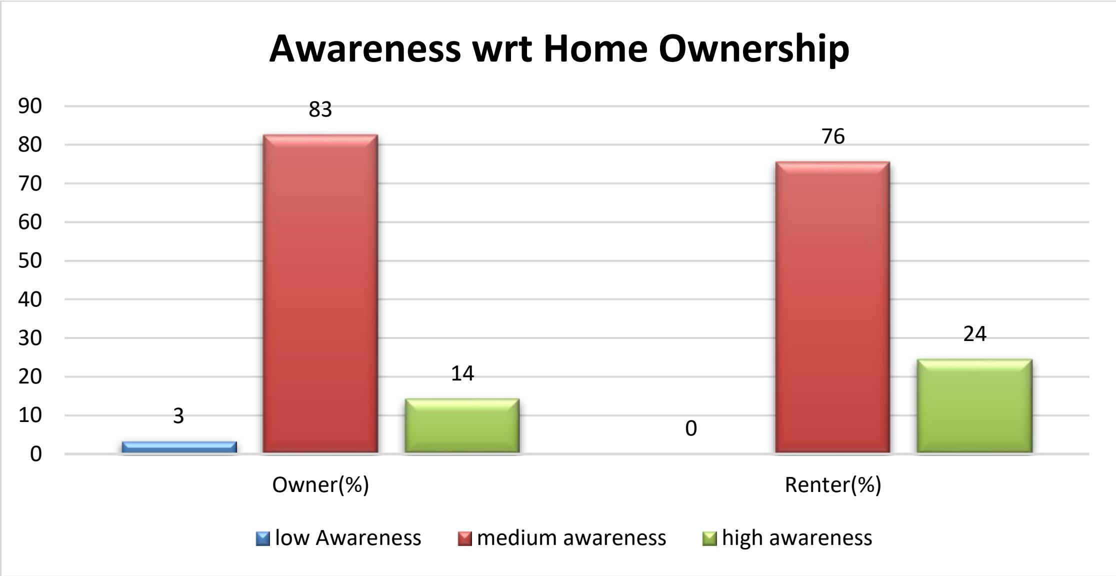


**Figure 4- 17: Awareness with respect to Home Ownership**

Based on economic status, students and employed respondents were found to be highly aware (21) percent about the rain gardens. The employees and students are in the phase of learning and sharing knowledge and new ideas that can lead to improvement in any way. Therefore, both showed higher rate of awareness about the rain gardens as compared to the unemployed 2 percent and retired zero percent. Ninety-seven (97) percent of unemployed respondents while 88 percent of retired respondents were moderately aware about rain gardens. Only 2 percent of students, 2 percent of employed respondents and 11 percent of retired respondents showed no awareness about rain gardens.

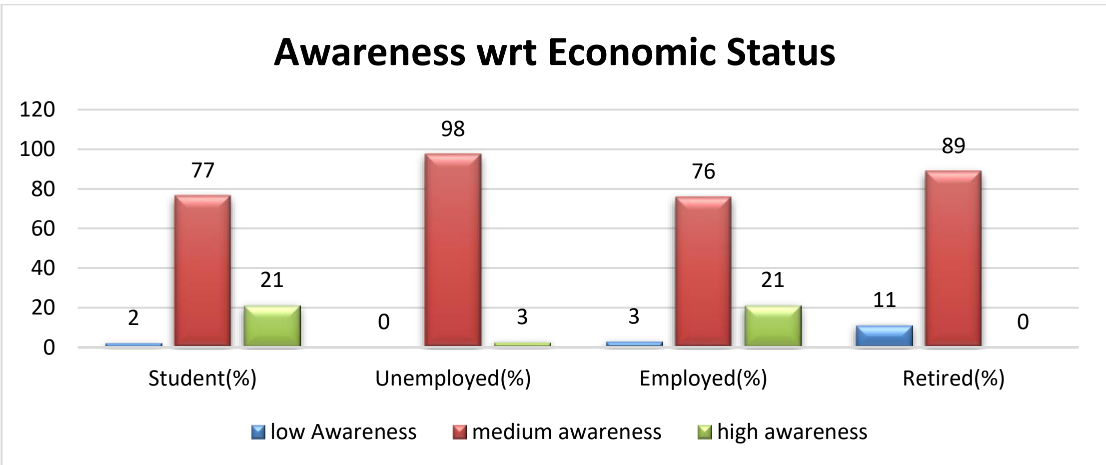


**Figure 4- 18: Awareness with respect to Economic Status**

## 4.5 Satisfaction of Residents with Current Rain Water Management Strategies

The satisfaction level was calculated based on satisfaction index variables with respect to the demographic details of the participants. The level of satisfaction of participants was assessed about the current water management practices as how much they think such practices give satisfactory results to deal with water scarcity.

To answer this question, the respondents were inquired about their level of satisfaction about the current practices of water storage. These were use of rain barrels, Pavement area removal, lawn removal, plantation of more trees, natural gardening, use of dry wells for rain water storage and use of infiltration planters.

According to the results only 2 percent people of both the societies used rain barrels for storing rain water, rest 98 percent people did not use them. Next was inquired about pavement area removal, 2 percent people of Askari and 32 percent people of Gulshan-e-Abad were using this technique. While remaining 98 percent people of Askari and 68 percent people of Gulshan-e-Abad were not using. Lawn removal technique was also not used by either of the residents. Ninety-one (91) percent people of Askari and 69 percent people of Gulshan-e-Abad planted trees as a water management strategy. Natural gardening technique was used by majority of people of both societies. Eighty-three (83) percent people of Askari and 73 percent people of Gulshan-e-Abad used natural gardening while remaining 17 percent of Askari and 27 percent of Gulshan-e-Abad were not using this technique. Dry wells were used by only 8 percent of the people of Askari and zero percent people of Gulshan-e-Abad, and infiltration planters were used by none of them.

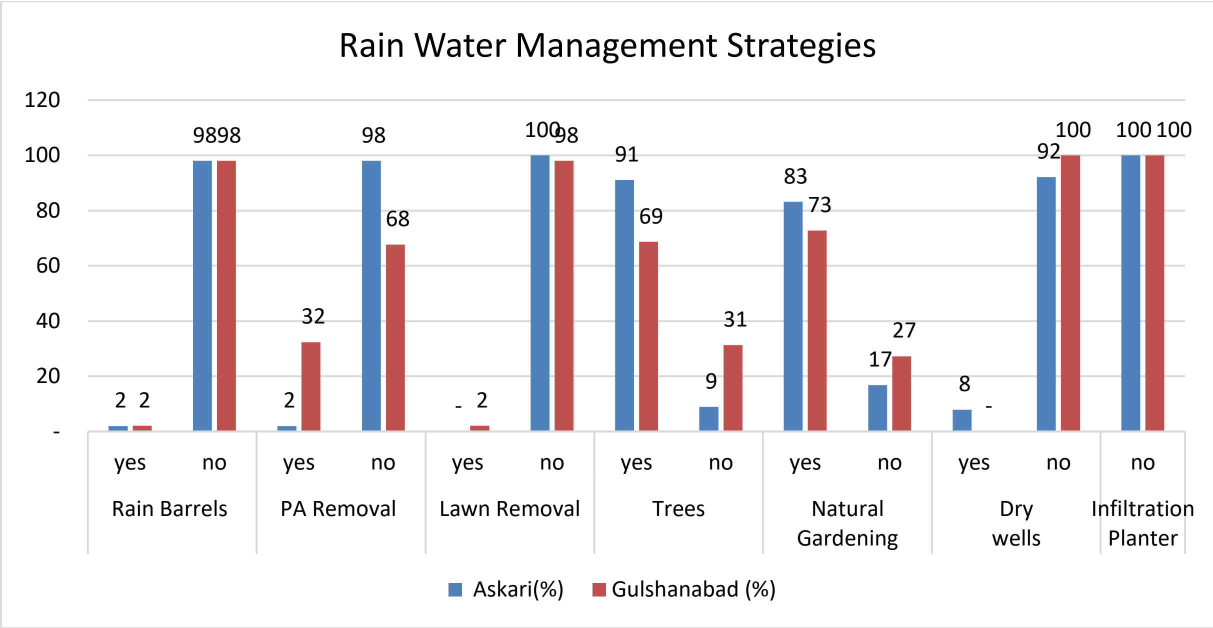


**Figure 4- 19: Current Rain Water Management Strategies**

### 4.5.1 Satisfaction Index Variable of Residents

The satisfaction index variables were evaluated in SPSS based on the survey questions related to satisfaction of residents with current rain water management strategies. The satisfaction index variables were divided into low, medium and high levels. Low satisfaction meant that the individual is not at all satisfied with current rain water management strategy. Medium satisfaction meant that the individual gave a mild response, they may be somewhat satisfied with rain water management strategy. High satisfaction meant a complete satisfaction. The satisfaction index variable chart is shown.

| Satisfaction Index variables | Range |
|---|---|
| Low | 1.01 – 2.61 |
| Medium | 2.62 – 3.68 |
| High | 3.69 – 5.0 |

1.01-2.61 shows low satisfaction index variable. Medium range was from 2.62-3.68 and 3.69-5.0 Showed high satisfaction index variable range.

According to the results of the study, it is shown in Figure below that the satisfaction level was low both in males' 84 percent and females' 94 percent. When asked about the satisfaction level with the techniques used to store water only 5.3 percent of men reported to be completely satisfied with the current practices of water storage while none of the female showed complete satisfaction. Whereas 9.8 percent of males and 5.8 percent of females were moderately satisfied.

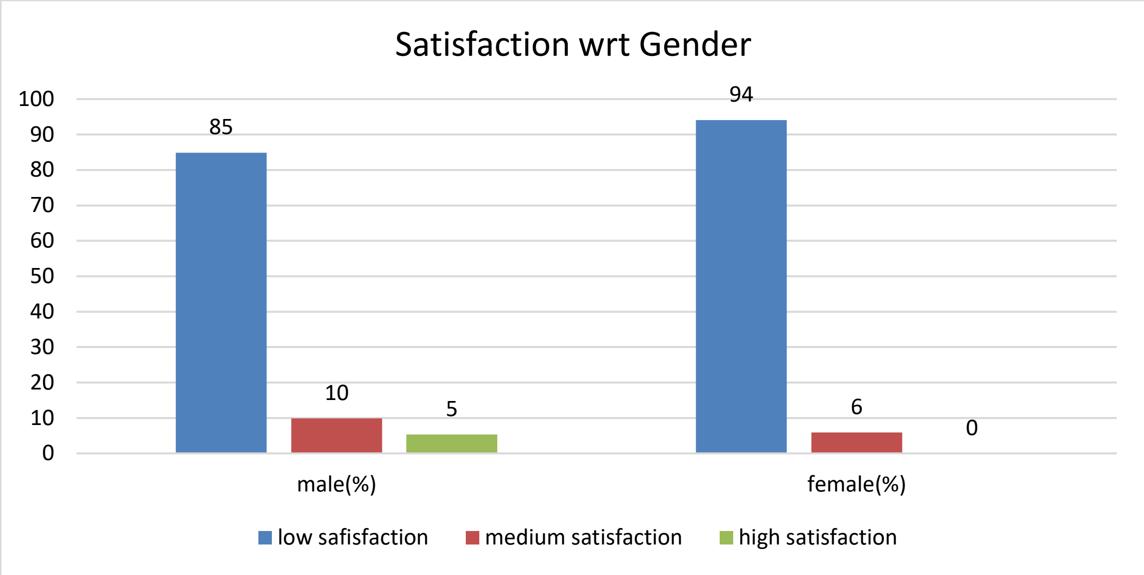


**Figure 4- 20: Satisfaction Index with respect to Gender**

When the satisfaction level was analyzed based on age factor, it is shown that the higher level of satisfaction was recorded when the respondents belonging to age group of 20-30 years were asked about current water management practices. Nearly all participants from all age groups were dissatisfied with these rain water management practices. The major reason behind this reduced level of satisfaction among the respondents of all age groups could be inefficient and ineffective water storage practices carried out by them.

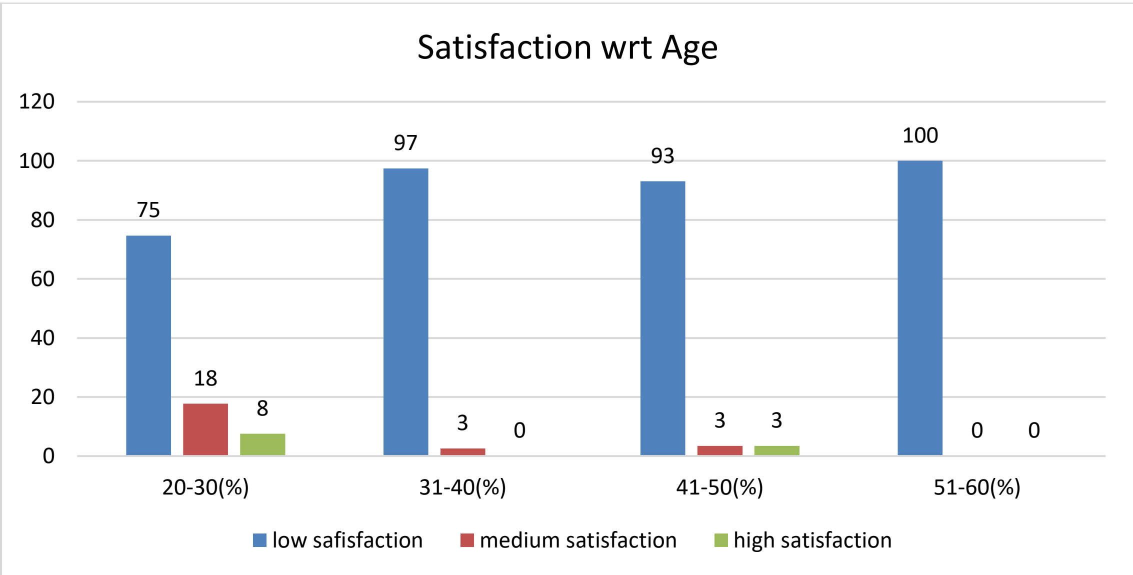


**Figure 4- 21: Satisfaction Index with respect to Age**

The higher interest of participants in the water storage plans could also be the reason behind this low satisfaction with the outdated water management practices that are in current use in both communities. Based on place of living, 11 percent of participants living in Askari 14 and only 6 percent of residents of Gulshan-e-Abad were moderately satisfied. On the other side only 1 percent resident of Askari 14 and 6 percent residents of Gulshan-e-Abad were completely satisfied with the current storage of water. This reduced level of satisfaction among the residents of both societies about current practices of water storage could be because of the little amount of rain water storage.

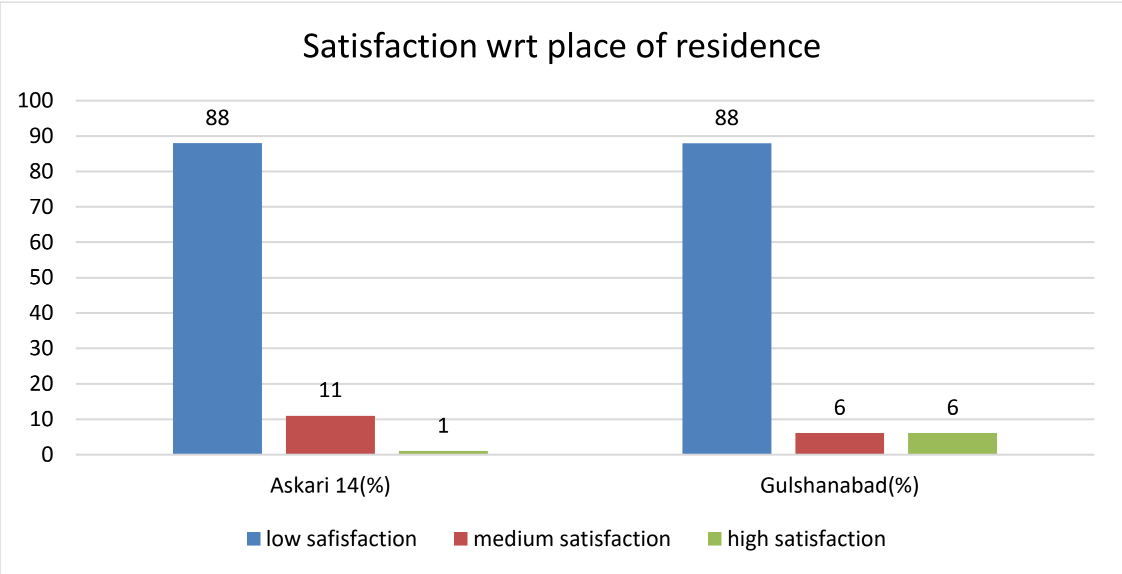


**Figure 4- 22: Satisfaction Index with respect to place of residence**

All the respondents of the student group were dissatisfied with the current water management practice. The satisfaction of the college (84) percent and university going students (90) percent was also recorded to be low whereas the students with the higher school diploma showed medium satisfaction (25) percent. Only students who were undergoing bachelor’s program reported to have higher satisfaction level (5) percent with the existing water management practices among all the respondents interviewed as might be they were using rain barrels technique to store water. Even the post graduate individuals shoed low satisfaction (79) percent.

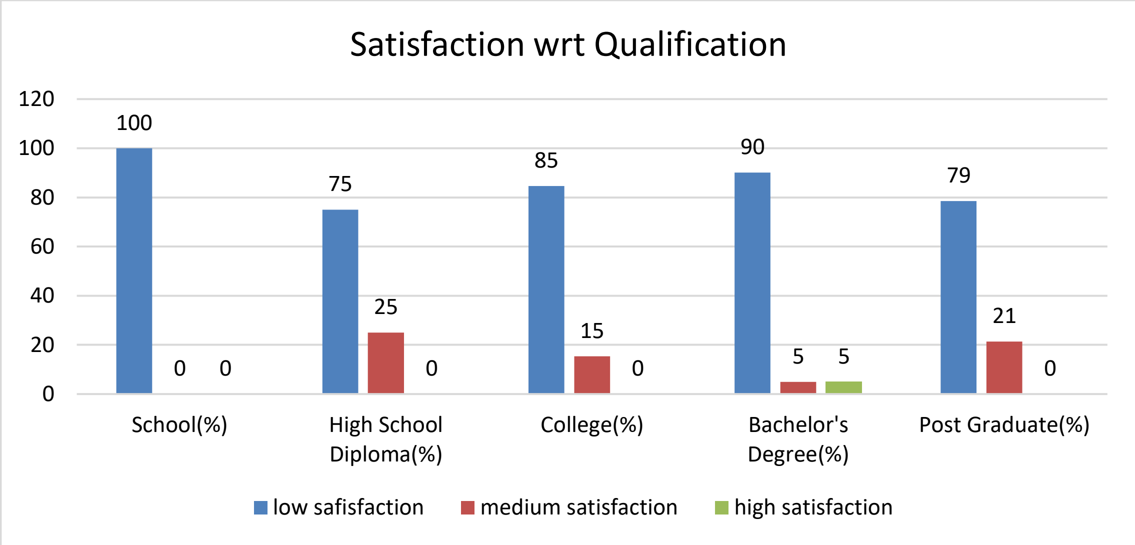


**Figure 4- 23: Satisfaction Index with respect to Qualification**

The satisfaction level was further assessed with respect to the home ownership. As it was previously mentioned that the home owners are less aware about the new concepts and ideas for community betterment when compared with the home renters. This concept was found to be in correlation in the case of satisfaction level. Majority of renters (95) percent and majority of home owners (85) percent showed low level of satisfaction with the present water storage practices in the community. On the contrary, 5 percent of the respondents belonging to home ownership had higher satisfaction level with the current water supply but none of the home renter's respondent showed high level of satisfaction with the water management practices.

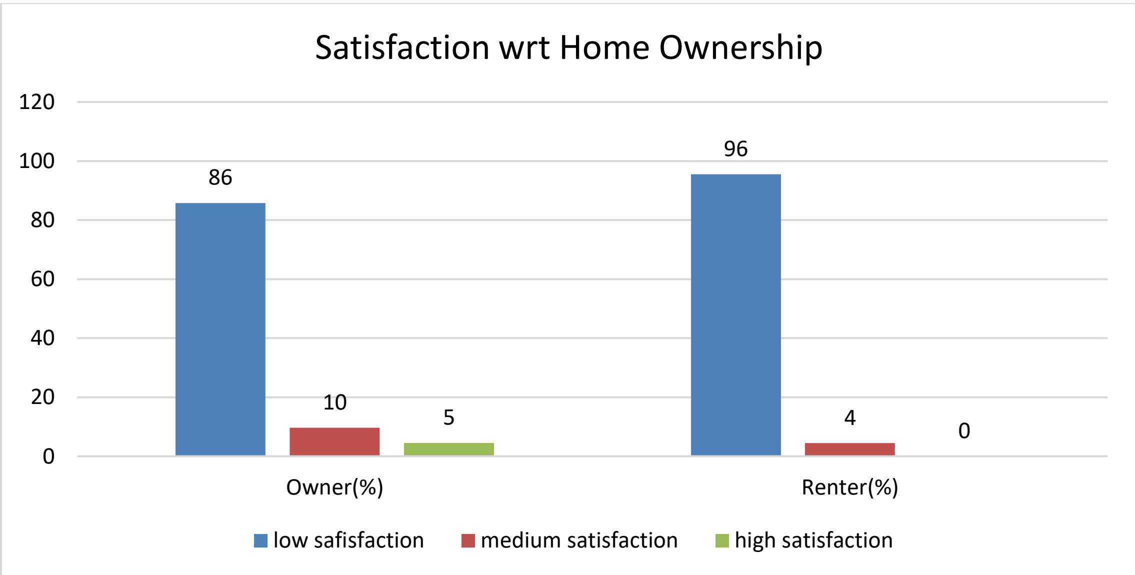


**Figure 4- 24: Satisfaction Index with respect to Home Ownership**

The respondents were then classified based on their economic status. Twenty-five (25) percent of students and 4 percent of employed personals were found to be moderately satisfied with the practices of water storage, 13 percent of students showed complete satisfaction with the water practices present in their community. All the participants who were unemployed showed 100 percent lower satisfaction with the current water practices.


**Figure 4- 25: Satisfaction Index with respect to Economic Status**

## 4.6 Willingness of Residents to install home based Rain Gardens

The respondents were asked questions about their willingness to adopt rain gardens and to install rain gardens in their own lawn. They were asked whether they will install the rain garden if financial assistance is provided to them or they will help their neighbors in the installation. Based on these questions willing index variables were made in SPSS in order to find willingness of residents. The willingness index variables were divided into low, medium and high levels. Low willingness meant that the individual is not at all willing to install rain gardens. Medium willingness meant that the individual gave a mild response, they may be somewhat willing to install rain gardens if provided proper knowledge and assistance. High willingness meant individual is completely willing to install rain gardens.

The willing index variable chart is shown. 1.01-2.61 shows low willingness index variable. Medium range was from 2.62-3.68 and 3.69-5.0 Showed high willingness index variable range.

| Willingness Index variables | Range |
|---|---|
| Low | 1.01 – 2.61 |
| Medium | 2.62 – 3.68 |
| High | 3.69 – 5.0 |

According to the figure both males (49) percent and females (57) percent showed higher level of willingness for installation of rain gardens. Forty-seven (47) percent of males showed moderate willingness as compared to 40 percent females. This moderate willingness in both genders could be attributed to the presence of the moderate level of awareness among the respondents which leads to moderate and low willingness level to the installation of rain gardens.

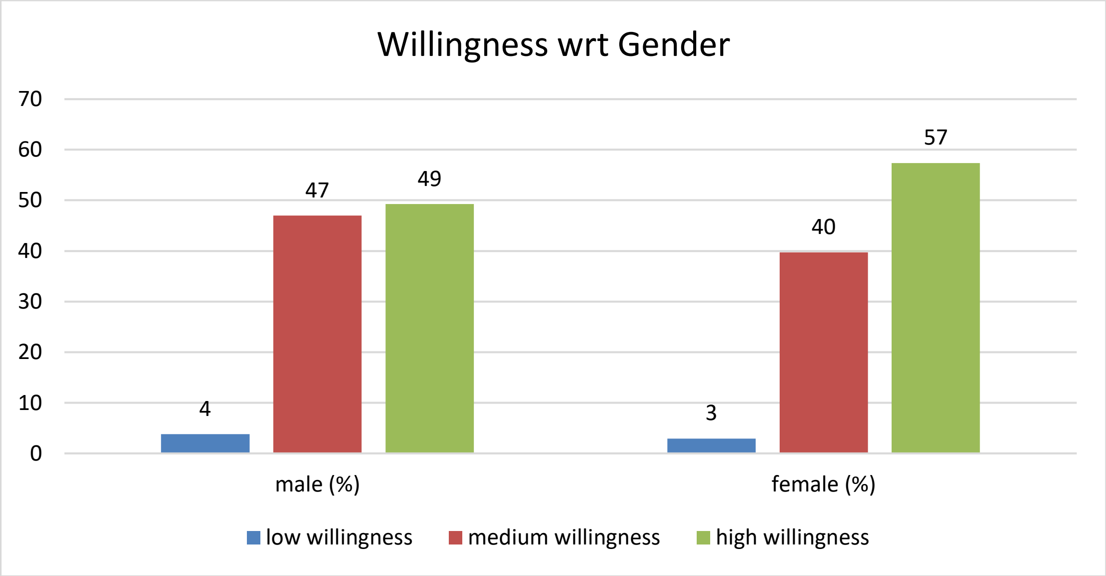


**Figure 4- 26: Willingness Index with respect to Gender**

When the willingness index is categorized based on the age group, it is obvious to see that the respondents in the young age group 30-40 and 40-50 showed 73 percent and 65 percent high willingness towards rain gardens installation in their own yard and the whole neighborhood. Whereas, 71 percent of retired personals and 64 percent of people from 20-30 age group showed moderate level of willingness towards rain gardens installation.

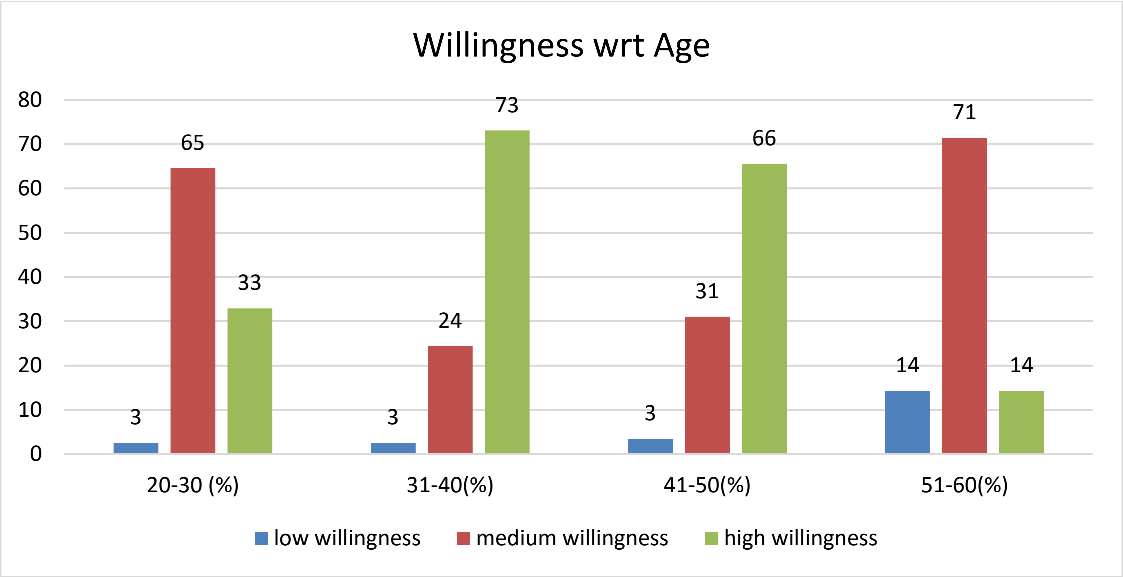


**Figure 4- 27: Willingness Index with respect to Age**

The residents of Askari 14 showed more willingness towards installation of rain gardens (60) percent as compared to the residents of Gulshan-e-Abad (44) percent. Seven percent respondents of both societies showed low willingness towards rain gardens installation. This reduced willingness level in Gulshan-e-Abad area could be due to the presence of good or better water management practices in the area in comparison to the Askari 14. Thirty-eight (38) percent respondents of Askari 14 and (51) percent of Gulshan-e-Abad were moderately willing to install rain gardens.

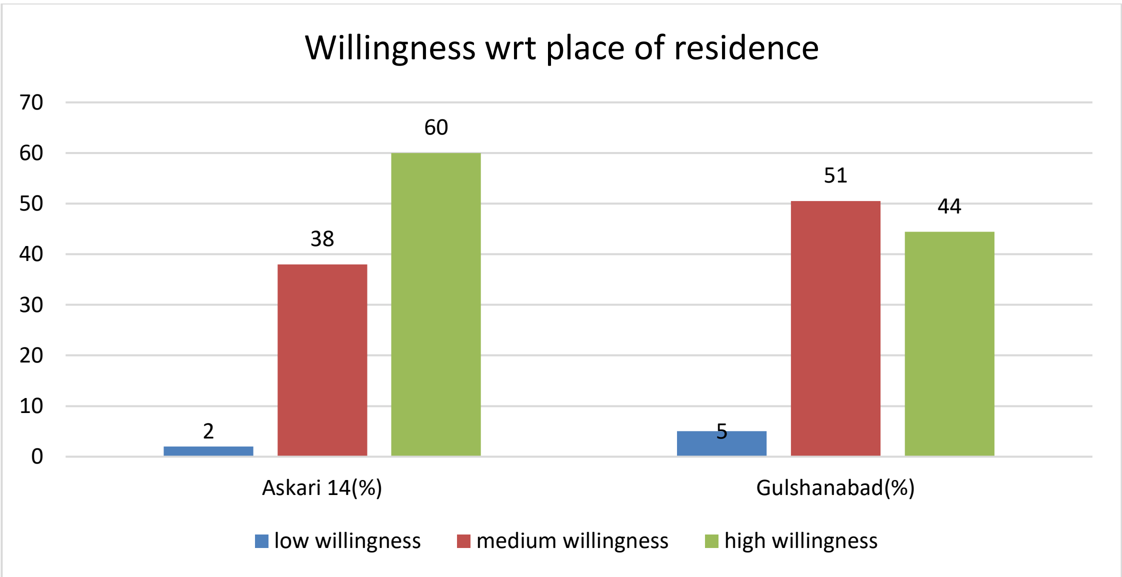


**Figure 4- 28: Willingness Index with respect to place of residence**

The respondents of different qualification were interviewed about the rain gardens installation in their home and neighborhood. Nearly all the students from school group showed full willingness towards installation of rain gardens. They were also found very energetic towards installation of rain gardens in their neighbor's home as they were all willing to help each other. On the other side, only 25 percent of respondents with higher school diploma and 38 percent respondents with college degrees were showed willing to launch this new concept in their community.

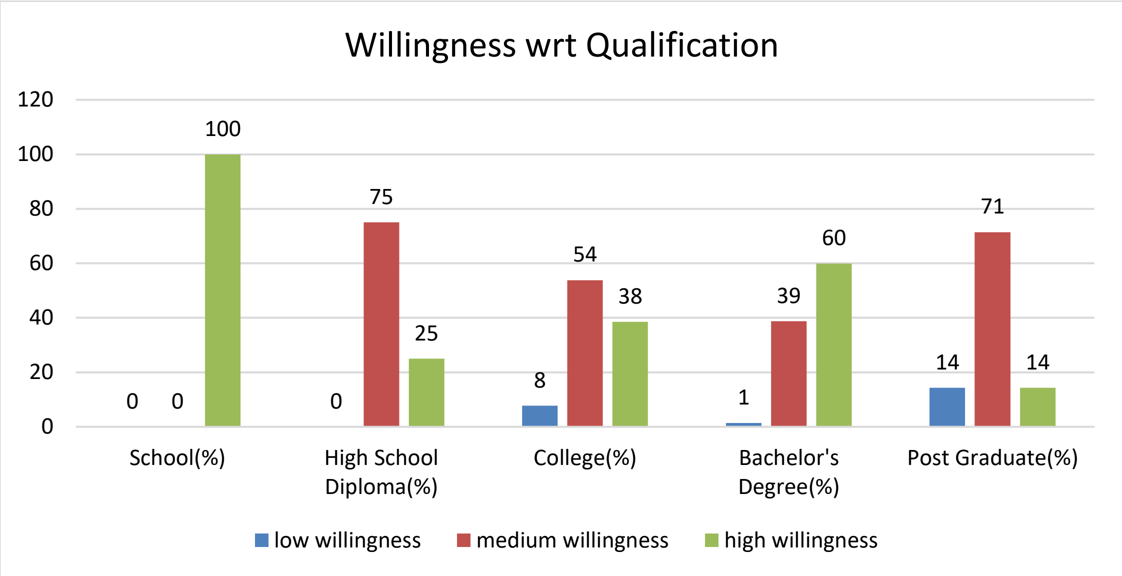


**Figure 4- 29: Willingness Index with respect to Qualification**

According to the graph below among the home ownership status and willingness Index, it is clearly shown that a total of 56 percent home owners were highly willing to install rain garden in order to store more water in a useful way. But, on contrary, majority of home renters (64) percent were showing moderate willingness towards rain garden installation in their own lawn or in their neighbors' lawn.  This could be due to the reason that they don't own the land and thus, taking the consent from the home owners might be challenging for them, thus they were moderately willing.

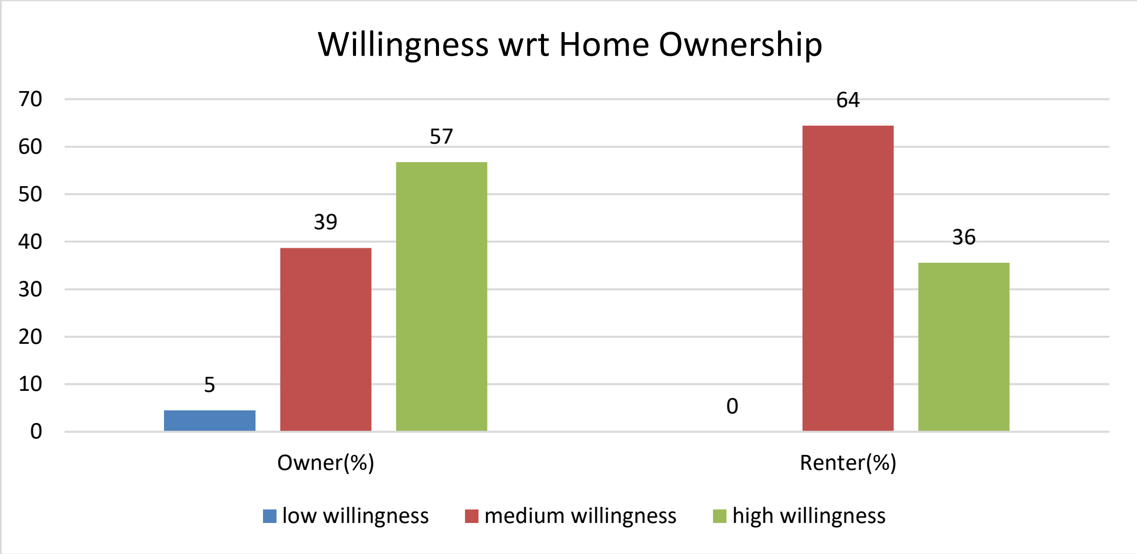


**Figure 4- 30: Willingness Index with respect to Home Ownership**

The participants were also classified based on their economic status as the employed and unemployed individuals showed higher level of willingness, (52) percent and (72) percent, respectively. On the other side, majority of students (60) percent and retired individuals (77) percent were moderately willing to install the rain garden. This moderate willingness among the group of students and retired personal may be due to the lower knowledge about rain gardens. There is a possibility that increasing the knowledge or awareness about rain gardens among such groups might increase the willingness level.

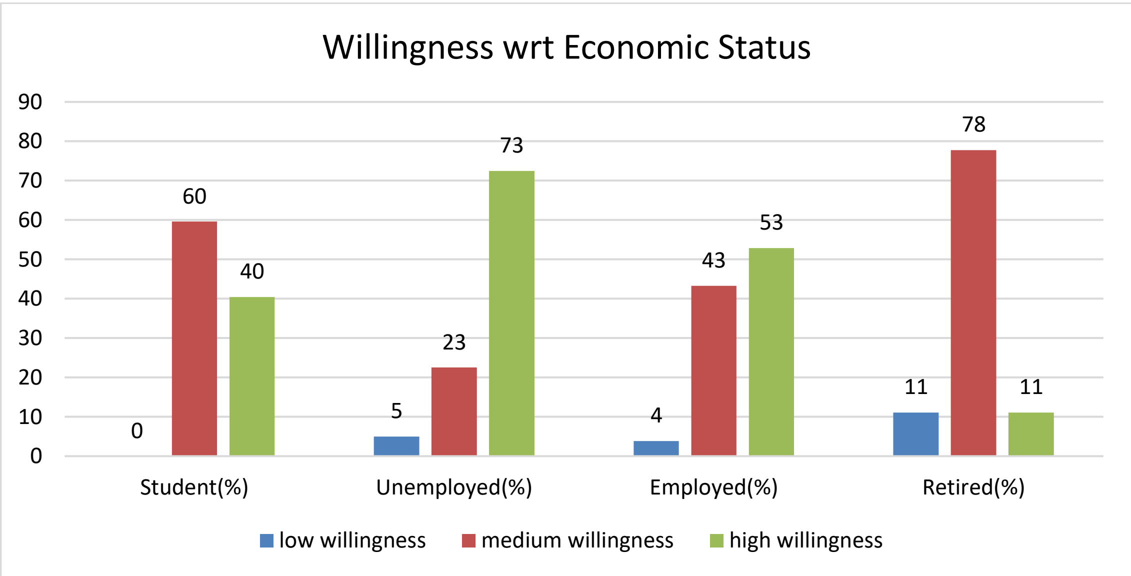


**Figure 4- 31: Willingness Index with respect to Economic Status**

## 4.7 Managements Perception about Rain Gardens

According to Askari Management, Rain Gardens are not only a solution to overcome water shortage issue but will also have a positive effect on flora and fauna. It should be an integral part of the housing's design.

However, Gulshan-e-Abad management informs that there is complete lack of awareness about rain gardens in their society. It should be the part of the construction principles, if left to individuals the concept would likely to fail. Rain gardens should be made part of design specifications in coordination with RDA because the society does not have enough funds for installation of rain gardens. It is beyond their capacity.

According to Askari management they utilize rain water by blocking certain drains and that water is used for plantation. Any extra rain water is directed towards sewers. The surface drain channels 100'X 6'X 4' exist near Army Public School, where they are converted into storage. 25000 gallons' rain water is stored approximately, but there is a dire need to pond rain water for which minimum two (02) acres of land is required.

In Gulshan-e-Abad the rain water is directed towards sewers and drains. There is no proper system that stores rain water for further utilization. Residents might store rain water at house hold levels. But the society has no such system for storage of rain water.

In Askari 14, the water is not enough for the community needs as a greater number of people are shifting in, thus increasing consumption. Initially three (03) boreholes were drilled to meet the requirement of community. Current requirement of water is 600,000 gallons per day and production is almost 560,000 gallons per day. The difference between demand and supply can be reduced by reduction in wastage rate and increasing storage capacity.

Water tankers of 300 gallons' capacity are provided to residents in case of water shortage. In Gulshan-e-Abad demand of water is increasing day by day as the society is getting populated. The sources of water supply mainly are wells and collection tanks. The society has water tankers which supply water when the shortage prevails. The society provides water at the rate of rupees three hundred per tanker to its residents. Four tube wells drilled near River Swan are source to provide water to the residents in case of water shortage.

**Table 4-1: Comparison of Askari 14 and Gulshan-e-Abad**

| ASKARI 14 | GULSHAN-E-ABAD |
|---|---|
| **Installation of Initial Water Scheme:**<br><br>Askari 14 was established in 2006, presently comprising of 1689 houses. Tube wells are sunk near Military college of signals and from there water is pumped up to Askari 14. | **Installation of Initial Water Scheme:**<br><br>Gulshan-e-Abad society was launched on 27th March 1983. It's a very old housing society comprising of approximately 3000 houses and is divided into four sectors. Initial water scheme was commenced in year 1985 and its was completely functional in the year 1990. |
| **Depth of Water Table:**<br>In 2005 average depth/strata was 400 feet at Morgah/Lalkurti area. In 2010 average depth/strata was 500 feet at Morgah/Lalkurti area.<br>In 2017 average depth/strata was 600 feet at Morgah/Lalkurti area.<br>Rate of depletion of water level in Adyala region is 5 feet per annuum. Currently the depth of water table is 650 feet to 700 feet. | **Depth of Water Table:**<br>Initially water was supplied by society water supply system and the depth of water table was around 100 to 300 feet in different sectors. Now the depth is around 600 to 700 feet. |
| **Seasonal Variation of Water Table:**<br>Seasonal variation of water table situation depends upon the number of tube wells | **Seasonal Variation of Water Table:**<br>The water level tends to rise in rainy season, exact figures were not available with the |

| | |
|---|---|
| operating at a location, duration of operation of tube wells, season or climatic condition. In monsoon season water tables increases to 5' from the month of August to October. Water borne sites are explored irrespective of the distance to manage water table variation. | management. Society has a total of five tube wells from which water is transported to collection tanks for further distribution to houses. |
| **Bore Hole information:**<br>The depth of the bore hole is determined by water table. It takes approximately 7 days to explore site of new bore, 650 feet depth bore is required catering for the water table. This 8" wide bore is done through Rotary boring system and it costs around 50 million. Rotary drilling is used to form a deep observation borehole. The drilling method involves a powered rotary cutting head on the shaft end, which is driven into the ground as it rotates. Recently 3 boreholes were dug 1 in sector C, and the other 2 in sector B. All had 8" wide diameter and their depth is approximately 600' to 675 feet. The boreholes dry up at a rate of 10percent of the total bore developed. They dry up because of lowering of water table, and technical capability of the system lowered. | **Bore Hole information:**<br>The bore hole runs out of water frequently and requires re-boring. Generally, it takes 1, 20,000 Rs to dig a new bore hole. |

## 4.8 Experts perception about rain gardens

### 4.8.1 Opinion about rain gardens in modern times:

There is absolutely no doubt regarding the importance and benefits of rain gardens in modern times subject to following conditions: there should be enough rain in the area under consideration and favorable land topography and area conditions. Rain garden are important in urban areas as looking at urban development. As there is less space for water absorption due to urban development so its importance has been increased with appropriate design to take all of rain water. With an increase in urbanization, rain gardens can become the source for ground water recharge for urban areas within paved surfaces. It has importance of holding and soaking of rain water runoff that flows from roofs, driveways, patios or lawns. They help in keeping water clean by filtering rainwater runoff before it reaches local waterways. They also help in protecting communities from flooding and drainage problems.

### 4.8.2 Worth of rain gardens at household level:

It is utmost need of the hour to make rain gardens in housing societies at household level, as they promote simple and effective form of storm water treatment. Rain gardens help in replenishing area aquifers by increasing the amount of water filtering in the ground. Also, it can raise awareness among people that how good storm water management contributes to healthy waterways.

### 4.8.3 Rainfall in Potohar region:

Though Potohar region is known to have highly variable precipitation characteristics in terms of frequency and distribution, but water conservation is really needed in this area and rain gardens are the means to conserve water.

### 4.8.4 Feasibility of rain gardens concept in Pakistan:

Rain gardens are an inexpensive, simple to implement and environmentally sound solution to urban storm water runoff. The benefits of planting rain gardens are numerous. Rain gardens benefits include pollution control, flooding protection, habitat creation and water conservation. So, people of Pakistan can be convinced. People of Pakistan are to be educated for different storm water management techniques, as storm water becomes a great problem in urban cities of Pakistan, such techniques can raise awareness and will also work efficiently in Pakistan.

### 4.8.5 Government or NGO's to give Financial Assistance:

Government should make laws and implement them, as ground water level is decreasing day by day. If it's for once applied by law, then people will follow it. Govt. can facilitate / compensate people in many ways not only financially. Many NGO's are still working in this field. Also, government will play key role in this matter as it is a matter of prosperity for the Pakistan country.

### 4.8.6 Policy for rain water management:

There should be a proper policy for the management of rain water. A special society or department should be created regarding the rain water management. In current situation as we are facing water shortage (river flow is lessened) so rain water management can help us to improve the situation little better.

### 4.8.7 Barriers faced by management in embedding rain gardens in design policy:

Space allocation might be the problem for embedding rain gardens in already constructed societies but for new under constructed housing societies, there shouldn't be any hurdle. Funding will play the main role in this matter.

### 4.8.8 Acceptability ratio of people for rain gardens concept:

Awareness campaign should be run for educating people about water scarcity and effectiveness of rain gardens. In current situation people will support it foreseeing the water shortage issues.

### 4.8.9 Seasonal variation of water table:

Seasonal variation of ground water is decreasing rapidly in Pakistan, so variation may be only in ft. depth decreased. In our region summer monsoon have higher rainfall as compared to winters. Therefore, water table is higher with higher rainfall and infiltration. As new housing societies are being developed and population is increasing day by day so demand of water is increasing and being fulfilled by ground water. Recharging is less due to lesser rains and urban development, so water level is getting lower day by day.

### 4.8.10 Rain gardens a possible solution to water scarcity:

Yes, rain gardens can effectively utilize stormwater and are a source of recharging ground water. They conserve water and reduce groundwater depletion. As compared to wasting water by dumping into sea.

***Chapter 5***

# Conclusion and Recommendations

## 5.1 Conclusions:

The basic purpose of our research was to find out the level of awareness about rain gardens in two communities of Rawalpindi and hence work towards the adoption of rain gardens. Rain gardens are very beneficial in present era. The population is increasing at rapid pace from last 20 years due to urbanization. Urbanization has decreased the underground water level due to increased consumption. As we study the ground water situation in Rawalpindi, we conclude that ground water table is decreasing day by day by the increasing population in the region. In such situation, rain garden is the best solution to contribute in rising water table level and deal with water stresses.

Ground water table situation of Rawalpindi has decreased due to excessive increase in the number of wells from 1998 to 2002. In the year 1998, ground water table of Rawalpindi region was 1607.61 ft. But after the addition of 41 tube wells in the year 2003, the ground water table was drastically reduced to 1574.8 ft. Ground water table is decreasing day by day due to the excessive withdrawal of water. This withdrawal is increasing due to the increase in the population. Rawalpindi is becoming more and more populous with the passage of time. From 1998 to 2003, total decrease in the ground water table is 45.93 ft. It has been seen that the ground water table is reduced further 49.21 ft till 2007. This is the drastic decrease from 1998 to 2007 i.e. 45.93 ft in 5 years and 15m in further 4 years. The ground water table was significantly 1968.5 feet at Margalla Hills and 1476.38 feet around the Soan River. If you see the history, before 1998, ground water table was decreased 4.593 ft annually from the year 1988 to 1995. But now, it has an annual 12 to 13 feet drop every year. Groundwater permitting system is absent in Pakistan and everyone is free to drill, making it difficult to create and update the inventory of wells

Another part of our research was to determine the satisfaction of residents with rain water management strategies which they already were using. These were use of rain barrels, Pavement area removal, lawn removal, plantation of more trees, natural gardening, and use of dry wells for rain water storage and use of infiltration planters. Majority of the residents were not satisfied with current rain water management strategies. Only a few of them were using, as these strategies did not help in storing and conserving rain water for longer duration.

There are few difficulties in installing rain gardens. The first and the most important thing is that, common man is unaware of such useful and economic thing. People were somewhat aware about the concept of rain gardens, but they were not completely aware about its functionality. They find rain gardens important for ground water recharge and were willing to install rain gardens but want incentives to be provided by the Government or NGO's.

Rain gardens can effectively utilize stormwater and are a source of recharging ground water. They conserve water and reduce groundwater depletion. As compared to wasting water by dumping into sea.

## 5.2 Recommendations:

Proper Institutions responsible for monitoring of groundwater quantity should be made in Pakistan . Ground water extraction must be regulated by the concerned authorities through rule, regulations and fine fines should be charged in case of unlawful acts.

The first and the foremost strategy we must adopt is to create awareness among the people about the advantages of the rain gardens. Campaigns needs to be launched to sensitize people that how storm water management contributes to ground water recharge. If people get to know about advantages and the long-term usage of rain gardens, they will promote this concept by constructing rain gardens in their lawns.

Large number of government organizations should work on the promotion of rain gardens. It is need of the hour to embed rain gardens as mandatory part of house design. It calls for regulations to be made by the regulatory authorities. The purpose of such regulations is to make the nation aware of the advantages and the long-term usage of rain gardens. Govt. can facilitate / compensate people by giving incentives for initial installation of rain gardens. Once they are initially installed then maintenance should be done by people themselves. Incentives can be given in the form of reduction in property taxes for installation of RGs in houses.

## 5.3 Limitations and Future Avenues:

This study also has some limitations like due to security issues of Pakistan, people don't feel safe sharing their personal information which hinders the exact results. A study with large number of case studies and large sample sizes needs to be conducted. If there was a bigger sample size, the results would have been clearer.

Further research on implementation of rain gardens and their impacts on groundwater table must be conducted.

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# Annexure

## Annexure-A

### Tables

**Table 0- 1: Calculation of average annual rainfall and average water table of Rawalpindi**

| YEAR | Avg. Annual RF (mm) | AVG WT (ft.) |
|---|---|---|
| 2000 | 982.88 | 140 |
| 2001 | 1177.02 | 144 |
| 2002 | 580.85 | 148 |
| 2003 | 1144.44 | 152 |
| 2004 | 1056.49 | 156 |
| 2005 | 966 | 160 |
| 2006 | 1598 | 164 |
| 2007 | 1796.22 | 168 |
| 2008 | 1476.32 | 180.5 |
| 2009 | 581.2 | 193 |
| 2010 | 1086 | 205.5 |
| 2011 | 1238.2 | 218 |
| 2012 | 1032.1 | 230.5 |
| 2013 | 1951.7 | 243 |
| 2014 | 1627 | 255.5 |
| 2015 | 1742.5 | 268 |
| 2016 | 1051.1 | 280.5 |
| 2017 | 973.49 | 293 |
| 2018 | 1215.19 | 305.5 |

**Table 0- 2: Demographics Details of Residents with Respect to Place of Residence**

| Demographic Data of Residents | | | | |
|---|---|---|---|---|
| Housing Societies | | | | |
| | | Askari 14 | Gulshan-e-Abad | Total |
| | | N% | N% | N% |
| Gender | Male | 55(100) | 77(78) | 132(66) |
| | Female | 55(100) | 22(22) | 68(34) |
| Age | 20-30 | 26(26) | 53(54) | 79(40) |
| | 31-40 | 45(45) | 33(33) | 78(39) |
| | 41-50 | 21(21) | 8(8) | 29(15) |
| | 51-60 | 9(9) | 5(5) | 14(7) |
| Qualification | School | 0(0) | 1(1) | 1(1) |
| | High School Diploma | 2(2) | 2(2) | 4(2) |
| | College | 21(21) | 18(18) | 39(20) |
| | Bachelor's Degree | 73(72) | 69(70) | 142(71) |
| | Post Graduate | 5(5) | 9(9) | 14(7) |
| Economic Status | Student | 21(21) | 26(26) | 47(24) |
| | Unemployed | 32(32) | 8(8) | 40(20) |
| | Employed | 41(41) | 63(64) | 104(52) |
| | Retired | 7(7) | 2(2) | 9(5) |
| Household Income | <15,000 | 1(1) | 1(1) | 2(1) |
| | 15,000-24,999 | 0(0) | 1(1) | 1(1) |
| | 25,000-34,999 | 1(1) | 2(2) | 3(2) |
| | 35,000-49,999 | 1(1) | 38(38) | 39(20) |
| | 50,000-74,999 | 25(25) | 16(16) | 41(21) |
| | 75,000-99,999 | 51(50) | 18(18) | 69(35) |
| | >100,000 | 22(22) | 23(23) | 45(23) |
| Home Ownership | Owner | 83(82) | 72(73) | 155(78) |
| | Renter | 18(18) | 27(27) | 45(23) |
| Duration of Stay | 1-4 | 74(73) | 64(65) | 138(69) |
| | 5-9 | 26(26) | 20(20) | 46(23) |
| | 10-14 | 1(1) | 8(8) | 9(5) |
| | 15-19 | 0(0) | 7(7) | 7(4) |
| **Total** | | **101** | **99** | **200** |

**Table 0- 3: Awareness Index with respect to Gender**

| Gender | | Male (%) | Female (%) | Total (%) |
|---|---|---|---|---|
| Awareness Index Variables | low Awareness | 3(2) | 2(3) | 5(3) |
| | medium awareness | 105(80) | 57(84) | 162(81) |
| | high awareness | 24(18) | 9(13) | 33(17) |
| **Total** | | **132** | **68** | **200** |

**Table 0- 4: Awareness Index with respect to Age**

| Age | | 20-30 (%) | 31-40 (%) | 41-50 (%) | 51-60 (%) | Total (%) |
|---|---|---|---|---|---|---|
| Awareness Index Variables | low Awareness | 2(3) | 1(1) | 0 | 2(14) | 5(3) |
| | medium awareness | 55(70) | 69(88) | 27(93) | 11(79) | 162(81) |
| | high awareness | 22(28) | 8(10) | 2(9) | 1(7) | 33(17) |
| **Total** | | **79** | **78** | **29** | **14** | **200** |

**Table 0- 5: Awareness Index with respect to place of residence**

| Place of Residence | | Askari 14 (%) | Gulshan-e-Abad (percent) | Total (percent) |
|---|---|---|---|---|
| Awareness Index Variables | low Awareness | 1(1) | 4(4) | 5(3) |
| | medium awareness | 98(98) | 63(64) | 161(81) |
| | high awareness | 1(1) | 32(32) | 33(17) |
| **Total** | | **100** | **99** | **199** |

**Table 0- 6: Awareness Index with respect to Qualification**

| Qualification | | School (%) | High School Diploma (%) | College (%) | Bachelor's Degree (%) | Post Graduate (%) | Total (%) |
|---|---|---|---|---|---|---|---|
| Awareness Index Variables | low Awareness | 0 | 1(25) | 2(5) | 0 | 2(14) | 5(3) |
| | medium awareness | 1(100) | 3(75) | 27(69) | 124(87) | 7(50) | 162(81) |
| | high awareness | 0 | 0 | 10(26) | 18(13) | 5(36) | 33(17) |
| **Total** | | **1** | **4** | **39** | **142** | **14** | **200** |

**Table 0- 7: Awareness Index with respect to Home Ownership**

| Home Ownership | | Owner (%) | Renter (%) | Total (%) |
|---|---|---|---|---|
| Awareness Index Variables | low Awareness | 5(3) | 0 | 5(3) |
| | medium awareness | 128(83) | 34(76) | 162(81) |
| | high awareness | 22(14) | 11(24) | 33(17) |
| **Total** | | **155** | **45** | **200** |

**Table 0- 8: Awareness Index with respect to Economic Status**

| Economic Status | | Student (%) | Unemployed (%) | Employed (%) | Retired (%) | Total (%) |
|---|---|---|---|---|---|---|
| Awareness Index Variables | low Awareness | 1(2) | 0 | 3(3) | 1(11) | 5(3) |
| | medium awareness | 36(77) | 39(98) | 79(76) | 8(89) | 162(81) |
| | high awareness | 10(21) | 1(3) | 22(21) | 0 | 33(17) |
| **Total** | | **47** | **40** | **104** | **9** | **200** |

**Table 0- 9: Current Rain Water Management Strategies**

| Rain Water Management Strategies | | Askari 14 (%) | Gulshan-e-Abad (%) | Total (%) |
|---|---|---|---|---|
| Rain Barrels | yes | 2(2) | 2(2) | 4(2) |
| | no | 99(98) | 97(98) | 196(98) |
| PA Removal | yes | 2(2) | 32(32) | 34(17) |
| | no | 99(98) | 67(68) | 166(83) |
| Lawn Removal | yes | 0 | 2(2) | 2(1) |
| | no | 101(100) | 97(98) | 198(99) |
| Trees | yes | 92(91) | 68(69) | 160(80) |
| | no | 9(9) | 31(31) | 40(20) |
| Natural Gardening | yes | 84(83) | 72(73) | 156(78) |
| | no | 17(17) | 27(27) | 44(22) |
| Dry wells | yes | 8(8) | 0 | 8(4) |
| | no | 93(92) | 99(100) | 192(96) |
| Infiltration Planter | no | 101(100) | 99(100) | 200(100) |
| **Total** | | **101** | **99** | **200** |

**Table 0- 10: Satisfaction of Residents with respect to Gender**

| Gender | | Male (%) | Female (%) | Total (%) |
|---|---|---|---|---|
| Satisfaction Index Variables | low satisfaction | 112(85) | 64(94) | 176(88) |
| | medium satisfaction | 13(10) | 4(6) | 17(9) |
| | high satisfaction | 7(5) | 0 | 7(4) |
| **Total** | | **132** | **68** | **200** |

**Table 0- 11: Satisfaction of Residents with respect to Age**

| Age | | 20-30 (%) | 31-40 (%) | 41-50 (%) | 51-60 (%) | Total (%) |
|---|---|---|---|---|---|---|
| Satisfaction Index Variables | low satisfaction | 59(75) | 76(97) | 27(93) | 14(100) | 176(88) |
| | medium satisfaction | 14(18) | 2(3) | 1(4) | 0 | 17(9) |
| | high satisfaction | 6(8) | 0 | 1(3) | 0 | 7(4) |
| **Total** | | **79** | **78** | **29** | **14** | **200** |

**Table 0- 12: Satisfaction of Residents with respect to Place of Residence**

| Place of Residence | | Askari 14 (%) | Gulshan-e-Abad (%) | Total (%) |
|---|---|---|---|---|
| Satisfaction Index Variables | low satisfaction | 88(88) | 87(88) | 175(88) |
| | medium satisfaction | 11(11) | 6(6) | 17(9) |
| | high satisfaction | 1(1) | 6(6) | 7(4) |
| **Total** | | **100** | **99** | **199** |

**Table 0- 13: Satisfaction of Residents with respect to Qualification**

| Qualification | | School (%) | High School Diploma (%) | College (%) | Bachelor's Degree (%) | Post Graduate (%) | Total (%) |
|---|---|---|---|---|---|---|---|
| Satisfaction Index Variables | low satisfaction | 1(100) | 3(75) | 33(85) | 128(90) | 11(79) | 176(88) |
| | medium satisfaction | 0 | 1(25) | 6(15) | 7(5) | 3(21) | 17(9) |
| | high satisfaction | 0 | 0 | 0 | 7(5) | 0 | 7(4) |
| **Total** | | **1** | **4** | **39** | **142** | **14** | **200** |

**Table 0- 14: Satisfaction of Residents with respect to Home Ownership**

| Home Ownership | | Owner (%) | Renter (%) | Total (%) |
|---|---|---|---|---|
| Satisfaction Index Variables | low satisfaction | 133(86) | 43(96) | 176(88) |
| | medium satisfaction | 15(10) | 2(4) | 17(9) |
| | high satisfaction | 7(5) | 0 | 7(4) |
| **Total** | | **155** | **45** | **200** |

**Table 0- 15: Satisfaction of Residents with respect to Economic Status**

| Economic Status | | Student (%) | Unemployed (%) | Employed (%) | Retired (%) | Total (%) |
|---|---|---|---|---|---|---|
| Satisfaction Index Variables | low satisfaction | 29(62) | 40(100) | 99(95) | 8(89) | 176(88) |
| | medium satisfaction | 12(26) | 0 | 4(9) | 1(11) | 17(9) |
| | high satisfaction | 6(13) | 0 | 1(1) | 0 | 7(4) |
| **Total** | | **47** | **40** | **104** | **9** | **200** |

**Table 0- 16: Willingness of residents to install home based rain gardens with respect to Gender**

| Gender | | Male (%) | Female (%) | Total (%) |
|---|---|---|---|---|
| Willingness Index Variables | low willingness | 5(4) | 2(3) | 7(4) |
| | medium willingness | 62(47) | 27(40) | 89(45) |
| | high willingness | 65(49) | 39(57) | 104(52) |
| **Total** | | **132** | **68** | **200** |

**Table 0- 17: Willingness of residents to install home based rain gardens with respect to Age**

| Age | | 20-30 (%) | 31-40 (%) | 41-50 (%) | 51-60 (%) | Total (%) |
|---|---|---|---|---|---|---|
| Willingness Index Variables | low willingness | 2(3) | 2(3) | 1(4) | 2(14) | 7(4) |
| | medium willingness | 51(65) | 19(25 | 9(31) | 10(71) | 89(45) |
| | high willingness | 26(33) | 57(73) | 19(66) | 2(14) | 104(52) |
| **Total** | | **79** | **78** | **29** | **14** | **200** |

**Table 0- 18: Willingness of residents to install home based rain gardens with respect to place of Residence**

| Place of Residence | | Askari 14 (%) | Gulshan-e-Abad (%) | Total (%) |
|---|---|---|---|---|
| Willingness Index Variables | low willingness | 2(2) | 5(5) | 7(4) |
| | medium willingness | 38(38) | 50(51) | 88(44) |
| | high willingness | 60(60) | 44(44) | 104(52) |
| **Total** | | **100** | **99** | **199** |

**Table 0- 19: Willingness of residents to install home based rain gardens with respect to Qualification**

| Qualification | | School (%) | High School Diploma (%) | College (%) | Bachelor's Degree (%) | Post Graduate (%) | Total (%) |
|---|---|---|---|---|---|---|---|
| Willingness Index Variables | low willingness | 0 | 0 | 3(8) | 2(1) | 2(14) | 7(4) |
| | medium willingness | 0 | 3(75) | 21(54) | 55(39) | 10(71) | 89(45) |
| | high willingness | 1(100) | 1(25) | 15(38) | 85(60) | 2(14) | 104(52) |
| **Total** | | **1** | **4** | **39** | **142** | **14** | **200** |

**Table 0- 20: Willingness of residents to install home based rain gardens with respect to Home Ownership**

| Home Ownership | | Owner (%) | Renter (%) | Total (%) |
|---|---|---|---|---|
| Willingness Index Variables | low willingness | 7(5) | 0 | 7(4) |
| | medium willingness | 60(39) | 29(65) | 89(45) |
| | high willingness | 88(57) | 16(36) | 104(52) |
| **Total** | | **155** | **45** | **200** |

**Table 0- 21: Willingness of residents to install home based rain gardens with respect to Economic Status**

| Economic Status | | Student (%) | Unemployed (%) | Employed (%) | Retired (%) | Total (%) |
|---|---|---|---|---|---|---|
| Willingness Index Variables | low willingness | 0 | 2(5) | 4(4) | 1(11) | 7(4) |
| | medium willingness | 28(60) | 9(23) | 45(43) | 7(78) | 89(45) |
| | high willingness | 19(40) | 29(73) | 55(53) | 1(11) | 104(52) |
| **Total** | | **47** | **40** | **104** | **9** | **200** |

**Annexure-B**

# National Institute of Transportation (NIT)

## To study perception of people about rain gardens and current rain water management practices prevailing in housing societies

**Respondent profile:**

1. Name of respondent: ______________________________
2. Gender: Male ☐ Female ☐
3. Age: ______________
4. Place of residence: ________________________
5. Highest level of education:

☐ School ☐ High School Diploma ☐ College

☐ Bachelor's Degree ☐ Post Graduate

6. Economic status:

☐ Student ☐ Unemployed ☐ Employed ☐ Retired

7. What is your approximate household income?

☐ Less than 15,000 ☐ 15,000 – 24,999

☐ 25,000 – 34,999 ☐ 35,000 – 49,999

☐ 50,000 – 74,999 ☐ 75,000 – 99,999

☐ Over 1, 00,000

8. How long you lived in your current residence? ____________ Years __________ Months
9. What kind of building do you live in?

☐ Single unit house ☐ Semidetached house

☐ Semi attached house ☐ Other

10. Home Ownership:

☐ Owner ☐ Renter

**What are Rain Gardens?**

Rain gardens are slight depressions constructed in the landscape that hold water which would otherwise contribute to storm water runoff. They allow storm water to infiltrate slowly in the soil, so that pollutants in the water are processed biologically and filtered physically through the soil. A variety of plants are used to landscape rain gardens so that not only are they functional, but they contribute to the beauty of your landscape as well.

**Answer the following statements regarding rain gardens:**

1. What is your awareness about rain gardens?

| Not at all aware | Slightly aware | Somewhat aware | Moderately aware | Extremely aware |
|---|---|---|---|---|
| | | | | |

2. Are you willing to install a rain garden in your yard?

| Strongly Not Willing | Not willing | No Opinion | Willing | Strongly Willing |
|---|---|---|---|---|
| | | | | |

3. If you build a rain garden in your yard, the value of your property will increase?

| Strongly disagree | Disagree | No opinion | Agree | Strongly agree |
|---|---|---|---|---|
| | | | | |

4. Building a rain garden in your yard will improve the appearance of your property?

| Strongly disagree | Disagree | No opinion | Agree | Strongly agree |
|---|---|---|---|---|
| | | | | |

5. Building a rain garden, will improve wildlife attraction to your yard like butterflies, birds and frogs.

| Strongly disagree | Disagree | No opinion | Agree | Strongly agree |
|---|---|---|---|---|
| | | | | |

6. Building a rain garden would create standing water that can attract mosquitoes.

| Strongly disagree | Disagree | No opinion | Agree | Strongly agree |
|---|---|---|---|---|
| | | | | |

7. Building a rain garden in your yard, will store storm water from rooftop, driveway and paved ways.

| Strongly disagree | Disagree | No opinion | Agree | Strongly agree |
|---|---|---|---|---|
| | | | | |

8. Increasing your property value is important to you?

| Not important | Somewhat Important | Important | Very Important | Extremely Important |
|---|---|---|---|---|
| | | | | |

9. The appearance of your property will increase with rain garden.

| Strongly disagree | Disagree | No opinion | Agree | Strongly agree |
|---|---|---|---|---|
| | | | | |

10. Increasing wildlife habitat at your yard is desirable to you.

| Not Desired | Somewhat Desired | Desired | Very much Desired | Extremely Desired |
|---|---|---|---|---|
| | | | | |

11. Preventing standing water that can bring mosquitoes is important to you?

| Not important | Somewhat Important | Important | Very Important | Extremely Important |
|---|---|---|---|---|
| | | | | |

12. Are you interested in learning more about rain water management practices?

| Not interested | Somewhat Interested | Interested | Very much interested | Extremely Interested |
|---|---|---|---|---|
| | | | | |

13. Are you interested in having more rain water management events?

| Not interested | Somewhat Interested | Interested | Very much interested | Extremely Interested |
|---|---|---|---|---|
| | | | | |

14. Would you be willing to have rain gardens in your whole neighborhood?

| Strongly disagree | Disagree | No opinion | Agree | Strongly agree |
|---|---|---|---|---|
| | | | | |

15. Would you recommend your neighbors for rain garden too?

| Strongly disagree | Disagree | No opinion | Agree | Strongly agree |
|---|---|---|---|---|
| | | | | |

16. Will you be willing to build a rain garden in your property if sufficient information is delivered to you?

| Strongly disagree | Disagree | No opinion | Agree | Strongly agree |
|---|---|---|---|---|
| | | | | |

17. Will you be willing to build a rain garden in your property if you receive cost sharing assistance?

| Strongly disagree | Disagree | No opinion | Agree | Strongly agree |
|---|---|---|---|---|
| | | | | |

18. Will you be willing to build a rain garden if your neighbors also build one?

| Strongly disagree | Disagree | No opinion | Agree | Strongly agree |
|---|---|---|---|---|
| | | | | |

19. Will you be willing to help your neighbors in making rain garden if they asked for your help?

| Strongly disagree | Disagree | No opinion | Agree | Strongly agree |
|---|---|---|---|---|
| | | | | |

**Please tell about your current practices of rain water management:**

1. Do you have water shortage problem in your house?

   ☐ Yes ☐ No ☐ Sometimes

2. Are you currently using any of the below mentioned rain water management strategies? (Mark the appropriate answer)

| Sr. | Rain water management strategies | Yes | No |
|---|---|---|---|
| **1** | Bios wales (landscape elements to remove pollution and slit out of the surface runoff water) | | |
| **2** | Downspout disconnection (process to separate roof downspout from sewer system by redirecting the runoff roof on different pervious surfaces or lawns) | | |
| **3** | Eco roofs (green roof of the building which is covered with vegetation either completely or partially) | | |
| **4** | Rain barrels for use of water (water tank used for collection and storage of rain water runoff via pipes) | | |
| **5** | Removal of paved areas | | |
| **6** | Removal of lawn | | |
| **7** | Trees | | |
| **8** | Natural gardening | | |
| **9** | Dry well or soak trench (porous and covered wall chambers offering soaking of water in ground slowly) | | |
| **10** | Infiltration planter (structures or containers with the open bottoms to allow infiltration of storm water in ground) | | |

3. Are you using any of the above mentioned storm water management practice with help of financial assistance?

   ☐ Yes ☐ No

4. Your current rain water management practice needs higher maintenance?

   ☐ Yes ☐ No

5. Your current rain water management practice retains less water?

   ☐ Yes ☐ No

6. Are you really satisfied with the current rain water management practice?

| Extremely Dissatisfied | Dissatisfied | No opinion | Satisfied | Extremely Satisfied |
|---|---|---|---|---|
| | | | | |

7. Will you be willing to install a rain garden in your yard, if your current rain water management is not sufficient?

| Strongly disagree | Disagree | No opinion | Agree | Strongly agree |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|

8. Is the government funding you for the rain water management practice?

☐ Yes ☐ No

9. Is any NGO funding you for the rain water management practice?

☐ Yes ☐ No

10. Have you attended any workshop for management of rain water?

☐ Yes ☐ No

11. Is it hard to maintain the current rain water management practice?

☐ Yes ☐ No

12. Do you want to know more about rain gardens?

☐ Yes ☐ No

13. Is your current water management practice costly?

☐ Yes ☐ No

14. Do you want to leave the current water management practice and shift to rain gardens?

☐ Yes ☐ No

15. Do you use water tanker daily for water supply?

☐ Yes ☐ No ☐ Sometimes

16. Is your water supplied directed to any treatment or disinfection?

☐ Yes ☐ No

17. Is your water supply and distribution system checked each day?

☐ Yes ☐ No

18. Does one additional water tanker supply sufficient for your household?

☐ Yes ☐ No

19. Do you think rain gardens will help in solving water shortage issues?

☐ Yes ☐ No

20. Do you want to give any other better suggestion for rain water management?

______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________

**Annexure-C**

NUST

NATIONAL UNIVERSITY
OF SCIENCES & TECHNOLOGY

# National Institute of Transportation (NIT)

**INTERVIEW FOR SURVEY**

(PROFESSIONALS ONLY)

This Interview is conducted for the purpose of research of a Master's candidate, from the department of Urban and Regional Planning, School of Civil and Environmental Engineering, NUST, Islamabad. The purpose of this research is to suggest rain gardens concept, as a way forward, to release water scantiness in built up areas.
Please give answers to the following questions. Other ideas and recommendations will also be appreciated.

**PERSONAL INFORMATION:**

**NAME:** ______________________________

**AGE:** ______________________________

**PROFESSION:** ______________________________

**QUESTIONS:**

1. What is your opinion about importance of rain gardens in modern times?

______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________

2. Keeping in mind the benefits and future prospects of water, is it worth making rain gardens at household level and open spaces, in housing societies?

______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________

3. Is there sufficient rainfall in Potohar region to make rain gardens?

______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________

4. Will the concept of rain gardens work in Pakistan?

5. Will the government or any NGO be willing to give financial assistance in making rain gardens?

6. In your opinion, should there be a policy for rain water management?

7. What would be the barriers or hurdles, faced by management of housing societies, in embedding rain gardens in their design?

8. In your opinion, what would be the acceptability ratio of people, living in societies, for the rain gardens concept?

______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________

9. Please comment on the seasonal variation of water table level?

______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________

10. In your opinion, is rain gardens a possible solution to overcome/minimize the issue of water scarcity, and will it have a positive effect over our environment?

______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________

**Any Other Recommendations:**

______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________

**Annexure-D**

NUST

NATIONAL UNIVERSITY OF SCIENCES & TECHNOLOGY

# National Institute of Transportation (NIT)

## To study perception of Management about rain gardens and current rain water management practices prevailing in housing societies

### Interview Questionnaire

**Housing Society:** ______________________________

**Interviewer:** _________________ **Interviewee:** ______________

1. When was the society launched?

_______________________________________________________________________

_______________________________________________________________________

_______________________________________________________________________

2. What was the initial water scheme and when was it installed?

_______________________________________________________________________

_______________________________________________________________________

_______________________________________________________________________

_______________________________________________________________________

_______________________________________________________________________

_______________________________________________________________________

3. What was the depth of water table initially?

_______________________________________________________________________

_______________________________________________________________________

_______________________________________________________________________

4. What is the depth of water table now?

_______________________________________________________________________

_______________________________________________________________________

_______________________________________________________________________

5. What is the situation of water table in different seasons?

_______________________________________________________________________

_______________________________________________________________________

_______________________________________________________________________

_______________________________________________________________________

6. Why there is variation in water table and how do you manage this variation?

____________________________________________________________________________

____________________________________________________________________________

____________________________________________________________________________

____________________________________________________________________________

7. How long does it take to sink the borehole?

____________________________________________________________________________

____________________________________________________________________________

____________________________________________________________________________

8. Can a borehole run out of water?

____________________________________________________________________________

____________________________________________________________________________

____________________________________________________________________________

9. How much does a borehole cost?

____________________________________________________________________________

____________________________________________________________________________

____________________________________________________________________________

10. How deep should the boreholes be?

____________________________________________________________________________

____________________________________________________________________________

____________________________________________________________________________

11. Recently when borehole was dug and what was its depth?

____________________________________________________________________________

____________________________________________________________________________

____________________________________________________________________________

12. Is water sufficient for the community needs?

____________________________________________________________________________

____________________________________________________________________________

____________________________________________________________________________

____________________________________________________________________________

____________________________________________________________________________

13. In your opinion what are the reasons of water table drop down?

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

14. Is there any simpler or cheaper way to increase water supply?

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

15. Are there only borehole for the overhead tank or water is taken from the other sources as well?

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

16. Do the residents need to purchase water tanker for their excessive needs?

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

17. What is the rate of one water tanker unit provided by the management?

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

18. Water from which sources is used to fill tankers and then provided further to residents?

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

19. What are the likely reasons for water shortage?

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

20. Is there any special system to store rain water?

_______________________________________________________________________________

_______________________________________________________________________________

_______________________________________________________________________________

21. In your opinion do we have enough rain water to utilize it?

_______________________________________________________________________________

_______________________________________________________________________________

_______________________________________________________________________________

22. If we have enough rain water then why it is not utilized?

_______________________________________________________________________________

_______________________________________________________________________________

_______________________________________________________________________________

23. Where does the rain water go?

_______________________________________________________________________________

_______________________________________________________________________________

_______________________________________________________________________________

24. Why is the rain water directed to sewers and drains?

_______________________________________________________________________________

_______________________________________________________________________________

_______________________________________________________________________________

(Rain gardens are slight depressions constructed in the landscape that hold water which would otherwise contribute to storm water runoff. They allow storm water to infiltrate slowly in the soil, so that pollutants in the water are processed biologically and filtered physically through the soil. A variety of plants are used to landscape rain gardens so that not only are they functional, but they contribute to the beauty of your landscape as well.)

25. What is your perception about rain gardens?

_______________________________________________________________________________

_______________________________________________________________________________

_______________________________________________________________________________

_______________________________________________________________________________

_______________________________________________________________________________

26. Do you think implementation of rain gardens will help to increase level of water table?

____________________________________________________________________

____________________________________________________________________

____________________________________________________________________

____________________________________________________________________

27. Would you like to embed the installation of rain gardens in your design?

____________________________________________________________________

____________________________________________________________________

____________________________________________________________________

____________________________________________________________________

28. Are you going to fund the society in installation of rain gardens?

____________________________________________________________________

____________________________________________________________________

____________________________________________________________________

____________________________________________________________________

____________________________________________________________________

29. In your opinion is rain garden a possible solution to overcome water shortage issue to some extent and will have a positive effect over our environment?

____________________________________________________________________

____________________________________________________________________

____________________________________________________________________

____________________________________________________________________

____________________________________________________________________

____________________________________________________________________

____________________________________________________________________

____________________________________________________________________

____________________________________________________________________