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Water management in a fast growing Mega City Kabul, Afghanistan

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Abstract

This dissertation seeks to analyse the situation of water in the fast growing city of Kabul in Afghanistan and to state the challenges faced by the people and the city in regards to the worsening situation.

Initially the study has focused on providing background information and analysis of the problems and the current situation in Kabul city. Accordingly, it goes on to take a deeper look at the trials and expand on them and their dire consequences. The reports and data of international donors in the case of water in Kabul shows that huge problems in relation to water continue to plague the city; problems such as clean water supply, piping network, civil services, waste water management, limited and risk averse water sources and so forth.

The reports of the international organizations that have worked upon this issue are important for future research, aid and projects as well. Moreover, they have provided solutions to some of the dire issues.

This dissertation concludes that for the replenishment and sustenance of water in the city, the respectful institutions must apply solutions such as artificial recharge an improvement of the water supply network and wastewater management.

The case of water and access to clean drinking water is one the most important issues in the world. In developing, war stricken Afghanistan, the situation of water can be considered as a crises and must be tackled upon as one of the most crucial issues in the country.

There is an urgent need to identify significant water related problems and find solutions rather than waiting for it further deteriorate.

Key words: Water supply, sanitation, pollution, wastewater, planned and unplanned areas, master plan, environment, artificial recharge, Kabul, Afghanistan.

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Chapter 1: Introduction

1.1 Overview

Water is a vital source of life and access to clean drinking water is a human right (un.org, 2014). However, in war stricken Afghanistan, clean drinking water is an unattainable dream for many people. After the decades of war in the country the infrastructure of water supply in Kabul has been completely damaged and since the sharp increase of population in 2001 the government has failed to find the opportunity or the means to rebuild and develop the water supply system. Geographical constraints, climate change and the lack of education on clean water and sanitation has also contributed to the problem (hydrate.org, 2012). Piping water supply to households is weak and underdeveloped; today in various parts of Kabul people bring their drinking water by tanker and through filling containers from other places. Drinking water is bought per liters, which is provided by water tanker cars. The rate of water is very expensive and the quality is not guaranteed, for many of Kabul's population, access to a regular source of clean drinking water still seems inaccessible.

As for the rural areas and less developed parts of the country, people continue to rely on wells, rivers, streams or water tanks for drinking water. There have been no new built water pipelines and even the older ones require maintenance since they contain many leaks, which are responsible for losing nearly half of the water (GIZ, 2013).

The government of Afghanistan has failed to properly use the water resources that are available to them; simultaneously, there are no measures in place to maintain the existing systems. While the country has seen much development in other areas as compared to the past, in the case of the water sector there has not been much achieved.

As a mega-city Kabul faces numerous challenges in a war stricken Afghanistan and after 40 years of war in the country, Kabul needs a review of its master plan and management. The infrastructure of the city was initially created for 500,000 people, but in 2010 Kabul consisted of nearly 4 million inhabitants (USGS, 2010). The population of Kabul city increased at a rate of about 4 percent per year

during 2002–07 (Fahkri, 2014). High population growth rates in the Kabul Basin are expected to continue; on the basis of United Nations population projections, the population of the Kabul Basin could possibly double to 9 million by 2057 (USGS, 2010).

Only 48 percent of Afghanistan's population has access to safe drinking water and only 37 percent use improved sanitation facilities – which has serious health implications, especially for children, according to the UN Children's Fund (GIZ, 2008).

While some parts of the country are physically water scarce, most people lack access to safe water because of inadequate infrastructure and poor management rather than insufficient resources, claims a report published by the Centre for Policy and Human Development at Kabul University (GIZ, 2008).

Afghanistan's Human Development Report states the following:

"During three decades of turmoil in Afghanistan, water supply infrastructure has been neglected or destroyed, while the relevant institutions responsible for management and service delivery have collapsed," (irinnnews.org, 2011 p. 1). The report also states that a huge number of the population relies on inadequate facilities to supply water, many of these facilities are increasingly becoming contaminated and impaired (irinnews.org, 2011).

This study focuses on Kabul's water problem, water sources, water supply and potential of available solutions for the future. Furthermore, many international NGOs have already worked with the government of Afghanistan in terms of research and water supply in Kabul city and their work and achievements will also be addressed. The paper will also address potential solutions and recommendations to the problems stated.

1.2 Definition of the problem

Based on the research of DACCAR (Danish Committee for Aid to Afghan Refugees) in 2013 it is clear that Kabul needs a very concise review and new

plan in the close future. Availability of water is very limited and at risk. The rate of population growth shows that Kabul will have around 9 million inhabitants in 2015 but the availability of water is enough for 5 million inhabitants in the best possible situation. Furthermore, DACAAR states that under ground water in Kabul basin was 7.5m deeper in 2013 from what it was in 2003, thereby, the usage and recharge of water are not equal (DACAAR, 2013).

1.2.1 Aim of the research

The aim of this research paper is to analyse the current situation of Kabul's water supply and to propose available solutions to save and recharge the water sources in Kabul.

1.2.2 Objectives of the research

- Data will be obtained from known government reports and reports of credible NGO's and other organizations to analyse and investigate the current situation of Kabul's water supply
- Data will also be obtained from will known individuals who are experts in the field, their names and positions will be stated in the methodology
- The information will be used to describe the problems and its effect on the inhabitants of Kabul
- Solutions will be suggest to tackle the issues based on the gathered data

1.2.3 The necessity of the problem

Since 2002 Afghanistan has received billions of dollars in aid money to rebuild and restore the country in all aspects. Yet clean drinking water and sanitation has not been a priority in this respect. Many families lack running water in their homes and they are left with little choice than to retrieve it from other means. It is a common site to see children fill up large plastic containers and take it to their families under harsh climates and dangerous security situations. At times, the water they take home holds the risk of being contaminated and deadly. Afghanistan is also home to one of the highest infant mortality rates in the world with one in five children dying under the age of five on a yearly bases, one of the

main reasons behind this tragedy is drinking contaminated water (Al Jazeera, 2011). Drinking unclean water carries a number of substantial risks and diseases such as schistosomiasis, diarrhea, cholera and are responsible for many more fatal consequences (who.int, 2015). Taking all of these issues at hand once can states that the situation of water in Afghanistan can be termed as a crises and therefore it is crucial and necessary to address this problem and attempt to demonstrate solutions to tackle the issues.

1.3 Methodology

The methodological approach to address the problem is mostly based on secondary information from online sources and libraries. Moreover, other sources such as government reports are used to further the research. Secondary data will be reviewed initially through the university library, academic abstracts, bibliographic databases, and internet searches.

Furthermore, the research has taken advantage of primary sources, which will include interviews of individuals who have been involved in the topic and have done research on it extensively. These interviews will provide qualitative information to enrich the study. The following people have been interviewed:

- Sulaiman Osmankhail, Head of department Architecture in Kabul Polytechnic University
- Dawood Shah Farooq, Head of department Urban Planning in Kabul Polytechnic University
- M. Ibrahim Najaf, Professor of Hydrology in Kabul Polytechnic University
- Abdulkhaliq Nemat, Advisor in the Ministry of Urban Development of Afghanistan
- Abdul Ahad Wahed, Deputy Maior of Kabul Municipality

1.3.1 Limitations

Since Afghanistan is a country that has been shattered by war for the past four decades the biggest limitation is that fact that not enough data exits about its water and water issues- this is even true for modern day Afghanistan, since the

government has not taken the issue of water too seriously. Most of the existing information about Afghanistan's water is from the 1980's when the country was relatively peaceful. After the year 2001, international donors like GIZ, World Bank, USAID and JICA conducted their own researches and help programs in cooperation with the government of Afghanistan, while this information is useful it still lacks information about water from the decades of war.

Another limitation is the fact that most of the data and information is in the Persian (Farsi) language and it is slightly problematic when one has to translate the information into English or any other language.

1.4 Structure of the thesis

In this chapter an analysis of the water specific problems and challenges of Kabul city has been given. Moreover, the chapter provides a general view of the situation of water currently in Kabul city.

Chapter two analyses the water-specific problems and their sources.

Chapter three will focus on the possible solutions and the achievements of water supply and sanitation by international donor organizations and local government in regards to water-specific problems in Kabul city.

Finally, chapter four concludes and reports findings and reflects on how to improve the situation.

Chapter 2: Analysis of water-specific problems in the city of Kabul

2.1 General information about the geographical setting of Kabul

Kabul the Capital of Afghanistan, is the country's largest city and the political, cultural, commercial and industrial center.

The Kabul Basin is vital to the well-being and development of Afghanistan. It is an 80-kilometer-long valley which is formed by the Paghman Mountains to its west and the Kohe Safi Mountains its east, these mountain ranges frame Kabul City and the surrounding areas in Afghanistan (Figures 1, 2).

Sub basins of the Kabul Basin are produced by inter basin ridges and river drainages, which include Central Kabul, Paghman and Upper Kabul, Logar, Deh Sabz, Shomali, and Panjsher (Figure 1).

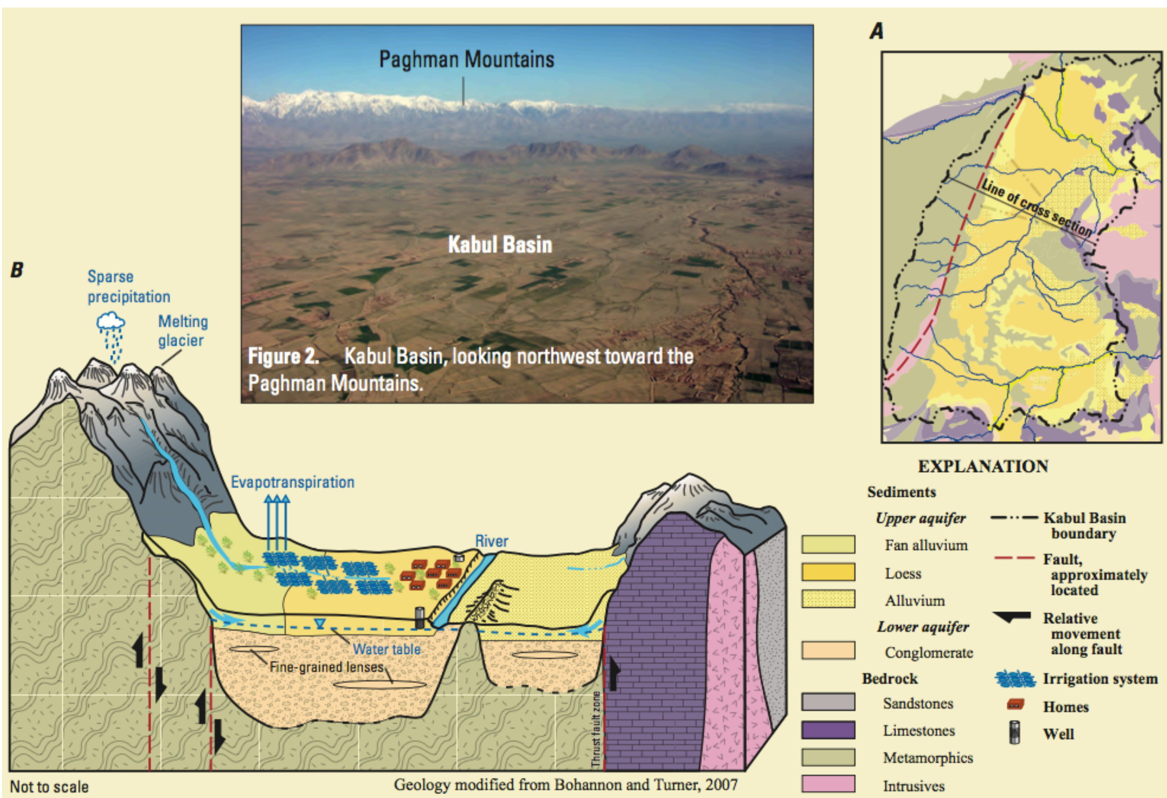


Figure 2. Kabul Basin, looking northwest toward the Paghman Mountains.

Figure1. Generalized geology and topography of the Kabul Basin, Afghanistan: *(A)* simplified geologic map and *(B)* schematic cross section. The line of cross section is shown in *(A)*. USGS, 2010

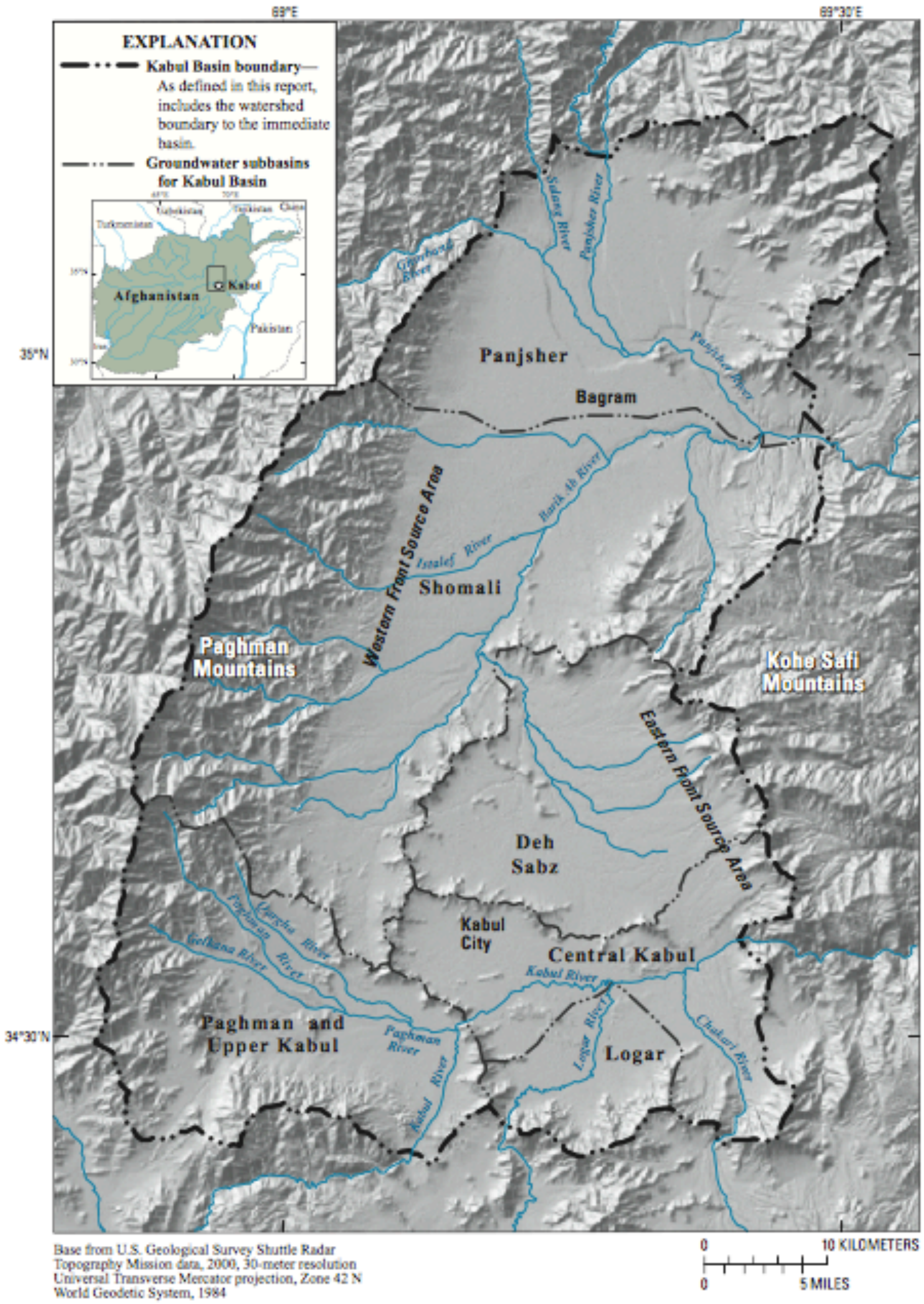


Figure 2. Location of Kabul basin in Afghanistan, USGS, 2010

The Kabul Basin as presented in (Figure 2) is in a “basin and range” setting. The valleys consist of sediments containing sand and gravel. The mountain ranges are constituted of uplifted bedrock. The primary aquifer, which is the upper aquifer comprises sands and gravels that typically are less than 80 meters thick in the valleys. These sands and gravels are extremely absorbent, this aquifer is situated under a secondary aquifer which consists of less porous, densely compacted sands, gravels and clays which could be 1,000 meters thick or more in some parts of the valley (USGS, 2010).

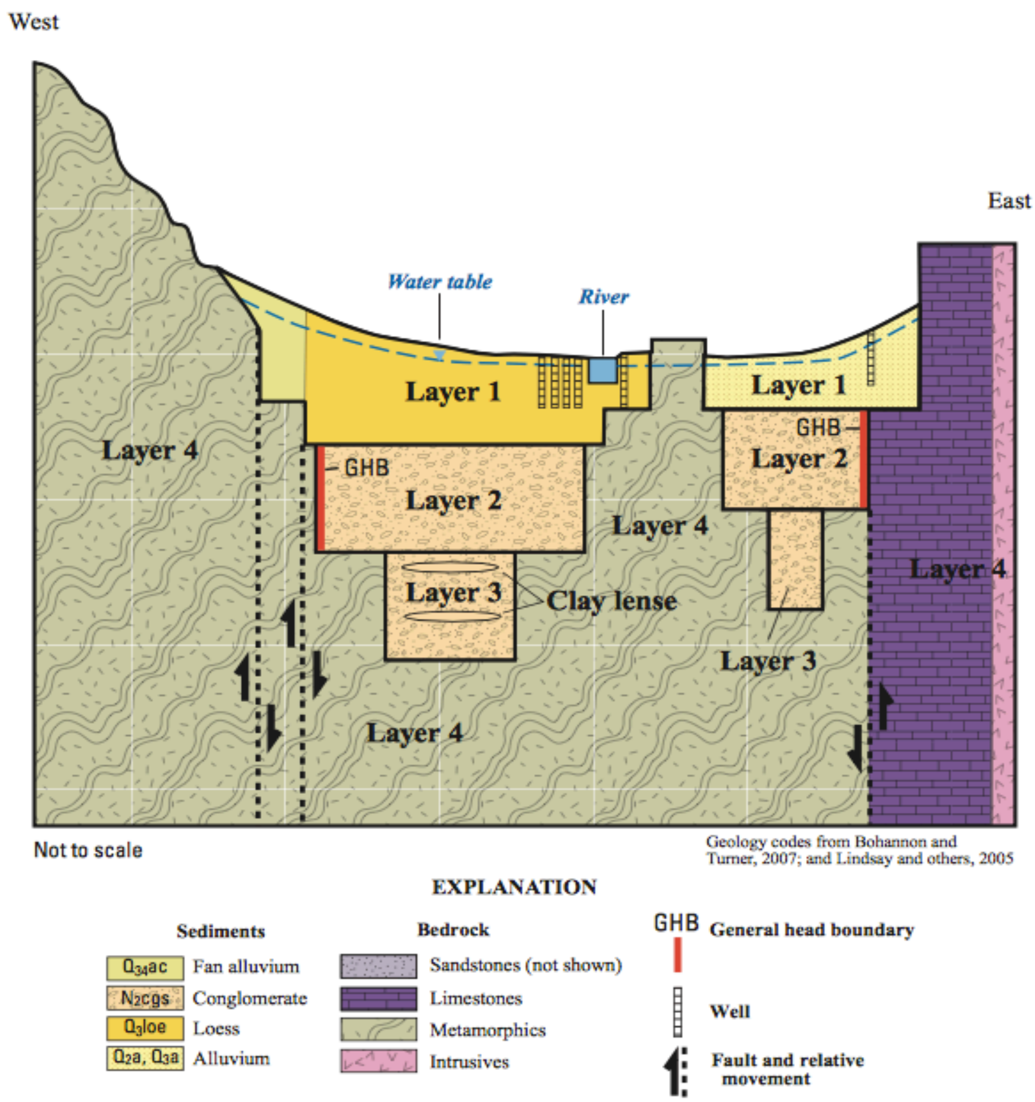


Figure 3. Generalized hydrogeologic representation, including numerical-model layers, of the Kabul Basin, Afghanistan USGS, 2010

The level of water in Kabul is directly linked with the weather and rainfall during the winter and spring (Figure 4).

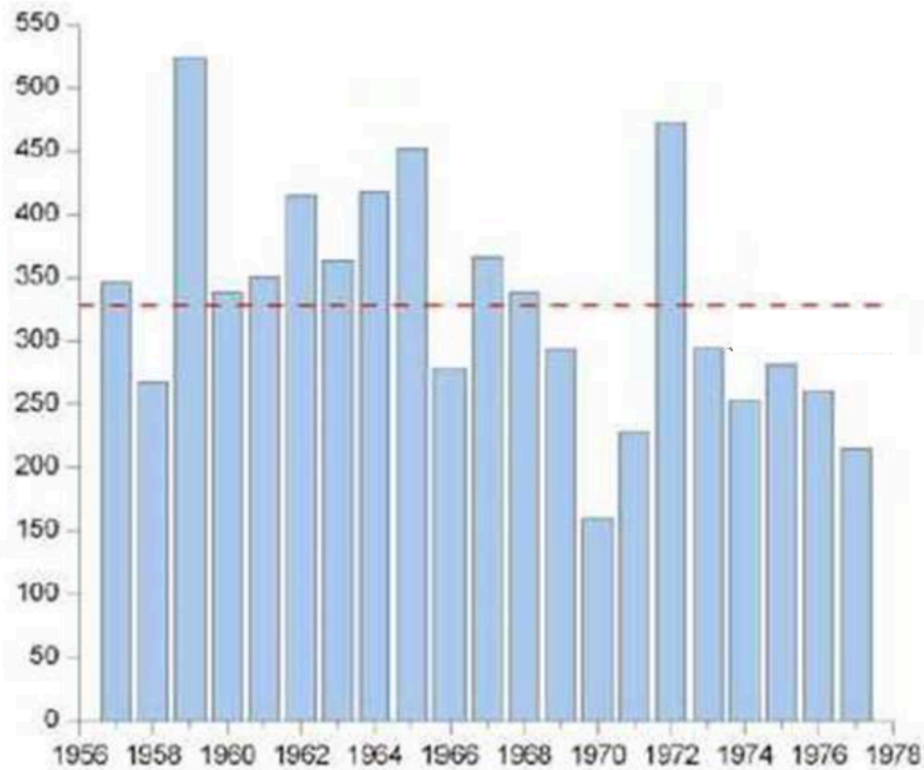


Figure 4. Kabul's rainfall between 1956-1978. USGS, 2010

Kabul has semi-arid climate and studies from 1956 to 2007 show a fluctuation in the rainfall and weather. From 1957 to 1977 the average rainfall in Kabul was 330 mm. The same amount of precipitation has also been recorded from the years 2003 till 2006, however this amount of rainfall has not been consistent in the city, for instance in the year 1959 the amount of rainfall was about 525 mm/year and in there have been many periods in the 2000's of no rainfall at all, thereby the last decade the country has been faced with a degradation of water levels due to the low amounts of rainfall and also due to the wasting of water (USGS, 2010).

The city is also surrounded by a mountain range and is separated to above and below parts by Asmaie and Gozargah Mountains. Throughout the country, many

high snow capped mountains are common, which are advantageous to save snow. Yearly rainfall is collected and goes through the shallow ground water and underground sources. Paghman, Shakh Bronti, Logar and Chemcha Mast mountains are the main sources of Kabul's water (USGS, 2010).

2.2 Water supply by surface and ground water in Kabul city

The Kabul River is a 700-kilometre long river that emerges in the Sanglakh Range of the Hindu Kush Mountains in Afghanistan and empties into the Indus River in Pakistan, it is the main river in eastern Afghanistan. Kabul zone accounts for 12 percent of Afghanistan's space and 26 percent of all Afghanistan's water are in this zone. Kabul River's watershed is 76908 Km^2 in 8 sides (USGS, 2010).
The Kabul River passes through the cities of Kabul and Jalalabad in Afghanistan before flowing into Khyber Pakhtunkhwa in Pakistan about 25 kilometers north of the border crossing at Torkham. The major streams of the Kabul River are the Logar, Panjshir, Kunar, Alingar, Bara and Swat Rivers. While the river is barely a dribble for most of the year, it increases during the summer due to the melting of snow. Its largest tributary is the Kunar River, which starts out as the Mastuj River, flowing from the Chiantar glacier in Chitral, Pakistan and after flowing south into Afghanistan it is met by the Bashgal River flowing from Nurestan. The Kunar River meets the Kabul River near Jalalabad (Noori, 2014).
A study by JICA (Japan International cooperation Agency) claimed that Kabul has 425 square Kilometers area and its main water sources are located in four areas: North Kabul, Pole Charkhi, Darulaman, Logar (2006).

Kabul's underground water sources in Paghamn till Pole Artal, Dehmazang, Guzargah, Darulaman, Qargha and Ali Abad mountain are the most rich side of Kabul basin and this area compromises the first zone of Kabul in the west and northwest of the city. (Figure 6)

Wells In these areas supply drinking water for people in Krarte 3, Karte 4, Jamal Mina and Karte Mamoorin. The quality and amount of water in these areas is excellent for drinking (DACAAR, 2011).

The second zone of water sources in Kabul is located between Pole Artal and Pole Charkhi. Lalandar River, Kabul River, Logar River and Kole Hashmat Khan recharge this zone's underground water, this area is in the center and south of Kabul (Figure 5).

Figure 5. Water zones in Kabul. Google map 2015. Edited by Obaidullah Mahdi

In Khairkhana (northern Kabul) the wells are active and there lengths are 6 meters to 15 meters deep, but the quality is not good. Due to the high concentrations of dissolved calcium carbonate (limestone) and calcium sulfate (gypsum), the water has a bad taste. The land has lime and plaster resulting in the bitter taste of the water, which makes it undrinkable (Noori, 2014).

Affect of climate: Another factor that affects ground water resources in the city is climate change. For instance an increase in the surface temperatures results in the snow melting during periods that it does not do so normally in the year. This comes as Afghanistan is predicted to have a 10 percent reduction in rainfall in the next fifty years (USGS, 2010). The US Geological Survey carried out a 10 percent reduction recharge simulation to asses the hydrologic effect of potential climate change on groundwater resources in the Kabul Basin. The results showed that a decrease in groundwater-level could cause about one quarter of all existing shallow supply wells to become unworkable or dry (2010).

"In the headwater areas of the Paghman and Upper Kabul and Shomali subbasins, more than 50 percent of the shallow supply wells could become inoperable. Where water use is large and recharge is small—in Kabul City, for example—groundwater-level declines may reach tens of meters. Currently, most of the total annual recharge occurs in late winter and spring, during peak" (Figure 4) (USGS, 2010 p. 4).

The change in climate and an increase in temperatures may also cause recharge earlier in the year, moving away from recharge in the summer, when people need water the most.

"A comparison of stream flow in the Panjsher River at Shukhi in 2006 with historical monthly stream flow observations indicates a shift in peak monthly stream flow to earlier in the year, as indicated by the observation of a period-of-record high flow in May and below-normal flows in June and July of that year" (USGS, 2010 p.4)

2.3 Digging of illegal deep wells

In the last decade Kabul's populating has seen a sharp increase and refugees have returned to the country after years of being away. These returnees and other people from throughout the country who have settled in the capital city for better opportunities have created illegal settlements throughout the country, such as on mountains and green areas, all of which are against Kabul's master plan. The returnees have started a new life without any civil services; most importantly they have been lacking water services, a primary need everywhere in the world. Because of the lack of water, the communities in the areas have created new intrusion hills but without any control, the facilities were given to them by NGOs and companies. Since the problem of water is crucial to the survival of all human beings, the government of Afghanistan could not do anything to halt the situation since they had no alternative option at the time.

In the past 25 years, thousands of new wells have been dug and all over the city, the majority of which are not activated because the level of water is deeper. People who have dug their own wells have not obeyed the rules and more water than needed was used. The wells are not created with expertise and therefore they do not function properly, also the quality of the water is questionable (Noori, 2014). The challenges posed by the population influx will is addressed in greater detail further in the study.

There are many causes for Kabul's deteriorating water. Some, as earlier are natural such as geographic position, poor water management, climate changes, droughts with other are human activities that have directly affected the water quality and the amount. Yet, human activities and wastage of water are also having a direct affect in the quality, pollution and amount of water (DACAAR, 2011). Many illegal wells are active in Kabul and people use water with no control as an unlimited source and a lot of water is wasted through the process. The main reasons are clear in the chart bellow:

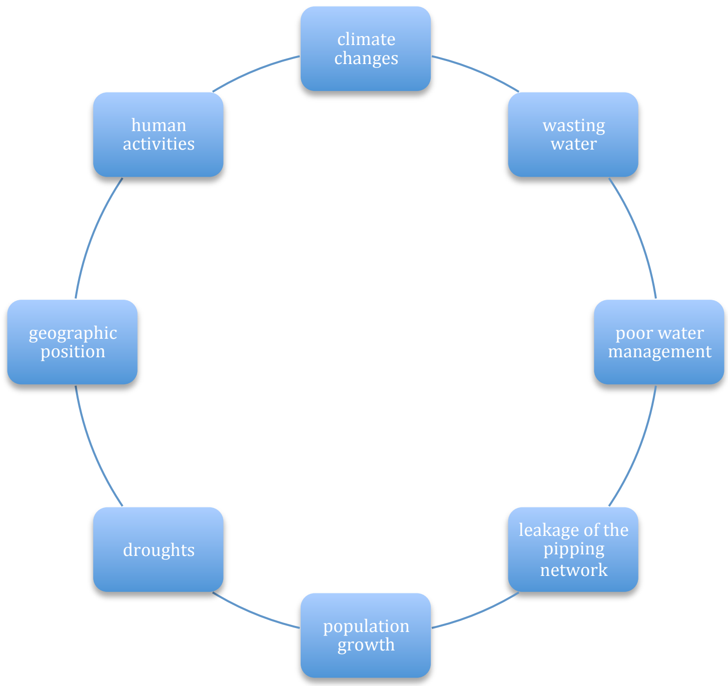


Figure 6. Main reasons for Kabul's deteriorating water

Illegal usage of water destroys the quality and amount of water. Kabul's underground water does not recharge as much as it uses and it creates major problems for its inhabitants presently and if the same scenario continues, so will the problems for the future Kabul inhabitants.

Studies show that the water sources in Kabul belong to four main stations (Sange Naweshta, Tangi Gharoo, Tangi Saiedan and Pole Sokhta).

Two million people of Kabul inhabitants enjoy clean drinking water of these water stations. However, in past three decades, Kabul has faced drought, additionally the population of Kabul has risen 10 times more in 2015 than what is was in 2001 Therefore, the usage of water has exceeded 10 times more in the past 14 years, which has complicated the situation (GIZ, 2008) (Figure 7).

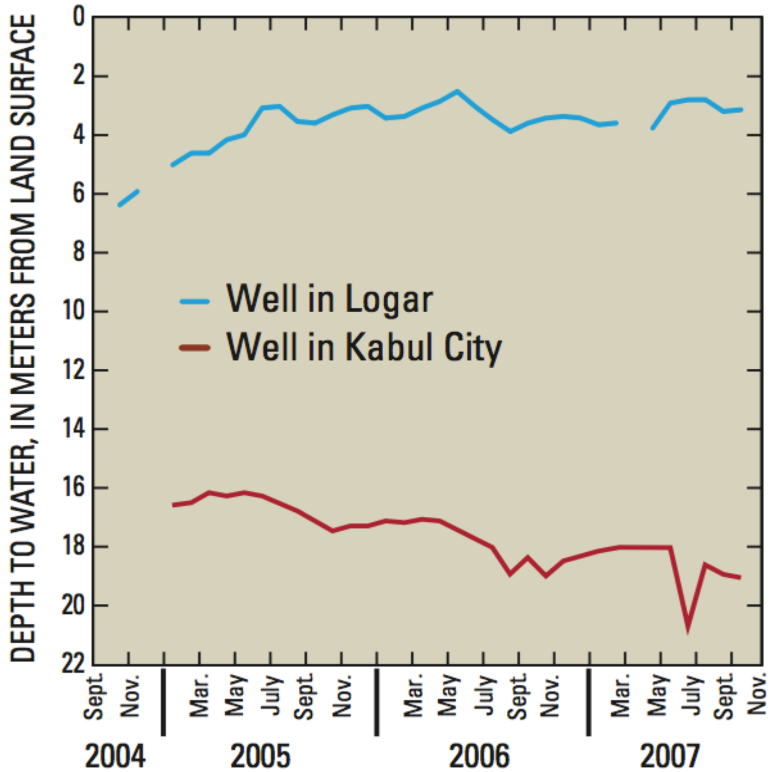


Figure 7. Groundwater level in two wells in the Kabul Basin, 2004- 2007

Consequently, the usage of Kabul's water sources is larger than its recharge. The average underground water levels are deeper now than the previous years, in 1963 the average of shallow ground water level was 1 meter and today it is 9.5 meters (Figure 8). Moreover, the heat of water in Kabul's wells is has changed throughout the decades, in 1970 it was 13^0 centigrade and today it is 7^o centigrade on average. As much as the level of water is deeper in the land, it will be cooler (DACAAR, 2011).

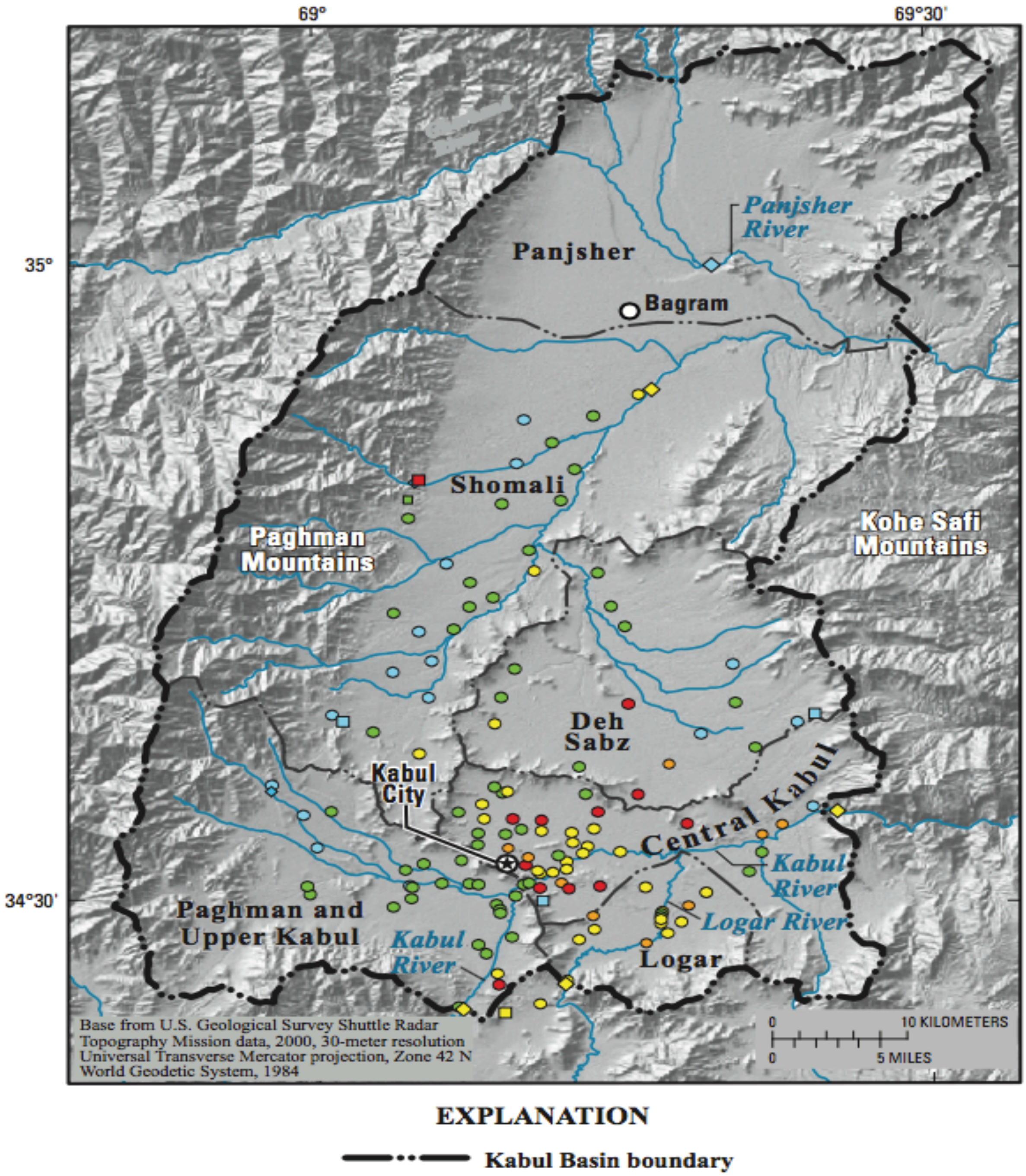


Figure 8. Study area of the Kabul Basin, Afghanistan, with major geographic features and subbasins. USGS, 2010

Finally, because of the years of war, very limited research data is available in regards to water from 1980 till 2001. Existing data is from the years before 1980 (before the beginning of war in Kabul) from Department of Hydrographic Engineering, and after the fall of the Taliban regime in 2002. This gathered data presents the level of under ground water in Kabul was between 5 and 10 meters

higher in 1980 compared to water levels today (Noori, 2014).

2.4 Urban drainage and water quality in Kabul city

Urban drainage and wastewater in the Kabul city are treated mainly on site by infiltration and evaporation even in the city center. This causes frequent flooding of roads and return of wastes by overflow due to poor drainage. Deterioration of the quality of shallow groundwater by wastewater has also been pointed out. The on-site treatment by infiltration, however, helps maintain the groundwater tables.

Figure 9.Kabul 2014- Photo from Pajhwok Online newspaper

In most areas of Kabul there are not enough drainage canals, at the same time, these canals are not connected with each other properly. The rainwater does not reach the river, rather it causes an overland flow (surface runoff), then in infiltrates into the soil and is evaporated. After flowing in the streets, the rainwater evaporates or consumed in the land (Soufizada, 2008).

Rainwater is the only available water source to recharge the ground water sources in Kabul however it does not collect and does not direct through canals. (Figure 9)

Kabul does not have a canalization system in the majority of the city, only a few districts in Kabul have canalization (Macrorayan's 1,2,3 and 4) (Figure 10)

In other parts of the city every single building has its own septic well. Some of the

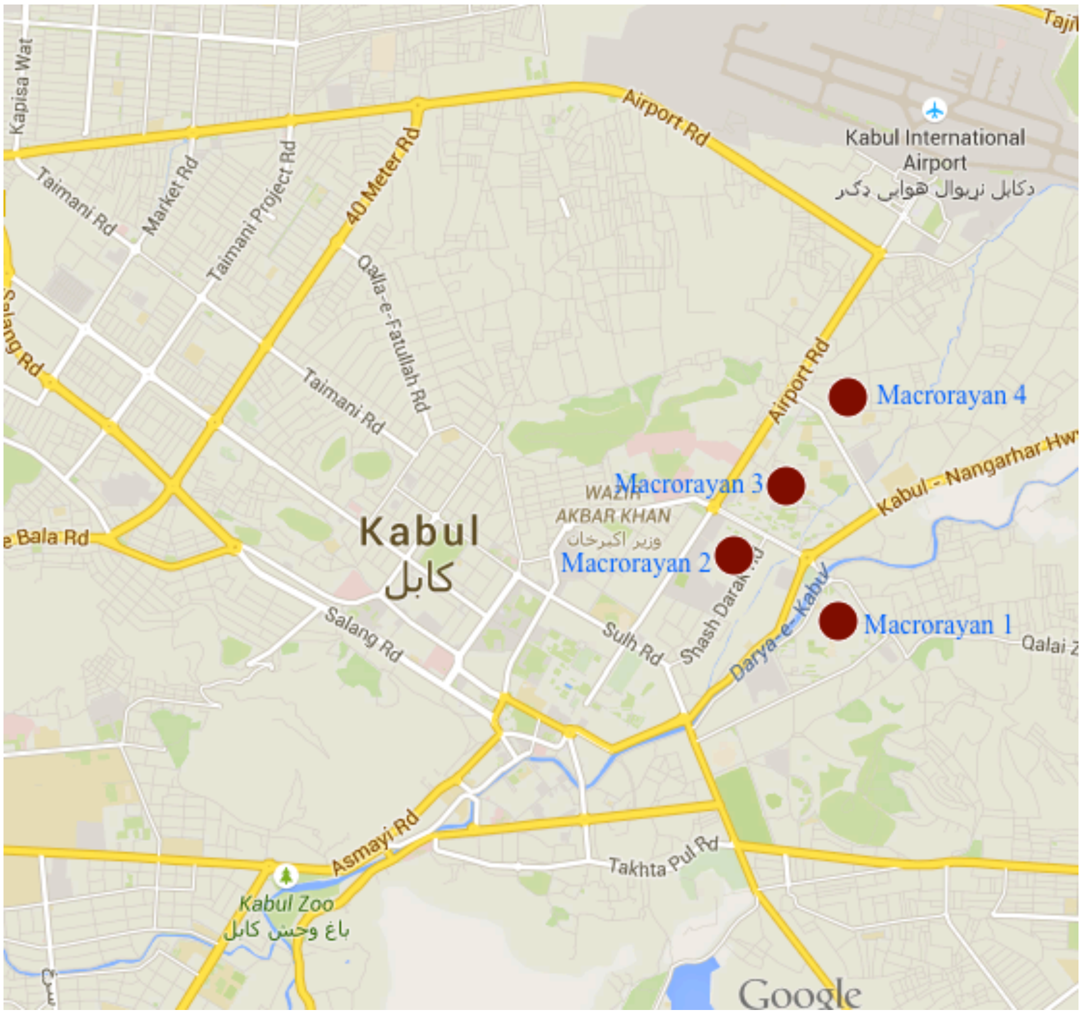


Figure 10. Makrorayan 1, 2, 3 and 4 positions in the Kabul map. Google map 2015, Edited by Obaidullah Mahdi

septic wells are open in upper ground and some of them are in underground of the house (Soufizada, 2008).

Rainwater mixes and pollutes with wastewater, which creates a huge sanitary challenge. Rainwater is polluted with wastewater and finally it goes through the ground water and pollutes the water sources at the end.

In the some of the areas human waste is collected from the septic holes and tanks occasionally and applies to agricultural lands. But it is very expensive for people. However this process is available in those septic tanks, which are isolated. People prefer to have non-isolated septic holes, through this, the wastes and water are consumed in the ground and there is no need to empty the septic hole for years (Figure 11) (Soufizada, 2008).

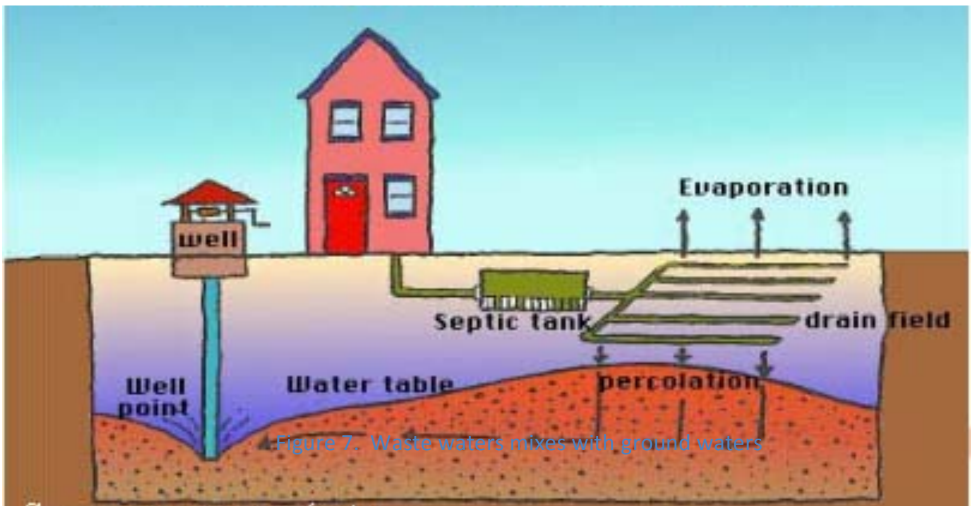


Figure 11. Wastewater mixes with drinking water

Additionally, Kabul's water has been polluted with Faecal and Nitrate as stated by a GIZ research for Kabul Water Program, the Nitrate comes from septic wells through water sources (2003).

Most of Kabul city does not have a canalization system, however a few parts and zone do, the old soviet build areas such as Makrorayan 1, 2, 3 and 4 have these systems in place. The wastes and sewage in these areas are collected in one system and transferred to a biologic refinery.

In the previous chapter it was mentioned that the years of drought has caused many difficulties and has created a shortage in surface water, as a result, ground water is now the major source of drinking water, ground water is recharged by "direct exfiltration from the rivers after the snowmelt and foothill infiltration at the rim of the basin" (BGR, 2004). At the same time, climate again rainfall: Kabul's low rainfall and high evaporation rates impedes groundwater from recharging

through rainfall and with the drought and rising population, groundwater resources have been exploited; more water is being pumped than can be naturally replaced (BGR, 2004).

Private water supply companies want to sell the water and control the sources as well. In many parts of Kabul, when people think the piped-water supply is not enough they start to drill their own wells. A majority of the population obtain water through open wells or hand pumps, according to the Ministry of Public Health of Afghanistan polluted drinking water has been one of the main reasons of sickness for people in Kabul. Open wells and hand pumps are located in neighborhoods where there is no canalization system to collect wastewaters. Whenever septic tanks located in the underground of buildings and houses collect the wastewaters and human wastes, it then mixes with water source; these septic tanks are polluting the water sources very fast (GIZ, 2013).

Stress on the urban water supply is projected to increase significantly in the future due to extended droughts, rising population numbers, and severe ground water contamination from the absence of a functioning waste water disposal system.

2.5 Natural quality of surface and ground water and the influence of human activities

A study by the American Geological Survey in 2010 which collected water samples from 8 surface-water sites and 92 groundwater, springs, and Karez (tunnel system used to extract shallow ground water) sites in the Kabul Basin, concluded that bacterial contamination was frequently discovered in both surface water and groundwater at levels that exceed international drinking-water standards. Furthermore, the more populated areas of the basin, values of several water-quality parameters, such as specific conductance.

The report states that human activities have been responsible for the contamination of the water, as seen by the levels of chloride, nitrate, and boron. The study reflects the lack of waste and wastewater treatment facilities, at the same time, it may also reflect the mismanagement of wells and their construction

without grouting, which can subject the water to pollution from surface sources. Moreover, the water detected in areas with less inhabitants showed a better quality of water, which again indicates that one of the causes of contaminated water is due to human activities (USGS, 2010).

Furthermore, it states that an analysis of samples the surface water and groundwater indicated that groundwater less than 100 meters below the land surface is normally 20 to 30 years old. However, the groundwater in deeper aquifers is possibly thousands of years old, while this indicates that a considerable amount of reserve groundwater exists it can be dangerous to use currently since it has not been studied. Most of the recharge water is a resulted from the leakage of stream flow (USGS, 2010).

The availability of groundwater in the Kabul Basin differs significantly among and within its sub basins but it mainly depends on the following points:

- Surface-water infiltration from rivers and streams
- Water leakage from irrigated areas
- Subsurface groundwater inflows from mountain fronts
- Groundwater storage in thick sediments (DACAAR, 2011)

2.6 Traditional bathroom problems

Kabul Municipality lacks a centralized municipal sewerage system, only a limited number of sewerage systems exist in some apartments and complexes of the city. Macroyan is the only area connected to a biological treatment system and most other parts of the accumulated wastewater are delivered to on site tank systems. In fact Koch reports that in 2007 only 172, 200 residents of Kabul were connected to a sewerage system, 330,000 were connected to on site tank systems and 2.5 million people were served by dry vault toilets, or toilets with no or low flush (2007) (Figure 12).

Figure 12. A traditional bathroom in Kabul. Koch, 2007

These bathrooms are used for human wastes only and have not been designed for washing the body. The government has voiced interest in improving these areas to make a better environment for the city and its people. Many of Kabul's population are not able to afford better facilities, thereby they are not able to have access to water over a limited amount. Most houses have only one sink and the sink is usually available in the garden, the houses also lack piping systems; traditional bathrooms are usually also located in the garden outside of the house (Soufizada, 2008).

The present system "Sewerage System" can be classified as follows:

1. Dry vaults with no or very low flush
2. Septic tanks, serving a house up to a single apartment block; these are unconnected to a sewerage system
3. Properties served by sewerage- this system complies all properties to discharge to a public sewer system and the sewage is treated at a wastewater treatment plant. Yet, some of the properties manage with their own full or partial treatment plans (Koch, 2007).

Traditional bathrooms are not designed to be connected with canalization system because they are very dry and not enough liquid to can move in the system and therefore more water is needed to push the sewage. Therefore it will make more liquid sewages which go through underground much faster (Soufizada, 2008).

In district 11th of Kabul a sample project had been applied to find out if it is possible to connect the traditional bathroom to a septic well or not, the results was very good. Traditional bathrooms are open because they need maintenance and cleaning after sometimes and therefore they are created to be in the same level of the ground floor. It smells and looks bad in the neighborhood and they also pollute the environment. Connecting the traditional bathrooms with a septic well is at least better in regards to the city culture, attractiveness and public health. Instead of “holes” in the traditional bathroom, they can possibly be replaces with regular toilets, but more water is required and a simple piping system to push the sewages to the septic wells (Soufizada, 2008).

2.6.1 Tank-systems (cesspits and septic tanks)

Because of disorganization the emptying of the tank systems is normally done by private enterprises, however in order to save money Andreas Koch reports that the suction trucks dispose the sewage at disposal sites and creeks in an uncontrolled manner (Koch, 2007) (Figure 13).

Figure 13. Pollution caused by on-site systems

“The liquid portion of the wastewater infiltrates into the soil and leads to a severe pollution of the shallow wells and some deep wells also showing high contents of coli-form bacteria indicating direct contact between groundwater and wastewater” (Koch, 2007, p. 5).

2.6.2 Dry vault-toilets

Koch explains that the strategy for the areas with dry vault toilets will be improvement of the facilities and the reactivation of disposal alternatives that are important in curbing the issue, such as night soil, particularly because of the limited water supply.

“Because of the limited water supply possibilities the water consumption will be less than 50 l/cap/d in these areas. Therefore the wastewater amount will be too low to install a sewerage system. In addition night soil collection and disposal has to be organized properly, existing toilets have to be improved” (Koch, 2007 p. 7).

2.6.3 Septic tanks and cesspits

Areas where properties and households are connected to a septic tank system and cesspits are normally areas where the standard of living is higher in comparison to areas that are do not have this system in place. Water supply to residents in former mentioned areas is constant therefore water consumption is higher which results in a large quantity of wastewater that needs to be disposed. Koch suggests that the ecological endangerment for the ground water is a crucial difficulty of these systems and could be resolved without greater difficulties by their connection to a new sewer system (2008).

2.6.4 Priorities

One of the main causes of polluted water sources is unmanaged wastewaters and sewages that are not emptied properly which are then mixed with underground water sources (Soufizada, 2008).

The following factors are the main reasons for the vital need of a canalization system in the areas that have the following characteristics:

- In areas where there is no canalization and the inhabitants are faced with sanitation and health problems, specially in the high density populated areas
- In the areas where the groundwater level is high, wastewater mixes with groundwater quickly
- In the areas where people use groundwater for drinking but the quality of water is not good and it has polluted with wastewater.

Areas that are close to each other can also connect to the same canalization system for example Wazir Akbar Khan can be connected with Makrorayan's canalization exit system. Wazir Akbar Khan is close to Makrorayan of Kabul and does not have a canalization system, also the groundwater has been highly polluted (Soufizada, 2008).

2.7 Influence of the growing population on water quality and quantity

Kabul's infrastructure was built for some 500,000 residents. Refugee influx resulting from the war has led to an additional five million inhabitants, haphazard construction, and fading green spaces within the Afghanistan capital. A large number of people have made their new living areas without the government's control and these unplanned areas are face the majority of the city's problems in regards to water supply.

Some 70 percent of the urban population lives in unplanned areas or in illegal settlements, while 95 percent lack access to improved toilets. In Kabul 80 percent of the population live in unplanned settlements (around 3 Million people) where poor sanitation and lack of access to safe drinking water are common (Bertaud, 2005).

Kabul city has two kinds of areas they are against the master plan of the city: unplanned and illegal areas. These areas have caused a huge challange for Kabul Municipality and its offices they are faced with fixing these issues on a daily basis.

Some areas are private property and owners have used the land for agriculture in the past, however this land was in dubbed as a Grean Area" in the master plan of the city, but now many of the lands have had buildings been created on them. Kabul municiplaity is not ready to give them civil services like water, electricty, roads and other facilities. There is also no way for collecting waste water. The government faces huge challenges all over the city, as of till now there has been no practical solution. Only a few of the cases have been tackled where the government bought properties and gave the owners other land and compensation. However, this solution has not been practiced all over the city, the government has does not have enough money and the process is very time consuming. If the government wants to exchange the properties with people, it needs to seize 2,0000 properties per year for Kabul's development (Bertaud, 2005) (Figure 14).

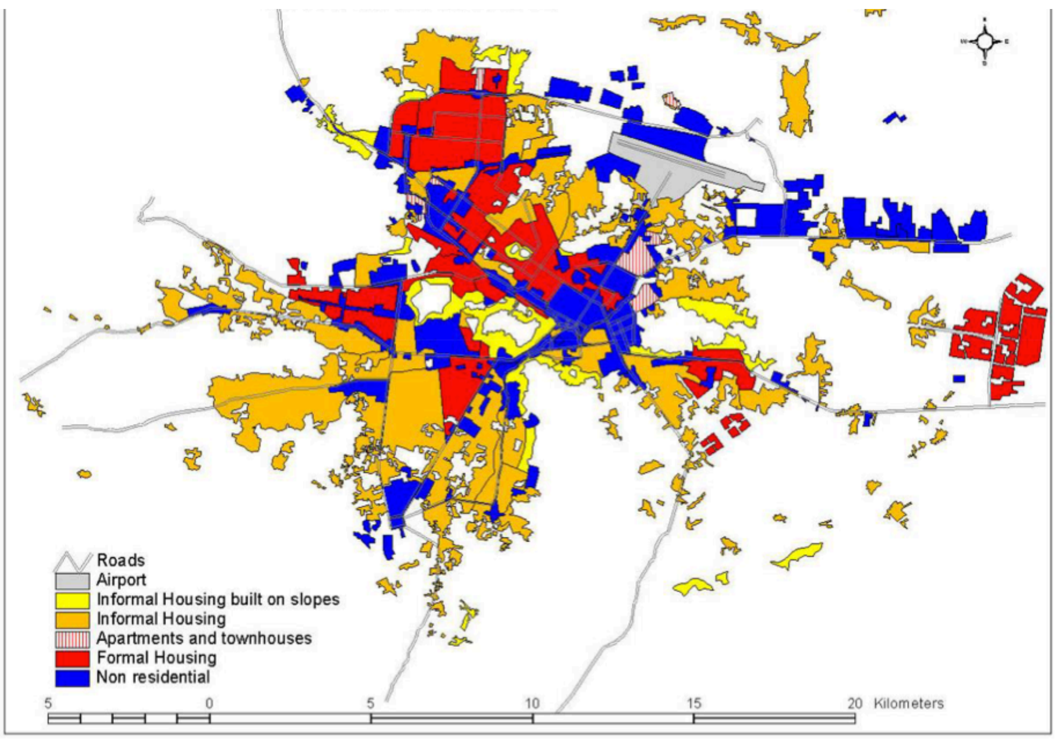


Figure 14. Kabul planned and unplanned area. World Bank 2005

On the other hand, illegal settlements are evident throughout the city. People have build their settlements in the government areas. After the war in 2001,

many refugees returned back from abroad, in fact 25% of the population of Afghanistan today are refugee returnees and because of the lack of jobs in the underdeveloped parts of the country, many of these refugees have chosen to live in Kabul (UNHCR n.d.). They have built shelters and housing throughout the city. These settlements have been built with very good construction materials but have legal problems, their owners do not know how long they will be allowed to live there since there is no guarantee that exists for illegal housing. Nevertheless, these illegal areas have helped national economy of Afghanistan. The rate of homelessness is 0.5 percent only in Kabul and the price of house are about 3 billion US dollars investment. The government of Afghanistan is not able to give them another alternative home, because of this the government and international funders decided to help the unplanned and illegal areas in terms of civil services and facilities. In these illegal areas, the people are ready and to pay taxes and receive some services like water and electricity. In some areas, government and international funders planned to give clean drinking water for the communities. Some areas already have water supply services but others do not.

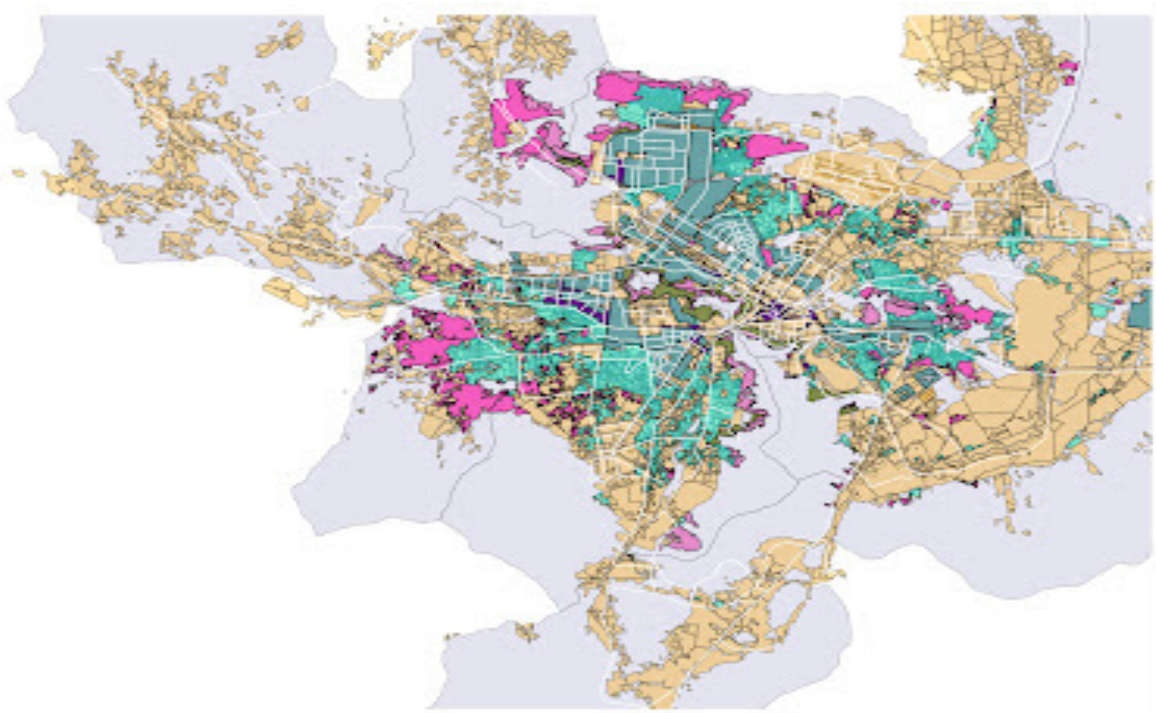


Figure 15. Kabul, Afghanistan 2001 Formal and Informal Housing [green] vs. 2006 Informal Housing [purple] (Map- Sutika Sipus 2012) World Bank, 2005

Kabul’s unplanned areas houses are bigger than planned areas houses. The average number of houses in one hectare is 22 in planned areas of Kabul but the 20 in unplanned a1reas (Figure 15) (Bertaud, 2005).

Problems related by the unplanned and illegal settlements of Kabul:

- Illegal areas are not included in the master plan
- There is no guarantee for the future of their property
- Very limited civil facilities
- Environment and sanitation problems (clean drinking water, road, clinic, school, park)
- Density of population (7.5 people/house)

The advantages of the unplanned and illegal settlements of Kabul:

- A huge help for national economy (3 Billion US dollars investment not including the price of the land)
- Built with very good construction materials
- Able to pay tax in order to have some important services
- Bigger then the planned areas (22 houses/hectare)
- Now only 0.5 % of Kabul population do not have housing

It is estimated that Kabul’s population will rise to 8 million by 2025, according to a comprehensive water study by JICA team on 2007. The population of the Kabul Basin is expected to rise more than 9 million by 2057. Water availability in Kabul city is to the tune of 166 million cubic meters per year, which suits for only five million people with an average of 90 liters per person per day, whereas the international standard is 120-150 liters per person on a daily basis (JICA, 2006).

The country faces an immediate need for the demands of Kabul Basin’s increasing population. Climate change, low rainfall, the digging of illegal wells, urban drainage issues, unhelpful human activities and the rising population affect the current existing water supplies. The quality of water has deteriorated and

may not be sufficient enough for future needs. The next section of this paper will attempt to give solutions to Kabul’s water crises.

Chapter 3: Potential options and the achievements in water supply and wastewater collection

3.1 Overview

In the capital city of Afghanistan only one in ten households has access to clean drinking water, according to GIZ, one out of ten household is connected to the rundown public water supply; additionally in the provincial towns, the figure is one in five. As for the rural areas of the country, the population relies on traditional forms of attaining clean water, which is through public wells, rivers, streams or water tankers. The report also reiterates the problems with the overuse of water resources and leaks in the pipe networks causes nearly 40 percent of the loss of water, also the lack of technical skills of workers has contributed to the problems (GIZ, 2014).

The previous chapters discussed general information about Kabul's water issues and exposed the problems in regards to water supply, sanitation, pollution, wastewater, unplanned areas and so forth. This chapter attempts to give solutions to the issues discussed and to reiterate the research and achievements by various international NGO's and international donors in partnership with the government of Afghanistan.

3.2 Kabul urban water supply program

USAID reports that the average liter of drinking water per person on a daily bases is 15 liters, therefore the current supply of water in Kabul continues to be exceptionally limited. It goes on to state that the current piped water system which is operated by the Afghanistan Urban Water Supply and Sewerage Company (AUWSSC) covers the needs of less than 20 percent of the entire population; furthermore, the distribution system is highly unreliable since it delivers water for only 12 hours per day; households are forced to find other means or store water for the remaining time of the day (2013). The majority of Kabul's inhabitants obtain water through open wells or hand pumps, which can be seen all over the city. USAID projects that stress on the urban supply system will continue in the future due to the same reasons as previously mentioned:

rising population numbers, water contamination, droughts and an absence of a waste water disposal system (2013); because of these mentioned reasons groundwater is now the main source of drinking water in the Kabul Basin. The German Development Bank (KfW) in partnership with the government of Afghanistan has responded to these issues by organizing the Kabul Urban Water Supply (KUWS) program to increase the piped water coverage to 50 percent of the population of Kabul (USAID, 2013) (Figure 11).

A new water pricing structure (water tariff) was introduced in 2012, which has significantly boosted the income of the water utilities in Kabul. For example, the amount of money people spent water had risen from 37 per cent to 54 per cent in Kabul, from 58 per cent to 84 per cent in Herat, and from 52 per cent to 59 per cent in Kunduz (GIZ, 2013). A rise in price also promotes the less usage of water since it is more expensive to do so.

Renewing of the water supply system is one of the funded programs by the government of Germany; this program also has a development section. On the 23rd of September in 2013, two drinking water supply systems were launched in Kabul. The systems were able to serve 1.1 million people. The project was supported through providing modern equipment, which was able to make 45,000 cubic meters from Bagrami water sources to the city water network. The project was very robust and a useful step in Kabul's water supply dilemma; it was funded by the German Development Bank (KfW, 2013).

Saving of water and usage of new equipment finally gave the opportunity for people to have access to clean drinking water and developed capacity building for local employees, which was also included in the project.

3.3 GIZ water supply project in Kabul

After the fall of the Taliban regime in 2001, the Immediate Assistance Program (IAP) with the help of KfW was launched a year later with the purpose to repair parts of the installations to increase water production since water supply was still insufficient in the country, particularly since the during the previous years the piped water system in the country was seriously neglected (TSP, 2006). The

implementation of the project started in 2005 and continued till 2011; the goal was to serve more than 2 million people, KfW paid 30 million Euro's for the investment (TSP, 2006).

The Transitional Support Program also known as the "TSP" began a project to ensure the sustainable operation of the new installations for the Afghan Urban Water Supply and Sewerage Corporation (AUWSSC); TSP construction this through the operational training and support for AUWSSC.

TSP pledged a proficient and sustainable operation of the new systems and lead a program that gave operational support and training for the Kabul Branch of the Central Authority for Water Supply and Sewerage (CAWSS) which was corporatized in 2009 as Afghan Urban Water Supply and Sewerage Corporation (AUWSSC). GIZ was also part of the team in this project and the role of GIZ was mainly financial and commercial management, TSP on the other hand covered general technical and management issues (TSP, 2006).

The consulting services indicate the following activities:

The Support of the process of institutional reform and institution building of CAWSS Kabul, which included:

- HR roles such as a review of organizational and staffing structure and the development of job descriptions in the technical departments
- The process of development and completion of of operational regulations and procedures
- Implementing a clear outline of administrative regulations and procedures
- Establishing and a development of business planning which was in cooperation with GIZ
- Obtaining of important equipment (TSP,2013).

The support and training in imperative administration and technical fields of the water supply system included:

- The guidance of CAWSS Kabul executives in overall management;
- The technical management, its operation and maintenance of all the reformed installations;
- Support in technical areas such as engineering, detection and repair and so forth
- Support in the groundwater resources management, monitoring , protection and in groundwater and distributed water quality control
- A clear definition of performance indicators as a basis for the future management (TSP, 2006).

3.3.1 Description of the project

The projects main objective was to extend Kabul's water supply system to another 3.5 million people who did not have access to the system. The extension included the following factors: the construction of well fields, pumping stations, trunk mains, distribution networks, administration building and maintenance facilities. The program was said to be worth 150 million euro's and The Central Authority for Water Supply and Sanitation (AUWSSC) was responsible for the implementation of the project (GIZ, 2013).

3.3.2 Project components and technical data

- 26 new wells, delivery rate: 125-175 m^3/h
- 6,200 m^3/h additional high-lift pumping capacity in 5 (five) pumping stations
- 63 km of trunks and well field collectors
- 925 km of distribution network
- 23,000 m^3 of additional reservoir capacity
- Target water production: 34 million m^3/y sold and 44 million m^3/y produced
- (GIZ, 2013 p. 26)

3.3.3 Scope of services

- Topographic survey
- Subsoil investigations
- Sampling / Analysis
- Hydrogeological studies
- Geophysical studies
- Hydraulic investigations
- Site selection
- Detailed engineering design
- Tender docs / Tender action
- Tender evaluation / Assist. in contract award
- Construction supervision
- Final handing-over
- Start-up operation
- Training
- Awareness building
- Monitoring & Evaluation
- Follow-up during warranty period
- Project management & Controlling
- Geographic Information Systems (GIS)
- Workshops
- GIZ, 2013 p. 27) (Figure 15)

3.4 USGS water supply project in Kabul

The USGS water supply project in Kabul has collaborated with scientists and the Afghanistan Geological Survey (AGS), the Afghanistan Ministry of Energy and Water (MEW) and various scientists to assemble hydrogeologic data on Afghanistan's water resources. Furthermore, since the hydrologic and climate data collection activates were halted in the 1980's there has been no apparent data-collection networks available except for the few historical records that were saved from the conflicts. Investigators have made great use of the limited data and the records that have been left behind.

Initially AGS-USGS focused on providing facilities to manage water resources in Afghanistan through capacity building programs of local Afghans in the field of water; from scientists to officials who monitor the sites. Strengthening the relevant institutions was also key to providing a positive result, institutions such as ministries. Additionally, the developing and strengthening of national, regional or local water resources databases was key. Finally AGS-USGS was responsible for training and providing equipment (USGS, 2010).


Figure 16. People use clean drinking water, which has provided by new program. GIZ, 2013

"Project participants concentrated their efforts on analyzing water resources and their availability in the Helmand and Kabul basins in southern and central Afghanistan, respectively, and on collecting stream flow data in central, southeastern, and northern parts of the country. Stream gage data for much of Afghanistan can be accessed using the interactive map below" (USGS, 2010 p. 2)

One area that stood out as particularly important to the water project team was the Kabul Basin, which is responsible for the ground water resources of the capital city and its population of roughly 4 million. As mentioned before, due to the years of drought, Afghanistan's water was heavily impacted and Kabul Basin was no exception, while data from 2005 states that water began to increase

slowly in rural parts of the country due to normal rainfall and stable ground water withdrawals, it failed to do so in Kabul. Ground water levels in Kabul have decreased die to the increase of people in the capital city and its continuous growth. Groundwater resources in northern Kabul Basin are not as risk averse as those in the city of Kabul, those in the north are more sustainable than the groundwater resources in the city since they as susceptible to long term water sustainability. It is necessary to continue monitoring the groundwater in regards to the changing climate. USGC reports:

"The rate of groundwater-level decline in the city was greater from 2008 to 2012 (1.5 m/y on average) than from 2004 to 2008 (0 to 0.7 m/y on average). Many community supply wells were installed only a few meters below the water table and are vulnerable to seasonal drying" (USGC, 2010 p. 3) (Figure 16).

3.5 Master Plan of Sewerage and Drainage

The Kabul Municipality sewage system is not centralized. Very few sewerage systems only exist in some apartment complexes of the city. Most parts of the generated wastewater are conveyed to on site tank systems. Only the area of Macrorayan is benefited of the biological treatment system.

Only about 172,200 residents of Kabul are connected to a sewage system. The existing sewerage and wastewater systems are affected from the unreliable power supply, which results in the direct discharge of untreated wastewater into the nearest receiving water (Koch, 2007).

Just one treatment plant exists for treatment of public, domestic and commercial wastewater for Kabul, which serves the apartment complexes of Macrorayan 1 to 4. The Consultant carried out several inspections and it was found that only the first purification stage, the mechanical screening and settling stage was working good and other parts are not working good. The biological purification stage and the chemical treatment, a chlorination system, did not work. The effluent is discharged to the Kabul River without disinfections.

The existing situation is as following:

- The Project Area covers the Municipality of Kabul, with a population currently estimated at 2.5 – 3.0 million, fast growing due to the influence of refugees
- More than 90% of the Kabul Municipality does not have a centralized sewerage system
- A restricted number of sewerage systems only exist in some apartment complexes of the city. Only the area of Macrorayan is connected to a biological treatment plant.
- Most parts of the generated wastewater are conveyed to on site systems.
- From a Population of 3 Mio Inhabitants:

  - 330,00 inhabitants are connected to on-site tank systems (cesspits/septic tanks)

  - 175,000 inhabitants are connected to sewerage systems

  - 2.5 Mio are served by traditional vault toilets or pit-latrines (no or low-flush systems)

According to Koch, in the future a centralized collection and treatment of wastewater in possible in areas that have the following features:
A High population density, thereby a possible high connection rate and finally technical possibilities according to the design (2007).

3.5.1 Existing Sewerage Systems

In the future the system can be connected to the central sewerage system without considerable problems. The existing sewerage systems of all complexes have to be restored successively. Suitable rehabilitation methods concerning hydraulic, constructional and financial requirements must be evaluated in the following design stages.

The central sewerage system will be connected to new central WWTP(s) (Soufizada, 2008).

3.5.2 Proposed Solution and Priorities

The project included the selection of 6 possible main catchment areas for centralized sewerage systems and 3 various locations for treatment plants are required because of the geographical restrictions and the requirement to minimize pumping systems. The project confirmed a direct connection between groundwater pollution and unchecked wastewater disposal which was the result of a missing or un-operating wastewater disposal.

The following factors are frequently used as the basis of a decreasing order of quality:

1. In the areas where unsanitary living conditions exist due to the lack of sewer system;

2. Areas with high density populations and low porous grounds

3. Areas that have cesspit thanks and their frequent emptying is not practice and is costly

4. Areas where the quality of the groundwater has become unacceptable level by septic tank wastes

5. Commercial centers (Koch, 2007) (Figure 17).

According to Soufizada's report, it is estimated if the project of new canalization system is built, 4,056,588 people will use it by 2030.

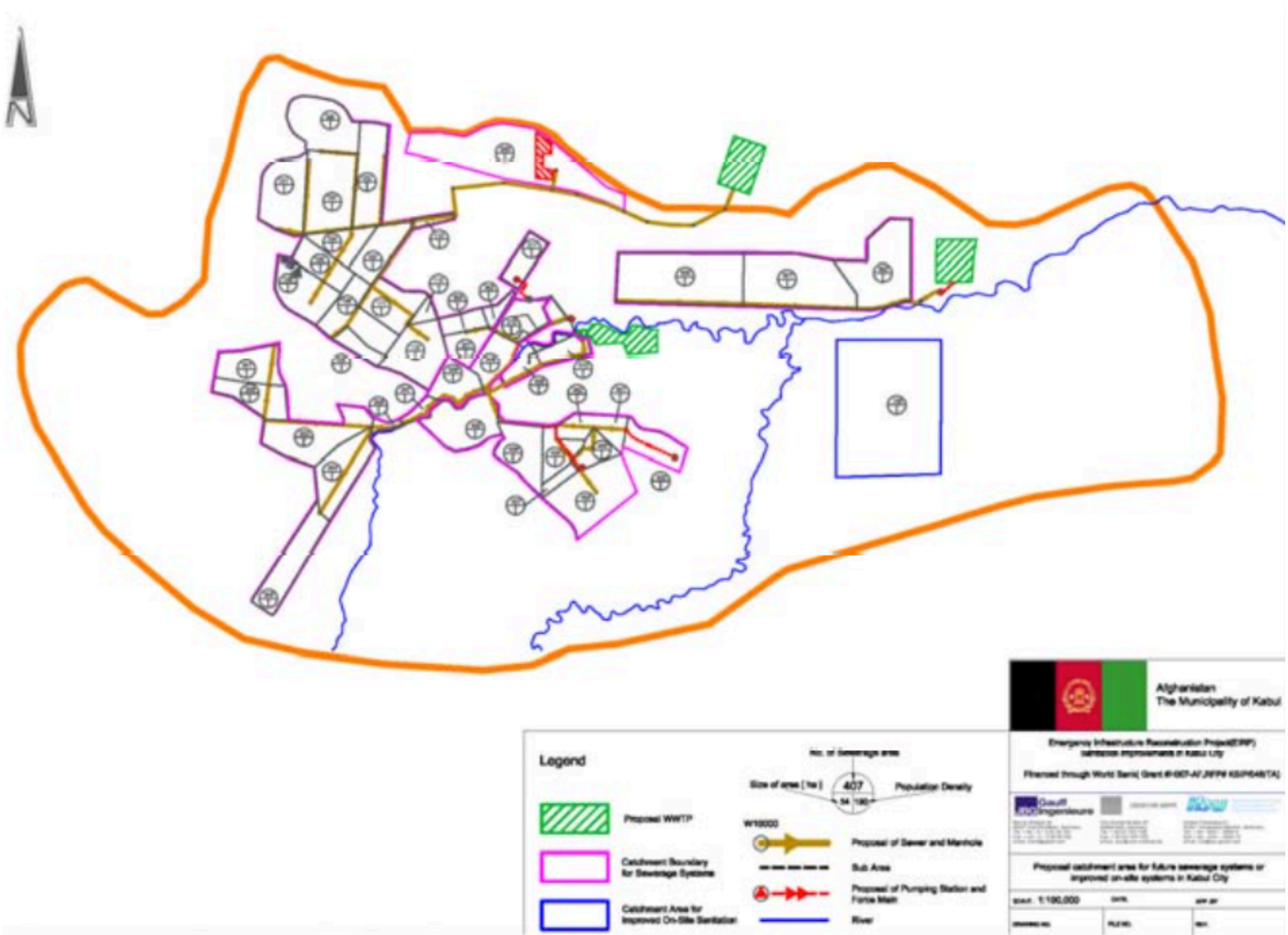
Traditional bathrooms users	1.844.282 people
Septic wells users	829.195 people
Canalization system users	1.383.000people (2008)

Makrorayan’s refinery needs to be renewed quickly because it’s the only one in Kabul city and around 700.000 people from Makrorayan 1,2, 3 and 4 use it. It needs to be developed and supported by new equipment in future as well.

According to the World Bank sanitation and canalization program in Kabul, the second refinery should be built in the 18th district of Kabul. 685.000 people will benefit of this service. This refinery will be in 150-hector area and supported with cheap equipment and this is possible to develop in the future.

The 3rd refinery will take place in the east side of Pole-Charkhi in the 100-hector area. Pole-Charkhi is the industrial zone of Kabul. Numbers of construction companies, oil and gas, workshops and so forth are located in Pole-Charkhi area. This refinery will be in the service of 100,000 people (Soufizada, 2008).

Figure 17. Proposed Catchment Area for Future Sewerage Systems or improved on-site systems in Kabul City. Koch 2007



3.6 Wastewater collection management in Kabul

KfW (Kreditanstalt fr iederaufbau) is a major funder in water supply programs in Kabul additionally the World Bank is also one of the biggest funders of the Kabul sanitation and canalization system, in all of these programs, local and international experts work together. Donors work in cooperation with government and departments who are enrolled in the particular program. In the water programs in Kabul, donors usually work with Kabul Municipality, Ministry of Energy and Water and the Ministry of Urban Development (Soufizada, 2008).

Management of sanitation and extraction of sewages and wastewater in Kabul includes the following three parts:

1. Solid waste management which includes domestic and municipal waste as well as building and construction waste, it may also include harmful industrial waste and infectious hospital waste
2. On site sanitation facilities that includes waste matter, disposal systems and soak pits
3. Network systems that includes storm-water, drainage channels and sewerage

Donors such as the World Bank, GIZ, KfW, USAID, Asia Develop Bank (ADB) funded the above-mentioned points (Soufizada, 2008).

In 2007 Kabul had only one refinery network system that was located in Macroyan area. The Municipality of Kabul covered a project area with an estimated population of 2.5 – 3.0, million in this area. One of the Project's main objectives was the preparation of a sewerage master plan that developed various alternatives and examined their advantages and disadvantages in order to find the most beneficial option (Koch, 2007). Kabul municipality conducted a survey to find out the situation of the network and refinery in the four Macroyan areas; finally they announced that the process had three steps:

- First step was to analyze and mechanic separation which worked well

- Second step was a biological and chemical analysis, this step had not been working because of poor machinery and equipment's also the damaged network system
- Third step was disinfection and it did not work. All wastes went to the Kabul river after the third step but with out disinfection (Soufizada, 2008) (Figure 18)

Figure 18. Kabul River's pollution. GIZ, 2013

After this survey, Kabul Municipality decided to make a plan for canalization facilities and achieve to the goals in 2030.

This plan will be based on the canalization master plan of 1974 and will apply to an area of 41860 hectare.

Kabul Municipality has decided to make its plan for collecting the wastewater in the future. For collecting the water in general, Kabul needs two separate systems, first one for sewages and polluted wastewater and second for rainwater collection. Rainwater canals can be emptied in the open lands to recharge the underground water sources (Soufizada, 2008).

3.6.1 Activities and Achievements

In 2013 GIZ conducted a project throughout the country in terms of wastewater management and the training of people and local employees and partners. Local people and a number of famers were trained in the handling of residues in the wastewater plants. The experience gained from building the pilot plants was also fed back into the design of wastewater management policy (2013).

Another major achievement has been the preparation of a four-part program by KfW for the extension of the services and the finance of the designed packages, as reported by USAID (2013).

Additionally, a short-term program, jointly funded by KfW and the World Bank‘s Afghanistan Reconstruction Trust Fund (ARTF) has expanded the existing Kabul water setup. Another program known as the Medium Term Program Phase 1 (MTP-1) consists of three sections; as per a USAID report “This will be for an expansion of the Logar II well field, a pumping facility, and a water storage reservoir. This project will take 28 months to construct and will cost approximately 20 million dollars” (2013, no pagination).

Furthermore, in 2013, KfW and the French Development Agency had planned to jointly finance the construction of two additional sections, consisting of a transmission line, neighborhood pipe network, and household connections; currently the project is in progress (USAID, 2013).

3.6.2 Projected Accomplishments

USAID, one of the largest donor agencies in the country has laid out the program to finance and complete the following objectives by the end of 2030:

- Increase piped water coverage to a total of at least 1.4 million people (or about 29 percent of the Kabul population of 4.5 million in 2010);
- Increase production from 60,000 to 120,000 cubic meters m^3)/day, (approximately 44 million m3/annually);
- Increase reservoir capacity from 32,700 to 73,000 m3;
- Increase the distribution network from approximately 500 to 1,300

kilometers; and,

- Increase house connections from 30,000 to 90,000. (USAID, 2013 no pagination).

While International donors provide finances and commercial support to the water supply system they have also been active in providing advisory services such as training and advising local employees and the people working on the projects in Afghanistan. For instance, GIZ have aided the ministries responsible for the water supply to take important policy decisions regarding the issue. Additionally, since 2008 GIZ has also been advising and training the staff of the Afghan Urban Water Supply and Sewerage Corporation (AUWSSC) in various areas. GIZ reports that between 2011 and 2013 nearly 2,000 people were trained through the organizations courses in the water sector. Another factor that can be considered as an achievement in this regard is GIZ's support of government ministries involvement in raising water standards. GIZ have given support to the Ministry of Urban Development Affairs (MUDA) initiative to partner with the World Health Organization (WHO), Ministry of Health and the Afghan National Standards Authority to review the standards of drinking water.

Moreover, GIZ has backed the MUDA and AUWSSC in developing national policies and strategies for urban wastewater management; and with GIZ's partnering with KfW Development Bank the support for a functioning infrastructure has been useful. Furthermore, a wastewater management policy has been credited for helping to resolve Kabul's wastewater issues (GIZ, 2013).

Table 1. Projects of international donors and the government of Afghanistan in the field of water in Kabul

Organization	Type of problem to tackle	Type of solution suggested	Period of activity	Donor	Financial volume	Achievements	Citation
AUWSSC	Water supply	Piping water supply	Till 2013	USAID	No data available	Clean drinking water for 20% of population	USAID, 2013
GIZ	Water supply	IAP Immediate Assistance Program	2005- 2011	KfW	30 million Euros	Clean drinking water for 2 million people	TSP, 2006
GIZ	Water supply	KUWS Kabul Urban water supply	2012-2013	KfW	No data available	Clean drinking water for 1.1 million people	GIZ, 2013
GIZ	Water supply	KUWS Kabul Urban water supply	2013- 2015 (Target year)	KfW	150 million Euros	extending the current water supply system for 3.5 million people (including previous achievements)	GIZ, 2013
USAID	Water supply	New equipment and renewing of pipe water network	2010-2030	USAID	No data available	Piped water coverage for 1.4 Million people by 2010	USAID, 2013
GIZ & AUWSSC	Maintainable operation of the renews and new systems	Transitional Support Program (TSP)	2006- 2009	GIZ	No data available	Transitional Support, technical and management of local employees	GIZ, 2013
USGS & AGS & MEW	Water supply	Research and database	2005-2010	USAID	No data available	New database, training and providing equipment, pumping facilities	USAID, 2010
JICA	Urban development	Civil services	2007	JICA	No data available	New database and research	JICA, 2006
World Bank	Urban Development	Helping inhabitants in civil services	Jan- Apr 2005	World Bank	No data available	Research	World Bank, 2005
DACAAR	Water sources at risk	Artificial recharge	2013	DACAAR	No data available	Artificial recharge can be an excellent solution	DACAA, 2013
Kabul Municipality	Wastewater management	Master plan of sewerage and drainage	2007- 2030	World Bank	No data available	4,056,588 users by 2030	Koch, 2007
GIZ	Wastewater management	Training of people	2013	KfW	No data available	Local people and a number of famers were trained	GIZ, 2013

3.6.3 Good areas for liquid sewages refineries

Kabul municipality has decided to make refineries in some parts of the city and use the water after refining in the agricultural lands. Based on the Master Plan the refineries should take place in districts 5 and 18 and the east side of Pole Charkhi.

According to the report of Ministry of Agriculture in 2005, Kabul has 56400-hectare agricultural land. Wastewaters can be used for agriculture after the refining in the agricultural areas. Even now, farmers buy the liquid sewages of Makroian refinery and use it in the agricultural lands (Soufizada, 2008).

3.7 Natural groundwater recharge

The principle source of groundwater replenishment is rain and the melting of snow. Groundwater recharge is an important process for sustainable groundwater management. The volume of water that may be extracted from an aquifer without causing depletion is primarily dependent upon the ground water recharge, this volume must be equal to the volume that is recharged (Kumar and Seethapathi, n.d.).

"Moisture movement in the unsaturated zone is controlled by suction pressure, moisture content and hydraulic conductivity relationships. The amount of moisture that will eventually reach the water table is defined as natural ground water recharge. The amount of this recharge depends upon the rate and duration of rainfall, the subsequent conditions at the upper boundary, the antecedent soil moisture conditions, the water table depth and the soil type" (Kumar and Seethapathi, n.d. p.1).

The issue with natural groundwater recharge is that it can be obstructed through many ways such as human activities, development climate and so forth. In the case of Afghanistan, such an obstruction has taken place due to heavy fighting for decades, increase in population and drought. Recharge happens both naturally (through the water cycle) and through anthropogenic processes

(artificial groundwater recharge), where rainwater and or reclaimed water is sent to the subsurface (Noori, 2014).

3.8 Why Artificial recharge?

Briefly stated artificial recharge to groundwater aims at the augmentation of groundwater by transforming the natural use of surface water through the utilization of various techniques by human activities resulting in an increase in the amount of groundwater available (wrmin.nic.ir, 2000).

Based on DACAAR's research between 2003 to 2013, Kabul's underground water's level has decreased 7.5 meters (DAACAR, 2013) (Figure 19).

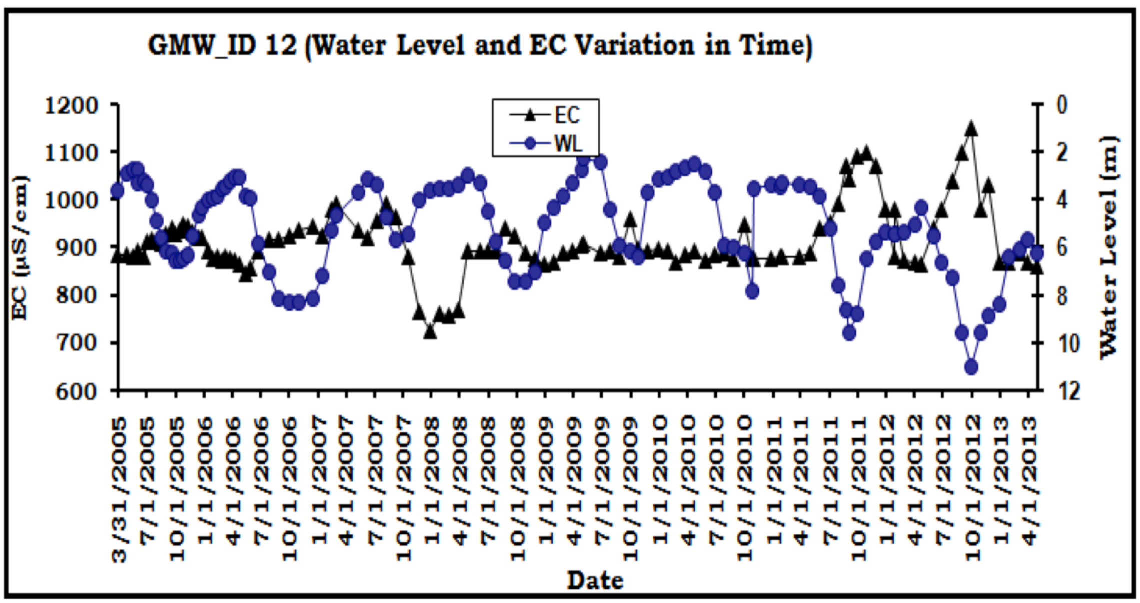


Figure 19. Kabul underground water's level fluctuation between 2003 and 2013, (DACAAR, 2013)

Kabul had many lakes, wetlands and prairies like Kole Aabchakan, Chamane Babrak, Chamane Dehboori, Chamane Mirwaez, Chamane Khajarawash, Chamane Bagrami. These lakes and prairies were the natural groundwater recharge's sides. Because of the decrease of the groundwater and underground water levels in the past years, these lakes and prairies are not active anymore.

The only active lake is Kole Hashmat khan and the government takes care of it (Noori, 2014).

Currently in many parts of Kabul city, the natural sides of ground water and underground water recharges don't work, because of the concrete and asphalt roads and new buildings have taken over locations of the lakes and prairies (Noori, 2014).

In the two first chapters, we analyzed the situation and problems of Kabul's population in terms of water supply and sanitation and the causes of water shortage in the Kabul Basin.

In this chapter we will discuss the accessibility of artificial recharge of ground water in Kabul, collecting of water from the mountains and roads and finally putting in the drainages and canals then in the soak and dug wells.

3.9 Artificial recharge of groundwater

The increased demand for water has increased awareness towards the use of artificial recharge to increase or change the level of ground water supplies. Groundwater recharge, deep drainage or deep percolation is a hydrologic process where water moves downward from surface water to groundwater. This process usually occurs in the vadose zone below plant roots and is often expressed as a flux to the water table surface (Noori, 2015).

"Artificial recharge is a process by which excess surface-water is directed into the ground – either by spreading on the surface, by using recharge wells, or by altering natural conditions to increase infiltration – to replenish an aquifer. It refers to the movement of water through man-made systems from the surface of the earth to underground water-bearing strata where it may be stored for future use. Artificial recharge (sometimes called planned recharge) is a way to store water underground in times of water surplus to meet demand in times of shortage" (Bhattacharya, 2010).

3.10 Techniques of artificial recharge to groundwater

The Indian Ministry of Water resources categorizes the methods of artificial recharge as the following: (Table 2)

3.10.1 Surface (spreading) methods surface

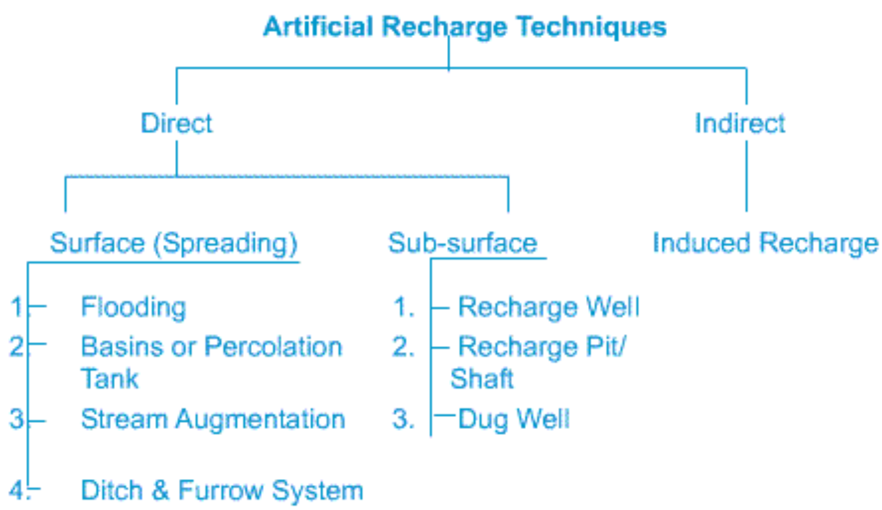


Table 2. Artificial recharge techniques, Central Groundwater Board, 2013

The methods stated in Table 4 are suitable where a large area of the basin is accessible and the aquifers are unconfined to resistant layers on top of them. Water quality will affect the rate of infiltration also a sandier the top soil equals to a higher the rate of infiltration; lands without guiles or ridges are most well suited for techniques of surface water spreading (cdwg, n.d.).

3.10.1.1 Flooding

Flooding is a very useful technique of artificial recharge to groundwater, particularly for topography that is some-what flat where water must be spread over thinly and require a distribution channel (cdwg.gov, n.d.).

3.10.1.2 Basin & Percolation Tanks

In this method water is controlled through a succession of basins or filtration tank while an efficient use of space is altered to suit the accessible space and conditions of the topography. The viability of this method is more in tune with hard rock formation; this method is very common (cdwg.gov, n.d.).

3.10.1.3 Stream Augmentation

When total water supply existing in a stream or river exceeds the rate of penetration, the excess is lost as run off. This waste from natural streams or rives are one of the most important sources of the groundwater basin. The run off can be arrested through check bunds or a widening of the vapor beds, this creates a larger area that is available to spread the river water thus increasing infiltration. In order to facilitate recharge in a short span of time, the site must have sufficient thickness of porous bed or a weathered formation (cdwg.gov, n.d.).

3.10.1.4 Ditch & Furrow system

Ditch and furrow system deliver maximum water contact for recharge water source stream or canal in areas with irregular topography. The technique requires less soil preparation and is less sensitive silting. How it works is through a system of shallow, flat bottomed and closely spaced ditched, furrows are used to carry the water from the source, imitating a stream (wrmin.nic.in, 2000).

3.10.2 Sub- Surface method

In this method the structure lies below the surface and recharges ground water directly (cgwb.gov, n.d). The significant structures regularly used are recharge wells, recharge shaft and dug wells; these structures are discussed below.

3.10.2.1 Recharge Well

Recharge wells are classified as two types (1) Injection well and (2) Recharge well,

1) The injection well is the sort of well where water is pumped in for recharge and are similar to tube well. Injection wells are fitting for augmenting and changing the groundwater storage of aquifers that are deeper by pumping in surface water that has been treated. This technique is also suitable to recharge both single and multiple aquifers. The downside of this recharge method is that it is costlier to do so since it requires specialized techniques

of tube well construction and maintenance to protect the well from being clogged.

2) The recharge well is where water flows under gravity, and this method is good for shallow water table aquifers up to 50 meters and are cost effective since recharge takes place only under gravity flow. The recharge well can be either wet or dry. Wet wells have shown to be more successful since the dry wells have proven to be more prone to clogging (cgwd. gov, n.d.).

3.10.2.2 Pits & Shafts

In areas where impenetrable layer is met with a shallow depth the pits and shafts method is the most suitable structure for artificial recharge. While there are risks of choking of the aquifer by air bubbles or water if the technique is not done right, however Pits and shafts hold the advantage of being cost effective and recharging the aquifer directly. Also, they do not require large pieces of land and there is practically no water loss through soil moisture or evaporation, unlike the other methods (cgwd. gov.in, n.d.).

3.10.2.3 Dug wells

In alluvial areas (areas with a deposit of clay, slit, and sand left by flowing water) and hard rock areas, thousands of dug wells have either gone dry or the water levels in the space has significantly deteriorated. These dry dug wells can be put to good use by being used as structures to recharge the ground water reservoir, all surplus water can be transferred to these structures to directly recharge the aquifer. The water of the recharge is guided through a pipe to the bottom of the well to avoid set up of bubbles in the aquifer (cgwb.gov.in, n.d.).

3.10.3 Induced recharge

The induced recharge is functional method where the steam bed is connected to aquifer by a sandy texture formation. This is indirect method of artificial recharge, which includes pumping from the aquifer hydraulically connected with surface

water at rates lower than the water level, thus stimulating the surface water to replenish the ground water (cgwb.gov.in, n.d.).

3.11 Basic Requirements for Artificial Recharge

The basic requirements for artificial recharging groundwater are the availability of source water, which is assessed in terms of rainfall, its frequency, its variation and its number of days (cwdg.gov.in, n.d.).

3.12 Rain water harvesting

The rainwater in urban area can be conserved through Roof Top Rain Water Harvesting Techniques for artificial recharge to ground water. This technique entails connecting the outlet/drop pipe from roof of the building to divert the rainwater to either existing wells/ tube wells / bore well or specially designed structure.

The advantages of Rain Water Harvesting are:

1. Rainwater is bacteriologically pure, free from organic matter and soft in nature.
2.It will help in reducing the flood hazard.
3.To improve the quality of existing ground water through dilution.
4. Rainwater may be joined at place of need and may be utilised at time of need.
5.The structures compulsory for harvesting the rainwater are simple, economical and eco-friendly.

3.13 Artificial recharge to groundwater through dug wells

Recharging existing dug wells using rainfall run-off from the agricultural fields in order to enable an improvement in the affected areas where ground water issues exist. By improving the situation of the ground water through this scheme, the general irrigated agricultural efficiency will improve, which in turn will improve the fluoride-affected areas of ground water and the overall quality of it.

Ground water plays a vital role in a city or country, some of which are in accordance to the survival of people such as food production, clean drinking water supply, drought mitigation and economic development.

One of the most efficient tools for controlling the decline in ground water, increase in ground level water and sustainability of wells is through the artificial recharge of ground water.

A scheme on artificial recharge to ground water through dug wells was prepared, keeping in mind the concerns of the over exploitation of ground water resources, safeguarding sustainable water resource management and assured irrigation facilities in the areas that were affected (Noori, 2008).

In the year 2013, DACAAR started a practical research in Botkhak (Bagrami district) (Figure 20) in the outskirts of Kabul city. Geological Situation of Near Botkhak (Figure 21) shows the actual situation of the side in terms of geology.

Figure 20, Location of Botkhak and artificial recharge area. DACAAR 2014

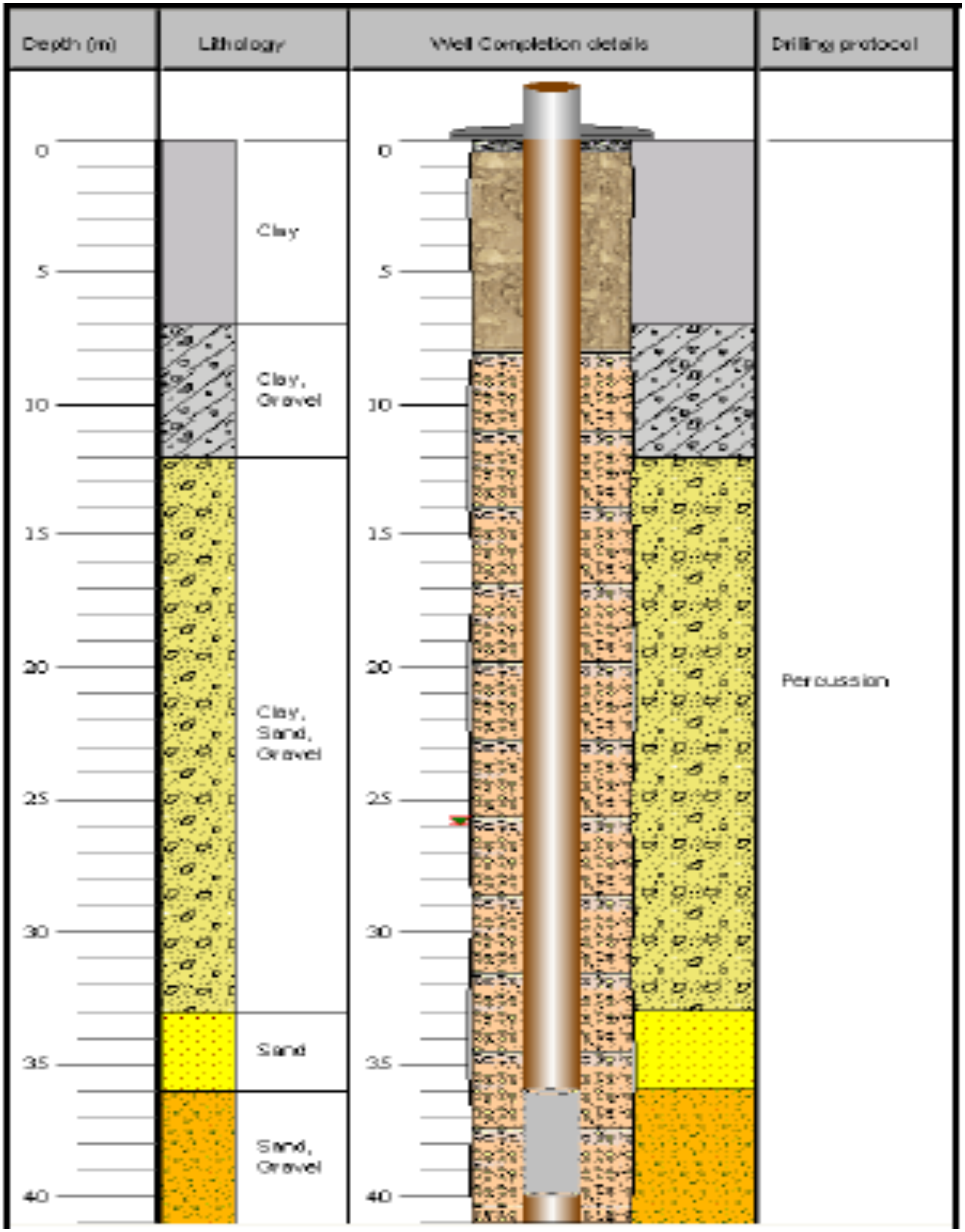


Figure 21. Geological Situation of Near Botkhak. DACAAR 2013

Closed to the area, DACAAR built soak pits and dug wells connected with drainages network to process the artificial recharge's work. (Figure 22)
The wells work like filters, the collected water go by the canals to the building and after it is filtered it falls down to the groundwater bed (Table 3) (Figure 23 & 24).

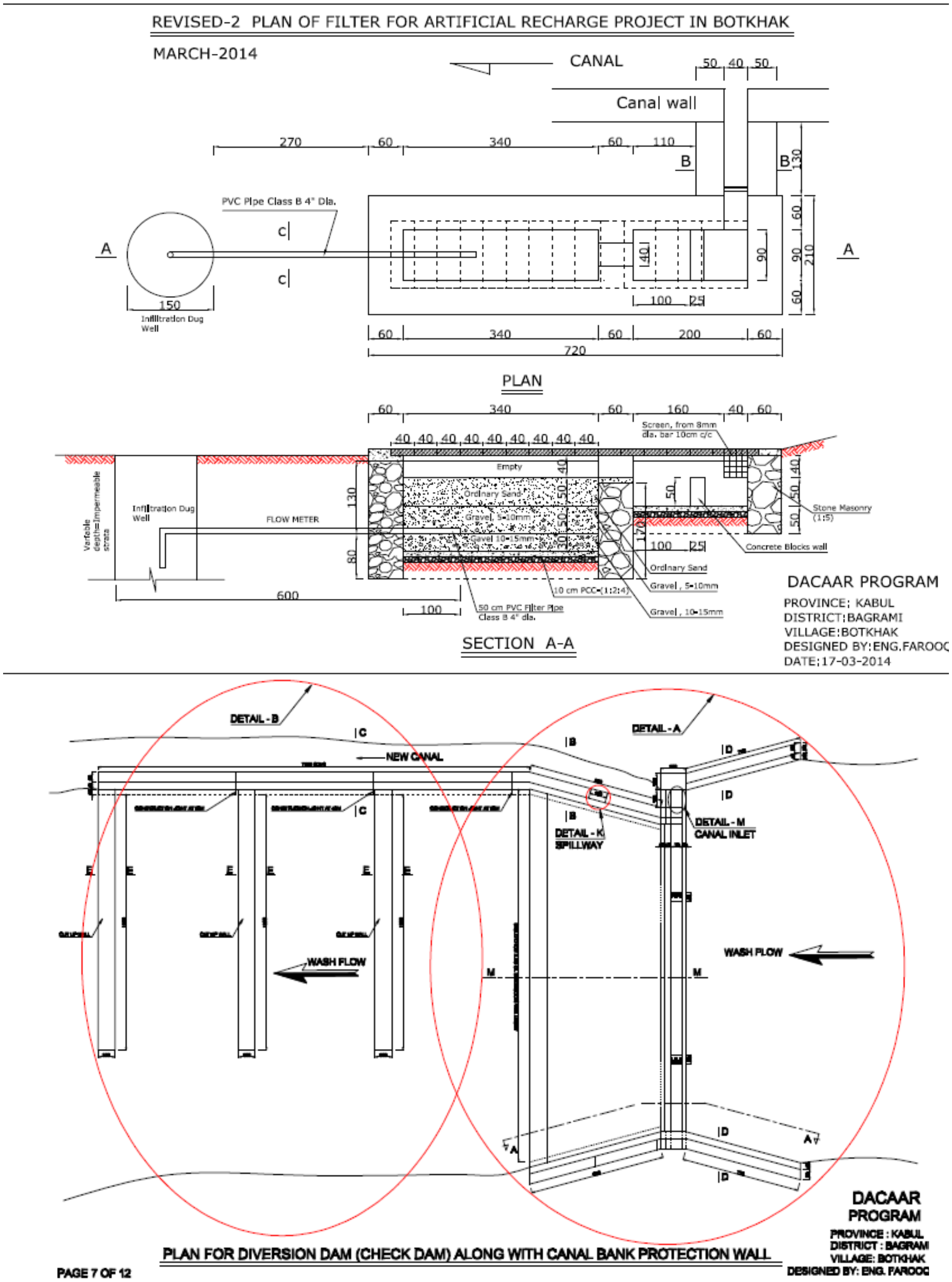


Figure 22. Plan and section of artificial recharge building in Botkhak area of Kabul, DACAAR, 2014

Sn	Description of filtration sand and ingredients in the water filter	Type of Infiltration Rate (cum/sqm/d)
1	Fine sand	0.2-0.4
2	Sand stone	0.3-0.5
3	Medium size sand	1-2
4	Coarse sand	4-6
5	Gravel	10-20

Table 3. Infiltration Rates, DACAAR, 2014

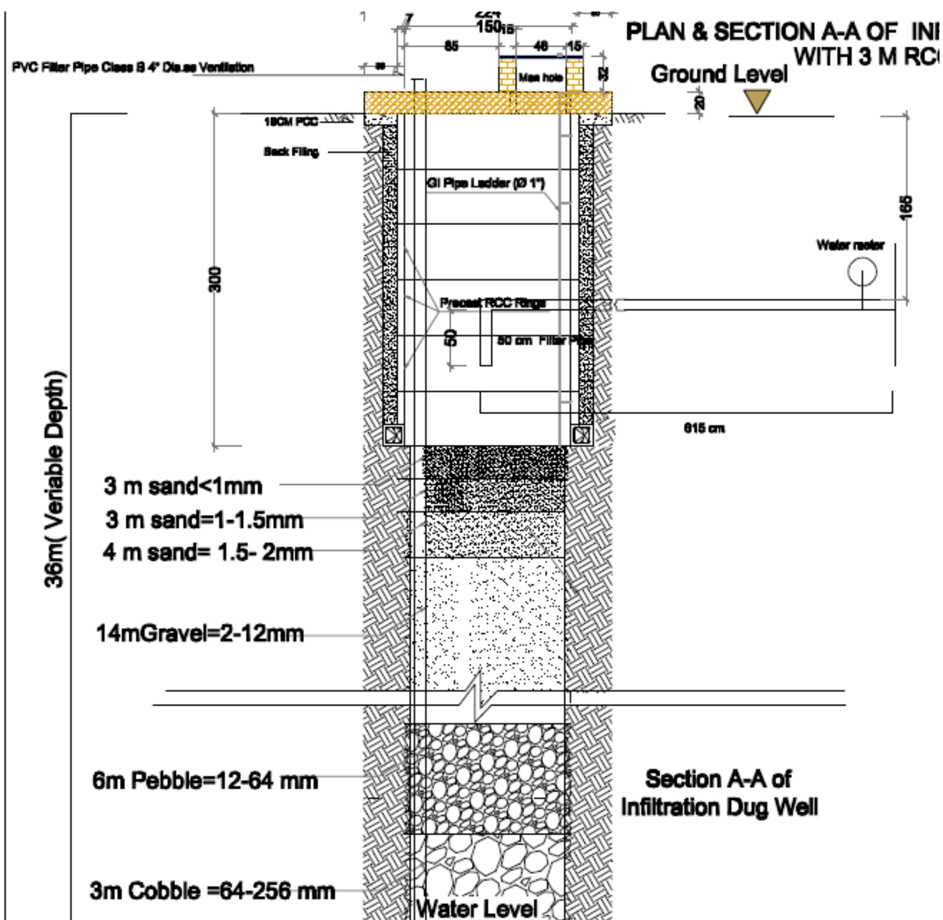


Figure 23. Section of infiltration dug well, DACAAR, 2014

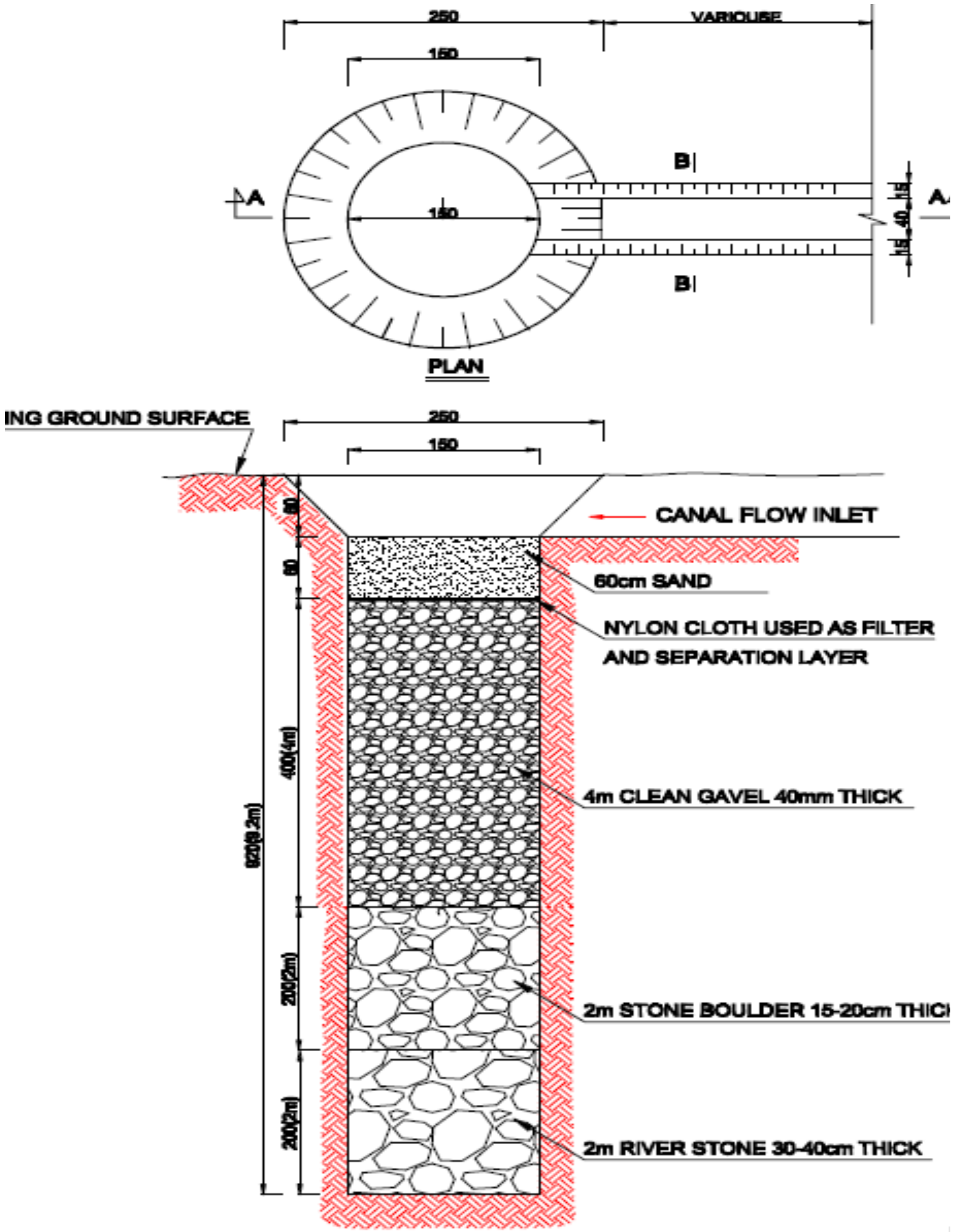


Figure 24. Plan and section of soak pit for artificial recharge. DACAAR 2014

Figure 25. Drainages for artificial recharge. DACAAR, 2014

As we explained in the chapter two, rainwater creates major problems for Kabul inhabitants in terms of transportation and environment. Therefore, rainwater from mountains and hills can be collected and be put to good use in the drainages and also for artificial recharge of groundwater sources, particularly since Kabul is surrounded by mountains and these mountains provide a very useful environment for the process (Figure 25).

This process can also be useful for other parts of Kabul to achieve the following two goals. First, to collect rainwater and make facilities for Kabul inhabitants and second, to use this water to recharge the groundwater sources. In five months, the level of ground water increased 80 cm and it was an excellent achievement and success. (Figure 26)

DACAAR has proposed this solution for Tangi No-3 in Kabul. (Figure 27)

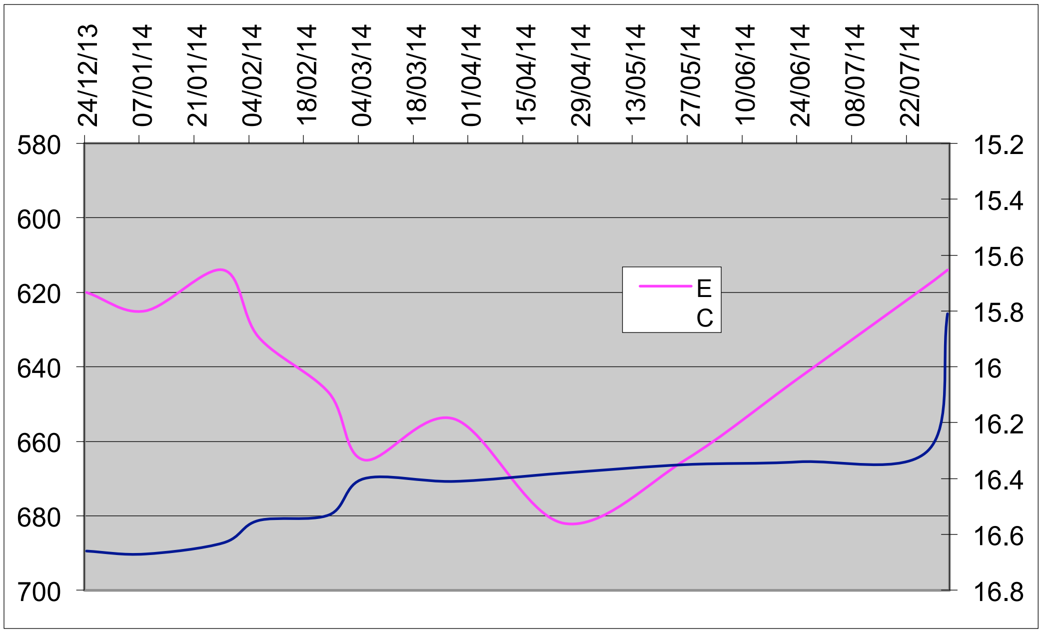


Figure 26. Groundwater level's Increase after artificial recharge in Botkhak Kabul, DACAAR, 2014

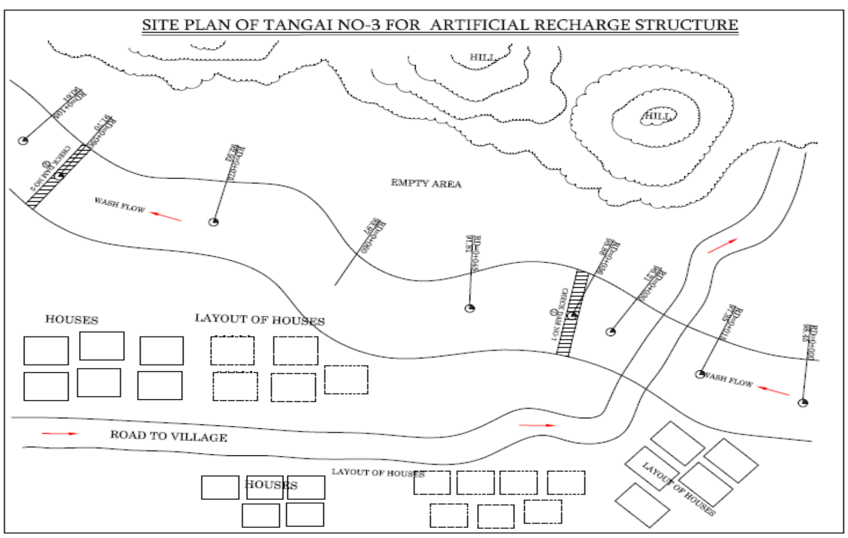


Figure 27. Site plan of Tangi No-3 for Artificial recharge structure. DACAAR, 2014

In order apply this process, the following conditions and information is important to have:

- Groundwater monitoring records

- National level rainfall
- Community awareness about the importance of ground water recharge for the effect
- Recharge component should be integrated with water supply for the sustainability of the project (DACAAR, 2014).

3.14 Roof top rain water harvesting

The consequence of rapid urbanization and the repatriation or thousands of refugees back into Kabul has led to the over exploitation of the available water which is not catered to providing for the current number of people in the city. Open land urbanization activities affect the natural recharge to ground water, causing it to reduce significantly in urban areas. Thereby, with the points mentioned, currently there is a crucial need to increase groundwater storage through the process of roof top rain-water which drains off in to the sewerage of urban settlement and has proven to be very useful and affective. Roof top harvesting is the best option for Kabul city's groundwater issues. (IRD, 2013)

3.14.1 What is roof top harvesting

In Urban or city areas, rooftop water can be collected and conserved for the recharge of ground water. Roof top harvesting requires linking the outlet pipe form the roof of a structure in order to divert the incoming rainfall. This rainfall water is then diverted to existing wells, tube wells, bore wells or any other specially designed structure created for conserving and collecting water. Thereby, rooftop harvesting can be termed as the process of accumulation of water for reuse (IRD, 2013).

3.14.2 Why roof top harvesting is required

Rooftop harvesting holds many advantages, primarily that it collects water which can later be used for drinking or even other functions, such as irrigation by providing an independent supply, in the case of Kabul, rainwater harvesting is required for the following reasons:

- With a increasing population, the process of roof top harvesting or rainwater collection can the meet ever increasing demand for water in Kabul city
- To reduce the runoff, which is responsible for choking the storm drains
- To avoid the flooding of roads, which is a common scene in Kabul city
- To boost ground water
- To reduce the ground water pollution which is also a major problem and the cause of many sicknesses to the people of Kabul
- To improve the lacking quality of ground water in Kabul
- To provide water in times of drought; as mentioned before, Kabul has faced major droughts in the past
- To reduce the dependence on wells
- Finally, the process is needed to reduce the soil erosion (IRD, 2013)

3.14.3 What are the advantages of roof top harvesting

Roof top harvesting or rainwater collection has proven to be effective and advantageous due to the following reasons:

- It has proven to be an ideal solution where there is a lack of ground water and surface water supply, or if the water resources are minor which can be very useful for Kabul city due to its lacking of ground water and surface water supply.
- Rainwater collection is also useful for utilizing the rainfall runoff going to sewers or storm drains.
  This process is also bacteriologically pure and free from organic matter.
- It can also immensely help the reduction of flood hazards, Kabul city faces numerous incidents of flooding during rainy seasons, therefore rainwater collection can be useful in this regard.
- It also improves the quality of existing groundwater through the process of dilution.
- Bacterial and other impurities resulting from sewage, waste-water can also

be removed through this process; as mentioned before Kabul's water contain much dangerous bacteria that affects the health of its society, thereby this factor is crucial.

- The process can also be harnessed at a place, likewise it can be utilized at a time of need- particularly since because of the unpredictable climate changes can affect rainwater production in Kabul.
- Finally, the structures required for harvesting the rainwater are simple, economical and eco-friendly. While Afghanistan's government has many other priorities, this factor can prove beneficial in helping the government achieve its goal in. (IRD, 2013)

We can also look at the success cases of rainwater harvesting in India, a country that has also struggled with providing clean water to its inhabitants but has seen great success through this process.

"A survey conducted by CSE of several villages facing drought in Rajasthan, Gujarat and western Madhya Pradesh in December 2004, found that all those villages that had undertaken rainwater harvesting or watershed development in earlier years had no drinking water problems and even had some water to irrigate their crops" (Goyal and Bhushan, n.d. p.3)

Rajasthan, another city in India has seen immense benefits from the process, in fact some 3000 "Johads" or small earthen dams have been revided across 650 villages. Madhya Pradesh, has seen the annual potential irrigation of 90 percent of its village fields due to rainwater harvesting (Goyal and Bhushan, n.d.).

3.14.4 How is roof-top harvesting done

Roof top rainwater is recharge of ground water reservoir through the following factors:

- Abandoned dug well

- Abandoned/running hand pump
- Recharge pit. Recharge trench
- Gravity head recharge well. Recharge shaft (IRD, 2013)

3.14.5 Design guidelines abandoned dugwell

A dry or unused dug well can be used as a recharge structure for a building or structure that has a roof area of more than a 1000 square meters. The recharge water is guided through a pipe all the way till the bottom of the well, this is done to avoid having an abrasive affect at the bottom. It also helps to avoid the trapping of air bubbles in the aquifer. Likewise, before the usage of a dug well as a recharge structure, its bottom should be cleaned thoroughly and this must be done so regularly by the chlorination of water for controlling bacteriological contamination (IRD, 2013).

3.14.6 Availability of roof-top rainwater harvesting for groundwater recharge

Collecting water from roofs and use for recharging groundwater is one of the proposals, which usually proposes in the case of Kabul. From my point of view, this technique is not very useful in Kabul because of these reasons:

- Kabul's inhabitants are usually poor and they don't have enough money to create this technology in their house
- This project would be very costly for the government to implement
- This project would also be very difficult and costly for the government to control

Based upon these points, this research concludes that artificial recharge by soak pits and dug wells are a useful technique to implement and are possible to do so in many parts of Kabul. Kabul is surrounded by mountains and hills and makes the city can benefit immensely from water collecting in the foothills, particularly since the city faces numerous floods during the winter and spring season.

Chapter 4: Conclusion and personal reflection

4.1 Conclusion and personal reflection

Kabul Basin has limited water sources and in the last decades the rate of rainfall and snow has immensely decreased at the same the level of underground water is deeper in comparison with the previous years. Kabul River is almost dry and extremely polluted. The river's bed is used for garbage and sewages by the surrounding neighborhoods. The only available and clean water source is underground water.

A major problem in the water supply services of Kabul is the management of wastewater and sewages. Kabul does not have a central canalization network to collect and transfer the discharged water and the rainwater. Instead all of the wastewater is absorbed by the ground which results in polluting the groundwater.

Macrorayan area of Kabul is the only area connected with a canalization network and the majority of Kabul's inhabitants continue to use dry toilets which poses as a challenge for urban planners and Kabul's municipality to connect to with a network and to transport the sewages outside of the neighborhoods and communities. Additional, unplanned and illegal areas of the city are another major problem in terms of civil services and development projects. The problems are growing on a daily basis specially since the population has been sharply increasing for the past decade.

International donors in partnership with the government of Afghanistan have created a well researched foundation on the current situation and availability of water; this is perhaps one of the most vital results of their work, particulary since Afghanistan was lacking data in this regard. The information and data collected by international donors and organizations can used for future programs and projects respectfully. At the same time these international organizations have gone beyond just providing research GIZ, DACAAR, JICA, USAID, USGS and the World Bank have also developed projects, brought equipment and machinery, took part in capacity building and training and have helped in creating a better environment for the people of Kabul; all of which that have helped two million people in Kabul to enjoy drinking clean water.

In regards to the solutions, practical research has proven that artificial recharge can be a very good and durable solution to recharge the underground water sources. Through the use of dug wells and soak pits, artifical recharge can recover the underground water sources. Roof–top harvesting has also been proven to be a very good solution to collect rainwater and direct it to a water tank, however, this solution is perhaps too costly for the people of Kabul to attend to.

The government of Afghanistan must take concrete steps to continue improving the water projects of the country. After the years of war and the large repatriation processes created trouble for Kabul’s master plan specially since settlements were created in the green areas of the city, this caused a major disruption in the ares of natural groundwater recharge. Also with development of the country came some downside, the new asphalt and concreate roads with new drainages and canals beside the roads closed the way for natuaral groundwater to recharge in areas that it did so previosuly. Kabul municipality should design and build new roads and drainages that are able to collect rainwater and use it for artificial recharge.

In the last decade Kabul has also seen a huge rise in trees and greenart which has been beneficial to the environment. Kabul municipality should use this to the advantage of the population and create a plan to use the rainwater of roads for the irrigation of these trees and plannts.

Finally, the government of Afghanistan must play an important rold in this entire process by asking the public to back them in these projects; through education programs, media announcemnts and religious institutions the administration in Kabul state the importance of the issues of water and sanitation. The people of Afghanistan must be prepared to have enough water for the future.

Appendixes

Appendix 1: Average of Raining in the Kabul Basin in mm (millimeter) (Noori 2014)

Water year 2008 – 2009																
No	Station	River	Province	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1	Dakah	Kabul	Nangarhar													
2	Pul-i-kama	Konar	Nangarhar	11.69	15.75	9.09	18.2	28.05	25.15	31.68	20.14	8.02	9.6	26.09	4.28	207.74
3	Naw abad	Konar	Konar							0.73	46.74	25.94	15.48	22.2	1.68	
4	Chaghasarai	Pech	Konar	6.71	11.26	15.1	29.65	38.79	50.59	46.31	25.3	13.88	7.02	11.21	18	273.82
5	Asmar	Konar	Konar	3.44	14.76	24.18	54.18	84.21	84.87	85.66	55.49	16.68	28.58			452.05
6	Pul-i-behsod	Kabul	Nangarhar						23.72	39.22	34.65	7.68	7.8	5.85	5.57	124.49
7	Sultanpur	Surkhrud	Nangarhar													
8	Pul-i-qarghai	Laghman	Laghman					4.64	36.86	54.93	22.14	11.9	10.7	16.33	11.08	
9	Pul-i-nalyar	Alinigar	Laghman									11.43	26.27	15.28		
10	Pul-i-islam abad	Alishing	Laghman									4.59	7.02	14.62	8.65	
11	Naghlu	Kabul	Kabul	5.7	6.74	48.32	39.91	40.26	30.91	9.62	4.82	1.93	0.2	0.2	0.2	188.81
12	Bagh-i-lala	Salang	Parwan			32.17	62.72	82.16	84.88	102.26	24.93	0.4	3.1	1.23	2.7	396.55
13	Pul-i-ashawa	Ghorband	Parwan							136.48	30.31	2.11				
14	Stalif	Stalif	Kabul												3.86	
15	Shakardara	Shakardara	Kabul									4.42	1.57	2.71	5.36	
16	Near chahardehy	Parsa	Parwan													
17	Lolenj	Lolenj	Parwan										0.42	0.00	7.19	
18	Bagh-i-omomi	Shutul	Parwan	28.40	7.62	50.38	51.90	131.57	81.39	129.74	24.80	2.90	2.71	3.33	0.50	515.24
19	Tang-i-gulbahar	Panjshir	Parwan	7.43	14.20	9.64	24.50	73.83		6.83	24.80	2.90	2.71	3.33	0.50	170.67
20	Doabi	Dara-i-hazara	Panjshir								27.82	4.69	4.90	1.30	4.32	
21	Keraman	Hazara	Panjshir								8.42	4.00	13.30	7.35	1.95	
22	Omarz	Panjshir	Panjshir								15.82	6.56	0.00	0.40	1.93	
23	Khawak	Panjshir	Panjshir													
24	Near khawak	Paryan	Panjshir													

25	Qala-i-malik	Paghman	Kabul	3.77	11.30	16.06	42.76	45.62	57.44	0.00	0.00	4.75	4.07	1.94	1.81	189.52
26	Below qargha	Paghman	Kabul	5.22	3.41	11.88	38.77	50.47	54.75	83.64	21.90	3.33	4.38	2.18	2.81	282.74
27	Above qargha	Paghman	Kabul													
28	Tang-i-saydan	Maidan	Kabul													
29	Pul-i-surkh	Maidan	Wardak							7.14	35.60	20.06	12.33	14.08	22.80	
30	Domandi	Shamal	Khost													
31	Shukhi	Panjshir	Kapisa													
32	Sabay	Hazarnaw	Nangarhar													
33	Chamkani	Khuram	Paktia													
34	Matun	Matun	Khost													
35	Sang-i-naweshta	Logar	Kabul													
36	Tang-i-gharu	Kabul	Kabul													
37	Near domandi	sperah	khost													

Water year 2009 – 2010																
No	Station	River	Province	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1	Dakah	Kabul	Nangarhar	0	17.89	17.07	15.44	34.92	28.33	32.5	32.96	7.91	18.39	27.3	24.98	257.72
2	Pul-i-kama	Konar	Nangarhar	4.14	16.05	1.03		24.62	5.05	5.89	8.1	0.96	62.84	19.41	19.82	167.91
3	Naw abad	Konar	Konar	12.78	27.6							12.70	180.40	45.11	29.69	
4	Chaghasarai	Pech	Konar	5.56	12.68	14.2	26.31	36.91	50.51	54.87	28.01	14.63				
5	Asmar	Konar	Konar	8.2	31.35	15.72	61.47	84.92	103.74	58.96	55.49	16.73	0			436.58
6	Pul-i-behsod	Kabul	Nangarhar	2.56	15.14	14.26	11.3	29.12	26.51	33.02	14.15	3.81	10.74	12.25	10.59	183.45
7	Sultanpur	Surkhrud	Nangarhar													
8	Pul-i-qarghai	Laghman	Laghman	20.26	11.2	2.65	8.5	47.97	5.8	6.5	29.58	10.23	79.51	9.61	17.27	249.08
9	Pul-i-nalyar	Alinigar	Laghman	4.49	9.02	15.68	16.32	30.54								
10	Pul-i-islam abad	Alishing	Laghman	6.3	17.91	13.81	23.09	47.76	35.7	40.13	37.21	12.44	8.47	18.88	13.39	275.09
11	Naghlu	Kabul	Kabul	1.79	9.33	23.25	41.4	42.26	16.1	25.5	8.66	4.21	6.29	1.67	4.02	185.48
12	Bagh-i-lala	Salang	Parwan	5.60	15.62	34.04	54.12	84.32	70.52	96.13	33.42	3.49	5.58	3.26	3.60	409.7
13	Pul-i-ashawa	Ghorband	Parwan	2.50	17.01	45.73	53.42	82.27	74.85	91.75	32.95	4.70	4.77	6.72	1.72	418.39

14	Stalif	Stalif	Kabul	4.82					80.31	98.46	29.92	6.64	5.85	3.55	3.31	
15	Shakardara	Shakardara	Kabul	3.61	21.58	34.04	50.40	82.38	66.12	97.00	39.01	5.41	7.86			
16	Near chahardehy	Parsa	Parwan	9.19	24.50	9.36	8.49	29.00	0.42	99.18	45.61	5.84	0.00	0.40	0.82	232.81
17	Lolenj	Lolenj	Parwan	5.15	22.27	10.06	10.81	54.50	8.20	34.46	43.88	0.63	2.34	13.24	10.36	215.90
18	Bagh-i-omomi	Shutul	Parwan	3.33	22.14	47.02	52.66	87.63	88.30	101.08	30.07	3.49	7.02	3.75		446.49
19	Tang-i-gulbahar	Panjshir	Parwan	7.24	16.68	28.33	52.35	77.28	67.32							
20	Doabi	Dara-i-hazara	Panjshir	2.63	32.55	28.27	31.60	66.84	51.06	41.73	27.19	3.32	7.01	2.21	4.28	298.69
21	Keraman	Hazara	Panjshir	8.61	15.51	27.91	31.92	46.94	54.10	58.47	19.71	3.61	19.99	2.40	3.18	292.35
22	Omarz	Panjshir	Panjshir	6.06	21.91											
23	Khawak	Panjshir	Panjshir													
24	Near khawak	Paryan	Panjshir													
25	Qala-i-malik	Paghman	Kabul	4.65	21.15	16.96	28.31	52.58	40.64	42.90						
26	Below qargha	Paghman	Kabul	2.96	24.08	13.32	38.14	55.12	48.30	28.55	29.84	4.77	6.82	4.22	2.90	259.02
27	Above qargha	Paghman	Kabul													
28	Tang-i-saydan	Maidan	Kabul													
29	Pul-i-surkh	Maidan	Wardak	7.87	30.02	27.58	37.85	68.73	31.16	18.02	59.56	8.60	53.02	52.69	13.12	408.22
30	Domandi	Shamal	Khost													
31	Shukhi	Panjshir	Kapisa													
32	Sabay	Hazarnaw	Nangarhar													
33	Chamkani	Khuram	Paktia													
34	Matun	Matun	Khost													
35	Sang-i-naweshta	Logar	Kabul													
36	Tang-i-gharu	Kabul	Kabul													
37	Near domandi	sperah	khost													

Water year 2010 – 2011																
No	Station	River	Province	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual

1	Dakah	Kabul	Nangarhar	0	0	14.93	15.4	30.21	36.68	33.33	17.7	1.53	7.18	7.06	12.63	176.65
2	Pul-i-kama	Konar	Nangarhar	0	18.66	2.24	0.6	27.91	36.44	29.34	4.97	22.1				142.26
3	Naw abad	Konar	Konar	0	7.9	1	102.23							0.84	40.67	
4	Chaghasarai	Pech	Konar		0	16.08	24.38	38.05	51.16	64.58	19.88		5.62	9.58	14.39	243.72
5	Asmar	Konar	Konar													
6	Pul-i-behsod	Kabul	Nangarhar	0	7.56	14.25	16.45	28.09	37.16	25.64	18.62	6.22	6.95	25.61	16.14	202.69
7	Sultanpur	Surkhrud	Nangarhar													
8	Pul-i-qarghai	Laghman	Laghman	0	12.34	2.04	52.48	35.68	47	32.71	2.17	0.21	0	6.28	8.45	199.36
9	Pul-i-nalyar	Alinigar	Laghman													
10	Pul-i-islam abad	Alishing	Laghman	0	7.64	0	21.93	47.94	35.72	54.02	13.84	0	5.36	5.35	10.04	201.84
11	Naghlu	Kabul	Kabul	0	6.24	0	36.3	45.97	33.7	27.67	3.55	4.7	6	7.31	1.2	172.64
12	Bagh-i-lala	Salang	Parwan	0.00	12.40	0.00	51.90	88.01	88.04	98.13	24.25	1.16	0.30	0.90	5.49	370.58
13	Pul-i-ashawa	Ghorband	Parwan	4.51	5.89	0.55	42.60	72.55	72.17	47.53	18.96	0.67	0.00	0.00	4.01	269.44
14	Stalif	Stalif	Kabul	5.08	23.39				96.89	89.20	21.42	1.10	5.54	12.41	8.88	
15	Shakardara	Shakardara	Kabul													
16	Near chahardehy	Parsa	Parwan													
17	Lolenj	Lolenj	Parwan	0.00	2.52											
18	Bagh-i-omomi	Shutul	Parwan	7.45	12.60	0.10	53.31	99.48	92.15	93.25	29.14	0.00	0.20	0.60	5.38	393.66
19	Tang-i-gulbahar	Panjshir	Parwan	7.48	12.95	3.88	62.77	96.84	85.65	38.73	165.7					
20	Doabi	Dara-i-hazara	Panjshir	0.10	13.91	18.90	30.60	68.89	52.11	29.12	14.27	0.41	0.00	0.40	7.05	235.76
21	Keraman	Hazara	Panjshir	2.75	13.47	0.00	35.57	48.43	51.85	46.47	10.94	0.31	14.80	1.19	1.16	226.94
22	Omarz	Panjshir	Panjshir	0.94	19.00	0.00	31.90	69.33	55.96	38.79	22.10	0.32	0.00	0.10	6.47	244.91
23	Khawak	Panjshir	Panjshir													
24	Near khawak	Paryan	Panjshir													
25	Qala-i-malik	Paghman	Kabul		0.00	13.60	26.91	58.82	54.73	57.28	20.75	3.24	4.10	9.29	8.48	257.2
26	Below qargha	Paghman	Kabul	0.10	4.42	15.40	18.98	61.89	26.43	34.80	9.40	1.06	1.49	5.69	2.65	182.31
27	Above qargha	Paghman	Kabul													
28	Tang-i-saydan	Maidan	Kabul													
29	Pul-i-surkh	Maidan	Wardak	6.23	4.80	1.74	9.09	108.7	18.87	50.18	13.37	15.49	23.91	35.78	28.51	316.67
30	Domandi	Shamal	Khost													
31	Shukhi	Panjshir	Kapisa													
32	Sabay	Hazarnaw	Nangarhar													

33	Chamkani	Khuram	Paktia													
34	Matun	Matun	Khost													
35	Sang-i-naweshta	Logar	Kabul													
36	Tang-i-gharu	Kabul	Kabul													
37	Near domandi	sperah	khost													

Water year 2011 – 2012																
No	Station	River	Province	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1	Dakah	Kabul	Nangarhar	9.58	27.05	0	17.79	21.87	32.33	32.17	19.4	1.6	0	7.84	9.63	179.26
2	Pul-i-kama	Konar	Nangarhar	49.69	107.57	2.67	14.26	28.86	50.71	49.09	3.26	0	0.88	1.15	8.39	316.55
3	Naw abad	Konar	Konar	54.34	7.41	0	60.76	51.73	33.58							
4	Chaghasarai	Pech	Konar										0	25.87	43.97	
5	Asmar	Konar	Konar		0	0	0	0	7.66	87.41	32.03	22.66	26.63	6.42	21.47	204.28
6	Pul-i-behsod	Kabul	Nangarhar	5.37	15.7	0	12.98	20.29								
7	Sultanpur	Surkhrud	Nangarhar													
8	Pul-i-qarghai	Laghman	Laghman	29.46	3.08	0	27.48	36.39	18.36	48.7	10.38	0	5.33	6.57	16.37	202.12
9	Pul-i-nalyar	Alinigar	Laghman													
10	Pul-i-islam abad	Alishing	Laghman	9.62	6.4	15.97			44.37	56.56	6.25	0.23	77.54	2.08	48.44	267.46
11	Naghlu	Kabul	Kabul	10.12	5.68	23.6	47.37	33.98	33.12	37.03	4.77	0.8	2.78	2	10.84	212.09
12	Bagh-i-lala	Salang	Parwan	73.80	20.25	19.40	62.29	80.65	126.42	61.10	27.07	0.72	2.64	2.70	18.25	495.29
13	Pul-i-ashawa	Ghorband	Parwan	41.36				73.82	89.40	95.75	31.25	2.29	2.45	1.16	4.05	
14	Stalif	Stalif	Kabul	7.73												
15	Shakardara	Shakardara	Kabul													
16	Near chahardehy	Parsa	Parwan													
17	Lolenj	Lolenj	Parwan													
18	Bagh-i-omomi	Shutul	Parwan	22.32	36.06	34.76	87.68	88.26	104.23	1.36	30.53	1.36	0.50	2.70	7.58	417.34
19	Tang-i-gulbahar	Panjshir	Parwan			35.25	0.60	0.30	19.24		44.28			125.91	49.55	

20	Doabi	Dara-i-hazara	Panjshir	13.16	33.27	0.00	35.57	31.85	58.37	38.76	43.03	2.32	0.00	0.11	9.14	265.58
21	Keraman	Hazara	Panjshir	0.00	0.00	0.00				20.38	29.38	2.73	0.00	2.58	42.73	
22	Omarz	Panjshir	Panjshir	43.49	23.71	22.70	35.89	40.09	67.41	45.81	26.30	0.92	0.00	0.76	6.40	313.48
23	Khawak	Panjshir	Panjshir													
24	Near khawak	Paryan	Panjshir													
25	Qala-i-malik	Paghman	Kabul	33.53	38.78	0.00	33.24	52.74	42.13	40.66	20.58	2.16	9.97	15.49	24.37	313.65
26	Below qargha	Paghman	Kabul	4.44	24.99	14.70	32.89	62.79	65.39	44.74	26.16	0.64	3.85	6.62	18.98	306.19
27	Above qargha	Paghman	Kabul													
28	Tang-i-saydan	Maidan	Kabul													
29	Pul-i-surkh	Maidan	Wardak	0.38	1.10	1.82	2.54	3.26	3.98	4.70						
30	Domandi	Shamal	Khost													
31	Shukhi	Panjshir	Kapisa													
32	Sabay	Hazarnaw	Nangarhar													
33	Chamkani	Khuram	Paktia													
34	Matun	Matun	Khost													
35	Sang-i-naweshta	Logar	Kabul													
36	Tang-i-gharu	Kabul	Kabul													
37	Near domandi	sperah	khost													

Water year 2012 – 2013																
No	Station	River	Province	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1	Dakah	Kabul	Nangarhar													
2	Pul-i-kama	Konar	Nangarhar	0.21	4.25	20.42	1.82	114.39	95.92	12.9	4.21	1.91	21.07	12.32	0	289.42
3	Naw abad	Konar	Konar	3.74	10.68	87.25	13.56	66.11	44.21	56.40		7.48	9.69	28.84	0.05	328.01
4	Chaghasarai	Pech	Konar	13.82	10.09	58.37	15.91	84.74	57.71	40.43	12.83	50.06	86.99	36.04	0.08	578.57

5	Asmar	Konar	Konar	8.89	0.62	59.4	14.88	142.18	134.72	31.88	12.83	50.06	86.99	36.04	0.08	578.57
6	Pul-i-behsod	Kabul	Nangarhar	2.22	4.32	18.3	2.23	113.74	80.54	18.27	1.49	31.11	40.08	10.81	4.26	327.37
7	Sultanpur	Surkhrud	Nangarhar	11.8	4.9	28.7	3.59	131.25	64.7	6.04	3.92	0.54		24.13	0	279.57
8	Pul-i-qarghai	Laghman	Laghman	34.55	2.51	42.11	0	0	0	0	99.76	7.19	14.99	8.44	0.86	210.41
9	Pul-i-nalyar	Alinigar	Laghman													
10	Pul-i-islam abad	Alishing	Laghman	55.97		34.34	7.72	50.44								
11	Naghlu	Kabul	Kabul	1.42	6.81	16.01	11.92	101.76	10.23				15.8	58.32	3.3	225.57
12	Bagh-i-lala	Salang	Parwan	3.73	11.67	74.23	41.42	176.17	121.52	76.78	3.93	8.14	3.70	6.30	2.60	530.19
13	Pul-i-ashawa	Ghorband	Parwan	5.39	25.96	60.46								2.95	0.5	
14	Stalif	Stalif	Kabul	64.95											9.52	
15	Shakardara	Shakardara	Kabul													
16	Near chahardehy	Parsa	Parwan													
17	Lolenj	Lolenj	Parwan													
18	Bagh-i-omomi	Shutul	Parwan	1.37	33.05	75.56	48.12	162.72	104.95	54.84	1.06	6.68	5.20	3.80	1.80	499.15
19	Tang-i-gulbahar	Panjshir	Parwan	42.44	2.22	1.10	0.80	2.00	11.48				60.65	2.93		
20	Doabi	Dara-i-hazara	Panjshir	15.16	10.45	46.41	49.67	0.00	17.20	72.67	19.32	1.85	9.44	18.35	1.85	262.37
21	Keraman	Hazara	Panjshir	0.00	0.00	7.08	13.04	41.22	69.20	70.70	14.45	1.64	0.00	0.00	0.00	217.33
22	Omarz	Panjshir	Panjshir	3.51	7.54	26.14	21.54	56.97	69.38	56.89	9.40	0.82	4.76	0.00	0.00	256.95
23	Khawak	Panjshir	Panjshir	2.01	3.20	18.18	32.96	9.89	70.16	68.12	24.75	11.06	0.00	0.63	0.00	240.96
24	Near khawak	Paryan	Panjshir													
25	Qala-i-malik	Paghman	Kabul	9.99	19.20	69.70	32.49	147.11	71.73	40.96	5.18	17.31	0.00	0.00	13.59	427.26
26	Below qargha	Paghman	Kabul	6.59	7.42	65.03	45.89	134.54	68.45	54.03	5.96	12.82	3.90	11.32	2.23	418.18
27	Above qargha	Paghman	Kabul													
28	Tang-i-saydan	Maidan	Kabul			18.24				39.96	12.71	5.59	0.24	1.67	0.22	
29	Pul-i-surkh	Maidan	Wardak													
30	Domandi	Shamal	Khost				17.48	141.75	2.18	84.94	15.32	25.00	19.32	68.80	0.68	

31	Shukhi	Panjshir	Kapisa			23.27				168.88	1.55	1.43	2.45	8.98	0.84	
32	Sabay	Hazarnaw	Nangarhar						77.88	52.10	4.25					
33	Chamkani	Khuram	Paktia				18.42	168.08	73.24	110.43	43.24	36.54	10.95	103.57	24.34	
34	Matun	Matun	Khost			0.00	4.53	2.76		51.24	21.04	44.89	77.48	145.16	34.88	
35	Sang-i-naweshta	Logar	Kabul													
36	Tang-i-gharu	Kabul	Kabul													
37	Near domandi	sperah	khost										3.59	53.83	0.00	

Appendix 2. Water-quality data for the period July 2004 through July 2007, for the Kabul Basin, Afghanistan Continued (USAID, 2013)

ID	Local name	Date (month/ day/year)	Time (hhmm)	Subbasin or source water area	Water temper- ature (°C)	Delta 2H x1000	Delta 18O x1000	Tritium TU	Tritium Plus Minus	CFC11 (pg/kg)	CFC12 (pg/kg)
2.1	Well 2.1	06-07-06	0945	Eastern Front	20.5	-58.9	-9.7				
6	Karez N6	05-10-06	1140	Eastern Front	16.3	-54	-9.04				
7	Well 7	06-04-06	0945	Eastern Front	12.6	-48.8	-8.78				
8	Well 8	06-07-06	1025	Deh Sabz	17.4	-55	-8.29				
10	Karez 10	05-10-06	1205	Eastern Front		-54.6	-9.23				
13	Well 13	05-16-06	1200	Deh Sabz	20.1	-56.6	-8.98	16.7	0.5	246	185
15	Well 15	05-30-06	1510	Deh Sabz	15.8	-52.4	-8.02				
20	Well 20	06-10-06	0925	Western Front	13.2	-45.8	-8.16				
21	Well 21	06-12-06	0920	Western Front	14	-53.1	-9.01				
22.1	Well 22.1	06-12-06	0945	Shomali	14.1	-47.9	-8.11				
24	Well 24	06-14-06	0950	Shomali	15.5	-50.1	-8.47				
25	Well 25	06-14-06	1015	Shomali	15.8	-52.8	-8.55				
28	Well 28	05-23-06	1300	Shomali	13.7	-52.4	-8.49	15.8	0.5	424	219
33	Well 33	05-23-06	1030	Western Front	16.3	-49.5	-8.43	20.1	0.6	203	142
37	Well 37	05-14-06	1000	Deh Sabz	18.8	-63	-9.69	0.87	0.13	195	134
41	Well 41	05-28-06	0950	Western Front	18.1	-50.2	-8.7				
42	Well 42	05-28-06	0810	Shomali	15.8	-55.8	-9.08	8.29	0.28	309	172
43	Well 43	05-28-06	0925	Western Front	15.2	-52.3	-8.9				
45	Well 45	05-30-06	1220	Western Front	18.2	-56.2	-9.29				
47	Well 47	05-30-06	1345	Shomali	16.1	-53.7	-8.62	8.41	0.28	447	234
52	Well 52	06-10-06	1030	Western Front	13.8	-45.7	-8.15				
54	Well 54	05-21-06	1145	Deh Sabz	18.2	-59.1	-9.03	5.08	0.21	128	77
59.1	Well 59.1	05-10-06	1005	Eastern Front	17.7	-55.2	-9.3	5.25	0.22	245	204
64	Well 64	06-24-06	0830	Central Kabul	16.9	-55.9	-8.87				
65	Well 65	05-25-06	0930	Central Kabul	21.6	-60.7	-9.28	9.0	0.3	195	108
66.1	Spring 66.1	05-10-06	1110	Eastern Front	15.3	-50.5	-8.85	12.7	0.4	322	232
67	Well 67	12-09-06	1300	Western Front	14.5	-56.9	-9.34	11.8	0.4		
67.1	Kheelre Spring	05-23-06	1145	Shomali	16.7	-49.9	-8.24	18.0	0.5	383	248
67.2	Spring 67A	06-17-06	1120	Shomali	18.6	-51.7	-8.53				
68.1	Spring 68	05-21-06	1000	Shomali	14.9	-50.1	-8.38	16.3	0.5	473	225
69.1	Karez 69.1	05-10-06	1030	Eastern Front	18.3	-50	-8.72				
71	Azizi Hotak Tank	06-05-07	0940	Eastern Front	20	-56.5	-9.46	0.41	0.17	220	157
72	Well 72	06-12-07	0900	Shomali	15.2	-50	-8.39	17.4	0.5	600	233
73	9 Pola Qare Bagh	06-17-07	1015	Western Front	16.3	-55	-9.18	8.64	0.27	232	122
74	Well 74	06-19-07	1140	Shomali	15.2	-57.5	-9.17	10.4	0.4	471	279
100	Swedish well 224	06-03-06	1100	Western Front	13.2	-46.8	-8.19				
101	Spring 101	05-13-06	1130	Western Front	11	-45.9	-8.16	11.0	0.3	752	360
104	Well 104	05-13-06	1100	Western Front	14.4	-50.3	-8.46	7.56	0.25	491	251
104	Well 104	12-03-06	1220	Western Front	12.1	-48.3	-8.34	13.1	0.4		
105	Karez 105	05-13-06	1000	Paghman/Upper Kabul	14.7	-41.9	-6.94	11.4	0.3	364	221
107	Well 107	05-15-06	1040	Paghman/Upper Kabul	15.5	-59.8	-9.29	6.78	0.22	191	99.5
112	Well 112	06-03-06	1200	Paghman/Upper Kabul	16.2	-55.3	-8.47				
113	Well 113	05-29-06	0930	Paghman/Upper Kabul	15.4	-56.2	-8.84				
115	Well 115	05-29-06	1015	Paghman/Upper Kabul	19.5	-47.5	-8.43				
116	Well 116	05-29-06	1105	Logar	15.9	-54.7	-8.58				
117	Well 117	05-15-06	1220	Paghman/Upper Kabul	16.6	-53.1	-8.48	15.2	0.5	440	252
124	Well 124	05-27-06	0900	Central Kabul	14.5	-56.1	-8.87				
129	Well 129	05-24-06	1255	Central Kabul	17.6	-55.6	-8.79	15.0	0.5	437	539
133	Well 133	05-27-06	0930	Central Kabul	16.2	-55	-8.52				
135	Well 135	05-17-06	1050	Logar	15.3	-53.9	-8.28	15.90	0.50	396	221
140	Well 140	05-29-06	1220	Logar	15.8	-54.7	-8.18				
143	Well 143	05-29-06	1200	Logar	14.5	-55.3	-8.27				

2.1	06-07-06												
6	05-10-06												
7	06-04-06												
8	06-07-06												
10	05-10-06												
13	05-16-06	29.6	49.9	73.1	45.5								
15	05-30-06												
20	06-10-06												
21	06-12-06												
22.1	06-12-06												
24	06-14-06												
25	06-14-06												
28	05-23-06	55.6	84.8	85.3	84.5								
33	05-23-06	20.3	41.6	57	31.6	16.5	0.559	0.167	24.5	0.0000	45.4	13	186.5
37	05-14-06	32.8	38.8	52.1	49.6								
41	05-28-06												
42	05-28-06	38.6	60.6	65.8	57.6								
43	05-28-06												
45	05-30-06												
47	05-30-06	54.2	87.2	89.3	80.3								
52	06-10-06												
54	05-21-06	16.5	25.9	30.5	25.4	13.8	0.481	1.91	14.7	0.0000	592.6	22.2	230.7
59.1	05-10-06	47.2	49.8	81.1	72.8								
64	06-24-06												
65	05-25-06	21.9	39.8	43.1	34.1								
66.1	05-10-06	41.7	62.1	88.5	60.9								
67	12-09-06												
67.1	05-23-06	48.5	73.9	94.2	70.8								
67.2	06-17-06												
68.1	05-21-06	59.5	91.3	85.7	86.9								
69.1	05-10-06												
71	06-05-07	36.1	50	70.3	63.8	19.3	0.579	0.136	22.1	0.0000			
72	06-12-07	61.9	114	88.5	89.5	15.8	0.542	0.131	23.5	0.0000			
73	06-17-07	28	40.6	42.5	36.9	17.8	0.585	0.152	11.5	0.0000			
74	06-19-07	68.6	83.2	98.2	91.5	16.1	0.576	0.321	38.5	0.0000			
100	06-03-06												
101	05-13-06	67.9	145	137	99.1								
104	05-13-06	62.2	103	103	99.4	14.4	0.489	0.148	22.1	0.0000	59	16	224.2
104	12-03-06												
105	05-13-06	47.9	73.9	87.8	73.9								
107	05-15-06	20.8	39.9	40.5	32.9								
112	06-03-06												
113	05-29-06												
115	05-29-06												
116	05-29-06												
117	05-15-06	57.3	90	101	89								
124	05-27-06												
129	05-24-06	42.2	88.8	214	65.1	16	0.542	0.133	38.6	0.0000	144.3	136.8	210.8
133	05-27-06												
135	05-17-06	53.1	80.5	87.8	81.9								
140	05-29-06												
143	05-29-06												

148	Well 148	06-05-06	1015	Central Kabul	18.1	-55.3	-7.97				
152	Well 152	06-05-06	1000	Central Kabul	16.6	-52.5	-8.24				
153	Well 153	05-20-06	1305	Central Kabul	20	-45.4	-7.34	7.95	0.27	96.3	193
156	Well 156	05-27-06	1000	Central Kabul	15.3	-46.1	-7.18				
157	Well 157	05-27-06	1010	Central Kabul	18	-57.6	-8.56				
162.2	Well 162.2	05-31-06	1020	Central Kabul	16.6	-55.2	-8.58				
163	Well 163	05-31-06	1040	Central Kabul	16.1	-53.3	-8.38				
165	Well 165	05-22-06	1000	Central Kabul	16.2	-59	-9.14	2.81	0.15	160	1630
167	Well 167	06-20-06	0945	Central Kabul	20.4	-62.4	-9.37				
168	Well 168	05-22-06	1040	Central Kabul	18.4	-58	-9.06	7.78	0.28	1560	890
170	Well 170	06-18-06	1150	Central Kabul	17.6	-50.3	-7.75				
172	Well 172	05-22-06	1145	Central Kabul	22.5	-54.6	-8.5	12.3	0.4	222	455
173	Well 173	06-18-06	1050	Central Kabul	16.1	-60.3	-9.17				
180	Spring 180	05-17-06	0945	Central Kabul	18.6	-53.5	-8.6	18.0	0.6	4.91	67.2
181	Chari Sib Spring	05-17-06	1135	Logar	14.8	-55.1	-8.79	12.5	0.4	407	253
182	Well 182	06-02-07	1155	Paghman/Upper Kabul	16	-50.5	-8.48	11.5	0.4	506	246
183	Hootkhel-Nowbahar Pump Station	06-04-07	0905	Central Kabul	18.1	-54.2	-8.62	12.4	0.4	167	8,880
184	Well 184	06-06-07	0920	Paghman/Upper Kabul	15.6	-56.6	-8.96	10.9	0.4	520	1,080
185	Well 185	06-16-07	1050	Central Kabul	20.3	-58.6	-8.97	2.01	0.19	270	161
186	Well 186	06-18-07	0940	Central Kabul	18.5	-62.4	-9.36	0.56	0.10	209	109
187	Hotuk Pump Station	06-20-07	1030	Logar	15.4	-54.6	-8.25	8.5	0.4	265	219
201	Well 201	06-13-06	1045	Logar	14.6	-56.2	-8.41				
202	Well 202	06-13-06	1000	Logar	15.1	-56.8	-8.45				
203	Well 203	05-20-06	1110	Logar	16.2	-56.8	-8.6	12.0	0.4	379	210
204	Well 204	06-13-06	1020	Logar	14.4	-56.4	-8.33				
208	Well 208	05-20-06	0930	Central Kabul	18.3	-56.2	-8.89	12.3	0.4	380	241
210	Well 210	05-31-06	0940	Central Kabul	16.7	-55.1	-8.76				
211	Well 211	06-08-06	0915	Paghman/Upper Kabul	16.1	-56.2	-8.76				
212	Well 212	06-08-06	0950	Paghman/Upper Kabul	15	-55	-8.78				
213	Well 213	05-15-06	1305	Paghman/Upper Kabul	15.1	-54.3	-8.74	14.1	0.4	545	412
214	Well 214	06-11-06	1245	Paghman/Upper Kabul	16.3	-50.6	-8.04				
216	Well 216	06-11-06	1125	Paghman/Upper Kabul	15.4	-53.5	-8.6				
217	Well 217	06-11-06	1100	Paghman/Upper Kabul	17.1	-52.4	-8.43				
218	Well 218	06-20-06	1030	Central Kabul	20.1	-64.5	-9.56				
219	Well 219	06-20-06	1000	Central Kabul	19.1	-63.3	-9.38	2.57	0.17	159	106
220	Well 220	06-20-06	1100	Central Kabul	20.8	-61.9	-9.29				
221	Well 221	12-05-06	1120	Logar	13	-56.1	-8.44	6.77	0.22		
221	Well 221	02-19-07	1120	Logar	13.8			6.80	0.22	224	150
222	Afshar 6B	12-10-06	1220	Paghman/Upper Kabul	12.7	-56.2	-9.04	14.5	0.4		
223	US Embassy CAFE well	02-22-07	1400	Central Kabul	16.3	-59.1	-9.16	6.95	0.25	130	158
301	Istalef River at Istalef	12-04-06	1310	Shomali	5.3	-54.8	-9.44				
301	Istalef River at Istalef	12-18-06	0945	Shomali	4.4	-47.7	-8.38				
301	Istalef River at Istalef	01-02-07	1220	Shomali	4.6	-48.4	-8.42				
301	Istalef River at Istalef	01-16-07	1050	Shomali	4.2	-47.6	-8.49				
301	Istalef River at Istalef	01-30-07	1040	Shomali	7.5	-47.7	-8.39				
301	Istalef River at Istalef	02-13-07	1145	Shomali	7.6	-50.7	-8.75	7.77	0.26	638	326
301	Istalef River at Istalef	02-27-07	1100	Shomali	6.9	-52.3	-8.75				
301	Istalef River at Istalef	03-13-07	1045	Shomali	6	-52	-8.9	10.2	0.4		
301	Istalef River at Istalef	03-27-07	1000	Shomali	11	-52.9	-9.12				
301	Istalef River at Istalef	04-10-07	0845	Shomali	9.4	-51.6	-9.09	10.1	0.4		
301	Istalef River at Istalef	04-24-07	1055	Shomali	12.5	-52.9	-9.16				

148	06-05-06												
152	06-05-06												
153	05-20-06	23.6	19.5	76.3	36.4								
156	05-27-06												
157	05-27-06												
162.2	05-31-06												
163	05-31-06												
165	05-22-06	14.2	32.5	647	21.8	15.7	0.527	0.144	23.5	0.0000	93.2	29.2	236.9
167	06-20-06												
168	05-22-06	36.1	317	352	55.6								
170	06-18-06												
172	05-22-06	25	45	180	38.6								
173	06-18-06												
180	05-17-06	2.43	0.947	25.6	3.55								
181	05-17-06	57.7	78.6	96.2	84.3								
182	06-02-07	60.7	95.9	93	87.3	17.4	0.544	0.138	30	0.0000			
183	06-04-07	27.7	30.7	3260	38.6	18	0.56	0.14	17.9	0.0083			
184	06-06-07	30.3	120	484	54.1	21.1	0.507	0.111	38.1	0.0000			
185	06-16-07	34.4	54.2	64.2	52.8	15.2	0.46	0.125	17.2	0.0000			
186	06-18-07	25.1	51.7	52.2	48.5	18.3	0.485	0.117	7.62	0.0000			
187	06-20-07	50	38.8	65.7	54.3	20	0.615	0.139	32.1	0.0000			
201	06-13-06												
202	06-13-06												
203	05-20-06	49.8	76.8	83	76.7								
204	06-13-06												
208	05-20-06	44	77.2	95.5	67.9								
210	05-31-06												
211	06-08-06												
212	06-08-06												
213	05-15-06	61.2	111	163	94.5								
214	06-11-06												
216	06-11-06												
217	06-11-06												
218	06-20-06												
219	06-20-06	19.8	32.5	42.1	30.6								
220	06-20-06												
221	12-05-06												
221	02-19-07	22.9	44.8	58.5	34.7	15.8	0.538	0.334	22.1	0.0000	1,760	21.9	
222	12-10-06												
223	02-22-07	12.2	26.1	61.8	18.5	16.9	0.548	0.169	23.6	0.0000	695.8	38	
301	12-04-06												
301	12-18-06												
301	01-02-07												
301	01-16-07												
301	01-30-07												
301	02-13-07	89.1	98.4	102	102								
301	02-27-07												
301	03-13-07												
301	03-27-07												
301	04-10-07												
301	04-24-07												

301	Istalef River at Istalef	06-14-07	0920	Shomali	14.7	-52.4	-9.06			1,090	256
301	Istalef River at Istalef	07-15-07	1105	Shomali	17.8	-48.8	-8.52			398	202
302	Panjshir River at Sayad	12-09-06	1155	Shomali	9.5	-61.9	-10.02				
302	Panjshir River at Sayad	12-26-06	1210	Shomali	11.4	-60.1	-9.79				
302	Panjshir River at Sayad	01-09-07	1115	Shomali	9.1	-61.6	-9.92				
302	Panjshir River at Sayad	01-23-07	1125	Shomali	9.4	-62.4	-9.9				
302	Panjshir River at Sayad	02-06-07	1130	Shomali	12.5	-60.9	-9.81	11.2	0.4	505	250
302	Panjshir River at Sayad	02-20-07	1140	Shomali	10.5	-60.7	-9.84				
302	Panjshir River at Sayad	03-06-07	1100	Shomali	12.7	-59.1	-9.74	10.8	0.4		
302	Panjshir River at Sayad	03-20-07	0945	Shomali	8.9	-63.4	-10.25				
302	Panjshir River at Sayad	04-03-07	1210	Shomali	11.2	-62.1	-9.95	9.9	0.4		
302	Panjshir River at Sayad	04-17-07	0855	Shomali	12.3	-59.7	-9.83				
302	Panjshir River at Sayad	06-19-07	1030	Shomali	14.8	-66.5	-10.68			532	270
303	BarikAb River	12-26-06	1030	Shomali	2.3	-63.1	-9.91				
303	BarikAb River	01-09-07	1015	Shomali	0.6	-62.9	-9.73				
303	BarikAb River	01-23-07	1240	Shomali	0.7	-62.4	-9.7				
303	BarikAb River	02-20-07	1020	Shomali	11.1	-53.3	-8.51	8.61	0.29	494	270
303	BarikAb River	03-06-07	1000	Shomali	7.5	-60.2	-9.47				
303	BarikAb River	03-20-07	0830	Shomali	9.4	-50.5	-8.52	8.67	0.29		
303	BarikAb River	04-03-07	1055	Shomali	9.2	-51.3	-8.84				
303	BarikAb River	04-17-07	1000	Shomali	14.8	-55.4	-9.48	6.65	0.24		
321	Logar River	12-05-06	1010	Logar	4.9	-61	-9.44				
321	Logar River	12-19-06	1040	Logar	4.1	-61.6	-9.28				
321	Logar River	01-06-07	0950	Logar	0.5	-61.1	-9.28				
321	Logar River	01-21-07	1050	Logar	0.7	-61.5	-9.24				
321	Logar River	02-07-07	1100	Logar	7.8	-61.2	-9.41	6.52	0.23	623	333
321	Logar River	02-21-07	1055	Logar	6.2	-60.4	-9.25				
321	Logar River	03-07-07	1000	Logar	9.1	-60.2	-9.02	6.7	0.4		
321	Logar River	03-19-07	0955	Logar	9.6	-58.6	-9.14				
321	Logar River	04-04-07	0955	Logar	11.2	-60.2	-9.22	8.0	0.4		
321	Logar River	04-18-07	1010	Logar	16.4	-59.5	-9.27				
321	Logar River	06-20-07	1110	Logar	22.2	-51.7	-7.65			238	162
322	Kabul River at Tang-i-gharu	12-05-06	1320	Central Kabul	6.2	-58	-8.95				
322	Kabul River at Tang-i-gharu	12-25-06	1335	Central Kabul		-60	-9.23				
322	Kabul River at Tang-i-gharu	01-06-07	1225	Central Kabul	0.8	-59.9	-9.12				
322	Kabul River at Tang-i-gharu	01-21-07	1340	Central Kabul	4.2	-58.4	-9.04				
322	Kabul River at Tang-i-gharu	02-07-07	1300	Central Kabul	10	-59.6	-9.11	7.15	0.25	701	319
322	Kabul River at Tang-i-gharu	02-21-07	1340	Central Kabul	7.8	-60.7	-9.24				
322	Kabul River at Tang-i-gharu	03-07-07	1000	Central Kabul	10.9	-57.7	-8.93	8.1	0.4		
322	Kabul River at Tang-i-gharu	03-19-07	1105	Central Kabul	8.8	-55	-8.8				
322	Kabul River at Tang-i-gharu	04-04-07	1200	Central Kabul	11.8			9.2	0.4		
322	Kabul River at Tang-i-gharu	04-18-07	1235	Central Kabul	16.9	-59.3	-9.48				
322	Kabul River at Tang-i-gharu	06-04-07	1115	Central Kabul	22.6	-47.7	-7.71			78.9	178
322	Kabul River at Tang-i-gharu	07-04-07	0955	Central Kabul	22.9	-54.1	-8.27			363	166
323	Paghman River at Paghman	12-10-06	1300	Paghman/Upper Kabul	8.5	-47.2	-8.62				
323	Paghman River at Paghman	12-25-06	1205	Paghman/Upper Kabul	3.7	-49.8	-8.7				
323	Paghman River at Paghman	01-10-07	1220	Paghman/Upper Kabul	4.6	-49.2	-8.58				
323	Paghman River at Paghman	01-25-07	1130	Paghman/Upper Kabul	7.5	-48	-8.6				
323	Paghman River at Paghman	02-10-07	1350	Paghman/Upper Kabul	5.7	-52.9	-9.22	7.15	0.25	689	331
323	Paghman River at Paghman	02-24-07	1245	Paghman/Upper Kabul	6.3	-52.9	-9.04				
323	Paghman River at Paghman	03-10-07	1225	Paghman/Upper Kabul	7.7	-55.1	-9.31	10.2	0.4		
323	Paghman River at Paghman	03-24-07	1215	Paghman/Upper Kabul	12.3	-56.4	-9.4				

301	06-14-07	72.2	245	114	126
301	07-15-07	51	104	103	106
302	12-09-06				
302	12-26-06				
302	01-09-07				
302	01-23-07				
302	02-06-07	64	92.4	90.8	89
302	02-20-07				
302	03-06-07				
302	03-20-07				
302	04-03-07				
302	04-17-07				
302	06-19-07	71.3	114	115	119
303	12-26-06				
303	01-09-07				
303	01-23-07				
303	02-20-07	67	88.6	96.1	91
303	03-06-07				
303	03-20-07				
303	04-03-07				
303	04-17-07				
321	12-05-06	84.5	92.4	100	93.1
321	12-19-06				
321	01-06-07				
321	01-21-07				
321	02-07-07				
321	02-21-07				
321	03-07-07	32.4	76.4	99	83.9
321	03-19-07				
321	04-04-07				
321	04-18-07				
321	06-20-07				
322	12-05-06				
322	12-25-06				
322	01-06-07				
322	01-21-07				
322	02-07-07	82	116	106	101
322	02-21-07				
322	03-07-07				
322	03-19-07				
322	04-04-07				
322	04-18-07				
322	06-04-07	40	0	110	105
322	07-04-07	39.1	120	103	104
323	12-10-06				
323	12-25-06				
323	01-10-07				
323	01-25-07				
323	02-10-07	92.6	100	99	99.4
323	02-24-07				
323	03-10-07				
323	03-24-07				

323	Paghman River at Paghman	04-07-07	1230	Paghman/Upper Kabul	11.8	-55.6	-9.44	9.6	0.4		
323	Paghman River at Paghman	06-02-07	1030	Paghman/Upper Kabul	18	-57.2	-9.58			399	208
323	Paghman River at Paghman	07-02-07	1005	Paghman/Upper Kabul	18	-55.6	-9.38			4.46	51.9
324	Kabul River at Tangi Saedan	12-10-06	1020	Paghman/Upper Kabul	5.5	-54.8	-8.92				
324	Kabul River at Tangi Saedan	12-25-06	1045	Paghman/Upper Kabul	14.7	-56.9	-9.2				
324	Kabul River at Tangi Saedan	01-10-07	0955	Paghman/Upper Kabul	2.7	-55.2	-8.96				
324	Kabul River at Tangi Saedan	01-25-07	1010	Paghman/Upper Kabul	6.3	-54.3	-8.98				
324	Kabul River at Tangi Saedan	02-10-07	1100	Paghman/Upper Kabul	6.9	-58.8	-9.3	10.8	0.3	656	327
324	Kabul River at Tangi Saedan	02-24-07	1130	Paghman/Upper Kabul	6.3	-54.5	-9.01				
324	Kabul River at Tangi Saedan	03-10-07	0900	Paghman/Upper Kabul	6.4	-57.4	-9.21	10.6	0.3		
324	Kabul River at Tangi Saedan	03-24-07	1040	Paghman/Upper Kabul	8.1	-59.3	-9.47				
324	Kabul River at Tangi Saedan	04-07-07	1010	Paghman/Upper Kabul	11.2	-58.8	-9.55	10.8	0.5		
324	Kabul River at Tangi Saedan	04-21-07	1015	Paghman/Upper Kabul	11.4	-59.3	-9.64				
987	Panjshir River at Shukhi	05-11-06	0000	Panjsher		-61.8	-10.13	12.1	0.6		

323	04-07-07				
323	06-02-07	52.3	100	103	103
323	07-02-07	1.59	1.25	28.2	3.53
324	12-10-06				
324	12-25-06				
324	01-10-07				
324	01-25-07				
324	02-10-07	90.2	95.7	97.3	97.4
324	02-24-07				
324	03-10-07				
324	03-24-07				
324	04-07-07				
324	04-21-07				
987	05-11-06				

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