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ASSESSMENT OF GROUNDWATER LEVEL TO IMPROVE WATER RESOURCE IN KABUL CITY, AFGHANISTAN

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***Abstract*— reports have long confirmed that groundwater fluctuation table is lowered by 8 to 25 meters in central Kabul and Paghman basins, compared with 1960. In Kabul, shallow wells were re-excavated or dried out by ground water deducted during 1998-2002 and in the years 2006-2016, the reports show that large number of the hand pomp wells, which were excavated during 1998 to 2013, are dried out. Ground water is the main sources of water in Kabul, which is basically used for daily necessities. Currently, the number of wells is increasing day by day because it is less costly and an easy way to extract water. In places where people living are on agricultural lifestyle, wells are widely used during dry seasons for irrigation, yet no clear data is available on the percentage and terms of usage. In the past, the depth of groundwater table varied from 2-10m, but due to strong extraction, increased population in Kabul, and climate change the water level have been deepening further. Since 2017, water table of Kabul aquifer lays in much greater depth. Water table in the main areas of Kabul city, in Shahr-e-Naw for instance, was 2-3 m in 1965 while the depth increased to 9.5 m in 2005 (BGR-2005, others) and now (2017) it's near 25 m. This study suggests construction and implementation of mud dam as an important measure for water storage and groundwater recharge. The method is the most efficient in addressing the problem of drinking water in Kabul city and region.**

Index Terms— Groundwater, water level, source recharge, Kabul city, shallow well, seasonal rainfall, mud dam.

I. INTRODUCTION

Groundwater is one of Kabul's main water resources, and investing in this unutilized resource can contribute to building a better economy for the country as well as improving people's life style (HDI), and lead to sustainable development. In order to access surface water, majority of Afghans are forced to dig water pits and directly use underground water for their daily use such as drinking, washing, cleaning, and farming. As Danish committee for Aid to Afghan Refugees (DACAAR) affirms, investing on "groundwater is a strategic storage and it is plying the lead role for various purposes such as, domestic, irrigation, industries and environmental security" (2013).

Kabul has a huge and growing population due to massive and continuous rural–urban migrants and returnees, who flew into the city seeking a 'better' life. The newly migrants are remain excluded from the original city plan due to exorbitant living costs and thus have to live outside the "mainstream" community in unplanned pre-urban settlements. As a result, slums develop fast and turn to be a source of concern for the settlements and authorities. Conventional water supply is not a sustainable option for the developing cities and Kabul's case is no exception in that regard. The expanding costs of existing infrastructure, lack of access to safe drinking water, improper water resource management practices, and the drawbacks of conventional supply system make it necessary to take locally appropriate strategies, adopt technology and management system with regard to Kabul's specific context rather than simply imitating the experience of developed countries.

Based on Japan International Cooperation Agency (JICA) survey the city extended in an area of approximately 1023 km2 (2009), and is elevated 1800m above the sea level in average. Due to rapid population growth, uncontrolled birth, and internal migration, there are different numbers for the city's population. It would say that real statistic on the Afghan population, including population of Kabul, is missing.

A. Kabul City Groundwater Basin's

All the main upper Kabul, Lower Kabul, and Dehsabz, basins are located in the area of urban growing land use, Shomali and Logar Basins are located on agricultural field on the north and south of city boundaries.

A survey conducted by USGS-AGS in 2004-2006, JICA in 2011, Ministry of energy and water in 2017, ground water fluctuation in Kabul region represent; during mentioned time water level trends decreases, seasonal water fluctuation from September 2005 to May 2006 rated 1 to 8m, and 5 to 25m of drawdown due to pumping, depth of wells are 4.9 to 160m, range of groundwater is from 1.5 to 68m.

Kabul ground water basin consist of gravel and fractured conglomerate layer by a thickness of 70 m, as an aquifer, which has installed many wells in it as source for water supply. Electromagnetic survey conducted by JICA water study team illustrate that the maximum Neogene layer is about 1000m in depth and water permeability is poorer than quaternary. Total discharge of groundwater in Kabul basin is not clear but ground water is the only resources for fresh water.

Water supply and sewerage sector report shows presently 19*104 M3/day groundwater discharged by its population. The wells represent an easy and only way to get water from the past until today and even in the future. However, in agriculture land, many wells are extracted for irrigation and used in dry season, the discharge amount is unknown. The Lower Kabul river aquifer near the river seems to have highest permeability in the Kabul groundwater basin from the data.

B. Hydrology of Kabul Valley

Statistics show that 27% after subtracting the evaporation and considering the drainage, water waste and loss of water in the city is directly acquired from precipitation, which means that, between 1957 and 1977, the annual 330mm precipitation was expected to flow 90mm water underground (Proctor and Redfern, 1972). In the above statistic, due to lack of consideration of snowmelt and precipitation rate might make one expect a much lower level of water production from this aquifer (BGR-2005).

As Thiele and Bockh (1971) state, Kabul has four main aquifers, which is generally consisting of sandy gravel deposits formed as river terraces. Paghman-Darulaman basin has two aquifers lying along the course of the Paghman River and the upper course of the Kabul River.

Generally, groundwater flows from the west, south-west and North-West through the eastern basin margin. The aquifers are mainly consists of gravel, sand, loess and clay. The thickness generally reaches up to a few meters and the pore spaces of the sands and gravely parts of the aquifers are partially cemented by secondary mineralization process. Locally, the thickness of the aquifer can be up to 80 m and its permeability ranges from 2.3*10-5m/s to 1.3*10-3 m/s. The aquifers' thickness reaches up to 80m and the range of permeability varies from 2.3*10-5 m/s to 1.3*10-3 m/s (Bockh, 1971).

The Kabul aquifer lies along the Kabul River with 10km length and 4km width, which is consist of conglomerates, sandstone, sand, and gravel. With a porosity of 7.5%, overlying loam is very thin in the plain areas, between 2 to 9m, and in the lower zones, the thickness reaches to up to 20m. The lower beds have become more consolidate and more compact with depth. While the lowest conglomerate and sandstone layer has a thickness of 30 m to 65 m, the whole aquifer has a total thickness of 40-80 m (JICA 2009). AGS –USGS water level studies in Kabul basin estimates the depths of water between 5m to 68 m, which corresponded to water level altitude, and expands at a range of 1466-2279 m above the sea level from the top hillside to depth of valleys, Watershed area is located in the high mountain range, with an approximate height of 2250m in the north and 3000m in the south and southeastern parts as snowfall.

It is mentionable that, between 1997 and 2005, approximately 1500 wells with median depth of 22m were installed by DACAAR and other NGOs in Kabul urban areas, yet more than 75% of the wells are reported not to function or got dried up.

The wells' condition show fluctuation along the Kabul River; while the rate is constantly increasing from November through April and May, it lowers from June to September. Groundwater regeneration arises because of water filtration in the river bed and reaches to maximum point when the permeable sands and gravels in the vicinity of the river are flooded. It indicates that the change in water table and discharge of water are connected to the flow of river and surface stream.

The aquifer in the northeastern part of the city was identified as a major gravel bed after observation as it has a length of 11 Km, a width of around 2 km, and a thickness of 30 m. But the east part of the area is contaminated by salt in Aut-khil, which is considered as a big risk for this aquifer. On the other hand, this aquifer is strongly contaminated by sewage in the immediate vicinity of Kabul, where it has poorer water quality (JICA 2009).

Surface infiltration at transition zones, between consolidated and unconsolidated rocks, and ex-filtration along the rivers make the main contribution to the ground water regeneration in the Kabul basin. Infiltration from precipitation accounts as 27% for years 1957-1977, which is 90-100 mm of precipitation, followed directly into the ground water every year. After deducting the real evaporation and losses allowance, the possible average groundwater regeneration for this period would be 10% of precipitation. In all these aquifers, infiltration from river beds is the predominant means of ground water recharge and infiltration from precipitation accounts for only a minor of precipitant. As BGR (the federal institute for geoscience and natural resources) confirms, the effective rainfall of the area is 27 mm/m2/a (2005).

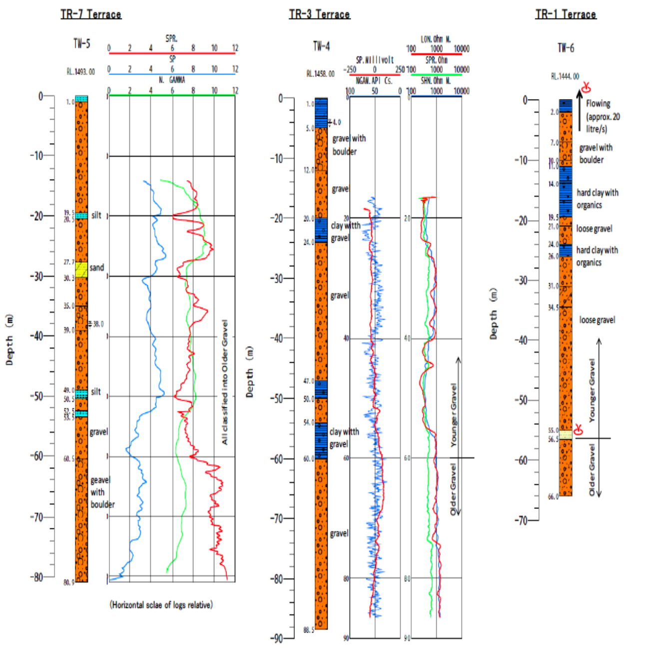

Figure 1, Illustrate the Structure of Aquifer in Kabul Regions (Source: JICA's Reprort 2009)

However, estimation can be made from USGS geological map and using the HENIN-AUBERT drainage index. The estimation allows calculation of the amount of water D in mm that could infiltrate in a specific type of soil. According to mean annual values of rainfall P and temperature T,

$D= \gamma' P^3/(1+ \gamma' P^2)$ where; $\gamma' = \alpha \gamma$ and $\gamma=1/(0.15T-O.13)$

Where α=1 for silts, 2 for sand, and 0.5 for clay, states JPIAS report.

Kabul	Silt soil	Sandy soil	Clay soil
D (mm)	20.5	39.1	10.8

Table 1, Shows the Henin Aubert Drainage Index for Kabul Based on soil Type

The table shows that the soil infelt ability in Kabul is 39.1 mm for sandy and 20.5 mm in silt areas. These two values are used according to the extent of the different types of soils which are identified in the geological map. It considers an ideal infiltration of 100 of effective rainfall 27 mm/m^2/ (BGR, 2005).

II. Domestic water use

Future population rate tends to increase at a rate of 2% natural growth and 1% social growth rate per year. It is expected by 2030; around 7.5 million people will be inhabited in Kabul urban area. It is the time to find the real statistics for the country as no real estimate of population exists so far. The current growth rate is assumed 4% yearly, and the real rate will be a value between provincial and countrywide growth in the future. Based on this, the domestic water consumption may increase in a greater rate due to improving living standards and infrastructure facilities. Domestic water consumption is calculated considering the estimated population and determined rate of per capita water use, 138-liter/ day as normal rate (Omid 2015).

UNESCAP's report in 2007 shows that the current domestic per capita water use is 30 L/C/D in rural and suburban areas whereas it is 60 L/C/D in urban and core urban areas. Yet, the research states that the amount of water use in urban areas is about only half or one third of water use in the nearby countries.

As SagerFeldt affirms, "the abuse resulting from improper operation and use will ultimately lead to irreversible degradation of natural and water resources". He adds that water distribution will be one of the most crucial crises in the future "as the world supply of water becomes limited due to overuse and degradation of quality" (Segerfeldt, 2005).

Many authors have given various definitions to sustainable water demand. In general, sustainable water demand may be described as the most appropriate to the purpose and local conditions (institutional, socio-cultural, economic, and technical) of its intended users. Factors such as consumption, low costs, low maintenance requirements, local availability of installation, operation and maintenance materials, resources and skills as well as adequate institutional capabilities and social acceptance among others determine the appropriateness hence sustainability of a technology.

The challenge presented by lack of access to safe drinking water is not new, but it is huge and growing in Kabul city. Its impact on the dignity and quality of life especially of the urban poor can be debilitating – a gripping cycle of disease, poor health and poverty from which escape seems almost impossible.

A. Water Stress and Security

Other than lack of water resources, lack of water regulation, lack of distribution of water resources, poor water supply institutions, impotent of water management such as having proper updated data on the amount and capacity of water resources, lack of monitoring on the system, frail of control over the direction of water resources and its wide flow into other countries outside Afghanistan, lean of water storage infrastructures such as dames, recharge wells, and water storage saviors are the main reasons behind water scarcity in Afghanistan (DACAAR-2013, and others). We do have numerous rich domestic water resources, but fail to use it on an efficient manner.

DACAAR categorizes the countries with annually less than 1,700 cubic meters of water per capita as Water Stressed and those having less than 1,000 cubic meters of water per year and per capita as Water Scarce. According to the World Business Council for Sustainable Development, "A country's fresh water availability should be at least 1700 on an annual per capita basis for it to be sufficient" (2013).

Urbanization, increasing population of a country, increasing domestic and industrial use of water, and agriculture are the primary reasons, which lead to water scarcity. Climate change, especially in the bared and dry areas of the world, intensifies the problem and increases the possibilities of drought in the countries which already suffer from water shortages. UN-Water affirms that climate change accounts for about 20% the world's water scarcity (2006).

B. Climate Overview

The average annual perception is reported 290-330 [mm], except drought years. Generally rainfall and snowfall accruing in winter mounts and early spring season, the Average monthly precipitation is less in summer mounts 0-5 [mm], maximum Precipitation occurs partially as snow in winter season and rainfall by average 60-80 [mm] in December to April. In the warm summer winds and scorching temperatures are extremely dry. Most precipitation occurs in winter preceded in Kabul Province and neighbors.

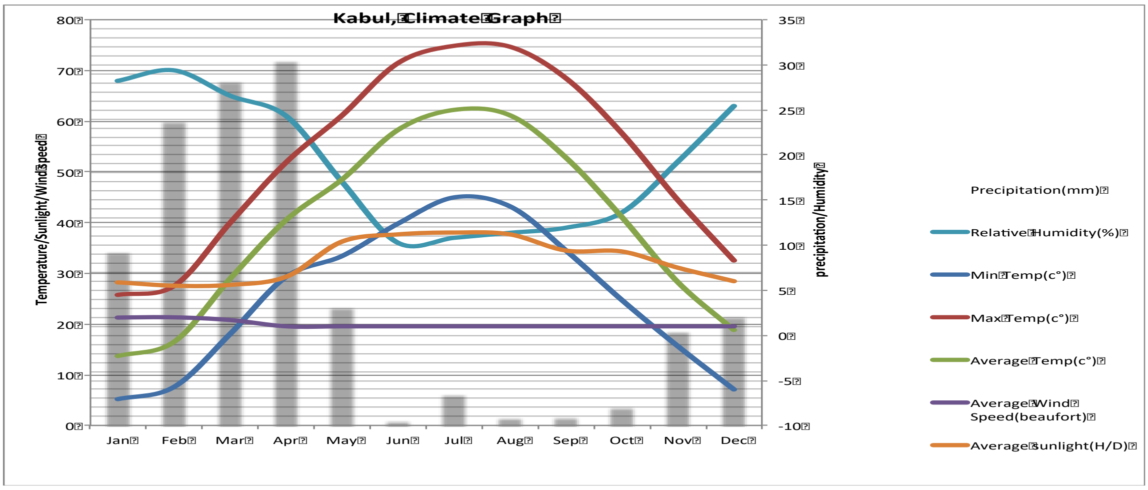

Figure 2, Illustrate the Average Monthly Variation of Air Temperature, Relative Humidity, Wind Speed, Precipitation and sunlight in Kabul

kabul's climate varies as semi-arid. having an average annual precipitation of almost 330 [mm], the city often has hot summers and cold winters (usgs, 2009). the mean monthly precipitation varies by season: from february to april, it is often between 58 -84 [mm], it is the highest throughout the year, from november to january it falls from 21 to 33 [mm], which is moderate, and it reduces from june to october, between 1 to 5 [mm].

III. Water Resources Potential

Ground water recharged by snowmelt and direct rainfall, that could be surplus runoff or storage in aquifer, the inter flow is rapid than the base flow runoff which is regarded to be supplied from groundwater Aquifer through ground water recharge.

The figure (2) portrays the annual precipitation other climate parameters differences at the Kabul. Depending on the climate in different seasons, the annual average precipitation of Kabul city varies around 300 mm, (JICA, 2009).

Surface Water potential

As a result of the huge snowmelt in winter and early spring season, Kabul has numerous flowing rivers; the snowmelt is not only in spring but occurs in different seasons. More often, the abrupt snowmelts and heavy seasonal rainfalls causes flood in spring season while in the late spring and summer. In the summer, the monsoon wind blows into the country from Indian subcontinent, Bengal bay and cause rainstorms. In different parts of the country and different seasons, the areas with larger rivers experience more floods than the areas with smaller canals.

At the Tangi Gharu, as decussating point of south and central flows at the Kabul River Basin, JICA asserts that, "the quasi-natural flow is estimated at 771.1 MCM/year, the runoff rate is calculated at 15.2%, and the total average annual consumption (net water use = supply - return) is estimated at 304.3 MCM/year, which is about 40% of the quasi-natural flow" (2009). Due to the huge water extraction, high water demand and use, and low water production and supply, tow third of the people in the area encounter water shortage (313MCM annually in Kabul city), says Omid 2015.

Station Name	Shukhi	Naghlu	Dakha (border)
Catchment area (km^2)	10.88	26.14	53.77
Minimum monthly discharge (m^3/s)	22.6	29.2	58.9
Annual runoff (MCM)	2925.1	3385.7	19287.1
Data period	1967-80, 2003-10	1962-87	1962-87

Table 1, Average Water Discharge at the Main Hydrological Station and Runoff Rate Potential

Table 2 Evaluates the Average Discharge at the main Hydrological Stations and the Runoff Rate Potentially at the area. (Source: JICA 2011)

At the Shukhi compilation point of northern streams, including the Panjshir river basin, JICA estimates that, "the quasi-natural flow is 3,607.0MCM/year, the runoff rate reaches to 43.5%, and the total average annual consumption is estimated at 541.0MCM/year, which is about 15% of the quasi-natural flow". It is time, that by mismanagement of the water resources the area deals with an annual water deficit of around 131.7MCM and at least the districts are located in both side of rivers affected by the shortage in domestic and irrigation system (JICA, 2009).

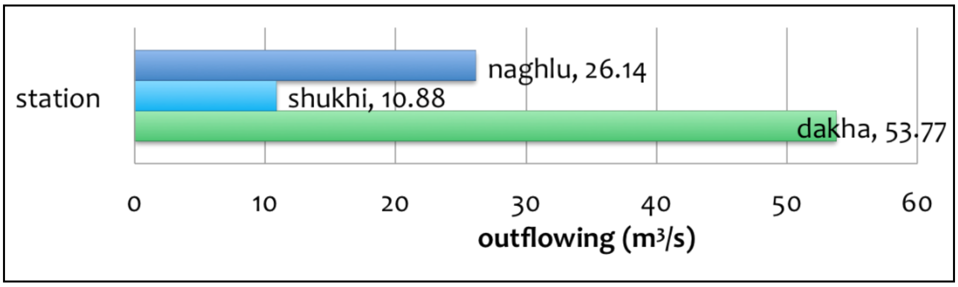

Figure III, Explains Average Annual Water Flow in Naghlu, Shukhi and Dakha Stations

Ground Water Level in the Research Area

Between 1960 and 2000, a dramatic decline of water level have occurred in the study area "as a result of low-normal precipitation" and increasing population in the urban areas of the Kabul (USGS, 2009). To fulfill the need and supply sufficient water to meet the increasing domestic water demand, the Danish Committee for Aid to Afghan Refugees, set up around 1,500 wells, with average 22m depths or more, in different areas of Kabul (Safi and Vijselaar, 2007). However, with the increasing rate of population in the city, up to 75% of these water supply wells are reported to be inoperative or dried. Moreover, the recent droughts and increasing water use in the city led up to 25% declines in water level of the wells respectively.

water levels indicate that groundwater levels are rising in response to extract, for example, in well 167 (USGS) in the Central Kabul sub-basin, most likely in response to increasing withdrawals. The horizontal groundwater gradients are steep near mountain-front recharge areas and decrease towards the centers of the basins. A comparison of water levels from Akbari and others (2007) to water levels reported by Myslil and others (1982) indicate that water levels have declined more than 10 m in upslope areas and 15 to 16 m in the city of Kabul till 2009 and more than 20 meter in 2017 (self-measurement on private shallow wells). Shallow lakes and marshes that were present in the city of Kabul in 1980 are now dried out, the similarity is extended on Groundwater-level conditions in the Central Kabul, DehSabz, Paghman and Upper Kabul, sub-basins are discussed. (Ministry of Energy and water 2017, USGS, and others).

East Kabul

Wells which is extracting ground water is the main water source in the eastern part of Kabul. Statistics show that water level ranges from 2.5m (Well 156, USGS, 2005) to a maximum of 23 m below land surface (Well 220, January and February 2006). The data indicate that typically, the wells which are closely located to Kabul River "have decreasing depths to water" whereas distant wells "have increasing depths to water". Water level fluctuates from 0.5 to 3m in different seasons and "pumping appears to cause a drawdown of about 8 m in Well 208 (USGS 2009), while the Khair Khana wells appear to have pumping drawdowns of about 25 m" (USGS, 2007). USGS's data clarifies that "in the Central Kabul sub basin, water-table altitudes range from 1,785 to 1,775 m ASL and the depth to groundwater along most stream channels is less than 15 m" (USGS, 2009).

Observation wells show the fluctuation of groundwater level from March 2011 to June 2012, measured monthly below ground surface. In terrace-7 Ground water lies at 12 m to 33 m which is 0 m to 7 m at terrace-3(USGS 2007) Groundwater level rising by rainfall mostly in the wells located at river bank or nearby areas, as showed at figure (4) fluctuation is highest in may, June but lowest level in September, to February, ground water level smoothly fluctuates without peak sharp (USGS-AGS 2009).

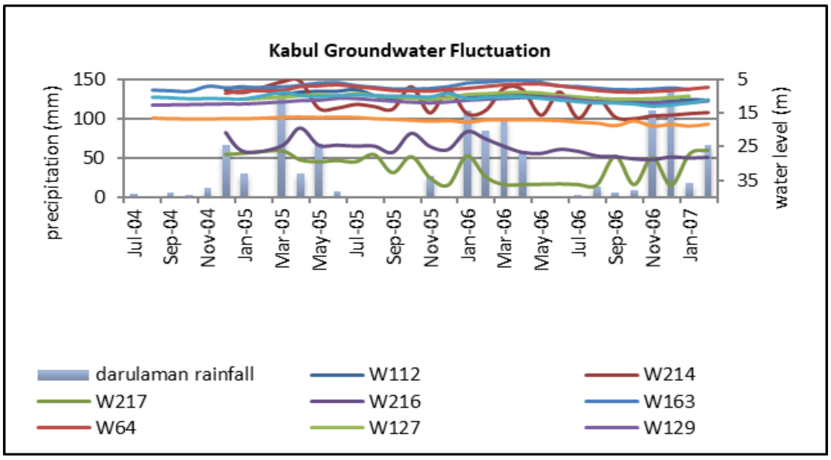

Figure 4, Seasonal Ground Water Fluctuation in and around Kabul (Data source: USGS-2007)

New Deh-Sabz City

The wells' depth varies from 7.2 to 150 m and "the superficial geology at the wells varies from Quaternary loess to Quaternary conglomerate and sandstone". The area doesn't have any persistent water resource but has many seasonal water resources with different capacities in the mountain bases. Similar to the other described areas, the water level is highly dependent on the snowmelt and precipitation level. The area's "static water levels range from a minimum of 4 m below land surface (Well no 7, March 2007) to a maximum of 40 m below land surface" (Well 59.1, August 2006). There is no fixed water depth or water supply trend in the area due to high irregular seasonal fluctuations, from 0.5 to 2m (USGS-2007).

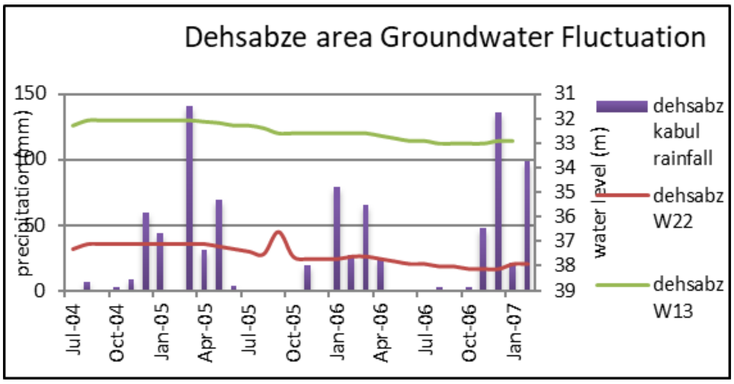

Figure 5, Groundwater Seasonal Fluctuation in Dehsabz area (Data source: USGS-2007)

West Kabul

The Paghman groundwater includes the western and central Kabul and constitutes a very huge water resource, which provides water for both urban domestic and irrigation use. Generally, "there are 12 monthly monitoring wells in the Paghman groundwater area that range in depth from 4.9 to 99.7m.

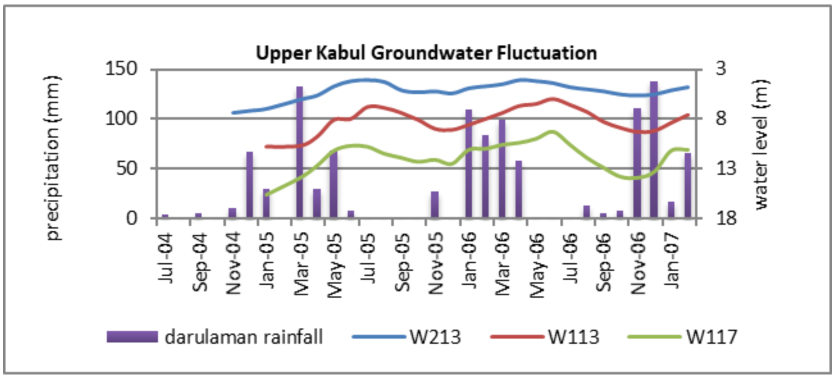

Figure 6, Groundwater Seasonal Fluctuation in Upper Kabul(Data source: USGS-2007)

The surficial geology at all well sites consists of Quaternary loess, alluvium, or colluvium; Wells are on south (Alla-uddin) and north (Afshar) of the mean stream. In the Paghman ground-water area, static water levels range from a minimum of 3 m below land surface (Well 212, April 2006) falling down up to 28 m below land surface" (Well 217, January 2006). USGS confirms that, "in this area, long-term trends during the monitoring period vary: depths to water have increased at Wells 112 and 114, while depths to water decreased at Wells 113, 115, and 117. Static water levels have seasonal fluctuations from 0.5 to 3 m. Static water levels have seasonal fluctuations that are larger for wells near the Kabul River than at wells that are not near major surface-water sources. Pumping appears to cause a drawdown of about 5 m at Well 211 in the Alla-uddin well field, Well 214 at Kabul University, and at Well 216 in Afshar village" (2007).

IV. CONCLUSION

This study has provided a summary of the situation of water in different areas of Kabul and found the similarities and differences, and a huge decrease in water level and shortage of water in Kabul groundwater resources in and around Kabul city.

Over the past two decades, population growth in Kabul has caused a lot of pressure on the environment and, in particular, has on groundwater resources, both quantitatively and qualitatively. In the region seasonal and sudden floods have been increased.

Considering the structural, hydrological and topographical structure of the Kabul valley and surroundings, recharging the seasonal water into groundwater through implementing mud dam is the most efficient method.

Mud dams are the most common type of dams that can be made using local materials. The cost of constructing earth bases for it is also very low compared to the amount of water stored in it. Labor cost is also very low and it could be constructed using lightweight equipment with minimal facilities, the methods that can lead to sustainable development and fulfill the domestic use.

This study suggests construction and implementation of mud dams as an important measure for water storage and water recharge. The method is the most efficient in addressing the problem of drinking water in Kabul city and the region.

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