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Water resource management in Kabul river basin, eastern Afghanistan

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Abstract Severe drinking water shortage affects all resident of the Kabul river basin. Two and a half decades of civil war in Afghanistan (it began in late 1978) have resulted in widespread environmental degradation and water resource development throughout the country. The war has already finished and, therefore, water resource management for supplying water is one of the most important tasks for Afghanistan's government. The Kabul river basin which is the most populated area in the country is located in the eastern part of Afghanistan. This article deals with the water resource properties of the Kabul river basin and also water demand in the important cities of the basin, such as Kabul, the capital and the largest city in the country**.** Also a few suggestions for providing water for domestic and agriculture purposes in short term, medium time and long term have been discussed.

Keywords Basin · Groundwater · Kabul · Management · River · Water resources

1 Introduction

In Afghanistan, over 80% of the population relies directly on the natural resources based to meet daily needs. The major natural resource in Afghanistan is water, as expressed in a number of Afghan proverbs, and therefore sound water management is essential for the successful future development of the country (Raphy Favre, Watershed Consultant 2004). The lack of water resource experience, management, and money, along with the growing urbanization and socioeconomic development, has already severely threatened in Afghanistan, particularly in many urban areas.

Agriculture is the dominating sector of the Afghan economy. It supplies approximately two-thirds of the national income. Therefore, development of the water sector is one of the highest priorities of Afghanistan's government, but the country lacks qualified human resources and technical, institutional and managerial capacities to attain this objective. However, the country is confronted by multiple water-related problems, such as drought, famine, and environmental degradation from overexploitation of aquifers. For example, successive droughts from 1998 to 2002 sharply reduced wheat (the major staple of Afghanistan) harvests and livestock populations (Chabot and Dorosh 2006). Therefore, Afghanistan needs to act urgently in order to ensure water security for its people.

Afghanistan is a land-locked country lying in the south Asia, and it is strategically located at the crossroads of three main regions: the Indian sub-continent to the east, Central Asia to the north and the Middle East to the west. Afghanistan is dominated by high mountain ranges and is covered by a relatively dense network of rivers. The main five river basins are the Amu Darya river basin, the Northern river basin, the Harirrod-Murghab river basin, the Hilmand river basin, and the Kabul river basin. It is the last one that we discuss in this article (Fig. 1). So there is a good potential for the development of the water supply. Due to more than two and half decades of civil war in the country, water supplies have not developed yet. This article

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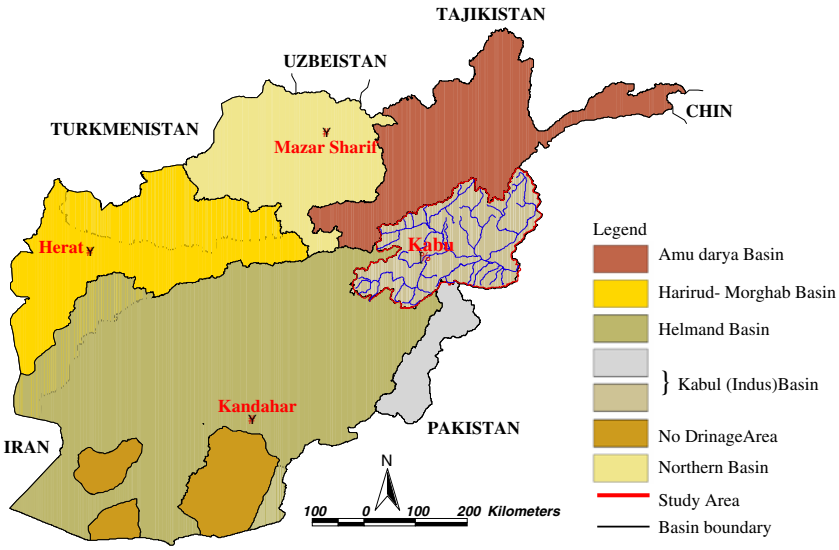

Fig. 1 Location of the five main river basins and the Kabul river basin in Afghanistan

deals with the water resources in the Kabul river basin and also development. Potential water supplies will be discussed for protection of water resource to stabilize and improve their quality and quantity. At the end of the article, we suggest some policies for supplying water for drinking, agricultural, and industrial purposes.

2 Physiographic of the basin

Afghanistan is a mountainous country and over three quarters of the land is mountainous. More than one quarter of the national territory lies above 2,500 m (Kapos et al. 2000). Afghanistan lies to the west of the border where Tajikistan, China, India, and Pakistan meet in the neighborhood of the world's most difficultly accessible mountain area—here the world's highest mountains Himalaya, Karakoram, Kunlun, and Pamirs meet Eastern Hindu Kush.

The Kabul river basin is surrounded by mountains located in the eastern central part of the country, and is the site of the Afghan capital. The Kabul river basin lies between longitude 67°40′ to 71°42′ east, and latitude 33°33′ to 36°02′ north, and it is a shared river with Pakistan. However, as an upstream country, Afghanistan cannot unilaterally undertake water resources development in this basin without establishing cooperation with the downstream country. Much of the discharge of the Kabul river results from the melting snow accumulated during the winter season in the mountains. However, winter rains, which are common in late winter and early spring, falling on a ripe snow pack in the highlands, can greatly augment the flow of the main streams. Kabul city and seven another provinces are located in the Kabul basin river. Important cities in this basin are Kabul, Jalalabad, Charikar, Pol-Alam, Mehtarlam, and Asadabad.

Kabul is not only the capital of Afghanistan but also the largest city in the country, with about 3.0 million inhabitants (Tunnemeier and Houben 2005). Kabul lies along the Kabul river with an elevation of about 1,800 m, making it one of the highest capital cities in the world. The basin has five major catchments, with a total area of 53,150 km^2 (Table 1). The Kabul river basin is located in eastern Afghanistan, neighboring the Pakistan border. The Kabul river is 435 miles (700 km) long, of which 350 miles are in Afghanistan. Rising in the Sanglakh Range 45 miles west of Kabul city, it flows east past Kabul and Jalalabad, north of the Khyber Pass into Pakistan, and past Peshawar; it joins the Indus river northwest of Islamabad. The Kabul river, is the most important (although not the largest) river in Afghanistan (http://www.encyclopedia.jrank.org/Jan_KHA/KABUL).

The climate in Kabul is semi-arid area and strongly continental. The data covering a period from 1957 to 1977 reveal major fluctuations in the level of precipitation and temperature. The average annual precipitation during this period was 330 mm, while the annual average temperature during the conservation period varies between 10 and 13°C (Tunnemeier and Houben 2005). Figure 2 shows annual precipitation and temperature for the observed period for Kabul airport station.

Maximum precipitation of the basin is reported more than 1,600 mm and has occurred in the north, which consists of mostly mountains and high lands. This precipitation is typically snow, which has melted in spring and summer seasons and has increase river flow in the basin. Therefore, rivers which are located in the north of the basin have higher base flow in comparison with the rivers in the southern part. Mean monthly and annual discharge of main rivers in the basin in some hydrometric station are shown in Table 2. The location of

Table 1 Watershed characteristics of the Kabul river basin

Watershed	Area		Snow cover		Population	
	km^2	%	km^2	%	Settled population	%
Alingar	6,234	0.97	1052.48	7.20	287,099	1.39
Chak Wa Logar Rod	9,968	1.54	0.00	0.00	607,283	2.93
Ghorband	12,964	2.01	871.86	5.96	14,40,757	6.96
Kabul	12,997	2.01	53.66	0.37	35,91,820	17.36
Kanar	11,664	1.81	2096.15	14.37	600,237	2.90
Kabul basin total	53,827	8.34	4074.15	27.79	1,19,92,196	31.54

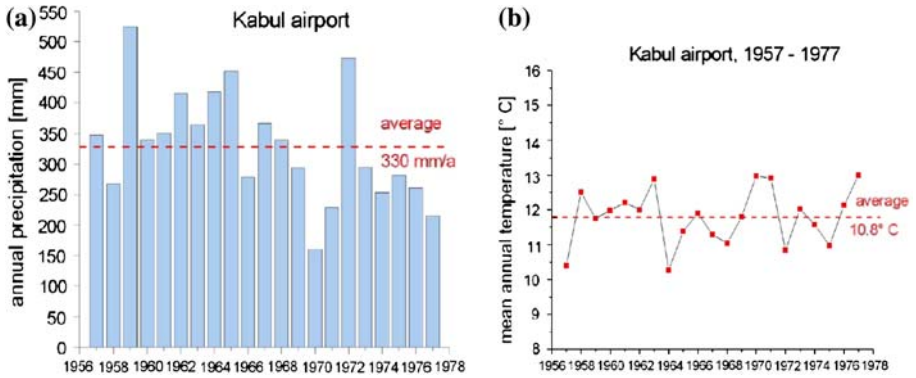

Fig. 2 (**a**) Precipitation, (**b**) Temperature data in Kabul airport 1956–1978 as annual averages (from Tunnemeier and Houben 2005)

rivers and snow cover area on Landsat-7 image is shown in Fig. 3.

The Kabul river basin is a main tributary of the Indus basin river. The Indus basin river system is the world's largest contiguous irrigation system (UNITAR Hiroshima Office for Asia and the Pacific 2004). The Indus, one of the mightiest rivers of the world and the second longest in western Asia, has a mean annual discharge of 207.5×10^9 m^3. The Indus River system has ten times the volume of flow of the Colorado river in the United States and Mexico, and more than three times that of the Nile. (http://www.unu.edu/unupress/unupbooks/80858e/80858E04.htm). The average discharge of the Kabul river in Dakeh station close to the Pakistan boarder is 608.4 m^3/s or in other words 19.2×10^9 m^3 of the annual discharge of the Indus river basin is provided by the Kabul river basin.

The highest elevation in the study area is about 6,000 m.a.s.l in northeast of the basin, and the lowest area is in the outlet of the Kabul river to Pakistan, and its elevation is 420 m.a.s.l (Toossab Consulting Engineers 2006). A digital elevation map for the basin by using SRTM (90 m) data and checked by 1:250,000 topographic maps is provided (Fig. 4). Figure 4 shows high mountains in the north of basin and also there are two flat plains (Parwan & Jalal Abad) as agriculture land.

Table 2 Mean monthly and yearly flow at stations of the main rivers in the basin (m^3/s)

Station	Month												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Gulbahar	10.4	10.3	13.8	37.0	96.4	213.2	142.3	56.0	25.7	17.8	14.5	12.0	54.1
Pol-e Ashva	8.8	8.4	14.7	35.3	55.4	62.9	30.0	11.7	8.4	9.0	10.1	9.8	22.0
Tange seidan	2.5	2.7	6.2	15.7	10.9	4.3	1.0	0.4	0.3	0.5	1.1	1.7	3.9
Sangneveshte	16.3	16.2	17.8	22.3	10.5	1.7	1.7	0.7	1.2	3.6	11.4	14.9	9.9
Shukhi	35.6	31.6	39.8	122.4	191.7	350.0	206.6	62.4	32.1	28.4	29.4	33.4	96.9
Pol-e-Gharghe	4.3	6.6	24.3	103.4	162.6	224.1	110.0	31.0	9.7	7.5	5.8	4.5	57.8
Pol-e-Kame	105.3	100.5	141.3	344.6	607.0	981.8	1133.6	953.2	465.9	209.0	150.8	123.3	443.0
Dakeh	165.8	158.8	238.5	603.9	947.9	1502.7	1445.3	1076.3	523.3	254.0	203.3	181.3	608.4

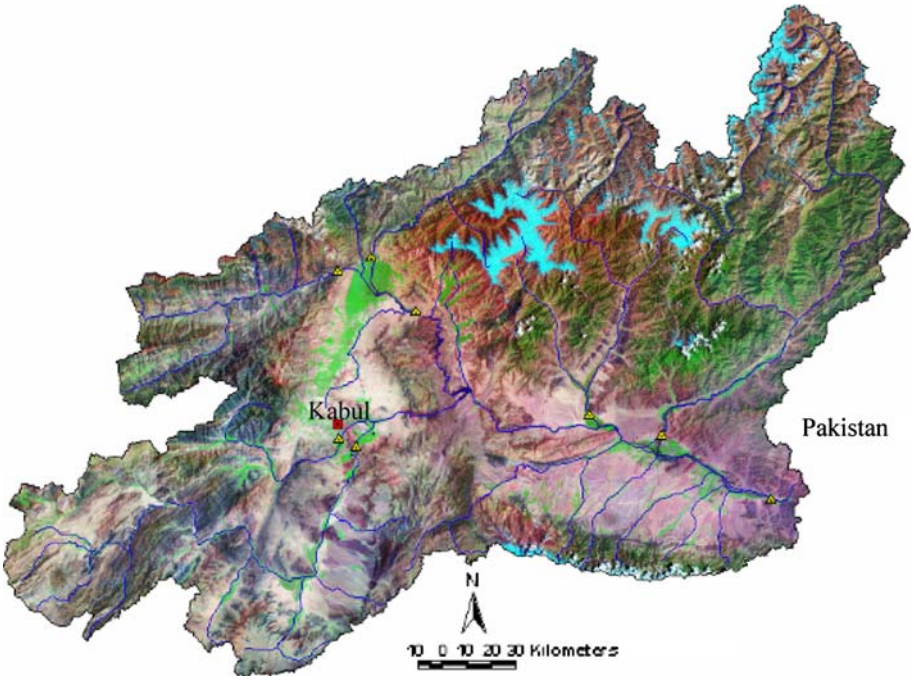

Fig. 3 Location of rivers, hydrometric stations, and snow cover areas on the Landsat-7 image

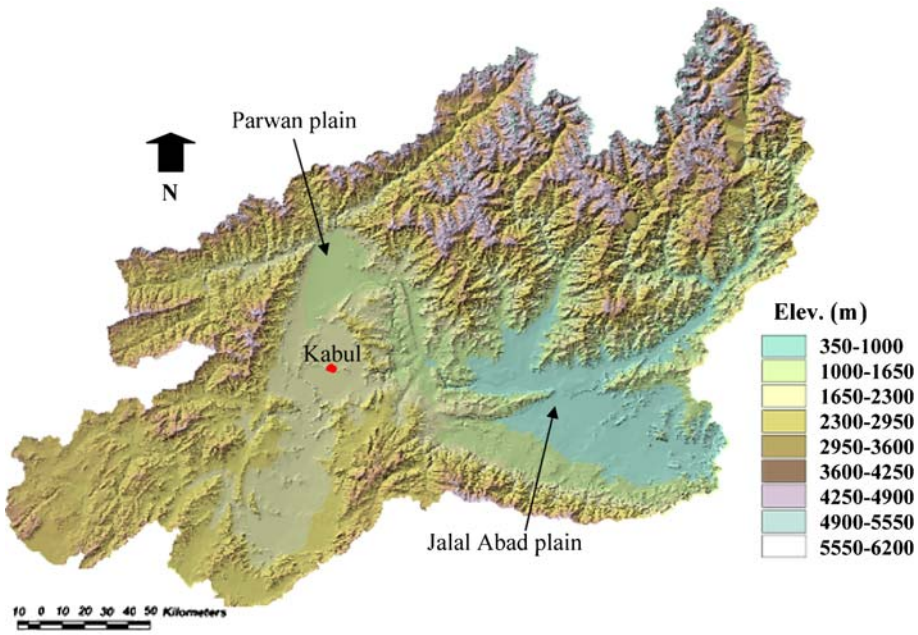

Fig. 4 Digital elevation map (DEM) of the basin

3 Geology

The Kabul river basin is a basin structure, which arose as a result of plate movements during the Late Palaeocene (Tertiary). It is surrounded and underlain by largely metamorphic rocks (Tunnemeier and Houben 2005). The Kabul basin sediment consists of an accumulation of terrestrial and lacustrine sediments, mainly of Neogene age. Most of these sediments consist of sand and gravel. Geophysical surveying revealed the total thickness of the sediments as up to 600 m (Proctor and Redfern Int. Ltd. 1972).

Geology of a basin plays an important role in the quality of surface and underground waters. The map of main rock group distribution in the Kabul river basin is shown in Fig. 5. This map shows that most of the areas in the northern part are covered by metamorphic (gnise, schist, quartzite, and slate) and igneous (granite, granudiurite, and

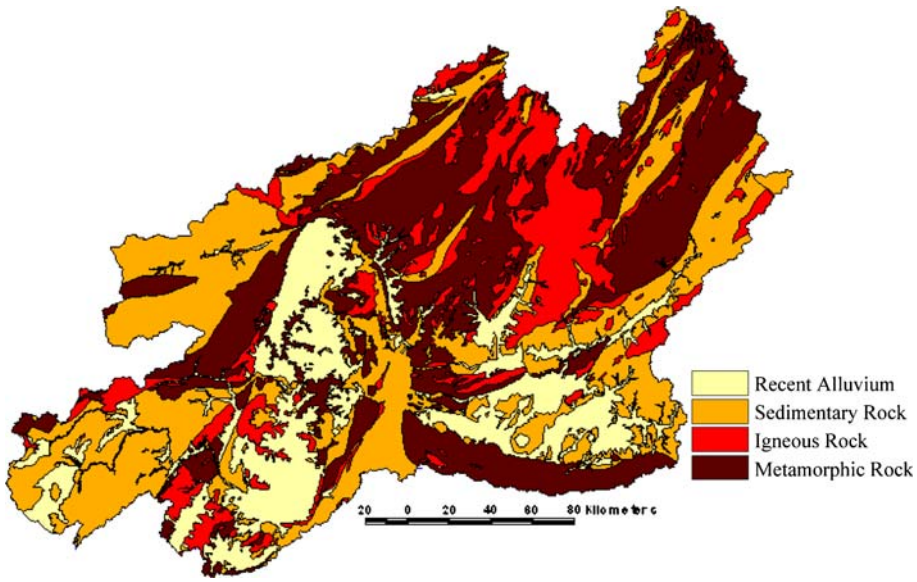

Fig. 5 Distribution the main rocks type in the basin

site) rocks. The southern part is covered by sedimentary (limestone, travertine, dolomite, sandstone, and marl) rocks. Therefore, rivers which flow in the northern part usually cross metamorphic and igneous rocks. These types of rocks with high resistance usually do not play as an important role on the degradation of the water quality.

4 Constructed dams in the basin

For providing electricity and water for drinking and agriculture purposes, a few small projects, such as small reservoir dam and small hydropower project were completed before the civil war. Information about these projects is shown in Table 3 (Toossab Consulting Engineers 2006).

5 Groundwater aquifers in the basin

In places around the world groundwater is gaining a much too important role as a water supply source for drinking, domestic, and agricultural purposes. Countries to the east of Afghanistan, such as South Asian countries, have emerged as the world's largest user of groundwater in irrigation. Results from the first socioeconomic survey of its kind, involving 2,629 well-owners from 278 villages from India, Pakistan, Nepal Terai, and Bangladesh, show that groundwater is used in over 75% of the irrigated areas in the sample villages; far more than what secondary estimates suggest (Shah et al. 2006). Despite these facts, there is little intervention by governments in developing countries. Sufficient knowledge, awareness and understanding of the groundwater resources, and their proper management are lacking in these countries, as well as in the international community (Villholth 2006). However, it is anticipated that the cycle of development will eventually increase resulting in greater demands for groundwater. Hence, an appropriate knowledge of the groundwater properties is imperative for the groundwater management within this discipline.

At present, the bulk of urban and rural water supplies for domestic and other municipal purposes in Kabul are obtained from groundwater sources, e.g., springs, karezes, and manmade wells (http://www.afghan-engineers.org/water_supply.html). A number of dug wells and a water

Table 3 Properties of the constructed dam and hydropower projects in the basin

Dam name	Type of dam	Target	Vol. (MCM)	Install capacity (MW)
Mahipar	Diversion dam	Electricity	0.2	66
Naglu	Gravity dam	Electricity	580	100
Surubi	Diversion dam	Electricity	6.5	22
Jabal-al-Seraj	Diversion dam	Electricity	–	2.4
Chak Vardak	Diversion	Electricity	–	3.3
Darunta	Gravity dam	Irrigation–electricity	41	11.5
Ghaghe	Earth dam	Irrigation	15	–

gallery discharge artificially supply groundwater in the locally known Kareze. There are many alluvial groundwater aquifers in the basin, such as Parwan, Shekar Dare, Paghman, Darulaman-Chehlstun, Northern Kabul, Logar, Zeid Abad, Pachasaheb, Gambery, Jalal Abad, East Jalal Abad, and Kame. Of these aquifers, Logar, Kabul, and Paghman are important for providing drinking water for Kabul.

The strategy of the Ministry of Energy and Water for supplying drinking water is to develop groundwater resources. As a result, in the near future, water extraction from groundwater sources will increase. Table 4 shows properties of the aquifers are supplying drinking water for Kabul. These aquifer are already being over-exploited, resulting in a fall in the aquifer levels. The results of an observation well in Kabul aquifer show that water table has dropped approx. 6–7 m within 40 years from 1965 to 2005 (Tunnemeier and Houben 2005). However, the over-exploitation of groundwater is an environmental hazard, which may cause the salinity of groundwater and makes it unsuitable drinking purposes and land subsidence.

The quality of groundwater in the Kabul basin varies widely from place to place. In some areas, groundwater quality is excellent, with low concentrations of dissolved solids and no problematic constituents. In other areas, however, high concentrations of dissolved solids and the presence of some constituents at concentrations deemed harmful to humans and crops render untreated groundwater marginal or unsuitable for public supply and/or agricultural use. However, the quality of the groundwater is significantly affected by sewage in the vicinity of the built-up areas. Of particular concern are elevated concentrations of nitrate, boron, and dissolved solids, as well as an indication of fecal pollution in some parts of the basin (Broshears et al. 2005).

6 Water demand

One of the priorities of the Afghanistan's government should be water. Due to conclusion the civil war and returning refugees, the rate of population growth has been reported to be very high. For example, in Kabul, the population was estimated to have increased from 720,000 in 1978 to 2,076,000 in 2005 (http://www.afghan-engineers.org/water_supply.html). At present time, inhabitants of the Kabul metropolitan area total about 3.0 million (Tunnemeier and Houben 2005) and the residents receive water only for 2–3 h per day. Moreover, the agricultural sector is the prime sector of Afghanistan's economy. Under these circumstances, the most important task for Afghanistan's government is providing water for drinking and agricultural purposes. However, water sector development is one of the highest priorities of Afghanistan's government, but the country lacks qualified human resources, technical, institutional, and managerial capacities to attain this objective.

Master plan studies of the water resources of the Kabul river basin were prepared by Montreal Engineering Company in 1980, which also addressed the Kabul city water supply. The master plan studies showed that the need for water in Kabul and surround areas for irrigation and hydroelectric power can be met by the water resources of the basin. This need can be satisfied by careful selection of the projects to be developed and by taking full advantage of opportunities for multipurpose use and management. In this study drinking water demand is calculated for the basin's settlements for a short time (up to 2008), medium time (2015) and a long time (2025). At first, based on the rate of population growth, water demand was calculated, and water sources are mentioned in Table 5. This table shows that most demand for water comes from Kabul city. There are not serious problems in the other cities of the study area.

The best option for providing water in addition to groundwater is constructing a new dam on Maydan or Logar river. Because of the fact that there is not enough electricity for pumping water in the region and water from these rivers flows to Kabul city by gravitational forces without the need for any pumping stations. The suggestion for supplying water in the medium term is construction of a dam on the Maydan river. This river has a negligible effect on the groundwater recharge and, therefore, environmental change. In the long time, construction of a new dam on the Logar river is suggested. There is a large copper mine around this river, therefore, water can be polluted. For this reason, dam must be construction before Pole Alam city. The suggested site for the dam is 25 km east of Pol Alam.

Table 4 Properties of three main groundwater aquifers around Kabul city (from Brockh 1971; Tunnemeier and Houben 2005)

Average thickness of aquifers (m)	Mean porosity (%)	Transmissivity (m^2/day)	Average range of permeability (m/s)	Stored volume ($m \times 10^6$)	Aquifer
30–40	7.5	4.1×10^{-2}–9×10^{-2}	1.4×10^{-4}–1.3×10^{-3}	81	Logar
30–70	7.5	1.3×10^{-3}–5.3×10^{-2}	4.5×10^{-5}–1.5×10^{-3}	90	Paghman
40–80	7.5	1.0×10^{-5}–6.8×10^{-2}	5.0×10^{-5}–7.5×10^{-4}	31	Kabul

Table 5 Water demand for important cities and place of water providing in the Kabul river basin in short, medium, and long terms (in McM)

Long time (2025)					Medium time (2015)					Short time (since 2008)					City name
Place	Shortage	Groundwater		Water demand	Place	Shortage	Groundwater		Water demand	Place	Shortage	Groundwater		Water demand	
Clombi Dam (247)	247	Logar II (25) Darulaman (16) Paghman (7) Pachasaheb (10)	56	330	Logar I (53) Maydan dam (90)	142	Logar II (25) Darulaman (16) Paghman (7) Pachasaheb (10)	58	200	Maydan dam (55)	55	Logar II (25) Darulaman (16) Paghman (7) Pachasaheb (10)	58	113	Kabul
Konar River (0.7)	0.7			0.7	Konar River (0.3)	0.3			0.3	Konar River (0.1)	0.1			0.1	Asadabad
Clombi Dam (0.6)	0.6	Logar (0.5)	1.1	1.1		0	Logar (0.5)	0.5	0.5		0	Logar (0.2)	0.2	0.2	Polalam
Darunta Dam (12.8)	12.8	Jalalabad (3.2)	18	18	Darunta Dam (2.8)	2.8	Jalalabad (8)	8	8		0	Jalalabad	3.2	3.2	Jalalabad
	0	Parvan (4.2) Shekar dare (2)	6.2	6.2		0	Parvan (2.6)	2.6	2.6		0	Parvan (1.2)	1.2	1.2	Charicar
	0	Parvan (0.4)	0.4	0.4		0	Parvan (0.2)	0.2	0.2		0	Parvan (0.1)	0.1	0.1	Mahmudraghi
Laghman River (1.2)	1.2				Laghman River (0.5)	0.5			0.5	Laghman River (0.2)	0.2			0.2	Mehtarlam
Maydan River (0.6)	0.6			0.6	Maydan River (0.3)	0.3			0.3	Maydan River (0.2)	0.2			0.2	Maydan Shahr

7 Conclusions

The Kabul river is the most important (although not the largest) river in Afghanistan. Due to more than two decades of war and conflict in the country, there is a lack of water information in the Kabul river basin.

This study includes the most populated area in the country with Kabul city. and it may be helpful for supplying water and reconstruction in this part of the country. Nowadays, the Kabul river (Indus) is an international transborder river. The Kabul river has a mean annual discharge of more than 1.9×10^9 m^3 that goes out to Pakistan border.

Rivers which flow in the northern part of the basin crossed metamorphic and igneous rocks. These rocks have high resistance and do not play an important role in the deterioration in water quality. Therefore, erosion and sedimentation in the northern rivers is lower than rivers in the southern part.

The most important city in the study area is Kabul, the capital as well as the largest city in the country, with the highest water demand. One of the priorities of the government should be the water supply. In the medium and long term, drinking water for this city should be provided from both groundwater and surface water. However, to solve the water problem, an integrated water resource management approach is needed for the Kabul river basin. This will include the following:

- Development of alternative water resources.
- Re-infiltration of river water during wet seasons into aquifers.
- Demand management implemented at the level of the river basin.
- Protection of water resource in the basin to stabilize and improve their quality and quantity.

The aquifers around Kabul are already being overexploited because of overdraft of renewable groundwater, resulting in a fall in the aquifer level. The survey reveals a general decline in the groundwater level in this area. The view of the unit hydrograph of the Kabul aquifer from 1965 confirms that water levels experiencing a decline of around 6–7 m. This warning of groundwater level has been brought about by the speedy growth of population.

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