Water Scarcity in Qatar and Prospects for Resolutions

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Abstract

Qatar is an arid country with limited water resources. With no surface water and an average annual rainfall of 76 mm per year, Qatar relies on desalination to meet the increasing water demand. The groundwater aquifer receives less than 40 million m^3 per year as natural recharge, whereas abstraction is more than 220 million m^3 per year, mainly used for agriculture. As a result, the water table has dramatically dropped to unprecedented levels and salinity increased, in addition to other adverse environmental impacts.

In the light of Qatar's 2030 National Vision, three grand challenges facing the future of Qatar were identified. These grand challenges are energy, water and cyber security. Qatar Environment and Energy Research Institute (QEERI), which is part of Qatar Foundation, focus its efforts on addressing the grand challenges associated with energy and water. This paper focuses on artificial groundwater recharge, which is part of the water security grand challenges. The urgency of this project arises due to scarcity of water, increasing demand, and fast depletion of groundwater. The country is fully relying on desalination to meet all of its domestic and industrial water demand, which has adverse environmental effects from burning fossil fuels used in water desalination and power production.

The overall objective of the Water Security Grand Challenge (WSGC) is to achieve water security in Qatar by having access to high quality, adequate, affordable and sustainable water that meets and supports it's fast expanding and evolving social and development programs. The WSGC programme includes three thrust areas: (1) water desalination, (2) water reuse, and (3) aquifer recharge from concepts to near market products. The specific goals of these challenges is to be achieved by 2020 are: to reduce desalination energy consumption and cost by 40%; to increase water reuse to more than 30% with minimal health risks and environmental impacts; and to raise water table in the strategic water storage aquifers to pre-1980 levels.

The groundwater recharge project aims at artificially storing water in the aquifer for future use. The stored water should be of acceptable quality (mainly desalinated water) and should be

enough quantitatively to meet the domestic needs of the State of Qatar in case of an emergency. When completed, the recharge project will serve as a national secure water reservoir, which is not exposed to contamination or quick depletion. As Qatar relies completely on desalination to meet the increasing domestic, industrial and agricultural demands, introducing another source of water will increase the water security and will reduce the reliance on desalination.

This paper outlines the water situation in the State of Qatar and discusses the challenges in the way of water security grand challenge. It also presents the different phases of the proposed artificial recharge scheme over the coming six years.

Introduction

Qatar is an arid country located in the eastern part of the Arabian Peninsula. It is a small peninsula with a maximum length of 180 km in the north-south direction and a maximum width of 65 km; thus the total area of Qatar is 11,586 km^2. The country is surrounded by the Arabian Gulf from East, North and West, and bounded by Saudi Arabia in the South (Figure 1).

As a result of rapid economic expansion, the population of Qatar has dramatically increased from 600,000 in 2000 to 2,200,000 in 2014 (World Bank Data, 2014). With little rain and little groundwater resources, Qatar is relying on desalination of seawater to meet the increasing demand of its rapidly increasing population. The produced and stored desalinated water at any time meets the population needs for a few days only, and thus it is considered as one of the national security grand challenge to diverse water resources, including artificial groundwater recharge.

The groundwater aquifers have been overexploited over the last three decades, resulting in a great drop in groundwater levels and deterioration of water quality. The abstracted groundwater is mainly used for irrigation, which is concentrated in farms in the northern and central parts of the country (see Figure 1).

Figure 1: Location map of Qatar

Hydrogeology

Qatar peninsula is part of the Arabian Shelf, which covers the eastern part of the Arabian Peninsula. It is underlain by a series of little dipping and flat lying deposits over the rocks basement. The surface of Qatar is of low relief with the highest altitudes of about 107 m occurring in southern Qatar, where large sand dunes and hills exist.

Several anticlines rose above the main geological platforms in the Arabian Shelf, and extending in the north south direction. In Qatar two major anticlines exist; the Dukhan anticline in the west and Qatar anticline (Qatar Arch) in the middle of the country (Figure 2). The main geology in Qatar comprises formations from Neogene and Paleogene periods, as shown in Table 1, overlain by Quaternary deposits. The most recent deposits are the Dam Formation which covers most of the country except for small areas in the north, where older Rus Formation is exposed. Dam Formation is underlain by Dammam Formation, which covers wide areas of Eastern Arabian Peninsula. Rus Formation (Lower Eocene Epoch) is the main aquifer, underlain by Umm er Rhaduma Formation (Paleocene Epoch), which contains brackish and salty water. Table 1 summarizes the stratigraphy and lithology of different geological formations in Qatar.

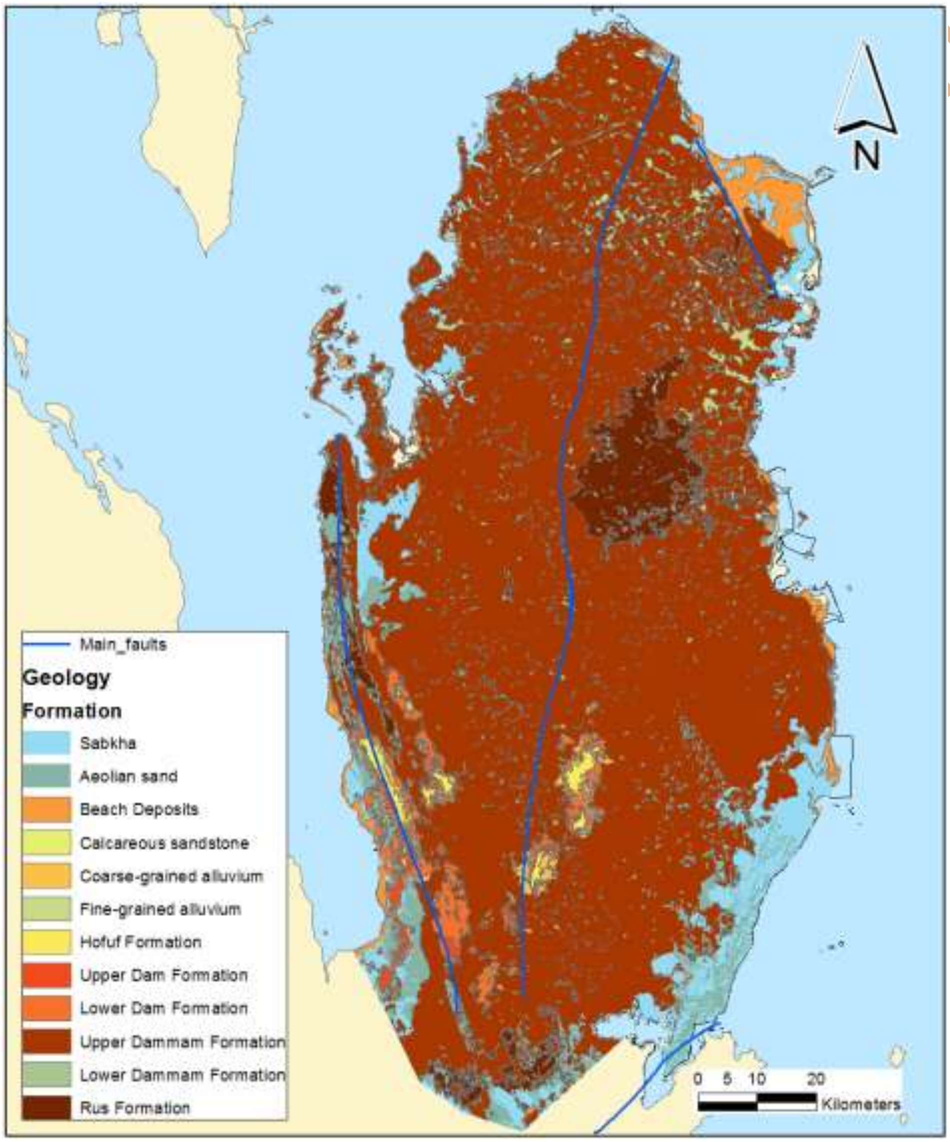

Figure 2: Surface geology of Qatar

Table 1: General stratigraphy and geological events in Qatar (modified after Boukhary et al 2011, Al-Yousef, 2003, Alsharhan et al 2001).

Age	Formation	Member	Lithology	Thickness	Remarks
Quaternary		Beach deposits	Calcareous sand of marine origin, coastal dunes locally cemented	variable	Isolation of Qatar by marine transgression
		Sabkha	Saline and gypsiferous sand and silt flats		
		Alluvium, Aeolian sand & calcareous sandstone	Mud, continental gravel, siliceous sand & conglomeratic sandstone		
Upper Miocene	Hofuf		Continental gravel, sand & conglomerate	12 m	Qatar arch uplift
Middle Miocene	Dam	Abu Samrah	calcareous sediments	80 m	
		Al-Nakhsh	Limestone, chalk & clay with gypsum & celestite beds		
		Salwa	Siliciclastic calcareous sediments		
Middle Eocene	Dammam	Abarug	Dolomite & limestone	62 m	
		Umm Bab / Simsima	Dolomite & limestone		
		Dukhan Limestone & Midra Shale	Shale, dolomite & limestone		
Lower Eocene	Rus	Al Khor	Limestone & Dolomite	110 m	Basin isolation
		Trina	Limestone & Dolomite		
Paleocene	Umm er Rhaduma		Limestone and dolomite, with some evaporite	300 m	

Groundwater in Qatar occurs either in Dammam Formation or in the underlying Rus Formation. Aquifers are categorized into three basins; the northern, central and southern basins. The northern is the main one, with least salinity. Groundwater occurs in form of fresh lenses situated atop of more brackish and saline groundwater. Most abstraction wells exist in this basin. The central basin is more saline than the northern but still usable for agriculture. The southern basin is the smallest and contains poor-quality water.

Inflow into the aquifer

The climate in Qatar is hot and humid in summer with a short winter between November and March. Rainfall is the main source of aquifer replenishment, with an annual average between 10 mm and 200 mm (AL Shahran et al. 2001). The long term average is 76 mm per year. Rainfall occurs between December and April (Atlas, xxx). The highest rainfall occurs in the north and gradually decreases southward (AL Shahran et al. 2001). Groundwater recharge from rainfall is quite variable due to erratic nature of rainfall event in desert climate. Most recharge occurs in land depressions, which resulted from collapse of karst features. After heavy storms, surface runoff accumulates in these depressions and recharges the aquifer. No studies have been undertaken to estimate recharge from rainfall, but figures in the literature give variable estimate of it. Vecchioli (1976) indicated that rainfall recharge is 20.9 million m^3/year, whereas another study (Kimrey, 1985) suggested 27 million m^3/year. A recent study by FAO (2014) estimated rainfall recharge at 65 million m^3/year, which is close to the Department of Agricultural and Water Research estimation (Department of Agricultural and Water Research, 2006). Lateral inflow from Saudi Arabia is 2 million m^3/year (FAO, 2014). Irrigation return flow is another source of aquifer recharge, and it is estimated at 55 million m^3 per year (Schlumberger 2009). Leakage from water system adds to inflow into the aquifer. The current water leakage is 15% of supply, which is 280 million m^3 (Al Mansouri, J. 2014). Thus, the inflow from losses is 42 million m^3, as per 2014.

Groundwater abstraction

Municipal water supply in Qatar used to come exclusively from groundwater prior 1960 (Vecchioli 1976). Currently, all municipal supply comes from desalination plants and groundwater is used mainly for agriculture, and small proportion goes to industrial and domestic use. The agricultural water demand in Qatar has increased from 44 million m^3 in 1974 (Kimrey, 1985) to 238 million m^3 per year in 2013 (Ali et al. 2014). Figure 4 shows the increase in groundwater abstraction for different purposes in the period between 1976 and 2009. About 70% of abstraction takes place in the northern part of the country, where wells penetrate the Rus formation with a depth between 60 and 70 meters. The total number of different purposes wells is more than 8500 (Schlumberger Water Services, 2009).

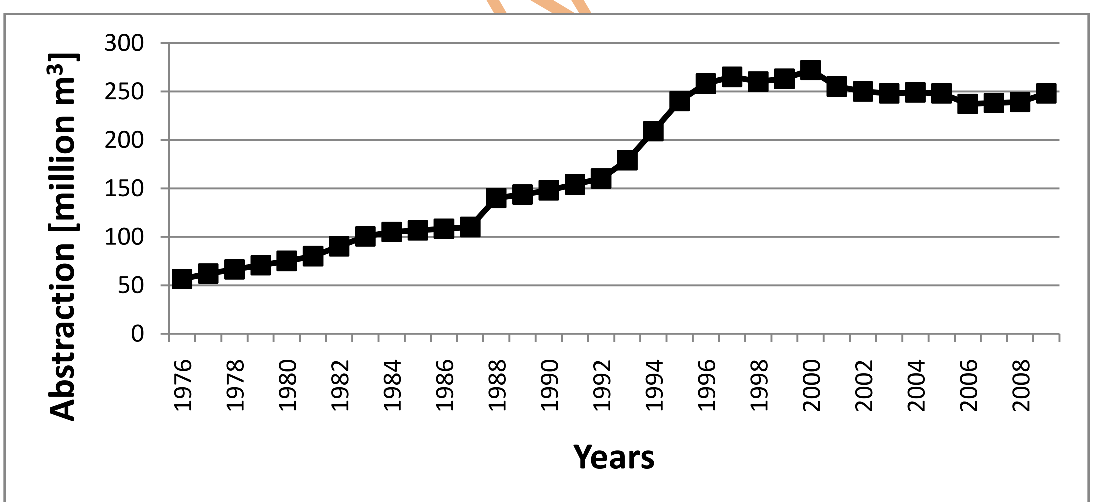

Figure 3: Trend in total groundwater abstraction (modified after Schlumberger Water Services, 2009)

Irrigation takes place mainly in the northern part of the country where many farms exist (Figure 1). The agriculture techniques are old and not efficient, which resulted in great losses. In absence of regulations on water use, groundwater resources have been overexploited, which resulted in great discrepancy between natural input into the aquifer and abstraction. In addition, the quality of groundwater has deteriorated due to upconning of brackish and saline water from lower layers underneath the fresh groundwater lenses and intrusion of seawater. Figure 4 shows contour maps of Total Dissolved Solids (TDS) in groundwater as salinity indicator for the years 1971 and 2009. A comparison between the two maps shows a reduction in fresh groundwater lenses and increase in salinity. The TDS level of the northern and central aquifers varies from 500 to 5000 mg/l, and it reaches 10000 mg/l near the shoreline.

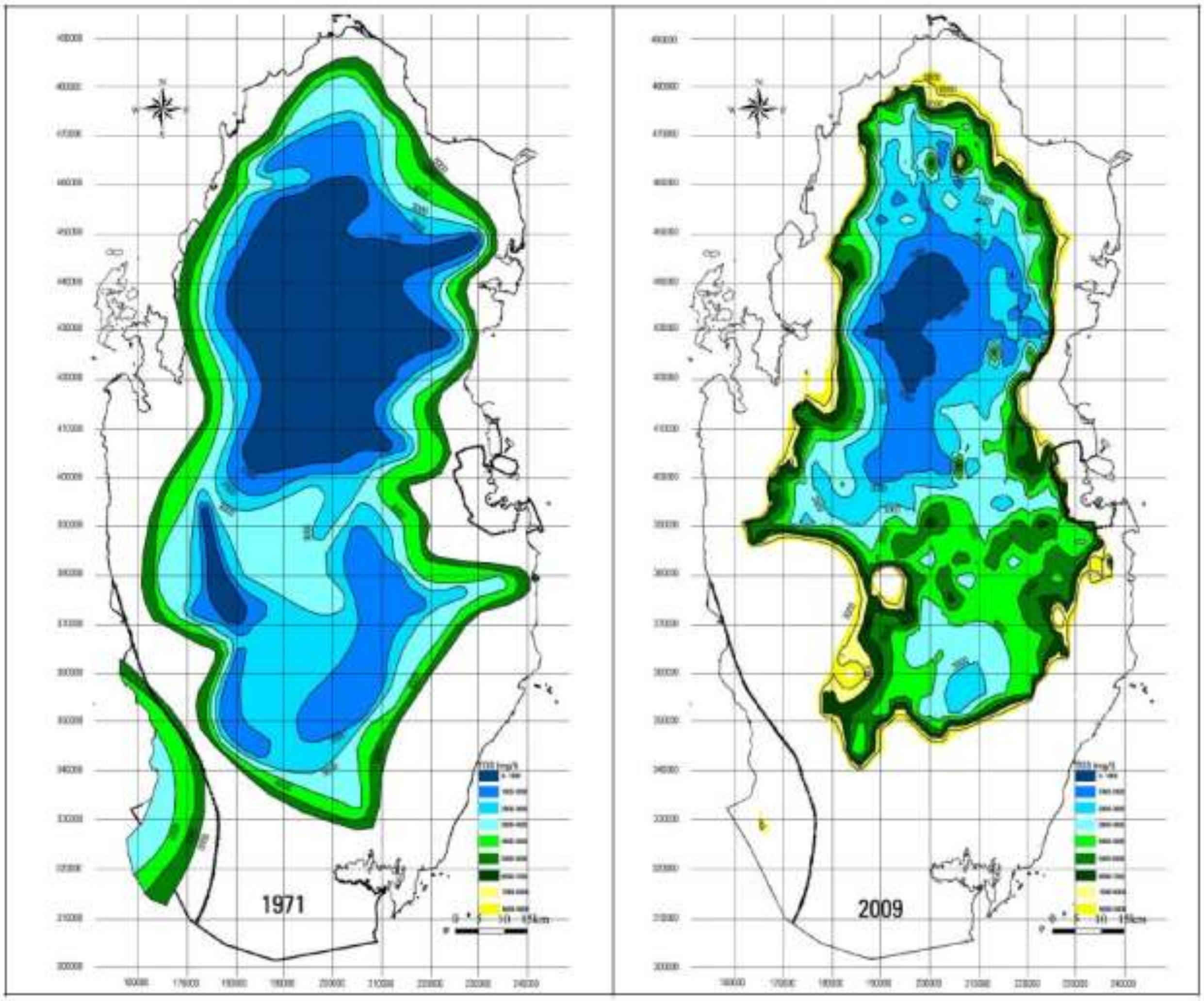

Figure 4: Total dissolved solids (TDS) in groundwater in 1971 and 2009 (Schlumberger Water Services 2009).

Evaporation

One of the main sources of water discharge is the evaporation from sabkhas. Schlumberger Water Services (2009) estimated evaporation rate to be between 33 and 56 million m^3 per year.

Water Balance

The groundwater balance for Qatar is shown in Table 2 below for year 2014, using information outlined above. Some components such as evaporation have no exact value so the average value was used. The results show a discrepancy of 136 million m^3. It should be noted that the discrepancy or deficit in water balance started as early as 1971 (Harhash and Yousif, 1985) and increased over time.

Table 2: Groundwater balance as per 2014

Component	Inflow [million m^3]	Outflow [million m^3]
Rainfall Recharge	55	
Lateral inflow into aquifer	2	
Irrigation return flow	55	
Leakage from water network	42	
Abstraction		250
Evaporation		40
Total	**154**	**290**
Discrepancy	**-136**	

This discrepancy is evident in the drop of groundwater level over the last three decades and in the shrinkage of the fresh lenses of groundwater, as shown in Figure 4. This highlights the urgent need of artificial groundwater recharge.

Artificial recharge

The previous analysis highlights the urgency of artificial groundwater recharge in Qatar. To establish a successful artificial recharge scheme, many factors should be taken into consideration. The first one is the location to get a maximum recovery rate. The middle of the northern aquifer, where the salinity of groundwater is low, is the best place for such a scheme. It should be also as far as possible from coastal areas to avoid seawater intrusion and to maximize recovery rate. The other criterion is the topography. Land depressions are ideal for surface recharge, as rainfall accumulate in these depressions after storm events. The third criterion is the hydraulic properties of the aquifer, including transmissivity and storativity of aquifer, thickness of unsaturated zone and infiltration capacity. Previous studies have been undertaken to evaluate groundwater recharge (Vecchioli 1976, Kimrey 1985). It was established that the use of injection wells is preferred over other means of recharge such as infiltration ponds, to avoid evaporation losses. Vecchioli (1976) estimated the injection capacity of a single well to be at least 1000 m^3/day. Therefore, 1000 injection wells would recharge the aquifer at least by 36 million m^3 per year.

Conclusions and recommendations

Results of preliminary investigations show it is possible to recharge the aquifer in Qatar, especially in the north, using the surplus desalinated water. The intended artificial recharge will provide a national secure storage for the people of Qatar and will counter the deterioration of groundwater quality and to raise water table to pre-development levels (i.e. 1980). The aquifer can be used as a reservoir and a backup for desalination in case of emergency or failure. Improvement of groundwater quality is expected after artificial recharge starts.

To establish a successful artificial recharge scheme, groundwater flow mechanism and hydrogeological settings should be studied further. This will be done through numerical modelling of groundwater flow and quality, lab testing of hydrological properties and field work.

It is recommended to reduce losses in irrigation practice through using modern irrigation techniques. Despite scarcity of water, per capita consumption of water in Qatar is the highest in the world. It is estimated the per capita consumption of water is 500 l/day. Rationing of municipal water use would reduce the demand and ease the pressure on desalination plants. The treated wastewater should be used for irrigation of backyards, landscaping and washing cars, which consume significant amounts of water. Current volume of treated wastewater is more than 100 million m^3 per year (Ali et al 2014). Part of this treated wastewater is being used for landscaping. It is recommended to use more treated wastewater in agriculture to ease the pressure on groundwater resources.

References:

Al Mansouri, J. 2014 .The State of Qatar's experience in reducing loss in the potable water network. . Second Arab Water Conference, Doha, Qatar.

Ali, Hanan; Mohamed, Hagga ; Hama, Yousef; Al-Murikhi, Abdulaziz. (2014). Current and future water source for agriculture in Qatar State. Second Arab Water Conference, Doha, Qatar.

Alsharhan, A. S.; Rizk, Z.A.; Nairn, A.E.M.; Bakhit, D.W. and Alhajari, S.A. (2001) Hydrogeology of an arid region : the Arabian Gulf and adjoining areas. Elsevier.

Al-Yousef, Mariam (2003). Mineralogy, geochemistry and origin of quaternary sabkhas in the Qatar peninsula, Arabian Gulf; 437 pages. PhD Thesis, University of Southampton.

Boukhary, Mohammad; Hewaidy, Abdel Galil ; Luterbacher, Hanspeter; Bassiouni, Mohamed El-Amin; and Al-Hitmi, Hind. (2011) Foraminifera and ostracodes of Early Eocene Umm er Radhuma Formation, Dukhan Oil Field, Qatar. micropaleontology, vol. 57, no. 1, plates 1-6. Pp 37-60

Department of Agricultural and Water Research (DAWR) (2006). Groundwater data and balance. Doha, Qatar.

Food and Agriculture Organisation of the United Nations (FAO) (2014). AQUASTAT global water information system. [http://www.fao.org/nr/water/aquastat/main/index.stm] last accessed October 2014

Harhash, I.E. and Yousif, A.M. (1985). Groundwater recharge estimates for the period 1972-1983. Ministry of Industry and Agriculture. Qatar.

Kimrey, John (1985). Proposed artificial recharge studies in northern Qatar. United States Department of the Interior Geological Survey. Open file report 85-343.

Schlumberger Water Services (2009). Studying and developing the natural and artificial recharge of the groundwater in aquifer in the State of Qatar.

The World Bank (2014). [http://www.worldbank.org/] Last visited October 2014

United Nations (2013). Inventory of shared water resources in western Asia. /ESCWA/SDPD/2013/ Inventory. ISBN-13. 978-92-1-128361-7

Vecchioli, John (1976) Preliminary Evaluation of the Feasibility of Artificial Recharge in Northern Qatar. United States Geological Survey. Open File Report (76-540).