Chapter 14
Groundwater Crisis of a Mega City: A Case Study of New Delhi, India

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Abstract This chapter analyses the groundwater table data derived from various wells across Delhi for the 2007–2011 period in order to examine the fluctuation in the groundwater table. Due to the inconsistency in data coverage, data for only one pre-monsoon month (May) was analysed. It was found that the depth to the groundwater table increased during 2007–2010 for all of the districts except the northeast district. Nevertheless, this trend changed in 2011 due to the groundwater recharge and heavy rains in 2010. Parameters influencing the groundwater availability (e.g., population growth and density, urbanisation etc.) indicate that Delhi may soon face a groundwater crisis if efforts to retard population influx into Delhi is not checked. This could be done by improving economy and infrastructure in the adjoining states thus making Delhi less attractive for the migrating population. In addition, the practice of apartmentisation (converting single or double story homes into multiple apartments) should be slowed down or permitted wisely by bearing in mind future groundwater sustainability.

Keywords Groundwater crisis • Sustainability • Groundwater table • Popolation influx • Migration

14.1 Introduction

Delhi is one of the mega cities in the world with the current population (including suburbs) exceeding 20 million. In the past few decades, its population has grown rapidly. People from other states migrate to Delhi for various reasons and thus contribute significantly to its peri-urban growth. Homeowners who owned a single family home 20–30 years ago now have redesigned or reconstructed their homes converting them in multi-storey apartments to earn rental income. The plot that housed a

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B. Maheshwari et al. (eds.), *Balanced Urban Development: Options and Strategies for Liveable Cities*, Water Science and Technology Library 72, DOI 10.1007/978-3-319-28112-4_14

single family of five or six people 20–30 years ago is now occupied by 20 or more people. In addition, commercially developed multi-apartment complexes have added significantly to the population thus enhancing the water demand enormously. To ensure the water availability for the increased population is one of the main concerns Delhi faces today. Urbanisation and development works (Rohilla 2012) cause an increase in built-up area leaving less area as permeable land that is able to recharge the groundwater table.

Due to the lack of a municipal water supply for the increased population, many households, particularly rapidly developing multi-story apartments, have set up their own tube wells to extract groundwater to meet their water demands. Such a practice has caused a decline in the groundwater table over a long period of time. With uncertainties both in the development practices and in the arrival of the monsoon, the declining groundwater table can lead to a crisis. This chapter discusses fluctuations in the groundwater table in the context of the population growth and suggests incorporating the groundwater availability as an increasingly important factor in all developmental plans for the city.

14.2 Study Area

The study area includes the National Capital Territory (NCT) of Delhi, India. Delhi is currently a pseudo-state, unlike other regular states of India, and is governed by both the federal government and the state government. The total geographical area of Delhi is about 1483 Km^2 (Shekhar et al. n.d). Its geographical coordinates are centered approximately at 28.38° North latitude and 77.13° East longitude. The responsibility of providing water for various purposes (domestic, agricultural, industrial, recreational.) rests with the state government. Both the surface and the groundwater resources are used to meet the water demand of Delhites.

Delhi receives about 755 mm of annual rainfall (average for the 1981–2005 period; rainwaterharvesting.org), about 80 % of which falls during the monsoon period (June through September). Administratively, Delhi is divided into nine districts (Central, North, South, East, Northeast, Southwest, New, Northwest, and West Delhi) as shown in Fig. 14.1.

Significant variation in the depth to groundwater table exists across Delhi (Dash et al. 2010). The groundwater situation in these districts depends on the hydrogeological formations (Maria 2006), the population density, and the urban versus rural area ratio.

Delhi's population has increased rapidly in recent decades. However, the growth rate varied significantly across districts. Figure 14.2 presents how the population density has varied during 1991–2011. The East and the Northeast districts have registered much higher growth rate in population density than the remaining districts.

Fig. 14.1 Administrative districts of Delhi, India

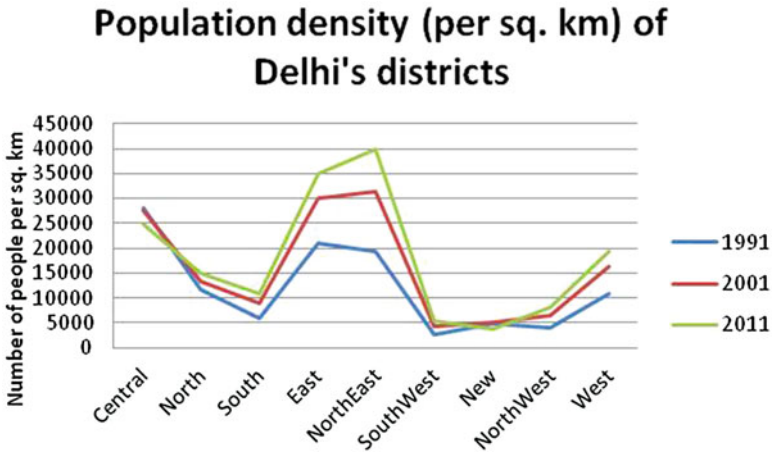

Fig. 14.2 The population density of different districts of Delhi

14.3 Methods

The objective of this study was to examine the variation in the groundwater table in different districts of Delhi. Ideally, the study required the groundwater data for a longer period, for example, since 1980, but the actual data were not available by the

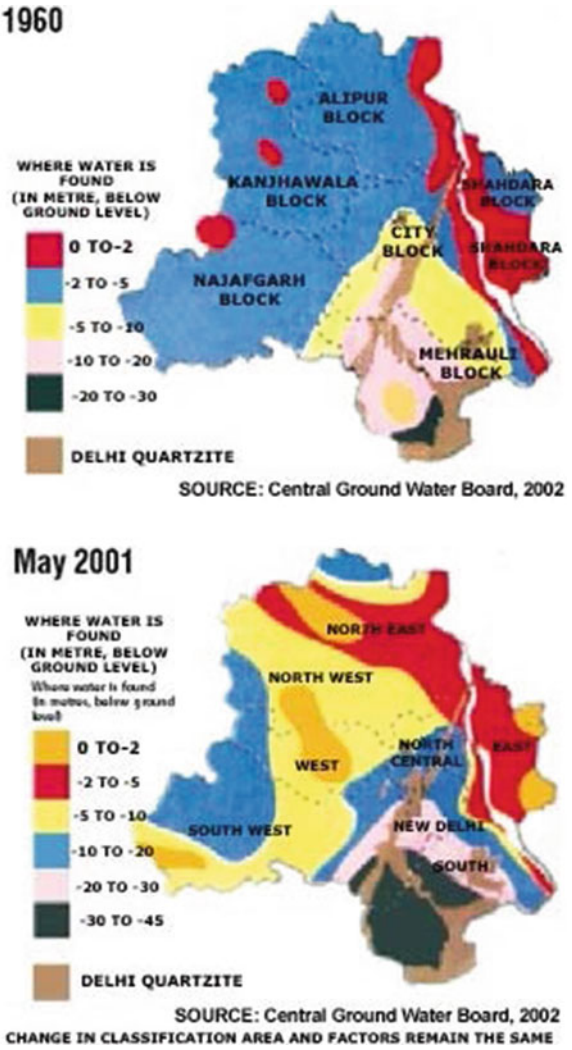

Fig. 14.3 The depth to ground water in Delhi in 1960 and 2001

time this chapter was written. The author is continuing his efforts to acquire data for a longer period. Figure 14.3 shows the depth-to-groundwater data in 1960 and 2001 showing significant fall in the water table.

14.3.1 Delhi's Water Demand

A significant number of Delhi homes are unofficially connected to the municipal water supply and therefore do not pay their water bills. For unknown reasons, Delhi's Water Department does not enforce monitoring of unofficial/unmetered

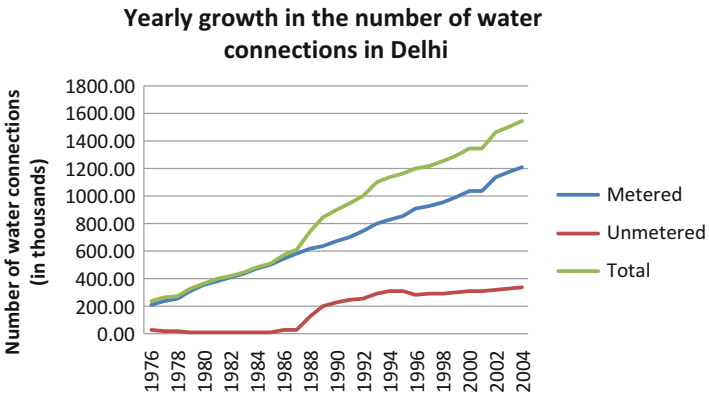

Fig. 14.4 The growth in the number of water connections in Delhi

connections. Figure 14.4 shows the growth in metered and unmetered connections. The unmetered connections are more common in rural or semi-urban areas of Delhi. Under such a situation, it is hard to estimate the actual water usage.

14.3.2 Data Collection

The depth-to-groundwater table data were collected from the Central Groundwater Board, New Delhi. The data were available only for the 2007–2011 period; no data were made available for the period prior to 2007. Significant inconsistency in the data existed. The depth to the groundwater table was measured in different months of the year in different wells across Delhi. The maximum observations were made in the month of May, prior to the beginning of the monsoon/rainy season. Therefore the May data were analysed for this study to achieve greater consistency and reliability. The wells with missing data for more than 1 year were not included in the analysis.

The number of wells for which data were consistently available was 2 for Central Delhi, 14 for East Delhi, 23 for New Delhi, 11 for North Delhi, 5 for Northeast Delhi, 39 for Northwest Delhi, 38 for South Delhi, 43 for Southwest Delhi, and 12 for West Delhi district.

14.4 Data Analysis

The depth to the groundwater table, averaged for each district during the month of May is shown in Fig. 14.5a, b for each year during the 2007–2011 period. Table 14.1 shows the statistical characteristics (min, max, average, standard deviation, and the coefficient of variation) of this fluctuation.

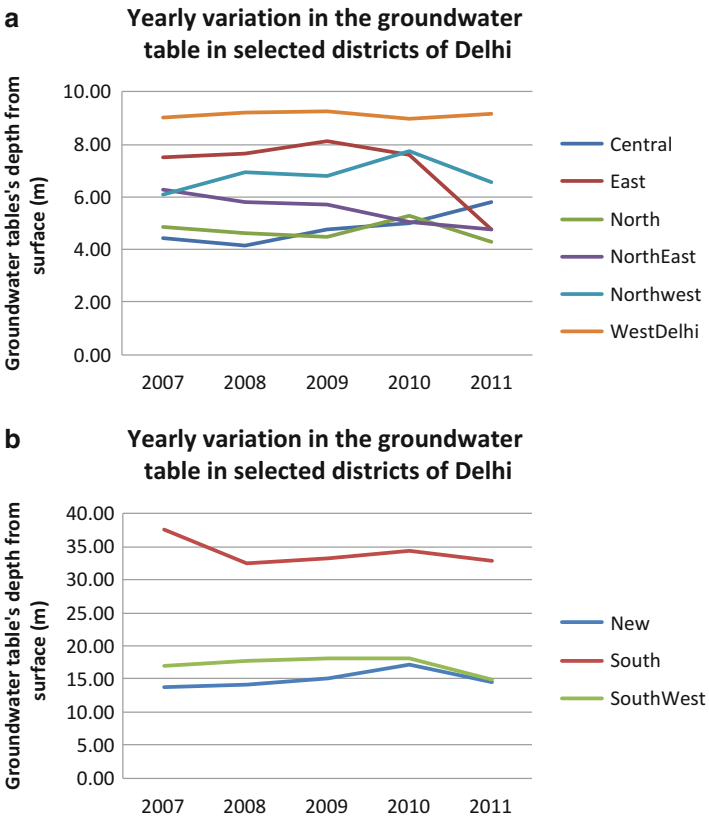

Fig. 14.5 (**a**, **b**) Fluctuation in the groundwater table in different districts of Delhi in the pre-monsoon month (May) as derived from the well-data (Central Groundwater Board n.d)

Table 14.1 Statistical characteristics of variation in groundwater table measured in pre-monsoon time during 2007–2011 period for Delhi, India

District	No. of wells	Fluctuation in ground water table				
		Minimum (m)	Maximum (m)	Average (m)	Standard deviation	Coeff. Of variation (%)
Central Delhi	2	0.90	9.26	4.83	3.71	76.8
East Delhi	14	2.40	13.07	7.39	2.86	38.7
New Delhi	23	0.96	44.1	14.90	7.21	48.4
North Delhi	11	1.88	14.77	4.71	2.21	46.9
Northeast Delhi	5	1.65	8.05	5.49	1.90	34.6
Northwest Delhi	39	0.8	27.08	6.87	4.26	62.0
South Delhi	38	1.99	66.70	34.11	20.05	58.8
Southwest Delhi	43	2.16	59.5	17.31	11.75	67.9
West Delhi	12	1.8	33.5	9.13	7.77	85.1

The data thus collected were analysed to study the fluctuation of the groundwater table over time and seek suggestions to improve the groundwater availability for Delhi dwellers.

As shown in Table 14.1, the depth to the groundwater table measured in May (a pre-monsoon month) during 2007–2011 ranged between 4.83 and 34.11 m across different districts. These depths could be classified into four categories – Low (0–10 m), Medium (10–20 m), High (20–30 m) and Very High (greater than 30 m). According to this criterion, six districts (Central, East, North, Northeast, Northwest, and West Delhi) had Low depths, two districts (New Delhi, Southwest Delhi) had Medium depths, and One district (South Delhi) had Very High depth (from the surface) of the groundwater table.

14.4.1 Groundwater Fluctuation

Figure 14.5a, b shows the fluctuation in the depth to the groundwater table during 2007–2011. Various factors contribute to fluctuations in the groundwater levels, such as the hydrogeological formation, permeability of the surface, groundwater extraction and population density.

It is apparent from Fig. 14.5a, b that the depth to groundwater table showed somewhat increasing trend for all of the districts except Northeast district during the 2007–2010 period. However the trend changed in 2011 for a few districts apparently due to enough groundwater recharge resulting from the heavy rainfall (about 1056 mm) received in 2010.

14.4.2 Impact of the Population Density

The population density of different districts has grown over time at different rates as shown in Fig. 14.2. Areas with low living costs have grown faster. Fluctuation in the groundwater table is a complex function of the population density, the groundwater recharging capacity/hydrogeological formations, proximity to the river, amount of rainfall received and the runoff produced. Apparently the districts with a high population density have favourable conditions for the groundwater recharge due to high percolation rate in the flood plains.

14.5 Future of Groundwater Resources

In order to examine the sustainability of water resources for Delhi, one has to evaluate the demand and supply of water. As the population and urbanisation continues to expand, the water sustainability will continue to decline. Delhi is more than 90 %

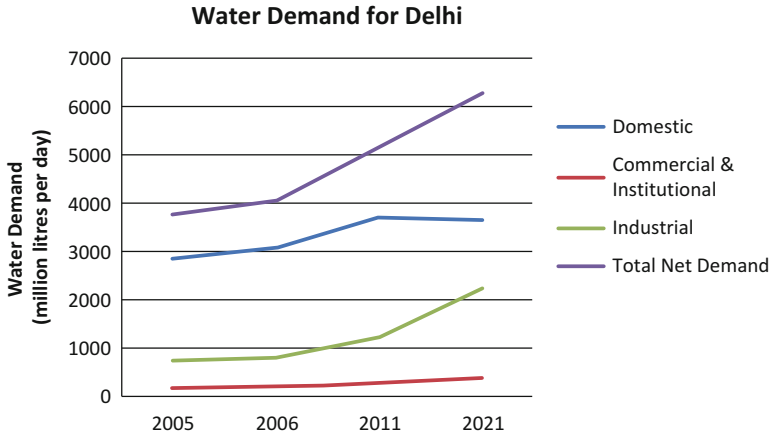

Fig. 14.6 Water demand for different sectors in Delhi (Source; Delhi Jal (water) Board, In: Statistical Handbook of Delhi)

urban and this percentage tends to continue increasing as the rural/agricultural land is being urbanised to absorb the increasing population influx.

It has been a difficult task to estimate the total water consumption in Delhi due to the substantial number of unmetered connections as well as unmetered groundwater extraction in privately owned homes/apartment buildings. The total water demand for Delhi is likely to rise significantly (Fig. 14.6; Singh 2007). In addition, the amount of the surface water flows in the Yamuna River is expected to decline in future due to global warming and the Himalayan glaciers that feed this river retreating (Rodell et al. 2009). If the urbanisation of and the population influx to Delhi is not restricted, Delhi's existing water problem will worsen. Urban development laws relating to residential expansion need to be strictly followed to retard the growth in population density that directly influences the groundwater availability.

14.6 Conclusion

This chapter has highlighted factors relating to increasing water usage in Delhi. Although the groundwater table data for a longer period was desired and sought, the same could not be made available. Based on the 2007–2011 data, it was found that the groundwater table fluctuated significantly across Delhi districts due to the change in rainfall, the hydrological formation and population density. The groundwater table exhibited a declining trend in all of Delhi's districts except the Northeast district during the 2007–2010 period. However the trend changed in 2011 in a few districts due to the groundwater recharge that resulted from the heavy rainfall received in 2010. Population growth, particularly due to the permanent migration to Delhi and also due to temporary migration of the workforce of all levels including

less skilled labour is one of the main causes of fluctuation in the groundwater availability. There is an urgent need to retard both the urbanisation of and the migration to Delhi by improving economy, infrastructure, and industrialisation, job prospects in nearby states and elsewhere in rural India. Also, the apartmentisation of homes needs to be restricted in order to retard growth in population density in order to avoid a water crisis for Delhi in the future. If the global warming fears come true in form of estimated low flows in River Yamuna, Delhi will likely face groundwater crisis in near future.

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