Change and cause analysis of water resources in Fengtai district of Beijing in recent 61a (from 1956 to 2016)

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Abstract. The calculation of water resources is the fundamental basis for legitimate utilization, effective protection, optimal configuration and optimal dispatch of water resources. Affected by climate change, economic development, and population expansion, the amount of water resources in Fengtai district, one of the central urban areas of Beijing, has undergone major changes. By comparing the results of the second investigation and evaluation of water resources (1956-1998), the paper analyzes the dynamic changes and causes of surface water resources, ground water resources and total water resources in Fengtai district in recent 61a (1956-2016). The results show that the surface water resources of Fengtai district in recent 61a is 37.978 million m^3, which is 2.572 million m^3 less than the previous investigation; the ground water resources is 92.959 million m^3, a decrease of 13.848 million m^3; the total water resources is 104.981 million m^3, which is 13.830 million m^3 less than the previous investigation. The gradual reduction of regional atmospheric precipitation is the main cause of the decline in surface runoff and rainfall infiltration recharge. At the same time, the continuous water-cutting of Yongding River (the biggest inflow river in Fengtai) since 2000 and the anti-seepage project implemented in 2010 further reduced the infiltration of river infiltration .

1 Introduction

Water is a fundamental natural and strategic economic resource, a controlling factor of the ecosystem, and an important support and guarantee for economic and social development. Water will become the most important global resource issue in the 21st century[1]. As a developing country, China is a country with severe drought and water shortage. The total amount of water resources is about 2.8 trillion cubic meters, and the per capita water resource is only 2,034 cubic meters, which is only 1/4 of the world's per capita water resource. China is one of the countries with the most lack of per capita water resource in the world[2-3]. Beijing is China's political, cultural, international exchange, science and technology innovation center, which carries important strategic capital functions, but the per capita water resource is only 1/20 of the national average, and the per capita water resource is less than 100 cubic meters, which is a serious shortage. The water area is also one of the most severely water-deficient cities in the world[4-5]. Fengtai District is one of the six districts in the central city of Beijing. The per capita water resource is only 1/2 of that in Beijing[6]. The shortage of water resources will become the main factor restricting the economic development of the region.

Fengtai District conducted the second water resources survey and evaluation at the beginning of this century. The time in the survey was from 1956 to 1998. However, in recent years, due to climate change, sustained and rapid development of the social economy, and the expansion of population, the water resources in Fengtai District have undergone large changes. It is urgent to analyze and calculate the existing water resources in this region. Through comparing the results of previous surveys, this paper analyzes the dynamic changes of surface water resources, groundwater resources and total water resources of Fengtai District in the near 61 years (1956-2016), which aims to better guide the future water resources of Fengtai District. The rational use of water resources, effective protection, optimal allocation, and optimal dispatching also provide theoretical basis and data support for Fengtai District's advanced planning of “Beijing Urban Master Plan (2016-2035)”.

2 Overview of Fengtai District

Fengtai District is in the southwest of Beijing City (Figure. 1). The total area of this area is 305.9km^2, which ranks 3rd in the city's six districts[7]. From north to south,the main stream of Yongding River is divided into two parts: Hedong area and Hexi area. Hexi is mainly low mountains, hills and terraces with an area of 126km^2; Hedong area is Yongding River alluvial plain with an area of 179.9km^2.

There are 43 rivers in Fengtai District and 16 rivers in the district. Among them, 8 rivers are mainly located in the Daqing River system in Hexi area, and the other 8 rivers belong to the Bei Canal water system in Hedong area (Table. 1).

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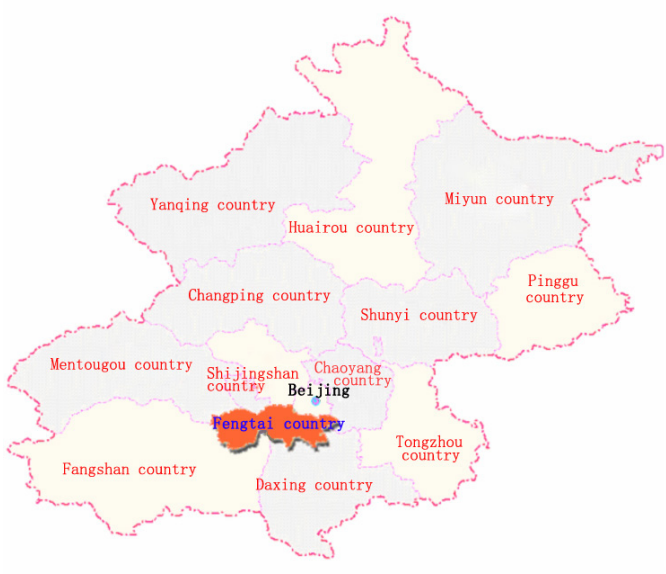

Figure 1. Geographical position of Fengtai district.

Table 1. Water system of Fengtai district.

Water system	Serial number	River name	Water system	Serial number	River name
Daqing river(Hexi district)	1	Xiaoqing river south ditch	Beiyun river(Hedong district)	1	Liangshui river
	2	Xiaoqing river north ditch		2	Shuiya ditch
	3	Xiaoyaba river		3	Fengcao river
	4	Jiuzi river		4	Macao river
	5	Python cow river		5	Han river
	6	Dianqi river		6	Xiaolong river
	7	Mang cow river		7	Baoli ditch
	8	Xiaoqing river		8	Huangtugang irrigation canal

3 Amount of water resources

3.1 Surface water resources

The amount of surface water resources refers to the amount of dynamic water that can be updated year by year in rivers, lakes, glaciers and other surface water bodies formed by precipitation, which is expressed by the annual runoff of rivers [8]. The calculation of surface water runoff in Fengtai District is mainly based on the surface runoff from the domestic production area. However, due to the lack of hydrological stations in Fengtai District and the lack of long-series measured runoff data, the regional main rainfall station is near 61 years (1956~2016). Rainfall data and runoff coefficients are calculated.

Due to the mountainous areas and hills in Hexi area, the impact of human activities and urban development and construction is small, and the underlying surface conditions are not changed much. The runoff coefficient adopts 0.25, which is the runoff coefficient of in the previous water resources survey and evaluation. The average runoff coefficient of Hedong area is 0.21, according to the average runoff coefficient calculated by

precipitation and runoff data of Liangshuihe Dahongmen Hydrological Station from 2011 to 2016 (Table 2), which is greater than the previous survey value of 0.16. The reason is that the Hedong area is an urban construction area. In recent years, the development degree is relatively fast, and the impervious area of the underlying surface has increased significantly.

Table 2. Calculation of runoff coefficient based on Dahongmen hydrometric station in Liangshui River of Fengtai district.

Year	Precipitation (mm)	Runoff (million m^3)	Runoff depth (mm)	Runoff coefficient
2011	868.07	15.652	119.04	0.14
2012	1060.34	18.055	137.32	0.13
2013	643.94	19.797	150.57	0.23
2014	472.00	16.036	121.97	0.26
2015	557.78	17.023	129.47	0.23
2016	960.93	31.059	236.23	0.25
Mean	760.51	19.604	149.10	0.21

The change trend of surface water resources in Fengtai District from 1956 to 2016 was analyzed (Figure. 2). The annual variation of surface water resources was obvious, but the overall trend was downward, and the surface water production decreased slightly. Calculated for many years (1956~2016), the average surface water resources were 37.78 million cubic meters, which was 2.572 million cubic meters compared with the previous results.

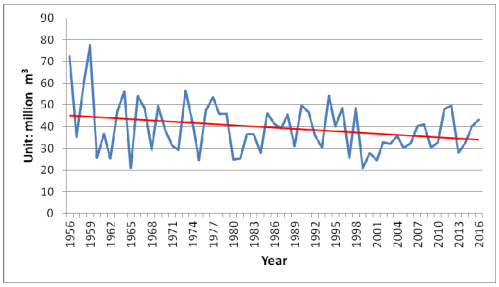

Figure 2. Variation trend of surface water resources in recent 61a in Fengtai district.

3.2 Groundwater resources

The total recharge of groundwater in the plain area of Fengtai District mainly includes rainfall infiltration replenishment, river seepage recharge, lateral inflow recharge, canal and canal infiltration replenishment and well recharge. For the calculation method of various groundwater infiltration, refer to the "Water Resources Evaluation" (the 2nd Edition), which will not be detailed here. According to calculation, the groundwater resources of near 61 years in Fengtai District are shown in Table 3.

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Table 3. Comparison of groundwater resources in recent 61a in Fengtai district with previous survey results.

Year	Rainfall infiltration (million m^3)	River channel leakage (million m^3)	Irrigation canal infiltration (million m^3)	Lateral recharge (million m^3)	Groundwater discharge (million m^3)	Total (million m^3)
1956-1998 (43a)	33.940	47.594	0.742	21.741	2.79	106.807
1956-2016 (61a)	31.332	34.779	2.317	21.741	2.79	92.959

It can be seen from the Table 3 that the average precipitation infiltration from 1956 to 2016 in the sequence year is less than that in the second water resources survey, and the canal infiltration increases, and the total groundwater resources are smaller than the second water. The resource survey and evaluation decreased by 13.848 million cubic meters.

3.3 Total water resources

The total amount of water resources represents the maximum potential of the available water resources under current natural conditions, thus providing a basis for the rational development and utilization of water resources. Surface water and groundwater are interconnected and transformed into each other. The river runoff derived from part of the groundwater discharge, and part of the total groundwater recharge, part of the infiltration of surface waters. So, the surface water resources and groundwater resources cannot be directly as a total amount of water resources, the amount of repeated water converted from each other should be deducted [8]. which is

$$W=R+Q-D$$

In the formula: W—The amount of total water resources,
unit: 104 cubic meters;
R—The amount of surface water resources, unit: 104 cubic meters;
Q—The amount of groundwater resources, unit: 104 cubic meters;
D—The amount of repetitive resources of

surface water and groundwater, unit: 10^4 cubic meters.

After calculation (Table 4), and deducting the surface water and groundwater repetitive amount, the total amount of water resources in Fengtai District near 61 years is 104.981 million cubic meters, which is 13.83 million cubic meters less than the previous survey results. The main contribution is the reduction of groundwater resources.

Table.4 Comparison of total water resources in Fengtai District between the previous investigation and the recent 61a

Year	Surface water resource (million m^3)	Groundwater resources (million m^3)	repeated amount (million m^3)	Total water resources (million m^3)
1956-1998 (43a)	40.550	106.807	28.546	118.811
1956-2016 (61a)	37.978	92.959	28.351	104.981

4 Cause analysis

4.1 Reduced atmospheric precipitation

Both surface water resources and groundwater resources are dynamic waters that can participate in the modern water cycle and can be updated. Therefore, changes in rainfall have a crucial impact on the evolution of total water resources. This paper analyzes the variation of precipitation in a long sequence (1956~2016) and three short sequences (1956~1998, 2001~2016, 1981~2016) to study the amount of precipitation on water resources. Impact.

Considering the topography and geomorphology of Fengtai District is more obvious from northwest to southeast, and the rainfall station is unevenly distributed in this area. In this paper, the Tyson polygon is used to calculate the average rainfall in the area, and the ArcGIS software is used to plot the Kriging interpolation contour map of rainfall [9-10]. The calculation results are shown in Figure. 3, Figure. 4, Figure. 5, Figure. 6, and Table 5, respectively.

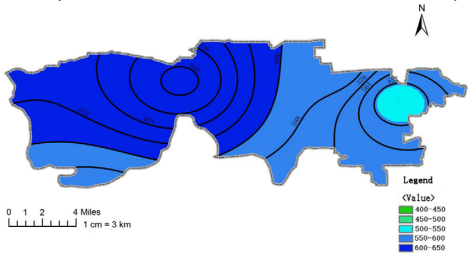

Figure.3 Contour distribution of mean annual rainfall in Fengtai district from 1956 to 1998

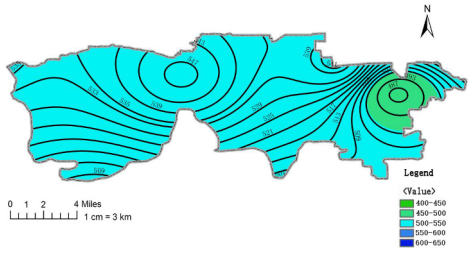

Figure.4 Contour distribution of mean annual rainfall in Fengtai district from 1981 to 2016

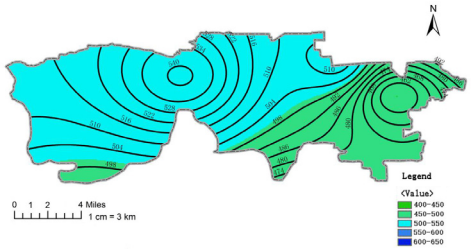

Figure.5 Contour distribution of mean annual rainfall in Fengtai district from 2001 to 2016

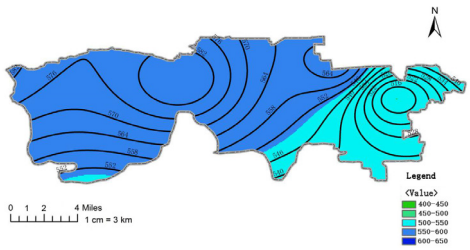

Figure.6 Contour distribution of mean annual rainfall in Fengtai district from 1956 to 2016

Table.5 Comparison of annual average rainfall over different periods in Fengtai district

Year / Rainfall	1956a~2016a	1956a~1998a	1981a~2016a	2001a~2016a
Rainfall（mm）	569.5	599.5	534.3	516.7

From the four different years of average annual rainfall contour maps, it can be seen that the rainfall from 1981 to 2016 and 2001 to 2016 is significantly decreased compared with the rainfall from 1956 to 1998 and from 1956 to 2016. And the precipitation distribution from 2001 to 2016 is less than the rainfall from 1981 to 2016. In addition, it can be seen from the series of pictures that the overall distribution of precipitation gradually decreases from northwest to southeast, and is directly related to the topographical features of Fengtai District.

Table 5 shows that the precipitation from 2001 to 2016 decreased by 17.6 mm from 1981 to 2016, and decreased by 65.2 mm from 1981 to 2016 compared with 1956 to 1998, which visually reflects the second water. Since the evaluation of resource surveys, the average

precipitation is small, which is the main reason for the decrease in total water resources.

4.2 Yongding River cutoff

Yongding River is the largest transit river in Fengtai District. Since 2000, it has continued to cut off water. Particularly, Yongding River implemented the "Yongding River Green Ecological Development Belt Construction Project" in 2010. In order to maintain the anti-seepage project on the water surface of the river, further the actual infiltration replenishment of the Yongding River has been reduced, which has reduced the infiltration of groundwater in Fengtai District.

The calculation of the infiltration of the Yongding River is based on the Lugou Bridge and Gu'an as the upper and lower sections respectively. After deducting the amount of water drawn from the interval, the factor of reduction is 0.9 (according to the evaporation loss), and the difference in permeability of the river section is considered. The calculation results are shown in Table 5. The results show that the infiltration of the Yongding River Fengtai District is mainly concentrated in 1978-2000. Except for the water cuts in a few years from 1992 to 1994 and 1999, there are certain river sections in other years. Infiltration, the infiltration of the Fengtai section of the period from 1978 to 1984 and 1995 to 1996 exceeded 10 million cubic meters; but since 2000, the Yongding River has been shut down in successive years, and the groundwater infiltrated into the Fengtai District is no longer counted. Compared with the second water resources survey and evaluation results, the infiltration capacity of Yongding River in Fengtai District (2013 million cubic meters) decreased by 8.99 million cubic meters, which is one of the main factors leading to the decrease of total water resources in Fengtai District. The infiltration of the Yongding River in Fengtai District over the years can be seen in the Table 6.

Table.6 Annual infiltration of yongding river in Fengtai district

Year	Lugou bridge annual runoff (million m^3)	Gu'an annual runoff (million m^3)	Interval introduction (million m^3)	Interval infiltration (million m^3)	Infiltration in Fengtai district (million m^3)
1978	185.00	0.06	0.00	184.94	49.71
1979	594.00	244.00	0.00	350.00	94.08
1980	525.00	54.30	0.00	470.70	126.52
1981	82.40	0.00	0.00	82.40	22.15
1982	66.90	0.00	0.00	66.90	17.98
1983	123.00	0.00	0.00	123.00	33.06
1984	43.20	0.00	0.00	43.20	11.61
1985	7.09	0.00	0.00	7.09	1.91
1986	1.82	0.00	0.00	1.82	0.49
1987	0.49	0.00	0.00	0.49	0.13
1988	4.51	0.00	0.00	4.51	1.21
1989	10.01	0.00	0.00	10.01	2.69
1990	7.36	0.00	0.00	7.36	1.98
1991	0.54	0.00	0.00	0.54	0.15
1992	0.00	0.00	0.00	0.00	0.00
1993	0.00	0.00	0.00	0.00	0.00
1994	0.00	0.00	0.00	0.00	0.00
1995	91.83	10.50	0.00	81.33	21.86
1996	337.10	172.20	50.00	114.90	30.88
1997	19.50	0.00	0.00	19.50	5.24
1998	3.80	0.00	0.00	3.80	1.02
1999	0.00	0.00	0.00	0.00	0.00
2000	3.00	0.00	0.00	3.00	0.81
2001	0.00	0.00	0.00	0.00	0.00
2002	0.00	0.00	0.00	0.00	0.00
2003	0.00	0.00	0.00	0.00	0.00
2004	0.00	0.00	0.00	0.00	0.00
2005	0.00	0.00	0.00	0.00	0.00
2006	0.00	0.00	0.00	0.00	0.00
2007	0.00	0.00	0.00	0.00	0.00

Year	Lugou bridge annual runoff (million m^3)	Gu'an annual runoff (million m^3)	Interval introduction (million m^3)	Interval infiltration (million m^3)	Infiltration in Fengtai district (million m^3)
2008	0.00	0.00	0.00	0.00	0.00
2009	0.00	0.00	0.00	0.00	0.00
2010	0.00	0.00	0.00	0.00	0.00
2011	0.00	0.00	0.00	0.00	0.00
2012	0.00	0.00	0.00	0.00	0.00
2013	0.00	0.00	0.00	0.00	0.00
2014	0.00	0.00	0.00	0.00	0.00
2015	0.00	0.00	0.00	0.00	0.00
2016	0.00	0.00	0.00	0.00	0.00
Total	2106.55	481.06	50.00	1575.49	423.48
Average	55.44	12.66	1.32	41.46	11.14

5 Conclusion

(1) As the statistical analysis of Fengtai District data from 1956 to 2016 shows, the surface water resources of Fengtai District in the past 61 years was 37.78 million cubic meters, which was 2.572 million cubic meters less than the previous survey; the groundwater resources were 92.959 million cubic meters, a decrease of 13.848 million cubic meters; The total amount of water resources was 104.981 million cubic meters, which was 13.83 million cubic meters less than the previous survey.

(2) The regional atmospheric precipitation is gradually decreasing. The average annual rainfall in the past 16 years is 516.7mm, which is 14% less than the multi-year average of the previous survey (599.5mm in the 1956-1998 series), which is caused by surface runoff and the main reason for the decrease in rainfall infiltration recharge.

(3) The impact of human activities on the amount of water resources in Fengtai District has increased. The Yongding River has been shut off since 2000. The anti-seepage project implemented in 2010 has led to a significant reduction in underground infiltration recharge, which in turn has affected the amount of groundwater resources.

Acknowledgement

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