Evaluation of shallow groundwater resources in Xiangfuzhu water source, Yuanyang county

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Abstract

In order to find out the status of shallow groundwater resources in Xiangfuzhu water source, the total amount of shallow groundwater resources was calculated and analyzed.The results show that the annual total recharge of shallow groundwater is 26.48 million m3/a， the excretion is 24.56 million m3/a, and the equilibrium difference is 1.92 million m3/a，using the water balance method.The calculated water level in the equilibrium area is close to the measured water level, indicating that the calculated parameters are reasonable and the calculated recharge and excretion are reliable.The shallow groundwater in the study area is abundant in water and good in water quality, which is suitable for production and use, providing a scientific basis for water resources management, development and utilization in the region.

Keywords

Water source,Shallow groundwater,Water resources assessment,Water balance method.

1. Introduction

Shallow groundwater resources are the main water supply source in Yuanyang County[1]。In recent years, due to the unique geographical advantages in the integration development of Zhengzhou and Xinxiang, Yuanyang County ushered in the opportunity of rapid development, urban construction developed rapidly, and the scale of urban water supply population expanded rapidly. There is a large gap in urban water demand in the future.According to the original plan, it is planned to construct the water diversion project of the Yellow River in the south of Yuanyang County to meet the demand of urban water supply, but it was terminated due to the impact of the project on the construction of the central city.Therefore, according to the new plan, it is proposed to construct a groundwater source near the Xiangfuzhu Yellow River Project to realize the joint dispatch of surface water and groundwater to form a dual-source water supply pattern and improve the guarantee of urban water supply.There are many hydrological survey data in the study area, but there is no complete evaluation of groundwater resources. This paper makes full use of the hydrological and hydrogeological data of Yuanyang County for many years, and the research results of the predecessors, in order to study the production and living water supply in the study area, shallow for the study area. [2]The groundwater resources are evaluated and the scientific basis for the development and utilization of water resources in the region is provided.

2. Overview of the research area

Yuanyang County is located in the northern part of Henan Province, on the north bank of the Yellow River, separated from the provincial capital Zhengzhou by a river. The county is 60km long from east to west and 20km wide from north to south. The total land area is 1339 km2. It is located between 113°35´-114°15´east longitude and 34°53´-35°11´north latitude. Xiangfuzhu water source is located about 15km southeast of Yuanyang County. Its scope is centered on the lead Yellow River water storage pool tank of Xiangfuzhu, about 10km from east to west, 6km from north to south, and about 60km.The study area is located in the Central Plains of the Yellow River Basin and is a continental monsoon climate. The average annual temperature is 14ºC, the average annual precipitation is

637.80mm, and the average annual evaporation is 1701mm. The relative humidity is 66.25% and the absolute humidity is 12.89Mpa. The strata of the study area belong to the North China strata. The study area is located in the alluvial plain of the Yellow River, and Quaternary loose deposits are widely distributed in the area. The Quaternary system is well developed in the area, with complete formations and extensive distribution. It is composed of loose sediments with a total thickness of about 400m.The aquifer of Xiangfuzhu water source is a shallow aquifer group, and the aquifer is mainly composed of sand layer, which is mainly composed of all kinds of sand layers of upper pleistocene and Holocene, mostly three layers, and the thickness distribution of weak aquifer in the middle is uneven. The top of the upper sand layer generally has a fine sand layer with a thickness of nearly 10 m. The deposition conditions are similar and the stratigraphic structure is similar. The depth of the bottom plate is about 100m. The shallow aquifer above 100m is mainly the Quaternary Upper Pleistocene and the Holocene Yellow River alluvial deposit. The thickness of the aquifer is about 60m.

3. Groundwater resource calculation

According to the topography, geomorphology, hydrogeological conditions of the water source and the scope of impact of the water source after mining, the scope of the water source evaluation calculation is determined: The southern part is bounded by the Yellow River embankment， The West is bounded by the Song Dabin and Xiao Dabin， The north side is bounded by Jiawan, Liuyuan and Nanliuhou， The east side is bounded by Dawuzhuang and Doummen Township， Area 58.00km^2.

3.1 Determination of calculation parameters

The selection of the selected parameters of this calculation mainly refers to the results of the "Hydrogeological Exploration Report of Guanchang, Zhulou, Yuanwu Water Source, Yuanyang County, Henan Province" and the results of the pumping test conducted this time.The main values of hydrogeological parameters are:specific yield(μ)is 0.1;hydraulic conductivity(K)is 30m/d;Precipitation infiltration coefficient(α)is 0.23;Irrigation back permeability coefficient(β)is 0.15;Hydraulic gradient(I)is 0.18.

3.2 Establishment of groundwater equilibrium equation

According to the principle of groundwater balance[4]， Based on the recharge, runoff and discharge conditions of shallow groundwater in this area, the equilibrium equation is established as follows:

$$Q_{supply} - Q_{excretion} = \mu \cdot F \cdot \frac{H}{\Delta t}$$

among them:

$$Q_{supply} = Q_{River} + Q_{Precipitaton} + Q_{Irrigation} + Q_{runoff} + Q_{Canal}$$

$$Q_{excretion} = Q_{Mining} + Q_{evaporatin} + Q_{Runoffexcretion}$$

In the above formula:Q_{supply} is the total recharge of groundwater（million m^3/a）; $Q_{excretion}$ is the total excretion of groundwater（million m^3/a）; μ is the specific yield; F is the area of the equilibrium area（km^2）; △t is the equilibrium time; H is the water level variation corresponding to △t;Q_{River} is the lateral recharge of the Yellow Rive（million m^3/a）; $Q_{Precipitation}$ is the precipitation infiltration recharge (million m^3/a); $Q_{Irrigation}$ is the Irrigation permeation recharge(million m^3/a);Q_{runoff} is the Groundwater lateral runoff recharge（million m^3/a）; Q_{Canal} is the Canal infiltration replenishment（million m^3/a）; Q_{Mining} is the amount of industrial, agricultural and domestic water exploitation（million m^3/a）; $Q_{evaporation}$ is the amount of evaporation（million m^3/a）; $Q_{Runoff\ excretion}$ is the lateral runoff excretion（million m^3/a）.

3.3 Calculation of groundwater recharge

The total recharge of groundwater is the sum of lateral infiltration of the Yellow River, precipitation infiltration, irrigation permeation， lateral runoff， and canal infiltration replenishment[5].

3.3.1 The lateral recharge of the Yellow Rive

The south side of the water source is adjacent to the Yellow River embankment. Under the current conditions, the Yellow River replenishes the groundwater in the form of lateral seepage, and uses the Darcy formula to calculate the lateral recharge of the Yellow River:

$Q_{River}=K \cdot M \cdot I \cdot L$

In the above formula: Q_{River} is the lateral recharge of the Yellow Rive (million m^3/a); K is the average permeability coefficient of the calculated section (m/d); M is the average aquifer thickness of the calculated section (m); I is to calculate the average hydraulic gradient of the section (%); L is the calculated section length (km).

3.3.2 Precipitation infiltration recharge

The amount of precipitation is substituted into the following formula to calculate the amount of precipitation infiltration replenishment.

$Q_{Precipitation}=Pi \cdot \alpha \cdot F$

In the above formula: $Q_{Precipitation}$ is the precipitation infiltration recharge (million m^3/a); Pi is the amount of precipitation during the equilibrium period (mm); α is the atmospheric precipitation infiltration coefficient of the equilibrium zone; F is the area of the equilibrium area (km^2).

3.3.3 Irrigation permeation recharge

According to irrigation quota, irrigated area and related agricultural production data, the irrigation permeation recharge is calculated by the following formula.

$Q_{Irrigation}=\beta \cdot F \cdot A$

In the above formula: $Q_{Irrigation}$ is the Irrigation permeation recharge (million m^3/a); β is the irrigation coefficient; F is the area of irrigation; A is the quota for irrigation.

3.3.4 Groundwater lateral runoff recharge

$Q_{runoff} = K \cdot B \cdot M \cdot I$

In the above formula: Q_{runoff} is the groundwater lateral runoff recharge (million m^3/a); K is the average permeability coefficient of the calculated section (m/d); B is the calculated section length (km); M is the average aquifer thickness of the calculated section (m); I is to calculate the average hydraulic gradient of the section (%).

3.3.5 Canal infiltration replenishment

The natural canal flows through the Xiangfuzhu water source. Because of the siltation, the current riverbed is higher than the groundwater level on both sides, and the river water infiltration replenishes the groundwater. The calculation formula is:

$$Q_{Canal} = 86400 \cdot \varepsilon \cdot \sigma \cdot L \cdot \Delta t$$

In the above formula: Q_{Canal} is the Canal infiltration replenishment (million m^3/a); ε is the correction coefficient of seepage loss of lining channel (according to anti-seepage measures, lining ε is between 0.05~0.70, unlined ε is 1); σ is the water loss rate within the unit length of the canal (%/km); L is the length of the canal(km); $\triangle t$ is the time(d/a).

3.4 Calculation of groundwater excretion

The total excretion of groundwater is the sum of industrial, agricultural and domestic water exploitation, lateral runoff excretion and groundwater evaporation[5].

3.4.1 Industrial, agricultural and domestic water exploitation

The amount of agricultural exploitation in the study area is calculated based on the statistical irrigated area and the irrigation quota. Domestic water consumption According to the survey data, the daily water consumption is calculated according to $0.1m^3$ per capita per day. The amount of township industrial exploitation is calculated based on statistical data.

3.4.2 lateral runoff excretion

$$Q_{Runoff\ excretion} = K \cdot B \cdot M \cdot I$$

In the above formula: $Q_{Runoff\ excretion}$ is the lateral runoff excretion (million m^3/a); K is the average permeability coefficient of the calculated section (m/d); B is the calculated section length (km); M is the average aquifer thickness of the calculated section (m); I is to calculate the average hydraulic gradient of the section (%).

3.4.3 Shallow groundwater evaporation

The evaporation coefficient of the dive is related to the buried depth of the groundwater level[6].When the water level is buried more than 4m, evaporation is weak and is considered as non-evaporation. The shallow groundwater level in the study area is generally less than 4 m, and the maximum groundwater level is 4 m. The surface lithology of the study area is mostly silt, and the groundwater evaporation is strong. The evaporation amount is calculated by the following formula:

$$Q_{evaporation} = \varepsilon \cdot F$$

$$\varepsilon = \varepsilon_0 \bullet \left(1 - \frac{\overline{\Delta}}{\Delta_0}\right)^n$$

In the above formula: $Q_{evaporation}$ is the amount of evaporation(million m^3/a); ε is the evaporation intensity of groundwater(m/a); ε_0 is the water surface evaporation intensity at the corresponding time(m/a); F is the area of the equilibrium area(km^2); $\overline{\Delta}$ is the average water level depth(m); n is the lithology-related index, and the silt is 1; Δ_0 is the shallow groundwater level evaporation limit depth(m).(When $\overline{\Delta} > \Delta_0$, take Δ_0)

3.5 Annual equilibrium calculation

The following conclusions are drawn from the annual equilibrium calculation of the study area. The total amount of groundwater recharge is 26.48 million m^3/a, The total amount of groundwater excretion is 24.56 million m^3/a, Groundwater recharge is greater than excretion, and the equilibrium difference is 1.92 million m^3/a. The corresponding water table should rise by 0.33m.The measured value of the measured water level rise in the long-term observation well on the 23rd in Taiping Town is 0.49m.The calculated water level is close to the measured water level, indicating that the calculated parameters are reasonable, and the calculation of each replenishment and consumption is consistent with the actual situation. The results of the equilibrium calculation are shown in Table 1.

Table 1.Annual equilibrium calculation result

Recharge		Excretion	
Project	Units million m^3/a	Project	Units million m^3/a
lateral recharge of the Yellow Rive	11.83	Agricultural exploitation	4.31
precipitation infiltration recharge	6.88	Industrial water exploitation	3.02
Irrigation permeation recharge	3.94	Domestic water exploitation	4.13
lateral runoff recharge	3.61	lateral runoff excretion	4.48
Canal infiltration replenishment	0.22	Evaporation	8.62
Total	26.48	Total	24.56
Balance difference		1.92	
Balanced calculation comparison			

<table>
<tr><td rowspan="2">calculation</td><td>The measured value of the measured water level rise in the long-term observation well on the 23rd in Taiping Town is 0.49 meters.</td></tr>
<tr><td>$S=Q_{Balance\ difference}/\mu\cdot F$ Calculated that the groundwater level should rise by 0.33 meters</td></tr>
<tr><td>The difference between the actual water level change and the calculated water level change</td><td>0.16</td></tr>
</table>

4. Analysis of the exploitable amount of groundwater resources

The amount of groundwater that can be extracted is related to the balance of groundwater formed by recharge and discharge[7], and does not include uncompensated storage in the aquifer. Under the current mining conditions, the recharge of groundwater is mainly lateral recharge of the Yellow Rive, precipitation infiltration recharge, irrigation permeation recharge, lateral runoff recharge, canal infiltration replenishment etc. The excretion of groundwater is mainly industrial, agricultural and domestic water exploitation, lateral runoff excretion and evaporation etc. The equilibrium equation when the groundwater level reaches stability under mining conditions is:

$$\left(Q_{River}+Q_{Precipitaton}+Q_{Irrigation}+Q_{runoff}+Q_{Canal}\right)-\left(Q_{Mining}+Q_{evaporatio}+Q_{Runoffexcretion}\right)=0$$

$$Q_{Mining}=\left(Q_{River}+Q_{Precipitaton}+Q_{Irrigation}+Q_{runoff}+Q_{Canal}\right)-\left(Q_{evaporatio}+Q_{Runoffexcretion}\right)$$

In the above formula:Thelateral recharge of the Yellow Rive is 11.83million m^3/a;The precipitation infiltration recharge is 6.88million m^3/a;The irrigation permeation recharge is 3.94 million m^3/a;The lateral runoff recharge is 3.61million m^3/a;The canal infiltration replenishment is 0.22million m^3/a;The lateral runoff excretion is 4.48million m^3/a;The evaporation is 8.62million m^3/a.

The calculation results are as follows: Under the current conditions, the amount of shallow groundwater that can be mined is 11.50million m^3/a.

5. Shallow groundwater quality assessment

The shallow groundwater in the study area is mainly used as production and domestic water. Therefore, this evaluation uses "Sanitary Standard for Drinking Water"(GB/5749-2006)[8]as the evaluation standard. According to the results of groundwater sampling analysis, the shallow groundwater in the study area is divided into water chemical types such as HCO_3^-—$Ca^{2+}\cdot Mg^{2+}$, HCO_3^-—$Na^+\cdot$ $Ca^{2+}\cdot Mg^{2+}$, HCO_3^-—$Ca^{2+}\cdot Na^+\cdot Mg^{2+}$, HCO_3^-—$Ca^{2+}\cdot Mg^{2+}$and $HCO_3^-\cdot Cl^-$—$Na^+\cdot Mg^{2+}$.

According to the sanitary standards for drinking water, the evaluation of shallow groundwater drinking water in the area is as follows:

By testing the drinking water samples taken from hydrogeological boreholes in the study area, all other indicators except Fe^{3+} are in line with drinking water standards. By analyzing the water samples of drinking water wells in the study area, all other indicators except Fe^{3+},Mn^{2+} are in line with the standard of drinking water. The maximum content of Fe^{3+} is 1.67mg/L，Over the standard 5.57 times. The maximum content of Mn^{2+} is 0.31mg/L，Over the standard 3.1 times. In addition, the total hardness of individual samples is slightly exceeded. All in all, the shallow groundwater in the water source has good water quality and is suitable for drinking after proper treatment.

6. Conclusion

In order to evaluate the groundwater resources of Xiangfuzhu water source in Yuanyang County, the water balance method is used to evaluate the groundwater resources.The amount of shallow groundwater that can be mined in the study area is 11.50million m^3/a.According to the water quality analysis results, the shallow groundwater has good water quality and is suitable for production and domestic use after proper treatment.

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