Study on Groundwater Occurrence in Southern Margin of Tarim Basin, Xinjiang

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Abstract: Based on the theory of hydrogeology and with Qarqan River basin as an example, this paper analyzes the characteristics of groundwater occurrence in the southern margin of Tarim Basin in Xinjiang and discusses current situation and existing problems of its development and utilization. Countermeasures are advanced for the sustainable utilization of groundwater resources, and decision-making help is provided for optimizing the allocation of water resources and exploitation of groundwater resources in this area. On this basis, a reference for the rational development and utilization of other resources in western China is proposed.

1. Introduction

Located between Tianshan Mountain, Kunlun Mountain and Pamir Plateau, Tarim Basin is the largest inland basin in China with area of 53 × 104km2. Due to its inland location, closed terrain and extremely arid climate, the annual precipitation at the edge of the basin is about 100 ~ 400mm, and only 20 ~ 80mm inside the basin, or even less. The vegetation in the basin is sparse, and desert are widespread, including the largest desert in China, Taklimakan Desert (with area of about 3317 × 104km2) [1]. Due to the dry climate, groundwater resources are the most basic conditions for human survival in the basin. Therefore, it is of great significance to study the groundwater occurrence conditions in this area, to protect the ecological environment and promote social and economic development. Located in the southern margin of the Tarim Basin, east Kunlun Mountains and the northern foot of the Altun Mountains, Qiemo County is located between longitude 83 ° 25 '~ 87 ° 30' and latitude 35 ° 40 '~ 40 ° 10'. It is 320km wide from east to west and 460km long from north to south, with total area of 140.25km2. Qarqan River, which originates from the northern slope of Kunlun Mountains, flows through Qiemo County and forms the Qiemo oasis, whose groundwater occurrence conditions are very representative. Consequently, this paper focuses on the study of groundwater occurrence conditions in Qarqan River basin in Qiemo County.

2. Regional Overviews

2.1 Landform

The terrain and landform of Qiemo County are complicated. The overall terrain is high in the south and low in the north. From south to north, it is composed of four landform units: mountain area, alluvial fan, alluvial plain and desert. The mountain area belongs to the Qinghai-Tibet plateau, with elevation of 4000 ~ 7000m and area of 62350km2[2]. The alluvial fan and alluvial plain are high in the south and low in the north, sloping from the northwest to the southeast, with elevation of 800 ~ 1300m and terrain slope of 1.6 ~ 6.3‰, and area of 24150 km2. The desert area is 53800 km2. Human and social economic activities mainly occurs in alluvial fan and alluvial plain, with pasture in the fore-mountain zone and irrigated areas along banks of Qarqan River.

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2.2 Meteorology

The annual average temperature in Qiemo county is 10.1℃, the highest and lowest monthly average temperature are 24.8℃ and -8.7℃, respectively, and the average daily range of temperature is 15.9℃. In addition, the climate in Qiemo is extremely dry with little rain. The average annual precipitation is only 18.6mm, the maximum and minimum annual precipitation is 54.9mmand 1.9mm, respectively, and the annual evaporation is 2506.9mm. The drought index is 77, indicating an extreme arid area. The annual frost-free period is 243d, and the annual sunshine hours are 2853.2h. Northeast wind prevails throughout the year, resulting in windy, floating dust and sandstorm weather.

2.3 Hydrology

Qarqan River is the only river flowing through the Qiemo oasis, with total length of 813 km. It is an inland river flowing into the Tarim Basin, mainly replenished by melt water from glaciers of Kunlun Mountain. The topographical conditions of the source region are complex, and all tributaries originate from the spring flow, and form a deep valley after the convergence of the Tula intermountain basin, and then flow out of the mountainous area to the north. Out of mountain pass, multi-level terraces are formed by the bigger terrain slope, the gravel layer under the riverbed is below 100m, and the river water largely seeps into the sand and gravel layer. Passing the slope of the gravel plain, the valley gradually changed from deep to shallow, until the river began to drift from 12 km south of the county. After flowing 40km to the north of the county, the river flows to the northeast and finally into the Taitema lake in the heart of the desert.

3. Hydrogeological Condition

3.1 Overviews

The annual precipitation is about 100 ~ 300mm in the mountainous area of Qarqan River basin in Qiemo county, and mainly occurs over June to August in summer. Abundant precipitation forms a developed hydrological network in mountainous areas. In the process of runoff, the river continuously collects surface water and groundwater in the mountain area, and the runoff volume increases and reaches a maximum of 8.15×108m3 at the mountain pass, and then flows to the plain area. The annual precipitation in plain areas is rare, generally about 18.6mm, which has no practical significance for groundwater recharge. The main recharge source of groundwater is the river water infiltration. The groundwater recharge varies with different hydrogeological conditions. The underground water-rich areas are mainly distributed in the upper and middle part of the alluvial fan gravel belt in front of the mountain and the alluvial sloping plain, as well as in the agricultural irrigated areas along the river. The overall direction of groundwater runoff is basically the same as that of river extension, flowing from south to north. The runoff at the top is rather intense, and the hydraulic gradient is about 4.5‰, while the groundwater migration speed is relatively slow in the middle and lower part, and the hydraulic gradient is about 1.6~3.0‰. Affected by the lithology of the local aquifer, the migration speed and alternating circulation of groundwater are different, and the local groundwater is in a stagnant state, forming small marshes or salt marshes, which act as the site of vertical groundwater discharge.

3.2 The Burial and Distribution of Groundwater

According to the geophysical data and pumping test results [3], the thickness of the loose sediment in study area is from 350m to 150m in the south-north direction. The aquifer is mainly gravel strata, and the middle part is silty sand strata with a thickness of 15~50m. The thickness of aquifer gradually decreases from south to north, and the fine sand strata in the middle of the aquifer thickens gradually. In the east-west section of the vertical river channel in the middle of the irrigated area, the loose sediment is basically unchanged in the east-west direction, with a thickness of 175 ~220m. The aquifer is still mainly composed of gravel strata, and there are 20~30m silty sand strata in the middle. The buried depth of groundwater gradually becomes shallower from south

to north, from over 100m before the mountain pass to 3~5m before the front of alluvial fan. In the alluvial plain, the aquifer is composed of sand and gravel, which is characterized by simple structure, large thickness and good water storage conditions, therefore the abundant river water seepage recharges the groundwater. In the upper reaches of the irrigated areas, the surface slope is large, the water table is about 3-10m, and the TDS of groundwater is 0.6-1.9g/L. In the middle part of the irrigated area, the surface slope becomes gentle, the stratum has multiple structures, and the aquifer particles become fine mainly with medium and fine sand. The water table is between 1.0 m and 2.5 m, the TDS of groundwater is 1.0~3.0g/L, and water-abundance decreases. In the lower reaches of the irrigated area, the aquifer is dominated by fine sand, which is sandwiched between thin layers. The water table is between 0.8 m and 2.5 m, and there is local groundwater overflow. The TDS of groundwater is between 5.0~30g/L. In the eastern part of the river, the water table is generally between 1m and 3m. Due to evaporation and concentration, the water quality becomes worse, and the TDS of groundwater is between 3 g/L and 20 g/L.

Qiemo oasis has a pore aquifer system with a single structure. In particular, in the 2-8km region on both sides of Qarqan River, the phreatic water aquifer is controlled by the alluvial sedimentary law, and the sedimentary particles grow from large to small along upstream to downstream, and they gradually become thinner from south to north in the direction of the river. The area near the river is of great water abundance, and the water table is 1~3 m. In the desert zone far away from the river banks, the water table is greater than 3.0m. In the low-lying areas, the water table is less than 1m. The statistical data of different buried depth in the basin is shown in Table 1.

Table 1 the Statistical Data of Different Buried Depth in the Basin

No.	Buried Depth (m)	Area (km^2)	%	Accumulative Area (km^2)	%
1	<1	30.55	1.79	30.55	1.79
2	1~2	213.91	12.56	244.46	14.36
3	2~3	328.17	19.28	572.63	33.64
4	3~5	527.54	30.99	1100.17	64.62
5	5~10	258.58	15.19	1358.75	79.81
6	10~20	165.06	9.7	1523.81	89.51
7	>20	178.67	10.49	1702.48	100
Total		1702.477	100		

3.3 Recharge, Runoff, Discharge of Groundwater

3.3.1 Rcharge

The recharge of groundwater is mainly river water leakage, followed by the seepage of canal water and irrigation water in the irrigated area.

(1) River seepage recharge

Due to its strong water permeability, a large amount of seepage from the river water recharges the groundwater and becomes the main source of groundwater recharge when Qarqan River flows through the gravel belt. . According to the measured data, the water loss is $0.998 \times 10^8 m^3$ and the rate of water conveyance loss is 0.0041%/km from mountain pass to Bashkeqike hydropower station with the distance of 30km. The water loss is $2.07\times10^8 m^3$ and the rate of water conveyance loss is 0.0058%/km from Bashkeqike hydropower station to Qiemo hydrometric station with the distance of 50km.

(2) Channel leakage

The annual intake amount is $2.57\times10^8 m^3$ in the irrigation area. The canal system water conveyance way is long, and the leakage quantity is large for lack of effective anti-seepage measure in the majority of the channel.

(3) Irrigation water leakage

There are 2.28×10^4ha of farmland and forest in the irrigated area. Most of the ploughed layer is silty soil and silty sand soil. The average permeability coefficient is 1.8m/d, hence, the amount of leakage is large.

3.3.2 Runoff

The flow direction of groundwater in the basin is basically the same as that of the river and the terrain slope, which is from south to north. Affected by the low terrain of Qarqan River, the river channel becomes the main drainage of groundwater. Generally, the hydraulic gradient decreases gradually from upstream to downstream: 3.0-5% in the southern plain region, 3.0-2.0% in the oasis and the downstream region. Due to the relatively poor horizontal runoff conditions, the groundwater migration speed is slow, the buried depth of groundwater is very shallow, and several small pieces of swamp wetlands were formed. In those areas, the groundwater discharge is mainly vertical.

3.3.3 Discharge

The way of groundwater discharge includes evaporation in aeration zone, wetland, flow into the river and drain, evapotranspiration from vegetation, artificial exploitation etc. The climate of the study area is quiet dry with an average annual evaporation of 2506.9 mm (E20); and evaporation is the main way of drainage for the shallow buried underground water. The current annual average groundwater withdrawal is about 986 x 10^4 m^3, mainly applied to irrigation, industry and domestic water.

4. Hydrogeological Division

The units-inflow is 2.9~30.0 $m^3/h \cdot m$ in study area. According to dividing standards [4], the water-abundance is of good or medium standard, as shown in Fig.1. The top and middle of alluvial plain are of great water-abundance, its aquifer with thick particles has good permeability and water storage performance; groundwater can flow freely in this area. The area of great water-abundance distributes about 3 to 5 kilometers along either side of Qarqan River, the water-abundance is good because of the multi-layer structure in the aquifer of this area. The area of medium water-abundance located 6 km outside the Banks of Qarqan, and its groundwater recharge conditions is poor, the particles forming the aquifer are fine and hence its water permeability and water storage are relatively poor.

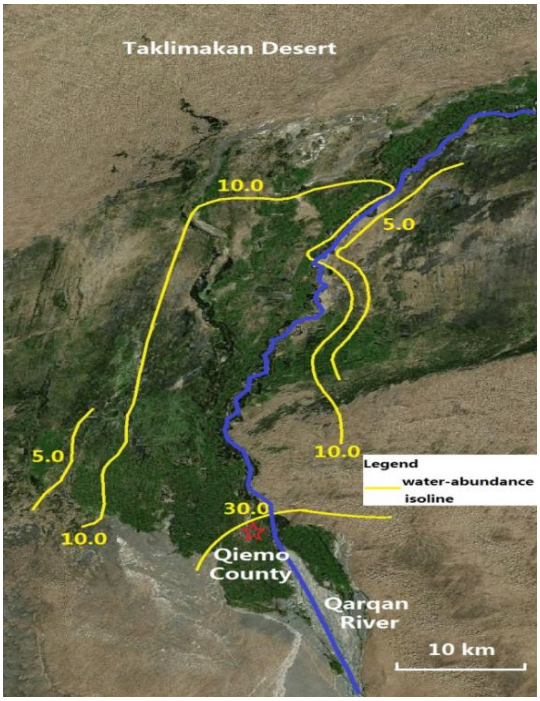

Fig.1 Sketch Map of Groundwater Division

5. Conclusions

In summary, the region of about 3 to 5 kilometers along either side of Qarqan River, is suitable

for groundwater exploitation. The aquifer with multi-layer structure has good permeability and water storage performance, and pump-output of single well is large by pumping test. However, scientific and reasonable plans for exploitation and water conservation should be made during the exploitation of groundwater resources. Especially, water saving in field should be strengthened so as to reserve enough water for the ecological environment and promote the harmony of human and nature.

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