A Study on Water Resource Allocation in Jinghuiqu Irrigation Area

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Abstract. In Jinghuiqu irrigation area, improper use of groundwater leads to continuous decline of water level. To simulate the water flow in the area, a two-dimensional model of transient flow of groundwater in the area is developed. Use the model to simulate the water field in the area in 2030, the results show that the buried depth of groundwater will be more than 20m in upstream area basically, and between 5m and 10 m in downstream area basically. Based on the water demand, a water resource allocation plan is proposed. Simulation results show that the water level will recover to a rational degree in 2042 using the allocation plan.

Introduction

Water resource is an essential part for human life and social development. As one of the most important resources, water is drawing more and more attention from the public. Water shortage has had a serious impact on social economy and people's life, especially on agricultural production [1]. In arid and semiarid areas of north China, shortage of water resources and low utilization of water resources lead to regional drought vulnerability, which seriously hindered the development of agriculture in the area [2]. At the same time, lack of scientific and reasonable planning leads to long-term unreasonable exploitation and utilization of water resources. It seriously affected the sustainable utilization of water resources and produces a series of ecological environment problems.

In some places unreasonable exploitation of groundwater has already led to continuous decline of underground water level. If this situation continues, more and more environmental problems will occur. So, to recover the declined groundwater level is imperative. The objectives of this study were to: (a) develop a model by Visual MODFLOW to simulate the flow of groundwater in the area. (b) Using the established model to predict groundwater level. (c) Proposing a water allocation plan for irrigation to properly improve the underground water level.

Study Area

Jinghuiqu irrigation area is located in the middle of Guanzhong Plain, northwest China. The district's latitude ranges from 34°25'20'' to 34°41'40''N, while its longitude ranges from 108°34'34'' to 109°21'35''E[3]. It includes six counties and forty eight towns. It's one of the grain, cotton and non-staple food production bases in Shaanxi Province. Jinghuiqu irrigation area employed well-channel irrigation mode. Surface water used to irrigate mainly comes from Jinghe River. Groundwater is Quaternary unconsolidated rock pore water. The recharge condition of groundwater is good and water quantity is abundan[4]. In recent decades, influenced by arid climate, the amount of precipitation and river water is decreasing. In well-channel irrigation area, lack of unified planning and optimization deployment leads to deficient use of surface water and serious overexploitation of groundwater. So, water table lowers greatly in recent decades, as shown in Fig.1, making the sustainable utilization of water resources in Jinghuiqu irrigation area impossible[5].

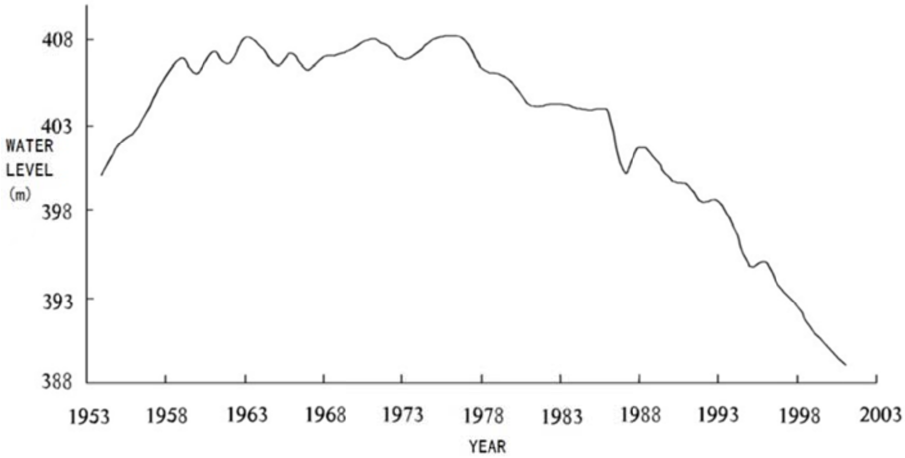

Fig. 1 Interannual variability of water level in Jinghuiqu irrigation area

Model of Groundwater

Model Development. The simulated area is bound to the southwest by Jinghe River, to the southeast by Weihe River, to the east by Shichuanhe River, to the northwest and part of northeast by the Loess Plateau. It's about 10 km long from east to west and 1.5 km wide from south to north, covering an area of about 1390 km^2. The water used to irrigate in the area is phreatic water, so the aquifer system is conceptualized as a layer, namely the unconfined aquifer. The southeast, southwest, and east boundaries are conceptualized as rivers. Northwest and part of northeast boundaries are conceptualized as constant flow boundary. After analyzing hydrogeological data and predecessors' research results, the study area is divided into seven hydrogeological parameter areas, see Fig.2.

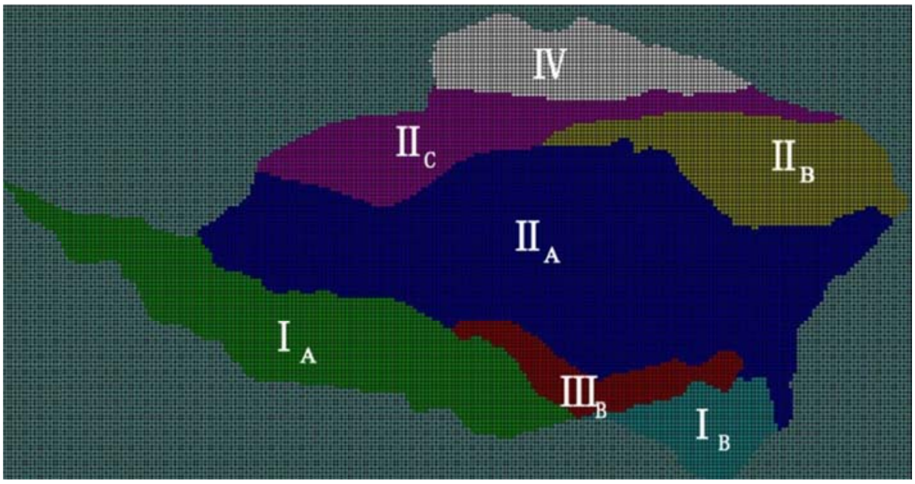

Fig. 2 Different hydrogeological parameter zones in the model

Recharge module is used to add precipitation into the model. Meanwhile, other recharge that almost covers the whole study area such as canal seepage, irrigation infiltration and well irrigation regression canal system is also added into the model by recharge module. Evaporation is simulated by Evapotranspiration (EVT) module in Visual MODFLOW, and limit depth of phreatic evaporation is 7 m.

Interpolating the measured water level data of January 1990 and use it as initial water level of the model.

Calibration of the Model. Take the data from January 1990 to January 2000 into the model, including exploitation, excretion, boundary conditions and hydrogeological information to calibrate parameters. After constantly adjustment, the result became acceptable. The comparison of simulated and measured groundwater flow field in January 2000 is shown in Fig.3.

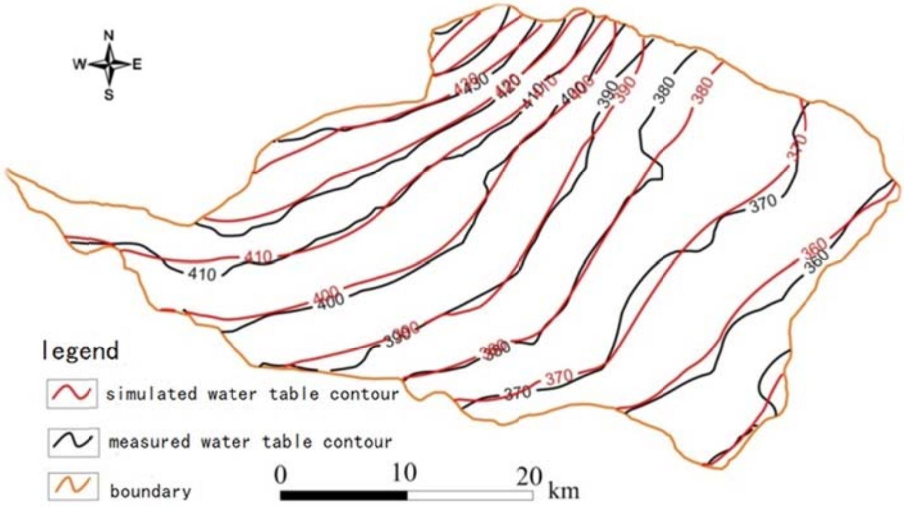

Fig. 3 The comparison of simulated and measured groundwater flow field in January 2000

It can be seen that the simulated flow field is consistent with the measured flow field. Therefore, the established model is able to accurately reflect the actual situation of study area, and can be used to forecast groundwater level in the area.

Test of the Model. Take the data from January 2000 to August 2013 into the model to calculate the water table in August 2013. Measured water level of January 2000 is regarded as initial water level. Use the observed groundwater flow field in August 2013 as a test, to verify the rationality of model parameters and conceptualization of hydrogeological conditions. The comparison of calculated and measured groundwater flow field in August 2013 is shown in Fig.4.

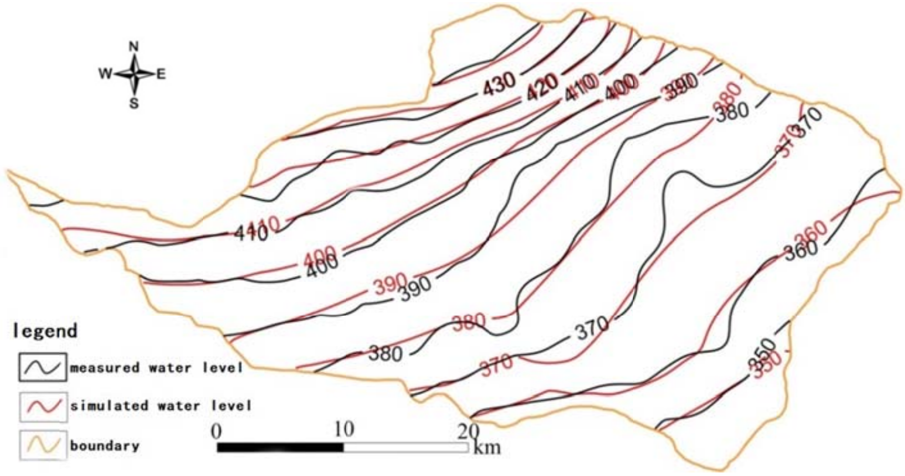

Fig. 4 The comparison of simulated and measured groundwater flow field in August 2013

It can be seen that two flow fields are similar and the result is acceptable. Therefore, the established model is suitable to predict water level in the future.

Water Resources Allocation

Aim of Water Resources Allocation. Since the 1980s, the irrigation area relies on groundwater to irrigation, resulted in continuous decline of water level. On average, buried depth deepens 5m every decade. From 1980s to 2013, the average buried depth increases from 3~5m to 20m. In some places, the buried depth is even more than 40m.

If current groundwater exploitation continues, buried depth will increase further. Use the established model to predict groundwater flow field in 2030. Prediction of buried depth of groundwater in 2030 is shown in Fig.5。

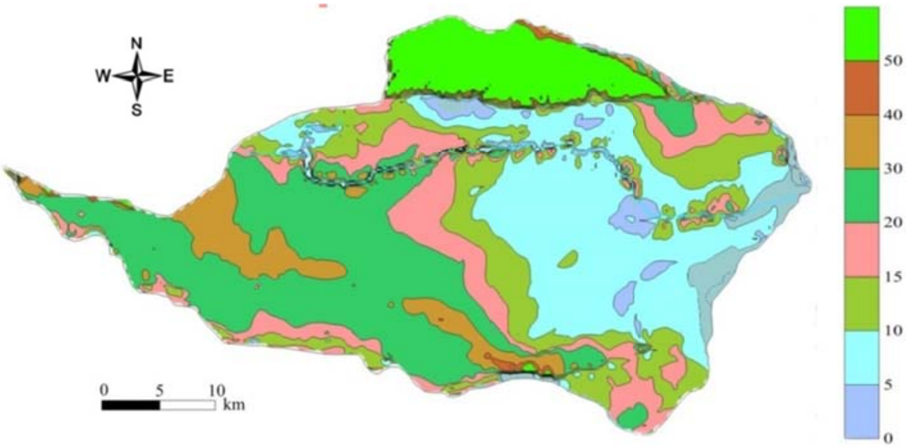

Fig.5 Prediction of buried depth of groundwater in 2030

It's obvious that until 2030, in upstream area, the buried depth of groundwater will be more than 20m basically, and in downstream area, between 5m and 10 m basically. To improve the ability to deal with long time drought event, ensure sustainable utilization of water resources in the area, this article will focus on solving the problem of insufficient irrigation water by water resources allocation after the completion of the Dongzhuang Reservoir. Groundwater level in the area should be recovered to a reasonable level by water resources allocation. Soil salinization caused by high water level should be considered. So water level should be recovered to 5-10 m in most places. For some geomorphic units, buried depth can reach 10m to 15 m. The buried depth of groundwater can be more than 20m in a few place besides loess tableland area.

Calculation of Water Demand. Assume that in the future, crops planting structure and crop planting area in irrigation area are the same as in 2010. Until 2030 irrigation water use coefficient reached 0.624 through the implementation of water saving measures and the improvement of the management. Based on the crop planting structure, irrigation program, and related government documents, net irrigation water requirement for crops is calculated.

Analysis of Water Resources Allocation. In recovery period, irrigation water all comes from Qushou Reservoir and Dongzhuang Reservoir. Assume that Dongzhuang Reservoir starts to run in August 2030, based on the buried depth of groundwater in August 2030 and hydrogeological division, the study area is redivided into 13 zones, see Fig.6. In the area that buried depth is between 5m and 10m, groundwater can be exploited in irrigation time to stabilize the water level. Groundwater will not be used in the area that water table is embedded deeply. Suppose that the reservoir can satisfy the irrigation water requirement in each irrigation time. The supply and demand of water resources in recovery period is calculated, see Table1.

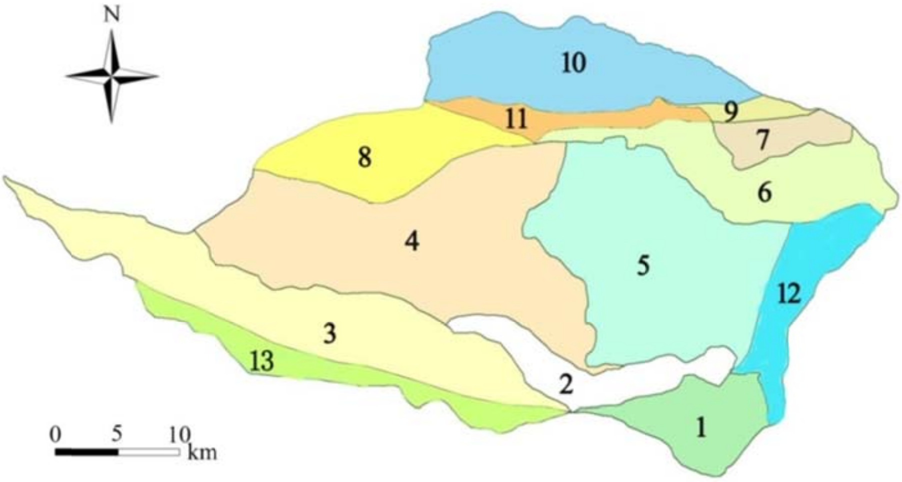

Fig.6 Different zones for water resources allocation in recovery period

Table1 The supply and demand of water resources（104m^3/year）

Zone	Water demand	Water supply		
		Surface water	Groundwater	Total
1	1001.18	1001.18	0	1001.18
2	967.48	967.48	0	967.48
3	3292.96	3292.96	0	3292.96
4	4619.59	4619.59	0	4619.59
5	3754.11	1126.23	2627.88	3754.11
6	1684.42	0	1684.42	1684.42
7	472	472	0	472
8	1453.3	1017.31	435.99	1453.3
9	200.23	0	200.23	200.23
10	2245.35	2245.35	0	2245.35
11	521.98	260.99	260.99	521.98
12	1069.06	106.91	962.15	1069.06
13	791.09	553.763	237.327	791.09

The established model is used to simulate this water allocation plan. The results show that, groundwater level will recover to a reasonable degree basically in 2042. Water balance condition between 2030 and 2042 in the irrigation area is shown in Fig.7. Buried depth of groundwater in 2042 is shown in Fig.8.

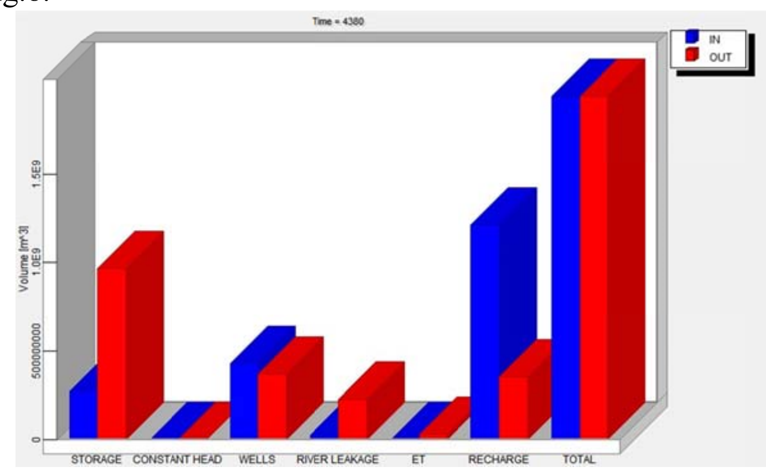

Fig.7 Water balance condition between 2030 and 2042

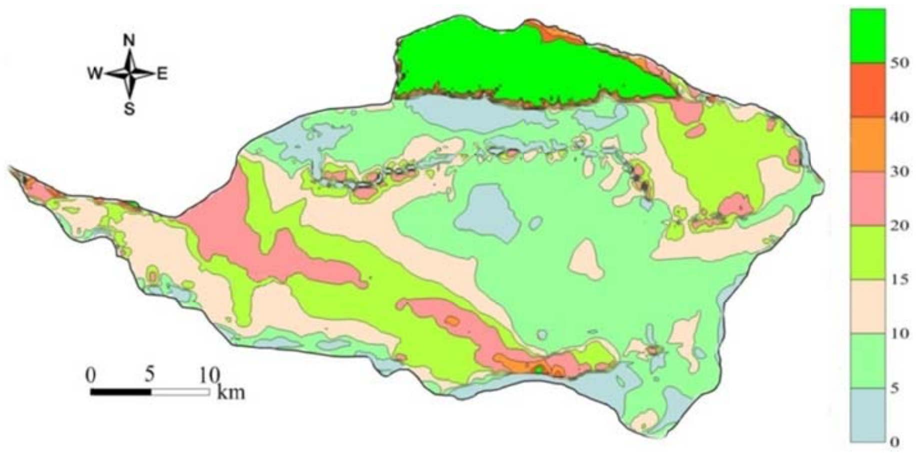

Fig.8 Buried depth of groundwater in 2042

It can be seen that due to a little exploitation of groundwater and heavy use of surface water, recharge condition of groundwater is good. Groundwater recovers effectively by the year 2042, buried depth is between 5m and 10m in most places. Buried depth in most area in first terrace of Wei River and Jinghe River, as well as transition zone of north Qinghe River and loess tableland, is between 0m and 5m. Due to the terrain, in some places buried depth is more than 15m, in rare places buried depth is more than 20 m, and in loess tableland buried depth is more than 50 m.

Conclusions and Suggestions

Conclusions. (1) Use Visual MODFLOW to establish two-dimensional model of transient flow of groundwater in the study area. Measured water level of January 1990 is used as initial water level. Measured water levels of January 2000 and August 2013 are used to calibrate and test the model respectively.

(2) Using the established model to predict water level in 2030. Result shows that flow direction of groundwater does not change drastically, and buried depth keeps increasing.

(3) Assume that irrigation water all comes from Qushou Reservoir and Dongzhuang Reservoir when Dongzhuang Reservoir is accomplished in 2030. To recover the groundwater level, a water allocation plan is proposed. Simulation results show that water level will recover to a rational degree in 2042 using the allocation plan.

Suggestions. (1) Administrator should pay attention to the serious condition of groundwater level decline in Jinghuiqu irrigation area. The water allocation plan and simulation results in this paper can be used as references.

(2) There isn't enough water storage work in the irrigation area, which resulted in water deficit in dry seasons. So Dongzhuang Reservoir should be completed and put into use as soon as possible to increase water storage and adjustment ability in Jinghuiqu irrigation area.

(3) Strengthening the management of irrigation area and reform of operation system. Encouraging people to use channel water to irrigate by developing reasonable water price, and at the same time, eliminating waste of water resources.

Acknowledgments

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