Quantitative Simulation of Groundwater by Mathematical Model in Muzhu River Aquifer using GMS

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Abstract. Excessive exploitation of groundwater resources in Muzhu river aquifer has caused serious problem such as groundwater shortage and pollution. Therefore, information about the quantity of Muzhu river aquifer is an urgent necessary for optimum protection, management of groundwater resources, and stopping the future damages. In this study, the quantity of Muzhu river aquifer is investigated by numerical simulation software GMS. The numerical model for this aquifer was calibrated by observed data. Results showed these: the amount of recharge to aquifer is $12557.53 \times 10^8$ m$^3$/a, the amount of discharge from aquifer is $11805.09 \times 10^8$ m$^3$/a, and the net recharge is $752.44 \times 10^8$ m$^3$/a, it indicated that available groundwater resources have reached its limitation. Therefore, we suggested that exploitation of groundwater should be reduced and discharge from some of agricultural wells should be stopped.

1. Introduction
Muzhu River is one of the largest rivers in the eastern part of the Jiaodong Peninsula, which covers many key projects and natural landscapes in Weihai City, such as Kunyu Mountain National Forest Park, Mishan Reservoir Nature Reserve, Wendeng District, Qingwei Expressway, Wendeng South China Sea New District, Muzhus River Estuary Nature Reserve and so on. In order to fully understand the geological environment and serve the local social and economic development in Muzhu River Basin, the research area belongs to the whole Muzhus River Basin, the administrative district belongs to the south of Huancui District of Weihai City, the Lingang Economic and Technological Development Zone of Weihai City and most of the jurisdiction area of Wendeng District of Weihai City (Fig.1), namely: west of Sunzi Town, Wendeng District of Weihai City, east to Tianfu Town, Wendeng District of Weihai City, south of Yangting Town, and south to Zeku Town, Wendeng District of Weihai City, with an area of 1,416.53km$^2$. The geographical coordinates of the extremum are: longitude $121^\circ 42' 00''$-$122^\circ 13' 00''$ E, latitude $36^\circ 52' 00''$-$37^\circ 24' 00''$ N.
2. Overview of the Study Area
Muzhu river basin belongs to the ludong hilly hydrological geological area, the area of magmatic rocks is widely distributed, the Quaternary distribution area is small, the thickness is thin, mainly along the intermountain valley and coastal strip spread, groundwater resources are relatively scarce. According to the difference of geomorphology, tectonic characteristics, types of water-bearing rock formation, rich water and groundwater movement law in this area, Kunyushan-Weideshan is taken as the watershed, which can be divided into the hydrogeological sub-region of the north slope of Jiaobei uplift and the hydrogeological sub-region of the south slope of Jiaonan and Jiaobei uplift.

The working area is mainly located in the hydrogeological sub-region of the south slope of Jiaonan and Jiaobei uplifts (III3), which is located south of Kunyu Mountain-Weide Mountain. The groundwater is dominated by bedrock fissure water, which belongs to the hilly fissure weakly rich water section.

3. Numerical Model of Groundwater
3.1 Conceptual model of hydrogeology
The hydrogeological conceptual model simplifies the actual hydrogeological conditions and organizes the relevant data according to the purpose of modeling, so as to be able to analyze the groundwater system and provide the basis for the establishment of the numerical simulation model of groundwater flow. Through the generalization of hydrogeological conditions, the scope and boundary conditions of the model, the hydrogeological structure, the groundwater flow field, the hydrogeological parameters and the source sink are determined, which lays the foundation for the establishment of the numerical model of groundwater.

Making the most of it collected according to the characteristics of Quaternary lithology distribution, the aquifer in the study area is generalized into two layers: The Quaternary aquifer and the bedrock weathered aquifer.
3.2 Penetration coefficient
The permeability coefficient characterizes the permeability of rock and soil and is an important parameter in groundwater resource calculation. The main methods are pumping test method, empirical value method and so on. The permeability coefficient of the aquifer is divided according to the results of this hydrogeological borehole pumping test. The permeability coefficient of the Quaternary aquifer varies from 3.0 m/d to 15.0 m/d (Figure 2), and its overall change trend changes from large to small on both sides of the Muzhu riverbed. Bedrock fissure water aquifer permeability coefficient value of 0.02 m/d.

3.3 Separation of time and space

3.3.1 Space separation. According to the aquifer structure, boundary conditions and characteristics of groundwater flow field in the study area, the study area was cut into a regular rectangular grid of 601 rows in the plane, 451 column (100 m × 100 m), of which 45568 were in the first layer and 141,756 in the second layer, as shown in Figure 3.

3.3.2 Determination of the simulation period. According to the project cycle as well as data collection, this simulation period is from January 2018 to December 2018, and the whole simulation period is divided into 12 stress periods, each stress period is one natural month, and each stress period is 2 steps. During each stress period, the strength of all source sinks remains the same.
3.4 Simulation results

By establishing the numerical model of groundwater in Muzhu River Basin from January 2018 to December 2018, the groundwater equilibrium in this area is obtained, and the total subsidy of Muzhu River Basin is $12557.53 \times 10^4$ m$^3$. Total excretion of $11,805.09 \times 10^4$ m$^3$/a, $752.44 \times 10^4$ m$^3$/a, showing positive equilibrium as a whole.

It can be seen from the equilibrium table that the main source of groundwater recharge in the region is atmospheric precipitation recharge, and the infiltration recharge is $11745.55 \times 10^4$ m$^3$/a, which is 93.53 percent of the total replenishment. Submersible evaporation is the main expenditure term of groundwater discharge, with an evaporation capacity of $8619.80 \times 10^4$ m$^3$/a, which is 73.43 percent of the total excretion, followed by agricultural mining $2230.47 \times 10^4$ m$^3$ which is 18.19 percent.
4. Conclusions
(1) The spatial structure of the aquifer system is systematically divided, and the pore aquifer formation of loose rock is zonal along the gully zone, with a depth of 2~11 m at the bottom, which is the main water-rich rock formation in the region. The bedrock fissure aquifer group is distributed in the hilly area on both sides of the gully. The bottom interface is buried at a depth of 30~40 m, the aquifer is rich in water, and the water supply is of little significance. The boundary characteristics of groundwater system in Muzhu river basin were identified. Regional groundwater recharge, runoff, discharge conditions and characteristics of groundwater dynamic change were identified.

(2) A three-dimensional groundwater flow model was established for Muzhu River Basin. Calculation of Muzhu River Basin Total replenishment of $1.2557.53 \times 10^4$ m$^3$. Total excretion of $1.1805.09 \times 10^4$ m$^3$/a, $752.44 \times 10^4$ m$^3$/a, showing positive equilibrium as a whole.

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References

[1] Yan Ping, Xing Fang, Xu Shiguang, Chen Fei. Numerical simulation of groundwater pollution in a tailings pond in Baoshan based on gms software [j]. Geological Hazards and Environmental Protection, 2019, 30 (03): 102-107.

This reference has two entries but the second one is not numbered (it uses the ‘Reference (no number)’ style.

[2] Tai Ningning, Li Yingshu, Xu Shiguang, Shen Qiu. Application of gms in numerical simulation and prediction of groundwater solute transport——Taking the construction of a reservoir in an irrigation district in Longchuan County, Yunnan as an example [j]. China Water Transport (second half), 2019, 19 (07): 74-76.

[3] Bai Xue. Analysis and Evaluation of Groundwater Resources in Xinghe Logistics Park, Wulanchabu City, Inner Mongolia [d]. China University of Geosciences (Beijing), 2019.

[4] Chen Jingjing, Han Qiangqiang, Li Ying. Application of gms software in groundwater resource evaluation of Ligang water source area [j]. Groundwater, 2018, 40 (04): 25-28 + 51.

[5] Wang Tingting. Numerical simulation of groundwater in a mining area based on gms [d]. Chinese Academy of Radiation Protection, 2018.

[6] Fan Shanshan. Application of gms in groundwater resources evaluation of water source [j]. Journal of China Environmental Management College, 2017, 27 (04): 52-56.

[7] Zuo Depeng, Xu Zongxue, Li Fulin, Zhang Mingfang, Liu Pin. Study on the spatiotemporal characteristics of water resources in the sow river basin based on the swat model [j]. Journal of Beijing Normal University (Natural Science Edition), 2014, 50 (05): 461-466.

[8] Chen Yan. Simulation of runoff in sow river basin based on gis and swat model [d]. China University of Mining and Technology, 2014.

[9] Liu Hongling. Water environmental capacity of major rivers in the Jiaodong Peninsula and its application [d]. Shandong Normal University, 2008.

[10] Qu Yanhua, Cui Wenke, Sun Tao. Establishment and Application of Water Quality Model for the East Sow River [j]. Shandong Environment, 1994 (05): 23-25