Evaluation of Groundwater Exploitation Scheme in Water Source Area of Kang Ping Power Plant Based on GMS

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Abstract. On the basis of finding out the existing conditions of groundwater in the source area of Kang Ping power plant, GMS is used to construct the 3D perspective of aquifer structure and the numerical simulation model of groundwater flow system. According to the water demand of the water source area, two mining schemes are proposed. Based on GMS software, the groundwater flow field evolution of the two mining schemes in the study area from 2019 to 2022 is simulated by using the model. The results show that the overall groundwater level in the study area presents a stable situation under the mining condition of scheme I 9600 m³/d, and under the mining condition of scheme II 12000 m³/d, the groundwater depression funnel is expanding. It is suggested to adopt scheme I comprehensively, the water supply capacity can be guaranteed, and the mining volume can be appropriately expanded in case of large water demand, but it should not exceed 12000 m³/d.

1. Introduction
Groundwater numerical simulation methods have been widely used at home and abroad. As a representative of groundwater simulation software, GMS is the most widely used [1-3]. Kangping County is located in the northern part of Liaoning Province. In order to help Kangping County to get rid of poverty and become rich quickly, according to Kangping County’s location at the edge of Tiefa Coal Mine and its rich coal resources, Guodian Kangping Power Plant was built in the south of Kangping County with a designed water demand of not less than 9600 m³/d. In order to solve the water source problem, it is planned to construct a water source in the Weijiawopu-Sanhepu area in the northeastern part of Kangping County. This paper uses GMS software to conduct numerical simulation of groundwater resources and forecast groundwater based on the water resources development and utilization plan of Kangping Power Plant’s water source [4-5].

2. Conditions of Occurrence of Groundwater
The study area is located in the northeast of Kangping County, about 8km away from the county seat, with an area of about 30km², as shown in Figure 1. It is located in the Liaohe alluvial first-level terrace, the Quaternary system is widely distributed, the terrain is flat and open, and the thickness of loose deposits is large, mainly containing abundant pore water. The groundwater aquifers in the area are the early Holocene alluvial facies (Q₁al) and the late Pleistocene alluvial facies (Q₃al) with medium-fine sand to medium-coarse sand with gravel. The thickness of the aquifer is generally 27-35m. According to the wellbore data in the area, GMS is used to simulate the groundwater aquifer system in the study area (Figure 2), and the perspective view of the aquifer structure (Figure 3).
3. Numerical Simulation Model of Groundwater

3.1 Hydrogeological Conceptual Model
The aquifer in the study area is a porous water-bearing medium, and there is little difference in water richness and hydrogeological parameters of each section, which can be generalized as a heterogeneous isotropic water-bearing medium. According to a comprehensive analysis of the groundwater flow field in the study area (Figure 4), groundwater moves from north to south, consistent with the slope direction of the terrain, and the natural hydraulic slope of groundwater changes little. The top boundary of the study area is a phreatic surface, which exchanges water with the outside through an aeration zone, and the bottom is Cretaceous Quantou Formation mudstone and siltstone, which can be generalized as undulating water-proof boundary; lateral boundary is generalized as artificial delineation. The second-class traffic boundary. The main source of groundwater replenishment is atmospheric precipitation infiltration replenishment, followed by lateral runoff replenishment; the main excretion method is diving evaporation and excretion, followed by lateral runoff excretion.
3.2 Mathematical Model of Groundwater Flow

Mathematical model of groundwater flow: According to the analysis of the above-mentioned hydrogeological conceptual model, the groundwater flow system in this area is generalized into a heterogeneous and isotropic, quasi-three-dimensional unsteady groundwater flow system, which can be described by the following definite solutions.

\[
\begin{align*}
\frac{\partial}{\partial x} [K(h-B) \frac{\partial h}{\partial x}] + \frac{\partial}{\partial y} [K(h-B) \frac{\partial h}{\partial y}] + \varepsilon_1(x, y, t) - \varepsilon_2(x, y, t) &= \mu \frac{\partial h}{\partial t} (x, y) \in D, t \geq 0 \\
h(x, y, 0) &= h_0(x, y) \\
K(h-B) \frac{\partial h}{\partial n} |_{z=0} &= q(x, y, t) (x, y) \in \Gamma_2, t \geq 0
\end{align*}
\]

- \( h, B \) —— water level and aquifer floor elevation (m);
- \( \varepsilon_1(x, y, t), \varepsilon_2(x, y, t) \) —— Recharge intensity and discharge intensity of aquifer (m/d);
- \( q(x, y, t) \) —— Single-width traffic at the second type boundary (m³/m·d);
- \( K \) —— The permeability coefficient (m/d);
- \( h_0(x, y) \) —— The initial water level (m);
- \( \mu \) —— Coefficient of groundwater aquifer storage.

The mathematics model simulation calculation adopts the widely used GMS software at home and abroad [6-7]. Since the groundwater flow in the simulation area is gentle and the hydraulic slope changes little, automatic rectangular grid division is used. According to the groundwater dynamics and precipitation distribution characteristics, a hydrological year of the simulation period is divided into the following stress periods: high water period, June 15 ~ September 30 (108d); dry season, October 1 to June 14 of the following year (257d). Select the high-water period for mathematical model identification, and the low-water period for mathematical model verification. The analysis shows that the mathematical model can truly reflect the characteristics of the groundwater flow system and can be used for the prediction of groundwater exploitation schemes.

![Figure 4. Groundwater flow field map in the study area](image-url)
4. Evaluation of Groundwater Exploitation Plan in the Water Source Area of Kangping Power Plant

4.1 Calculation of Groundwater Sources and Sinks under the Current Conditions of the Study Area

According to the statistical data of precipitation in the study area for many years, the average annual precipitation is 518.1mm, and the source and sink items of the groundwater system are calculated (table 1).

| Source and sink                                    | average year (m³/d) |
|---------------------------------------------------|---------------------|
| The recharge item                                 |                     |
| atmospheric precipitation infiltration            | 28834.32            |
| lateral boundary supply                           | 3009.85             |
| total                                             | 31844.17            |
| The discharge item                                |                     |
| the evaporation of diving water                   | 23255.44            |
| lateral boundary excretion                        | 8588.60             |
| total                                             | 31844.04            |
| Poor equilibrium                                  | 0.125               |

4.2 Prediction of Groundwater Exploitation Programmes

4.2.1 Prediction scheme

Two schemes are prepared for the prediction, as shown in Table 2: (1) Meeting the requirements of water supply of 9600m³/d, the number of Wells for exploitation of water source is 8, and the water supply of a single well is 1200m³/d; (2) On the basis of meeting the proposed water supply requirements of 9,600m³/d, expand the production capacity to reach 12,000m³/d. The production well layout and plan 1 are the same, and the water supply per well is 1,500m³/d.

| Water source production(m³/d) | 2019 | 2020 | 2021 | 2022 |
|-------------------------------|------|------|------|------|
| plan 1                        | 9600 | 9600 | 9600 | 9600 |
| plan 2                        | 12000| 12000| 12000| 12000|

4.2.2 Determination of source and sink terms in the forecast stage

Analysis of supply item: According to the observation sequence of local annual average atmospheric precipitation, the annual average precipitation is determined to be 518.1mm. The forecast includes precipitation cycles that normally distribute precipitation during both high and low water periods, taking into account both high and low water periods.

Determine the excretion term: Due to the exploitation and pumping of the aquifer, the buried depth of the diving position increases, gradually exceeds the limit of evaporation depth, and the evaporation of the diving decreases and even disappears. Therefore, in the forecast stage, only the extraction quantity is extracted.

4.2.3 Analysis of the development trend of groundwater flow field under the condition of forecast scheme

(1) Programme I

According to the operation simulation model of mining amount forecast in Table 2, the evolution trend of underground water flow field in the simulated area is obtained, as shown in Figure 5 ~ figure 8.
From the simulation results, it can be seen that under the condition of unchanged exploitation layout and exploitation quantity, the groundwater funnel decreases from 2019 to 2022, the water level rises slightly in some years, and the groundwater level decline rate in the simulated area is basically stable. It indicates that the exploitation amount of 9,600 m$^3$/d is favorable for maintaining the regional groundwater level, and it is guaranteed to carry out the exploitation according to 9,600 m$^3$/d.

(2) Programme II

According to the operation simulation model of mining amount forecast in Scheme 2 in Table 2, the evolution trend of underground water flow field in the simulation (demonstration) area was obtained, as shown in Figure 9 ~ 12.

Figure 5. Forecast flow field on the dry season in 2019

Figure 6. Forecast flow field on the dry season in 2020

Figure 7. Forecast flow field on the dry season in 2021

Figure 8. Forecast flow field on the dry season in 2022
From the simulation results, it can be seen that under the condition of unchanged mining layout and 12000 m$^3$/d mining amount, the groundwater funnel will expand from 2019 to 2022, and the groundwater level in the simulated area will slowly decline. Due to the increase in the amount of exploitation, compared with the first plan, the water level drops more sharply. Compared with the initial water level at the end of the fourth forecast year, the local water level falls to a depth of 7 m, reaching the upper limit of allowable depth, indicating that the exploitation amount of 12,000 m$^3$/d has reached the limit of groundwater exploitation in this region. According to the 12000 m$^3$/d scheme, short-term mining is able, but long-term mining guarantee degree is poor.

5. Conclusion
Based on the numerical simulation prediction results of scheme 1, under the mining condition of 9,600 m$^3$/d, the regional groundwater level will rise from the dry period to the wet period, and the overall groundwater level in the simulated area will be stable. Therefore, under the condition of not destroying the balance of supply and demand, the production water demand of 9600 m$^3$/d is still favorable for
maintaining the regional groundwater level.

According to the second numerical simulation results of the scheme, under the condition of the mining of 12000 m$^3$/d, the groundwater depth in the simulated area increases year by year, and the drop funnel appears. The water level of individual wells drops to 7 m. Combined with the forecast of scheme 1, the water supply capacity of scheme 1 is high and the exploitation capacity can be expanded appropriately when the water demand is large, but not more than 12000 m$^3$/d.

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7. References
[1] Xue Yuqun. Present Situation and Prospect of Numerical Simulation of Groundwater in China [J]. Journal of University Geology, 2010 (1):1-6.
[2] Ji Yuanyuan, Zhou Jinlong, Yang Guangyan. GMS Application in Evaluation and Management of Groundwater Resources in China [J]. Groundwater, 2013, 35 (2):76-79.
[3] Sun Yue, Yue Yunhua, et al. Evaluation of groundwater resources in emergency water sources near river based on GMS [J]. Geology and Resources 28(1):72-77.
[4] Li Yuanjie, Jiang Xinhui, Chen Jun, et al. Prediction of Groundwater Flow Field in Linhe District of Bayannur City Based on GMS [J]. South-to-North Water transfer and Water Conservancy Science and Technology. 2016,14(4): 36-40.
[5] Zhang Xin, Xu Shiguang, et al. The Application of GMS in Numerical Simulation of Groundwater ---- Taking a Reservoir in Wenshan Prefecture, Yunnan Province as an example [J]. Henan Science. 2015,33(11): 1994-1997.
[6] Zhang Lishu, Bian Jianmin, etc. Numerical Simulation of Groundwater Flow in the Water Source of Kangping Development Zone and Sensitivity Analysis of Medium Parameters [J]. China Rural Water Conservancy and Hydropower, 2010(4):16-21.
[7] Simulation Model of Groundwater Flow in Bohai Bay Area Hehai University, 2006.