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Drainage Evaluation of Limestone Aquifer Based on Visual Modflow

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Abstract The underground dewatering test carried out in the north eighth mining area of Taiyuan group limestone confined aquifer was the subject investigated. The hydrogeological and mathematical models of limestone aquifer under the floor of 10# coal were built. The accuracy of the model was verified by identifying and testing of Visual Modflow based on the data obtained from the pumping test. The drainage of aquifer was evaluated and the results showed the drainage of aquifer was poor. The results can provide basis for water prevention measures in the next stage.
Keywords Visual Modflow, pumping test, aquifer, groundwater

Introduction

Visual Modflow is one of the most popular and advanced visual software solving the simulation of underground water and solute transfer (Liu 2009). It can solve different groundwater flow types and has been used widely to research the groundwater seepage field (Wu and Dong 1999). Visual Modflow was used for water prevention of coal mines, the numerical simulation of groundwater seepage and the drainage of aquifer in Huaibei mining area (Wu and Shi 2000). Pumping test is an important method for hydrogeological exploration and the artificial descending seepage field is the basis for groundwater numerical simulation. In addition, it can provide guiding role for the drainage of aquifer (Xu and Gui 2002).

Geological and hydrogeological conditions about research area

The north eighth mining area is located in the north of Taoyuan Coal Mine. The west boundary of the mining area is the Taiyuan Group limestone subcrop. The north boundary of mining area is cut by F1 fault. The south boundary of mining area is cut by F2 fault connecting with the south of Coal Mine. The eastern limestone of mining area is extending to the deep and remote.

The largest fall head of F2 fault is 420 m and the dip of the fault is NNE. The north eighth mining area is located in the hanging wall of the F2 fault and it may exist the docking and replenishment phenomenon from the Ordovician limestone aquifer. So, some anomalies showed up in the water quality of Taiyuan Group limestone aquifer. Meanwhile the water temperature and water pressure appeared high abnormal phenomenon showing the complex hydrogeological conditions. Therefore, it was necessary to carry out the underground dewatering test of Taiyuan Group limestone confined aquifer in order to understand the hydraulic connection between the Taiyuan Group limestone aquifer and the Ordovician limestone aquifer. In addition, the hydrogeological parameter of aquifer can be calculated and it can provide the water prevention and control method for the safety mining of the lower series coal.

The water abundance of the 1st to 4th Taiyuan Group limestone is rich and it is far from the lower limestone. The 1st to 4th Taiyuan Group limestone aquifer is the main water-inrush source of coal floor while mining the lower series coal. So, the 1st to 4th Taiyuan Group limestone aquifer was the dewatering test section.

Mathematical model of aquifer system and test process

Mathematical model

Three-dimensional mathematical model of non steady flow was built based on the principle of water balance and Darcy's law. The model was shown as flow:

$$\left.\begin{array}{ll} \frac{\partial}{\partial x}(k_{xx}\frac{\partial H}{\partial x})+\frac{\partial}{\partial y}(k_{yy}\frac{\partial H}{\partial y})+\frac{\partial}{\partial z}(k_{zz}\frac{\partial H}{\partial z})-w=Ss\frac{\partial H}{\partial t} & (x,y,z)\in\Omega \\ H(x,y,z,0)=H_0(x,y,z) & (x,y,z)\in\Omega \\ H(x,y,z,t)\mid_{\Gamma 1}=H(x,y,z) & (x,y,z)\in\Gamma_1 \end{array}\right\}$$

Where k_{xx}, k_{yy}, k_{zz} was the coefficient permeability in the direction *x, y, z*; *H* was the water level of groundwater; H_0 was the initial water level; W was source sink term; Ss was the elastic water release rate of aquifer; t was test time; Γ_1 was the first boundary; Ω was the calculation area.

Pumping test process

Simulation time choose the duration of pumping test. The test was carried out in three stages. The first stage was from September 16 to 21, 2012 last 5 days. The second stage began on September 21 and finished on September 25. The date of the third stage was from September 25 to 29. The three stages of test were divided into three groundwater periods. The step of each period was 10 and the increase factor was 1.2. The first two stages were used as the identification stage of model in total 9 days and the last stage was used as the verification stage in total 4 days.

Simulation in identification stage

The first two stages were used for identification of model. The water level of observation hole (11-2 hole) was used for fitting. The change curve of water level between observation hole and calculated value was shown as fig.1.

Simulation in verification stage

The model need verifying after identified. The last stage of the pumping test was used for verification of model and it last for 4 days.

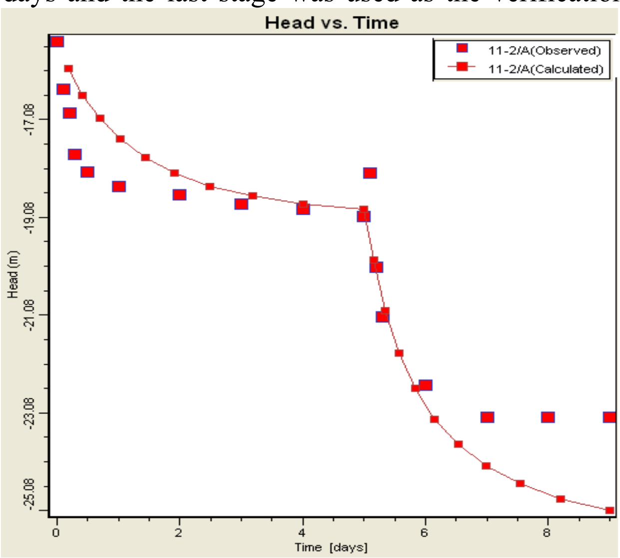


Fig.1 *Water level between observation hole and calculated value in identification stage*

Observation hole used for verification was the same as the identification stage. The water level between simulation value and calculated value was shown as fig.2.

We can find that the water level between observation hole and calculated value was similar and the fitting precision was high. The error was caused by inhomogeneity of hydrogeological parameters and parameter adjustment was difficult leading to little error. The variation trend of water level was the same indicating the fitting degree of water level of observation hole was reasonable and the model had built was accurate.

Because the simulation range was wide, the boundary conditions were hard to be controlled accurately. Meanwhile, the existence of lateral recharge caused by F2 fault lead to the water level of observed hole near the boundary rising and the water recharge of observed hole far from the boundary inadequate. So, the fitting degree of calculated value and observed value was not accurate enough. In addition, the fractures of limestone aquifer were opening while the pumping test was going on and this may lead to the variance of coefficient permeability of limestone. Besides, the Karst development was heterogeneity. The variance of coefficient permeability was not being considered and this was one of the reasons caused the fitting error. However, the groundwater flow field of numerical simulation and actual flow field were basically the same. Although there were fitting error in identification stage, the water level between calculated and observed was nearly same in verification stage. So, the error didn't affect the reasonable of the numerical model.

So, we can take advantage of the model to research the drainage of aquifer in Taoyuan coal mine.

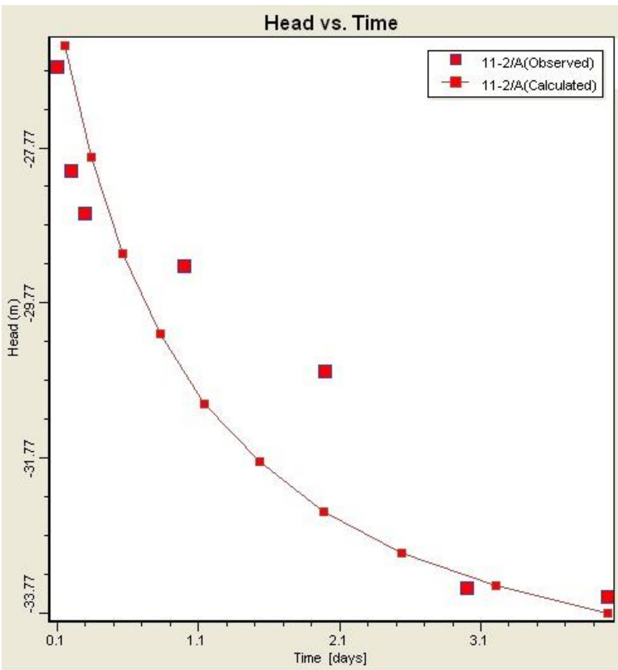
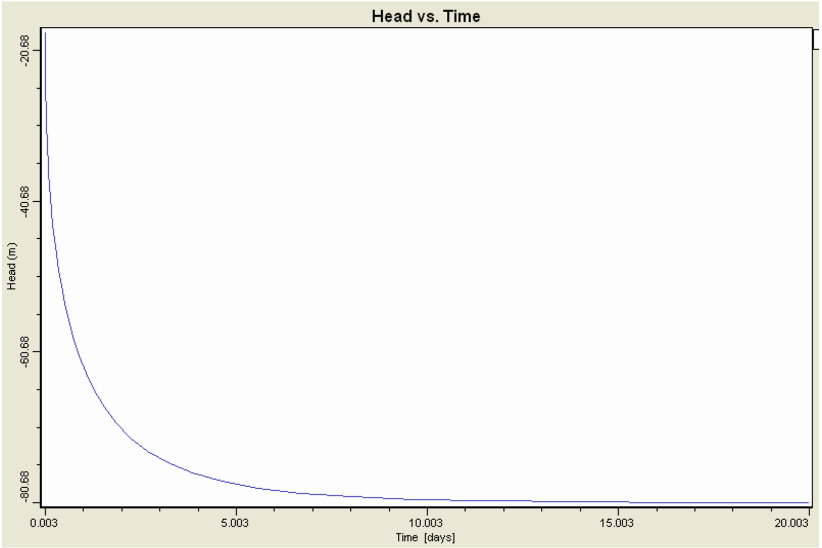


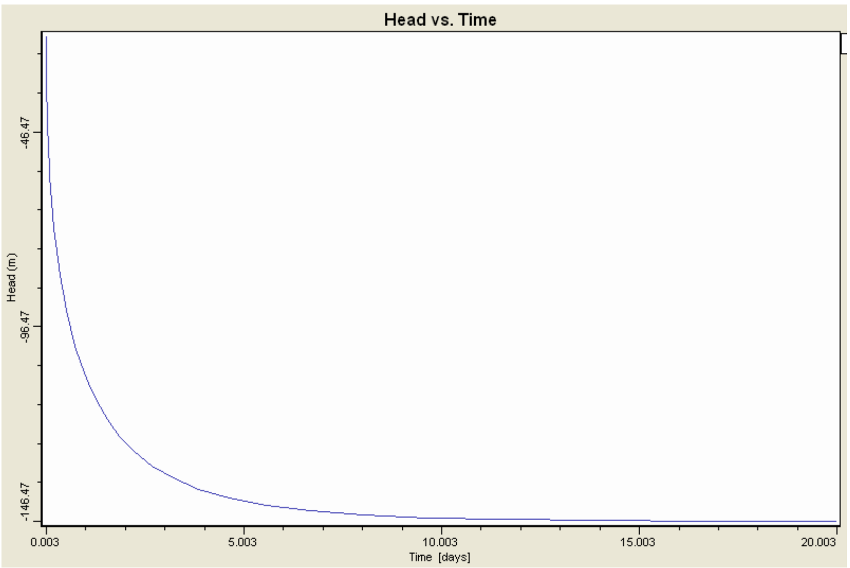
Fig.2 *Water level between observation hole and calculated value in verification stage*

Drainage evaluation of limestone aquifer in north eighth mining area

After the verification of numerical model was finished, virtual drainage holes were arranged by the model. We choose different virtual drainage quantity 1000 m^3/h and 2000 m^3/h to research the drainage of aquifer. The initial drawdown was increasing with increasing of the water quantity and the drawdowns were 67 m and 133 m. The water level reached the stable quickly as fig.3 shown indicating the recharge was adequate. In addition, it still can't reach the safety water level with such a large amount of water quantity. So, we can conclude the drainage of Taiyuan group limestone aquifer in north eighth mining area was poor.



a-1000 m^3/h



b-2000 m^3/h

Fig.3 *Water level change curve of different water quantities*

Conclusions

The numerical model was built based on the reasonable generalization of the geology and hydrogeology conditions by Visual Modflow.

The water level between observation hole and calculated value was similar and precision of the model was high and reliability of numerical model was verified.

The results show the drainage of Taiyuan group limestone aquifer in north eighth mining area was poor. To realize safety mining by groundwater drainage was not suitable and effective. Other methods such as coal floor grouting should be taken to ensure safety mining of 10# coal seam.

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