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Mine Discharge Prediction in Steeply Dipping and Deep Mining Coal Seam in the Zhaogezhuang Mine

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Abstract The NO. 3839 coal working face at the West panel ofthe Zhaogezhuang mine, is deeply minied. After nearly 100 years' mining, comparing with shallow seam mining, the mine water conditions have been significantly changed. In order to predict the mine discharge of the 3839 coal working face, firstly, we carried out the detailed analysis of the mining area of upper 9～13 levels in nearly 30 years, in terms of precipitation, Ordovician limestone water level, mining depth, and the correlation between the mining area of upper level and the mine discharge. Secondly, we selected the highest correlation factors of discharge (such as goaf water accumulation), precipitation, the change magnitude of Ordovician limestone water level and mining depth. Finally, we produced a predicting function of mine discharge by using multivariate linear regression analysis. After validating the function by using the discharge data of 2012, we can conclude that the regression factor is highly correlated. After predicting mine discharge in the 3839 coal when mining in 2013, the results are close to the predicted by use of the analogy method and the analytical method. It is suggested that this method is feasible in the prediction of mine discharge, but the resulting regression factor applies only to this mine, i.e. case specific.
Keywords steeply dipping seam, deep mining, mine water infiow prediction, multiple linear regression models

Introduction

Mine water discharge is a very important foundation work. Coal mining in the upper group coal, has accumulated a lot of mine discharge predict theory and mathematical models. Through scholarly analysis and research, a lot of effective predictive methods have been made to predict mine discharge, such as related analogy method (Zhou and Gu 2010), analytical method (Hua 2009), water balance method (Du 2009), numerical method (Song 2008). and time series analysis(Tang and Yang 2007) or other methods. When predicting mine discharge in steeply dipping and deep mining, error calculation is too large(Gao 2004)and providing an inaccurate predicted mine discharge data, for the complex hydrogeological conditions, hydrogeological parameters lacking of representative and the inappropriate mathematical model, etc. Consequently, it is a worthwhile topic to predict mine discharge in steeply dipping and deep mining.

Studying area

General situation and mining condition coal working face of 3839

Zhaogezhuang field is in the northeast GuZhi District of Tangshan City, Hebei Province, and in the northeast of Kai Ping coal field. 3839 coal working face is in the West Wing 8 crosscut of the 13 level, up to 12 level, coal working face 2137 which above 12 level was completed in 2007; down to the 13 level, below which is no mining engineering; east to F2 fault, coal working face 3639 is completed, West to 13 West 8 crosscut, no more western mining projects.

Mine discharge dynamic of coal working face 3839

From mine discharge change curve of 12 level's west 10 crosscut and 11 crosscut, it is observed that since September 2012, the mine discharge of 12 level crosscut and 3839 air passage increase at the same time, having been lasting until the end of January 2013. During the same period, 13 level 7 and 8 crosscut mine discharge values remain small. There is gushing phenomenon sometimes, and the water discharge of 8 crosscut is larger than 7 crosscut, but both of the discharge are less than 0.35 m^3 /min. Since 2013, 8 crosscut had basically no gushing phenomenon and 7 crosscut had only once on March 1st 2013, the mine discharge was 0.16 m^3/ min.

Coal working face 3839 water filling factors analysis

(1) The old pond water

Based on analysis of mining coal working face of the water in the position, part of old pond water sources is from the west side of 12 west 11 crosscut top, which is above 0033, 1237, 2137 coal working face old pond of vertical infiltration.

(2) Precipitation intensity

The size and intensity of precipitation is closely related to the Ordovician limestone water's level rise, and have no obvious relation to the Ordovician water level. when the water level of Ordovician limestone are -120m in June 1977, July 1987, there is no mine discharge increasing phenomenon;

(3) Dynamic characteristics analysis of Ordovician limestone water

In 2012, which is rich in precipitation, the Ordovician limestone water level was approaching the warning level -150m. But after the rainy season, Ordovician limestone water level has dropped to -250.29m by April 5th 2013 (fig.1).

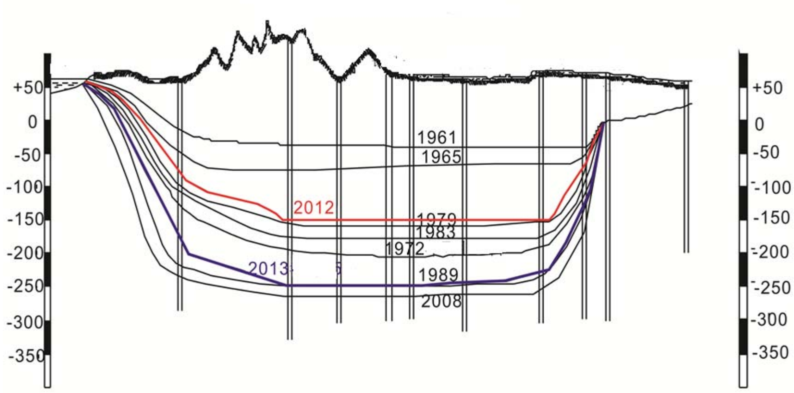

Fig. 1 *History water levels of Ordovician karst aquifer in the studying area*

(4) Small coal mines

Without considering the precipitation, only on small coal mines, shutting down have basically no influence on the mine water gushing. Analysts say that local coal mines' suspend production for rectification in Zhaogezhuang mine has little effect on discharge, even causing the mine discharge decreased.

Multiple linear regression to predict mine discharge

Determine the formula to predict mine discharge of the studying area

Use mine discharge (Q) and the mining area (S), precipitation (P), the Ordovician limestone water level (H_0) and mining depth (S_0) to fit formula and establish multiple linear regression equation(table.1).

For the regression equation four sets of data requires a minimum of five sets of data, but each level has only three complete sets of data (the 8 level has 4 sets of data), so combined two adjacent horizontal data to do the simulation.

The equation of 8-9 and 10-11 level is ineffective. The equations of 9-10, 11-12, 12-13 level are very good. So use these 3 formulas to predict mine discharge. According to the normal mine discharge (Q) and old empty water quantity (q), precipitation (P), Ordovician limestone water level magnitude (H_0) and mining depth (S_0) to fitting formula.According the level in11-12 level data to fit mine discharge with mining area, precipitation, Ordovician limestone water level and mining depth and the multiple linear regression equation:

Table 1 *Mine discharge and the related factors*

Levels	Year	discharge (m^3/min^{-1})	area (m^2)	precipitation (m)	water level (m)	mining depth (m)	old empty (m^3)
The8	1982	1.135	11339.99	0.481	-161.877	-600	77792.75
	1983	1.042	17505.96	0.482	-161.954	-600	120091.6
The9	1985	1.951	7816.314	0.7871	-113.45	-700	19245.58
	1986	3.199	10679.2	0.7313	-129.992	-700	73259.75
The10	1988	0.136	18717.4	0.6331	-160.164	-800	128402.1
	1999	0.024	5195.288	0.381	-263.541	-800	22217.24
The11	2001	0.365	3659.934	0.4566	-255.955	-900	7109.521
	2002	1.029	4845.35	0.3157	-290.985	-900	33239.29
The12	2005	0.276	773.3294	0.49207	-265.925	-1000	5305.07
	2009	0.487	9572.252	0.5647	-258.984	-1000	77107.9
The13	2010	0.042	4100.336	0.5605	-273.154	-1100	4100.336
	2012	21.863	974.6536	0.8395	-221.379	-1100	6686.161

$$Q=-1.13599+2.9429610^{-6}q-3.05809P+0.00737H_0-0.00308S_0$$

In this linear regression equation, R_2 = 0.9996, correlation is high, indicating a better fit equation.

Verify the formula

In the first method, using the regression equation of 12-13 levels, in the second method, using the 11-12 levels regression equation to predict mine discharge(table.2).

Table 2 *Comparison of measured and predicted values unit: m^3/min*

Level	Method	Years	Actual	Perdition	Deviation	Deviation rate
13	1	2010	0.042	0.041	0.001	2.38%
		2011	0.04	0.03	0.01	25.00%
		2012	21.863	21.842	0.021	0.10%
	2	2010	0.042	0.054	0.012	28.57%
		2011	0.04	0.041	0.001	2.50%
		2012	21.863	21.817	0.046	0.21%

From the two methods above to predict different levels of the mine discharge, the first predicted data is closer to the measured data.

Mine discharge prediction in the studying area

According to the calculation method above for the determination by the following four factors linear regression equation for 13 level workspace mine discharge prediction in 2013.

$$Q=-7.94118-5.30287 10^{-4}S+74.36692P-0.01888H_0+0.03301S_0$$

Prediction data of normal mine discharge and maximum mine discharge (table.3).

Table 3 *The predicted dates of mine discharge in 2013 unit: m^3/**min***

Month	mine discharge		Month	mine discharge		Month	mine discharge	
	normal	maximum		normal	maximum		normal	maximum
Jan.	0.3	0.32	May	0.17	0.17	Sep.	1.45	5.32
Feb.	0.32	0.38	Jun.	0.34	0.81	Oct.	0.3	2.6
Mar.	0.31	0.371	Jul.	12.9	18	Nov.	0.15	0.22
Apr.	0.2	0.21	Aug.	7.47	15.5	Dec.	0.4	0.4

Conclusion

Based on the calculations above, the predicted values of 13 level mine discharge are between 2.06 m^3/min and 2.73 m^3/min by using regression method, analytical method and simulation method, average 2.395 m^3/min, which are closed to the measured values (table 4). Waiting to obtain further parameters of 14 level in detail, mine discharge in 14 level corresponding coal working face can be forecasted.

Table 4 *The values between different prediction methods and actual mine discharge (m^3 / min)*

Methods	Regression	"Large diameter well method"	Analogy method one	Analogy method two	Actual mine discharge
Prediction	2.06	2.53	2.73	2.51	2.41

To sum up, we can draw the following conclusions:

(1) In the process of water discharge prediction, should take various methods to determine the value after comprehensive comparison.

(2) Overall, the " large diameter well method " and considering the"Mining area - drawdown" predicted results are closer to the actual value of the formula.

(3) The results of multiple regression method are smaller, mainly due to the difficulty of predicting the large amount of water in upper goaf, leading to the large final predicting error, but we cannot deny the important influence that amount of water of upper goaf has on deep mining.

(4) The error of multiple regression model of predicting water discharge is about 15%, far less than the actual productive range of the common error of 50%, showing that the model is feasible. With the further study of the various factors, the model accuracy will gradually increase as well as provide reference data for the requirement of productive design.

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