Journal of Rock Mechanics and Geotechnical Engineering 7 (2015) 298–305

Contents lists available at ScienceDirect

Journal of Rock Mechanics and Geotechnical Engineering

journal homepage: www.rockgeotech.org

Full length article

Impact of longwall mining on groundwater above the longwall panel in shallow coal seams

Yang Li[a,*], Syd S. Peng[b], Jinwang Zhang[a]

[a] College of Resources and Safety Engineering, China University of Mining and Technology, Beijing 100083, China
[b] Department of Mining Engineering, West Virginia University, Morgantown, WV, USA

ARTICLE INFO

Article history:
Received 20 November 2014
Received in revised form
17 January 2015
Accepted 1 March 2015
Available online 7 April 2015

Keywords:
Groundwater
Longwall mining
FLOW3D model
Dewatering

ABSTRACT

Since longwall mining causes subsidence through the overlying strata to the ground surface, the surface water and groundwater above the longwall panels may be affected and drained into the lower levels. Therefore, loss or interruption of streams and overburden aquifers is a common concern in coal industry. This paper analyzed the potential effects of longwall mining on subsurface water system in shallow coal seam. In order to monitor different water level fluctuations throughout the mining period, three water wells were drilled down to the proposed deformation zone above the longwall panel. A GGU-SS-FLOW3D model was used to predict water table contours for the periods of pre- and post-mining conditions. The field data from the three water wells were utilized to calibrate the model. The field test and numerical model can help to better understand the dewatering of shallow aquifers and surface waters related to ground subsidence from longwall mining in shallow coal seam.

1. Introduction

Longwall mining method is a highly productive underground mining method in which a panel or a block of coal is completely extracted (Peng, 2006, 2008; Qian and Shi, 2003; Wang, 2009). When a longwall panel with sufficient width and length is excavated, the overburden roof strata are disturbed in order of severity from the immediate roof toward the surface, or even the aquifers, which can lead to serious mine-flooding accidents and increasing damages to ecological environments (Miao and Qian, 1995; Qian and Miao, 1995; Qian et al., 1996). Thus it is absolutely essential to determine the degree of dewatering for prevention of water inrush and protection of groundwater resources (Li, 2011; Li and Qiu, 2012). In this paper, three water wells drilled in site and a GGU-SS-FLOW3D model are used to monitor different water level fluctuations throughout the mining period. The potential effects of longwall mining on subsurface water system are analyzed in shallow coal seam with the field data measured from the three water wells and the numerical model.

2. Geology and mining conditions of study area

The geology of the study area includes sedimentary rocks of Pennsylvanian and Permian ages (Paleozoic). Alluvial deposits of Quaternary age occupy the valley bottom of the dissected topography. The boundary between the Pennsylvanian and Permian systems is indistinct, but it is generally defined by the sequence of rocks extending from the base of the Waynesburg coal bed to the present topographic surface.

The Dunkard Group consists of the Greene Washington and Waynesburg formations. The lower section of the Dunkard Group resembles that of the Monongahela Group which contains laterally persistent Pittsburgh coal. The top bedrock unit is the Dunkard Group, which belongs to the Permian age.

The longwall panels B5 and B6 studied in this paper are located in the Appalachia Coalfield, United States (Fig. 1). The overburden depth varied from 600 ft to 900 ft (1 ft = 0.3048 m). The average mining height was 7 ft. The length of panels B5 and B6 was 12,000 ft and 5700 ft, respectively. The width of the both panels was 1433 ft. The width of headgate and tailgate entries was 16 ft. The chain pillar system between panels B5 and B6 was 200 ft wide. The average longwall face retreat rate was 30–50 ft/d during the longwall face mining in the study area.

3. Groundwater monitoring

In order to determine the water system distribution in the study area, three water wells W1, W2 and W3 have been drilled above the panel B6 before longwall face mining in panels B5 and B6. The

* Corresponding author. Tel.: +86 13810109490.
E-mail address: kobe8leon@163.com (Y. Li).
Peer review under responsibility of Institute of Rock and Soil Mechanics, Chinese Academy of Sciences.
1674-7755 © 2015 Institute of Rock and Soil Mechanics, Chinese Academy of Sciences. Production and hosting by Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.jrmge.2015.03.007

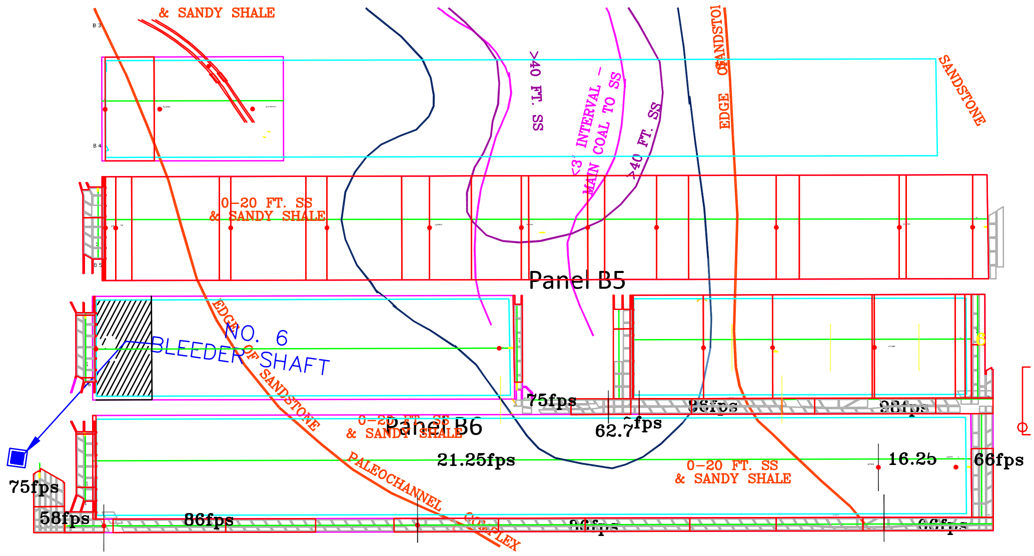

Fig. 1. Layout of longwall panels B5 and B6.

water well W1 contained three wells of different depths (Fig. 2). The well W1S was the top well, which was located in the limestone and shale. The average water column in the well was 22 ft. The deep well W1D was located between Waynesburg and Uniontown sandstones. The average water column in the well was 70.76 ft. The shallow well W2S was located in the shale. The average water column in the well was 32 ft. The well W2I (intermediate well) was located in the sandstone above a little Washington coal. The average water column in the well was 18 ft. The deep well W2D was located at the bottom of Waynesburg sandstone layer and the water column in the well was 190.4 ft. The well W3S was located in the shale. The average water column in the well was 15.17 ft (before mining of panel B5). The well W3I was located in the shale and the average water column in the well was 49 ft. The well W3D was located between the bottom of Waynesburg sandstone and upper Waynesburg coal. The water column in the well was 21.38 ft.

The water well W4 was located over the center of panel B5. Before mining this panel, the water levels in shallow well W4S and intermediate well W4I located in the shale were 23.4 ft and 21.7 ft, respectively. The water level in well W4D located in the Waynesburg sandstone was 22.8 ft.

The water level in well W2D was higher than that in W2I. This was not reasonable as compared to those in wells W1D and W3D. It was, therefore, postulated that surface water seeped into the Waynesburg aquifer because of the sealing construction.

Fig. 3 shows the cross-section of water wells and water levels before panels B5 and B6 longwall faces passed the study area.

Water enters the subsurface in Greene County mainly as precipitation or stream flow. When precipitation hits the ground, some is evaporated, some flows overland and some seeps into the subsurface. Of the portion that percolates into the subsurface, some returns to the atmosphere by transpiring plants and the remainder percolates downward to the subsurface unconfined aquifers. The water in the unconfined aquifers flows from the higher hydraulic heads toward the lower ones. The water flow rate depends on hydraulic conductivity and hydraulic head gradient.

The hydraulic conductivity K is the most important quantitative parameter charactering the flow of groundwater. It is defined as the ratio of Darcy's velocity to the applied hydraulic gradient. It is dependent only on the physical properties of the porous medium, grain size, grain shape, arrangement of pore size, and interconnection in general. The dimension of K is the same as that for velocity, that is, length per unit of time (LT^{-1}).

The properties of hydraulic conductivity before mining at the study area were measured by the slug test. The slug test consists of measuring the recovery of head in a well after near-instantaneous change in head at that well.

4. Determining the post-mining hydraulic conductivity of panel B6

The post-mining hydraulic conductivity of panel B5 should be determined in order to analyze the groundwater flow system after the panel B6 is mined out. The slug tests for wells W1–W3 were performed 10 months after the longwall face of panel B6 passed under the three well locations, i.e. the slug tests were performed in September 2009. Before the slug test, all wells were checked carefully in order to determine whether they were needed to inject or withdraw volumes of water during the slug test. Wells W1S, W1D, W3S, W3I and W3D were warped severely due to subsidence when panel B6 was mined, and wells W2S, W2I and W2D were completely dewatered. Therefore, all slug tests in water wells W1–W3 were performed by instantaneously injecting a volume of water, and measuring and recording the depth to water and the time at each reading. Fig. 4 shows the cross-section depicting a slug test in a monitoring well. Table 1 summarizes the hydraulic conductivity in both pre- and post-mining conditions.

5. GGU-SS-FLOW3D model

5.1. Purpose of groundwater modeling

A numerical groundwater flow model is the mathematical representation of an aquifer in a computer. Groundwater models describe groundwater flow and transportation processes using mathematical equations based on certain assumptions. These assumptions typically involve directions of flow, geometries of aquifers, heterogeneity or anisotropy of sediments or bedrocks within aquifers. Because of the assumptions embedded in the mathematical equations and many uncertainties in the values of