Conceptual Model of Darezar Copper Mine and Designing Observation and Dewatering Wells

Mahdi Janparvar[1*]; Mahmoud Alipour[2]

[1*]TOOSSAB Consulting Engineers, Department of Water Resources, Mashhad, Iran
[2]National Iranian Copper Industries, Sarcheshma Copper Mine, Kerman, Iran

Parvar1998@gmail.com

Abstract

Darrezar Copper mine is located in west of Kerman province, south of Sarcheshmeh Copper mine, central Iran. This study was accomplished to prepare the conceptual model of Darezar mine aquifer. The study area is located in Central Iran geological zone and Orumieh – Dokhtar volcanic belt. Due to small scale of the study area, the lithological variety across the study area is not wide and comprises of sedimentary formation and igneous rocks. Igneous rocks are dominant in the area. Major trend of faults and fractures in the study area is Northeast – Southwest. The fault systems could be classified in three classes as first, second and third categories, from which, the first prepared the ground for intrusion, the second caused many fractures and joints in adjacent rocks and substitution in deep intrusive masses and the third displaced both former fault systems. In Darezar intrusive, densities of joints are high and joint surfaces are completely oxidized. To unveil the subsurface characteristics in Darezar area, a number of 171 exploratory drillings were drilled. In Darezar area the dominant lithology in drillings are quartz diorite and diorite. To compare borehole data, boreholes logs were processed in Groundwater Modeling System environment by using Borehole module. To assess the potential of geological formations, a data collection of water resources in the study area was done. In order to estimate the expansion of aquifers, results of borehole drillings and specifically RQD index were used and cores were categorized in five classes as highly porous, porous, moderate porous, low porous and very low porous. The results imply that the aquifer in Darezar mine extends to a depth of about 300 meter. A number of observation and dewatering wells was designed based on study assessment.

Keywords: Copper Mine, Conceptual Model, Sedimentary Formation, Igneous Rock, Joint, Fault, RQD

1. Introduction

Prior to develop a mathematical model, it is important to build a conceptual model [2]. Conceptual model tends to simplify the subject under study [1], hence the idea of parsimony, starting simple and building complexity slowly, is emphasized [4]. A conceptual groundwater flow model is a simplification of a real world groundwater problem such that it captures the essential features of the real world problem and it can be described mathematically, the sole purpose of simplification is to make the problem fit one of our mathematical models [7]. In modeling a fractured media, the first major problem is that a representative elemental volume can only be defined when fracture densities are above some critical density which is defined as that density of fractures that provides connectivity of the network, so the concept of representative elemental volume probably does not fit for some fractured media and consequently these systems cannot be modeled by using continuum approach, for which discrete modeling approach may be applicable [12]. The concept of critical density and fractures schematically showed in figure 1.

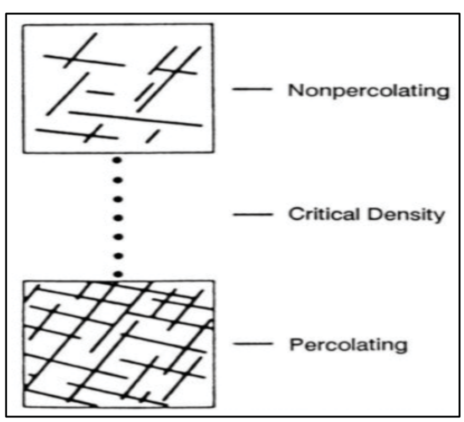

Figure1. Critical density, non-percolating and percolating network of fractures

Depending on data availability, in subsurface conceptualization, many geological, geotechnical, hydrogeological and water quality data are overlaid and applied, over which Rock Quality Designation (RQD) index is of special importance. The RQD has been used as an index of rock quality since 1967. The RQD is an index of rock quality in that problematic rock that is highly weathered, soft, fractured, sheared, and jointed is counted against the rock mass. It is recommended that the calculation of RQD be based on the actual drilling run length used in the field, preferably no greater than 1.5 m [5]. The RQD is defined according to formula 1.

$$RQD = \left(\frac{\sum \text{Length of Core Pieces} > 10cm}{\text{Total Core Run Length}}\right) * 100 \tag{1}$$

The boring logs in conjunction with geologic mapping provide early information on distribution of rock types, degree and depth of rock weathering, and zones of rock weakness and close fracturing. This information could be used to estimate the required depth of excavation for different engineering purposes. It is at this stage that RQD has been used a particularly helpful tool in comparing one boring with another, one depth with another, and one part of a site with another. The RQD values, as determined with depth and across the site, have been found by experience to be extremely helpful in making design decisions. RQD data has been used to evaluate the fracturing degree of the medium for significant depths by means of geostatistic interpolation [3] and obtain a three dimensional distribution of the level of fracturing [6]. The frequency of fractures has been related to RQD as showed in formula 2 [11].

$$RQD = 100\ e^{-0.1\lambda}\ (0.1\lambda + 1) \tag{2}$$

Where λ is the number of fractures per meter on scan line surveys. Low RQD values of core samples were considered as an indicator of relatively high hydraulic conductivity in the bedrock due to intense fracturing in Pebble Project [9]. A multivariate analysis of the RQD and its relation with hydraulic conductivity of 17 dewatering wells in an open-pit mine in central Mexico was applied as a tool for groundwater exploration in fractured aquifers [8]. Water trappings or aquifers were recognized due to low RQD values, usually lower than 50 percent, in a fractured diorite in Block Cave Mine, Indonesia [10].

2. Discussion

Darezar Copper mine is located in west of Kerman province, south of Sarcheshma Copper mine. The purpose of this study is to prepare a conceptual model of the Darezar mine aquifer for the latter mathematical model. From geological point of view, Darezar mine area comprises of sedimentary formation, e.g. sandstone, and igneous rocks which are dominant in the area, e.g. granodiorite, porphyritic diorite and porphyritic quartz diorite. The geology of the study area is presented in figure 2.

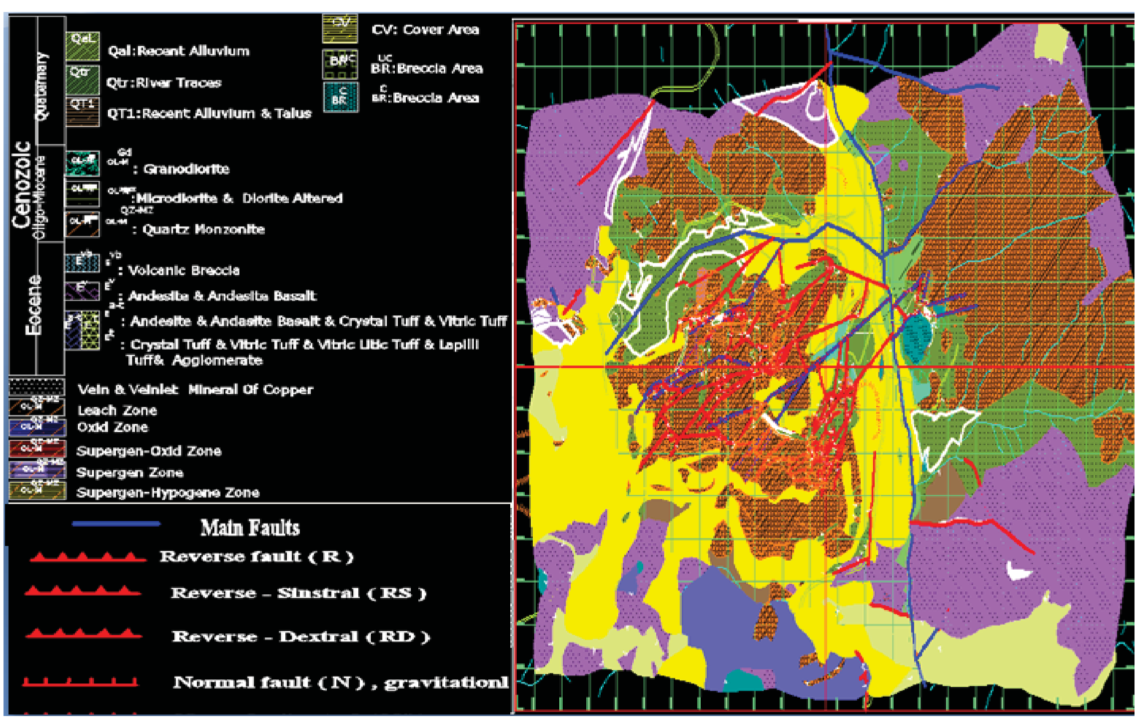

Figure2. Geology of Darezar mine area

The study area is located in Central Iran geological zone and Orumieh – Dokhtar volcanic belt. The fault systems could be classified in three classes as first, second and third categories, from which, the first prepared the ground for intrusion, the second caused many fractures and joints in adjacent rocks and substitution in deep intrusive masses and the third displaced both former fault systems. In Darezar intrusive, densities of joints are high and joint surfaces are completely oxidized. In Darezar mine, a number of 171 boreholes were drilled and the dominant lithology in drillings is Quartz Diorite and Diorite. Besides, the other lithologies are Granodiorite, Andesite and Microdiorite. To assess the downward expansion of aquifer, results of exploration drillings and specifically RQD index were used. Based on Deere classification [5], the cores quality could be classified in five categories. Though specifying an exact relation between RQD result and hydrodynamic coefficient of the aquifer needs more pumping tests and exploration studies, but in general it could be expressed that there is an inverse relation between RQD and aquifer porosity[7] and [8]. Assuming this, cores were categorized in five classes as highly porous, porous, moderate porous, low porous and very low porous as showed in table 1.

Table1. Classification of core quality based on RQD

RQD (%)	Rock Mass Quality	Porosity
< 25	Very Poor	Highly porous
25 - 50	Poor	Porous
50 - 75	Fair	Moderate porous
75 - 90	Good	Low porous
90 - 100	Excellent	Very low porous

Comparison of RQD versus depth in Darezar mine is presented in figure 3. Based on porosity classification, it seems that across the mine, aquifer is extended to a depth of 300 m. Below this depth, except in some area of mine, the porosity is decreased as RQD increases. The area within the green rectangle represents the aquifer domain. RQD versus depth for DAZ-80 borehole in Darezar mine is illustrated in figure 4 as a sample of Darezar boreholes.

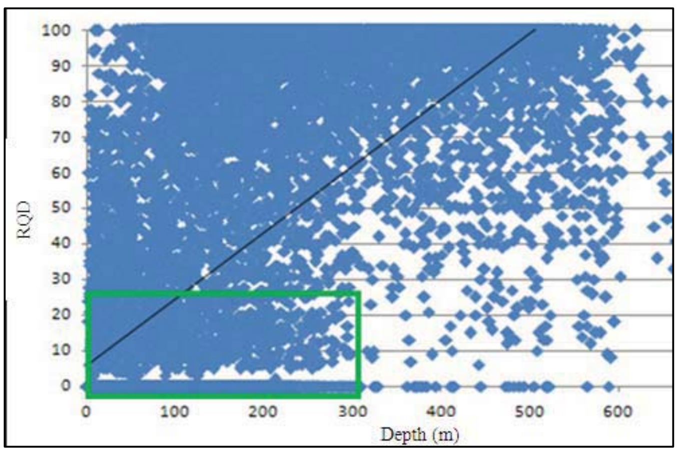

Figure3. Comparison of RQD versus depth in Darezar mine

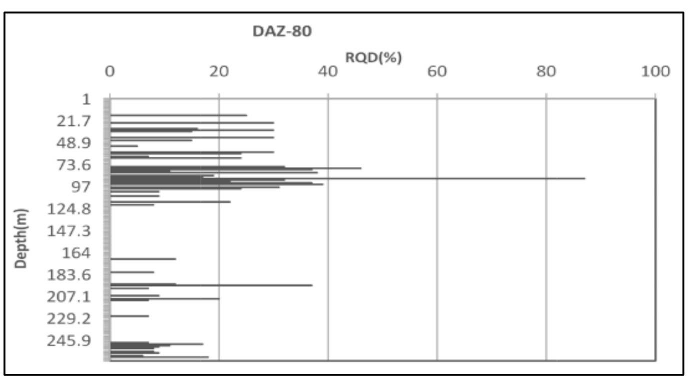

Figure4. RQD versus depth in DAZ-80 borehole in Darezar mine

The Borehole module of Groundwater Modeling System (GMS) was applied to obtain a comprehensive view of porosity in different parts of Darezar mine, as showed in figure 5. It is seen from figure that from central area of mine pit toward west and northeast, the aquifer has high porosity up to the pit depth. Toward southeast from the center of pit, aquifer porosity decreases as depth increases. In east part of mine, the aquifer has high porosity to the pit depth. Water resources survey in Darezar mine are another evidence of potentiality of Darezar mine geology to make groundwater reservoirs. Based on survey, there are 31 qanats in Darezar mine area. Maximum, average and minimum yielding of these qanats are 21.8, 4 and 0.1 l/s respectively. Sum of the yielding of qanats is 128 l/s. A number of qanats are in downstream of Darezar mine, so pollutants may be transported to some of them. A number of 28 springs have been surveyed in Darezar mine study area. Minimum, maximum and yielding sum of springs are 0.1, 10 and 27 l/s respectively. Most of these springs are located in the upstream of Darezar mine and so may not be polluted by mining activity [13].

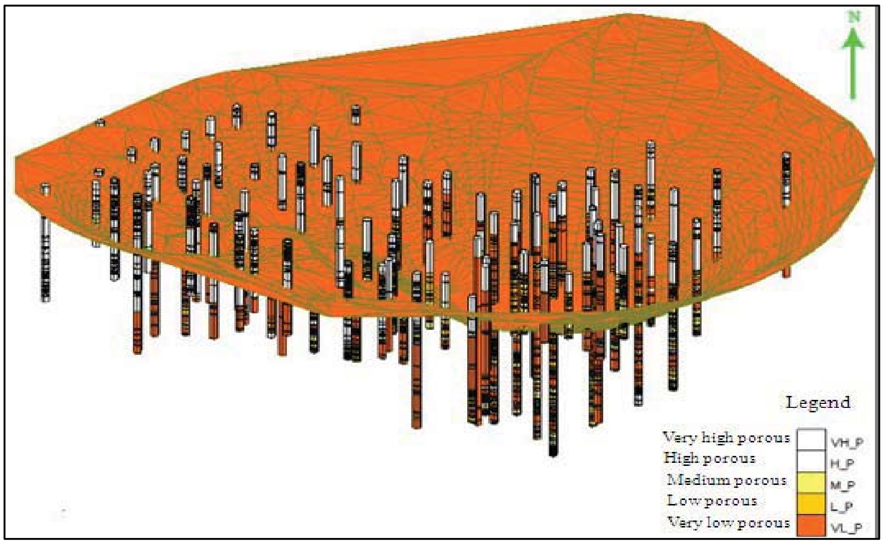

Figure5. Darezar mine pit and porosity in 3D view in different parts of Darezar mine

Based on above mentioned data, the boundaries of hydrological basin are considered as aquifer boundaries, so mine pit encounters groundwater throughout mine exploitation, hence designing dewatering and observation wells is necessary from the early stage of mining, thus a network of 14 observation wells with total depth of 2095 meter were planned to be drilled in Darezar mine in the early phase of mine pit development as presented in table 2 and figure 6. Besides, to attain hydrodynamic properties of the aquifer at this phase, 2 pumping dewatering wells as of table 3 were proposed to be drilled in Darezar mine.

Table2. Characteristics of observation wells in Darezar mine

Name	X	Y	Z (m)	Drilled depth (m)	Cased material	cased depth(m)	Slotted depth(m)
DOB01	393173	3309986	2740	84	PVC, ID 100	34	50
DOB02	391942	3309361	2890	70	PVC, ID 100	20	50
DOB03	394724	3309477	2830	75	PVC, ID 100	25	50
DOB04	392744	3308063	2830	160	PVC, ID 100	40	120
DOB05	394023	3308172	2620	142	PVC, ID 100	22	120
DOB06	394900	3307737	2760	138	PVC, ID 100	18	120
DOB07	395986	3307015	2830	133	PVC, ID 100	13	120
DOB08	394084	3306941	2540	215	PVC, ID 100	15	200
DOB09	391845	3306580	2545	135	PVC, ID 100	15	120
DOB10	393213	3306281	2620	230	PVC, ID 100	30	200
DOB11	395060	3306255	2610	240	PVC, ID 100	40	200
DOB12	394163	3305576	2540	213	PVC, ID 100	13	200
DOB13	393130	3304760	2500	130	PVC, ID 100	10	120
DOB14	395715	3304713	2490	130	PVC, ID 100	10	120
Total				**2095**		**305**	**1790**

Figure6. location of proposed observation wells in Darezar mine

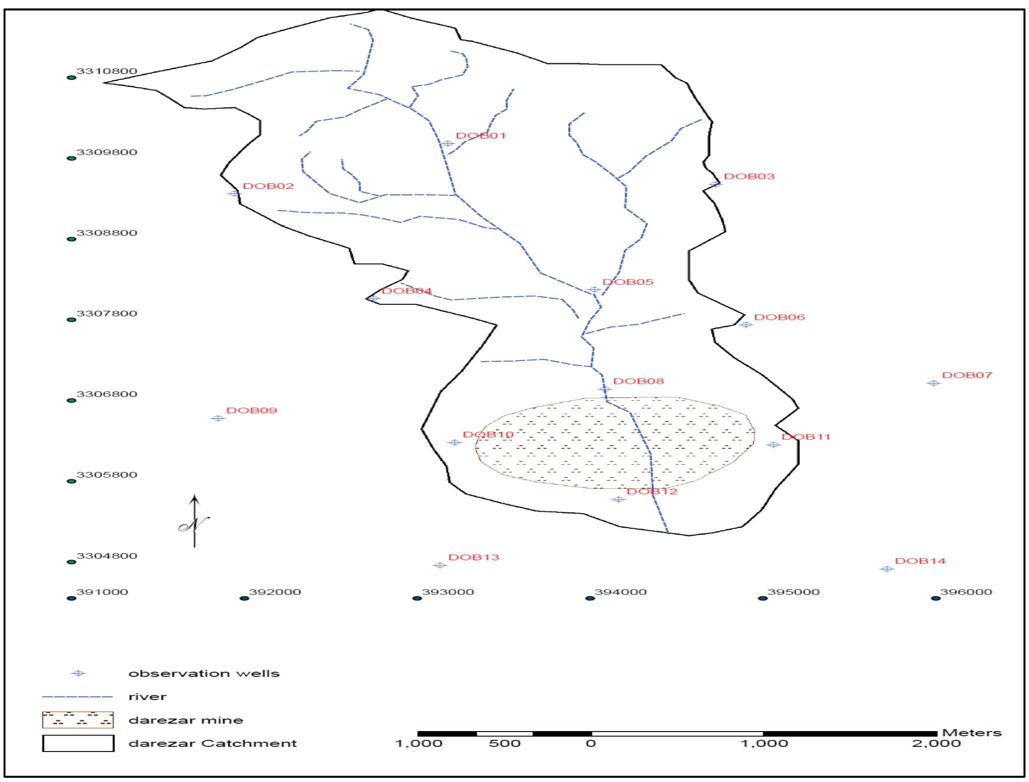

Table3. Characteristics of proposed pumping dewatering wells in Darezar mine

Name	X	Y	Drilled depth (m)	cased depth(m)	Slotted depth(m)
DP01	389673	3310971	100	20	80
DP02	388673	3310435	100	20	80
Total			**200**	**40**	**160**

3. Results

Comparison of RQD versus depth in Darezar mine denotes that the aquifer is extended to a depth of 300 m, below this depth, except in some area of mine, the porosity is decreased as RQD increases. Central area of Darezar mine pit toward west and northeast, the aquifer has high porosity up to the pit depth. Toward southeast from the center of pit, aquifer porosity decreases as depth increases. In east part of mine, the aquifer has high porosity to the pit depth. Water resources survey in Darezar mine are another evidence of potentiality of Darezar mine geology to make groundwater reservoirs. Based on survey, there are 31 qanats in Darezar mine area. Maximum, average and minimum yielding of these qanats are 21.8, 4 and 0.1 l/s respectively. Sum of the yielding of qanats is 128 l/s. A number of qanats are in downstream of Darezar mine, so pollutants may be transported to some of them. A number of 28 springs have been surveyed in Darezar mine study area. Minimum, maximum and yielding sum of springs are 0.1, 10 and 27 l/s respectively. Most of these springs are located in the upstream of Darezar mine and so may not be polluted by mining activity. Based on current assessment, the boundaries of hydrological catchment are considered as aquifer boundaries, so mine pit encounters groundwater throughout mine exploitation, hence a network of dewatering and observation wells were proposed.

4. References

[1] Anderson, M.P., Woessner,W., 1992. Applied Groundwater Modeling, Simulation of flow and Advective Transport. Academic press,Inc, San Diego.

[2] Bredehoeft, J.D., 2003. From models to performance assessment – the conceptualization problem. Ground Water 41(5): 571-577.

[3] Cherubini Claudia & Francani Vincenzo, Editors: S. Sorab, H. Ktrakis. N.Kobasko, 2007. A hydrodynamic model of a contaminated fractured aquifer, Proceeding of the 5th IASME/WSEAS Int. Conference on Heat Transfer, Thermal Engineering and Environment, Athens, Greece.

[4] Cooley, R.L., Konikow, L.F., Naff, .R.L., 1986. Nonlinear regression groundwater flow modeling of a deep regional aquifer system. Water Resources Research 22(13):1759-1778.

[5] Deere, D.U., 1963. Technical Description of Rock Cores for Engineering Purposes, Felsmechanik und Ingenieurgeologie (Rock Mechanics and Engineering Geology),Vol.1, No.1, pp. 16 – 22.

[6] Dershowitz William S., La Pointe P. R., Doe Thomas W., 2004. Advances in Discrete Fracture Network Modeling: Current Status and Future Trends U.S. EPA/NGWA Fractured Rock Conference: State of the Science and Measuring Success in Remediation.

[7] Haitjema, H.M., 1995. Analytic Element Modeling of Groundwater Flow. School of Public and Environmental Affairs, Indiana University, Bloomington, Indiana. Academic press,Inc.

[8] Herrera, E., Garfias, J., 2013. Characterizing a fractured aquifer in Mexico using geological attributes related to open-pit groundwater. Hydrogeology Journal, 21: 1323-1338.

[9] Northern Dynasty Mines Inc., 2007. Pebble Project, Environmental Baseline Studies, Proposed 2007 Study Plans. Chapter 5, Groundwater Hydrology.

[10] Pormando, S. et al., 2012. Geological Aspect for the Wet Muck Material Forming at the Deep Ore Zone Block Cave Mine, Papua, Indonesia. Proceeding Pit IAGI Yogyakarta, the 41st IAGI Annual Convention and Exhibition.

[11] Priest, S.D. and Hudson, J.A.,1976. Discontinuity spacing in rock. Int.J.Rock Mech. Min.Sci. & Geomech. Abstr., Vol.13, pp. 135-148.

[12] Schwartz et al., 1990. Ground Water Models, Scientific and Regulatory Applications, National Academy Press, Washington, D.C.

[13]TOOSSAB Consulting Engineers, 2012. Hydrogeological Studies of Darezar Mines Area. TOOSSAB.