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A review of Open Channel Design for Mine Dewatering System Based on Environmental Observations

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Abstract

The purpose of mine dewatering system is to control runoff water that enters mine openings so that the mining process is not disturbed. The rainfall discharge (Q) is 0.0951 m^3/second and the runoff discharge (Q) is 0.69 m^3/second, making the total mining discharge entering the location 0.781 m^3/second. The open channel design has dimensions of Channel wall slope (α) =60°, Water depth (h) = 0.73 m, Channel depth (d) = 0.83 m, Channel base width (B) = 0.73 m, Surface width (b) = 1.57 m, Wet cross-sectional area of channel (A) = 0.92 m^2, and Channel wall length (a) = 0.97 m. The sedimentation pond has thefollowing dimensions and compartments: Total length (l) = 104 m; width (b) = 8m; depth (H) = 4 m; partition width = 4 m; partition depth = 4 m; partition length = 7 m. It consists of 3 compartments: conditioning compartment, separation between solids and mine water, and flow with an area of 277 m^2 per compartment. The sedimentation pond volume is 3094 m^3 with a total area of 830 m^2. The results of the study obtained information that to control runoff water entering mine openings, a pond capacity as a settling site was needed of more than 3094 m^3 with a maximum dredging time of settling pond particles that can be done once every 10 months.

Keywords: mine dewatering system, rain catchment area, runoff water, open channel design, settling pool

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INTRODUCTION

Coal mining is very influential for the availability of energy at this time, both used as a power plant, cement manufacturing industry, iron ore smelting, and others. This can be seen from the increasing demand for coal, both from domestic and foreign markets (Adjiski et al., 2017; Bahrani & Kaiser, 2020). So that requires many mining companies to compete to increase their coal production to compete to meet the demand for the world coal market. In achieving the production target, the smooth running of a mining activity is the most important factor, namely by minimizing the obstacles that can hinder mining activities (Adjiski et al., 2017; Chen et al., 2021). Water constraints are a vital aspect that cannot be separated from the open pit mining system, the more land to be mined, the more water will enter the mine . Therefore it is necessary to design a good drainage system to prevent the mining front from being flooded (Briffett et al., 1996; Division of Early Warning and Assessment, 2003; FAO, 2016; Nikmatin et al., 2022).

The problems faced by the company at PT. Harmak Indonesia are high rainfall, causing water to enter the front line of work, which will certainly disrupt mining productivity. During extreme weather conditions such as high rainfall, the water can flood the floor and cause the mining front to become muddy (Division & Water, 1995; Malekzadeh & Sivakugan, 2021; Wateren, 2018). Another problem is the observation of a large catchment area during on-site activities. In addition, the existing sedimentation pond and channel are not in accordance with the expected conditions. A problem is formulated at PT. Harmak Indonesia, in the initial determination of PT. Harmak Indonesia's problems, the basis for mine drainage design will determine the relevant drainage system in the andesite quarry mining at PT. Harmak Indonesia. PT. Harmak Indonesia has a problem with high rainfall, before determining the geometry design of the mine drainage system, PT. Harmak Indonesia needs the amount of mine water entering the mining site in determining the volume and area of the mine drainage system geometry planning. The problem of irrelevance between the channel geometry and settling pond with the amount of water entering the mining area at PT. Harmak Indonesia, in its handling, requires a recommendation for a mine drainage system design that supports the mining activities, including: the shape, dimensions, and location of open channels and sedimentation pond (Michlowicz & Wojciechowski, 2021; Wateren et al., 2018).

Coal mining activities carried out by PT. Harmak Indonesia consists of one pit, then divided into two parts, namely the western pit and the eastern pit. At this time mining activities are focused on the west pit. In connection with the expansion of the mining area in the western pit, the rainwater catchment area has become wider (Hu et al., 2020; Michlowicz & Wojciechowski, 2021). Where the rainwater catchment area is divided into four, namely the first rainwater catchment area flows into the main mine sump, the second and third rainwater catchment areas flow outside the mining area, the fourth rainwater catchment area flows into the open channel . With the presence of the rainwater catchment area above, the resulting discharge of rainwater also increases and causes an increase in the volume of water in the sump (Hu et al., 2020; Obracaj et al., 2022; Rozkowski et al., 2021). The condition of the open channel is not well cared for, resulting in the walls of the open channel falling off easily and the soil material being classified as sandy so that water can easily escape from the pores of the sandstone. Therefore, good pumping performance is needed, as well as re-planning the mine drainage system for the mine progress area to the west of the pit. In order for mining activities to run smoothly and the mining front is free from standing water after rain, the drainage system must be properly designed (Adnyano & Bagaskoro, 2020; Haryanto et al., 2021; Rozkowski et al., 2021).

Based on the background and stated problem, the author aims to understand the selected drainage system for the andesite rock quarry mining in PT. Harmak Indonesia, calculate the water flow of the mining into the mining site, design a drainage system that can support the mining activities, including: shape, dimension, and location of open channels and settling ponds.

METHOD

The solution to the problem requires a combination of theory and field data, particularly primary data obtained from the company (PT. Harmak Indonesia). By combining both, a certain approach can be obtained. The data collection involves direct observation at the research site, including environmental observations and interviews with relevant stakeholders. The primary data includes research documentation, actual dimensions of open channels and settling ponds, site topography, catchment area, and channel wall material. The data was obtained from the company regarding the research on the mine drainage system and includes: location and accessibility maps, regional geology maps, topography and mine layout maps, rainfall data, runoff coefficients, and stratigraphy data.

Literature Study, Previous Research Reports, and Journal Articles

This involves studying the theories directly related to the problem that will be discussed in the field through available books or literature.

Field Orientation

The purpose of field orientation is to directly observe the problems that will be discussed, specifically the conditions of the research area at PT. Harmak Indonesia in Kokap District, Kulonprogo Regency, Special Region of Yogyakarta, Indonesia. Administratively, the location of andesite stone mining and processing by PT. Harmak Indonesia is located in Celapar III Hamlet, Hargowilis Village, Kokap District, Kulon Progo Regency, approximately 10 km from Wates, the capital of Kulon Progo Regency. Geographically, it is situated at coordinates S 70 47' 29.50" - S 70 47' 52.80" and E 1100 08' 09.0" - E 1100 08' 31.5", with a mining license area of 21.5 Ha.

Data Collection

Fiel data collection is carried out after the literature study and field orientation have been completed. The data collected is primary and secondary data. The collection of this type of data is direct data obtained from the research object, mainly observations at the research location, including observations of the surrounding environment and interviews with relevant informants. Where primary data includes: Research documentation, Actual open channel dimensions and actual settling pond, Location topography condition, Catchment area, Open channel wall material. This type of data is obtained from the company regarding related mine drainage system research, the data obtained is: Location maps and area coverage, Regional geology maps, Topography maps and mine layout, Rainfall data, Runoff coefficient, Stratigraphy data

Data Verification

Data verification is the process of re-checking the data that has been collected and if there is missing data, it must be completed immediately so that it can proceed to the next stage. Data Processing. The data processing and analysis techniques that will be discussed in this research are: Rainfall data is processed to obtain planned rainfall and then we can obtain rainfall intensity data. Then we determine the rainfall discharge, runoff discharge, mine discharge, and finally determine the dimensions of the open channel in the drainage system and obtain the settling pond design.

Analysis and Discussion

The results of the analysis from this research will attempt to obtain relevant results with respect to the objective of this research which are: To understand the mine drainage system selected in the andesite quarry mining at PT. Harmak Indonesia, To calculate the amount of mine discharge entering the mining location. To create a mine drainage system design that supports mining activities, which includes: the form, dimensions, and location of open channels and settling ponds.

RESULTS AND DISCUSSION

Based on the rainfall data obtained from the Kokap Station for 10 years (from 2011-2020), therainfall values in the study area range from 65-275 mm/year. The air temperature ranges from 25- 30°C, and the air humidity ranges from 60-80/6. Therefore, the study area is considered to have a relatively large amount of rainfall. PT. Harmak Indonesia is mining Andesite in Clapar III hamlet, Hargowilis village, Kokap district, Kulon Progo Regency, Yogyakarta Special Region using a quarry method. One of the supporting tasks in the Andesite mining process is the drainage system. In the general design of the mine drainage system, the climate conditions can be quite difficult to predict accurately (Taljaard et al., 2018). Therefore, the climate conditions need to be carefully considered, especially with regards to rainfall. To that end, the planned rainfall rate of 110,025 mm/day is used in the mine drainage design. The planned rainfall rate can be determined using several methods, one of which is the Gumbell method. Based on the calculation results, the planned rainfall rate was found to be 153,882mm. In this drainage system study, a rainfall return period of 3 years is used. The 3-year rainfall return period results in a hydrological risk of 86.83% compared to a 4-year rainfall return period, which has a hydrological risk of 76.27%. Based on the data obtained from PT. Harmak Indonesia, themine life is 5 years and the rainfall return period used is 3 years, resulting in a hydrological risk of 86.83%. The planned rainfall intensity is used in determining the runoff flow rate for determining the dimensions of an open channel cross-section (Kumar et al., 2013). The determination of planned rainfall intensity is carried out by processing the data using the Mononobe formula (Rowland et al., 2017). Based on the calculation results, the rainfall intensity value is about 26.91 mm/hour, with a t-value of 2.82 hours.

Determination of Mine Drainage System

Generally, the solution to water problems in open pit mines is carried out through a combination of two drainage systems, namely the mine drainage system and the mine dewatering system.

Mine Water Flow Measurement

The measurement results of the DTH area showed that it was 101900 m^2 or 0.1019 km^2. The measurement results of the Mine Opening area showed that the area was 53400 m^2 or 0.053 km^2, which can be seen in Figure 1. In the mine opening area, the coefficient of runoff water used is 0.9. The mine water flow used in the calculation is the largest flow originating from the fifth year push back. The water flow that is considered is water originating from rain and runoff. The amount of water entering the mine opening from DTH I (Q1) is 0.781 m^3/second. An example of rain flow, runoff flow that enters the mining location from each rain catchment area can be seen in **Table 1** and **Figure 1**.

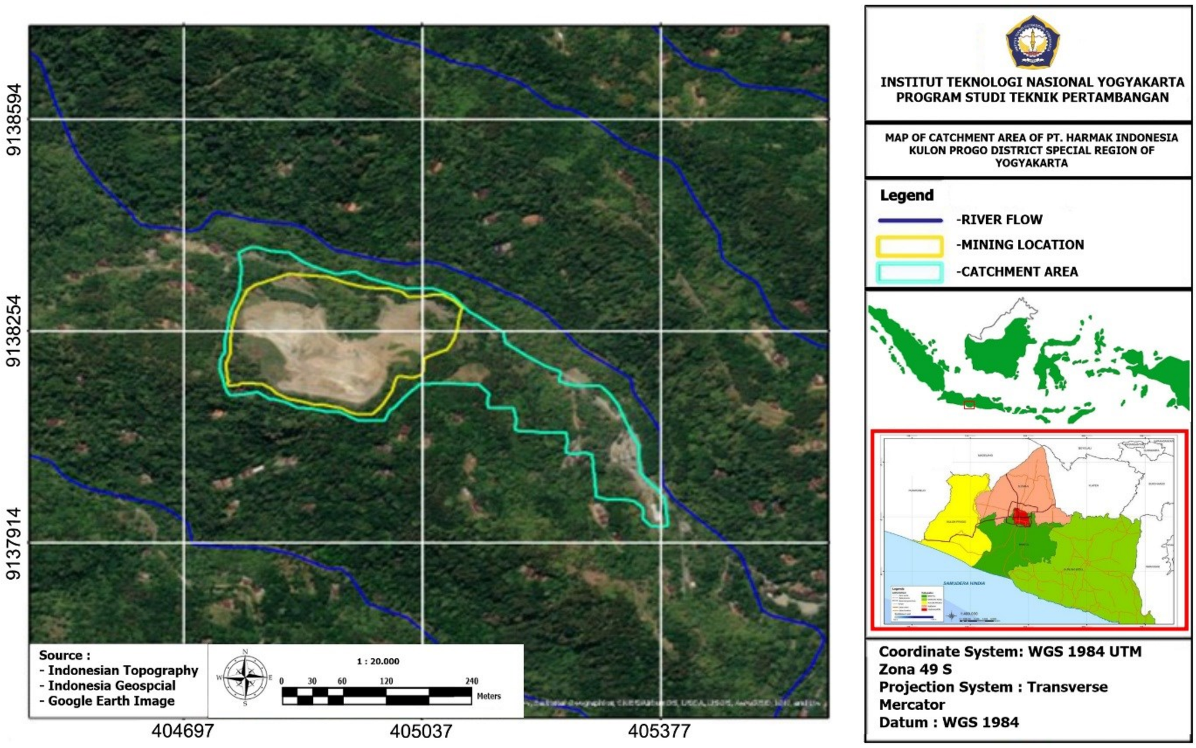

Figure 1. Map of PT. Harmak Indonesia's Rainfall Catchment Area in Kulon Progo Regency, Yogyakarta, Indonesia

Table 1. Mine Water Debit Results

DTH	Runoff Discharge (m^3/s)	Rainwater Discharge (m^3/s)	Total Discharge	
			(m^3/s)	(L/s)
CP1	0.69	0.0951	0.781	781.44

Source : Data of this study

Implementation of Mine Drainage System Creation

The creation of the mine drainage system design is meant to channel the excess water in the mining site and its surroundings to avoid interfering with the main activity of Andesite mining. The implementation of the mine drainage system creation in PT. Harmak Indonesia consists of the creation of an open channel and a sedimentation pond.

Implementation of Open Channel Plan Design

The open channel functions to flow the water to avoid pooling in the mining area. The dimensions of the open channel that are designed for the research location have anticipated the maximum flow rate in the fifth push back year which is 0.781 m3/second. This is to make sure that the water that flows through the open channel does not overflow. Furthermore, the use of the maximum flow rate for dimension calculation is done to keep the dimensions consistent every year. The use of the fifth push back year in the open channel is also done to determine its location, so that the location of the open channel is not changed every year. By using the fifth push back year as a reference, it is more efficient and effective in the design of the open channel. The open channel is designed using a trapezoidal cross-section with a channel wall made of soil (Division & Water, 1995; Malekzadeh & Sivakugan, 2021; Wateren, 2018). The open channel is divided into three parts, which are determined based on the rain catchment area that affects each part of the open channel. The dimension calculation of the open channel is based on the excess water flow rate and the topography of the research area. The dimensions of the open channel can be calculated using the Manning formula.

The planned Open Channel is located to the west of the mining site. This open channel flows water from the mining site to the sedimentation pond (Michlowicz & Wojciechowski, 2021; Wateren et al., 2018). The mine water that is channeled through theOpen Channel comes from the rainfall flow rate and the excess water flow rate, with a total flow rate of 0.781 m3/second. The chosen shape of the open channel is a trapezoid with a 60º angle. The following are the dimensions of the Open Channel located to the west of the mining site, which can be seen in **Table 2** and **Figure 2**.

Table 2. Recommended Open Channel Design Plan

Information	The calculation results	Unit
Mine Water Debit (Q)	0.781	m^3/sec
Channel wall slope (α)	60	°
Water depth(h)	0.73	m
Channel depth(d)	0.84	m
Channel base width (B)	0.73	m
Surface width (b)	1.57	m
Channel wet cross-sectional area (A)	0.92	m
Channel wall length (a)	0.97	m

Source : Data of this study

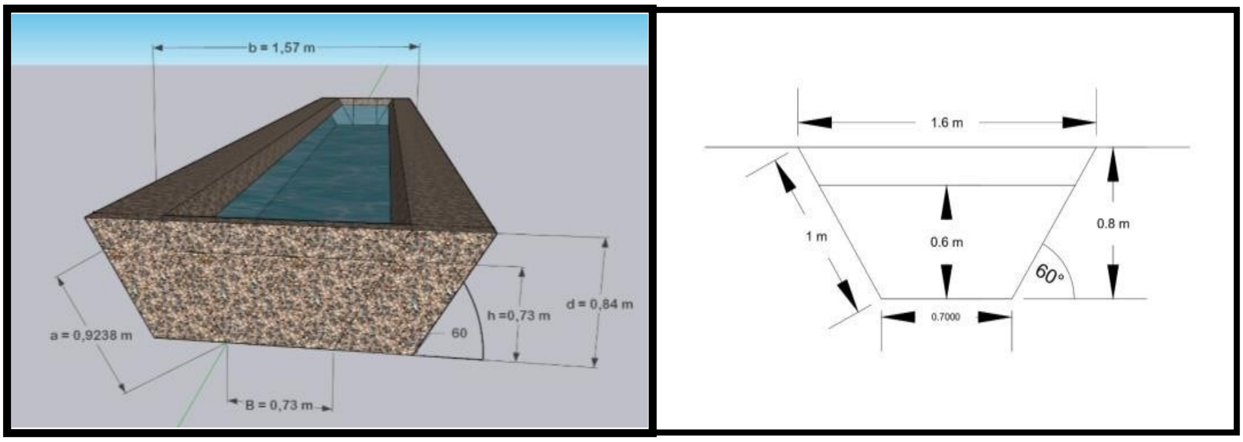

Figure 2. Open Channel Dimensions

In PT. Harmak Indonesia, there is no sump but only a sedimentation pond that serves to clarify the mined water that will be rerouted back to the river so that the water remains clear and does not pollute the surrounding river flow. The sedimentation pond acts as a place to settle solid particles carried by water from the mining area. Water that has passed through the sedimentation pond is then directed to the river with the hope that the water is clear because solid particles have settled (Hu et al., 2020; Obracaj et al., 2022; Rozkowski et al., 2021). The required sedimentation pond area for each compartment is 277 m^2. The sedimentation pondconsists of three compartments: the conditioning compartment, the separation between solid and mined water, and the flow compartment. The conditioning compartment is used to regulate the flow rate of water, the separation compartment between solid and mined water is used to settle solidmaterials carried by water, and the flow compartment is used to flow clear water. The mined water flow entering the sedimentation pond is 0.78 m^3/sec with a sedimentation rate of 2.829 x 10^{-3} m/sec.Therefore, the required sedimentation pond area for each compartment is 277 m^2. The basis for thecalculation of the dimensions of the sedimentation pond is based on the excavation tool used, whichis the Excavator PC 200-8 Komatsu. The dimensions of the sedimentation pond can be seen in **Table 3** and **Figure 3**.

Table 3. Recommended Settling Pond Designs

Information	The calculation results	Unit
Mine Water Debit (Q)	0.781	m^3/sec
Depth (H)	4	o
Width (b)	8	m
Length of each compartment (l)	35	m
The total length of the pool	105	m
Baffle width	4	m
baffle length	7	m
Sealing depth	4	m
The total area of the pool	830	m^2
Pool volume	3094	m^3

Source : Data of this study

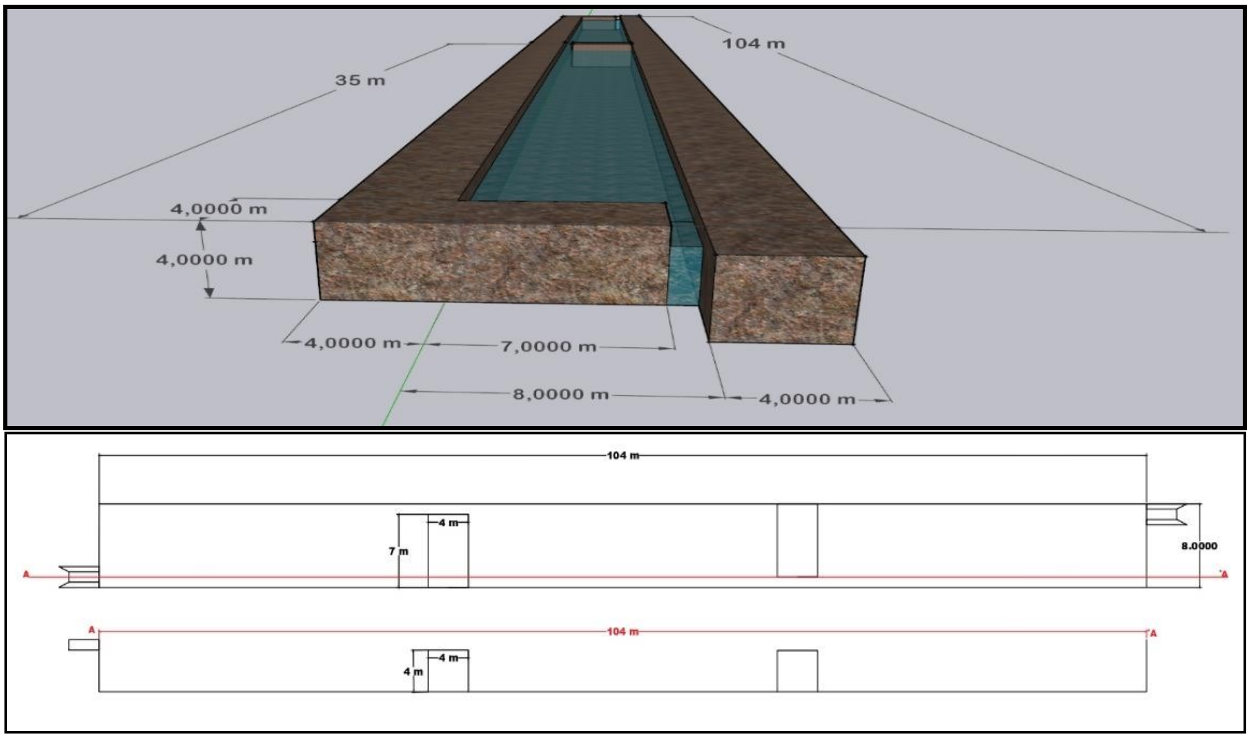

Figure 3. Dimensions of the Settlement Pond

The dimensions resulted in a sedimentation pond volume of 3094 m^3. The incoming solid particle flow rate was 3,907 x 10^{-3} m^3/second. Only 75% of the total solid particles entering the pond were effectively sedimented. Hence, the amount of sedimented particles in a day was 11 m^3/day. The sedimented particles in the sedimentation pond will gradually accumulate and fill up the pond (Adnyano & Bagaskoro, 2020; Kumar et al., 2013; Rowland et al., 2017; Taljaard et al., 2018). Therefore, maintenance of the pond is required by removing the accumulated particles. The calculation of the cleaning time was based on the pond volume and the total amount of sedimented particles per day. The calculation showed that the cleaning should be done every 293 days (10 months) at once.

CONCLUSION

The conclusion from the technical evaluation and analysis of the activities of the limestone mining unit at PT. Harmak Indonesia, as described in previous chapters, is as follows: The chosen mine dewatering system is chosen because there is only rainwater and runoff water that directly enters the mine source, with no groundwater or seepage. The water that enters the mine area comesfrom the rainwater and runoff that originates from the surrounding rain catchment areas. The rainfall discharge (Q) that originates from the mine opening is 0.0951 m^3/second and the runoff discharge (Q) that originates from the rain catchment area I is 0.69 m^3/second, resulting in a total mine waterdischarge of 0.781 m^3/second. The planned mine dewatering system design includes an open channel designed based on the runoff discharge from each rain catchment area and with a trapezoidal cross-section. The results of the open channel design are as follows: The open channel is located to the west of the mining location and channels water from the rain catchment area I with a discharge of 0.781 m^3/second. It has dimensions such as channel wall slope (α) = 60°, water depth (h) = 0.73 m, channel depth (d) = 0.83m, channel base width (B) = 0.73 m, surface width (b) = 1.57 m, wetted channel cross-sectional area (A) = 0.92 m, and channel wall length (a) = 0.97 m. The designed sedimentation pond has dimensions and compartments as follows: Total length (l) = 104 m; width (b) = 8 m; depth (H) = 4 m; partition width = 4 m; partition depth = 4 m; partition length = 7 m. It consists of 3 compartments for conditioning, separating solids from the mine water, and flow, with a total area of 277 m^2 each. The sedimentation pond volume is 3094 m^3 with a total area of 830 m^3. The sediment removal in the sedimentation pond must be performed every 293 (10 months) times.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest concerning the publication of this article. The authors also confirm that the data and the article are free of plagiarism.

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