



Application of Mine Dewatering Methods to Reduce Wastewater Pollution in The Environment: Implications for Andesite Mining

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Abstract

Wastewater pollution in mining areas often occurs and becomes a problem in the surrounding groundwater aquifer system. One of the efforts to determine the distribution of wastewater pollution is to calculate the discharge and volume of wastewater. In this study, an open channel in the form of a ditch or commonly referred to as a drainage system is carried out to determine the total water discharge entering the research location, design the dimensions of the sump and design the optimal cross-sectional dimensions of the ditch to overcome the discharge of water that comes out and pollutes the environment. The method used is to make an open channel in the form of a trapezoid to be used around the andesite rock mining site which then drains the mine water to the settling pond. Efforts to drain the water that has entered the main sump (mine dewatering system) are carried out by making wells, after which the waste water is channeled into the settling pond using a pump. From the results of the study, information was obtained that the total water discharge entering the sump was 235,175 m so that the volume of the sump made was 300 m with dimensions of top area: 20m x 10m, bottom area: 10m x 10m, with a depth of 2m for total water discharge for ditches. 0.0237 m so that the volume of the trench made is 0.228 m.

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INTRODUCTION

Mining mineral exploration is indeed an activity carried out by all countries in the world. In its activities, the impact of mining mineral exploration is not only profitable, but also has the potential to cause negative impacts on the environment (Arunee et al., 2019), one of which is mining waste water pollution (Listiyani., 2017). One of the mining exploration sites observed in this article is andesite mining by CV. Anugerah Bumi in Cilacap Regency, Indonesia. In the process of mining andesite rock, often waste water mixed with mining minerals spreads and affects the quality of surface water and even groundwater around it (Tanimizu et al., 2021). Other influences such as high rainfall can expand the contamination of aquifer water in the environment. On the other hand, mining exploration carried out using an open pit mining system (all mining activities are directly related to environmental conditions such as climate and weather conditions, rain, heat, and air pressure)

greatly affects mining activities (Ivaz et al., 2020), namely: the inhibition of loading and unloading activities due to muddy roads (Adnyano et al., 2020).

In mining activities, one of the important factors in mining activities is the availability of water. Water will be needed if it is in the right amount, and if it exceeds the need, the water will be a problem that can certainly affect mining activities (Wu et al., 2013). The source of water entering the open pit mining area comes from rainwater. During the rainy season, the amount of water produced is so large that it can affect the work of tools, workplace conditions, and the safety of workers which in turn will affect mine productivity (Pizarro and Fuenzalida, 2021).

One of the factors that must be considered in the mining process is the problem of water handling, or more commonly referred to as mine drainage. The mining method that is directly exposed to the outside air is the open pit mining method. Where it is strongly influenced by the climate such as rainy weather, hot weather, etc., it will affect the working conditions of the tools and workers' conditions, which in turn can affect mining productivity. On the other hand, the requirements for mining activities to run as planned, good working conditions are needed, so that there is no puddle of water in the work area and mining roads (Cahyadi et al., 2020). Therefore a water drainage system is needed in the mining area accordance with technical requirements, so that rainwater, runoff water and existing groundwater can be controlled. The mine drainage system in open pit mines is broadly divided into two, namely preventing water from entering the mining area (mine drainage) and controlling water that has entered the mine dewatering development area (Gautama, 1999).

Water in large quantities is a big problem in mining work, both directly and indirectly affecting productivity (Putri, Y. E., 2014). This applies to both open mining and under mining. The definition of a mine drainage system is an effort that is applied to a mining area to prevent, dry, or remove water that enters the mining area (Endhrianto and Ramli., 2013). This effort is intended to prevent disruption of mining activities due to the presence of excessive amounts of water, especially during the rainy season (Bambang, S. 1985). In addition, this mine drainage system is also intended to slow down tool damage and maintain safe working conditions, so that the mechanical equipment used in the area has a long life (Hartono., 2013).

Sources of water that enter the mining site, can come from ground water or underground water. Water that seeps into the ground partially flows into the ground (percolation) filling groundwater which then comes out as springs or flows into rivers. Eventually the water flow in the river will reach the sea. This continuous process is known as the hydrologic cycle (Wang et al., 2021). Surface water is water that exists and flows on the ground surface. This type of water includes surface runoff water, river water, swamps or lakes in the area, waste water (waste), and springs. While underground water is water that exists and flows below the ground surface. This type of water includes groundwater and seepage water (Bo et al., 2014). Handling water problems in an open pit mine can be divided into two types (Bai et al., 2021) namely mine drainage and mine dewatering.

Mine drainage is an effort to prevent water from entering the mining area. This is generally done for the treatment of groundwater and water originating from surface water sources (Chen et al., 2013). Meanwhile, mine dewatering is an attempt to remove water that has entered the mining area. This effort is mainly to handle water that comes from rainwater (Bai et al., 2018).

One way to control rainwater and runoff in mining areas is to make an open channel in the form of a trench. The trench is one part of the mine drainage system which is made with the aim of controlling rainwater and runoff water that is inside or from outside the mining area but has the potential to enter the mining area. The trench made must be based on certain terms and conditions so that the ditch can accommodate and drain runoff water so that it does not interfere with all existing mining activities. In field conditions CV. Anugerah Bumi Cilacap, the existing ditch is still not optimal in accommodating water, the ditch is not connected properly so the road becomes muddy. The purpose of the drainage system research is to determine the total water discharge entering the research location, to design the dimensions of the sump and to design the optimal cross-sectional dimensions of the ditch to overcome the water discharge.

METHOD

The research method used is a quantitative research method. Quantitative type research can be used if the data collected is in the form of quantitative data or other types of data that can be quantified and processed using statistical techniques. In addition to using quantitative research methods in this study, applied research methods are also used. Applied research emphasizes the application of science and applications or the use of knowledge or for certain purposes (Siyoto, S., and Sodik, A.M., 2015). The series of data collection in the field is carried out as follows **Figure 1**.

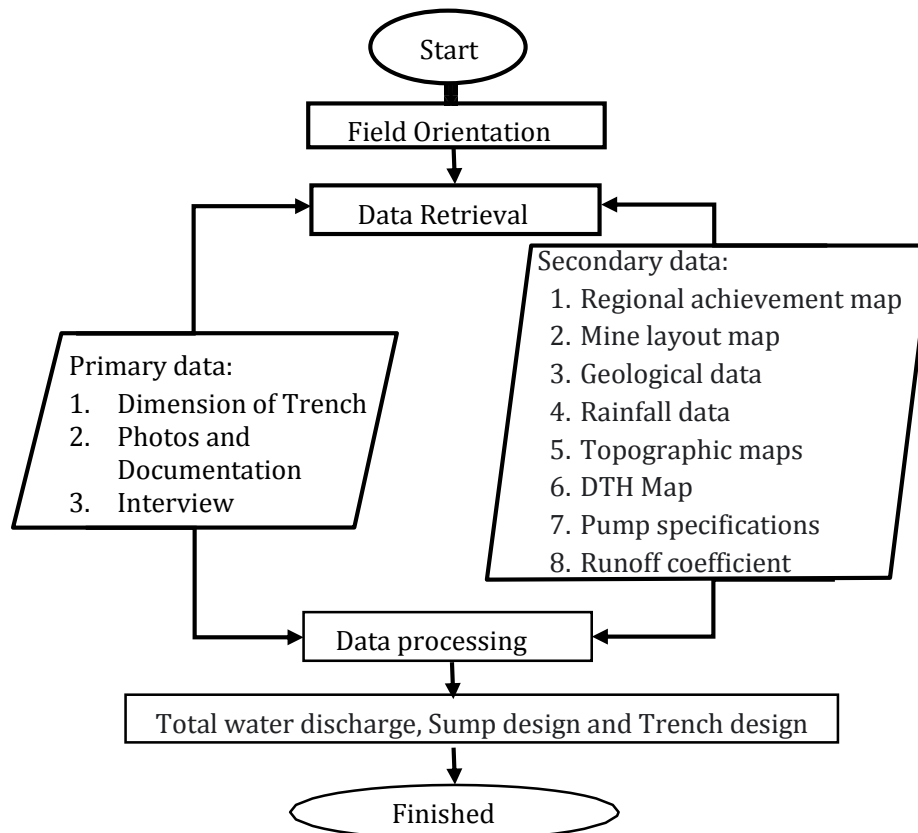


Figure 1. Research flow chart

Data Collection and Data Analysis Stage

The data collection stage begins by taking primary data in the form of the highest point elevation, the elevation of the exhaust pipe and suction pipe, determining the catchment area, runoff water discharge, groundwater discharge, and the farthest distance from the drainage concentration area. Secondary data in the form of topographic maps at the time of the study, maximum daily rainfall data, pump specifications, pipe length and diameter, settling pond excavation equipment specifications, TSS value.

The catchment area, which can be referred to as a drainage basin, watershed or watershed, is an area that is limited by the ridges of the hills or the highest point when it rains, the rainwater will flow to the lowest point in the area (Utama et al., 2016). Determining the catchment area in a mining area can be determined by analyzing topographic maps and mining progress maps. The catchment area is obtained by connecting the highest points on the map with and paying attention to the direction of water flow in the area until a closed polygon is obtained. The area of the polygon is calculated using a planimeter, millimeter block or with the help of software (Gautama, 2019).

Rainfall used from 2016-2020. This data processing can be done by the Gumbel method, which is a method based on the normal distribution (extreme price distribution) (Gumbel, E.J., 1941).

$$X_t = \bar{X} + \frac{sd}{sn}(Y_r - Y_n) \quad (1)$$

Where X_t is the planned rainfall (mm/day), \bar{X} is the average rainfall (mm/day), X is the maximum rainfall (mm/day), n is the number of samples available, sd is the standard deviation, Y_n is

reduce mean, sn is reduce standard deviation, and Yt is reduce variate. In determining the intensity of rainfall, it can be obtained using the Mononobe formula (Gautama, 2019).

$$I = \left(\frac{R_{24}}{24}\right)\left(\frac{24}{t}\right)^{2/3} \quad (2)$$

Where I is the intensity of rainfall (mm/hour), t is the length of rain in units (hours), and R_{24} maximum daily rainfall in units (mm). To estimate the runoff water discharge requires some existing data and the Rational formula can be used (Gautama, 2019).

$$Q = 0,278 \times C \times I \times A \quad (3)$$

Where Q is the water discharge (m^3 /second), C is the runoff coefficient of an area, I is the rainfall intensity (mm/hour), and A is the area of the rain catchment area (km^2). Rainwater discharge is the amount of rainwater that will enter the well or bottom pit in an open pit and can be calculated by the formula:

$$Q = X_t \cdot A \quad (4)$$

Where Q is the rainwater discharge (m^3 /second), X_t is the planned rainfall (mm/hour), and A is the area of the rain catchment area from the topographic map. The sump in the mine serves as a temporary reservoir for water and mud before being pumped out. In determining the dimensions of the sump to be used, equation (6) is used (Gautama, 2019).

$$V = (\text{Top area} + \text{Bottom area}) \frac{1}{2} \times T \quad (5)$$

Where V is the volume (m^3), and T is the sump height to be determined. The design of the dimensional cross-section of the channel is carried out to drain water and prevent water from entering the mining site, using the manning method (Cahyadi et al., 2016).

$$Q = 1/n \times A \times S^{1/2} \times R^{2/3} \quad (6)$$

Where Q is the water discharge to be flowed (m^3 /second), A is the wet cross-sectional area of the ditch (m^2), n is the roughness coefficient value of the channel wall according to manning, R is the hydraulic radius in units (m), and S is the slope channel base with units (%).

RESULTS AND DISCUSSION

Rainfall data were obtained from the Environment Agency of Indonesia, CV. Anugerah Bumi Cilacap located in the Cilacap area, Central Java, Indonesia. The analysis was carried out for the last 15 years from 2016 to 2020 including rainfall data for each time period and maximum daily rainfall (Keputusan Menteri Lingkungan Hidup Nomor 113 Tahun 2003). The rainfall data is raw data that cannot be used directly for mine planning. But the data needs to be processed first with statistical principles. The results of this processing are the estimated maximum rain heights that are considered to occur once in the planned return period of rain. Rainfall data processing is intended to obtain rainfall data for each time interval and rainfall intensity that is ready to be used for planning. The method used in processing rainfall data is using the Gumbell analysis method (Liu et al., 2017).

The research location is located on CV. Anugerah Bumi Cilacap with a main sump base at an elevation of 129 masl and a sludge settling pond at an elevation of 142 masl with an open channel surrounding the mining area. Based on field observations, the pumping system uses 1 pump line, 1 pump discharge line to the mine settlingpond. The pump used for the mining area is 1 Honda WB30XN with 80mm IN/OUT hole specifications, maximum discharge $80m^3$ /hour, max total head 23m, max suction head 7.5m and has a power of 3,600rpm. Furthermore, all water entering the mining area will be discharged to the settlingpond.

Table 1. Maximum rainfall data for 2016-2020

Month	Year					Average
	2016	2017	2018	2019	2020	
January	9.88	14.14	21.00	17.81	9.81	14.5
February	20.11	20.29	12.79	17.65	14.91	17.2
March	10.60	9.29	9.20	21.47	18.86	13.9
April	24.40	26.79	18.89	23.08	13.14	21.3
May	15.62	11.15	4.90	14.58	25.20	14.3
June	23.21	18.92	5.67	2.93	18.35	13.8
July	39.12	5.13	4.37	2.9	4.09	11.1

August	14.63	1.35	1.00	0	3.46	4.1
September	34.67	25.33	1.79	0	11.00	14.6
October	27.45	23,22	6.46	1.47	33.26	13.7
November	20.45	16.5	24.33	16.11	33.04	22.1
December	16.00	20.94	23.59	5.88	20.52	17.4
Total	39	27	24	23	33	
Average	3.26	2.23	2.03	1.92	2.77	
Maximum Amount of Rainfall						177.9
Amount of Average Rainfall						12.215

(Source : Data of this study)

Calculating planned rainfall using the Gumbel equation using the equation with data from **Table 1**. The results can be seen in **Table 2**, the planned rainfall using equation 1 is 99.74 mm/day. Calculation of rainfall intensity using equation 2. It is obtained 7.20mm/hour.

Table 2. Calculation of planned rainfall

Year	Max Rainfall (x)	X ²	\bar{x}	(x- \bar{x})	(x- \bar{x}) ²	n	m	Yn	Yn ²	Yn average	(Yn - Yn average)	(Yn - Yn average) ²	Sn	S
2016	39,1	1530,3	29,3	9,8	96,11	5	1	1,7	2,90	0,459	1,243	1,55	0,8	20,2
2017	26,8	717,7	46,1	-19,3	371,64	5	3	0,3	0,13	0,459	-0,092	0,01	0,8	20,2
2018	24,3	591,9	46,1	-21,7	472,54	5	4	-0,09	0,01	0,459	-0,553	0,31	0,8	20,2
2019	23,1	532,6	46,1	-23,0	528,44	5	5	-0,5	0,34	0,459	-1,042	1,09	0,8	20,2
2020	33,3	1106,2	46,1	-12,8	164,04	5	2	0,9	0,81	0,459	0,444	0,20	0,8	20,2
Total	146,5	4478,9	46,1		1632,7	5	2,2	4,19	0,459	0,00	0,00	3,14	0,8	20,2
Average	29,3	895,7			326,56			0,4	0,84	0,00	0,00	0,63		

(Source : Calculation data of this study)

Determination of rainfall intensity is intended to obtain a duration curve which will later be used as the basis for calculating runoff water in the research area. Rainfall data processing is intended to obtain a duration curve which will later be used as the basis for calculating runoff water in the research area (Shen et al., 2018). The amount of runoff that enters the mining site is calculated using the rational formula equation 3, and the calculation results are in **Table 3**.

Table 3. Total runoff water discharge

Location	C	I (mm/hour)	A (km ²)	Q (m ³ /detik)
DTH I Extend	0,278	0,6	7,20	0,05378783
DTH II road	0,278	0,9	7,20	0,01317

(Source : Calculation data of this study)

The calculation of the rainwater discharge is carried out with equation 4, which can be 2,625mm/hour. Calculation of the dimensions of the well/sump can be calculated based on the discharge of water entering the mine. The water discharge entering the mine opening is 235.175 m³/hour. The shape of the well is a trapezoidal shape, so to accommodate the total volume the following calculations are used, for a pit with a trapezoidal shape the slope of the well is 61 ° and the planned depth of the pond is 2 meters, the calculation uses equation 5. So to accommodate 235.175 m³, it is necessary there are improvements/changes in sump dimensions (**Figure 2**).

The open channel in the drainage system in an open pit is useful for collecting and draining runoff water to the sump or flowing to the setlingpond. The dimensions of the open channel are designed according to the amount of runoff water that will be flowed and the terrain of the research location.

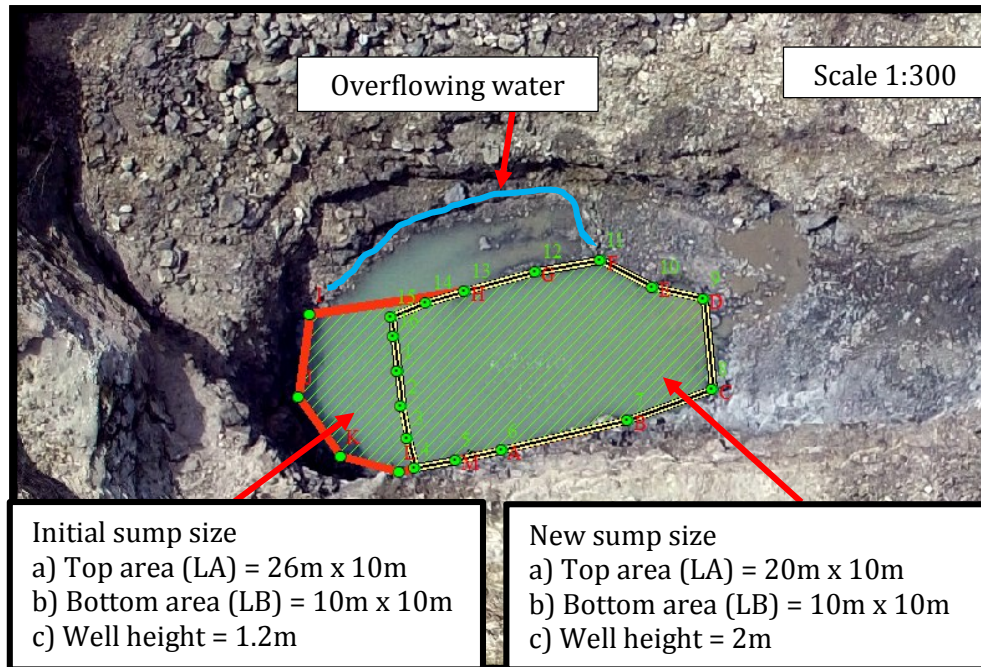


Figure 2. Location of repair/change of sump dimensions

Based on the research location, an open channel has a trapezoidal cross section with dimensions (Depth of flow: 0.29m, Depth of channel: 0.35m, Width of channel bottom: 0.33m, Width of top surface: 0.67, Length of wall slope: 0.40m, and 20cm guard height) on the side of the road and culverts with dimensions (Flow depth: 0.91m, Circular diameter 1.7m, water crest width: 0.024m, and Wet cross-sectional area: 0.31m) for connections between ditches that crosses the road. The following is the cross-sectional design of the trapezoidal trench and circular cross-section (Culverts) which are calculated by equation 6, as shown in **Figure 3** and **Figure 4**.

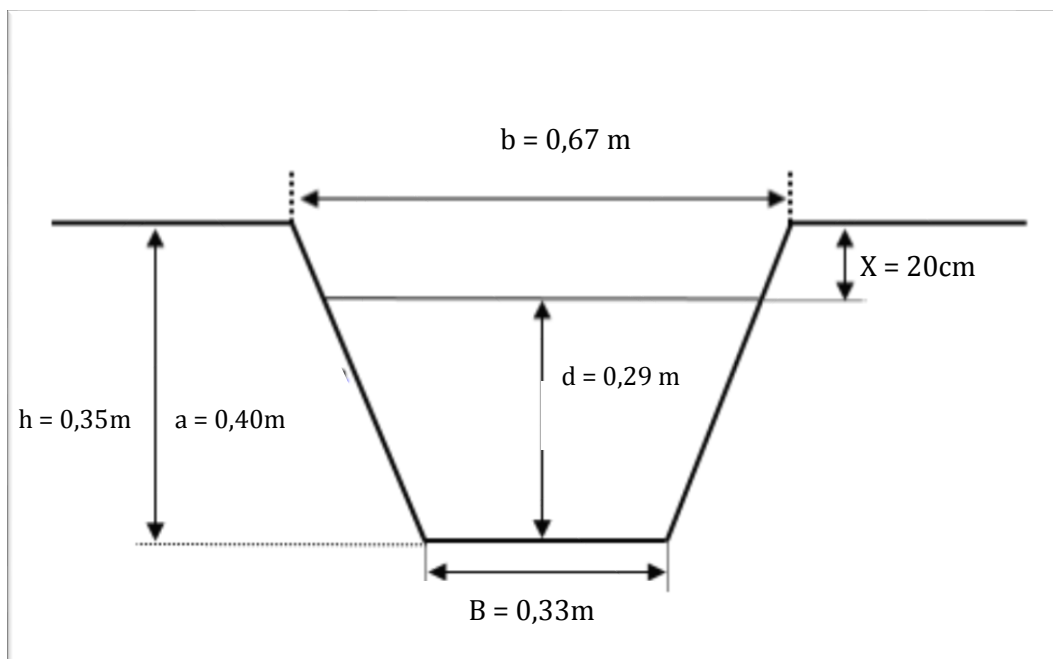


Figure 3. Trapezoidal cross-section design

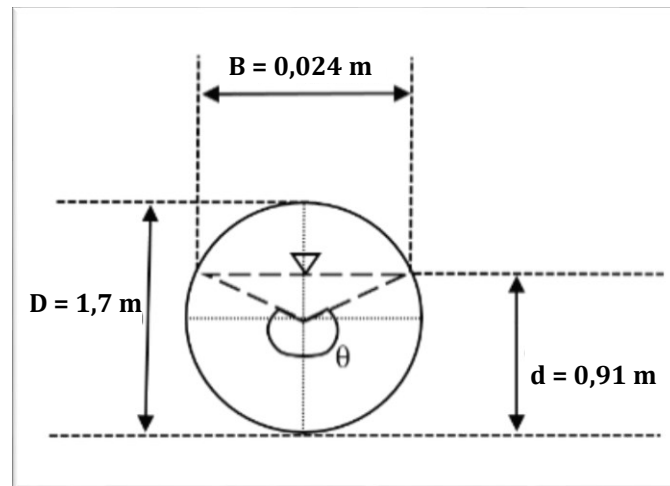


Figure 4. Circular cross-section design

The form of a settling pond is usually only described in a simple way, namely in the form of a rectangular pond, but in fact the shape can vary, adapted to the needs and conditions of the field. Although the shape can vary, but in every settling pond there will always be four important zones that are formed due to the solid material deposition process, namely 1. Inlet zone; 2. Deposition zone; 3. Mud deposition zone; 4. Output zone.

Determination of the location of the settling pond must pay attention to several provisions, including the settling pond to be made outside the mining area so that it does not interfere with mining activities, made in a low area by taking into account the topography of the mining area, located close to natural channels that will lead to final disposal.

The shape of the planned settling pond is rectangular and curved so that the velocity of water and incoming material can be minimized, with a small flow velocity, the time for deposition of solid material in the settling pond will be longer. With the settling pond, it is hoped that all water that comes out of the mining area is actually water that has met the threshold permitted by the Decree of the Minister of the Environment of the Republic of Indonesia Number 113 of 2003 for Ph, suspended residue, total iron (Fe) and Manganese (Mn). the total must be according to the rules ([Keputusan Menteri Lingkungan Hidup Nomor 113 Tahun 2003](#)), thereby preventing environmental pollution.

CONCLUSION

The total water discharge that enters the study area is Rain Catchment Area I: 235.175m and Rain Catchment Area II: 0.0237m³. The sump at the mining site has not been able to cope with the incoming water so it needs to be redesigned with the following dimensions: (top area: 20m x 10m, bottom area: 10m x 10m, depth 2m). The current open channel has not been able to accommodate and drain runoff water properly so it is necessary to redesign the open channel section with trapezoidal dimensions: (Flow depth: 0.29m, Channel depth: 0.35m, Channel bottom width: 0.33m , Top surface width: 0.67, Wall slope length: 0.40m, and Guard height 20cm) and circular dimensions: (Flow depth: 0.91m, Circular diameter 1.7m, Water crest width: 0.024m, and Cross-sectional area wet: 0.31m) which is able to drain runoff water so that it does not become inundated and mining activities continue to run smoothly. Based on the results of the research, conclusions that are suggested for researchers and exploration actors in the future include 1). During the excavation process, you should pay attention to the slope of the mine opening floor so that water can flow properly to the sump so that there is no puddle of water on the mine opening floor; 2. The need for regular and scheduled pump maintenance to avoid damage to the pump during operating hours; 3. The walls of the settling must be properly maintained. So that if it rains, there will be no erosion or erosion of the walls of the setting pond which creates high turbidity. Sludge settling ponds must be considered and dredged regularly in order to function properly and optimally.

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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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