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Technical Study of the Drainage System (Mine Dewatering) at the Open Mine at PT. Bukit Makmur Istindo Nikeltama

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Abstract: The high rainfall that occurred throughout 2024 caused the capacity of the existing sedimentation pond to be unable to accommodate it, resulting in water overflowing and flooding the mining area. This study aims to examine the existing drainage system using quantitative and qualitative research methods. Based on the 2014-2023 rainfall analysis, Log Pearson III distribution with a 5-year return period, the planned rainfall was 142.25 mm/day, Rain Intensity 23.31 mm/hour for a rainfall duration of 3.08 hours/day. The total discharge entering the main sump was 7,771 m3/day and was discharged through the sump outlet mouth, connected by a ditch to Settlingpond 8. At this research location, there were 3 trapezoidal ditches namely: Ditch I 1.78 m3/sec, Ditch II 1.85 m3/sec, Ditch III 2.2 m^3/sec. The calculation results showed that the main sump and ditch could still accommodate the total incoming discharge. The capacity of Sedimentation Pond 8, with a volume of 7,025 m^3, is not sufficient to accommodate the total inflow of 8,293 m^3/second and a sedimentation rate of 40-50%. Considering that the research area cannot be expanded due to land limitations, it is necessary to increase the height by 5 meters in the three settling pond compartments to enhance sedimentation efficiency. In addition, it is necessary to add 1 Ebara 200 x 150 FS4NA pump in the last compartment to help discharge water with a total discharge of 8,293 m^3/day. The benefit of this research is that it is able to provide recommendations for managing the mine drainage system.

Keywords: ditch, settling pond, sump, total discharge

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1. Introduction

Nickel mining at PT Bukit Makmur Istindo Nikeltama has a significant impact on the mine surface, creating steep slopes that increase the risk of erosion, landscape alteration, and sedimentation [1]. High rainfall conditions have the potential to increase runoff discharge in the mining area [2]. Given the high rainfall in the research location, this significantly impacts the amount of water that must be managed and addressed to prevent disruption to mining activities and environmental pollution [3]. Environmental pollution caused by the presence of water will certainly increase the potential for high acid water levels [4], [5]. This increase in acid water will undoubtedly disrupt mining and post-mining activities, especially during the land reclamation process [6].

In this research location, the problem arises from the inability of the settling pond capacity around the Hauling Road area to accommodate the incoming water flow. Furthermore, the mismatch in the sump capacity, which is largerthan the settling pond capacity, causes the water entering the settling pond to exceed its capacity and cause overflow. Therefore, proper handling of incoming water is needed so that the mine drainage system is effective and efficient, indicated by the absence of water overflowing onto the hauling road.

2. Methods

This study began on July 25, 2024 - September 17, 2024 by collecting primary and secondary data. Primary data collection, namely data obtained from direct observation at the research location, the data obtained in the form of dimensions of the ditch, sump and settling pond in the form of length, width, and depth of the ditch, sump and settling pond as well as the bottom and top width of the ditch. Meanwhile, in secondary data collection, the data obtained in the form of rainfall data for the last 10 years, rainy days, rainfall duration and topographic data. **Figure 1** presents a flowchart illustrating the process of research data handling for the mine drainage system.

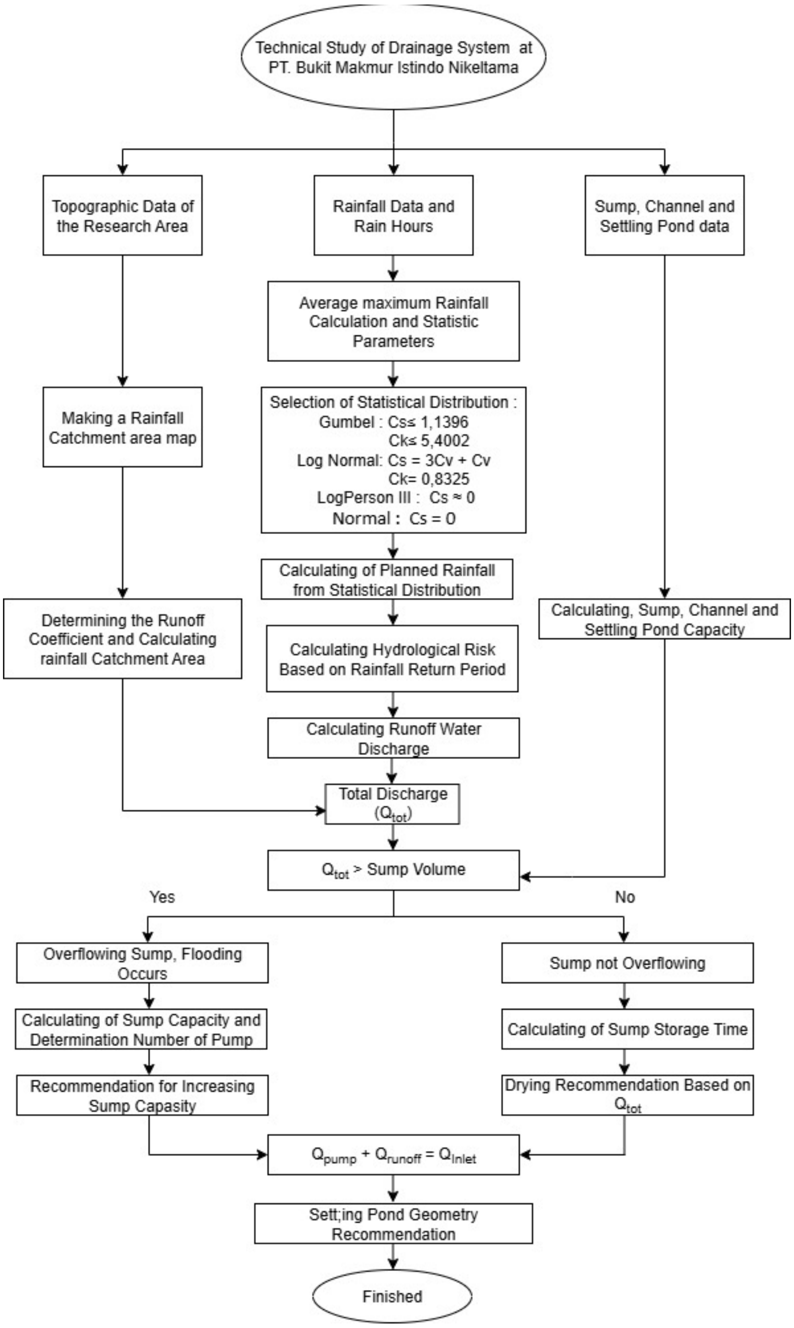

Figure 1. Data Processing Flowchart

2.1. Runoff and rainfall discharge

Runoff is the portion of rainfall that flows over the land surface toward rivers, lakes, or the sea [7]. To calculate runoff discharge, use the rational formula (1).

$$Q = C \; x \; I \; x \; A \qquad (1)$$

Where :
Q = Maximum runoff discharge (m^3/second)
C = Coefficient
I = Rainfall intensity (m/hour)
A = Catchment area (m^2)

Meanwhile, the rainfall discharge is influenced by the size of the mine opening. The larger the mine opening, the greater the resulting discharge [8], [9]. The calculation of rainwater discharge is the multiplication of the mine opening area and the planned rainfall.

2.2. Drainage Channels and Temporary Storage Pond (Sump)

Drainage channels are channels that function to collect and channel water to a collection point (retention pond) or another pond. Rainfall is a crucial factor in drainage system planning, as high or low rainfall in a mining area will affect the amount of water entering the study area [10]. Therefore, these channels are crucial for controlling and managing mine water, especially in open-pit mines. The design of these channels can be determined by considering the water discharge rate, material type, and ease of construction. The capacity of this channel can be calculated using Manning's formula (2).

$$Q = \frac{1}{n} \; x \; R^{\frac{2}{3}} \; x \; S^{\frac{1}{2}} \; x \; A \qquad (2)$$

Where :
Q = Discharge (m^3/second)
R = Hydraulic radius (m)
S = Channel slope (%)
A = Wetted cross-sectional area (m^2)
n = Manning's hardness coefficient

A sump is a well that functions to store mine water, whether it flows through the trench network or as surface runoff [11]. The main advantage of this well drainage system is the flexibility in pumping arrangements throughout the life of the pit[12]. When constructing a sump, its dimensions must be adjusted to the water volume and the highest average daily rainfall to prevent overflow[13].

2.3. Pumps

A pump is a device used to suck and remove water from a mine. This pump selection is carried out to determine the number of pumps required to drain the sump. Several calculations can be performed to determine the pump's capacity, which can then determine the total pump head required [14]. The pump installation conditions can be used to determine the total pump head required to transport a specific amount of water as anticipated. The total pump head is written as formula (3).

$$H = H_s + H_p + H_f + ({V^2}/{2g}) \qquad (3)$$

Where :
H = Total pump head (m)
hs = Static pump head (m)
hp = Pressure head difference between the two water surfaces (m)
hf = Head to overcome various resistances in the pump and pipe (m), including bend head and other factors.
g = Acceleration due to gravity (9.8 m/s^2)

2.4. Settlingpond

A settlingpond is a pond designed to collect and settle runoff particles from the mining area and surrounding areas[15]. There are four zones in a settlingpond: the inlet zone, the settling zone, the mud deposition zone, and the outlet zone. There are several parameters that need to be calculated in the drainage system in the settling pond, namely settlement velocity calculation.

If the solids content (% solids) of the mine water is less than 40% [16], Stokes' law applies as shown in formula (4)

$$Vt = \frac{g\,.D^2.(\,\rho\rho - \rho a)}{18\mu} \quad (4)$$

Where:
Vt = Settling Particle Velocity (m/sec)
G = Gravity (m/s^2)
Pp = Particle Specific Gravity (kg/m^3)
Pa = Water Specific Gravity (1000 kg/m^3)
μ = Dynamic water viscosity (kg/m.sec)
D = Particle Diameter (m)

Settlement time:

$$Tv = \frac{h}{vt} \quad (5)$$

Where:
Tv = Settlement time (minutes)
V = Settlement velocity (m/sec)
H = Into the channel (m)

Exit velocity Sedimentation pond 1 (one) to sedimentation pond 2 (two) and so on horizontally using the following formula (6).

$$Vh = \frac{Q\ total}{A} \quad (6)$$

Where:
Vh = Particle settling time (m/s)
Qtotal = Inflowing discharge (m^3/s)
A = Surface area (m^2)

After all calculations, it is clear that Tv is less than Th if the particles can settle effectively. The settling process will occur if the time required for settling is less than the time required for the water to drain [17].

$$\text{Sedimentation (\%)} = \frac{time\ required\ for\ water\ to\ exit}{time\ required\ for\ water\ to\ exit + settling\ time}\ x\ 100 \quad (8)$$

From the formula above, it can be concluded that the more diverse the particle spectrum, the faster the settling and the more successful the sedimentation [18].

3. Result and Discussion

Rainfall is a weather component that significantly impacts mining activities. Rainwater entering the mining area is considered runoff. This rainfall data processing is carried out to obtain the planned rainfall and maximum rainfall intensity. The data used for this rainfall analysis covers the last 10 years, from 2014 – 2023 (**Table 1**).

Table 1. Maximum Daily Rainfall Data

No	Years	Maximum Daily Rainfall (Xi)
1	2014	88
2	2015	98
3	2016	130
4	2017	119
5	2018	113
6	2019	110
7	2020	156
8	2021	166
9	2022	116
10	2023	117

In determining the amount of planned rainfall, there are several types of distributions, namely normal distribution, log normal, gumbel, and log Person III using several approaches so that the type of distribution selected is in accordance with the results of existing rainfall processing data. The selection of this distribution, needs to be tested first using statistical parameter calculations in order to determine what distribution is used in calculating the planned rainfall. In calculating the planned rainfall, this researcher uses the Log Person Type III Distribution. After determining the distribution method for calculating the planned rainfall, the calculation of the planned rainfall is then carried out using the distribution method that has been obtained. Based on calculations using Based on the IDF analysis, the rainfall intensity is 51.28 mm/hour for the 5-year return period with hydrological risk of 89.26%.

3.1 Open Channel Analysis

At the research site, there are three interconnected ditches with varying capacities. The Manning equation can be used to calculate the open channels, with a Manning hardness coefficient of 0.030 because the walls of the ditches are not cemented but rather soil. Based on the calculation results, Type I, Type II, and Type III ditches are capable of accommodating the incoming runoff discharge. The results in **Table 2**, indicated by yellow shading, show the incoming runoff discharge and the actual volume of the ditches.

Table 2. Open Channel Calculation Results

Parameters	Unit	Actual channels I	Actual channels II	Actual channels III
Open Channel Base Width (b)	m	0.63	0.7	0.55
Open Channel Top Width (t)	m	1	1.49	1
Manning Hardness Coefficient (n)		0.03	0.03	0.03
Channel Length (L)	m	783	12	23
Channel Depth (h)	m	0.48	0.52	0.52
Open Channel Storage Discharge (Q storage)	m^3/s	1.78	1.85	2.2
Inflowing Runoff Discharge (Q runoff)	m^3/s	0.34	0.62	0.036
Flow Velocity (V)	m/s	3.07	3.3	4.48

3.2 Culvert Analysis

At the research site, there are two culverts with the same diameter, 0.5 m. Culvert I is located in drainage channels I and II, which are near the entrance to Rolling Stone. This culvert was constructed to channel water through channels I and II. The runoff discharge through this culvert is 0.6 m^3/s, while the runoff discharge through culvert II is 0.082 m^3/s. Based on calculations, culvert I requires an increase in its design diameter of 0.72 m to accommodate the incoming water. Culvert II does not require an increase, as its 0.5 m diameter can already channel a discharge of 0.08 m^3/s.

3.3 Sump Analysis

Based on field observations, there are three main sump locations and four transport sump locations, each with varying capacities. These sumps do not use pumping to drain water, but utilize a ditch. An outlet is created in the pond to provide the water outlet, utilizing gravity. This outlet prevents overflow of the sump. Before reaching the upper limit of the sump, the water flows through the ditch and then into settling pond 8. The processing results show the total volume of the transport sump and the main sump located at the location, sorted by elevation from highest to lowest, as shown in **Table 3**. The existing sump volume can still accommodate the total incoming discharge without pumping.

Table 3. Sump Volume Calculation Result

Sump Name	Elevation	Wide (m^2)	Volume (m^3)
Sump Transport			
Sump I	322	405	607.5
Sump II	290	228	342
Sump III	250	398.4	796.8
Sump IV	237	76	152
Sump V	221	189	199.01
Sump VI	192	733	1128
Sump VII	164	440	580
Main Sump			
Sump VIII	81	3000	9,000.00
Sump IX	77	733	1,620.00
Sump X	69	78	156.00

3.4 Settling Pond Analysis

Based on field observations, there are three compartments in settling pond 8, each with a different area. According to field information from PT Bukit Makmur Istindo Nikeltama, each compartment has a different depth. The settling pond at this location has a volume of 7,025 m^3 with varying sedimentation percentages of 42-50%. This difference in sedimentation percentages is due to the varying area and depth of each compartment. The results of the settling pond analysis are shown in **Table 4**.

Table 4. Results of sedimentation calculations with TSS

Calculation of Inlet to *Outlet*		
Information	Unit	Compartment I - III
Runoff Water Discharge	m^3/s	0.06
	m^3/day	626.69
Runoff Water Discharge from Sump	m^3/day	0.7
	m^3/s	7771
Total Discharge	m^3/s	0.75
	m^3/day	8293
TSS	mg/l	20
	gr/cm^3	0.00002
Sedimentation Percentage	%	42-50

Table 4 shows that the settling pond's capacity is unable to accommodate the total discharge of 8,293 m^3/day. The pond's total capacity is only 7,025 m^3, meaning it can only accommodate approximately 87% of the daily inflow, which can lead to water overflow from the settling pond. This inability of settling pond 8 to accommodate water can affect the percentage of particle sedimentation.

3.5 Recommendations

Based on the findings and analysis results, several recommendations are proposed to enhance the performance and efficiency of the system

a. Settlingpond Analysis

In the Settlingpond analysis, the inlet discharge is adjusted to the total discharge from the existing sumps (**Table 5**). There are two points:

- The total actual capacity of Settlingpond 8 can only accommodate 7,025 m^3, while the daily inlet discharge is 8,293 m^3/day. This affects the sedimentation percentage, as seen in **Table 4**. The small capacity of Settlingpond 8 cannot accommodate the inlet discharge, requiring additional depth in each compartment. Limited land at this location means that the Settlingpond cannot be expanded further; the only option is to increase its height.
- The recommended capacity increase for this pond is adjusted to the total inlet discharge so that even if rainfall of the same intensity occurs, the pond can still accommodate it. At the research location to handle so that there is no overflow in Settlingpond 8, researchers recommend increasing the height of the pond because if it is to be expanded, the location of Settlingpond 8 no longer has land because it is limited by the Hauling Road located in front of Settlingpond 8 and the Office located next to Settlingpond 8 so it cannot be widened further. This increase in height is 5 meters per each compartment of the pond. By taking into account the capabilities of the Komatsu SK 200 long arm excavator.

Table 5. Settlingpond 8 Recommendation Recapitulation Calculation

Inlet to Outlet Calculation		
Parameters	Unit	Compartment I-III
Runoff Water Discharge	m^3/s	0.06
	m^3/day	626.69
Runoff Water Discharge from Sump	m^3/s	0.7
	m^3/day	7771
Total Discharge	m^3/s	0.75
	m^3/day	8293
Deph (h)	M	5
Total Pond Capacity	m^3	10000
Particle Settling Time (tv)	Second	5096
	Minute	84.94
Settlement Percentage	%	73%
Rain Concentration Time	hour/day	3.08
Volume Settled	m^3/day	0.72

b. Recommendation for Pumping Needs for Settling Ponds

At this research site, pumps are used to help drain water from the Settling Pond into the river to prevent overflows like the previous year. The addition of these pumps is necessary because the Settling Pond's capacity is smaller than the existing sump's capacity. Although the height of Settling Pond 8 has been increased, the sump's capacity is still greater. Furthermore, due to the large runoff flow entering Settling Pond 8 from the three sump locations, the researchers recommend adding pumps to the settling pond to assist during high-intensity rainfall events (based on the PUH) to prevent overflows like the previous year. Pumping for this settling pond is carried out in the last compartment of Settling Pond 8, which is closest to the river. Furthermore, water discharge through these pumps is carried out with due consideration to the water quality in the last compartment. Based on TSS values obtained from company data for the last three months, namely April and May, the highest TSS was recorded in July at 20 mg/L. The volume of water entering settling pond 8 represents the total discharge from the existing sump.

Based on the calculation results, it can be seen that the total head is 40.07 on the ebara 200 x 150 FS4NA pump, where this pump has the ability to release 582 m^3/hour of water with 14 hours 15 minutes of working hours divided into 2 shifts, namely the morning shift for 7 hours 15 minutes and the night shift for 7 hours 15 minutes. With 14 hours 30 minutes of working hours, this pump can release 8,322 m^3/day of water. The following results of the Head calculation can be seen on **Table 6**.

Table 6. Head Calculation Result

No	Parameters	Result
1.	Static Head (Hs)	6 m
2.	Velocity Head (Hv)	9.57 m/s
3.	Friction Head (Hf)	20.37
4.	Shock Head (Hf2)	0
5.	Total Head	40.07

4. Conclusion

At this research site, the main sump's capacity is greater than that of the existing Settlingpond 8. This is due to the numerous sumps at the Hauling Road location, which can accommodate overflow in each direction. If the total discharge from these sumps were to enter Settlingpond 8, its much smaller area would cause it to overflow. The existing Settlingpond 8 only has a capacity of 7,056 m3, while the existing main sump has a capacity of 9,000 m3. Because it is not pumped but relies on water outlets from the corners of the sump pools and utilizes gravity, when the maximum rainfall according to the PUH occurs, Settlingpond 8, with a capacity of only 7,056 m3, will overflow. Therefore, Settlingpond 8 was designed to handle the large discharge from the transport sumps and the main sump. The design was carried out by increasing the height of the pool to 5 meters per compartment and adding 1 pump to the last compartment of settling pond 8 with working hours of 14 hours 15 minutes and divided into 2 shifts.

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