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Distribution system dewatering in coal mining at PIT Sena Sungai Lilin District, Musi Banyuasin Regency, South Sumatra Province

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Abstract: The purpose of this research is to calculate the total design discharge of water entering the mining site in the sena pit of PT Putra Muba Coal (PMC), design the appropriate shape and dimensions of the sump to accommodate the amount of water entering the mining site and calculate the number of pumps needed to remove water entering the mine to the settling pond. The source of water entering the mine area comes from rainwater entering the mine opening, water runoff from the rainwater catchment area in the area around the mine opening, and groundwater rise. Based on the results of the analysis of rainfall data for 2013-2022, a rainfall plan of 77, 225 mm/day, rainfall intensity of 9.714 mm/hour with a rainfall return period of 2 years was obtained. The rainfall catchment area at the research site is 72,936 m^2 with a discharge generated of 0.03 m^3/second and groundwater discharge of 0.00812 m^3/second. To remove the water entering the mine, it is flowed naturally into the sump with dimensions of 50 m length, 14 m top width, 13 m bottom width, and 5 m depth. The dimensions of the open channel are planned with a channel width of 32 cm, a flow depth of 28 cm, a wet cross-sectional area of 13.6 cm^2, a wet circumference of 97 cm, a hydraulic radius of 9.25 cm, and a channel length of 233m. The water in the sump is pumped into an open channel. The pump used has a maximum discharge of 150 m^3/hour and a total pump head of 11.8712 m with a pipe diameter of 6 inches.

Keywords*:* Open pit mining; Pump; Mine drainage; Coal; Sump; Rainfall

1. Introduction

Open pit mining is one of the mining methods, where mining activities are influenced by climate and mine water conditions. This will interfere with mining activities such as accelerating equipment damage, affecting slope stability, and work safety (Iqra & Prabowo, 2021). One of the main points in the open pit mining method is the influence of climate in mining activities, including rain, heat (temperature), puddles that can affect workplace conditions, which in turn can affect mine productivity. Acid mine drainage has a major influence on mine productivity, therefore water drainage is made so that water does not enter the work front. Drainage in a mining area aims to minimize water entering the mining area (Mutiara Nur Fajryanti et al., 2021).

Based on direct observation in the field, the dewatering system planning used at PT Putra Muda Coal (PMC) is not optimal, because it has two sumps in the sena pit with the size of the first sump 15 m x15 m x 2 m, the second sump 40 m x 40 m x 2 m. with the existing sump size causes a lot of working fronts to be used and the open channel used still uses natural swamps to drain water from the mine face to the settling pond so that it affects the biota in the swamp. Therefore, it is necessary to plan a good pit dewatering system (Enim et al., 1999). After knowing some of the descriptions above, it is hoped that mining operations at PT Putra Muba Coal (PMC) can run according to plan (Husen et al., 2018). The open channel used in the sena pit to the settling pond still uses natural swamp so that it can affect the life of biota in the swamp. Researchers formulated several problems seen from several aspects, namely: What is the total design discharge of water entering the mining site in the sena pit of PT Putra Muba Coal (PMC)? What is the shape and dimension of the pond that is suitable for accommodating the design discharge that enters the mining location? What is the number and specification of pumps needed to drain the water that will enter the mining front? What is the shape and dimension of an open channel (ditch) that is suitable for flowing from the mining site to the settling pond? (Andrianto et al., 2019). The objectives of this research are as follows: Knowing the total design discharge of water entering the mining site in the sena pit of PT Putra Muba Coal (PMC). Knowing the shape and dimensions of the sump that is suitable for accommodating the amount of water entering the mining site in the sena pit of PT Putra Muba Coal (PMC). Knowing the specifications and number of pumps needed to discharge the water entering the mining site to the settling pond. Knowing the shape and dimensions of the open channel (ditch) leading to the settling pond based on the discharge generated from pumping (Putra et al., 2021).

2. Methods

Data collection method

Before conducting research, the author first collects data on each activity observed to be used as problem solving data. The data needed by the author in solving the problem is as follows (Prabowo, 2020).

1. Primary data
   Primary data is data taken directly from the field such as:
   a) Catcthment area
   b) Groundwater discharge
2. Secondary data
   Is data obtained from the literature of PT Putra Muba Coal (PMC) to support a research data, for example:
   a) Pump specifications
      That is the capacity of the pump to be able to suck the discharge per hour (m^3/hour)
   b) Rainfall data
      The amount of rain that occurs in an area, this data is obtained from the company archives.
   c) Research topography map

Data analysis method

The data is an activity to find solutions to existing problems based on the data that has been collected (Chakti & HAR, 2021).

1. Calculating design rainfall
   Rainfall calculations are obtained from rainfall data which is then analyzed so that it will get the design rainfall for the next few years.
2. Determining the size of the catchment area
   Determination of the catchment area is done by analyzing the topographic map using autocad software. In analyzing the topographic map, the polyline command is carried out to draw the catchment area, after the catchment area is perfectly drawn, the next step is to see how much the catchment area is by double-clicking on the catchment area that has been drawn, it will be seen in the information table how much the catchment area is.
3. Calculating Concentration Time (Tc)
   Calculating the concentration time is done to find out how long a catchment area is exposed to rain.
4. Calculating Rainfall Intensity in the Catchment Area
   The calculation of total rainwater discharge aims to determine how much water enters the mining site.

5. Calculating the Discharge of Runoff Water Entering the Mining Area
   The calculation of total rainwater discharge aims to determine how much water enters the mining site.
6. Calculating Groundwater
   To calculate groundwater discharge, the author measured groundwater discharge by measuring the water rise in the sump every 10 minutes for 1 hour. The sump dimensions are 15 m x 15 m x 2 m and the sump area is 225 m^2 with a volume of 450 m^3.
7. Calculating Total Water Discharge
   The total water discharge in the pit is the sum of runoff water and groundwater.
8. Calculating Sump Geometry
   The geometry calculation aims to plan the construction of the sump in the pit itself.
9. Calculating Channel Cross-Section
   The calculation of the channel cross-section aims to plan the channel that will be used to drain groundwater from the mining site to the settling sump.

3. Results and discussion

In reviewing the existing mine drainage system, some supporting data processing is required. Then from the results of observations, the discharge of groundwater into the mine is water that arises from runoff water from the surface of rainwater. To calculate a discharge that enters the mine opening location, there are several parameters that must be known, namely the catchment area and rainfall intensity. Rainfall is the most important data in an open pit mine drainage plan. The rainfall figures obtained cannot be directly used for mine water control planning, but the rainfall data must be processed first to obtain more accurate data. In this case study, the rainfall analysis used is the last few years of rainfall data from 2013 to 2022. The following are the data that the author uses in planning mine drainage in the sena pit of PT Putra Muba Coal:

1. Catchment area of pit opening = 72,936 m^2
2. Groundwater discharge = 0.00812 m^3/sec.

Calculating rainfall

Before calculating the design rainfall, it is necessary to calculate the average rainfall, standard deviation and frequency factor. These calculations can be seen below:

1. Calculating average raifall

This calculation is done to find out how much the average is, and the calculation can be seen below:

Table 1. Rainfall data 2013-2022

Rainfall Data		
NO	**Year**	**Rainfall (Xi)**
1	2013	43,8 mm
2	2014	120 mm
3	2015	94 mm
4	2016	45 mm
5	2017	128 mm
6	2018	96 mm
7	2019	32 mm
8	2020	126 mm
9	2021	105 mm
10	2022	35,5 mm
Total		**825,3 mm**

2. Calculating Standard Deviation (S)

This calculation is done to find out how much the deviation value is, and the calculation can be seen below:

Table 2. Calculation of standard deviation

Standard Device Calculations			
Xi (mm)	**xi (mm)**	**Xi-xi**	**(Xi-xi)**
43,8	82,53	-38,73	1.500,0129
120	82,53	37,47	1.404,009
94	82,53	11,47	131,5609
45	82,53	-37,53	1.408,5009
128	82,53	45,47	2.067,5209
96	82,53	13,47	181,4409
32	82,53	-50,53	2.553,2809
126	82,53	43,47	1.889,6409
105	82,53	22,47	504,9009
35,5	82,53	-47,03	2.211,8209
Total			**13.852,681**

3. Calculating the K Factor

After calculating the standard deviation, the next step is the frequency factor. In this case the values of Yn, Sn, and Ytr can be calculated with a total sample size of 10. The results of the frequency factor calculation can be seen in table 3.

Table 3. Frequency factor calculation result (K)

Return Period (Tr)	(Ytr)	(Yn)	(Sn)	K
2	0,3668	0,4952	0,9496	-0,155
5	1,5004	0,4952	0,9496	0,979
10	2,251	0,4952	0,9496	1,73
25	3,1993	0,4952	0,9496	2,678
50	3,9028	0,4952	0,9496	3,34
100	4,6012	0,4952	0,9496	4,08

4. Plan rainfall calculation

After calculating the average rainfall, standard deviation and frequency factor, the calculation of design rainfall can be calculated. Calculation of design rainfall can be seen in table 4.

Table 4. Results of plan rainfall calculation

Return Period (Tr)	Xi	K	S mm/month	Planned Rainfall (Xt) mm/day
2	82,53	-0,155	39,232	-0,155
5	82,53	0,979	39,232	0,979
10	82,53	1,73	39,232	1,73
25	82,53	2,678	39,232	2,678
50	82,53	3,34	39,232	3,34
100	82,53	4,08	39,232	4,08

In the Gumbel method, to determine the design rainfall based on the amount of rainfall data available, in this case the amount of maximum daily rainfall from 2005 to 2014, from the calculation of the rainfall plan, the maximum rainfall in 2015 is used Xt of 77.225 mm/day with a return period of 2 years.

Determining the catchtment area

Determination of the catchment area is done by analyzing topographic maps using autocad software. In analyzing the topographic map, the polyline command is used to draw the catchment area, after the catchment area is perfectly drawn, the next step is to see how much the rain catchment area is by double-clicking on the rain catchment area that has been drawn, it will be shown in the information table how much the catchment area is (Welly & Rusli, 2022). From the results of drawing the catchment area on the topographic map, the catchment area is 72,936 m^2.

Calculating the discharge of runoff water entering the mining area

Before calculating the design rainfall, it is necessary to calculate the average rainfall, standard deviation and frequency factor. These calculations can be seen below:

1. Calculating the time of concentration (Tc)

After analyzing the catchment area, the next step is to calculate the concentration time:
Tc = 0.019 [L/S.0.5] 0.77
Tc = 4.58 hours

2. Calculating rainfall intensity in the catchment area

After calculating the concentration time, the next step is to calculate the rainfall intensity (I). calculation of rainfall intensity:

I = Rtr/24 x (24/Tc) 2/3
I = 9.714 mm/hour

3. Calculating runoff water discharge

After obtaining the value of the concentration time and rainfall intensity, the runoff water discharge can be calculated. Runoff water discharge calculation:

QL = a x b x I x A
QL = 0.15 x 1 x 0.009714 m/jam x 72.936 m^2
QL = 106,275 m^3/day = 0,03 m^3/day

4. Groundwater discharge calculation

The location of the sena opening at PT Putra Muba Coal (PMC) is close to the swamp flow, therefore the author feels the need to measure groundwater discharge by measuring the increase in water in the existing sump with a sump area of 255 m^2 with a volume of 450 m^3 and the increase in water level in the sump. Data that can be fielded can be seen in table 5.

Table 5. Analysis of groundwater rise

Ground water rising analysis		
No	**Time/10 Minute**	**Water rising in sump (CM)**
1	10 minute = 600 second	1 cm = 0,001 m
2	20 minute = 1200 second	4 cm = 0,04 m
3	30 minute = 1800 second	6,1 cm = 0,061 m
4	40 minute = 2400 second	8,4 cm = 0,084 m
5	50 minute = 3000 second	11 cm = 0,11 m
6	60 minutet = 3600 second	13 cm = 0,13 m

From the table above, groundwater discharge can be calculated by multiplying the sump cross-sectional area of 225 m^2 by the increase in water for one hour in the sump. The calculation can be seen below.

Qr = A x Water rise in the sump
Qr = 225 m^2 x 0.13 m
Qr = 29.25 m3/hour = 0.00812 m^3/second

From the above calculation, the groundwater discharge in the sena pit opening of PT Putra Muba Coal (PMC) for 1 hour of measurement is 0.00812 m^3/second.

5. Calculation of total water discharge in pit sena PT. Putra Muba Coal

Qtotal = Q runoff + Q groundwater
Qtotal = 0.03 m^3/second + 0.00812 m^3/second
Qtotal = 3,293.568 m^3/day

Calculating sump geometry

Unknown:

Total water discharge = 3,293.568 m^3/day
Sump plan = Trapezoidal

Planning a trapezoidal sump opening with:

Length	= 50 m
Top width (La)	= 14 m
Bottom width (Lb)	= 13 m
Depth (h)	= 5 m

Cross-sectional area of a trapezoid:

L = number of parallel sides/2 x t or i.j+in/2 x h
L = 13 m + 14 m /2 x 5 m
L = 67,5 m^2

Volume that can be accommodated by the sump:

V = L x P
V = 67.5 m^2 x 50 m
V = 3.375 m^3

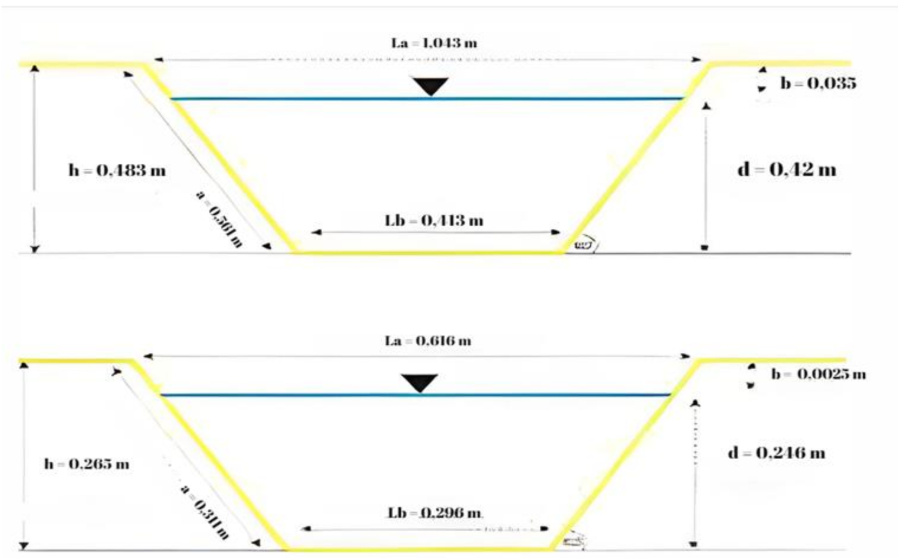

Figure 1. Sump plan

Calculating pump requirements

Before calculating the pump requirements needed to remove water from the sump out of the mining area, the total pump head must be calculated. The process of calculating the total pump head is as follows:

1. Calculating the total pump head (Ht)

Unknown:

Pipe diameter (D) = 0.1524 m = 6 inch
Flow velocity (V) = 1 m/second
Water viscosity (v) = 1.6 x 10-6 m^2 / second
Suction pipe elevation (h1) = + masl
Exhaust pipe elevation (h2) = +24
Pipe length (L) = 50 m

a. Static head (hs) calculation

hs = exhaust side elevation- suction side elevation
hs = + 24 - (+7) = 17 m

b. ^hp = hp2-hp1

Where:

Hp2 = 10.33 (1-0.0065xH2/288) 5.526
Hp2 = 10,33 (1-0,0065 x 24/288) 5,526
Hp2 = 10,2991 m

Hp1 = 10.33 (1-0.0065 x H1/288) 5,526
Hp1 = 10,33 (1-0,0065 x 7/288) 5,526
Hp1 = -0,0218 m

c. Head loss in pipe (hf)

1) Head of friction loss in the pipe (hf1)

Reynold's number price:

Re = vD/v
Re = 1 x 0.1524 / 1.6 x 10-6
Re = 0,1524/0,0000016
Re = 95,250 m^2/second

Since the value > 4,000, the flow is turbulent, so the coefficient of friction loss in the pipe:

f = 0.020 + 0.0005/D
f = 0,020 + 0,0005/0,1524
f = 0,020 + 0,00328
f = 0,02328
hf1 = f x L/D x v2/2g
hf1 = 0.02328 x 50/0.1524 x (1)2/2 x 9.8
hf1 = 0.02328 x 328.084 x 0.05102
hf1 = 0,389 m

2) Head loss at the inlet end of the pipe (hf2)

The loss in this inlet pipe depends on the shape of the inlet end of the suction pipe to be used. However, in this planning the author uses a suction end that is dipped below the water surface with a value of f = 0.4.

hf2 = f v/2g = 0.4 x (1 m/sec)2/2x9.8 m/sec = 0.4 x 0.051 = 0.002 m
Head loss at the turn 45 derjat (hf3)
Pipe turning coefficient (f) = 0.32
hf3 = f v2/2g = 0.32 x (1 m/sec)2/2 x 9.8 m/sec
hf3 = 0,32 x 0,051
hf3 = 0,0163 m

So the head loss in the pipe (hf)
Hf = hf1 + hf2 + hf3
Hf = 0,389 + 0,02 + 0,0163
Hf = 0,426

d. Head loss due to installation of fittings and installation of constructions in the installation (hsv)
Hv = 32 x D
Hv = 32 x 0,1524
Hv = 4,877 m
hsv = Le/L x hf
hsv = 4,877/50 x 0,426
hsv = 0,0416 m

e. Outgoing pipe end velocity head loss (hv)
Hv = v2/2y
Hv = (1 m/sec)2/2 x9.8 m/sec
Hv = 0,051

So the total head of the pump is:
Ht = hs + ^hp + hf + hsv + hv
Ht = 11 + (-0,0218) + 0,426 + 0,0416 + 0,051
Ht = 11,8712 m

2. Amount of water that has been inundated

This calculation is done to find out how much water is stagnant in the sump.
Known:

Sump size 1:		Sump size 2:	
Length (P)	: 15 m	Length (P)	: 40 m
Width (L)	: 15 m	Width (L)	: 40 m
Height (T)	: 2 m	Height (T)	: 2 m
Water depth	: 1 m	Water depth	: 1 m

Water volume in sump 1 = P x L x Water Depth
= 15 m x 15 m x 1 m
= 225 m3

Water volume in sump 2 = P x L x Water Depth
= 40 m x 40 m x 1 m
= 1.600 m^3

Flooded water volume = Vol of water in sump 1 + vol of water in sump 2
= 225 m^3 + 1,600 m^3
= 1.825 m^3

3. Number of water pumps required

From the data that has been analysed, the calculation of how many pumps are needed can be seen below.

Total water discharge = 137.232 m^3/hour
Stagnant water volume = 1,825 m^3
Maximum pump working hours = 20 hours/day
Maximum pump capacity = 150 m^3/hour
Pumping time = Q / maximum pump capacity
Pumping time = 137.232 m^3/hour
Pumping time = 0.9 hours
Pumping time = 54 minutes

From the data that has been analysed, the first day requires two pumping units and the second day onwards only requires one pumping unit.

4. Calculating channel cross-section

Determining the dimensions and size of a channel is an important issue in designing a good mine drainage system. With the value of B obtained, we can then substitute it in the following equation:

A = y (B + my)
A = 1,73 y2
P = B + 2y root 1+m2
P = 3,46 y
R = A/P
R = 0,34 y
T = 2y root 1+m2
T = 2,31 y

Channel dimensions can be known with the following equation:

V = 1/n x R2/3 x S1/2
V = 0,974 y
Q = A x V
0.03812 = 1.73 y2 x 0.974 y
y = 28 cm

After we get the value of y, we know the dimensions of the channel that can be needed:

a. Channel bottom width (B) = 1.15y
   Channel bottom width (B) = 32.2 cm
b. Flow depth (y) = 0.28 m (28 cm)
c. Wet cross-sectional area (A) = 1.73 y 2
   Wet cross-sectional area (A) = 13.6 cm2
d. Wet perimeter (P) = 3.46 y
   Wet perimeter (P) = 97 cm
e. Hydraulic radius (R) = 0.34 y
   Hydraulic radius (R) = 9.52 cm
f. Water table width (T) = 2.31 x y
   Water table width (T) = 65 cm
g. Guard height (j) = 25% x y
   Guard height (j) = 7 cm
h. Channel length = 233

4. Conclusion

From the results of analyses, calculations and processing of research activities on the topic of Open Pit Mine Drainage System Analysis for Mining Operations at Pit 2 West Banko PT Bukit Asam, Tbk. Muara Enim Regency, South Sumatra Province, it can be concluded:

1. The total discharge of water flowing into the mine area from runoff and groundwater is 137,232 m^3/hour.
2. The required sump plan with an upper width of 14 m, a lower width of 13 m, a length of 50 m, and a depth of 5 m, with this size being able to accommodate a capacity of 3,375 m^3.
3. From the total discharge of water entering the mine site, a Selwood H150 type pump specification is required with a capacity of 150 m^3/hour, a total pump head of 11.8712 m, a pump power of 138 kW and a maximum working hour of 20 hours/day, so that it can overcome a total discharge of water entering and being inundated, the first day requires two pump units and the second day onwards only requires one pump unit.
4. From the results of the discussion, it is necessary to measure the dimensions of a trapezoidal open channel with a channel base width (B) of 32 cm, a flow depth (y) of 28 cm, a water level width (T) of 65 cm, a wet cross-sectional area (A) of 13.6 cm2, a wet perimeter (P) of 97 cm, a hydraulic radius (R) of 9.52 cm, a guard height (j) of 7 cm, and a channel length of 233m.

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