Analysis of Hydrogeology and Rainwater Prevention Systems at Sepo Village in Central Halmahera Regency, North Maluku

Nurany Lukman¹, Razak Karim²
¹Mining Engineering Study Program Faculty of Engineering, Khairun University Ternate, North Maluku Indonesia
²Mining Engineering Study Program Faculty of Engineering, Muhammadiyah University Ternate, North Maluku Indonesia

Abstract. Mining water is one of the main problems that has a great importance on mine productivity. In mining implementation, it is necessary to study the Mining Water (Hydrogeology) system to support a good mine design. The Mining Water drainage system is a method for making work sites in the mining area always dry. Prior to mining, hydrogeological analysis and rainwater management methods are carried out. Calculation of rainfall intensity using Gumbel Probability estimation and water capture area analysis obtained CA-1 Q = 915,35, m³ / day CA-2 Q = 1149, CA-3 Q = 141116, 01CA-4 Q = 1407.89, the form of rainwater trapping channels in the form of trapezium and pump requirements in each catchment area of 1 (one) pump each.

Preliminary
The main problems in the open pit method is the influence of climate on mining activities. These climate elements include: rain, temperature, air pressure and others, which can affect workplace conditions. Mine water has a major influence on mine productivity. Because it is Mine Water distribution system is always to make the work location in the mining area dry, because if it is not controlled it can cause problems, for example the work site is flooded, the road is muddy and slippery, mine slope stability prone to landslides, mine equipment quickly damaged, difficulties in take an example (sampling), decreased work efficiency, and threatened the safety of workers and their health. What must be considered in the mine drainage system is controlling the amount of existing mine water. Therefore an analysis of methods is needed to regulate the flow of water that enters the working front. What is the potential of water entering the mining area and how to handle it so that the mining process can run well. Analysis of hydrogeological factors by calculating rainfall and rainfall intensity using the Gumbel Probability approach, knowing the catchment area around the mine openings calculates runoff and groundwater discharge in the mine openings area, determines the dimensions of the mine channel and calculates the number of needs and pump capacity, so based on the results of the analysis will be used as a reference for the mine planning system

2. Basic Theory
2.1. Rainfall Intensity
Rainfall intensity is the amount of rain per unit time, denoted by letter (I), expressed in units of mm/hour, which means that the height of the rainwater column occurs in mm in an interval of 1 hour. To get the value of rain intensity in an area, you can use a manual or automatic rain gauge. If rainfall data is measured using an automatic measuring device, then the intensity of rain, "I" can be determined by the slope reading (tangent) of the rainfall curve with time. If the rainfall data is measured by a manual gauge, the intensity of the rain in any time can be determined using the "Mononobe" approach formula as follows:

\[ I = \frac{(R_24 : 24) \times (24/t)}{m} \]  

Information :
I : Rainfall intensity (mm / hour)
T : Time of rain (hours)
R24 : Maximum rainfall in an interval of 24 hours (mm)  
M : Konstanta = 2/3. (standard value used in Indonesia).

2.2. Probability of Gumbel

Gumbel distribution is used for maximum data analysis, for example for flood frequency analysis. Gumbel distribution has a coefficient of skewness (skwen coefficient) or CS = 1,139 and a kurtosis coefficient (Coefficient Curtosis) or Ck <4,002. This method usually uses extreme distribution and value with an exponential double distribution. [1]

The steps for calculating the planned rainfall with the Gumbel Method are as follows:

$$X_T = X + Sx$$  \hspace{1cm} (2)

Information:

- $X_T$ = Rain plan (mm)
- $X$ = Average value of rain
- $S$ = Standard deviation from rainfall data
- $K$ = Gumbel frequency factor:

$$K = \frac{Y - \bar{Y}}{S}$$  \hspace{1cm} (3)

- $Y_i$ = reduced variate
- $S_n$ = reduced standard
- $\bar{Y}_n$ = reduced mean

Calculate standard deviation:

$$S = \sqrt{\frac{\sum_{i=1}^{n} (X_i - \bar{X})^2}{n - 1}}$$ \hspace{1cm} (4)

2.3. Catchment area

The Catchment Area is an area or rain catchment area where the boundary of the catchment area is determined from the highest elevation points so that finally it is a closed polygon, where the pattern is adjusted to topographic conditions, by following the direction of the water flow. The water flow is not only in the form of surface water flowing in the river channel, but also includes the flow on the slopes of the hills that flow towards the river channel so that the area is called the watershed. This area is generally limited by topographic boundaries, which means it is determined based on surface water. This limit is not determined based on underground water because the groundwater level always changes according to the season and the level of activity of use [2]

A higher area is a recharge area and a lower area is a discharge area, which is a coastal and valley area with a river flow system. More specifically the catchment area is defined as part of a watershed (catchment area) where the flow of ground water (saturated) away from the ground water table. Usually in the catchment area, the water table is located at a certain depth.

Rainwater that affects directly a mine drainage system is rainwater flowing above the surface of the ground or surface water (run off) plus a number of effects of groundwater. Rainwater or surface water flowing into the mining area depends on the condition of the rain catchment area which is affected by the surrounding area. The area of rain catchment can be determined based on topographic map analysis. Based on the condition of the area such as the presence of forest areas, landfill locations, drainage channel density, and grid conditions.
2.4. Runoff water

Runoff is part of the rainfall that flows above the ground to the mining area. There is rainwater that falls to the surface of the soil, which directly enters the soil or is called infiltration water or groundwater. Rainwater or surface water flowing into the mining area depends on the condition of the rain catchment area which is affected by the surrounding area. The area of rain catchment can be determined based on topographic map analysis. Based on the condition of the area such as the presence of forest areas, landfill locations, drainage channel density, and grade conditions.

2.5. Coefficient of Runoff (C)

Coefficient of runoff (C) is influenced by land cover factors, slope and intensity and duration of rain. This coefficient is a constant that describes the impact of the infiltration, evaporation, land use conditions and slope of the land.

2.6. Channel Dimension

Determination of the dimensions of the channel to divert runoff water outside the Pit is carried out by using the following equation.

\[
Q = \frac{A^{1/3} S^{1/2}}{n P^{2/3}}
\]

Information:

- \( Q \) = Debit
- \( A \) = Area of wet cross section
- \( S \) = Gradient
- \( N \) = Manning roughness coefficient (channel wall roughness). For concrete walls \( n = 0.011 \), and for ground walls, \( n = 0.02 \)
- \( P \) = Wet circumference

2.7. Hydrogeology

Hydrogeology is the relationship between the existence, distribution and flow of groundwater with a geological perspective [3]. The tested layer is a layer that is estimated to be permeable or impermeable which is considered as a source of water that has the potential to seep into the mine openings. The results of hydrogeological research can determine the amount of groundwater discharge.

2.8. Groundwater

Groundwater is water that is contained in layers of soil or rock below the surface of the soil. The formation of groundwater follows the cycle of water circulation on earth called the hydrological cycle, which is a natural process that takes place in water in nature, which undergoes a sequential and continuous displacement of places.[4]

2.9. Regional Geological Conditions

Based on the Geological Map of Ternate, North Maluku published by the Bandung Geological Research and Development Center, the physiography of Halmahera Island is divided into 3 (three) main parts, namely the Mandala East Halmahera, West Halmahera, and the Archipelago of the Quaternary Volcano. The mandala of East Halmahera includes the northeastern arm, the southeast arm, and several small islands to the east of Halmahera Island.

Research areas included in the southeast arm of Mandala East Halmahera. The morphology of the mandala consists of steep slope mountains and deep river incisions, and some have karst morphology. The morphology of steep sloping mountains is a reflection of hard rock. The types of rocks that make
up these mountains are ultramafic rocks. Karst morphology is found in limestone areas with relatively low hills and land slopes.

2.10. Topography and Morphology
The activity location is ±10 km north of Sepo Beach, including in conversion production forests and outside plantations and residential areas. The entire area of activity was initially covered by tropical forests that were still dense and some had been used by timber companies. In some locations there are sloping to steep morphologies, sometimes even cliffs with contours of a tight limestone topography with a height between 250 - 450 m. The highest morphology of this area is Moro-Moro Hill with an altitude of ±600 m above sea level.

2.11. Local Geology of Sepo Area and its surroundings
Nickel ore deposits contained in Sepo are included in the type of laterite formed as a residual concentration from the results of mechanical and chemical weathering from the original rock which is ultrabasa such as peridotite, serpentinite.

The origin rock from the formation of laterite nickel deposits in Sepo is ultrabasa peridotite rock where the main component consists of olivine minerals which usually contain nickel elements in a small percentage [6]

3. Research Methods

The methodology used in this research is by conducting a field survey, taking secondary data from rainfall data from BMKG, company groundwater data, open pit plan area data, then calculating rainfall and rainfall intensity using the Gumbel Probability approach, to know the catchment area in the mine area and around the mine openings, determine the dimensions of the mine channel that matches the existing water discharge and calculate pump requirements.

4. Result and Discussion

4.1. Rainfall
Annual rainfall in the Central Halmahera region in 2018 ranges from the lowest 19 mm in September and March to the highest of 387 mm in May. The spread of rainy days around the study sites ranged
from the lowest 5 days in September to the highest 20 days of rain in March and July [7]. The lowest annual rainfall occurs in October and the highest in June (2014-2018).

| Table 1. Rainfall Data (BMKG) |
|-------------------------------|
|                              |
| Tahun | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|       | m   | h   | m   | h   | m   | h   | m   | h   | m   | h   | m   | h   |
| 2014  | -    | -   | -   | -   | -   | 24  | 14  | 4   | 2   | 88  | 17  | 3   | 11  |
| 2015  | 12   | 9   | 22  | 1   | 17  | 1   | 27  | 1   | 28  | 2   | 29  | 2   |
| 2016  | 5    | 7   | 4   | 1   | 6   | 9   | 2   | 6   | 5   | 1   | 9   | 1   |
|       | 6    | 9   | 2   | 6   | 8   | 5   | 9   | 1   | 9   | 1   | 8   | 1   |
|       | 1    | 4   | 1   | 3   | 1   | 14  | 1   | 1   | 20  | 1   | 29  | 2   |
|       | 1    | 4   | 1   | 3   | 1   | 2   | 14  | 1   | 20  | 1   | 94  | 1   | 90  |
|       | 2017 | 1    | 18  | 1   | 20  | 1   | 16  | 1   | 26  | 2   | 30  | 2   |
|       | 24   | 2   | 2   | 49  | 2   | 26  | 2   | 20  | 1   | 13  | 1   | 10  |
|       | 26   | 1   | 2   | 7   | 7    | 6   | 7   | 5   | 4   | 3   | 0   | 7   |
|       | 27   | 1   | 2   | 4   | 38   | 1   | 24  | 1   | 29  | 2   | 15  | 1   |
|       | 3   | 2   | 0   | 9   | 5    | 7   | 9   | 3   | 2   | 0   | 8   | 3   |
|       | 1    | 0   | 20  | 1   | 17  | 8   | 19  | 7   | 97  | 1   |
|       | 0    | 7   | 9   | 1   | 20  | 1   |

4.2. Hydrology
At the location of the activity there is the Waleh River along with some of its tributaries and the Seley River. In the mine area there is also the Para-Para River which empties into the Waleh River. In the rainy season, erosion occurs around the mining site so that river water brings some material through runoff to the Waleh River which causes deep brown river water.

4.3. Catchment Area
The catchment area is determined based on the study on topographic maps resulting from data on the contour situation of mine situations.

For the region the mining plan has 4 (four) influential catchments Pit area of the plan, namely:
- Catchment area 1 (CA-1), with an area of 49620,346 m²
- Catchment area 2 (CA-2), with an area of 43765,679 m²
- Catchment area 3 (CA-3), with an area of 32549,524 m²
- Catchment area 4 (CA-4), with an area of 53153,175 m²

4.4. Water discharge runoff
The Research area in the highlands, pit peaks and morphological pit outer areas so that falling rainwater flows out of the pit, the potential for runoff from the outside of the pit is minimal and is considered non-existent.
Table 2. Calculation of Runoff Discharge in Pit

| CA  | Area (m²) | Rainfall Intensity (m/h) | Koof Runoff | Water Discharge (m³/h) |
|-----|-----------|--------------------------|-------------|------------------------|
| 1   | 49620.346 | 0.00085                  | 0.9         | 37,95956               |
| 2   | 43765.679 | 0.00085                  | 0.9         | 33,4807                |
| 3   | 32549.524 | 0.00085                  | 0.9         | 24,9003                |
| 4   | 53153.175 | 0.00085                  | 0.9         | 40,6621                |

4.5. Ground Water Discharge

Table 3. Total Ground Water Discharge Actual PIT Condition

| Total recapitulation | Q (m³/s) | Q (m³/h) |
|----------------------|---------|----------|
| CA 1                 | 0.05    | 18       |
| CA 2                 | 0.04    | 14.4     |
| CA 3                 | 0.06    | 21.6     |
| CA 4                 | 0.05    | 18       |
| Total                | 0.2     | 72       |

Measurement of groundwater discharge by calculating the time needed to fill a sump that has a known volume. The procedure used for the measurement of discharge is the measurement of volume by making a small dam at the bottom of the mine. The point is so that the flow of water can be concentrated at an outlet.

4.6. Estimated Total Pumps

Table 3. Maximum Debit of Water Entering PIT and Pumping Estimates

| CA | Runoff m³/h | GW m³/h | Q m³/h | Q m³/day | Pump Capacity (m³/h) | Working Hours | Pump Estimation |
|----|-------------|---------|--------|---------|----------------------|---------------|-----------------|
| A  | B           | A+B     | (A+B)*24 | C       | D                    | (A+B)*24/(C*D)|                |
| 1  | 37.96       | 18      | 38.14  | 915.35  | 250                  | 4 Hours       | 1               |
| 2  | 33.48       | 14.4    | 47.88  | 1149.14 | 250                  | 5 Hours       | 1               |
| 3  | 24.90       | 21.6    | 46.50  | 1116.01 | 250                  | 5 Hours       | 1               |
| 2  | 40.66       | 18      | 58.66  | 1407.89 | 250                  | 5 Hours       | 1               |

In catchment area 1 (CA 1) with runoff air discharge 37.96 m³/day and ground air discharge 18 m³/day obtained the total volume of air discharge in Pit Area CA 1 is 915.35 m³/day so requiring pumps requiring 250 m³/day with working time for ± 4 hours. Likewise in CA 2, CA 3 and CA 4, each with a number of pumps 1 unit with the same capacity, which has different pump hours. If we need smaller pump hours, we can procure a pump with a larger capacity.
4.7. Design of mine openings runoff water channel
The recommended channel is a trapezoidal shape. The channel dimensions will be determined based on the calculation of the wet cross section area and wet circumference using equation 5. The channel gradient is determined based on the difference in topographic height between the two ends of the channel plan, and the channel wall roughness value is $n = 0.025$. Simulation and calculation of the approach using the formula, the wet channel area ($A$), wet circumference ($P$), and flow velocity ($V$) can be determined for the diversion plan.

From the calculation of the channel discharge from the simulation results, it is recommended that trapezoidal runoff water can be calculated well enough to divert runoff water over the time of nickel ore mining in the Sepo area of North Weda District.

For catchment areas 1, 2, 3, and 4, with simulations, the canals around the Pit of the nickel ore mining area can be determined and calculated enough to be able to flow through the calculated runoff water. Recommended channel dimensions are as in Table 4.

Table 4. Minimum Dimension of Water Transfers Outside Pit

| No. | Geometri Paritan               | CA 1    | CA 2    | CA 3    | CA 4    |
|-----|--------------------------------|---------|---------|---------|---------|
| 1   | Debit of Runoff (m/day)        | 915,349 | 1149,1368 | 1116,0072 | 1407,8904 |
| 2   | Width of Top Channel (m)       | 6.29    | 5.63    | 5.38    | 4.82    |
| 3   | Width of Bottom Channel (m)    | 2.86    | 4.25    | 2.45    | 1.28    |
| 4   | Channel Depth (m)              | 2.57    | 11.76   | 3.67    | 4.41    |
| 5   | Wall Slope                     | 1.5:1   | 1.5:1   | 1.5:1   | 1.5:1   |
| 6   | Area of the wet section (m)    | 18.41   | 54.84   | 7.78    | 11.25   |
| 7   | Wet Arround                    | 8.83    | 117.78  | 7.54    | 7.40    |
| 8   | Gradient (%)                   | 0.01    | 0.01    | 0.01    | 0.01    |
| 9   | Koofisien of Manning           | 0,025   | 0,025   | 0,025   | 0,025   |
| 10  | Maks Debit Of Channel          | 1132,14 | 1738,12 | 349,45  | 731,487 |
| 11  | Flow Speed (m/sec)             | 61,50   | 31,70   | 349,45  | 65,03   |
| 12  | Flow Speed (km/h)              | 221,41  | 114,11  | 44,94   | 1,39    |

Figure 5. Channel Geometry for CA-1

4.8. Control of Water Runoff in the Catchment Area
Water runoff from Catchment Area 1, because of the topography, no allows it to be overcome by creating a Pit and side channel flow it gravitationally outside the Pit area. Therefore, what can be done is by flowing through channels from north to south along 650 m, and from south to north along 375 m. Control of runoff water from Catchment Area 2, is done by way make a transfer channel along the outer edge of the Pit limit, and attempted to flow gravitationally to follow the contour to the direction of the river that flows outside the mine area as well as catchment areas 3 and 4.
4.9. Water Management System at Bench
Rainwater that falls in the area of the mine openings (Pit area) on level surface, overcome by making several channels channeling at each level. The water channeling system at this level aims to regulate the flow of water on the level surface, so that there is no puddle on the surface level, and can flow to the well on the mine floor. On every level, a vertical direction channel is created that connects between level with horizontal distance every 60 m. On the mining floor at the level the lowest is made Pit sump which functions as a place final shelter of all water in the Pit area. Water in the Pit sump is usually pumped to settling pond, which is usually made at the top and outside the Pit. Water the settling pond is then flowed to the controller pool (monitoring pond) to monitor the quality of the water, before it flows to to the river.

![Figure 6. Water Management System at Bench](image)

5. Conclusions and Recommendation

5.1. Conclusions
From the results of the calculation and analysis of the results that have been can be concluded as follows.

- The rainfall intensity in the Central Halmahera area is 0.85 mm / hour or 0.00085 m / hour
- For the region the mining plan has 4 (four) influential catchments Pit area of the plan, namely:
  - Catchment area 1 (CA-1), with an area of 49620,346 m²
  - Catchment area 2 (CA-2), with an area of 43765,679 m²
  - Catchment area 3 (CA-3), with an area of 32549,524 m²
  - Catchment area 4 (CA-4), with an area of 53153,175 m²
- Debit of Runoff water is:
  - Catchment area 1 (CA-1), Q = 915, 3494 m3/day
  - Catchment area 2 (CA-2), Q = 1149,1368 m³/day
  - Catchment area 3 (CA-3),Q = 1116, 0072 m³/day
  - Catchment area 4 (CA-4), Q = 1407,8904 m³/day
- The recommended channel is a trapezoidal shape.
- Pump needs in CA-1 with Q = 915, 3494 m3/day are 1 pump with a capacity 250m/h and working time of 4 hours / day
- Pump needs in CA-2 with Q = 1149,1368 m³/day are 1 pump with a capacity 250m/h and working time of 5 hours / day
- Pump needs in CA-3 with Q = 1116, 0072 m³/day are 1 pump with a capacity 250m/h and working time of 5 hours / day
- Pump needs in CA-4 with \( Q = 1407.8904 \text{ m}^3/\text{day} \) are 1 pump with a capacity 250m/h and working time of 5 hours / day

5.2. **Recommendation**
- To calculate the intensity of rainwater data should be taken more than 10 years

6. Reference

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