



Rainfall Analysis as a Hydrological Cycle in Mine Drainage: Implications for Mitigating Nickel Mining Damage in Pomalaa, Southeast Sulawesi Province, Indonesia

Jumbadi

PT. Antam Tbk Unit Geomin, Pomalaa,
Southeast Sulawesi,
INDONESIA

Erwin Setiawan

PT. Antam Tbk Unit Geomin, Pomalaa,
Southeast Sulawesi,
INDONESIA

T. Listyani R.A.*

Department of Geological Engineering, Institut
Teknologi Nasional Yogyakarta,
INDONESIA

*Correspondence: E-mail: lis@itny.ac.id

Article Info

Article history:

Received: October 15, 2024

Revised: February 13, 2025

Accepted: February 18, 2025



Copyright : © 2025 Foundae (Foundation of Advanced Education). Submitted for possible open access publication under the terms and conditions of the Creative Commons Attribution - ShareAlike 4.0 International License (CC BY SA) license (<https://creativecommons.org/licenses/by-sa/4.0/>).

Abstract

Inadequate mining management can harm the surrounding environment, including runoff that transports materials from mining sites to bodies of water or the sea. To prevent environmental damage, it is essential to implement mitigation measures in the mining area, such as constructing settling ponds. The research aims to understand the hydrological cycle in the context of nickel mining and develop strategies to mitigate environmental damage caused by mining activities. By examining rainfall data and its effects on mine drainage, the study seeks to provide insights into effective water management practices that can minimize the negative impacts of nickel mining on the environment. The data used is the value of rainfall for 10 years (2008 – 2017). The analysis was carried out on rainfall, runoff water discharge, and the rain catchment area. The results showed that the hydrological risk was 95.76% for the 10-year return period, the average rainfall was 119.84 mm, the designed rainfall was 175.85 mm, and the rain intensity was 38.41 mm/hour. The total discharge of runoff water in the north mine is 13.39 m³/sec, the middle is 25.34 m³/sec and the south is 11.02 m³/sec. The settling pond is designed in three working areas, namely the northern (991.72 m²), central (1,877.33 m²), and southern mining (816.241 m²) areas.

Keywords: environmental damage; hydrological cycle; mining; mitigation; rainfall analysis; nickel

To cite this article: Jumbadi., Setiawan, E. and Listyani, R, A, T. (2025). Rainfall Analysis as a Hydrological Cycle in Mine Drainage: Implications for Mitigating Nickel Mining Damage in Pomalaa, Southeast Sulawesi Province, Indonesia. *International Journal of Hydrological and Environmental for Sustainability*, 4(1), 01-12. <https://doi.org/10.58524/ijhes.v4i1.557>

INTRODUCTION

Studying the rainfall patterns of an area is crucial for supporting mining activities. Rainfall is the primary source of groundwater, making regional rainfall analysis essential. Areas with high rainfall typically have significant groundwater potential. However, high rainfall intensity can adversely affect mining operations, especially in open pit mines, where basin topography facilitates water accumulation, thereby hindering mining activities. Additionally, runoff water can carry materials that damage the surrounding ecosystem, such as contaminating nearby seawater (Purnama et al, 2023).

It is important to know that not all rainwater infiltrates the ground; some evaporates, while some becomes runoff. Rainfall can create surface runoff, which flows over the land and through rivers to the sea, both as surface runoff and interflow. Runoff can disrupt mining activities and cause pollution to water bodies and groundwater. Maintaining adequate quantity and quality of water resources in a mining area is crucial for supporting mining operations. However, high rainfall often

leads to excessive runoff. Conducting hydrological and hydrogeological surveys is essential to assess an area's potential for groundwater, runoff, and groundwater quality. The quality of surface water and groundwater can be determined by examining the pollution index according to established standards (Listyani, 2022).

The study of runoff is closely linked to land use. Changes in land use are significant contributors to environmental degradation. Mining activities can cause extensive deforestation and land degradation, altering the environmental structure of a watershed (Listyani and Peni, 2020). The expansion of critical land areas within a watershed can lead to flooding due to reduced water catchment areas. Local communities, particularly indigenous peoples, are highly vulnerable to the impacts of mining activities, especially those affecting land and water. Understanding land use development is essential to predict future changes and mitigate the impact of mining. Mining often transforms green zones into barren lands. Therefore, analyzing rainfall and runoff is crucial for designing drainage systems that preserve the mining environment (Listyani and Putranto, 2022).

In addition to generating runoff, rainfall can infiltrate the ground and flow through porous media, which are materials containing pores (voids) filled with fluids (gas or liquid) (Putri et al, 2023). The transport of fluids in porous media is critical in various applications (Blanco et al, 2022), such as CO₂ sequestration in deep saline aquifers (Benson and Cole, 2008; Huppert and Neufeld, 2014) and soil-air contaminant transport (Jin and Kuznetsov, 2024). In the context of mine drainage, aquifers play a vital role in storing rainwater as groundwater reserves (Petit et al, 2001).

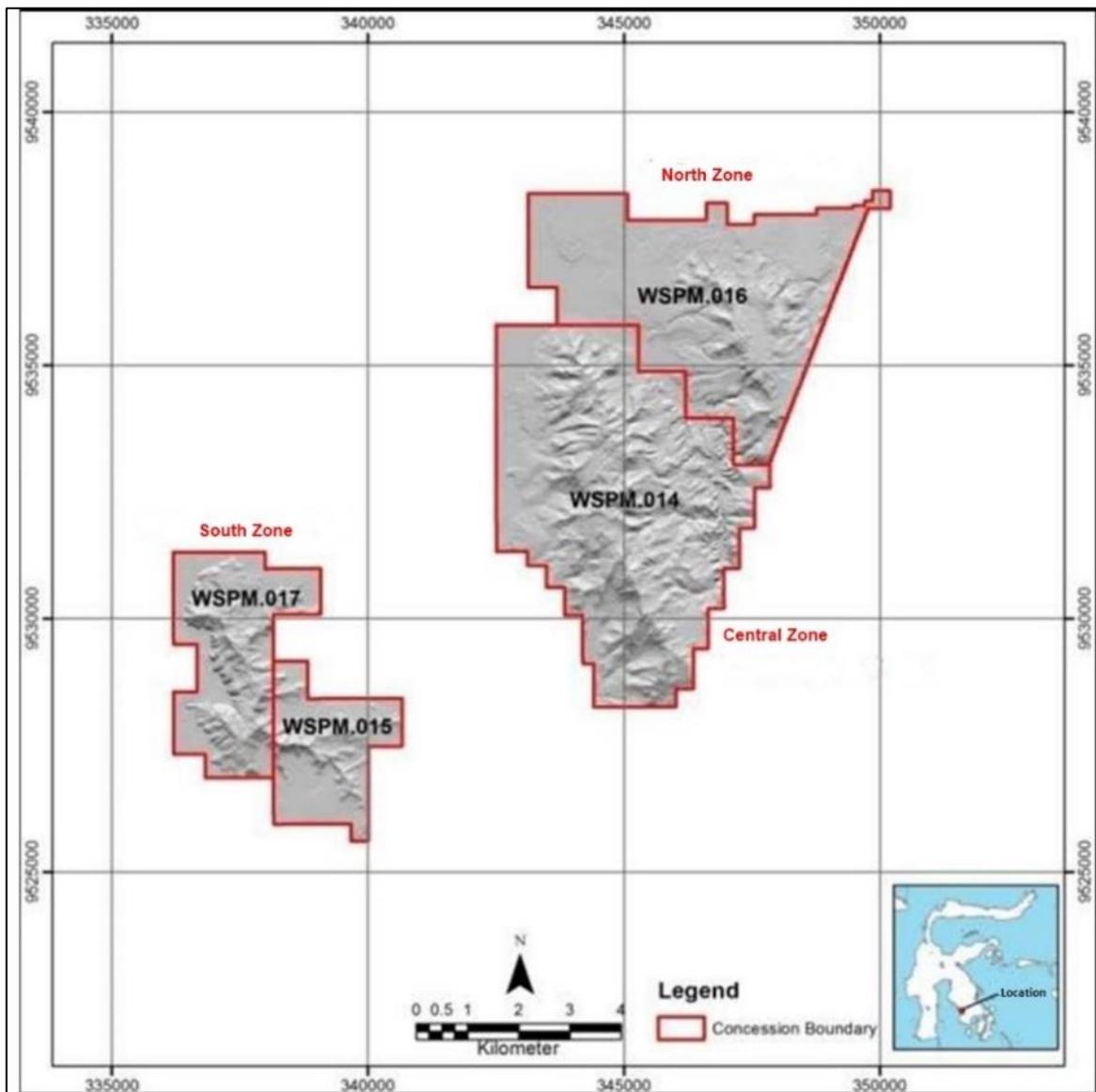


Figure 1. Location of the research area

One of the nickel mining activities that we highlight in this study is the PT. Aneka Tambang (ANTAM) Kolaka Nickel Mining area in Pomalaa, Southeast Sulawesi Province, Indonesia (**Figure 1**), which has had a significant impact on the local environment, mainly through changes in the natural hydrological cycle. This area has high rainfall, which exacerbates the challenges associated with mine drainage and runoff. This study aims to analyse rainfall patterns and their role in the hydrological cycle in the context of mine drainage. By understanding these dynamics, we can develop effective strategies to mitigate the environmental damage caused by nickel mining. This study focuses on the implications of rainfall on mine drainage systems and explores potential solutions, such as the construction of settling ponds, to minimise adverse impacts on surrounding ecosystems. It is hoped that this study will provide valuable insights into sustainable mining practices and highlight the importance of integrating hydrological analysis into environmental management plans for mining operations (Patil and Chore, 2014).

The research area is located at PT. ANTAM Tbk Kolaka Nickel Mining Business Unit, a subsidiary of MIND ID Mining. This company is involved in all stages of nickel mining, from exploration and mine planning to production, processing/refining, and marketing. The Kolaka mine spans 6,232.5 hectares and is situated in Pomalaa District, Kolaka Regency, Southeast Sulawesi Province, approximately 185 km from Kendari, the provincial capital.

The topography of the Pomalaa mining area is hilly, where the best area for nickel ore deposition is the ridge, due to mechanical and chemical weathering as an important factor in the formation of nickel ore deposits. In steep areas, rainwater that falls to the surface is very likely to become runoff rather than seep into the ground, therefore it is necessary to construct a settling pond to accommodate material carried by runoff water so as not to damage the environment outside the mining area. To maintain the convenience of mining activities, this research is intended as a geological and rainfall study of the Pomalaa nickel mine area, to obtain a drainage system in the form of a settling pond material design and determine its dimensions.

METHOD

The methodology of this study involves examining rainfall data and conducting the following analyses: first, determining the frequency of rainfall in the Pomalaa mining area over a 10-year period (2008-2017); second, calculating rainfall intensity using direct frequency analysis; third, calculating runoff water discharge; fourth, determining the catchment area; and lastly, identifying the settling pond area and calculating its dimensions to accommodate material carried by runoff water. The Hydrological Risk (Pt) value can be obtained using the following formula (Gumbel and Lieblein, 1954):

$$Pt = 1 - \left(1 - \frac{1}{Tr}\right)^{TL} \times 100\% \quad (1)$$

where Pt : Hydrological Risk (%), Tr : Return Period (years), and TL : Mine Life (years).

Design rain is the maximum average rain that may occur during the life of the mine. Determination of designed rainfall begins with calculating the average rainfall of the study area.

1. Calculation of the average value of high rainfall (Gumbel and Lieblein, 1954).

$$\bar{X} = \sum_{n=1}^n \left(\frac{X_i}{n}\right) \quad (2)$$

where \bar{X} : Average maximum rainfall (mm), X_i : Maximum average rainfall data i , and n : Number of data.

2. Calculation of design rainfall

The design rainfall calculation uses the Gumbel distribution (Gumbel and Lieblein, 1954), namely the design rainfall calculation is carried out using a partial series. This method is done by

determining the maximum daily average rainfall threshold. Calculations are made on rainfall above the threshold value.

$$X_t = \bar{x} + k \cdot SD \quad (3)$$

$$K = (Y_t - Y_n) / S_n \quad (4)$$

where X_t : Design rainfall (mm/day), \bar{x} : Average rainfall (mm/day), K = Reduce factor variance, Y_t : Reduce variate, Y_n : Reduced mean, S_n : Reduced standard deviation, and SD = Standard deviation.

Rainfall intensity is the amount of rain per unit of time, usually, the units used are mm/hour, mm/minute, or mm/second. Rainfall intensity values are used to calculate runoff water discharge. Calculation of rainfall intensity per hour is calculated using partial series, then proceeds with the Gumbel distribution. Due to the absence of short-duration rainfall data, it is assumed that it rains an average of 2 hours in 24 hours, so the calculation of one hour's rainfall intensity is carried out using the Mononobe formula as follows.

$$I = \frac{X}{24} \left(\frac{24}{t} \right)^{\frac{2}{3}} \quad (5)$$

where I : Rainfall intensity and X : Designed rainfall (mm). The value of the runoff coefficient (C) of the Pomalaa mining area can be determined using the Gumbel equation as follows (Gumbel and Lieblein, 1954).

$$C = C_t + C_s + C_v \quad (6)$$

where C : Runoff coefficient value, C_t : Topographic coefficient, C_s : Soil coefficient, and C_v : Vegetation coefficient. Then, the calculation of the maximum runoff water debit uses the rational formula, namely (Gumbel and Lieblein, 1954):

$$Q = 0.278 \cdot C \cdot I \cdot A \quad (7)$$

where Q : Maximum runoff water discharge (m³/sec), C : Runoff coefficient, I : Rainfall intensity (mm/hr), and A : Catchment area (km²).

RESULTS AND DISCUSSION

Rainfall parameter is necessary to be understood in order to know water recharge in mining area. Although sediment texture in the aquifer varies greatly across the area, groundwater recharge temporal trends appear to be primarily related to the amount of rainfall in all places (Van et al, 2023). When annual rainfall amounts decreased, groundwater recharge rate also decreased. Therefore, rainfall characteristics need to be studied to support mining activities, as well as the drainage system.

Monthly rainfall data for 2008 – 2017 for the Pomalaa area can be seen in **Table 1**. Based on these data it is known that the highest rainfall occurred in December 2015, namely 162.70 mm, and the lowest in September 2014, namely 0.00 mm. Determination of rainfall is done by using a series of partial analyses. This method uses the maximum rainfall threshold value, which is calculated on rainfall above the maximum rainfall threshold value. The data were processed using the Gumbel distribution (Gumbel and Lieblein, 1954). In the drainage design, the rainfall threshold value taken is the maximum annual average rainfall, which is 87.63 mm.

Table 1. Rainfall data for the 2008 – 2017 period (mm) (Aneka Tambang, 2019)

Year	Month												Total	Average	R max.
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec			
2008	45.70	15.90	95.50	51.40	33.00	48.70	25.40	30.80	31.40	63.60	74.30	22.80	538.50	44.88	95.50
2009	35.00	42.00	44.20	44.90	71.40	17.80	51.80	11.80	1.10	31.30	62.50	45.20	459.00	38.25	71.40
2010	25.70	96.60	96.70	112.1	44.30	67.60	109.4	55.00	134.3	98.80	162.7	48.30	1,051.50	87.63	162.70
2011	39.40	34.00	67.40	21.60	79.40	38.60	48.00	5.60	71.90	43,10	41.50	45,20	535.70	44.64	79.40
2012	39.20	43.20	85.80	39.70	110.8	16.00	63,90	5.40	24.20	77.00	22.40	32.70	560.30	46.69	110.80

2013	71.20	34.00	40.30	146.5	57.10	38.40	106.8	12.30	12.20	13.30	58.90	97.50	688.50	57.38	146.50
2014	21.6	58.8	111	111	85.5	58.9	22	28.5	0	3	25	60	585.30	48.78	111.00
2015	50	98	69	85.5	58	57	7	7	5	5.5	11	161	614.00	51.17	161.00
2016	78.9	52.3	53.8	66.5	67.1	62.9	59.2	25.6	38.6	22.6	68.8	130	726.30	60.53	130.00
2017	94.7	130.1	43.6	47.1	41.8	71.9	51.7	23.6	33.0	46.5	54.3	62.0	700	58.36	130.10
Total Maximum Rainfall													1,198.40		
Number of Average Rainfall per year													119.84		

Return Period and Hydrological Risk

Mining in the Pomalaa area is estimated to have a mine life of 30 years. The return period used in the 10-year design is shown in **Table 2**. The Hydrological Risk (Pt) value which can be obtained using the formula (1) expressed in this table. Whereas, the results of hydrological risk calculations with different return periods can be seen in **Table 3**. Based on calculations using the Hydrological Risk (Pt) equation for the drainage design for 10 years, a hydrological risk of 95.76% is obtained.

Table 2. Rainfall return period for drainage facilities.

Explanation	Rain Return Period
Open area	0.5
Mine facilities	2 – 5
Mine slopes and	5 – 10
Main well	10 – 25
Mining around	25
River diversion	100

Table 3. Hydrological risk at different return periods.

Return	Hydrological Risk
2	100
3	100
4	99.98
5	99.98
6	99.58
7	99.02
8	98.18
9	97.08
10	95.76

Designed Rainfall

Based on statistical calculations using Formula (2-4), the average value of rainfall (\bar{X}), standard deviation (S), Reduced Mean (\bar{Y}_n), and reduced standard deviation (S_n) is 119.84, 31.95, 1.00, and 31.95 mm, respectively. The values of these variables can be seen in **Table 4**.

Table 4. Designed rainfall at different returned periods.

Returned period	2	3	4	5	6	7	8	9	10
Hydrological risk	100	100	99.98	99.98	99.58	99.02	98.18	97.08	95.76
Standard	31.95	31.95	31.95	31.95	31.95	31.95	31.95	31.95	31.95
Reduced standard	1.0009	1.0009	1.0009	1.0009	1.0009	1.000	1.000	1.000	1.000
Average rainfall	119.84	119.84	119.84	119.84	119.84	119.8	119.8	119.8	119.8
Designed rainfall	115.73	132.84	143.79	151.90	158.35	163.7	168.2	172.2	175.8

Rainfall Intensity

Based on the analysis of available data, the designed rainfall is calculated in the return period of 10 years. Then, the amount of rain intensity per hour (I) using formula (5) is:

$$I = \frac{175.85 \text{ mm/day}}{24} \left(\frac{24}{t}\right)^{\frac{2}{3}} \text{ mm/day}$$

$$I = 38.41 \text{ mm/hr}$$

From these calculations, the value of rain intensity with a return period of 10 years is 38.41 mm/hour. The results of calculating rainfall intensity with different durations with different return periods can be seen in **Table 5**.

Table 5. Rainfall intensity with different durations.

Duration (hr)	Rain Intensity (mm)	Duration (hr)	Rain Intensity (mm)	Duration (hr)	Rain Intensity (mm)
1	60.96	9	14.09	17	9.22
2	38.40	10	13.13	18	8.88
3	29.31	11	12.33	19	8.56
4	24.19	12	11.63	20	8.27
5	20.85	13	11.03	21	8.01

Runoff

Runoff water is water that flows over the surface of the land due to rainfall that exceeds the infiltration capacity. Runoff water is very dangerous if not treated properly and planned. Factors that affect runoff water, include:

- Rain characteristics: rainfall, rain intensity, and frequency.
- Soil/rock: topography, the slope of the land surface, and geological structure.
- Soil cover condition: density, type, and type of vegetation.
- Rain catchment area.

Runoff flowing in mining areas often carries residual or sedimentary material to form tailings. Due to the distribution of rain, the highest rainfall area usually has a high groundwater potential (Purnama et al, 2023). Tailings are the parent material residue produced from a separation process of valuable metal-bearing minerals. In the mining process, there is sometimes overburden mixed with tailing materials. Then it cannot be avoided due to high and intensive rainfall so that the overburden can flow naturally through the river flow system (Taberima et al, 2020).

Runoff and the sediment it carries also trigger erosion in an area. Among the natural indicators that degrade land, soil erosion appears as the most often indicator (Nasare et al, 2023). Land degradation causes a global threat that directly affects the productivity of various life activities such as agriculture (Wang et al, 2020). Degradation is caused by various ecological processes that result in the loss of agricultural land, and forests or the emergence of deserts that need to be restored (Reynolds et al, 2011). Although land degradation is prevalent worldwide, the impacts are most severe in developing countries where they are heavily dependent on natural resources and land-based livelihoods (Nkonya et al, 2016; Ayuk and Oku, 2017). Therefore, the amount of runoff needs to be studied to avoid land degradation.

Furthermore, the rural poor rely on the land to obtain food and other economic goods in developing countries, thus, land degradation greatly impacts human well-being (Nachtergaele et al, 2010). For example, the cause of mercury pollution in soil and river bodies is the high rate of erosion in the watershed. Due to the erosivity of rainfall and the high erodibility of the soil, Hg contamination of soil and water can be significant (Yuwono et al, 2023). The process of soil erosion occurs due to runoff which is influenced by various factors including precipitation (intensity, duration, and rainfall), physical properties of the soil, land cover, and slope (steepness and length) (FAO, 2019). In wet tropical countries like Indonesia, water is the main cause of erosion. Soil erosion by water is a series of three main processes, namely the release of soil particles from its mass, the movement of loose material, and deposition (Weil and Brady, 2017; Gachene et al, 2019).

Runoff Coefficient

To determine the runoff discharge, it is necessary to determine the runoff coefficient in an area. The Pomalaa mining plan area has different runoff coefficients according to the area of the catchment area and the type of surface. The factors that need to be considered in determining the runoff coefficient are as follows (Table 6).

Table 6. Runoff coefficient (Hassing, 1995).

Topography (Ct)		Soil (Cs)		Vegetation (Cv)	
Flat < 1%	0.03	Sand and	0.0	Forest	0.04
Undulating 1 - 10%	0.08	Sandy loam	0.0	Agricultur	0.11
Hills 10 - 20%	0.16	Mud and silt	0.1	Meadow	0.21
Mountains > 20%	0.26	Stone layer	0.2	No plants	0.28

The runoff coefficient value (C) is obtained from several considerations that the planned mining area is still a forest with a layer of clay. As for the open areas in the form of slope-forming rocks with a slope greater than 10%. The mining area coefficient value takes into account the following conditions:

- Topography (Ct): hills 10% - 20%, Ct = 0.16
- Soil (Cs): catchment area contains clay and silt, Cs = 0.16
- Vegetation (Cv): the vegetation found in the mining area is forest, Cv = 0.04

The value of the runoff coefficient (C) of the Pomalaa mining area can be determined using the Gumbel equation 6 (Gumbel and Lieblein, 1954) as follows.

$$C = 0.16 + 0.16 + 0.04 = 0.36$$

Runoff Discharge in the Rain Catchment Area

Mine drainage is largely determined by the amount of rainfall, as is assessing the potential of a groundwater basin. Morphometric analysis of the basin area is very useful for surface water catchment and watersheds management. The runoff and recharge characteristics are usually in accordance with the relationship between morphometric factors (Patil & Bhagwat, 2023). Rainfall is one of the main influencing parameters of hydrogeological conditions. Furthermore, rainfall has a direct influence on the groundwater zone as main source of replenishment (Seifu et al, 2023).

The amount of runoff is closely related to rainfall and the catchment area. The rain catchment area is an area that we need to know apart from being a source of runoff, but on the other hand, this area can develop as a recharge zone. By understanding the existence of recharge zones we can also maintain the sustainability of groundwater resources in an area (Listyani & Prabowo, 2023).

With the presence of runoff water on the surface of the mining area, it is very important to know the runoff water discharge. Based on the topographic map of the catchment area (CA) and the direction of runoff, it can be seen that there are catchment areas in the northern, central, and southern mine areas as shown in Figure 2, while the calculations are presented in Table 7-9. Factors that affect the amount of runoff water such as soil/rock type, the slope of the land surface, cover conditions, and geological structure are considered in the calculation of runoff water discharge.

Table 7. Runoff water discharge for each CA in the northern mine area of Pomalaa.

No	Location	Runoff Coefficient	Rain (mm/hr)	Aperture Area (A) (km ²)	Aperture Area (A) (m ²)	Runoff (Q) (m ³ /sec)
1	CA 1	0.36	38.40	1.55	1,554,466.392	5.97
2	CA 2	0.36	38.40	0.39	394,693.894	1.52
3	CA 3	0.36	38.40	0.27	273,549.7142	1.05
4	CA 4	0.36	38.40	0.26	260,500.7315	1.00
5	CA 5	0.36	38.40	0.38	377,409.3476	1.45
6	CA 6	0.36	38.40	0.62	623,110.4658	2.39

Hydrological conditions, including weather, need to be considered in the mine drainage planning process. Even, extreme weather around the world is causing more and more serious natural disasters, including an increase in the frequency of flooding in an area (Rong et al, 2024). For this reason, mine drainage planning needs to be prepared carefully.

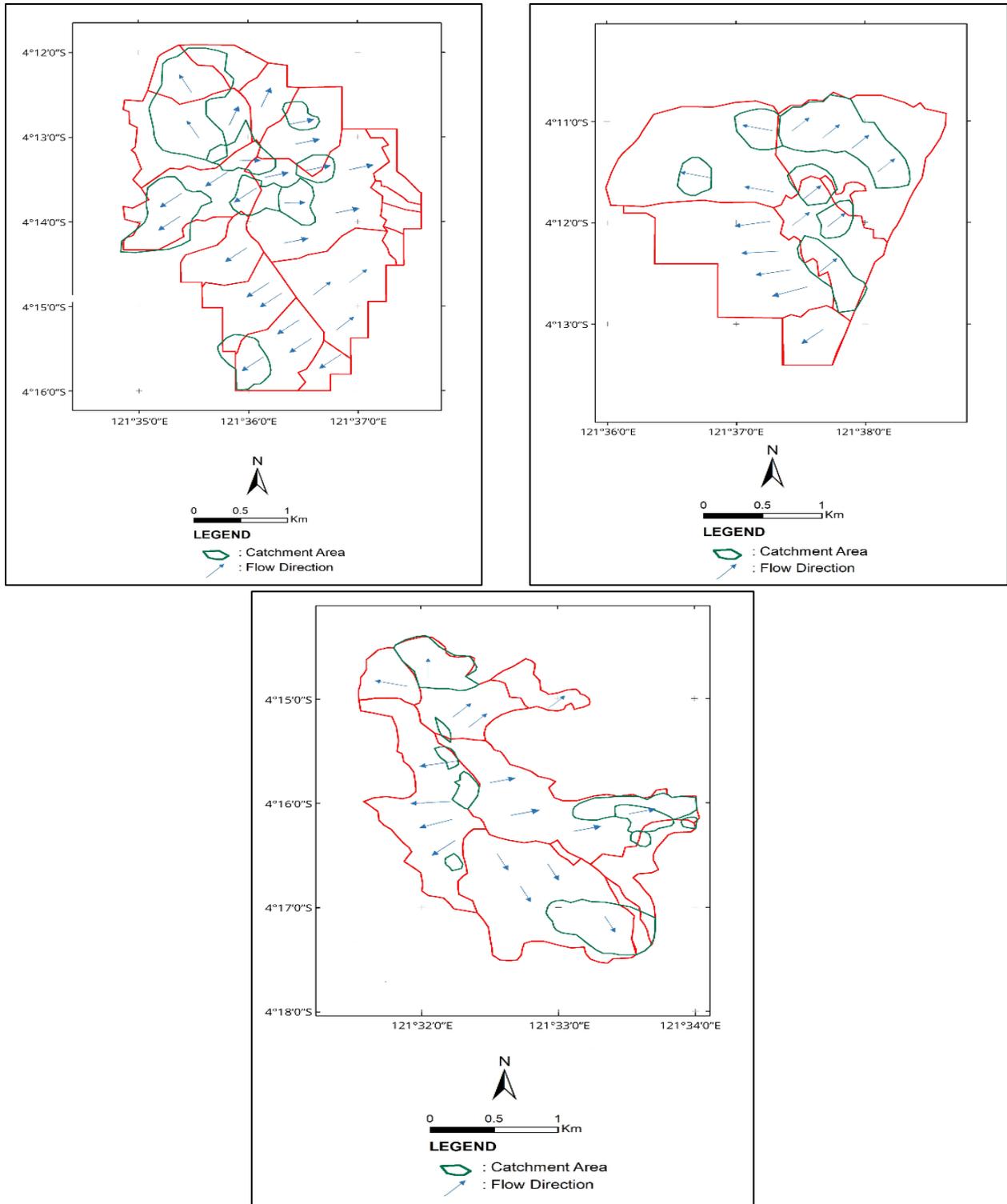


Figure 2. Rain catchment areas of the north (a), middle (b), and south (c) mining areas.

Table 8. Runoff water discharge for each CA in the Pomalaa central mine area.

No	Location	Runoff Coefficient	Rain	Aperture Area (A)		Runoff (Q)
			(mm/hr)	(km ²)	(m ²)	(m ³ /sec)
1	CA 1	0.36	38.40	2.37	2,372,737.973	9.12
2	CA 2	0.36	38.40	0.68	683,780.8523	2.63
3	CA 3	0.36	38.40	0.23	229,999.3434	0.88
4	CA 4	0.36	38.40	0.33	334,411.9593	1.29
5	CA 5	0.36	38.40	0.45	452,452.0292	1.74
6	CA 6	0.36	38.40	0.52	519,245.5212	2.00
7	CA 7	0.36	38.40	1.31	1,314,167.696	5.05
8	CA 8	0.36	38.40	0.69	687,950.7494	2.64

Table 9. Runoff water discharge for each CA in the south Pomalaa mine area.

No	Location	Coefficient runoff	Rain Intensity (I)	Aperture Area (A)		Runoff (Q)
			(mm/hr)	(km ²)	(m ²)	(m ³ /sec)
1	CA 1	0.36	38.40	0.64	639,321.3866	2.46
2	CA 2	0.36	38.40	0.06	63,636.1606	0.24
3	CA 3	0.36	38.40	0.05	54,832.2027	0.21
4	CA 4	0.36	38.40	0.01	5,997.7709	0.02
5	CA 5	0.36	38.40	0.14	138,858.91	0.53
6	CA 6	0.36	38.40	0.04	41,025.3197	0.16
7	CA 7	0.36	38.40	1.03	1,033,872.541	3.97
8	CA 8	0.36	38.40	0.89	889,780.1771	3.42

Settling Pond Dimensions

Making a settling pond is urgently needed before runoff goes out into open waters or the sea. To calculate the dimensions of the settling pond around the mining area, particle settling velocity data is needed. Particle deposition data has been obtained from the results of previous research, namely 0.0135 m/sec (Aneka Tambang, 2019). The settling pond dimensions can be seen in Table 10, where the calculations were carried out using the Stokes law approach for solid particles <40%, the total solids in the study area were 24.6% which could be compacted in the settling pond, referring to the water quality test in the field (Aneka Tambang, 2019) (Table 10).

Table 10. Dimensions of settling pond (Aneka Tambang, 2019).

No	CA	Discharge (m ³ /sec)	Area (m ²)	Dimensions			
				Length	Width	Depth	Volume
1	North Mine	13.39	991.72	165.28	6	3	2,975.162
2	Central Mine	25.34	1,877.33	312.88	6	3	5,632.019
3	Southern Mine	11.02	816.241	136.04	6	3	2,448.741

Settling Pond Design

The settling pond is determined based on the minimum volume of water that will enter the settling pond. The pond height has been determined to be 3 meters deep, according to the availability of tools at the Pomalaa site using a PC 200 digger. This tool can later be used for the maintenance of settling ponds which are used to remove accumulated mud. The settling pond dimensions per section are made with a width of 6 meters, which aims to make it easier for heavy equipment to reach all parts of the settling pond. The dimensions of the settling pond may change according to the conditions in the field if the volume of the pond cannot accommodate the volume of incoming water.

The settling pond design refers to the solid parameter data of 246 mg/L, this value is taken from water quality tests in the field (Aneka Tambang, 2019). The solids parameter value of 246 mg/L

is equivalent to 24.6% of the total solids that have been successfully deposited. The pond dimensions at each site can be seen in **Table 11**.

Table 11. Dimensions of settling pond at each mine site (Aneka Tambang, 2019).

Parameters (m)	Mine Location		
	North	Middle	South
Length	165.29	312.89	136.04
Width	6	6	6
Depth	3	3	3
Baffle width	3	3	3
The length of each compartment	6	6	6
Channel width between compartments	1	1	1

CONCLUSION

The results of research on the study of rainfall and mine drainage systems in the Pomalaa nickel mining area show the results of the calculation of rainfall in the 2008-2017 mining area in the Pomalaa area using the Gumbel distribution method with a threshold value of the maximum average rainfall per year, namely 87.63 mm and a rain return period of 10 years, obtained a hydrological risk of 95.76%. The average rainfall in the study area is 119.84 mm and the designed rainfall is 175.85 mm. The total discharge of runoff water in the north mine is 13.39 m³/sec, the middle is 25.34 m³/sec and the south is 11.02 m³/sec. The calculation results for the mine drainage design show that the pond area in the north mine is 991.72 m², in the middle is 1877.33 m², and in the south is 816.241 m². Each pond in the North, Central, and South mining areas is designed to be 6 meters wide and 3 meters deep by adjusting the availability of heavy equipment.

ACKNOWLEDGMENT

The author would like to thank the relevant parties who have provided support for this research. The author expresses many thanks, most of all to the company PT Antam Tbk., which has provided the author with the facilities and infrastructure in conducting research. The authors also thank their superiors and co-workers as well as the Yogyakarta Mineral & Coal Studio team who always provide analytical and moral support to the authors so that this writing can be completed properly.

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.

REFERENCES

- Aneka Tambang. (2019). *Report of Feasibility Study Geomin-MCS, Geotechnical and Hidrology Team Pomalaa, Southeast Sulawesi*.
- Ayuk, E.T. & Oku, E.E. (2017). *Promoting green economy: implications for natural resources development, food security and poverty reduction in Africa*. United Nations University Institute for Natural Resource.
- Benson, S. M. & Cole D. R. (2008). CO₂ sequestration in deep sedimentary formations. *Elements* 4(5), 325–331.
- Blanco, G.D., Fernández-Llamazares, Á., Blanco, G.D., Baker, J., Tagliari, M.S.M., Hayata, M.A., Campos, M.L. & Hanazaki, N. (2022). The impacts of mining on the food sovereignty and security of indigenous peoples and local communities: a global review. *Science of the Total Environment*, 855:158803, doi:10.1016/j.scitotenv.2022.158803.

- FAO (Food Agriculture Organization). (2019). *Soil Erosion: The Greatest Challenge to Sustainable Soil Management*. Rome.
- Gachene, C.K.K., Nyawade, S.O. and Karanja, N.N. (2019). Soil and water conservation: an overview. *Zero Hunger* 1-15, doi:10.1007/978-3-319-69626-3_91-1.
- Gumbel, E.J. & Lieblein, J. (1954). *Statistical Theory of Extreme Values and Some Practical Applications: A Series of Lectures*, Vol. 33. US Government Printing Office, Washington.
- Huppert, H. E. & Neufeld J. A. (2014). The fluid mechanics of carbon dioxide sequestration. *Annu. Rev. Fluid Mech*, 46, 255–272.
- Jin, Y. & Kuznetsov, A.V. (2024). Multiscale modeling and simulation of turbulent flows in porous media featured. *International Journal of Fluid Engineering* 1, 010601.
- Listyani, R.A.T. (2022). *Pengantar Hidrogeologi*. Deepublish Publisher, Yogyakarta.
- Listyani, R.A.T. & Peni, S.N. (2020). Potential of Water Pollution in Girimulyo, West Progo. *1st International Conference on Environment, Sustainable Issue, and Community Development (INCRID)*, Universitas Diponegoro, Semarang, <https://iopscience.iop.org/article/10.1088/1755-1315/448/1/012038/pdf>.
- Listyani, R.A.T. & Prabowo, I.A. (2023). Recharge Zone of Shallow Groundwater at Southeastern of Kulon Progo District Area based on Groundwater Facies. *International Journal of Economic and Environmental Geology (IJEEG)*, 13 (4), 10-15, <http://www.econ-environ-geol.org/index.php/ojs/article/view/754/439>
- Listyani, R.A.T. & Putranto, T.T. (2022). Groundwater quality assessment for drinking and clean water in Bagelen and its surrounding area *Sustinere: Journal of Environment and Sustainability*, 6(2), 121-131, <https://doi.org/10.22515/sustinere.jes.v6i2.188>
- Nachtergaele, F., Petri, M., Biancalani, R., Van Lynden, G. & Van Velthuizen, H. (2010). Global land degradation information system (GLADIS). Beta version. An information database for land degradation assessment at global level. Land degradation assessment in Drylands technical report, no. 17. Rome, FAO, Italy.
- Nkonya, E., Mirzabaev, A. & von Braun, J. (2016). *Economics of Land Degradation and Improvement – A Global Assessment for Sustainable Development* (eds), Springer Open, Cham, ISBN 978-3-319-19168-3, doi:10.1007/978-3-319-19168-3.
- Nasare, L.I., Rahman, L.A. & Darko, F.D. (2023). Indigenous knowledge systems for land condition assessment and sustainable land management in the Talensi District, Ghana. *Journal of Degraded and Mining Lands Management*, 10(2), 4209-4217, doi:10.15243/jdmlm.2023.102.4209.
- Patil, S.K., & Bhagwat, T.N. (2023). Morphometric analysis and hydrological inferences for water resource management in Warana River basin of Maharashtra, India, using remote sensing and GIS. *Songklanakarin Journal of Science and Technology*, 45 (1), 113–120.
- Patil, S. B. & Chore H. S. (2014). Contaminant transport through porous media: An overview of experimental and numerical studies. *Adv. Environ. Res.* 3(1), 45.
- Petit, C., Scudder, T. & Lambin, E. (2001). Quantifying processes of land-cover change by remote sensing: resettlement and rapid land-cover changes in south-eastern Zambia. *International Journal of Remote Sensing*, 2(17), 3435-3456, doi:10.1080/01431160010006881.
- Purnama, S., Cahyadi, A., Sekaranom, A.B., Febriarta, E., Firmansyah, A.J. & Riyanto, I.A. (2023). Aquifer characteristics and groundwater potential for domestic requirements in Kediri Regency, Indonesia. *Journal of Degraded and Mining Lands Management*, 10(2):4081-4092, doi:10.15243/jdmlm.2023.102.4081.

- Putri, L.A., Akbar, A.A. & Romiyanto. (2023). The impact of traditional gold mining on land use changes and vegetation index in Mandor Subwatershed, West Kalimantan. *Journal of Degraded and Mining Lands Management*, 10(2):4219-4232, doi:10.15243/jdmlm.2023.102.4219.
- Reynolds, J.F., Grainger, A., Stafford Smith, D.M., Bastin, G., Garcia-Barrios, L., Fernández, R.J. and Zdruli, P. (2011). Scientific concepts for an integrated analysis of desertification. *Journal of Degraded and Mining Lands Management*, 22(2):166-183.
- Rong, L., Böhle, M. Yandong, G. (2024). Improving the hydraulic performance of a high-speed submersible axial flow pump based on CFD technology. *International Journal of Fluid Engineering* 1, 013902.
- Seifu, T.K., Tenalem Ayenew, T., Alemayehu, T., & Woldesenbet, T.A. (2023). Groundwater potential mapping using GIS and remote sensing with multi-criteria decision-making in Shinile sub-basin, eastern Ethiopia. *Songklanakarin Journal of Science and Technology*, 45 (1), 121–130,
- Taberima, S., Junaedi, E., Sarwom, R., Lindongi, L.E. & Mulyanto, B. (2020). The acid mine drainage (AMD) impact of tailings and non-tailings on the ecosystem changes in the ModADA sedimentation area, Timika. *Journal of Degraded and Mining Lands Management*, 7(2): 2085-2094, DOI: 10.15243/jdmlm. 2020.072.2085.
- Van, L.L.T., Lertsirivorakul, R., Vuong, B.T., & Thang, C.H. (2023). Groundwater recharge in Mekong River Delta: An application of the water-table fluctuation method in the Long Xuyen Quadrangle and the Ca Mau Peninsula. *Songklanakarin Journal of Science and Technology*, 45(1), 51–58.
- Wang, W., Feng, C., Liu, F. and Li, J. (2020). Biodiversity conservation in China: a review of recent studies and practices. *Environmental Science and Ecotechnology*, 2:100025, doi:10.1016/j.ese.2020.100025.
- Weil R.R. and Brady, N.C. (2017). *The Nature and Properties of Soils*. 15th Edition Global Ed. Pearson Education Limited, England.
- Yuwono, S.B., Banuwa, I.S., Suryono, N., Somura, H. & Dermiyati. (2023) Mercury pollution in the soil and river water of the Ratai watershed by artisanal and small-scale gold mining activities in Pesawaran District, Lampung, Indonesia. *Journal of Degraded and Mining Lands Management*, 10(2), 4233-4243. doi:10.15243/jdmlm.2023.102.4233.