

RESEARCH ARTICLE

Design of Disposal Area Transition and Drainage at Pit 2AA PT Sentosa Laju Sejahtera Site CV Anggaraksa Adisarana Loa Janan

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Abstract

This research discusses the design of the disposal area transition and drainage system in Pit 2AA of PT Sentosa Laju Sejahtera to overcome the limited space of the stockpile due to the use of the backfilling method. The main issues include effective drainage design, selection of alternative disposal sites, and embankment slope stability analysis. The planned rainfall was calculated using the Gumbel distribution with rainfall data for the last 10 years (2014-2023), while the runoff water discharge was calculated using the Rational method, resulting in a discharge of 7.8 m³/second. The open channel was designed with two trenches, Trenches A and B, with capacities of 9.59 m³/sec and 7.92 m³/sec, respectively. The disposal design was placed outside the Life of Mine boundary, using the gradual finger disposal method with three levels from elevation 93 to 105 meters. The slope geometry consists of a tier height of 4 meters, a tier width of 15 meters, a single slope angle of 30°, and an overall slope of 13°. The total disposal capacity reached 441,310 BCM. Slope stability analysis was conducted using the Janbu Simplified method, showing that the factor of safety (FK) value is in the range of 1.308-2.404, meeting the minimum FK ≥ 1.3 according to the Decree of the Minister of Energy and Mineral Resources No. 1827 K/30/MEM/2018. The results show that the drainage and disposal designs are technically feasible and support the sustainability of mine operations.

Keywords: Disposal, Drainage, Factor of Safety

1. Introduction

Mining is the activity of extracting minerals from the earth for processing and maximum utilization in various industries and daily life. In mining activities to find valuable materials or minerals, the overburden or covering layer is first removed (Purba, 2024). In the mining industry, disposal area management and drainage systems play a crucial role in maintaining smooth operations and minimizing environmental impact (Suci et al., 2024).

PT Sentosa Laju Sejahtera is a company engaged in mining contracting, particularly in coal and minerals. One of PT Sentosa Laju Sejahtera's coal mining projects is located in the Mining Activity Permit (IUP) area of CV Anggaraksa Adisarana in Batuah Village, Loa Janan District, East Kalimantan. The IUP of CV Anggaraksa Adisarana covers a mining area of 127 hectares. Mining activities are conducted using the open-pit method with backfilling techniques. The backfilling method implemented by PT Sentosa Laju Sejahtera is more efficient as it utilizes abandoned mine pits (mine outs) as disposal sites. However, the method used also causes narrowing of the coal front, disrupting coal extraction operations. Additionally, the movement of the overburden soil from the first layer or base of the disposal contains muddy material. According to Jalil et al (2023), the mud in the base affects soil movement because as the volume in the upper layer increases, it experiences pressure and cannot withstand the load above it.

PT Sentosa Laju Sejahtera currently faces the need to relocate the disposal area outside the Life Of Mine (LOM) boundaries to optimize the storage capacity of overburden material. This relocation aims to improve the In Pit Dump

disposal area, which has suffered a landslide, so it can be reused after maintenance. According to Pamungkas et al (2021), the disposal design was created considering the drainage system in the disposal area to control surface water flow. Additionally, this study also accounted for the recommended slope stability safety factor values from the company, ensuring the design can be used safely. Therefore, the objective of the disposal transition design is to determine an alternative location that is more suitable by considering geotechnical factors, drainage systems, and operational aspects to avoid risks to slope stability and the sustainability of mining activities.

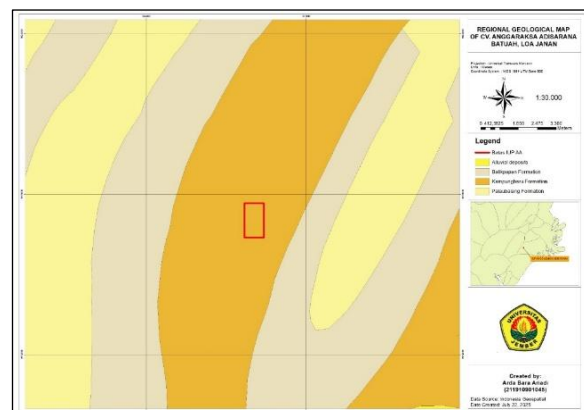


Fig 1. Regional Geological Map

2. Research Method

2.1 Regional Geological

According to (Sasmito, 2014), the Kutai Basin has several formations, namely the Pulaubalang Formation, the Balikpapan Formation, and the Kampungbaru Formation. The Kutai Basin is one of the largest basins in Indonesia and is rich in hydrocarbon content. The Balikpapan Formation in the Kutai Basin is one of the formations that has reservoir potential with significant hydrocarbon reserves (Rohmana et al., 2019). The Kampungbaru Basin was formed through complex geological processes that influenced the deposition and distribution of coal layers. According to Fahrudin & Yoga Aribowo (2024), This form has Factors such as tectonic activity, sedimentation, and past environmental conditions contributed to variations in the thickness, quality, and distribution of coal layers in this basin (fig 1).

2.2 Rainfall

According to Hidayat et al (2024) Rainfall is the amount of water that falls to the earth's surface in the form of rain during a certain period of time, which is usually measured in millimeters (mm). The purpose of determining rainfall data is to obtain rainfall values that will be used in planning (Rakhmawati et al., 2023) These values are the main reference in the design of mine drainage systems. The rainfall data analyzed is the annual maximum rainfall from the past few years (Khalik et al., 2020). Rainfall calculations can be performed using several methods, including Normal, Log Normal, Gumbel, and Log Pearson III, based on their distribution characteristics (Samsudin, 2015). The requirements and types of distribution models for goodness-of-fit testing are shown in Table 1.

Table 1. Distribution terms and models

No.	Distribution Type	Requirements
1.	Gumbel	$Cs \leq 1,396$ $Ck \leq 5,4002$
2.	Normal	$Cs \approx 0$ $Ck \approx 3$
3.	Log Normal	$Cs \approx 3$ $Ck = 5,383$
4.	Log Pearson III	$Cs \neq 0$

2.2 Rainfall Intensity

In this study, rainfall intensity at each time was calculated using the Mononobe equation, which is based on daily rainfall data (Bees & Partarini, 2024). The Mononobe formula is a development of equations previously proposed by Talbot (1881), Sherman (1905), and Ishiguro (1953). The following are several rainfall intensity formulas used to analyze short-duration rainfall (Manibuy, 2022).

$$I = \frac{R24}{24} \left(\frac{24}{t} \right)^{2/3}$$

2.3 Runoff Coefficient

The runoff coefficient is a dimensionless number ranging from 0 to 1. The C value is the ratio of rainfall that becomes runoff to total rainfall (Yuono et al., 2024). A low runoff coefficient value indicates that more rainfall is absorbed into the soil, while a value close to one indicates that most of the rainfall flows on the surface as runoff (Farida & Aryuni, 2020). In mining areas, the C value tends to be high because the surface is compact, does not absorb water, and tends to be barren (Akmal & Rachmanto, 2024). According to Bunganaen et al (2024), the runoff coefficient value can be determined using equation 1.

$$C = CT + CS + CV \quad (1)$$

The reference for determining the runoff coefficient value is influenced by several parameters described in Table 2 below.

Table 2. Determination of runoff coefficient values

Type	Parameters	Value
Topographic Coefficient	Flat (<1%)	0,03
	Undulating (1-10%)	0,08
	Hills (10-20%)	0,16
	Mountain Range (>20%)	0,26
Soil Coefficient	Sand and Gravel	0,04
	Sandy loam	0,08
	Clay and Lanau	0,16
	Rock layer	0,26
Vegetation Coefficient	Forest	0,04
	Agriculture Grassland	0,11
	Without vegetation	0,21
		0,28

2.4 Catchment Area

A catchment area is defined as an area that drains rainwater to a single collection point, with boundaries determined based on the highest elevation contours in the surrounding area (Kasih et al., 2024). Similar findings related to groundwater characteristics in coastal areas were also reported by Listiawan et al (2024) Rainfall catchment areas drain runoff to a single water collection point. The area of a catchment area is calculated using topographic maps equipped with contour lines, which help determine the direction of runoff flow (Hidayat et al., 2025).

2.5 Runoff Water Debit

According to Binolombangan et al (2023), runoff discharge can be calculated using the rational formula. The rational method is the maximum flow occurs when the duration of rainfall is equal to the duration of the concentration of the catchment area. Mathematically, the rational formula can be written in equation 2.

$$Q = 0,278 \times C \times I \times A \quad (2)$$

2.6 Drainage

According to Hengkesa (2022), open channels are artificial or natural structures used to drain water from the ground surface to sedimentation ponds or rivers. The dimensions of open channels are designed based on the volume of runoff from the catchment area. If the size of the channel is not adjusted to the volume of runoff, there is a risk that the water flowing into the channel will exceed its capacity. According to Binolombangan et al (2023), the flow capacity of an open channel can be calculated using the following Robert Manning equation.

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

The value (n) or manning coefficient is determined based on the hardness of the open channel wall, which can be seen in Table 3.

Table 3. Determination of Manning coefficients

Type of drainage	Value
Cast iron coated	0,014
Glass	0,01
Concrete channel	0,013
Bricks coated with mortar	0,015
Pair of cemented stones	0,025
Clean soil channels	0,022
Land channel	0,03
Channel with stone base and grassy banks	0,04
Channels in rock excavations	0,04

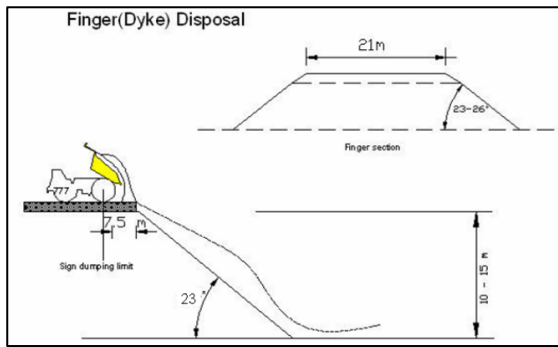


Fig 2. Finger Disposal

2.7 Disposal

Disposal is an area designed as a place to store overburden material resulting from excavation activities in a mining area. This process is carried out through excavation stages using excavators, followed by transportation using transport vehicles to the disposal site (Hardianti et al., 2024). The characteristics of the stored material are an important factor that affects the design and stability of the disposal structure. One of the most commonly used disposal types is the disposal finger, which is a method of disposal with a gradual dumping point, with a height of less than 15 meters (Mulyanti, 2008). The material is transported using dump trucks and leveled using a dozer to reach the planned disposal limit. The disposal boundary will continue to move forward as the volume of fill increases to maximize space capacity. According to Ikram (2022) the filling process requires continuous material to strengthen the dumping foundation area, with a final slope angle between 26° and 30° and a minimum safety factor of 1.3 (fig 2).

2.8 Janbu Simplified

In 1954, Janbu developed an analysis method that could be applied to both singular and non-singular landslide

surfaces. Janbu formulated a general equilibrium equation by solving the vertical and horizontal components at each intersection base, taking into account the overall force equilibrium (Subagio & Kuningsih, 2019).

$$FoS = \frac{\sum_{i=1}^n \frac{(c' \cdot \Delta L_i + (W_i - u_i \cdot \Delta L_i) \cdot \tan(\phi'))}{m_i \cdot FoS}}{\sum_{i=1}^n W_i \cdot \sin(\alpha_i)} \quad (4)$$

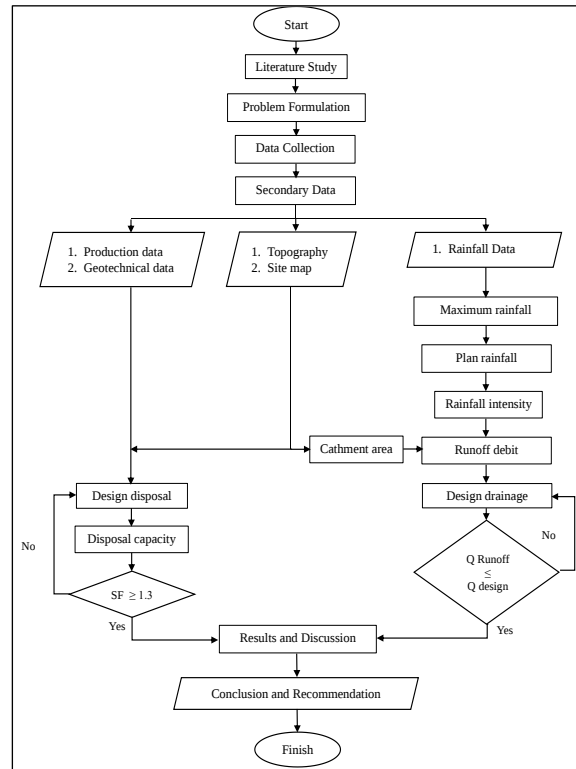


Fig 3. Research Flowcart

Table 4. Material Properties

Material Name	Color	Unit weight (kN/m ³)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Hu	Ru
Bedrock		21	Infinite strenght			none			0
Disposal		22	Mohr-Coulomb	25	5	Water surface	Automatically calculated	1	

3. Result and Discussion

3.1 Rainfall

Rainfall data in this study was obtained from the company's engineering department for the last 10 years (2014-2023). The rainfall data contains monthly rainfall amounts. Planned rainfall calculations were used to determine the rainfall intensity and runoff discharge in the study area. Planned rainfall was calculated using an annual series involving the use of maximum rainfall data for each year to analyze rainfall frequency and risk (Meliane, 2021). The maximum daily rainfall value was 376.5 mm/day, which occurred in 2015, and the average maximum rainfall was 316.07 mm/day.

The calculation of planned rainfall using the Gumbel distribution method is closely related to the previously determined rainfall recurrence period. The rainfall return period is the time span (in years) indicating the likelihood of a rainfall event of the same intensity recurring (Ardiansyah et al., 2022). In this planning, a return period of 2 years was

used, considering the operational lifespan of PT Sentosa Laju Sejahtera's mine, which is planned for 5 years. Based on this period, the calculated hydrological risk reached 97%.

Table 4. Return Period Analyze

RPA (years)	Mine Life (years)	Hydrological Risk (%)
1	5	100%
2	5	97%
3	5	87%
4	5	76%
5	5	67%

3.2 Rainfall Intensity

In this study, the Mononobe formula was used to calculate rainfall intensity based on daily rainfall data at each time interval. The Mononobe formula used is an extension of formulas previously proposed by Talbot (1881), Sherman (1905), and Ishiguro (1953). The rainfall intensity value was 93.74 mm/hour.

3.3 Runoff Water Debit

Runoff water is water that flows from a high elevation to a lower elevation (Fatnanta et al., 2024). Runoff water is calculated using a rational formula. The data required for this calculation includes the runoff coefficient, rainfall intensity, and catchment area.

The amount of runoff water is listed in Table 5 as follows:

Table 5. Results of runoff water discharge calculations

Catchment Area (Km ²)	Runoff Coefficient Value (C)	Rainfall Intensity (mm/hour)	Runoff Water Debit (m ³ /second)
0,83	0,36	93,74	7,8



Fig 5. Drainage Map

3.4 Drainage

In this study, the ditches were designed with the following functions:

1. Ditch A is located southeast of the transition disposal plan and is designed with a length of 178 m and functions to drain transition swamp 1 to swamp 2.
2. Ditch B is located south of ditch A and is designed with a length of 261 m and functions to drain water from swamp 2 to the nearest river.

The construction of the channel began with trench B, which connects swamp 2 at an elevation of 90 meters with trench B at an elevation of 88 meters. The function of trench B is to lower the water in swamp 2 from an elevation of 90 meters to 88 meters. The construction of trench B will bring the water level of swamp 2 to an elevation of 88 meters, so that the elevation is the same as that of swamp 1. After the construction of ditch B and the elevation of swamp 2 is the same as swamp 1 at an elevation of 88 meters, the construction of ditch A continues, which connects swamp 1 with swamp 2. Ditch A drains runoff water from DTH by creating a temporary storage pond near the transition disposal base. The main function of this pond is as a temporary storage for runoff water from the DTH. As the volume of water entering the pond increases, the hydrostatic pressure formed will push the water to overflow in a controlled manner toward ditch A. The temporary pond constructed in this swamp area is designed with a rectangular geometric shape to facilitate the construction process and water flow management. The pond has a surface area of 0.25 hectares, enabling it to store a water volume of up to 5,252 cubic meters. With these dimensions and capacity, the pond functions as a temporary peak flow control unit before the water is channeled to ditch A. The pond design also considers the efficiency of water overflow toward higher channels while maintaining slope stability and preventing excessive flooding in the mining area. The ditch is constructed with trapezoidal dimensions to

facilitate construction and maintenance. The ditch can be seen in Table 6.

Table 6. Dimensions of Drainage

Parameter	Drainage A	Drainage B	Unit
Slope (s)	0.008	0.006	%
Elevation difference	1.5	1.5	m
Open channel length	178	261	m
Channel base width (b)	2.5	2.5	m
Flow depth (h)	1.1	1.1	m
High alert (f)	0.4	0.4	m
X	1	1	-
Y	1	1	-
Manning (n)	0	0	-
Channel top width (CW)	5.5	5.5	m
Water surface width (W)	4.7	4.7	m
Height of channel (H)	1.5	1.5	m
Wet area (A)	3.96	3.96	m ²
Wet perimeter (O)	5.611	5.611	m
Hydrolic radius (R)	0.706	0.706	m
Debit total	9,59	7,92	m ³ /second

Based on the data presented in Table 6, it is known that the water discharge value flowing in channel A reaches 9.59 m³/second, while in channel B it is recorded at 7.92 m³/second. With these flow rates, the design results for channels A and B indicate that both channels have sufficient capacity to accommodate and convey runoff water from the Rainfall Catchment Area.

3.5 Disposal Transition Plan

The design of the disposal site involves selecting a suitable location from the site map and creating the disposal boundary by considering the situation and conditions at the time of field observation. The design is created using mining planning software. This design is based on the topographic map and the latest site conditions of the mining area obtained on July 31, 2024, thereby reflecting the current existing conditions as shown in Figure 4. The disposal boundary design is created outside the LOM pit boundary with an area of 7.62 hectares. The material disposal (dumping) method used in this design is the disposal finger method, which involves disposing of materials in stages, starting from the bottom and continuing to the top. This method is supported by a dozer to level and shape the materials according to the planned design. The disposal design is planned with three tiers, starting from an elevation of 93 meters up to the peak elevation of 105 meters. The first layer begins at an elevation of 93 meters up to 97 meters, the second layer from 97 meters to 101 meters, and the third layer from 101 meters to the peak elevation of 105 meters. The highest elevation in this disposal design is aligned with the planned reclamation land elevation, so that after mine closure is complete, the land contours can be integrated with the reclamation area, which serves for environmental restoration.

The road construction in the disposal design is designed in detail, taking into account operational efficiency and work safety aspects. The road design is made in two different levels, where each level has a ramp or connecting road with different slopes according to the difference in elevation. Gradually, the road in this disposal design starts from an elevation of 93 meters to an elevation of 97 meters, then continues from an elevation of 97 meters to an elevation of 101 meters. The slope of the road designed at each level is adjusted to the technical provisions stated in the Decree of the Minister of Energy and Mineral Resources of the Republic of

Indonesia Number 1827 K/30/MEM/2018 concerning Guidelines for the Implementation of Good Mining Practices, specifically related to the maximum permitted slope of mining roads, which is 12%. In this planning, the slope of the disposal road is set at 6.5%, which not only meets the applicable regulatory requirements but is also adjusted to the operational capabilities of the transport equipment used on-site.

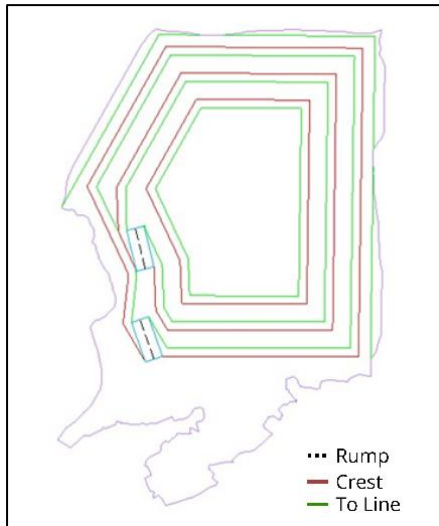


Fig 6. Disposal design plan

The technical specifications of the main transport unit used by PT Sentosa Laju Sejahtera, namely the Hino 500FM 280JD dump truck, serve as the primary reference for road geometry planning. Based on the vehicle specifications, the road design includes two lanes: one for units entering the disposal area and one for units exiting the area. The road width was designed to accommodate the widest unit operating on-site, the Hino 500FM 280JD dump truck, which has a total width of 2.49 meters. Based on technical calculations considering vehicle width and minimum maneuvering space for operational smoothness and safety, the minimum required road width was determined to be 8.715 meters. However, to anticipate potential congestion on the transportation route and to enhance flexibility and work safety, the road width in the final disposal design was increased to 15 meters. This decision was made as a form of operational risk mitigation and to support the smooth disposal of mining materials at the disposal site.

3.6 Disposal Capacity

The volume capacity of a disposal design is a measure of an area's ability to accommodate waste material, particularly material resulting from the removal of overburden. In the context of mining activities, this volume capacity serves as the final storage for material transported using transport equipment such as dump trucks from the pit location to the disposal area. Therefore, volume capacity calculations are crucial in supporting operational efficiency and managing material stockpiles to ensure they do not exceed the planned storage capacity.

In this study, the disposal site was designed with an area bounded by a boundary of 7.62 hectares. The disposal design for the transition phase has a total storage volume capacity of 441,310 BCM. This volume is calculated based on the final design geometry and existing topographic conditions obtained from the latest data. The disposal design for the first layer starts at an elevation of 93 meters and reaches an elevation of 97 meters, with a step height of 4 meters and a

step width of 15 meters. In this first layer, the storage capacity that can be accommodated is 284,554 BCM. This first layer serves as the base layer, designed to withstand and support the load of materials that will be placed on the subsequent layers above it. The stability of the base layer is critical as it will affect the overall stability of the material pile within the disposal structure.

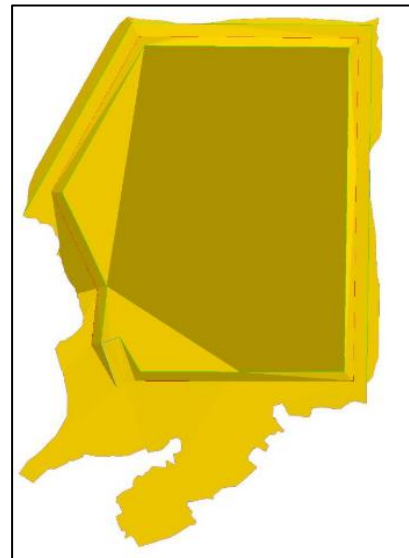


Fig 7. Layer 1

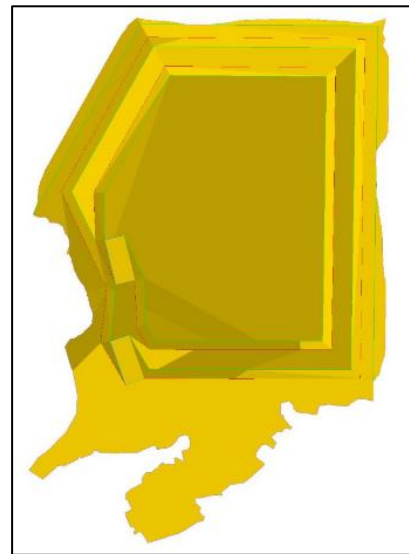


Fig 8. Layer 2

The disposal design for the second layer is a continuation of the first layer design that was built previously. This second layer is designed to expand the waste material storage capacity while ensuring the continuity of the vertical structure of the embankment. Geometrically, the second layer starts at an elevation of 97 meters and reaches a peak elevation of 101 meters, with a bench height of 4 meters. The bench width is maintained at 15 meters, following the dimensions applied in the previous layer to maintain design consistency and slope stability. With this configuration, the storage capacity of the second layer can accommodate 99,555 BCM. This volume is calculated based on the disposal area and the elevation difference between the base and the top of the layer, while considering the safe slope angle in accordance with applicable mining technical guidelines.

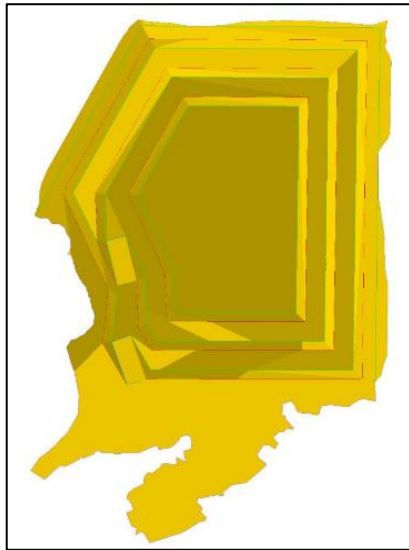


Fig 9. Layer 3

The disposal design on the third layer is the final stage of the stepped embankment structure designed to accommodate waste material from mining activities. This third layer starts at an elevation of 101 meters and reaches a peak elevation of 105 meters. With a bench height of 4 meters and a bench width of 15 meters, this design maintains the consistency of vertical and horizontal dimensions applied in previous layers to ensure the overall stability of the embankment. Based on volume calculations using topographic data and the defined geometric boundaries, the material storage capacity of the third layer is 57,201 BCM. This volume is calculated based on the surface area of the disposal area, the elevation difference between benches, and other relevant geometric parameters considering the existing conditions on-site.

This third layer is designed as part of the vertical development of the disposal structure, which is adjusted to the maximum capacity of the available land and takes into account the final elevation limits planned in the reclamation design. The peak elevation of 105 meters is set as the maximum elevation of the embankment because it has been adjusted to the final post-mining contour plan that will be used for reclamation and land function restoration purposes.

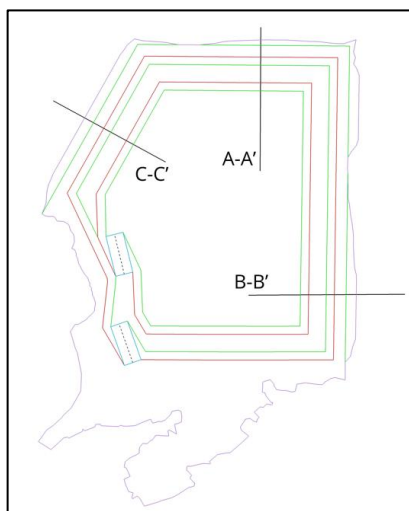


Fig 10. Cross section

3.7 Janbu Simplified

Slope stability is a key factor in mining plan design. Slope stability is a reference point before mining begins. Slope

geometry in the design also affects slope stability. The single slope angle in the design is 30° , with a bench width of 15 m, bench height of 4 m, and overall slope of 13° . These specifications are recommendations from the company, taking into account the safety factor of the slope geometry. The method used in SF calculations is the Janbu Simplified method. This method is commonly used in research and is recommended for non-circular slip surfaces, which are common in disposal slopes due to their irregular shape and material composition, formed from overburden deposits (Banggur et al., 2024). From the design results using mine planning by creating several cross-sections on various sections of the slope, it can be observed that (fig 10).

Slope stability analysis in disposal design was also performed using the Janbu Simplified method with the aid of safety factor calculation software. The Janbu Simplified method is a limit equilibrium method that calculates slope stability based on the equilibrium of horizontal forces on each cross-section, but does not take into account moment equilibrium. Although this approach has limitations, it is still widely used for initial slope stability evaluation, especially for slopes with simple geometry and well-defined soil parameters.

The results of safety factor calculations using the Janbu Simplified method on three cross sections are shown in Table 7.

Table 7. Safety factor value using the Janbu Simplified method

Cross Section	Safety Factor
A-A'	1,440
B-B'	1,315
C-C'	2,404

Based on the table above, the safety factor values for cross sections A-A' are 1.440, cross sections B-B' are 1.315, and cross sections C-C' are 2.404. The safety factor values for all three cross sections are within the minimum recommended limit specified in Ministry of Energy and Mineral Resources Regulation No. 1827 K/30/MEM/2018, which is 1.3 for static conditions. This indicates that the slopes across all cross sections are technically stable and safe against the possibility of landslides under normal operational conditions.

According to Amri et al (2021) Janbu Simplified method influences the shape of non-circular slip surfaces, as this method is more flexible compared to others that tend to assume a circular shape. Additionally, the Janbu Simplified method calculates stability based on horizontal force equilibrium, which under certain conditions can result in higher safety factor values if pore water pressure or load is not overly dominant.

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4. Conclusion

The drainage design in the transition area of PT Sentosa Laju Sejahtera consists of two channels, namely Paritan A and Paritan B. Paritan A drains water from swamp 1 to swamp 2, while Paritan B drains water from swamp 2 to the nearest river. The flow capacity of each channel is $9.59 \text{ m}^3/\text{second}$ and $7.92 \text{ m}^3/\text{second}$, respectively, sufficient to accommodate a runoff flow of $7.8 \text{ m}^3/\text{second}$.

The disposal design is located outside the LOM pit boundary with an area of 7.62 hectares, using a phased finger disposal method from an elevation of 93 to 105 meters. The design consists of three layers with a total capacity of 441,310 BCM. The disposal access road is constructed with two lanes and a slope of 6.5%, in accordance with technical specifications and adapted to the specifications of the transport equipment used at PT Sentosa Laju Sejahtera.

Slope stability analysis was conducted using Janbu Simplified. The analysis results indicate that all safety factor values are above the minimum threshold of 1.3, in accordance with Ministry of Energy and Mineral Resources Regulation No. 1827 K/30/MEM/2018.

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