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Determination of erosion and sedimentation potential for sump design at the nickel mine site of PT VALE Petea Indonesia

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***Abstract*— PT. Vale Indonesia is planning to conduct open-pit mining at the Petea location, which is situated upstream in the Lamunto watershed. Prior to the mining activities, measures need to be taken to prevent any harm and damage to the surrounding environment, especially with regard to soil erosion, which could potentially impact the Lamunto watershed, as it serves as the outlet for the mining location. The USLE (Universal Soil Loss Equation) method, aided by the ArcGIS application, was used to analyze the potential erosion that could occur. Additionally, the sedimentation rate was calculated using the SDR (Sediment Delivery Ratio) equation, based on the erosion rate and the area of the mining plan, in order to plan for sediment storage tanks, or sumps. The results of the study revealed that the sediment potential for sumps A, B, C, D, E, F, G, and H was 550.39 m3/year, 1195.31 m3/year, 1588.43 m3/year, 1908.27 m3/year, 2423.33 m3/year, 1899.53 m3/year, 1941.76 m3/year, 2169.15 m3/year, and 2756.29 m3/year, respectively. The slope factor (LS) was found to be more influential than the catchment area in calculating sediment potential, as evidenced by the greater sediment potential in sump D compared to sump F.**

Keywords— ***Mining Site; Universal Soil Loss Equation, Sediment Delivery Ratio; Sump.***

Introduction

The mining industry is a worldwide sector that poses risks to public health and safety, as well as the environment, including the land, water, and forests in the surrounding areas. Local subsidence, caused by mining excavations, can lead to property damage and endanger human life. Moreover, deforestation, which is often done to enable mining, can worsen natural disasters like landslides and floods that can occur during heavy rains. These issues have been documented in various sources [1]-[6].

The mining process in Indonesia is commonly carried out through open-pit mining. This mining system involves the clearing or opening of forests, followed by the removal or disposal of the topsoil layer [7]. Changes in topography can lead to changes in land use, including the transformation of land into barren areas, the emergence of steep slopes, and the formation of depressions in former mining areas, as well as soil erosion [8]-[11].

Erosion on exposed hillsides, mining disposal sites, and sedimentation caused by drainage, tributaries, and rivers can have significant impacts on the surrounding areas. Soil erosion is influenced by factors such as climate conditions, soil erodibility, slope length and steepness, land cover, soil conservation practices, and catchment drainage characteristics. Mining activities often significantly alter these factors, and severe sediment production can occur in locations such as topsoil stockpiles, excavated landfills, waste disposal sites, deforested topsoil areas, steep and gentle slopes, and haul roads [12].

PT. Vale, the largest nickel company in eastern Indonesia, is planning to conduct open-pit mining at the Petea location, situated in the upstream part of the Lamunto watershed. This has raised concerns about potential environmental hazards, especially regarding soil erosion. The mining activities could have a significant impact on the Lamunto watershed, which is the outlet for the planned mining location. To prevent any disturbances to the erosion and sedimentation balance that could lead to alterations in the riverbed and banks, and potentially disrupt river structures such as dams, embankments, and bridges, an effective sump system is required to collect the eroded material from the mine slopes.

This study aimed to comprehensively evaluate the erosion and sedimentation potential at the planned mining site in Petea. The study's results were used as a reference for effective management of the mine. To estimate erosion, the Universal Soil Loss Equation (USLE) was used, which was an indirect calculation method. This method predicts the average

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erosion rate in hilly areas with a specific rainfall pattern for each planting variant and soil management activity [13]-[16]. Additionally, to determine the sediment yield from an area, the Sediment Delivery Ratio (SDR) method was utilized, which was essential for obtaining a realistic estimate of the total sediment yield that may occur in a region [17]. Thus, calculating the total sediment yield based on the total erosion at the Petea mining site was crucial for addressing potential issues that may arise in the Lamunto Watershed [18], and for planning an effective sump system at the mine location.

Materials and Method

Figure 1 shows the plan for PT Vale Indonesia Tbk's mining location and the proposed research site located in Petea, Luwu Regency, South Sulawesi Province, Indonesia. Administratively, the research area is located at 2°31'21.61"S - 121°31'48.14"S and falls within the Lamunto watershed.

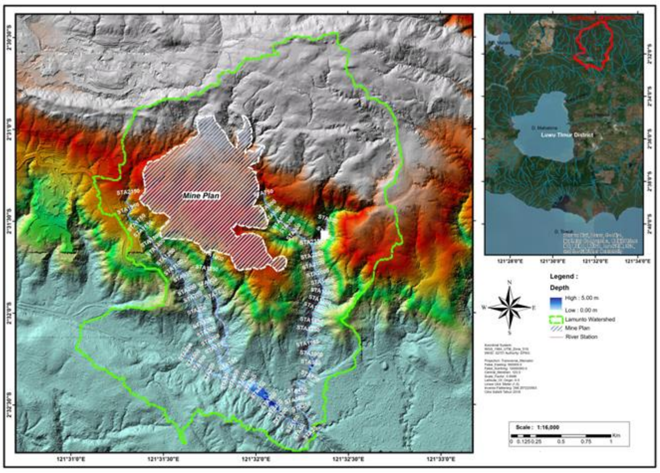

Figure 1. Research location

The research was carried out by gathering data from various sources including PT. Vale Indonesia Tbk, the Pompengan Jeneberang River Basin Agency, and relevant websites. The data collected from PT. Vale Indonesia Tbk consisted of topographic maps of the Petea Mining Area, while rainfall data from the Petea Station was obtained from the Pompengan Jeneberang River Basin Agency. The South Sulawesi Environmental Agency provided land use maps, while relevant data from websites included the Bungku Segi Empat Sulawesi 1:250,000 Geological Map and the World Soil Type Map. The collected data was analyzed using ArcGIS software and Microsoft Excel to overlay spatial data such as administrative, soil type, land use, river networks, and topography to obtain the Soil Map Unit. This information was used to calculate erosion using the USLE (Universal Soil Loss Equation) method. The sedimentation rate was then determined using the SDR (Sediment Delivery Ratio) equation based on the calculated erosion rate and the area of the planned mining. This information was used to plan the sediment retention pond.

USLE Method (Universal Soil Loss Equation)

In the USLE, the average annual soil loss is expressed as a function of six erosion factors:

$$E=R\times K\times LS\times CP \qquad (1)$$

where E is the amount of soil lost per year (tons/ha/year), R is the rainfall erosivity index (Kj/ha), K is the soil erodibility index (ton/kj), L is the slope length factor, S is the slope steepness factor, C is the cover-management factor, and P is the support practice factor [19].

1. Rainfall Erosivity Factor (R):

Rainfall erosivity is the ability of rain to cause erosion. Rainfall erosivity occurs due to the direct impact of rain on the soil surface. The ability of rainwater to cause erosion is due to the rate and distribution of rainfall drops, both of which greatly influence the kinetic energy of rainfall [20]-[22]. The R factor is determined based on monthly rainfall with the Lenvain approach (1989):

$$R_m=2{,}21\ P_m^{1{,}36} \qquad (2)$$

where R_m is the monthly rainfall erosivity and Pm is the monthly rainfall (cm).

2. Soil Erodibility Factor (K):

The erodibility factor of soil indicates the ability of soil particles to be detached and transported by the kinetic energy of rainwater. The erodibility of soil can be determined by looking at several soil characteristics such as soil texture, aggregate stability, infiltration capacity, and organic and chemical content [23].

3. Slope Length and Steepness Factor (LS):

Slope length and steepness are the two topographic elements that most influence surface runoff and erosion. Other factors that may affect erosion are slope configuration, uniformity, and direction. The steeper and longer the slope, the greater the erosion. Slope steepness is analysed using topographic data, which is then analysed using the ArcGIS geographic information system software according to the slope classification (%) with Class I (0 - 8%) as flat, Class II (> 8 - 15%) as gently sloping, Class III (> 15 - 25%) as moderately steep, Class IV (> 25 - 45%) as steep, and Class V (> 45%) as very steep [24].

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4. Crop Management Factor (C):

The crop management factor is the ratio of soil erosion under a specific crop management practice to soil erosion under a similar land surface condition without vegetation cover or with vegetation cover but without specific crop management practices [25].

5. Support Practice Factor (P):

The soil conservation practice factor is the ratio of soil loss if conservation practices (terracing, vegetation, etc.) are applied to soil loss when no conservation practices are applied. Soil conservation is not just a mechanical or physical activity but rather an effort to reduce the potential for soil erosion [26]. The selection or determination of the P factor should be done with caution due to the variety of land conditions and conservation techniques that can be found in the field.

SDR (Sediment Delivery Ratio):

Indirectly, sedimentation calculations can be carried out through an estimation of the erosion results that occur in a region. After erosion in an area is determined, calculations should be based on erosion models or other methods, followed by an estimate of the sediment delivery ratio (SDR).

$$Sy = SDR \times E \quad (3)$$

$$SDR = 0{,}41 \times A^{-0{,}3} \quad (4)$$

Where Sy is the sediment transport volume (ton/year), SDR is sediment delivery ratio, E is the amount of soil erosion (ton/ha/year), and A is the catchment area [17]..

Results and Discussion

Rain Erosivity Factor Value (R)

The rainfall erosivity value is calculated based on the monthly rainfall data from Petea Station, which is the nearest rainfall station to the research location. The monthly rainfall data from Petea Station can be seen in Table 1.

The rainfall erosivity factor is calculated using the Lenvain erosivity equation. The results of the rainfall erosivity factor (R) calculation obtained from Equation (2) can be seen in Table 2. Table 2 shows that the average planned erosivity value for the mining location is 2198.29 Kj/ha.

Table 1. Monthly rainfall amount at Petea Station (mm)

Month/Year	2012	2013	2014	2015	2016	2017	2018	2019	2020
January	313.9	309.1	243.7	132.9	135.3	253.7	106.2	209.1	115.0
February	328.0	370.1	305.9	595.1	268.3	246.0	244.6	301.2	237.5
March	221.0	259.5	201.6	324.8	577.1	342.1	208.0	235.8	452.4
April	467.3	543.2	352.1	648.7	559.0	247.6	254.6	430.0	387.9
May	264.4	334.5	333.6	307.4	295.3	552.3	243.4	143.7	195.6
June	281.2	332.0	319.4	312.5	269.8	252.0	233.0	552.4	375.1
July	202.7	458.3	215.6	77.2	144.4	345.4	266.1	98.0	336.8
August	64.6	120.1	73.4	4.4	179.9	253.1	192.5	51.8	136.8
September	104.9	82.6	68.8	19.4	108.0	180.1	81.6	33.4	178.3
October	125.8	23.7	53.6	2.4	289.2	227.3	68.2	69.9	68.7
November	326.0	287.8	233.4	318.7	269.0	426.4	268.6	132.6	
December	262.8	159.8	238.6	304.7	273.5	128.0	380.1	126.0	

Table 2. Monthly rainfall erosivity

Month/Yr	2012	2013	2014	2015	2016	2017	2018	2019	2020
January	239.9	234.9	170.0	74.54	76.38	179.5	54.94	138.0	61.23
February	254.6	300.1	231.6	572.5	193.7	172.2	170.8	226.8	164.1
March	148.8	185.1	131.3	251.3	549.1	269.6	137.0	162.5	394.3
April	412.1	505.7	280.4	643.8	525.8	173.7	180.4	368.0	319.9
May	189.9	261.5	260.6	233.1	220.7	517.3	169.7	82.90	126.0
June	206.5	258.9	245.6	238.4	195.2	177.9	159.9	517.4	305.6
July	132.3	401.3	143.9	35.61	83.45	273.2	191.6	49.26	264.0
August	27.95	64.95	33.25	0.72	112.5	179.0	123.3	20.70	77.53
September	54.03	39.05	30.44	5.44	56.21	112.6	38.40	11.39	111.1
October	69.18	7.15	21.68	0.32	214.6	154.6	30.08	31.11	30.38
November	252.5	213.1	160.3	244.9	194.4	363.8	194.0	74.31	
December	188.4	95.78	165.2	230.3	198.9	70.83	311.2	69.33	
Total	2176	2567.	1874.	2531.	2621.	2644.	1761.	1751.	1854.
Average	2198.29								

Rain Erosivity Factor Value (R)

Soil erodibility value depends not only on topography, slope, and human activities but also on the influence of soil texture, aggregate stability, infiltration capacity, organic and inorganic content. For some types of soil in Indonesia issued by the Department of Forestry's RLKT Service, the value of K can be obtained according to Table 3 [27]. Based on the soil type map in the research or mining plan location and the erodibility factor table K, it was obtained that the soil type is red-brown latosol with an erodibility value (K) of 0.43 ton/Kj.

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Table 3. Soil erodibility factor (K)

No.	Soil Type	Erodibility Factor (K)
1	Reddish brown Latosol and Litosol	0.43
2	Reddish yellow Latosol and Litosol	0.36
3	Mediterranean complex and Litosol	0.46
4	Reddish yellow Latosol and Litosol	0.56
5	Grumosol	0.20
6	Alluvial	0.47
7	Regosol	0.40

Crop and Soil Processing Factor Value (CP)

The crop and soil processing factor was determined based on field conditions. The U.S. Soil Conservation Service (1977) had issued guidelines for determining the value of CP for various land uses as shown in Table 4.

Table 4. The CP factor values for various types of ground cover vegetation (U.S. Soil Conservation Service, 1977).

Ground Cover Vegetation		Type	Low Vegetation (Cover Percentage (%))					
Type and Height of Canopy	Canopy Cover		0	20	40	60	80	95-100
Bare Ground Condition		G	0.450	0.200	0.100	0.042	0.013	0.003
		W	0.450	0.240	0.150	0.090	0.043	0.011
Low Shrubs (0.5 m from the ground)	25.00	G	0.360	0.170	0.090	0.038	0.012	0.003
		W	0.360	0.200	0.130	0.082	0.042	0.011
	50.00	G	0.260	0.130	0.070	0.035	0.012	0.003
		W	0.260	0.160	0.110	0.075	0.039	0.011
	75.00	G	0.170	0.100	0.060	0.031	0.011	0.003
		W	0.170	0.120	0.090	0.075	0.038	0.011
ow Shrubs (2 m from the ground)	25.00	G	0.400	0.180	0.090	0.040	0.013	0.003
		W	0.400	0.220	0.140	0.085	0.042	0.011
	50.00	G	0.340	0.160	0.085	0.038	0.012	0.003
		W	0.340	0.190	0.130	0.081	0.041	0.011
	75.00	G	0.280	0.140	0.080	0.036	0.012	0.003
		W	0.280	0.170	0.120	0.770	0.040	0.011
Low Shrubs (4 m from the ground)	25.00	G	0.420	0.190	0.100	0.041	0.013	0.003
		W	0.420	0.230	0.140	0.087	0.042	0.011
	50.00	G	0.390	0.180	0.090	0.400	0.013	0.003
		W	0.390	0.210	0.140	0.085	0.042	0.011
	75.00	G	0.360	0.170	0.090	0.039	0.012	0.003
		W	0.360	0.200	0.130	0.083	0.041	0.011

Assumptions used: 1) Vegetation/litter distribution is random, 2) Sufficient litter thickness. Unproductive soil can be interpreted as land that has not been utilized for three consecutive years. It can also be interpreted as a forest area whose harvesting has been completed (less than three years apart), 3) The average height of free-falling water from the canopy to the ground surface, 4) The area of the ground covered by plant canopy when viewed from above (top view), and G = grass or grass-like plants, with a height of about 2.5 cm, and W = shrubs with broad leaf canopies or undecomposed litter [18]. Based on observations at the research location or mining plan and the CP factor table, the bare ground condition of type G with a 0% cover percentage was chosen because deforestation will be carried out in the future, resulting in a CP value of 0.45 being used.

Length and Slope Factor Value (LS)

The formation of terraces with a -2% slope on the planned mining topography aimed to reduce the width and facilitate flow in the carrier channel. The slope classes at the site were divided into 5 groups as shown in Figure 2 and the LS values refer to the standard of the Forestry Department as shown in Table 5 [28], [29].

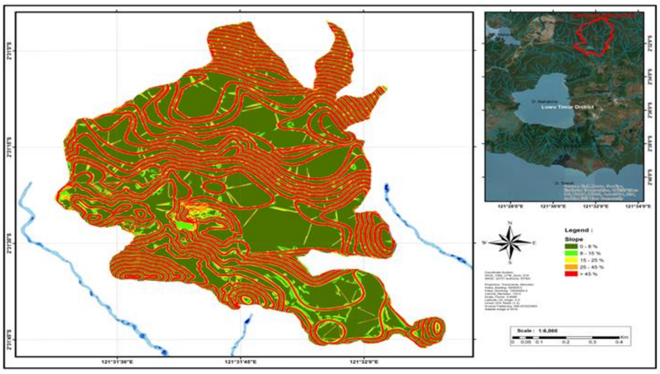

Figure 2. Soil Slope Map

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Table 5 shows that a steep slope in a land unit will result in a high LS factor value as well. This is because if the surface slope becomes steeper, it will increase the surface runoff velocity in transporting soil.

Table 5. The assessment of slope class and LS factor

Class	Slope (%)	Desciption	LS values
I	0 - 8	Flat	0.4
II	8 - 15	Slight slope	1.40
III	15 - 25	Slightly steep	3.10
IV	25 - 45	Steep	6.80
V	> 45	Extremely steep	9.50

Sump Layout Plan

The Sump Layout Plan was based on the planned topographic data and the flow direction from the mining site. After analysis, there were 8 recommended locations for the sediment trap sump plan before the water from the mining area enters the river, as shown in Figure 3 and the flow direction scheme shown in Figure 4.

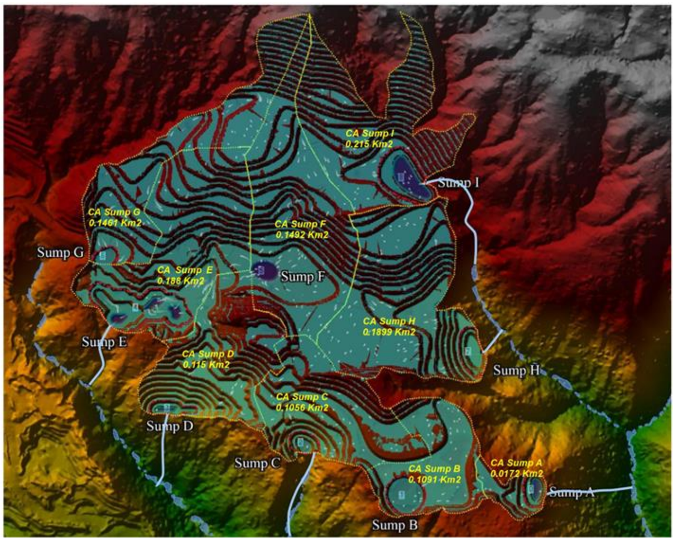

Figure 3. Layout Plan and Catchment Area of Sump.

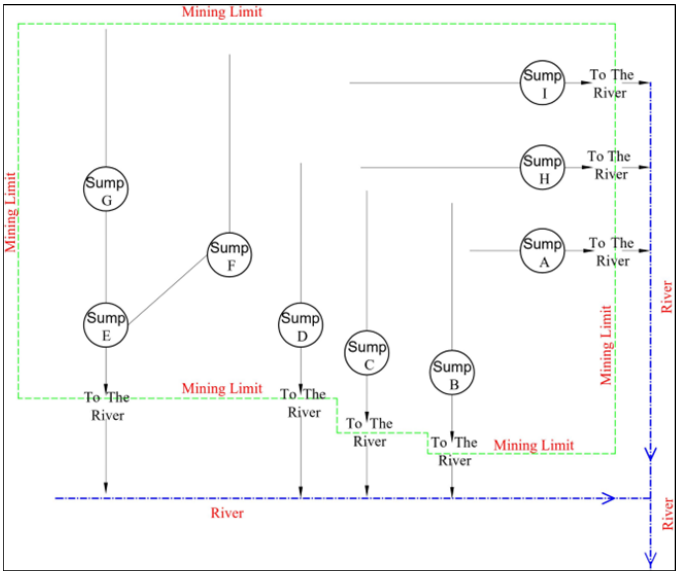

Figure 4. Sump Flow Direction Scheme (Sediment Trap)

Figure 3 shows the catchment area of each planned sump, namely Sump A with an area of 0.0172 km2, Sump B with an area of 0.1091 km2, Sump C with an area of 0.1056 km2, Sump D with an area of 0.115 km2, Sump E with an area of 0.188 km2, Sump F with an area of 0.1492 km2, Sump G with an area of 0.1461 km2, Sump H with an area of 0.1899 km2, and Sump I with an area of 0.215 km2. Meanwhile, Figure 4 shows that Sump A, Sump B, Sump D, Sump H, and Sump I are independent, meaning that there are no connection with other sumps, unlike Sump E which is downstream of Sump F and G.

Potential Erosion and Sedimentation

After calculating and observing each factor (R, K, LS, and CP), the erosion value in the mining plan area can be calculated using equation (1). After obtaining the erosion value in the mining plan area, to calculate the amount of sediment deposited in the sump (Sy), it can be calculated using equation (SDR) (Equations 3 and 4). From the previous analysis, the value of rainfall erosivity (R) was obtained at 2198.29 Kj/ha, soil erodibility value (K) at 0.43 ton/Kj, land and crop management value (CP) at 0.45, and from secondary data, the sediment density was obtained at 3.50 gr/cm3. The calculation of erosion and sedimentation potential was carried out on each sump as shown in Tables 6-13.

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Table 6. Erosion and sedimentation potential of sump A

No.	Topography	Slope Class	LS	Area per seg-ment	Potential Erosion	SDR	Potential Sediment
		%		ha	ton/year		
1	Flat	0 - 8	0.40	0.57	97.67	0.48	47.3
2	Gentle Slope	8 - 15	1.40	0.09	56.29	0.83	46.84
3	Moderately Steep	15 - 25	3.10	0.13	169.03	0.76	128.35
4	Steep	25 - 45	6.80	0.25	714.22	0.62	445.5
5	Extremely Steep	> 45	9.50	0.68	2727.92	0.46	1258.38
Total Potential Sediment						ton/yr	1926.37
Total Potential Sediment						m^3/yr	550.39

Table 7. Erosion and sedimentation potential of sump B

No.	Topography	Slope Class	LS	Area per segment	Potential Erosion	SDR	Potential Sediment
		%		ha	ton/year		
1	Flat	0 - 8	0.40	7.12	1211.43	0.23	275.64
2	Gentle Slope	8 - 15	1.40	0.87	515.30	0.43	220.64
3	Moderately Steep	15 - 25	3.10	0.48	634.13	0.51	323.85
4	Steep	25 - 45	6.80	0.80	2314.28	0.44	1014.51
5	Extremely Steep	> 45	9.50	1.65	6653.61	0.35	2348.93
Total Potential Sediment						ton/yr	4183.58
Total Potential Sediment						m^3/yr	1195.31

Table 8. Erosion and sedimentation potential of sump C

No	Topography	Slope Class	LS	Area per segment	Potential Erosion	SDR	Potential Sediment
		%		ha	ton/year		
1	Flat	0 - 8	0.40	5.12	871.58	0.25	218.90
2	Gentle Slope	8 - 15	1.40	0.88	524.62	0.43	223.43
3	Moderately Steep	15 - 25	3.10	0.56	737.69	0.49	360.02
4	Steep	25 - 45	6.80	1.06	3070.88	0.40	1236.66
5	Extremely Steep	> 45	9.50	2.94	11860.57	0.30	3520.50
Total Potential Sediment						ton/yr	5559.52
Total Potential Sediment						m^3/yr	1588.43

Table 9. Erosion and sedimentation potential of sump D

No.	Topography	Slope Class	LS	Area per segment	Potential Erosion	SDR	Potential Sediment
		%		ha	ton/year		
1	Flat	0 - 8	0.40	4.75	808.06	0.26	207.61
2	Gentle Slope	8 - 15	1.40	0.70	418.45	0.46	190.72
3	Moderately Steep	15 - 25	3.10	0.62	822.67	0.47	388.58
4	Steep	25 - 45	6.80	1.29	3736.13	0.38	1418.61
5	Extremely Steep	> 45	9.50	4.13	16700.41	0.27	4473.42
Total Potential Sediment						ton/year	6678.94
Total Potential Sediment						m^3/year	1908.27

Table 10. Erosion and sedimentation potential of sump E

No.	Topography	Slope Class	LS	Area per segment	Potential Erosion	SDR	Potential Sediment
		%		ha	ton/year		
1	Flat	0 - 8	0.40	9.36	1593.37	0.21	333.93
2	Gentle Slope	8 - 15	1.40	0.99	591.88	0.41	243.12
3	Moderately Steep	15 - 25	3.10	0.95	1253.22	0.42	521.73
4	Steep	25 - 45	6.80	1.80	5213.70	0.34	1791.30
5	Extremely Steep	> 45	9.50	5.68	22969.38	0.24	5591.59
Total Potential Sediment						ton/yr	8481.66
Total Potential Sediment						m^3/yr	2423.33

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Table 11. Erosion and sedimentation potential of sump F

No.	Topography	Slope Class	LS	Area per segment	Potential Erosion	SDR	Potential Sediment
		%		ha	ton/year		
1	Flat	0 - 8	0.40	8.48	1442.09	0.22	311.41
2	Gentle Slope	8 - 15	1.40	0.56	336.08	0.49	163.59
3	Moderately Steep	15 - 25	3.10	0.53	693.94	0.50	344.94
4	Steep	25 - 45	6.80	0.99	2861.69	0.41	1177.07
5	Extremely Steep	> 45	9.50	4.37	17657.35	0.26	4651.35
Total Potential Sediment						ton/yr	6648.36
Total Potential Sediment						m^3/yr	1899.53

Table 12. Erosion and sedimentation potential of sump G

No.	Topography	Slope Class	LS	Area per segment	Potential Erosion	SDR	Potential Sediment
		%		ha	ton/year		
1	Flat	0 - 8	0.40	7.92	1347.86	0.22	297.02
2	Gentle Slope	8 - 15	1.40	0.55	329.25	0.49	161.26
3	Moderately Steep	15 - 25	3.10	0.62	816.33	0.47	386.48
4	Steep	25 - 45	6.80	1.06	3069.67	0.40	1236.32
5	Extremely Steep	> 45	9.50	4.46	18004.00	0.26	4715.08
Total Potential Sediment						ton/year	6796.16
Total Potential Sediment						m^3/year	1941.76

Table 13. Potensi Erosi dan Sedimentasi Sump H

No.	Topography	Slope Class	LS	Area per segment	Potential Erosion	SDR	Potential Sediment
		%		ha	ton/year		
1	Flat	0 - 8	0.40	11.27	1917.08	0.20	380.08
2	Gentle Slope	8 - 15	1.40	0.62	370.91	0.47	175.28
3	Moderately Steep	15 - 25	3.10	0.64	847.55	0.47	396.77
4	Steep	25 - 45	6.80	1.19	3429.46	0.39	1336.06
5	Extremely Steep	> 45	9.50	5.27	21299.48	0.25	5303.82
Total Potential Sediment						ton/yr	7592.02
Total Potential Sediment						m^3/yr	2169.15

Table 13. Potensi Erosi dan Sedimentasi Sump I

No.	Topography	Slope Class	LS	Area per segment	Potential Erosion	SDR	Potential Sediment
		%		ha	ton/year		
1	Flat	0 - 8	0.40	10.46	1779.46	0.20	360.77
2	Gentle Slope	8 - 15	1.40	0.85	506.14	0.43	217.89
3	Moderately Steep	15 - 25	3.10	0.90	1183.68	0.42	501.29
4	Steep	25 - 45	6.80	1.68	4866.32	0.35	1706.90
5	Extremely Steep	> 45	9.50	7.61	30761.47	0.22	6860.18
Total Potential Sediment						ton/yr	9647.03
Total Potential Sediment						m^3/yr	2756.29

Tables 6 to 14 show the potential volume of sediment that will enter each sump per year. The total potential sediment in Sump A is 550.39 m^3/year, Sump B is 1195.31 m^3/year, Sump C is 1588.43 m^3/year, Sump D is 1908.27 m^3/year, Sump E is 2423.33 m^3/year, Sump F is 1899.53 m^3/year, Sump G is 1941.76 m^3/year, Sump H is 2169.15 m^3/year, and Sump I is 2756.29 m^3/year. From these results, it can also be seen that the slope factor (LS) has a greater influence than the catchment area (A) in calculating sediment potential, as evidenced by the greater total sediment potential in Sump D compared to Sump F. The total potential sediment obtained will be used as a reference in designing a Sediment Storage Basin (SSB).

Analysis of Capacity and Dimension of Planned Sump

The dimension of the sump was planned according to the existing contour by calculating the sump capacity to accommodate sedimentation for more than 1 year using the trial and error method. The dimensions and capacities of each planned sump based on the planned topographic data are shown in Figure 4 and Table 15.

The data presented in Table 15 indicates that, based on the analysis of erosion and sedimentation potential in each catchment area, each sump still has the capacity to accommodate sedimentation for over a year. To enhance the effectiveness of each sump, excavation was carried out initially at the bottom of the sump location, and subsequently upstream of the sump, allowing the sump at the bottom to remain functional. For standalone sumps, excavation can be conducted simultaneously. Therefore, Sump A, Sump B, Sump C, Sump D, Sump E, Sump H, and Sump I can be simultaneously excavated, whereas Sump F and Sump G can be excavated after the mining activities in Sump E are completed.

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Table 15. The erosion and sedimentation potential for all sumps

Sedimentation Basin (Sediment Storage Tank)	Total Sedimentation Potential	Sump Capacity	Sump Service
	m^3	m^3	Year
A	550.39	10812.15	19.64
B	1195.31	34239.66	28.65
C	1588.43	7132.69	4.49
D	1908.27	4707.02	2.47
E	2423.33	5351.73	2.21
F	1899.53	22192.49	11.68
G	1941.76	2175.62	1.12
H	2169.15	5321.48	2.45
I	2756.29	35038.38	12.71

Conclusion

According to the analysis conducted, the potential sediment in each sump is as follows: Sump A is 550.39 m3/year, Sump B is 1195.31 m3/year, Sump C is 1588.43 m3/year, Sump D is 1908.27 m3/year, Sump E is 2423.33 m3/year, Sump F is 1899.53 m3/year, Sump G is 1941.76 m3/year, Sump H is 2169.15 m3/year, and Sump I is 2756.29 m3/year. It was observed that the slope factor (LS) had a greater impact on calculating sediment potential than the catchment area (A), as demonstrated by the higher total sediment potential in Sump D compared to Sump F. The service life and capacity of each sump depend on the sediment potential analysis results in their respective catchment areas, with a service life of over 1 year for each sump. The recommended mining sequence for sump locations is to start from the bottom and move upstream to ensure that the bottom sump remains usable. For standalone sumps, mining can be carried out simultaneously. Therefore, Sump A, Sump B, Sump C, Sump D, Sump E, Sump H, and Sump I can be excavated concurrently, while Sump F and Sump G can be excavated after mining in Sump E is complete.

References

[1] J. S. Ahn and C.-M. Chon, “Geochemical Distributions of Heavy Metals and Cr Behavior in Natural and Cultivated Soils of Volcanic Jeju Island, Korea,” Geosystem Eng., vol. 13, no. 1, pp. 9–20, Mar. 2010, doi: 10.1080/12269328.2010.10541304.

[2] Y. Choi, H. Yi, and H.-D. Park, “A New Algorithm for Grid-Based Hydrologic Analysis by Incorporating Stormwater Infrastructure,” Comput. Geosci., vol. 37, no. 8, pp. 1035–1044, Aug. 2011, doi: 10.1016/j.cageo.2010.07.008.

[3] H. T. Hanh, J.-Y. Kim, S. Bang, and K.-W. Kim, “Sources and Fate of As in the Environment,” Geosystem Eng., vol. 13, no. 1, pp. 35–42, Mar. 2010, doi: 10.1080/12269328.2010.10541307.

[4] J. Suh, Y. Choi, T.-D. Roh, H.-J. Lee, and H.-D. Park, “National-Scale Assessment of Landslide Susceptibility to Rank the Vulnerability to Failure of Rock-Cut Slopes Along Expressways in Korea,” Environ. Earth Sci., vol. 63, no. 3, pp. 619–632, Jun. 2011, doi: 10.1007/s12665-010-0729-6.

[5] C. Sunwoo, W.-K. Song, and D.-W. Ryu, “A Case Study of Subsidence over an Abandoned Underground Limestone Mine,” Geosystem Eng., vol. 13, no. 4, pp. 147–152, Dec. 2010, doi: 10.1080/12269328.2010.10541322.

[6] C. Teparut and S. Sthiannopkao, “Mae Moh Lignite Mine and Environmental Management,” Geosystem Eng., vol. 14, no. 2, pp. 85–94, Jun. 2011, doi: 10.1080/12269328.2011.10541335.

[7] I. M. Muhtasar, M. Sholichin, and R. Asmaranto, “Studi Erosi Dan Sedimentasi Tambang Batubara Pada Pit Pinang South Pt. Kaltim Prima Coal Menggunakan Geographic Information System (ArcGIS),” J. Teknol. dan Rekayasa Sumber Daya Air, vol. 2, no. 1, pp. 218–230, 2022.

[8] Subowo, “Penambangan Sistem Terbuka Ramah Lingkungan Dan Upaya Reklamasi Pasca Tambang Untuk Memperbaiki Kualitas Sumberdaya Lahan dan Hayati Tanah,” J. Sumberd. Lahan, vol. 5, no. 2, pp. 83–94, 2011.

[9] D. H. Wafi and W. D. Ratminah, “Rencana Reklamasi Lahan Bekas Penambangan CV Jati Kencana, di Desa Karangjati, Kecamatan Bergas, Kabupaten Semarang,” in Seminar Nasional Sains dan Teknologi Terapan, 2019, pp. 507–512.

[10] C. N. Ezugwu, “Sediment Deposition in Nigeria Reservoirs: Impacts and Control Measures,” Innov. Syst. Des. Eng., vol. 4, no. 15, pp. 54–62, 2013.

[11] S. Sarminah, D. Kristianto, and M. Syafrudin, “Analisis Tingkat Bahaya Erosi Pada Kawasan Reklamasi Tambang Batubara PT Jembayan Muarabara Kalimantan Timur,” ULIN J. Hutan Trop., vol. 1, no. 2, pp. 154–162, Feb. 2018, doi: 10.32522/ujht.v1i2.793.

[12] A. Ward, A. Smith, and J. Caldwell, “Surface erosion and Sediment Control at Opencast Mines in Southern Africa,” in Challenges in African Hydrology and Water Resources (Proceedings of the Harare Symposium), 1984, pp. 517–527.

[13] V. Ferro and M. Minacapilli, “Sediment Delivery Processes at Basin Scale,” Hydrol. Sci. J., vol. 40, no. 6, pp. 703–717, Dec. 1995, doi: 10.1080/02626669509491460.

[14] V. Ferro, “Further Remarks On A Distributed Approach to Sediment Delivery,” Hydrol. Sci. J., vol. 42, no. 5, pp. 633–647, Oct. 1997, doi: 10.1080/02626669709492063.

[15] U. C. Kothyari and S. K. Jain, “Sediment Yield Estimation Using GIS,” Hydrol. Sci. J., vol. 42, no. 6, pp. 833–843, Dec. 1997, doi: 10.1080/02626669709492082.

[16] V. Ferro, P. Porto, and G. Tusa, “Testing a Distributed Approach for Modelling Sediment Delivery,” Hydrol. Sci. J., vol. 43, no. 3, pp. 425–442, Jun. 1998, doi: 10.1080/02626669809492136.

[17] B. Tribiyono, S. B. Yuwono, and I. S. Banuwa, “Estimasi Erosi dan Potensi Sedimen DAM Batutegi di DAS Sekampung Hulu Dengan Metode SDR (Sediment Delivery Ratio),” J. Hutan Trop., vol. 6, no. 2, p. 161, Sep. 2018, doi: 10.20527/jht.v6i2.5404.

[18] C. Asdak, Hidrologi dan Pengelolaan Daerah Aliran Sungai. Yogyakarta: Gajah Mada University, 2010.

[19] Aflizar, R. Afrizal, and T. Masunaga, “Assessment Erosion 3D Hazard with USLE and Surfer Tool: A Case Study of Sumani Watershed in West Sumatra Indonesia,” J. Trop. Soils, vol. 18, no. 1, pp. 81–92, Mar. 2013, doi: 10.5400/jts.2013.v18i1.81-92.

[20] T. Sudarmadji and W. Hartati, “Observasi Potensi Erosi Tanah pada Lahan Revegetasi Pasca Tambang Batubara PT Multi Tambangjaya Utama (MTU) di Barito Selatan, Kalimantan Tengah,” in Prosiding Seminar Nasional Masyarakat Peneliti Kayu Indonesia (MAPEKI) XVI, 2013, pp. 290–306.

[21] F. Isma, M. Purwandito, and Z. Ardhyan, “Estimasi Erosi dan Sedimentasi Lahan Pada DAS Langsa Berbasis Sistem Informasi Geografis (SIG),” Teras J., vol. 9, no. 1, pp. 29–41, Apr. 2019, doi: 10.29103/tj.v9i1.169.

[22] L. Sari, J. K. Nasjono, and A. H. Rizal, “Perkiraan Sedimentasi

Menggunakan Metode USLE di Bendungan Rotiklot," J. Tek. Sipil, vol. 9, no. 1, pp. 127–140, 2020.

[23] R. I. Siregar and I. Indrawan, "Studi Komparasi Pemodelan 1-D (Satu Dimensi) dan 2-D (Dua Dimensi) Dalam Memodelkan Banjir DAS Citarum Hulu," Educ. Build., vol. 3, no. 2, pp. 31–37, Dec. 2017, doi: 10.24114/eb.v3i2.8255.

[24] S.-M. Kim, Y. Choi, J. Suh, S. Oh, H.-D. Park, and S.-H. Yoon, "Estimation of Soil Erosion and Sediment Yield from Mine Tailing Dumps Using GIS: A Case Study At The Samgwang Mine, Korea," Geosystem Eng., vol. 15, no. 1, pp. 2–9, Mar. 2012, doi: 10.1080/12269328.2012.674426.

[25] I. W. Sutapa, "Analisis Potensi Erosi Pada Daerah Aliran Sungai (DAS) di Sulawesi Selatan," J. SMARTek, vol. 8, no. 3, pp. 169–181, 2010.

[26] D. Marganingrum and R. Noviardi, "Pencemaran Air dan Tanah di Kawasan Pertambangan Batubara di PT. Berau Coal, Kalimantan Timur," J. Ris. Geol. dan Pertamb., vol. 19, no. 2, pp. 11–20, Jun. 2009, doi: 10.14203/risetgeotam2010.v20.30.

[27] I. G. Tunas, "Pengaruh Prosedur Perkiraan Laju Erosi Terhadap Konsistensi Nisbah Pengangkutan Sedimen," J. SMARTek, vol. 6, no. 3, pp. 135–143, 2008.

[28] B. Ristanto, E. R. Indrayatir, and K. Nisa, "Analisa Tingkat Bahaya Erosi di DAS Asam - Asam Kabupaten Tanah Laut Dengan Sistem Informasi Geografis," J. Sylva Sci., vol. 2, no. 4, pp. 655–666, 2019, doi: DOI: https://doi.org/10.20527/jss.v2i4.1846.

[29] F. S. Tuhepaly, U. Andawayanti, and R. Asmaranto, "Analisa Laju Erosi dan Arahan Konservasi Lahan Berbasis ArcGIS pada DAS Parangjoho Kabupaten Wonogiri Jawa Tengah," J. Tek. Sumber Daya Air, vol. 2, no. 1, pp. 315–327, 2022.