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Contribution of Rainfall To The Risk Of Landslides At Cisumdawu Toll Road Phase 3 STA 0+975 Case Study

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ABSTRACT

Java Island is an area with hydrological disasters, especially landslides, which are classified as frequent. The landslide occurred because Java, especially West Java, has an extensive watery area of the entire region and has a high rainfall intensity. Geographical conditions that are dominated by basins in the form of ravines and cliffs make this area prone to hydrological disasters in the form of landslides. One of the areas prone to the hydrological disaster is the Cileunyi Sumedang - Dawuan (Cisumdawu) Toll Road Section. The purpose of this study is to examine the danger of landslides on the main road in Cileunyi section 1 phase 3 at STA 0 + 975 in order to determine the right solution in securing roads from hydrological disasters. The stages of the study began with the collection of primary data through soil investigations and documentation of existing conditions. Secondary data such as rainfall data, topographic maps, contour maps, maps of satellite images, and maps of rainfall posts were collected from related institutions. Data processing in the form of geotechnical analysis to determine slope stability, hydrological calculations to determine the planned rain flow, and groundwater level calculations using the tank model method. Slope stability analysis calculated using plaxis software shows that the slope has a displacement, and the safety rate is less than the requirement. So that a strengthening/protection is needed to maintain the stability of the groundwater level while reducing the risk of landslides in the project area.

***Keywords**: Cisumdawu, Landslide, Rainfall, Tank Model.*

1. INTRODUCTION

Indonesia, in general, is a landslide-prone area, one of the most vulnerable areas is in West Java, precisely in the Cisumdawu toll area. The reason is due to the development of a very dense population, as well as high rainfall [1]. In addition, the location of the toll road is in a basin surrounded by three volcanic mountains, namely Mount Tampomas, Manglayang, and Patuha, so that it has geographical conditions in the form of ravines and cliffs. Coupled with unstable soil conditions and large vehicle loads [2].

The storage tank model is the amount of runoff and infiltration, which are considered a function of the amount of water stored in the soil or underground reservoir. The storage tank model concept consists of several simple storage tanks arranged vertically. In this study, the structure of the storage tank model consists of 4 storage tanks arranged vertically. Rainfall on the ground will fill the uppermost tank. The storage tank has holes in the wall and bottom of the storage tank. The flow through the side hole of the water tank will produce runoff, and the flow through the water passing through the bottom of the tank is Infiltrated and becomes groundwater flow [3]. This research aims to determine the effect of rainfall on the elevation of critical groundwater levels to predict the risk of landslides using the tank model application. Therefore protection is needed to anticipate climate change, which causes extreme weather unexpectedly.

2. RESEARCH METHODS

2.1. Study Area

The Cisumdawu toll road is a 60-kilometer toll road that is part of the Trans Java toll road in West Java. Its function is to connect the Cileunyi, Sumedang, Dawuan or Padalenyi toll roads with the Palimanan-Kanci toll road. The total land area is 825 hectares . The construction of the toll road will be divided into 6 stages, namely Cileunyi-Tanjungsari stage 12.0 km, Tanjungsari-Sumedang stage 17.51 km, Sumedang-Cimalaka stage 3.73 km, Cimalaka-Legok stage 6.96 km, and Lego (Legok) stage Ujungjaya 16.35 km. The Ujungjaya-Kertajati stage is 4.0 kilometers along. In addition, the Cisumdawu toll road plan has seven interchanges or interchanges located at Cileunyi, Rancakalong, Sumedang, Cimalaka, Legok, Ujung Jaya and Dawuan. The research will be carried out on the main road of STA 0 + 975 in Phase 3 of Cileunyi as shown in Figure 1.

Figure 1. Final project research location
Source: Google Earth

2.2. Methodology

The research methodology is presented in the flowchart shown in Figure 2.

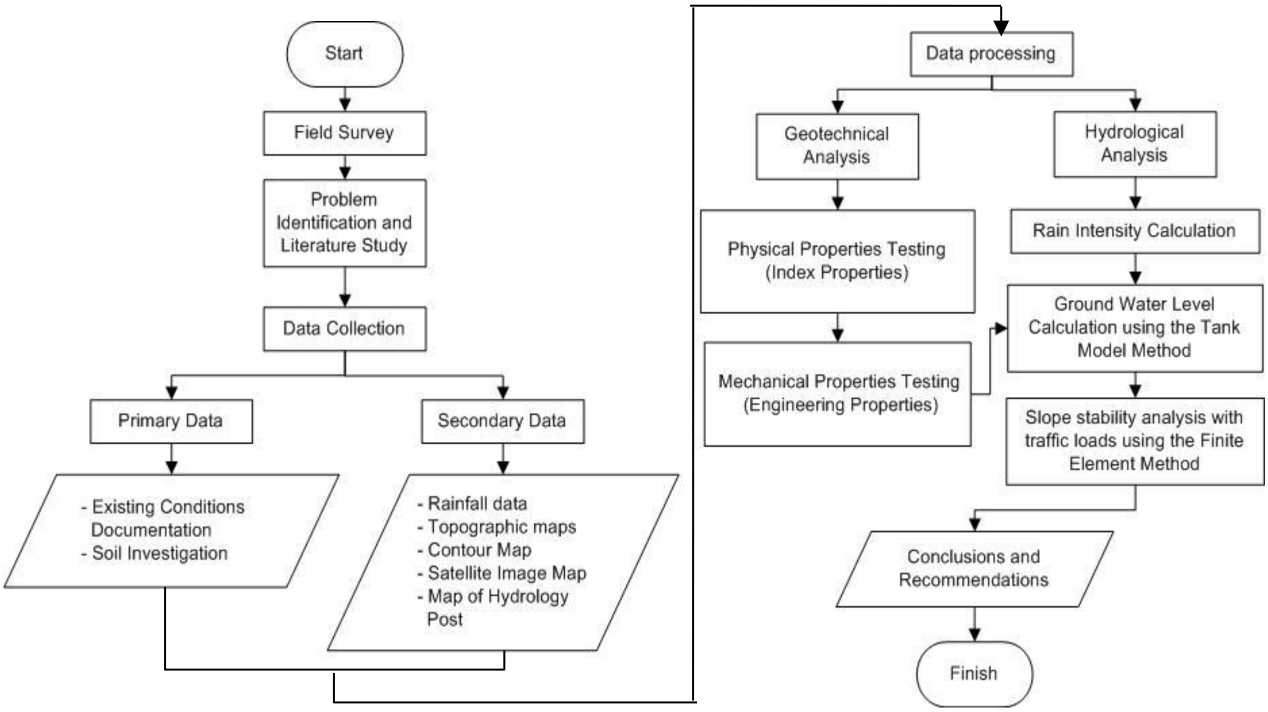


Figure 2. Research implementation flow chart

2.2.1. Geotechnical Analysis

Geotechnical analysis begins with testing the physical properties of the soil, which aims to determine the properties associated with the existing soil mass composition elements. The physical properties of the soil are closely related to the suitability of the many expected uses of the soil. Support strength and robustness, water storage capacity, plasticity are all closely related to the physical condition of the soil. Followed by testing the mechanical properties of the soil to determine the properties / behavior of the soil mass structure, namely experiencing a force or pressure that is technically described. Where the test is carried out, namely testing the Plasticity Index, Triaxial Law, Water Content, Density Volume Weight, Permeability and CBR.Furthermore, soil data is used as a reference parameter for hydrological analysis (tank model) and slope stability analysis (using 2D plaxis software). the output is used to estimate the potential for landslides on the slopes due to traffic loads and pavement loads.

2.2.2. Hydrological Analysis

The hydrological analysis begins with the calculation of rain intensity. Furthermore, the estimation of the critical groundwater level uses the Tank Model Application. The tank model in the field of hydrology is included in the conceptual model to divert rain into the flow. Conceptual models for diverting rain into discharge can provide information on low flow conditions of water availability. These models require calibration and are usually carried out to determine the parameters contained in the calculation. The basis for the conceptual model is to imitate the watershed behavior in the process of diversifying rain into streams with the concept of a number of tanks. The tank has holes in the tank wall and tank bottom. The flow through the side holes of the tank produces runoff, while the flow that passes through the bottom of the tank is infiltration and percolation and becomes groundwater flow [4]. The structure of a tank model is shown in Figure 3 below.

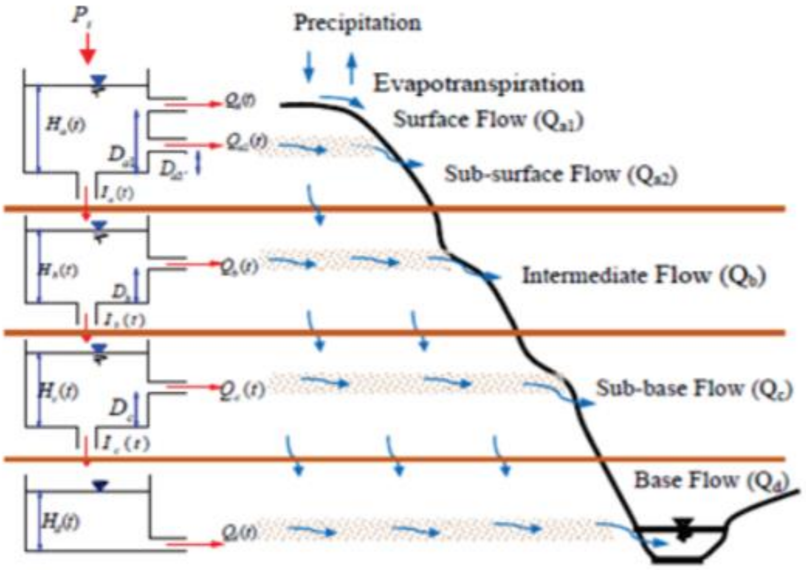


Figure 3. Schematic of the Tank Model[5]

The total outflow from the outlet (Q) of each sidewall of each water tank is regarded as the cumulative water flow of the system in the basin, and its equation is as follows[6]

$$P(t)=C.I.A \quad (1)$$

The water balance equation in the tank model: $\frac{d}{dt}H(t)=P(t)-Q(t)$ (2)

Where P is rainfall (mm/day), E is evapotranspiration (mm/day), total runoff (mm/day), H is water storage height (mm), t is time (day). At the initial time (t = 1), the initial conditions of storage water height in tank A (Ha (1)), tank B (Hb (1)), tank C (Hc (1)) and tank D (Hd (1)) are determined. For the next step (t + 1) the storage in each tank is updated as follows:

$$Ha\ (t+1) = Ha\ (t) + P\ (t) - Qa1\ (t) - Qa2\ (t) - Ia\ (t) \quad (3)$$

$$Hb\ (t+1) = Hb\ (t) + Ia\ (t) - Qb\ (t) \quad (4)$$

The criteria for determining the initial value on the outlet of the tank model have not been clear until now. This article introduces some research and reference materials. The initial value in the tank model can be approximated by the water level graph on the logarithmic scale paper. Next, search for the hydrological discharge peak, and then use the following formula to measure the discharge rate after the peak discharge [7]:

$$Q(t) = Q0.\ e - r.t \quad (5)$$

Where:

r = the constant rate of discharge,

e = exponential number = 2.718281828,

Q0 = initial peak discharge (m3/sec),

Q(t) = decrease of discharge (m3 /sec).

The value of the multiplier parameter (Ci, j) in each outlet is as follows [7]:

$$CIa = CQa1 = CQa2 = (1-r)/3 \quad (6)$$

$$CIb = CQb = CIa/5 \quad (7)$$

The determination of Da1 is obtained from the beginning of high rainfall, which leads to very rapid changes Da2 is determined based on the onset of high rainfall, and the duration of rainfall after drought has no effect on river flow. It can be assumed that the parameters Db and Dc are equal to Da2. These parameters will affect the runoff time of the second and third tanks under dry conditions. From Sugawara's point of view, it can be seen that the values of the following tank parameters are worthless for a certain proportion of the above tank parameters. The runoff coefficient C represents the comprehensive impact of loss on the watershed and therefore depends on natural surface conditions, surface slope, and rainfall intensity. The influence of rainfall intensity is not in the existing C value table. The coefficient C is defined as the ratio between the peak surface current and the rainfall intensity. Table 1 lists some typical C values [8].

Table 1. Coefficients C

Types of Areas	Value of C
A. Urban Area	
Lawns	
- Sandy Soil, flat 2%	0.05-0,10
- Sandy Soil, steep 7%	0,15-0,20
- Heavy Soil, average 2-7%	0,18-0,22
Residential Areas	
- Single family areas	0,30-0,50
- Multi units, attached	0,60-0,75
Industrial	
- Light	0,50-0,80
- Heavy	0,60-0,90
- Streets	0,70-0,95
B. Agriculture Area	
Flat	
- Tigh Clay, Cultivated	0,50
- Tigh Clay, Woodland	0,40
- Sandy Loam, Cultivated	0,20
- Sandy Loam, Woodland	0,10
Hilly	
- Tigh Clay, Cultivated	0,70
- Tigh Clay, Woodland	0,60
- Sandy Loam, Cultivated	0,40
- Sandy Loam, Woodland	0,30

The infiltration coefficient (CIa) is calculated by the equation:

$$CIa = 1 - C \quad (8)$$

CIa = Infiltration coefficient value at sub-watershed ith

Ai = area of sub-watershed ith

2.2.3. Finite Element Methode

The slope stability analysis calculation aims to determine the total displacement and safety rate of the slope. The method used is the finite element method that Clough and Woodward first introduced in the field of geotechnical sciences in 1967. Plaxis (Finite Element Code for Soil and Rock Analysis) is a summary of the finite element program that has been developed to analyze rock and soil deformation and stability in civil planning. Simple graphics of the data input process (soil properties) can create complex finite element models and provide detailed display output of calculation results. The calculation of the program is completely automatic, and the program is written based on appropriate numbers [9]. The minimum safety factor used is FK> 1.25 provided that:

FK> 1.25: Slopes are in a safe condition.
FK <1.07: Slope in an unsafe condition.
FK 1.07> 1.25: Slope is in critical condition.

3. RESULTS AND DISCUSSION

3.1. Geotechnical Analysis

Geotechnical analysis in the form of an index and mechanical properties testing is carried out to obtain parameters used for hydrological analysis and slope stability analysis using the finite element method, presented in Table 2 below [10].

Table 2. Input data parameters of soil test results

Type of soil	**Depth**	**Soil Model**	**Saturated Content Weight (γsat)**	**Dry Content Weight (γ dry)**	**Angle of Repose**	**Effective Cohesion (C')**	**modulus of elasticity**	**Poisson Ratio (v)**	**Permeability**
	m		**KN/m^2**	**KN/m^2**	ϕ	**KN/m^2**	**KN/m^2**		**m/day**
Silty Clay	0-3	Mohr Coloumb	17	9,6	12,8	27,5	5000	0,4	0,0000864
Clayey Silt 1	3-4	Mohr Coloumb	17,5	11,5	13	20	5000	0,4	0,000864
Clayey Silt 2	4-7,5	Mohr Coloumb	17,5	12,5	30	40	20000	0,3	0,000864
Boulder	7,5-14	Mohr Coloumb	22	17,5	40	1	75000	0,15	0,864
Gravel	14-18	Mohr Coloumb	20,5	17	40	1	85000	0,2	0,0864
Sand 1	18-20	Mohr Coloumb	19	16	35	1	70000	0,2	0,00864
Sand 2	20-22	Mohr Coloumb	19	16	35	1	70000	0,2	0,00864
Sand Trace Gravel	22-30	Mohr Coloumb	19	16	35	1	70000	0,2	0,00864

Source: Cisumdawu Project Data

3.2. Hydrological Analysis

The hydrological analysis was carried out to determine the value of rain intensity and groundwater level calculations using the tank model application. After taking soil samples, it is known that the groundwater level is -7 m. The analysis of the tank model is carried out as high as 7 m or as much as 2 layers of soil. The recapitulation of calculations is presented in Table 3

Table 3. Tank model parameters

Parameter	**Value**	**Unit**
Rainfall Station	Tanjungsari and Jatiroke	-
Rainfall R24	102	-
A (Catchment Area)	0,001339	Km^2
I (Rain Intensity)	264,753	mm/hour
E (Evapotranspiration)	3,421	mm/day
P (Precipitation)	0,213	m^3/s
Qa1(t)	0,073	m^3/s
Qa2(t)	0,095	m^3/s
Qb(t)	0,045	m^3/s

3.3. Slope Stability Analysis

Furthermore, the slope stability analysis was carried out by using the finite element method, namely using the Plaxis 2D software. Plaxis input parameters use data from soil test results previously described in the geotechnical analysis. Software modeling is carried out by adding traffic loads and pavement loads to obtain the value of the safety factor (SF), the total displacement on the slope, and the potential slope against landslides [11]. Starting with the slope geometric design shown in Figure 4 below.

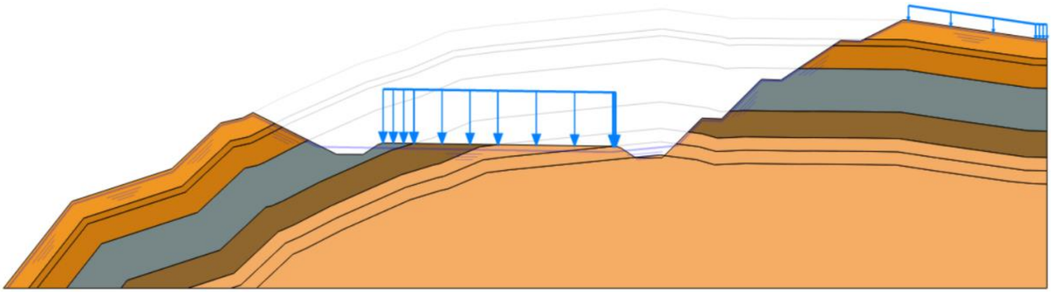


Figure 4. Slope conditions with additional traffic and pavement load

The second stage is the calculation of the safety factor to see the potential for landslides in the area presented in Figure V below.

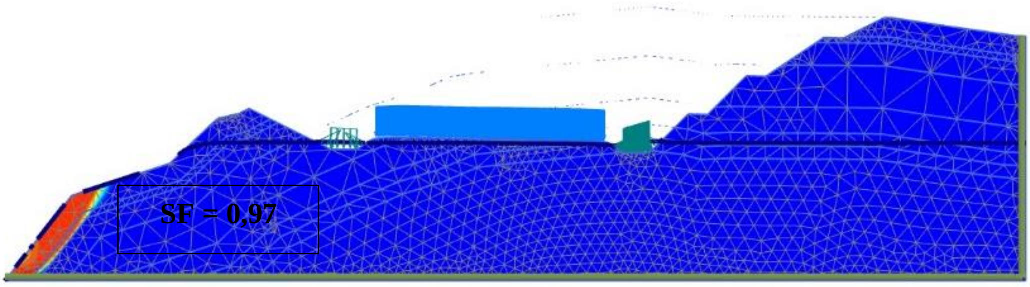
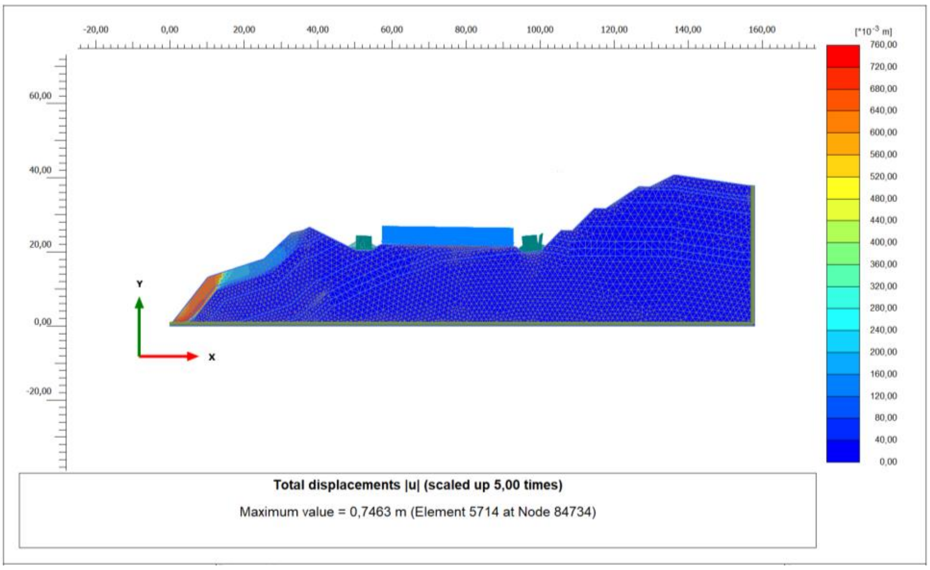


Figure 5. Potential field of slope collapse after being given additional traffic and pavement load

The last stage is the simulation of the displacement on the slopes presented in Figure VI below.



Total displacements |u| (scaled up 5,00 times)

Maximum value = 0,7463 m (Element 5714 at Node 84734)

Figure 6. The displacement of Slopes after being given additional traffic and pavement load

Based on the analysis using plaxis software, the landslide field against the slopes in the Cisumdawu STA 0 + 975 Project after being given traffic loads and pavement loads, the safety factor (SF) value is 0.97, and the displacement is 0,7463 m [12].

4. CONCLUSION

After taking soil samples and conducting soil testing in the lab, it can be concluded that the calculation results of the tank model analysis is P = 0.213 m^3/s, Qa1 = 0.073 m^3/s, Qa2 = 0,095 m^3/s, and Qb = 0.045 m^3/s are obtained. = 0.360 m3 / s. And to analyze the stability of the slope using the Plaxis 2D software, the value of SF = 0.97 and the displacement that occurs on slopes after being given traffic and pavement load is 0,7463 m, which means the slope was in an unsafe condition or had the potential to landslides. So that, to overcome the potential for landslides, reinforcement on the slopes can be carried out.

REFERENCES

[1] Iin Karnisah, Yackob Astor, Bambang Setio Budianto, Fitra Ramdhan Arrizal, Reynaldy Putra (2019), *Analysis Of Drainage Capacity To Resolve Inundation Problem On Jend. H. Amir Machmud Street Cimahi City West Java Province,* International Journal of GEOMATE, Vol.16, Issue 57, pp.195 – 200.

[2] Subhan. (2019). *Identifikasi dan Analisis Karakteristik Longsor di Kabupaten Garut*. Jurnal Teknik Sipil Universitas Syiah Kuala. Volume 8, Nomor. 2

[3] Sugawara, M., Watanabe, E. Ozaki, E., and Katsuyama, Y. (1984). *Tank model with snow component.* The National Research Center for Disaster Prevention, Science and Technology Agency, Japan.

[4] C. D. Soemarto. (1999). *Hidrologi Teknik*, Penerbit Erlangga, Jakarta.

[5] Aqili, S. W. (2016). "*Application of Modified Tank Model to Simulate Groundwater Level Fluctuations in Kabul Basin, Afghanistan".* Journal of Water and Environment Technology, Vol.14, No.2: 57–66.

[6] Nana MA. (2011). *Application of Tank Model for Predicting Water Balance and Flow Discharge Components of Cisadane Upper Catchment*. JMHT Vol. XVII, (2): 63–70.

[7] Suryoputro, N, Suhardjono, Seotopo W. (2017). *Calibration of infiltration parameters on hydrological tank model using runoff coefficient of rational method.* AIP Conf. Proc. 1887, 020056-1–020056-9; doi: 10.1063/1.5003539 Published by AIP Publishing. 978-0-7354-1570-6.

[8] M. Sugawara and M. Fuyuki, "A Method of Revision of River Discharge by Means of a Rainfall Model," A collection of Research Papers about Forecasting Hydrologic Variables, pp. 14-18, 1956.

[9] Plaxis Connect Edition V20. (2019).

[10] Cileunyi - Sumedang - Dawuan Toll Road Project Data.

[11] SNI 8460-2017 Persyaratan Perancangan Geoteknik.

[12] Hans-Georg Kempfert. Berhane Gebreselassie. Excavations and Foundations in Soft Soils. 2006.