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Stability Analysis of Steep Bank River Slope with Clay Type in Amphibile Vehicle Landing

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Abstract

In river crossing operations using amphibious vehicles, the landing process is a critical point for the success of the operation. This study aims to obtain an overview of the potential failure of amphibious vehicles during landing due to the stability factor of the slope / slope caused by topographic conditions in the form of steep bank slopes and geological conditions in the form of poor soil bearing capacity. This study begins with observations on one of the rivers to obtain an overview of the presence of steep riverbanks, followed by a literature study on an amphibious vehicle, and observations of the landing process of an amphibious vehicle in training activities at the Gedebage reservoir, Bandung. This study obtains an illustration that there is an area in the watershed (DAS) with steep geometric shapes on its banks, which becomes an obstacle in the amphibious vehicle landing operation which will be found during the operation. Another illustration is when the steep banks of the river have low soil bearing capacity, there will be a potential failure of amphibious vehicles to land due to the collapse of the river bank slopes.

Keywords
amphibious vehicles; river crossings; landing on steep banks; clay soil; talud stability

I. Introduction

Indonesia is an archipelagic country located between 6° N – 11° South Latitude and 95° West – 141° East Longitude, has a total of 16,056 islands with a total area of 1,916,906.77 km² (Central Bureau of Statistics, 2020). With such a large country, it becomes a challenge for Indonesia to maintain its sovereignty, secure its territory from various threats both from within the country and from abroad which include military threats, non-military threats and hybrid threats (Tippe, 2017, pp. 105- 117). All of these threats will have consequences in the form of preparedness and ability to anticipate as well as awareness to carry out state defense from all components of the nation in accordance with the universal national defense doctrine.

The role of the Indonesian National Armed Forces, which is the main component of the national defense system, is in accordance with the mandate in Law No. 34 of 2004 concerning the TNI article 7 paragraph 1 which states that the main task of the TNI is to uphold state sovereignty, maintain the territorial integrity of the Unitary State of the Republic of Indonesia which based on Pancasila and the 1945 Constitution of the Republic of Indonesia, and protect the entire nation and the entire homeland of Indonesia from threats and disturbances to the integrity of the nation and state. Threats can come from a foreign military invasion, as well as a group of people who have armed strength and the ability to carry out combat.

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The sovereignty of the land area is the duty and responsibility of the TNI-AD. Defense in the land area will be carried out both through offensive and defensive operations. Threats originating from foreign military invasions are carried out defensively, namely carrying out defense strategies in their own territory (the unitary territory of the Republic of Indonesia). Threats originating from a group of Indonesian citizens who have armed forces with the mission of undermining the sovereignty of the Indonesian state must be faced offensively, namely by carrying out battles and pursuing their power bases. In dealing with these threats, Indonesia has implemented a national defense strategy that involves all components of society, which is often known as Sishankamrata.

Indonesia is also a country that has a topography of mountains with tropical forests and rivers that flow due to the existence of these mountains and forests. In the defense system, the presence of mountains and rivers on one side becomes a defense facility, but it will also become an obstacle, and make it difficult to move operations.

In combat operations, both offensive and defensive, the Indonesian Army always deploys troops consisting of combat units and combat aid units. In accordance with their duties, combat units carry out battle tasks in accordance with the tactics and strategies that have been prepared. Meanwhile, combat assistance units provide assistance to carry out operations carried out by combat units. The field in battle operations is always used as a natural defense fortress by enemy forces in defense, while for troops carrying out attacks it will be a separate obstacle. As an illustration in attack operations or ambush operations against armed groups involving elements of maneuvering troops, natural obstacles such as a river flow will be encountered and become obstacles to movement.

One of the units in the function as a combat assistance unit is the Army Engineer unit which has the main task of functioning to cross maneuver troops and their fighting equipment such as tanks, tactical vehicles, logistics vehicles, ambulances and others by using a defense equipment that has the ability as a vehicle. amphibian designed for the basic mission of river crossing. Amphibious vehicle is a multi-purpose vehicle concept, where its use can be for commercialization purposes, as well as military operations and can also be used for rescue missions when a disaster occurs (Abdurahman, Harsono, Prihanto, & Gultom, 2020).

The function of the crossing is basically not only in conditions and missions of military operations of war (OMP) but can also be carried out in military operations missions other than war (OMSP) for example in natural disaster mitigation, namely when a flood disaster occurs which causes road cuts in an area. In these circumstances amphibious vehicles can be relied on to carry out the mitigation mission. In general, the use of amphibious vehicles has been able to overcome obstacles in the form of a river to support operations in river crossings as well as disaster mitigation with the requirement that there is an ideal foundation on the banks of the river, which has a slope that is in accordance with the capabilities of the amphibious vehicle. This foundation can be in the form of natural formations or also shaped in such a way that it becomes a land contour with a sufficient slope. Another requirement that must be met by a landing strip is a fairly hard and stable ground surface as a safe footing for landing. A river or water with a gently contoured bank (such as a beach) is an ideal terrain for an amphibious vehicle to land. But what if such conditions are not found, instead what is found is the surrounding area which is an area with steep or muddy edges. The alternative that can be done is to find an ideal location or force a landing. In conditions like this, accidents can be experienced by amphibious vehicles such as being trapped in river bank mud or also malfunctioning when the vehicle enters water in important compartments such as the cabin or engine room due to the steepness of the runway. Amphibious vehicles generally require a runway for landing, either landing on water (ground to water) or landing on the beach / land (water to ground), namely a surface with a slope / sloof adapted to the hull design the amphibious vehicle, so that this vehicle does not sink during landing. Besides that, it is also necessary to have a surface that is sufficiently hard or stable, so that at the time of landing it is not trapped on the runway.

The question that will arise is what if the ideal landing pad is not found? and what will happen to the amphibious vehicle landing process?

Questions for these conditions can be categorized as das sein and das solen of an amphibious vehicle mission in terms of their ability to provide operational support in the form of crossing facilities.

The above conditions will greatly affect the mobility aspect for the success of operations (OMP and OMSP). Mobility in OMP refers to the ability of a weapon system, combat unitor armed forces to move towards target. Combat troops with higher mobility are able to move faster, and/or across terrain, than troops with lower mobility. Meanwhile, mobility in OMSP refers to the ability to move the defense equipment prepared for the mission to achieve its target in carrying out activities in accordance with the tasks assigned, for example in disaster management mitigation.

II. Research Method

This research is to obtain an overview of the potential that will occur if the amphibious vehicle landing process encounters obstacles in the form of topographic and geological factors from the environmental conditions of the operating area. This study uses the observation method, which is to prove the existence of a river with steep banks and analyze the phenomena that will occur when an amphibious vehicle lands.

2.1 Restricting the problem

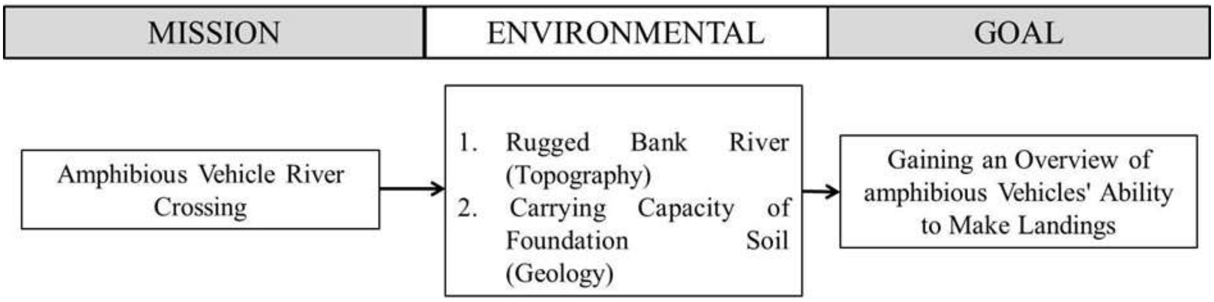
Problems in landing amphibious vehicles are very complex, several factors including water currents, topography and geology as well as the propulsion system owned by amphibious vehicles. In this study, it is limited to discussing topographical factors in the form of steep river bank slopes and geological factors in the form of clay-type soil structure conditions which have low soil bearing capacity characteristics.

2.2 Research Place

The research was carried out in 2 (two) locations, namely the Citarum river, Cianjur district to get an overview of the diversity of the riverbanks as a landing field for amphibious vehicles and at the Gedebage reservoir in Bandung along with crossing simulation exercises carried out by the 9th Combat Engineer Battalion Kostrad / Lang Lang Bhuwana using vehicles. Amphibious RIG M3 on October 20 to 24, 2021, is to get an idea of the potential that will occur when an amphibious vehicle makes a landing on a steep edge of clay type.

III. Result and Discussion

According to (Randa, Sutikno, & Sujatmoko, 2017) the characteristics of the river are the climate and physiography of the area in the river area, with the large division consisting of the topography of the watershed (DAS), rock formations, rain catchment areas and vegetation, which will experience changes including the geometric shape, type, nature and behavior of the river with all its aspects and changes in the dimensions of space and time. discussion of the ability of amphibious vehicles to make landings is faced with environmental conditions in the form of river characteristics in the form of topography and geology, carried out as shown in Figure 1.

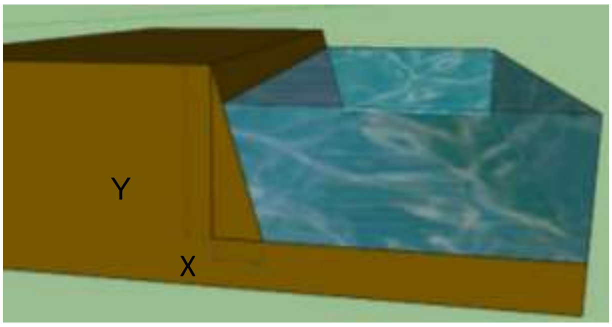


Source processed by the author, (2021)
***Figure 1**. Discussion Flow*

3.1 Topographical Characteristics of the River

According to Rosgen (1996) in (Starr, 2009) the pattern of various river characteristics in one watershed is described as having sloping banks and steep river banks. According to Van Zuidam, (1989) in (Kalay & Lopulissa, 2018) the classification of slopes is based on the criteria for flat slopes of 0-3%, gentle slopes of 3-8%, sloping slopes of 8-14%, very sloping slopes of 14-21%, steep slopes 21-56%, very steep slopes 56-140% and steep slopes >140%.

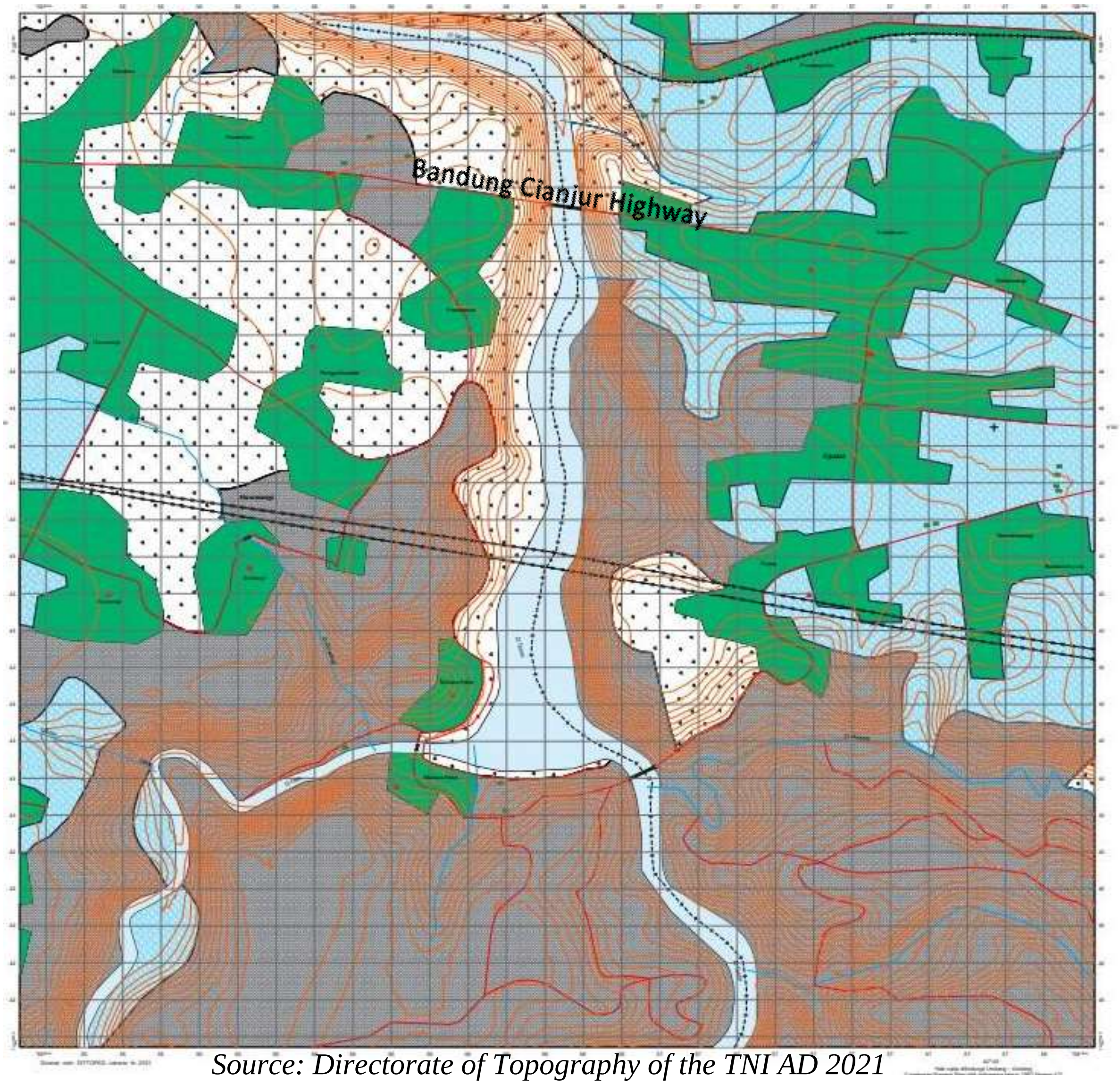
Characteristics of rivers that have the potential for amphibious vehicles to be unable to land are topographic conditions with very steep to very steep edges/slopes. The illustration of the edge is as shown in Figure 2 as follows.



Source: Processed by the author (2021)
***Figure 2.** Illustration of River Slope Slope Classification*

The calculation of the slope percentage is determined based on the ratio between the elevation (Y) and the horizontal distance (X) multiplied by 100%.

Based on the results of observations of the Citarum river flow located in Cianjur district, West Java, coordinates 6°50'26.48” S 107°19'24.00” T. The topography of the observation area is shown in Figure 3.



Source: Directorate of Topography of the TNI AD 2021
***Figure 3.** Topographical Map of River Flow Citarum*

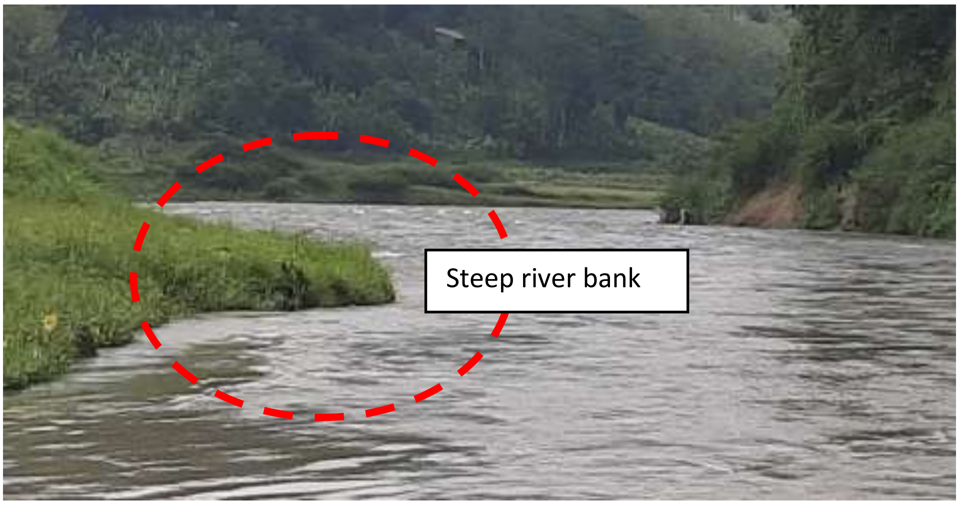
Observations along ± 1,500 meters show that there are variations in river banks along the flow including:

a. Sloping river banks such as beaches with rocky sand surface type, this type of bank is ideal for an amphibious landing, vehicles will easily in/out of the river. The shape of the sloping bank in the observation area on the Citarum river is shown in figure 4.

Source: Author's documentation dated November 9, 2021.
***Figure 4.** Sloping bank of the Citarum River*

The shape of the riverbank above does not require any equipment or assistive methods for amphibious vehicles to exit or enter the river. if the amphibious vehicle has a track *wheel*.

b. Another variation of the bank, namely the characteristics of a steep bank, as shown in Figure 5. The condition of a steep riverbank will be a limiting factor for amphibious vehicles in making landings.



Source: Author's documentation dated November 9, 2021.
Figure 5. *The steep banks of the Citarum River*

Topographic conditions in the form of steep river slopes based on the results of research conducted by Tison, (2019) do not allow amphibious vehicle landings to be used. Tison's research, (2019) discusses the phenomenon of the ability of amphibious vehicles to make landings on the obstacle variable, namely the slope of the runway which is carried out by simulating the landing of an amphibious vehicle weighing 30 tons using the *Computer Fluid Dynamic (CFD)* and the Wong method, concluding that only a maximum slope of 25º (46%) / up to steep slopes) that can be climbed by amphibious vehicles.

3.2 River Geological Characteristics

The rock and soil formations of the riverbanks are the geological conditions of the river on the carrying capacity of the landing pad for amphibious vehicles that must be taken into account.

Soil is a material consisting of aggregates / granules and solid minerals that have adhesive and cohesive properties with the physical properties of the soil in the form of solid or loose grains. According to Terzaghi, (1996) in (Nina Fahrriana, Yuliana Ismina, Ellida Novita Lydia, 2019) soil divides the materials that make up the earth's crust broadly into two categories, namely soil (soil) and rock (rock).

In the trial and practice of operationalizing the *Amphibious RIG M3* in the Gedebage reservoir, Bandung, the bank characteristics of the Gedebage reservoir represent a river with steep banks and clay types. This fact is in line with the results of research (Siska & Yakin, 2016) which classifies the Gedebage area as classified as inorganic clay with high plasticity, *fat clay and* inorganic silt or fine sand diatomase, elastic silt.

Clay soil has high plastic properties resulting in a cohesive soil that has a strong bond between the grains. The greater the cohesiveness of the soil, the greater the liquid limit, this allows the bearing capacity of the foundation to be worse when the soil water content is higher. This condition will be a problem for a vehicle when passing, especially for amphibious vehicles when making a landing.

3.3 Analysis of Riverside Slope Stability

Data needed to discuss / unravel the problem of amphibious vehicle landings on the stability aspect of riverbank slopes include data on amphibious vehicles in this case using the *Amphibious RIG M3 vehicle,* and clay soil data as shown in table 1.

Table 1. Amphibious Vehicle Data and Clay

No	Name Part	Value Quantity	Source
A	**Amphibious Vehicle RIG M3**		
1	Tire dimensions	605 x 80 x R250 mm	General Dynamic,(2019)
2	Vehicle weight	28.2 tons	General Dynamic,(2019)
B	**Clay**		
1	Weight Type (ɤ)	2.2 – 2.6 gr/cm^3	(Das, 1994 pp 165-186)

Source: Author's Collection Results (2021)

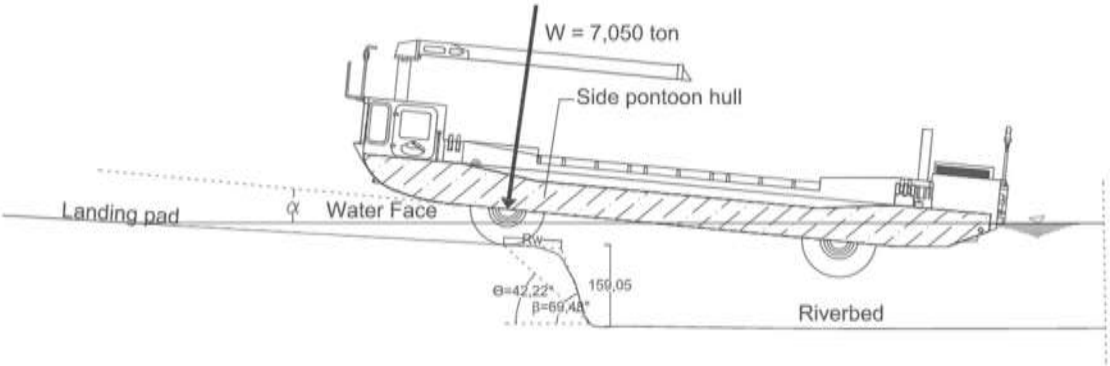
Other data are the geometric dimensions of the landing pad for amphibious vehicles carried out during the exercise at the Gedebage reservoir. The embankment is a bank with steep characteristics, and so that amphibious vehicles can make a landing, excavation is carried out until the ideal slope of the runway is obtained (ie 1.1 : 8 = 13.75%). as shown in Figure 6 as follows.

Source: observation results October 23, 2021
Figure 6. *Landing Platform.*

Factors that will cause Amphibious vehicles the potential for unsuccessful landing (*NO GO*), especially landing from the river to the mainland in the above conditions can be caused by sinkage and wheel slip, as well as the occurrence of collapse on the slope of the runway edge. In accordance with the limitation of the problem, the discussion will focus on the analysis of landing failure due to the collapse of the riverbank wall (talud stability). In the case of the practice at the Gedebage reservoir, Bandung, several *moments* where the amphibious vehicle failed to land. Figure 7 is a snippet of a monitored and documented video showing the incident of an amphibious vehicle failing to land.

Source Documentation of the author October 23, 2021
Figure 7. *No Go on Amphibious Landing*

The phenomenon in the picture above when analyzed using the approach of the theory of talud stability (Das, 1994 pp 165-186) and using the principle of *Newton*-III can be explained as shown in Figure 8 and equations 1 and 2 as follows



Source: Data processing in Figure 7 (2021)
Figure 8. *River bank Elevation Stability Analysis*

In the case of the Amphibious landing at the Gedebage Dam, Bandung, the analysis that can be put forward is related to the stability of the bank wall which results in the vehicle not being able to make a landing, as follows:

a. The condition of the clay-type landing pad that is submerged in water will be a critical point for the collapse of the riverbank wall when the wheels hit the ground. The banks of the river walls will become critical to failure, considering that the plastic properties of clay will decrease as the *liquid limit* (LL) number gets higher
b. Analysis using Newton-III law principles (F_{action} = - $F_{reaction}$) is the stress due to axle pressure (Fg) = max talud stress (), where stress is pressure (weight) per unit area. From Figure 7 the axle pressure of 1 (one) wheel against the ground is.

$$F\ g = W / (Rw.\ b_{ti}) \qquad (1)$$

Where:
b_{ti} is the width of the amphibious tire (605 mm);
R_w is D_w (outer diameter of 984 mm amphibious tires) and
W is the axle weight of 1 (one) wheel = 7.050 Kg
So that
F g = 1.184 Kg/cm^2

The magnitude of the stress that occurs in the embankment due to the geometric shape uses equation 2.

$$\sigma = \tfrac{1}{2}\, \gamma\, H \left[\frac{\sin(\beta-\theta)}{\sin\beta \sin\theta} \right] \cos\theta \sin\theta \qquad (2)$$

Where:

σ is the maximum stress;

ɤ is the density of the soil (2.2 – 2.6 gr/cm^3);

H is the height of the cliff/bank 159.05 Cm

From the above equation, it is obtained that the magnitude of = 69.16 gr/cm^2 or 0.0692 Kg/cm^2 < Fg so that the embankment/slope will collapse.

IV. Conclusion

The success of operations using amphibious vehicles cannot be separated from its ability to make landings. An ideal landing pad is needed in the form of a gentle slope area with good soil bearing capacity so that amphibious vehicles can land. The fact on the ground is that not all river banks have gentle slopes, there will be areas of steep river banks that must be used as landing pad areas. The condition of the landing pad area in the form of steep edges with poor soil bearing capacity will have the potential for amphibious vehicles to be unable to land. The analysis in this study revealed that there was a potential for failure of amphibious vehicles during landing, one of which was caused by a collapse on the slopes of the river bank.

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