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Land Movement Zone of the Rumpin and Surrounding Areas, Bogor Regency, West Java Province

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Abstract— *Disasters are events that can endanger life and disrupt people's lives. It can be caused by natural and non-natural factors, as well as those caused intentionally by humans, resulting in fatalities, property losses, natural and environmental damage, and psychological effects on disaster victims. Natural disasters themselves are a threat to the community and the Regent. The Rumpin District, Bogor Regency, as the capital of the candidate for the newly autonomous region of West Bogor Regency, has triggered population growth and the development of the area has become very fast. Deliberation of the potential and resources owned and assessed to be a strategic area because it borders the City of South Tangerang, Banten. Therefore, the activities of managing natural resources and the environment as well as regional development must pay attention to the preservation of their functions and capabilities so that development activities do not become a trigger for disasters, and the location of the development must be in an area that is safe from disasters. This study was conducted to find out how the geological conditions are related and the factors that affect the potential for landslides, and to make a map of the land movement susceptibility zone in the research area. This research uses Geographic Information System (GIS) and the parameter assessment method, where the parameters needed are geological parameters, soil type, rainfall, land use, and slope. The disaster risk zoning is expected to be a source of knowledge for the community and the city government of Bogor for disaster mitigation and increase awareness related to land movement vulnerability zones.*

Keywords— *Natural Disaster, Landslide, Rumpin Landslide Zone, Bogor Regency*.

I. INTRODUCTION

Regional planning is more emphasized in spatial planning, while activity planning is emphasized in regional development planning (Tarigan, 2004). The two types of planning must be mutually sustainable. Spatial planning and activity planning must be related to their implementation (Zai, Regional Development Analysis with Sectoral and Regional Approaches in Bogor Regency, 2017). Regional development carried out by exceeding the carrying capacity of the area will cause ecological damage so that the principle of sustainable development will not be realized (Ashraf M. Dewan, 2009). Regional development can utilize and combine internal (strengths and weaknesses) and external factors (opportunities and challenges) that exist as potentials and opportunities that can increase the regional production of goods and services of the region which are a function of the needs both internally and externally (Rudi Aries, et al., 2016).

These internal factors, such as natural resources, human resources, and technological resources, while the external factors can be in the form of opportunities and threats that arise along with their interactions with other regions. In Law Number 26 of 2007 concerning Spatial Planning, an area is a space that is a geographical unit and all elements related to it whose boundaries and systems are determined based on administrative and/or functional aspects. Whereas, Law Number 11 of 2020 concerning Job Creation also contains changes to provisions related to spatial planning. In this job creation law, it is explained that spatial planning is a system of spatial planning, space utilization, and space benefit control. In the spatial planning bulletin entitled "Digital Transformation of Spatial Planning", it is stated that spatial plans in each country are prepared with the same goal, namely to utilize limited space so that humans can carry out their activities to maintain life.

The Rumpin region is a very strategic area because, administratively, it borders the cities of South Tangerang and Banten. In terms of topography, the Rumpin area has many springs that function as reservoirs or water catchment areas and can be used for agriculture and aquaculture. In addition, the Rumpin area has tourism potential that shows beautiful scenery and stores a number of historically valuable sites. Natural resource potential in the form of the best andesite stone in Indonesia. Holcim and Waskita companies are conducting exploration in the Rumpin area. The purpose of this study is to conduct a geological potential, soil and rock geotechnical investigation, create units of land capability and carrying capacity, and make recommendations for residential development in the Rumpin area.

According to Fajarini (2015), the results of the analysis of the 2005–2025 Regional Spatial Plan with the predicted land use for 2025 show that there is a discrepancy with the spatial allocation that has the potential to become a spatial planning problem of 75.577 ha, or 25.29%, with details of the potential loss of forest functions, agricultural functions, wetlands, water body functions, and water body functions were 72.41%, 33.62%, and 24.64%, respectively. The Rumpin region is a very strategic area because, administratively, it borders the cities of South Tangerang and Banten. In terms of topography, the Rumpin area has many springs that function as reservoirs or water catchment areas and can be used for agriculture and aquaculture. In addition, the Rumpin area has tourism potential that shows beautiful scenery and stores a number of historically valuable sites. Natural resource potential in the form of the best andesite stone in Indonesia. Holcim and Waskita are some of the dozens of mineral companies exploring the Rumpin area.

II. Methodology

The method used to support environmental geological mapping is based on the analysis of environmental geological aspects such as physical condition factors, topography, geology, and other related elements, such as land use and regional spatial planning.

The research includes several stages, including the primary data collection stage by taking field data and taking rock samples, such as geological observations in the form of rock distribution, landforms, and observing land use conditions which currently include settlements, agriculture, plantations, forests or shrubs. In addition, aerial photos were recorded using drones and soil samples were taken at different locations using a hand drill. Secondary data such as Regional Geological Maps of Jakarta and Seribu Islands were also used. Regional Hydrogeological Map of Bogor at 1:250.000 scale, as well as other supporting data.

In the Land Capability Unit map overlap with field data verification, the superimpose/overlay process is carried out using GIS-based mapping software by determining and calculating unit values and map assessment, then the Land Capability Unit map is overlaid. The results of this research are in the form of a City Land Suitability Map which will be used as regional development recommendations for planning experts.

III. Result and Discussion

Geology of Research Area

The study area's lithology was divided into four (4) rock units, which included inseparable volcanic rock (Qva), volcanic breccia (Qvb), volcanic lava (Qvt), and the Bojongmanik Formation (Tmb). The study area is dominated by volcanic rocks, intrusive rocks, and consists of the rocks from the Bogor zone along with rocks from the southern mountain zone in the form of tertiary sediments. Based on the regional geological map of Jakarta and Kepulauan Seribu, the research area has 6 (six) lithological group units (Figure 4.1). The Rumpin area consists of volcanic rocks, intrusive rocks, and rocks from the Bogor zone as well as rocks from the southern mountain zone, which are tertiary sedimentary rocks, in the form of (a) Alluvium and alluvial fans: This unit covers 20% of the eastern part of the study area, with an area of 728,1 Ha. Predominantly on a slope of 0-15%. This unit is formed by surface deposits originating from erosion/transport debris deposited on a land/river environment. This unit is very easy to dig. (b) Sandstone (Tmb), Conglomerate (Tpss), and Breccia (Qvu): This unit covers 60% of the study area from north to south, covering an area of approximately 2074.7 Ha. Almost all of these units are on a slope of 0-15%. The lithological composition is formed by alternating sandstone and claystone, tuffaceous sandstone, and conglomerate. This unit is rather compact and easy to excavate in weathered soil. (c) Andesite (Qvas): This unit covers 20% of the area from the center to the southwest of the study area with an area of approximately 1037.6 Ha. Almost all of these units are on a slope of >25%. The lithological composition is formed by igneous rocks including andesite and breccia, which are rather compact/hard. (Figure 1).

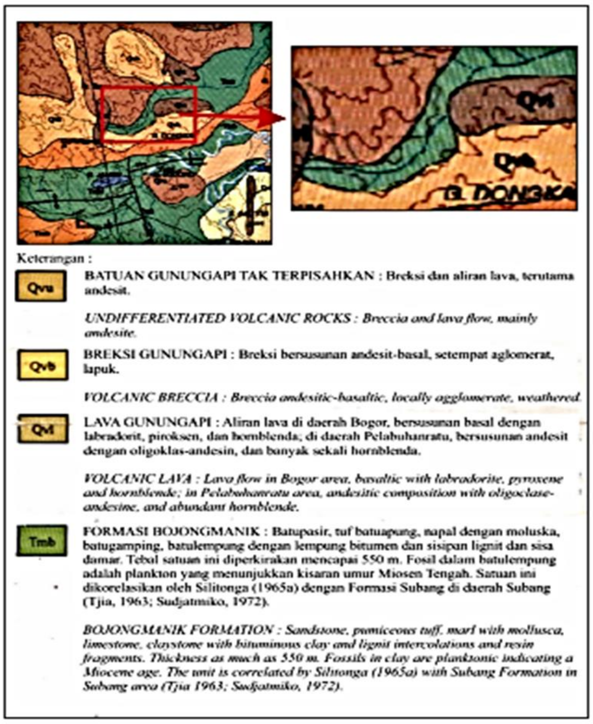

Fig. 1. Geological Map of Research area, Rumpin and surrounding areas.

a. Alluvium and alluvial fans

This unit is a loose material deposit consisting of pebbles, granules, and clay whose deposition process is still ongoing until now (Holocene). In addition, this unit consists of layered fine tuff, conglomerate tuff alternating with sandy tuff and pumice tuff. Fine tuff is light gray in color, thinly layered, solid, conglomerate tuff and sandy tuff is light gray in color, poorly sorted, fine-coarse grained. The constituent materials are Pleistocene young volcanic rocks in the Bogor highlands.

b. Sandstone (Tmb)

This unit consists of alternating sandstone and sandy claystone intercalated with limestone at the bottom and tuffaceous sandstones and tuff at the top. In addition, this unit is also part of the Genteng Formation with a lithological composition of tuff with pumice, tuffaceous sandstone, conglomerate, andesite breccia, and intercalation of tuffaceous clay. Tuff with pumice, white to gray, fine to coarse-grained.

c. Conglomerate (Tpss)

This unit consists of alternating sandstone, conglomerate, siltstone and claystone with plant residues, pumice conglomerate, and pumice tuff.

d. Breccia (Qvu)

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This unit consists of breccias and lava flows, mainly andesite.

e. Andesite (Qvas)

This unit covers the northwest and southeast of the study area, occupying approximately 5% of the study area. This unit consists of andesite from Mount Sudamanik

f. Member of Bojongmanik Formation

This unit covers the southern part of the study area, consisting of limestone-containing mollusks. This unit is in the form of lenses in the Bojongmanik Formation, which is the age equivalent to the Middle Miocene.

Fig. 2. Clastic limestone members of the Bojongmanik Formation, the southern part of the study area, which has a rock layer direction

Geomorphology of Research Area

Geomorphology is the science of landforms that form the earth's surface, both above and below the water surface, and emphasizes the origin of future developments and their context with the environment (Verstappen, 1983). The geomorphological analysis of the research area uses the analysis method of ASTER GDEM images, topographic maps, and geomorphological data retrieval using the drone method, as well as field observations. The analysis, geomorphological units, and determination of the body of the volcano. The basic concept of landforms consists of geomorphological aspects, i.e., morphography, morphometry, and morphogenetics.

Landforms are features that are formed by natural processes and have a certain composition, physical, and visual characteristics wherever the landform is found (Van Zuidam, 1979). Landforms undergo a dynamic process of change during the geomorphological process working on these landforms. The energy that works is called geomorphological energy, namely all natural agents capable of eroding and transporting material on the earth's surface. This energy can be in the form of flowing water, groundwater, waves, currents, tsunamis, winds, and glaciers. Based on the processes that work on the earth's surface, are known as fluvial, marine, aeolian, dissolving, and glacier processes. The geomorphology of the Rumpin area is a hilly area to steep hills, because the Rumpin area is controlled by an active geological structure.

The morphology of the Rumpin area can be grouped into 2 (two) units, namely the fluvio-volcanic undulating plain geomorphological unit, which occupies ±80% of the study area, and the fluviatile sedimentary plain unit. The results of field observations indicate that the research area has undulating hills and there is a depression zone in the hilly area.

Fig. 3. Geomorphology of Research Area

Slope

The slope of the research area is based on topographic data that is processed using GIS software and refers to the 1986 Guidelines for the Preparation of Land Rehabilitation and Soil Conservation. From these results, the research area is divided into three classes of the slope, namely (Figure 4 and Table 1):

a. Flat-Slightly Rugged (0-15%)

Based on the topographic appearance of this unit, it consists of a slightly elevated plain that has a slope of 0–15%. This unit occupies 60% of the research area, with an area of 2382 ha. Areas with these slope values are covered almost throughout the north, middle, and south of the study area. This unit has a dominant lithological composition of sandstone, alluvium, conglomerate, and slightly weathered breccia and andesite. The area with these slope values has the potential for weathering and erosion to occur.

b. Rather Rugged (15-25%)

This unit consists of a rather rugged morphology, which has a slope of 15–25%. This unit occupies 10% of the study area, with an area of approximately 412.8 ha. Areas with these slope values are covered in the north and southwest of the study area. This unit has a lithological composition that is dominated by breccia. The area with these slope values has the potential for weathering and erosion to occur.

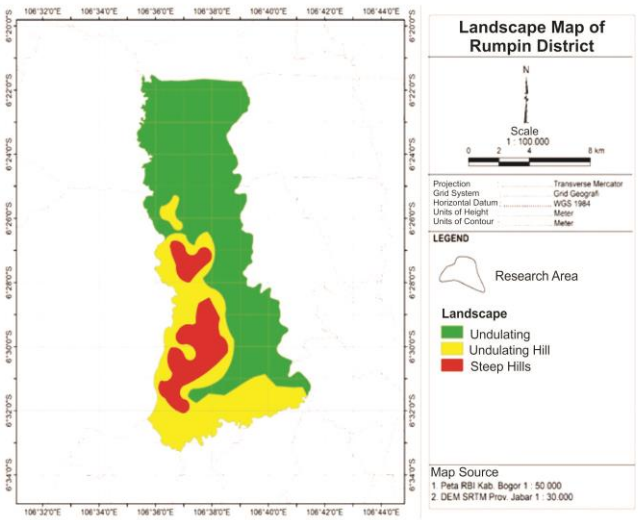

Fig. 4. Slope Class-Map of the Research Area

c. Rugged-Very Rugged (> 25%)

This unit consists of rugged to very rugged morphology, which has a slope of 25–45%. This unit occupies 30% of the

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research area, with an area of about 1062 ha. Areas with these slope values are dominantly distributed in the southwest and slightly in the east of the study area. This unit has a lithological composition that is dominated by breccia and andesite. The area with these slope values has the potential for weathering and erosion to occur.

TABLE I. Table of Slope-class

No	Unit	Description	Values	Assessment	VxA
1	Undulating (0-15%)	Based on the topographic appearance of this unit, it consists of a slightly elevated plain that has a slope of 0–15%. This unit occupies 60% of the research area, with an area of 2382 ha. Areas with these slope values are covered almost throughout the north, middle, and south of the study area. This unit has a dominant lithological composition of sandstone, alluvium, conglomerate, and slightly weathered breccia and andesite. The area with these slope values has the potential for weathering and erosion to occur.	5		20
2	Undulating Hill (15-25%)	This unit consists of a rather rugged morphology, which has a slope of 15–25%. This unit occupies 10% of the study area, with an area of approximately 412.8 ha. Areas with these slope values are covered in the north and southwest of the study area. This unit has a lithological composition that is dominated by breccia. The area with these slope values has the potential for weathering and erosion to occur.	3	4	12
3	Sharp Slashed Hill (> 25%)	This unit consists of rugged to very rugged morphology, which has a slope of 25–45%. This unit occupies 30% of the research area, with an area of about 1062 ha. Areas with these slope values are dominantly distributed in the southwest and slightly in the east of the study area. This unit has a lithological composition that is dominated by breccia and andesite. The area with these slope values has the potential for weathering and erosion to occur.	1		4

Land Movement

Rumpin is part of the mineralized pathway area. This can be seen from the results of geological mapping and microscopic descriptions that there are several minerals that have been changed, such as in the Rumpin area. There are small intrusions in the Rumpin area that are used as a C or non-metal mine materials. Based on observations at the disaster site, the rocks that make up the disaster area are volcanic products in the form of weathered andesite breccia and overlapping andesite lava flows, while the base rock is sandstone, pumice tuff, marl with mollusks, limestone, and claystone (Bojongmanik Formation). Weathered soil in the form of muddy sand has a high tuff content. Based on field investigations, a lot of old landslide material was found in the fields/land in the form of rock boulders at a distance of 40 meters from the settlement (Figure 5a). Landslides that occur in the Rumpin area are slides that move sequentially and continue to decline (Figure 5b).

High rainfall, poor drainage, and rugged slopes cause rainwater to enter the weathered soil so that the slopes are saturated with water. As a result, the weight of the soil mass increases and the shear strength decreases, as well as high rainfall resulting in weak slope resistance and then driven by gravity, causing landslides. In addition, the weathered soil that rides on andesite lava with a steep slope causes the slope to move easily (both fast and slow types). The location of andesite mines in the Rumpin District is expanding and is getting closer to residential areas. Then it causes the slope of the excavated cliff to be unstable, as high as approximately 40 meters, even though piles are being added as reinforcement. As can be seen from the evidence of landscape photos, engineering principles in slope reinforcement are not visible in the field. Representatives from BNPB said that the inappropriate use of regional space was the main problem with the land movement (Figure 6).

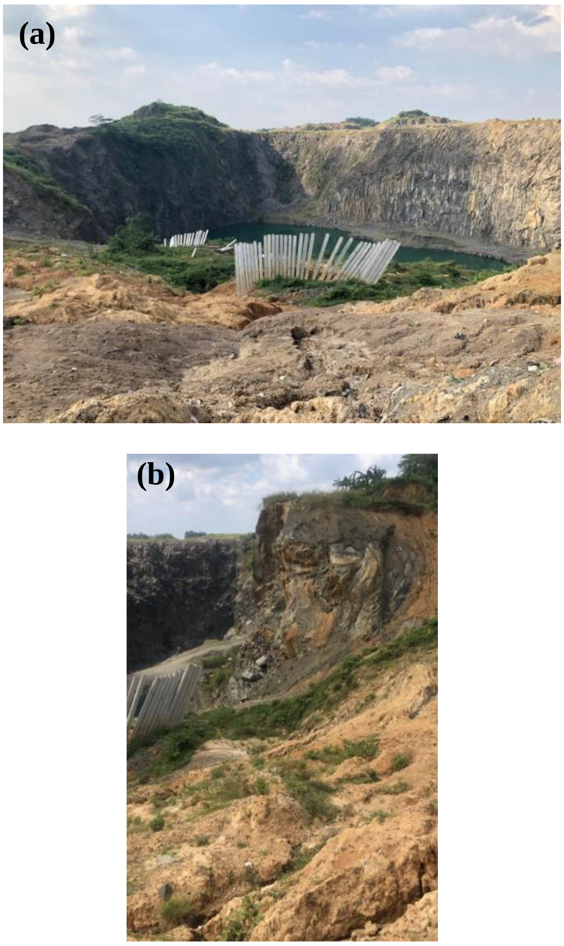

Fig. 5. (a) Land Movement in the former Rumpin Mining Area, (b) Slide Land Movement in the Rumpin Area

Fig. 6. Aerial Photographs Using Drones in Landslide Areas

Zoning of Land Movement in the Rumpin area

The map of the Land Movement Disaster was made based on the map of the Bogor City and Regency Land Movement Vulnerability Zone (Center of Volcanology and Geological

Hazard Mitigation). From the map, it is known that the research area is divided into 4 classes, i.e. (Fig 7 and Table 2):

a. Very Low Land Movement Vulnerability Zone

This zone covers 20% of the study area and has a low level of vulnerability to causing land movement and landslides. Generally, this zone has slopes ranging from 5–15% to 50–70%, depending on the condition of the physical properties and mechanical properties of the rock and soil forming the slope. Administratively, this zone is located in Sukasari Village, Rumpin Village, and Sawah Village.

b. Low Land Movement Vulnerability Zone

This zone covers 48% of the total area of the study area. This area has a medium level of vulnerability to the land movement. This zone has a range of slightly rugged slopes of 5-15% and rugged to almost upright (>70%) depending on the physical and mechanical properties of the rock and weathering soil forming the slope.

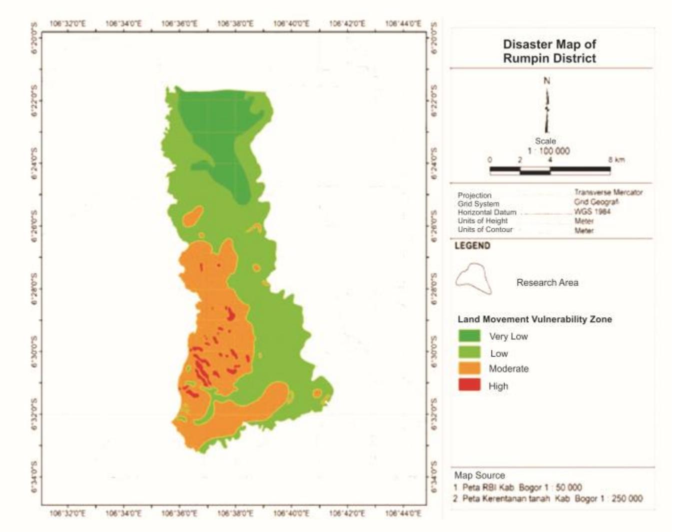

Fig. 7 Land Movement Vulnerability Zone Map

TABLE II. Table of Land Use

No	Unit	Description	Values	Assessment	VxA
1	Very Low Vulnerability Zone	This zone covers 20% of the study area, has a low level of vulnerability to causing land movement and landslides.	4	5	12
2	Low Vulnerability Zone	This zone covers 48% of the study area, has a low level of vulnerability to causing land movement and landslides.ran	3		9
4	Moderate Vulnerability Zone	This zone covers 22% of the study area. This area has a medium level of vulnerability to being affected by land movement.	2	10	6
4	High Vulnerability Zone	This zone covers 10% of the study area. This area has a medium level of vulnerability to being affected by land movement.	1		3

c. Moderate Land Movement Vulnerability Zone

This zone covers 22% of the total area of the study area. This area has a medium level of vulnerability to the land movement. This zone has a range of slightly rugged slopes of 5-15% and rugged to almost upright (>70%) depending on the physical and mechanical properties of the rock and weathering soil forming the slope.

d. High Land Movement Vulnerability Zone

This zone covers 10% of the total area of the study area. This area has a medium level of vulnerability to the land movement. This zone has a range of slightly rugged slopes of 5-15% and rugged to almost upright (>70%) depending on the physical and mechanical properties of the rock and weathering soil forming the slope.

IV. CONCLUSION

The results of field observations show that the landslide disaster from the former non-metal mine is the initial potential for a large landslide in the Rumpin area. The disaster caused 22 families to be evacuated. The rocks that make up the disaster area are volcanic products in the form of weathered andesite breccia on the top of andesite lava flows, while the base rocks are sandstone, pumice tuff, marl with mollusks, limestone, and claystone (Bojongmanik Formation).

Weathered soil in the form of muddy sand has a high tuff content. The results of the field survey in the Rumpin area found a lot of landslide material in the fields and land in the form of boulders, about 100 meters from the settlement. The type of land movement that occurs in Cilamur Pabuaran, Leuwibatu Village is a slide of soil and rocks.

These cracks (creeping) appeared due to pull but have closed again. Avalanches occur because of the contrast in permeability between the weathered soil and the andesitic lava beneath it. High rainfall, poor drainage, and rugged slopes cause rainwater to enter the weathered soil so that the slopes are saturated with water. As a result, the weight of the soil mass increases and the shear strength decreases, as well as high rainfall resulting in weak slope resistance and then driven by gravity, landslide-type land movements occur. In addition, the weathered soil above the andesite lava with a steep slope causes the slope to move easily (both fast and slow types).

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