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Determination of Weak Zone using Wenner Configuration in Jendral Sudirman Street Section Muara Bulian, Batang Hari

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Abstract

Jenderal Sudirman road is an alternative road used to avoid traffic congestion located on the National Causeway in Muara Bulian District, Batang Hari, Jambi. The road has a weak zone so that the purpose of this study, determines the subsurface structure and distribution of the weak zone on Jenderal Sudirman roads, Muara Bulian, Batang Hari, Jambi. The weak zone, namely the soil, decreases due to a large load so that there is ablaze on the road. Road damage one of which is damaged edges can result in accidents. Determination of weak zones using Wenner Configuration Geoelectric Method and DCPT data. Lines 1 and 2 are in the alluvial area (Qa) and Line 3 and 4 in the Kasai Formation (QTk). The first line of the weak zone at 17 – 44 m with a thickness of 3 – 10 m is located near the surface and below the surface at 45 – 95 m is estimated at a depth of 3 – 10 m with a thickness of 8 m with fine sandstone lithology. The weak zone on line 2 is near the surface at 20 – 28 m is estimated to be 6 m thick and at 40 – 77 m it is estimated at a depth of 3 – 5 m with a thickness of 2 – 6 m located under the surface of the clay periphery to a layer of fine sand saturated with water. The weak zone on line 3 is located at 20 – 56 m with a depth of 8 m and a thickness of 6 m located below the surface. The weak zone on track 4 is located at 35 – 87.5 m with a depth of 3 m and a thickness of 3 – 10 m. DCPT results from Robertson's 1986 chart and sondir graph obtained a weak zone at a depth of 0 m to 10.60 m with a conus pressure below 20 kPa.

Keywords: DCPT; weak zone; Wenner configuration.

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Introduction

Background

Economic growth is getting higher and the population is increasing. This has an impact on traffic density, especially national roads that connect between cities. In addition, economic activities are also increasing, such as the opening of mining areas, oil palm plantations are increasingly widespread, demanding dense mobilization and can occur congestion due to accidents or cars stopping because they are damaged due to too large car loads. The car load of coal trucks and palm oil tanks, if it continues to increase, will cause subsidence and even collapse due to weak zones that can cause the road to deteriorate quickly. even due to road compaction there are accidents that cause deaths.

The congestion of the National Cross Road has caused several vehicles to switch to using alternative roads, one of which is the Jendral Sudirman Road, Muara Bulian Village, Muara Bulian District, Batang Hari Regency, Jambi. However, this road also has a weak zone that at any time within a certain period of time will cause road damage. The threat of road damage due to subsurface weak zones will result in natural disasters, such as liquefaction, the level of soil layer density is very loose and the geological area consists of sandstones and sedimentary deposits as shown in Figure 1. (Yudiana et al., 2020).

Figure 1. Sighting of the Jendral Sudirman Road, Muara Bulian, Batang Hari.

This research also contains data from the Dutch Cone Penetration Test (DCPT), which is an effective method to determine the soil in situ, especially in areas with unconsolidated rock and soil layers, soft materials, organic materials and materials that have the potential for liquefaction. (Pranantya et al., 2018).

Weak zones are zones in rocks that have low resistivity values and high porosity and have very loose soil density. This zone will collapse if exposed to continuous loads. One of the geophysical methods that can be used to investigate rock weak zones is the geoelectric method (Makmur et al., 2016). This research is intended to determine the subsurface structure and determine the distribution of weak zones based on the Wenner configuration geoelectric method located on Jendral Sudirman Road, Muara Bulian, Batang Hari.

Regional Geology

The Jendral Sudirman Road, Muara Bulian, Batang Hari crosses 2 formations, which are the alluvial formation (Qa), and the kasai formation (QTk) based on the Regional Geological Map of Muara Bungo Sheet (Appendix 1-2).

Physiographically, the Batang Hari area is located in the western part of the South Sumatra Basin, which is a lowland area in eastern Sumatra, bounded by the Semangko Fault and Bukit Barisan to the southwest, the Sunda Shelf to the northeast, the Lampung Plateau to the southeast separating the basin from the Sunda Basin, and the Twelve Mountains and Thirty Mountains to the northwest separating the South Sumatra Basin from the Central Sumatra Basin (Wisnu & Nazirman, 1997).

Basic Theory

1. Weak Zone

A weak zone is an area of soil or rock with lower soil mechanics than the surrounding rock mass. Weak zones are defined as subsurface layers of highly susceptible materials, including wet clay, dry clay, dry sand, water and subsurface air voids. Weak zones can be fault zones, shear zones, weak layers or materials (Ramadianti et al., 2019).

The weak zone can be associated with liquefaction, which is the phenomenon of soil masses experiencing a loss of shear resistance value due to conditions that are monotonous, repetitive, cyclic (dynamic) and shock loading so that the soil is like a liquid that flows until the shear stress that occurs in the soil mass has a value as low as the shear resistance value (Sladen et al., 1985).

The weak zone can also be seen from the road collapse event which shows that the stability of the supporting rock below the road surface has decreased due to disruption of the continuity of rock strength in the subsurface structure (Soedarsono, 2006). One of the methods to identify weak zones in roads is the geoelectric method, which is the first step to investigate the subsurface geological structure (Akinlalu et al., 2016).

2. Geoelectric Method

The basic concept of the geo-metric method is Ohm's Law. In 1826 George Simon Ohm conducted research that determined the relationship between the voltage (V) on the conductor and the current (I) through the conductor within the limits of the characteristic parameters of the conductor. This parameter is called resistance R, which is defined as the quotient of voltage (V) and current (I), so it is written as:

$$R = \frac{V}{I} \; or \; V = IR \qquad (1)$$

The earth is assumed to be an isotropic homogeneous medium but in reality it is a nonhomogeneous medium consisting of many layers with different resistivity values, so that the measured resistivity value is not the true resistivity value but the apparent resistivity value. The apparent resistivity value is formulated as follows:

$$\rho_a = K\frac{\Delta V}{I} \qquad (2)$$

with ρ_a is the apparent resistivity value, ΔV is the potential value and I is the current value. The value of K depends on the type of configuration to be used.

Mapping is the collection of data in the form of changes in subsurface resistivity in the lateral (horizontal) direction. acquisition of data collection with fixed current and voltage electrode spacing, the measuring point is moved or shifted horizontally. The electrode configuration commonly used is the Wenner configuration.

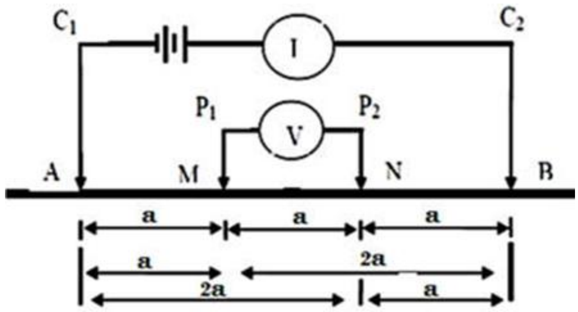

Figure 2. Wenner Configuration Electrode Arrays (Loke and Barker, 1996).

The Wenner configuration is one of the configurations in geophysical exploration with electrode arrays located in a line symmetrical to the center point. The Wenner electrode configuration has good vertical resolution, high sensitivity to lateral changes but weak current penetration to depth. The electrode arrays of the Wenner configuration can be seen in Figure 2.

The distance between electrodes in the Wenner configuration is the same as shown in Figure 2. The value of each electrode distance is substituted into Equation (2), then the value of K Wenner configuration is obtained, as follows:

$$K_S = 2\pi a \qquad (3)$$

then the apparent rho equation is obtained

$$\rho_a = 2\pi a \frac{\Delta V}{I} \quad (4)$$

where ρ_a is apparent resistivity, I is current strength, a is electrode distance, and ΔV is potential.

Resistivity states the typical properties of a material, which is the amount of resistance of a material that has a certain length and cross-sectional area with units of ohmmeter (Ωm). if a material with the same constituent minerals but the ratio is different, the resistivity will be different. By considering geological conditions, the value of the resistivity of several types of rocks that have been known based on the classification of Telford et al. (1990) in Table 1.

Table 1. Resistivity value constant according to Telford et al. (1990).

No.	Material	Resistivity (Ωm)
1.	Air	~
2.	Limestone	500-10000
3.	Sandstone	200-8000
4.	Slate	20-2000
5.	Marls	3-70
6.	Clays	7 - 30
7.	Alluvium	10-800
8.	Gravel	100-600

3. DCPT (*The Dutch Cone Penetration Test)*

DCPT (*The Dutch Cone Penetration Test)* is known as the sondir test which is widely used in Indonesia. DCPT is a test to calculate the bearing capacity of soil. The values of static cone resistance or conus resistance (qc) obtained from the field can be directly correlated with the bearing capacity of the soil (Hardiyatmo, 1992).

In 1986 Robertson developed a chart with twelve soil types (Figure 3). The use of these charts can be done in the field using the qt-Fr soil type zones shown in Table 2 (Robertson et al., 1986).

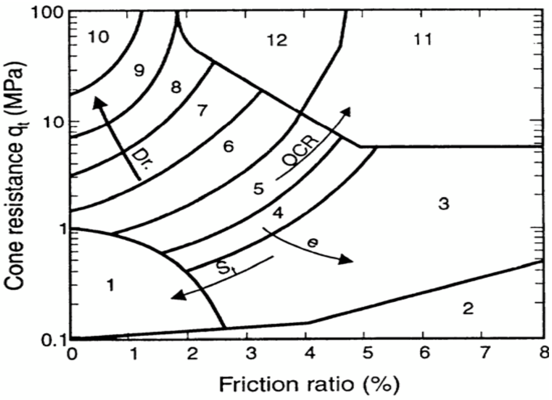

Figure 1. Soil type zone qt-Fr (Robertson et al., 1986).

Table 2. Soil type zone qt-Fr (Robertson et al., 1986).

Zone	Soil Behavior Test
1	Sensitive fine grain
2	Organic
3	Clays
4	Silty clay to clay
5	Clayey silt to silty clay
6	Partially drained sandy silt to clayey silt
7	Silty sand to sandy silt
8	Sand to silty sand
9	Sand
10	Gravelly sand to sand
11	Fine to stiff grain
12	Sand to clayey sand

Research Method

This research was conducted on Jenderal Sudirman Road, Muara Baulian, Batang Hari, Jambi using the Wenner configuration geoelectric method as many as 4 lines and a line length of 100 m and the electrode spacing distance is 5 m based on the acquisition map which can be seen in Figure 4. The results obtained from the acquisition of geoelectric data are the current value (I) in units of Ampere (A) and potential difference (V) in units of millivolts (mV). These values are used to obtain Apparent Rho (ρa) through Microsoft Excel Software calculations. after that is the next stage to obtain a 2D subsurface cross section using Res2DInv Software. This 2D cross section is interpreted based on Table 2.

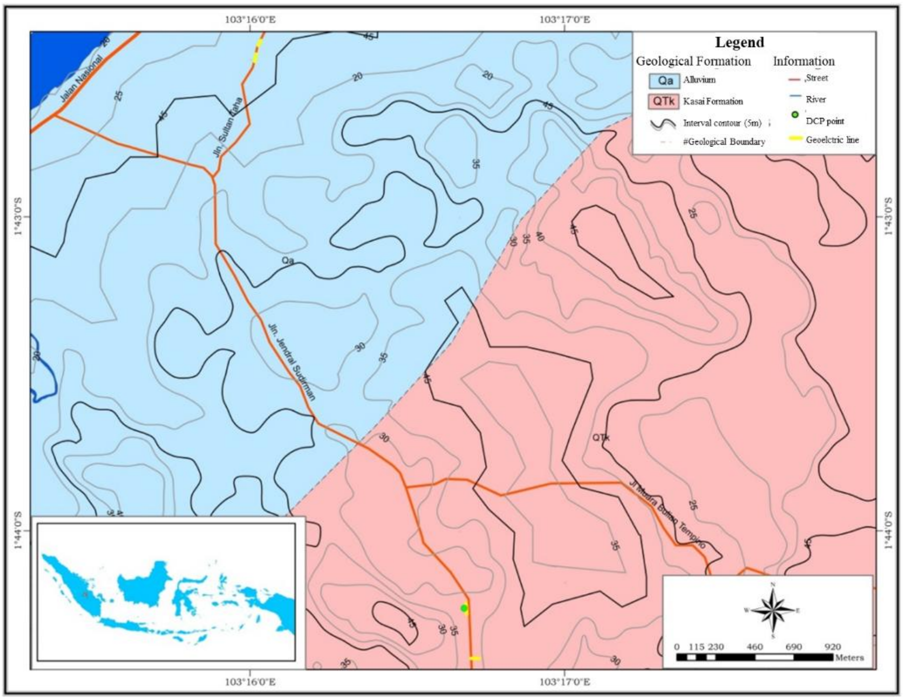

Figure 2. Wenner configuration geoelectric acquisition design (modified from Badan Informasi Geospasial, 2017).

Tools and Materials

1. *Resistivity meter* as a data measurement tool such as current strength (I) and potential value (V).
2. Electrodes 4 pieces as a conductor to channel electric current.
3. Cable 4 pieces as a connection between the power source and the electrode.
4. Accu/ Battery as a source of electric current.
5. Hammer used to stick the current and potential electrodes.
6. Tape measure used to measure the length of the line.
7. GPS, used to determine the position at each research point.
8. Microsoft Excel 2010 software, used for geoelectric data processing to obtain apparent resistivity (ρa) and DCPT data processing to obtain conus value (qc).
9. Res2DInv software, used for processing the results of the apparent resistivity (ρa) to obtain a two-dimensional subsurface cross section.

Results and Discussion

Processing of Wenner configuration geoelectric data obtained in the field then through the calculation stage and the inversion process the results obtained 2D cross section on line 1 to 4 which has a color image in the form of blue, green, yellow, orange, red to purple color groups that represent the resistivity value of a subsurface material / rock with a vulnerable value of 8.35 – 453 Ωm and a depth of 16.6m.

Table 3. Resistivity values obtained in the field.

No.	Color Scale	Rho (Ωm)	Materials
1		4.54 – 20.2	Fine sandstone, sand
2		50.4 – 74.9	Clay, claystone
3		91.3 – 175	Siltstone, silty clay
4		399 – 579	Sandstone, swamp

2D geoelectric cross-sections produce different color images to interpret subsurface rock types. Based on Table 3 to determine the weak zone, there are layers of water-saturated sand, clay, silt clay because in the area there are 2 formations, which are alluvial and Kasai Formation.

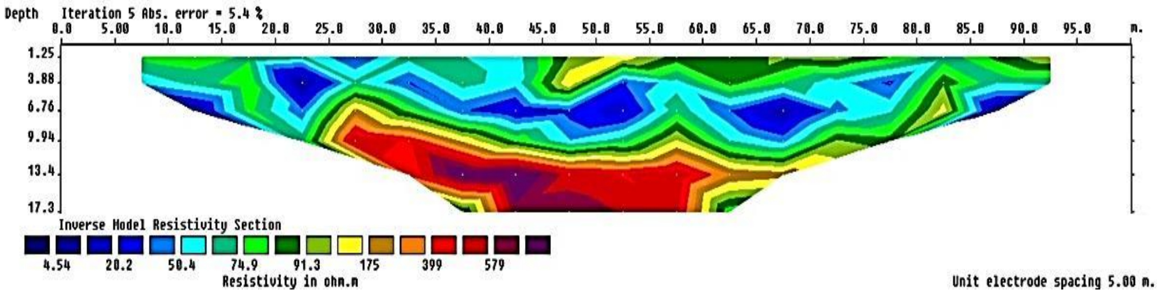

Figure 5. 2D Subsurface Cross Section Line 1.

Line 1 (Figure 5) was taken in an alluvial area (Qa), the area is close to swamps and rivers. The presence of lithology is indicated by rock resistivity values from 4.54 - 20.2 Ωm, these rocks are interpreted as water-saturated fine sand represented by blue color. The resistivity value of 50.4 - 74.9 Ωm is interpreted as semi-permeable sandy clay sedimentary rock represented in green. The resistivity value of 91.3 - 175 Ωm is interpreted as mudstone sedimentary rock, represented by dark green to yellow color. The red to orange color has a resistivity value of 399 - 661 Ωm estimated as sandstone. The presence of weak zones almost along Line 1 is because the area is near swamps and rivers. There are 2 parts of the weak zone, which are near the surface and below the ground surface. The weak zone on the ground surface is located at a distance of 17 - 44 m with a thickness of 3 - 10 m. The second part of the weak zone is located below the ground surface. The second part of the weak zone is found in the subsurface at a distance of 45 - 95 m, estimated at a depth of 2 - 10 m with a thickness of 8 m. The weak zone is estimated to be dominated by water-saturated fine sand shown in blue along the 100 m track.

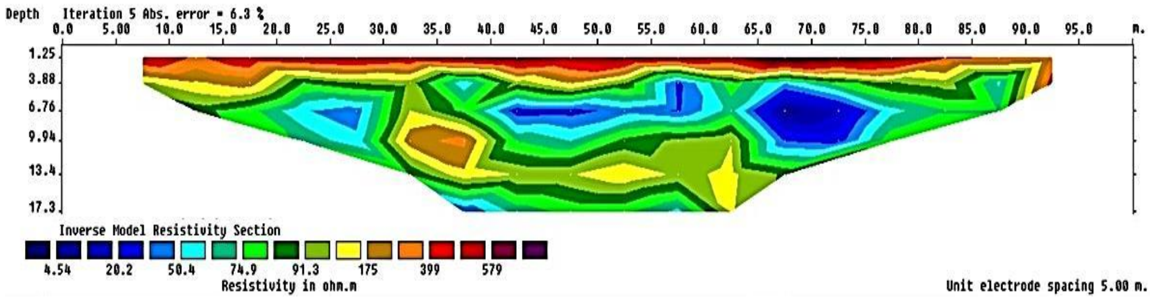

Figure 6. 2D Subsurface Cross Section Line 2.

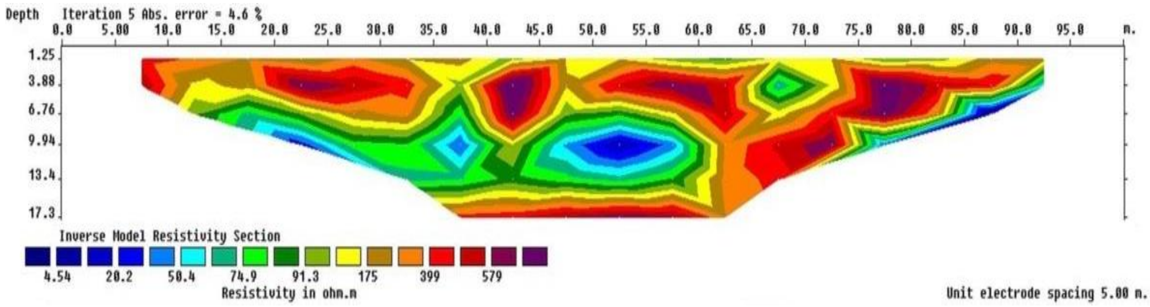

Figure 7. 2D Subsurface Cross Section Line 3.

Line 2 was taken in the Alluvial area (Qa) which can be seen in Figure 6. The presence of lithology is indicated by rock resistivity values from 4.54 – 20.2 Ωm, these rocks are interpreted as water-saturated sand represented in blue. The resistivity value of 50.4 – 74.9 Ωm is interpreted as passive clay sedimentary rock represented with green color, 91.3 – 175 Ωm is interpreted as clay, represented with dark green to yellow color. While the presence of a layer of soil with a high resistivity value of 399 – 661 Ωm is represented by black to orange color which is thought to be fill soil because the road is adjacent to the swamp. The weak zone on line 2 is in the subsurface at a distance of 20 – 28 m estimated to be at a depth of 4 m with a thickness of 6 m and part 2 at a distance of 40 – 77 m estimated at a depth of 2 – 5 m with a thickness of 2 – 6 m. This weak zone is of clay lithology. This weak zone is lithologically clay to water-saturated fine sand layers. According to Yudiana et al. (2018) the weak zone is caused by the arrangement of the overlying rock layers of sandy clay to dense sand which is buried into a layer of water-saturated sand and silty clay so that it is impermeable and has high porosity, above this layer there is sand that can pass water so that it has the potential for liquefaction.

Line 3 was taken in the Kasai Formation (QTk) which can be seen in Figure 7. The presence of lithology is indicated by rock resistivity values from 4.54 – 20.2 Ωm interpreted as water-saturated fine sand represented in blue. The resistivity value of 50.4 – 74.9 Ωm is interpreted as passive clay sedimentary rock represented in green. The resistivity value of 91.3 – 175 Ωm is interpreted as clay or mudstone represented by dark green to yellow color. While the presence of lithologies with high resistivity values of 399 – 661 Ωm is represented by red to orange colors which are interpreted as sand and sandstone. The weak zone in line 3 is located at a distance of 20 – 56 m with a depth of 8 m and a thickness of 6 m. This line is not dangerous for buildings above. This line is not dangerous for the building above it because it has a strong and very compact soil layer with dense sand lithology and there are no weak zones close to the surface.

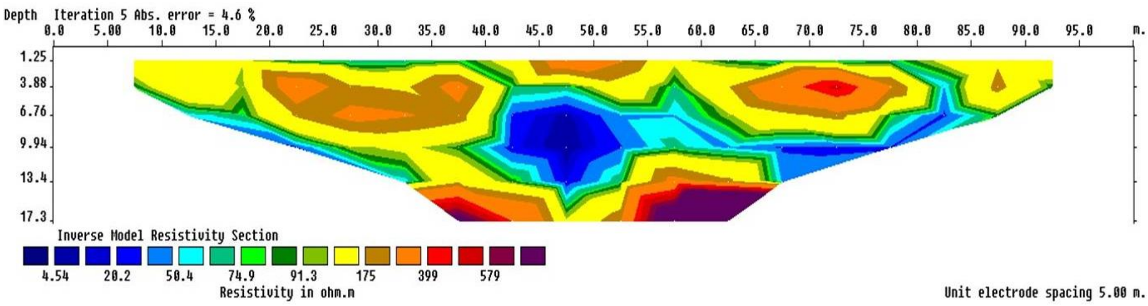

Figure 8. 2D Subsurface Cross Section Line 4.

Line 4 was taken in the Kasai Formation (QTk) which can be seen in Figure 8. The presence of lithology is indicated by rock resistivity values from 4.54 – 20.2 Ωm, these rocks are interpreted as water-saturated fine sand represented in blue. The resistivity value of 50.4 – 74.9 Ωm is interpreted as semi-permeable sandy clay sedimentary rock represented in green. The resistivity value of 91.3 – 175 Ωm is interpreted as sand sedimentary rock, represented by dark green to yellow color. While the presence of lithology with a high resistivity value of 399 – 579 Ωm is represented by red to orange color which is interpreted as sandstone. The weak zone on line 4 is located at a distance of 35 – 87.5 m with a depth of 3 m and a thickness of 3 – 10 m. According to Yudiana et al. (2018) the existence of a weak zone is due to the rock layers arranged undergoing burial, namely a layer of water-saturated passive to dense clay, silt clay is immobile and has high porosity and is overlain by sandstones that can pass water so that it has the potential for liquefaction.

The value of conus resistance (qc) at a depth of 0.00 m – 7.20 m from the ground surface is 196 kPa to 1,176 kPa (1 kPa = 0.0102 kg/cm^2) as shown in Figure 9. At a depth of 7.40 m to 10.60 m the conus pressure decreases to a conus value of 196 kPa. At a depth of 10.80 m to a depth of 11.60 m the conus pressure continues to increase reaching hard soil with a conus value of 14,700 kPa. Shear resistance (fs) values range from 0.13 – 1.67 kg/cm^2. The total shear value (TF), which is the ability of the soil to withstand loads, increased to a value of 328 kg/cm^2 at a depth of 11.6 m from the ground surface. The friction ratio (Rf) value with a value of >1% can be said to be a cohesive soil. A groundwater table was found at a depth of 8 m. The presence of weak zones is estimated at a depth of 0 – 10.60 m as shown in Figure 10.

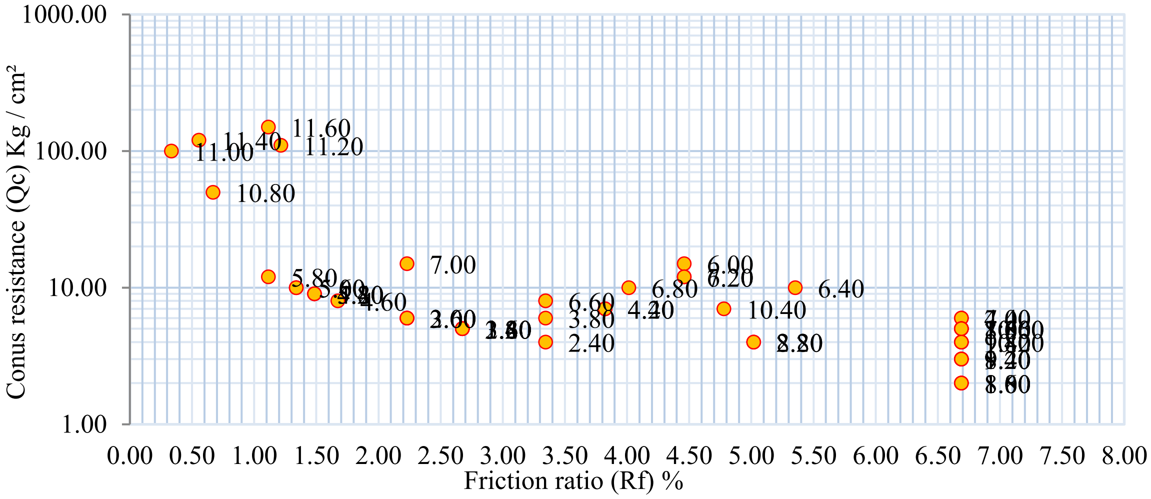

Figure 9. Robertson's 1986 graph (Robertson et al., 1986).

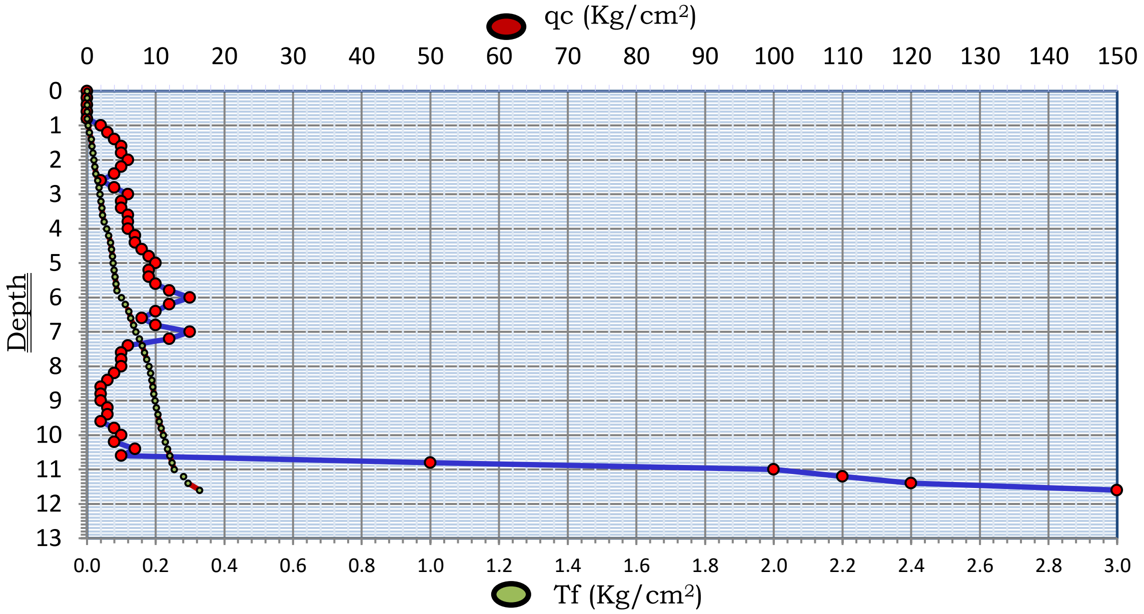

Figure 3. Sondir Test Graphics.

Conclusion

Research on the determination of weak zones using the Wenner configuration geoelectric method was conducted at Jenderal Sudirman Road, Muara Bulian, Batang Hari, Jambi. The acquisition has been carried out in two formations which are alluvial (Qa) and Kasai Formation (QTk), each formation has 2 lines. Based on the results of the study, the resistivity value variation of the subsurface layer consisting of fine sand to fine sandstone with a resistivity value of 4.54 - 20.2 Ωm, clay to mudstone with a resistivity value of 50.4 - 74.9 Ωm swamp soil with a resistivity value of 399 - 579 Ωm and siltstone has a resistivity value of 91.3 - 175 Ωm.

The results prove that on Jenderal Sudirman Road, Muara Bulian, Batang Hari, Jambi, there is a weak zone with a water-saturated fine sand to fine sandstone lithology. Based on the interpretation of 2D subsurface geo-electrical cross-section of Line 1 and Line 2, there is a weak zone in the subsurface and close to the surface, line 3 weak zone is far below the surface so it is possible that there is no collapse, while line 4 is almost all a weak zone estimated to be up to 10 m deep. The weak zone in traverse 4 is found in the sondir/ DCPT test with the result that the depth of 0 - 10.6 m is a weak zone because the conus value (qc) is below 20 kPa.

The weak zones found in the study area are interpreted as soft and non-compact rocks that are unable to withstand loads, and can cause road damage.

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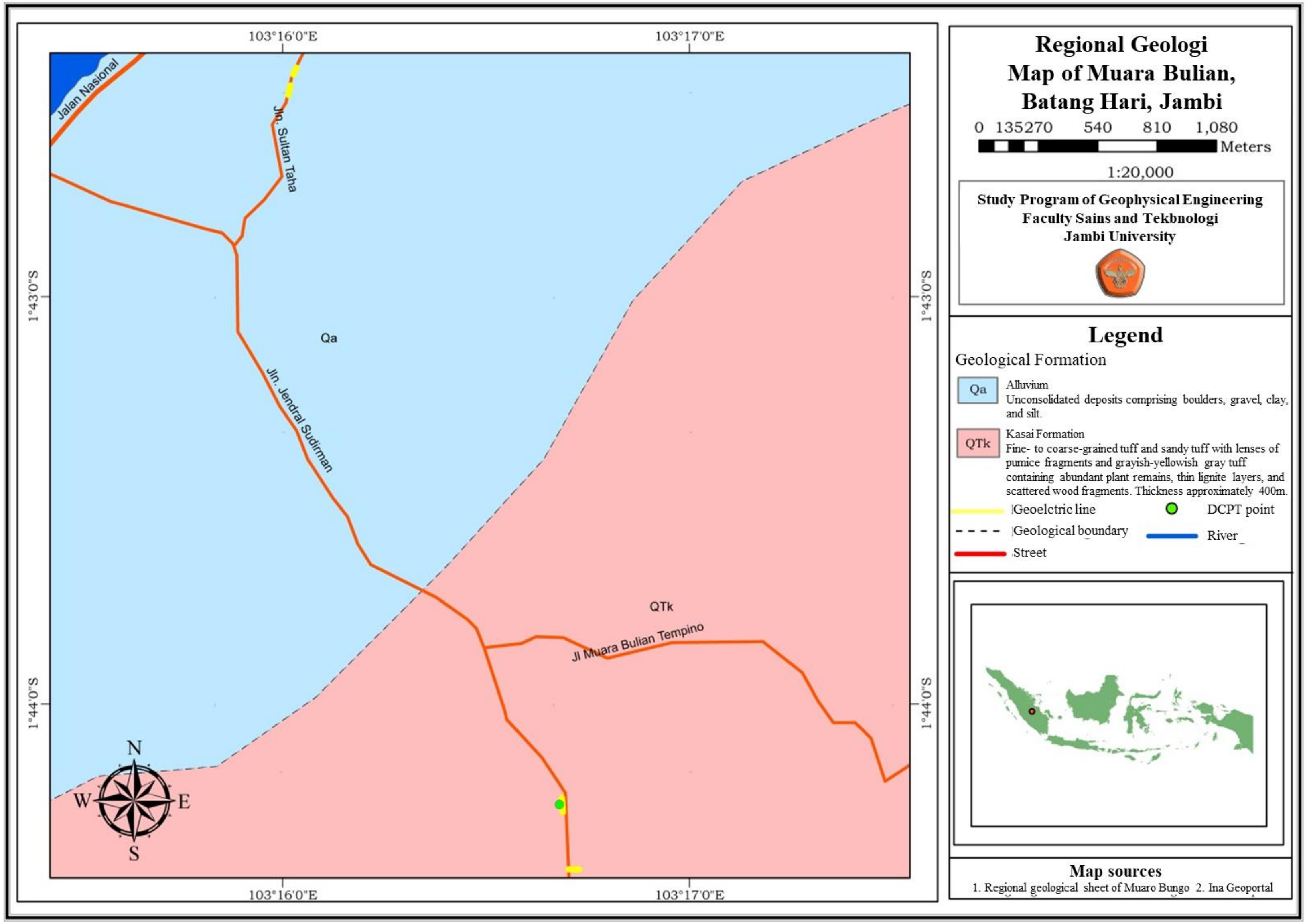
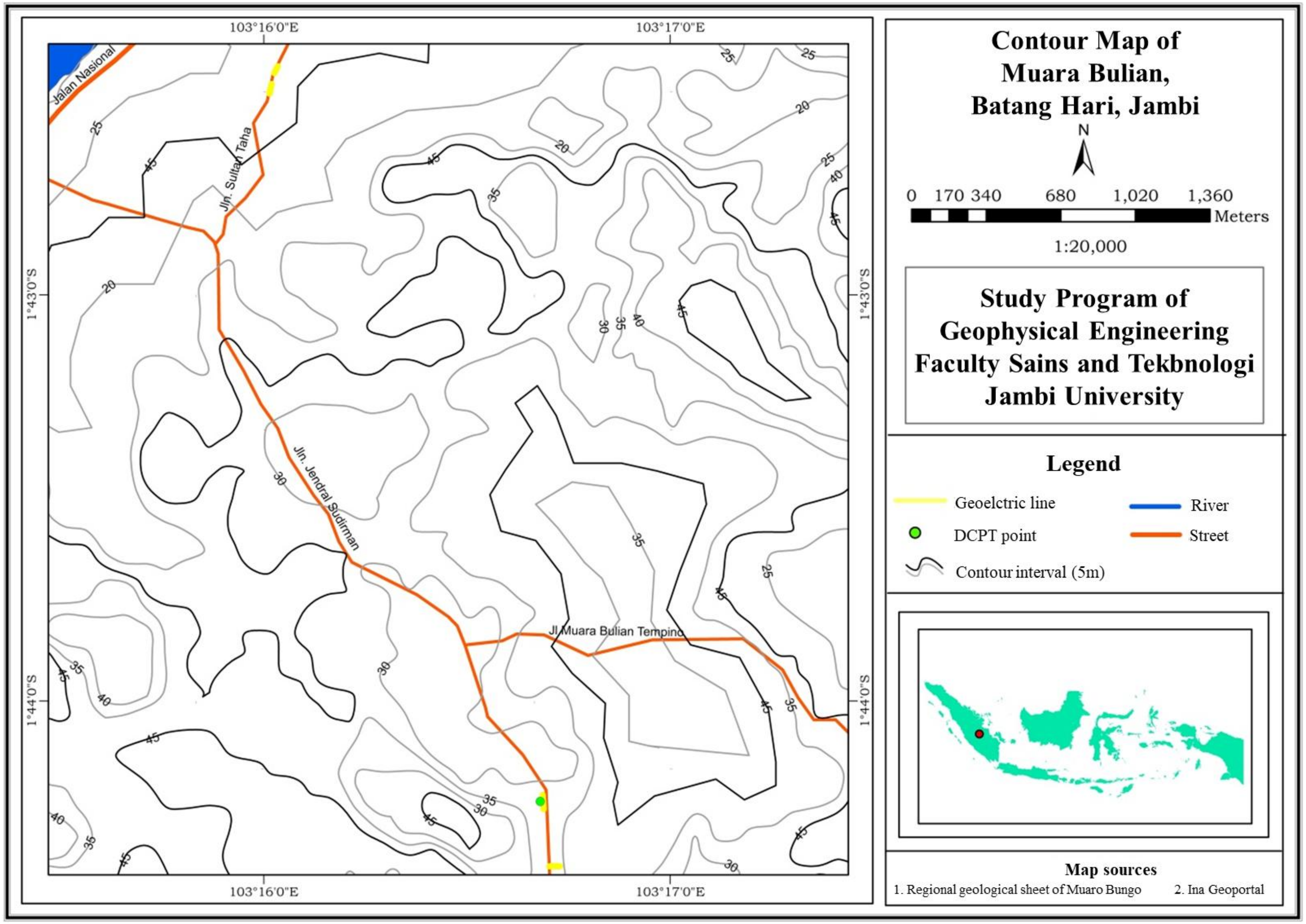


Appendix 4. Regional geology map of Muara Bulian, Batang Hari.



Appendix 5. Contour map of Muara Bulian, Batang Hari.