Quest Journals
Journal of Research in Environmental and Earth Sciences
Volume 8 ~ Issue 11 (2022) pp: 86-96
ISSN(Online) :2348-2532
www.questjournals.org

Research Paper

Subsurface Identification using the Frequency Wavenumber Method in the Kalialang Lama Landslide Area, Sukorejo Gunungpati Village, Semarang, Central Java, Indonesia

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ABSTRACT: *Kalialang Lama Sukorejo Gunungpati Semarang, which is in front of SD Negeri 3 Sukorejo, became the research area which experienced a landslide on January 7, 2022 and caused the road to sink. The phenomenon of landslides in the same area also occurred in 2017 and 2019 so it is necessary to study subsurface characteristics to determine the cause of landslides. This activity makes use of the value of Vs and the ratio of Vp/Vs. Acquisition of data using a microtremor array with 11 linear configuration paths, each of which contains 8 vertical geophones, each path lasting 10 minutes. The value of Vs is generated from the inversion of the dispersion curve. The dispersion curve is obtained from the F-K data processing. This activity resulted in 2D modeling of the value of Vs and the ratio of Vp/Vs. The result of this activity is that the surface to a depth of 100 meters has a Vs value of 177 m/s to 1260 m/s. The soil surface to a depth of 22 meters indicates medium and fine soil which has the types of gravel, sandy gravel, and loam. At a depth of 20 – 73 meters, it is indicated that the soil is hard, soft rock and the soil is fine – stiff which has the type of sandstone and new limestone. At a depth of more than 73 meters, it is indicated that the rock is rigid and has a schist soil type.*
KEYWORDS: *F-K, Microtremor array, Vs, ratio Vp/Vs*

R*eceived 15 Nov., 2022;* ***R****evised 28 Nov., 2022;* ***A****ccepted 30 Nov., 2022 © The author(s) 2022.*
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I. INTRODUCTION

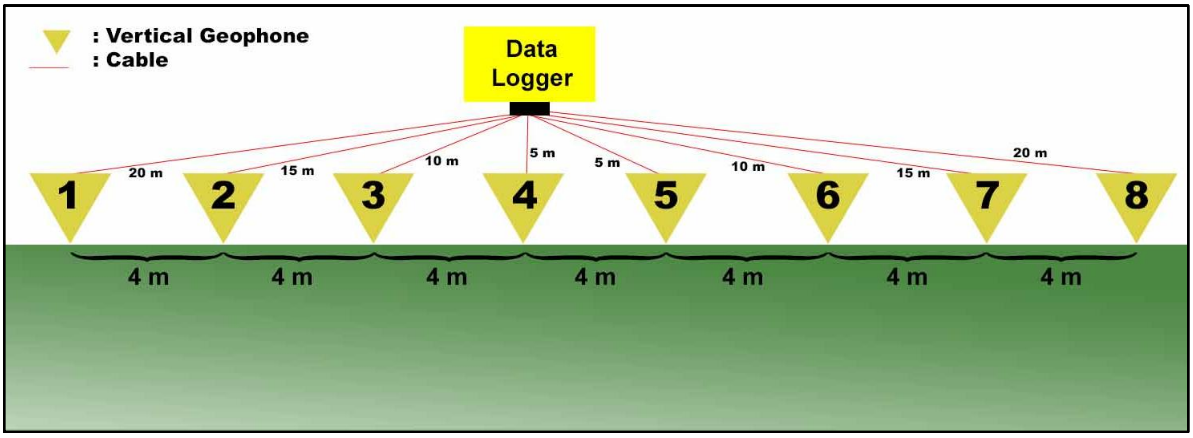
There has been a landslide in front of SD Negeri 3 Sukorejo actually at Kalialang Lama Street Sukorejo Gunungpati Semarang on January 7, 2022. This landslide caused the main road to collapse so that public access was cut off. Based on public information, in 2017 and 2019. Landslides can occur due to internal factors (subsurface lithology) and external factors (rainfall and slope). The geological map sheet Semarang–Magelang shows that Sukorejo Gunungpati Village has the Kalibeng Formation which consists of marl, sandstone and limestone [1]. Further research related to regional lithology is needed to determine the causes of frequent landslides in the area.

S wave velocity parameter (Vs) can determine the subsurface lithology [2]. There have been many studies using geophysical methods to get the value of Vs because it is quite easy and does not require a lot of funds like drill data. This research uses a microtremor array with the Frequency wavenumber (F-K) method to identify the value of Vs in the research area. Microtremor array F-K method obtains the value of Vs by inverting the Rayleigh wave dispersion curve [3]. The use of vertical seismometers that record simultaneously, array microtremor is effective for estimating the value of Vs. Compact processing also makes the F-K method easy to process.

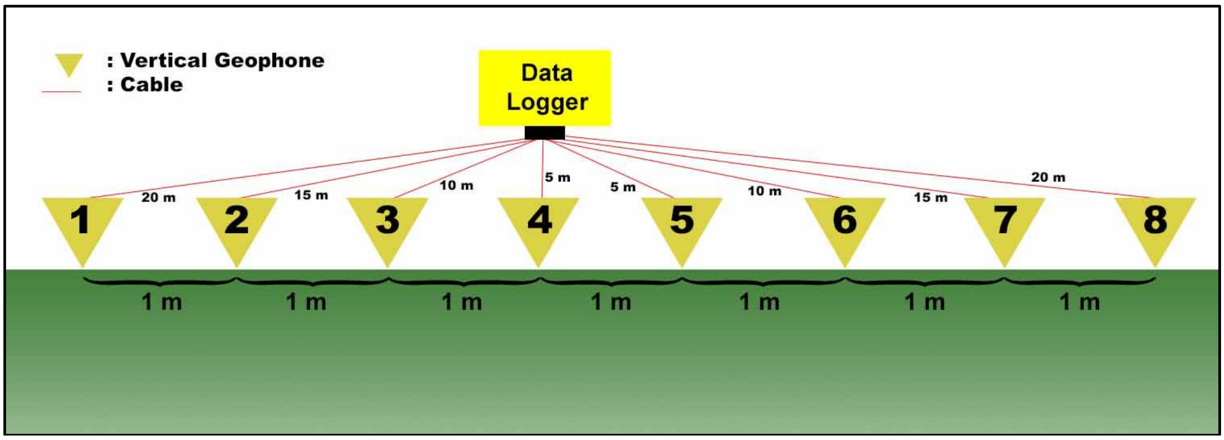
Landslide that often occur in the study area make this research very important to carry out. With the value of Vs, the subsurface lithology can be known so that the cause of the landslide can be known. The purpose of this study is to identify the value of the S wave velocity (Vs) and indicate the nature of the subsoil based on the value of Vs and the ratio of Vp/Vs in the study area. The results of the value of Vs and the ratio of Vp/Vs made 2-dimensional profiling so that it can identify the lithology and properties of the subsurface soil.v

II. METHODS

The data acquisition location is in the landslide area in front of SD Negeri 3 Sukorejo, actually at Kalialang LamaStreet , Sukorejo Village, Gunungpati District, Semarang City. The coordinates of the acquisition area are 7º 1' 33,613" South Latitude to 7º 1' 32.733" South Latitude and -110º -22' -46,091" West to -110º -22' -46,631" West. The acquisition area is 446.87 m2. This study uses 11 lines of linear configuration microtremor array data. Each track has 8 geophones and 1 DI710 data logger with a recording duration of 10 minutes per track. The placement of the geophones is in Figure 1. The data acquisition design looks like in Figure 2.

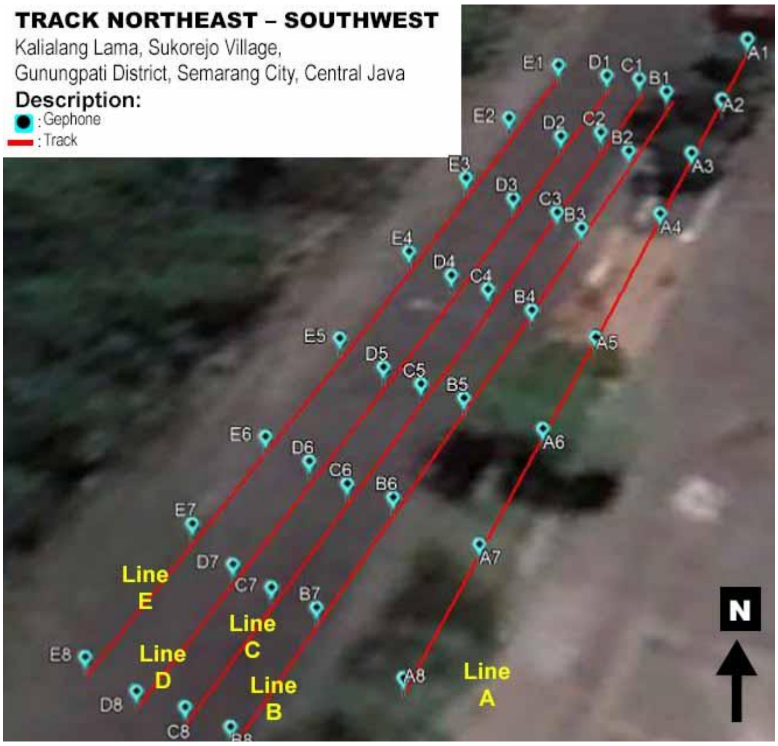


(a)

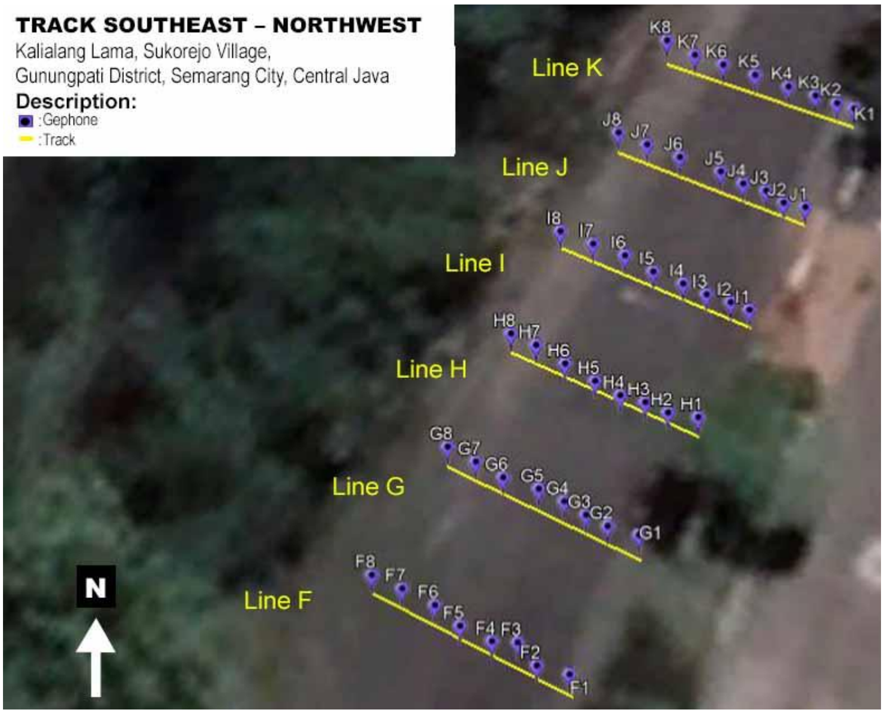


(b)

Figure 1. Geophone distance on (a) northeast – southwest trajectory; (b) southeast – northwest



(a)



(b)

Figure 2. Path acquisition design (a) southeast – northwest; (b) northeast – southwest

The stages of data processing starts from designing the acquisition and then carrying out data acquisition to obtain the microtremor array recording data. The recorded data is then processed using Geopsy with the F-K toolbox to obtain a histogram of frequency (f) – slowness (s). Histogram in Max2curve software is picked on the color that indicates the highest amplitude so as to produce a dispersion curve. The dispersion curve is then inverted using Dinver software to obtain a 1-dimensional profile of Vp, Vs, and . Next, 2-dimensional modeling was carried out using Surfer 10 software. The modeling obtained 2 incision profiles, each of which had 2 parameters, namely the ratio Vp/Vs and the value of Vs. Incision 1 traverses paths A, B, C, D, and E parallel to the landslide direction (Figure 3). Incision 2 crosses paths F, G, H, I, and J perpendicular to the avalanche direction (Figure 4).

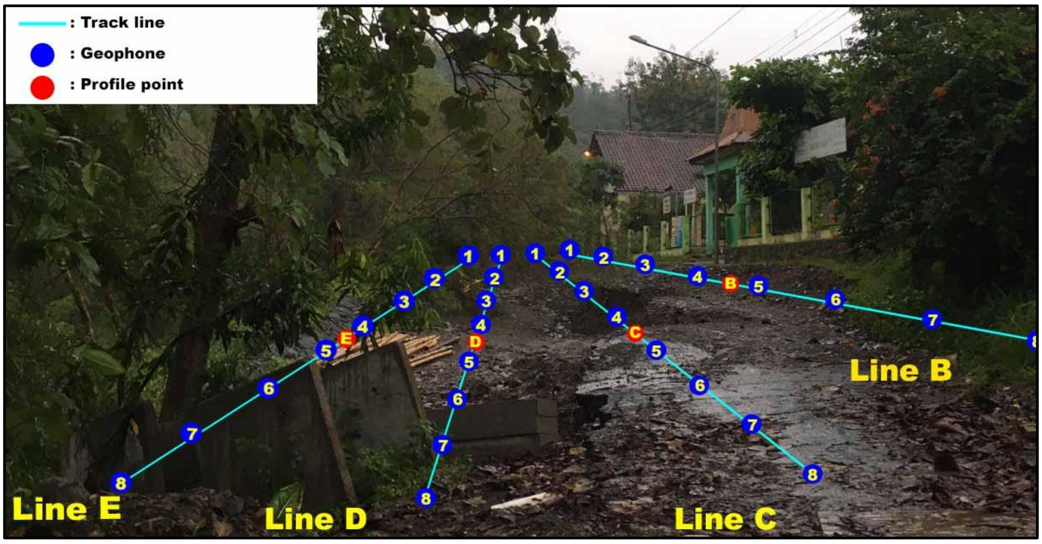


Figure 3. Profile stretch 1

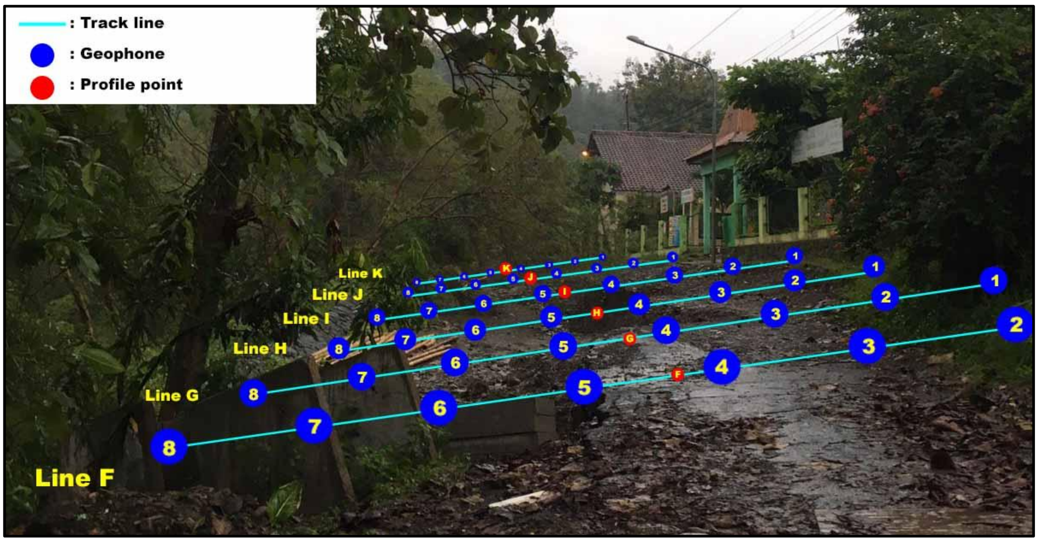


Figure 4. Profile stretch 2

The results of the Vs modeling were analyzed using the classification of Table 1 and the Vp/Vs modeling was analyzed using the classification of Table 2 the results of the analysis resulted in conclusions.

Table 1 Rock class Vs [4]

Rock class (rock type)	**Vs(m/s)**
Hard rock (dolomite, gneiss, basalt, granite)	**>1500**
Rock (sandstone, schist)	**750–1500**
Hard soil and soft rock (sandstone, limestone)	**350– 750**
Medium ground (clay, gravel sand)	**175–350**
Soft soil (sand)	**< 175**

Table 2. Rock properties Vp/Vs [5]

Rock properties (rock type)	**Vp / Vs**
Very hard (granite, gneiss, basalt)	**1,45 – 1,5**
Very stiff (schist, dolomite)	**1,5 – 2**
Rigid (schist)	**2 – 3**
Smooth - stiff (limestone, sandstone, conglomerate)	**3 – 4**
Smooth (gravel, clay, gravel sandy)	**4 – 6**
Smooth saturated (sand)	**5 – 8**

III. RESULT AND DISCUSSION

3.1 Research Area Analysis

The research area is the landslide area on Street Kalialang Lama, Sukorejo Village, Gunungpati District, Semarang City, bordering the Kripik River in the northwest and the SD Negeri 3 Sukorejo building in the southeast. The landslide leads to the northwest where there is a river called the Kripik river. The research area was originally a paved road. The landslide caused the road to collapse and the retaining wall at the riverside area collapsed.

3.2 Distribution result Vs

The results of the Vs profile 1 (Figure 5) show that the soil surface up to a depth of 21 meters has a Vs value of 180 – 350 m/s so that it indicates medium soil. At a depth of 20 – 73 meters has a value of Vs 350 – 750 m/s so that it indicates hard soil with soft rock. At a depth of > 73 meters has a value of Vs > 750 so it indicates rock. Incision profile 1 is also indicated by a slip plane with a value of Vs 300 m/s at a depth of 13 - 15 m which is marked by a white dotted line.

The results of the Vs profile 2 (Figure 6) show that the soil surface up to a depth of 22 meters has a Vs value of 175 – 350 m/s so it indicates medium soil. At a depth of 20 – 72 meters it has a value of Vs 350 – 750 m/s so that it indicates hard soil with soft rocks at a depth of 20 – 70 meters which is marked by a light blue color. At a depth of > 70 meters has a value of Vs > 750 m/s so it indicates hard soil. Incision profile 2 is also indicated by a slip plane with a value of Vs 300 m/s at a depth of 14 m marked by a white dotted line.

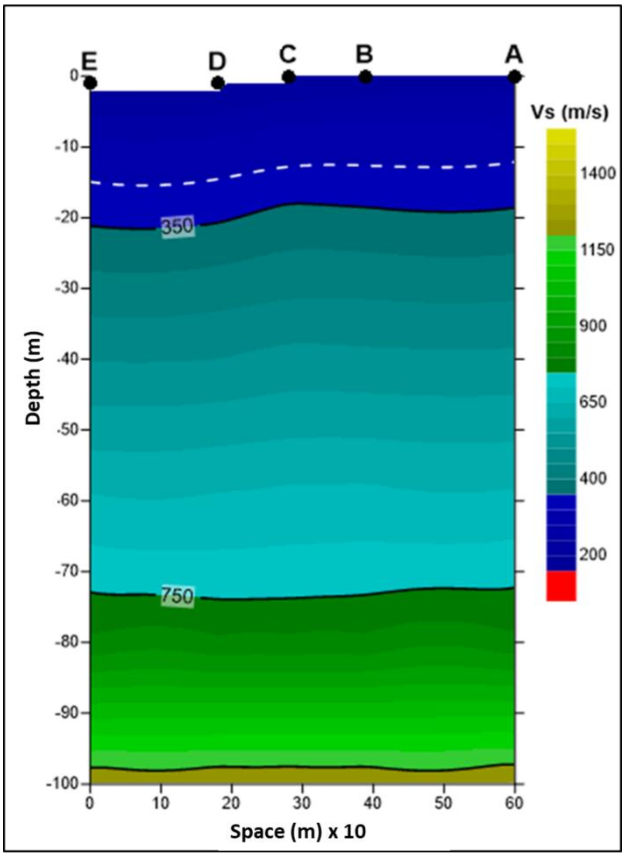


Figure 5. Incision profile 1 Vs distribution modeling

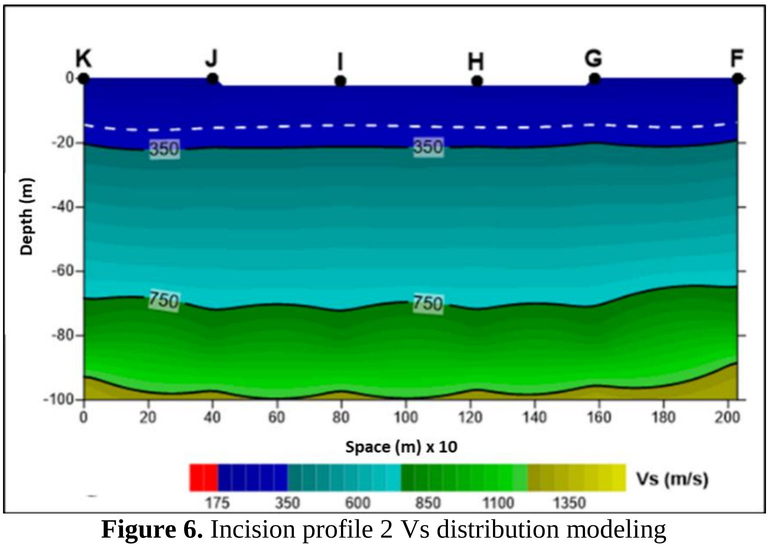


Figure 6. Incision profile 2 Vs distribution modeling

3.3 Result of ratio Vp/Vs

The results of the Vp/Vs profile 1 (Figure 7) show that the soil surface to a depth of 23 meters has a Vp/Vs ratio of 6 - 4 which indicates the soil is smooth. At a depth of 23 – 68 meters it has a Vp/Vs ratio of 4 – 3 which indicates that the soil is smooth - stiff. At a depth of more than 60 meters it has a ratio of Vp/Vs 3 so it indicates a rigid soil. Point A on the surface has a smaller Vp/Vs ratio than the other points. Points B, C, D, and E are areas affected by landslides.

The results of the Vp/Vs profile 2 (Figure 8) show that the soil surface to a depth of 23 meters has a Vp/Vs ratio of 6 – 4 which indicates that the soil is smooth. At depths ranging from 23 – 60 meters it has a Vp/Vs ratio of 4 – 3 which indicates that the soil is smooth - stiff. At a depth of more than 60 meters has a ratio of Vp/Vs 3 which indicates that the soil is rigid.

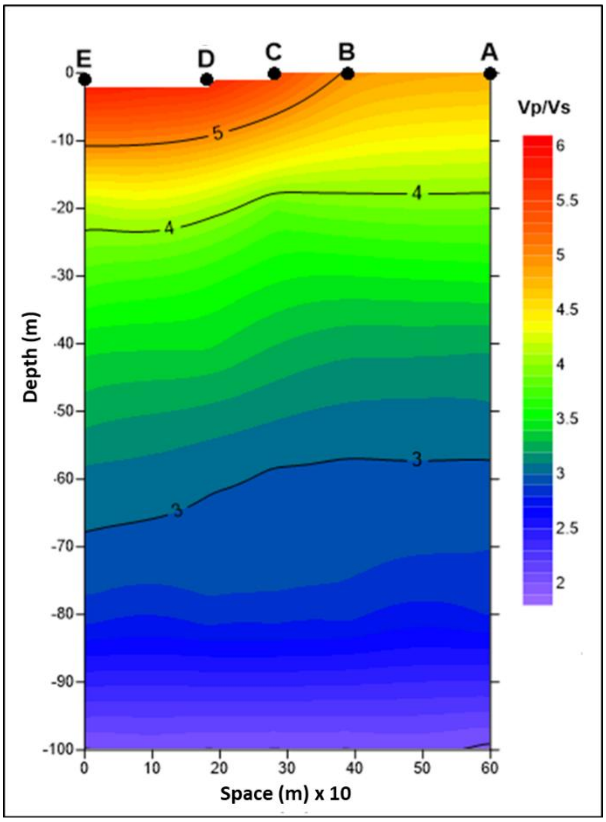


Figure 7. Incision profile 1 modeling the distribution of Vp/Vs

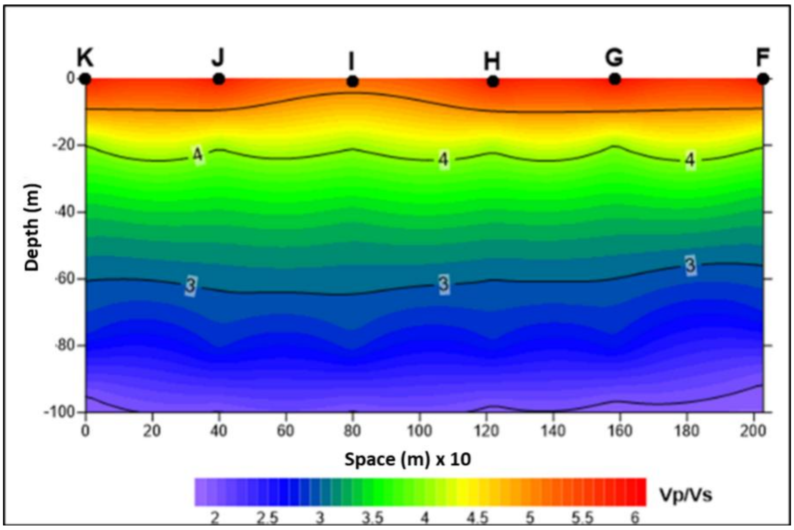


Figure 8. Incision profile 2 modeling the distribution of Vp/Vs

3.4 Discussion

The results of profiles 1 and 2 are subsurface depths up to 22 meters which indicate medium soil class and are fine. Soil at this depth consists of gravel, sandy gravel, and loam. Depth 13-15 identified slip plane. Research [6] in Clapar Village using a geoelectric method indicates the slip plane is clay soil. Clay acts as a slip plane because it has expansive properties, namely when wet it will expand and when dry it will shrink [22].

The consistency of the soil surface is smooth, making the study area has a high fracture due to the large Vp/Vs ratio. The P wave can propagate in all mediums so that the value of Vp will increase with increasing depth, but the S wave does not propagate in the fluid which makes the value of Vs decrease when there is fluid. The presence of fluid indicates that there are fractures and makes the soil easy to pass water (permeable). When fractures allow water to pass, water accumulates in the impermeable layer and increases soil mass so that the soil becomes weathered. High water content also weakens the shear strength between soil layers so that the weathered layer becomes unstable [7]. The weathered layer moves down on the impermeable plane which causes road subsidence in the study area. The northwest part of the area is a river that has different elevations so that the weathered layer moves towards the river which has a lower elevation.

At a depth of 20 – 73 meters, profile 1 and profile 2 have a hard soil class of soft rock that is smooth - stiff. The soil at this depth has limestone and sandstone types. At a depth of more than 73 meters, profile 1 and profile 2 have a rigid rock soil class. Rocks at this depth have a type of schist. The rock results in this study are in accordance with the Semarang-Magelang geological map according to [1] which explains that the Sukorejo Gunungpati area has the Kalibeng formation where marl composed of clay is on top and is followed by sandstone and limestone (limestone).

The research area still has a layer of sediment (Vs<750 m/s) which is up to 73 meters thick. This thick layer of sediment makes the research area have a thick weathered layer so that it is dangerous in case of soil movement. According to [8] the thicker the sediment layer, the higher the soil movement because the sediment layer is easily amplified.

Based on the results of the study, it is known that landslides that often occur in the front area of SD Negeri 3 Sukorejo or on Street Kalialang Lama Sukorejo Gunungpati Semarang, are caused by the presence of clay that acts as a slip plane and a thick layer of sediment. In addition, the presence of a river in the northwest makes the research area have different elevations. The soil surface of the study area also has smooth soil properties with gravel and sandy gravel types that allow water to be easily absorbed.

IV. CONCLUSION

Based on the results and discussion, this study obtained the following conclusions S wave velocity (Vs) below the surface of the study area to a depth of 100 meters has a value of 177 m/s to 1260 m/s. The distribution of the value of Vs<750 m/s is at a depth of up to 73 meters.The soil surface up to a depth of 22 meters has a Vs value of 177–350 m/s and a Vp/Vs ratio of 6 – 4, indicating that the soil is medium and fine, which consists of gravel, sandy gravel, and clay. At a depth of 20 – 73 meters it has a Vs value of 350 – 750 m/s and a Vp/Vs ratio of 4 – 3 so that it is indicated that the soil is hard, soft rock and the soil is smooth – stiff which has the type of sandstone and new limestone. At a depth of more than 73 meters has a value of Vs > 750 m/s and a ratio of Vp/Vs 3, indicating that the rock is rigid and has a schist soil type.

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