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Modeling of 3D Aquifer Layers using Poisson's Ratio Analysis HVSR Method in Tembelang Village, Candimulyo District, Magelang Regency

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ABSTRACT

Water is one of vital needs for human beings. People use water to drink, bath, irrigate, and etc. Water supply has become a severe problem over the two past years especially in Tembelang Village, Candimulyo District, Magelang Regency. The research aims to determine the aquifer layers. The method used in this research is seismic method with HVSR (Horizontal to Vertical Spectral Ratio) microtremor survey with 71 measurement points. The HVSR microtremor data is processed to determine Poisson's ratio from V_p/V_s ratio. The obtained V_p/V_s ratio from 71 measurement points ranges from 1.63 to 2.64 and Poisson's ratio ranges from 0.20 to 0.42. The V_p/V_s ratio parameter to determine an aquifer is more than 1.73 and the Poisson's ratio is more than 0.25. There are 4 zones which are considered to have aquifers, namely at line 1 near point P22 depth of over 184 meters, line 2 near point P8 depth of 108-180 meters, line 3 near point P2 and P3 depth of 91-161 meters, line 4 near point P16, P17, and P18 depth of 32-187 meters. line 5 near point T22 depth of 63-157 meters, point T31 depth of 122-152 meters, and point T40 depth of 71-178 meters. The V_p/V_s ratio and Poisson's ratio are then modeled by using Rockwork 15 to obtain 3D models of acquifers based on the V_p/V_s ratio and Poisson's ratio.

1. Introduction

Water is a vital need for individuals. Water is a source of life for human beings to carry out activities, for instance, drinking, bathing, irrigation and others. Sufficient water availability must be considered on the basis of human survival. Humans who continuously use water now have to experience watrer scarcity due to the lack of water resources [1]. Water scarcity often occurs in Tembelang village, Candimulyo district, Magelang regency during the dry season. Some water borehole drilling has been carried out, but there is still no fresh water resources due to drilling positioning errors.

Fig. 1: The administration map of Tembelang village, Candimulyo district, Magelang regency.

Fresh water originating from groundwater is highly dependent on aquifer layers that have high permeability to pass water [2]. Groundwater beneath the earth's surface is difficult to observe and track directly, so monitoring, mapping and modeling is necessary to understand groundwater availability [3]. The geophysical method that is generally used to find groundwater aquifers is the geoelectrical method. The current studies showed that the microtremor method can be applied to groundwater studies [5].

The HVSR method is typically used in three-component passive seismic (microtremor). The components measured in soil will characterize the local geology, natural frequency and amplification with respect to subsurface physical parameters [6]. The HVSR method will compare the spectrum of the horizontal component to the vertical component of the microtremor waves.

Microtremor is a micro wave emitted by the earth and vibrations that come from humans, machine vibrations, and etc. Microtremor waves consist of Rayleigh waves with the peak period of the H/V ratio giving the S-wave period. The HVSR method provides a comparison between the P-wave velocity

(Vp) and the S-wave velocity (Vs) so that it can determine the Poisson's ratio value which is used as a parameter to determine groundwater aquifers. with a Poisson's ratio of more than 0.25 and a Vp / Vs ratio of more than 1.73 [7].

This research aims to create 3D models of the aquifer layers using the Poisson's ratio values and the Vp/Vs values in Tembelang village, Candimulyo district, Magelang regency, as it will be beneficial for water drilling.

2. Experimental method

The microtremor data acquisition was carried out on September 25th and 26th 2018 in Tembelang Village, Candimulyo District, Magelang Regency with 71 measurement points with 6 lines shown in Fig.2.

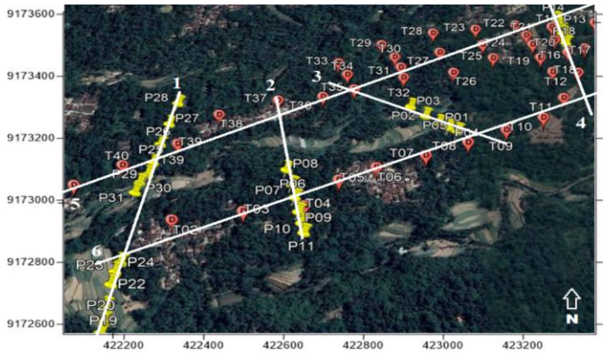


Fig.2: Survey design.

The data was processed using Geopsy, then converted with dinver, 2D-modeled using Surfer12, and 3D-modeled using Rockwork15.The research was carried out by conducting survey design, microtremor data acquisition, geopsy data processing, Vs analysis, Vp/Vs distribution analysis and Poisson's ratio value distribution analysis, then 2D and 3D modeling.

The research data processing was carried out by changing the microtremor data file to .txt form using notepad ++ then displaying the HVSR curve with Geopsy for frequency and amplitude values shown in Fig. 3, followed by inversion using dinver which gave Vp and Vs values shown in Fig. 4, then making contours using Surfer 12 and 3-dimensional modeling using Rockwork 15.

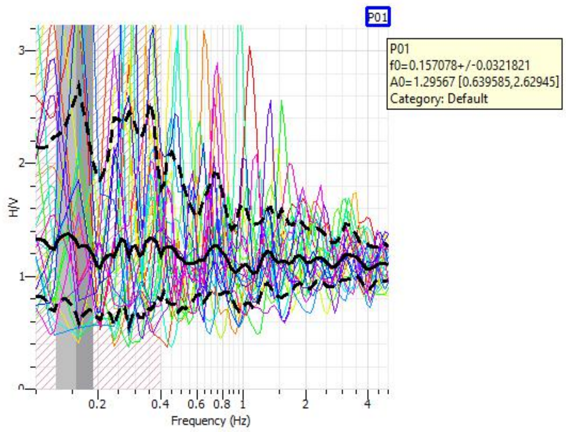


Fig. 3: HVSR curve of P01.

The curve showed the time-frequency information of the vertical component of noise wave field that acts as a trigger. It is also correlated with continuous wavelet transformation (CWT) that is performed on the east, north, and vertical component. The horizontal and vertical components provide amplification, frequency, and time; and then they are stored to estimate the ratio of H/V. The vibrant curves in the histogram mainly represent DFA, ellipticity, H/V microtremor, time-frequency value, and equal contribution of Rayleigh and love waves [8].

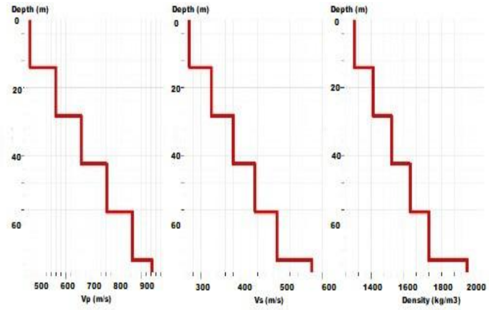


Fig. 4: Inversion of P01.

3. Results and discussion

Frequency and Amplification Contour

The frequency value is directly proportional to the transverse wave velocity value and is inversely proportional to the thickness of the rock. Thus, the frequency value will provide information about the thickness of the sediment layer and the transverse wave velocity passing through each layer. Moreover, the frequency value represents the characteristics of the sediment layer [9]. The frequency values in the study area range from 0.12 to 0.65 Hz. The frequency contours are shown in Fig. 5.

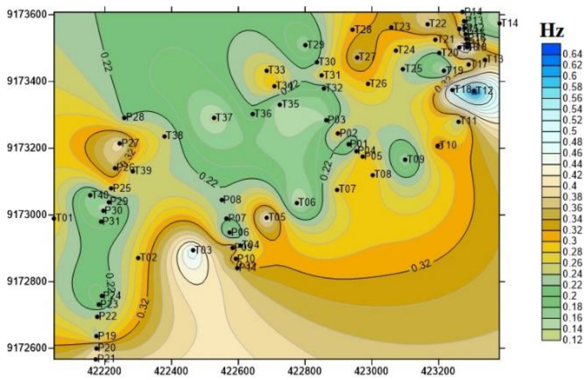


Fig. 5: Frequency contour of the 71 measurement points.

The Amplification values provide an overview of the distance from the change in the acceleration of motion in the soil from the bedrock to the surface [7]. The amplification values in the study area range from 1.06 to 2.38 m. The amplification contour is shown in Fig. 6.

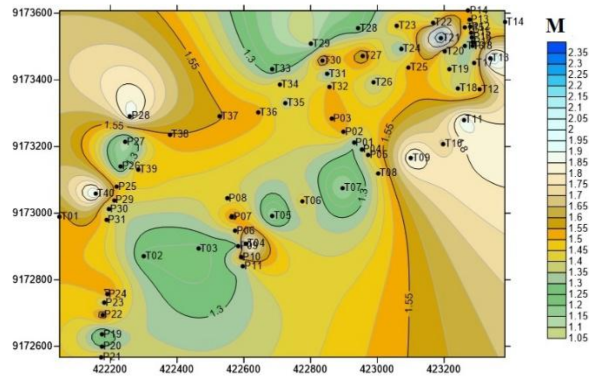
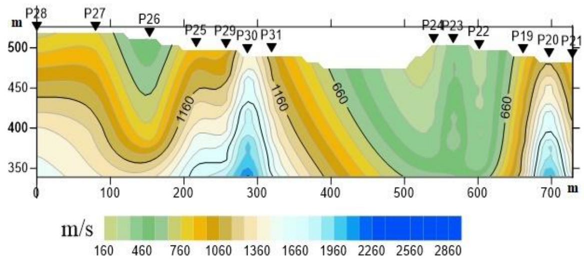


Fig. 6: Amplification contour of the 71 measurement points.

Transverse Wave Velocity Modeling (Vs)

Transverse wave velocity (Vs) affects the value of the wave velocity in the basement and shows the thickness of the sediment through its wave propagation [10]. The transverse wave (Vs) profile analysis determines the bedrock and sediment layer based on the contrast values of the transverse wave. It also provides the depth of the layers [11]. The quarter wavelength at the resonant frequency also contributes to the transverse wave velocity to a certain depth [12]. The transverse wave values vary from 169.27 m/s to 2909.78 m/s. The 2-dimensional modeling of transverse wave velocity (Vs) values on lines 1, 2, 3, 4, 5, and 6 are shown in Fig. 7 and the 3-dimensional modeling of transverse wave velocity (Vs) values are shown in Fig. 8.



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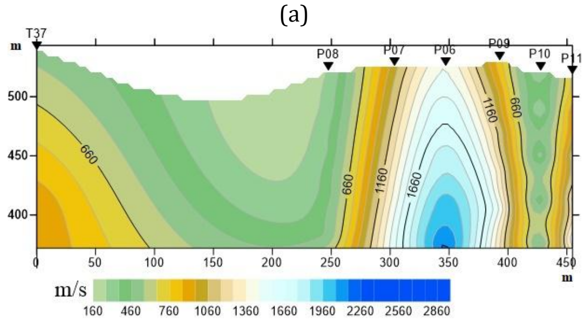

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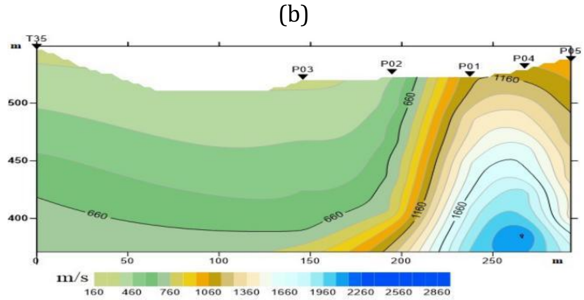

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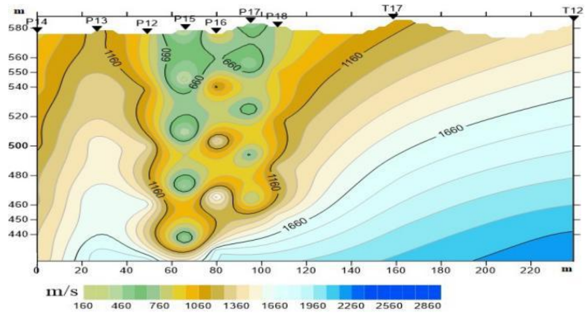

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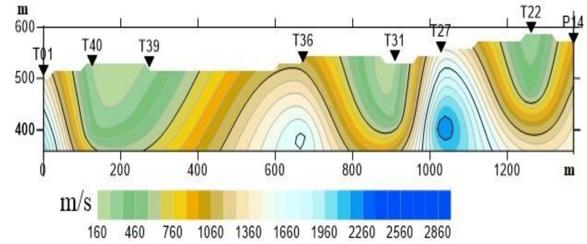

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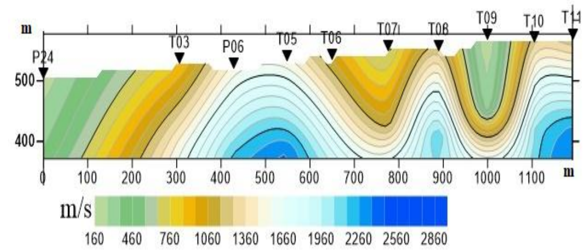
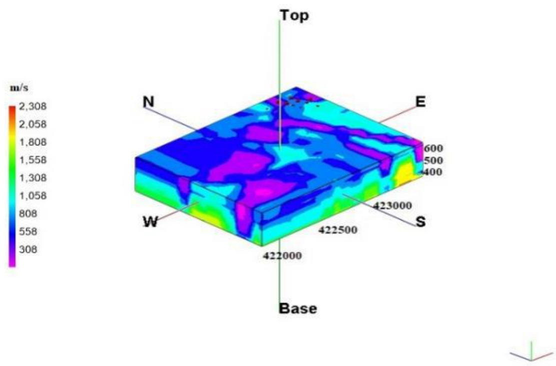
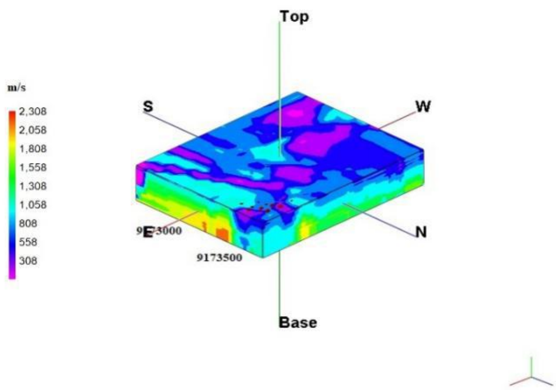


(f)

Fig. 7: (a) 2D modeling of transverse wave on Line 1, (b) Line 2, (c) Line 3, (d) Line 4, (e) Line 5, and (f) Line 6.



(a)

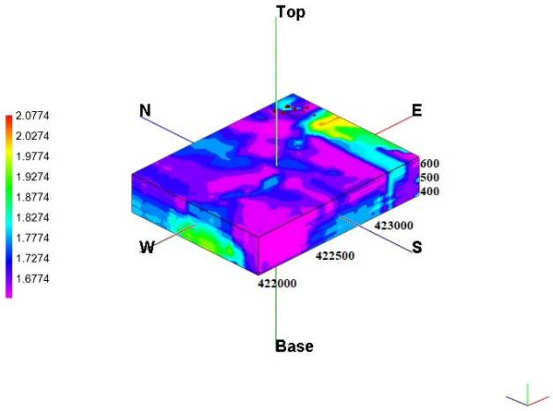


(b)

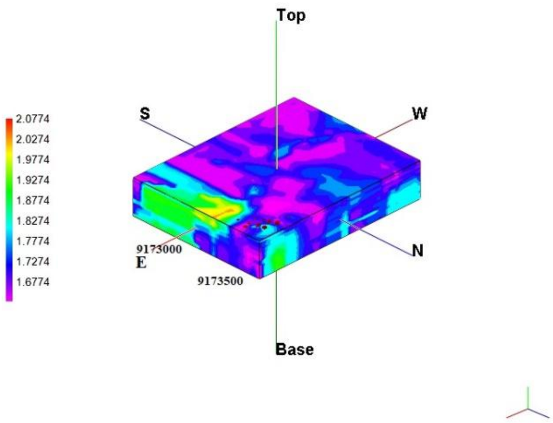
Fig. 8: (a) 3D modeling of transverse wave in W-E direction and (b) E-W direction.

Vp/Vs Modeling

The Vp/Vs ratio determines the lithology of the rock layers. Vp/Vs ratio with a value above 1.73 is a wet condition with an assumption that there are rocks filled with water. Vp/Vs ratio with a value below 1.73 is interpreted in relation to a dry and gaseous rock. The greater the Vp/Vs value, the higher the porosity value of a rock [13].The values of the Vp/Vs ratio range from 1.63 to 2.11. The 3-dimensional modeling of the Vp/Vs ratio are shown in Fig. 9.



(a)



(b)

Fig. 9: (a) 3D modeling of Vp/Vs in W-E direction and (b) Vp/Vs in E-W direction.

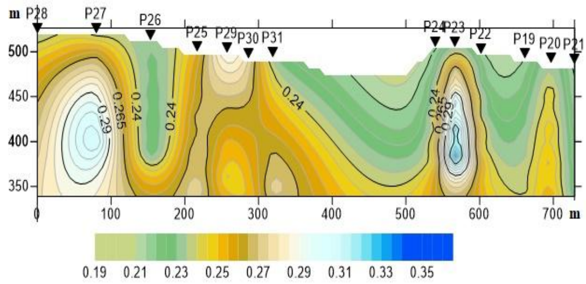
The modeling showed that point P09, P12, P15, P19, P21, P24, P26, T04, T05, T07, T08, T09, T17, T24, T28, T34 and T39 were below 1.73, thus they were interpreted in relation to a dry and gaseous rock. As the Vp/Vs ratio is above 1.73, it is a condition of high-water prospects and porosity. The higher the Vp/Vs ratio, the greater the rock porosity value, this is what causes water to accumulate in the rock [5].

Poisson's Ratio Modeling

Poisson's ratio with a value above 0.25 has water prospects that is directly proportional to the Vp/Vs ratio value [1].The relationship between Poisson's ratio (σ) and the ratio of Vp/Vs can be formulated as follows [11] :

$$\sigma = \frac{V_p^2 - 2V_s^2}{2(V_p^2 - V_s^2)} = \frac{(V_p/V_s)^2 - 2}{2[(V_p/V_s)^2 - 1]} \qquad (1)$$

The Poisson's ratio values in the study area range from 0.20 to 0.35. Two-dimensional modelings of Poisson's ratio values on lines 1, 2, 3, 4, 5, and 6 are shown in Fig. 10, and three-dimensional modeling of Poisson's ratio values are shown in Fig. 11.



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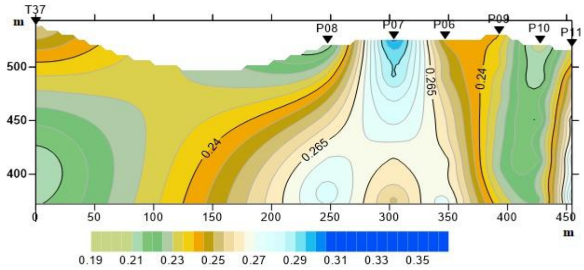

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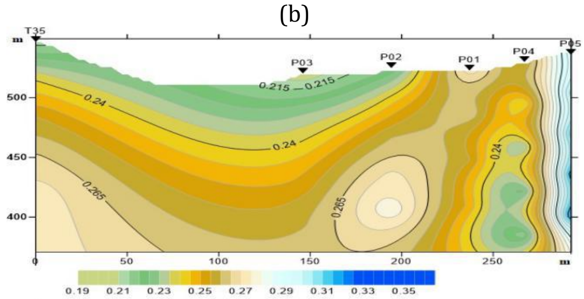

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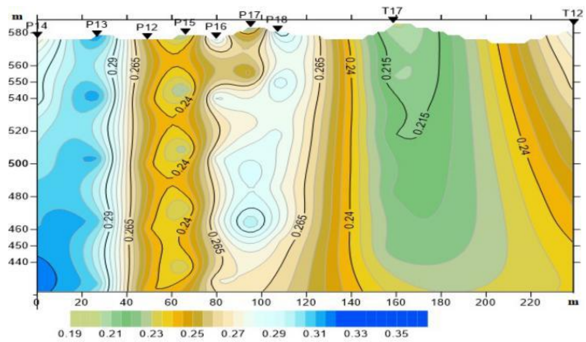

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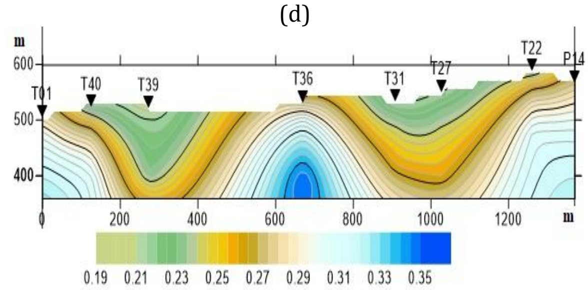

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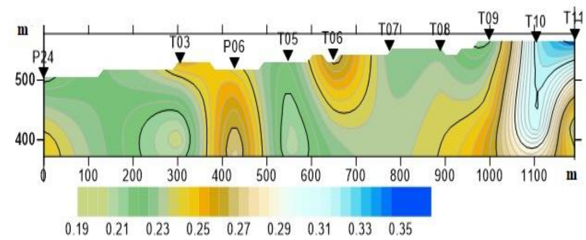
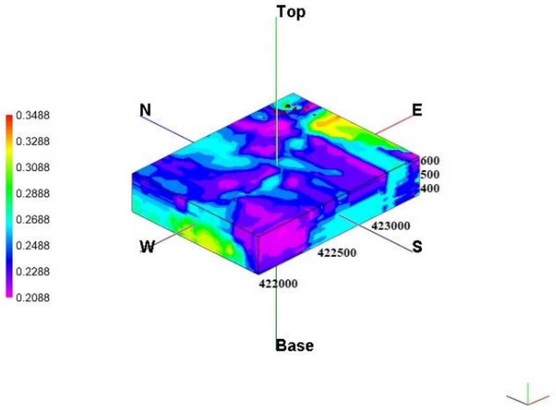
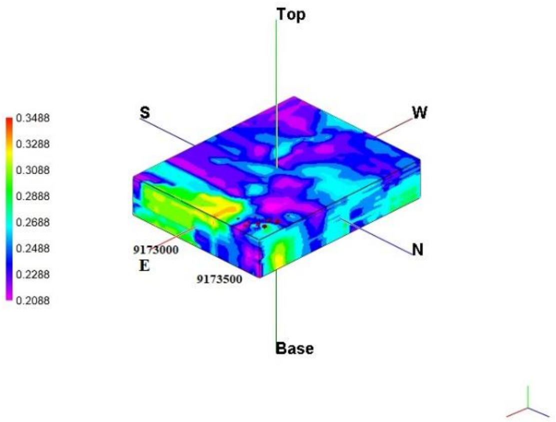


(f)

Fig. 10: (a) 2D modeling of Poisson's Ratio on Line 1, (b) Line 2, (c) Line 3, (d) Line 4, (e) Line 5, and (f) Line 6.



(a)



(b)

Fig. 11: (a) 3D modeling of Poisson's Ratio in W-E direction (b) E-W direction.

The prospects were found on line 1 around P22 with a Poisson's ratio value ranging from 0.21 to 0.25. line 2 around P8 with a Poisson's ratio value ranging from 0.20 to 0.28, line 3 around P2 with a Poisson's ratio value ranging from 0.22 to 0.28 and P3 with a Poisson's ratio value ranging from 0.20-0.26, line 4 around P16 with a Poisson's ratio value ranging from 0.21 to 0.29, P17 with a Poisson's ratio value ranging from 0.20 to 0.30, and P18 with a Poisson's ratio value ranging from 0.21 to 0.30, and line 5 around T22 with a Poisson's ratio value ranging from 0.22 to 0.29, T31 with a Poisson's ratio value ranging from 0.20 to 0.26, and T40 with a Poisson's ratio value ranging from 0.21 to 0.31.

4. Conclusions

The frequency values, the amplification values, and the transverse wave velocity values comprehensively represented a significant explanation about the thickness of the sediment layers. The Vp/Vs ratio values and the Poisson's ratio values confirmed the water prospects. Three-dimensional modeling of groundwater aquifers based on Vp/Vs and Poisson's ratio were successfully performed with Vp/Vs values ranging from 1.63 to 2.11 and Possion's ratio values ranging from 0.20 to 0.35. It is suspected that the confined aquifer layer was found on line 1 around point P22 with a depth of more than 184 m, line 2 around point P8 with a depth ranging from 108 to 180 m, line 3 around point P2 and P3 with a depth ranging from 91 to 161 m, line 4 around points P16, P17, and P18 with a depth ranging from 32 to 187 m, line 5 around point T22 with a depth ranging from 63 to 157 m, point T31 with a depth ranging from 122 to 152 m, and point T40 with a depth ranging from 71 to 178 m, line 6 does not show any aquifer layers.

References

[1] Kusnoputranto, "Kesehatan Lingkungan Jakarta," *FKM UI*, (2000).

[2] Santosa, L. W. and T. N. Adji, "Karakteristik Akuifer dan Potensi Air tanah Graben Bantul," *UGM*, (2014).

[3] D. Hess, "A L and_scape Appreciation, 11th edn", *McKinight's Phys. Geograp*. New York: Pearson Publishers, (2014).

[4] Sungkono and B. J. Santosa, "Karakterisasi Kurva Horizontal-To-Vertical Spectral Ratio, Kajian Literatur dan Permodelan," *ITS, Surabaya,* (2011).

[5] C. Sorensen and M. Asten, "Microtremor methods applied to groundwater studies," *J. Explor. Geophys.,* **38**, 2, (2007).

[6] D. Fäh, M. Wathelet, M. Kristekova, H. Havenith, B. Endrun, G. Stamm, V. Poggi, J. Burjanek, and C. Cornou, "Using ellipticity information for site characterisation," *NERIES deliverable JRA4 D4*, (2009).

[7] G. P. Hersir, and A. Bjornsson, "Geophysical Exploration for Geothemal Resources Principles and application," *UNU Geotherm. Training Programme Reykjavik*, Iceland, (1991).

[8] B. S. Mulyanto, and S. S. Arifin, "Penentuan Zona Rawan Guncangan Bencana Gempa Bumi Berdasarkan Analisis Nilai Amplifikasi HVSR Mikrotremor Dan Analisis Periode Dominan Daerah Liwa Dan Sekitarnya," *J. Explor. Geophys.*, **2**, (2013).

[10] Y. Nakamura, "Method of dynamic characteristics estimation of subsurface using microtremor on the Ground Surface," *Quar. report of RTRI, Railway Tech. Res. Inst.*, **30**, (1989).

[11] M. I. Von Seht and J. Wohlenberg, "Microtremor Measurements Used to Map Thickness of Soft Sediments," *Bull. Seismol. Soc. Am.*, **89**, 1, 250–259, (1999).

[12] W. B. Joyner and D. M. Boore, "Measurement, Characterization, and Prediction of Strong Ground Motion," *Earthquake Eng. and Soil Dynamics II, Proc. of Am. Soc.Civ.Eng.Geotech. Eng. Div. Specialty Conference*, 43–122, (1988).

[13] P. M. Shearer, "Introduction to Seismology," Cambridge University Press, USA, (2009).