

Identification of Potential Groundwater Aquifer Using Microtremor HVSr and Poisson's Ratio Modeling in Banyusidi, Pakis, Magelang, Central Java, Indonesia

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ABSTRACT

Groundwater exploration in mountainous agricultural areas requires an efficient method for identifying subsurface zones that may store and transmit groundwater. This study aims to delineate potential groundwater aquifer zones in Dusun Ngepoh Kidul, Banyusidi, Pakis, Magelang, Central Java, using the microtremor Horizontal-to-Vertical Spectral Ratio (HVSr) method and subsurface elastic-parameter modelling. Twenty-five observation locations, including station 4B, were distributed across the study area. The acquired microtremor data were interpreted using HVSr inversion to obtain subsurface parameters, particularly shear-wave velocity and Poisson's ratio. The resulting models were visualized in three dimensions and evaluated through the spatial relationship between Poisson's ratio anomalies, subsurface stiffness, and depth. The three-dimensional interpretation identifies a potential groundwater-bearing zone beneath station 4, with an estimated depth of approximately 50 m and a possible maximum depth of about 60 m. The potential zone extends southward toward station 4B and westward in the area south of station 5. A separate depth interpretation

indicates that the most prospective aquifer interval occurs at approximately 30–50 m beneath station 4B. The target is interpreted as a potential unconfined aquifer occupying a depression or basin-like subsurface geometry within relatively hard material. The results demonstrate that microtremor HVSr inversion combined with Poisson's ratio and 3D modelling can provide useful preliminary information for groundwater exploration. Nevertheless, the interpreted aquifer should be verified using electrical resistivity, borehole, well-log, or pumping-test data before groundwater development.

Keywords: groundwater; aquifer; microtremor; HVSr; Poisson's ratio; V_p/V_s ; subsurface modelling; Magelang

INTRODUCTION

Groundwater is an important component of freshwater resources and is widely used for domestic, agricultural, and economic activities. Its occurrence and distribution are controlled by lithology, porosity, permeability, fractures, compaction, and the degree of saturation of subsurface materials. Because direct drilling provides information only at discrete locations and can be costly, geophysical methods are commonly used to characterize the subsurface before drilling.

The Horizontal-to-Vertical Spectral Ratio (HVSR) method is a passive seismic technique that uses ambient vibrations recorded at the ground surface. The method was introduced by Nakamura [1] and has subsequently been widely investigated for estimating resonance characteristics and subsurface impedance contrasts [2,3]. Microtremor inversion can provide estimates of shear-wave velocity (V_s), compressional-wave velocity (V_p), layer thickness, and other elastic parameters useful for geological interpretation [4,5]. Poisson's ratio is a complementary elastic parameter derived from the relationship between V_p and V_s . For an isotropic elastic medium, $\nu = [(V_p/V_s)^2 - 2] / \{2[(V_p/V_s)^2 - 1]\}$. Previous groundwater studies have demonstrated the usefulness of V_p/V_s and Poisson's ratio for delineating potential aquifer zones. Zuhri et al. [6] used 71 microtremor stations in Candimulyo, Magelang, and obtained Poisson's ratio models for aquifer delineation. Yuliyanto and Nurwidyanto [7] demonstrated 2D and 3D aquifer delineation from Poisson's ratio. More recent work has shown that combining microtremor with geoelectrical data can strengthen aquifer interpretation [8]. The present study focuses on Dusun Ngepoh Kidul, Banyusidi, Pakis, Magelang, Central Java. The field summary contains 25

observation locations and a three-dimensional model of Poisson's ratio and subsurface stiffness. The source interpretation identifies a potential groundwater zone beneath station 4 at approximately 50 m depth, extending to a possible maximum depth of 60 m and spreading toward station 4B and westward south of station 5. A separate depth model identifies the most prospective aquifer interval at approximately 30–50 m beneath station 4B. The objective is to formulate these observations into a systematic geophysical interpretation and delineate the geometry and depth of the potential groundwater aquifer.

MATERIALS & METHODS

Write here procedure/technique

Study area and measurement design

The study was conducted in Dusun Ngepoh Kidul, Desa Banyusidi, Kecamatan Pakis, Kabupaten Magelang, Central Java, Indonesia. The measurement network consists of 25 locations: stations 1–25, with an additional position identified as station 4B. Coordinates range from approximately 429309–429490 m Easting and 9175503–9175591 m Northing, while elevations range from 1060–1073 m above sea level (Table 1 and Fig.1)

Table 1. Coordinates and elevations of the microtremor observation locations

Station	Easting (m)	Northing (m)	Elevation (m)
1	429490	9175507	1071
2	429449	9175506	1070
3	429405	9175504	1067
4	429359	9175503	1061
4B	429348	9175492	1060
5	429310	9175508	1062
6	429490	9175525	1071
7	429448	9175527	1069
8	429403	9175527	1066
9	429356	9175524	1063
10	429309	9175522	1062
11	429488	9175550	1073
12	429445	9175546	1069
13	429405	9175544	1067
14	429354	9175553	1066
15	429309	9175537	1064
16	429487	9175570	1073
17	429446	9175566	1069

18	429405	9175569	1067
19	429356	9175566	1066
20	429308	9175563	1065
21	429485	9175591	1073
22	429446	9175588	1070
23	429407	9175590	1067
24	429358	9175588	1067
25	429309	9175587	1067



Figure 1. Distribution of microtremor observation stations in Ngepoh Kidul, Banyusidi, Pakis, Magelang. The map and station coordinates are reproduced from the uploaded field summary.

Microtremor HVSR analysis

The microtremor records were analysed using the Horizontal-to-Vertical Spectral Ratio (HVSR) approach. The horizontal

spectral amplitude is related to the two horizontal components and the vertical component provides the reference spectrum:

$$HVSR(f) = \sqrt{[H_{NS}^2(f) + H_{EW}^2(f)]/V_z^2(f)} \quad (1)$$

The resulting H/V response is used to characterize subsurface resonance and impedance contrast. Data acquisition and processing should follow the quality-control principles of the SESAME guidelines [2]. The uploaded summary does not provide the instrument model, data logger, recording duration, sampling frequency, window length, smoothing algorithm, or inversion-search parameters; these values should be inserted from the original field and processing records before final submission.

Inversion and Poisson's ratio

HVSR inversion was used to estimate the subsurface elastic structure. The principal parameters considered for groundwater interpretation are V_p and V_s . Poisson's ratio was calculated from the V_p/V_s relationship:

$$v = [(V_p/V_s)^2 - 2] / \{2[(V_p/V_s)^2 - 1]\} \quad (2)$$

The Poisson's ratio scale of approximately 0.20–0.46.

Three-dimensional interpretation

The inverted parameters were spatially interpolated to generate three-dimensional subsurface models. Potential aquifer zones were identified from coherent Poisson's ratio anomalies and their spatial relationship with interpreted subsurface stiffness. The 3D interpretation was then evaluated using the depth model to estimate the vertical extent of the potential aquifer.

RESULT

Spatial distribution of the potential aquifer

The three-dimensional Poisson's ratio model shows spatially variable zones, with a principal anomaly in the southern part of the survey network. The source interpretation marks the most important potential zone beneath station 4. The anomaly is

interpreted to occur at approximately 50 m depth, with a possible maximum depth of about 60 m, and to spread southward toward station 4B and westward in the area south of station 5.

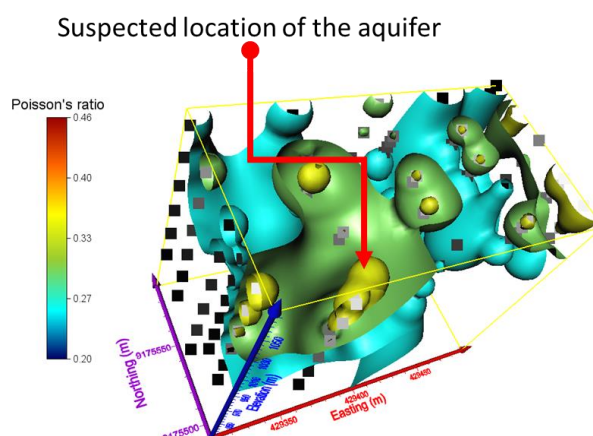


Figure 2. Three-dimensional Poisson's ratio model and plan-view interpretation of the potential groundwater zone.

The main target is beneath Station 4 at approximately 50 m depth, with possible continuation toward station 4B and west of the area south of station 5.

The Poisson's ratio colour scale ranges approximately from 0.20 to 0.46. The target is not interpreted from Poisson's ratio alone; the anomaly is evaluated together with the 3D geometry and the subsurface stiffness model. This integrated approach is consistent with previous Magelang studies

using V_p/V_s and Poisson's ratio for aquifer delineation [6,7].

Subsurface stiffness and geological boundary

The stiffness model identifies a relatively hard subsurface zone interpreted in the source report as having high water-storage potential, together with a separate unit characterized by moderate-to-high stiffness. The model also indicates an interpreted boundary between the soil layer and the underlying rock layer.

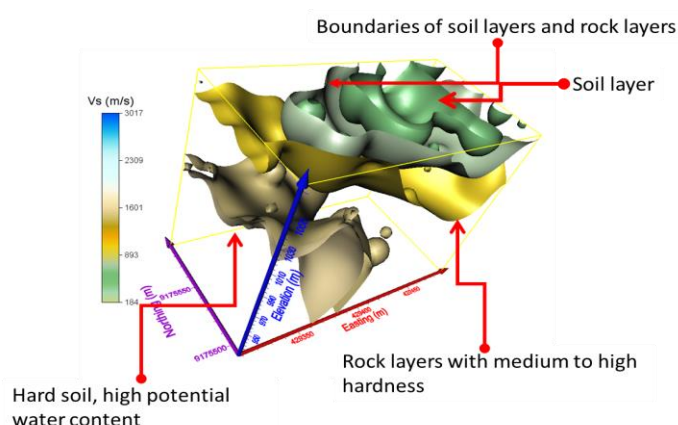


Figure 3. Three-dimensional model of subsurface stiffness and the interpreted boundary between soil and rock units. The original interpretation identifies a relatively hard layer with potential for water storage and a deeper unit with moderate-to-high stiffness.

The spatial relationship between the potential aquifer and the stiffness boundary suggests that the groundwater target may be associated with a local depression or basin-like geometry within a relatively competent formation. Such geometry can favour groundwater accumulation where sufficient permeability and hydraulic connectivity are present. However, seismic stiffness alone cannot determine hydraulic conductivity or transmissivity.

Depth of the most prospective aquifer

The depth model identifies the most prospective aquifer interval beneath Station 4B at approximately 30–50 m depth. This refines the broader 3D interpretation, which places the potential zone beneath Station 4 at approximately 50 m and allows a possible maximum depth of approximately 60 m. The apparent spatial offset is reasonable because station 4B lies immediately south of station 4 and the interpreted anomaly is described as extending southward.

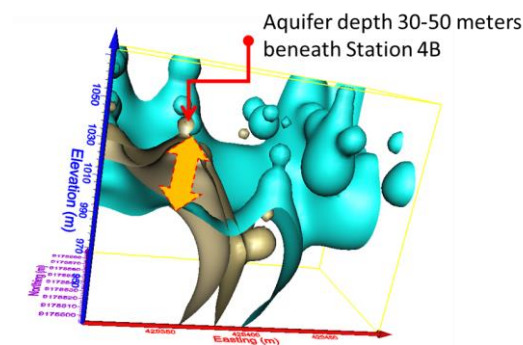


Figure 4. Three-dimensional depth interpretation of the most prospective groundwater aquifer. The interpreted aquifer interval occurs at approximately 30–50 m depth beneath the vicinity of Station 4B.

DISCUSSION

The combined results indicate one principal groundwater target rather than multiple independent aquifers. The target is interpreted as an unconfined aquifer with a basin-like geometry. The source conclusion identifies the most prospective location beneath station 4 at 30–50 m depth. The inferred geometry and Poisson's ratio response are consistent with the general use of elastic-property contrasts for groundwater delineation, but they do not directly establish groundwater level, hydraulic conductivity, transmissivity, or yield.

Previous research in Candimulyo, Magelang, demonstrated that Poisson's ratio derived from microtremor inversion can be used to construct 3D aquifer models [6]. Yuliyanto and Nurwidyanto [7] similarly demonstrated 2D and 3D aquifer delineation from Poisson's ratio. Recent combined microtremor–geoelectrical research in Magelang indicates that independent resistivity information can strengthen

aquifer interpretation [8]. A recent study in coastal Demak also used Vs together with Poisson's ratio to distinguish potential aquifers from aquicludes [9].

The most appropriate validation is a 2D electrical-resistivity survey crossing stations 4–4B and the area south of station 5. Existing well or borehole data should be used to validate the interpreted depth. If drilling is planned, the station-4/4B target should receive priority, followed by pumping tests to determine transmissivity, hydraulic conductivity, and sustainable yield.

CONCLUSION

Microtremor HVSR analysis and three-dimensional subsurface modelling identify a principal potential groundwater aquifer in Dusun Ngepoh Kidul, Banyusidi, Pakis, Magelang. The main anomaly is located beneath the vicinity of station 4 at approximately 50 m depth, with a possible maximum depth of about 60 m, and extends

southward toward station 4B and westward south of station 5. The most prospective interval is interpreted at approximately 30–50 m depth beneath station 4B. The target is interpreted as a potential unconfined aquifer with a basin-like geometry. The elastic parameter shown as 'Rasio Poisson' is correctly treated as Poisson's ratio, not porosity. Integration of Poisson's ratio, subsurface stiffness, spatial continuity, and depth modelling provides a useful preliminary framework for groundwater exploration. The interpretation should nevertheless be validated by electrical resistivity, borehole, well-log, or pumping-test data before groundwater exploitation.

Declaration by Authors

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