Yadanabon University Research Journal, 2019, Vol-10, No.1

Estimation of Sedimentary Layered Media at Prambanan Area, Yogyakarta Indonesia

Pyi Soe Thein*, and Subagyo Pramumijoyo**

Abstract

In this study, we investigated the sedimentary layered media at Prambanan area, Yogyakarta. Several powerful earthquakes have struck the Opak River Fault during recent years. An earthquake occurred at Sengir village, Prambanan District, Yogyakarta on May 27, 2006, and caused several casualties. Following the event, we conducted a microtremor survey to estimate the shaking intensity distribution during the earthquake. We performed single observations of microtremor at 124 sites in Prambanan area. We also conducted 2-site bore holes investigation to gain a representative determination of the soil condition of subsurface structures in Prambanan. From the Standard Peneration Tests (SPT) of borehole observations, the prambanan area corresponds to relatively soil condition with Vs 298 m/s, the predominant periods due to horizontal vertical ratios (HVSRs) are in the range of 0.95 to 1.92 s and the frequency are in the range of 0.48 to 1.19 Hz. By making these observations, we can obtain a relationship between predominant periods, frequency, general soil types and peak ground acceleration. The results enabled us to estimate the site-dependent shaking characteristics of earthquake ground motion.

Keywords: Opak river Fault, Microtremor observations and SPT

1 Introduction

The magnitude of the main shock was Mw 6.2 and the epicenter was located at 8.04 South Latitude and 110.43 East Longitude (Indonesian Bureau for Meterological and Geophysics, 2006) or at 8.007 South Latitude and 110.286 East Longitude (USGS, 2006). The duration of strong ground shaking was 57 seconds (Karnawati and Fathani, 2006). The largest earthqukake occurred at the slope of tuffaceous sandstone situated in Sengir Village, Prambanan District (Figure1). Microtremor observations and subsurface geological investigation were carried out to analyze the strong ground motion characteristics at Prambanan area. The subsurface geological investigation included, drilling and logging of two boreholes with an aggregate depth of 30 m. In recent years, microtremor observations have become popular for the purpose of investigating soil structure, because they do not require much manpower and cost. A microtremor is a small ground vibration excited by artificial sources or natural phenomena such as factories, traffic, wind, waves, etc. As the vibration propagates through the ground surface, the surface waves such as the Rayleigh and Love waves are dominant.

2. Seiscimity

Historical seismicity of Yogyakarta was reported since 19th century. Location of epicenters and level of intensity were still approximate based on the European resident note. The most important earthquakes that stroke Yogyakarta occured in 1840, 1867 and 1875 (Newcomb and McCann, 1987). The events of historical earthquakes around Yogyakarta are listed in Table 1, including the instrumental records. Since there are no GPS data for the first four and 6th events, the locations are assumed to be center of the affected area [1].

Earthquake magnitude and depth and refers the sources (USGS, ISC and BMKG). In Figure 1, the Yellow Circle indicates the most affected earthquake potentials can be expected within the radius of 200 km and the red circles indicate distribution of epicenters of the earthquakes with magnitude < 70 km, 70-300 km and > 300 km in depth. The projections in this figure are

* Department of Geology, Yadanabon University, Mandalay, Myanmar
** Geological Engineering Department, Gadjah Mada University, Yogyakarta, Indonesia

Yadanabon University Research Journal, 2019, Vol-10, No.1

based on Digital Elevation Model from SRTM satellite image in 90 meter resolution. The variation in sizes of the circle suggests relative magnitude.

Table 1 Historical earthquakes around Yogyakarta (Compiled from 1USGS, 2Mid American Earthquake Center, van Bemmelen, 1949, 3Newcomb and McCann, 1987, and 4Tokuji Utsu, 2002)

Date	Latitude	Longitude	Ricter Scale, Intensity, or the reported description	Depth (km)
1797 *2	-	-	8.4	-
1833 *2	-	-	8.7	-
1840 Jan 4 *2,3	-	-	Tsunami	-
1859 Oct 20 *2,3	-	-	Tsunami	-
1867 June 10 *2,3,4	-7.8	110.5	MM>VIII	-
1875 Mar 28 *2,3	-	-	MM= V~VII	-
1921 Sept 11 *2	11.35	110.76	7.5 (Ms)	-
1924 Nov 12 *4	7.3	109.5	-	-
1924 Dec 2 *4	7.3	109.9	-	-
1937 Sept 27 *2	8.88	110.65	7.2 (Ms)	-
1943 July 23 *3,4	8.6	109.9	8.1	90
1955 May 29 *2	10.30	110.50	6.38 (Ms)	-
1957 Oct 12*3	8.3	110.3	6.4	-
1974 Sept 7 *2	9.80	108.48	6.5 (Ms)	-
1979 Jul 24 *2	11.15	107.71	6.9 (Ms)	31
1979 Nov 2 *2	7.66	108.25	6.0 (Ms)	25

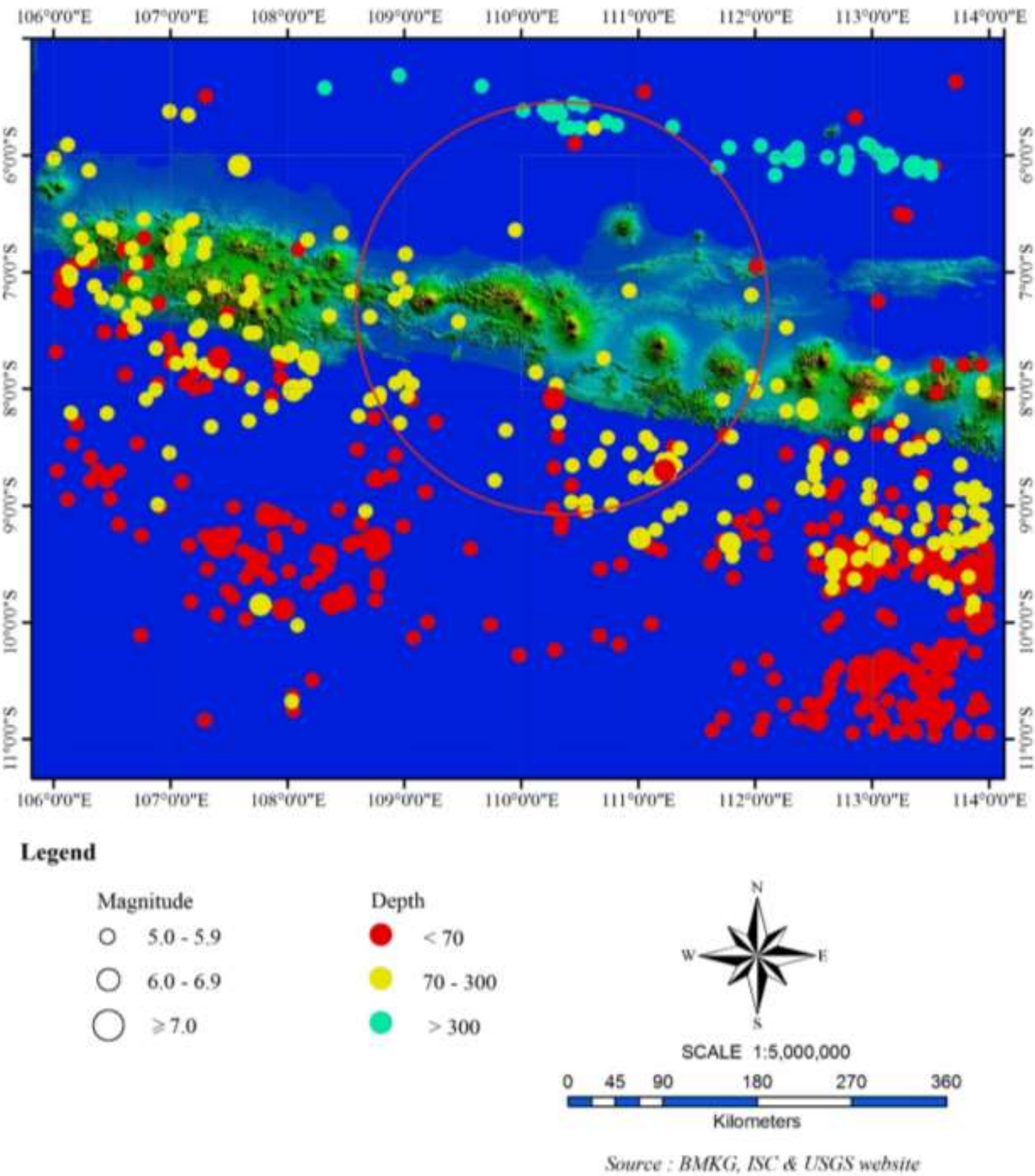


Figure 1 Epicentral distribution of some important earthquakes around Prambanan province [2]

3. Observation Instruments And Site Lay-Out

The instrument that are used for microtremor measurements are primary instruments for this research. The instrument shown in the Figure 2, model GPL 6A 3P that produced by Mitutoyo Corporation was also used for microtremor measurements in Prambanan area. All instruments have 3 sensors and measures for 3 direction; N-S, E-W and U-D. (Figure 3,4,5)

Yadanabon University Research Journal, 2019, Vol-10, No.1

Figure 2: Instrument of Microtremor GPL- 6A3P Model, Mitutoyo Corporation.

Figure 3: Microtremor single station measurement at Prambanan temple area.

Figure 4: Microtremor single station measurement at Plaosan temple area.

Figure 5 Microtremor single station measurement at Sawchiwan temple area.

4. Microtremor Single Station Observations

A three-component accelerometer with data logger, GPL-6A3P, produced by the Mitsutoyo Co. Ltd., was used. Observations were done in the daytime at the places away from noises sources such as vehicle traffic and which provide stable conditions for the installed equipment such as a concrete or asphalt base. The number of single point observations was 124 (Figure 6). The sampling frequencies were 100 Hz or 500 Hz and the observation periods were 10 to 15 minutes.

Yadanabon University Research Journal, 2019, Vol-10, No.1

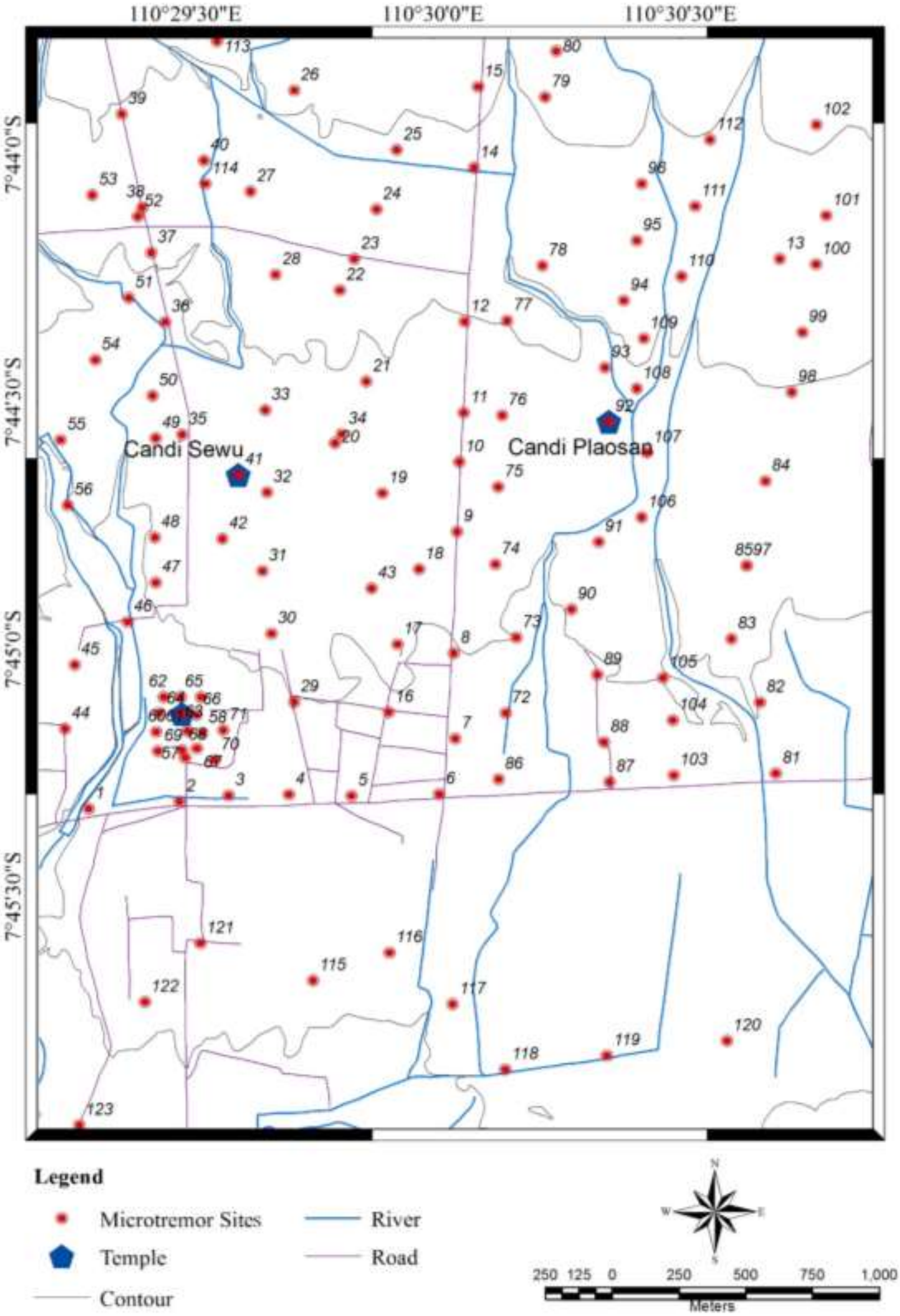


Figure 6 Location of the microtremor observation sites.

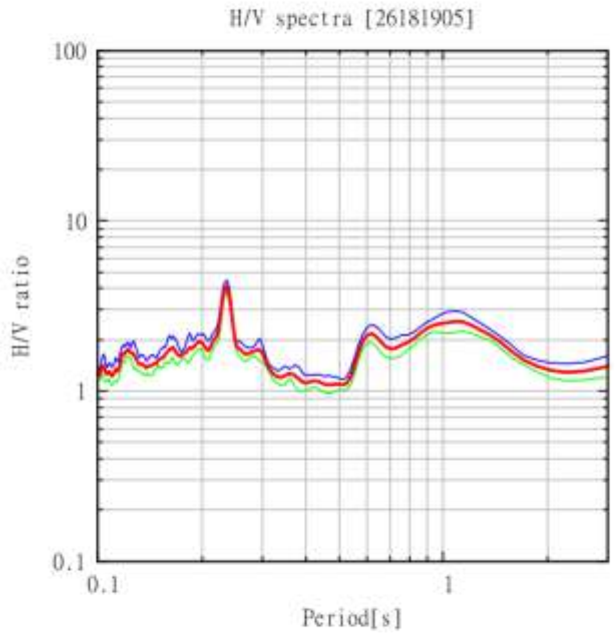
4.1. Predominant Period of H/V and Frequency

The spectral ratio of horizontal and vertical motion obtained by microtremor observations is called the H/V spectrum. The predominant period of an H/V spectrum is thought to be equivalent to the predominant period of the ground directly beneath the site [3].

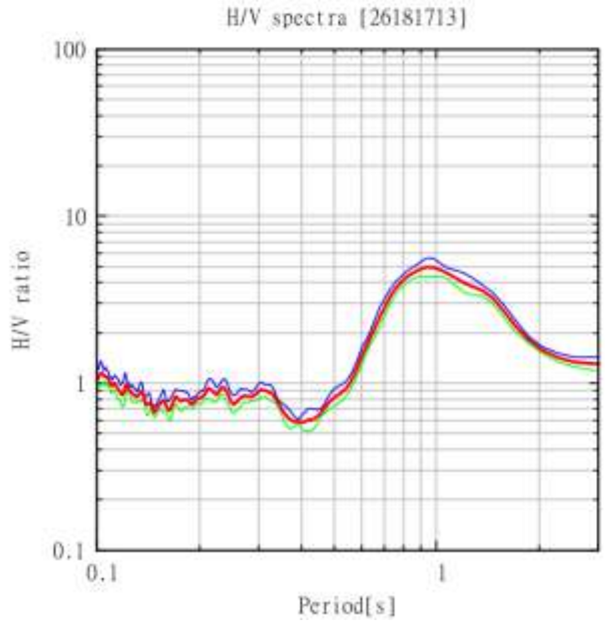
Yadanabon University Research Journal, 2019, Vol-10, No.1

H/V spectra at each site in the target area were calculated. We classified the H/V spectra calculated into three types according to the shape of the spectra.

- ✓ Type A: with short period peak (Figure 7(a))
- ✓ Type B: with long period peak (Figure 7(b))
- ✓ Type C: those without clear peaks



(a) short period peak



(b) long period peak

Figure 7: Example of the H/V Spectrum ratio (a) short period peak and (b) long period peak (mean value and 1σ).

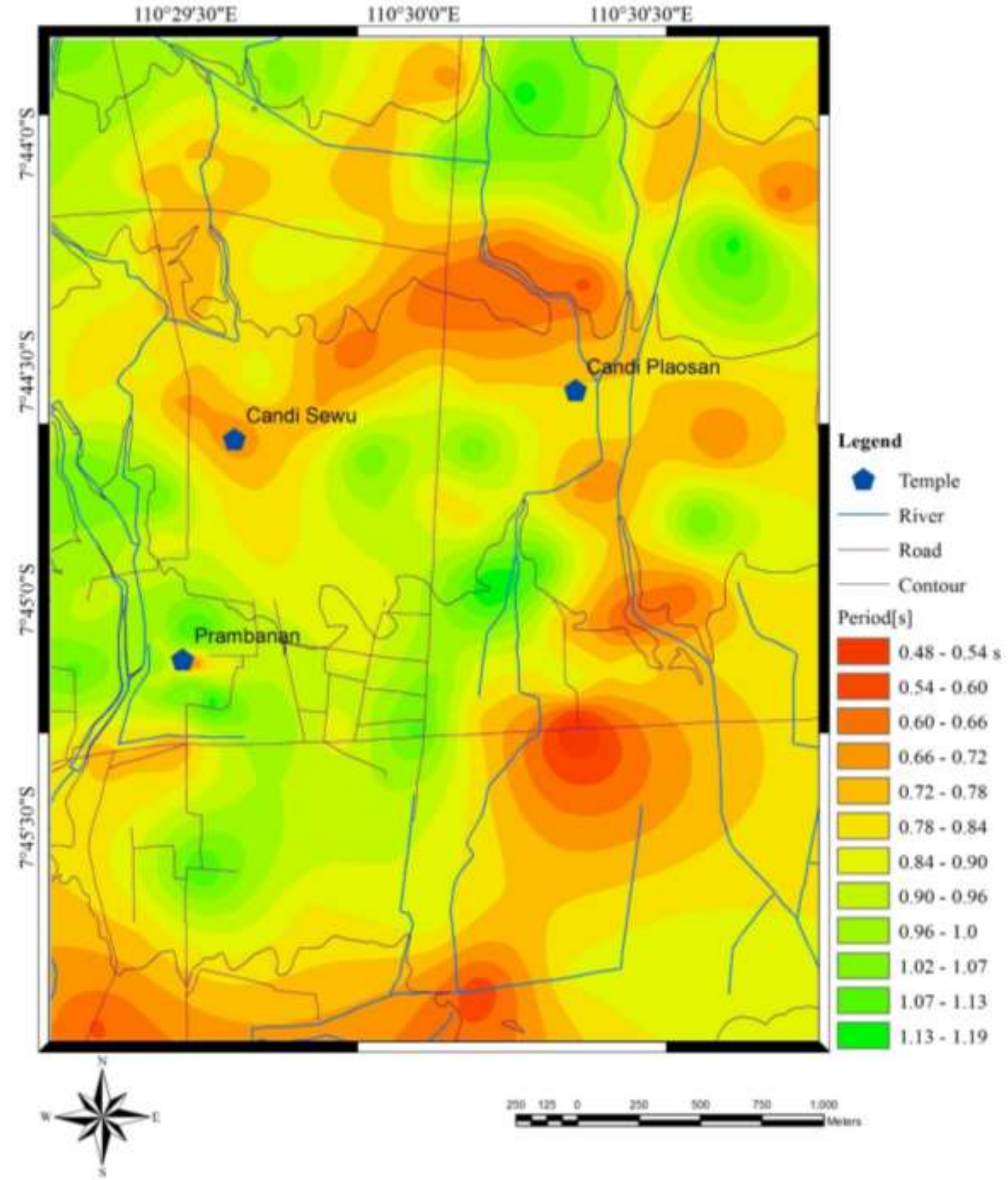


Figure 8: Spatial distributions of longer predominant period.

Equation (1) shows the method used to calculate HVSR using the observed records.

$$HVSR = \frac{\sqrt{(F_{NSi}(\omega))^2+(F_{EWi}(\omega))^2}}{F_{UDi}(\omega)} \qquad (1)$$

where, $F_{NSi}(\omega)$ and $F_{UDi}(\omega)$ denote the Fourier amplitude of the NS, EW and UD components of each interval, respectively, and (ω) is the frequency.

Distinct peaks express the characteristics of the layers for which the shear wave velocity is quite different. The shorter and longer periods are corresponding to a shallow and a deep soil layer. Types A and B reflect an effect of the shallow and the deep soil layer, respectively. Type C is an observation site that has hard soil. Thus, we established the data for both long and short predominant periods [4, 5, 6, 7]. Although the predominant period does not always indicate the characteristics of an individual layer because typically the actual shaking mode of the ground is complex, we assumed that the long and short periods reflected information from each layer. Although there are 124 observation points, the points are not adequate to cover all the target area. If each value of the predominant period obtained is considered to be a realization of a stochastic random field. Space interpolation is conducted by ordinary kriging technique [8]. The results are shown in Figure 8. Figure 9 shows frequency distribution of the Prambanan area.

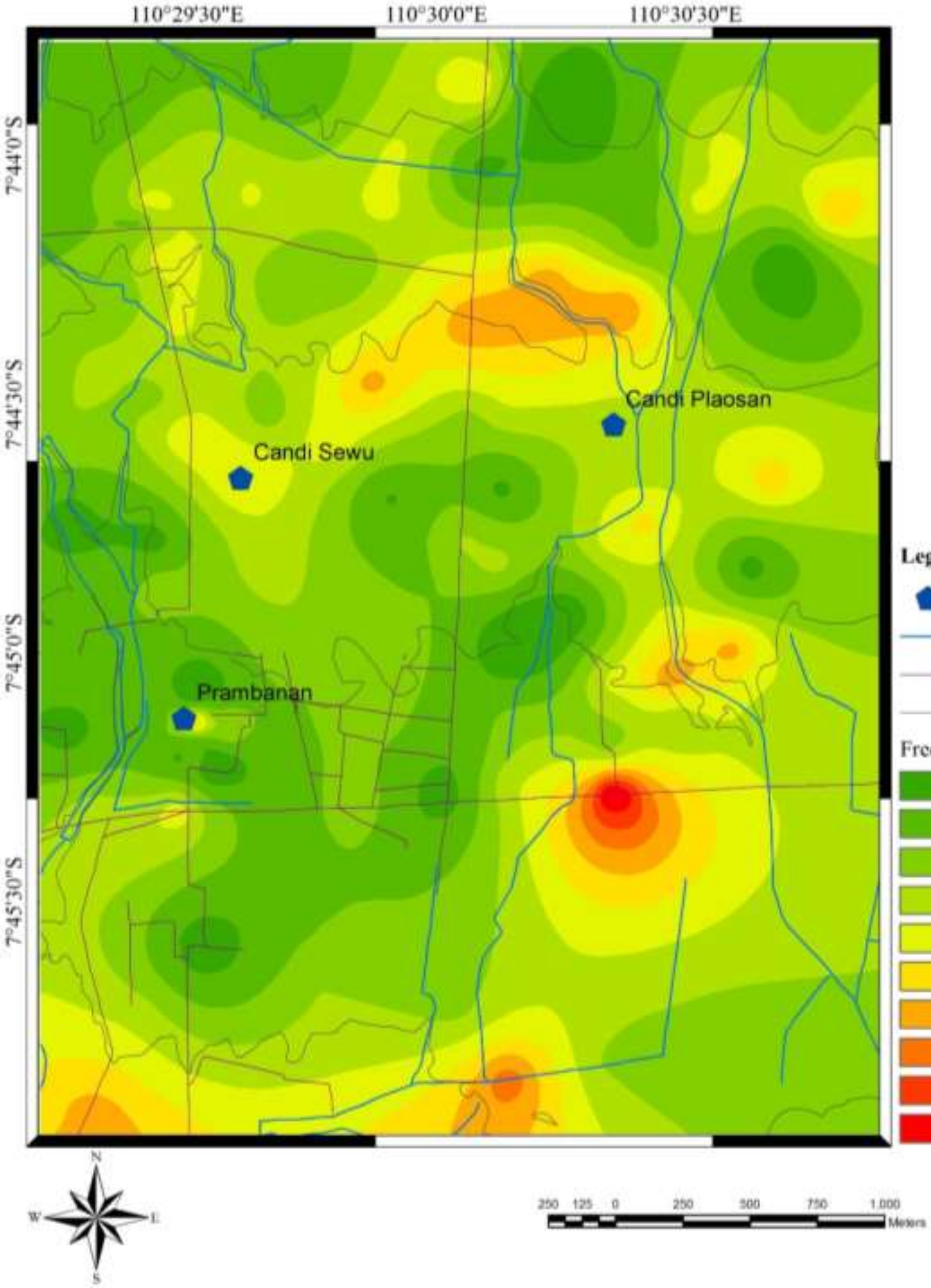


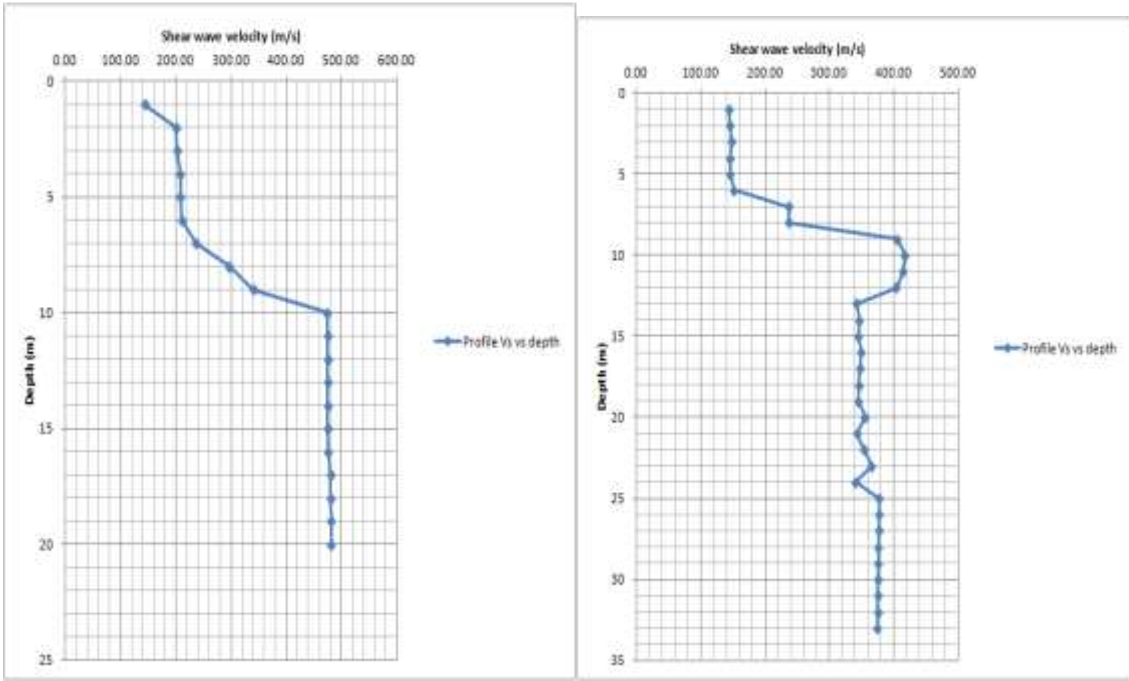
Figure 9: Frequency distributions of the Prambanan area.

5 Modeling of Sedimentary Layered Media at Prambanan Area

We could obtain Vs structures at two bore holes sites i.e, Plaosan and Sewu temple, however, the ground profiles are not uniquely determined. Shear wave velocity of the first layer modeled is Vs ≤ 298 m/sec. Figure 10 shows Vs structure at Sewu and Plaosan temple area. By combining with the first peak of *H/V* data, we can obtain the thickness of the first layer. The technique used was the 1/4 wavelength principle, which can approximately be extended to multi layered media.

$$T = 4H / VS \qquad (4)$$

where, *H* is a thickness of a layer, *Vs* shear wave velocity and *T* predominant period. The distribution of thickness for the first layer of which *Vs* is less than 298 m/sec in Prambanan area is shown in Figure 11, in which the rapidly varying area of the subsurface condition and dense observation area are enclosed.



(a)Vs structure of the Sewu temple. (b)Vs structure of the Plaosan temple.

Figure 10 Vs structure at (a) Sewu temple and (b) Plaosan temple area.

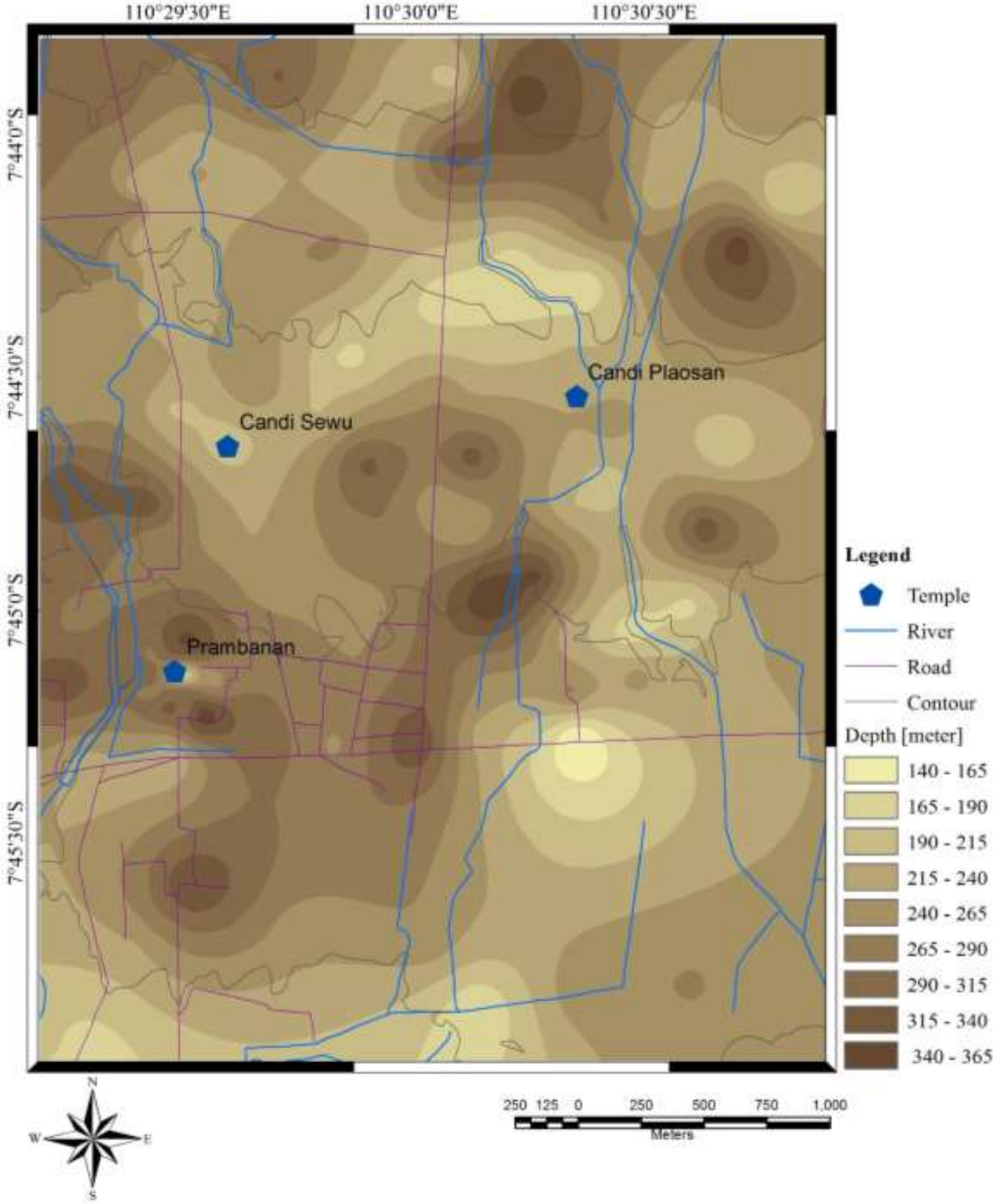


Figure 11 Depth of the engineering bed rock.

6. Conclusions

Our observations and analyses provide useful and practical data for earthquake disaster mitigation in Prambanan area. The procedure employed and conclusions obtained in this study are as follows.

Microtremor observations were carried out for constructing a subsurface ground model in Prambanan area. The Kriging method can be used for the interpolation of subsurface information such as shear wave velocity and depth of irregular boundary. By means of an inversion analysis for the calculation of dispersion curves, the subsurface structure beneath the site can be estimated. The shear wave velocity of the top layer is $Vs \leq 298$ m/s. By combining above two-layer model and the results of single point observation, we proposed the distribution of the first layer thickness of the sediment.

Acknowledgements

This study was supported by the Grant-in-Aid of JICA/SEED-Net. We sincerely thank Gadjah Mada Universities for their help in undertaking the observations in Prambanan area, Indonesia.

References

[1] Naing, T., 2010, Analysis of Microtremors for site amplication characteristics and ground motion in Yogyakarta, Indonesia. Doctoral thesis, Gadjah Mada University, Yogyakarta, Indonesia.
[2] BMKG, ISC & USGS, (2007), *Historical Worldwide Earthquakes.*
[3] K. Aki (1957): Space and time spectra of stationary stochastic waves, with special referent to microtremor, Bull. Earth. Res. Inst., Vol.35, No.3, pp.415-456.
[4] S. Pramumijoyo., A. Setianto., W. Wilopo., P. S Thein.,(2012): The Steps to earthquake mitigation for Palu City, the Capital of Central Sulawesi Province, Indonesia. The 5th AUN/SEED-Net Regional Conference on Geodisaster Mitigation in Asean, Manila, Philippines,.
[5] P.S.Thein, S. Pramumijoyo., K.S.Brotopuspito.,W. Wilopo., J.Kiyono and , A. Setianto (2013):Investigation of Subsurface Soil Structure by Microtremor Observation at Palu, Indonesia, The 6th ASEAN Civil Engineering Conference (ACEC) & ASEAN Environmental Engineering Conference (AEEC), Civil and Environmental Engineering for ASEAN Community, Bangok, Thailand,. p.C-6
[6] J. Kiyono, Y. Ono, A.Sato, T. Noguchi and , Rusnardi, P. R. (2011): Estimation of subsurface structure based on Microtremor observations at Padang, Indonesia, ASEAN Engineering Journal, Vol.1, No.3, pp.66-81.