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EARTHQUAKE MICROZONATION STUDY ON BATUBESI DAM OF NUHA, EAST LUWU, SOUTH SULAWESI, INDONESIA

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ABSTRACT: A study entitled to Earthquake Microzonation on Batubesi Dam of Nuha, East Luwu, South Sulawesi, Indonesia has been conducted. The study was conducted to obtain a map of peak ground acceleration (PGA) based on the historical seismicity in Sorowako and surrounding area, as well seismic vulnerability index (Kg) based on the measurement of local microtremor on site. The study was conducted at a location between 2.71428 degree - 2.70585 degree South Latitude and 121.3013 degree - 121.3117 degrees East Longitude. This research is expected to obtain the spatial distribution of the amplification factor (Ao), resonant frequency (Fo), PGA, and Kg to estimate the earthquake hazards potential on location. The maximum ground acceleration value or PGA obtained by microtremor wave analysis based on Kanai formula. As for determining the Kg used Nakamura or Horizontal to Vertical Spectral Ratio (HVSR) method. Based on the results of data processing obtained the value of PGAmin is 0.079 Gal. at the point of MSBB25, PGAmax is 0.381Gal at the point of MASBB21, and PGAavg is 0.18 Gal. As for the Kg obtained value of Kgmin is 0.28 at the point of MSBB22, Kgmax is 43.42 at the point of MSBB10, and Kgavg is 9.81. While based on the interpretation by means of the PGA value has been estimated that the MMI intensity is in the range of VII-IX with seismic risk level at a medium range of III until great of III. By means of the dominant frequency (fo) and dominant period (To) was estimated that soil classification for Kanai in the range of II until IV and the range of B - C for Omote-Nakajima.

Keywords: Microzination, Peak Ground Acceleration (PGA), seismic vulnerability index (Kg), Batubesi Dam

1. INTRODUCTION

Sulawesi Island is one of the islands that has undergone a very complex tectonic process in the geological time. This island form that resembles the letter K at least gives an idea that this island has different characteristics, especially in the geological conditions. [1,2]

The condition of Sulawesi island formed by the interaction of at least three of the earth's plates i.e. Pacific plate with the relative movement to the west, an Indo-Australian plate that moving relative to the north, and Eurasian plate that stable relatively. Due to the interaction between the three tectonic plates mentioned above, so the earthquake that occurred in some places in South Sulawesi is not an extraordinary thing, but it is a necessity. [1, 2]

Starting from the understanding of the condition of seismicity of the Sulawesi island at above, it is wise if made geological variables, especially geotectonic condition as one of the variables in the formulation of development policy of Sulawesi, whether national, regional or local scales. One of the buildings that need attention from the aspect of the above is the dam, where on the island of Sulawesi, precisely is the island of South Sulawesi there are 3 (three) dams that also functions as a power plant (hydropower), i.e. Batubesi dam, Balambano dam and Karebbe dam.

In this research, Microseismic data acquisition and geology data collecting have been done at Batubesi Dam location. The existence of dams that are in the areas with an earthquake or high seismicity must be monitor from time to time to determine the vulnerability of the three dams, including at the Batubesi dam. [3]

Basically, if an earthquake happens then the level of damage will depend on the strength and quality of the building and infrastructure, geological or geotechnical conditions, the maximum land acceleration or peak ground acceleration (PGA), as well as the seismic vulnerability index (Kg). Thus the characterization effort of a region, in this case, is in the Batubesi dam by means of the maximum ground acceleration parameter or peak ground acceleration (PGA), as well as seismic vulnerability index (Kg) index is a necessity to do. [4], [5], [6]

One of the most widely used methods to estimate the damage caused by an earthquake is the microtremor study. Microtremor analysis is particularly important in estimating the risks posed by seismic activity as well as other natural vibrations. This is due to microtremor analysis done with consideration of the local geological conditions and the seismicity data, so is the best approach for estimating local geological effects due to seismic wave propagation. [4], [5], [6]

2. METHODS

The study was conducted at a location between 2.71428 degree - 2.70585 degree South Latitude and 121.3013 degree - 121.3117 degrees East Longitude. The main equipment used in this research is a three-component seismometer of DS-4A type with feedback short-period seismometer and the digitizer with the type of TDL 303S Digital Portable Seismograph.

From the data acquisition results obtained a number of 25 points that are distributed in the dam zone and surrounding, i.e. measurement point with the name points of MSBB_01 until measurement point of MSBB_25. The location of research and distribution of microseismic data acquisition point, i.e. at Batubesi dam of Nuha, East Luwu, South Sulawesi, Indonesia can be seen in Fig. 1.

Mathematically, the basic resonance frequency at a location can be determined by means of the ratio of the horizontal component (H) and the vertical component (V) of the natural vibration spectrum, wherein ω is the angular frequency, S is secondary wave, NS is North-South direction, and EW is East-West direction, as shown in equation 1. [7]

$$\frac{H}{V} = \left[\frac{S^2(\omega)NS + S^2(\omega)EW}{2S^2(\omega)V}\right]^{1/2} \quad (1)$$

Mathematically too, the seismic vulnerability index (Kg) is defined as the ratio between the quadratic amplification and the dominant frequency of the soil or rocks as shown in equation 2. [8]

$$K_g = \frac{A_0^2}{f_0} \quad (2)$$

Where K_g is seismic vulnerability index, A_0 is amplification factor, and f_0 is dominant frequency.

Meanwhile, the Peak Ground Acceleration (PGA) obtained from historical data of the earthquake using the empirical model of Mc.Guirre R.K [9] as shown in equation 3.

$$\propto_g = \frac{5}{\sqrt{T0}} 10^{0,61M-\left(1,66+\frac{3.6}{R}\right)\log R+0,167-\frac{1,83}{R}} \quad (3)$$

For the calculation of peak ground acceleration (PGA), used the values of dominant period (T0), also USGS seismicity data is used for hypocenter data (R) and surface wave magnitude (M) by means of earthquake epicenter that located around the Sorowako region in the time range of 1909 - 2014 or 105 years recent time range at any value of magnitude. Based on these conditions obtained a number of 178 earthquake events. From a number of earthquake data above, it can be seen that the earthquake event contributing the value of peak ground acceleration (PGA) is the earthquake that occurs in 1909 with have epicenter a depth of 33 km, and earthquake magnitude 7.1 in Richter scale. [10], [11], [12]

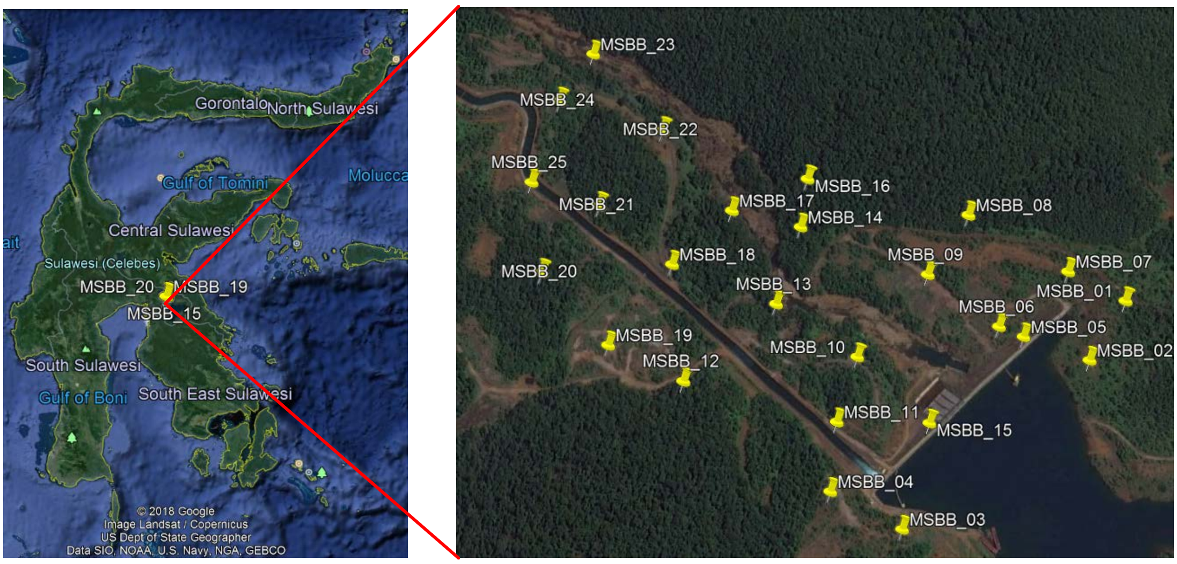

Fig. 1. Location of research and distribution of microseismic data acquisition point on Google map.

Based on the data from data acquisition and data collecting from USGS data, has been performed data processing as shown in Fig. 2.

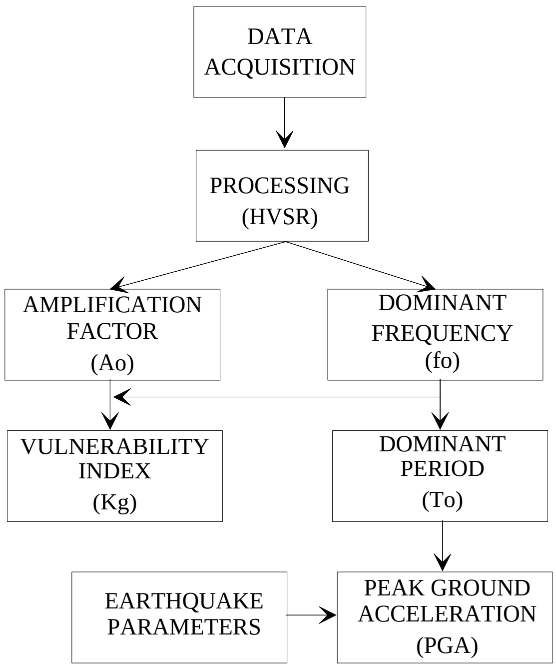

Fig. 2. Flowchart of data processing

3. RESULTS AND DISCUSSION

The data analysis is based on the main parameters from the results of data processing and interpretation in the form of dominant frequency (fo), dominant period (To), amplification factor (Ao), (seismic vulnerability index (Kg), and peak ground acceleration (PGA). Table 1 is showing the Dominant Frequency (f0), dominant period (T0), and amplification factor (A0) values [13], meanwhile table 2 is showing the seismic vulnerability index (Kg) values, peak ground acceleration (PGA), and level of risk values at local microseismic points, i.e. at Batubesi dam of Nuha, East Luwu, South Sulawesi, Indonesia[14]. Referring to the terminology of Fauzy et.al. [16], the level of risk used in this case is that if the PGA value is less than 0.05 it is included in the low, if the PGA value between 0.05 - less than 0.2 is included in medium, and if the PGA value is greater than 0.2 then high. Based on the research results indicate that the research area is located on the distribution of level of risk from medium to high. With the details that from a number of 25 points showing 11 points are high and 14 points is medium. Details the distribution of vulnerability index (Kg), peak ground acceleration (PGA), and overlapping of both on Google map can be seen in Fig. 3, Fig. 4, and Fig. 5 respectively.

Table 1. Dominant Frequency (f0), Dominant Period (T0), Amplification factor (A0) values.

No.	Point	f0	T0	A0
1	MSBB_01	3.49	0.29	4.94
2	MSBB_02	3.98	0.25	4.67
3	MSBB_03	3.94	0.25	6.55
4	MSBB_04	2.99	0.33	7.78
5	MSBB_05	0.81	1.23	5.83
6	MSBB_06	0.92	1.09	3.28
7	MSBB_07	3.24	0.31	3.35
8	MSBB_08	3.37	0.30	4.79
9	MSBB_09	4.08	0.25	3.06
10	MSBB_10	3.03	0.33	11.47
11	MSBB_11	3.55	0.28	6.25
12	MSBB_12	3.84	0.26	7.77
13	MSBB_13	6.36	0.16	2.65
14	MSBB_14	4.14	0.24	3.51
15	MSBB_15	1.79	0.56	2.77
16	MSBB_16	4.30	0.23	3.51
17	MSBB_17	6.17	0.16	4.28
18	MSBB_18	3.75	0.27	4.75
19	MSBB_19	0.74	1.35	3.59
20	MSBB_20	1.91	0.52	1.98
21	MSBB_21	13.68	0.07	3.96
22	MSBB_22	6.42	0.16	1.35
23	MSBB_23	1.73	0.58	1.97
24	MSBB_24	0.69	1.45	2.73
25	MSBB_25	0.59	1.69	2.55

Table 2. Seismic vulnerability index (Kg), peak ground acceleration (PGA), and level of risk.

No	Point	(Kg)	PGA	Level of Risk
1	MSBB_01	6.99	0.187	Medium
2	MSBB_02	5.48	0.199	High
3	MSBB_03	10.89	0.198	High
4	MSBB_04	20.24	0.173	Medium
5	MSBB_05	41.96	0.090	Medium
6	MSBB_06	11.69	0.096	Medium
7	MSBB_07	3.46	0.180	Medium
8	MSBB_08	6.81	0.184	Medium
9	MSBB_09	2.30	0.203	High
10	MSBB_10	43.42	0.174	Medium
11	MSBB_11	11.00	0.189	Medium
12	MSBB_12	15.72	0.197	High
13	MSBB_13	1.10	0.253	High
14	MSBB_14	2.98	0.205	High
15	MSBB_15	4.29	0.134	Medium
16	MSBB_16	2.87	0.209	High
17	MSBB_17	2.97	0.250	High
18	MSBB_18	6.02	0.195	High
19	MSBB_19	17.42	0.086	Medium
20	MSBB_20	2.05	0.139	Medium
21	MSBB_21	1.15	0.373	High
22	MSBB_22	0.28	0.256	High
23	MSBB_23	2.24	0.133	Medium
24	MSBB_24	10.80	0.084	Medium
25	MSBB_25	11.02	0.078	Medium

Data interpretation results were also associated with earthquake risk, classification of surface soil types according to Kanai, and soil type classification according to S.Omote and N.Nakajima.

To obtain distribution of the seismic vulnerability index (Kg) value and distribution value of peak ground acceleration (PGA) at the microseismic data acquisition point at research location, created a contour map by interpolating all values of Kg between points one to another for distribution of Kg value and interpolating all values of PGA between points one to another too for distribution of PGA value.

Fig. 3 is showing the contours map of the distribution of seismic vulnerability index (Kg) at the location of microseismic data acquisition points on Google map. Fig. 4 is showing the contour map of the distribution of peak ground acceleration (PGA) values at the location of microseismic data acquisition points on Google map. Fig. 5 is showing the overlapping of the contour map of PGA and Kg values distribution at the location of microseismic data acquisition points on Google map i.e. at Batubesi Dam of Nuha, East Luwu, South Sulawesi, Indonesia.

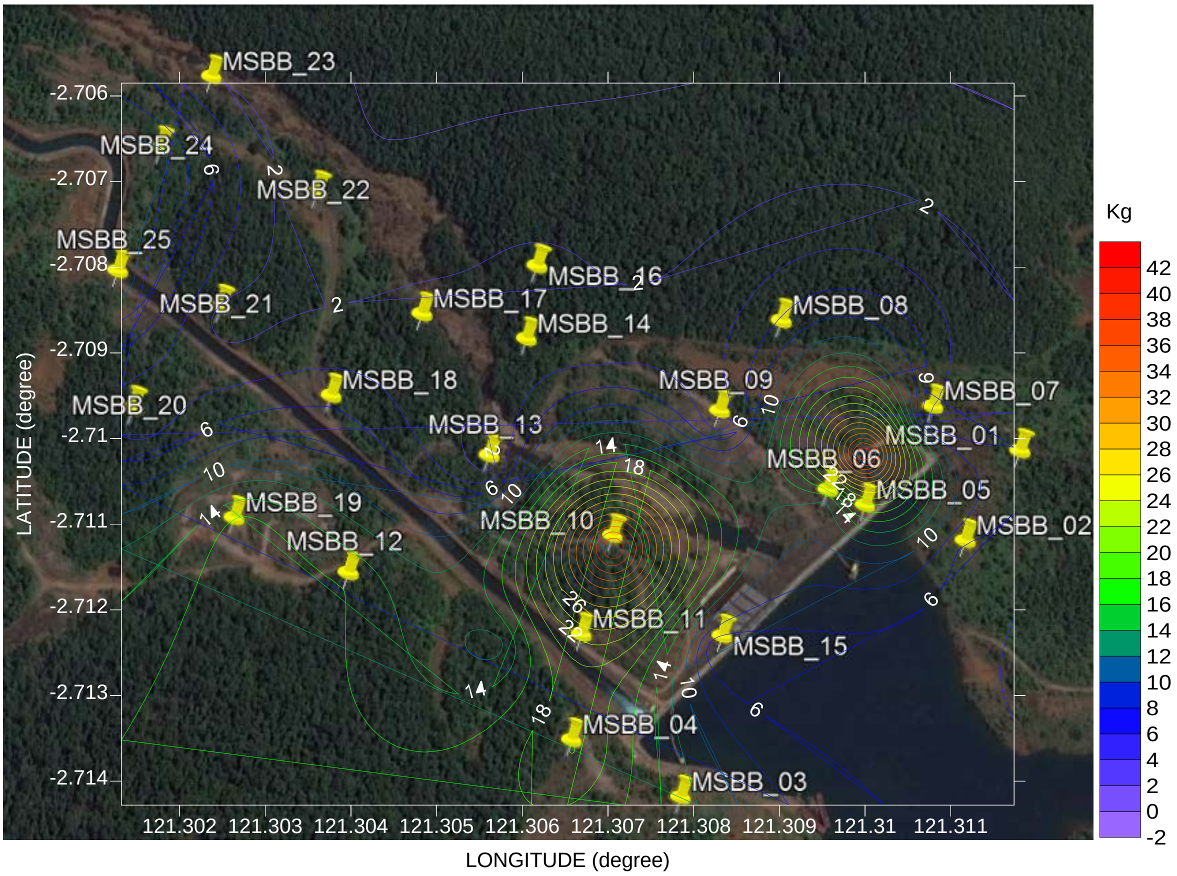

Fig. 3. Contours map of the distribution of seismic vulnerability index (Kg) at the location of microseismic data acquisition points on Google map.

The discussion of this research based on interpretation results from the contour map of peak ground acceleration (PGA) and the contour map of seismic vulnerability index (Kg) value distribution by converting the both microseismic and earthquake data, i.e. PGA and Kg to a physical characteristic of rocks or soils contained.

The seismic vulnerability index indicates the magnitude of the damage that an earthquake will cause. Characteristics of sediment layers or seismic vulnerability index can be known from the dominant frequency measurement (fo) and amplification factor (Ao) from the spectral ratio of H/V [15]. The seismic vulnerability is determined by the value of the seismic vulnerability index (Kg) which describes the level of surface layer vulnerability to deformation during earthquakes. The seismic vulnerability index is related to geomorphological conditions [16], [15]. The seismic vulnerability index indicates the level of risk or hazard due to particle movement, the weak zone marked with high Kg values can cause damage in the event of an earthquake. Therefore, this index value is useful to detect areas that have a weak zone in the event of an earthquake. [15].

The maximum ground acceleration or the peak ground acceleration (PGA) is an acceleration value calculated at the observation or data acquisition point (x,y,z) on the earth's surface based on earthquake history with the largest selected calculated value in a given period of time. The geological condition of the soil that determines the magnitude of the PGA value is the degree of soil density in the research area. The denser of the rocks or soil in the research area will give the value of PGA is getting smaller. [16]

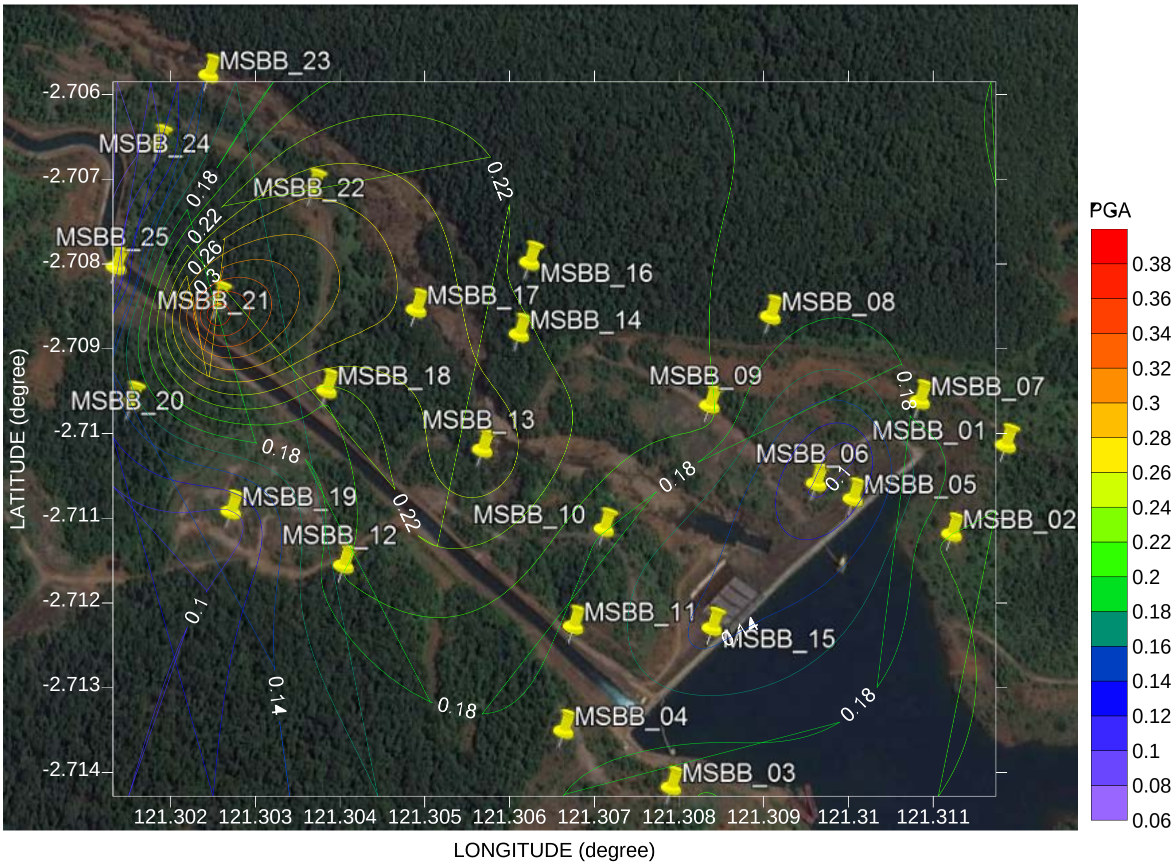

Fig. 4. Contour map of the distribution of peak ground acceleration (PGA) values at the location of microseismic data acquisition points on Google map.

Referring to the classification of earthquake risk level [16] for the PGA value, it is showing that 0.078 Gal at the point MSBB_25 to 0.373 Gal at the point MSBB_21 is at MMI Intensity in the range of VII-IX with moderate to very high-risk level large I. Refers to the dominant frequency (fo) value in relationship with the ground and the recommended of building levels [17] were obtained the values of fo in the range of 0.59 Hz at the point of MSBB_25 up to 13.7 hz at the point of MSBB_21. From the Kremer classification above, it is suggested that the building that can be constructed is spread over the range of classification of II. Meanwhile, based on the classification of soil for earthquake resistant building planning for the dominant period (To) in the range of 0.07s at the point of MSBB_21 up to 1.69s at the point MSBB_25 that was estimated the soil classification for Kanai in the range of II-IV as well as the B-C range for Omote - Nakajima classification. Meanwhile, based on magnitude, characteristic effects, frequency, and MMI scale of the earthquake [18] obtained that for MMI scale VII-IX obtained magnitude 5.5-6.9 on the Richter scale, the effect of shock characteristics in the form of minor-building damage, and frequency 500 - 100 per year.

Rocks, soil, and building can have the same frequency and period with the earthquake. If the period or frequency of the building is equal to the period or frequency of earthquake that reached the surface, there will be resonance and vibration interference thus will increase and multiply the intensity of damage that caused by the earthquake. Accordingly, in the construction of important buildings or buildings including the dams must take into account the level of soil characteristics factors that include: the type of surface soil, maximum rocks or soil acceleration and the dominant period of the surface soil.

The buildings have a tendency to resonate, this happens if the dominant frequency of rock or soil is equal to the natural frequency of the buildings or structures. This resonance will increase and multiply structural shocks and strengthen the vibrations of rocks that can lead to damage to buildings or structures. The damage of the buildings associated with resonance between the frequency of ground motion due to earthquakes and the natural frequency of buildings. In relation to the design and construction of buildings, not only the magnitude of the earthquake should be considered but also the nature of ground motion.

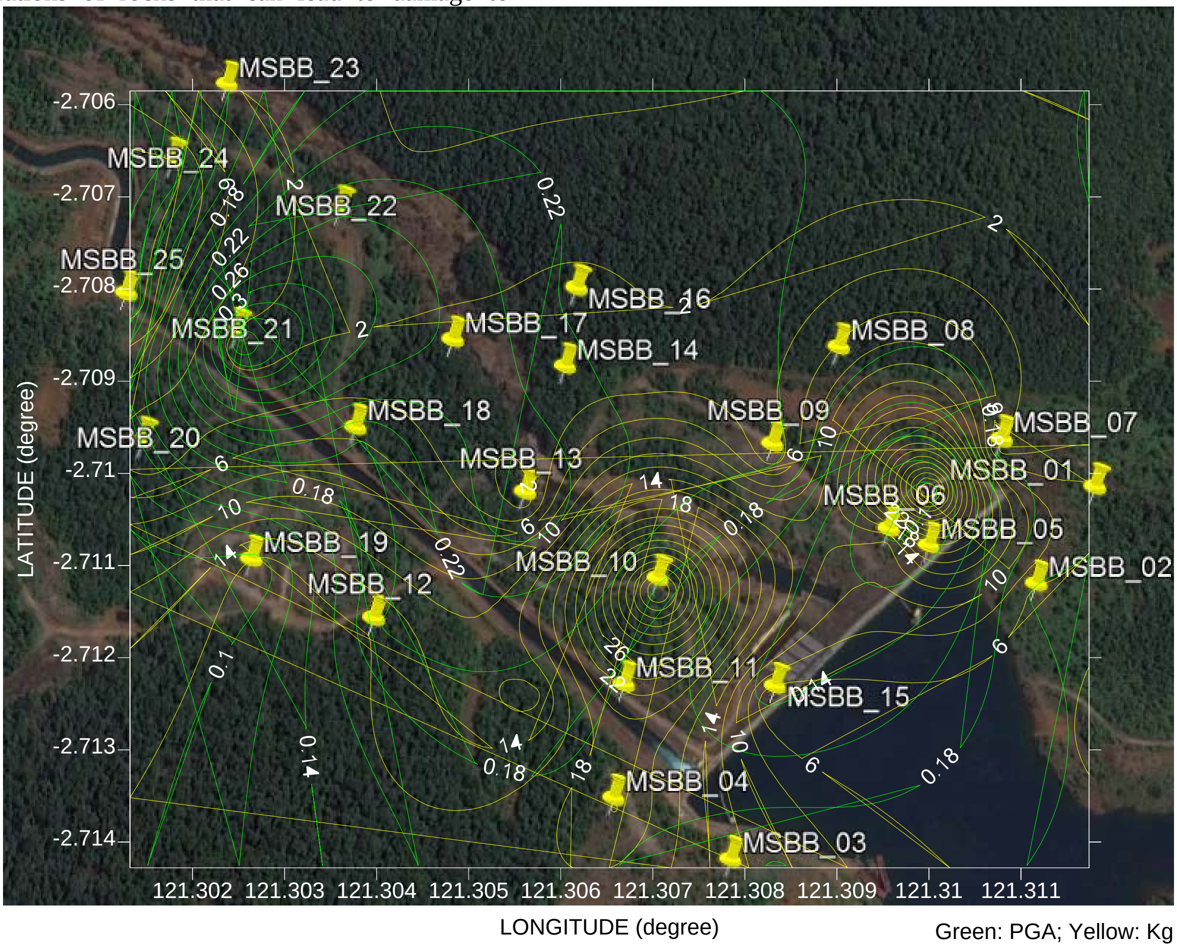

Fig. 5. Overlapping of the contour map of PGA and Kg value distribution at the location of microseismic data acquisition points on Google map.

4. CONCLUSION

Based on the research of earthquake microzonation study on Batubesi dam of Nuha, East Luwu, South Sulawesi, Indonesia that has been done then it can be concluded things as follows:

1. The acquisition of microseismic data is carried out by a number of 25 points that were distributed in the dam zone and surrounding, i.e. at the point of MSBB_01 up to point of MSBB_25.
2. For the calculation of Peak Ground Acceleration (PGA) values, USGS data is used for epicenter located around the Sorowako area in the period 1909 - 2014 (105 years) at any magnitude of 178 earthquake events.
3. Processing and interpretation of data on PGA value obtained for the level of risk that 11 points are high and 14 points are low. The weak zone with a high value of Kg located at the point of MSBB_06 and MSBB_11.
4. Based on the value of Peak Ground Acceleration (PGA) it is estimated that the intensity of MMI in the range of VII-IX and the level of seismic risk in the medium range II - is very large I. Based on the dominant frequency value (fo) it is estimated that the building that can be built is spread over 2- high. While based on the predominant period (To) it is estimated that the soil classification for Kanai in the range II - IV as well as the B - C range for Omote - Nakajima.

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