SEISMIC STATIONS CATEGORIZATION AND ITS EFFECT ON THE BMKG EARTHQUAKE MAGNITUDE PARAMETERS DETERMINATION

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ABSTRACT

The responsibility to send information within five minutes causes the magnitude disseminated by BMKG only from limited seismic records. The result shows that the magnitude produced in the first five minutes can fluctuate and cause a difference in the final magnitude. In the SeisComP system at BMKG, the event magnitudes of each type of magnitude MLv, mb, mB, and Mwp, are the result of the station magnitude average using trimmed mean, so the largest or smallest station magnitudes will become outliers and are eliminated in event magnitude calculation. However, the drawback of the trimmed mean is seismic stations that always tend to be outliers have the potential to be still involved in determining the event magnitude in the early minutes so that it can disrupt the magnitude calculation. This study aims to reduce the fluctuations in determining the magnitude in the first five minutes by identifying seismic stations that are often eliminated by the trimmed mean method and classifying them. We validate them with the site quality of the station and create two main categories of seismic stations. The first category is primary stations to determine the location and magnitude of earthquakes. The second category is secondary stations used only at the earthquake site, then tested using SeisComP playback by replaying 256 earthquake events. The results show a correlation where good site quality will also produce a good magnitude value, indicated by 285 seismic stations, and can be categorized as primary stations. The remaining 126 seismic stations are categorized as secondary stations. The playback results show that the fluctuation of magnitude determination in the first five minutes using the primary station can be reduced, as indicated by the mean residual and the deviation to the final magnitude.

Keywords: Magnitude, trimmed mean, site quality, primary station, secondary station

1. Introduction

The Meteorology, Climatology, and Geophysics Agency (BMKG), part of the Indonesian Tsunami Early Warning System (InaTEWS), has the duty and responsibility to provide earthquake information to the public and policymakers by the mandate of Law no. 31 of 2009 [1]. Based on Standard Operational Procedure (SOP), earthquake information must be sent within five minutes of the earthquake. The community and policymakers use this information to implement further mitigation procedures [2].

Earthquake information within five minutes affects the accuracy of the earthquake parameters because of limited seismic wave records. This limitation causes differences in seismic parameters, such as the magnitude sent by the BMKG in the first 5 minutes as early warning, with the final magnitude. The final magnitude was obtained after the entire network of BMKG seismic stations recorded the earthquake, and the moment magnitude (Mw) was obtained 5 – 15 minutes after the earthquake [31], which is informed as the final parameter in the earthquake narrative and press release. In the guidelines of the National Tsunami Warning Center [3], the difference between the final magnitude and the magnitude in early warning information should not exceed ±0.3 magnitude value.

In the BMKG processing system using SeisComP [8], each type of magnitude MLv [4], mb [5], mB [6], and Mwp [7] is calculated at each seismic station that records earthquake waves as a station magnitude, and network magnitude or event magnitude is magnitude value summarizing several station magnitudes values of one origin [9].

The event magnitude for each type of magnitude is obtained based on the average station magnitude results. It means fluctuations and errors in determination can occur due to several factors, such as the amount of station magnitude data and also the contribution of the seismic station condition itself, which is caused by sensor conditions, or the effects of local and regional geology such as amplification factors, so the value of the station magnitude generated at a seismic station can be inaccurate (too large or too small) compared to the final event magnitude [10, 11].

To eliminate the inappropriate contribution of station magnitude values, the SeisComP uses trimmed mean [9,12,13], where the station magnitude at seismic stations are too large or too small will be considered as outliers and will be eliminated so they are not used in determining the event magnitude. The event magnitude value after the earthquake will be updated continuously along with the increasing number of station magnitude data, so the event magnitude value is very sensitive to the amount of data and the distance from the earthquake source to the seismic station network [13].

The trimmed mean method on SeisComP has the disadvantage that it still uses seismic stations with a tendency for the station magnitude value, which can be outliers (too large or too low). That can cause inaccurate in determining the event magnitude, especially when the amount of station magnitude data is very limited, and the earthquake location is near that seismic station in the first 3-4 minutes after the earthquake. As a result, there needs to be more consistency of event magnitude in the early minutes and a difference between the event magnitude in the early warning information and the final information in the press release.

There are several ways to improve consistency in determining the event magnitude. One of them is by identifying seismic stations that tend to produce inaccurate station magnitude and providing a magnitude correction factor, as has been done in previous studies in the British Columbia seismic station network [14], India [15], and the seismograph network in Hawaii [16].

In this study, we will only identify which seismic stations tend to produce inaccurate station magnitude without determining the correction factor at that seismic station. Next, we validate it with the site quality of the seismic station. Seismic stations that are good in determining the magnitude and good in site quality will be categorized as primary stations used to determine location and magnitude parameters. Seismic stations with poor quality in determining the magnitude (often becoming an outlier) and poor site quality will be categorized as secondary stations that are only used in determining earthquake locations. Secondary stations will be excluded from the beginning of the event magnitude determination process.

We hope that determining the magnitude using only selected primary seismic stations can improve the consistency and accuracy of the event magnitude and minimize fluctuations in the magnitude value in the early minutes after the earthquake, which is an important time in the Indonesian Tsunami Early Warning System (InaTEWS).

2. Methods

Data. The primary data used are earthquake parameters from BMKG in bulletin format containing location, depth, event magnitude for each type of magnitude, preferred magnitude as the value and type of final magnitude of an earthquake event, the arrival time of the seismic wave phase at each station, and each magnitude value at the seismic station (station magnitude) from 411 BMKG seismic stations that have been installed and operating until June 2021 was downloaded from the BMKG repository [17].

This study uses observational data from January 2010 - June 2021 with $M \geq 5$, with the status "confirmed" or "final" which indicates that the earthquake event has been quality controlled by seismologists. The amount of data obtained was 1979 earthquake events (figure 1) and then processed with the python application. In addition, we also use seismic sensor location quality data (site quality) from the BMKG Research and Development Center [18].

Method. Overall, the data processing in this study is divided into three stages, 1) classification of seismic stations based on the results of station magnitude; 2) Validation of results with seismic sensor site quality and seismic station categorization; 3) Testing the results with SeisComP playback.

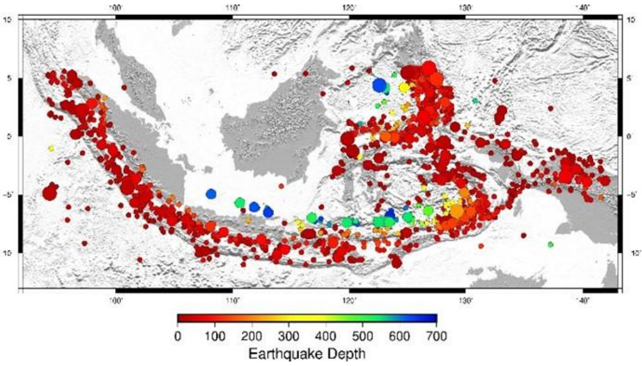

Figure 1. Earthquake seismicity map $M \geq 5$ used in the study from January 2010 – June 2021, purple triangles indicate seismic stations, colored circles indicate the location of the earthquake and its depth

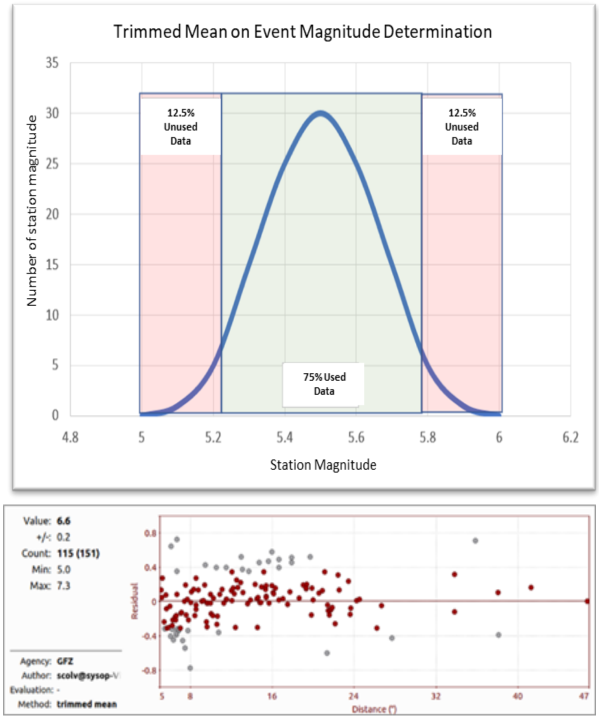

Figure 2. The trimmed mean method on the SeisComP system for determining event magnitudes (above), and an example of the trimmed mean of SeisComP (below), the red circle is the station magnitude used, the gray circle is the station magnitude that was eliminated

Table 1. Distribution of station categories based on the results of determining the magnitude.

CLASSIFICATION	DESCRIPTION
A	Good Station
B	Stations with **1** type of magnitude that are often eliminated
C	Stations with **2** type of magnitude that are often eliminated
D	Stations with **3** type of magnitude that are often eliminated
E	Stations with **4** type of magnitude that are often eliminated

In the first stage, the classification of seismic stations is determined based on the results of their station magnitude. In the trimmed mean method used by SeisComP (figure 2), the station magnitude values of all seismic stations for an earthquake event are sorted from the smallest to the largest value, then 12.5% of the stations with the largest station magnitude values and 12.5% of the stations with the largest station magnitude values. The smallest magnitude will be trimmed or eliminated, using only 75% of the best consistent seismic stations, while 25% of the eliminated data will be considered outliers [9,13]. This is done for each type of magnitude (MLv, mb, mB, and Mwp).

In this study, we propose a new method for classifying seismic stations by statistically finding which ones are most frequently eliminated by the trimmed mean method for each type of magnitude. This means these seismic stations often produce inaccurate station magnitudes, either too large or too small.

The procedures in this stage are:

1. Calculate the number of station magnitudes determined by a seismic station (for example, seismic station A has determined 100 station magnitudes of type MLv from 100 earthquake events) as shown in Figure 4A.
2. Determine the percentage of the number of station magnitudes that are eliminated by the trimmed mean at a seismic station (for example, 100 MLv that was determined by station A, 40 of them were eliminated or became outliers, so the percentage eliminated is 40%)
3. Points 1 and 2 are carried out at all 411 seismic stations in Indonesia.
4. Determine the average and deviation of the elimination percentage for all seismic stations in Indonesia, as shown in Figure 5.
5. Seismic stations with a more significant percentage of elimination than the upper deviation will be classified as the most frequently eliminated

BMKG SeisComP determines MLv, mb, mB, and Mwp, so the procedure at points 1 to 5 above are carried out for each type of magnitude (figure 4A – 4D, and figure 5A – 5D).

Furthermore, seismic stations are classified based on the number of magnitude types that are most often eliminated at a seismic station. We made five classifications A to E (table 1), based on the number of magnitudes determined by the BMKG. Classification A is the best station in determining the magnitude because the station magnitude is always used by the trimmed mean. In contrast, classification E is a seismic station where the station magnitude results of all types of magnitudes (MLv, mb, mB, and Mwp) are always eliminated.

The second stage is the validation of the results of the first stage classification with the quality of the seismometer location (site quality), which has been carried out by the BMKG Research and Development Center team. The results of the classification of seismic stations in the first stage are purely statistical processing results, so the validation stage needs to be carried out by matching the results of the first stage with site quality at each seismic station in Indonesia.

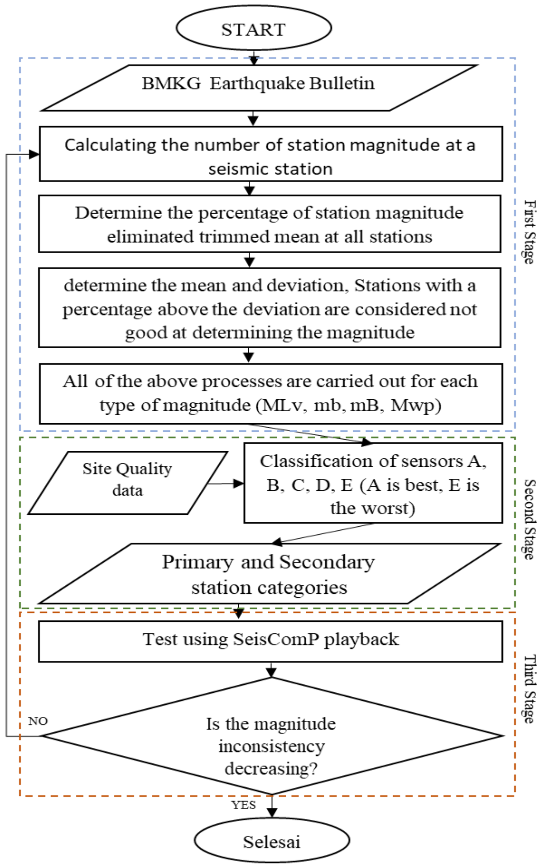

Figure 3. Research flowchart.

Site quality data processed by the BMKG Research and Development Center team has considered various factors, including (1) geological factors of the sensor location [19], (2) environmental noise model based on the Peterson noise model [20], (3) Site Class based on the HVSR dominant period [21], and (4) rock hardness based on Vs30 [22]. The results of these four parameters are used to divide seismic stations into groups: Very Good, Good, Fair, and Poor. The Very Good and Good seismic station groups indicate that the location is good for placing seismic sensors [23]. This second stage aims to see the effect of site quality on determining the magnitude. After that, seismic stations are divided into two main categories: Primary Seismic Stations and Secondary Seismic Stations.

The primary seismic station is a classification A station with very good, good, and fair site quality (generally, the seismometer is located on bedrock and has low noise). However, because we also consider the configuration of the primary station network, which must cover the entire territory of Indonesia, we also use seismic stations in categories B and C with very good and good site quality in determining mB and Mwp as Primary Seismic Stations. The other sensors will be categorized as secondary seismic stations. The primary seismic station will be used in determining the location and magnitude, while the secondary seismic station will only be used in determining the location.

The last stage is to try to determine the earthquake magnitude parameter by playing back the earthquake event (playback) using SeisComP, which is one of the features of SeisComP, to test various configurations on the system [24]. In addition, SeisComP also allows us to choose which seismic stations are used in determining the location and magnitude of the earthquake and which seismic stations are only used in determining the location [25].

Playback is carried out using stations that have been selected as primary stations and secondary stations and playing back recordings (waveforms) of earthquakes with Mw $\geq$ 5, in the observation period January 2015 - June 2021 with a total of 256 earthquake events. By replaying this earthquake, it can be seen the difference in magnitude parameters before and after the seismic station is selected, especially in the first five minutes after the earthquake.

3. Results and Discussion

Classification of seismic stations based on their magnitude result. The result of the first procedure in stage one is to determine how many station magnitudes of each type of magnitude have been calculated at each seismic station in Indonesia, as shown in Figure 4 A – D, which shows the number of station magnitudes varies for each seismic station and type of magnitude. For MLv, the highest number of MLv ever determined by a station is 940, meaning that the station has determined MLv 940 times out of 940 different earthquake events. Then for mb, the highest number is 1229, 1008 mB, and 515 for Mwp.

The difference in the number of station magnitudes for each type is because, in one earthquake event, it is not certain that each type of magnitude can be determined. For example, there is an earthquake event that can be determined by MLv, mb, mB, and Mwp, but there are also other earthquake events that can only be determined by mB and Mwp values, or there is one type of magnitude whose value cannot be determined.

The physical properties of earthquakes can also affect whether an earthquake event can be determined for each type of magnitude [26]. This is what determines whether an earthquake event fulfills the characteristic criteria for determining a type of magnitude at a seismic station or not because each type of magnitude is determined in a certain wave frequency range. For example, if there is an earthquake event with a relatively small strength, the seismic waves are rich in high frequency, so it is well determined by the type of magnitude that measures the maximum amplitude in a high-frequency range, such as MLv and mb.

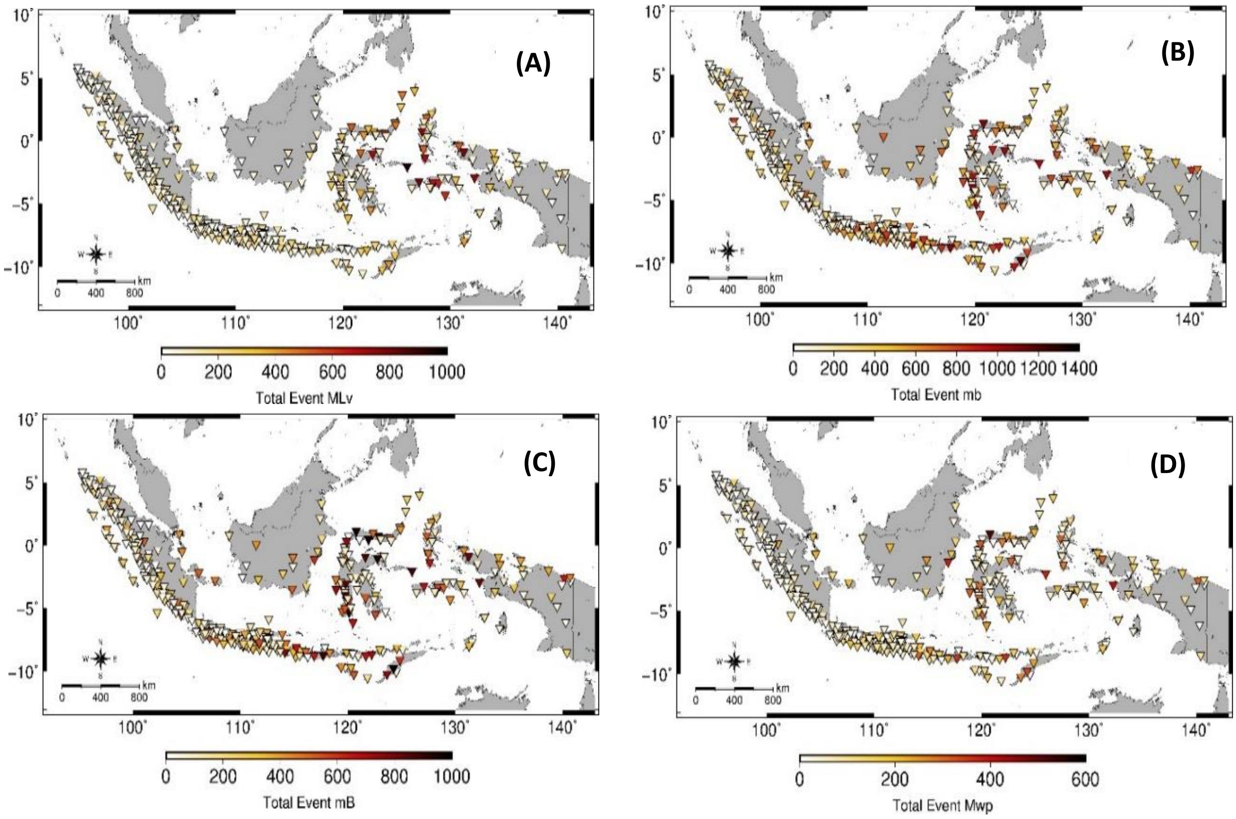

Figure 4. **The total number of station magnitudes that have been determined from earthquake events that have been recorded by every seismic sensor (total event) in Indonesia for each type of magnitude MLv (A), mb (B), mB (C), and Mwp (D). The inverted triangle is the location of the BMKG's seismic station**

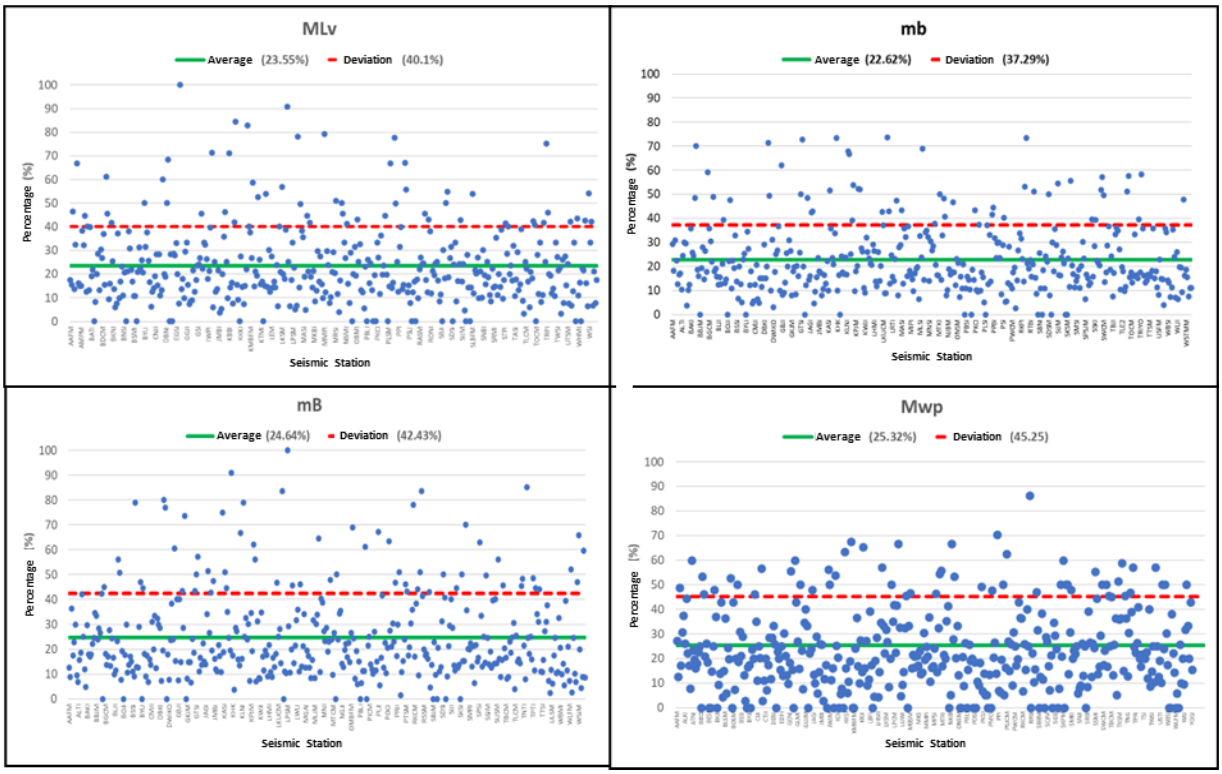

Figure 5. **Graph of the percentage of station magnitude data eliminated by the trimmed mean method at each seismic station for each type of magnitude MLv (A), mb (B), mB (C), and Mwp (D). The green line shows the average, the red line shows the highest deviation.**

Another thing that affects the difference in the highest number of station magnitudes for each type of magnitude at a seismic station is the distance criterion. MLv is calculated at < 8º while mb, mB, and Mwp it is calculated at 5º – 105º [9]. So that although the criteria for determining the magnitude are in almost the same frequency range as MLv and mb, the highest number of mb is more than MLv because the range of events can be determined as a wider magnitude.

Then the next thing that distinguishes the highest number of station magnitudes is the location factor and the installation time of the seismic station. Seismic stations that are installed in areas that are more seismically active and have been installed for a long time, the number of magnitudes that seismic stations have determined will be larger.

Furthermore, based on the results of Figure 4, we look for the percentage of the total station magnitude eliminated by the trimmed mean at each seismic station for each type of magnitude shown in Figure 5. Figure 5 shows the average percentage and deviation of the total station magnitude eliminated at each seismic station. For example, the SANI station (Sanana, North Maluku, which was installed from 2009) is the seismic station that determines the most MLv, which has determined 940 MLv, has a trimmed mean percentage of the total eliminated MLv of 24%, meaning as much as 24% of 940 values The MLv that was generated by SANI or around 226 MLv was not used (eliminated) in the final MLv determination because the values were too large or too small and were considered as outliers.

For MLv, the average percentage of the number of MLv that is eliminated at seismic stations is 25.55% with the highest deviation is 40.1%. For mb, the average eliminated is 22.62%, with the highest deviation being 37.29%. And for mB and Mwp they have eliminated averages are 22.64% and 25.32%, and the highest deviations, respectively are 42.43% and 45.25%. For seismic stations whose percentage of eliminated data is above the highest deviation for each type of magnitude, it will be considered as the most frequently eliminated seismic station (outlier). From the results shown in Figure 5, which stations are most often eliminated will be known.

Furthermore, a compilation is carried out based on the data from Figure 5 to determine how many types of magnitudes are most often eliminated at each seismic station and then make a categorization. The classification of a seismic station is good (Classification A) when the magnitude value of the station is rarely eliminated. The classification will decrease to B if a station has at least 1 type of magnitude, whether it is MLv, mb, mB, or Mwp, whose data is often eliminated. Then in classification C there are at least two types of magnitude whose values are often eliminated, such as MLv and mb, MLv and Mwp, up to classification E, which is included in the worst class in determining the magnitude of MLv, mb, mB, and Mwp, because this station has never used its data or permanently eliminated for all kinds of magnitudes. The results of seismic station categorization can be seen in Figure 6 and Table 2.

Table 2. Number of stations in each classification based on the results of determining the magnitude.

CLASSIFICATION	TOTAL
A	262 Station
B	89 Station
C	32 Station
D	24 Station
E	4 Station

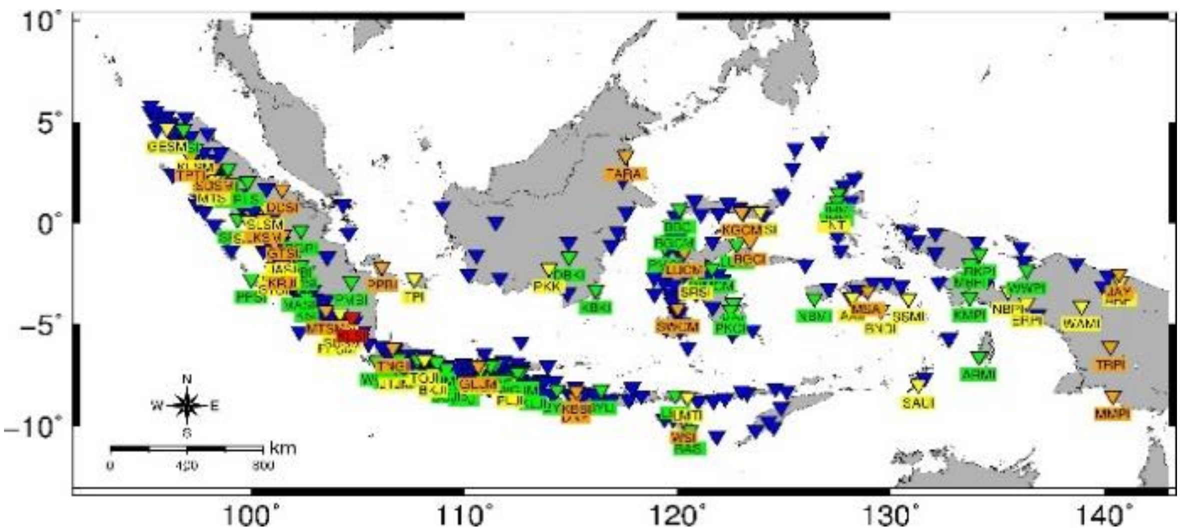

Figure 6. Distribution map of seismic station categories based on the results of determining the magnitude. Color indicates category based on Table 1.

Validation of the classification based on station magnitude result with the quality of the seismic sensor site quality and the dividing of station categories. The results of the first stage of the classification are purely statistical processing to determine which stations have a tendency for station magnitudes to be eliminated for each type of magnitude. Due to its purely statistical, the reason why a station always has a tendency to be eliminated is not considered further.

Therefore, the next stage is to validate the seismic sensor classification with site quality for each seismic sensor. Validation with site quality is carried out because the determination of each type of magnitude is based on the maximum amplitude of the seismic record at a seismic station which can be affected by its site quality. The amplitude of earthquake waves can be increased (amplification) due to the location of the seismic sensor, which is located on sediment, and the amplification will affect the magnitude value at that station.

Site quality for each seismic sensor in Indonesia has been determined by the BMKG Research and Development team by considering various factors. Such as factors affect the hardness or softness of the soil conditions at the seismic sensor location, which is determined by the parameters of the geological conditions related to the type of rock, the HVSR parameter values related to the dominant period and site class at the sensor location, and the parameter value of s wave velocity at a depth of 30 meters (Vs30) which can determine the rock hardness at the sensor location. In addition, the noise factor at the location is also used because if the recorded seismic sensor signal is filled with environmental noise, it will be difficult to determine the maximum amplitude value of the recorded earthquake. The noise factor in determining site quality is determined based on the Petterson noise model at each seismic station.

All these parameters are calculated and given their respective weights for use in grouping seismic stations, which are divided into four site quality groups: Very Good, Good, Fair, and Poor. Seismic stations with site quality in the Very Good, Good, and Fair groups are generally located in hard rock and have low noise, so these locations are proper and ideal for recording seismic waves because the resulting recordings are not amplified and look more precise.
The grouping results based on site quality by the BMKG Research and Development Center [18] (figure 7) show that 16.1% of Indonesia's total seismic stations, or around 66 seismic stations are very good groups, 47.0% or around 193 seismic stations are in the good group, 29.4% or around 121 seismic stations are included in the fair group, and the remaining 7.5% or around 31 seismic stations are in the poor group.

Figure 8 shows a graph of the relationship between site quality for each classification of seismic sensors based on their magnitude result of the first stage to divide the categories after validation. The figure shows an excellent correlation where seismic stations with very good, good, and fair site quality groups are generally found in classification A in determining magnitude (blue box, figure 8), which means that seismic stations are located in good and ideal locations (hard and low noise) will produce a good magnitude value as well. Whereas for stations that are not good (poor), there is at least 1 type of magnitude whose value is often eliminated.

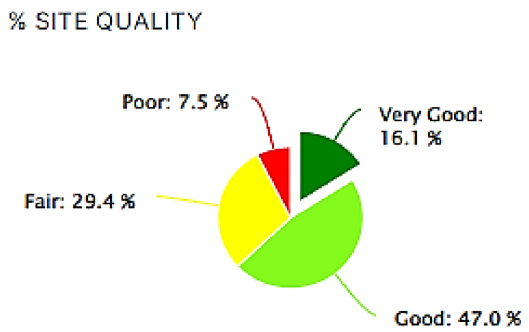

Figure 7. Percentage diagram for the number of seismic stations based on site quality groupings

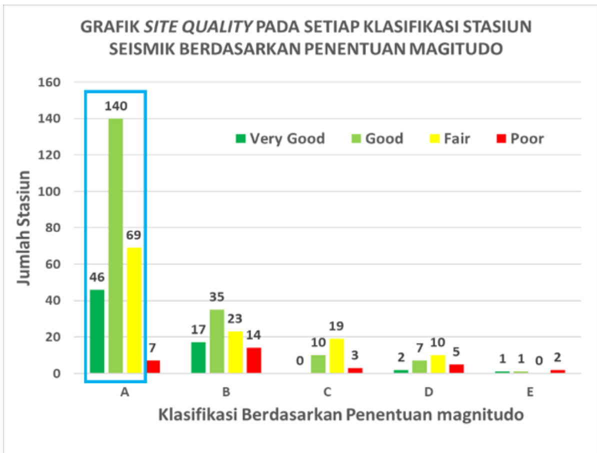

Figure 8. Graph of site quality for each seismic sensor classification based on magnitude determination.

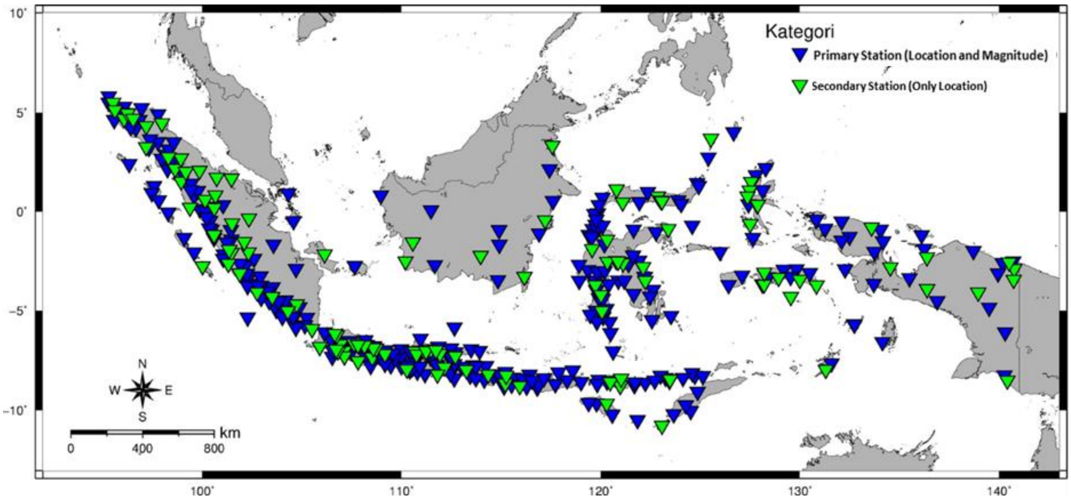

Figure 9. Map of the distribution of primary and secondary stations, which will be used for testing to determine the magnitude with SeisComP playback.

Table 3. Number of selected seismic stations in each category.

KATEGORI	A	B	C	D	E	TOTAL
STASIUN PRIMER (LOKASI + MAGNITUDO)	255	25	5	0	0	285
STASIUN SEKUNDER (LOKASI)	7	64	27	24	4	126

This correlation shows that, in general, the location of the site has an influence on determining the magnitude. However, Figure 8 also shows that there are several very good, good, and fair seismic stations whose data are often eliminated or produce magnitude values that tend to be incorrect. This shows that the factors affecting the magnitude are very complex, and the site quality factor is only one among many other factors that need further study.

Next, we made a simpler category that considered site quality and station classification based on magnitude results at each seismic station into two main categories, that is, primary stations and secondary stations. The primary station is a seismic station with classification A in the very good, good, and fair site quality groups, plus seismic stations in classifications B and C in the very good site quality group, good (good), and quite good (fair), with the results of mB and Mwp still quite good even though other types (MLv, or mB) are often eliminated. The types of magnitude mB and Mwp are preferred because these magnitudes are calculated over a wider broadband frequency range, so their saturation values will be higher than MLv and mb, and they will be better if used to determine earthquakes with larger magnitudes [27, 26]. 285 stations have been selected to be seismic primary and will become priority stations used in determining the location and magnitude of earthquakes. Meanwhile, the other 130 stations will still be used as secondary stations, which are only used for location determination (figure 9 & Table 3).

Testing the magnitude determination with the primary seismic station using SeisComP playback

After the seismic stations were divided into two categories, testing was conducted to determine the magnitude of the selected primary stations using the SeisComP playback feature. To facilitate the analysis of these differences, a timeline graph is made showing the fluctuation of the magnitude differences (residuals) for each magnitude every ten seconds in the first five minutes for each final magnitude value (figure 10A).

The graph in the red box column in Figure 10A is the result of magnitude processing by BMKG, showing that for the magnitude of MLv in the first minute, after MLv is determined (130 – 190 seconds after the earthquake), there are significant fluctuations (green box, figure 10A), where generally the MLv at each event (gray line) has a large enough residual and some even have a difference of -1 from the final MLv. Overall, the maximum residual average of MLv to the final MLv is -0.19 at 150 seconds after the earthquake, with a maximum deviation of $\pm$ 0.286.

Furthermore, the BMKG results also show significant fluctuations, where the maximum of average residual mb to the final mb is -0.29 at the 140th second after the earthquake, with a maximum deviation, is $\pm$ 0.334. mB also shows quite large fluctuations, tend to be unstable, and is changeable, just like MLv and mb. The maximum average residual mb to the final mb is -0.14 at the 160th second after the earthquake, with a maximum deviation of $\pm$ 0.28. As for Mwp, fluctuations in the first 1 minute also often occur, which is marked by a large deviation at the start of the determination. However, when compared with MLv, mb, and mB, the average residual and Mwp deviation are the smallest, with a value of 0.041 $\pm$ 0.186.

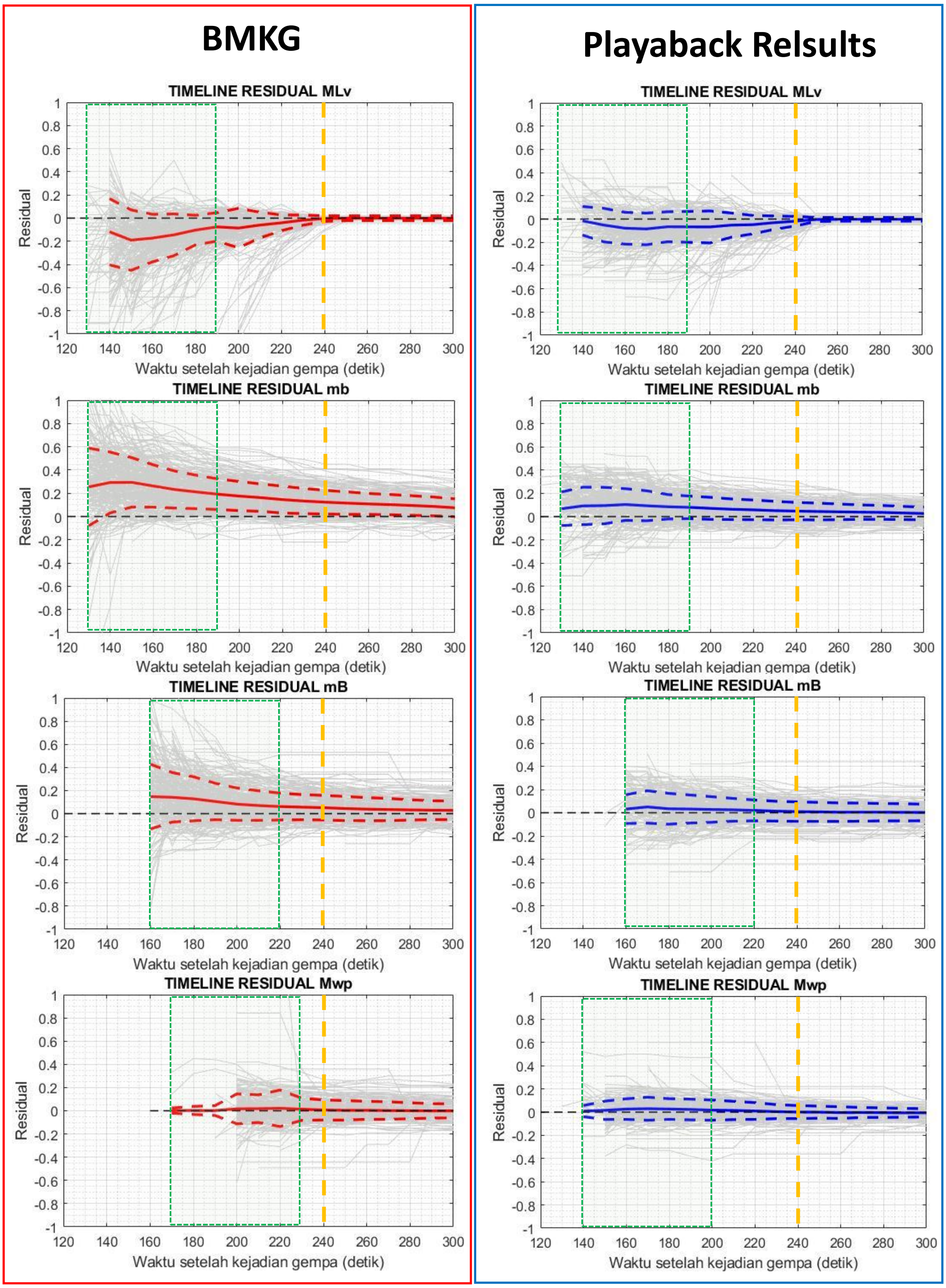

Figure 10. Graph of the residual timeline for each type of magnitude to its final magnitude value. The gray line is the residual timeline of the 256 earthquake events that were played back. The thick red line and the dashed red line are the average residual and standard deviation of the BMKG data, and the thick blue line and the dashed blue line are the average residual and standard deviation of the playback results. The green box represents the area one minute after each type of magnitude was first determined, and the yellow dotted line represents the average dissemination time of 240 (± 30) seconds after the earthquake occurred occurred.

Table 4. Table of residuals and deviation of each type of magnitude to the final magnitude.

Residual hasil BMKG

	MLv	mb	mB	Mwp
Rata-rata (Max)	-0.190	0.294	0.147	0.041
Deviasi (+/- Max)	0.286	0.334	0.280	0.186

Residual Hasil Playback

	MLv	mb	mB	Mwp
Rata-rata (Max)	-0.085	0.104	0.050	0.029
Deviasi (+/- Max)	0.144	0.161	0.140	0.099

Table 5. Table of residuals and deviation of each type of magnitude on the Mw BMKG

Residual hasil BMKG

		MLv	mb	mB	Mwp
Rata-rata	**Min**	0.120	0.141	0.412	-0.009
	Max	0.376	0.430	0.615	0.270
Deviasi	**+/- Min**	0.248	0.224	0.180	0.057
	+/- Max	0.420	0.410	0.349	0.312

Residual Hasil Playback

		MLv	mb	mB	Mwp
Rata-rata	**Min**	0.286	0.196	0.438	-0.001
	Max	0.436	0.337	0.527	0.113
Deviasi	**+/- Min**	0.266	0.240	0.190	0.159
	+/- Max	0.297	0.300	0.233	0.186

The result of testing is shown by the column in the blue box (figure 10B); the residual fluctuations for each type of magnitude in the first minutes (green box, figure 10B) appear to be reduced significantly, which is marked by many gray lines that are closer together with a residual value close to 0. This indicates that the determination of earthquake magnitude by the selected stations has a smaller residual value for each final magnitude.

The average residual and deviation for each type of magnitude are smaller (table 4), indicating that determining the magnitude using the primary station has better results than before. In addition, the time required to determine each type of magnitude is also not significantly different because the primary station configuration is still good enough to cover all earthquake source locations in Indonesia, and the location determination is not affected too much because the locations are still determined by all 411 seismic stations which is a combination of primary stations and secondary stations.

The fluctuations of magnitude at the first minute of determining each type of magnitude from the BMKG results are caused by seismic stations that tend to magnitude values that are too large or too small (which is most often eliminated by the trimmed mean) and are still used for data in determining the magnitude. For example, if an earthquake occurs near station A which tends for the resulting magnitude to be too high, then station A will still use its data at the first minute of determining the magnitude because it is the closest station, and the stations that count are still limited so that at the beginning of determining the magnitude it tends to be larger, as time goes by and the number of stations that count increases, station A will be eliminated in determining the magnitude and the resulting magnitude will be more stable. The primary station was chosen so that at the beginning of determining the magnitude, only the best stations were used so that in cases like station A above, they were not involved from the first time determining the magnitude, and this was proven in better playback results than before seismic station selections.

Although, as a whole, it appears that the fluctuation after the station is selected is getting smaller and better, the fluctuation in determining the magnitude still exists, especially for the type of magnitude that is calculated in the high-frequency range, such as MLv and mb where at stations that are quite close to the source of the effect local geology will be very influential, especially at high frequencies. In addition, the attenuation correction value factor in determining MLv should be adjusted to the local geological conditions of each region [26]. Meanwhile, the attenuation correction value factor for determining the magnitude in Indonesia still uses the Southern California attenuation correction for the entire Indonesia [28]. In addition, the attenuation correction values for mb and mB still use the global correction model, which is actually better used for stations with distances above 20o, because for distances below that, the amplitude values will be greatly influenced by regional structures and upper mantle structures so the attenuation correction values will be more complex and vary from region to region. In contrast to other types of magnitude,

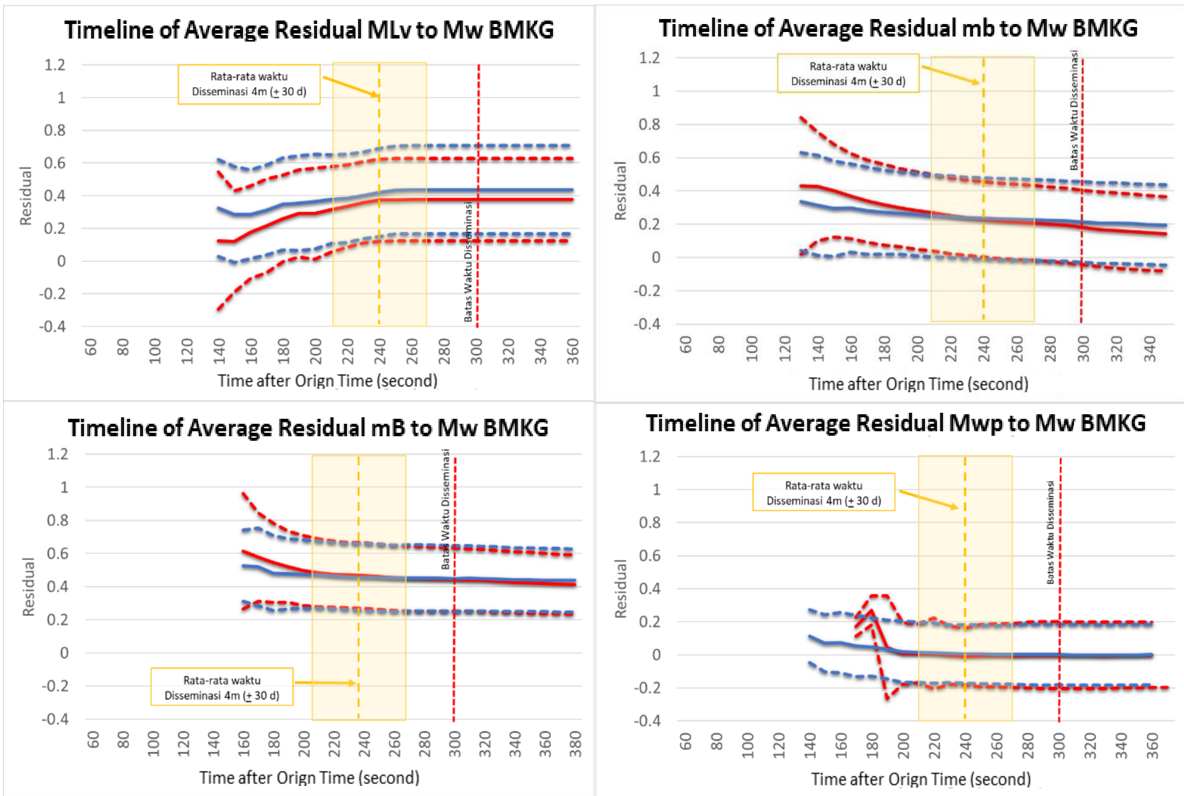

Figure 11. Graph of the residual timeline for each type of magnitude to Mw (moment magnitude), and deviation from playback results. The yellow box is the average dissemination time area, 240 (±30) seconds after the earthquake.

Mwp tends to be more stable because in the process of determination, double integration of the seismic velocity wave naturally resulting filtered signal to a lower frequency and can reduce local and regional effects naturally [7], so the fluctuations at the beginning of Mwp determination is not as big as other types of magnitude.

In addition to graphing the residuals of each type of magnitude to their final value, we also graphed the residual timeline of each type of magnitude to the Mw (moment magnitude) of the BMKG (figure 11). We do this because Mw is a type of magnitude that is used as a preferred for the final magnitude of an earthquake event obtained from the inversion of the moment tensor so that Mw is used as a reference for accuracy in determining magnitude where a good magnitude results at the first five minutes is one that is close to the final Mw BMKG.

In general, the average residual and deviation of 256 of the playback results to the final Mw (blue line) show better results than before (red line). This is indicated visually; the blue line is more sloping and tends to be flat from the beginning till five minutes after the earthquake, which means that the magnitude value is more stable after the primary station is used. Although the magnitudes of MLv, mb, mB, and Mwp are more stable, the difference to the final Mw tends to be quite large with an average residual around 0.28 for MLv, 0.19 for mb, 0.43 for mB, and the smallest are Mwp -0.0011 (table 5). The residual for each type of magnitude to Mw can occur due to differences in characteristics in the calculation [26]. Mwp is a type of magnitude that has the smallest residual to Mw, which means that the results of Mwp are not too different from Mw; this is because Mwp was developed to estimate Mw values based on the P wave phase [7]. This indicates that the determination of each type of magnitude MLv, mb, mB, and Mwp with the primary station only makes the determination of the magnitude value more stable at the beginning, which is characterized by a sloping average residual and smaller deviation but does not make the value of each type the magnitude becomes closer to the Mw value.

Based on all these results, the selection of primary and secondary category stations can improve the stability of determining each type of earthquake magnitude where the very large residuals at the beginning of determining the magnitude can be well reduced. In addition to determining the types of magnitudes MLv, mb, mB, and Mwp, BMKG also determines the type of magnitude M which is the weighted average of the types of magnitudes MLv, mb, Mw(mB), and Mw(Mwp) [9] which are generally the magnitudes that are informed to the public in early earthquake information. The types of magnitudes Mw(mB) and Mw(Mwp) are the estimated magnitudes of the moment magnitudes of Mw based on the regression formulation of the relationship between mB and Mw [29] and Mwp and Mw [30]. This research has succeeded in stabilizing the determination of each of these types so that it can be used as a basis for updating the empirical formula for estimating the value of Mw and also updating the formulation for determining M so that the resulting value will be better with residuals on the final Mw which is not too large.

4. Conclusion

There is a very good correlation where a good site quality (hard soil and low noise) will produce a good magnitude value (always used in the trimmed mean). Then after seismic station categorization, there are 285 primary seismic stations (which are good in terms of site quality and magnitude determination results) that can be used in determining the location of the earthquake and magnitude. The remaining 126 are secondary seismic stations that are only used in determining earthquake locations. The testing results for determining the magnitude using SeisComP playback using 285 primary stations show that fluctuations in the value of each type of magnitude in the first few minutes can be adequately reduced compared to the results before the seismic station is selected. This is indicated by the decrease in the average residual and the deviation of each type of magnitude to the final magnitude where the maximum average residual MLv decreases from -0.19 + 0.28 to -0.08 + 0.14, mb maximum average residual decreased from 0.29 +0.33 to -0.10 + 0.16, the maximum mB average residual decreased from 0.14 + 0.28 to -0.05 + 0.14, and for the average Mwp the maximum residual decreases from 0.04 + 0.18 to -0.03 + 0.01. The magnitude fluctuations that can be reduced after only using the primary station indicate that the resulting magnitude is much more stable and consistent in the early minutes than previous results.

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