Conformity Analysis on the Use of Hydro Enforcement Method to Produce Digital Terrain Model Using the LiDAR Data as Indonesian Basic Geospatial Information, Case Study: Sumedang District, West Java, Indonesia

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ABSTRACT: Basic geospatial information is a basic information that must be collected in all regions of Indonesia. One of the basic geospatial information is Digital Terrain Model (DTM) which contains surface altitude information. There are several methods for constructing DTM, one of them is by using the Light Detection and Ranging (LiDAR) data. LiDAR is one of the active remote sensing system and is growing rapidly for many applications. LiDAR data contains altitude information which can be processed to produce DTM. The acquisition of LiDAR data in Indonesia uses infrared electromagnetic waves which has low quality for identifying water objects. Therefore, the visualization of aquatic objects in Lidar-based DTM is not optimal, thus a method to improve the quality of DTM is needed. The hydro enforcement is one of the methods to improve the quality of Lidar-based DTM which employs the principle that water flows from high to low place. By using this method, the water object on the DTM would appear smoother and represent the actual conditions of the river. The purpose of this research is know the suistability form hydro enforcement method to produce DTM in Indonesia. This research was conducted in Sumedang Districts due to the topographic characteristics−hills and large rivers in the valley, which needs a good visualization for water objects. The pre-processing of Lidar data includes the calculations of strip adjustment value, point density value, and point spacing value−which is used to determine quality, and determination of optimal scale. Based on the calculations, the value of strip adjustment was 0.0001625, which indicates a good quality LiDAR data. The point density value was 1.125 and the value of point spacing was 0.94375, thus obtaining the optimum scale to be 1:1,000 based on the provisions of Indonesian Geospatial Information Agency (BIG). Processing of LiDAR data using hydro enforcement method can be performed by removing mass point on the water body and make break-line along the riverbank. The result showed that the water objects on DTM constructed from hydro enforcement method had a better visualization compared to DTM without using this method. Conformity analysis−considering the provisions made by BIG, shows that the hydro enforcement method done is suitable to make the DTM in this study area.

1. INTRODUCTION

Remote sensing is the science and skill to obtain information about an object through analysis of data obtained from devices that record electromagnetic waves without direct contact with the object (Lillesand and Kiefer, 2004). There are two known types of remote sensing, namely passive remote sensing system (Figure 1a) and active remote sensing system (Figure 1b). Active remote sensing system generates and emits its own energy and records any reflecting pulses from the objects, whereas passive remote sensing system records the reflectance energy from solar radiation. The examples of active remote sensing systems are Radio Detection and Ranging (RADAR) and LiDAR.

A

B

Figure 1. Remote sensing systems: (a) passive remote sensing system and (b) active remote sensing system. (source: www.rfwireless-world.com)

LiDAR is an active remote sensing system technology that utilizes light energy form laser light in the process of recording an object. The laser beam can produce information regarding the position and height of objects on the the Earth surface. The laser beam is produced by a LiDAR sensor which are then shot towards the surface of the earth and then reflected back by objects on the surface of the earth and received by the LiDAR sensor. The time period in which the LiDAR light energy was shot and reflected back to the sensor is used as a variable to calculate the distance between the object and the sensor (Sari, 2016). The difference time between the first reflection and the last reflection can be used to detect the height of objects from the ground surface carefully. The LiDAR device has a timer that functions to record the time when the laser beam is emitted and received again by the sensor so that it can generate altitude information on each point cloud produced (Kandia, 2012).

Unlike the LiDAR system in other countries that utilize blue (450-510nm) and green (530-590nm) waves which makes them suitable for water bodies detection, most of LiDARs in Indonesia work using infrared waves (700-1500 nm) as energy to interact with objects. The use of infrared waves has poor properties when they are reflected on water objects or bodies of water (Figure 2). This is depicted in the spectral reflection curve that explains how the condition of the aquatic object when recorded on an infrared wave. Spectral reflection curves are graphs that illustrate the characteristics of objects in absorbing or reflecting electromagnetic waves. Spectral reflection in aquatic objects has decreased from the blue spectrum to near infrared. This is due to the energy in this spectrum is absorbed entirely by water.

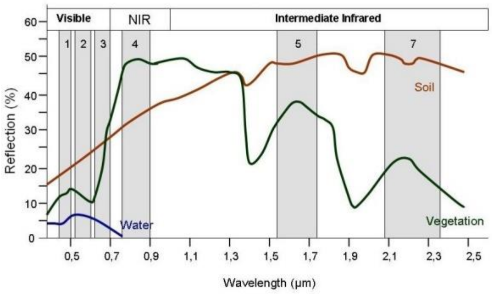

Figure 2. Spectral reflectance curves of main Earth objects (source: https://www.brainkart.com/).

The value of the spectral reflection recorded by the sensor is influenced by the nature of the water and the (content of) organic and inorganic materials contained therein. Thus, height data obtained from recording aquatic objects using LiDAR are information from objects other than water contained in the water itself. One of the main products of recording LiDAR data is Digital Terrain Model (DTM). DTM is digital data from the Earth's surface consisting of 2D heights (Hirt, 2015). The process of constructing DTM using LiDAR data is done based on Triangular Irregular Network (TIN) (Axelsson, 2000).

Recording LiDAR data using infrared waves can affect the quality of the resulting DTM. That is because the point cloud that is in the aquatic object requires the input to create DTM. In fact, the point cloud that is in a water object is not a representation of the bottom of the water body or the body of water itself. Point clouds in the waters may be noise or other objects that are not water but are recorded and produce point clouds in water bodies. DTM results from LiDAR data that include point clouds in water bodies as input will produce DTM visualization on uneven water objects. The disadvantages of recording using LiDAR require a method to overcome the resulting deficiencies. One method that can be used to make better DTM visualization on aquatic objects is the hydro enforcement method. The formation of DTM using the hydro enforcement method is a new thing that is now used by the Geospatial Information Agency (BIG) in the terms of reference for making maps of the Earth (Putri, 2016). LiDAR data processing using the hydro enforcement method is done by changing the ground class point cloud on the river object to the water class.

Water objects such as rivers require data in the form of altitude points that are used for river flow analysis. The process of constructing DTM in the river area is based on the principle that water will always move from high to low places due to the earth's gravitational force which causes water to have a heavier mass than air (Narulita, 2008). Water will only apply otherwise when there are other forces that cause it to move from the bottom up like the capillary force, the gravitational pull of the moon, the force of pressure, and so forth. Thus, the results of constructing DTM will provide information on how rivers flow based on the height value.

The use of infrared waves in the acquisition of lidar data causes problems such as 1.) The use of infrared waves in LiDAR causes the results of DTM visualization in water bodies to be poor and does not reflect the actual conditions, 2.) The results gathered by constructing DTM require a quality control test to ensure the resulting data is appropriate with standards set by the Spatial Information Agency (BIG), 3.) There is a double interpretation of the results of the DTM visualization of water objects, and 4.) The existence of hydrological disasters that occur due to the unavailability of data on the direction of river flow. Therefore, this study aims to create a Digital Terrain Model (DTM) and map the direction of river flow using the hydro enforcement method using point cloud LiDAR data.

2. METHODS

2.1. Study Site

This research was conducted in a part of Sumedang Regency, West Java. The study area is located at 60^o 59' 35"S – 60^o 59 '37"E and 60^o 57' 57"S – 60^o 59' 35"E. LiDAR data used to conduct this research are the result of work on LiDAR data acquisition and aerial photography of PT Waindo Specterra Indonesia. The location of the data acquisition is in Sumedang Regency, West Java Province. The area of the study site is 6.425 km^2. The study site has a hilly topography with a large river, the Kali Cimanuk River in the valley as shown in Figure 3.

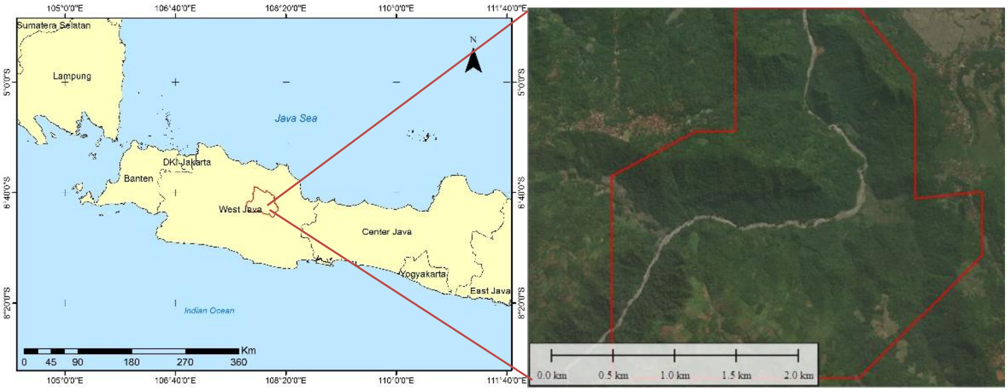

Figure 3. Map of study area.

2.2. LiDAR Processing

The software used in this research is Bentley Micro Station Version 8.1 and Global Mapper as data processing software. The data used is las raw point cloud data, trajectory raw, and aerial photo mosaic. This research uses a quantitative method involving the calculation of numbers, namely the calculation of the value of the strip adjustment and determination of the optimum map scale that can be made through the relationship between point density and point spacing. The method used to make DTM visualization on water objects better is the hydro enforcement method. Hydro enforcement method is a method used to modify the elevation value or height of a water object from LiDAR data in the form of point cloud data, point clouds are a collection of three-dimensional geometry coordinates that have X, Y and Z coordinates. The work stages carried out in the study are illustrated in this diagram (Figure 4).

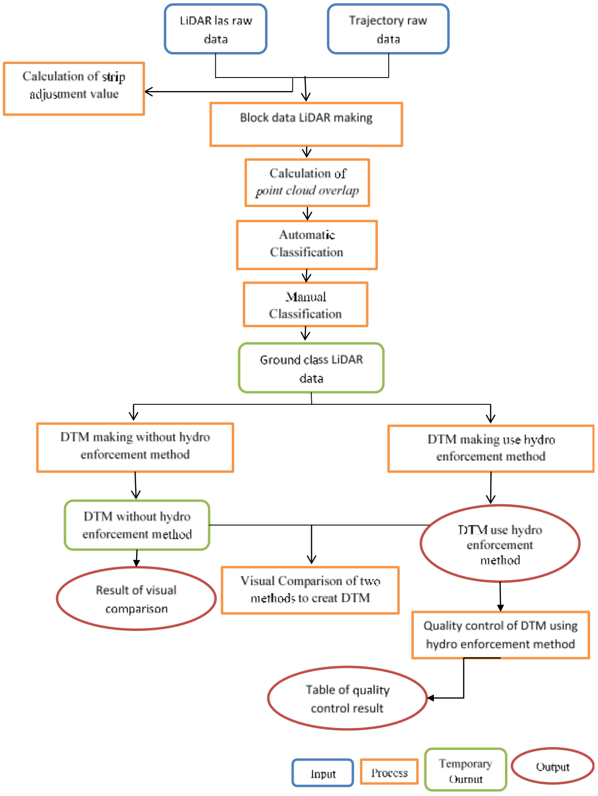

Figure 4. Flow diagram of the research steps.

2.3. Research Steps

2.3.1. Calculation of strip adjustment value

The strip adjustment value is calculated based on the distance (Z) between las raw LiDAR data and the raw trajectory containing Inertial Measurement Unit (IMU) information. IMU itself is an integration with the Global Positioning System (GPS) available on the LiDAR recording device (Liu, et al, 2017). Based on BIG regulations, the maximum allowable strip adjustment value is 0.1.

2.3.2. Calculation of optimum scale

The optimal scale can be found by calculating the point density and point spacing values which are then adjusted to the table of the relationships between point density, point spacing, contour intervals, and map scales issued by BIG (Table 1).

Table 1. Relationship between point density, point spacing, contour interval, and map scale (source: BIG, 2016).

Point Density (poin/m^2)	Point Spacing (m)	Contour Interval	Map Scale
8	0.354		

7	0.377		
6	0.408		
5	0.447		
4	0.5	0.150	1:400
3	0.577	0.170	1:500
2	0.707	0.2155	1:750
1	1	0.3048	1:1000
0.25	2	0.6096	1:2000
0.11	3	0.9144	1:3000
0.06	4	1.2190	1:4000
0.04	5	1.5240	1:5000

2.3.3. Construction of LiDAR block data area

The construction of LiDAR data blocks in the study area is intended to facilitate the processing of LiDAR data. The size of the block made is 1,000 x 1,000 meters. The LiDAR cloud point data is cut according to the AOI (Area of interest) which is the boundary of the specified study area.

2.3.4. Point cloud overlap removal

Las raw data of LiDAR which is a point cloud data on each flight path when recording LiDAR data produces overlapping point clouds. This means that there is a point cloud that is the same point cloud so that one must be removed or included in the overlap class.

2.3.5. Automatic classification

Automatic classification is intended to explain the point cloud ground that is used as input in constructing DTM. Automatic classification uses certain parameters that form the basis for software in describing point clouds that are ground or not. These parameters include the maximum building size, terrain angle, and iteration angle. These parameters are determined by the most appropriate value in order to properly explain the point cloud ground. This automatic classification uses Run Macro so that it can be used directly in all blocks of the study area.

2.3.6. Manual classification

Manual classification is a continuation of the automatic classification that has been done before. Manual classification is intended to see and improve the surface appearance of the ground class point cloud results from automatic classification. The method used to do a manual classification is to compare the surface ground results of each block with existing aerial photographic data. This is done in order to see the discrepancies that exist in the automatic classification of the ground class, so that it can be fixed manually.

2.3.7. DTM construction without hydro enforcement method

Constructing DTM without using the hydro enforcement method is intended as a comparison of visualization with constructing DTM using the hydro enforcement method. Constructing DTM using the hydro enforcement method involves all ground class point clouds that exist in the study area, meaning that the point cloud ground that is in the body of water is also used as input. The results of constructing DTM without using the hydro enforcement method are also used as input for making contours from DTM results. Making contours is intended to create a river center line that has a height, so that it can be used to determine the break line on the river.

2.3.8. Constructing DTM with hydro enforcement method

Constructing DTM using the hydro enforcement method does not include ground class point clouds that exist in water bodies. This means that the ground class point cloud contained in the body of water had to be removed before the DTM manufacturing process is carried out. To get the height of the body of water in accordance with the surrounding area, we need a break line that is also used as input in the process of constructing DTM with this method. Constructing DTM by using this method is expected to produce DTM with better visualization on aquatic objects.

2.3.9. DTM comparison of the two methods

The comparison of the DTM of the two methods is done by using a visual comparison. Visual comparison is done using two ways, namely by looking at the overall appearance of the body of water on the DTM with and without using hydro enforcement and making a cross-profile on several parts of the body of water, so that conditions can be compared when viewed transversely. A visual comparison of the two methods is then analyzed to see differences in the appearance of the body of water with DTM without the hydro enforcement method and DTM with the hydro enforcement method.

2.3.10. Quality control of DTM hydro enforcement method

A quality control test is then carried out to the DTM that has been made using the hydro enforcement method in accordance with the provisions given by BIG. The intended quality control test table is described in Table 2.

Table 2. Parameter of DTM quality control test using hydro enforcement method (source: BIG, 2016).

No.	Parameter of Quality Control Test
1.	There is no mass point in the waters
2.	Formation in accordance with the breakline and waters
3.	The smoothness of the DTM is consistent and does not form mound
4.	There is no height below 0 meters except for depression or basin
5.	Depressions and terraces with a height difference of more than 1 meter are formed
6.	No extreme height values (spikes)
7.	The body of water has the same height
8.	DTM along the direction of water flow (rivers, grooves) flows smoothly.
9.	The DTM transverse profile is smooth and logical
10.	Compliance with adjacent map number.

3. RESULTS AND DISCUSSION

3.1. Calculation of Strip Adjustment Value

Calculation of the strip adjustment value using the terra match tool available on the terrasolid device. At the study site, there are 7 flight paths that will be tested for accuracy of the data point cloud in it. This strip adjustment value is obtained by comparing the position of each point cloud with the trajectory lines recorded in the LiDAR data acquisition. Based on BIG regulations, the maximum strip adjustment value is 0.1 meters. This means that if the calculation results of the strip adjustment exceed 0.1 meters, the LiDAR data is of poor quality.

The results of the calculation of the value of the strip adjustment using terra match shows that each flight path has a strip adjustment value below 0.1 meters (Table 3). Meanwhile, if the strip adjustment value of each flight path is averaged it will produce a value of 0.0001625. Based on these values, it can be concluded that the LiDAR data that will be used is LiDAR data that has good quality.

Table 3. Calculation result of strip adjustment value.

Flightline	Points	Magnitude	Dz
0	107600	0.0782	0.0025
1	10729	0.0876	0.001
3	94493	0.1063	0.0158
4	462140	0.084	-0.003
5	582337	0.0817	-0.008
6	627958	0.0716	0.02
2	116667	0.0642	0.0009
7		0.0718	-0.0279

3.2. Calculation of Optimum Scale

The results of the calculation of the average value of point density and point spacing for all LiDAR cloud data points are 1.125 and 0.94375. Based on these results, the equivalent interval contour values depicted on a 1: 1,000 scale maps are 0.3048. The existence of this optimum scale value is intended to provide information that the data generated by the LiDAR point cloud will have the best visualization if depicted on a map with 1: 1,000.

Table 4. Calculation result of optimum scale.

Block	Point Density	Point Spacing
1	1.02	0.99
2	1.11	0.95
3	1.13	0.94
4	1.05	0.97
5	1.11	0.95
6	1.28	0.89
7	1.23	0.9
8	1.07	0.96
Average	1.125	0.94375

3.3. Block Data LiDAR Area Making

The creation of a LiDAR data block is intended to facilitate the further processing of LiDAR data. Each LiDAR data block has an area of 1,000 m x 1,000 m, which means that the entire LiDAR data on the raw LiDAR welding is divided into several blocks with a size of 1,000 m x 1,000 m. In this study area, it is divided into 8 blocks, with 4 full point cloud blocks and the remaining 4 blocks only partially (Figure 5).

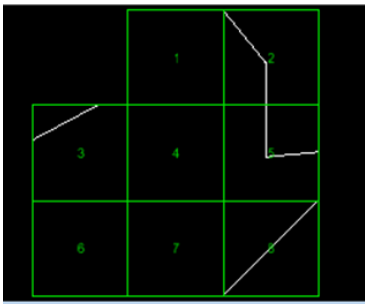

Figure 5. Block area of LiDAR data.

3.4. Point Cloud Overlap Removal

LiDAR data which was originally in the form of LiDAR data for each flight path will produce point clouds that overlap at each flight path meeting. The overlapping point cloud must be removed because it will affect the results of the subsequent LiDAR point cloud processing. Eliminating point cloud is done by making overlapping macro cut so that overlapping point cloud can be removed one of them. Based on the results of the overlap cut, in each block there is a point cloud overlapping, so it is necessary to remove one overlapping point cloud to produce good LiDAR data (Figure 6).

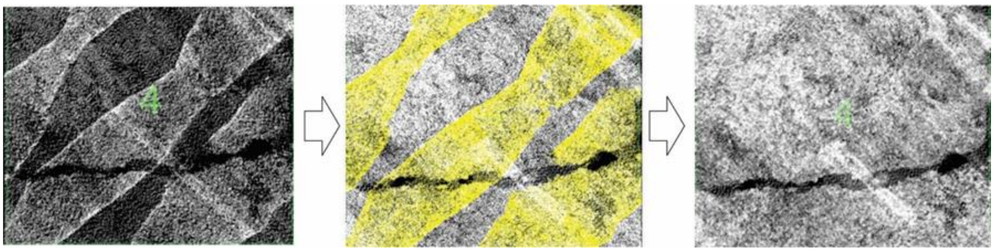

Figure 6. Point cloud overlap removal.

3.5. Automatic Classification

Automatic classification is intended to explain the LiDAR point cloud into a ground class in accordance with predetermined parameters. This automatic classification uses the Bentley Microstation V8i software which is integrated with TerraSolid. This automatic classification process uses macros by entering the ground classification function with parameters that have been changed. These parameters are determined according to the needs and topographical conditions of the study area (Table 5). It is intended that the resulting classification will be more accurate in explaining point cloud ground.

Tabel 5. Parameter value to ground classification.

No.	Parameter	Value
1	*Maximal Building Size*	60 meters
2	*Terrain angle*	88°
3	*Iteration angle*	6°

Maximum building size value of 60 meters was chosen following the topography of the study location that had hilly topography. This is intended because the value of 60 meters indicates a distance of 60 meters between two ground surface points, meaning that each distance is equal to this parameter, there is at least one-point cloud ground. Terrain angle value of 88o indicates that a field has a maximum slope value of 88o so that it is inserted into the ground cloud point. Whereas an iteration angle of 6° indicates a change in the maximum tilt angle between two iterations during ground level analysis. Based on parameters that have been determined, shows the results of a good ground classification. Evidenced by the lack of errors in the form of point cloud miss classification which should be explained to be ground. Thus, overall the results of the ground classification using the automatic method are quite representative in describing the condition of the earth's surface in the study area (Figure 7).

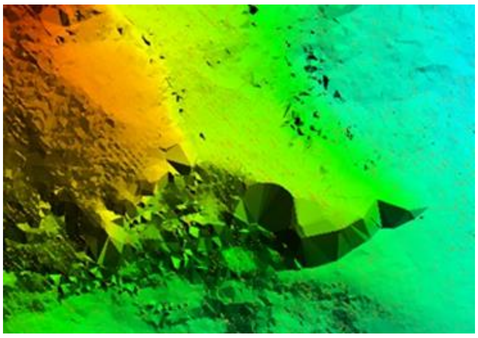

Figure 7. Automatic classification result.

3.6. Manual Classification

Manual classification is done in order to check the results of data obtained from the automatic classification carried out. The results of ground classification by automatic means show that there are some areas that are miss-classified. Some unexplained extent is then reclassified manually. The manual classification process requires an aerial photo mosaic as reference data used to see the actual appearance in the study area. Miss-classified data generated from the automatic classification process is then re-classified manually according to the objects that appear on the aerial photo mosaic. Because the results of the automatic classification are already representative, only a small amount of data requires a manual classification process (Figure 8).

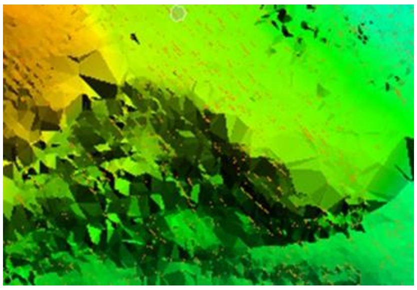

Figure 8. Manual classification result.

3.7. Manual and Automatic Classification Comparison

The results of the DTM without using the hydro enforcement method show visualization of aquatic objects that appear coarse and do not describe the actual height but are affected by the presence of other material content in water. This condition is explained in the graph where the water object has a very varied height on one river segment that should have the same height.

A different appearance is shown in the DTM results using the hydro enforcement method which describes the results of the water object appearing smooth and visualizing the actual height. This condition is explained in the cross-section graph where water objects have the same height for each river segment that has the same average height. The results of the DTM with the hydro enforcement method are more logical because in DTM without using hydro enforcement the water level varies greatly. The DTM and cross-section result comparison is presented in Figure 9.

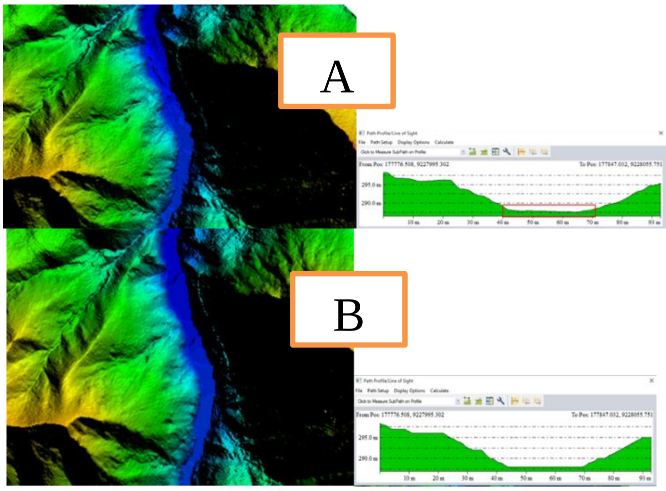

Figure 9. (A) DTM without hydro enforcement method, (B) DTM with hydro enforcement method

3.8. Quality Control of DTM Using Hydro Enforcement Method

Based on the DTM quality control tests conducted (Table 6), there are 7 appropriate parameters, 1 does not match, and 2 does not exist in the study area. It can be concluded that the DTM data which results from the hydro enforcement method has good quality.

Tablel 6. Quality control test assessment.

No.	Parameter of Quality Control Test	Corresponding	Not Corresponding	Ther is no
1.	There is no mass point in the waters	√		
2.	Formation in accordance with the breakline and waters	√		
3.	The smoothness of the DTM is consistent and does not form mound	√		
4.	There is no height below 0 meters except for depression or basin	√		

5.	Depressions and terraces with a height difference of more than 1 meter are formed			√
6.	No extreme height values (spikes)	√		
7.	The body of water has the same height		√	
8.	DTM along the direction of water flow (rivers, grooves) flows smoothly.	√		
9.	The DTM transverse profile is smooth and logical	√		
10.	Compliance with adjacent map number.			√

4. CONCLUSION

Automatic classification uses predetermined parameters, resulting in a representative point cloud ground which means it can represent the condition of the earth's surface even though there are still some areas of point cloud miss classified. Constructing DTM by using the hydro enforcement method produces better visualization results than without using this method as evidenced by the results of a cross-section graph showing the same height at one river segment. The DTM quality control test refers to the Geospatial Information Agency's terms of reference with results in the form of 7 appropriate parameters, 1 does not match, and 2 does not exist in the study area. The results of DTM quality control tests that have been done illustrate that the DTM that has been made is of good quality.

5. ACKNOWLEDGEMENT

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