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UTILIZATION OF DRONE MAPPING (PHOTOGRAMMETRY) APPLICATION TO EVALUATE THE VOLUME OF INUNDATION AREA AT MARGATIGA DAM

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ABSTRACT

In 2017 the planned volume of the Margatiga Dam inundation area at an elevation of +23,000 is 42,311,835.60 m3. Using the drone mapping method (photogrammetry) there is a difference in the volume of the puddle area at an elevation of +23,000 with a result of 41,005,959.97 m3. The method used to evaluate the volume of the inundation area at the Margatiga Dam is taking field data using drones in the form of aerial photography, testing the accuracy of GCP (*Ground Control Point*) geometry and calculating volume using *Autodesk Civil 3D software.* The volume was obtained after going through an accuracy test on the geometry of GCP alternative one with an accuracy test value of 0.723 meters and an RMSE value of 0.438. Processing *using Agisoft software* is processed into two parts, namely the first processing using alternative GCP geometry 1 and the second processing using alternative GCP geometry 2. The design of the planning consultant in 2017 regarding the reservoir volume at the Margatiga Dam at an elevation of +23,000 was 42,311,835.60 m3. By evaluating the volume of inundation using the photogrammetric method, a volume of 41,005,959.97 m3 was obtained with a selection of contour intervals of 0.75 meters.

Keywords: *dam margatiga, evaluation, photogrammetry, GCP, volume*

INTRODUCTION

At the beginning of the planning for the construction of the Margatiga Dam, the inundation area reached approximately 3000 hectares. With this area, if terestris measurements are carried out in the field, it will usually take a long time. To speed up the process of taking topographic data at the Margatiga Dam location, a measurement method is needed that can be measured, processed, and produce meticulous results in a short time. Photogrammetry is a survey and mapping method that is quite effective today (Setiyo et al., 2016). This method can retrieve data in a wide area coverage from a short distance and in a short time. UAV (*Unmanned Aerial Vehicle*) photogrammetry opens up new applications in the near range, combining aerial and terrestrial photogrammetry, as well as introducing new applications in *real-time* and *low-cost* alternatives (Bone & Bolkcom, 2003).

Most UAV technologies are equipped with commercial-grade GPS (*Global Positioning System*) so as to produce photos with errors up to meters (Vetrella et al., 2019). Such errors must be minimized so that the quality of aerial photographs can meet geometric accuracy specifications. For that GCP (*Ground Control Point*) is used to solve this problem (Ch’ng et al., 2019). GCP is a soil control point used in the photo georeferencing process, so the photo has a soil coordinate system. Aerial photography processing then produces DEM (*Digital Elevation Model*) and *orthophoto maps* that are georeferenced according to the coordinate system used (Martınez-Casasnovas, 2003). From this DEM data, it will then be used as a calculation of the volume of the inundation area at the Margatiga dam.

METHOD

The research method used is by taking aerial photo data using drones in the Margatiga dam inundation area plan, then collecting reference point data obtained by conducting surveys in the field and using SNI (Indonesian National Standard) guidelines for Horizontal Control Nets and Vertical Control Nets as standard references for GCP measurements which are then used in the orthorectification process. GCP measurements are carried out using geodetic GPS measuring instruments. The location to be studied is the inundation area on the Margatiga Dam in the Margatiga District, East Lampung Regency. It can be seen in **Figure 1**.

Gambar 1. Lokasi Penelitian

The stages of data collection are as follows:

1. Flyway Creation: Flyway creation is the process of planning a flight path to get the desired photo from aerial photographs or photos using drones. The making of the flight path made must be adjusted to the area, the signal range on the remote control, the *start and* end *locations* when starting to fly the drone and the battery used in one flight. In making flight paths must also pay attention to *overlap* and *sidelap* between flight paths.
2. GCP Installation Design: Things that need to be considered in GCP installation are the distribution / density of GCP positions, unobstructed areas, GCP design must be contrast and the center of the GCP point must be clear, be aware of differences in ground elevation, and accuracy when measuring GCP using measuring instruments.
3. Data acquisition with drones: Data acquisition using automated methods. Some things to consider in automatic settings are flight height, flight speed, amount of *overlap and* sidelap, *camera angle, and direction when taking data.*
4. Aerial photo processing: Aerial photo processing is by using *Agisoft software*. The data processed is in the form of aerial photos that have been taken then through the align photos process in Agisoft *software. Align* photo is the process of identifying points in each photo and matching the same points in two or more photos. This process produces the initial 3D

model, camera position and photos in each recording which will then proceed to the next process to become DEM (*Digital Elevation Model*) data. After the *photo align* process is complete, then proceed by entering GCP coordinate and elevation data.

5. Making GCP Geometry: The GCP geometry used is divided into two, where these two geometries will be used as research material to determine the influence of GCP geometry on the processed photogrammetric data. The accuracy in the processing process of these two GCP geometries uses accuracy tests and RMSE values against ICP (*Independent check* points) points in the field. More precise results will later be used in processing data into DEM data and photo maps.

Figure 2. Geometry GCP alternative 1

Figure 3. Alternative GCP Geometry 2

This study uses two GCP geometries, namely the first geometry or called alternative one (**Figure** 2) consisting of 40 GCPs plus 2 *bench mark* points with a minimum placement of one to two GCPs per flight path. The second geometry or called alternative two (**Figure 3**) consists of 23 GCPs plus 2 *benchmark* points with the placement of one GCP per flight path.

6. Selection of contour intervals: The contour intervals in this study are divided into three, namely contour intervals of 0.75 meters, 1 meter and 1.5 meters. Contour intervals are obtained from DEM data through the process of *generating contours* in the *Global Mapper software*. The resulting three contour intervals will be used in calculating the volume of the inundation area.

Calculation of the area and volume of the puddle area: The method of calculating the area and volume of the puddle area is *using Autodesk Civil 3D software* using two *different surfaces. The* first surface is as a base or called *the base surface*. *Base surface* is a *surface* processed by aerial photography. Then the second surface is as a plan or often referred to as a *comparison surface*. This contour contains the planned water high elevation in the inundation area i.e. elevation +23,000. This elevation is used as the basis for calculating between the volume of planners and the volume of evaluation results using data collection methods using aerial photography or drone mapping.

RESULTS AND DISCUSSION

Processing using Agisoft software is processed into two parts, namely the first processing using alternative GCP geometry 1 and the second processing using alternative GCP geometry 2. Processing using Agisoft software supports the creation of automatic processing reports containing basic project parameters, processing results, and accuracy evaluation (Hasyim & Taufik, 2009). The report presents data such as camera location and image overlap including information on flying height, number of images, area coverage, ground resolution, camera model, focal length, pixel size, and so on (Siebert & Teizer, 2014). Camera calibration includes images and illustrations for each sensor involved in the project, Ground Control Point (GCP), Digital Elevation Model (DEM), and processing parameters (Pujianto, 2016).

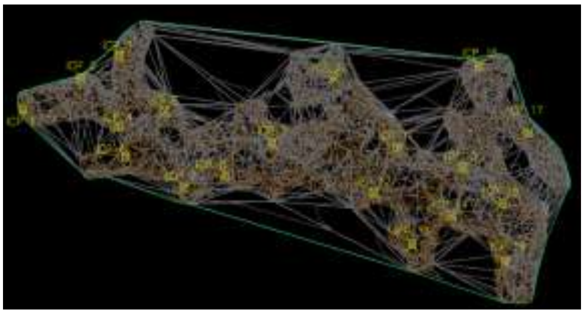

Figure 4. ICP on Autodesk Civil 3D

Checking the data of aerial photo processing in the form of DEM will then be checked using ICP data in the field, namely by comparing the results of aerial photo processing and the measurement results of ICP points in the field (Kaimaris et al., 2017). **Figure 4** is the result of *plotting* ICP points in *Autodesk Civil 3D* where the yellow dots are ICP points while the brown lines are the *corridors* of the inundation area plan. The results of the actual elevation and DEM checks resulting from aerial photography between the geometry of GCP alternative one and GCP alternative two are shown in **Table 1** and **Table 2**.

Table 1. Comparison of actual elevation and DEM of photogrammetric results (GCP Alternative 1)

ICP Number	Coordinates		Z (Elevation)		
	X	And	Elevation ICP	Elevation .DEM	Deviation (m)
ICP 1	540506,316	9428108,799	24,001	24,391	0,390
ICP 2	542079,049	9428860,608	24,521	24,997	0,476
ICP 3	543568,308	9429398,196	32,132	32,670	0,538
ICP 4	542954,055	9427840,655	22,055	21,674	-0,381
ICP 5	544422,185	9428062,921	24,612	25,000	0,388
ICP 6	543388,024	9427026,116	23,593	24,216	0,623
ICP 7	545020,068	9426471,509	24,221	24,529	0,308
ICP 8	545825,149	9426534,086	35,363	35,000	-0,363
ICP 9	547379,121	9427370,975	31,812	31,998	0,186
ICP 10	548605,430	9429022,138	26,545	26,664	0,119
ICP 11	550694,715	9427079,865	34,401	34,766	0,365
ICP 12	549588,610	9426130,671	25,332	25,000	-0,332
ICP 13	551198,659	9424790,758	18,882	20,000	1,118
ICP 14	552075,050	9425633,297	16,683	16,830	0,147
ICP 15	552432,735	9426696,649	16,921	16,816	-0,105
ICP 16	552831,525	9429037,800	31,493	31,984	0,491
ICP 17	554443,223	9427501,087	29,683	30,035	0,352
ICP 18	553492,955	9425709,484	16,222	16,514	0,292
ICP 19	553414,144	9424387,072	39,792	40,011	0,219

Table 2. Comparison of actual elevation and DEM photogrammetry results (GCP Alternative 2)

ICP Number	Coordinates		Z (Elevation)		
	X	And	Elevation ICP	Elevation .DEM	Deviation (m)
ICP 1	540506,316	9428108,799	24,001	22,253	-1,748
ICP 2	542079,049	9428860,608	24,521	24,004	-0,517
ICP 3	543568,308	9429398,196	32,132	32,667	0,535
ICP 4	542954,055	9427840,655	22,055	22,888	0,833
ICP 5	544422,185	9428062,921	24,612	23,988	-0,624
ICP 6	543388,024	9427026,116	23,593	22,000	-1,593
ICP 7	545020,068	9426471,509	24,221	23,006	-1,215
ICP 8	545825,149	9426534,086	35,363	36,001	0,638
ICP 9	547379,121	9427370,975	31,812	32,665	0,853
ICP 10	548605,430	9429022,138	26,545	26,479	-0,066

ICP 11	550694,715	9427079,865	34,401	34,295	-0,106
ICP 12	549588,610	9426130,671	25,332	24,000	-1,332
ICP 13	551198,659	9424790,758	18,882	19,990	1,108
ICP 14	552075,050	9425633,297	16,683	20,000	3,317
ICP 15	552432,735	9426696,649	16,921	16,010	-0,911
ICP 16	552831,525	9429037,800	31,493	32,196	0,703
ICP 17	554443,223	9427501,087	29,683	32,000	2,317
ICP 18	553492,955	9425709,484	16,222	17,411	1,189
ICP 19	553414,144	9424387,072	39,792	40,022	0,230

The data in Table 1 and Table 2 are then tested for accuracy by calculating the RMSE value and accuracy. The results of the accuracy test will determine the next process where which DEM data will be selected between GCP alternatives one and two. The results of the aerial photography accuracy test can be seen in **Table 3** and **Table 4.**

Table 3. Alternative GCP accuracy test 1

Point Name	**With (Elevasi ICP)**	**With (Elevasi DSM)**	**(D Z)**	**(D Z)^2**
A	**B**	**C**	**D**	**And**
ICP 1	24,001	24,391	0,390	0,152
ICP 2	24,521	24,997	0,476	0,227
ICP 3	32,132	32,670	0,538	0,289
ICP 4	22,055	21,674	-0,381	0,145
ICP 5	24,612	25,000	0,388	0,151
ICP 6	23,593	24,216	0,623	0,388
ICP 7	24,221	24,529	0,308	0,095
ICP 8	35,363	35,000	-0,363	0,132
ICP 9	31,812	31,998	0,186	0,035
ICP 10	26,545	26,664	0,119	0,014
ICP 11	34,401	34,766	0,365	0,133
ICP 12	25,332	25,000	-0,332	0,110
ICP 13	18,882	20,000	1,118	1,250
ICP 14	16,683	16,830	0,147	0,022
ICP 15	16,921	16,816	-0,105	0,011
ICP 16	31,493	31,984	0,491	0,241
ICP 17	29,683	30,035	0,352	0,124
ICP 18	16,222	16,514	0,292	0,085
ICP 19	39,792	40,011	0,219	0,048
			Sum	3,652
			Average	0,192
			RMSE	0,438
			Accuracy	0,723

Map Accuracy 1:5000 scale				
Accuracy	**LE 90 test result**	**Class 1**	**Class 2**	**Class 3**
Vertical	0,723	1,0	1,5	2,5

From **Table 3** and **Table 4** the results are respectively as follows:

a. **Table 3** shows DEM results from processed aerial photographs using GCP alternative one which yields an RMSE value of 0.438 and an accuracy value of 0.723 meters.

b. DEM data with the results of aerial photography using alternative one (**Table 3**) can be categorized into class 1 maps with a scale map accuracy of 1:5000 according to the regulation of the Head of the Geospatial Information Agency Number 15 of 2014 concerning Technical Guidelines for Base Map Accuracy. This is based on the results of the accuracy test close to the class 1 value, which is 1.0 meters.

c. **Table 4** shows DEM results from aerial photographic processing using GCP alternative two resulting in an RMSE value of 1.298 and an accuracy value of 2.142 meters.

d. DEM data with the results of aerial photography using alternative two (**Table 4**) can be categorized into class 3 maps with a scale map accuracy of 1:5000 according to the regulation of the Head of the Geospatial Information Agency Number 15 of 2014 concerning Technical Guidelines

Base Map Accuracy. This is based on the results of an accuracy test close to the class 3 value, which is 2.50 meters.

Table 4. Alternative GCP accuracy test 2

Point Name	**With (Elevasi ICP)**	**With (Elevasi DSM)**	**(D Z)**	**$(D Z)^2$**
A	**B**	**C**	**D**	**And**
ICP 1	24,001	22,253	-1,748	3,056
ICP 2	24,521	24,004	-0,517	0,267
ICP 3	32,132	32,667	0,535	0,286
ICP 4	22,055	22,888	0,833	0,694
ICP 5	24,612	23,988	-0,624	0,389
ICP 6	23,593	22,000	-1,593	2,538
ICP 7	24,221	23,006	-1,215	1,476
ICP 8	35,363	36,001	0,638	0,407
ICP 9	31,812	32,665	0,853	0,728
ICP 10	26,545	26,479	-0,066	0,004
ICP 11	34,401	34,295	-0,106	0,011
ICP 12	25,332	24,000	-1,332	1,774
ICP 13	18,882	19,990	1,108	1,228
ICP 14	16,683	20,000	3,317	11,002

ICP 15	16,921	16,010	-0,911	0,830
ICP 16	31,493	32,196	0,703	0,494
ICP 17	29,683	32,000	2,317	5,368
ICP 18	16,222	17,411	1,189	1,414
ICP 19	39,792	40,022	0,230	0,053
			Sum	32,020
			Average	1,685
			RMSE	1,298
			Accuracy	2,142

Map Accuracy 1:5000 scale

Accuracy	**LE 90 test result**	**Class 1**	**Class 2**	**Class 3**
Vertical	2,142	1,0	1,5	2,5

By referring to the Regulation of the Head of the Geospatial Information Agency Number 15 of 2014 concerning Technical Guidelines for the Accuracy of the Base Map in table 5 and table 6 and analyzing the results of both geometries compared with measurements of ICP points in the field, the DEM processed by aerial photographs that will be used as a calculation of the volume of the puddle area is DEM from the first geometry with a total of GCP 40 pieces plus 2 benchmark points.

Regulation of the Head of the Geospatial Information Agency Number 15 of 2014 concerning Technical Guidelines for Base Map Accuracy. The geometric accuracy table of the Indonesian Earth Map (RBI) can be seen in **Table 5**.

Table 5. Geometry Accuracy of RBI Map

Scale	**Contour intervals**	**RBI Map Accuracy**					
		Class 1		**Class 2**		**Class 3**	
		H (m)	**H (m)**	**H (m)**	**H (m)**	**H (m)**	**H (m)**
1:1.000.000	400	200	200	300	300,00	500	500,00
1:500.000	200	100	100	150	150,00	250	250,00
1:250.000	100	50	50	75	75,00	125	125,00
1:100.000	40	20	20	30	30,00	50	50,00
1:50.000	20	10	10	15	15,00	25	25,00
1:25.000	10	5	5	7,5	7,50	12,5	12,50
1:10.000	4	2	2	3	3,00	5	5,00
1:5.000	2	1	1	1,5	1,50	2,5	2,50
1:2500	1	0,5	0,5	0,75	0,75	1,25	1,25
1:1.000	0,4	0,2	0,2	0,3	0,3	0,5	0,50

The value of accuracy in each class is obtained through the provisions as stated in **Table 6**.

Table 6. RBI Map Geometry Accuracy Provisions by Class

Accuracy	Class 1	Class 2	Class 3
Horizontal	0.2 mm x scale number	0.3 mm x scale number	0.5 mm x scale number
Vertical	0.5 x internal contour	1.5 x grade 1 rigor	2.5 x grade 1 rigor

The method of calculating the volume of the puddle area used is calculation with Autodesk Civil 3D software. The reference used in calculating the volume of the Margatiga dam is to use an elevation of +23,000 as the elevation of the inundation area. The data used as a calculation is DEM data resulting from photogrammetric processing by generating contour using three contour intervals in the Globbal Mapper application. The contour intervals are intervals of 0.75 meters, intervals of 1 meter and finally intervals of 1.5 meters. The value of the interval is based on the result of the map accuracy of 0.723 so that what is used in the use of this contour interval is the smallest at 0.75 meters.

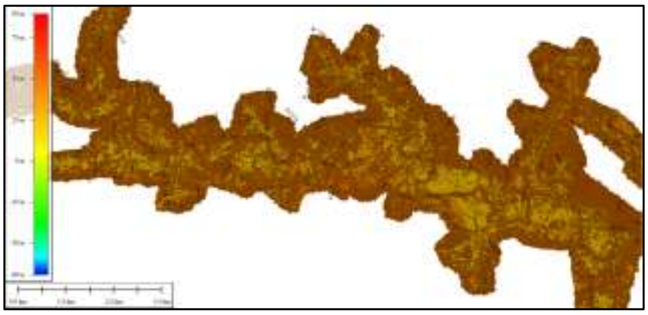

Figure 5. Contour interval 0.75 meters

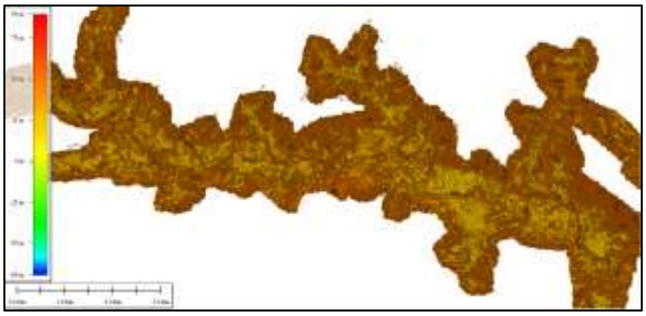

Figure 6. Contour interval 1 meter

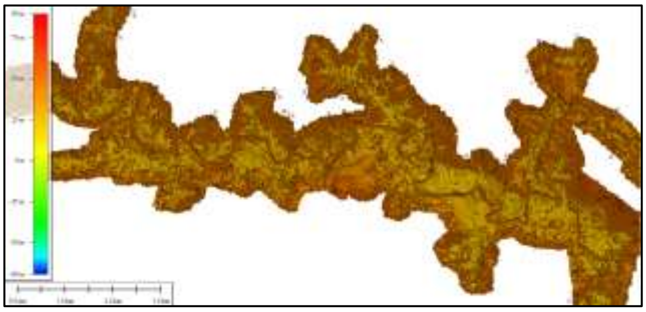

Figure 7. Contour interval 1.5 meters

The difference between the three contour intervals of 0.75 meters, 1 meter, and 1.5 meters can be seen from the density of the brown lines in Figure 5, Figure 6, and Figure 7.

The way to calculate the volume of the puddle area is to present two data surfaces. The first surface or what we call a base surface is a surface processed by DEM into three contour intervals, each of which will be calculated for each contour interval. While the second surface or what is referred to as the comparison surface is the target surface that will be used as a plan for calculating the volume of the puddle area. The target surface in this study used a surface with an elevation of +23,000. The calculation results on the three contour intervals (base surface) to contours with an elevation of +23,000 (comparison surface) can be seen in **Figure 8**, **Figure 9** and **Figure 10.**

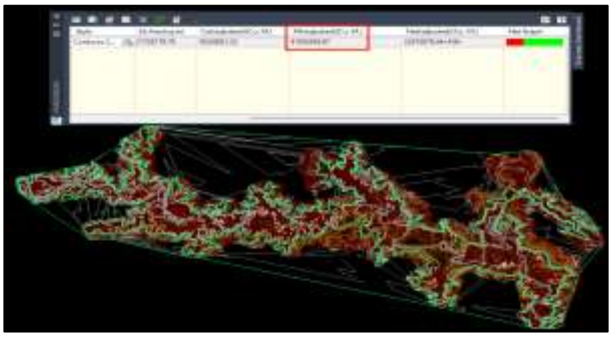

Figure 8. Calculation of the volume of the contour interval of 0.75 meters

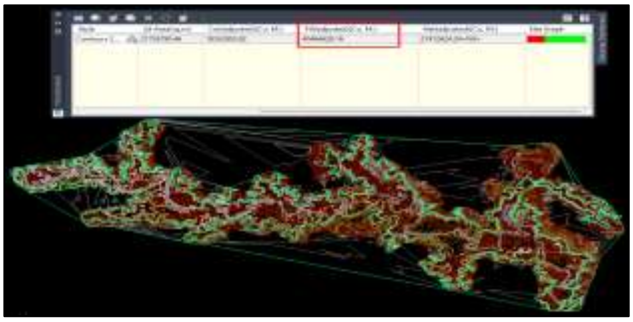

Figure 9. Calculation of the volume of the contour interval of 1 meter

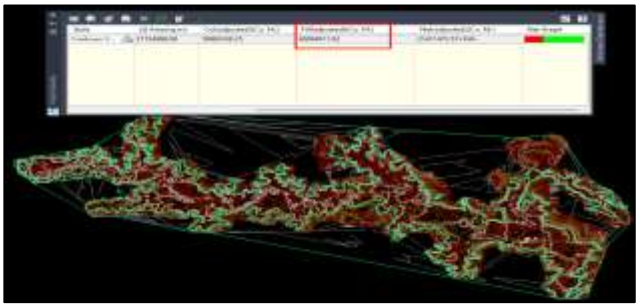

Figure 10. Calculation of the volume of the contour interval of 1.5 meters

From the calculation of the volume of the inundation area of the Margatiga dam using three contour intervals, the following results were obtained:

1. The volume of the inundation area in the DEM data with a contour interval of 0.75 meters is 41,005,959.97 m3
2. The volume of the inundation area in the DEM data with a contour interval of 1 meter is 40,464,628.16 m3
3. The volume of the inundation area in the DEM data with a contour interval of 1.5 meters is 40,094,811.82 m3

Table 7. Data on the calculation of the physical characteristics of reservoir reservoirs. [2]

Elevation	Height Difference Between Contours	Puddle Area	Puddle Volume Between Contour Intervals	Reservoir Reservoir Volume
(m)	(Z)	(m2)	(m3)	(m3)
13,00	0,00	164.882,89	0,00	0,00
14,00	1,00	249.463,05	205.718,89	205.718,89
15,00	2,00	533.875,47	382.759,96	588.478,85
16,00	3,00	707.206,70	618.515,28	1.206.994,13
17,00	4,00	1.077.220,33	885.751,14	2.092.745,27
18,00	5,00	1.907.034,40	1.472.512,12	3.565.257,39
19,00	6,00	4.505.497,27	3.114.588,87	6.679.846,26
20,00	7,00	6.590.246,07	5.514.936,92	12.194.783,18
21,00	8,00	8.936.222,78	7.733.525,04	19.928.308,22
22,00	9,00	11.174.467,07	10.034.521,22	29.962.829,44
23,00	10,00	13.562.043,41	12.349.006,16	42.311.835,60
24,00	11,00	16.043.490,96	14.785.404,34	57.097.239,95
25,00	12,00	19.209.756,78	17.602.877,74	74.700.117,68
26,00	13,00	22.776.888,80	20.968.022,14	95.668.139,82
27,00	14,00	25.920.877,55	24.331.950,52	120.000.090,35
28,00	15,00	29.998.585,97	27.934.919,48	147.935.009,83

Table 7 is the calculation data of the Margatiga Dam reservoir by planning consultants in 2017 which contains the elevation, area, and volume of the Margatiga Dam reservoir. Figure 11 shows the relationship between reservoir capacity and reservoir inundation area previously calculated by planning consultants in 2017. From the calculation of the volume of the dam inundation area from the results of aerial photography processing, then checking the design of the dam plan carried out by planning consultants (Bonwell & Eison, 1991). The reservoir storage volume at an elevation of +23,000 is 42,311,835.60 m3, while in the aerial photo processing data with 0.75-meter interval DEM data, the volume of the inundation area is 41,005,959.97 m3.

Figure 11. Reservoir capacity curve [2]

With these two results, there is a difference in the volume of the inundation area of 1,305,875.64 m3. With the difference in volume, an analysis of the resulting area was carried out at the inundation elevation of +23,000.

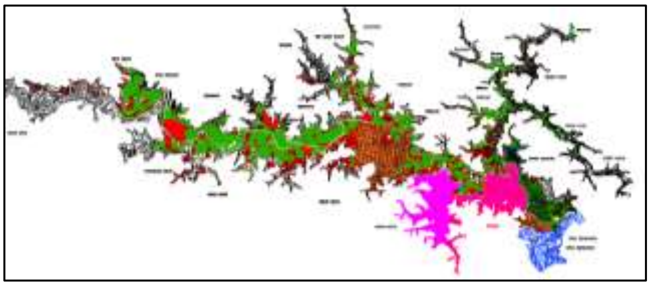

Figure 12. Land acquisition design of inundation area on elv. +23,000

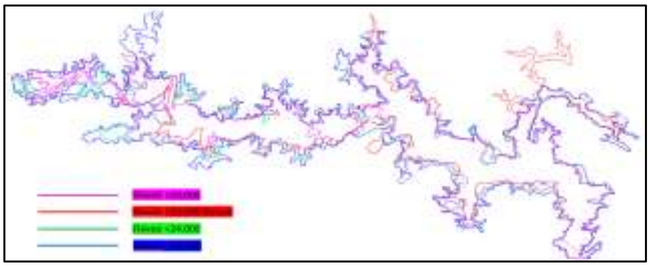

Figure 23. *Plotting the* area on the contours of the planner design and the results of aerial photography

The analysis carried out was plotting the design at an elevation of +23,000 from the planning consultant's design drawings against the processed aerial photo data at an elevation of +23,000. In addition to the material for analysis, the contour area is also added at an elevation of +24,000 and an elevation of +28,000. This is done as a control to analyze contour lines

+23,000 not bumping into or not exiting the contour area corridor at elevations +24,000 and +28,000 as shown in Figure 13.

Figure 14 shows the results of plotting the area area on the contours of the planner design and the results of aerial photography. The pink line shows the area of aerial photography at an elevation of +23,000. The red line shows the area of the planning consultant's design at an elevation of +23,000. The green line shows the area of aerial photography at an elevation of +24,000. The blue line shows the area of aerial photography at +28,000 elevation. The plotting results show that there is a +23,000 contour area difference between the planner's design and the aerial photography.

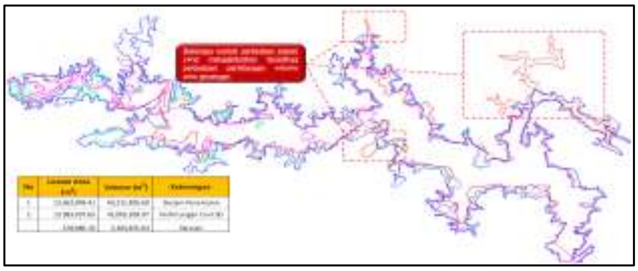

Figure 34. The results of differences in the area of inundation design planners and aerial photography results

From **Figure 14** the following results are obtained:

1. The area in the planner design at an elevation of +23,000 is 13,562,043.41 m2 with a volume of inundation area of 42,311,835.60 m3.
2. The area of aerial photography at an elevation of +23,000 is 13,383,057.65 m2 with a volume of inundation area of 41,005,959.97 m3.
3. The deviation between the area of the planner design and the results of aerial photography is 178,985.76 m2.
4. The dotted red line indicates a cross-sectional difference in area at the same elevation of +23,000.

The occurrence of differences in area between the design of the planner and the processed aerial photographs can be caused by the following factors:

a. Data Acquisition Methods

The process of collecting data from the field has several methods used. In this study, researchers tried to take field data in the Margatiga dam inundation area using aerial photography methods using drones which then carried out data processing by making corrections through measuring ground control points using GPS measuring instruments as position and elevation control (xyz).

Another method is through the process of direct measurement in the field, which uses several combinations of measuring instruments including Waterpass, Theodolite, Total Station, GPS and several other measuring instruments which are then processed into a contour map to obtain terrain conditions in the field.

There is also a method to obtain data in the field using DEMNAS provided by the Geospatial Information Agency (BIG) which can be downloaded on the internet website. This DEMNAS data is data that has been in the form of DEM that can be used to determine terrain conditions in the field.

b. Data Processing Methods

If the data acquisition method used is the same, for example in using the aerial photography method, there can also be differences in data processing results caused by differences in data processing. For example, in determining overlapping flight paths, determining GCP geometry, determining the pixels used, the process of forming ground contours from DSM (Digital Surface Model) data to DEM (Digital Elevation Model) or DTM (Digital Terrain Model) data.

c. Reference Points

Reference points may also result in different data processing results. This happens when in the process of retrieving data with the same position but the value used is different, it will have an impact on the value produced during data processing. For example, in determining the GCP value between one measurement and another, it will have an impact on the processed aerial photography.

CONCLUSION

The design of the planning consultant in 2017 regarding the reservoir volume at the Margatiga Dam at an elevation of +23,000 was 42,311,835.60 m3. By evaluating the volume of inundation using the photogrammetric method, a volume of 41,005,959.97 m3 was obtained with a selection of contour intervals of 0.75 meters. From the analysis of GCP geometry calculations used in this study, it was produced that the alternative GCP geometry was one with a total of 40 GCPs plus 2 benchmark points with a minimum placement of one to two GCPs per flight path resulting in RMSE values and better accuracy in the accuracy test of aerial photography results with RMSE values of 0.438 and accuracy values of 0.723 meters.

There is an effect of different yield sizes on DTM with contour intervals of 0.75 meters, 1 meter, and 1.5 meters. At a contour interval of 0.75 meters, the volume of the inundation area was 41,005,959.97 m3. In the contour interval of 1 meter, the volume of the inundation area was 40,464,628.16 m3 and the contour interval of 1.5 meters resulted in the volume of the inundation area of 40,094,811.82 m3. This difference is because the calculation of volume at smaller contour intervals will be more detailed than contours with large intervals.

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