Utilization of Small Unnamed Aerial Vehicle(SUAV) Technology in Mapping the Lake Tondano Ring Road at STA 0+00 to Sta 21+100

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Abstract. Mapping using a Small Unnamed Aerial Vehicle (SUAV) is a process of making maps using aerial photos with high resolution images in a faster and more efficient manner so that it can save time when compared to using conventional methods. Ground Control Point (GCP) was created to increase the accuracy/geometry correction of drone aerial photography results. This GCP point was observed using geodetic GPS with submillimeter accuracy. This research was carried out on the Tondano Lake ring road, along Kakas Village - Kiniar Village (STA 0+00 - 21+100) with a road length of 21.1 kilometers using a DJI Mavic 2 Pro drone. The results of this research showed that the horizontal RMSer value for the orthophoto was 0.00170 and the vertical RMSEz value was 0.00245. Thus, the resulting map is a class 1 (one) map at a scale of 1:1000. This research is a field study with data carried out on the Tondano Lake Ring Road, Minahasa Regency, North Sulawesi Province. Data collection uses a Small Unnamed Aerial Vehicle (SUAV) for aerial photography and Geodetic GPS. Drone is utilized to capture area objects, while Ground Control Point (GCP) measurements use the Real-Time Kinematic (RTK) method.

Keywords: Small Unmanned Aerial Vehicle); Ground Control Point; photogrammetry; orthophoto

1. Introduction

In the construction field, especially Civil Engineering, the development of a particular area requires very important data in the form of maps. One type of maps that contains graphic and geographical information is the use of aerial photographs which can usually be used as material for making topographic maps. Lake Tondano is the largest lake in North Sulawesi Province, located in Minahasa Regency. This lake is circled by provincial roads that connect several cities as well regency. Tondano Lake ring road section has never been mapped using aerial photogrammetry using the Unmanned Aerial Vehicle (UAV) method. It is necessary for a region or area to provide high resolution image quality map with accurate and up-to-date data.
Research problem are:
1.What are the stages and techniques in the aerial photogrammetry method using Small Unmanned Aerial Vehicle (SUAV) technology that comply with standards?
2.How accurate are the results from aerial photogrammetry using Small Unmanned Aerial Vehicle (SUAV) technology using Root Mean Square Error (RMSE) accuracy at the Ground Control Point (GCP)?
3. What is the picture of the current situation taken using the aerial photogrammetry method in the Lake Tondano Ring Road area STA 0+00 to 21+100?
The purposes of this research include:
1.Describe the stages and techniques in the aerial photogrammetry method using Small Unmanned Aerial Vehicle (SUAV) technology in accordance with standards.
2.Analyze how accurate the results of aerial photogrammetry are using Small Unmanned Aerial Vehicle (SUAV) technology using Root Mean Square Error (RMSE) accuracy at the Ground Control Point (GCP).

M. U. H. Al Rasyid and M. R. Mufid (eds.), *Proceedings of the International Conference on Applied Science and Technology on Engineering Science 2023 (iCAST-ES 2023)*, Advances in Engineering Research 230,
https://doi.org/10.2991/978-94-6463-364-1_69

3.Produce an overview of the current situation taken using the aerial photogrammetry method in the Tondano Lake Ring Road area STA 0+00 to 21+100.

2. Literature Review

2.1 Small Unmanned Aerial Vehicles (SUAV)

SUAV is a type of aircraft that is controlled by a remote control system via radio waves. SUAV is an unmanned system, namely an electro-mechanical based system that can carry out programmed missions with the characteristics of a flying machine that functions with remote control by the pilot or is able to control itself, the SUAV can be controlled manually via radio control or automatically by processing data on sensors (Saroinsong, 2018).

2.2 Mapping

Mapping is the grouping of a collection of areas related to several geographic locations which include plateaus, mountains, resources and population potential which have an influence on social culture and have special characteristics when using the right scale (Munir, 2012).
The resulting photo maps also usually have a large scale so they are very suitable for use in planning matters (Syauqani et al in Waney, 2022).
A map is a two-dimensional depiction on a flat plane the whole or part of the earth's surface projected with a certain comparison or scale (Nasution, 2016).

2.3 Photogrammetry

According to the American Society of Photogrammetry and Remote Sensing (ASPRS), photogrammetry is defined as the art, science and technology of obtaining reliable information about physical objects and their environment through the process of recording, measuring and interpreting photographic images and recorded electromagnetic energy radiation patterns. Aerial photogrammetry involves SUAV. Cameras mounted on SUAV usually point vertically at the ground. Aerial photographs are taken from the air with a special camera mounted on an aircraft over an area with the camera axis nearly vertical along the planned flight path.

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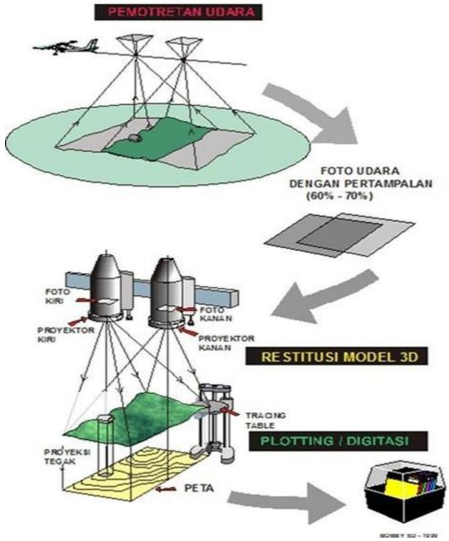

Fig 1. Taking aerial photos using triangulation (overlap), Source: upj.ac.id

The basic principle used by photogrammetry is triangulation. By taking photos from at least two different locations, what the so-called “line of sight” can be extended from each camera to a point on the object. These lines of sight mathematically intersect (sequential shots must overlap one another) to produce the 3-dimensional coordinates of the point of interest.

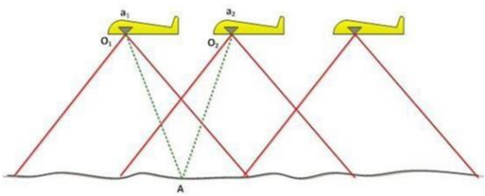

Fig 2. Basic Concepts of Photogrammetry, Source: Santoso, (2004)

Furthermore, shooting with unmanned aerial vehicles has a higher level of portability compared to using airplanes. It can also reduce expensive airplane rental costs. (Rokhmana in Waney 2022).

Ground Control Points (GCP)

GCP are points in the field that can be used to transforming the air coordinate system with the ground coordinate system of a mapped object. This control point will later be used during aerial photo processing at the aerial triangulation stage (Husna et al., 2016). The main function of GCP is to correct distortion in aerial photos. Distortion occurs due to many factors such as flight altitude, camera tilt, and UAV rotation. By using GCP, the difference between the actual coordinates on the GCP and the coordinates calculated from aerial photos will be calculated. The results of these calculations will be used to correct aerial photos and improve mapping accuracy.

The way GCP works is by being placed in strategic locations that cover the entire area to be mapped. These control points must be visible when taking aerial photos so that they can be used to correct distortion of aerial photos. To determine the GCP coordinates, measurements are taken using a GPS device or other device that has high accuracy.

Fig 3. Ground Control Point (GCP)

Determining the location and number of GCPs to be observed depends on the shape and extent of the Area of Interest (AOI) and must pay attention to the Strength of Figure (SoF) or network strength of the distribution of ground control points according to *Standar Nasional Indonesia* (SNI) bidang Kerangka Kontrol Horizontal (KKH). According to Suradji et al. (2009) in Taftazani et al. (2016), the location for determining GCP refers to a maximum obstruction of 15º in all directions, free from multipath effects, does not interfere with public facilities, and is easy to access and identify.

Furthermore, when shooting, try to be in clear weather conditions so that there are no errors in detecting tie points in each photo that has overlap and sidelap. When carrying out processing, use a computer with high specifications to obtain maximum mosaic and DSM (Digital Surface Model) results. When planning aerial photography, it is best to use unmanned aerial vehicles by creating as many ground control points as possible to minimize geometric errors due to camera distortion (Gularso, in Waney, 2022).

2.4 Vertical and Horizontal Accuracy Test

The calculated vertical and horizontal geometric accuracy is carried out in accordance with calculations based on Geospatial Information Agency Regulation No. 6 of 2018 concerning Amendments to the Regulation of the Head of the Geospatial Information

Agency No. 15 of 2014 concerning Technical Guidelines for Base Map Accuracy. The accuracy test in this research was carried out on horizontal coordinates (X,Y) and vertical coordinates (Z).
Root Mean Square Error (RMSE) is the square root of the difference between data coordinate values and coordinate values from an independent source with higher precision. Circular Error 90% (EC90) is the accuracy of horizontal geometric measurements which is defined as the radius of a circle that shows an error of 90% or the difference between the horizontal position of an object on the map and its actual position which is considered to be no greater than that radius. Linear error 90% (LE90) is vertical geometric accuracy (height), namely the distance value shows that 90% of the error or difference in the object's height value is mapped to the actual height value which is not greater than the distance value.

The formula for accuracy analysis using calculations based on Geopacial Information Agency Regulation No. 6 of 2018:

RMSEr:

$$\sqrt{\frac{\sum[(X_{pengukuran} - X_{peta})^2 + [(Y_{pengukuran} - Y_{peta})^2]}{n}}$$

RMSEz:

$$\sqrt{\frac{\sum(Z_{pengukuran} - Z_{peta})^2}{n}}$$

n : total number of checks on the map
X : coordinate value on the x axis
Y: coordinate value on the y axis
Z: coordinate value on the z axis

CE90 and LE90 values can be obtained using the US NMAS (United States National Map Accuracy Standards) formula as follows:
CE90 = 1.5175 x RMSEr
LE90 = 1.6499 x RMSEz
with,
RMSEr: Root Mean Square Error in x and y positions (horizontal).
RMSEz : Root Mean Square Error at position z (vertical).

3. Research Methodology

3.1 Determining the Accuracy of Aerial Photos

The accuracy of aerial photos describes the uncertainty of the coordinates of an object's position on the map compared to the coordinates of the object's position which is

considered to be the actual position. The accuracy of aerial photography is obtained from the quality of the GCP points and ICP points acquired in the field.
Geospatial Information Agency Regulation Number 6 of 2018 concerning Amendments to Regulations for the Head of the Geospatial Information Agency Number 15 of 2014 concerning Technical Guidelines for Base Map Accuracy in Position accuracy testing refers to the difference in coordinates (X,Y,Z) between the test point on the image or map and the actual location of the test point on the ground surface.

3.2 Research Methods and Types

The data collected will be classified into primary data and secondary data. Primary data is in the form of an Orthophoto Drone while secondary data is in the form of a base map of a capable program invention map, high resolution imagery, Digital Elevation Model (DEM)/ Digital Terrain Model (DTM). The data collection stage in this activity uses a spatial data approach in the form of photogrammetric data produced using the DJI Mavic 2 Pro drone, while data processing uses Agisoft Metashape Professional and ArcGIS software to obtain shapefile (shp) data.

3.3 Data Types and Data Collection Methods

This research uses primary data with a photogrammetric data collection method taken by SUAV with a GCP. Field data was collected through field measurement techniques using the Geodetic Comnav T300 GNSS RTK GPS tool which is tied to the National Control Net in the form of Cors BIG data located on the Observation Post page in Manado City, North Sulawesi and other supporting equipment as a reference for obtaining coordinate point values and data processing aerial photography using Agisoft Metashape Software and making final product layouts using ArcGis.

3.4 Equipment and Materials

The tools that must be prepared before conducting a survey in the field include:
1. DGI Mavic Pro 2 as a vehicle for taking aerial photos.
2. GPS Geodetic Comnav T300 GNSS RTK for retrieving GCP coordinates
3. Ipad Gen 6 for flight path planning and data collection in the field.
4. MSI GS75 Stealth 10SFS Laptop Intel(R) Core (TM) i7-10750H CPU @ 2.60GHz GPU(s) NVIDIA GeForce RTX 2070 Super with Max-Q Design 32GB RAM for data processing.

To be prepared before conducting a survey in the field include:
1. Orange tarpaulin measuring 0.2 m x 2 m for the Bench Mark point on the land
2. Red paint and brush for painting Bench Mark points on the road

Software used for data processing includes:

1. DGI Go 4 is the default application for DJI brand drones. In mapping, this application is only used to ensure the home point is locked properly and perfectly.
2. Pix4D Mapper is a developer application used to carry out auto pilot flight and shooting missions.
3. Agisoft MetaShape Professional
1.0.7 is a 3D modeling software using recorded photo data and aims for digital photogrammetry processing and producing 3D spatial data for use in GIS applications.
4. ArcGis is software based on Geographic Information System (GIS) which provides functions contained in GIS, including analysis needs for Geoprocessing features).
5. Microsoft Office Excel for analysis of horizontal and vertical accuracy test calculations in accordance with calculations based on Perka BIG No. 6 of 2018 concerning Technical Guidelines for Base Map Accuracy.

3.5 Research Flow Chart

The research diagram can be seen in the Figure 4.

3.6 GCP Coordinate Measurement Results

GCP measurements using Geodetic GPS tools.
In this research, there were 21 GCPs spread across the Tondano Lake ring road.
This GCP measurement is carried out at a point that has been given a benchmark as a binding point in the aerial photo data acquisition area with a distance between GCPs of approximately 1 (one) kilometer. The results of Geodetic GPS measurements are Easting, Northing and Altitude coordinate data which are connected to the WGS 84/UTM SONA 51 N coordinate system and have been corrected by CORS BIG located in Manado City. The GCP coordinates below were obtained using Geodetic GPS with the NTRIP method. The accuracy of these coordinates is around 2 mm because they were taken when the GPS showed "Fixed", which means very accurate. The following are the results of GCP recording and measurements.

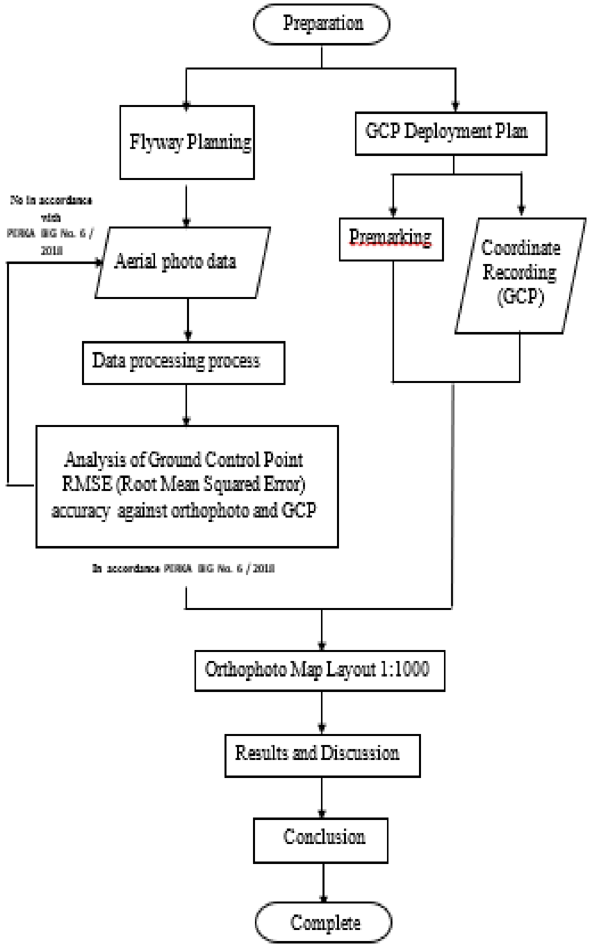

Fig 4. Research Flow Chart

Table 1. GCP Coordinates

Name	*Easting* (m)	*Northing* (m)	*Elevation* (m)
GCP01	130304.3746	709727.65	757.884015
GCP02	129327.7626	709667.943	763.888612
GCP03	128749.4663	710052.9357	772.048012
GCP04	129667.4052	710512.9944	757.982203
GCP05	129690.4571	711295.183	754.907931
GCP06	130995.434	711834.5621	755.217655
GCP07	131463.7931	711952.4726	756.651424
GCP08	132648.6514	711881.4884	757.138217

GCP09	133334.2454	712167.965	761.232688
GCP10	134287.7321	712469.6559	756.716146
GCP11	135231.7346	712747.1665	758.122459
GCP12	135687.5974	712989.6106	769.12598
GCP13	136025.3062	713665.0835	756.935957
GFP14	136720.6062	714414.7664	755.559566
GCP15	137567.7225	714847.1704	755.9482
GCP16	138538.3873	715022.0741	756.417572
GCP17	139242.9145	715198.0147	756.992665
GCP18	140343.3506	715456.4206	758.24265
GCP19	141312.1617	715490.2241	757.169039
GCP20	142053.3829	714876.6017	757.545643
GCP21	142651.1667	714070.7231	757.906641

3.7 Georeferencing Analysis

Georeferencing analysis is an analysis of the error level in creating GCP points between images in the software Agisoft Metashape. The table below shows the error results. Georeferencing, where the level of consistency in point placement is very small because it is only in millimeters, and when a very high error occurs, the GCP shift point needs to be changed again.

Table 2. Total Georeferencing Error, Source: *Agisoft Metashape*

Label	X error (mm)	Y error (mm)	Z error (mm)	Total (mm)	Image (pix)
GCP001f	-0.967193	0.6153	0.015177	1.14642	1.256 (31)
GCP002f	2.01108	-0.395195	-3.38796	3.95966	1.382 (40)
GCP003f	-0.325969	0.306575	0.0115448	0.447635	1.018 (34)
GCP004f	-0.593668	0.233395	-1.79675	1.90663	1.262 (24)
GCP005f	-0.013305	-0.911652	-1.06921	1.40517	0.667 (25)
GCP006	0.104384	0.0100711	-1.34481	1.3489	0.465 (19)
GCP007f	-0.373842	0.132927	-0.576198	0.699594	1.282 (11)
GCP008	0.427412	-0.609857	-0.782609	1.08032	1.903 (21)
GCP009	-0.00608351	0.422921	-1.31197	1.37847	0.853 (14)
GCP010f	-0.135242	0.0827605	-0.853586	0.868187	1.583 (13)
GCP011f	-0.499353	0.559792	-0.540668	0.924685	1.200 (17)
GCP012	0.618651	-1.59758	-2.01988	2.64857	1.776 (14)
GCP013f	-0.518885	1.16178	-0.0432846	1.27312	0.635 (17)
GCP014f	0.407251	0.169275	-2.43431	2.47393	0.948 (16)
GCP015f	-0.604458	-0.531496	-0.800485	1.13518	1.256 (16)
GCP016	1.07855	-0.684957	-1.42808	1.91621	0.902 (17)
GCP017	-1.29276	0.50355	-0.335414	1.42733	1.057 (19)
GCP018f	0.612723	1.5675	-2.35011	2.89059	1.820 (27)
GCP019	1.1274	-1.27133	-0.960918	1.95209	0.843 (28)
GCP020	-1.27038	-1.1317	-0.357093	1.73843	0.954 (21)
GCP021	0.105559	0.663357	-2.35944	2.45319	0.959 (21)
Total	**0.796688**	**0.790813**	**1.48463**	**1.86124**	**1.207**

3.8 Orthophoto Processing Results

It was found that the number of photo alignments in the form of tie points was 8,876,293 points, so the photo alignment process was successful. The next stage is dense cloud. Dense cloud is a collection of tie points in a certain number which is called a point cloud. After passing through the dense cloud stage, the next stage is Mesh and Texture formation. After completing the mesh and texture stages, we will continue with the Tiled Model and DEM stages. The final stage is the stage of creating an Orthomosaic which will form an Orthophoto which will continue with the stage of analyzing map accuracy and GCP error values. After that, proceed to the stage of analyzing the GCP error between the orthophoto and the earth's tie point.

Table 3. Photo Alignment Results

Result	Value
Number of Foto	3.839
Flying High	100 m
GSD	2.89 cm/pix
Region Length	21.1 km
An Area	4.74 km²
Tie Point	8.876.293

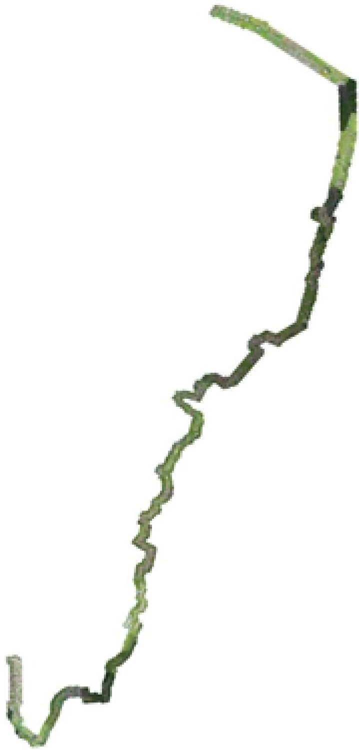

Fig 5. Orthophoto results (Whole), Source: Agisoft Metashape

3.9. Vertical and Horizontal Accuracy Results

The results of data processing found that the RMSEr value was 0.00247 meters. Accuracy standards according to NMAS (National Map Accuracy Standard) are:

NMAS Horizontal Accuracy = CE90 = 1.5175 x RMSEr (0.00247)

So a value of 0.002 meters is obtained for the horizontal accuracy value.

Then testing the results is carried out.
From the planimetric coordinate accuracy test, the results of aerial photo mapping obtained a CE90 value of 0.002 m or 2 mm, which means that the horizontal accuracy test of the map accuracy meets the 1:1000 scale, which is in the class 1 (good) order with a maximum accuracy of 0.3 m. The next stage is a vertical accuracy test where the standard map to be produced is 1:1000. From the results of data processing, the RMSEz value is 0.00135 meters. Accuracy standards according to NMAS (National Map Accuracy Standard) are:

NMAS Vertical Accuracy = LE90 = 1.6499 x RMSEz (0.00135)

So a value of 0.002 meters is obtained for the vertical accuracy value.

Then testing the results is carried out. The result of testing can be seen on table 4, below:

Table 4. CE90 Test for Vertical Accuracy

No	Nama Titik	Z di Peta	Z di Pengukuran	dz	dz2
1	GCP001	757.88402	757.884	0.0000	0.0000000
2	GCP002	763.88861	763.892	0.0034	0.0000115
3	GCP003	772.04801	772.048	0.0000	0.0000000
4	GCP004	757.9822	757.984	0.0018	0.0000032
5	GCP005	754.90793	754.909	0.0011	0.0000011
6	GCP006	755.21766	755.219	0.0013	0.0000018
7	GCP007	756.65142	756.652	0.0006	0.0000003
8	GCP008	757.13822	757.139	0.0008	0.0000006
9	GCP009	761.23269	761.234	0.0013	0.0000017
10	GCP010	756.71615	756.717	0.0009	0.0000007
11	GCP011	758.12246	758.123	0.0005	0.0000003
12	GCP012	769.12598	769.128	0.0020	0.0000041
13	GCP013	756.93596	756.936	0.0000	0.0000000
14	GCP014	755.55957	755.562	0.0024	0.0000059
15	GCP015	755.9482	755.949	0.0008	0.0000006
16	GCP016	756.41757	756.419	0.0014	0.0000020
17	GCP017	756.99267	756.993	0.0003	0.0000001
18	GCP018	758.24265	758.245	0.0023	0.0000055
19	GCP019	757.16904	757.17	0.0010	0.0000009
20	GCP020	757.54564	757.546	0.0004	0.0000001
21	GCP021	757.90664	757.909	0.0024	0.0000056
Jumlah					**0.0000463**
Rata-rata					**0.0000022**
RMSez					**0.0014846**
Akurasi Vertikal 90%					0.002

After calculating the accuracy of the value, it was checked on the PERBIG table No.15 of 2014. From the test table it was found that :

Table 5. PERBIG Accuracy Test Results No.06 of 2018

Ketelitian	Hasil Uji Peta Skala 1 : 1000			
	CE dan LE 90	Kelas 1	Kelas 2	Kelas 3
Horizontal	0.003	0.2	0.3	0.9
Vertikal	0.004	0.3	0.6	0.4

Map Layout

At this stage the aerial mapping process continues to the stage of creating a map as the final product in this research. The layout process uses ArcGIS software, where this software is only a supporting application in creating research output.

Fig 6. Map Layout, Source: Agisoft Metashape

4. Conclusion

The results of research on the use of Small Unnamed Aerial Vehicle (SUAV) technology in mapping the Lake Tondano Ring Road STA 0+00 to STA 21+100, the following conclusions were obtained:

1. This research was carried out on the Lake Tondano ring road, Kiniar Village to Kakas Village (STA 0+000 to STA 21+100) with a road length of 22.1 kilometers using a DJI Mavic 2 Pro drone, drone flying height 120 meters, total photos are 3,893 to get a map with a scale of 1:1000.

Research methodology uses primary data through aerial photo surveys and Ground Control Point (GCP) data from 2) GPS Geodetic Comnav T300 GNSS RTK as a reference for obtaining coordinate point values. Taking aerial photos using Pix4d Capture Software, processing aerial photos using Agisoft Metashape Software and creating final product layouts using ArcGis.

2. The horizontal RMSer value for the orthophoto was 0.00170 and the vertical RMSEz value was 0.00245. Thus the resulting map is a class 1 (one) map at a scale of 1:1000.

3. Map description of the Lake Tondano ring road section STA 0+00 to STA 21+100 with a scale of 1:500,000 processed in ArcGis software from the orthophoto results in Agisoft Metashape software.

Acknowledgment

The completion of this research project would not have been possible without the contributions and support of many individuals and organizations. It is deeply greatful to all those who played a role in the success of this research. Especially, thank to Director of Manado State Polytechnic and Head of Research and Community Service Centre of Manado State Polytechnic who provided financial support for this research.

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