AN EVALUATION OF LANDSAT 8 IMAGERY FOR MAPPING ON SHALLOW WATER USING STUMPF & HOLDERIED ALGORITHM (Case Study: Coastal Water of Narussalam District, East Aceh Regency)

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KEY WORDS : Remote sensing, optic Imagery, shallow water, Satellite Landsat-8, Stumpf & Holderied Algorithm.

ABSTRACT: Bathymetry mapping is conducted to produce some depth water information. The data of depth was obtain by measurement of directly to field across Indonesia takes time and high costs. Therefore, there is an alternative for doing bathymetry mapping shallow water to save time and money that is by using remote sensing. Technology remote sensing meant is to use Landsat 8 imagery. But this needs to be re-tested according to the charactheristics of the waters and tried to how accurate it is adjusted to the local area. The purpose of this research is to give a depth of the shallow water in be based on the image processing by using Stumpf & Holderied algorithm and to knows thoroughness Landsat 8 imagery for mapping bathymetry shallow waters. The research study area is located in Coastal Water of Narussalam District, East Aceh Regency. The research methodology consisted of collecting Landsat 8 image data, radiometric calibration, pan sharpening, cropping area, masking, application of Stumpf & Holderied algorithm and validated the result from image processing with data in situ. This study shows that the Landsat-8 Satellite Imagery has the potential to extract bathymetry information with vatiations of depth 0, 5, 10, 15 and 20 m. The coefficient of determination produced is 0,918 which means that the correlation between field data and image data is included in the category of very strong correlation. And by using linear model in Stumpf & Holderied algorithm on Landsat-8 Imagery there is errors obtained at depth intervals 0-5 m is 1.75 m, depth intervals 5-10 m is 1.92 m, depth intervals 10-15 is 2.07 m and depth intervals 15-20 is 3.77 m.

1. INTRODUCTION

Shallow water depth information is one very important aspect for several studies of marine resource activities including research and resource management and environmental needs (Subarno et al, 2015). To obtain information on shallow water depth, it was obtained through bathymetry surveys, namely measurements carried out directly into the field using echosounders. However, today remote sensing technology provides an opportunity for mapping bathymetry effectively and efficiently, especially for areas that have a rapid rate of depth change. Another advantage is that revision of shallow water mapping can be done quickly and cheaply, increasing spatial resolution provides various applications and methods in underwater mapping activities. The area of remote sensing data coverage is quite broad so it is very good to know what is happening in the surrounding environment to find out the relationship between one another (Bobsaid et al, 2015).

The development of remote sensing technology at this time has produced many types of satellite sensors with a good ability to assess the surface of the water and detect water columns to the bottom of shallow waters (Subarno et al, 2015). Satellite images that are widely used to inventory natural resources in shallow waters include Landsat, Alos, Ikonos, Spot, Quickbird and Worldview.

Jupp (1988) concluded that Landsat imagery can be used to determine water depth, for band 1 has the ability to penetrate water depths to a depth of 25 meters, band 2 is able to penetrate to a depth of 15 meters, band 3 is able to penetrate to a depth of 5 meters while band 4 is able to penetrate to a depth of 0.5 meters.

Several algorithms have been developed to estimate the depth of water from satellite imagery. Stumpf et al. (2003) was one of them who developed a water depth estimation algorithm by utilizing a ratio of 2 bands. The development of algorithms using the band ratio was carried out because of differences in the spectral response of the water column and the bottom of the water to electromagnetic waves (GEM) at different wavelengths (Subarno et al, 2015). But when the algorithm is implemented for regions with different environments, the results show a deviation (Arief et al. 2013). Therefore, this needs to be tested again according to local characteristics and tried to how accurate the algorithm is used in accordance with the research area, namely the Waters of Narussalam Subdistrict, East Aceh Regency.

Maulana, L., Suprayogi, A., & Wijaya, A.P. (2015). Analisis Pengaruh Total Suspended Solid Dalam Penentuan Kedalaman Laut Dangkal Dengan Metode Algoritma Van Hengel Dan Spitzer. Semarang: Jurnal Geodesi Undip. Vol. 4, No.2, ISSN:2337-845X.

Maurer, T. (2013). How To Pan-Sharpen Images Using The Gram-Schmidt Pan-Sharpen Method – A Recipe. Germany: *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, Volume XL-1/W1, ISPRS Hannover Workshop.

Nurkhayati, R. (2014). Pemetaan Batimetri Perairan Dangkal Menggunakan Citra Quickbird Di Perairan Taman Nasional Karimun Jawa, Kabupaten Jepara, Jawa Tengah.

Setiawan, K.T., Osawa, T., & Nuarsa, W. (2014). Aplikasi Algoritma Van Hengel Dan Spitzer Untuk Ekstraksi Informasi Batimetri Menggunakan Data Landsat. Lapan & Universitas Udayana.

Subarno, T., Siregar, V.P., dan Agus, S.B. (2015). Evaluasi Citra Worldview-2 Untuk Pendugaan Kedalaman Perairan Dangkal Pulau Kelapa-Harapan Menggunakan Algoritma Rasio Band. Journal of Geomatics and Planning, Vol 2, No 1, 30-37.

United States Geological Survei [USGS]. Diambil kembali dari https://earthexplorer.usgs.gov/ pada tanggal, pukul 15.17 WIB.

Wahyuningrum, Prihatin Ika. (2007). Pengembangan Algoritma Untuk Estimasi Kedalaman Perairan Dangkal Menggunakan Data Landsat-7 ETM+. : Bogor: Sekolah Pascasarjana Institut Pertanian Bogor.

The purpose of this study was to apply Landsat 8 satellite images for shallow water bathymetry mapping using the Stumpf & Holderied algorithm and calculate the accuracy of depth information generated by images in the waters of Narussalam Subdistrict, East Aceh District.

2. METHODS

2.1 Study Location

The location of this study is in the waters of East Aceh precisely in Narussalam Sub-District, East Aceh Regency. This water area is included in shallow marine waters because the depth value is not more than 200 m can be seen in Figure 1.

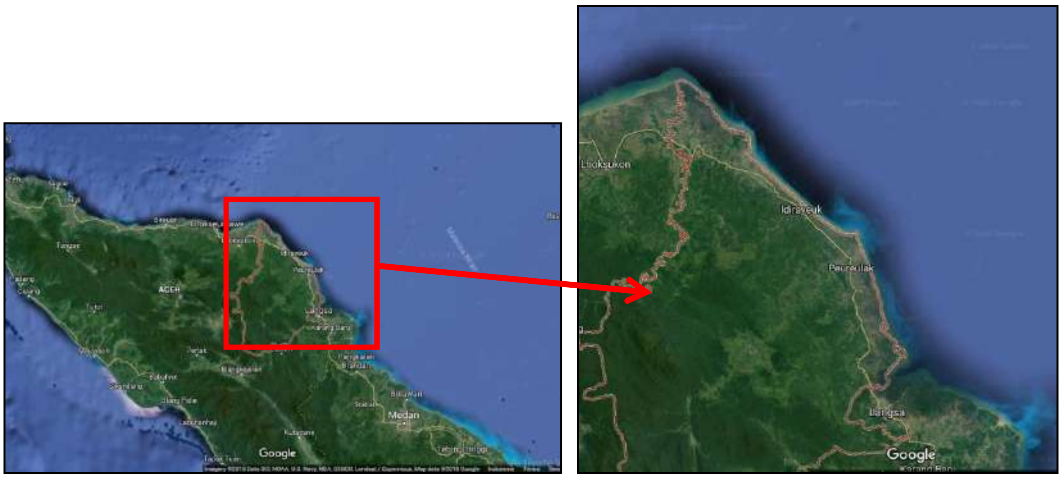

Figure 1 Study Location

2.2 Data and Software Used

The main data used for this research are Landsat-8 L1T Image data (path 130, row 56) obtained from the United States Geological Survey site (https://earthexplorer.usgs.gov/) can be seen in Figure 2 and field depth data obtained from the Geospatial Information Agency (BIG) used for validation tests can be seen in Figure 3. The software used in this study is the envi for digital image processing and arcgis for presenting data.

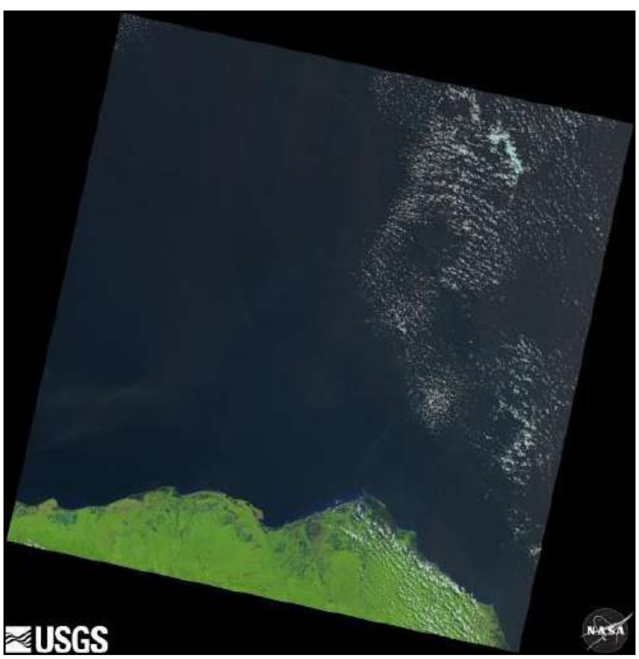

Figure 2 Landsat-8 Image Data

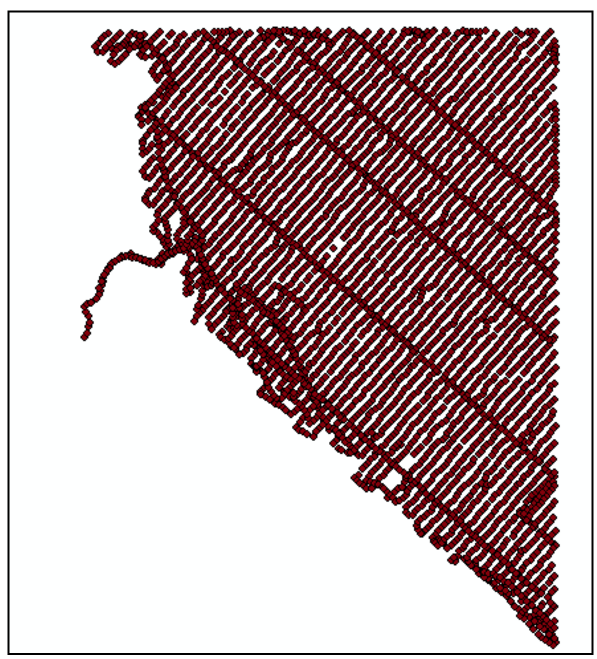

Figure 3 Insitu Data

2.3 Processing Data

The stages of this research consist of preparation, radiometric calibration, pan sharpening, cropping imagery, land and sea masking, Stumpf and Holderied algorithms, rigorous testing to get results in the form of Shallow Water Bathymetry Maps Based on Remote Sensing. The flowchart of the implementation of this research in more detail can be seen in Figure 4.

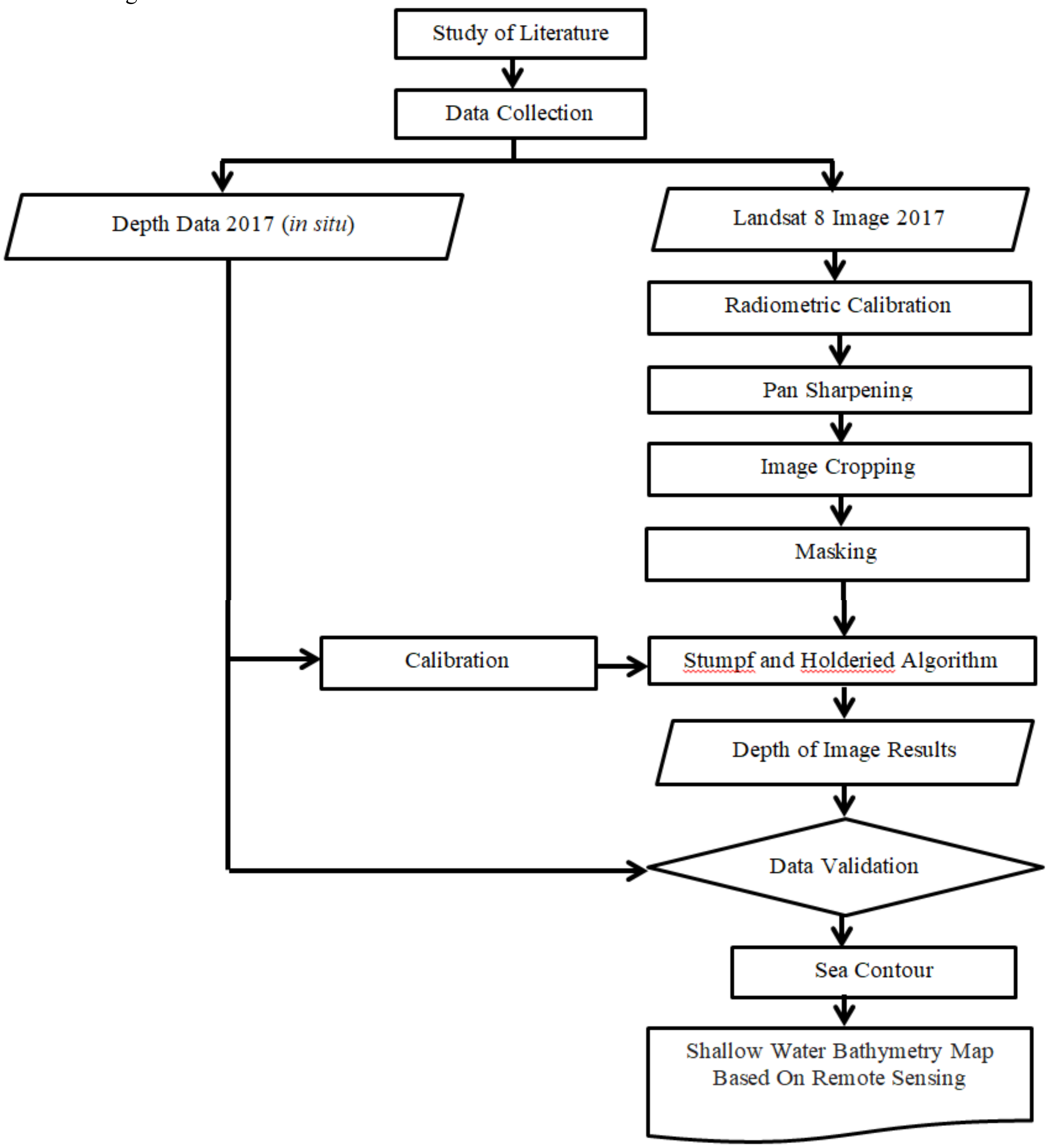

Figure 4 Research Flow Chart

a. Radiometric Calibration

The first step was radiometric calibration, which was to convert Landsat images that were still stored in Digital Number (DN) format into reflectance values. Landsat-8 data is corrected radiometrically using ToA correction which includes ToA Reflectance and sun correction. Correction of ToA Reflectance is done by converting the digital number (DN) value to reflectance value. Based on (USGS, 2014), the conversion equation for reflectance correction is to be seen in equation (1).

$$\rho\lambda' = M\rho Qcal + A\rho \quad \text{.......} \quad (1)$$

Where:
$\rho\lambda'$ = TOA reflectance, without correction for the angle of the sun.
$M\rho$ = REFLECTANCE_MULT_BAND_x, where x is the Band number
$A\rho$ = REFLECTANCE_ADD_BAND_x, where x is the Band number
Qcal = Digital value number (DN)

Furthermore, the image is corrected for the sun angle to eliminate the difference in the digital number (DN) caused by the position of the sun. The position of the sun on the earth changes depending on the recording time and location of the object being recorded. The equation for correction with the angle of the sun can be seen in equation (2).

$$\rho\lambda = \rho\lambda' / (\cos(\theta SZ)) = \rho\lambda' / (\sin(\theta SE)) \quad \ldots\ldots(2)$$

Where:
$\rho\lambda$ = ToA reflectance
θSE = sun elevation
θSZ = zenith angle of the sun, $\theta SZ = 90° - \theta SE$

b. Pan Sharpening

The next step is the pan sharpening process which aims to improve the spatial resolution of multispectral images with spatial resolution of panchromatic images. The pan sharpening method used in this study is the Gram-Schmidt method because the Gram-shmidt method is one of all methods with the highest quality that is widely recognized (T. Maurer, 2013). Landsat 8 multispectral imagery (bands 2,3,4 and 5) which have a spatial resolution of 30 mx 30 m will be combined with Landsat 8 (band 8) panchromatic images to produce a spatial resolution of 15 x 15 m. The image before performing the pan sharpening process can be seen in Figure 5 and the image that has done the pan sharpening process can be seen in Figure 6.

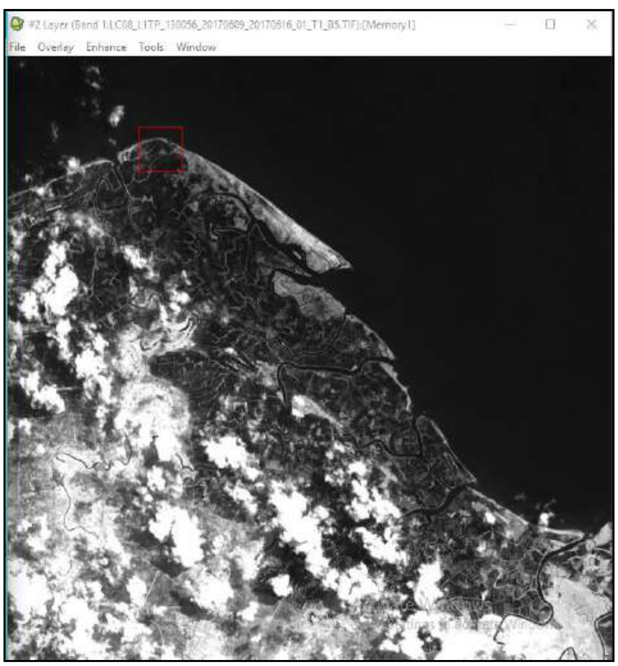

Figure 5 Before Pan Sharpening

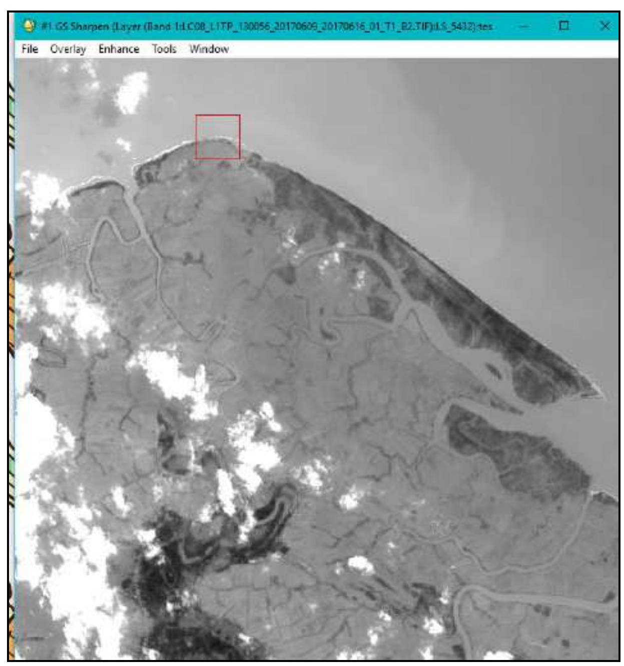

Figure 6 After Pan Sharpening

c. Image Cropping

After the pan sharpening process, the next step is to process the image cropping. Image cropping is done to take the area to be studied in the image, namely the waters of East Aceh so that not all scenes from the image are used. The cropping technique that was carried out in this study was to use vector data.

d. Masking

Masking is a stage to separate the waters and land by blocking the digital number (DN) of land with a zero value. This stage is carried out so that the land area does not affect the waters when entering the shallow water bathymetry algorithm. The results of the masking process that shows the digital number (DN) of the land area of 0 can be seen in Figure 7.

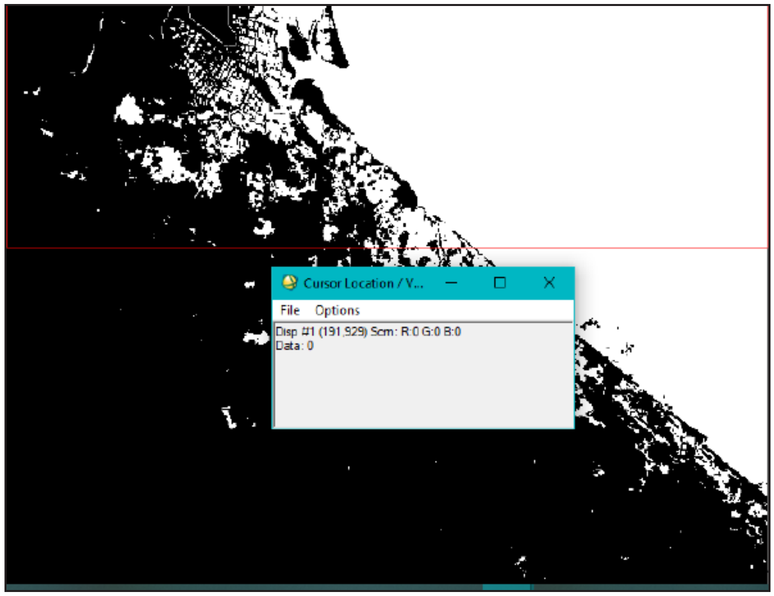

Figure 7 Masking Result

e. Stumpf and Holderied Algorithm

After all the processes are carried out then the next step is to process the image to get the shallow water depth value. To obtain information on water depth from Landsat-8 imagery, this study uses the ratio method processing technique developed by Stumpf (2003). The principle of this method is that light weakens through interaction with the water column, and light that penetrates the depth of the water depends on the wavelength of the light. Shorter wavelengths penetrate deeper waters than longer wavelengths (Nurkhayati, 2014). This depth model uses SPEAR module relative water depth on ENVI 4.5 software. This model is able to quickly predict the depth of the water from the image. Landsat-8 images are extracted pixel values to produce a model of water depth using an algorithm developed by Stumpf and Holderied (2003) as in equation (3).

$$Z = m_1 \frac{\ln(nR_w(\lambda_i))}{\ln(nR_w(\lambda_j))} - m_0 \quad \text{.......................................} (3)$$

Where:
Z = depth of estimation
m1 = calibration coefficient of each band
Rw () = pixel reflectance value in each band
m0 = correction factor for depth 0
n = constant to keep the ratio positive.

The coefficients m1 and m0 are obtained from the regression results of the band ratio to the depth of field.

f. Validation Data

After obtaining the depth value from processing satellite imagery, then an accuracy test is performed. Accuracy test was conducted to determine the level of truth from the results of the Stumpf and Holderied algorithm in generating depth data for 200 field sample points. Accuracy test is performed using the root mean square error (RMSE). Position accuracy analysis uses the root mean square error (RMSE), which describes the value of the difference between the test points and the actual point. RMSE is used to describe accuracy including random and systematic errors. (Geospatial Information Agency, 2014). The RMSE value is formulated as in equation (4).

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(p_i - a_i)^2}{n}} \quad \text{...} (4)$$

Where:
n = Amount of data
Pi = field data
Ai = image processing data

3. RESULTS

3.1 Digital Image Processing Results

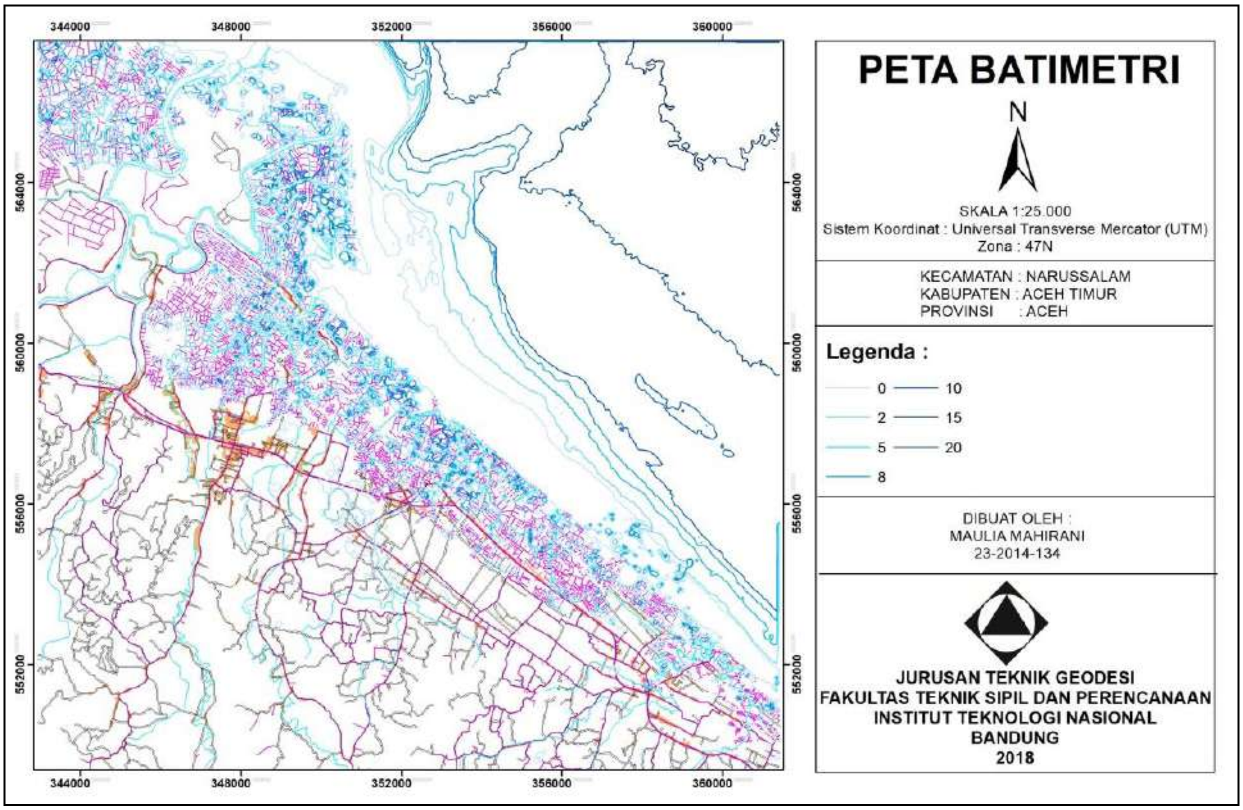

Figure 8 Shallow Water Bathymetry Map Based on Remote Sensing

Based on Figure 8, variations in the depth value of the waters of the kecamatan Narussalam Kab.Aceh Timur was obtained through the results of the implementation of the Stumpf and Holderied algorithms quite well. This Stumpf and Holderied algorithm in East Aceh waters is only able to detect optimum depth variations that can be estimated at depths of ± 20 m. A depth of more than 20 m cannot be recorded by the sensor anymore, this happens because sunlight cannot penetrate to the surface of the sea floor again (Maulana et al, 2015). This condition is close to the results of Jupp's (1988) study, that Landsat 8 is capable of detecting optimum depth variations that can be estimated to a depth of 25 m.

The ability of Landsat 8 to produce depth information in this study was also supported by the study of Bobsaid et al (2014) who obtained the results that Landsat 8 was able to detect optimum depth variations that can be estimated to a depth of 12,052 m in the waters of Poteran and Gili Iyang Madura Islands. Setiawan et al. (2014) found that Landsat 8 was able to detect optimum depth variations that could be estimated to a depth of ± 13 m in the waters of Menjangan Island. Maulana et al (2015) found that Landsat 8 was only able to detect optimum depth variations that could be estimated at a depth of ± 13 m in Semarang waters.

3.2 Correlation Test

Field depth data is correlated with depth data from image processing results. The use of correlation tests aims to determine the magnitude of the relationship between the depth data and digital values obtained through the Stumpf and Holderied algorithms. The graph in Figure 9 shows that the ratio between blue and green channels to depth increases with increasing depth, this is indicated by the existence of a positive linear relationship. This graph serves to determine the relationship between the green channel and the blue channel ratio to the depth of field data.

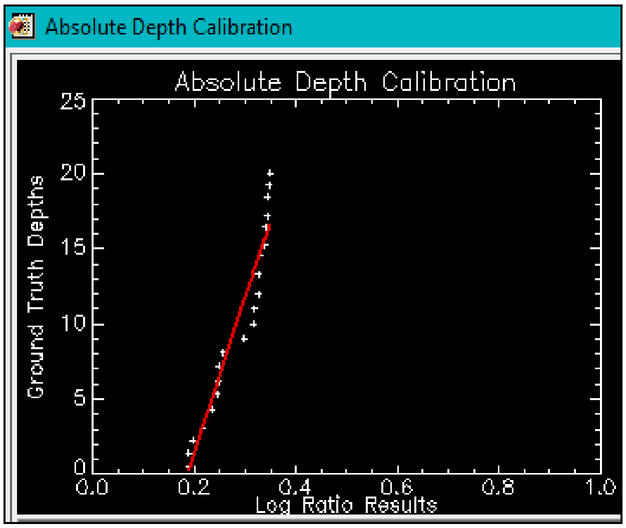

Figure 9 Graph of Linear Regression Equations

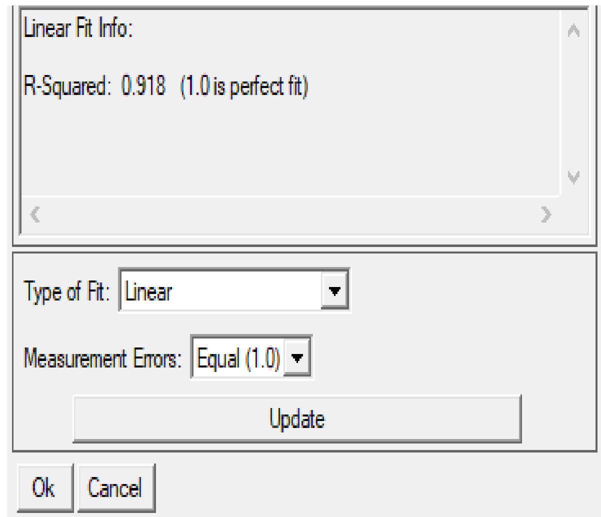

Figure 10 Determination Coefficient

Based on Figure 10, the coefficient of determination (R^2) produced is 0.918. The value of the coefficient of determination is better when compared to the coefficient of determination obtained by (Maulana et al, 2015) in his research which obtained the coefficient of determination (R^2) of 0.7127. This value shows a good relationship between the depth of field waters with the depth value of the image waters. The meaning of this value is the Stumpf and Holderied algorithm is good enough to get depth in the waters of East Aceh. This value is included in the level of the relationship that is 'very strong' between the field data with image data because the value of 0.918 is in the coefficient interval ‘0.80-1,000’ according to the criteria of the correlation coefficient in Table 1.

Table 1 Land Cover Area (Sugiyono, 2014)

NO	COEFFICIENT INTERVAL	LEVEL
1	0,00 – 0,199	Very low
2	0,20 – 0,399	Low
3	0,40 – 0,599	Medium
4	0,60 – 0,799	Strong
5	0,80 – 1,000	Very strong

3.3 Accuracy Test of Each Line

Test the accuracy of each lane using the distribution of sample points that have been evenly distributed as many as 200 sample points. This sample point is divided into 5 actor lines. The accuracy test for each lane is carried out so that the magnitude of deviations in each lane can be determined which have different depth variations. The results of the test of the accuracy of the data depth of the field with the depth of image based on 5 actor lines can be seen in Table 2.

Table 2 RMSE Each Line

LINE	RMSE
1	12.56
2	9.95
3	5.58
4	6.64
5	6.07

Based on the RMSE results from the 5 lanes obtained, in lane 1, the deviation of 12.56 m was obtained, in lane 2 it was obtained the deviation of 9.95 m, in lane 3 it was obtained the deviation of 5.58 m, in lane 4 it was obtained large deviation of 6.64 m and in lane 5, the deviation is 6.07 m. The smallest RMSE value is in lane 3 at 5.58 m and the largest RMSE is in lane 1 at 12.56 m. Extraction of variations in depth data that have deviations can be caused by several factors, one of which is the atmospheric effect, the condition of the waters, differences in the time of image coverage with the depth of field data and differences in tidal time conditions.

Atmospheric effects are able to affect electromagnetic waves from the sun to objects and from objects to the sensor which causes errors in image data, where image data obtained with the desired data is not the same. The influence of the atmosphere (noise) occurs during the image recording process where electromagnetic waves from the sun to the surface of the earth and from objects to the sensor experience interference when passing through the atmosphere, the interference can be scattering or absorption (Kristianingsih, 2016).

Water conditions can affect the depth value of the image processing results. In order for the depth value of the image processing to approach the true depth value, it is necessary to have shallow and clear water conditions. The magnitude of the deviation between the depth of the image processing results with the value of the depth of field in this study could be due to the condition of the shallow waters that are less clear.

Landsat 8 image data used is image data covered on June 9, 2017 while the depth data used is field data obtained on June 7-20, 2017 so that the time difference between the two data can cause differences in depth information obtained. The difference in depth information obtained occurs because the sea surface conditions change every time (Kurnianingsih et al, 2017). The depth generated by the image will likely be closer to the depth of field data and obtain a smaller RMSE if the time conditions of the two data are in the same timeframe.

Tidal time difference conditions also become one of the factors of irregularities obtained. Although the algorithm has gone through a calibration process on the depth of field data that has been corrected for tides, but still there will be differences in tidal time when image coverage with field data. The time coverage of Landsat 8 satellite imagery when crossing the equator is 10:00 to 10:15 a.m., so the tides obtained from the image coverage are only at that time period. While the tides in the field are obtained at different times at each depth point, so the tidal time of field data will be different from the tidal time of the image coverage.

3.4 Accuracy Test of Each Field Depth Interval

After testing the accuracy of each lane, the accuracy test was carried out again by making a classification based on the field depth interval class. The accuracy test for each depth contour interval is done in order to find out the deviations in each depth contour interval then can find out which depth contour interval has the smallest deviation and the biggest deviation. The test results of the accuracy of field depth data with depth of image based on each depth interval of the field can be seen in Table 3.

Table 3 RMSE Each Field Depth Interval

INTERVAL	RMSE
0-5	1.75
5-10	1.92
10-15	2.07
15-20	3.77

Based on the RMSE results from the 7 depth contour intervals obtained then at a depth of 0-5 m obtained a large deviation of 1.75 m, at a depth of 5-10 m obtained a large deviation of 1.92 m, at a depth of 10-15 m obtained a large deviation of 2.07 m, at a depth of 15-20 m obtained a large deviation of 3.77 m. The smallest RMSE is at a depth of 0-5 m at 1.75 m and the largest RMSE is at a depth of 15-20 m at 3.77 m.

Deviations at 15-20 m depth interval produce the biggest deviation because it is caused by the depth value of the waters. The deeper the depth value of the water, the depth value obtained by the results of processing the image will be further away from the depth value of the field size because the depth affects the amount of power reaching the bottom of the waters. The greater the depth, the smaller the sunlight that reaches the bottom of the water because this power is absorbed by many aquatic objects. Thus the less energy the object reflects on the sensor so that the spectral value will decrease (Nurkhayati, 2014).

3.5 Accuracy Test on Basic Map Accuracy Provisions

A total of 200 sample points used to test accuracy produce deviations in each depth of field contour interval. Table 4 shows the comparison of the RMSE value to the provisions of the accuracy of the Indonesian Coast Environmental Base map (LPI) on a scale of 1: 25.000.

Table 4 RMSE Image Comparison with LPI Map Depth Accuracy Provisions Scale of 1: 25.000

INTERVAL	RMSE	Depth Accuracy The LPI map is 1: 25,000 scale (m)
0-5	1.75	0.517
5-10	1.92	0.517
10-15	2.07	0.517
15-20	3.77	0.517

Based on Table 4, it can be seen that the results of image processing accuracy at each depth contour interval did not meet the standard Indonesian Coast Environment (LPI) base map depth accuracy scale of 1: 25,000, meaning that the depth information presented in the shallow water bathymetry map based on remote sensing in the study area this cannot be used as basic information for the Indonesian Coast Environment (LPI) base map.

4. CONCLUSION

The results is Processing of Landsat 8 images using the Stumpf and Holderied method is able to detect optimum depth variations that can be estimated at depths of ± 20 m with variations in shallow water depth values consisting of 0, 2, 5, 8, 10, 15 and 20 m, at a depth of 0-5 m obtained a large deviation of 1.75 m, at a depth of 5-10 m obtained a large deviation of 1.92 m, at a depth of 10-15 m obtained a large deviation of 2.07 m and at a depth of 15-20 m obtained a large deviation equal to 3.77 m and based on the image processing RMSE results obtained from each depth contour interval, this value does not meet the standard of Indonesian Coast Environment (LPI) base map depth scale of 1: 25.000 with the meaning that the depth information presented in the shallow water bathymetry map based on remote sensing in the region this study cannot be used as basic information for the Indonesian Coast Environment (LPI) base map.

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