The Preliminary Assessment of Reson Hydrobat Multibeam Echosounder for Seabed and Underwater Structures Mapping Under the Pier

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ABSTRACT

A pier is a man-made object that built on the sea or river using piles as its buffer structure. The mapping of those structures can use several methods such as satellite imagery, aerial photographs, terrestrial measurements as well as seafloor imagery. However, the seabed mapping under the pier is one of the challenges that must be encountered to map and monitor those structures. Single-beam echosounder which is a conventional depth measurement equipment cannot give a clear of seabed imagery. Ordinary multibeam echosounder equipment also cannot produce a detail seabed imagery. Along with the development of technology, Multibeam echosounder experiences a rapid development, one of them is high-resolution multibeam echosounder which has high depth resolution. The high-resolution multibeam can produce dense and detail seabed imagery so it can be used for underwater pier mapping.

This study aims to examine how far the ability of high-resolution multibeam sonar technology for underwater mapping of the pier's structures. The survey location was the pier of Penajam Government, North Paser, Indonesia. The main data of this research was multibeam data around the location. The Reson Hydrobat multibeam, which has a high resolution for the survey in shallow water (nearshore), was used in this study. The data was then processed using CARIS HIPS software. The result of data processing and image display showed that this technology can produce the seafloor imagery with adequate resolution and can be used to map the seabed under the structure of the building, to search objects on the seabed and for inspection purposes.

Keywords : High-Resolution, Multibeam, Pier, Underwater Mapping

1. Introduction

A pier usually has supporting piles as the main underwater structure support. These piles commonly cannot be seen from the surface. However, for inventory and marine assets maintenance purposes, these structures need to be mapped and be added to the existing map. The mapping and monitoring of a pier with its structure's complexity have a considerable challenge. Monitoring the part of the structures above water can be conducted with several methods such as visually or using Unmanned Aerial Vehicle (UAV) which is equipped with the aerial camera (Metni & Hamel, 2007).

However, mapping of the underwater structures such as piles needs particular methods. This mapping becomes important not only to obtain the seabed imagery below the upper structure but also for further study such as piles inspection, sedimentary monitoring as well as for biological habitat study below the pier. Those studies are important since these structures are vulnerable from scouring and settlement, which is in the long period, can risk the pier's structure (Pricket, 2005). The monitoring of the damage is important for repair, maintenance and management of the underwater structures.

Traditionally, mapping and inspection of underwater structures use conventional methods such as depth measurement sticks or diving services (Fukui & Otuka, 2001). Combination of both methods can lead to the risks not only those methods are not simple and risky from the strong current, but also need much time and costly. Another solution is using the underwater acoustic technologies. Several technologies can be employed such as single-beam echosounder, multibeam echosounder, side-scan sonar and sonar scanning. Single-beam echosounder, which is a conventional depth measurement equipment, cannot provide a clear image of the seabed. Similarly, the conventional multibeam echosounder also cannot give detail and dense seabed imagery.

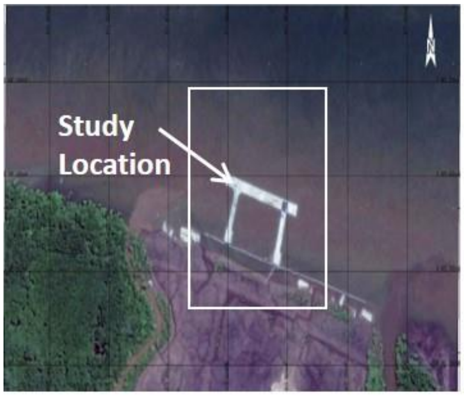
Reson Hydrobat multibeam echosounder is a hydro-acoustic instrument that has 112 beams number and 120° of swath width. It can be operated in the frequency of 160 kHz and can cover swath width 3.4 times of the depth (Reson Inc., 2010). The specification of this equipment can provide high resolution of the seabed imagery. Reson Hydrobat multibeam echosounder also has been used to detect the underwater objects in investigation survey of Mahakam Bridge accident in Kutai Kartanegara, Indonesia (Manik, 2014).

2. Methodology

2.1. Study Location

The study location was a pier of Government of Penajam Paser Utara, East Kalimantan, Indonesia which is located at Riko River Estuary, Buluminung, Penajam Paser Utara. The multibeam bathymetric survey was conducted by Technology Centre for Marine Survey, Agency of the Assessment and Application for Technology (BPPT), Indonesia. The project was a part of the assessment for Indonesian Maritime National Science and Technology Park (NSTP). The survey was conducted on 14 October 2015 and has a purpose to map the seabed of Riko River as the cruise line to the NSTP location. The survey location and the pier's structure can be seen in the picture 1 and picture 2 below.

Picture 1. Survey Location



Picture 2. a) Map of Survey Location (UTM Zone 50S), b) The Pier's piles in the location

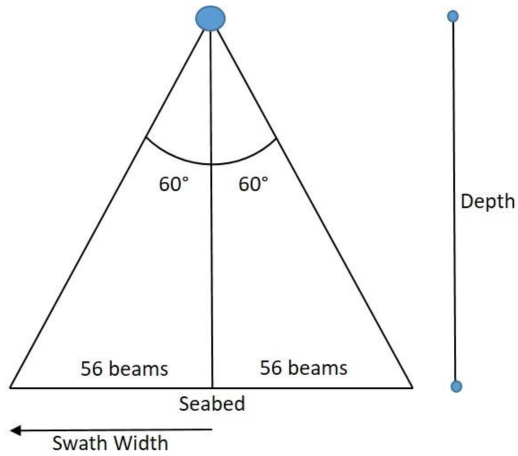
2.2. Multibeam Survey

The multibeam echosounder system consists of two different systems, interferometric multibeam and beamforming multibeam. Both systems use distance and angle measurements for measuring the depth of the seabed from the transducer. Mathematically, the beamforming system has more beams number to detect the distance from the sea surface. This study uses interferometric multibeam using phase measurement with an array of the transducer. The interferometric multibeam system measures the angle of incoming sound waves in sample time sequence, so that it can generate a lot of transverse depth in a single ping (Bathyswath, 2013). The interferometric method is a simple and effective method to map the seabed with large coverage and high resolution (Ărăcin & Calin, 2000).

This study used Reson Hydrobat which has the frequency of 160 kHz, 120° of swath width and 112 beam numbers (Reson B. V, 2011). The PDS2000 software was employed for the data acquisition that was used to integrate the sonar bathymetric data from the Reson Hydrobat with the position and inertial data (heave, pitch and roll) from the Octopus F180 GPS receiver. The PDS2000 has an ability for multibeam data acquisition, navigation control, data calibration and data post-processing (Di Maida et al., 2011). In addition, that software also can display the real-time multibeam coverage and real-time Digital Terrain Model (DTM) also positioning information that is used in navigation during the survey (Anzidei, Esposito, & De Giosa, 2006).

In order to get the accurate depth during the data acquisition, the Octopus F180 GPS receiver was used during the survey. This inertial navigation system is a positioning system that integrated with the real-time vessel inertial movement and real-time vessel geographical heading continually and accurately. This system consists of IMU (Inertial Measurement Unit) and dual-antenna GPS receiver (CodaOctopus, n.d.), so it can provide the real-time vessel attitude data such as heave, pitch and roll as well as the real-time coordinates and very powerful to be used for hydrographic survey applications.

The swath width of the multibeam can be divided into two sides, the left swath of the transducer and the right swath of the transducer. In general, the width of coverage each side of the transducer can be described using the illustration picture (Picture 3) as follows:



Picture 3. Geometric Illustration of Multibeam Measurement

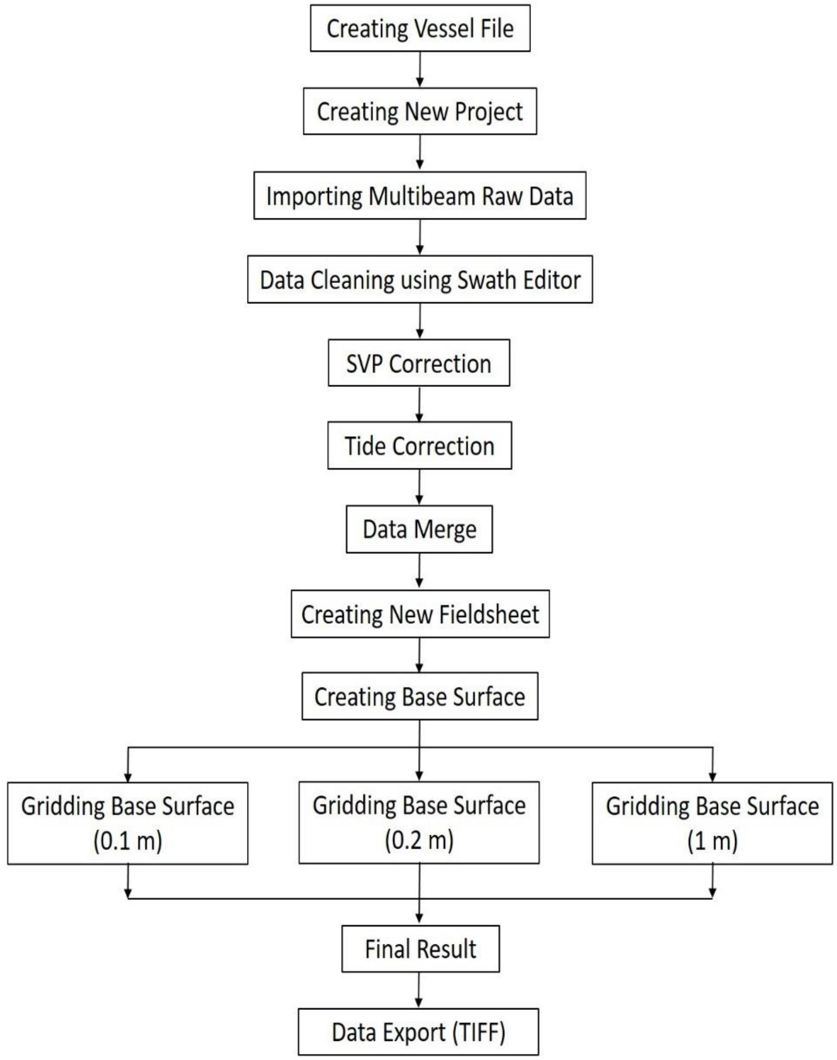
Based on picture 3, the coverage (C) of each swath can be calculated as follows:

$$C = tg\ 60° \times \text{depth of the location} \quad (1)$$

The equation can be used to determine the preliminary calculation of coverage during the multibeam survey preparation so the gap areas can be minimalized and the survey can be conducted effectively and efficiently.

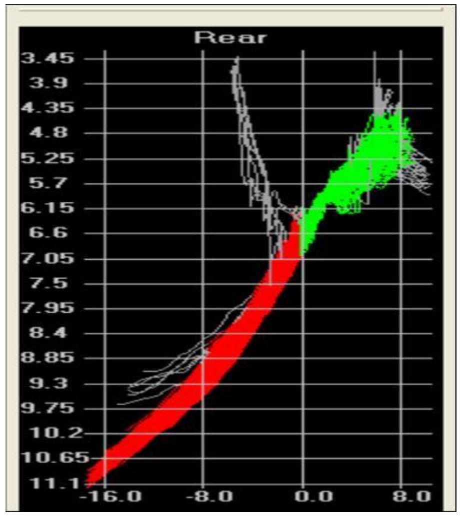
2.3. Multibeam Data Processing

The purpose of multibeam data processing is to obtain the seabed imagery below the pier. The CARIS HIPS 6.1 was used to process the data and the processing flowchart can be seen in the picture 4 below.



Picture 4. The Flowchart of Multibeam Data Processing in CARIS HIPS 6.1

The data acquisition using Reson Hydrobat multibeam system generates raw data files with *.S7K extension. That data then was processed using CARIS HIPS 6.1 software. That software has one tool namely Swath Editor that can be used to display the seabed profile during the data acquisition. The display of the Swath Editor can be seen in the picture 5 below.



Picture 5. Swath Editor in CARIS HIPS 6.1

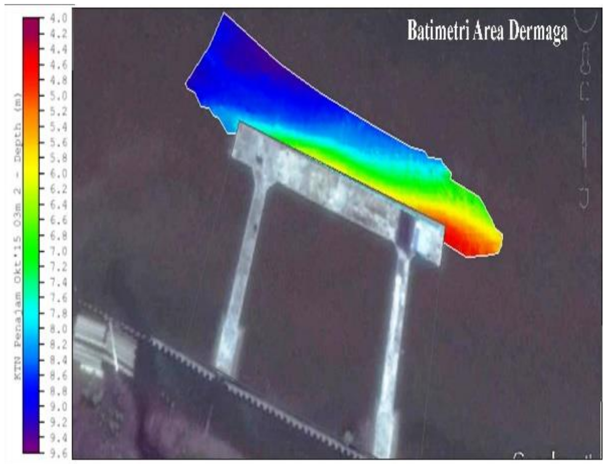
Picture 5 shows the display of Swath Editor tool in the CARIS HIPS 6.1. It can be seen that the depth profile in the location is not equal between the left and right swath. The seabed profile on the right side of the nadir has 8 m of maximum depth since the right side of the transducer covers the shallow seabed and the multibeam signal was obstructed by the pile structures. However, the seabed profile on the left side of the nadir has 16 m of maximum depth since it covers the deeper side of the river.

One of the important stages in the data processing is gridding process. Gridding is a process to obtain the irregular XYZ data and then creates grid file from that data that contains a regular array of depth data (Z). The irregular raw data leads to the blank spots in several locations due to the inconsistent of data acquisition. The Gridding process can be used to fill that blank spots using depth (Z) interpolation in the surrounding areas. A grid in gridding is a square location that consists of rows and columns. The Grid Point is the perpendicular of those rows and columns. The gridding process can generate the depth (Z values) in each of the Grid Point using interpolation and extrapolation the raw depth (Z) values (Golden Software, 2002).

The Gridding process in CARIS HIPS 6.1 is conducted as a part in the BASE surface process. The Gridding process is conducted by choosing and inputting the distance resolution value of each BASE surface points (CARIS, 2008). That software has several options such as using single resolution value for the entire BASE Surface or using several resolution values based on particular depth.

3. Result and Discussion

The result of multibeam data processing is displayed as a georeferenced seabed imagery (BASE Surface).That image then was overlaid with the Google Earth imagery of the study location (Picture 6).



Picture 6. Base Surface Result

The picture 6 depicts the colour gradation according to its depth, the red gradation shows the shallow seabed while the blue gradation represents the deep seabed. The picture 6 also shows that the depth below the pier has range between 4 – 10 m. That pier has 120 m of length and can be categorized as type C of coastal fishing port and can accommodate 30 units of 10 – 30 GT fishing boats (Kementrian Kelautan dan Perikanan Republik Indonesia, 2012).

That pier is also expected to support the fishing loading activities and marketing 5 tons of fish every day fish and to support the fish processing industry. According to the regulation, the type C of a coastal fishing port is required to have a dock pool deeper than 2 m and that pier has already met that requirement.

The pier is supported with piles that have diameter 1.5 m of each. To map those piles, a high-resolution multibeam sonar needs to be used to obtain the accurate result. Based on the equation (1), the coverage (C) of each side can be calculated as follows:

C = tg 60° x depth of the location

= 1.73205 x 7 m

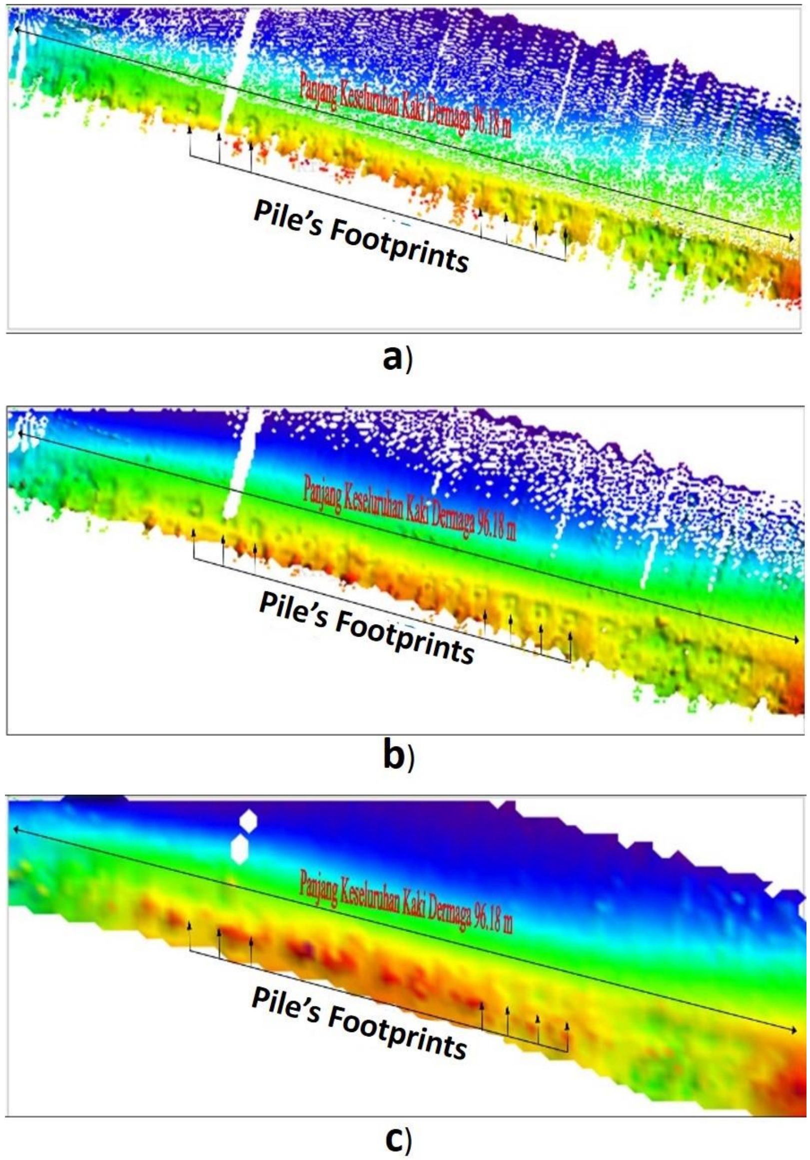
= 12.12 m

The study location has an average depth of 7 m, so the coverage of multibeam on each side of the transducer would be approximately 12 m and the total coverage of both sides is 24 m. That result has matched with the Reson Hydrobat technical specification that has a swath width of 3.4 times of the depth. In addition, the Reson Hydrobat has 56 beam numbers so the distance-density (K) of each beam on the seabed can be calculated as follows:

K = 12.12m / 56 beams

= 0.2 m

The result of the calculation shows that the horizontal resolution of the equipment is 0.2 m for the depth of 7 m in the location. That result has also been proven through the gridding process using several different gridding sizes (1 m, 0.2 m and 0.1 m). That gridding process was done using CARIS HIPS 6.1 software. The result of the gridding process can be seen in the picture below.



Picture 7. a)Base Surface with gridding size 0.1 m, b)Base Surface with gridding size 0.2 m, c)Base Surface with gridding size 1 m

The picture 7 depicts the result of the gridding process. Although the vertical structure of the piles cannot be seen clearly due to the limitation angle of the transducer, the picture 7 can portray the footprint of the piles. It can be seen that the base surface image with 0.2 m of gridding size (picture 7(b)) provides the clearest image of the footprint of the pile's structure. This result confirmed the horizontal resolution calculation of the equipment. However, the same gridding size (0.2 m) in the deeper depth will result the blank spots in several locations since the deeper of the seabed will decrease the resolution of the image. The smaller gridding size (0.1 m) can result a rough Base surface image (picture 7(a)). In contrast, picture 7(c) shows that the bigger gridding size (1 m) will result a smoother image, but it cannot depict the footprint of the pile's structure in detail. It is because of the size of the pile is 1.5 m and the bigger gridding size that is used will result the unclear and undetailed of the objects in the image.

It has been proven previously that the 0.2 m of gridding size is appropriate with the equipment's technical specification. This preliminary study has proven that the Reson Hydrobat multibeam echosounder is suitable to be used in mapping the coastal fishing port or other underwater structures that have minimal size 1.5 m and in the areas that have depth 5 – 10 m. However, the other methods such as tilt-angle transducer of high-resolution multibeam survey, side-scan sonar survey, scanning sonar survey as well as underwater video survey need to be used to support the further seabed mapping activities.

4. Conclusion

This study is aimed as a preliminary assessment of Reson Hydrobat Multibeam to map the underwater structures. The Reson Hydrobat is generally used to shallow bathymetric mapping, but this study tries to examine the use of this equipment to map the underwater structures in particular. The Reson Hydrobat has 112 beam numbers and 120°of swath width and it can be used in the area with 5 – 10 m of depth. The raw data then was processed and three different interpolation gridding values sizes (1 m, 0.2 m and 0.1 m) were used. The base surface images as the result of the gridding process show different smoothness. The 0.2 m of gridding size shows the best piles footprint image than the two others and it is also confirmed by the manual calculation using the 7 m of depth. That horizontal resolution will be decreased along with the increasing of the depth of the seabed. For that reason, the use of this equipment to map the structures bigger than 1.5 m and the depth over than 10 m needs a further assessment.

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