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River Depth Analysis Using Multibeam Echosounder for Coal Ship Cruise Line (Case Study: Mahakam River, East Kalimantan)

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Abstract*—Kalimantan is one of the largest coal producing regions in Indonesia. With abundant mining products, mining companies in Kalimantan need transportation media that can cover most of the mining areas. Water transportation is the answer that mining company need to transport mining products such a coal product. The Mahakam River is the main water transportation medium used to connect areas that can not be traversed by land in Kalimantan. In order to get safe transportation a cruise line must be developed. The cruise line is made from bathymetry survey using Multibeam Echosounder. The purpose of this study is to provide a safe cruise line for ships to pass the Mahakam River. A path will be made from bathymetry data and built from two specification. First specification is indonesian standard from kramadibrata and second is from ship specification itself. The data used for this research is from PT. Seascape Surveys Indonesia. Because the bathymetry data is the property of PT.Seascape Surveys Indonesia, the coordinates of this research area can not be mentioned and local coordinates are used to maintain the confidentiality of the company's data. Bathymetric data were corrected with survey error parameters consisting of tidal correction correction, sound velocity profiler, gradient, water level and patch test. The depth of bathymetry data has reference to EGM96 during data retrieval and LLWL with reference EGM08 for Map. From the analysis of bathymetry maps of the Mahakam River, there will be recommendation which ship can pass the mahakam river and which ship is can't.

I. INTRODUCTION

Hydrographic survey according to the International Hydrographic Organization (IHO) is the branch of applied sciences which deals with the measurement and description of the physical features of oceans, seas, coastal areas, lakes and rivers, as well as with the prediction of their change over time, for the primary purpose of safety of navigation and in support of all other marine activities, including economic development, security and defenses, scientific research, and environmental protection [1].

In the hydrographic survey used acoustic system. Acoustic system is very effective to explore the underwater appearance. The basic principle of sonar is to use sound to detect or locate objects, typically in the ocean. Currently the acoustic technology that plays a role in the hydrographic survey is Multibeam Sonar. Multibeam echosounders, like other sonar systems, emit sound waves in the shape of a fan from directly beneath a ship's hull. These systems measure and record the time it takes for the acoustic signal to travel from the transmitter (transducer) to the seafloor (or object) and back to the receiver [2]. Multibeam echosounder is very effective for depth surveys because the results given are accurate enough. The role of multibeam echosounder is quite large in determining the shipping path because the main data required in making the shipping path is depth data.

One part of the hydrographic survey is a survey of the cruise line. The ship cruise line is necessary to provide the information which ways is safe to pass by the ship. Given this information, the probability of a shipwreck due to a seabed strike can be significantly reduced. Determination of ship cruise line is not only done in sea, but also conducted in rivers that have an important role in economic of Indonesia. One of these rivers is the Mahakam River.

Mahakam River is the second longest river in Kalimantan and Indonesia with a length of 920 km. Mahakam River plays an important role in the economy of the people of Kalimantan, the river is used as the main transportation channel in Kalimantan if there is no access to land transportation, until now there are 100 channel of river transportation in mahakam river waters [3]. One of the role of the Mahakam River as a transportation channel is as a medium of delivery of coal mining products of mining companies in Kalimantan.

Kalimantan is one of the largest coal producers in Indonesia, as seen from the Mining Permit (MP) of coal mining area which tends to increase every year. In East Kalimantan alone, there are 221 MPs with 803,855 ha of coal mine area by 2014, 219 MPs with 792,596 ha in 2015 and 246 MPs with 944,043 ha in 2016 [4]. With the result of abundant coal mining used mahakam river as main transportation channel to send coal mine from one location to another location. With the making of the Mahakam River ship cruise line, it will facilitate navigation of coal transport vessels to search for safe shipping paths. This will reduce the rate of water traffic accidents in the Mahakam River.

II. METHODOLOGY

A. Study Area and Data

The location of this research is in the middle of Mahakam River, East Kalimantan. For the exact location can not be mentioned to maintain the privacy of corporate data PT.Seascape Survey Indonesia.

B. Data Processing

1. Data Gathering.

The data used in this study were obtained from PT.Seascape Surveys Indonesia consisting of Multibeam Echosounder

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(BMES) batimetry survey data of Mahakam River with an area of 6 km x 0.15 km, multibeam bathymetry survey data to calculate patch correction, bathymetry survey correction data consists of tidal exposure and Sound Velocity Profiler (SVP), singlebeam echosounder (SBES) bathymetry survey data, offset vessel and Global Positioning System (GPS) of mahakam river to calculate gradient values and water level data from tide pole of research area of Mahakam River. For other data obtained from outside PT.Seascape Surveys Indonesia consists of global geoid model EGM96 and EGM08 from www.earth-info.nga.mail and ship specification data from www.bki.co.id.

2. Multieam Processing.

First, MBES data need to be cleaned from unnecessary data, that is called with spike. Spike data is a data that is abnormal from unwanted object. Spike can be determined from significant depth jump. Then next step is combine all Digital Terrain Model (DTM) data from all measurement into one DTM. After that applied correction data for MBES such as SVP, patch test and tidal data. After it’s done apllied gradient correction, then change the reference datum from EGM96 into Lowest Low Water Level (LLWL) taken from tidal measurements for 10 years. Change reference again from LLWL to EGM96 into LLWL to EGM08 obtained from comparison of geoid model EGM96 and EGM08. Final step is plot the DTM.

3. Gradient Processing.

River is unique because it has something that sea doesn’t, that is gradient. Gradient is a slope between two point. This is a problem because chart datum (CD) is straight reference line from tide pole. To make river water surface equivalent with CD reference, we need to add some height from each point so the water surface is equivalent with CD. To make it happen, we compared EGM96 GPS data with SBES depth data so we will got depth data from EGM96. The data obtained is taken every 1 - 3 km to get the value of depth until kilometer kilometers (KP) 6 from the port, starboard and center in accordance with the flow of KP. Next step is calculates the gradient at each depth point then calculate the average of the gradient by comparing the gradient value with the value before and after. Next step is looking for KP value every two km with interpolation. After that calculates the average gradient of the KP every 2 km of the three paths. From calculated total gradient in every 2 km, we will get the average gradient in this research area.

4. Datum Transformation.

Datum transformation is used to convert DTM with LLWL reference to EGM96 model to LLWL reference to EGM08 model. Difference height data is obtained from comparing two geoid model which is EGM96 and EGM08. One point from each two kilometer along Kilometer Post (KP) is compared from two model. That difference then become reference from other point to transfrom from EGM96 to EGM08. Author using two kilometer from each point because research area is 6 km x 0.15 km which is inside 1’ global grid. The height difference inside that grid is not much difference even from two kilometer distance.

5. Creating Cruise line.

Cruise line is created from Indonesian National Standard specification (SNI). For depth specification, formula below is applied:

$$H = d + G + R + P \quad (1)$$

Variabel in formula (1) will be explained below,

H = Depth specificatoin
d = Ship draft
G = Ship vertical movement
R = Free space for ship movement
P = Measurement accuracy

Fomula (1) ilustration can be seen from Figure 1.

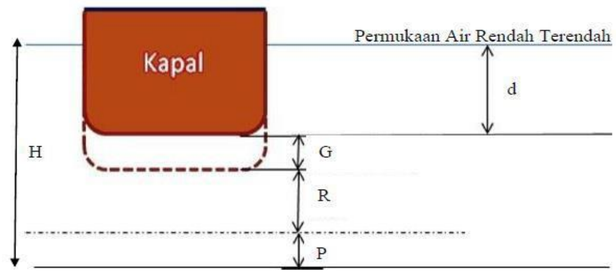

Figure 1. Depth Specification.

As for corridor specification, formula below is applied:

$$D1 = 4.6\ x\ A \quad (2)$$

Variabel in formula (2) will be explained below,

D1 = Corridor specification
A = Width ship

Formula (2) ilustration can be seen from Figure below,

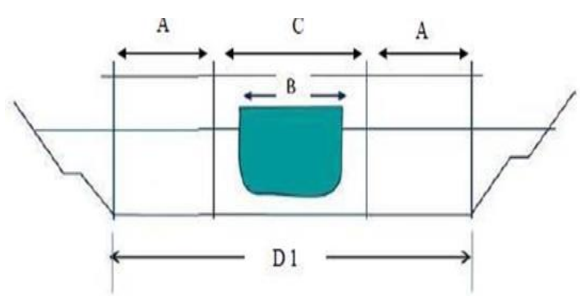

Figure 2. Corridor Specification.

As for ship specification can be seen from Table 1,

TABLE 1.
SHIP SPECIFICATION

Ship Name	Dead Weight Tones (DWT) (ton)	Length Over All (LOA) (m)	Width (m)	Underwater Draft when DWT (m)	Draft Above Water when DWT (m)
Katinga	336	30.51	12	2.4	0.6
Straits	3296.	75.7	24.5	3.3	1.1

Based on Table 1, it can be calculated cruise line specification for both depth and corridor. For depth specification, it’s calculated 6.671 m for Katingan ship and 9,011 m for Straits Phoenix ship. As for corridor specifiation,

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it's calculated 55.2 m for Katingan ship and 112.7 m for Straits Phoenix ship.

III. Result and Discussion

A. *Multibeam Result*

Multibeam result is DTM that has been corrected from many parameters. That parameter is water level, gradient, roll pitch heading, SVP and spike. For water level result, look at Figure 3.

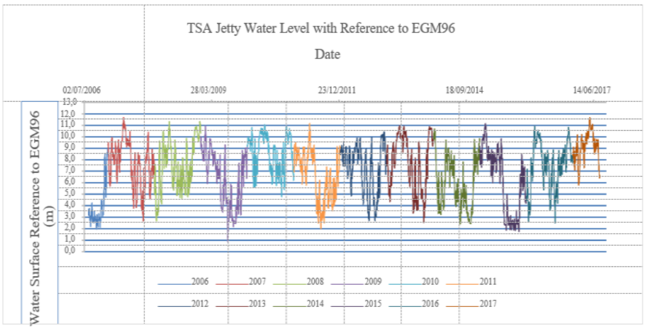

Figure 3. Water Level Result.

Water level has been surveyed for 10 years from 2006 to 2017. From water level data, LLWL will be decided to become reference chart datum. For more information from Figure 3, look at Table 2.

Table 2.
Water Level Result

Tahun	High Water Level (HWL) (m)	Mean Water Level (MWL) (m)	Low Water Level (LWL) (m)
2006	8.89	3.75	1.89
2007	11.65	7.69	2.61
2008	11.32	7.47	2.61
2009	10.94	6.30	0.79
2010	11.06	8.55	4.74
2011	11.14	6.54	1.95
2012	10.42	7.25	2.64
2013	10.95	7.70	2.47
2014	10.67	5.89	2.35
2015	11.13	6.04	1.69
2016	10.91	7.51	2.46
2017	11.65	9.12	5.74
Highest Average	11.65	- 6.99	-
Lowest	-	-	-
	-		0.79

From Table 2, it can be decided that chart datum reference is 0.79 m from EGM96 datum. Other parameter that need to be corrected is gradient. Gradient result can be seen from Table 3.

Table 3.
Gradient Result

KP (km)	Gradien (m)
0.000	0
2.000	-0.102
4.000	-0.204
6.000	-0.423

From Table 3, it can be analyze that the river water surface is tend to come down. For this research area, the river water surface is coming down to 0.423 m from KP 0. Table 3 is ilustrated by Figure 4.

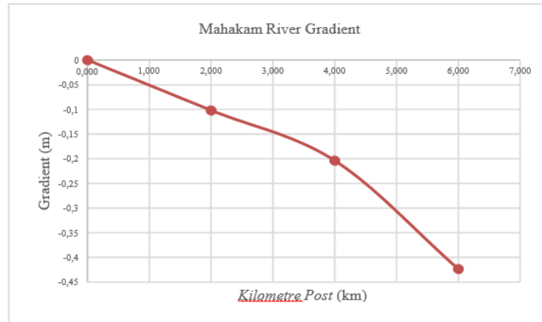

Figure 4. Gradient.

Other parameter that need to be corrected is roll pitch heading, SVP and tide when surveyed. That parameter is corrected when raw multibeam data is processed. It's calculated that roll value is 0.336, pitch value is 0.0002 and heading value is -0.939.

B. *Transformation Datum*

Datum is transformed because EGM08 geoid model is better than EGM96 geoid model. Data will be more accurate if reference height is EGM08 global datum. Vertical datum transformation from EGM96 to EGM08 is done by comparing the undulation value between the two models. The difference in the value of the undulation becomes the value to reduce the EGM96 point to EGM08. Here the researcher uses the global geoid model with 1' x 1' grid and the researcher takes the height every 2 km along the line of KP so that the four differences of undulation are found in KP 0, KP 02, KP 04 and KP 06. The height between two points of undulation in interpolation with a point spacing of 15 m. By comparing the DTM along the KP while still having the EGM96 refension up to EGM08, there is a difference in topographic shape according to the geoid model reference form. Look at Figure 5.

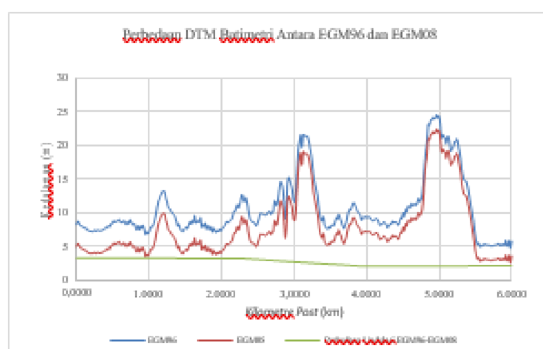

Figure 5. Datum Transformation.

From Figure 5, it can be analyze the riverbed difference between EGM96 and EGM08. EGM08 is placed below EGM96 so the riverbed is being dragged down. More information from Figure 5 is presented by Table 4.

TABLE 4.
DATUM TRANSFORMATION

X (m)	Y (m)	Δ Undulation EGM96-EGM08 (m)	EGM96 (m)	EGM08 (m)	KP (km)
1790,172	23,209	3,292	8,31	5,018	0,0000
1270,869	58,528	3,29	8,83	5,54	0,5
911,988	201,74	3,288	7,2	3,913	1
546,66	503,421	3,284	7,88	4,595	1,5
219,178	878,702	3,282	7,63	4,348	2
120,278	1253,388	3,087	9,21	6,123	2,5
77,906	1743,840	2,744	11,61	8,866	3
437,584	1828,599	2,402	7,84	5,438	3,5
1328,744	1593,879	2,096	9,38	7,284	4
1715,452	1613,501	2,112	10,08	7,968	4,5
2201,364	1922,193	2,13	23,15	21,021	5
2177,765	2277,958	2,146	6,02	3,874	5,5
1668,902	2386,842	2,162	5,85	3,688	6

It can be analyzed that EGM08 value is a results from EGM96 value reduced to Δ Undulation. After transforming datum, final DTM is presented by Figure 6.

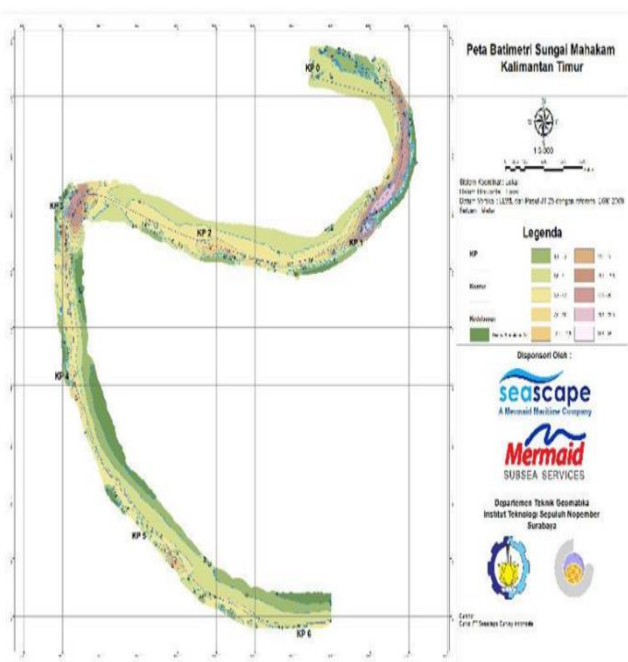

Figure 6. DTM Map.

C. Creating Cruise line

The cruise line is made with respect to the depth and width of the calculated groove specification. For the groove with SNI specification of ship Katingan obtained flow as follows.

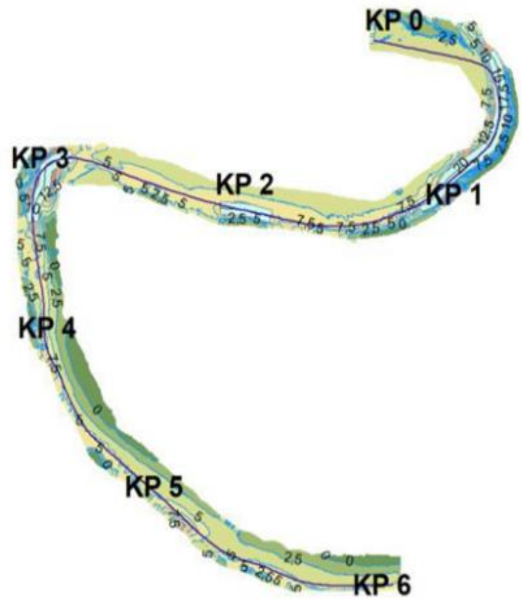

Figure 7. Katingan cruise line.

The ship's flow can be seen from the light blue polygon. In Figure 7, a plot that can be skipped is only a small part of the Mahakam River basin in this study. It can be concluded that Katingan ship can't have a sail in this research area. As for Straith Phoenix Ship, Straits Phoenix has a larger specification than Katingan Ship. Therefore, the flow of the Straits Phoenix Ship based on SNI can be seen in Figure 8 below.

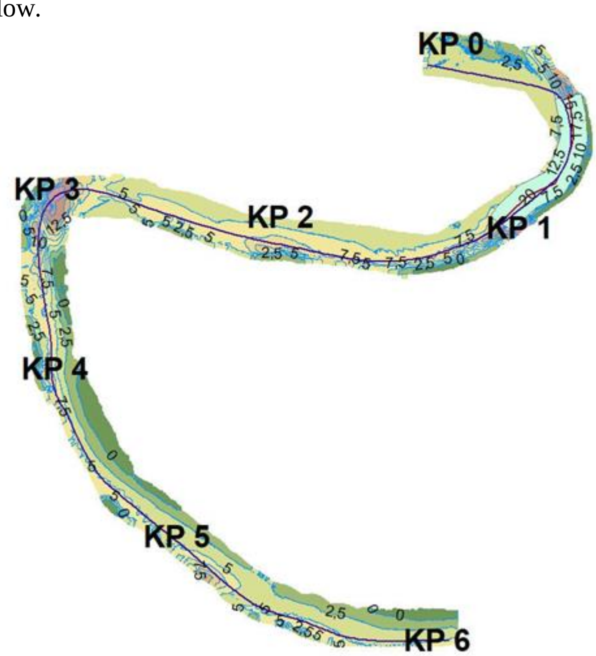

Figure 8. Straits Phoenix Cruise Line.

The ship's flow is presented in light blue polygon and it can be seen that only a very small portion of research area that can be sailed.

IV. CONCLUSSION

The conclusion of this research is there are no ship capable of passing in the Mahakam River watershed. The river depth is too shallow for both Katingan Ship dan Straits Phoenix Ship to pass by the river. Suggestion from this research that there is data of comparison of depth in the form of previous survey to make sure the depth taken is good or not. Another suggestion is tide pole should be made as much as possible to obtain a good datum reference chart and reduce gradient errors. The last suggestion in this study is bathymetry survey should be done as close as possible to tide pole to get more accurate depth reference.

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