Modeling of Sediment Distribution and Changes of Morphology in Estuary Flow Kapuas River, West Kalimantan

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Abstract. Pontianak Dwikora Port is a port that has been owned by Pontianak City since the Dutch colonial era and has been used as a trade center to export and import goods needed by West Kalimantan Province. Dwikora Port is located inside the Kapuas Kecil River and under the auspices of PT Pelabuhan Indonesia II (PELINDO II). Due to the location of the port in the river, the shipping channel is often disrupted due to silting (sedimentation) at the river mouth. So that the ships do not run aground, periodic dredging is carried out. This is to find out how much sediment is in the estuary. So, this study continues previous research by performing numerical modeling using Mike 21 software [1] to determine the sediment distribution flow patterns that affect silting that occurs in the Kapuas Kecil River Estuary. The data to be used are tidal data from field measurements, wind data from BMKG, wave generation data, river discharge, and TSS from previous research journals. The TSS used is derived from the river with the maximum taken from previous studies, namely 0.63 gr / L. The result is that the flow pattern of sediment distribution is strongly influenced by the confluence of flow patterns from rivers and sea. Sediment originating from the river slows down at the estuary as a result of the width of the river and is held back by waves from the sea, coupled with the tidal effect that occurs, the sediment oscillates and settles on the bottom of the mouth of the Kapuas Kecil River, causing changes in the basic morphology of the estuary.

1. Introduction
West Kalimantan Province has a port on the river since the Dutch colonial era, the location was chosen because it is close to the city center, namely Pontianak City. The problem that has not been resolved to date at the mouth is experiencing silting and disrupting shipping lanes that will go to or leave the Port of Dwikora Pontianak. In the past few years, the response has only been continuous periodic dredging every year. Ports that are located on rivers and estuaries are more susceptible to sediment rates and sediment deposition than ports directly facing the sea. However, the port at the mouth of the river is quieter and does not require a breakwater to protect the harbor [2]. Silting that occurs in this shipping channel is located in the Kapuas Kecil River which empties into Jungkat with a length of 13,000 m and a channel width of 80 m [3]. Silting due to sedimentation is a serious problem and often occurs in ports [4]. Sedimentation is the entry of sediment loads into a certain aquatic environment through water media and deposited in that environment [5]. Sedimentation from the upstream of the Landak and Kapuas Rivers is high at the mouth of the Kapuas River, there is silting (1.5 m - 3 m) and must be dredged 2 times within 1 year [6].
Sediment in the bay or river estuary area generally comes from agricultural activities in the watershed (DAS) which are driven by hydrodynamic processes towards the river estuary or bay [7]. In addition, the meeting of ocean currents and river discharge that occurs when heading for the tide causes a buildup of sediment in the area where the river flows and sea waters, resulting in a process of silting the estuary [8]. The high concentration in the estuary is due to the river being the point source [9]. Research conducted by [3] explains that bathymetry in the Kapuas Kecil River Estuary, West Kalimantan ranges from 0 m to 14 meters. The shipping channel along the Kapuas Kecil River has a minimum depth of -3 m, while at the mouth of the Kapuas Kecil River to the high seas it has a depth of up to 14 m. In the estuary there will often be changes in the speed of water flow. When the flow of water enters the estuary, there will be a change / transition of flow velocity: from a certain flow velocity from upstream to a speed that is close to zero in the sea, so there is a reduction of energy in it and there is very large deposition in the estuary so that the channel becomes very shallow [10]. If the river sediment transport is very high in the area where the river meets the sea and there is a sedimentation process due to the low flow velocity, the transported material will be deposited in the meeting area. The influence of the current will bring sediment towards the beach and leave the beach with the influence of the waves [11] and the difference in current velocity affects the sediment transport, where the greater the current formed, the large sediment transport, both in the form of bed load (bottom sediment) and suspended load (suspended sediment) in addition to other factors such as characteristics of sediment grain and coastal slope [11]. Rivers are considered to be the main source of nearshore sediment [12] which may dominate the coastal environment near the mouth of major rivers [13]. Research that has been done by [14] rivers tend to carry most of the suspended sediment load through various releases, with the most effective discharge being of moderate scale and having a fairly frequent occurrence rate, usually once to twice per year. More recent studies of undisturbed rivers have concluded that the effective discharge varies widely, from days to decades, and is associated with the enormous diversity of discharge, sediment, channel, and basin characteristics of the fluvial system [15]. In addition, several researchers have proposed several methods to improve the accuracy of sediment transport modeling due to the movement of waves, currents and their combination, including in the modeling of sediment transport rates in shore and at ports, i.e. [16]-[21].

Several years earlier, sedimentation analysis had been carried out along the river cross section from the port to the mouth of the Kapuas Kecil River. Based on research by [22] that, a large amount of silting is at the mouth of a river with a suspended sediment content of 0.63 g/liter. Based on previous research that has been done, this study will continue to do mathematical modeling using Mike 21 software to determine the flow pattern of sediment distribution that affects the silting that occurs in the Kapuas Kecil River Estuary.

**Figure 4.** Research sites at the estuary of the Kapuas Kecil River

2. Method

2.1. Research Sites

Research location from Dwikora Port Pontianak to the estuary. The location selection was based on the problem of silting the shipping channel which has not been resolved to date. Based on the results of
reading the literature and related information, siltation that occurs greatly affects the performance of the shipping lanes to enter/exit from Pontianak's Dwikora Port which is located in the Kapuas Kecil River.

2.2. Research Data

Research data is taken from several sources such as agencies related to previous research journals and field measurements.

| No | Information          | Type of Data | Range Data       | Source Data          |
|----|----------------------|--------------|------------------|----------------------|
| 1  | Wind Data            | Sekunder     | 1 year 2019      | BMKG data online     |
| 2  | Wave Data            | Sekunder     |                  |                      |
| 3  | River Discharge Data | Sekunder     |                  | Journal Research     |
| 4  | Tidal Data           | Primer       | 15 days Oktober 22 – November 6 2019 | Observation |
| 5  | Bathymetry Data      | Sekunder     |                  | Navionics            |
| 6  | Sediment Data        | Sekunder     |                  | Journal Research     |

2.3. Research Flow

In this research, modeling using Mike 21/3 Integrated Models and choosing Coupled Model FM [1]. The modules used are the Hydrodynamic Module, Sludge Transport and Spectral Wave Module.

3. Result

3.1. Wind

The wind data used are January 2019 - December 2019 wind data, using daily maximum wind speed data obtained from BMKG Online Data. The position of wind data collection is at Latitude -0.03 and Longitude 109.34, with an elevation of 4 m. The wind that blows the most is from the Southwest Direction.

![Figure 5. Result of Wind Direction and Speed in Mike Zero's Time Series](image-url)
3.2. Wave Generation

Wave height and period are obtained from the processing of 1-year wind data which has been converted first and continued with the calculation of waves in the deep sea.

| α (°) | Cos α | X (km) | X . Cos α |
|-------|-------|--------|-----------|
| 42    | 0.74  | 170    | 126.33    |
| 36    | 0.81  | 148    | 119.73    |
| 30    | 0.87  | 137    | 118.65    |
| 24    | 0.91  | 122    | 111.45    |
| 18    | 0.95  | 109    | 103.67    |
| 12    | 0.98  | 97     | 94.88     |
| 6     | 0.99  | 103    | 102.44    |
| 0     | 1.00  | 105    | 105.00    |
| 6     | 0.99  | 97     | 96.47     |
| 12    | 0.98  | 109    | 106.62    |
| 18    | 0.95  | 104    | 98.81     |
| 24    | 0.91  | 83     | 75.82     |
| 30    | 0.87  | 75     | 64.95     |
| 36    | 0.81  | 77     | 62.29     |
| 42    | 0.74  | 79     | 58.71     |
| Total | 13.51 | 1615.00| 1445.92   |

\[ F_{\text{eff}} = 107.02 \text{ km} \]

The calculation of wave forecasting in the deep sea produces a wave height (Hs) with a range of 1.4375 - 2.4 m.
3.3. River Discharge
The wide variation in river flow makes it difficult to choose a representative discharge in studying the flow characteristics of the river [23]. To get the river discharge value, an area and current velocity are needed. Current velocity and area data, namely the cross section of the river, were obtained from previous research journals. The point that will be used as the basis for calculating river discharge is point 49 which is located at the mouth of the Kapuas Kecil River.

| Name of Point | Flow Velocity (m/s) | River Width (m) |
|---------------|---------------------|-----------------|
| 9             | 0.45                | 449.4           |
| 18            | 0.75                | 834.6           |
| 26            | 0.6                 | 808.92          |
| 29            | 0.45                | 842.63          |
| 37            | 1                   | 269.6           |
| 47            | 0.15                | 898.8           |
| 49            | 0.8                 | 1977.3          |

Figure 8. Sediment Sampling Locations and Flow Velocity Measurements[22]

The point that will be used as the basis of river discharge is point 49 which is at the mouth of the Kapuas Kecil River. The area used is a cross section, namely, $A = 57.713 \text{ m}^2$, $V = 0.8 \text{ m/s}$ and $Q = 46.17008 \text{ m}^3/\text{s}$

3.4. Tidal
The tides used are the results of field measurements from 22 October 2019 - 6 November 2019 at Parit Haji Husen, near the Siantan PLTU Pier with the coordinates of the location at 0° 3'26.54" U and 109° 11'58.08" T. The tides that occur in that location are Mixed Tide Prevailing Diurnal. The results of the tide chart are the time series input in the Mike 21 software.
3.5. Sediment

Sediment sample data were obtained from previous research journals. The suspended sediment was taken at a depth of 0.6 d using a sample bottle connected to a rope that was given a weight under it, which was then taken to the soil quality and health laboratory [6]

| Name of Point | Total Suspended Sediment (g/L) |
|---------------|--------------------------------|
| 9             | 0.57                           |
| 18            | 0.55                           |
| 26            | 0.43                           |
| 29            | 0.45                           |
| 37            | 0.43                           |
| 47            | 0.45                           |
| 49            | 0.63                           |

The table above shows that the most Total Suspended sediments are at point 49, namely 0.63 gr / l (Muara Sungai Kapuas Kecil), and the least amount is at points 26 and 37 which is equal to 0.43 gr / l. So what will be inputted in the modeling is the maximum sediment data in the river estuary.

3.6. Model Simulation

Meshing Study Sites The first step in modeling is to convert the bathymetry layout in ArcMap to xyz format with the help of notepad and dxf to xyz software. The input file for Mike 21 software is land and water boundary. Display the results of modeling the xyz file input into the Mike21 software after meshing.
After that, determine the boundary conditions given on the bathymetric map according to the location where the sediment distribution pattern is to be studied. Code 1 is land, Code 2 is the condition of the waters from the sea while Code 3 is the condition of the waters of the river. The modeling results were carried out for 15 days with 1-hour intervals.

3.6.1. Hydrodynamic Module
This module will input wind data, tide data and river discharge. Wind data will be entered into the Wind Forcing option, while tidal data will be entered into boundary condition code 2 and river discharge will be entered into boundary condition code 3.
3.6.2. Mud Transport Module
In this module, the basic roughness and Total Suspended Sediment (TSS) will be input. The data will be entered in the Boundary Condition while TSS is 0.63 gr / L will be added to code 3 and code 2 is zero.

Changes in the bottom profile of the waters can occur due to processes of sedimentation or due to silting. The factors that affect the sedimentation or silting process include the movement of currents, waves, and tides and new buildings made in the mouth of the Kapuas Kecil river. In this study, changes in sediment were observed based on changes in the bottom profile of the waters (bed level change) and the distribution pattern of sediment at the mouth of the sea (SSC Fraction).

3.6.3. Spectral Wave Module
This module will input the output of the Hydrodynamic Module and wind wave generation data in the Wind Forcing section. In the Boundary Condition section in Code 2, wave generation data is also entered, while Code 3 becomes a closed boundary.

The interaction between the flow of water from the Kapuas River and the tidal currents that enter from the sea affects the sediment transport process both from rivers, the sea, and from the surrounding land. The modeling results also show that the sediment originating from the river cannot fully flow or is completely wasted away from its mouth because there is an interaction by holding waves, tides, and sluggish river flow due to the width of the river mouth as written by [10] at the mouth of a river, the deposition is caused by the small transport capacity due to the small flow velocity due to the meeting with the sea. The deposition here will cause a pond upstream of the estuary so that there will be great sedimentation here too. As research conducted by [25] found that the volume of water transported by sediment and sedimentation within the wandering range was closely related; When the concentration of
incoming sediment (sediment from upstream) increases, the amount of sediment transported and its deposition also increases and waves are basically important for the physical and biological functions of the estuary. So the waves are also very influential from the silting that occurs in the river mouth.

4. Conclusion

The sediment that becomes the simulation model is the Total Suspended Sediment from the Kapuas Kecil River, by taking one of the maximum samples, namely 0.63 g / L, where the sampling point is at the river estuary. The simulation results show that silting occurs due to the confluence or mixing of river flows from rivers, namely river discharge, and from the sea, namely sea waves and tides, and the wide river width at the estuary causes water flow from the upstream to slow down. Then the sediment is stuck at the bottom of the river estuary and spreads which causes changes in basic morphology and closes the shipping channel, the sediment concentration is getting smaller due to the dynamics of the flow that occurs.

References

[1] DHI Software 2007 Hydrodynamic Module, Mike 21 Spectral Wave Module, Mud Transport Module DHI Water and Environment.
[2] Hofland B, Christiansen H, Crowder R A, Kirby R, Van Keeuwen C W and Winterwerp J C 2011 The Current Deflecting Wall In Estuarine Harbour
[3] Nurdianti A K, Atmodjo W, Atmodjo Saputro S 2016 Studi Batimetri dan Kondisi Alur Pelayaran di Muara Sungai Kapuas Kecil, Kalimantan Barat Jurnal Oseanografi. Vol. 5 (4) 530 - 545.
[4] Winterwerp J C 2005 Reducing Harbor Siltation I : Metododlogy J. of Waterway Port, Coastal and Ocean Engineering. 131 (6) pp 258-267.
[5] Rijn L C 1990 Principle of Sediment Transport in Rivers Estuaries and Coastal Seas (Amsterdam: Aqua Publication University of Utrecht Departement of Physical Geography).
[6] Pertwii G E A 2017. West Borneo International Harbour Passenger.
[7] Sinha P C, Jena G K, Jain I R, Husain A D, Lokman M 2010 An Idealized Model and Systematic Process Study of Oxygen Depletion in Highly Turbid Estuaries Estuaries and Coast. 32 pp 606–620.
[8] Apriyantoro K, Saputro S, Hariadi 2016 Studi Sebaran Sedimen Dasar di Perairan Muara Sungai Kluwut, Kabupaten Brebes, Jawa Tengah. Jurnal Oseanografi. 5 (4) pp 435-440.
[9] Rachman H A, Hendrawan I G, Putra, I N N 2010 Studi Transpor Sedimen di Teluk Benoa menggunakan Pemodelan Numerik. Jurnal Kelautan. 9 (2) pp 144–154.
[10] Mulyanto H R 2010 Prinsip Rekayasa Pengendalian Muara dan Pantai (Yogyakarta : Graha Ilmu).
[11] Iskandar R, Tony Frans 2013 Studi Sedimentasi di Muara Sungai Angsana Kecamatan Angsana Kabupaten Tanah Bumbu Kalimantan Selatan Enviro Science 9 pp 106-111.
[12] Carter RWG 1988 Coastal Invironments: An Introduction To The Physical Ecological And Cultural Systems Of Coastlines (London: Academic Press).
[13] Wiseman W J, Garvine R W 1995 Plumes And Coastal Currents Near Large River Mouths Estuaries 18 pp 509–517.
[14] Wolman M G, Miller J P 1960 Magnitude And Frequency Of Forces In Geomorphic Processes J Geol. 68 pp 54–74.
[15] Nash D.B 1994 Effective Sediment-Transporting Discharge from Magnitude-Frequency Analysis The Journal of Geology 102 pp 79-95.
[16] Fattah A H, Suntoyo, Damerianne H A and Wahyudi 2018 Hydrodynamic and Sediment Transport Modelling of Suralaya Coastal Area, Cilegon, Indonesia IOP Conf. Series: Earth and Environmental Science 135 p 012024.
[17] Suntoyo, Tanaka H and Sana A 2008 Characteristics of turbulent boundary layers over a rough bed under saw-tooth waves and its application to sediment transport Coastal
Engineering 55 (12) pp 1102-1112.

[18] Suntoyo and Tanaka H 2009 Effect of bed roughness on turbulent boundary layer and net sediment transport under asymmetric waves Coastal Engineering 56 (9) pp 960-969.

[19] Suntoyo, Fattah A H, Fahmi M Y, Rachman T and Tanaka H 2016 Bottom shear stress and bed load sediment transport due to irregular wave motion ARPN J. of Engineering and Applied Sciences 11 (2) pp 825-829.

[20] Wijaya M M, Suntoyo and Damerianne H A 2016 Bottom shear stress and bed load sediment transport formula for modeling the morphological change in the canal water intake ARPN J. of Engineering and Applied Sciences 11 (4) pp 2723-2728.

[21] Tanaka H, Suntoyo and Nagasawa T 2003 Sediment intrusion into Gamo lagoon by wave overtopping Proceedings of the 28th International Conference pp 823-835.

[22] Lestari A D, Paramadita S, Simatupang, J M T 2017 Sedimentasi di Sungai Kapuas Kecil Pontianak Provinsi Kalimantan Barat Seminar Nasional Sains dan Teknologi 2017 (Fakultas Teknik Universitas Muhammadiyah Jakarta, 1 – 2 November 2017).

[23] Manonama T, Tanudjaja L, Binilang A 2013 Analisis Sedimentasi di Muara Sungai Saluwangko di Desa Tounelet Kecamatan Kakas Kabupaten Minahasa Jurnal Sipil Statistik 1 (6) pp 452-458.

[24] Jumarang M I, Muliadi, Ningsih N S, Hadi S, Martha D 2012 Studi Hidrodinamika Perairan Estuari Sungai Kapuas Kalimantan Barat Proc. Seminar Nasional dalam Rangka Semirata BKS-PTN Wilayah Barat Bidang MIPA pp 218 – 224

[25] Zhao Y A, Pan X D and Li Y 1993 Preliminary Study On Runoff For Transporting Sediment In The Lower Yellow River. (Beijing: China Environmental Science Press). (In Chinese)