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THE MODEL OF MACRO DEBRIS TRANSPORT BEFORE RECLAMATION AND IN EXISTING CONDITION IN JAKARTA BAY

MODEL DISTRIBUSI SAMPAH MAKRO SEBELUM REKLAMASI DAN KONDISI YANG ADA DI TELUK JAKARTA

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ABSTRACT

Jakarta Bay as one of an area with the densest population in Indonesia became one of the highest contamination level waters in the world includes pollution of debris. Reclamation activities in Jakarta Bay will change the water conditions, and will also affect the distribution of debris at sea. Therefore, this study conducted is to determine the movement of the marine macro debris before and on the condition of the existing reclamation island in the Bay of Jakarta. The method used is simulated by the hydrodynamic model and particle trajectory models using MIKE software. Data needed for the hydrodynamic model, namely wind, tides, bathymetry, and shoreline, while for the trajectory of the particles using a data type of debris, marine macro debris weight, and debris flux. The analysis was performed for hydrodynamic model simulation results and comparison of particle trajectory models. Hydrodynamics simulations indicate if a reclamation island formation does not change significantly in the offshore area, but a simple change in the surface current pattern of the reclamation area, it also causes a decrease in the flow velocity of ± 0.002 to 0.02 m/s at some point. Macro debris particle trajectory simulation shows if after reclamation, macro debris tends to accumulate in the eastern Jakarta Bay in the rainy season (January), as well as in the western and eastern regions during the dry season (July).

Keywords: Jakarta Bay, marine debris, models, particle trajectory, reclamation

ABSTRAK

Teluk Jakarta sebagai salah satu daerah dengan populasi terpadat di Indonesia menjadi salah satu perairan dengan tingkat pencemaran tertinggi di dunia termasuk pencemaran sampah. Kegiatan reklamasi di Teluk Jakarta akan mengubah kondisi air, dan juga akan mempengaruhi distribusi sampah di laut. Oleh karena itu, penelitian ini dilakukan untuk mengetahui pergerakan sampah makro laut sebelum reklamasi dan kondisi yang ada di Teluk Jakarta. Metode yang digunakan yaitu simulasi model hidrodinamik dan model lintasan partikel menggunakan software MIKE. Data yang diperlukan untuk model hidrodinamik adalah angin, pasang surut, batimetri dan garis pantai, sedangkan untuk lintasan partikel menggunakan data tipe sampah, berat sampah makro laut dan flux sampah. Analisis yang digunakan adalah simulasi model hidrodinamik dan perbandingan model lintasan partikel (particle trajectory models). Hasil simulasi hidrodinamika menunjukkan bahwa formasi pulau reklamasi tidak berubah secara signifikan di wilayah lepas pantai, tetapi perubahan sederhana dalam pola arus permukaan daerah reklamasi menyebabkan penurunan kecepatan aliran ± 0,002 menjadi 0,02 m/s di beberapa titik. Simulasi lintasan partikel sampah makro menunjukkan jika setelah reklamasi, sampah makro cenderung menumpuk di Teluk Jakarta bagian timur pada musim hujan (Januari), serta di wilayah barat dan timur selama musim kemarau (Juli).

Kata kunci: *Teluk Jakarta, sampah laut, model, particle trajectory, reklamasi*

I. INTRODUCTION

Marine debris is a solid object persistent, manufactured or processed by man, directly or indirectly in the marine environment, which consists of several types, one of which debris macro is measuring 2.5 cm - 1 m (Lippiatt *at al.,* 2013). Estimates sure of the amount of plastic in the oceans is still unknown, but the amount of marine macro debris floating in the sea level is estimated to be 93,000 tonnes (UNEP, 2009) and nearly 8,200 metric tons of macro debris collected along the 40,000 km of coastal globally (Axelsson, 2017). Macro debris in the ocean affect the microbial life to cause death (Derraik, 2002; Gregory, 2009; Rochman *et al.,* 2015) and may help the spread of invasive species and release toxic chemicals into the environment (Thompson *et al.,* 2009; Zettler, 2013).

One of the forecasts of the amount of marine macro debris in the sea carried out by Jambeck *et al.* (2015), mentioning if Indonesia is a country contributor of plastic macro debris in the ocean 2nd after China. Based on a review of Purba *et al.* (2017) of various research macro debris in Indonesia, macro and micro debris scattered on the surface and the water column of the sea, the mangrove ecosystem and the seabed. Other studies also indicate if there is a correlation between the distribution of marine macro debris at sea level and human populations activity (Purba, 2018).

Jakarta Bay as one of the coastal areas with high population density in Indonesia is one of the potential to release large amounts of macro debris into the waters of Jakarta Bay. This is supported by research (Rositasari *et al*., 2017), which prove if the plastic is a type of dominant macro bins, recorded 77.7% of the total macro debris is the macro plastic, followed by styrofoam (18.1%) in the area of Pantai Indah Kapuk Jakarta Bay. Reclamation activities are announced by the government is expected to change the environmental conditions of waters of Jakarta Bay, which then can affect the physical changes in the ocean, such as silt, changes in flow patterns, increased solid macro debris, and changes in the ecosystem, and will make a variety of macro debris trapped in the waters of Jakarta Bay (Rositasari *et al*., 2017).

Physical changes will alter the movement of water particles in these waters (Critchell *et al.,* 2015; Hardesty, 2017; Politikos, 2017), which later will affect the transport of marine macro debris in the oceans. The impact is mainly marine macro debris movement, can impede the flow of water and damage the surrounding ecosystem. Transport macro bins in the Bay of Jakarta, it is important to note because it has the potential to alter the waters of Jakarta Bay.

This study focuses on the movement of the macro marine macro debris from the river mouth Jakarta Bay before and after reclamation using a modeling approach. Modeling the flow of marine macro debris ever undertaken by Handyman (2017), Pangestu (2016), as well as Attamimi (2015). Based on these studies, the movement of the waters of hydrodynamics influenced macro debris and types of macro debris that are modeled. The results of this study could subsequently be informed in determining the macro debris management strategy macro estuary in Jakarta Bay.

II. MATERIAL AND METHODS

This research used simulation models who modeled the waters of Jakarta Bay hydrodynamic, that included the estuary of the Cisadane; Cengkareng; Angke; Pluit; Sunda Kelapa; Ciliwung; Sunter; Cakung; BKT; Blencong; Cikeas; Ciherang; Citarum river.

The method used in this study is model simulations using hydrodynamic models and a model of the trajectory of the particles (Pangestu, 2016; Handyman, 2017; Febriano, 2017; Attamimi, 2015).

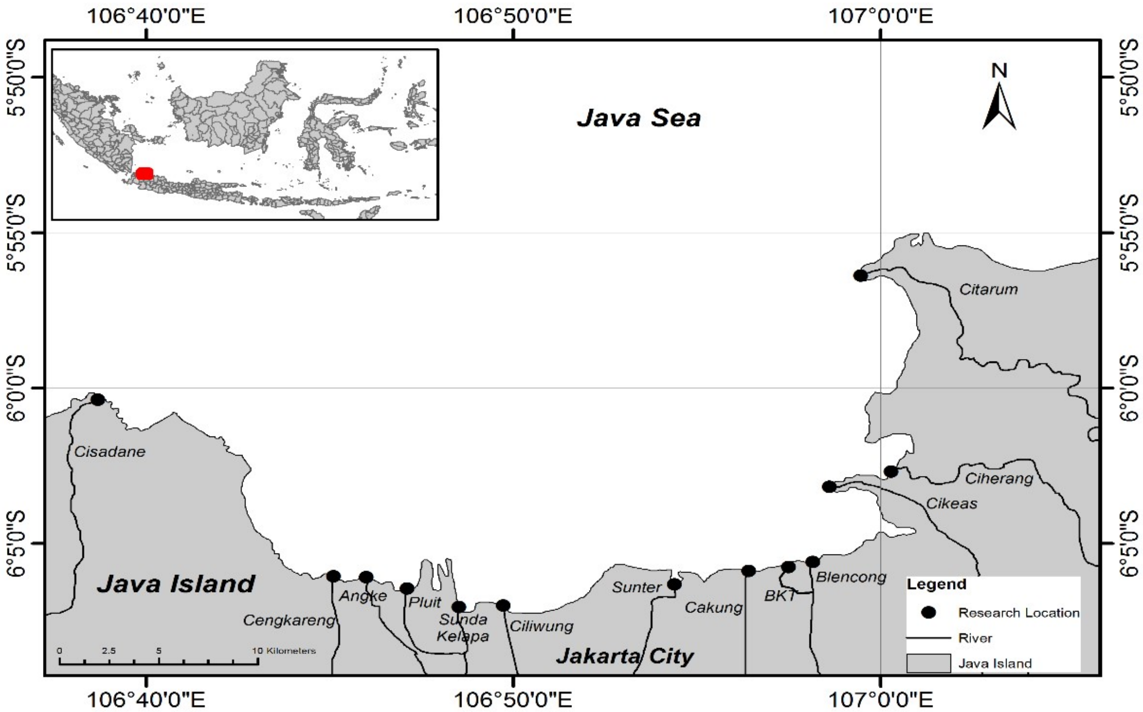

Figure 1. Research area maps.

Simulation models were conducted for one month representing the rainy season (Monsoon Transition II and West Monsoon) and drought (East Monsoon and Monsoon Transition I), on January and July (Rositasari *et al.*, 2017). Time simulation used in this study was in 2012 and 2017.

Bathymetric data were taken from DISHIDROS bathymetric maps of 2012 and 2017, the tides model from DHI-MIKE software, named Prediction of Tidal Height (PTH), winds from the ECMWF (European Center for Medium-Range Weather Forecasts) resolution of 0,125° x 0.125°, and the data streamflow of BBWS (Wulp *et al.*, 2016) and Book II NKLD (Setiawan, 2016). The data for the validation of the simulation results are tidal data from the IOC Sea Level Monitoring downloaded from the website http://ioc-sealevelmonitoring.org in Jakarta Kolinamil station. Sampling was conducted in the macro debris in March 2018. The tidal type was processed with admiralty method to get the formzahl value, as well as the RMSE (Root Mean Squares) value which was calculated to get the model error.

Selection of the type of debris by debris size, and kind of macro debris anthropogenic domestic data obtained from Greenpeace Indonesia in 2016 include bottle caps, shampoo sachets, plastic food wrappers, styrofoam food containers, plastic water bottle 330ml, plastic water bottle 650 ml bottle, 1,5 liter plastic drinks, shampoo bottles, plastic, glass beverage bottles, food cans, plastic detergent packaging, and bottles of detergent or other cleaners, which are further subdivided based on several categories, with weight of 4.55 g, 12.975 g, 21.225 g, 29.45 g, and 46.025 g.

Scenario simulations include two models before the formation of the island reclamation and after the formation of the island reclamation in 2017 (Figure 2). The assumptions used in this model is the degradation of marine macro debris not included, and annually hydrodynamics waters of Jakarta Bay is not changed, as the cycle and move with the surface current marine macro debris (Pangestu, 2016; Handyman, 2017).

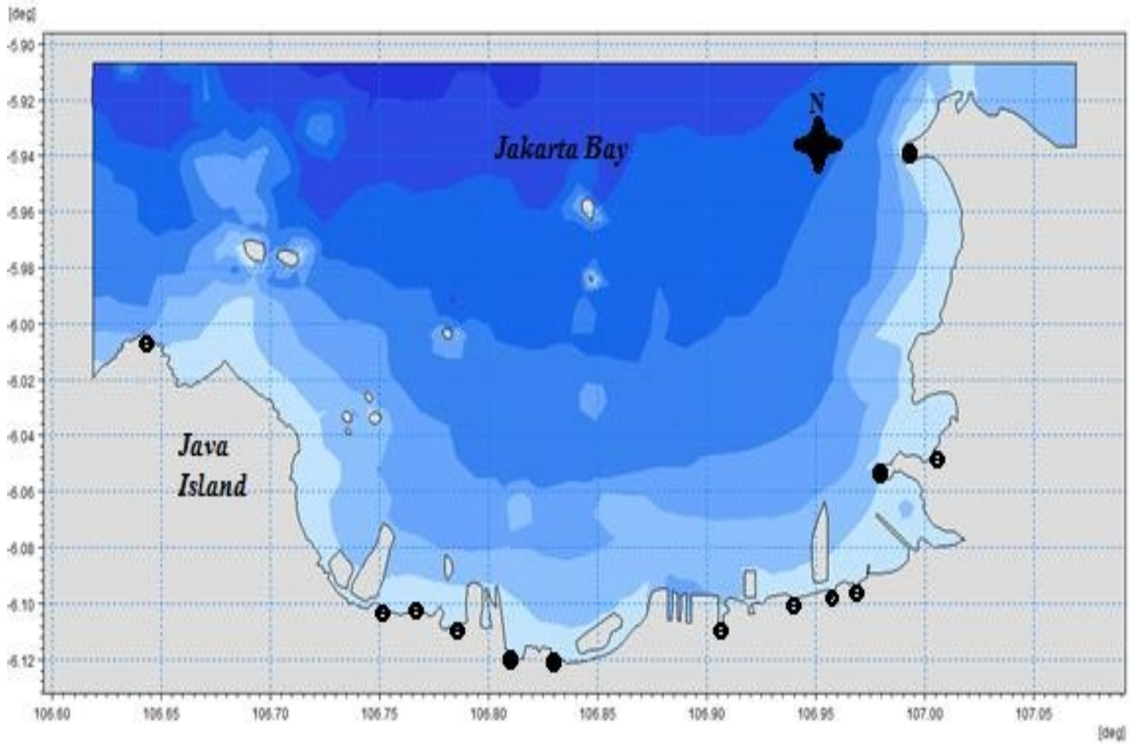

Figure 2. Model domain.

The analysis was performed for the results of the hydrodynamic model to determine the movement of winds, surface currents, and tidal models, and the results of the validation of the tides.

Further simulations using the movement of the macro debris particle trajectory module with a point source specified that the 13 estuaries in Figure 1, as well as a predetermined scenario. Analysis of the movement of marine macro debris from the source point of the movement pattern seen before reclamation model results and the results of the model after reclamation. Analysis of the results of the model was compared between before and after reclamation, as well as the hydrodynamic conditions in the waters of Jakarta Bay.

III. RESULTS AND DISCUSSION

3.1. Results

3.1.1. Physical Parameters

Based on the results of data processing bathymetry, water depth of Jakarta Bay ranging from 1 meter to 92 meters. Jakarta Bay waters, included in shallow waters since it has average depth around 15 meters, and the islands which create variations of depth in Jakarta Bay area tend to be more varied in the west than the east. In general, the depth in the waters of Jakarta Bay ranged from 5 to 32 meters (Rositasari *et al*., 2017), but other mention of 3 to 29 meters with an average depth of 15 meters (Coordinating Ministry for Economic Affairs, 2014).

The pattern of the wind movement in the Bay of Jakarta is strongly influenced by the monsoons. The use of time spent on this research that in January representing the west monsoon season, and in July representing the east (Figure 3).

The movement of the wind in January 2012 and 2017 tend to be similar (Figure 4), which is predominantly from the west, with the dominant speed ranged from 5.714 to 6.095 m/s to 2012 and from 4.190 to 5.571 m/s for the year 2017. This is related to the west season that occurs during December-February, which the wind is moving from west to east to the area of Java in general.

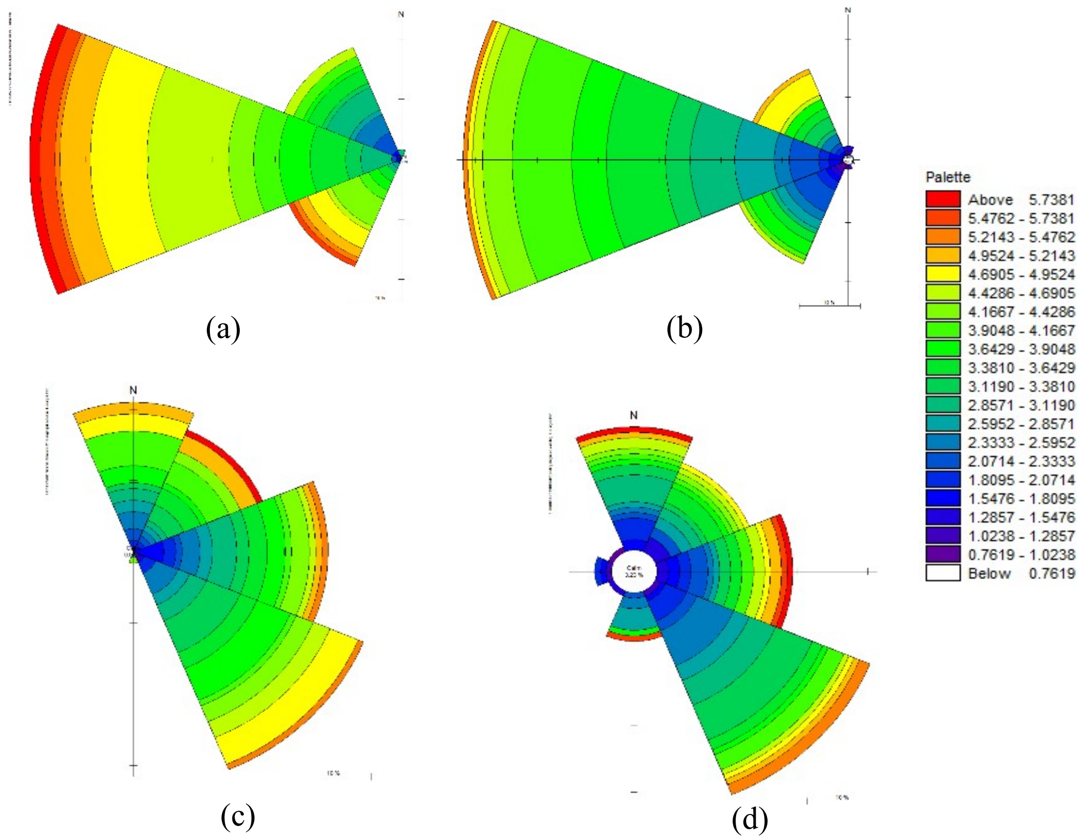

Figure 3. Windrose of Jakarta Bay in 2012 (a) January, (b) July, and in 2017 (c) January, (d) July.

Just as the movement of the wind in January, the movement of the wind in July 2012 and 2017 tend to be the same, that is dominant from the southeast, with the dominant speed ranges from 3.1 to 3.9 m/s for 2012 and from 2.6 to 2.8 m/s and 3.4 to 3.6 m/s for the year 2017. The dominant wind speed in January and July in 2012 and 2017 have quite the same value, with wind speeds of 2012 faster than the wind speed in 2017. According to Lubis and Yosi (2012), one of the characteristics of the western monsoon rainfall is in high intense, and the movement of the wind is strong enough, usually ranges from >15 knots accompanied the movement of ocean surface currents or waves that leads to the east, while in the eastern monsoon generally have wind speed are relatively small, dry, and have a weak sea waves.

Tidal patterns based on the data processing model using modules of software DHI-MIKE, namely Prediction of Tidal Height (PTH) by the method of admiralty, it is known if the tidal patterns in the waters of Jakarta Bay in January and in July that a single daily uniform (diurnal) with the value formzahl 3.5. In accordance with previous research that says that the waters of Jakarta Bay had a single daily tidal type with a value of 3.2 formzahl (Yogaswara *et al.,* 2016) up to 4.85 (Yuliasari *et al*., 2012), where a single daily tides occur in waters run into one of low and high tide in one day (Yogaswara *et al.,* 2016).

The tidal patterns for January (Figure 4), for the highest tides, occur between 00.00 to 05.00 am, and low tide occurs between 12.00 to 3.00 pm. The tidal patterns for each day during the month of July, to the highest tides, occur between 12.00 to 3.00 pm, and low tide occurs between 00.00 to 02.00 am.

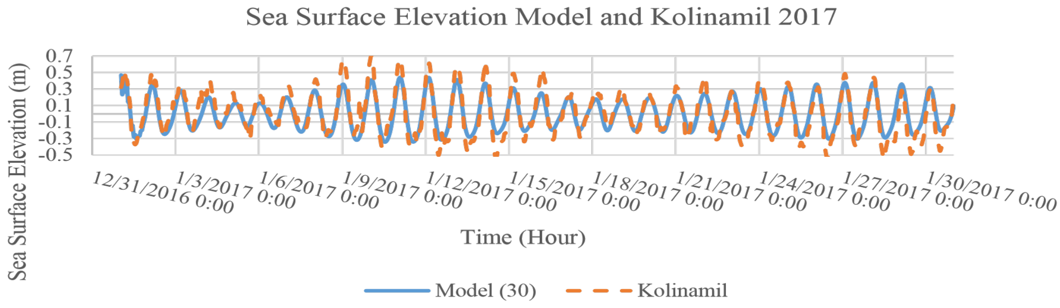

Figure 4. Comparison of sea surface elevation model and kolinamil january 2017.

The tests also indicate if the ups and downs or error RMSE values of the model that is equal to 8.5% -12.02%. RMSE value or value error in January greater compared with July. It is also evident from the pattern of the chart above. According to Veerasamy, et al., (2011), the RMSE values that represent a good prediction model is of value <0.3 or less than 30%. Therefore, with the error value simulation models can still be trusted.

3.1.2. Simulation Scenarios 1 and 2

The trajectory of particle and hydrodynamics simulations for both scenarios carried out within one month for each of the rainy season (January) and dry (July). Comparison of hydrodynamic simulations conducted on the speed and direction of surface currents, while for the trajectory of the particles do the patterns of movement of the particles. Particles come out of each estuary are assumed out one particle per hour.

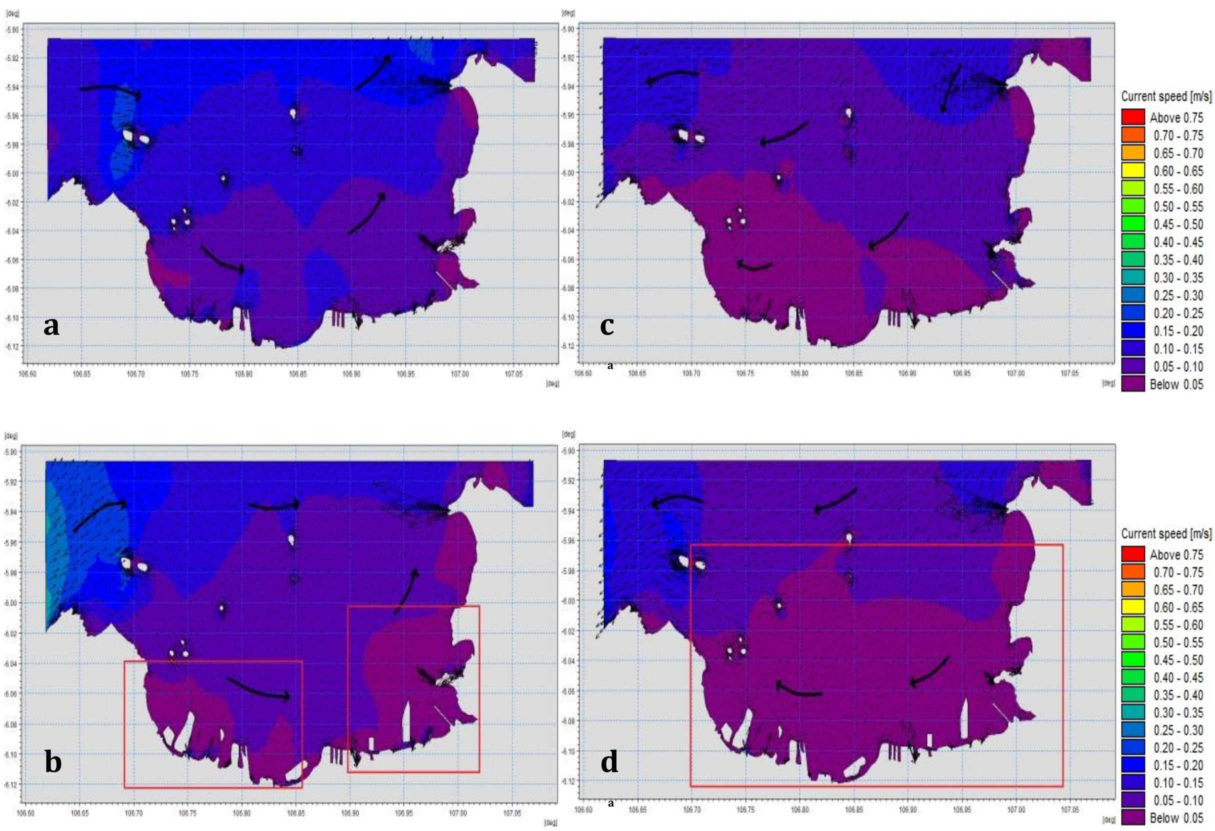

Figure 4. The flow movement pattern of january (a) scenario 1, (b) scenario 2, and july (c) scenario 1, (d) scenario 2.

The movement in January dominant surface currents moving eastward, according to the movement of winds from west to east (Figure 4a, 4b), but at a particular time, the surface current is moving toward the west to the northwest, while in July (Figure 4c, 4d) tend to move towards the west. The dominance of the direction related to wind and tidal factors. Based on the Figure above, the movement of surface currents in coastal areas experienced a deflection dependent on the topography of the coastline in the area, as well as the surface current through islands.

Overall, during the month of January for scenario 1 (Figure 4a) the average flow speed is 0.034 to 0.082 m/s, and scenario 2 (Figure 4b) is 0.032 to 0.08 m/s, while the average flow velocity in July of scenario 1 (Figure 4c) ranged from 0.02 to 0.082 m/s, and scenario 2 (Figure 4d) ranges from 0.02 to 0.08 m/s. Comparison of the average surface current speed for some point in scenario 1 January in a row, ie: 0.04 m/s; 0.048 m/s; 0.05 m/s; 0.056 m/s; 0.056 m/s; 0.046 m/s, scenario 2 are: 0.037 m/s; 0.05 m/s; 0.053 m/s; 0.039 m/s; 0.047 m/s; 0.04 m/s. Comparison of the average flow velocity at some point in scenario 1 July respectively are: 0.02 m/s; 0.023 m/s; 0.026 m/s; 0.029 m/s; 0.03 m/s; 0.036 m/s. as well as scenario 2. ie: 0.023 m/s; 0.02 m/s; 0.027 m/s; 0.022 m/s; 0.025 m/s; 0.033 m/s.

Observation of the particle trajectory simulation results does any multiple of seven days on the 1st, 7th, 14th, 21st, and 28th. The simulation results show if the movement trajectory of marine macro debris from the simulation results is influenced by the tidal, but more predominantly influenced by the wind. Simulation of January in scenario 1 (Figure 5a) indicates if within a period of less than 7 to 21 days of marine macro debris from the 13 mouth of the river moving towards the east out of the waters of Jakarta Bay, while in July (Figure 5c) the marine macro debris takes longer to get out of the waters of Jakarta Bay. Marine macro debris that comes from the mouth of the Ciliwung Cengkareng up takes nearly 28 days to get out of the waters of Jakarta Bay. Marine macro debris that comes from the mouth of the Citarum Sunter up still in the waters of Jakarta Bay within a period of one-month simulation.

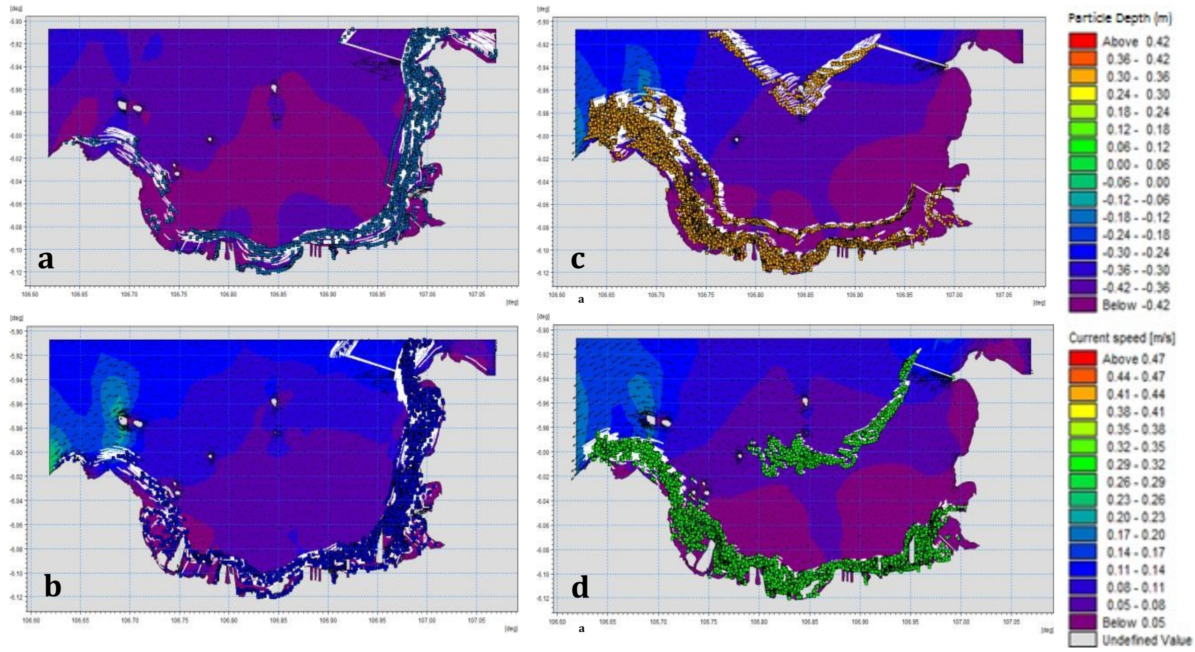

Figure 5. The macro debris particle movement of january (a) scenario 1, (b) scenario 2, and july (c) scenario 1, (d) scenario 2.

Results of particle trajectory simulation scenario 2 in January (Figure 5b), showing the movement of marine macro debris from the estuary in western and southern parts of Jakarta Bay tend to move much longer less than 7 to more than 21 days, because debris hampered movement by the island that has been reclamation island, namely the island of L and N. The movement of marine macro debris in July scenario 2 (Figure 5d) is longer than scenario 1, i.e., for the estuaries Cisadane to Angke takes 7 to 21 days to move out of Jakarta Bay, and from the mouth of Sunda Kelapa and Ciliwung which takes 21 to 28 days, and debris particle from the estuary Pluit not out of the waters of Jakarta Bay within a period of one month simulation.

The furthest debris particle mileage in January scenario 1 is 63.44 km from Cisadane estuary, and the shortest is 8.635 km from Citarum estuary, while in July the furthest mileage is 36.97 km from Cikeas estuary and the shortest is 6.34 km from Cisadane estuary. From scenario 2 in January, the furthest debris particle mileage is around 63 km from Cisadane estuary, and the shortest is 8.635 km from Citarum estuary, while in July the furthest mileage is 26.19 km from Cikeas estuary and the shortest is 6.34 km from Cisadane estuary.

3.2. Discussion

The flow velocity in the area near the mouth of the river both in January and in July was higher than other areas on the coast because there is a flow of water from inland rivers. Jakarta Bay velocity categorized weak pace for an average flow speed between 0-4 m/s (Daruwedho *et al.,* 2016), It relates to the Jakarta Bay area which is enclosed waters. Past research also shows if the surface current velocity in the Jakarta Bay generally ranges between 0,0341-0,277 m/s (Yogaswara *et al*., 2016).

The difference between the surface current movement patterns of the rainy season (January) with the dry season (July) lies in the direction of the surface current as well as surface current speed, where the speed of flow in July more slowly than in January. Atmadipoera and Adhyatma (2015) also shows if the surface current movement in the West season (monsoon) faster than East season (summer). Also, the average value of wind speed in January is also higher compared with July, both in 2012 and 2017.

Based on surface current speed comparison scenarios 1 and 2, indicating if the surface current movement patterns have not changed significantly in the near offshore region, but enough change in the reclamation area. In some parts of Jakarta Bay, especially near the reclamation island flow velocity decreased. Surface current movement patterns both before reclamation, and the existing condition remains to follow the coastline if through the island. It is also reinforced by the results of research Yuliasari (2012), in Marina Ancol, which states that if the condition of the pattern and direction of the surface current before reclamation did not change the pattern of significant, but the speed of the surface current is just different. Also, the surface current direction is also only changed at the end point of reclamation and follow the form of reclamation, then follow pattern of movement surface currents before reclamation (Yuliasari *et al*., 2012).

The particle trajectory model results as a whole show if the movement of macro debris in January before reclamation move to the east, while for July is likely to move to the west. Along with the surface current speed, the movement of the macro debris particle-based models also indicates if the dry season (July) the particles move more slowly than the rainy season, where marine macro debris takes longer to exit the waters of Jakarta Bay. When compared with the simulation results before the reclamation, the movement of macro debris particle in scenario two well in the wet season and the dry season is slower, characterized by the macro debris particle collected in some parts of the eastern Jakarta Bay when simulating in

January. Besides the movement of the particles, the formed reclamation islands indicate the changes with the debris particle mileage, where it tends to decrease when the reclamation island is already formed.

Particle trajectory simulation results in July for the second scenario also showed a significant difference, whereas in scenario two macro debris tends to build up and trapped in the western part of Jakarta Bay. The piles of marine macro debris stuck in between the crevices of the reclamation island. Based on this, the formation of the reclamation island is affecting the movement patterns of the macro debris particles which then can lead to the Jakarta Bay into a marine macro debris accumulation of land around the waters of Jakarta Bay.

IV. CONCLUSIONS

Surface current movement patterns before and after reclamation have not changed significantly in the offshore area, but a simple change in the surface current pattern of the reclamation area. Decreased flow velocity ± 0.002 to ± 0.02 m/s in the area around the island reclamation. The movement of particles of macro debris in January was influenced by the tides but the dominant moving towards the eastern Jakarta Bay, while in July of macro debris particles are also influenced by the tides tend to move towards the west bay of Jakarta at a slower pace compared to January. Model simulation of the trajectory of the particles from two scenarios indicates if a reclamation of island macro debris particles alters movement patterns, which in January of macro debris tend to trapped in the eastern Jakarta Bay, while in July the majority macro debris tends to accumulate in the western part of Jakarta Bay.

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