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# Modeling The Distribution of Wastewater and Determining Zone of Initial Dilution from Waste Discharge Into The Sea From Fuel Terminal Activities in Balikpapan Bay

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**ABSTRACT** - Sea water quality in Balikpapan Bay is determined by two driving factors: river flow and sea tides. This study aimed to conduct predictive modeling of wastewater distribution from industrial activities with the potential for seawater pollution, specifically for fuel terminals in Balikpapan Bay. The data source used was primary data for the initial environmental baseline, which was taken from the results of the analysis of 1 liter sample each from the wastewater treatment outlet outfall, and three points representing three sea areas receiving wastewater, and secondary data obtained from the Badan Informasi Geospatial (BIG) and ECWMF (European Center for Medium-Range Weather Forecasts). The tidal data obtained were analyzed using the least-squares method. The results of the wastewater distribution model showed that all parameters, including pH, TSS, BOD, COD, ammonia, fatty oil, salinity, TOC, and Total coliforms, met seawater quality standards both at high and low tide conditions in the West and East Monsoon based on Government Regulation No.22 of 2021 concerning the Implementation of Environmental Protection and Management Appendix VIII for ports.

**Keywords**: wastewater, fuel terminal. environmental modeling, balikpapan bay.



**How to cite this article:**

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## INTRODUCTION

Balikpapan Bay is a water body in East Kalimantan Province. Geographically, the waters of Balikpapan Bay are between 1˚13‟4.877” South Latitude – 1˚13‟28.691” South Latitude and 116˚48‟51.193” East Latitude – 116˚46‟49.774” East Longitude. The water of this bay is a connecting route between cities inside and outside East Kalimantan for the mobility of people and manufactured goods (exports and imports) as well as industrial development activities, mining, plantations, agriculture, and forestry (Sulardi 2016).

The Balikpapan Bay area is a semi-enclosed water area where the exchange of water masses inside the bay with water masses outside the bay still occurs and is mainly generated by tidal forcing. The mass flow pattern in the waters of Balikpapan Bay is determined by two factors: river flow and sea tides. At high tide, the flow of water masses leaving the bay is blocked by tidal masses, and most of the water masses are pushed into the bay upstream. The upstream area receives a lot of freshwater input from small rivers, resulting in erosion within the river basin in the form of mud and other organic materials (Rahman et al. 2022).

A fuel storage terminal is a facility that stores and manages fuel supply. These terminals are usually located near ports or distribution centers and can be very large (Chkara & Seghiouer 2020).

The fuel terminal consists of several facilities and equipment, such as storage tanks, pumps, pipes, and metering systems. This facility is used to transport, store, and distribute fuel to consumers. Due to its location on the coast, Fuel Terminals generally dispose of wastewater into the sea, which includes domestic waste, rainwater runoff, and the process of separating tank bottom water from hydrocarbon products (Abuhasel et al. 2021).

Fuel terminal industrial activities and the characteristics of Balikpapan Bay greatly influence the quality of seawater and the ecosystem of the surrounding waters (Adetunji & Olaniran 2021).

Therefore, conducting a predictive modeling study of wastewater distribution from industrial activities with the potential for seawater pollution, specifically for fuel terminals in Balikpapan Bay, is necessary.

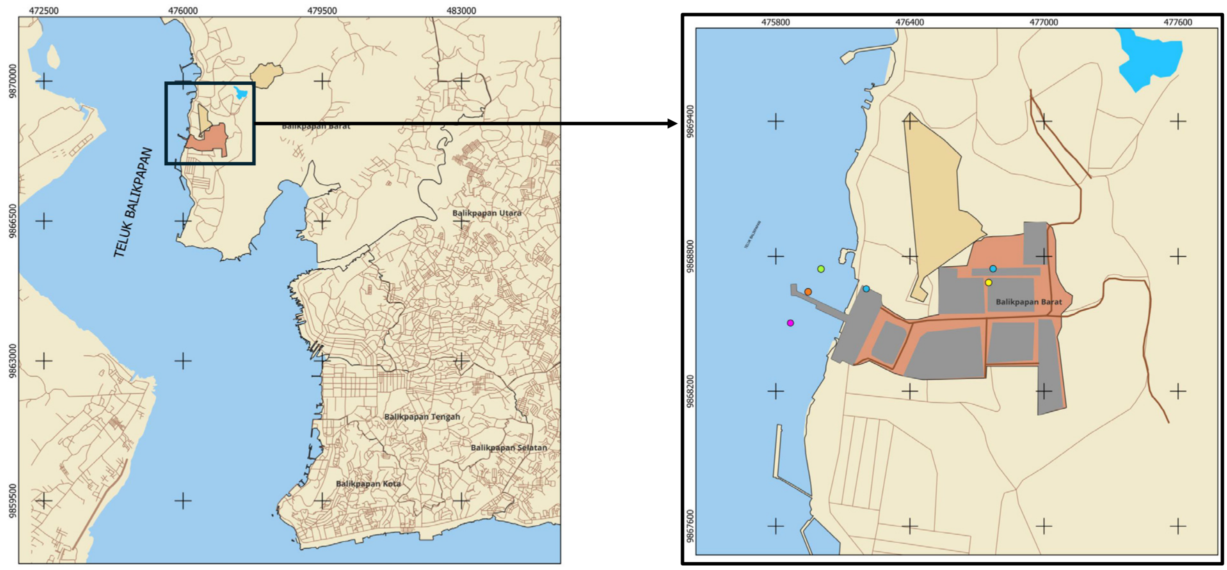



Figure 1
Fuel Terminal Wastewater Study Location

## METHODOLOGY

Prediction of the distribution of wastewater into the water body of Balikpapan Bay with the distribution pattern being influenced by the movement of water masses/currents because tidal conditions cause the current pattern in the waters. The current pattern is based on the conditions of the West and East monsoons. For high-tide and low-tide conditions, no significant difference existed, and the direction of movement remained the same. The wastewater distribution model aims to estimate the value of the added wastewater concentration in the receiving water body. This value also indicates the contribution of pollutants mixed with the body when receiving water.

### Materials

The data source used was primary data for the initial environmental baseline, which was taken from the results of the analysis of 1 liter sample each from the wastewater treatment outlet outfall, and three points representing three sea areas receiving wastewater, and secondary data obtained from the *Badan Informasi Geospasial* (BIG) and ECWMF (European Center for Medium-Range Weather Forecasts).

### Method

The modeling method is a numerical model in the form of a user interface software named DHI MIKE, which was developed by the Danish Hydraulic Institute (DHI) Water and Environment, Denmark.

The DHI MIKE model consists of several model packages, but in this study, the model package used is the DHI MIKE 21 Flow Model FM. The DHI MIKE 21 flow model FM is a model package used for 2-dimensional modeling (averaging over depth) based on a finite element approach. This model package comprises several modules to solve several problems that occur in aquatic environments. The hydrodynamics (HD) module was used to solve the water hydrodynamics (current circulation), and the MT module (MT) was used to solve the sediment dynamics when it entered the water. In this research, both modules were used for modeling based on data from sea tides, bhatimetry, current conditions, and the environmental baseline.

## RESULT AND DISCUSSION

### Identification of Sources, Quantities and Characteristics of Waste Water

The sea receives wastewater from various sources, including office activities, work environments, oil tanks, and seawater reverse osmosis (SWRO). Domestic wastewater and rainwater runoff were the dominant sources, with each source having a processing unit before discharge. The fuel terminal discharges wastewater into two channels: outfall 1, which receives domestic wastewater and rainwater runoff, and outfall 2, which combines desalination, domestic waste, and water draw-off activities.

The approach to the characteristics of wastewater channeled to the sea or at the outfall point is based on the waste processing unit process used in accordance with Table 1. In this modeling, a maximum discharge of 650 $m^3$/day or 19,500 $m^3$/month for outfall 1 was used, and 10 $m^3$/day or 30 $m^3$/month for outfall 2; the maximum concentrations are listed in Table 2.

### Environmental Baseline

Received water body quality data (environmental baseline) are shown in Table 3, which refers to the quality standards of Government Regulation (PP) No. 22 of 2021 concerning the implementation of environmental protection and management (Appendix VIII for ports).

### Current Pattern

The characteristics of the currents in the study area were obtained using hydrodynamic modeling. This modeling aims to obtain a comprehensive picture of the spatial and temporal characteristics of currents in the study area with tidal conditions, namely, high tide conditions, highest tides, low tide conditions, and lowest low tides. The current speed reaches maximum conditions at high tide to the highest tide and at low tide to the lowest low tide, whereas at the highest high tide and lowest low tide, the current speed due to the tidal phenomenon reaches a minimum condition, which is usually called slack water (Pond & Pickard 1983).

Apart from being influenced by the phenomenon of tides, ocean current patterns are also influenced by forces caused by wind. Ocean surface currents are generally driven by the wind tension acting on the sea surface. Wind tends to push the water layer on the sea surface in the direction of the wind movement. However, the Coriolis force causes the current not to move in the same direction as the wind but is deflected to the right in the Northern Hemisphere and the left in the Southern Hemisphere. The speed of currents generated by wind decreases with increasing depth (Aziz 2006).

Table 1
List of sources of wastewater that will be discharged into the sea

| No | Waste Water Source | Treatment Unit | Volume ($m^3$/day) | Outfall |
|---|---|---|---|---|
| 1. | Domestic waste water and rain water run off | Waste water treatment plant | 10 | Outfall 2 |
| 2. | Waste water desalination | Sea water reverse osmosis | 85 | Outfall 1 |
| 3. | Domestic wastewater | Biofill Tank (aeration & chlorination) | 4 | Outfall 1 |
| 4. | Rain water run off and water draw off activity in the fuel storage tank | Oil trap | 650 | Outfall 1 |

Table 2
Waste characteristics from fuel terminal activities

| No. | Parameter | Unit | Quality Standard | | Remark |
|---|---|---|---|---|---|
| | | | Outfall 1 | Outfall 2 | |
| 1. | pH | - | 6-9 | 6-9 | |
| 2. | TSS | mg/L | 30 | 30 | |
| 3. | BOD | mg/L | 30 | 30 | |
| 4. | COD | mg/L | 100 | 100 | |
| 5. | Ammonia | mg/L | 10 | 10 | |
| 6. | Oil and Grease | mg/L | 5 | 5 | |
| 7. | Salinity | % | 40 | - | Natural salinity |
| 8. | TOC | mg/L | 110 | 110 | |
| 9. | Total Coliform | Nos/100 ml | 3000 | 3000 | |

Table 3
Environmental baseline

| No | Parameter | Unit | Location | | |
|---|---|---|---|---|---|
| | | | North of Jetty 116°46'54" E 01°11'23,42" S | Middle of Jetty 116°46'54" E 01°11'18,42" S | South of Jetty 116°46'54" E 01°11'12,76" S |
| **Physics** | | | | | |
| 1 | Total Suspended Solid (TSS) | mg/L | 23 | 16 | 65 |
| 2 | Temperature | °C | 27 | 27 | 28 |
| 3 | Odor | - | Odorless | Odorless | Odorless |
| 4 | Clarity | m | 3.10 | 3.6 | 3.5 |
| 5 | Polluting Trash | - | Unpresent | Unpresent | Unpresent |
| 6 | Oil Layer | - | Unpresent | Unpresent | Unpresent |
| **Inorganic Chemistry** | | | | | |
| 1 | pH | - | 8.02 | 8.07 | 8.12 |
| 2 | Salinity | % | 25 | 25 | 25 |
| 3 | Ammoniac (NH3-N) | mg/L | 0.03 | <0.01 | <0.01 |
| 4 | Sulphide (H2S) | mg/L | <0.03 | <0.03 | <0.03 |
| 5 | Copper (Cu) | mg/L | <0.016 | <0.016 | <0.016 |
| 6 | Plumbum (Pb) | mg/L | <0.02 | <0.02 | <0.02 |
| 7 | Zinc (Zn) | mg/L | <0.007 | <0.007 | <0.007 |
| 8 | Mercury (Hg) | mg/L | <0.0002 | <0.0002 | <0.0002 |
| 9 | Cadmium (Cd) | mg/L | <0.005 | <0.005 | <0.005 |
| 10 | Total Hydrocarbon | mg/L | <0.005 | <0.005 | <0.005 |
| 11 | Polychlorinated Biphenyls (PCB) | mg/L | <0.0002 | <0.0002 | <0.0002 |
| 12 | Tributyltin (TBT) | mg/L | <0.0002 | <0.0002 | <0.0002 |
| **Organic Chemistry** | | | | | |
| 1 | Oil and Grease | mg/L | <5.0 | <5.0 | <5.0 |
| 2 | Methylene Blue Active Subtance (MBAS) | mg/L | 0.4 | 0.3 | 0.4 |
| 3 | Phenol | mg/L | <0.002 | <0.002 | <0.002 |
| **Microbiology** | | | | | |
| 1 | Total Coliform | MPN/ 100 mL | <1.8 | <1.8 | <1.8 |

*Source : PT Global Environment Laboratory (GEL) Laboratory Analysis Result*

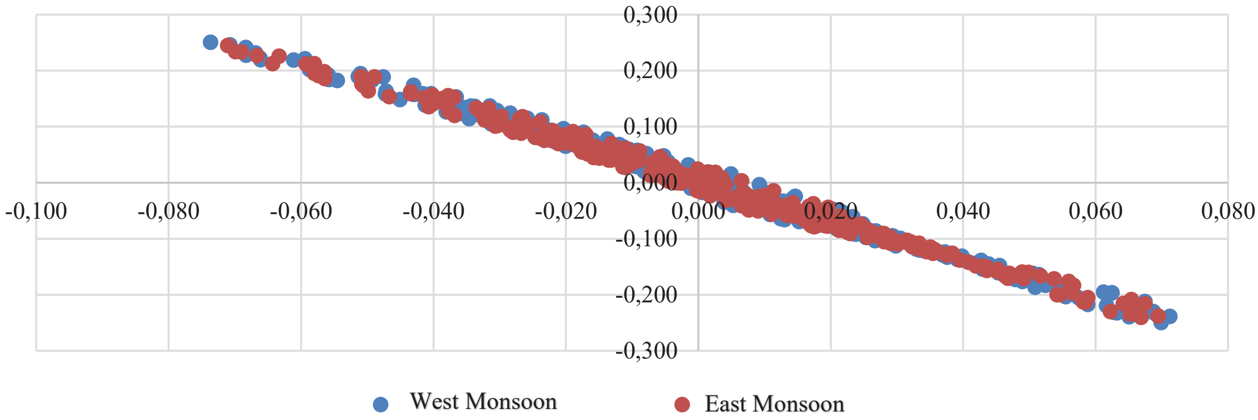



Figure 2
Model of West Monsoon and East Monsoon Current Patterns

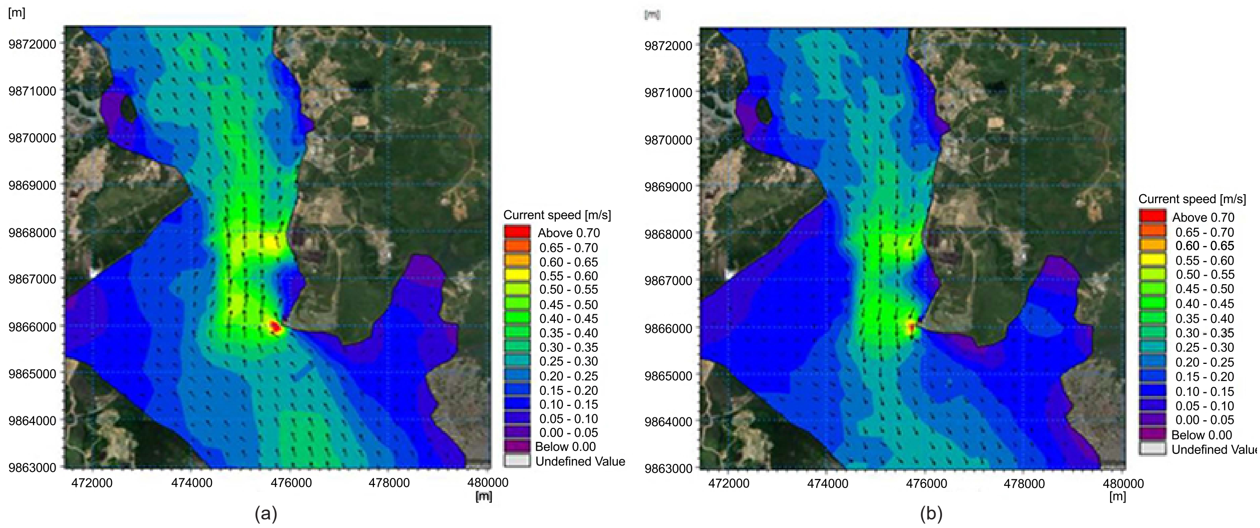



Figure 3
Model of West Monsoon Current Patterns at High Tide (a) and Low Tide (b)

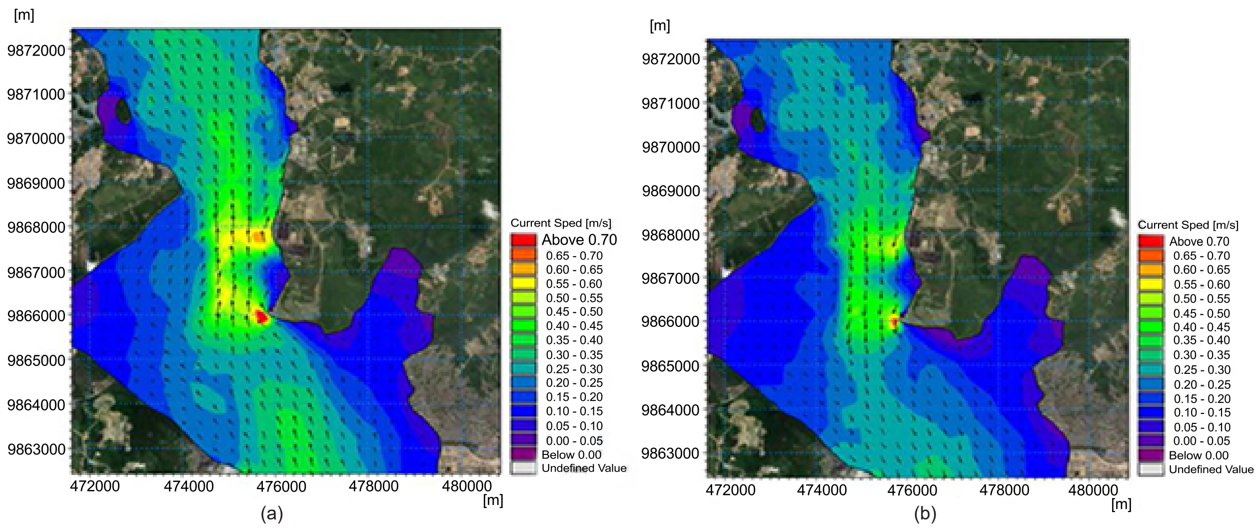



Figure 4
Model of East Monsoon Current Patterns at High Tide (a) and Low Tide (b)

The current pattern of seawater in Balikpapan Bay in the West and East monsoons is shown in Figure 2. Based on this figure, the current direction pattern between the West and East monsoons does not appear to have any significant differences or has almost the same direction of movement. However, the current speed in the East Monsoon was slightly higher when moving towards the north (tide conditions), while the current speed in the West Monsoon tended to be higher when moving towards the south (low tide conditions). This is because, in each monsoon, under these conditions, the dominant wind direction moves in the same direction as the current direction, which increases the current speed. The current patterns of high- and low-tide conditions in the west monsoon are shown in Figure 3, whereas the current pattern in the east monsoon is presented in Figure 4. The highest tide condition is where a change in the direction of current movement from the tidal phase occurs, resulting in the current speed being at its weakest point in this condition. When the water level recedes, the current direction is opposite to that of approaching high tide, moving out of Balikpapan Bay towards the South and Southeast, with the highest speed reaching 0.6 m/s. However, at the lowest ebb, the current reverses in the opposite direction at a very low speed, barely approaching 0 m/s. The results of the Balikpapan Bay water current model are also in line with previous research by (Putir et al. 2021), where the current pattern was predominantly influenced by the tidal phenomenon.

### Tidal Conditions

Tidal conditions (tides) in the study area are presented graphically in Figure 5 Next, to obtain the components or harmonic constants and types of tides in the study area, the tidal data were analyzed using the least-squares method. The results of the tidal harmonic constant calculations are presented in Table 4.

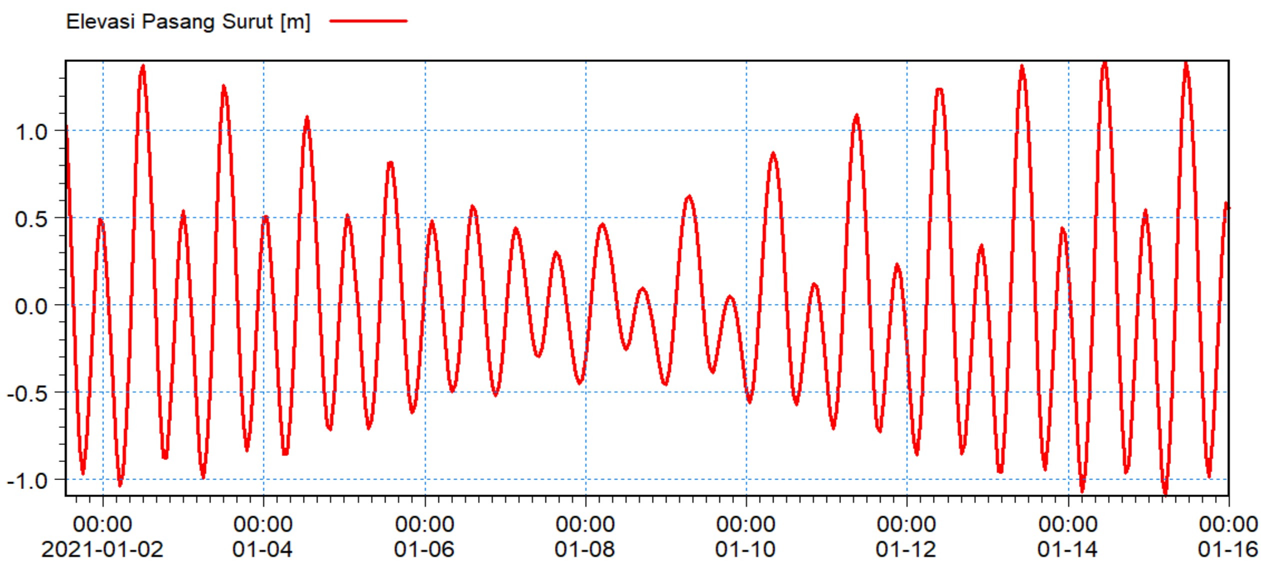



Figure 5
Tidal elevation graphic

Table 4
Tidal harmonic constant results of leastsquare method analysis

| Tidal Components | Harmonic Constants | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $S_0$ | O1 | P1 | K1 | N2 | M2 | S2 | K2 | M4 | MS4 |
| Amplitude (m) | 0 | 0.15 | 0.20 | 0.26 | 0.11 | 0.66 | 0.48 | 0.13 | 0.001 | 0.001 |
| Phase | | 187.08 | 302.49 | 296.06 | 341.27 | 92.14 | 207.92 | 0.41 | 66.242 | 354.031 |

Table 5
Important elevation of tidals in single daily inclined mixed tidal types
(Mixed mainly semidiurnal tides)

| Sea Level | Symbol | Formula | Result |
|---|---|---|---|
| Highest Astronomical Tide | HAT | $Z_0$+(all constituents) | 1.985 |
| Higher High Water Level | HHWL | $Z_0+(M_2+S_2+K_2+K_1+O_1+P_1)$ | 1.871 |
| High Water Spring | HWS | $Z_0+(M_2+S_2+K_1+O_1)$ | 1.547 |
| Mean High Water Spring | MHWS | $Z_0+(M_2+S_2)$ or $Z_0+(K_1+O_1)$ | 1.140 |
| Mean High Water Level | MHWL | $Z_0+(M_2+K_1+O_1)$ | 1.063 |
| Mean Sea Level | MSL | $Z_0$ | 0.000 |
| Mean Low Water Level | MLWL | $Z_0-(M_2+K_1+O_1)$ | -1.063 |
| Mean Low Water Spring | MLWS | $Z_0-(M_2+S_2)$ or $Z_0-(K_1+O_1)$ | -1.140 |
| Low Water Spring | LWS | $Z_0-(M_2+S_2+K_1+O_1)$ | -1.547 |
| Lower Low Water Level | LLWL | $Z_0-(M_2+S_2+K_2+K_1+O_1+P_1)$ | -1.871 |
| Lowest Astronomical Tide | LAT | $Z_0-$(all constituents) | -1.985 |

The tidal series graph in Figure 4 shows that tidal fluctuations in one day are twice as high and twice as low, and a difference between the first and second amplitudes still exists. The tidal rise, or difference between the highest and lowest tides, based on the data obtained, was 2.76 m. The tidal harmonic constant results of the analysis shown in Table 4 indicate that the amplitudes of the tidal constants M2 and S2 are more dominant than those of the other components. Because the M2 and S2 constants are components of semidiurnal tides (double tides), the tides at the study location were dominated by semidiurnal tides. This is in accordance with the visual form of the tidal graph shown in Figure 5

Quantitatively, the type of tide in the water can also be determined by calculating the ratio (ratio) between the amplitude of the main single tidal elements (K1+O1) and that of the main double tidal elements (M2+S2), known as the Formzhal number. The results of calculating the Formzhal number obtained a value of 0.36. Based on the Courtier criteria, this value range was included in the mixed, mainly semidiurnal tide type. This type of tide exhibits two high tides and two low tides in one day, but a difference exists between the amplitudes of the first and second tides. Based on the obtained constants, important tidal elevations were determined using several equations, as listed in Table 5. The tidal heights used were average sea level (MSL). Based on the calculated results, the highest astronomical tide (HAT) from the average water level reference was 1,985 m. The highest (HHWL) and lowest (LLWL) water levels during the full and new moons refer to average water levels of 1,871 m and -1,871 m, respectively.

The highest average water for both full moon and new moon conditions (MHWS) at the MSL reference was obtained at 1.14 m, while low water at average low tide (MLWS) was obtained at -1.14 m. The tidal rise value at high water, the average tide over a period of 19.60 years (MHWL), is 1,063 m, while for low water at the average low tide (MLWL), it is –1,063 m. The tidal range or distance between the highest tide (HAT) and the lowest tide (LAT) based on all components was found to be 3.97 m.

**Bhatimetry**

Water depth is an important parameter. If it is related to a pollutant when it enters the water, then depth is one of the factors that influences the dilution of pollutants in the water. Generally, if a body of water is shallow, the dilution of pollutants takes longer than that in deeper water. The depth characteristics of the study locations are shown in Figure 6. This figure shows the horizontal depth profile depicted by depth contour lines (isodepth). The depth characteristics around the study area varied considerably, with the visible depth ranges from 0.5 - 35 m. In general. water depth increased with increasing distance from the coastline.

## Distribution of Sea Water Quality Parameters

### pH

The pattern of increase in the pH value due to the entry of liquid waste into the seawater of Balikpapan Bay was relatively small, as shown in Figure 7 and 8.

Based on this figure, the maximum increase value only reaches 0.000074 from the natural pH value of 8.000074. This increase in value is still in accordance with the criteria for seawater quality standards for ports based on PP No. 22 of 2021 Appendix VIII, namely, seawater quality standards for ports with a pH value range of 7 – 8.5.

### Total Suspended Solid (TSS)

The distribution pattern of the increase in TSS parameters owing to the entry and mixing of waste into seawater bodies is shown in Figure 9 and 10.

The contribution of wastewater from Fuel Terminal activities to the increase in TSS that occurs in the waters of Balikpapan Bay, as shown in the figure, reaches 0.0022 mg/l with a distance of maximum spread of 250 m, and the TSS concentration value decreases as the distance from the outfall point increases; in this case, at a distance of 1000 m (north and south direction), the TSS concentration value is only approximately 0.0008 mg/l. The TSS quality standard for ports is based on PP No.22 of 2021 Appendix VIII, namely, the seawater quality standard for ports with a value of 80 mg/l. Thus, it can be said that the contribution of TSS from liquid waste to receiving water bodies is relatively small and still meets the required quality standards.

### Biochemical Oxygen Demand (BOD)

The distribution pattern of the maximum BOD modeling results (Figure 11 and 12) is seen in the west and east monsoons, which experienced an increase in the concentration of 0.0025 mg/l. This maximum value spreads to a radius of 200 m (north and south) from the outfall point. Furthermore, the concentration of BOD decreased as the distance from the outfall point increased, and at 500 m (north and south), the BOD concentration was 0.001 mg/l. In PP No.22 of 2021, Appendix VIII presents the seawater quality standards for ports where the BOD quality standard criteria are not included in the indicators but still have a maximum contribution from Fuel Terminal wastewater of 0.0125% of the seawater quality standard value. Thus, it can be concluded that the increase in the concentration was very small.

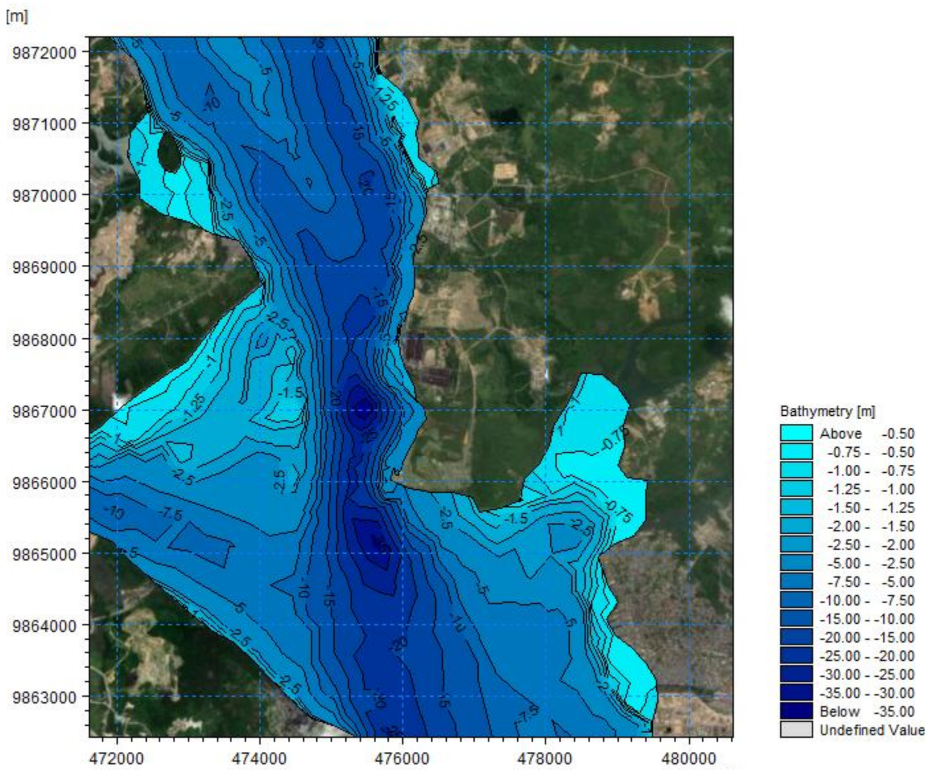



Figure 6
Horizontal plane contour of water depth around the research location

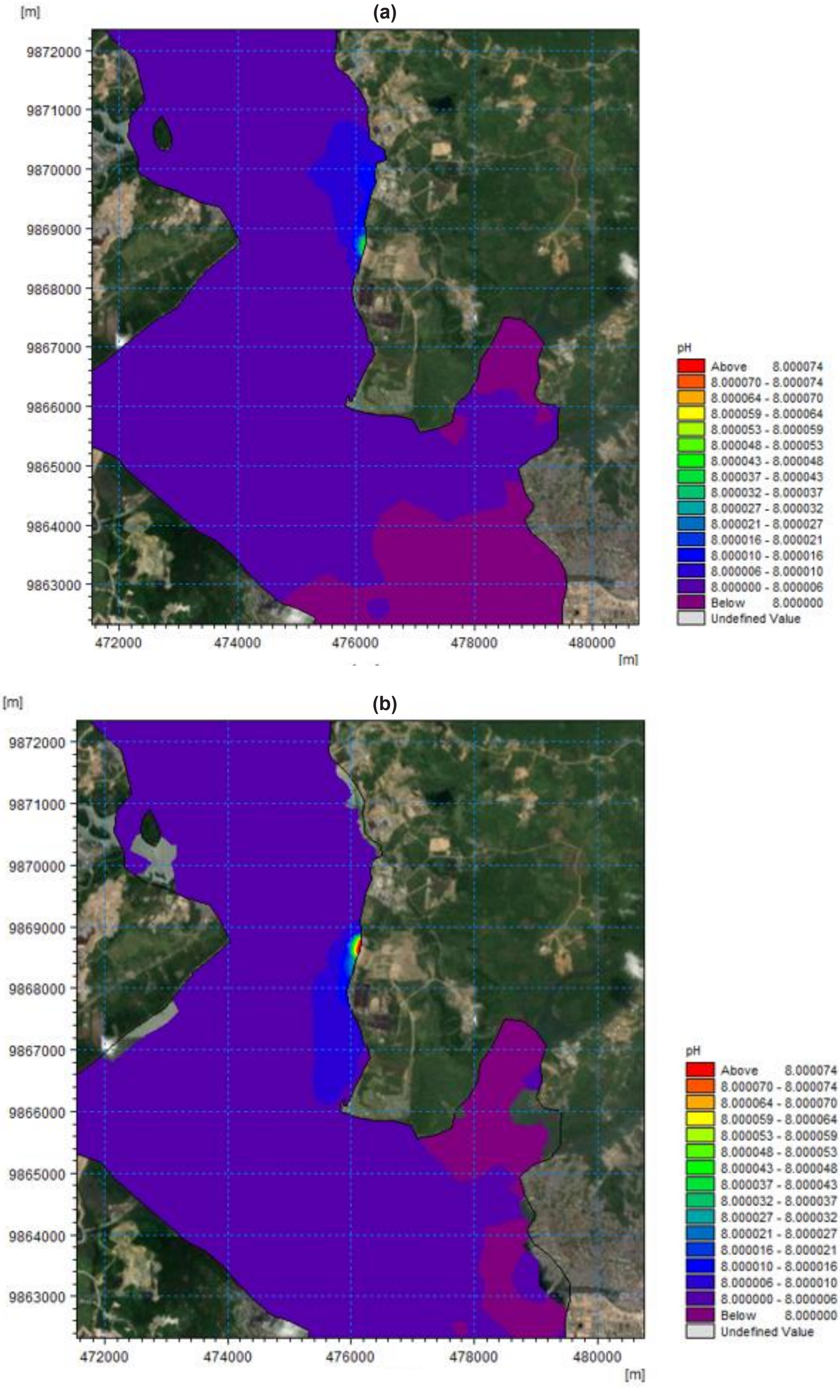



Figure 7
Model of pH distribution in the west monsoon during (a) high tide and (b) low tide

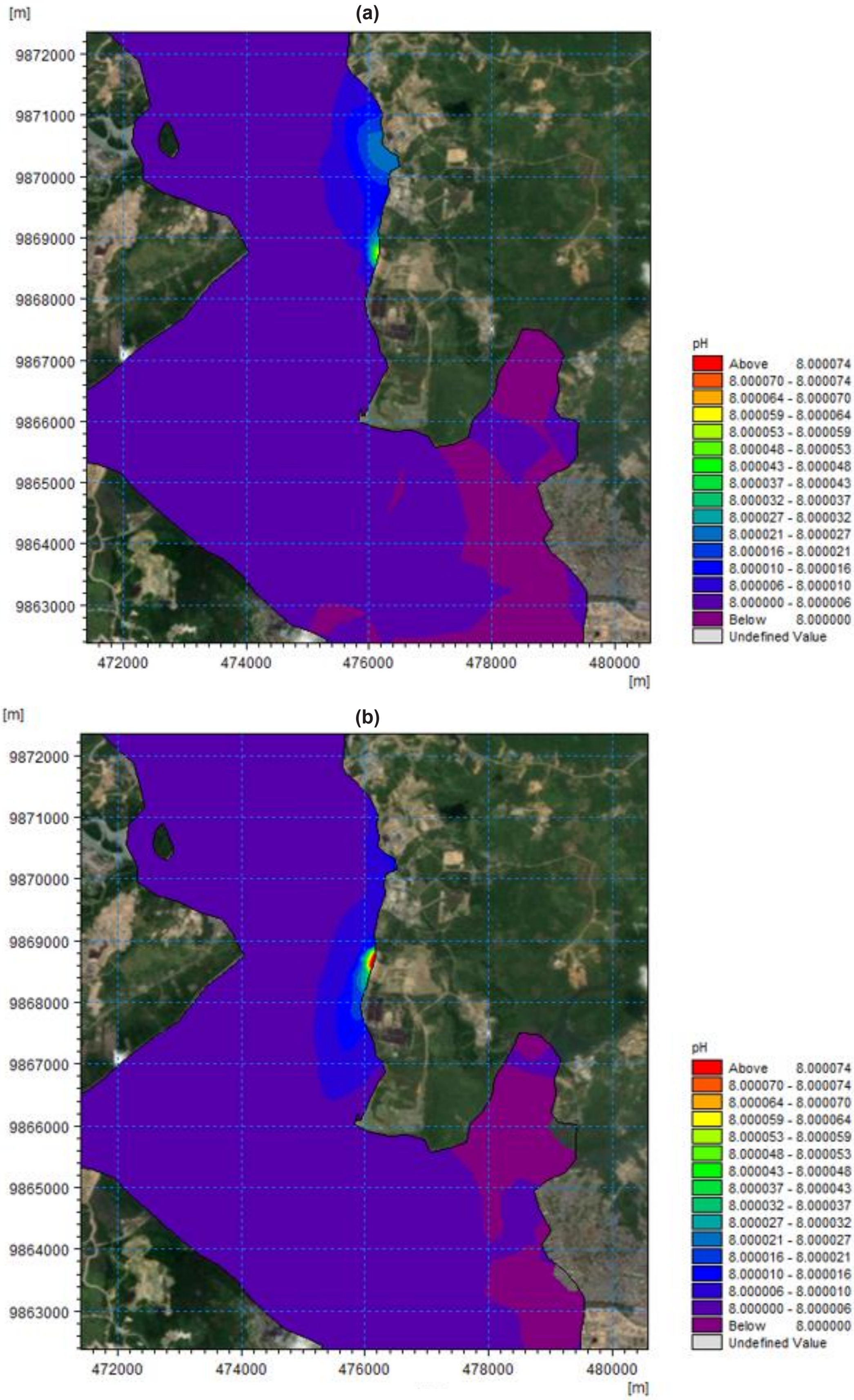



Figure 8
Model of pH distribution in the east monsoon during (a) high tide and (b) low tide

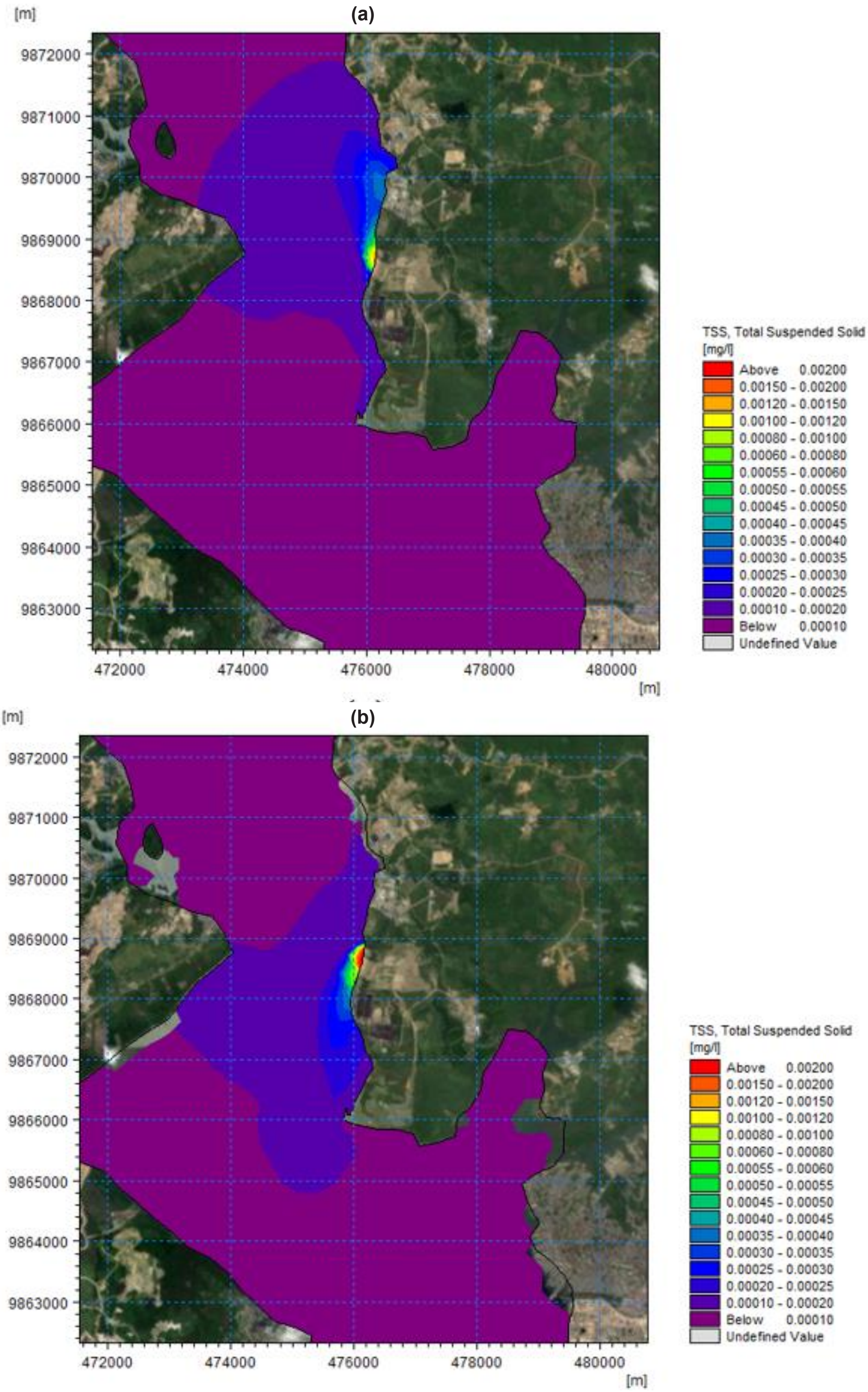



Figure 9
Model of tss distribution in the west monsoon during (a) high tide and (b) low tide

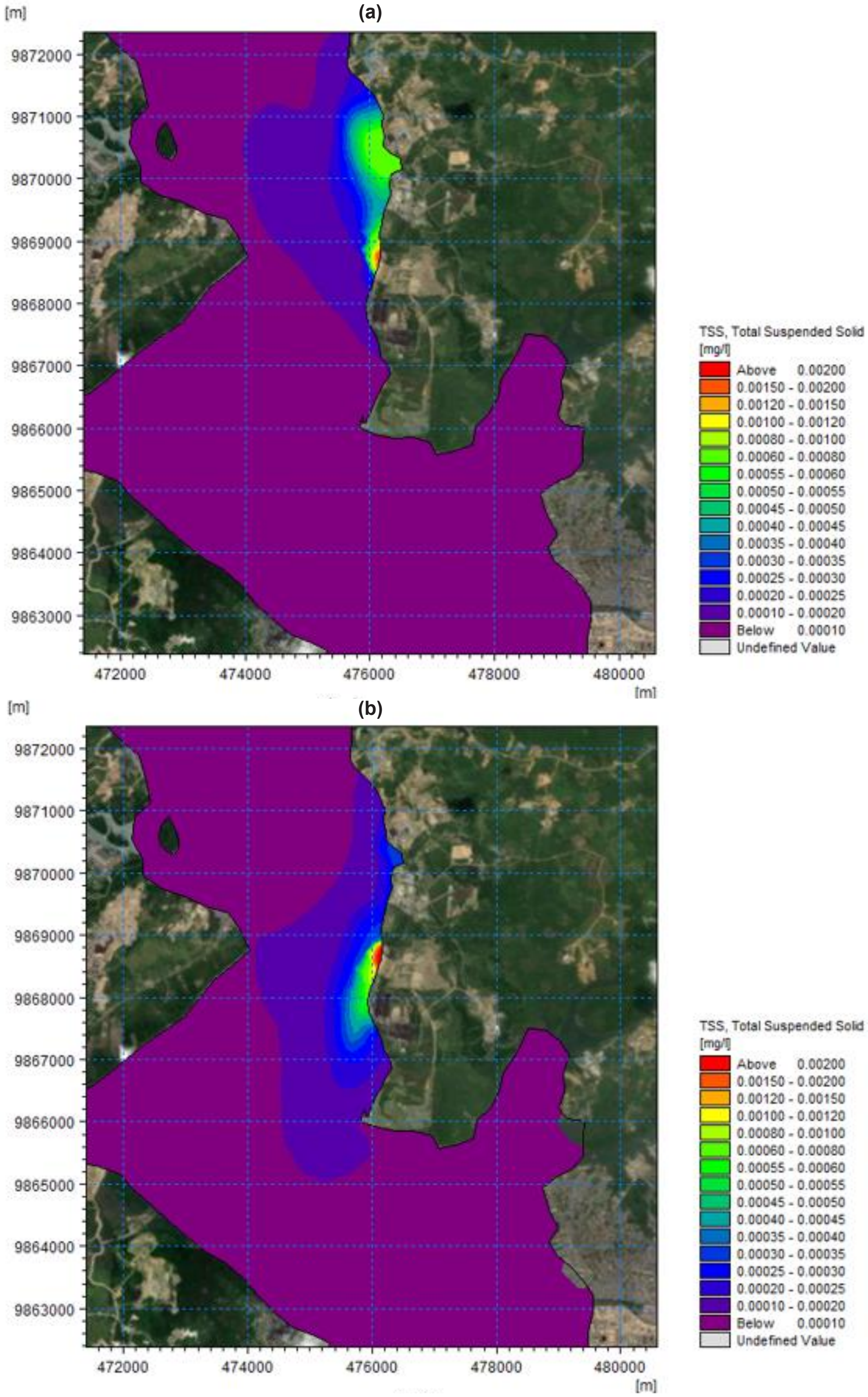



Figure 10
Model of tss distribution in the east monsoon during (a) high tide and (b) low tide

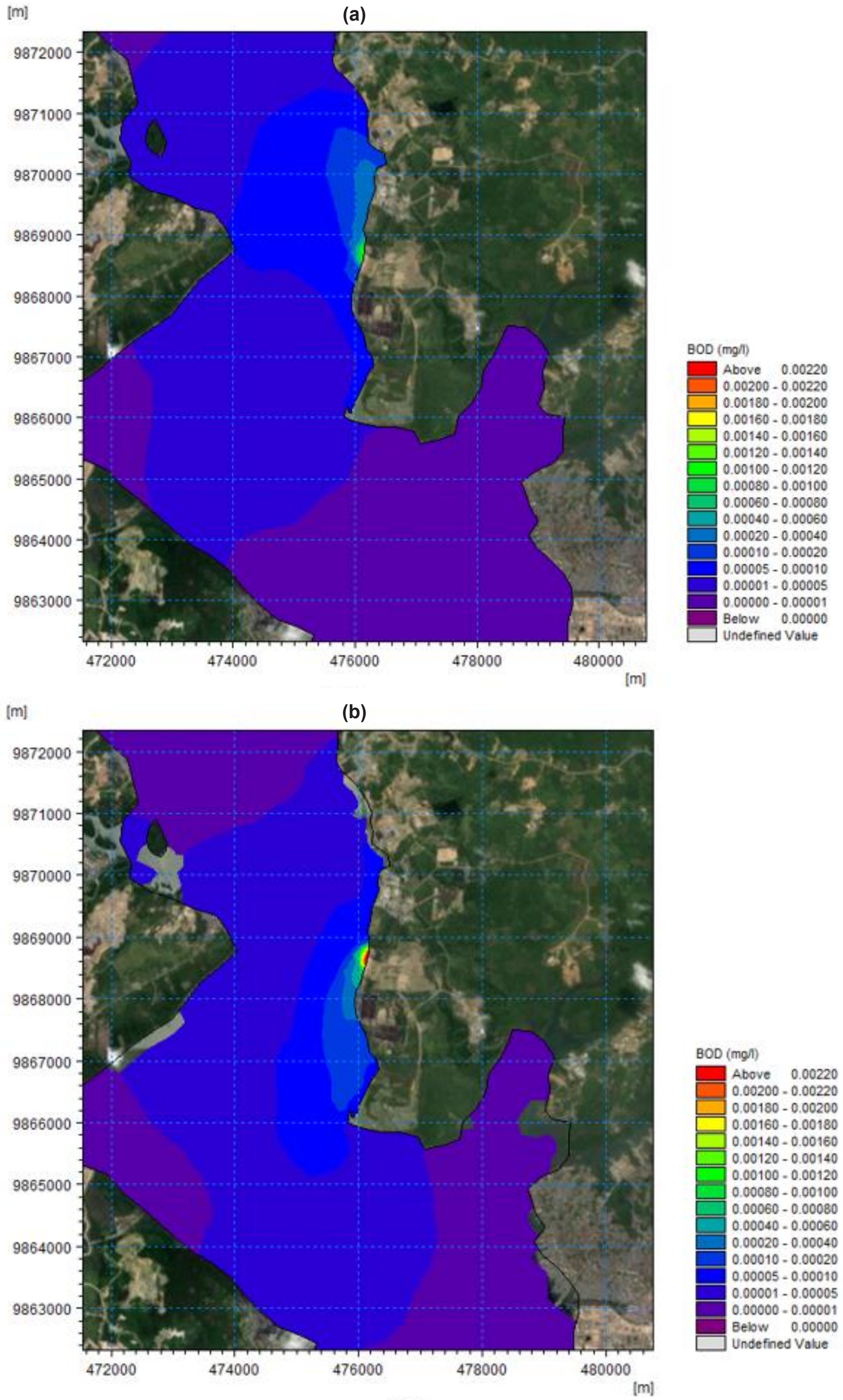



Figure 11
Model of BOD distribution in the west monsoon during (a) high tide and (b) low tide

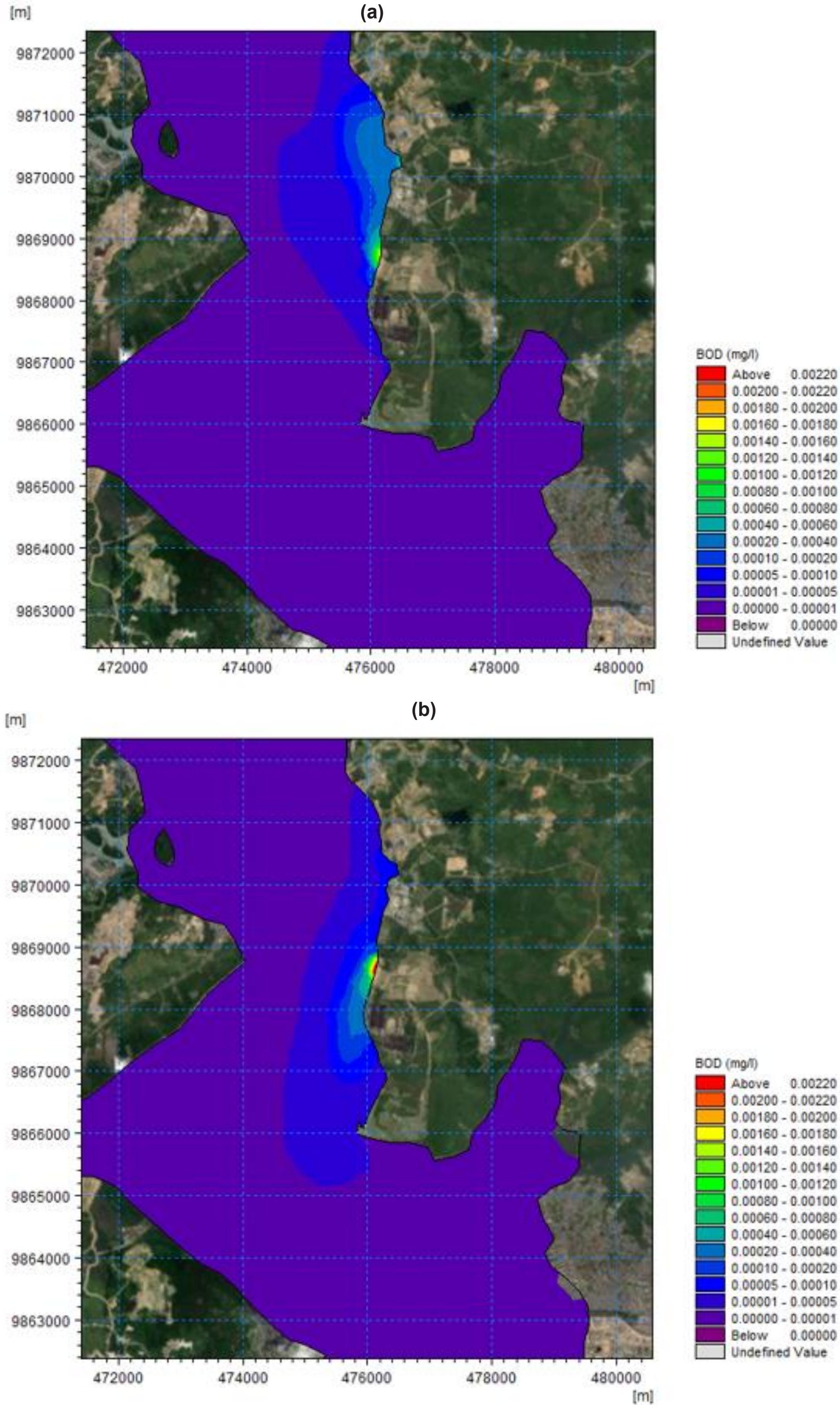



Figure 12
Model of BOD distribution in the east monsoon during (a) high tide and (b) low tide

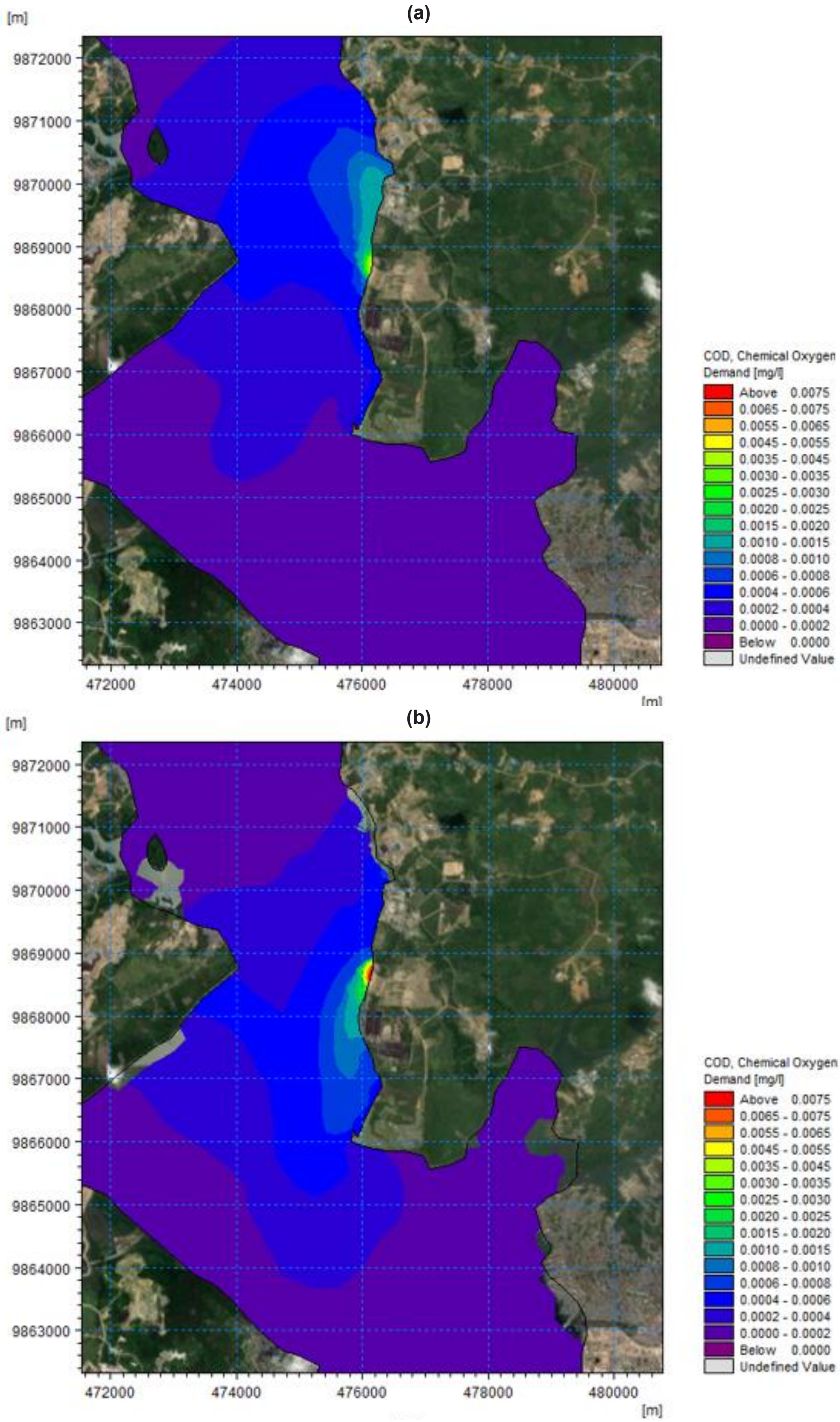



Figure 13
Model of COD distribution in the west monsoon during (a) high tide and (b) low tide

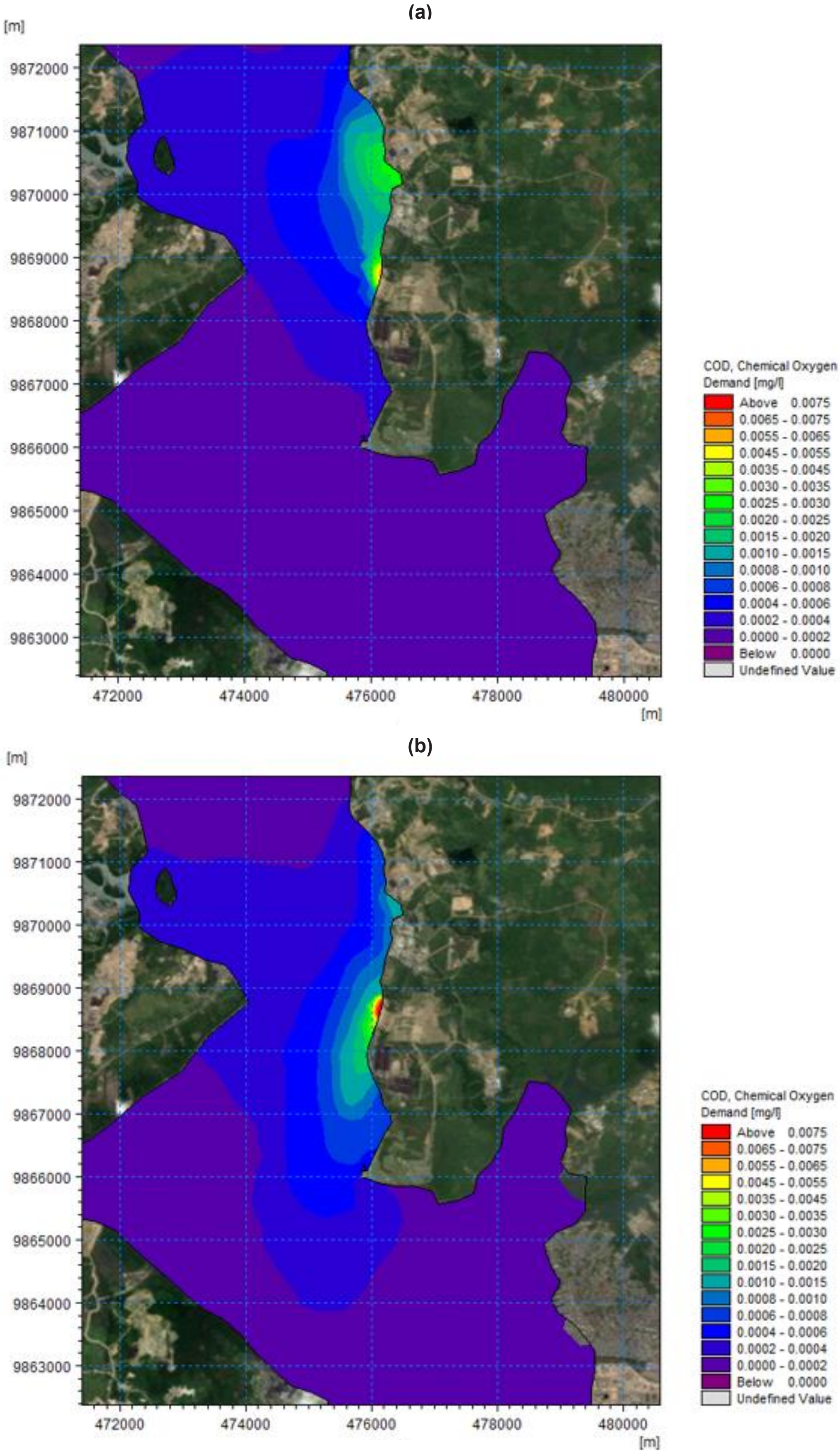



Figure 14
Model of COD distribution in the east monsoon during (a) high tide and (b) low tide

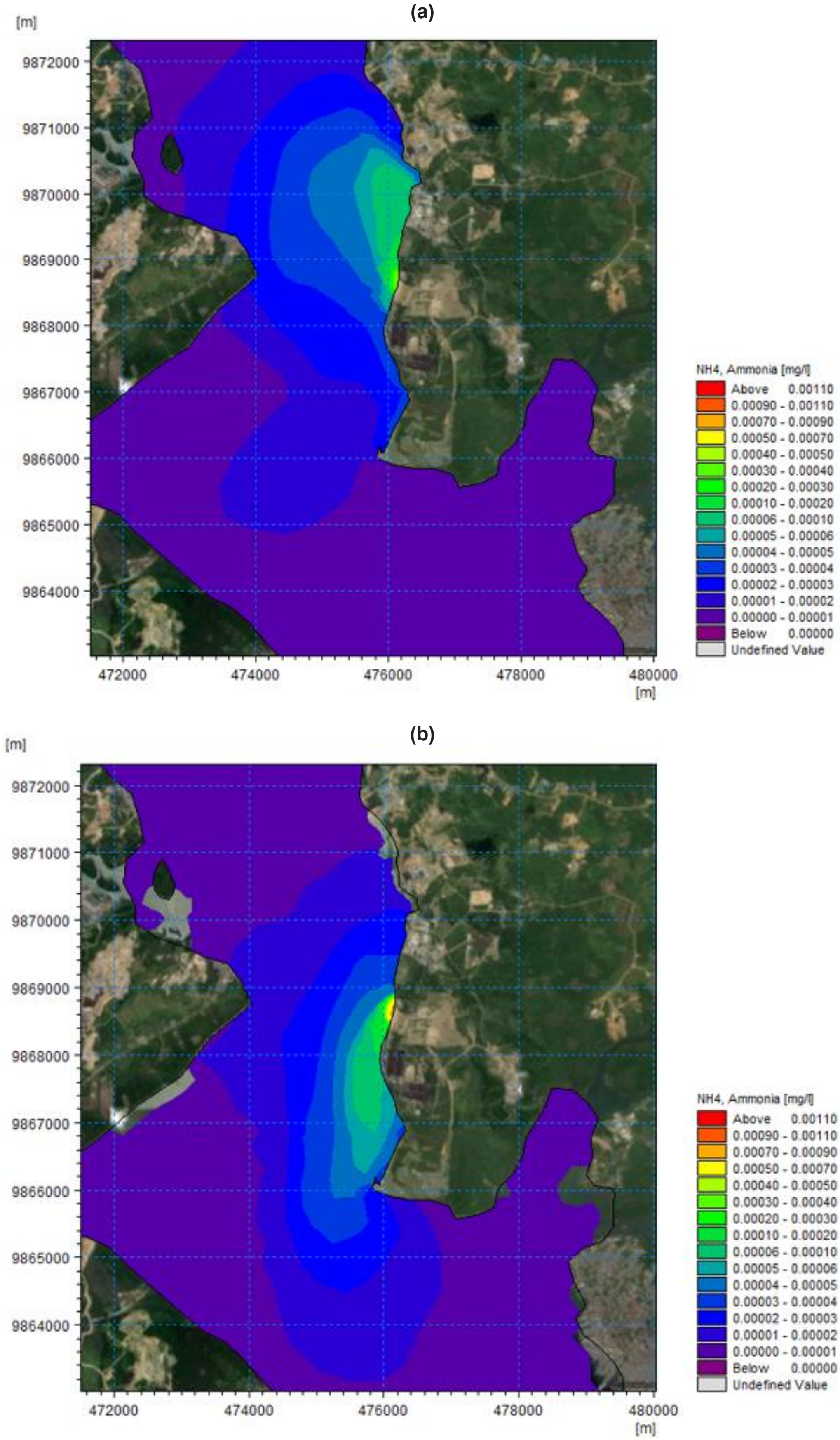



Figure 15
Model of ammonia distribution in the west monsoon during (a) high tide and (b) low tide

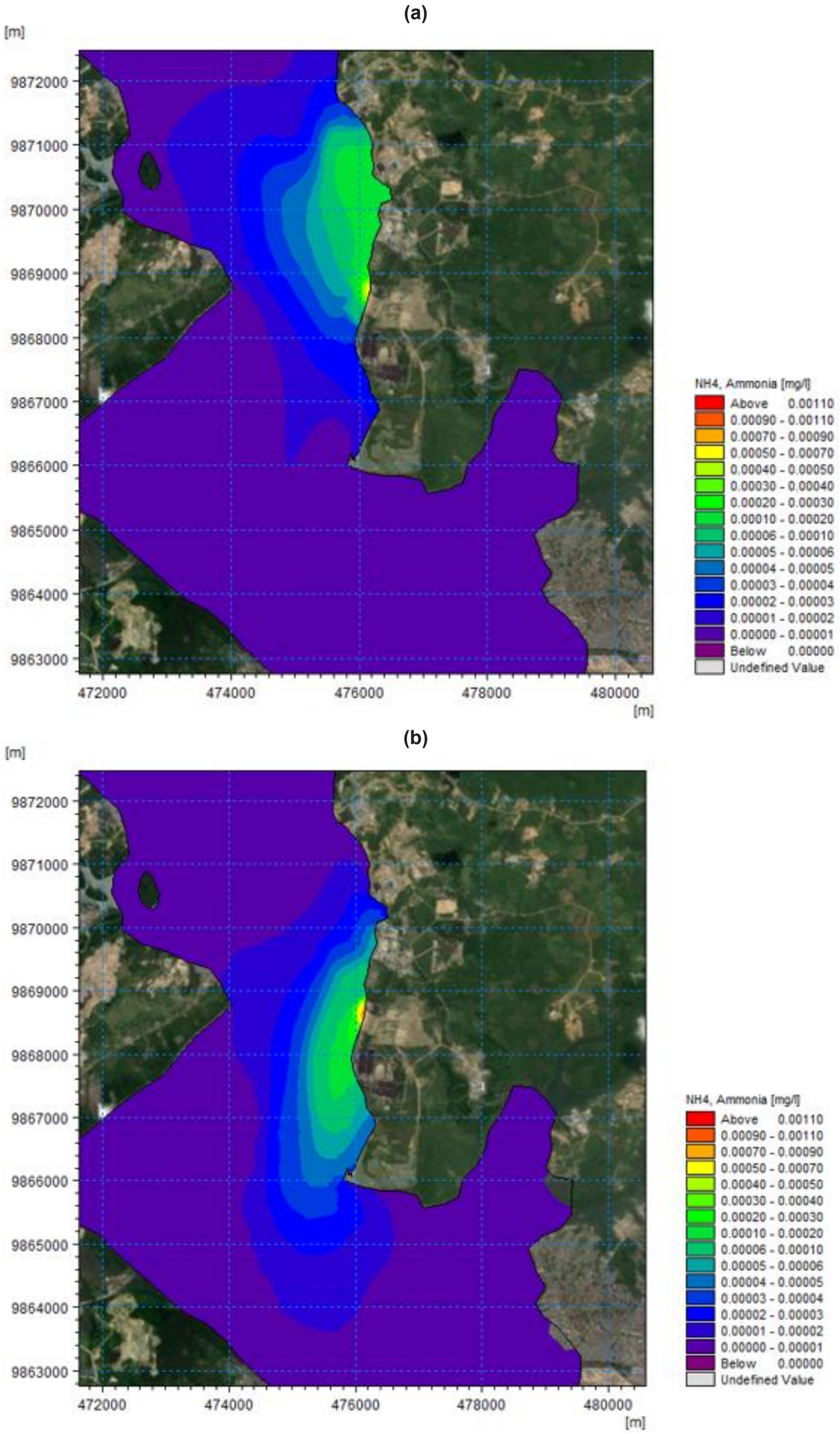



Figure 16
Model of ammonia distribution in the east monsoon during (a) high tide and (b) low tide

(a)

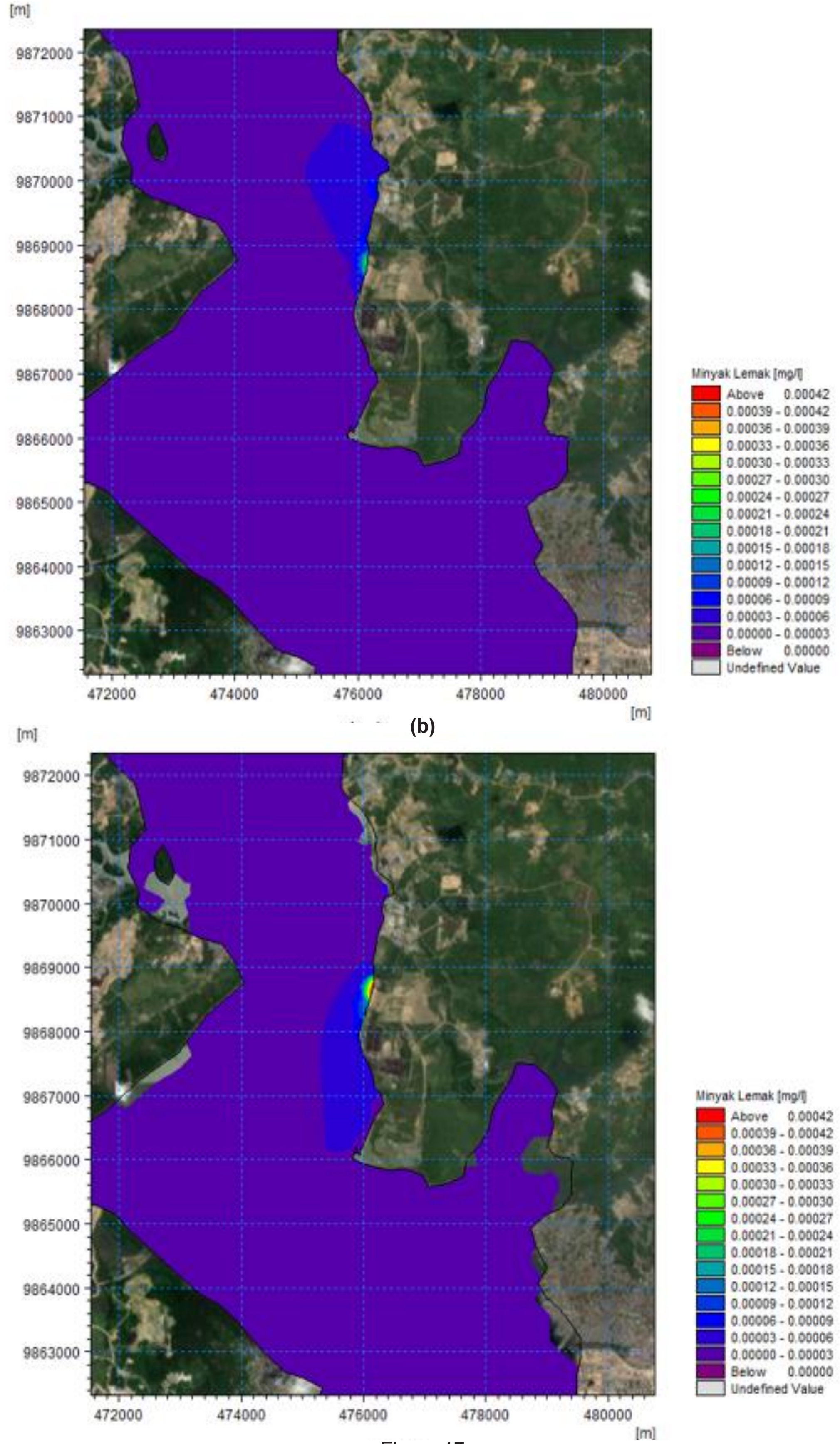



Figure 17
Model of oil and grease distribution in the west monsoon during (a) high tide and (b) low tide

(a)

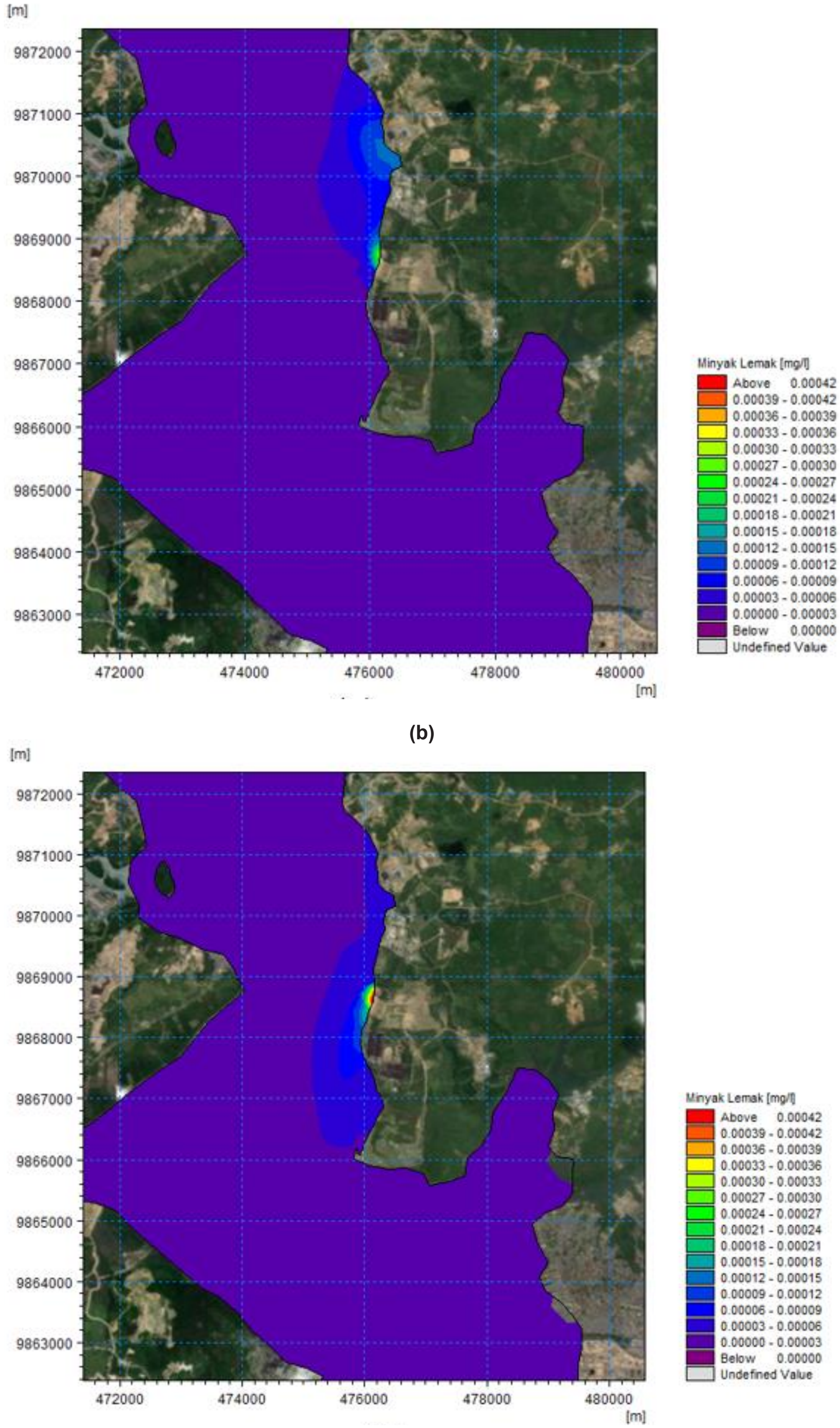



Figure 18
Model of oil and grease distribution in the east monsoon during (a) high tide and (b) low tide

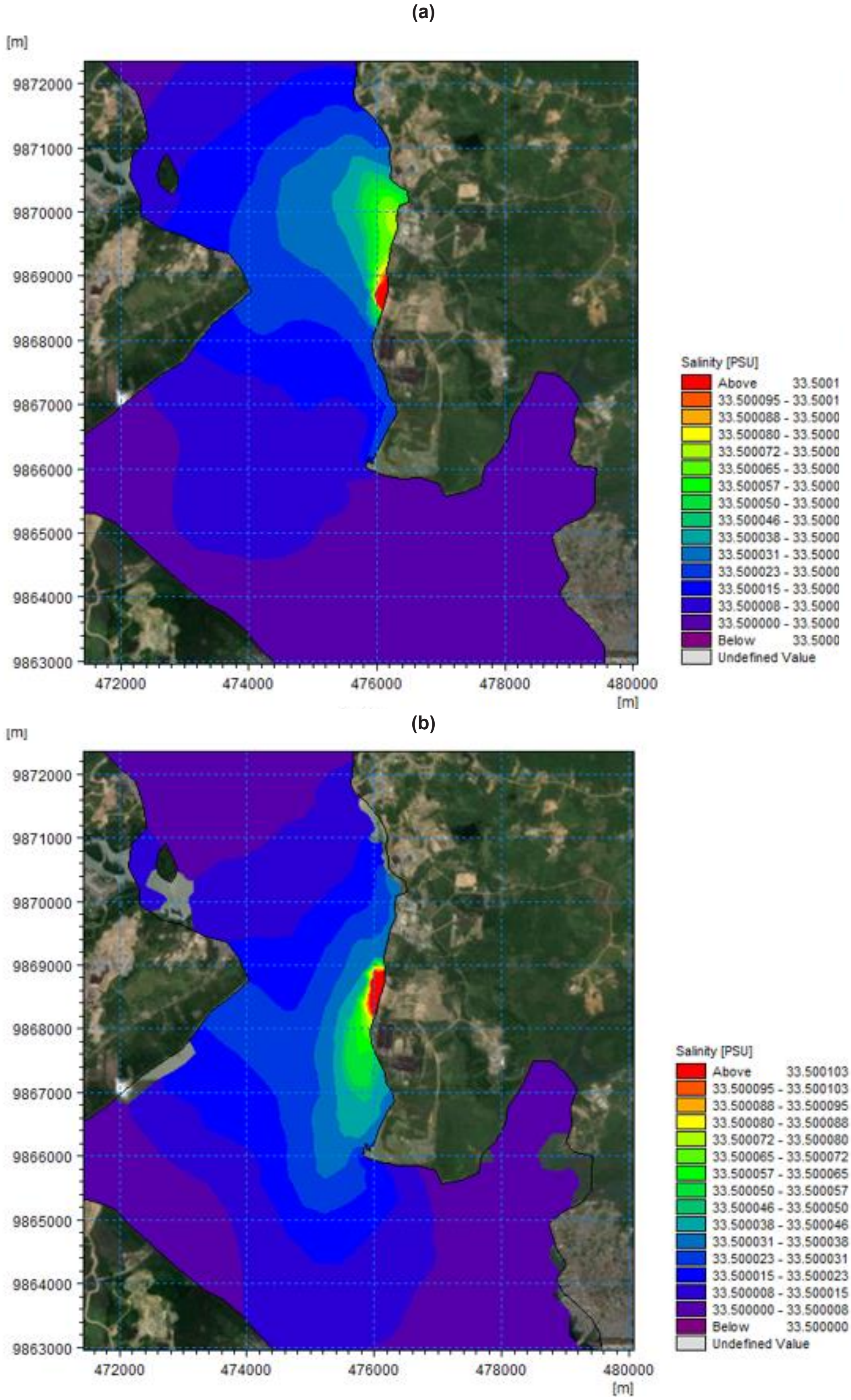



Figure 19
Model of salinity distribution in the west monsoon during (a) high tide and (b) low tide

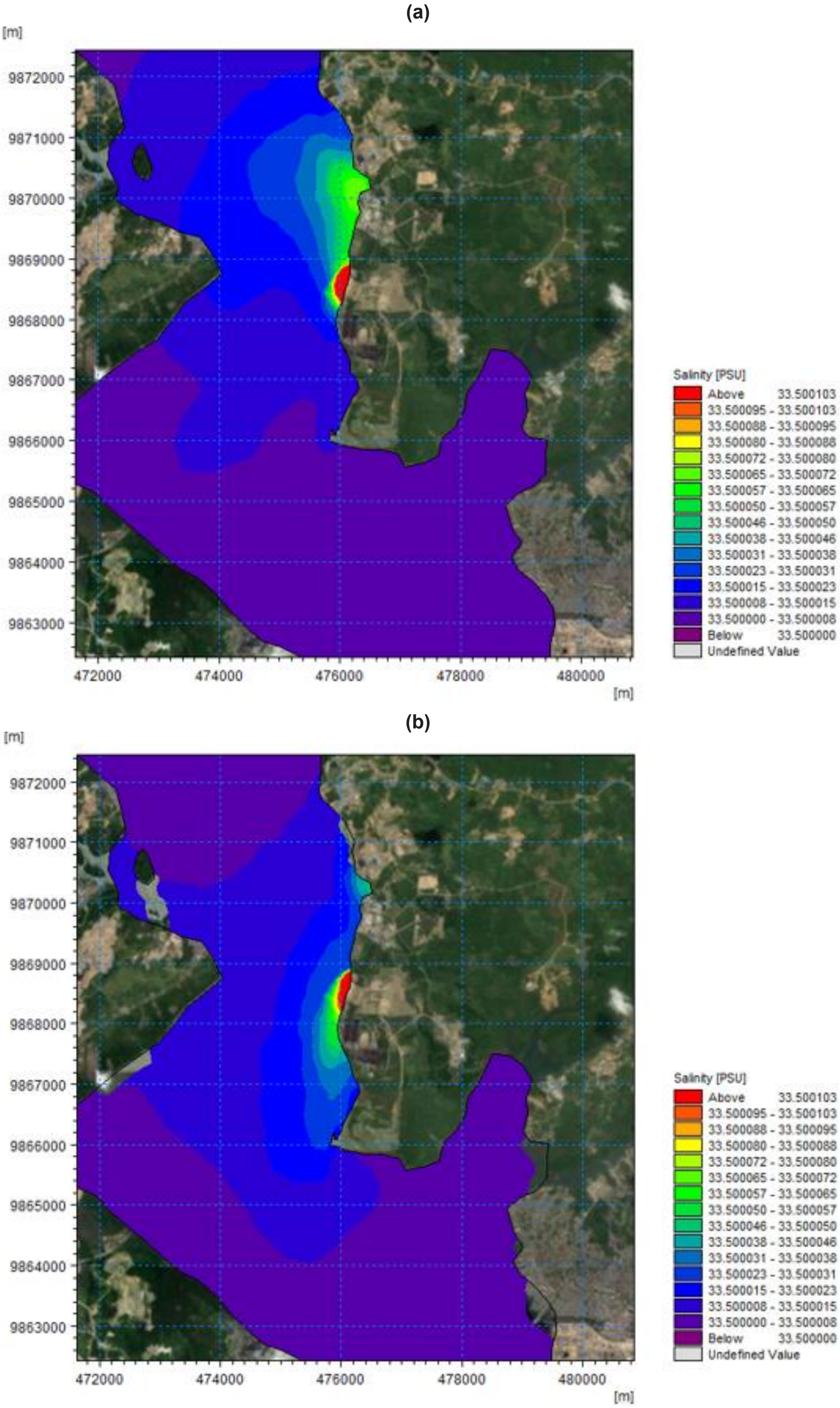
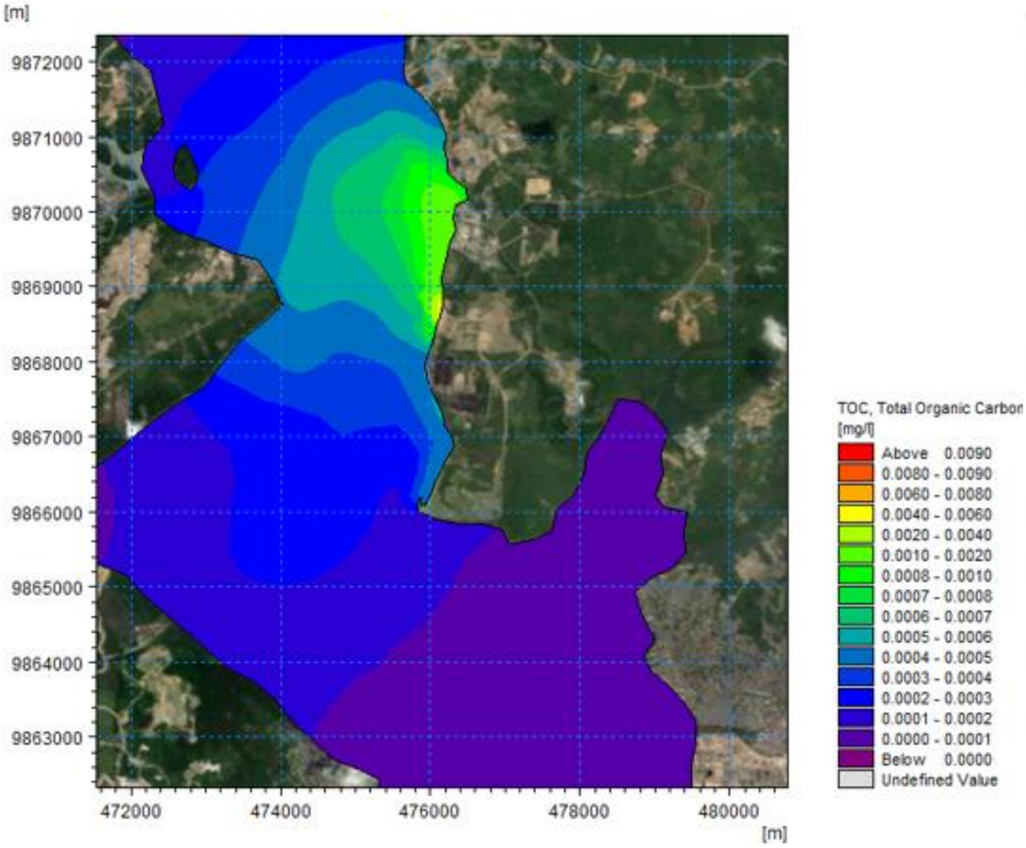



Figure 20
Model of salinity distribution in the east monsoon during (a) high tide and (b) low tide

**(a)**




**(b)**

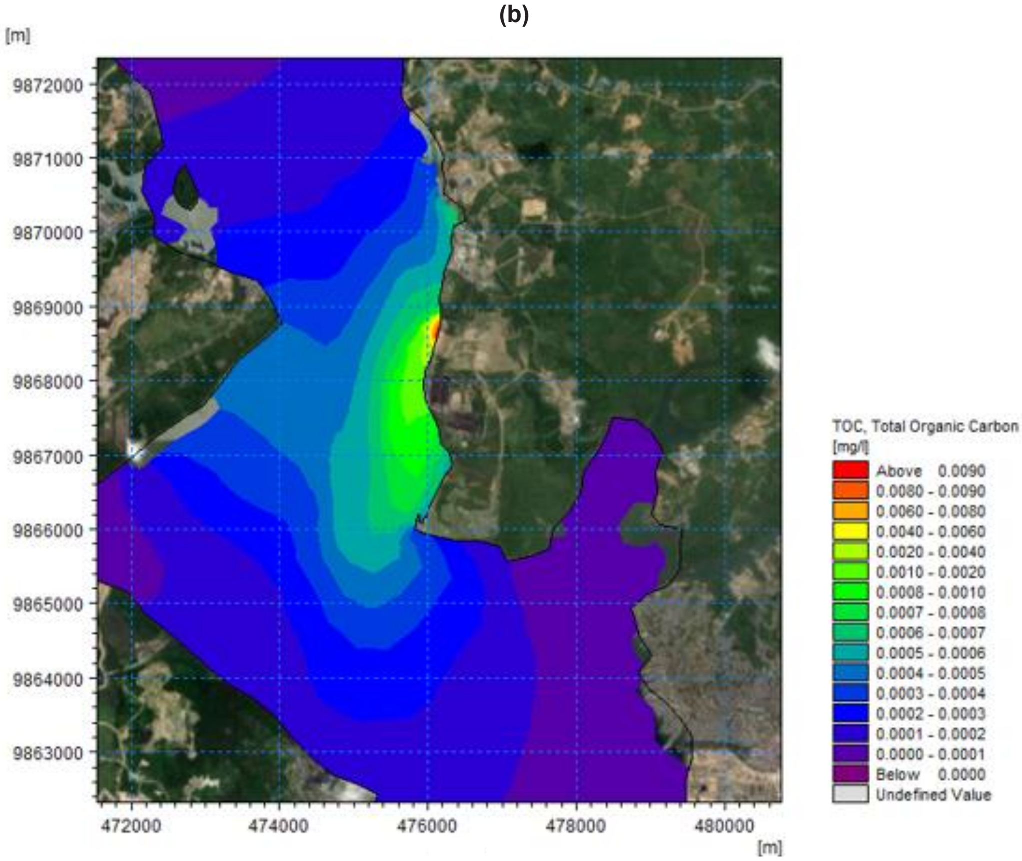
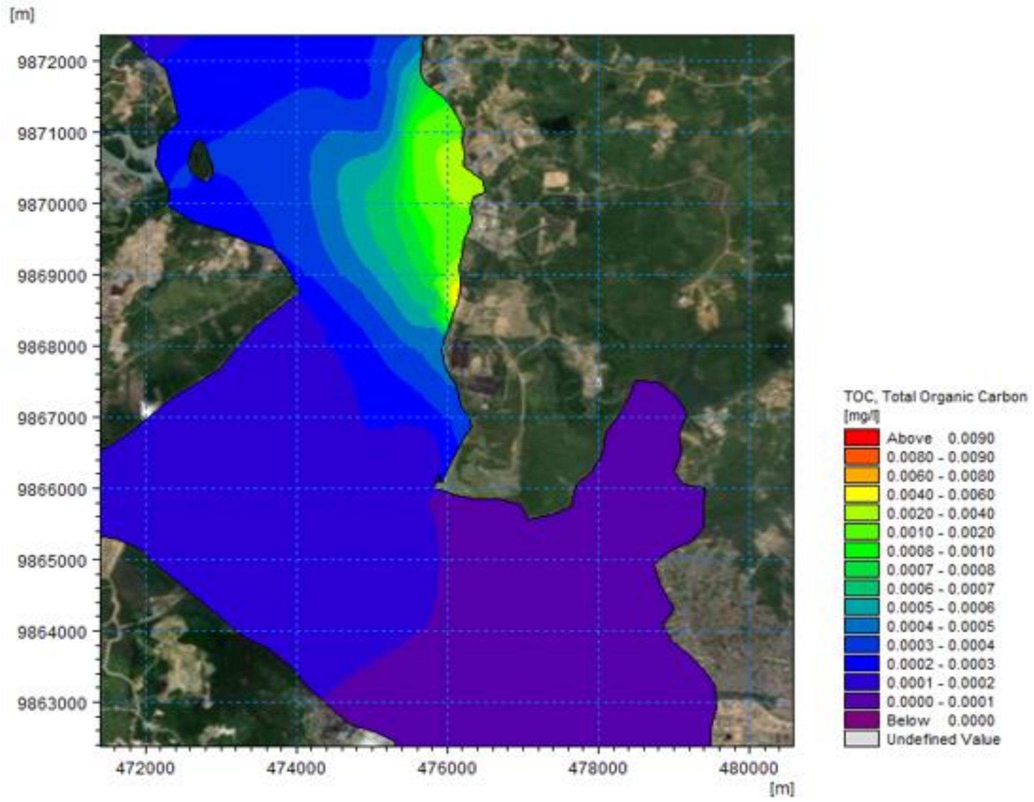



Figure 21
Model of toc in the west monsoon during (a) high tide and (b) low tide

**(a)**




**(b)**

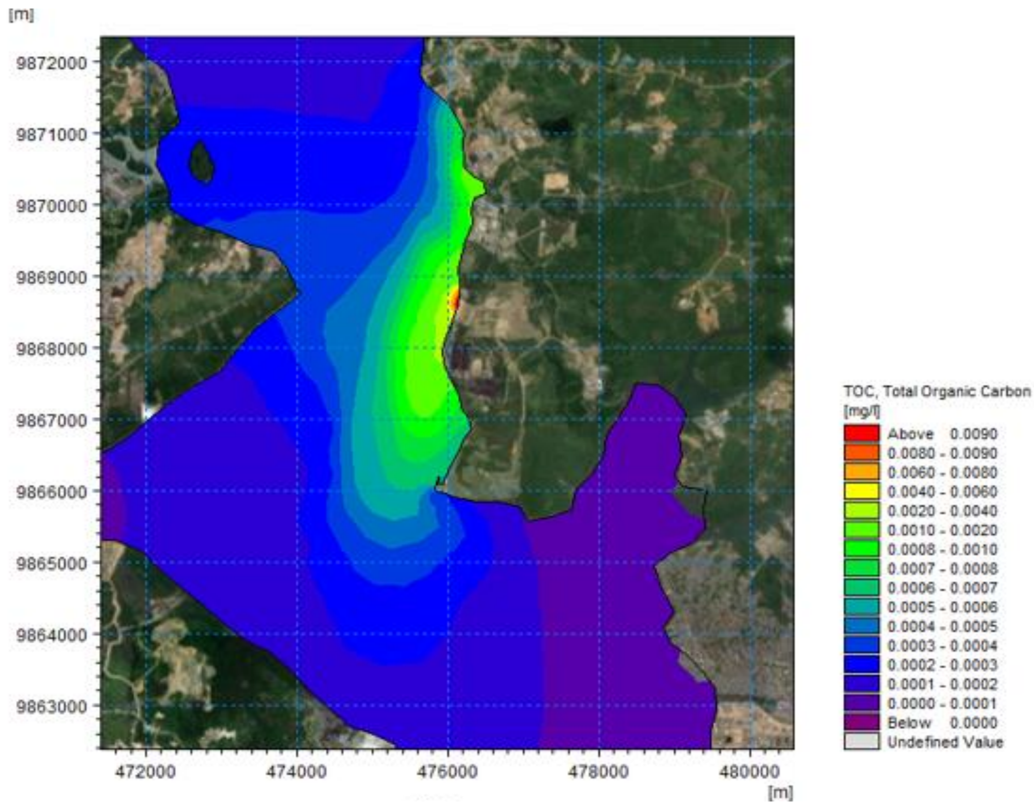
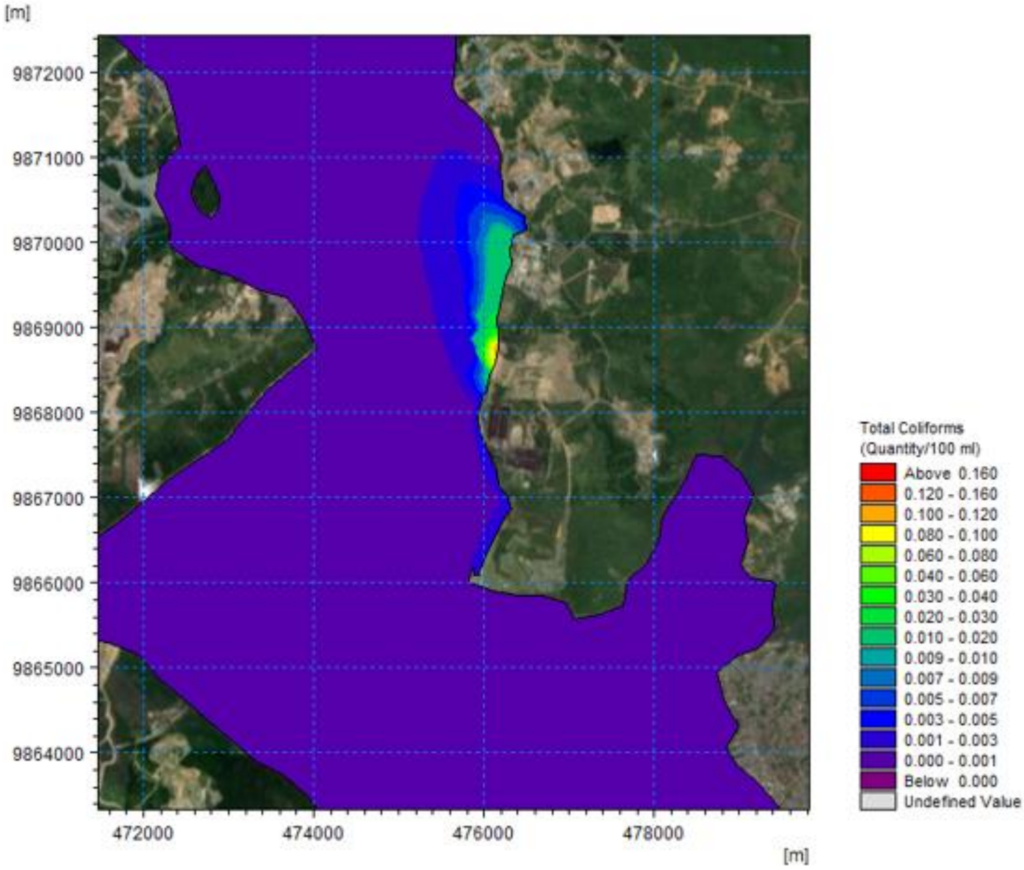



Figure 22
Model of toc in the east monsoon during (a) high tide and (b) low tide

**(a)**




**(b)**

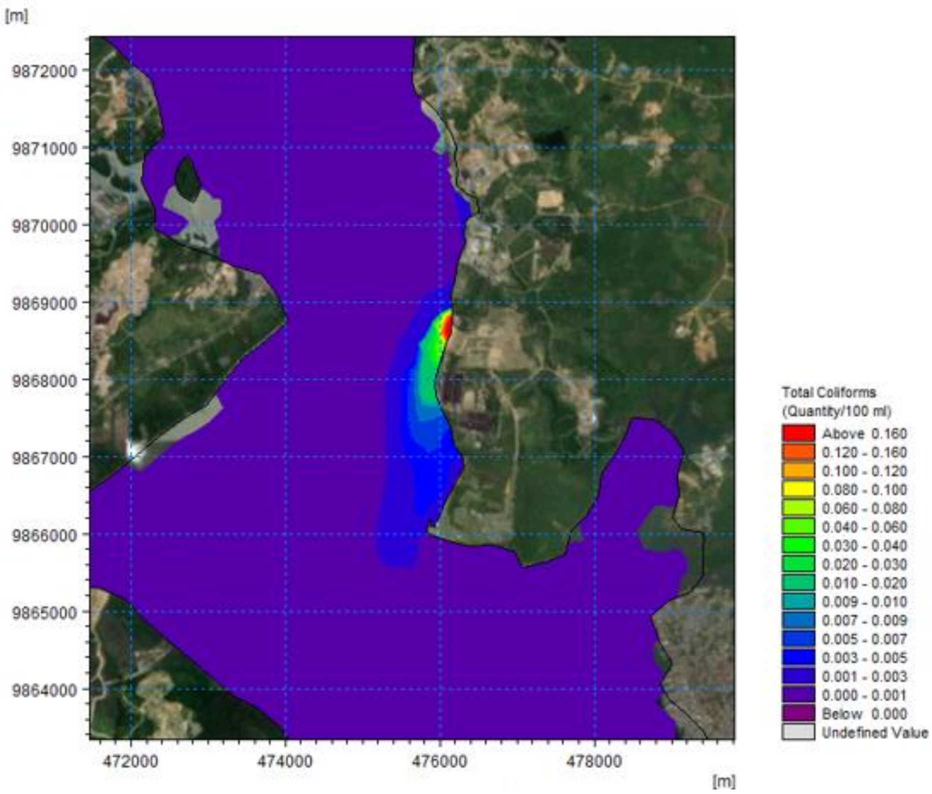
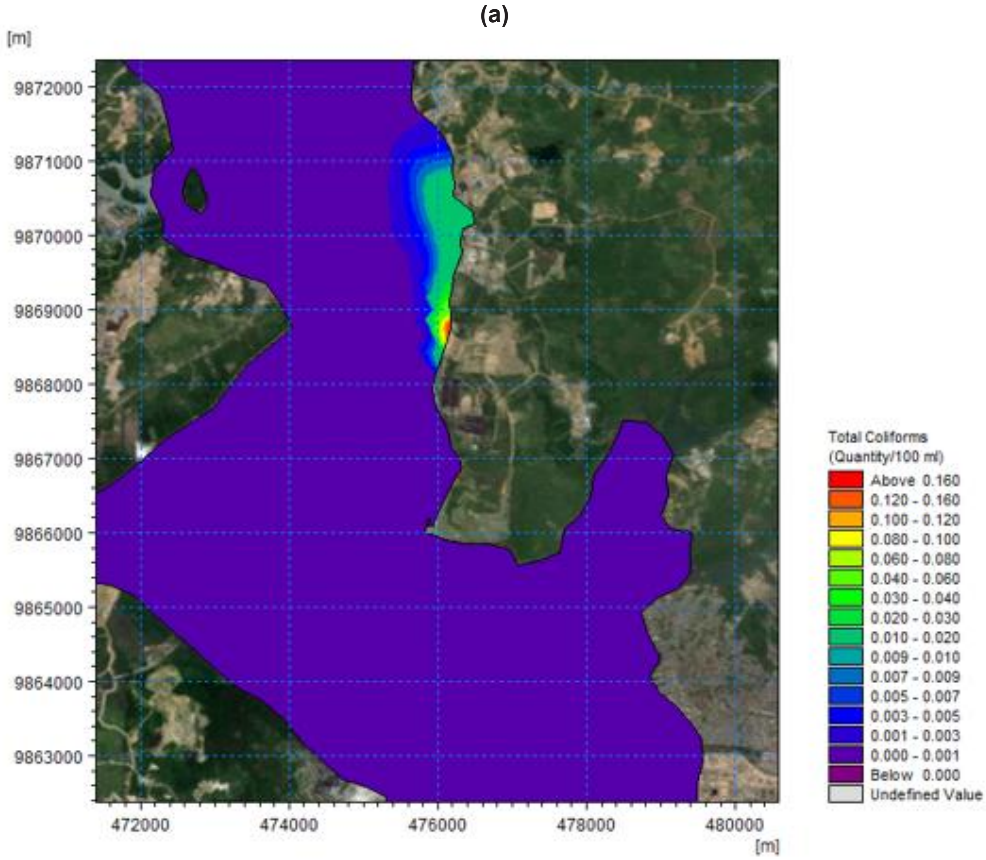



Figure 23
Model of total coliform in the west monsoon during (a) high tide and (b) low tide

**(a)**




**(b)**

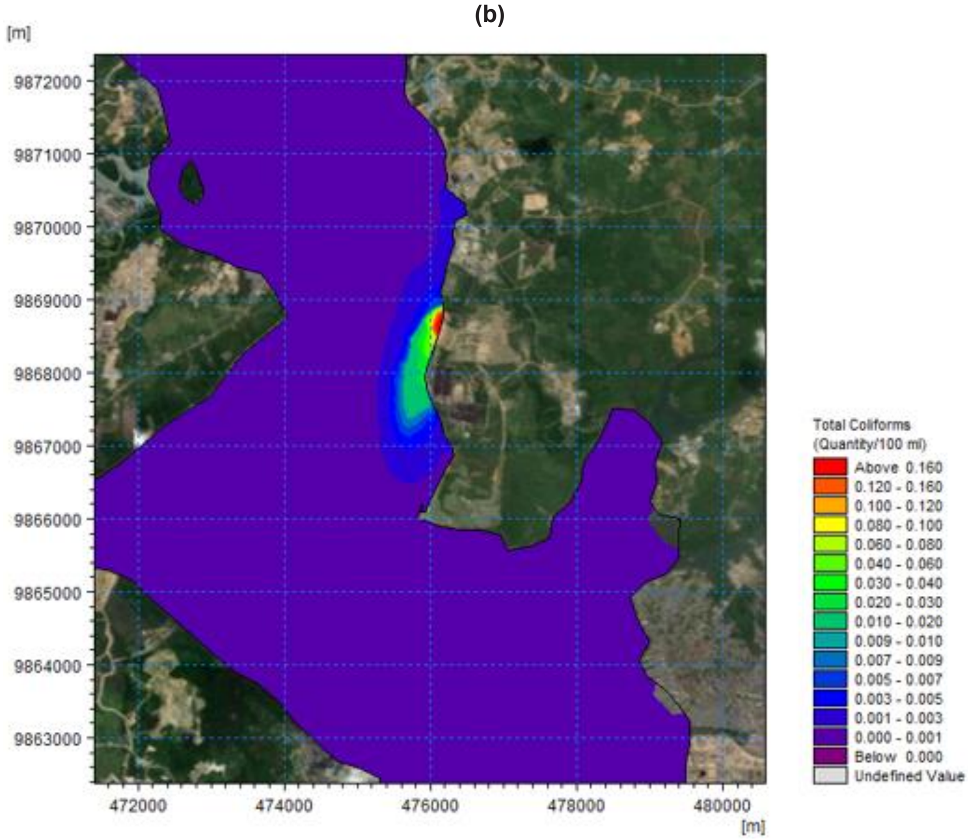



Figure 24
Model of total coliform in the east monsoon during (a) high tide and (b) low tide

**Chemical Oxygen Demand (COD)**

The distribution pattern of the increase in COD parameters owing to the entry and mixing of waste into seawater bodies is shown in Figure 13 and 14.

The contribution of Fuel Terminal wastewater to the increase in COD that occurs in the waters of Balikpapan Bay, as shown in the figure, reaches 0.01 mg/l with a maximum distribution distance. At 300 m (north and south), the COD concentration value decreased as the distance from the outfall point increased, and at 1000 m (north and south), the COD concentration value was only approximately 0.0025 mg/l. In PP No.22 of 2021, Appendix VIII, namely the Sea Water Quality Standards for ports, where COD quality standard criteria are not included in the indicators, it can be said that the contribution of COD from liquid waste to receiving water bodies is relatively small.

**Ammonia**

The distribution of ammonia ($NH_3$) parameters was found to increase at a maximum concentration of 0.0011 mg/l with a radius of <100 m, as shown in Figure 15 and 16.

This value still meets the standard criteria for seawater quality for ports according to PP No.22 of 2021, where Attachment VIII is the seawater quality standard for ports where the quality standard criteria value is 0.3 mg/l. Similar to the other parameters, the ammonia ($NH_4$) concentration decreased with increasing distance from the discharge point. At depths greater than 300 m (north and south), the concentration was 0.0003 mg/l.

**Oil and Grease**

The increase in the concentration distribution pattern of the Oil and Grease parameters due to the entry of Fuel Terminal wastewater into the seawater bodies is shown in Figure 17 for the West Monsoon and Figure 18 for the East Monsoon.

Based on this figure, the maximum contribution of liquid waste to increasing the oil and grease parameters in marine waters is 0.00045 mg/l. The increase in the oil and grease concentrations was very small, and the concentration decreased with increasing distance from the discharge point. At a radius of >300 m (north and south), this value still meets the criteria for seawater quality standards for ports according to PP No. 22 of 2021 Appendix VIII, namely, seawater quality standards for ports with a value of 5 mg/l.

**Salinity**

The results of modeling the distribution of maximum salinity (Figure 19 and Figure 20) in terms of the West and East monsoon have increased from the initial baseline of the marine environment of 0.00011 PSU where the initial baseline value is 33.5 PSU and the maximum salinity value due to waste input is 33.500011 PSU. The maximum value spread to a radius of 1000 m from the outfall point

Table 6
Characteristics of wastewater quality in the balikpapan bay sea
Prediction of distribution patterns/zone of initial dilution)

| No. | Parameter | Unit | Environmental Baseline | | Increase (+) of Parameter Concentration based on Distance Distribution (m) | | | | Environment Quality Standard |
|---|---|---|---|---|---|---|---|---|---|
| | | | Mak. | Min. | 250 | 300 | 500 | 1000 | |
| 1. | pH | - | 8.12 | 8.01 | | | | 0.000074 | 6.5-8.5 |
| 2. | TSS | mg/L | 65 | 16 | 0.0022 | - | - | 0.0008 | 80 |
| 3. | BOD | mg/L | - | - | 0.0025 | - | 0.001 | - | - |
| 4. | COD | mg/L | - | - | - | 0.01 | - | 0.0025 | - |
| 5. | Ammonia | mg/L | 0.03 | <0.01 | - | 0.0003 | - | - | 0.3 |
| 6. | Oil and Grease | mg/L | <5.0 | <5.0 | 0.0003 | - | - | - | 5 |
| 7. | Salinity | % | 25 | 25 | - | - | - | 0.00011 | Natural |
| 8. | TOC | mg/L | - | - | - | 0.002 | - | | - |
| 9. | Total Coliform | Nos/100 ml | <1.8 | <1.8 | - | 0.2/1000 | - | 0.02/1000 | 1000 |

(north and south), and the salinity concentration decreased closer to the natural value as the distance from the outfall point increased. Referring to PP No.22 of 2021 Appendix VIII, namely the Sea Water Quality Standard for ports regarding salinity, which is required to be < 5% of natural salinity, it can be said that the increase in concentration that occurs by 0.00011 PSU or 0.00033% of the natural salinity value is very small and meets the required value.

**Total Organic Carbon (TOC)**

The increase in TOC concentration due to the entry of Fuel Terminal wastewater into seawater bodies is shown in Figure 21 and 22 for the west and east monsoons, respectively. Based on this figure, the maximum contribution of liquid waste to increasing the TOC parameters in marine waters reaches 0.01 mg/l. The increase in TOC concentration was very small, and the concentration decreased with increasing distance from the discharge point. At a radius of > 300 m, the TOC increase decreased to 0.002 mg/l.

**Total Coliform**

For the total coliform parameter, the maximum concentration increase was 0.2/1000 ml at a radius of 300 m (north and south), as shown in Figure 23 and 24, respectively.

This value still meets the standard criteria for seawater quality in ports according to PP No. 22 of 2021 Appendix VIII, namely, seawater quality standards for ports with a value of 1/1000. In addition, similar to the other parameters, the total coliform concentration decreased with increasing distance from the discharge point. At 500 m (north and south), the concentration was 0.02/1000 ml.

The distribution pattern of all waste parameters follows the dominant current pattern, which tends to be influenced by tidal phenomena: during high tide, water masses move into the bay area (to the north), while during low tide conditions, they move out of the bay towards the open sea (south). The concentration of each parameter decreased as the distance from the outfall point increased, and the concentration of each parameter was influenced by tidal conditions. In this case, the concentration of waste parameters is higher under low-tide conditions because the mass volume of seawater, which acts as a solvent, is smaller than that under high-tide conditions.

## CONCLUSION

Based on the results of the waste parameter distribution model, it can be concluded that all parameters, including pH, TSS, BOD, COD, ammonia, fatty oil, salinity, TOC, and total coliforms, met seawater quality standards both at high and low tide conditions in the West and East Monsoon based on Government Regulation No.22 of 2021 concerning the Implementation of Environmental Protection and Management Appendix VIII for ports. The concentrations of pollutant parameters have a distribution distance pattern that varies from 250 m, 300 m, 500 m, to 1000 m, considering the conditions of the West and East monsoons. The following are the characteristics of wastewater in receiving water bodies based on distribution predictions. In Table 6, by considering the conditions of the initial environmental parameters (TSS parameters), the conditions of surrounding industrial activities, and the results of predictions (modeling) based on distance, the zone of initial dilution that is expected to be impacted by wastewater discharge into the sea can be determined, namely at a distance of 250 m from outfall 1 and outfall 2.

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## GLOSSARY OF TERMS

| Symbol | Definitions | Unit |
|---|---|---|
| | Degree celcius | °C |
| | Meter | m |
| | Miligram per liter | mg/l |
| | Most Probable Number per 100 mililiter | MPN/100 ml |

| Symbol | Definitions | Unit |
|---|---|---|
| | Quantitative measure of the acidity or basicity of aqueous or other liquid solutions | pH |
| | Total Suspended Solid | TSS |
| | Biological Oxygen Demand | BOD |
| | Chemical Oxygen Demand | COD |
| | Total Organic Carbon | TOC |
| | Meter per second | m/s |

## REFERENCES

Abuhasel, K. et al. (2021). Oilywastewater treatment: Overview of conventional and modern methods, challenges, and future opportunities. Water (Switzerland), 13(7). https://doi.org/10.3390/w13070980

Abdurrojaq, N. et al. (2022). The Effect of Methanol-Gasoline (M20) And Ethanol-Gasoline (E20) Blends on Material Compatibility. Scientific Contributions Oil and Gas, 45 (2) pp., 87-94. https:// doi.org/10.29017/SCOG.45.2.966

Adetunji, A. I., & Olaniran, A. O. (2021). Treatment of industrial oily wastewater by advanced technologies: a review. In Applied Water Science (Vol. 11, Issue 6), Springer Science and Business Media Deutschland GmbH. https://doi.org/10.1007/s13201-021-01430-4

Arina, H., & Nasikin, M. (2022). Enhancement of Flow Properties Biodiesel Using Sorbitan Monooleate. Scientific Contributions Oil and Gas, 45 (3) pp., 143-152. https://doi.org/10.23327/SCOG.45.2.34232.

Ainuddin, & Suryadilaga, M. A. (2021). Oil and Gas in the Dynamics of Time and Development, Scientific Contributions Oil and Gas, 44 (2) pp., 153-159.

Chkara, K., & Seghiouer, H. (2020). Criteria to Implement a Supervision System in the Petroleum Industry: A Case Study in a Terminal Storage Facility. Advances in Science, Technology and Engineering Systems Journal. vol. 5, no. 5, pp. 29-38. DOI: 10.25046/aj050505.

Kidung, B. W., Elis, I., & Indra, B. P. (2012). Kajian Pola Arus Perairan Teluk Lampung Menggunakan Pendekatan Model Hidrodinamika 2-Dimensi DELFT 3D. JOURNAL OF OCEANOGRAPHY, Volume 1, Nomor 2, Tahun 2012, Halaman 170

Lareno, B. (2015). Analisa Dan Perbandingan Akurasi Model Prediksi Rentet Waktu Arus Lalu Lintas Jangka Pendek. CSRID (Computer Science Research and Its Development Journal), 6(3), 148. https://doi.org/10.22303/csrid.6.3.2014.148-158

Octaferina, A. R., & Prasetya, F. V. A. S. (2021). Kajian Karakteristik Pasang Surut di Perairan Teluk Balikpapan Menggunakan Metode Admiralty. Buletin Poltanesa, 22(1). https://doi.org/10.51967/tanesa.v22i1.474

Petroleum Industry Wastewater Advanced and Sustainable Treatment Methods. (n.d.).

Panda, U.S. et al. (2015). Hydrodynamics and Water Quality in Chilika Lagoon - A Modelling Approach. 8th International Conference on Asian and Pacific Coasts (APAC 2015), Jurnal Procedia Engineering No.116, hal. 639-646.

Pond, S. & Pickard, G.L. (1983). Introductory dynamical oceanography. 2nd Edition, Pergamon Press, Oxford.Wardhana, G. S. et al. (2021). Algoritma Komputasi Machine Learning untuk Aplikasi Prediksi Nilai Total Organic Carbon (TOC). Lembaran Publikasi Minyak dan Gas Bumi, 55 (2) pp., 75-87.

Yusuf, A., & Tjandrasa, H. (2013). Prediksi Nilai Dengan Metode Spectral Clustering Dan Clusterwise Regression. Jurnal Simatec, VIII(1), 39–45.