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# Modeling River Water Levels in Tidal Swamp Areas using HEC–RAS to Determine the Hydrotopography of Tidal Farmland

Faiz Afnan Nurrahman[1,✉], Chandra Setyawan[1], Hanggar Ganara Mawandha[1]

[1] Department of Agricultural and Biosystem Engineering, Faculty of Agricultural Technology, Gadjah Mada University, Yogyakarta, INDONESIA.

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Corresponding Author:
✉ faiz.afnan.n@gmail.com
(Faiz Afnan Nurrahman)

**ABSTRACT**

*Swamp land is a natural resource that can be utilized to improve community welfare, because swamp land is one of the potential natural resources and can be used as agricultural land development. The aim of this research is to analyze the tidal water movement patterns of rivers and channels in the swamp irrigation area of Palingkau. The stages in this research included the installation of an Automatic Water Level Recorder (AWLR) to collect real-time water level data, then modeling the tidal movement of river water level using HEC–RAS modeling. The results of this research showed that the pattern of tidal water flow movement in the swamp irrigation area of Palingkau is diurnal tide, characterized by the existence of one high tide and one low tide in one day. Furthermore, HEC–RAS modeling can be used to describe the tide of water levels in the swamp irrigation area of Palingkau. Validation of the HEC–RAS model shows that the tidal flow modeling simulation is good and very suitable for use. Based on the hydrotopography class, the land at the research location is classified into 3 classes, namely hydrotopography classes of B, C, and D.*

## 1. INTRODUCTION

The territory of Indonesia geographically consists of thousands of islands connected by oceans. One type of land that is still possible to be developed for agricultural purposes is swamp land. In Indonesia, the term swamp has been agreed upon in two senses, namely tidal swamp and lowland swamp. Swamps spreading across Sumatra, Kalimantan and Papua are potential to be explored for farm purposes (Mulyani & Sarwani, 2013; Pujiharti, 2017). Swamp lands can be utilized to improve people welfare, because tidal swamp and lowland swamp lands are one of the natural resources that are very potential and their locations are spread almost throughout Indonesia. Some works reported that rice yield in swamp lands can be improved using new, superior swamp rice varieties (Suparwoto, 2019; Helmi 2019). Utilization of swamp areas, especially for agricultural purposes, is one strategy to meet the need for irrigated land, the area of which is currently not growing and even tends to decrease from year to year.

Indonesia has very large swamp land, the total area of swamp land in Indonesia is 34.12 million hectares consisting of 8.92 million hectares of tidal swamp land and 25.2 million hectares of lowland swamp land. The area of swamp land that is potentially available for the development of agricultural crops covers an area of 7.58 million hectares (BBSDLP, 2015). The contribution of swamp land to national rice production is still very low. This is because the area of swamp land used for rice farming is still very small, in addition to the very low productivity of rice in swamp land which averages less than 4 ton/ha. Kementerian Pertanian (2015), stated that of the total national production of 62.56 million tons of dry harvested grain, the contribution from swamp land only reached 1 – 1.5 percent. This means that rice production from swamp land is only around 600,000 - 700,000 tons per year.

In this current work, a study was conducted on the movement of river water regarding the effect of river water levels on swamp land around the river basin. The type of swamp land chosen in this study is tidal swamp land, which means that water flow of the river in the tidal swamp area has two directions following the high tide and low tide of sea water. The movement of river water levels can be analyzed using HEC–RAS (Hydrologic Engineering Center-River Analysis System) modeling (More *et al*., 2024) and produces a simulation of river water level movements in tidal swamp irrigation areas. The HEC-RAS method has the advantage of producing river geometry using spatial data and is very useful for canals with limited data (Ismail *et al*., 2020). Research on hydraulic models of an irrigation system using the HEC-RAS model is still very limited (Shahrokhnia & Javan, 2005). The simulation results of river water level movements from the HEC–RAS modeling were then studied and analyzed further and associated with swamp land around the river basin. The purpose of this research is to examine the relationship between the influences of river water level and tidal swamp land conditions, especially categorizing swamp land according to the hydrotopographic class of land around the river basin.

## 2. MATERIALS AND METHODS

### 2.1. Research Time and Location

This research used primary and secondary data where primary data collection was carried out from October 2020 to March 2021. The research location was in the Swamp Irrigation Area of Handil Rakyat Palingkau, located in Kapuas Murung District, Kapuas Regency, Central Kalimantan Province (2°46’43.94” to 2°49’46.79” S and 114°32’33.15” to 114°34’19.90” E). The elevation of the land was in the range of 0 – 20 m above sea level with a slope of 0 – 8% and was an area affected by the tide of sea water, so that the area has a fairly large potential for flooding due to overflowing sea water. Kapuas Murung District has 23 villages, but only 3 villages were included as the research location areas, namely Muara Dadahup, Mampai, and Tajepan with a total area of 15,016 ha. The research locations were directly adjacent to the Kapuas Murung River with area of 2,330 ha as shown in Figure 1.

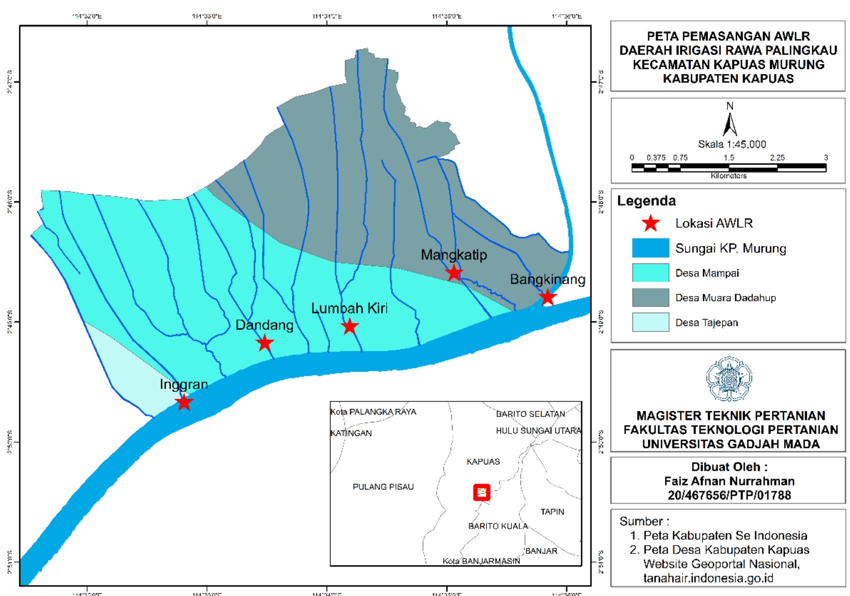

Figure 1. Research location with installation points for AWLR tools

### 2.2. Tools and Materials

The tools used in this research included the Automatic Water Level Recorder (AWLR) to measure water level automatically. This tool was chosen because it has the advantage of being able to record changes in water levels in real time so that the maximum and minimum water levels can be obtained. The AWLR used in this study was assembled with the power used coming from batteries and solar panels. In addition to primary data (water level), this study also used secondary data, including the geometry data of the Kapuas Murung River and the primary channel (locally called ”handil”) at the locations where the AWLRs were installed. All of the data was then processed using HEC–RAS software version 4.10 to create a water level modeling.

### 2.3. Stages of Research

#### 2.3.1. Installation of the AWLR Tool

A total of 5 AWLRs were installed in 5 handils, namely Handil Bangkinang, Mangkatip, Lumbah Kiri, Dandang, and Inggran (Figure 1). Handil Bangkinang was upstream of the research area, while Handil Inggran was downstream. The tools installed in the upstream and downstream areas were used as the input data for hydraulic modeling using HEC–RAS, and the other three in the middle areas were used for model validation. All AWLRs weare installed above the water surface, and the height of tools was measured based on the specified reference benchmark. The elevation measurement and installation of AWLR tools was portrayed in Figure 2.


Figure 2. Elevation measurement and installation of AWLR tools and illustration to determine NBA

#### 2.3.2. Water Level Measurement

Water level measurement is needed to determine the water level in the channel against sea water. In this way, the tidal pattern of water in rivers and channels can be determined. The data generated from the water level measuring device is the distance between the water surface and the AWLR measuring device, which is referred to as the Instrument Reading Value (NBA). Water level (TMA) is obtained from the difference between the Instrument Installation Height (TPA) and NBA as in Equation (1). The TPA value is measured from the zero reference point, namely the Mean Sea Level (MSL) which is the average sea level during a certain period and is used as the zero reference point for measuring height on land. An illustration of the AWLR installation is presented in Figure 3. Water level elevation data collection in this study was carried out for 14 days continuously at five different locations, with a data collection interval of every 60 min.

$$\text{TMA} = \text{TPA} - \text{NBA} \tag{1}$$

#### 2.3.3. Modeling for Tidal Movements of River

Tidal modeling of river water level was carried out using HEC–RAS 4.10 software. The input used for modeling using HEC–RAS was channel geometry data, boundary conditions that use measurement data of water level movement in the upstream and downstream parts of the river. In this modeling there were 3 stages of analysis, namely channel cross-section analysis, XS Interpolation analysis, and geometry model analysis. The results obtained from modeling using HEC–RAS was simulation of water level movement in river and channel in the research location area.

**Channel Cross-Section Analysis**

The secondary data used to create the cross-sectional shape of the river and channel for the tidal flow modeling was gained from PT. Virama Karya based on the actual shape of the river and channel. The channel cross section was analyzed using HEC–RAS software version 4.10. The analysis was carried out by selecting *Add a new Cross Section* in the *Geometric Data* window, then determining the *River Sta* of the channel cross section starting from the largest to the smallest *River Sta* points which is sorted from the upstream to the downstream of the channel. The next step was to enter the X-axis (station) and Y-axis (elevation) data in the cross section coordinates column. The X-axis was determined based on the width of the channel cross section, while the Y-axis was based on the elevation of the channel base. In the *Manning's n Values* column , it was filled with the roughness value adjusted to the existing channel conditions. In this study the natural channel was overgrown with grass and the roughness value was in the range of 0.030 to 0.035 (Fadilah *et al*., 2021). The next stage was to select the channel side edge boundary inputted in the *Main Channel Bank Stations* column. The product of this analysis is a cross-sectional image of the channel as in Figure 3.

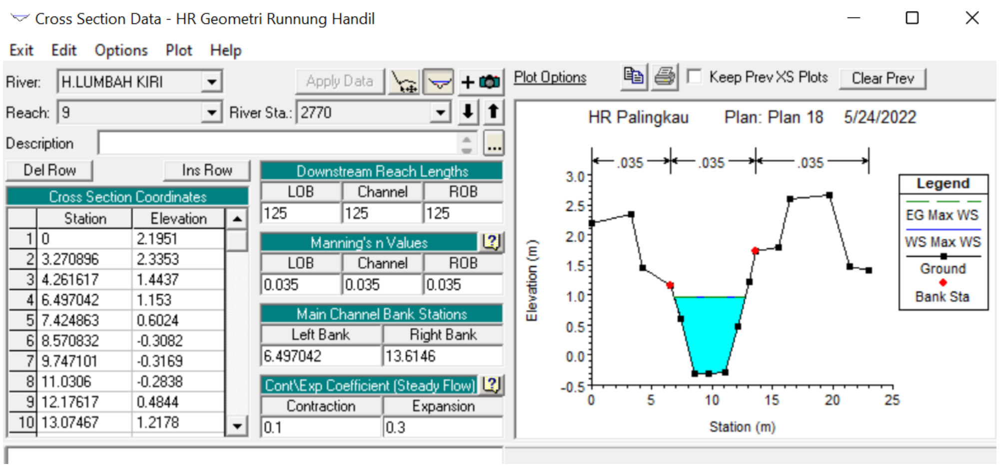


Figure 3. Example of channel cross-sectional analysis

**XS Interpolation Analysis**

The XS Interpolation analysis is a method used to find the station point value (X-axis) and elevation (Y-axis) of a channel cross-section located between two points of the channel cross-section where the X-axis and Y-axis values at both points of the channel cross-section are already known. The XS Interpolation analysis was carried out using the HEC–RAS software. This XS Interpolation was carried out to predict the shape of the channel cross-section at a location with no data, because no measurement of the cross-section profile was carried out at that location. If this channel cross-section interpolation analysis is not carried out, the tidal flow simulation in the channel can still be carried out, but the results of the tidal flow simulation obtained are greatly different from the actual conditions.

**Geometry Model Analysis**

The channel profile data in this study was secondary data, including data on channel width, channel length, and channel depth which were then combined into one to form a channel cross section. The cross-sectional shape of each channel was combined and analyzed into a geometric model. This geometric model was obtained from all channel profile data analyzed using the HEC–RAS software version 4.10. The geometric model analysis as the basis for tidal flow simulation was carried out to obtain channel model layout that is in accordance with actual geometric conditions.

**2.3.4. Modeling Validation**

Model validation was carried out to determine the correlation between the water level elevations resulted from the model simulation and those of measurement. Good modeling produced the water level values that are close to the observed values. If the validation get good results, then the model is suitable for use. In case that the results of model validation is not good, then it has to be recalibrated until good validation results are obtained (Brunner *et al*., 2018). The validation method used in the modeling simulation included the values of MSE (Mean Square Error), RMSE (Root Mean Square Error), and MAPE (Mean Absolute Percentage Error). MSE is the average of the squared error values between the observed values minus the values resulting from the modeling, while RMSE is the root of the MSE value (Chicco *et al*., 2021). The MAPE is a statistical measurement of the accuracy of the predicted values in modeling against observations. This MAPE method provides information on how much the percentage error value of the modeling results is compared to the actual value of the observation results. The smaller the percentage error value, the more accurate the modeling results are (De Myttenaere *et al*., 2016). The MSE and RMSE are used to evaluate models and check the deviation values in river water level elevations resulting from modeling, if the MSE and RMSE values are low or closer to zero, the results of the modeling are more accurate and good (Chai & Draxler, 2014). In this study, the values of MSE, RMSE, and MAPE are based on three primary channels or handils, namely Handil Mangkatip, Lumbah Kiri, and Dandang.

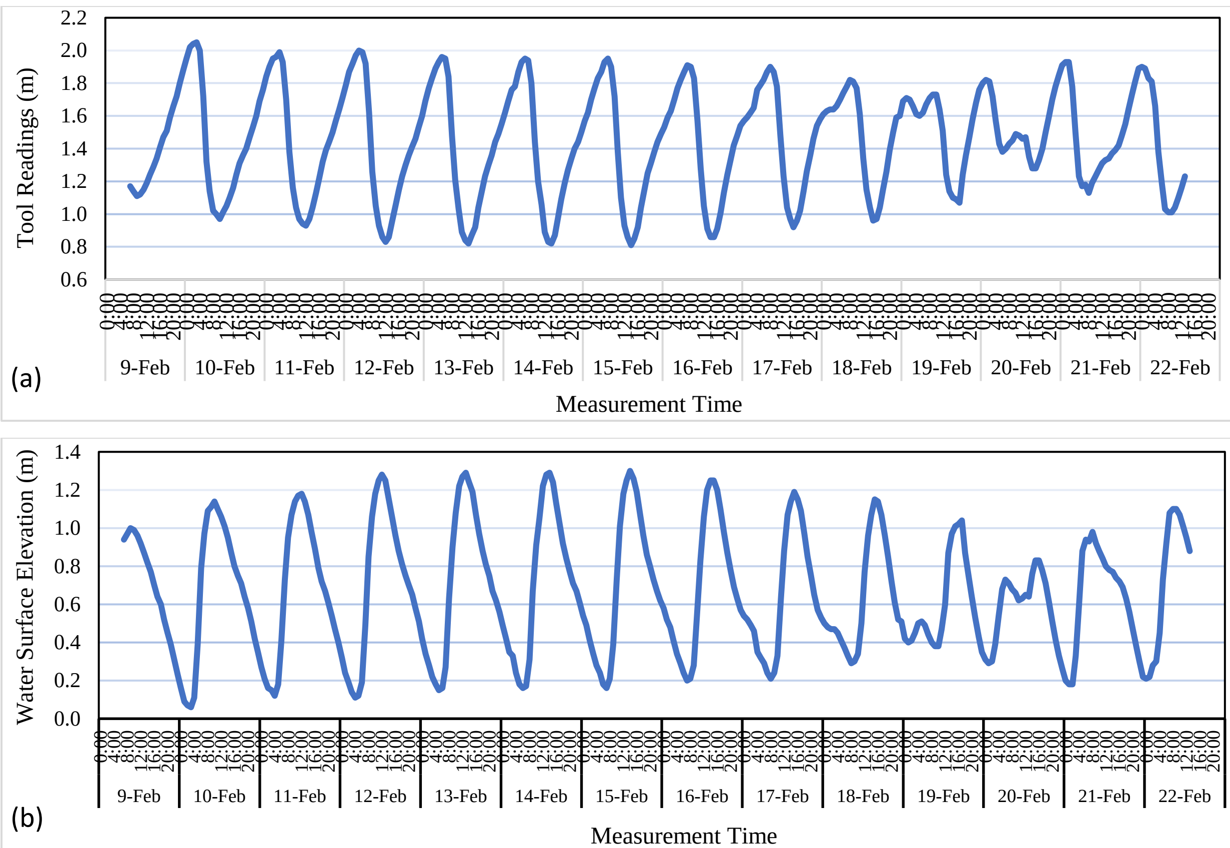


Figure 4. Measurement graphs resulted in Handil Bangkinang: (a) Instrument reading (NBA), and (b) Water level elevation (TMA)

## 3. RESULTS AND DISCUSSION

### 3.1. Results of AWLR Readings and River Water Level Elevation

#### 3.1.1 Upstream Section

Figure 4 shows a graph of the results of the measuring device readings during observations in Handil Bangkinang. Water level elevation measurement in Handil Bangkinang is very important and is one of the keys to the success of the model. This data is input or upstream boundary in the tidal modeling of river water levels using HEC - RAS. Measurement errors can occur due to wood or garbage floating on the water surface during data recording because the measuring device sensor will read the distance between the device and the surface of the wood or garbage which results in incorrect readings. This case was not found during the study.

The highest water level in Handil Bangkinang was 2.05 m which occurred on February 10, 2021 at 03.00, and the lowest value was 0.81 m on February 15, 2021 at 14.00. The high reading value from the measuring instrument indicates the lowest tide that occurred in the channel. Conversely, the lowest value on the measuring instrument indicates the highest tide that occurred in Handil Bangkinang as can be observed in Figure 7. For example, on February 10, 2021 at 03.00, the highest reading value of the instrument (NBA) was recorded (2.05 m), which means the lowest water level elevation (TMA) or the lowest tide. The installation elevation of the AWLR instrument (TPA) in Handil Bangkinang is 2.11 m and from Equation (1) the TMA is 0.06 m.

Based on the tidal graph, it can be concluded that the type of tide that occurs in Handil Bangkinang is a Mixed Tide because on average there is one high tide and one low tide (Diurnal Tide) in one day, but there was a Semidiurnal Tide on February 19 and 20, 2021 where there were two high tides and two low tides in one day with different heights and times. This is because the connecting line between the earth and the moon forms a 90° angle to the earth's axis of rotation. With these conditions, on the surface of the earth facing the moon there are two high tides and two low tides with different heights and times (Widyantoro, 2014). On February 12, 2021, there was a full moon or spring tide where the largest tidal interval was 1.17 m with a peak tide of 1.28 m and the lowest tide of 0.11 m. This happens because the Earth, Moon, and Sun are in a straight line. Meanwhile, the quarter tide occurred on February 20, 2021 when the Sun and Moon were perpendicular to the earth. At that time, the smallest tidal interval was 0.54 m with the peak tide at an elevation of 0.83 m and the lowest tide at an elevation of 0.29 m.

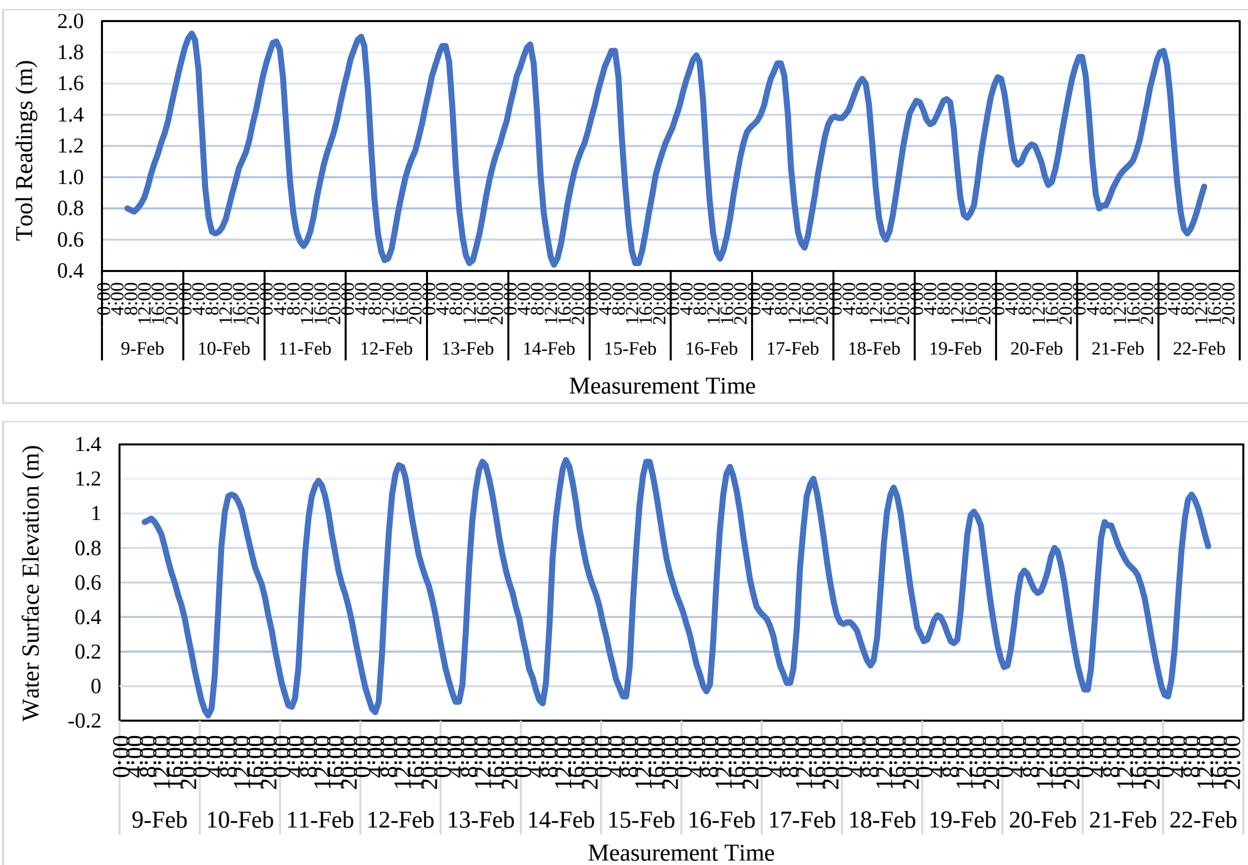


Figure 5. Measurement graphs resulted in Handil Inggran: (a) Instrument reading (NBA), and (b) Water level elevation (TMA)

### 3.1.2. Downstream Section

Figure 5 shows the graph of the NBA and TMA in Handil Inggran. AWLR data and river water level measurements in the downstream are as important as the upstream, because they will be used as input data for the downstream boundary, thus greatly influencing the success of the tidal hydrological model of river water levels. Measurements were carried out in the Handil Inggran channel located in Kapuas Murung District, Kapuas Regency, Central Kalimantan Province. The highest NBA data in Handil Inggran of 1.92 m occurred on February 10, 2021 at 02.00. While the lowest NBA of 0.44 m occurred on February 14, 2021 at 13.00. The elevation height of the measuring instrument installation in Handil Inggran is 1.75 m and is used to calculate the river water level elevation (TMA) according to Equation (1). For example, the highest NBA value of 1.92 m will produce the lowest TMA value of - 0.17 m = (1.92 - 1.75) m. While the lowest NBA of 0.44 m will produce a TMA of 1.30 m = (1.74 - 0.44) m.

Based on the graph in Figure 5, it can be concluded that the tidal type in Handil Inggran is no different from that in Handil Bangkinang. However, there was a difference on February 19, 2021 in Handil Inggran, there was a Semidiurnal tide or two high tides and two low tides, while in Handil Bangkinang there was only one high tide and one low tide or diurnal tide. This difference can occur because the first high tide is only a small tide and cannot reach the location of the equipment installation which is upstream or in Handil Bangkinang.

This tidal push causes the river flow coming from the upstream to be dammed and pushed back upstream. When there is a big tide, this tidal push can reach a distance of 100 km from the sea, but if there is only a small tide, the influence of this tidal push is not far. As happened on February 19, 2021, where the river water level in the downstream part of the research location was still affected by the tide, but in the upstream part of the research location it was no longer affected by the tide (Ngudiantoro, 2009). The full moon tide event in Handil Inggran also occurred on February 12, 2021, where the largest tidal interval was 1.42 m with a peak tide of 1.28 m at 11:00 and the lowest tide of minus 0.15 m occurred at 04:00.

### 3.2. Results of Tidal Modeling using HEC-RAS

Hydraulic simulation modeling is based on the actual existing channel conditions based on measurement results. The channel geometry is shown in Figure 6. The tidal modeling simulation is calibrated with primary data from river water level elevation observations on February 9-22, 2021. The existing simulation of the tidal flow of the river water level aims to determine the capacity of the channel cross-section in receiving and flowing water discharge during the ebb and flow, so that the channel water level can be identified as the minimum and maximum water elevations due to the ebb and flow events in the channel. The first stage in the flow simulation is to enter geometric data such as the channel cross section and the channel longitudinal section. The data is entered according to the measurement data at the research location. In this channel geometry analysis, the Manning's roughness coefficient *n* value is also included according to the results of the investigation in the channel. This coefficient is a function of the channel wall material, where all channels are classified as natural channels with the category of floodplains overgrown with short grass and tall grass so that they have a roughness coefficient *n* value of 0.035 (Fadilah *et al*., 2021).

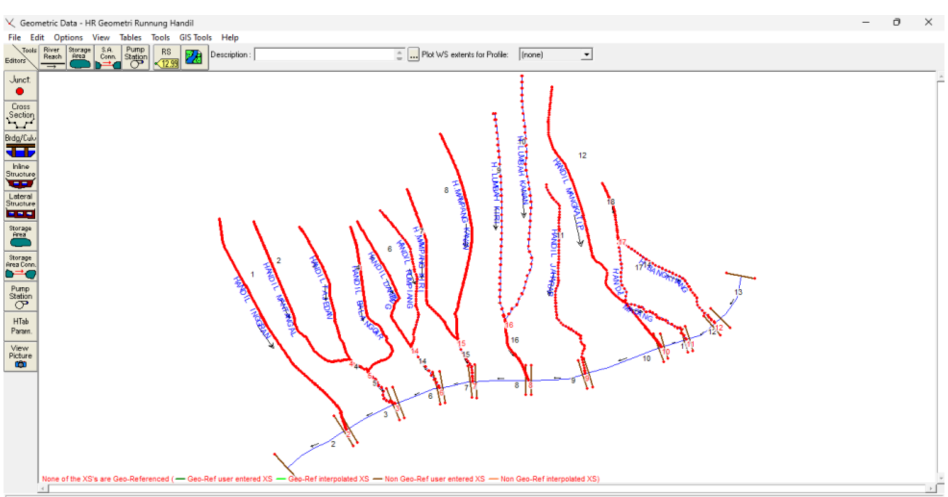


Figure 6. Channel geometry in modeling using HEC–RAS method

Tidal flow modeling using HEC - RAS in this study was simulated with unsteady flow. This type of flow was chosen to be able to determine changes in flow over time, so that the results of this modeling are expected to describe the tidal events of river water that are close to real events on site. Unsteady flow modeling requires 2 boundary conditions, namely upstream boundary conditions and downstream boundary conditions (Fadilah *et al*., 2021). In this study, upstream boundary conditions use primary data from observations of river water level elevation in Handil Bangkinang for 14 days with data collection every 60 minutes through the new moon phase until after the full moon phase. This water level elevation value is entered into HEC - RAS as a stage hydrograph, because the data used is water level elevation data, if using water flow discharge data, it is entered as a flow hydrograph (Istiarto *et al*., 2014). Meanwhile, the downstream boundary condition uses primary data from observations of river water level elevation in Handil Inggran with the same duration and observation interval. Figure 7 shows the highest tide value at +1.32 m and the lowest tide at -0.23 m.

The HEC – RAS simulation results show that there are several channels that overflow during high tide, but more channels do not overflow even when the highest tide occurs. This overflowing water condition will later be used as a reference for classifying land hydrotopography.

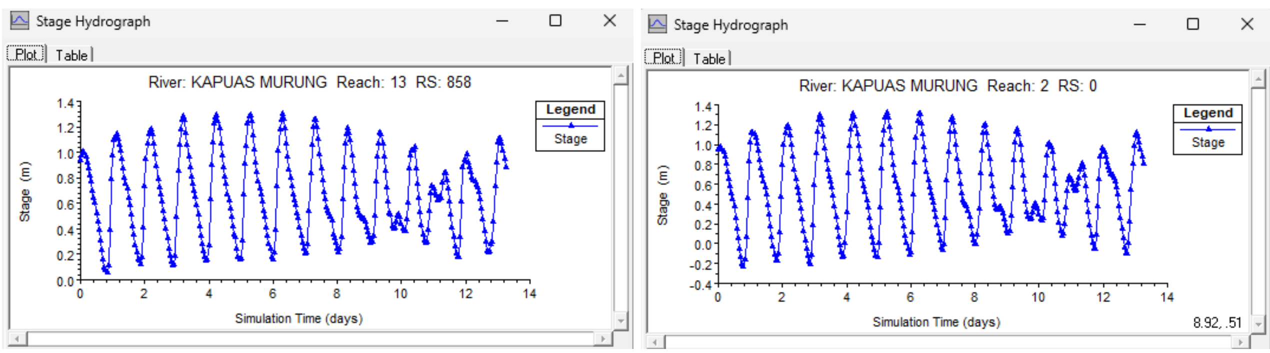


Figure 7. Stage hydrograph display for upstream boundary conditions (left) and downstream boundary conditions (right)

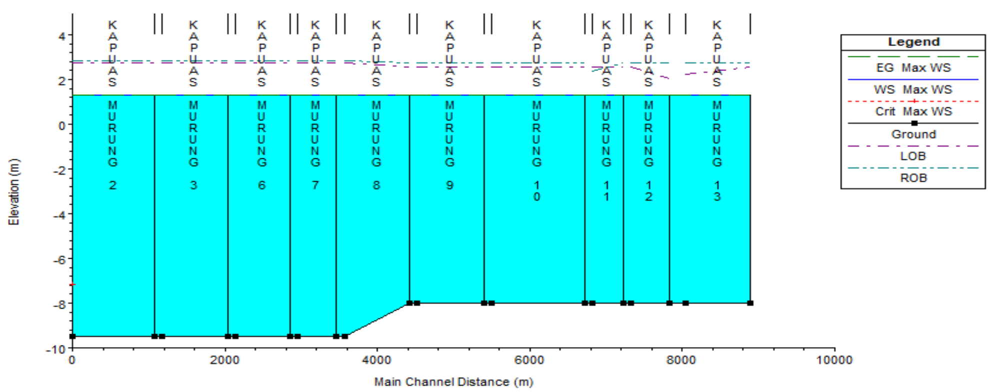


Figure 8. Longitudinal cross-section of the Kapuas Murung River

### 3.2.1. Kapuas River Murung

The modeling simulation using HEC – RAS in the Kapuas Murung River is the downstream boundary of each channel, because each channel empties into the Kapuas Murung River. The ebb and flow of water in this river affects the ebb and flow of water in each channel. Therefore, in this modeling, the Kapuas Murung River is divided into 10 sections or reaches. Each section in this modeling connects the Kapuas Murung River with a channel or handil as shown in Figure 8. The first section named Kapuas Murung 2 connects Handil Inggran with the Kapuas Murung River, which is the downstream boundary. The last section (Kapuas Murung 13) connects Handil Bangkinang with the Kapuas Murung River, which is the upstream boundary.

The cross-section of the Kapuas Murung River at the downstream has a width of 585 m (Figure 9a) at the top and 440 m at the base or riverbed with a depth of 6 m to 9.8 m. At the upstream of the research location, the cross-section of the Kapuas Murung River has a smaller width, which is 510 m at the top of the river and 370 m at the riverbed with a depth of 6 – 8 m (Figure 9b). Modeling simulation using HEC–RAS on the Kapuas Murung River shows that there is no flooding or overflow even during the highest tide.

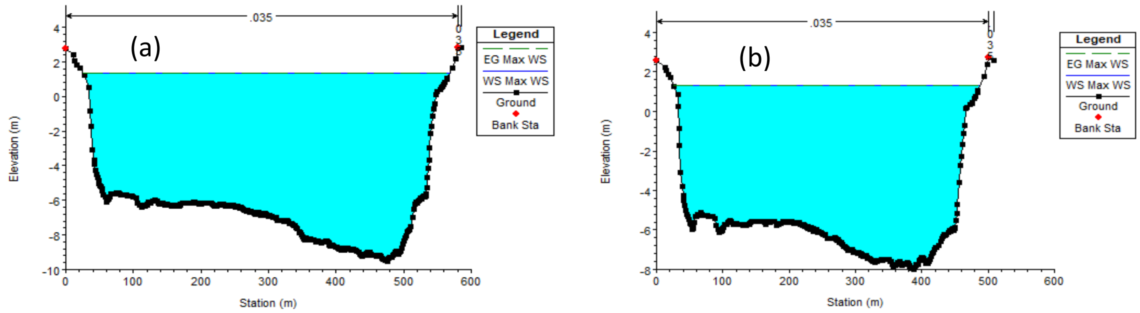


Figure 9. Cross-section of the Kapuas Murung River at the: (a) Downstream, and (b) Upstream

### 3.2.2. Handil Bangkinang

Handil Bangkinang is the upstream boundary in this study. Tidal modeling simulation in Handil Bangkinang is only divided into 1 segment (reach) with a channel length of 2.062 km (Figure 15). The downstream part of Handil Bangkinang is in the Kapuas Murung River, and the upstream part is in Handil Madang sta.22. The cross-section of the existing Handil Bangkinang (Figure 16a) at sta.0 has a width of 15.5 m at the top and 4.6 m at the bottom with a channel depth of 2.65 m to 2.85 m. The cross-section of the channel at sta.20 (Figure 16b) has a width of 19.5 m at the top and 7 m at the bottom of the channel with a channel depth of 1.85 m to 2.25 m. The Handil Bangkinang is a natural channels with Manning's *n* coefficient of 0.035 (Fadilah *et al*., 2021). The modeling simulation on Handil Bangkinang do not show any overflowing water during the highest tide and no dry channel during the lowest tide.

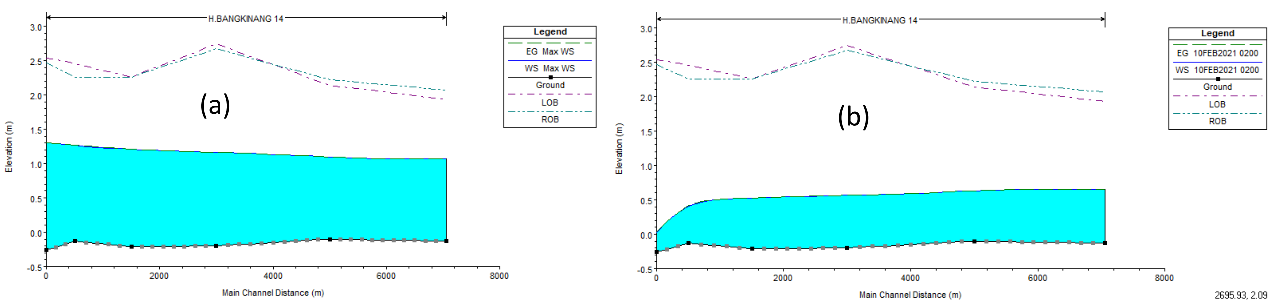


Figure 10. Longitudinal cross-section of Handil Bangkinang during: (a) high tide, and (b) low tide

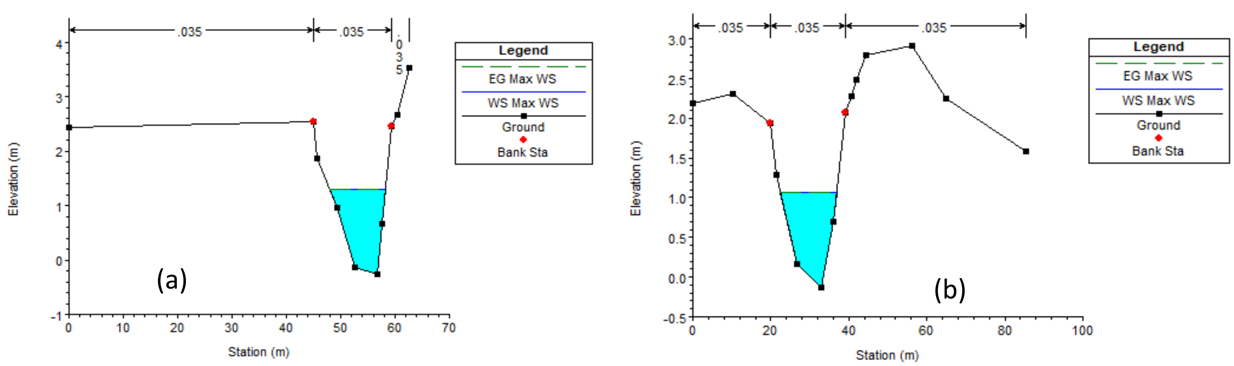


Figure 11. Cross-section of Handil Bangkinang at: (a) Sta. 0, and (b) Sta. 20

### 3.2.3. Handil Dandang

The modeling simulation on Handil Dandang along 2.98 km is divided into 2 sections. The first section is 0.77 km starting from station 0 near Kapuas Murung River to the branching of Handil Rumpiang at station 7+70. The second section is 2.21 km starting from the branching of Handil Rumpiang at station 7+70 to the upstream of Handil Dandang at station 29+80. The longitudinal cross-section of Handil Dandang at high tide is shown in Figure 12a and at low tide is shown in Figure 12b. The cross-section of Handil Dandang at Sta.0 (Figure 13a) has a width of 19.35 m at the top and 6.7 m at the bottom with a channel depth of 2 m to 2.3 m. The cross-section of the channel in the upstream section at Sta.29+80 (Figure 13b) has a width of 7.6 m at the top of the channel and 2 m at the bottom of the channel with a channel depth of 1.7 m to 1.85 m. The modeling simulation of the Handil Dandang show that there is an overflow of water or water puddle in the area around the channel during high tide. This overflow of water inundates the area around the Sta.0 channel (Figure 14b), and also puddles starting from around Sta.10 to Sta.10+50. This modeling also shows that the overflow does not last for a long time, because it will disappear when the water recedes in the channel.

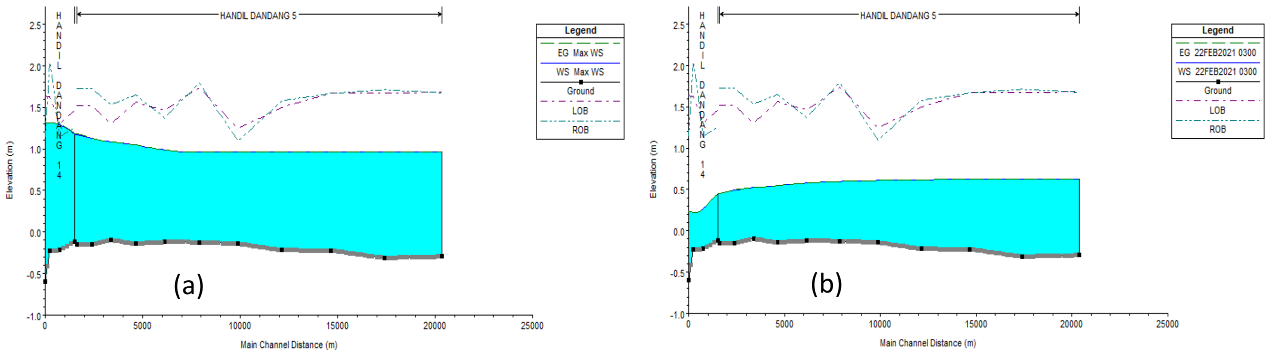


Figure 12. Longitudinal cross-section of Handil Dandang during: (a) high tide, and (b) low tide

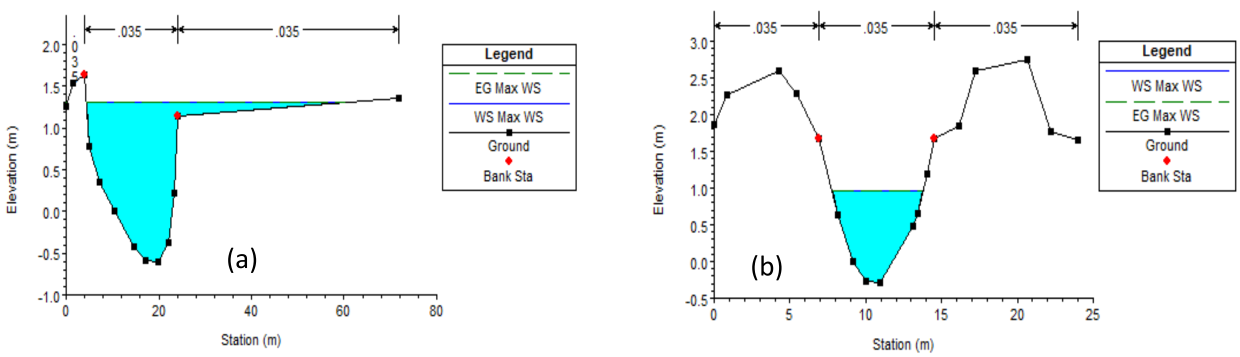


Figure 13. Cross-section of Handil Dandang at: (a) Sta.0, and (b) Sta.29+80

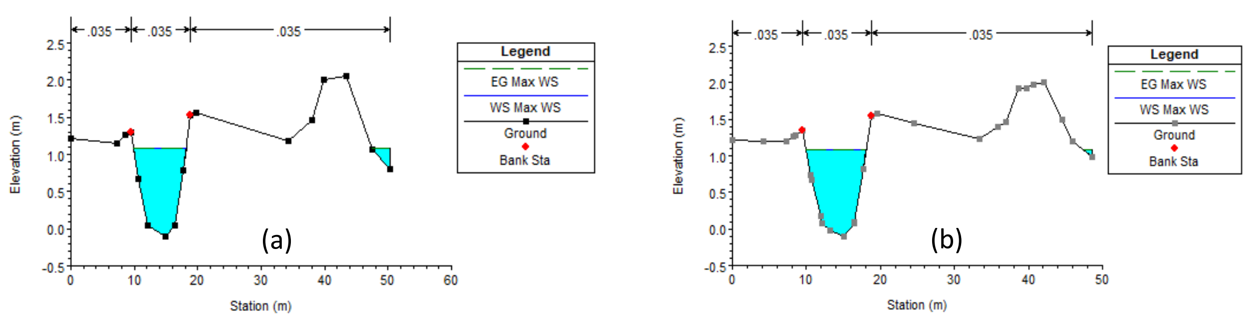


Figure 14. Cross-section of Handil Dandang at Sta. 10 showing (a) the highest water level around the channel and (b) the lowest water level around the channel.

The highest water inundation in the area around Handil Dandang occurs at around Sta.10 with a water level of 0.25 m as shown in Figure 14a. The lowest water inundation occurs around Sta.10+50 with a water level of only about 0.07 m as shown in Figure 14b. The simulation in Handil Dandang do not show any dry channel during the lowest tide.

### 3.2.4. Handil Inggran

The modeling simulation on tidal flow in Handil Inggran was carried out in one 3.85 km long section, because there are no branches or confluences with other handils. Handil Inggran is directly connected to the Kapuas Murung River at Sta.0 and the upstream channel at Sta.38+50. The longitudinal cross-section of Handil Inggran at high tide is shown in Figure 15a and at low tide is shown in Figure 15b. The cross-section of Handil Inggran at Sta.0 (Figure 16a) has a width of 48.5 m at the top and 18 m at the bottom with a channel depth of 2.25 m to 3 m. In the upstream section at Sta.38+50 (Figure 16b) the channel has a cross-section with a width of 10.8 m at the top of the channel and 1.6 m at the bottom of the channel with a channel depth of 1.4 m to 1.65 m.

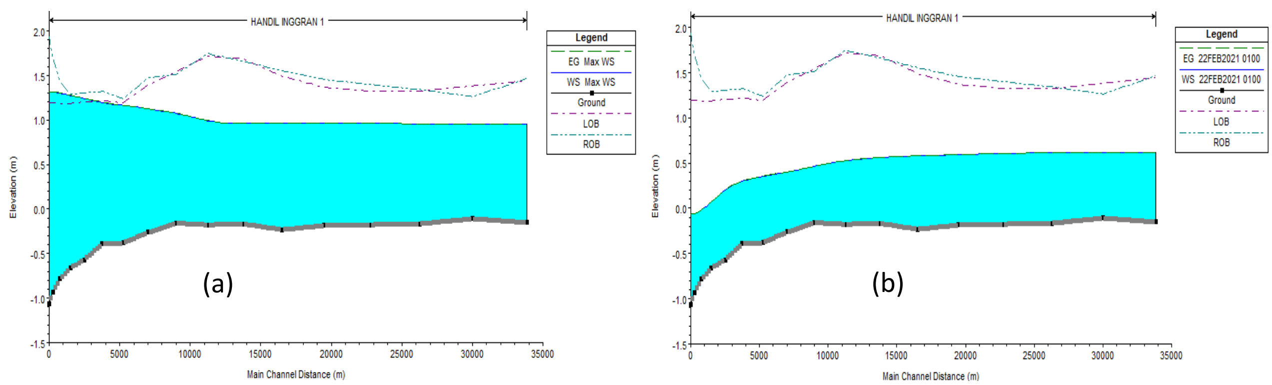


Figure 15. Longitudinal Cross-section of Handil Inggran during (a) high tide and (b) low tide

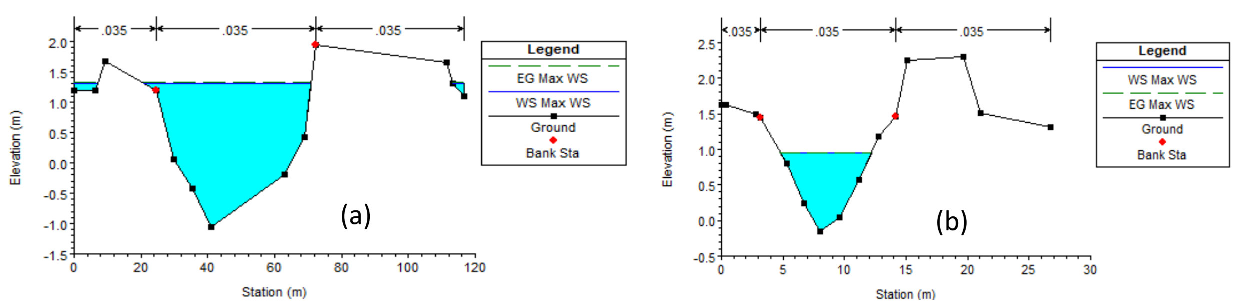


Figure 16. Cross-section of Handil Inggran at: (a) Sta.0 and (b) Sta.38+50

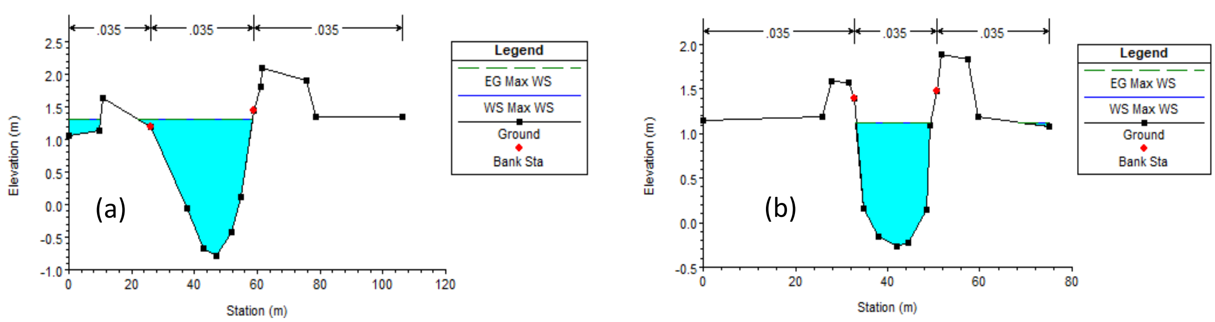


Figure 17. Cross-section of Handil Inggran at: (a) Station 5 showing the highest water level around the channel and (b) at Station 17+50 showing the lowest water level around the channel

The results of the tidal flow modeling simulation in Handil Inggran show that there is an overflow of water or water puddle in the area around the Sta.0 to Sta.1 channels (Figure 17a) which occurs during high tide. The simulation also shows that the overflow of water that occurs around the channel does not last long, and immediately disappears when the water recedes in the channel. Based on the modeling simulation, the highest water puddle in the area around Handil Inggran occurs around Sta.5 with a puddle height reaching 0.23 m (Figure 17a). The lowest water puddle of 0.05 m occurs around Sta.17+50 (Figure 17b). The modeling simulation does not show any dry channels in Handil Inggran during the lowest low tide.

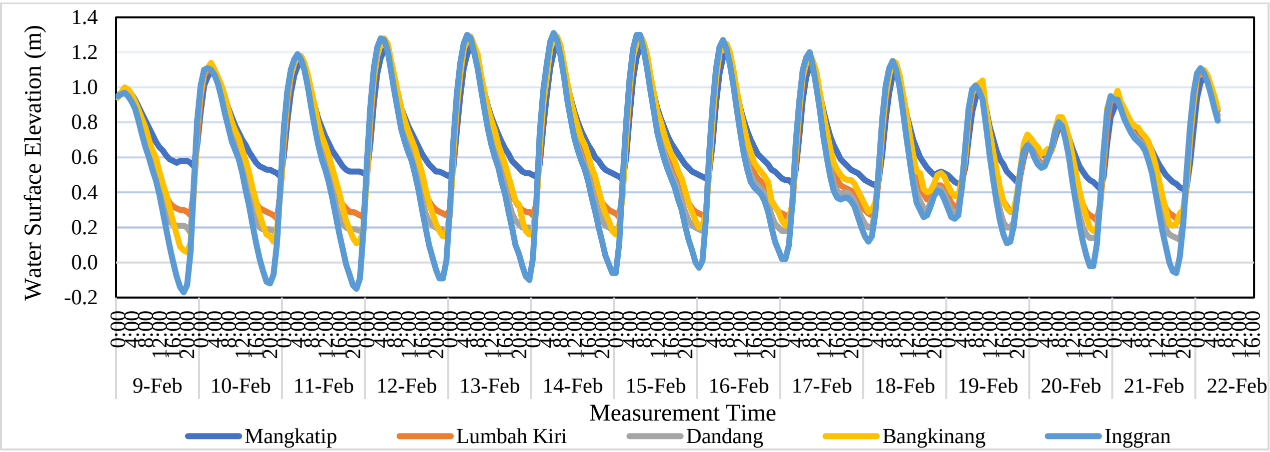


Figure 18. Graph of water level elevation in 5 Handils: Bangkinang, Mangkatip, Lumbah Kiri, Dandang, and Inggran

### 3.3. Model Validation

In this study, observations and measurements of water levels were carried out directly on five channels, namely Handils Bangkinang, Mangkatip, Lumbah Kiri, Dandang, and Inggran as presented in Figure 18. Data from Handil Bangkinang and Handil Inggran were used as input in the HEC–RAS modeling. For model validation, water level data from 3 channels were used, namely Handils Mangkatip, Lumbah Kiri, and Dandang. The validation results of the HEC-RAS model in the Rawa Palingkau Irrigation Area from three channels (Mangkatip, Lumbah Kiri, and Dandang) obtained an average MSE value of 0.016, an RMSE value of 0.121, and a MAPE of 18.57% (Table 1). The MSE and RMSE values are very low (approaching zero), while the MAPE shows a percentage error of <20% so that the results of forecasting the water level of the channel using the HEC-RAS modeling are classified as good and feasible to use. Figure 19 shows a scatter diagram of the water level predicted by the model vs. the direct measurement results. The diagram produces a coefficient of determination ($R^2$) of 0.9488 or 94.88%. This value indicates a high level of model reliability, so the tidal flow modeling simulation using HEC–RAS is good and very feasible (Chicco *et al*., 2021).

Table 1. HEC – RAS Modeling Validation Results

| Handil Name | MSE | RMSE | RRMSE | MAPE |
|---|---|---|---|---|
| Mangkatip | 0.025 | 0.158 | 19.50 % | 19.80 % |
| Lumbah Kiri | 0.013 | 0.114 | 14.80 % | 17.40 % |
| Dandang | 0.0088 | 0.090 | 12.40 % | 18.50 % |
| Average | 0.016 | 0.121 | 15.60 % | 18.57 % |

### 3.4. Hydrotopography of the Palingkau Swamp Irrigation Area

The Palingkau swamp irrigation area is an area that is influenced by the ebb and flow of sea water through the Kapuas Murung River. The hydrotopographic conditions of the land in this irrigation area are used as an initial consideration in making a plan for water management and land management in tidal swamp areas. The Palingkau Swamp Irrigation Area is a development of an agricultural area because more than 75% of the land has been prepared to be used as rice fields.

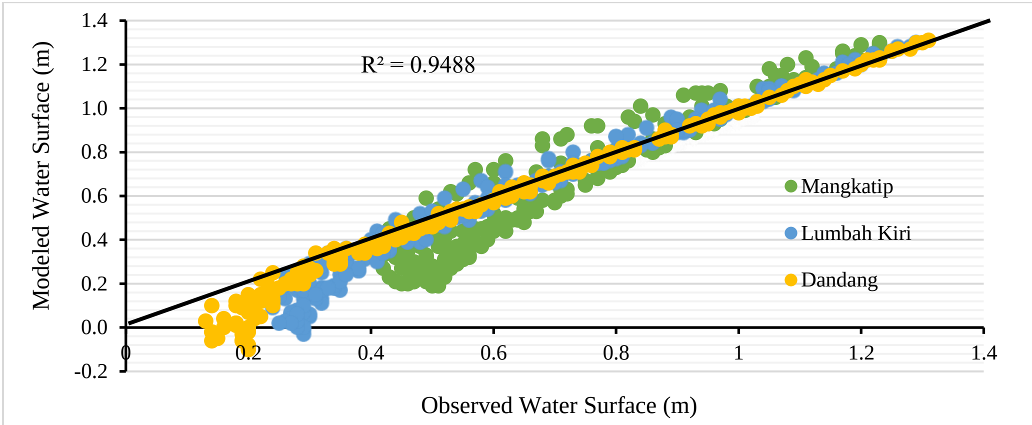


Figure 19. Scatter plot diagram of modeling validation in Handil Mangkatip, Handil Lumbah Kiri, and Handil Dandang

Hidrotopografi lahan didefinisikan sebagai perbandingan relatif antara elevasi permukaan lahan terhadap tinggi muka air yang berada di lahan rawa pasang surut (Herawati et al., 2020). Hasil pengukuran menunjukkan bahwa elevasi permukaan lahan berada pada rentang elevasi mulai dari –1.00 m sampai dengan +3.00 m. Peta topografi lahan Daerah Irigasi Rawa Palingkau disajikan pada Gambar 20. The topographic map need to be compared with the distribution of water level elevation to obtain hydrotopographic land map. The distribution of water level elevation is obtained from the results of modeling using HEC–RAS as in Figure 21 (Ngudiantoro, 2009). The elevation value used to compare the hydrotopography maps is based on the water level distribution data obtained from the HEC–RAS modeling (Kamil *et al*., 2024).

Based on the data on the distribution of water level, it can be concluded that the land surface that has an elevation of less than +0.65 m will always be exposed to water when the tide is high, so that land with a surface elevation of <+0.65 m is included in the class A hydrotopography category, because the land will always be exposed to water when

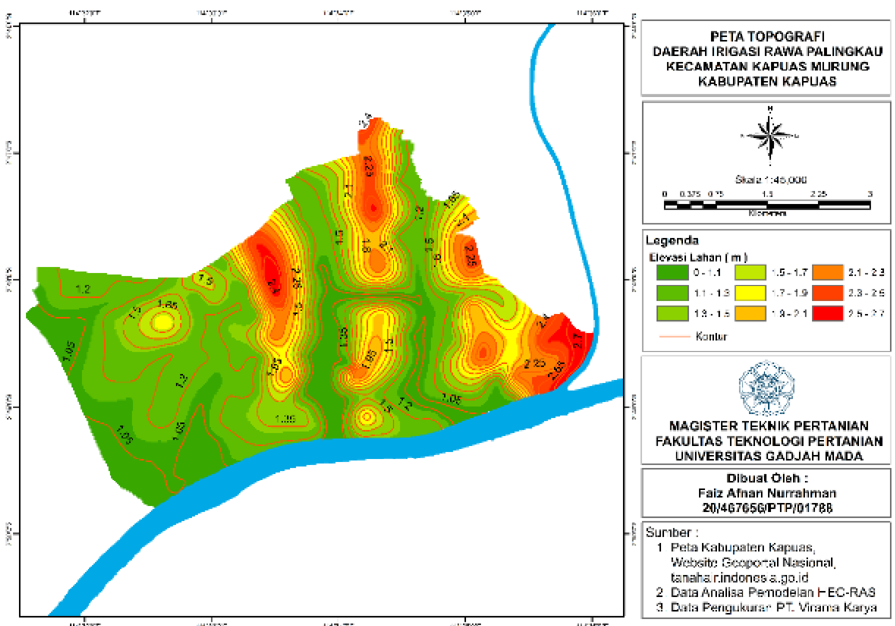


Figure 20. Topographic map of land in the Rawa Banyakkau irrigation area

the tide is high both in the rainy and dry seasons (Euroconsult, 1996). Meanwhile, class B hydrotopography lands have an elevation between the high water surface elevation (Ngudiantoro, 2010), which is between +0.65 m and + 1.4 m. The class C hydrotopography category is land that has a land surface elevation of no more than 50 cm above the water surface elevation when the tide is high, so that class C hydrotopography is land that has a land surface elevation between +1.40 m and + 1.90 m. Class D land hydrotopography is land that has a land surface elevation of more than 50 cm above the water surface elevation when high tide occurs, so that class D hydrotopography is land that has a land surface elevation >+1.90 m. The hydrotopography of class A, B, C, and D land in the Palingkau swamp irrigation area is depicted in the map in Figure 22.

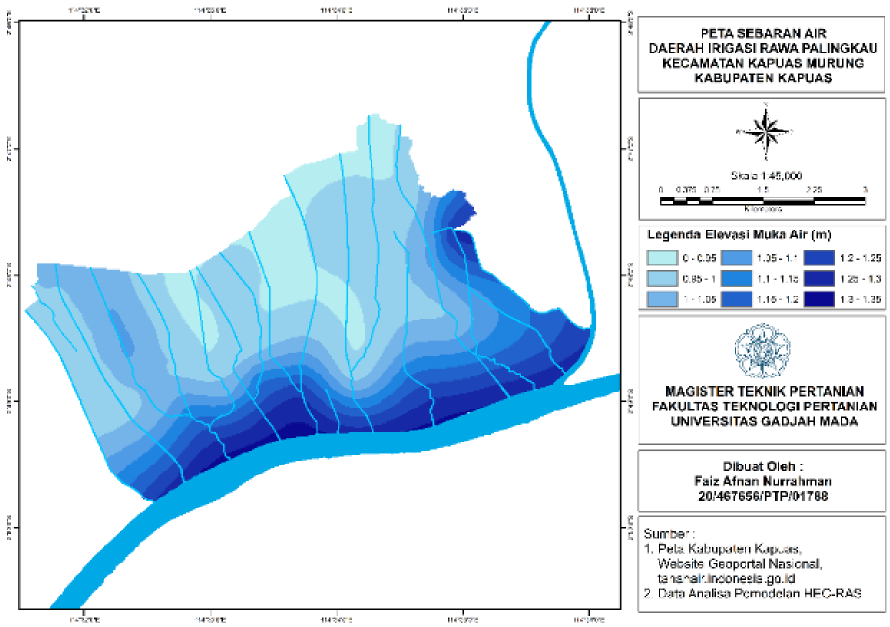


Figure 21. Water distribution map in Palingkau Swamp Irrigation Area

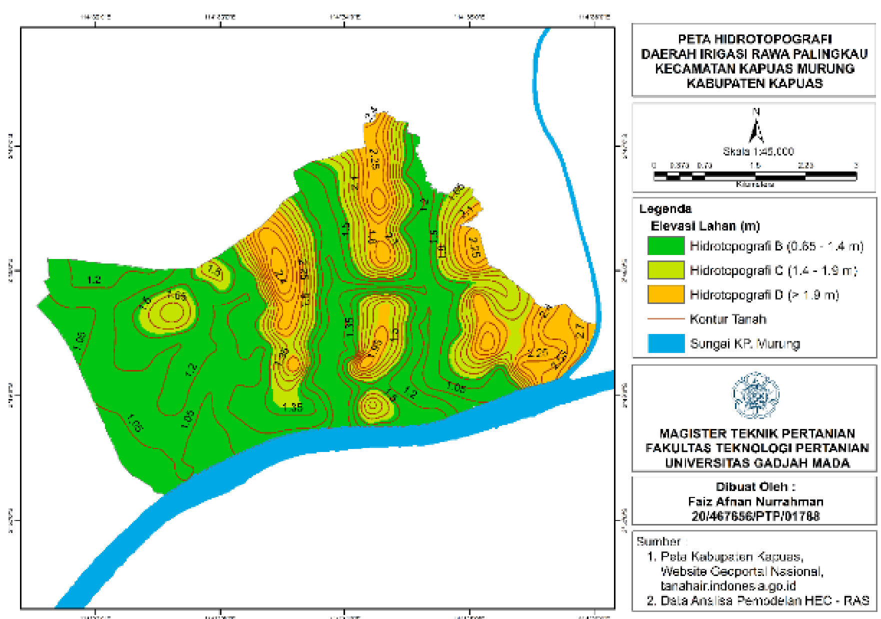


Figure 22. Hydrotopographic map of the Palingkau Swamp Irrigation Area

## 4. CONCLUSIONS

The pattern of tidal water flow in the Palingkau Swamp Irrigation Area is diurnal tide where in one day there is only one high tide and one low tide. HEC–RAS successfully predicts the tidal water flow in the Palingkau Swamp Irrigation Area, proven by the results of the validation of the MSE method model getting a value of 0.016, the RMSE method is 0.121, the MAPE method is 18.57%, RRMSE is 15.60% and the $R^2$ method is 0.9488. The impact of tidal water on swamp land in the Palingkau swamp irrigation area can be divided into 3 categories, namely class B, C, and D land hydrotopography, of which the class B hydrotopography is recommended for agricultural land development.

It is necessary to increase the observation period and measurement of river water levels, it would be better if the observation period includes the rainy season and the dry season, either by taking data separately or continuously for one year. The influence of hydrological factors such as rainfall and conditions during extreme rain on water surface elevation and its impact on swamp land is also important to be analyzed in Palingkau Swamp Irrigation Area.

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