Tidal Analysis for Planning the Tidal Flood Management and the Moveable Weir, Case Study in Parit River, Kawunganten Cilacap

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Abstract: The seawater level always rises globally. Sea level rise has an impact on human life. One of the effects of rising sea levels is the tidal flood which is one of the adverse natural phenomena. Kawunganten District, Cilacap Regency is one of the areas affected by the tidal flood. The construction of the moveable dam is a solution to prevent damage to the region due to tidal flooding. In carrying out dam design planning required accurate tidal data. This study aims to obtain data and analysis of tides along the river to the river mouth. In determining tidal data, observations are made using an automatic survey tool called DIVER. The tidal analysis is done by applying the least square method to obtain the tidal harmonic constant at the study site. Base on observation data for 75 days, the results of tidal data analysis as a reference for planning flood management and moveable. The analysis gives the value of MSL (Mean Sea Level) of 0,996 m, MHWS (Mean High Water Spring) of 1,7 m, MLWS (Mean Low Water Spring) of 0,292 m, HHWS (Highest High Water Spring) of 1,992 m and LLWS (Lowest Low Water Spring) of 0,00 m as elevation reference for the infrastructure development.

1 INTRODUCTION

Indonesia has diverse water characteristics. The diversity of waters in Indonesia is due to Indonesia's geographical condition which consists of various kinds of islands. Flood disaster is one of the disasters that often hit the Indonesian archipelago which has low land elevation. One type of flood that can provide many losses in various aspects is tidal flooding. The parameter that is very influential on the occurrence of seawater is sea level rise (Yudi R. K. et al., 2017).

Cilacap is one of the districts in Indonesia that is vulnerable to the occurrence of tidal flood. This is because the Cilacap area is a lowland area with very slow soil infiltration capability (Yani and Sumunar, 2019). Cilacap Regency is located in Central Java Province. Geographically, Cilacap Regency is on the southern side of Java, which faces the continuation of the Indian Ocean. The Cilacap district area that was harmed due to the tidal flood was Ujungmanik Village, Kawunganten District. This area has a distance of 16,662 m from the mouth of the Cilacap river. The tidal flood that occurred in this region came from the overflow of the Parit river along the Kawunganten district. Tidal floods reduce social and economic activities of the people in Kawunganten sub-district. One of the disturbed community activities is farming due to tidal floods that have risen to the ground causing sea water to damage crops in agricultural and plantation areas. In addition, the access road used by the community to carry out their activities was also affected due to sea level rise reaching the road surface. Housing, places of worship and schools were also affected by tidal flood that came from the overflowing moat river. Flood disasters always have widespread impacts on the destruction of infrastructure, the environment, ecosystems and human life (Salami et al.,2017). High levels of community resilience to flood disasters are represented at low levels of flood risk (Isa et al., 2018).

Floods have given various kinds of adverse effects to the community and therefore preventive measures are needed to reduce these impacts (Subiyakto et al., 2019).To overcome the problem of tidal floods, there are several solutions implemented. The application is done by structural and non-structural methods (Wahyudi N. R. et al., 2019). In solving the problem of tidal flooding that occurred in Kawunganten Village, it is necessary to apply the structural method.

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The structure needed is a polder system and a door that will be a solution to solving this problem. The polder system is effective in reducing the rise in water level due to tidal flooding and can reduce the risk caused by tides. Polder system is a technology in water control that is often applied in various cities with tidal flood problems. To optimize the performance of a polder system, it is necessary to have a good channel for the flow of water (Wahyudi et al., 2019). In the construction of polder systems, several infrastructures are needed which include retention ponds, drainage systems, water pumps, and dams/floodgates (Nugroho et al., 2016). To develop infrastructure to handle tidal floods it needs to be done in cooperation with the management and mitigation of tidal floods (Adi and Wahyudi, 2018).

In addition to building various types of infrastructure, parameters are also needed in planning infrastructure development, so that it can produce optimal and efficient results (Hunter J. R. et al., 2017). By considering tidal parameters, it can determine the number of costs incurred for the construction of the weir and as a reference for the amount of weir needed to overcome tidal floods (Hall et al., 2019). A very important parameter in polder system planning is tidal. Estimated water levels within the tidal range are a suitable tool for environmental management and risk management for tidal flood disasters (Sadeghian et al., 2016). Tides have the most dominant influence on the occurrence of tidal floods in Cilacap. A tide that comes from downstream across the river to the upstream direction. The increase in high seawater is increasing over time due to the influence of global warming that occurs.

This study aims to obtain primary data in the form of tidal conditions along the Parit river and Cilacap waters. The data that has been obtained is analysed to determine the type of tides. Tidal data is calculated and analysed to find important heights needed. Important elevation obtained is adjusted to the weir planning for handling tidal flooding and as a consideration in determining the structure of the weir.

2 METHOD

2.1 Water Level Measurement

Data is collected by using the DIVER survey tool. This tool is equipped with a pressure sensor, so the measurement of water elevation also takes into account air pressure. DIVER is a survey tool applying the principle of measuring water pressure at the location under study (Eijkelkamp, 2016). To calculate the water level, the pressure data are calculated using the following formula:

$$WC = 9806.65 \frac{P_{Diver} + P_{Baro}}{\rho . g} \quad (1)$$

Where WC = Water Column, P = pressure in cmH_2O, g = the acceleration due to gravity (9,81 m/s^2). The water level can be calculated by the following equation:

$$WL = TOC - CL + WC \quad (2)$$

Where WL = water level, TOC = pipe depth, CL = diver depth

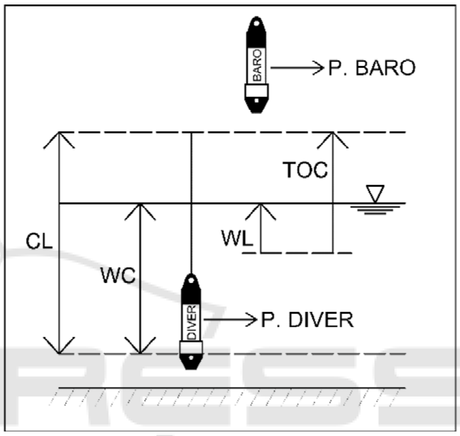

Figure 1: DIVER installation scheme.

2.2 Calculation of Tidal Harmonic Constants

Tidal data is processed using worldtide with the MATLAB programming language (Boon, 2007). In the tidal analysis, the least square method is used. The least-square method is a method for tidal calculations with the principle of minimizing the tidal elevation equation so that a simultaneous equation is obtained. The simultaneous equation is solved using a numerical method to produce harmonic constants (Dalpan and Pratomo, 2015). The least square method is one of the most widely used approaches and continues to be used in the tidal analysis (Foreman et al., 2009). The equation used in the least square method is:

$$h_{(t)} = h_o + \sum_{j=1}^{m} f_i H_j \cos(\varpi_j t + u_j - k_j) \quad (3)$$

Where t = time (in hours), $h_{(t)}$ = predicted water level, h_o = average water level, f_i = nodal correction factor for amplitude, H_j = average amplitude in the nodal cycle (18,6 years), ϖ_j = angular velocity of the tidal component to j, u_j = odal correction factor for the phase, k_j = phase lag between the equilibrium tide at the observation site and the equilibrium tide at Greenwich at 00.00, m = the number of tidal harmonics to be analysed (Williams, 2013).

Harmonic components that have been calculated are used as parameters in the calculation of important tidal elevations. The elevation is useful in analysing dam planning for the location under study because the water level is always changing at any time (Joesidawati et al., 2017). The calculated elevations are MSL (Mean Sea Level), MHWS (Mean High Water Spring), MLWS (Mean Low Water Spring), HHWS (Highest High Water Spring), and LLWS (Lowest Low Water Spring).

2.3 Tidal Types Calculation

The harmonic component is also used as a tidal type analysis at this research location. In determining the type of tides, it is necessary to calculate the value of formzahl numbers with the following equation:

$$F = \frac{A_{K1} + A_{O1}}{A_{M2} + A_{S2}} \quad (4)$$

Where F = formzahl numbers, A_{K1} and A_{O1} = the amplitude of a single daily tidal component, A_{M2} and A_{S2} = the amplitude of a double daily tidal component. classification of tidal types based on the value of formzahl numbers is divided into 4 types. Where the classification is a semidiurnal tides (0 $<$F $<$0,25), mixed mainly semidiurnal tides (0,25 $<$F $<$1,5), mixed mainly diurnal tides (1,5 $<$ F $<$3,0) and diurnal tides (F$>$ 3,0).

3 RESULTS AND DISCUSSION

3.1 Comparison of Water Level in the River and the Sea

Based on observations that have been made, it is known that the water elevation value at the study site is shown in figure 2 for 75 days from January-April 2020. The river observation locations are selected based on the area planned as tidal flood protection in Ujungmanik Village. Whereas the observation location at sea is based on the connectivity of the flow with the Parit river. The results of river and sea elevation are compared in graphical form by equalizing the MSL value in each data. These results are shown in Figure 3.

Figure 2: Tidal elevation monitoring locations.

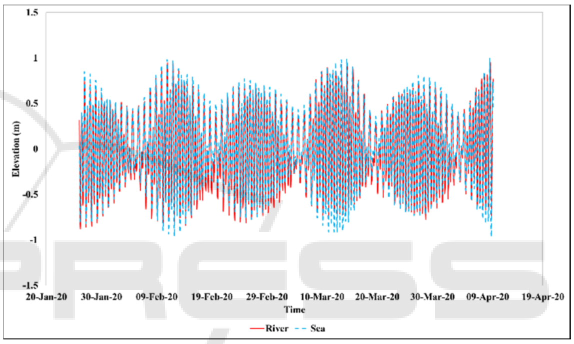

Figure 3: Water levels in the Parit River and Teluk Penyu Beach in Cilacap.

The results in Figure 3 show the different phases in the water elevation in the Parit river and Cilacap Bay Coastal Waters. The pattern of movement of tidal in the two study sites has the same tendency. The sea level is higher than the river water level. At ebb condition, the sea level is also dominantly lower than the river elevation value. This proves that the tidal conditions at sea affect the elevation of water in the river. The graph shows the time of the rise and fall of the water level in the sea is always faster than the water level in the river. This proves that there are differences in the tide and ebb levels in water elevations in rivers and sea.

3.2 Analysis of Least Square Tidal Results

Data of water elevation in the Parit River for 75 days previously obtained shown in Figure 4 was calculated using the least square method. With the least square method, the results of 9 tidal harmonic constants are shown in Table 1.

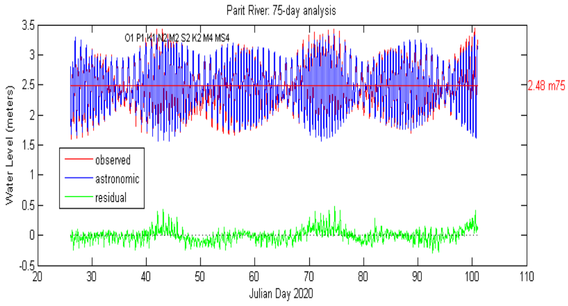

Figure 4: Comparison between observation data and tidal forecasting results.

Based on the comparison, the graph mentions of tidal forecasts with primary data obtained, and an error value of 0,101%. The error value obtained comes from the least square calculation which ignores the meteorological influence, so that the astronomical effect also does not participate in the effect of tidal generation on the model.

Table 1: Harmonic constants.

Constanta	A(m)	g°
M_2	0,457	201,470
S_2	0,247	331,730
N_2	0,088	94,540
K_1	0,179	288,920
O_1	0,113	230,300
M_4	0,037	176,130
MS_4	0,040	309,880
K_2	0,042	134,240
P_1	0,036	306,740

Where A is amplitude and go is a phase. From the 9 harmonic constants that have been obtained in table 1, we get the value of the formzahl number is 0,4148. With this value, the tidal type at the study site is classified as a mixed mainly semidiurnal tides because the value of formzahl numbers ranges from 0,25 <F <1,5. The characteristics of tidal types at this location occur two times the tide and two times the tide in a period of 1 day (24 hours). However, the water level elevation value that occurs is irregular and has a difference in elevation between two tides and two ebbs in one day.

From the calculated harmonic constants, we can get important tidal elevation results at the study site. MSL (Mean Sea Level) value of 2,48 m, MHWS (Mean High Water Spring) of 3,184 m, MLWS (Mean Low Water Spring) of 1,776 m, HHWS (Highest High Water Spring) of 3,476 m and LLWS (Lowest Low) Water Spring) of 1,484 m.

In planning LLWS dams it is used as a reference. So the LLWS value becomes 0. Then the results of other elevations become MSL (Mean Sea Level) value of 0.996 m, MHWS (Mean High Water Spring) of 1.7 m, MLWS (Mean Low Water Spring) of 0.292 m, HHWS (Highest High Water Spring) of 1,992 m and LLWS (Lowest Low Water Spring) of 0 m. The tidal graph with reference to +0.00 is LLWS can be seen in Figure 5.

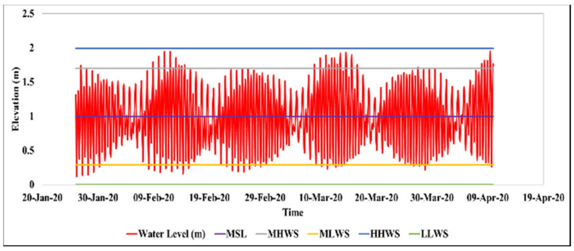

Figure 5: The water level in the parit river→ LLWS= 0.

3.3 Infrastructure Analysis with Tidal Elevations

Peil Scale as a tidal reference is placed under the bridge. The bridge's elevation based on Peil Scale is +4,20 m. Based on the receding elevation, the bridge floor elevation is around +2.72 or around 70 cm from HHWS. One function of tidal observation and analysis is to determine the +0.00 LLWS elevation used as a reference for bathymetry measurements. The results of bathymetry measurements can be seen in Figure 6.

Figure 6: Bathymetry in research location → LLWS= 0.

Based on observations of the plains along the Parit river ranging from +1.00 to + 2.00, so that when the tides are experiencing tidal inundation as shown in Figure 7.

Figure 7: Tidal flood affected areas.

Based on the results of tidal measurements and analysis, the elevation of water structures including weirs, embankment, and floodgates can be determined. Assuming a maximum tidal height of 1,99 m, the height of the water structure plus a freeboard (guard height), for example for embankment and weir is added 1,0 m or about = + 3,0 m.

4 CONCLUSIONS

1. Tides and ebb elevations of water at sea are always faster than elevations of water in rivers. This proves that there are differences in the tide and ebb levels in water elevations in rivers and seas. The sea level is dominantly higher than in rivers. Therefore tidal conditions in the sea affect the occurrence of tidal floods that occur to the inhabitants along the river area.
2. Formzahl numbers obtained from tidal analysis in the Parit River amounted to 0,4148, from this value known tidal types at the study site are classified as mixed mainly semidiurnal tides because the value of formzahl numbers ranges from 0,25 <F <1,5.
3. Tidal elevation obtained from the calculation of harmonic constants is the MSL (Mean Sea Level) Value of 0,996 m, MHWS (Mean High Water Spring) of 1,7 m, MLWS (Mean Low Water Spring) of 0,292 m, HHWS (Highest High Water Spring) of 1,992 m and LLWS (Lowest Low Water Spring) of 0 m.
4. The bridge's elevation based on Peil Scale is +4,20 m. Based on the receding elevation, the bridge floor elevation is around +2.72 or around 70 cm from HHWS. So in determining the height of the weir can be used +3.0 m elevation to prevent high tides flowing through the Parit River.

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REFERENCES

Adi, H. P., & Wahyudi, S. I., 2018. Tidal Flood Handling through Community Participation in Drainage Management System (A case study of the first water board in Indonesia). International Journal of Integrated Engineering, Special Issue 2018: Civil & Environmental Engineering, 10, 19–23.

Boon, J. D., and Consultant, M., 2007. WORLD TIDES.

Dalpan, E., Pratomo, A., Adil, I., 2015. Analisis Pasang Surut di Dermaga Sungai Enam Kijang Kabupaten Bintan Provinsi Kepulauan Riau. In *laporan Skirpsi* (pp. 1–11).

Eijkelkamp: Soil and Water., 2016. Product Manual: Diver. Retrieved from www.vanessen.com/manuals

Foreman, M. G. G., Cherniawsky, J. Y., & Ballantyne, V. A., 2009. Versatile harmonic tidal analysis: Improvements and applications. Journal of Atmospheric and Oceanic Technology, 26(4), 806–817. https://doi.org/10.1175/2008JTECHO615.1.

Hall, J. W., Harvey, H., & Manning, L. J., 2019. Adaptation thresholds and pathways for tidal flood risk management in London. Climate Risk Management, 24(April), 42–58. https://doi.org/10.1016/j.crm.2019.04.001.

Hunter, J. R., Woodworth, P. L., Wahl, T., & Nicholls, R. J., 2017. Using global tide gauge data to validate and improve the representation of extreme sea levels in flood impact studies. Global and Planetary Change, 156, 34–45. https://doi.org/10.1016/j.gloplacha.2017.06.007.

Isa, M., Sugiyanto, F. X., & Susilowati, I., 2018. Community resilience to floods in the coastal zone for disaster risk reduction. Jamba: Journal of Disaster Risk Studies, 10(1), 1–7. https://doi.org/10.4102/jamba.v10i1.356.

Joesidawati, M. I., Suntoyo, Wahyudi, & Sambodho, K., 2017. Sea Level Rise on Tuban Coast in East Java and its Consistency with MAGICC/SCENGEN Prediction. Applied Mechanics and Materials, 862, 83–89. https://doi.org/10.4028/www.scientific.net/amm.862.83.

Nugroho, H., Kurniani, D., Asiska, M., & Nuraini, N., 2016. Kajian Kinerja Sistem Polder sebagai Model Pengembangan Drainase Kota Semarang Bagian Bawah dengan Balanced Scorecard. Media Komunikasi Teknik Sipil, 22(1), 43. https://doi.org/10.14710/mkts.v22i1.12508.

Sadeghian, M. S., Salarijazi, M., Ahmadianfar, I., Heydari, M., 2016. Stage-Discharge relationship in tidal rivers for tidal flood condition. Fresenius Environmental Bulletin, 25(10), 4111–4117. https://doi.org/https://www.academia.edu/28947059/Stagedischarge_Relationship_In_Tidal_Rivers_For_Tidal_Flood_Condition.

Salami, R. O., von Meding, J. K., & Giggins, H., 2017. Urban settlements' vulnerability to flood risks in african cities: A conceptual framework. Jamba: Journal of Disaster Risk Studies, 9(1), 1–9. https://doi.org/10.4102/jamba.v9i1.370.

Subiyakto, R., Suwitri, S., Larasati, E., & Prayitno, P., 2019. Implementation Flood Disaster Policy base Community in Cilacap Regency, Central Java Province, Indonesia. Prizren Social Science Journal, 3(2), 50. https://doi.org/10.32936/pssj.v3i2.96.

Wahyudi, N. R., Wahyudi S. I., Husni, F., 2019. Wave Simulation to Compare Existing and Extended Jetty in River Estuary, Pekalongan, Central Java, Indonesia. In Advances in Engineering Research (pp. 127–131). Atla.

Wahyudi, S. I., Adi, H. P., Lekerkerk, J., Bakker, L., Van de Ven, M., Vermeer, D., & Adnan, M. S., 2019. Assessment of polder system drainage experimentation performance related to tidal floods in Mulyorejo, Pekalongan, Indonesia. International Journal of Integrated Engineering. Retrieved from http://www.scopus.com/inward/record.url?eid=2-s2.0-85078084388&partnerID=MN8TOARS.

Williams, S. J., 2013. Sea-Level Rise Implications for Coastal Regions. Journal of Coastal Research, 63. https://doi.org/10.2112/SI63-015.1.

Yani, R. D. F., & Sumunar, D. R. S., 2019. Track and Record Flood Disasters through Modeling Disaster. IOP Conference Series: Earth and Environmental Science, 271(1). https://doi.org/10.1088/1755-1315/271/1/012020.

Yudi, R. K., Nugroho, A. M., Darsono, S., Wulandari, D. A., 2017. Perencanaan Sistem Polder Wilayah Semarang Timur. Jurnal Karya Teknik Sipil, 6(2), 265–275. Retrieved from http://ejournal-s1.undip.ac.id/index.php/jkts.