The Comparation of Low Water Level Based on Observation Time Variations in Jakarta

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Abstract. The implementation of the sea toll program positively encourages the development of new marine infrastructure along the area it passes. One of the problems that arise in the development of new marine infrastructure is the unavailability of chart datum values. Therefore, there is a need for tidal observations to determine the value of the chart datum in the area. This study contains a comparison of the value of the chart datum from data of 15 days, 30 days, three months, six months, and one year in the Jakarta waters. This study is using data from Jakarta tidal station of BIG. The results of this study can be used to consider the efficiency of tidal observations, especially in determining the duration of observation. The value of the chart datum (LWL) is calculated from the tidal component generated from the harmonic analysis using MATLAB. Significance test for chart datum resulted from MATLAB carried out in Excel. The average value of LWL in Jakarta waters from 15 days data is 0.104 meter, 30 days is 0.192 meter, three months is 0.216 meter, six months is 0.221 meter, and one year is 0.222 meter. The most significant difference from the LWL result is 0.118 meter from 15 days and one year's data, and the smallest difference is 0.001 meters from six months and one-year data. The significance test determined that observation time variations didn't have a significant influence on chart datum (LWL) values that resulted. So, this study determines that we can only choose 15 days, or 30 days tidal observation despite three months, six months, or one year's tidal observations to result in Low Water Level value for a place.

1. Introduction
The Indonesian Government’s Sea Toll program is the implementation of regular sea transportation that connects hub ports and feeders from Sumatra to Papua by using large vessels to obtain economic benefits. The implementation of the sea toll program positively encourages the development of new marine infrastructure throughout the area it passes. One of the problems that may arise in the development of new marine infrastructure is the unavailability of the chart datum value for the object of development. Therefore, it is necessary to observe tides to determine the value of the chart datum in the area. Sea tides are periodic rise and downs of the sea level due to the interaction of meteorological objects (especially the sun and moon) to the mass of water on earth. The tide also is influenced by the centrifugal effect [1][2]. The centrifugal effect is an impulse towards the center of rotation [3].

The purpose of this study was to analyze the comparison of the value of chart datum in Jakarta waters resulting from observational data of 15 days, 30 days, three months, six months, and one year. In this study, a comparative analysis of the value of the chart datum from nine tidal harmonic constants (M2,
S2, K2, N2, K1, O1, P1, M4, and MS4). The choice of variation of observation time minimum of 15 days because in that period with the observation interval everyone hour there is one tidal cycle which neap and spring tides. More extended observations (30 days or more) provide more complete data [4]. In this study chart, the datum that calculated is Low Water Level (LWL). The harmonic analysis using the least square method with MATLAB. The results of this study can then be used to determine whether there are significant differences in the tidal datum chart values from different observation periods. The results of this study can be taken to determine the length of observation for practical purposes such as tidal observations for depth correction in bathymetry surveys, consideration of development in coastal and offshore areas, and interests that require observing tides.

2. Methodology

2.1 Data and Utility
This study use tides data from Geospatial Information Agency’s (BIG) tides station in Jakarta from 2017 to 2018. The harmonic analysis was done with MATLAB, and the correlation and hypothesis test was done with Microsoft Excel.

2.2 Data Processing.
Here the steps for processing tides data in this study.

![Data Processing's Flowchart](image-url)

**Figure 1.** Data Processing’s Flowchart.

The first step is the harmonic analysis of tides data for each observation time from the 2017 period using MATLAB. This process produced amplitude and phase for each tide components. The basis of harmonic analysis is that variations in sea level as superpositions of several tidal harmonic component waves, angular velocity, and phase can be calculated based on astronomical parameters [5]. The
principle of tidal analysis with the least-squares method is to minimize the difference in composite signals and size signals. The least-squares method equation can be seen as follows [6].

\[ h(t_n) = S_0 + \sum_{i=1}^{k} a_i \cos(\omega_i t_n) + \sum_{i=1}^{k} b_i \sin(\omega_i t_n) \]  

(1)

**Explanation:**
- \( h(t_n) \): Water level from time function (m)
- \( A_i \): Amplitude of the-i component (m)
- \( P_i \): Phase of the-n component (degree)
- \( \omega_i \): Angular velocity of the-i component
- \( t_n \): Observation time interval per one hour
- \( S_0 \): Mean sea level
- \( k \): Amount of tidal components

The least-square calculation can be done in the form of a matrix. \( F(n \times 1) \) is an observation or observation matrix, generated from tide observation data, \( A(n \times u) \) is a design matrix, and \( X(u \times 1) \) is a parameter matrix where \( n \) is the number of tide observation data, while \( u \) is the number parameter. The results of the tidal harmonic analysis process are amplitude and phase values of tidal harmonic constants. With the least square method, solutions are obtained using linear equations produce:

a. Amplitude of each tidal constants

\[ A_i = \sqrt{a_i^2 + b_i^2} \]  

(2)

b. Phase of each tidal constants

\[ P_i = \tan^{-1}\left(\frac{b_i}{a_i}\right) \]  

(3)

**Explanations:**
- \( A_i \): Amplitude of i constants (m)
- \( P_i \): Phase of i constants (degree)
- \( a_i \): a component of i constants
- \( b_i \): b component of i constants

The second step is to calculate the chart datum (LWL) values from the amplitude of tidal constants. The Low Water Level can be calculated using the following formula.

\[ LWL = S_0 - (M_2 + S_2 + O_1 + P_1) \]  

(4)

The third step is to compare the LWL values from each observation time variations to know how much the minimum or maximum of LWL values from each and all observation time variations.

The last step is analysis. From the previous stage, the value of the datum chart from each variation of the old observation was obtained, therefore a comparison of the chart datum analysis of each of the old variations of observation using the correlation coefficient significance test to determine whether there were significant differences from the value of each variation of time observation. The first step is to calculate the correlation coefficient value; in this study, Pearson Product Moment correlation method is used. The usefulness of Pearson's Product Moment correlation is to state whether or not there is a relationship between variable X and variable Y. The amount of variable contribution one to the other is expressed in percent. The following equation for calculating Pearson Product Moment correlation [7]:

\[ r = \frac{n \sum XY - (\sum X)(\sum Y)}{\sqrt[n \sum X^2 - (\sum X)^2][n \sum Y^2 - (\sum Y)^2]} \]  

(5)

**Notes:**
- \( n \): the number of data-pairs of X dan Y variable
- \( \Sigma X \): Total of X variable values (day)
- \( \Sigma Y \): Total of Y variable values (m)
- \( \Sigma X^2 \): The square of total of X variable values
\[ \sum Y^2 \]: The square of total of Y variable values
\[ \sum XY \]: Total of X and Y multiplication

Correlation coefficients are numbers that indicate the direction and strength of relationships between variables [8]. The strength of the relationship is indicated by the magnitude of the number of correlation coefficients ranging in magnitude from \(-1 \leq r \leq 1\).

**Table 1. Interpretation of Correlation Coefficient**

| Interval of Coefficient | Relation Level |
|-------------------------|----------------|
| 0.800 – 1.000           | Very High      |
| 0.600 – 0.799           | High           |
| 0.400 – 0.599           | Sufficient     |
| 0.200 – 0.399           | Low            |
| 0.000 – 0.199           | Very Low       |

Furthermore, the significance of the coefficient correlation was carried out. The significance test of the correlation coefficient is intended to find out whether there is a significant influence between two variables (X and Y) [7][9]. After knowing the correlation coefficient value, then do a significance test and the hypothesis of the correlation coefficient using the T-test. Testing the hypothesis is intended to see whether a proposed hypothesis is rejected or accepted. Hypotheses are assumptions or statements that may be true or false about a population. By observing the entire population, a hypothesis will be known whether a study is true or false. For practical purposes, random sampling from the population is beneficial. In testing the hypothesis, there are underlying assumptions, among others [10]:

- The null hypothesis is the hypothesis to be tested
- The alternative hypothesis is that the denial is interpreted by the acceptance of another hypothesis stated.
- Statistics test, calculated from data samples. Statistical test values are used to determine whether or not the null hypothesis is accepted. If the null hypothesis is rejected, that statistical sample calculations are not consistent with the population.
- Rejection area, that is, the range of values from statistical tests where the null hypothesis must be rejected. The area of rejection is closely related to the degree of trust used. If the statistical test results enter the rejection area, that the statistical sample of the null hypothesis is outside the interval of the degree of trust. The degree of trust that is often used is 95%, meaning that in decision making, there is a 5% chance of an error (5% significance level).

The significance test of the correlation coefficient is intended to determine whether there is a significant influence between the two variables (X and Y). After knowing the correlation coefficient values of variables X and Y, the significance test can be calculated using the t-test with the following steps (Riduwan 2003):

1. **Determine Hypothesis**
   
   Determine the Null Hypothesis and the Alternative Hypothesis. The Null Hypothesis (is X variables don’t have a significant impact on the values of Y variables, and the alternative Hypothesis (is X variables have a significant impact on the Y values. Determine Significance Level (\(\alpha\)). Determine the significance level (\(\alpha\)) that will be use.

2. **Determine Rejection Area**
   
   Determine two ways test, \(H_0\) will be rejected if \(t_{count} > t_{table}\), atau \(-t_{count} < -t_{table}\), so \(H_1\) will be accepted. The \(H_0\) will be accepted if \(-t_{table} < t_{count} < t_{table}\).

3. **Calculate Values of \(t_{count}\) and \(t_{table}\)**
   
   The value of \(t_{table}\) can be search in t-table for \(\alpha\) value and degree of freedom \((db) = n - k\) which \(n\) is total of samples and \(k\) is total of variables. The value of \(t_{count}\) can be calculated using this following formula:
\[ t_{\text{count}} = r \sqrt{n - 2} \sqrt{1 - r^2} \]  

(6)

Which \( r \) is correlation coefficient, and \( n \) is total of samples.

4. Taking Conclusion

After calculation the value of \( t_{\text{count}} \) and \( t_{\text{table}} \), fit them to the rejection area. If the value of 
\(-t_{\text{table}} < t_{\text{count}} < t_{\text{table}}\), so it can be concluded that \( H_0 \) is accepted and \( H_1 \) is rejected. If the value of \( t_{\text{count}} > t_{\text{table}} \) or \(-t_{\text{count}} < -t_{\text{table}}\), so it can be concluded that \( H_1 \) is accepted and \( H_0 \) is rejected.

3 Result and Discussion

Calculation of the datum chart aims to obtain MSL and LWS values for each variation of length of observation in Jakarta waters. The value of chart datum from each variation of observation time in Jakarta, Semarang, and Surabaya waters can be seen in Tables 2 to 6 below.

| Observation Time | LWL  |
|------------------|------|
| 1st 15 days      | 0.324|
| 2nd 15 days      | -0.359|
| 3rd 15 days      | -0.100|
| 4th 15 days      | 0.0644|
| 5th 15 days      | 0.132|
| 6th 15 days      | 0.438|
| 7th 15 days      | 0.449|
| 8th 15 days      | 0.055|
| 9th 15 days      | 0.062|
| 10th 15 days     | 0.143|
| 11th 15 days     | -0.050|
| 12th 15 days     | 0.045|

Table 2. LWL Values from 15 Days Data in Meter

The highest Low Water Level in Jakarta tides station from 15 days data produced from 7th 15 days data (1 – 15 of July 2017), the value is 0.449 meter. The lowest LWL value is -0.359 meter, which is produced from 2nd 15 days data (1 – 15 of February 2017). The average value of LWL in Jakarta tides station is 0.104 meters.

| Observation Time | LWL  |
|------------------|------|
| 1st 1 month      | 0.083|
| 2nd 1 month      | 0.044|
| 3rd 1 month      | 0.122|
| 4th 1 month      | 0.178|
| 5th 1 month      | 0.296|
| 6th 1 month      | 0.372|
| 7th 1 month      | 0.311|
| 8th 1 month      | 0.231|
| 9th 1 month      | 0.203|
| 10th 1 month     | 0.111|
| 11th 1 month     | 0.155|
| 12th 1 month     | 0.199|

Table 3. LWL Values from 30 Days Data in Meter

The highest Low Water Level in Jakarta tides station from one-month data produced from 6th one-month data (June 2017), the value is 0.372 meter. The lowest LWL value is 0.044 meter, which is
produced from 2nd one-month data (February 2017). The average value of LWL in Jakarta tides station is 0.192 meters.

| Observation Time | LWL   |
|------------------|-------|
| 1st 3 months     | 0.131 |
| 2nd 3 months     | 0.284 |
| 3rd 3 months     | 0.261 |
| 4th 3 months     | 0.187 |

The highest Low Water Level in Jakarta tides station from three-month data produced from 2nd three-month data (1st of April – 29th of June 2017), the value is 0.284 meter. The lowest LWL value is 0.131 meter, which is produced from 1st three-month data (1st of January – 31st of March 2017). The average value of LWL in Jakarta tides station is 0.216 meter.

| Observation Time | LWL   |
|------------------|-------|
| 1st 6 months     | 0.218 |
| 2nd 6 months     | 0.225 |

The highest Low Water Level in Jakarta tides station from six-month data produced from 2nd six-month data (1st of July – 28th of December 2017), the value is 0.225 meter. The lowest LWL value is 0.218 meter, which is produced from 1st six-month data (1st of January – 29th of June 2017). The average value of LWL in Jakarta tides station is 0.221 meter.

| Observation Time | LWL   |
|------------------|-------|
| 1 Year           | 0.222 |

The highest Low Water Level in Jakarta tides station from six-month data produced from 2nd six-month data (1st of July – 28th of December 2017), the value is 0.225 meter. The lowest LWL value is 0.218 meter, which is produced from 1st six-month data (1st of January – 29th of June 2017). The average value of LWL in Jakarta tides station from all variations is 0.359 meter which is produced from 2nd of 15 days data (1 – 15 of February 2017), and the highest produced from 7th of 15 days data (1 – 15 of July 2017), the value is 0.449 meter. The correlation coefficient from the correlation test value is 0.173. It can be determined that the observation times had a deficient level positive correlation with the value of LWL that produced.

Then conducted a significance test with a 95% confidence level on the old observation data and the MSL value with the following hypothesis.

- \( H_0 \): The duration of the observation did not significantly influence the value of the LWL predicted by the tide produced.
- \( H_1 \): The duration of the observation has a significant effect on the LWL value of the predicted tide produced. Jakarta station data produces a count value for LWL 0.947.
• The value of t in the table for the confidence level of 95% and the degree of freedom of data - 1 is ± 1.699. These results indicate that H0 can be accepted, and H1 can’t be accepted.
• It can be said that tide observation time in Jakarta didn’t have a significant effect on the LWL value with the smallest difference of the average values from each variation is 0.001 meters and the largest is 0.118 meters. It can be concluded that the good long-term predictive value of LWL can be obtained from observations for 15 days or 30 days only, despite doing one year or six months of observation. The LWL predictive value isn’t getting better when the observations are made more extended Jakarta tides station is 0.221 meter.

4 Conclusion

There is some conclusion from this study:
• The lowest LWL value in Jakarta tides station from all variations is 0.359 meter which is produced from 2nd 15 days data (1 – 15 of February 2017), and the highest produced from 7th 15 days data (1 – 15 of July 2017), the value is 0.449 meter.
• Tide observation time in Jakarta didn't have a significant effect on the LWL value with the smallest difference of the average values from each variation is 0.001 meters, and the largest is 0.118 meters. It can be concluded that the good long-term predictive value of LWL can be obtained from observations for 15 days or 30 days only, despite doing one year or six months' observation. The LWL predictive value isn't getting better when the observations are made longer.

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