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Tidal Analysis Using Least Square Method at Luwu Timur Waters

S Pongmanda[1], A Suprapti[1], R Karamma[1], A S Mustari[1]
[1]Department of Civil Engineering, Hasanuddin University, Indonesia
email: silmanpongmanda@unhas.ac.id

ABSTRACT

The tidal seas is the changing of sea water height caused by the attractive force happen between the earth and the space objects. The moon and the sun have the biggest influence on the tidal seas phenomenon. Analysis of tidal components can be done with several methods, namely least square method, admiralty and so forth. The least square method is a tidal harmonic analysis method used to analyze and to predict tides in this research. Daily observation data of 30 days in each hour was taken in August 7 until September 5, 2021. The analysis was carried out using tidal data in the waters around the port of Lampia. The water level data was obtained by observing for 30 days and has been analyzed using the least square method to get the tidal components. The tidal type in Luwu Timur waters is classified as mixed tide prevailing semidiurnal, where the Formzhal number is 0.71 (0.25 <F < 1.50). The tidal datums obtained are LLWS (0 cm), MSL (147 cm), HHWS (264 cm).

Keywords: Tidal seas, Water level, Least Square

1. INTRODUCTION

The tidal seas are the variations in sea water height generated by the attraction force between the earth and space objects. The moon and sun have the greatest influence on the tidal seas phenomenon. The effects of other objects can be neglected because of their greater distance or small size. Tides are a periodic phenomenon, so that tides can be predicted by obtaining their constituent components [5].

Marine and coastal areas in the Luwu Timur waters used for various activities human such as shipping, utilization aquatic biological resourses, tourism and others. In the implementation of activity is requires knowledge of parameters or oceanographic phenomena. One of this oceanographic fenomenon is tidal.

Several methods are often used to predict tides, namely the least square and admiralty methods. The method used to predict tidal datum in Luwu Timur waters in this study is the least square method [6].

2. ASTRONOMICAL TIDE GENERATION AND CHARACTERISTIC

A. *Description of Tides*

Astronomical tides can be seen as the periodic rising and falling of the earth's major water bodies' surfaces. Tides are caused by the gravitational attraction of the moon, sun, and (to a lesser extent) all other celestial bodies. Because of its proximity to the Earth, the moon has the greatest influence on tides. Tidal currents are caused by changes in the elevation of the water's surface.

Tidal height, or the vertical distance between the greatest and subsequent minimum sea surface elevations, fluctuates depending on the relative position of the moon and sun with respect to the earth. The major tidal cycle is usually associated with the passage of the moon over a fixed meridian. Each day, this happens an average of 50 minutes later. This lunar passage produces approximately two tides every solar day (referred to as semidiurnal), with a maximum tide occurring every 12 hours and 25 minutes. However, changes in the moon-sun relationship, combined with local factors, might result in tides with only one tidal cycle each day. These are known as diurnal tides. Mixed tides have features of both semidiurnal and diurnal tides. Two peaks each day are created at some times of the lunar month, whereas the tide is diurnal at other times. The contrast is explored further in the following sections.

The description of typical tidal variability begins with a brief overview of tide-producing forces, gravitational forces that cause tidal motion, and the descriptive tidal envelope that comes from those forces. This section will be followed by more qualitative descriptions of how the moon and sun positions affect the tidal envelope. Once this basic pattern is established, recorded tidal elevations may be shown to be a function of the continental shelf's and coastal boundary's influence on the propagating tide.

B. Tidal Components

The tidal component is a description of the resultant tidal driving force. The resultant tidal force is the resultant of the attractive forces between the earth, moon and sun. These tidal components are divided into three groups, namely the first group is the tidal component which is included in the semidiurnal tide group consisting of components M2, S2, N2, and K2. The second group is the tidal component which is included in the diurnal tide group which consists of components K1, O1, P1. The third group is the tidal component which is included in the Short Period group consisting of M4 and MS4 components. Each tidal component has a different period (T) and is calculated in units of time (hours)[3].

Table 1. Nine major tidal components.

Symbol	Period (hours)	Description
M_2	12.42	Main lunar semidiurnal component
S_2	12.00	Main solar semidiurnal component
N_2	12.66	Lunar component due to monthly variation in moons distance from earth
K_2	11.97	Soli-lunar component due to change in declination of sun and moon throughout their orbital cycles
K_1	23.93	With O_1 and P_1 accounts for lunar and solar diurnal inequalities
O_1	25.82	Main lunar diurnal component
P_1	24.07	Main solar diurnal component
M_4	6.21	Shallow water overtides of principal lunar
MS_4	6.10	Shallow water quarter diurnal constituent

C. Type of Tides

Any location's tidal record can be categorized as one of four types: semidiurnal, diurnal, mixed tide prevailing semidiurnal, or mixed tide prevailing diurnal. Triadmodjo (2010) defines them as follows:

a. Semidiurnal tide: For each of the two cycles, there are two high and two low water levels with almost the same vertical variation. The typical tide period is 12 hours and 25 minutes. Typical of the tides on the Malacca Strait to the Andaman Sea.

b. Diurnal tide: Each tidal day has only one high and one low water level. The tidal period is 24 hours 50 minutes. Typical of the tides on the waters of the Karimata Strait.
c. Mixed tide prevailing semidiurnal: There exist two distinct high tides and two distinct low tides, each characterized by varying heights and periods. Typical of the tides on the waters of Eastern Indonesia.
d. Mixed tide prevailing diurnal: there is one high tide and one low tide, but sometimes for a while there are two high tides and two low tides with very high and long periods. Typical of the tides on the Kalimantan Strait and the North Coast of West Java.

The Formzhal number is the division between the amplitude of the diurnal components (K_1+O_2) and the amplitude of the semidiurnal components (S_2+M_2). The results of the calculation of the Formzhal number will determine the types of tides that occur in a waters. The Formzhal equation is as follows [6]:

$$F = \frac{A(K_1) + A(O_1}{A(M_2) + A(S_2} \quad (1)$$

Table 2. Classification of Tide

Formzahl	Type of Tides
≤ 0,25	Semidiurnal
0,25 – 1,50	Mixed tide prevailing semidiurnal
1,50 - 3	Mixed tide prevailing diurnal
3 ≥	Diurnal tide

D. Tidal Datums

In different parts of the world and for different purposes, water and land elevations in the coastal zone are referenced to a number of tidal datums. Some of these facts are as follows: [4]:

a. Highest High Water Spring (HHWS) is the highest level that spring tides.
b. Mean High Water Level (MHWL) is the averaged highest level that spring tides reach over many years (often the last 19 years).
c. Mean Sea Level (MSL) is the averaged sea level. The MSL is constant for any location over a long period.
d. Mean Low Water Level (MLWL) is the averaged of all low water level reach over many years (often the last 19 years).
e. Lowest Low Water Spring (LLWS) is the lowest level that spring tides.

E. Least Square Method

The least square approach is a method for analyzing the tidal component in order to forecast tidal elevation. The tidal component caused by astronomical factors and shallow water tides is periodic, while the disturbance of meteorological factors is seasonal and sometimes only momentary. Tidal elevation is the sum of its constituent components and can be expressed in terms of a sine curve function without regard to meteorological factors. The equation can be written as follows [2]:

$$\eta(t) = S_0 + \sum_{i=1}^{N} A_i \cos(\omega_i t - P_i) \quad (2)$$

Where :

$\eta(t)$: water level as a function of time

A_i : amplitude components

ω_i : $2\pi/T$, T_i : period components

P_i : phase components

S_0 : mean sea level

t : time

N : number of components

F. Errors and Residuals

The calculation of errors and residuals aims to determine the difference between the simulation results and the measurement data, using the following equation:

a. Residual

$$Residual = Pre - Obs \tag{3}$$

b. Mean absolute error (MAE)

$$MAE = \frac{1}{N}\sum(|Pre - Obs|) \tag{4}$$

c. Root mean square error (RMSE)

$$RMSE = \sqrt{\frac{1}{N}\sum(Pre - Obs)^2} \tag{5}$$

d. Corellation coeffisien (r)

$$r = \frac{N\sum(Pred \times Obs) - (\sum Pred)(\sum Obs)}{\sqrt{\{N\sum Pred^2 - (\sum Pred)^2\}\{N\sum Obs^2 - (\sum Obs)^2\}}} \tag{6}$$

3. RESEARCH METHODOLOGY

The examination of tidal components can be conducted using many methodologies, including the least square approach and the admiralty method, among others. In this study, the least square approach is employed as a tidal harmonic analysis technique for the purpose of analyzing and predicting tides.

A. Research Area

The data used in this study were taken at the Lampia port with coordinates 1°27'57.50" North Latitude and 102°6'26.50" East Longitude. The location can be seen in Figure 1.

Figure 1. Observed location.

B. Research Data

The daily observation data for a period of 30 days, collected on an hourly basis, from August 7 to September 5, 2021, has been presented in Table 3.

Table 3. Daily 30-day observation data per hour.

Date	Time (hours)																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
07/08/2021	280	275	251	248	243	249	267	287	300	309	308	295	266	230	188	158	141	145	162	195	248	264	275	294
08/08/2021	291	279	260	252	237	235	247	269	291	310	315	312	295	256	214	178	144	135	147	170	210	241	283	302

09/08/2021	305	290	271	255	235	225	230	252	278	299	319	325	318	288	249	200	170	140	131	150	185	221	265	293
10/08/2021	310	315	282	253	243	228	219	242	263	286	309	328	334	320	275	242	200	153	132	138	165	208	243	281
11/08/2021	305	316	302	283	245	228	208	218	229	259	285	314	321	320	302	270	230	179	152	140	151	190	235	271
12/08/2021	303	320	322	303	269	240	212	195	204	226	257	289	315	324	322	284	259	220	178	154	157	177	218	256
13/08/2021	294	320	330	319	291	251	227	195	183	198	225	256	286	314	322	314	282	254	221	185	168	180	203	235
14/08/2021	291	314	332	339	310	282	245	206	179	174	192	220	245	280	300	310	301	271	250	213	190	185	205	230
15/08/2021	280	303	332	335	334	306	273	237	183	163	169	187	208	243	275	290	296	285	275	250	220	205	202	225
16/08/2021	247	271	306	326	338	325	297	267	217	197	160	168	183	203	234	255	281	280	285	269	249	232	220	230
17/08/2021	245	271	298	321	335	338	328	296	265	215	179	157	158	164	189	216	240	267	275	283	270	259	247	238
18/08/2021	243	262	292	320	335	338	330	324	299	258	220	180	163	158	155	168	210	237	261	278	284	282	271	258
19/08/2021	253	252	249	271	300	318	330	333	325	301	255	218	178	162	143	140	170	200	228	265	286	298	288	275
20/08/2021	260	255	250	248	263	292	310	331	335	328	302	256	215	181	143	128	135	159	192	235	267	300	307	298
21/08/2021	280	263	249	238	254	264	295	307	324	334	330	308	270	219	169	140	124	130	165	190	237	273	303	318
22/08/2021	304	285	250	241	234	238	245	276	303	325	339	336	303	265	220	172	138	125	139	172	225	255	291	318
23/08/2021	325	304	279	248	228	222	227	240	275	305	329	340	336	303	260	218	170	140	130	151	195	235	284	310
24/08/2021	332	330	298	267	233	210	203	213	241	278	309	329	335	331	296	252	208	167	145	151	180	219	269	300
25/08/2021	322	340	327	291	258	223	198	194	213	244	283	306	321	329	316	280	235	198	170	155	170	201	254	295
26/08/2021	315	335	338	318	275	235	199	188	195	205	252	281	300	313	316	280	260	231	190	173	178	191	230	272
27/08/2021	310	330	337	311	290	261	218	196	181	194	217	251	281	300	308	310	281	250	215	200	185	205	230	261
28/08/2021	300	318	330	335	307	275	235	207	182	182	191	223	253	280	287	300	290	261	235	218	205	200	231	250
29/08/2021	283	312	325	330	325	294	259	223	198	187	189	204	221	247	271	285	290	281	262	231	219	221	240	259
30/08/2021	273	300	312	326	317	297	273	239	211	197	180	194	202	229	246	265	276	278	273	254	241	235	241	256
31/08/2021	261	283	295	311	318	308	295	262	230	205	190	181	186	208	232	241	260	272	280	263	250	245	246	249
01/09/2021	253	270	286	298	305	306	302	281	255	224	202	185	181	188	208	224	240	251	263	275	270	261	255	258
02/09/2021	251	265	271	289	296	303	302	298	280	253	225	205	185	176	183	196	211	230	255	275	281	273	271	265
03/09/2021	262	260	267	271	285	294	303	302	292	282	268	230	202	183	172	180	190	210	235	261	275	286	285	280
04/09/2021	265	243	252	253	262	280	295	302	312	305	287	262	229	197	166	164	170	185	213	245	269	286	301	292
05/09/2021	280	271	256	246	240	258	278	295	313	316	311	290	263	221	190	166	155	169	191	217	259	282	305	318

4. RESULT AND DISCUSSION

The observational data obtained from the results were subsequently processed using La Kipas Software in order to derive nine tidal components. The determination of the chart datum relies on the utilization of tidal components, which are comprehensively outlined in Table 4.

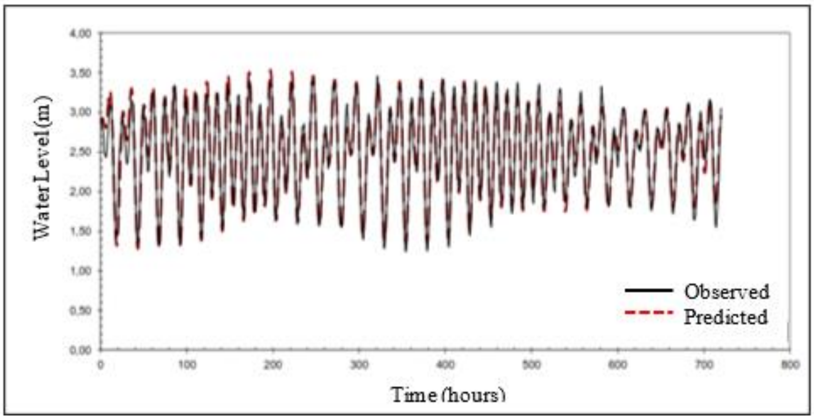

Figure 2. The observed and predicted tidal curves.

Table 4. Principal Tidal Component at Luwu Timur Waters.

Tidal Forecasting	Tidal Components								
	K_1	O_1	P_1	M_2	S_2	N_2	K_2	M_4	MS_4
A (m)	0.33	0.22	0.11	0.60	0.17	0.10	0.05	0.01	0.01
Phase (°)	226	238	38	252	69	218	106	260	160

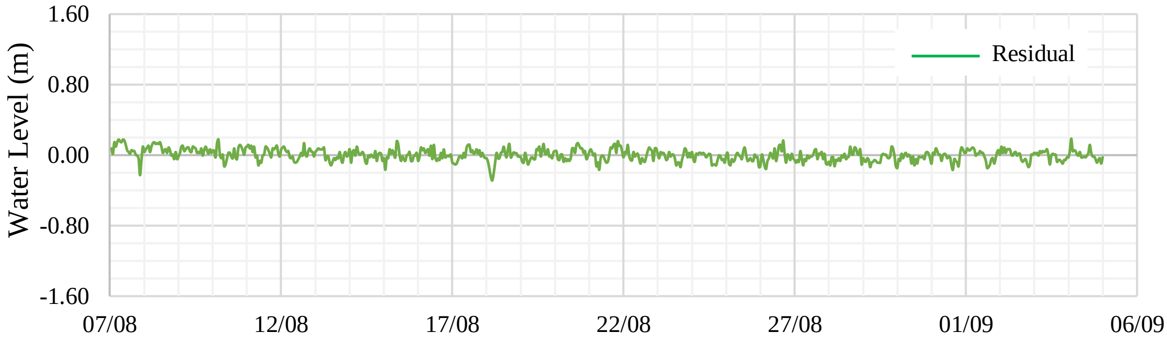

Figure 3. The residual data.

Table 5. Residual and errors of data.

Max. residu (m)	Min. residu (m)	MAE (m)	RMSE (m)	r
0.187	-0.283	0.053	0.067	0.992

Based on the results obtained for the tidal components using the least square method, it can be determined the type of tide that occurs in Luwu Timur waters based on the Formzhal number (F).

$$F = \frac{A(K_1) + A(O_1)}{A(M_2) + A(S_2)} = \frac{0.33 + 0.22}{0.60 + 0.17} = 0.71$$

The tidal type in Luwu Timur waters is classified as mixed tide prevailing semidiurnal, which is in the range of 0.25 <F < 1.50.

Table 6 provides the amplitude of the tidal component, which is utilized in the computation of water level and tidal range. Additionally, Figure 4 illustrates the tidal datum.

Table 6. Tidal Datum and Tidal Range.

Tidal Datum	Water Level (cm)
HHWS	264
MHWS	241
MSL	147
MLWS	26
LLWS	0,0
Tidal Range	264

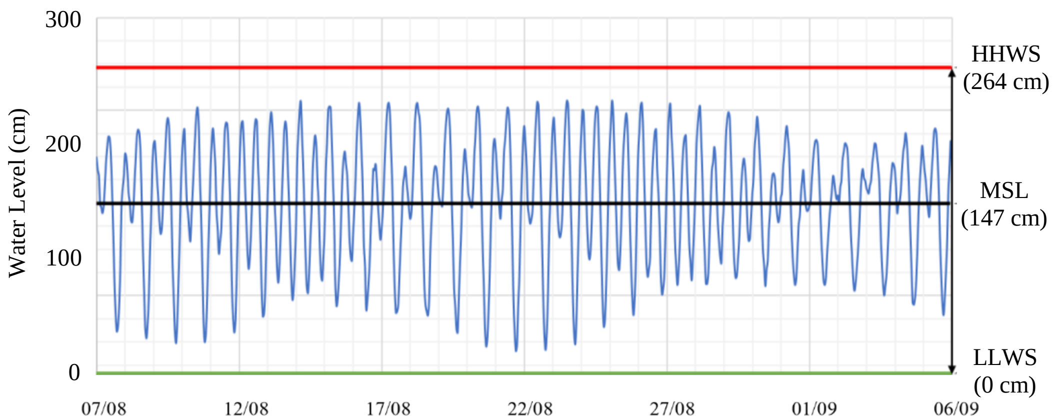

Figure 4. Tidal datums and the HHWS for Luwu Timur waters.

5. CONCLUSION

The water level data was acquired over a 30-day observation period and afterwards subjected to analysis using the least squares approach in order to determine the tidal components. The tidal type in Luwu Timur waters is classified as mixed tide prevailing semidiurnal, where the Formzhal number is 0.71 (0.25 <F < 1.50). The tidal datums obtained are LLWS (0 cm), MSL (147 cm), HHWS (264 cm).

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