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Methods of Tidal Approach for Determination of Sea Level Rise in Surabaya Waters

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ABSTRACT
The objective of this research is to analyze the sea level rise that occurred in the waters of Surabaya. The research uses methods, that is: harmonic analysis, trend analysis , and regression analysis. The results showed an increase in sea level in the waters of Surabaya. It is noted that sea level rise around 1.97 mm per year. The results of this study are expected to be useful as a reference in the development of Surabaya coastal region.

KEYWORDS *:sea level rise, tides, Surabaya coastal region.*

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I. INTRODUCTION

Sea level rise is an important issue that must be faced by coastal states or islands in the world. This natural phenomenon needs to be taken into account in all activities of the management of coastal areas, because it can have a direct impact on the shoreline retreat thus displacing residential areas and urban areas threatens the low, flooded productive land and contaminating fresh water supplies.

In general, sea level rise can be classified into three factors, namely global, regional factors and local factors (Numberi, 2009). Sea-level rise due to global factors are the main factors that greatly feared this moment, because it can cause coastal drowning. With the increase in the average temperature of 1.1 °C - 6.4 °C, the predicted sea level rise in the year 2090 to 2099 by 0.18 to 0.59 m (IPCC, 2007). Regional factors caused by tectonic activity in the region, while local factors caused by the process of land subsidence due to mass changes and fluid changes underground.

The rise in average sea levels accompanied by high waves that hit the ramps, especially in coastal areas with a slope between 0 ° - 30 ° is the cause tidal flooding in coastal areas concerned until far into the inland areas. Development beach wall (seawall) is one effort that could be considered to reduce losses due to flooding from the sea (Wibisono , 2011).

Wirasatriya *et al* (2006) analyzed the development of the position of sea surface waters Semarang then corrected with the analysis of the value of land subsidence in tidal stations. Tidal data of 2004 - 2005 was calculated to calculate tidal components that are known MSL value each year. The results indicate that sea level rise of 5.43 cm/year. The rate of land subsidence occurred at low tide station at 5,165 cm/year. Correction rate of land subsidence with sea level rise that is generating sea level rise due to global warming in the waters of Semarang by 2.65 mm/year.

Prasita and Kisnarti (2013) predicted the impact of the sea level rise in coastal areas of Surabaya. The method used is the field survey and methods of Geographical Information System (GIS). The results indicate that the impacts of sea level rise of 1 m is to inundate coastal areas in Surabaya area if 4,902.06 ha (15.02 %) in ten coastal districts. The largest impact is in the district of Gunung Anyar which is expected to inundate the tourist areas of mangrove.

Surabaya City is an urban area is low. Surabaya region geographically borders the Madura Strait in the north and east sides, with 80 % topography is low-lying with a height of 3-6 m and 20 % sloping hills with a height of less than 30 m (www.surabaya.go.id). North Coast Surabaya has been developed into industrial areas, ports and military bases. East Coast Surabaya has potential potential to be developed . This is evidenced, among others, with land use change so quickly as the presence of the rapidly expanding settlements, fishing ponds, agricultural, public facilities, tourism, and other utilization. Therefore the aim of this study is to analyze the sea level rise that occurred in the waters of Surabaya. The results of this study are expected to be useful as a reference in the development of Surabaya coastal region in the future.

II. RESEARCH ELABORATIONS

The research on sea level rise is conducted in the waters of the North - East Surabaya (7° 12' S - 112° 36' E and 7° 21'S - 127° 54' E) as shown in Fig (1).

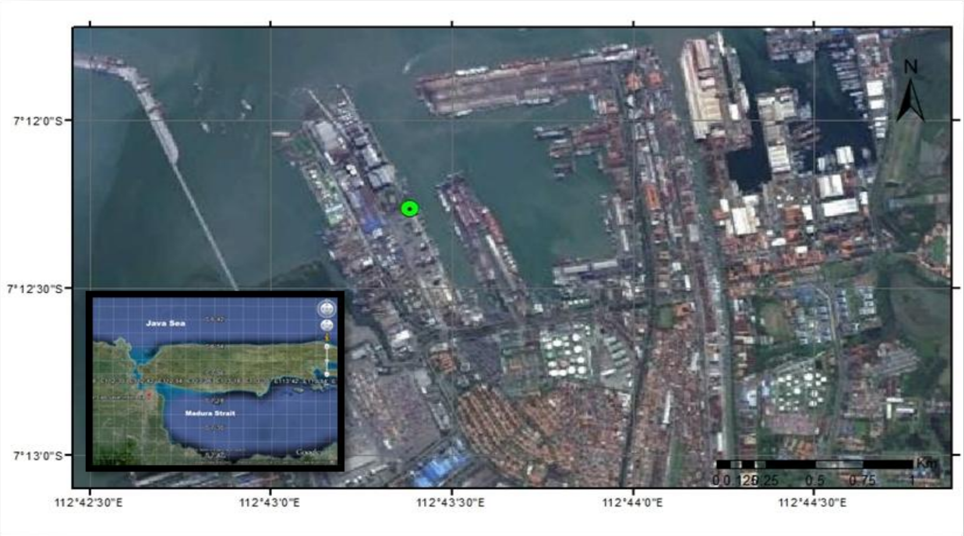

Fig (1) : Location of the research.

The data collected for this study are: [1]. Tidal data obtained from the Geospatial Information Agency / Badan Informasi Geospasial (BIG) in 1994-2011, [2]. Secondary data used in this study are: (a.) Data observations made at the coast of Kenjeran-Nambangan Perak, Surabaya Indonesia in June 2009 and June 2012, (b.) Observational data around Suramadu in August 2003 and July 2012. The research method used in this study included a survey method and regression analysis. In summary, this research flow diagram in presented in Fig (2).

2.1. Harmonic Analysis.

Harmonic analysis is performed to find the tidal harmonic constants. The method used in the harmonic analysis is a method of admiralty. With the admiralthy method will look for tidal harmonic constants which consist of the Mea Sea Level (MSL), the amplitude and phase of the 9 (nine) tidal constants main components (M2, S2 , N2 , K1 , O1 , M4 , MS4 , K2 and P1). Furthermore, it can determined the type of tidal formzahl using the formula in the following equation.

$$NF = \frac{AK_1 + AO_1}{AM_2 + AS_2} \qquad (1)$$

where:

NF = value of formzahl
AK1, AO1 = amplitude tidal of diurnal
AM2, AS2 = amplitude tidal of semi diurnal

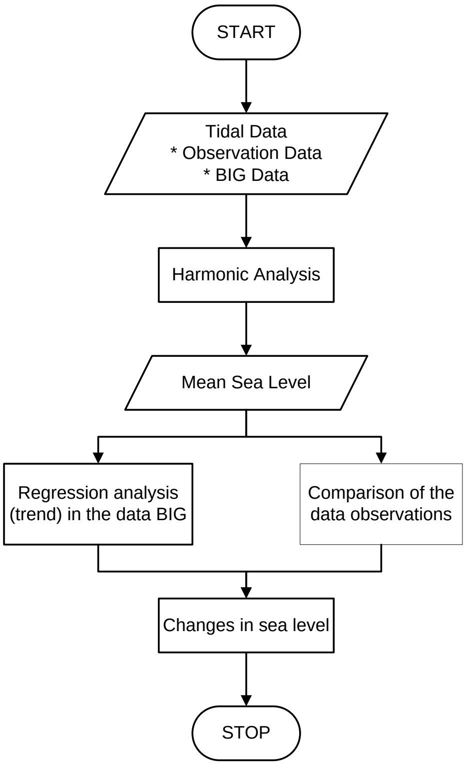

Fig (2) : Flowchart of the research methods

2.2. Trends Analysis

Trend analysis was conducted to determine the sea level rise that occurred. The data included in this analysis is data that has been calculated by Mean Sea Level (MSL) admiralthy method. To know the sea level rise that occurs, the data observations used in the comparison of the data in June 2009 and June 2012, the data in August 2003 until July 2012 which are acquired from BIG.

2.3. Regression Analysis

From the calculation admiralthy on BIG's data were analyzed further by the method of least squares regression analysis to obtain the trendline function so as to know the value of sea level rise can be required. Trendline function as in the following equation:

$$g(x) = a + bx \qquad (2)$$

with :

$$a = \bar{y} - b\bar{x}$$

$$b = \frac{n\sum x_i y_i - \sum x_i \sum y_i}{n\sum x_i^2 - (\sum x_i)^2}$$

III. RESULTS AND DISCUSSION

3.1. Tidal Type

The Tidal Data from the BIG's tidal stations located in Perak Port. This tidal stations using float type tide gauge. Working system used tide gauge can be seen in Fig (3). Admiralthy calculation results showed that the average value on the data formzahl BIG is 1.45. Thus the type of tidal in Perak Port, Surabaya-Indonesia is mixed semi diurnal (double).

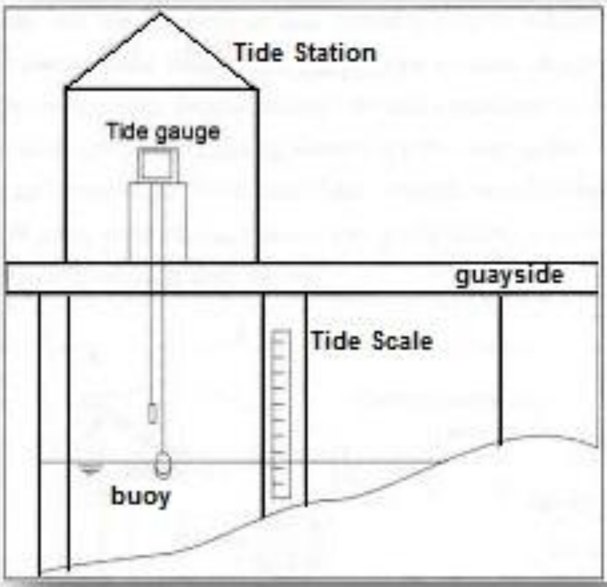

Fig (3) : BIG tide gauge system work in Port of Tanjung Perak, Surabaya-Indonesia.

The results of the calculations also showed that the type of tidal waters Nambangan, Kenjeran and around Suramadu Bridge is a mixed semi diurnal (double). Formzahl values F for tidal around the waters Nambangan, Kenjeran was 0.69 in 2010 and 00:57 in 2012, while around Suramadu Bridge also indicates the type of mixed semi diurnal (double). Rated F for approximately tidal in Suramadu Bridge is 0.49 for 2003 and 0.74 for 2012. (Table (1)).

Table (1) : Data Field Value Formzahl

Location	Year	Value of F
Suramadu Brigde	2003	0.49
	2012	0.74

Location	Year	Value of F
Nambangan, Kenjeran	2010	0.69
	2012	0,57

3.2. Sea Level Developments in Surabaya Waters

To know the sea level rise at Port of Tanjung Perak, performed a regression analysis on the data that has been acquired MSL. Assuming the value of MSL as a function of the month then there are data points are scattered in the xy curve. To obtain the trend of the function is then performed regression analysis least squares method to obtain a line function (g (x)) which represents the distribution of the data of f (x) or called trendline (Fig 4).

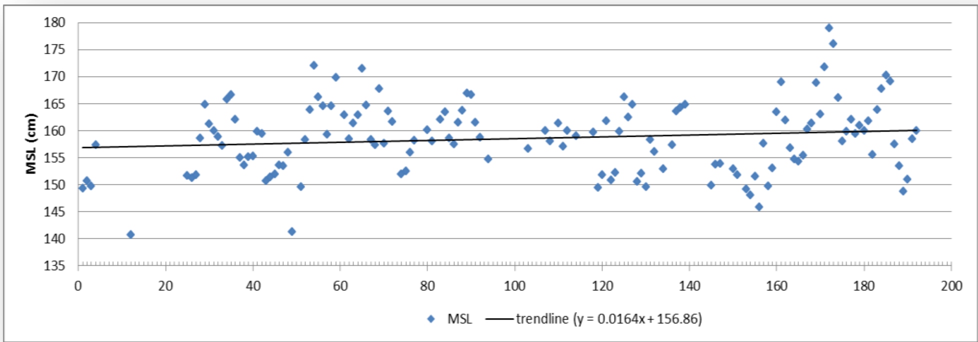

Fig (4) : MSL function graph and trendline.

So that the regression analysis trendline formula function is

y = 0.0164 x +156.86

Where the relation coefficient is 0.197.

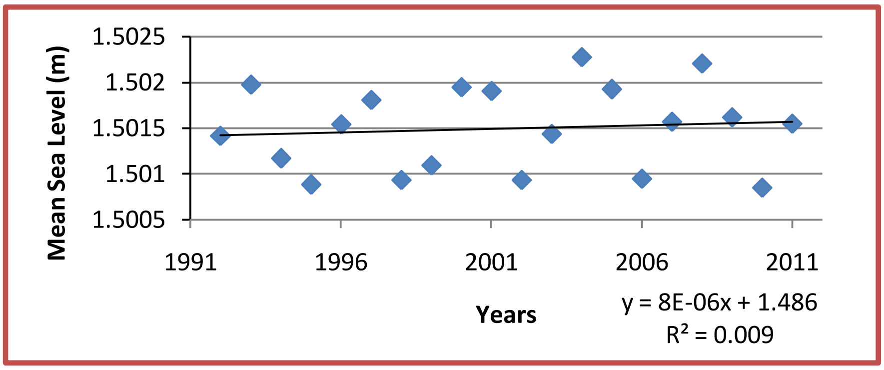

Fig (5) : Graph of Mean Sea Level 1992 – 2011

Table (2) : Mean Sea Level (MSL) 1992-2011

Years	MSL (m)	Years	MSL (m)
1992	1.501416	2002	1.500934
1993	1.501974	2003	1.501434
1994	1.501167	2004	1.502273
1995	1.50088	2005	1.501922
1996	1.501538	2006	1.500947
1997	1.501805	2007	1.501571
1998	1.50093	2008	1.502207
1999	1.501095	2009	1.501616
2000	1.501944	2010	1.500846
2001	1.501907	2011	1.501548

By extrapolation, it is known that the increase occurred during January 1994 - December 2009 amounted to 3.1362 cm or 0.0164 cm each month, so that the sea level rise per year is 0.0164 x 12 = 0.1968 or 1.97 cm per year mm per year (Fig (5) and Table (2)).

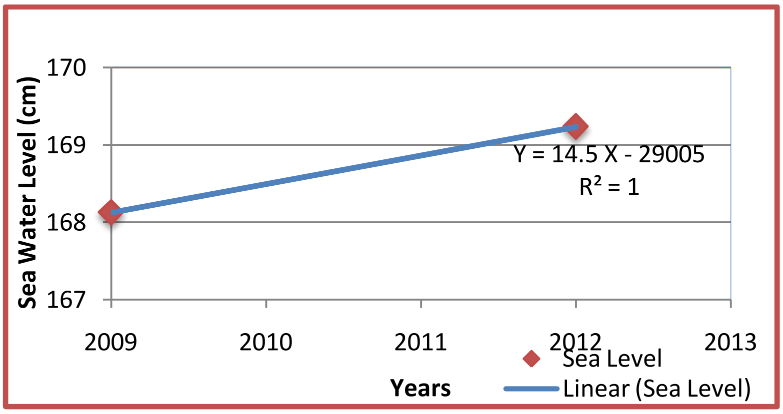

Fig (6) : Trend Graph of Height of Mean Sea Level (MSL) from year 2009 – 2012

By comparing the value of MSL in June 2009 and June 2012 from the data tidal in Nambangan Kenjeran Waters, Surabaya-Indonesia is known there has been a sea level rise of 1.1095 cm (Fig (6).). Therefore, the sea level rise in Kenjeran Waters, Surabaya-Indonesia during 2009 to 2012 by 3.7 mm per year.

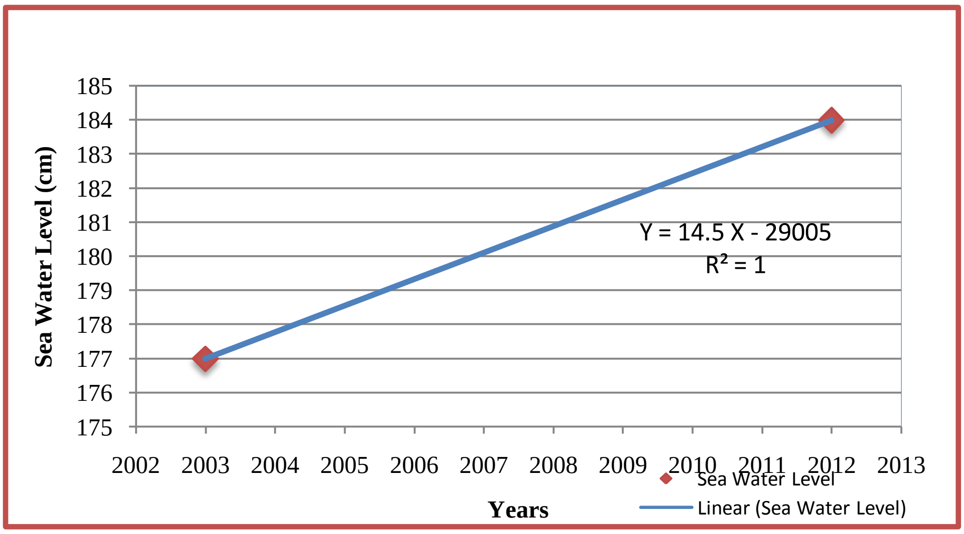

Fig (7) : Trend Graph of Height of Mean Sea Level in year 2003 and 2012

The trend graphs of the tidal data surrounding Suramadu Bridge Waters show that sea levels follow a linear pattern with Y = 0.7778 X - 1380.9 (R^2 = 1) (Fig (7).). Table (3) also shows that there is increase in the value of the Mean Sea Level as much as 7 cm / 9 years (Fig (7)). Therefore, the average annual sea level rise is 0.7 cm / year.

Table (3) : Height of Sea Level (MSL)

Location	Years	*MSL* (cm)
Suramadu Bridge	2003	177
	2012	184

Location	Years	*MSL* (cm)
Nambangan, Kenjeran	2010	140
	2012	169

Sea-level rise is happening in Kenjeran Waters and the Pelabuhan Perak Port of Surabaya not much different from sea level rise that occurred in the study area by Wirasatriya Semarang Water (2006). Sea-level rise due to global warming in the waters of Semarang by 2.65 mm/year.

IV. CONCLUSION

From this research,it can be concluded and recommended, as follows: (1) Surabaya waters has mixed semi diurnal type (double). Sea level rise observed in different places, that is in Kenjeran Waters and Perak Port. The results of tidal analysis at the Port of Tanjung Perak has showed an increase with the trendline function y = 0.0164 (x) + 156.86 for every month from January 1994 - December 2009 so that it is acquired sea level rise is arround 1.97 mm per year; (2) The sea level rise which acquired in Kenjeran Waters in June 2009 and in June 2012 is 1.1095 cm (3.7 mm per year). It seems the first one is more accurate because it uses the long time period data.

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