THE INFLUENCE OF LAND SUBSIDENCE TO THE CHANGES OF INUNDATION WIDTH IN SEMARANG CITY ALLUVIAL PLAINS
(Case Study: Northern Districts of Semarang)

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Abstract - Semarang city is geographically consisting two units of morphology, namely: in the southern part is a denudasional structural hills consisting of Tembalang, Tanah Putih, Tegalsari, Siranda, until Gajah Mungkur. While the alluvial plain lies in the northern part. Land subsidence in some parts of Semarang city becomes a serious problem, because the area is generally a settlement area. As a result of land subsidence, settlement areabecomes lower, because the settlement location partly close to the beach, during a tide it overflows into the mainland through rivers and drainage canals and then it pooled to the settlement. The purpose and goal of this study is to assess and predict the large and length of land subsidence on alluvial plain due to the load and the mechanical properties of the soil as well as to assess and predict the changes of the inundation width in the alluvial as a result of land subsidence. This research use experimental method. To test the analysis of alluvial sediment subsidence, it is obtained by the calculation based on samples and primary data in the laboratory. The calculation is done in two ways, the first way is calculating the physical model with 1D Terzaghi, while the second way is predicting the subsidence using PLAXIS software and the result is the prediction of the large and length of subsidence with load variations and different soil mechanical conditions. Furthermore, comparing the calculation result using a physical model with the calculation result using PLAXIS software to get the final result of how is the large and length of land subsidence and the tendency of the subsidence. Whereas to calculate the width of the inundation, it is planned the changes of the inundation width using GIS software (Geographic Information System). The result of this study which applies 1D Terzaghi approach, obtained the smallest subsidence is 64,2 cm for 17,781 years and the largest subsidence is 107.600 cm for 29,635 years. While the approach which applies PLAXIS software obtained the smallest subsidence is 65.8 cm for 17,781 years and the largest subsidence is 110,000 cm for 29,635 years. The subsidence tendency more northern is larger and the time is longer. Land subsidence in the alluvial plain continues to rise, therefore the inundation in the settlement that located close to the river and the beach continues to grow wider, between 2016 and 2045 there is additionalinundation of 493,63 Ha.

Keywords: *Alluvial, Subsidence, Inundation, GIS, PLAXIS*

1. Introduction

Semarang is one of coastal city in Indonesia. Based on the existing condition, Semarang is very often hit by tidal flood. The cause of the occurrence of tidal flood is the decrease or land subsidence that causes water flowing to the mainland. The areas that have a risk for the tidal flood is the coastal area of Semarang which covers six sub-districts namely North Semarang, Pedurungan, Gayamsari, Central Semarang, East Semarang, and Genuk. Land subsidence is a slow-moving disaster and it had still been occurring in the coastal areas of Semarang since the 1980s. The process of land subsidence occurs gradually, it consists of a large area and it is not fully realized by the society even though the impacts are clearly visible such as floods, damaged buildings, damaged road, damaged bridges, damaged industrial areas and damaged houses. A typical of land subsidence disaster affects material loss compared to loss of life. It is caused by the lack of awareness of the society and stakeholders can indicate a lack of knowledge about the processes and mechanisms of land subsidence.

The research of Tobing, et al (2001) land subsidence in part of Semarang reaches 15 cm per year where happened in Tanjung Mas towards the east to the beach in Genuk Subdistrict and part of Sayung Subdistrict in Demak, then, it is followed by Bandarharjo and surrounding area is 10 - 15 cm per year, Tanah Mas, Tawang Station, Karang Tengah, Marina and Tawang Mas 5 - 10 cm per year. In the South and Southeast such as Bangetayu and surrounding areas, land subsidence is generally below 5cm per year. Land subsidence in some parts of Semarang generally occurs on alluvial plains with different depths, increasingly to the North is generally larger subsidence. Holtz (1985) describes the causes of land subsidence thought to be due to the compression of alluvial sediment naturally, the load of the building, the disposal of soil and the extraction of groundwater beyond its ability (Safe Yield).

At this time, it is not known the prediction of the duration of land subsidence and the changes in the extent of inundation that occurred in the Semarang area, then the writer made a study entitled The Influence Land Subsidence to The Changes of Inundation Width in Semarang City Alluvial Plains with the area to be studied northern districts of Semarang. In this study will be calculated large and the duration of the subsidence at T90% which is the time to reach 90% consolidation.

The problem of the research location is the occurrence of soil subsidence (land subsidence) due to the load and mechanical properties of the soil and there is a change in the extent of inundation that occurred in the plains of Semarang which is caused by land subsidence.

The objectives of the study can be explained as follows: 1) To predict the magnitude and duration of subsidence in alluvial plains of Semarang at T90% .2) To predict the development of the extent of inundation on the alluvial plain of Semarang resulting from subsidence at T90%.

This research is expected to provide benefits to stakeholders about the location of inundations and their extent in the next few years as a reference for future development.

2. Methodology

This experimental study aims to analyze or investigate the amount of decline and duration of land subsidence and the extent of inundations that occur in the alluvial plains of Semarang manually or calculations based on several theories of geotechnical experts on consolidation and comparing the amount of decline by using special applications geotechnical.

The experiment begins by developing a cause-effect hypothesis between the dependent variable and the independent variable. Furthemore, it is done in a row: the measurement of the value (quality) of the dependent variable (pretest), implements the treatment (value-converting condition) to the independent variable, and re-measures the value of the dependent variable (posttest) to see whether there is a change of value (quality).

3. Result

In this study the physical and mechanical properties of the soil at the location of the research in the form of secondary data as much as 4 drill points scattered on alluvial plains with depth up to 25 m drill location, as shown in Figure 3.1

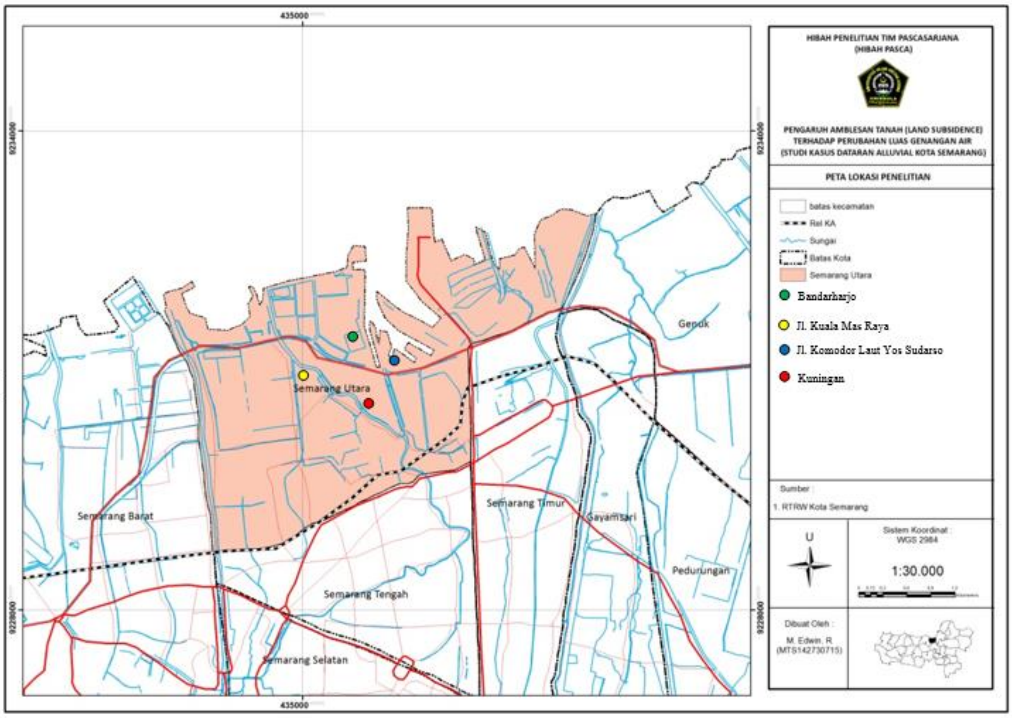

Figure. 1. Map Of Point Location Drill
Source: Analysis of Researchers

3.1. The Prediction of Subsidence Large dan Duration of *Alluvial Plain*

This analysis is aimed to test the primary hypothesis, ie, load above the land, soil mechanical properties have an effect on the large and the duration of land subsidence on alluvial plains spatially and temporally. Determination of analytical methods to predict the large and duration of alluvial degradation based on the opinion, Craig (1991) Das (1998) Weslay (1997).

The large and the duration predictions of alluvial plain subsidence can be explained as follows:

3.2. The Prediction of Subsidence Large dan Duration of *Alluvial Plain Using Consolidation 1D Terzaghi* Theory

The predicted rate and duration of land subsidence are calculated by the 1D consolidation theory approach developed by Das (1998) and Weslay (1997). The physical and mechanical properties of the soil used to calculate are: γ (original soil weight), γ (dry soil weight) σ' (effective stress) Cc (compression index), Cv (coefficient of consolidation) and and e_o (pore number). In this study the sample of 4 pieces (samples with a depth of 30m) in the form of drilling and laboratory analysis of soil mechanics scattered on alluvial plains are calculated large and the duration of subsidence.

Table. 1. The Prediction of Subsidence Large dan Duration of *Alluvial Plain Using Consolidation 1D Terzaghi*

No.	Location	Subsidence Large (cm)	Subsidence Duration (Year)
1	Bandarharjo	107,6	29,635
2	Jln Kuala Mas Raya	76,9	29,635
3	Kuningan	64,3	17,781
4	Jln Komodor Laut Yos Sudarso	83,6	23,708

Source: Analysis and calculation result

Interpolation results of land subsidence predictions can be calculated. Based on the results of soil mechanical analysis at the drill points, it is obtained 5 classes ranges of depth value of soil subsidence. Level I is the level showing the smallest depth while the level V indicates the largest depth of soil subsidence

Tabel. 2. The Level of Land Subsidence Depth by 1D dari Terzaghi Approach

Depth Rate	Value of Subsidence Depth	Location
Level I	0-20cm	-
Level II	21-40cm	-
Level III	41-60cm	-
Level IV	61-80cm	Kuningan, Jln Kuala Mas Raya
Level V	>80cm	Jln Komodor Laut Yos Sudarso, Bandarharjo

Source: Analysis and calculation result

3.3. The Prediction of Subsidence Large dan Duration of *Alluvial Plain Using Plaxis 8.2 Sofware*

To find out the tendency of large and duration of the subsidence, it needs to be recalculated with Plaxis 8.2 software, so the results can be compared with the previous calculation. Parameter plaxis model 8.2 by using elements up to the input data consisting of E modulus (*Modulus Young*), *poisson's ratio*, *cohession*, and *shearstrength*.

Table 3.The prediction of the magnitude of Alluvial Plain Degradation with Plaxis Software

No.	Location	Subsidence Duration (Year)	Subsidence Large (cm)
1.	Bandarharjo	29,635	110,000
2.	Jln Kuala Mas Raya	29,635	78,200
3.	Kuningan	17,781	65,800
4.	Jln Komodor Laut Yos Sudarso	23,708	86,500

Source: Analysis and calculation result

Table 4. The Prediction of the magnitude of Alluvial Plain Degradation on Calculations of 1D Terzaghi and Plaxis Software 8.2

No.	Research Point Location	Subsidence Duration (Tahun)	Subsidence Large 1D Terzaghi Theory (cm)	Subsidence Large of Plaxis 8.2 (cm)
1.	Bandarharjo	29,635	107,600	110,000
2.	Jln Kuala Mas Raya	29,635	76,900	78,200
3.	Kuningan	17,781	64,200	65,800
4.	Jln Komodor Laut Yos Sudarso	23,708	83,600	86,500

Source: Analysis and calculation result

The result of calculation of subsidence using 1D Terzaghi approach (local subsidence) and modeling with Software Plaxis 8.2 with the same soil mechanical data have similarity of large, long and tendency of subsidence at research location. Any calculations performed using the Terzaghi 1D approach (local subsidence) and modeling with Plaxis Software 8.2 appears different result between 3-5 cm each point which modeling with Software Plaxis 8.2 provides a larger decrease. This is basically caused the calculation with the program is more detailed and more recent compared than the consolidation theory that is currently used. In other hand, software of plaxis 8.2 appears parameters such as Modulus Young and Poisson Ratio which are not owned by the approach formula of 1D Terizaghi.

3.4. Prediction of Land Subsidence Per Five Years (2020, 2025, 2030, 2035, 2040, dan 2045)

After getting the results of large calculations and duration of land subsidence by using Terzaghi ID approach and software modeling plaxis 8.2, next will be searched for predictions per 5 years from 2016 until 2020.

At the research location, Bandarharjo, is known large subsidence of 107.6 cm with a long subsidence for 29.635 years. Furthermore, it is calculated to get big decrease per year equal to 3,631 cm. By this assumption, we can find out the subsidence in year 2020 by large decrease per year hence got result of decrease equal to 18,154 cm. In the year 2025 obtained a decrease of 36.308 cm, in the next year is the year 2030 decrease reach 54,463 cm. In the last year 2045 resulted decrease of 107.6 cm which has reached T90% (table 3.6).

Table 5. The Prediction of the magnitude of Alluvial Plain Degradation on Calculations per five years after the research with 1D Terzaghi approach

No.	Location	Subsidence Large of T90% (cm)	Duration Subsidence (year)	Subsidence Large Per Year (cm)	2016 (cm)	2020 (cm)	2025 (cm)	2030 (cm)	2035 (cm)	2040 (cm)	2045 (cm)
1	Bandarharjo	107,600	29,635	3,631	3,631	18,154	36,308	54,463	72,617	90,771	107,600
2	Kuala Mas Raya	76,900	29,635	2,595	2,595	12,975	25,949	38,924	51,898	64,873	76,900
3	Kuningan	64,200	17,781	3,611	3,611	18,053	36,106	54,159	64,200	-	-
4	Komodor Laut Yos Sudarso	83,600	23,708	3,526	3,526	17,631	35,262	52,894	70,525	83,600	-

Source: Analysis and calculation result

The location that does not have value subsidence in the next 5 years such as Kuningan and Komodor Laut yos sudarso because in that year there has not been subsidence anymore. For example, the Kuningan area has a large decrease in T90% of 64.2 cm. In other hand, if it is calculated 3,611 x 20 (year 2016 to 2035) it has reached 72.22 cm then the calculation is not valid at formula T90% because at the initial calculation, the decrease duration in the area is 17.781 years which means that in the 20th year (year 2035) the subsidence has reached T90%.

The results of calculation by using software of Plaxis 8.2 get same result with Terizaghi 1D approach. Komodor Laut Yos Sudarso Road get big decrease in T90% equal to 86,5 cm while if it calculated 3,649 x 25 (year 2016 to 2040) have reached 91,225 cm. the duration of subsidence in the area is 23,708 years which means that in the 25th years (in 2040) the subsidence has reached T90%.

Table 6. The Prediction of Magnitude of Alluvial Plain Degradation on Calculations per five years after research with the software of Plaxis 8.2

No.	Location	Subsidence Large of T90% (cm)	Duration Subsidence (year)	Subsidence Large Per Year (cm)	2016 (cm)	2020 (cm)	2025 (cm)	2030 (cm)	2035 (cm)	2040 (cm)	2045 (cm)
1	Bandarharjo	110,000	29,635	3,712	3,712	18,559	37,118	55,677	74,237	92,796	110,000
2	Kuala Mas Raya	78,200	29,635	2,639	2,639	13,194	26,388	39,582	52,775	65,969	78,200
3	Kuningan	65,800	17,781	3,701	3,701	18,503	37,006	55,509	65,800	-	-
4	Komodor Laut Yos Sudarso	86,500	23,708	3,649	3,649	18,243	36,486	54,728	72,971	86,500	-

Source: Analysis and calculation result

3.5. Classification of Subsidence Depth Rate

Below is a classification made for overlay of subsidence maps in 2016 to 2045:

Table 7. Level of land subsidence Depth with 5-year Plaxis Software Analysis

Level of Depth	Subsidence Depth Rate	Year of 2016	Year of 2020	Year of 2025	Year of 2030	Year of 2035	Year of 2040	Year of 2045
Level I	0-20 cm	Bandarharjo, Kuala Mas Raya, kuningan, Komodor Laut Yos Sudarso	Bandarharjo, Kuala Mas Raya, kuningan, Komodor Laut Yos Sudarso	-	-	-	-	-
Level II	21-40 cm	-	-	Bandarharjo, Kuala Mas Raya, kuningan, Komodor Laut Yos Sudarso	Kuala Mas Raya	-	-	-
Level III	41-60 cm	-	-	-	Bandarharjo, kuningan, Komodor Laut Yos Sudarso	Kuala Mas Raya	-	-
Level IV	61-80 cm	-	-	-	-	Bandarharjo, kuningan, Komodor Laut Yos Sudarso	Kuala Mas Raya	-
Level V	>80 cm	-	-	-	-	-	Bandarharjo, Komodor Laut Yos Sudarso	Bnadarharjo, Kuala Mas Raya

Source: Analysis and calculation result

3.6. The Effects of Land Subsidence toward the Area of Water Inundation

The preparation of a tidal/rob flood prediction is based on the components that influence the prediction. These components are the height of the tide, the topography of the city of Semarang and the warning of land subsidence. To get the highest tidal value from the ups and downs of Semarang city, tidal data calculation from BMKG of Semarang city from 2004-2014 to get Highest Height Water Level (HHWL) as the highest tidal value that happened during that period. From the calculation of tidal data using *least square* method can be seen that during the period of ten years from 2004-2014 the highest HHWL value is 0.9 meters. This value is used as the HHWL parameter in determining the threat/warning of flooding inundation. Furthermore, for the topography of the Semarang city, it is used Digital Data Geospatial Information Agency and *Digital Elevation Model* (DEM).

Table 8. North Semarang Inundation Area from 2015 to 2045

	Year of 2015-2016	**Year of 2020**	**Year of 2025**	**Year of 2030**	**Year of 2035**	**Year of 2040**	**Year of 2045**
Inundation Area (Ha)	562,62	674,56	763,88	839,20	917,48	986,36	1056,25

Source: Analysis and calculation result

Based on the above table it can be seen that the prediction of inundation area in 2015 until 2045 reached ± 493,63 Ha, per five year ± 111,94 Ha, and annually ± 22,38 Ha.

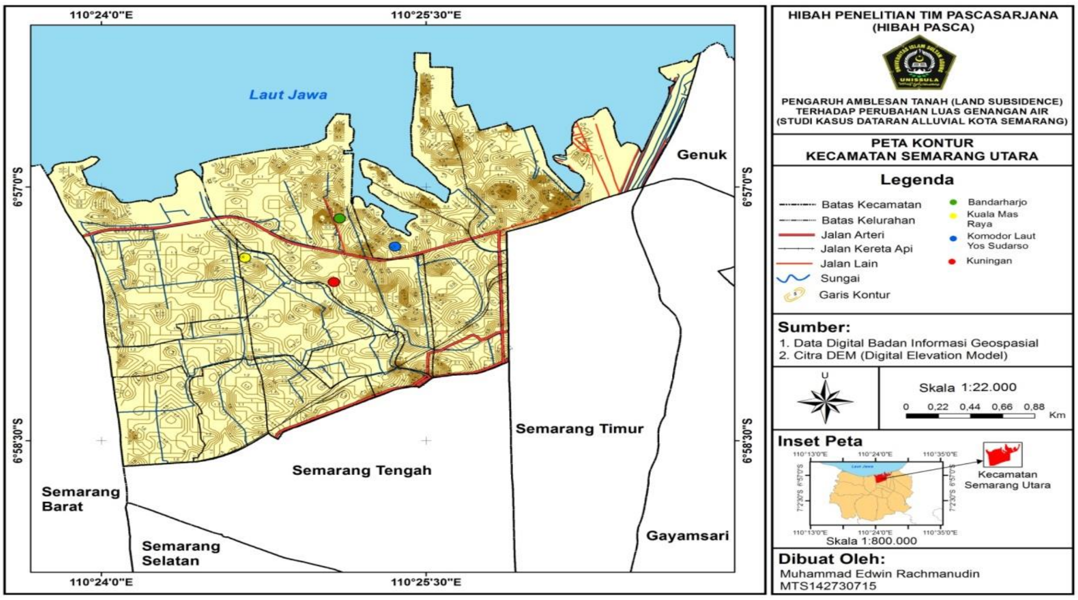

Figure. 2. Kontur Maps of Norh Semarang
Sources: Researcher Analysis

Based on the observations, there were found a number of puddles/inundation at the study site due to local rain, rain submission, and the non-functioning drainage system causing puddles/inundation when it rained and the decreasing of soil causing the soil decreasing and river water increased. The resulting high puddle/inundation at the location of each drill point in the area ± 20 cm.

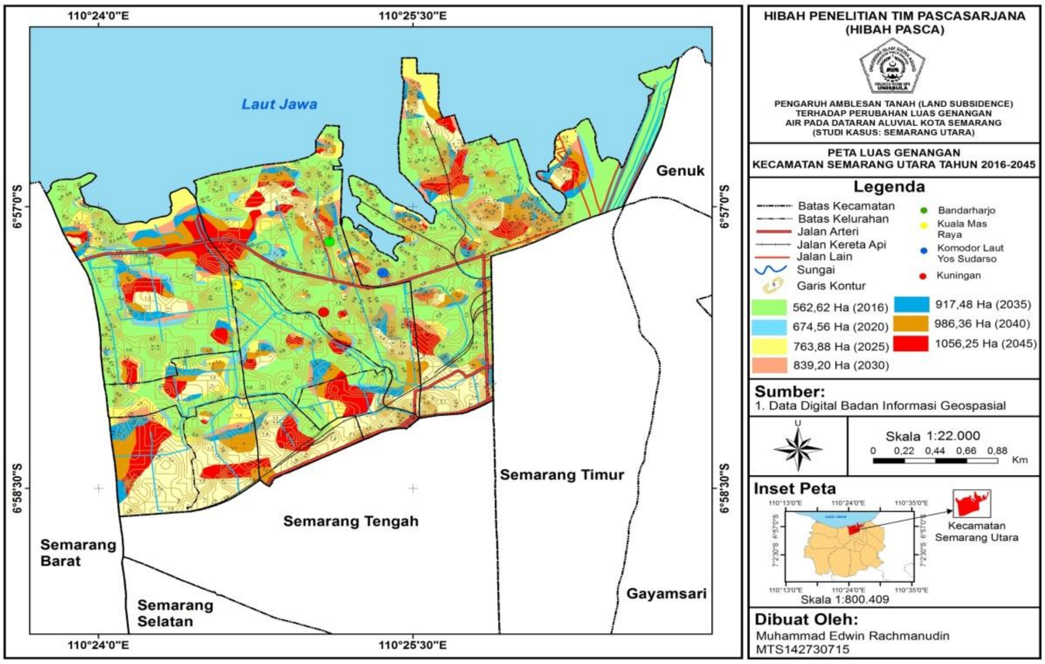

Figure. 3. Kontur Maps of Norh Semarang

Source: Researcher Analysis

Due to the increasing inundation, drainage cannot accommodate the water, but it is still exacerbated by the lack of optimal channel capacity due to sediment pile and several channels that winding so that the water takes a long time to the river.

4. Conclusion

Based on the results of data analysis and discussion can be concluded some points as follows:

1) The predictions of subsidence using the Terzaghi 1D approach with T90 obtained the smallest subsidence of 64.2 cm for 17.781 years and the largest subsidence 107,600 cm for 29.63 years.
2) The subsidence predictions using PLAXIS program, the smallest subsidence is 65,881 during 17,781 years and the largest subsidence of 110,000 cm over 29.6350 years.
3) The tendency of subsidence is the same as the northward direction (to the sea) and the subsidence becomes larger and the longer the duration.
4) Land subsidence on alluvial plains in parts of Semarang City is influenced by physical and mechanical properties of soil and loads above the ground.
5) The larger the subsidence rate and the longer subsidence time, this is affected by the compression index (Cc), and the consolidation coefficient (Cv). The larger of Cc of the subsidence becomes deeper and the smaller of Cv becomes longer of the subsidence time.
6) Predicted the changes of extent of inundation that occurred in the year 2016 until 2045 that is equal to ± 493.63 Ha, while the puddle/inundation area of per five years is ± 111.94 Ha, and per year is ± 22.38 Ha. The predicted results are calculated automatically by using GIS depending on the decreasing or subsiding of the soil.

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