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Influence the condition land subsidence and groundwater impact of Jakarta coastal area

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Abstract. Jakarta has been experiencing land subsidence for ten years due toerecting weight building and intensive extraction of groundwater for society drink water through ground water wells. Many groundwater extraction for drinkingwater has caused intensive scouring of land rock and further triggering land subsidence developed widely in coastal area of Jakarta. Measurement of the land subsidence has been performed by various experts and institutes. Between 1974 to 2010 subsidence has happened between 3 to 4.1 meters especially in Jakarta coastal area. Two major causes of the subsidence are identified. The first major cause is a result of erecting weight building such as hotels, appartments, and various human activities buildings. The second major cause is extracting ground water from aquifers bellow Jakarta land due to water deep wells down to the aquifer and traditional shallow water well of shallow or subsurface uncovered ground water. Weighter building and higher debit of water flow from deep water wells has fastened and deepened the land subsidence. Continuous measurement of land subsidence by means of geodetic as well as geophysical earth behaviour measurements need to be performed to monitor the rate, location as well as mapping of the land subsidence.
Keywords: costal area, groundwater, land subsidence

1. Introduction

Jakarta, the capital of Indonesia, has long been thesecond-largest megacity in the world, home of 10.5 million people. The city is having land subsidence problem. This problem has been worsened by the fact that the changes of climate and melting of polar ice has caused the rise of sea level. The two changes of groundwater level declining and sea level rising has caused worse land subsidence. The use of groundwater by people continuously has caused depletion of groundwater level. The land subsidence and sea water rise has been the attention to many experts.

Ground water withdrawal increased by 24 percent between 2011 and 2014, and is expected to continue to rise with increasing demand. The extraction of water has left large caverns under the city that are collapsing, a phenomenon that can be seen through the cracking of buildings, infrastructure and roads. Land subsidence is also increasing inland sea water intrusion and is causing a wider expansion of inland and coastal flooding areas.

Many experts have performed researches to solve the land subsidence problem. However, this is not a simple problem to be solved. Although it has been known that effect of human behaviour could be analysed, however, the solution is not simple. A lot of people who are using groundwater is identified to be the big problem. The depletion of ground water level had caused a more intensive land subsidence. From the research it has been recommended to the people to decrease using groundwater,

but this solution is not respected positively. It is now become the question how to reduce the rate of subsidence.

Currently informed that the head of Jakarta's environment agency has advised the city needs to "stop using groundwater" to reduce the rapid rate of subsidence. It is also informed that Jakarta is currently sinking at a rate of nine centimeters per year, with some areas experiencing subsidence rates up to 17 centimeters per year [2]. It is anticipated that this rate will increase due to the growing exploitation of groundwater and great levels of urbanisation. Water containment dams, the treatment of river waters, land reclamation, a sea wall and extended water pipelines are some of the proposed solution to solve the problem. However, the greatest investment to put into the contentious land reclamation project is now suspended due to Indonesian law problems.

2. Research Method

2.1. Groundwater Extraction

There are many researches that have been performed in connection to the land subsidence problem around Jakarta district and surrounding area. Groundwater level has been searched since long time ago. The groundwater level or piezometric level has been measured in various time period. The following information is the fact. Several wells have been searched with respect to the change of water level.

The groundwater extraction in Jakarta could be categorized into shallow (< 40 m) and deep (> 40 m) extraction. Shallow extraction is through dug wells or driven wells, operated with buckets, hand pumps or small electric pumps; whereas the deep extraction is mostly from drilled wells. Shallow extraction is mostly done by the population. It is well spread over the area, but its extraction rate per well is relatively low. Deep extraction is usually conducted by industry. It is usually more concentrated, and has a relatively high extraction rate per well [4], [5].

The subsidence rate is closely related to the rate of piezometric water level (head) deepening in the middle and lower aquifers. In the case of Jakarta, the increases in both population and industry, which require a lot of groundwater, could explain the above declining trend of piezometric heads, as shown in Figure 1. According to [5] , the piezometric level in North Jakarta has changed from 12.5 m above sea level in 1910 to about sea level in 1970's, and then deepened significantly to 30-50 m below sea level in 1990's [4], [5].

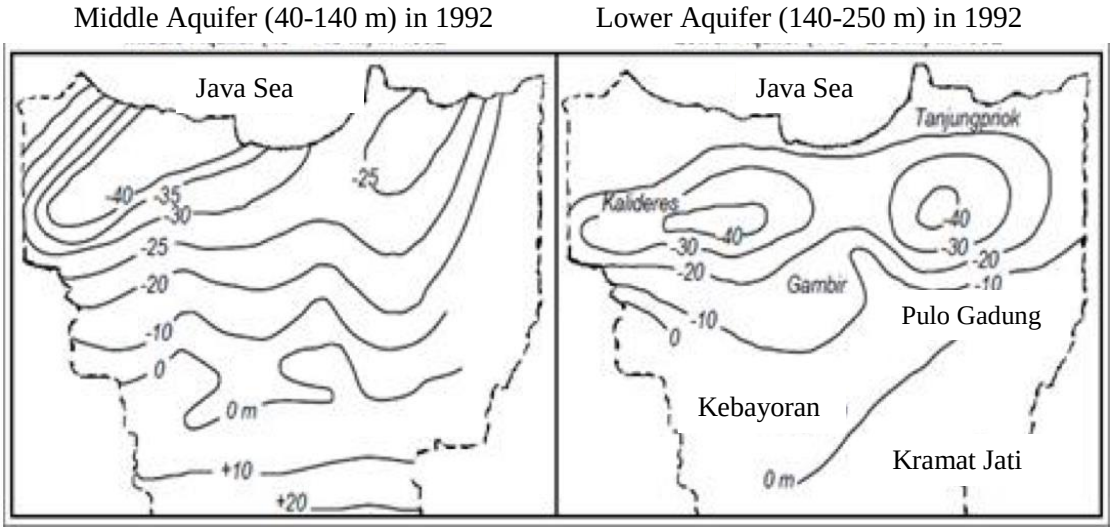

Figure1. Piezometric water level contours (in metres) inside Middle and Lower Aquifers of Jakarta in 1992 [4].

2.2. Land Subsidence Research

Experts also perform survey and research in land subsidence probelm of Jakarta area. The corelation between land subsidence and excessive groundwater taking in Jakarta can be illustrated using the subsidence results obtained from leveling surveys. Figure 2 shows the observed land subsidence during the period of 1982-1991 and 1991-97. Maximum subsidence during the period of 1982-1991 is about 80 cm, while for the period of 1991-97 is about 160 cm. In general the subsidence rates in Jakarta area during this period is about 1-5 cm/year and can reach 26 cm/year at several locations. During the period between 1982 and 1991, the maximum rate of subsidence is about -8 cm/year, while during the period between 1991 and 1997 it is about -26 cm/year.

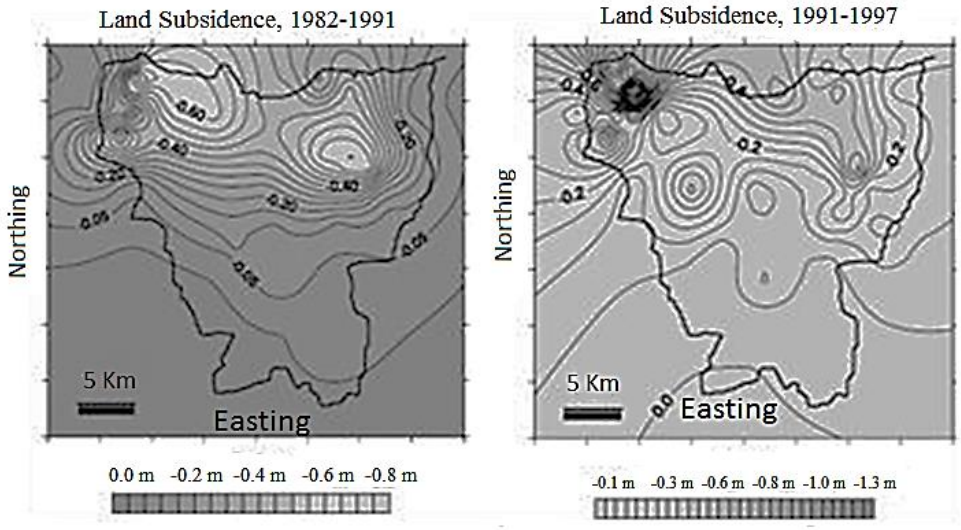

Figure 2. Land subsidence in Jakarta measured from leveling surveys (in metres), over the periods of 1982 – 1991 (left) and 1991 – 1997 (right) [6].

3. Results and Discussion

Other experts also performed survey and research about land subsidence in Jakarta area. Figure 3 shows the research output of Deltares research team in the periode between1974 and 2010. It is shown that the deepest land subsidence has happened at Ancol Beach and surrounding area. From this picture it is shown that the area has been subsided as deep as 4.1 meter during the period.

Figure 3 it can also be recognized that to the southern part of Jakarta region, the land subsidence is lessened, however, this problem cannot be neglected. The subsidence gives difficulties of people to erect building, houses, etc, because the land surface is continuously subsidized. The problem is effected by groundwater depletion has long been happened and continuously rating the subsidence because the water containing rocks undergoing decrease vertically that has caused subsidence up to the ground surface.The people population around Jakarta area also gives heavy impact to the subsidence problem, because the increase of population will need living area and other building needs (shops, markets, station, bus terminals). With the increase buildings and other needs it will increase the land surface weight and thus deepening the subsidence. Figure 4 shows the increase of living area and prerequisites causing by population increase in Jakarta region.

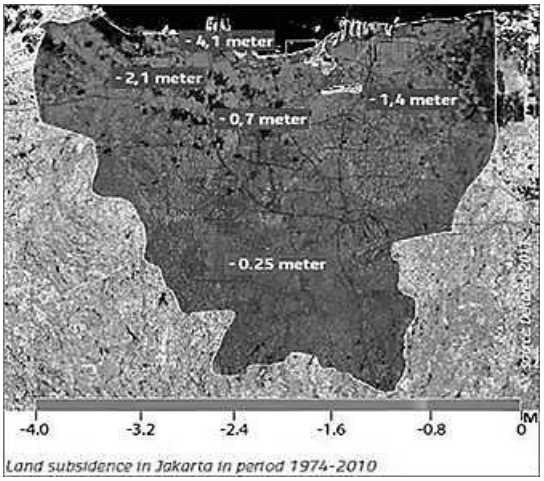

Figure 3. Output of land subsidence research around Jakarta area in a period of 1974-2010 [3].

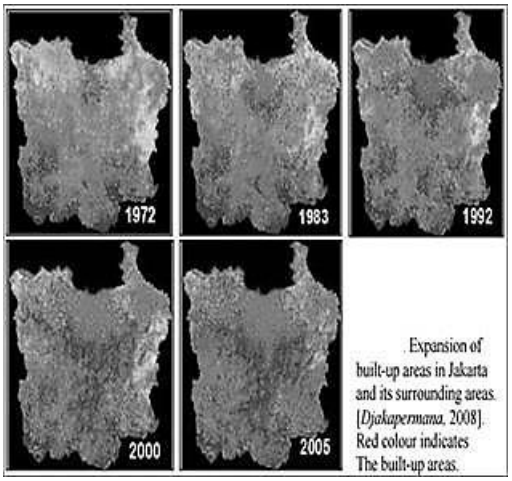

Figure 4. The development of people living area and its required facilities in Jakarta region and surrounding areas [4].

With the above explanation, it is clear that Jakarta people and local government face a number of problems in connection with land subsidence. Variety of researches can be performed to identify the land subsidence or any other land problems such as land slide, slump, etc. As an example, a land slide or subduction has been surveyed by geophysical survey and reasearch.

A group of geologists of Landslide Research and Risk Management Division (LRRMD), NBRO has performed to conduct an investigation on a land subsidence at Achchuweli area, Jaffna, suddenly occurred in the morning of 23rd January, 2016. It was observed clearly that cracks (1-5cm) have developed on the ground in a circular area with an approximate diameter of 70m. The affected area is a farming land. A house on the perimeter of said circle was severely cracked and tilted slightly. It was also noted that the cracks in the house have been developing. LRRMD geologists explored the area on 27th January, 2016 and also conducted a geophysical survey to understand the present subsurface ground condition of the affected area [8].

Geologically the area is composed of limestone which is a weak sedimentary rock and hence, easily dissolvable. As the formation of dissolution cavities and caverns are quite common in this kind of terrains, underground tunnels and cavities are found in many parts of the Jaffna Peninsula. According to the geophysical studies conducted, some underground discontinuities of the limestone terrain of the affected area were revealed indicating underground cavities possibly filled with water or moisture soil. Due to activation of such dissolution cavities, ground settling can be expected with time, leading to further subsidence in the affected area. Figure 5 shows geophysical measurement line especially resistivity method in the survey area.

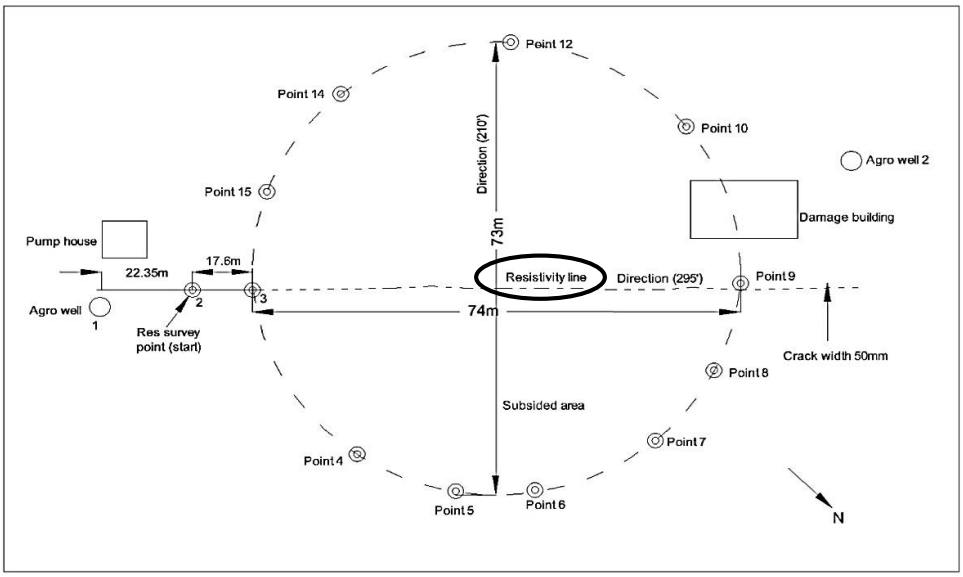

Figure 5. Geophysical measurement line in the land subsidence area of Achchuweli, Jaffna (Srilanka). Red line mark shows gephysical measurement line.

Land subsidence, land slide, slumps and other land problems has happened in Indonesia big cities including Jakarta, Semarang, Surabaya, and others. Many big cities in the world are positioned on the above of sedimentary rock layers that undergo land sliding or sunsidence. The world big cities other than Jakarta are Bangkok (Thailand), Tokyo (Japan), Osaka (Japan), Niigata (Japan), Taipei (Taiwan), Shanghai (China), Mexico, Venice (Italy), London (England), and other states in the United States of America also have land subsidence problem. The land subsidence that happens in non-coastal area cities may not give serious impact, however, for the coastal cities they may undergo trouble problems by rising sea water level into the land.

With the land subsidence causing from heavy load above the land surface such as big buildings, houses, and other infrastructures has been added the problem by increasing extraction of groundwater. Research may be performed into detail such as analysing the micro aspect of rock lithology. Figure 6 shows rock pores condition filled with groundwater. The pore pressure is continuously getting higher due to overburden pressure caused by load of heavy surface human buildings and land subsidence. When the water is extracted by deep water wells the rock grains will be compressed and crushed due to the load and land subsidence. Detail reasearch of petrology could be performed continuously to recognize the impact of land subsidence and groundwater extraction.

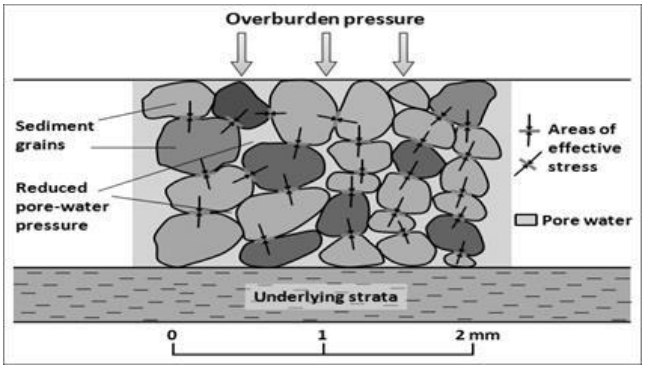

Figure 6. Detail investigation of compressing impact of a rock due to over burden pressure caused by overload and land subsidence problems.

Land subsidence, groundwater extraction and sea level rise have caused possible declining and dropping the city land below sea level. Although endeavors to solve the problem have been performed various researches could be performed. The following are possible new research area:

a) Measurement of the rate of land subsidence arround specific area such as Ancol Beach (North Jakarta) using GPS. This measurement is planned to ensure and acurateness of land subsidence rate in the area.
b) Geophysical measurement to analyse the geological structures causing by overload and land subsidence. Resistivity and refraction seismic could be performed to detect subsurface subsidence during a period of time. Geophysical method can be applied pasively to compare in a period of time or between different measuring locations. The geophysical methods can also operated actively by observing the land surface change in a period of time.
c) Rock and mineral sampling for geochemical analysis both on rock character changes and groundwater extraction impact. This can be performed using shallow well.

4. Conclusion

Land subsidence, groundwaterextractionand sea level rise are hardly faced by people in the cities. Measurements and reasearch with respect to solve the problem have been conducted. The subsidence, however, could continuously developed to be hardly overcome. Researches of different basic, method and purpose need to be performed to find possible solution. Geophysical and geochemical research and measurement using certain methods may be done to find data and information with respect to physical, chemical behaviour and geological structures that can be used to support data in finding the solution of the problem. Detail reasearch such as petrological and mineralogical research, experiments, tests and other ways to get important data and information could be performed. To perform further research, mesurement, and monitoring the land subsidence continuously, it is expected to receive sponsor and support to supply requirement including financial cost in order to solve the land subsidence, groundwater exctraction, and impact of sea water level rise problem particularly in Jakarta city.

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References

[1] de Lange G, Bucx T, Stuurman R, & Erkens G, Land subsidence, sea level rise and urban flooding, Deltares Research Institute, Aug 10, 2015.
[2] Haweya Ismail, Indonesia: Groundwater Decline is Causing Jakarta to Sink, Global Food and Water Crises Research Programme, Future Directions International Pty Ltd., 2016.
[3] Abidin H Z, Presentasi Asahi Research Finding 2014, LPPM-Institute Teknologi Bandung, 2014.
[4] Abidin H Z, Andreas H, Gumilar I, Gamal M, Fukuda Y, and Deguchi T, 2009. Land Subsidence and Urban Development in Jakarta (Indonesia), *7th FIG Regional Conference Spatial Data Serving People: Land Governance and the Environment – Building the Capacity*, Hanoi, Vietnam, 19-22 October 2009.
[5] Djakapermana R D, 2008, Kebijakan Penataan Ruang Jabodetabekjur, Paper presented at *One day Seminar celebrating World Water Day*, Environmental Management Technology Expertise Group, FTSL ITB, Bandung, 31 Maret 2008.
[6] Soetrisno S, Satrio H, and Haryadi T, 1997, To Anticipate Impacts of Reclamation of Jakarta Bay, A Groundwater Conservation's Perspective. Paper presented at Workshop on Coastal and Nearshore Geological/Oceanographical Assessment of Jakarta Bay : A Basis for Coastal

Zone Management and Development, Jakarta, 25 - 28 June.

[7] Abidin H Z, R Djaja, D Darmawan, S Hadi, A Akbar, H Rajiyowiryono, Y Sudibyo, I Meilano, M A Kusuma, J Kahar, C Subarya. March 2001. Land Subsidence of Jakarta (Indonesia) and its Geodetic-Based Monitoring System. Natural Hazards. *Journal of the International Society of the Preventation and Mitigation of Natural Hazards*. 23(2/3):365 - 387.

[8] Landslide Research and Risk Management Division, Recent Land Subsidence I Investigation at Achchuweli, Jaffna, National Building Research Organisation, 2016.