The effect of land subsidence on the selection of raw water sources in hotel and apartment buildings in Semarang city

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Abstract. The Semarang City Government prohibits groundwater/ deep wells in hotel and apartment buildings because the use of groundwater or deep wells in locations that have experienced subsidence will further aggravate the subsidence. The method used in this research is to purposively select hotel and apartment buildings in Semarang that have received an assessment by the Semarang City Building Expert Team and have received a certificate of serviceability. Furthermore, compare the map of land subsidence in some areas of the city of Semarang with the natural water sources used by the hotel and apartment buildings. The research results showed that from 10 hotel and apartment buildings, there were 7 that used deep wells in zone level II, namely subsidence between 2.1 to 4 cm/year. Meanwhile, 3 other hotel and apartment buildings use water from the Municipal Drinking Water Company of Semarang. The existence of hotel and apartment buildings that use groundwater/deep wells in zone level II will increase and trigger the more significant subsidence in the area, thereby increasing the level of subsidence to level III.

1. Introduction
The city of Semarang currently has Major Regulations. 24 of 2019 concerning Green Buildings. Article 10 states that the technical requirements for large buildings include energy efficiency, water efficiency, and indoor air quality management. Based on these technical requirements, water efficiency gets special attention because the proponent has neglected this water efficiency in several cases. Problems often ignored by proponents include selecting natural water sources not considering environmental problems around the location, especially the presence or absence of groundwater pollution at the site, seawater intrusion [1], or the occurrence of land subsidence. Land subsidence problems are often found in parts of Semarang City, especially in the northern part.

Land subsidence that occurred in some parts of Semarang City, Central Java, is very concerning. Among the causes of land subsidence that often occur are less dense soil [2], heavy loads on it, and excessive groundwater use.
Land subsidence in parts of Semarang City reaches 8 cm/year, occurs in Tanjung Mas (Semarang harbor) to the east to the coast in the Genuk District and part of Saying District, which is included in the Demak Regency area. The Bandarharjo area and surrounding locations reach 10 – 15 cm per year, Tanah Mas, Marina Tawang Mas, Tawang Railway Station, and Karang Tengah, 5 – 10 cm per year [3]. In South and Southeast areas such as Banget ayu and its surroundings, subsidence is generally less than 5 cm per year. Likewise, some parts of Semarang City experience land subsidence between 1–9 cm per year due to excessive groundwater extraction without being offset with increased water infiltration [4]. Subsidence in most of Semarang City mainly occurs on alluvial plains with varying depths, the further north. Generally, the subsidence that occurs is deeper [2]. The causes of land subsidence are building loading, natural compression of alluvial deposits, soil accumulation, and excessive use of groundwater.

Land subsidence on alluvial plains in some parts of Semarang City is a serious problem because the area is close to settlements. Land subsidence in the area is lower due to the location being close to the coast when high tides inundate residential areas due to water flowing inland through rivers and drainage channels [5]. This study examines and analyzes the relationship between land subsidence and the selection of natural water sources (groundwater and PDAM) and is used to measure the level of compliance of hotel and apartment building owners in Semarang City.

2. Methodology
The method used is to create a subsidence map in some parts of Semarang City, which is made from the results of interpolation from points based on secondary data. In mapping, this interpolation is the process of estimating values in areas that are not sampled or measured so that a map or distribution of values is made over the entire area. This interpolation uses the software Geographic Information System (GIS), namely ArcGIS, using the IDW (Inverse Distance Weighted) Interpolation method using the extension spatial analyst facility. The value generated by this method is based on the range of values from the interpolation points. This IDW method uses an average distance so that the resulting value is not smaller than the minimum value and not more significant than the maximum value.

The subsidence map that has been made will be compared with the actual conditions of hotel and apartment buildings in the city of Semarang. This comparison is used to determine and analyze the relationship between land subsidence and the selection of natural water sources (groundwater and PDAM) and is used to measure the level of compliance of hotel and apartment building owners in Semarang City.

Hotel and apartment buildings were chosen purposively; they were chosen intentionally for buildings that have received an assessment by the Building Expert Team (TABG) and have received a certificate of serviceability (SLF) from the Semarang City government. SLF is a certificate issued by the Regional Government except for notable function buildings to declare the functional feasibility both administratively and technically before its utilization.

3. Results and discussion
3.1. Land subsidence in part of Semarang city
Based on the results of the research that hotel and apartment buildings in the city of Semarang that already have a certificate of serviceability (SLF) are as follows:
Table 1. Research samples on hotel and apartment buildings.

| No. | Name of Buildings                  | Function          | Number of floors | Address                        | Raw water source |
|-----|-----------------------------------|-------------------|------------------|--------------------------------|------------------|
| 1   | The Pinnacle Hotel & Apartment    | Hotel & Apartment | 23               | Jl. Pandanaran No. 18 Semarang | MDWC             |
| 2   | Gumaya Tower Hotel                | Hotel             | 14               | Jl. Gajah Mada No. 59 - 61 Semarang | MDWC & Deep well |
| 3   | Holiday Inn Express               | Hotel             | 16 + 1 basement  | Jl. Ahmad Yani No. 145 Semarang | Deep well        |
| 4   | Hotel Santika Premiere            | Hotel             | 12               | Jl. Pandanaran No 116-120 Semarang | Deep well        |
| 5   | Ciputra                           | Hotel & Mall      | 12               | Jl. Simpang Lima No. 1         | MDWC & Deep well |
| 6   | Sentraland                        | Mixed use & Aparment | 19 + 1 basement | Jl. Kimangunsarkoro No. 36 Semarang | Deep well        |
| 7   | Hotel Horison Nindya              | Hotel             | 11 + 1 basement  | Jalan Brigend Sudiarto No. 496, Semarang | Deep well        |
| 8   | Hotel HA-KA                       | Hotel             | 9                | Jalan Ahmad Yani No. 173, Semarang | MDWC             |
| 9   | Star Hotel                        | Hotel & Mall      | 30               | Jl. MT. Haryono no. 972 Semarang | Deep well        |
| 10  | Marquis De Lafayette              | Hotel & Mall      | 18               | Jl. Pemuda No. 49              | MDWC             |

Note: MDWC = Municipal Drinking Water Company = PDAM (Perusahaan Daerah Air Minum)

Based on Table 1, above, the natural water sources used by hotel and apartment buildings consist of three types: MDWC, deep well, and a combination of MDWC and deep well. Sources of raw water originating from hotel and apartment buildings in the city of Semarang will be compared with the interpolated subsidence map in Figure 1 so that five classes of subsidence depth can be obtained in Table 2.

Table 2. Grade of subsidence depth value. [6]

| Depth Level | Grade of the subsidence depth value |
|-------------|-------------------------------------|
| Level I     | 0 – 2 cm/year                       |
| Level II    | 2.1 – 4 cm/year                     |
| Level III   | 4.1 – 6 cm/year                     |
| Level IV    | 6.1 – 8 cm/year                     |
| Level V     | > 8 cm/year                         |
Figure 1. Map of land subsidence in a part of Semarang city. [7]

Level I is a representation of the minor subsidence depth level, while Level V is a representation of the most significant subsidence depth. The results of the overlay map of subsidence and land use maps show the extent and depth of subsidence, as shown in Table 3.

Table 3. Land subsidence area based on depth level (m).

| No | Level | Class/Grade   | Area (Ha) | Percent(%) |
|----|-------|---------------|-----------|------------|
| 1  | I     | 0 – 2 cm/year | 852.87    | 7.58       |
| 2  | II    | 2.1 – 4 cm/year | 3951.46  | 35.11      |
| 3  | III   | 4.1 – 6 cm/year | 2908.36  | 25.84      |
| 4  | IV    | 6.1 – 8 cm/year | 1992.70  | 17.70      |
| 5  | V     | > 8 cm/year     | 1549.71   | 13.77      |
|    | Total |               | 11255.09  | 100        |
The magnitude and duration of subsidence are influenced not only by the soil's mechanical properties but also by the load due to land use. Figure 2 is a graph of land-use area.

![Figure 2. Graph of land-use area (ha).](image)

Based on Table 1, all hotel and apartment buildings that have received SLF are in a small subsidence zone at level 2, ranging from 2.1 to 4 cm per year. However, this land subsidence will be even greater if the use of groundwater is not limited in such a way, especially in the Gumaya Tower Hotel, Holiday Inn Express, Santika Premiere Hotel, Ciputra, Sentraland, Horison Nindya Hotel, and Star Hotel buildings. All of these seven buildings use deep wells to meet their water needs. Based on the level of subsidence, the seven buildings are allowed to use groundwater (deep well) for building operations on condition that there are water usage limits [8] and obtain a permit from the Central Java Province ESDM (Mineral Resources Energy) Office by the implementation Central Java Provincial Regulation No. 03 of 2018 concerning groundwater management in Semarang City [9]. There should be sub-metering to control groundwater/deep wells, not to increase subsidence in the area. However, it would be wise if the seven buildings would subscribe to PDAM water and completely release their dependence on groundwater/deep wells. Consideration of the use of water from PDAM will save the environment from more severe damage; in addition to land subsidence, excessive use of groundwater will decrease groundwater level [10], groundwater pollution [11], and the occurrence of water intrusion.

4. Conclusion
The results of research conducted on hotel and apartment buildings in the city of Semarang show that the use of water using groundwater/deep wells is highly favored by hotel and apartment building owners because apart from the relatively low cost, the quantity and continuity are relatively guaranteed when compared to must subscribe to MDWC However, the use of groundwater has exacerbated land subsidence in the city of Semarang. Of the 10 hotel and apartment buildings that have received SLF, 7 prefer to use groundwater instead of having to subscribe to MDWC; the result will be more labor-intensive. Subsidence conditions in the area.

All hotel and apartment buildings in Semarang City are at subsidence level II, which island subsidence between 2.1 – 4 cm/year. The use of groundwater in hotel and apartment buildings in the area can increase the level of subsidence to level III and so on. The number of hotel and apartment buildings that use groundwater occurred before the Mayor of Semarang City Regulation (Perwal) No. 24 of 2019 concerning Green Buildings was issued, while after the enactment of the regulation, newly
established hotel and apartment buildings will follow existing regulations and received an assessment by the Semarang City Building Expert Team. (SBET).

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