The Identification of Land Subsidance by Levelling Measurement and GPR Data at Tanjung Emas Harbour, Semarang

Identifikasi Amblesan Tanah melalui Pengukuran Sipatdatar dan Data GPR di Pelabuhan Tanjung Emas, Semarang

Purnomo Raharjo and Mira Yosi

Marine Geological Institute, Jl. Dr. Junjunan No. 236, Bandung, 40174

Corresponding author : uwemgi@gmail.com

(Received 27 Februari 2017; in revised from 29 July 2017; accepted 14 August 2017)

ABSTRACT: Recently, the main problem in Semarang City is flood. This area has low relief that consists of coastal alluvial deposits, swamp and marine sediments. The coastline is characterized by muddy, sandy, and rocky coasts, and mangrove coast. Ground Penetrating Radar (GPR) records show that subsurface geological condition of northern part of Semarang is coastal alluvial deposit and in the south is volcanic rocks. The aims of this research is to determine land subsidence by levelling measurement in 2005 in Tanjung Emas Harbour area built on 1995. During ten years, there are various land subsidance in this area: in Coaster Street (21 – 41 cm), container wharf (62 – 94 cm), north breakwater (64 – 79 cm), west breakwater (74 – 140 cm), east groin (76 – 89 cm), and stacking area (77 – 109 cm). According to this research, it is concluded that one reason causes of flooding in this area is land subsidence.

Keywords : flood, land subsidence, Levelling, Tanjung Emas Harbour, Semarang

ABSTRAK: Permasalahan yang berkembang di Kota Semarang saat ini adalah terjadinya banjir. Kawasan ini berelief rendah yang disusun oleh endapan aluvial pantai, rawa dan sedimen laut. Karakteristik garis pantai dicirikan oleh pantai berlumpur, berpasir dan berbatuan, serta pantai berbakau. Rekaman Ground Penetrating Radar (GPR) menunjukkan kondisi geologi bawah permukaan utara kota Semarang merupakan endapan aluvial pantai dan bagian selatan disusun oleh batuan vulkanik. Tujuan penelitian ini adalah untuk mengetahui kondisi penurunan tanah melalui pengukuran sifatdatar yang dilakukan pada tahun 2005, di kawasan Pelabuhan Tanjung Emas yang dibangun pada tahun 1995. Dalam kurun waktu 10 tahun, diketahui bahwa terdapat variasi penurunan tanah di kawasan ini: ruas jalan Coaster (21-41 cm), di kawasan dermaga peti kemas (62-94 cm), pemecah gelombang sebelah utara (64-79 cm), pemecah gelombang sebelah barat (74-140 cm), penahan gelombang sebelah timur (76-89 cm), dan pelataran peti kemas (77-109 cm). Berdasarkan penelitian ini, maka dapat disimpulkan bahwa salahsatu penyebab banjir di kawasan ini adalah akibat penurunan tanah.

Kata Kunci : *banjir, penurunan tanah, sipatdatar, Pelabuhan Tanjung Emas, Semarang*

INTRODUCTION

Tanjung Emas Harbour is one of the ten busy harbour in Indonesia. This harbour is located in the northern part of the capital city of Central Java Province. The main problem of this area is frequently flooding from the coast area into the city of Semarang. Beside human activities, natural occurence is considered affecting this flooding, including land subsidence and geological processes (Gumilar, 2013). In order to prove the occurrence of this subsidence, it is necessary to understand the development of the city formation. Therefore this research was conducted to observe the geology and characteristic of Semarang coast, including its sediment, basement rock and subsurface, correlated to the land subsidence in Tanjung Emas Harbour.

Based on *informasi-semarang.blogspot.com/2010/04/sejarah-kota-semarang.html,* the history of Semarang City can be resumed as:

- Pre 900 M Period, before alluvial plain was formed in G foot. The north coast border is Ungaran
- 900 – 1500 M period: alluvial plain/the formation of quartenary sediment, originated from Kali Kreo, Kali Kripik, and Kali Garang which played a role as the main transportation during Medang Kawulan Kingdom (924).
- 1500 – 1700 period: The beginning of Semarang City, and known as one of the important harbour.

The current coastal line was in Sleko. Semarang was a military defense and trading area (VOC).

- 1700 – 1906 period: The city was functioned as the center of colonial activity, the second base after Batavia, fortresses, offices, and government residence were built.
- 1942-1976 period: The fast development of Semarang as a city and land optimization.

The micro gravity anomaly research by Kaligawe industrial area and land subsidence acquires subsurface water dynamics data and field observation. Based on the combined analyses between inter period micro gravity and inter period vertical gradient during June 2004 – November 2005, the Kaligawe industrial area are divided into two zones, are subsurface water front subsidence zones and subsidence (Dino, 2008). Furthermore, gravity line interpretation reveals subsurface water front subsidence about 2-20 meter during the past 16 months. From leveling subsidence map, the subsidence has been occurred in about 0.5-10cm during this past 16 months.

The decrease of subsurface water front subsidence in Kaligawe in Kaligawe industrial area, suggest the occurrence of subsidence and rob. The increase of sea level resulting in various physical and environmental impact. The sensitivity level of an area to the sea level increase can be measured by fragility index method. By this method, it is observed that Marina Beach fragility index is lower (2.17) than that of Tanjung Emas Harbor (4.3). This suggested that Tanjung Emas Harbor is more sensitive (more vulnerable) to the flood (Ifan and Suhelmi, 2012). Physiographically, Semarang City is on alluvial plain which was resulted from sediment transportation through large rivers and sedimentation in coastal area (van Bemmelen, 1949). The alluvial plain lays from Serayu Utara mountain in the south, Kendeng hills in the east, and Java Sea in the north (Figure 1). Steepness of Semarang starts from plain 0-5%, wavy 5%-15%, abrupt 15%-30% and steep 30- > 70 % (Figure 2).

METHODS

The methods applied in this research are: coastal characterical mapping in order to understand the coastal type and geomorphology, GPR analysis to obtain subsurface conductivity which might reflect sediment type, and geodetic measurements to measure land subsidence in Tanjung Emas Harbor. Secondary data acquired is Semarang City history of developments (*information- semarang.blogspot.com/2010/04/ sejarah-kota-semarang.html).*

The GPR in general is similar to the conventional radar (Budiono, 2008). Some basic theories of GPR were described in Benson (1995). GPR sends energy pulses between 10 to 1000 MHz to the ground from antenna. Then it will record data in a very short time *(nanosecond).* The Tanjung Emas Harbor is presumed has been subsided, suggested from several buildings which are drowned by the seawater during maximum tide. Firstly, we tied the geodetic reference points before leveling. The tie points is estimated by polygon method using *"Total Station Sokkia"* equipment between Bench Mark (BM) BIG point in front of that is in terminal with BM 1 SPP II-1, BM 6, TB 1, TB 2 and TB3. Early azimuth coordinate as reference point TB 1 was measured by DGPS Trimble DSM 212 H. We used local coordinates as the geodetic reference point, afterwards it is transferred into UTM coordinates and WGS84 datum, before being used as survey reference point (BM). The transformation of coordinates is conducted by the BIG 'shift datum' procedure.

Geodetic measurement *(leveling)* on supporting point utilized *"waterpass"* tied. "Total station"was used as the reference point. Leveling has been done in Tanjung Emas Harbor in particular at Coaster Street, north breakwater, west breakwater, east groin, stacking area, and container wharf. The actual sea level for harbor development has been measured by tide measurement for 15 days with lowest sea level datum (LWS).

RESULT

The shoreline was characterized by mangrove, sandy and gravel, mud, and rock. Mangrove is rarely distributed, mainly at low relief beaches and in alluvium plains. Semarang City coastal zone is categorized by its lithology, coastal morphology, and coastal line characteristics (Dolan, 1975). The lithology in the coast of Semarang City is alluvium and volcanic breccias sediments. In general, Alluvium sediments occupy the low relief beaches and consist of low to medium resistance sediments such as mud, sand, and gravel. Medium to high resistance volcanic breccias occupy the medium relief beach in western area of the research area.

Sandy beaches and gravels lies in narrow parts of western part of research area. Rocky beaches can be found in eroded beaches and are used as erosion retaining wall, due to its function for shipyard and tourism object. Coastal line development is characterized by erosion and sedimentation. Erosion in the coast of Semarang City is occurred around the harbor, residence, tourism area, and on the western coast of moderate relief breccias. Coastal sedimentation in the middle area is characterized by muddy plain with mangroves.

Subsurface conductivity around Marina Beach (line 1) indicates varying conductivity, high conductivity is marked by blackish color while low

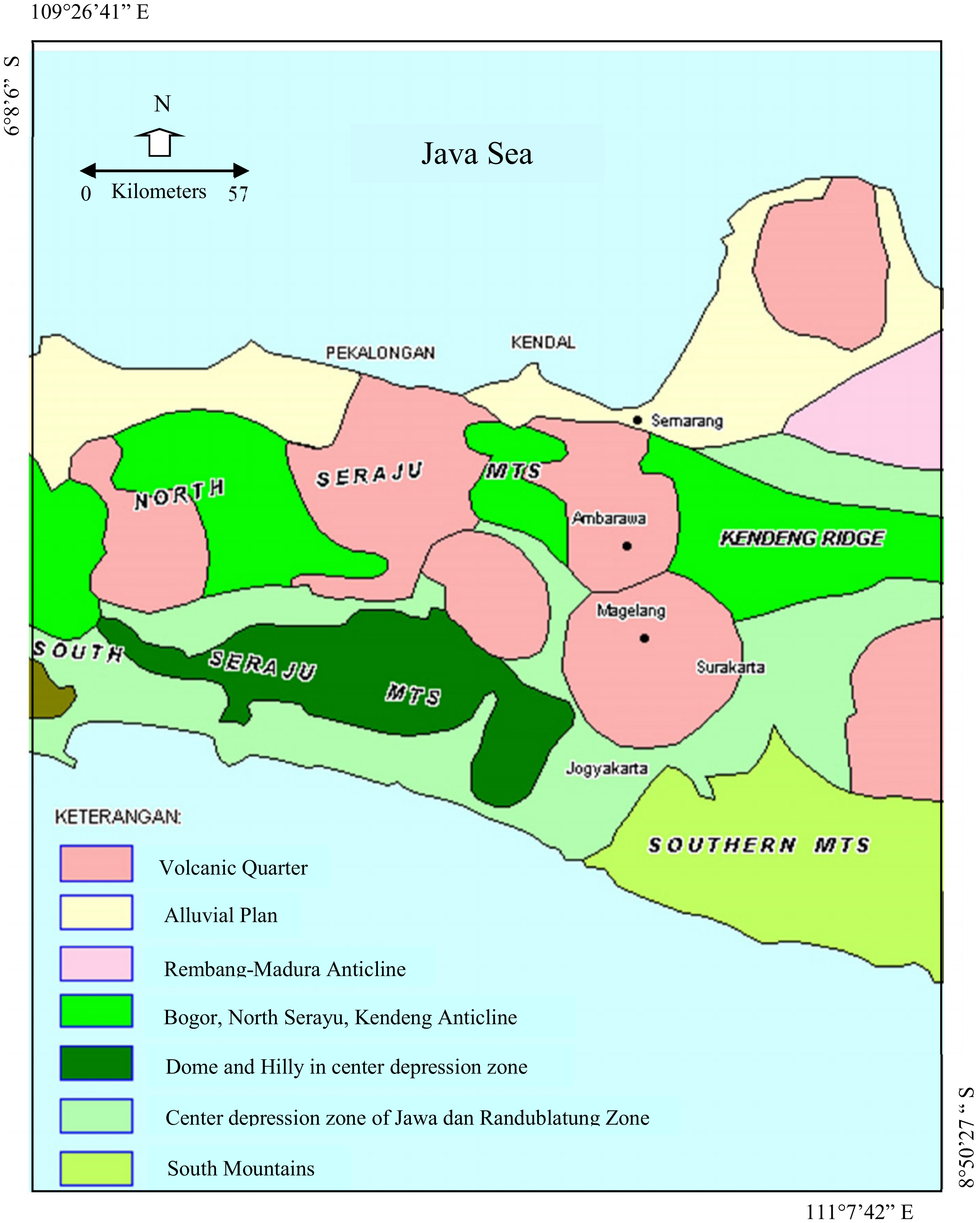

Figure 1. Central Java Physiography (Modified from van Bemmelen, 1949)

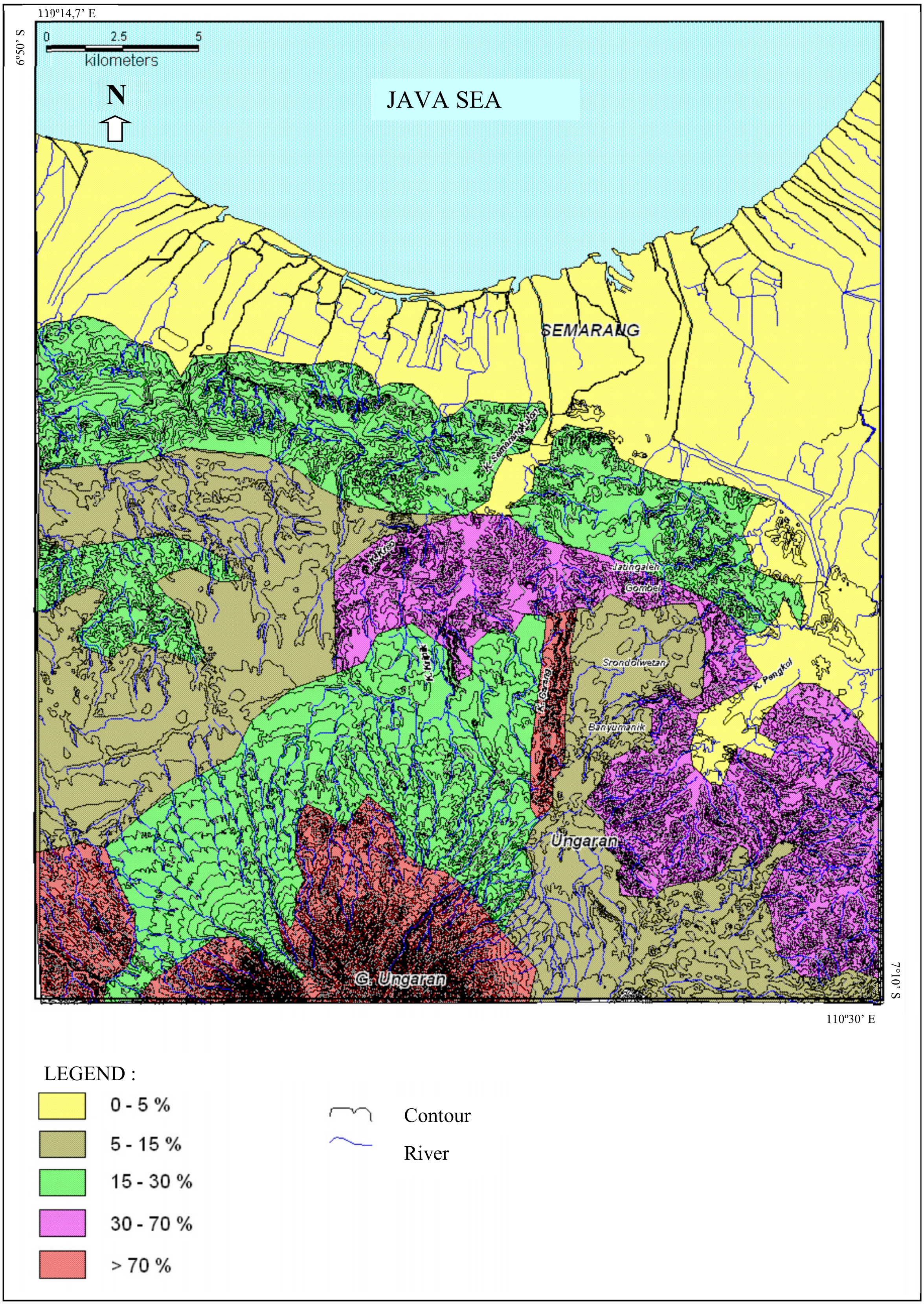

Figure 2. Semarang slope steepness and its surrounding (Raharjo and Kristanto, 2005)

conductivity is marked by lighter color (Figure 3). High conductivity sediments are usually clay or sandy sediments with relatively high water content, or in coastal area it could be other sediments with salty water content. GPR record of The Southern part of Semarang City (line 2) indicates volcanic rocks underlain by 0-10m thick of coastal alluvial or marine sediments (Figure 4). The GPR record exhibits high conductivity, which interpreted as clay or silt sediment that alternated sometimes with sand sediments. Below is interpreted as denser lithology marked by hyperbolic different with its seal, which possibly a volcanic breccias.

Tide measurement is important for coastal building construction and harbor planning. Mean sea determination and low water front is Admiralty method (Asrul, 1983). The highest and lowest sea level elevation is essential in building planning. For example, top shipyard elevation, breakwater, wave breaker, etc determined by high water level, while sail line or shipyard depth is determined by low water level. Tide calculation in 2004 resulting in *High Water Level (HWS)* = 2.475 m; *Mean Sea Level (MSL)* = 1.784 m; *Low Water Sea (LWS)* = 1.095 m (Figure 5).

The coordinates and reference points elevations resulted from polygon point measurement using Total Station and Waterpass based on *Low Water Sea (LWS)* tide measurement during 2004 survey are displayed in Table 1 and Figure 6.

Leveling on Tanjung Emas Harbour covers Coaster Street, north breakwater, west breakwater, east groin, stacking area, and container wharf (Raharjo et al., 2005). To observe the subsidence occurrence, the actual elevation data in 2005 was compared to the elevation data in 1995. The result indicates subsidence in Coaster Street in T4 is approximately 41 cm, in point T7 (21 cm), and in point T8 (40 cm), North breakwater has been subsided by approximately 64-79 cm, west breakwater (74-140 cm), east groin (76-89 cm), stacking area (77-109 cm), and container wharf (62–94 cm).

DISCUSSION

Semarang as capital city of Middle Java has long history since as muddy area then become modern environment and important city. Physiographically, Semarang lays on alluvial plain derived from land (van Bemmelen, 1949). Geologically, it's lithology consists of quaternary sediments which are alluvial, volcanic breccias, lava, and Penyayatan Formation, and Tertiary sediment composed of marine sediment. The steepness of Semarang ranging from plain (0-5%), wavy (5%-15%), abrupt (15%-30%) and steep (30% - > 70 %). Alluvial lays in low relief beach and consists of low to medium resistance sediment such as mud, sand, and gravel. Medium to high resistance volcanic breccias cover the medium relief beach in western part of research area. Coastal line characteristics are mangrove, sandy beach, and gravel muddy rocky beach. The development of coastal line is marked by erosion and sedimentation. Based on GPR, geology subsurface are clay or sandy sediments that is high water content alluvium or marine. Southern area is composed of volcanic rock underlain by coastal or marine alluvial sediment reveals as a 0-10m thick clay or silt. Semarang Old City around Simpang Lima and Gombel composed of volcanic rocks covered by coastal or marine alluvial sediment with high supporting. It can be said that Semarang is currently grow above coastal or marine alluvium sediment with low soil bearing capacity, resulting a subsidence. Previous research revealed low fragility level on coastal area with composite index 2,17 while Tanjung Emas Harbour has high fragility level with composite index 4,30 resulting in constant rob.

CONCLUSIONS

Lithology around Marina Beach is characterized by sandy clay which are coastal or marine alluvium sediments with high water content. The base of southern Semarang City around Simpang Lima is volcanic rocks covered by coastal or marine alluvium sediments with 0-10 meters thick. It consists of silty clay lithology that sometimes intercalated by sandy sediments.

Currently, most urban facilities in Semarang City are built northward to the coastal area with a low slope 0-5% facing towards the sea. This coastal area is cover by quaternary alluvium or marine sediments with low soil bearing capacity that might lead to the land subsidence. Therefore it is concluded that the current Semarang City condition is more vulnerable to the land subsidence occurrence compared with its previous condition.

Subsidence has been occurred in Tanjung Emas Harbor during 10 years (1995-2005) particularly on Coaster Street (21-41cm), north breakwater (64-79cm), west breakwater (74-140cm), east groin (76-89cm), stacking area (77-109cm), and container wharf (62-94cm).

ACKNOWLEGDEMENTS

We would like to express our gratitude to the local government of Semarang and Head of Marine Geological Institute who have provided an opportunity to conduct this research. We also wish to thank to Andi Sianipar for his suggestions and support.

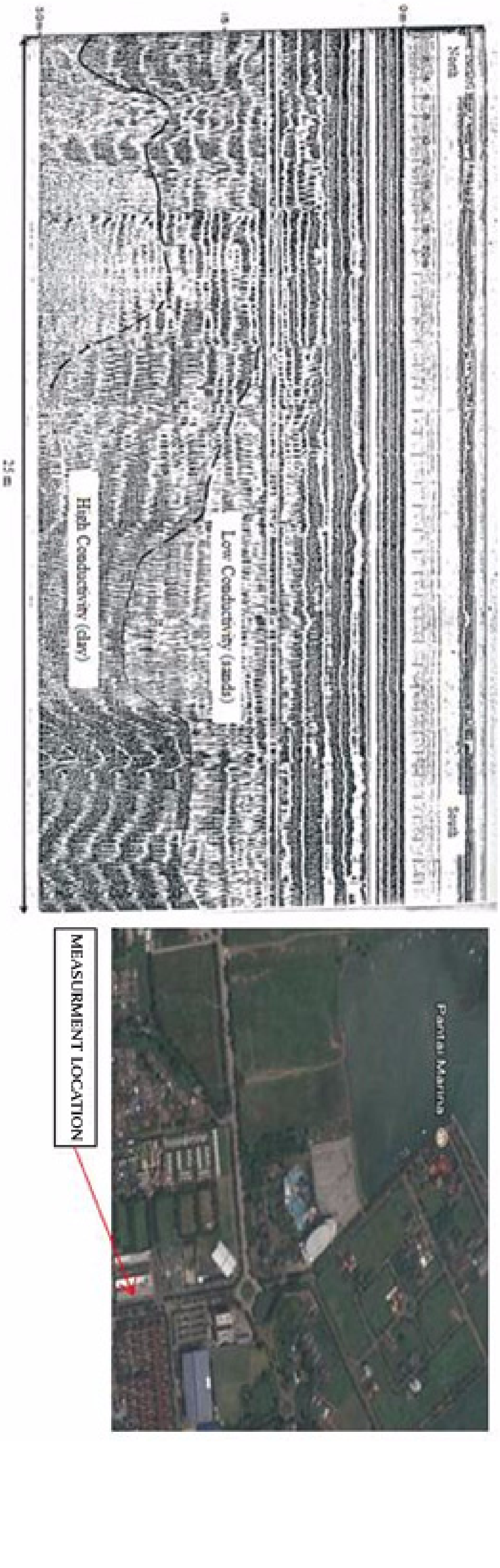

Figure 3. Georadar line 1 on Marina Tanjung Mas Beach

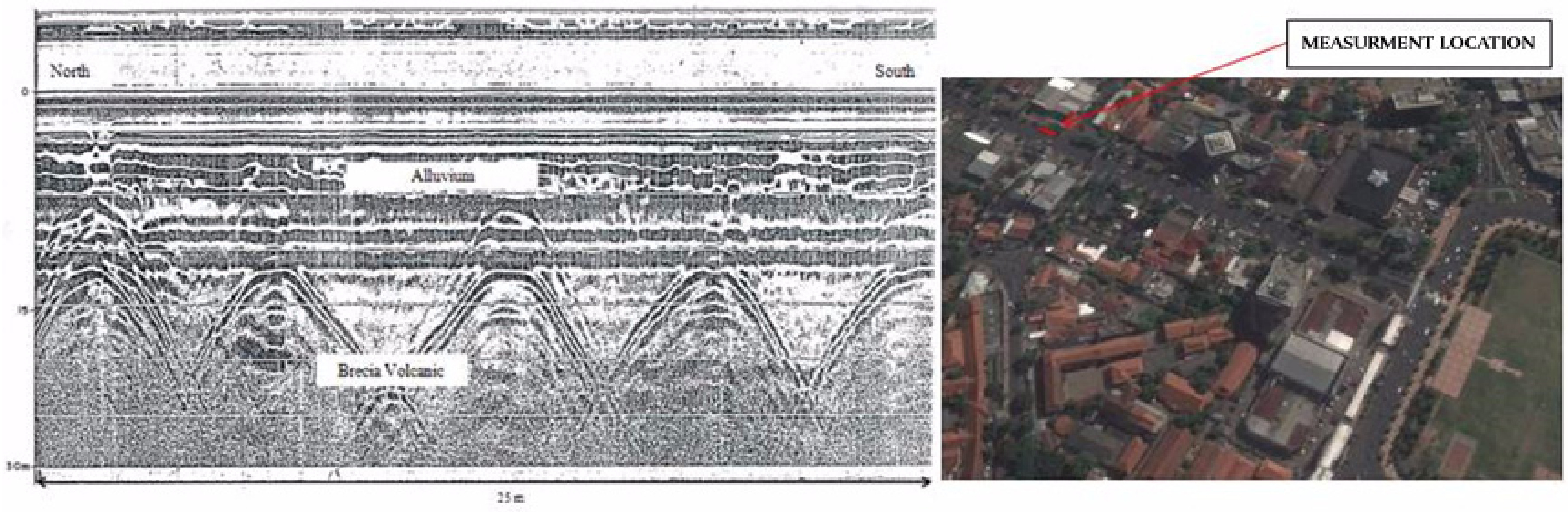

Figure 4. Georadar line 2 on Simpang Lima Semarang City

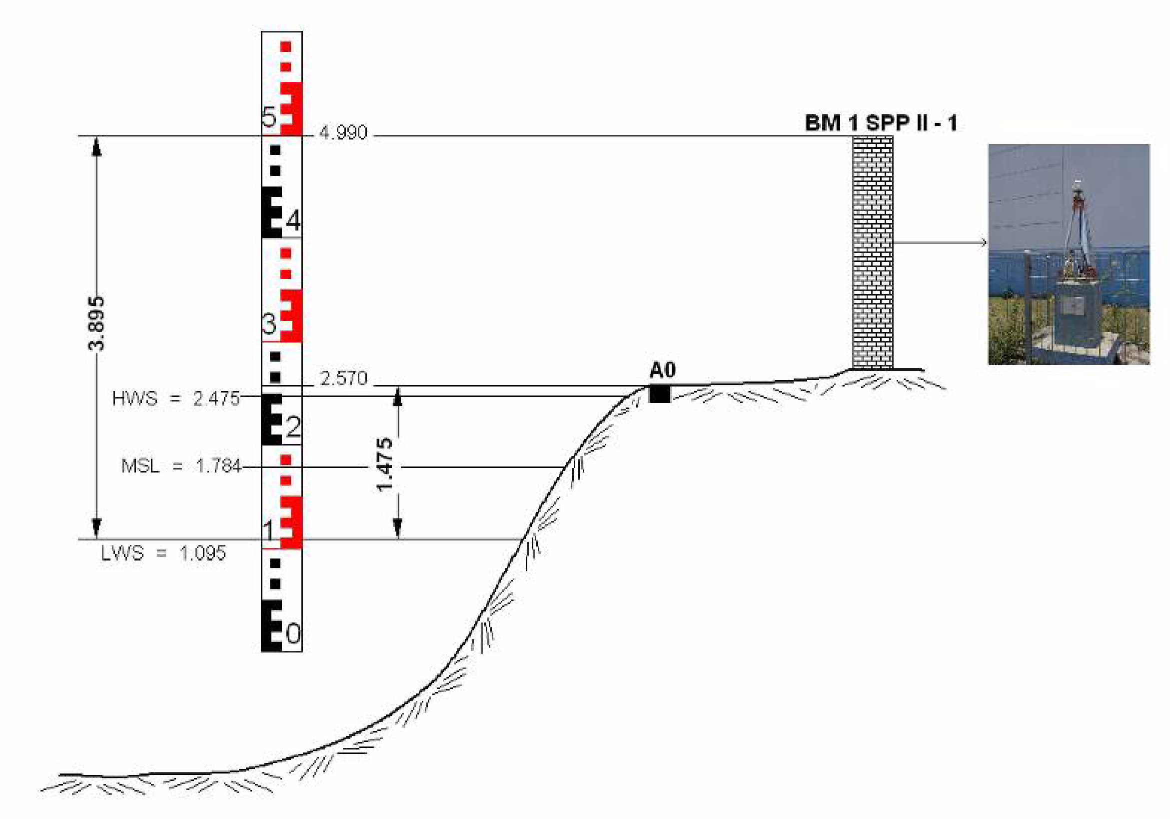

Figure 5. Vertical position of reference point (BM 1 SPP II-1) to vertical datum of low sea level (LWS) in Tanjung Emas Harbour, Semarang.

Table 1. Coordinates and measurement points elevation

Banch Mark	Coordinat Local		Coordinat UTM		Elevation (m)
	X	Y	X	Y	
BM BIG	667.219	649.514	436450.130	9232120.464	+3.105
BM 1 SPP II-1	1009.034	838.212	436771.945	9232309.162	+3.895
BM 6	978.157	678.908	436741.068	9232149.858	+2.431
TB 1	946.719	841.193	436685.323	9232412.820	+2.339
TB 2	922.412	941.870	436685.322	9232412.820	+2.494
TB 3	659.910	871.562	436422.821	9232342.512	+1.623

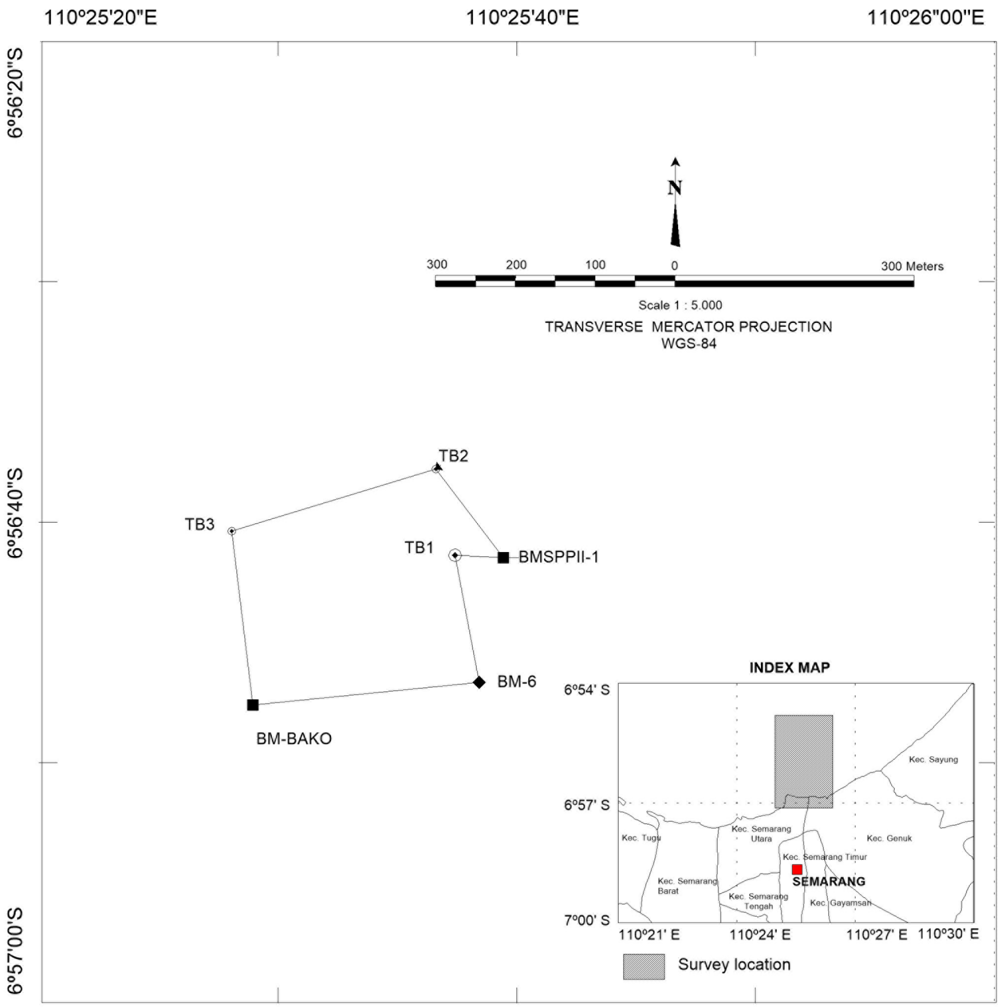

Figure 6. Coordinates and measurement points elevation location Map

REFERENCES

Anonim, 2010. informasi-semarang.blogspot.com/ 2010/04/sejarah-kota-semarang.html).

Basari, A.S., 1983. *Penerapan Metoda Admiralty untuk peramalan Pasut,* Geofisika Meteorologi FMIPA- Institut Teknologi Bandung.

Benson, A.K. (1995). Applications of ground penetrating radar in assessing some geological hazards: examples of groundwater contamination, faults, cavities. *Applied Geophysics,* 33(1-3), 177-193.

Budiono. K., 2008. Pemanfaatan metoda GPR (Ground Probing Radar) untuk penditeksian geologi bawah permukaan di kawasan pesisir. *Bunga Rampai PPPGL*, 31-38.

Dino, G.P, 2008., Aplikasi gayaberat mikro antar waktu untuk mendeteksi penurunan muka air tanah di industri Kali Gawe Semarang. *Jurnal Segara*, 4(1): 73-84.

Dolan. R, Hayden, B.P., and Vincent, M.K., 1975, Classification of coastal landform of the America Zeithschr Geomorphology, *In: Encyclopedia of Beaches and Coastal Environments,* P. 72-88.

Gumilar, I., 2013. Mapping And Evaluating The Impact Of Land Subsidence In Semarang (Indonesia), *Indonesian Journal of Geospatial*, 2(2): 1-41.

Ifan R.S., 2012. Penilaian kerentanan pesisir Semarang terhadap kenaikan muka air laut dengan menggunakan Indeks Kerentanan Komposit. *Jurnal Segara,* 8(2): 97-106.

Mellett, J. S. (1995). Ground Penetrating Radar applications in engineering, environmental management, and geology. *Applied Geophysics*, 33(1-3): 157-166.

Raharjo, P., Sianipar, A.H., and Yosi, M., 2005 Survey bathimetry, levelling land and breakwater/groin

Tanjung Emas Port PT. Wiratman. *Internal Report.* Unpublished.

Raharjo. P. and Kristanto, N.A., 2005. *Peta sudut lereng daerah Semarang dan sekitarnya dihitung berdasarkan Peta Topografi AMS 1949.* Direktorat Geologi Tata Lingkungan, Bandung.

Thaden. R.E., 1975, *Peta Geologi Lembar Magelang dan Semarang, Jawa* Pusat Penelitian dan Pengembangan Geologi.

Van Bemmelen, R.W., 1949, *The Geology of Indonesia. Vol. 1, The Hague, P. 194-213.*