

Sea Water Intrusion in Kaligawe Semarang Based on Resistivity Data

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Abstract. Semarang is a city on the north coast of the island of Java, Indonesia and it is lowland areas have experienced sea water intrusion. One of interesting area is Kaligawe which located at Eastern part of Semarang. Kaligawe has big population and industrial and it need water consumption. Excessive extraction of groundwater will be resulting height difference surface ground water to the surface of the sea water due to sea water intrusion. Electric resistivity method was used to detect for salt water intrusion. Dipole-dipole configuration was applied with 3 lines to get current, potential difference, and apparent resistivity from the field. 2D model has presented using Res2Dinv to get the true resistivity and the depth of each layer. A calibration of the model was conducted based on geological information. Result showed the subsurface area has 4 layers: sandstone, sandsilt, siltstone and clay. Moreover the sea water intrusion occurs in the Northwest, East and Southern part of the study area

1. Introduction

Kaligawe, which is located in Eastern Semarang Municipal Central Java Indonesia, is a village consisted by two main areas. The two are residencial area and industrial zone. the population of Kaligawe is 12.107 of people [1]. The high pupulation and industrial activities in that zone cause a rising in ground water consumption. Some researches show fact that withdrawing ground water excessively may induce gap between the height of surface ground water and the surface of sea water then results saline substrate of sea water, such as Chloride, infiltrates into the ground water[2].

Geographycally, Kaligawe lies on the North sea-coast of Java Island. Highly water usage in the coastal area leaves empty holes or pores in aquifer rocks, next it is potentially stimulate sea water intrusion[3][4]. Sea water infiltration into aquifer layer in the seaboard have been main attention since iy is generally a pollutant in freshwater [5]. Thus, understanding of sea water intrusion is urgently required for water and coastal resources management [6]. The intrusive movement of sea



water basically is process of salt water displacing under groundwater surface by passing aquifer layer that happens in land or in near sea region [7].

Hence the upon reasons inspired us to conduct research, which objective to determine the depth of salt water intrusion in Kaligawe based on resistivity data. Dipole-dipole configuration of the resistivity method were utilized to determine resistivity of each rock layer.

2. Geology and hydrogeology information

2.1. Geological setting

Semarang is basically underlain by two different geological units: the sedimentary rocks of the volcanic Damar formation in the South mainly consisting of tuffaceous sandstone and volcanic breccia and alluvial sediments in the North, which basically consist of sand and clay [8]. **Figure 1** presented the stratigraphic setting of Kaligawe is dominant of Alluvium (Qa). The Alluvium is deposit of coastal plain, river and lake. Coastal plain consists generally of clay, sand and some mixture with 50 m or more of thickness. River and lake deposits contains pebble, cobble, clay and silt.

Damar Formation (Qtd) consists of Tuffaceous sandstone, conglomerate, volcanic breccia. Tuffaceous sandstone has color of brownish yellow with smooth to coarse grain, the composition is mafic, feldspar, and quartz mineral with tuffa as the base mass and intermediate porosity. Conglomerate is colored by brownish-yellow to blackish, and has component of andesite, basalt, pumice, sized of 0,5 – 5 cm, middle rounded to perfect rounded, and probably fragile. Volcanic Breccia seems to be sedimented as lahar, blackish gray color and has component of andesite and basalt, sized 1-20 cm, middle pointed-rounded and looked solid.

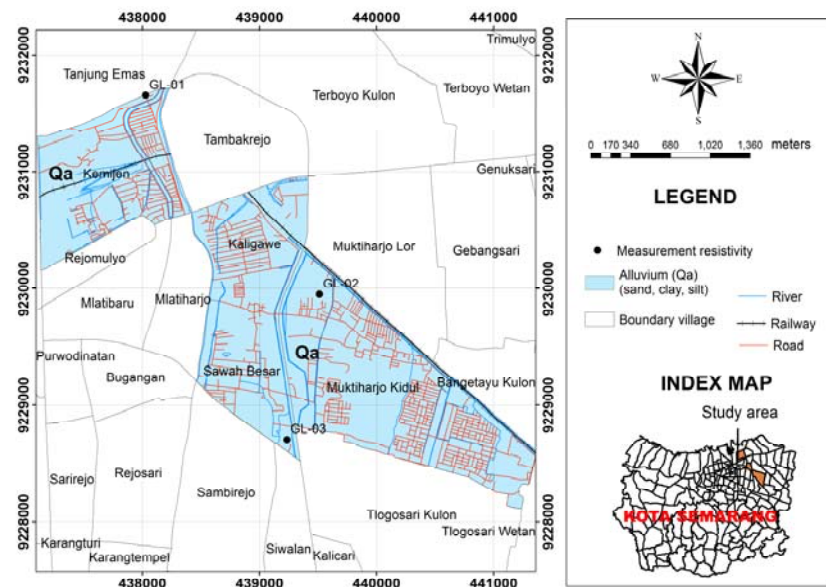


Figure 1. Geology map of research area.

2.2. Hydrological setting

Water potency in Semarang municipality is supplied from rivers which stream across Semarang, such as Kali Garang, Kali Pengkol, Kreo, Banjir kanal Timur, Kali Sringin, Kali Kripik, Kali

Dungadem and the others. Kali Garang is the main river that flows crossing Mount Ungaran's valleys, along the swiftly current of curved stream line [9]. Aquifer in coast of Semarang generally is alluvial sedimentation products and Kali Garang delta, that has variety depth from 60 meter to 90 meter, mainly in West Semarang District and more than 90 meter both in East Semarang District and North Semarang District [2].

3. Method

Resistivity method is measurement technique of geophysics that uses resistivity or electricity characteristic of rocks to observe subsurface of earth condition [10]. Measurement is conducted in the land surface by injecting electricity current (in miliAmpere) along two current electrodes (C1 and C2) then gaining potential difference (in miliVolts) from two potential electrodes (P1 and P2).

The result of that quantify procedure informs about resistivity distribution in the subsurface. Resistivity value is determined from resistivity substance of each rock. Electrical conduction of rock is defined from electrolyte distribution that occupies its rock pores [10]. The inner part of subsurface structure can be obtained by gradually making the space between each electrode, current and potential, wider [11].

There are positive correlation between space electrode and deep current penetrations. The widest electrodes space could be get a deep current penetration, hence the physical characteristics of deeper rock layer can be analyzed. Subsurface resistivity is linked to some geological parameters, such as mineral content, fluid, porosity and water saturation degree of rock [12]. The field data consists of electric current value (I) and electric potential or voltage (V) and leaves apparent resistivity (ρ_a) which is countable by this formula (1) [12].

$$\rho_a = k \frac{V}{I} \quad (1)$$

which ρ_a is apparent resistivity in Ohm, k is geometric factor relied on electrodes configuration. I is the injected electrical current while V is measured potential difference. adalah beda potensial yang terukur. Apparent resistivity has been considered as resistivity of fictional homogen medium that equivalent to the observed layered medium [12]. The configuration were applied is dipole-dipole as presented in **Figure 2**.

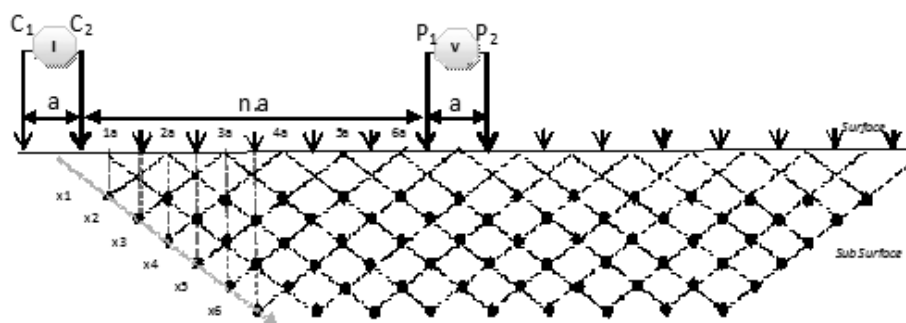


Figure 2. Dipole-dipole configuration ($n=1,2,3,..$) [13]

Geometric factor has given by formula 2

$$K_d = (n+1)(n+2)a \quad (2)$$

With K_d is konstanta of dipole-dipole configuration, a is the space between two same electrodes while na is the space of potential electrode and current electrode and n should be integers [13]. For getting various depth, n should be varied, the wider n the deeper depth that can be acquired. Sensitivity level of dipole-dipole configuration range is influenced by the number of a and the variety of n [14].

The geoelectric observation was done on 26 April to 09 June 2015 as three point measurement; North Western, Eastern and Southern part represented of Kaligawe area as **Figure 3**

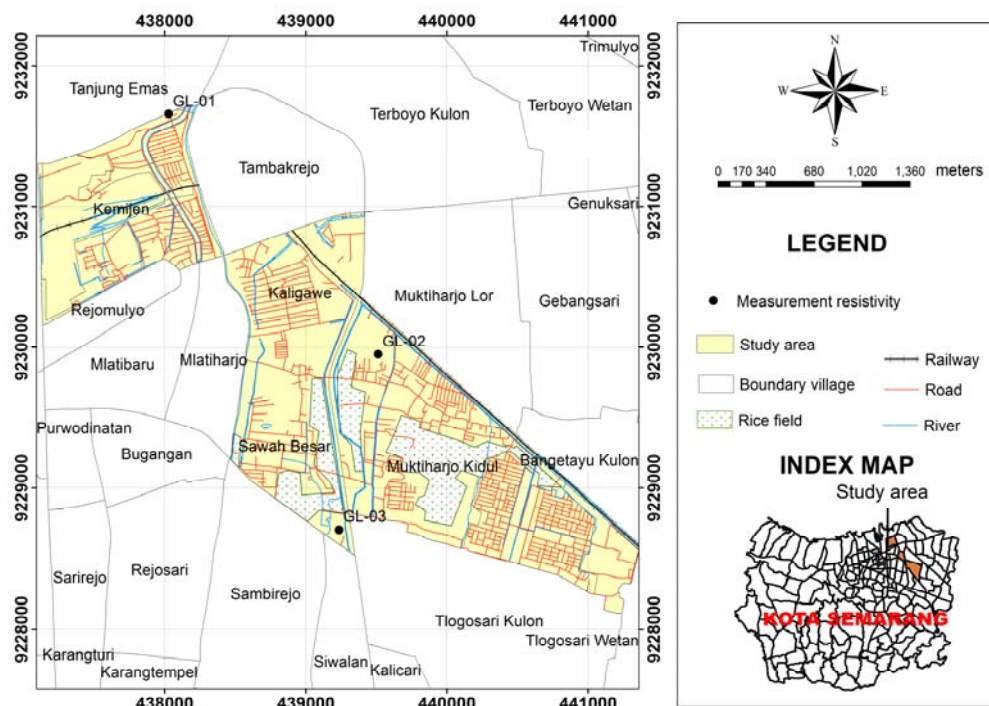


Figure 3. The geoelectric point measurement; GL-01, GL-02 and GL-03.

4. Result and discussion

4.1. GL-01 point measurement

GL-01 were located in the the North Western of research area, shows specific resistivity range of 4 rock layers as stated in **Figure 4**. The first layer has resistivity 2.07 -3.98 Ωm and at 0-35 meter of depth is considered to be sea water intrusion. We described the depth at 35-50 meter in second layer as clay stone, then in the deeper part at 50-70 meter is sandsilt while sandstone as the forth layer at 70-80 meter of depth.

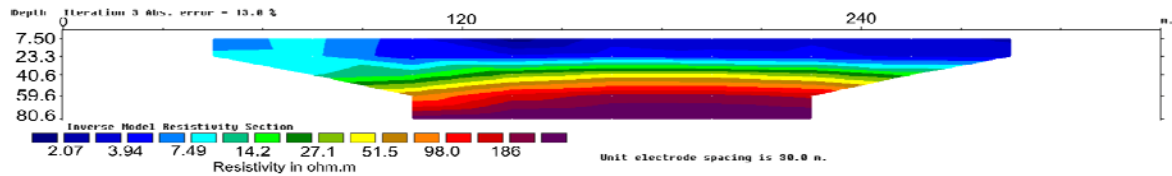


Figure 4. 2-D resistivity model of GL-01 which located in the North Western part of research area.

4.2. GL-02 point measurement

The result of GL-02 which was located in Eastern area, has specific resistivity range and similarity with the GL-01 in the number of layers as presented in **Figure 5**. In the first layer, we considered a 64 – 12.6 Ωm as saline intrusion happened in sandstone at 0 - 11.6 meter below surface. Subsequently the following layers specifications including each depth are sandsilt stone at 4-21 meter, siltstone at 22-29 meter and clay at 29-40.3 meter

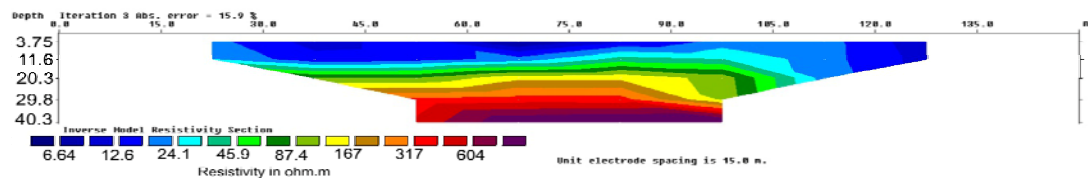


Figure 5. 2-D resistivity model of GL-02 which located in the North Western part of research area.

4.3. GL-03 point measurement

GL-03 was located in the southern part of research area, we can see the modeling result in **Figure 5**. Succeeding of four layers, the top layer has sandstone with 4.78 – 13.2 Ωm of resistivity and depth range 0 - 11.6 meter, where the intrusion zone takes place. The three next layers including their resistivity values are sandsilt with 22.2 – 37.2 Ωm , siltstone with 62.3 – 104 Ωm and clay as the last with 175 Ωm .

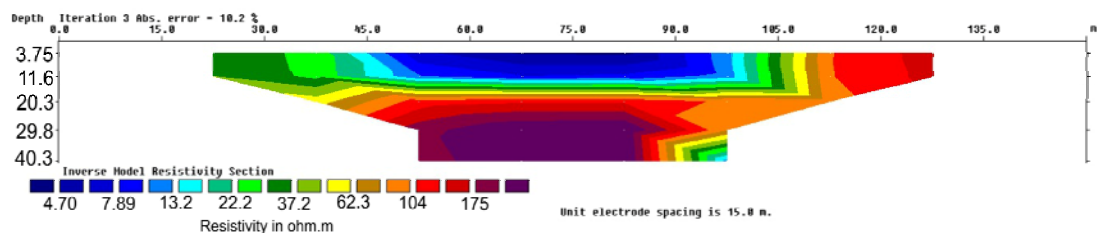


Figure 5. 2-D resistivity model of GL-02 which located in the North Western part of research area

The reason why we deduced the first layer as the place of sea water intrusion is caused by the existence of electrolyte solution comes from sea water. This condition leads to fine conductivity, thence it can transfer electricity finely. Low value in resistivity supports above statement because the contrary correlation between resistivity and conductivity. If the resistivity value of rock is lower then its conductivity will be higher resulting the ease in passing electricity. Moreover, reverse situation will be happened when the resistivity is low so the conductivity will be high.

The other side we conducted the chloride contents in several well as presented in **Table 1**. Several point has a big chloride content such as S-1, S-3 and S-7 which value of 819 -1799 mg/l. Based on the Ministry of Health regulation No. 492 Year 2010 the water can be drank if chloride contents less than 250 mg/l. Moreover according to adhoc ommittee of salt water intrusion Jakarta, 1986 the water contain 500 – 2000 mg/l chloride has contaminated .

Table 1. A table of chloride contents in research area.

Code	Longitude	Latitude	Chloride (mg/l)
S-1	439611	9230051	819.65
S-2	438899	9230209	92.15
S-3	437236	9231090	1799.35
S-4	439334	9230988	47.046
S-5	438628	9230379	153.26
S-6	439080	9228990	1697.5
S-7	439390	9229599	89.24

5. Conclusion

Based on the result analyses to investigate sea water intrusion, we conclude that the areas, where have been damaged by this, are in the North Western part, Eastern part, and Southern part of Kaligawe. This conclusion is supported by the existence of low resistivity range in the subsurface between 2.07-13.2 Ω m at 0-35 meter at deepness. Moreover in several area the water can not to drink caused the high chloride contained.

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