Application of Geoelectrical Resistivity Methods for Mapping of Seawater Intrusion

Nurul Azizah¹, Nadya Hari Pratiiwi², Annisa Permata Islami², Nur Islami¹

¹Physics Education – FKIP, Universitas Riau, Pekanbaru, 28293, Indonesia
²English Education, Universitas Riau, Pekanbaru, 28293, Indonesia.

azizah_nurul12@yahoo.com

Abstract. Excessive land exploitation in Dumai has been replaced by intrusion seawater in aquifers in the coastal area. This is indicated by the increasing number of society’s wells that turn into brackish. The intrusion has a wide impact on various aspects of life, such as decreasing soil fertility, damage the buildings, and disrupting public health. The aim of this study is to find out the saturated zone of water and the interface of water with fresh water, so it is known that water zones are suitable for daily use. The study used Geoelectrical Resistivity Survey with 1D Schlumberger configuration to determine the zone of aquifer and its thickness. Based on the research that has been done, the results of the boundary of the intrusion zone in Dumai were obtained that there is an intrusion zone boundary of seawater content. This is indicated by the low resistivity value. It is less than 10 ohms, which is found at the zone of less than 1 km from the beach line.

1. Introduction
Dumai is located on the east coast of Sumatra Island. It is in front of Rupat Island and the Malacca Strait between 10, 23-10-10, 24 °East Longitude and 101-23-23-27, 101-28-28'S North Latitude. Along the coast consists of peat swampland with a depth of 0 - 0.5 meters and several kilometers to the south with a slope of 0 - 5% with a total area of 1,727.38 km². The type of soil in Dumai generally consists of organosol humus and red-yellow podsolic which are suitable for plantations. Groundwater conditions in Dumai originated from shallow land, dug wells and pumping wells with an average depth of 1-2 meters and groundwater. But in general, the water was not good [1].

The increasing exploitation of groundwater is the cause of seawater intrusion in aquifers at the coastal area of Dumai. This is indicated by the increasing society’s wells that turn into brackish. The seawater intrusion has so many bad impacts to the environment, such as disturb health problems, decrease soil fertility, and damage to buildings [2].

Based on this description, an effort is needed to maximize water supply, one of which is to look for groundwater potential below the surface on the coast of Dumai. Subterranean ground water can be found in saturated layers of water or aquifers. The searching for aquifer potential is through the determination of seawater intrusion zones by the Geoelectric method.

The Geoelectric method is one of the geophysical methods that studies the nature of electricity in the earth (potential, currents, and electromagnetic fields) that occur either naturally or due to injection of current into the earth [3]. The subsurface characteristics are very important to determine the potential of groundwater and aquifers in the soil to determine the interface of seawater with fresh
water which is a zone of sea water intrusion [4, 5]. In this paper, the zone of seawater intrusion will be examined using the geoelectrical resistivity survey.

2. Methodology
This study was conducted in Dumai, Riau Province. This research was conducted in April-June 2019. The following picture is a location map of 6 research points. The map given in Figure 1 shows the location of 1D and 2D data collection.

![Research Location Map](image)

**Figure 1.** Research Location Map

This research uses the Schlumberger and Wenner Mapping configuration geoelectric method, carried out by injecting current through two current electrodes and measuring the potential difference generated from two potential electrodes. It should be noted in the transfer and installation of electrodes must be in accordance with the configuration used and made in such a way as to facilitate data acquisition. For groundwater samples in the coastal area of Dumai City and villages within 4 kilometers of panai lips are areas that have saline groundwater which is then taken from groundwater samples.

Whereas well measurements include measurements of resistivity, well depth, and groundwater height. Measuring the value of resistivity is carried out to determine the salinity of groundwater while measuring the depth of wells and groundwater levels is done to determine the position of the interface. The number of samples taken in this study were 3 wells spread throughout the study area. Of the three measurement pathways, it is known that the measurement path I is the coastal area of Dumai City.

The measurement data are in the form of: distance between electrodes (A), the amount of injection current (I), and the amount of potential difference (V) at each measurement point will be processed with Microsoft Exel. The data from the processing of Microsoft Exel will then be used as input for modeling freshwater seawater interfaces which will be processed with an inversion (Progress)
software program. The results of the above modeling will be obtained by mapping the price-price resistivity according to the resistivity value below the surface. Analysis and interpretation begins with the separation of rock layers according to their resistivity values. False resistivity values that have been converted using software inversion will be correlated with resistivity on direct measurements and soil samples taken. Finally, the subsurface model can be predicted, so that the thickness of each layer and the meeting of seawater with fresh water can be determined. The thickness of each location will be distributed to other zones using interpolation techniques.

The Indication Map is generated from the distribution data of resistivities generated in the inversion process. This data is calibrated directly by looking at the geochemical content of groundwater samples that have been analyzed for cations and anions so that a Geographical Indication Map can be obtained on the surface of Dumai City.

3. Results and Discussion
In this study geoelectric data was taken in 2 Dimensions and 1 Dimensions. Figure 3.1 shows a map of the location of the study and data collection. Figure 1 is obtained from Google Earth and the track location is a real location in the field and plotted on the map. Data collection is carried out in addition to the drainage on the roadside.

Figure 2 is the results of 2D geoelectric modeling for L1 and L2 trajectories. Geoelectric inversion modeling was carried out using Res2Dinv (from Geotomo) software. In the picture you can see the position of the electrode (x axis) and also at the depth (y axis). Both models show relatively small iteration errors (less than 10%), this shows the subsurface resistivity model is close to the actual resistivity shape and pattern.

![Figure 2. Geoelectrical Resistivity Result of 2D survey](image)

On the L1 survey path (Figure 2) there is a zone that has a low resistivity (smaller than 10 ohms.m) and a relatively high resistivity (above 70 ohms.m). While on the track survey 2, L2 (Figure 2) the smallest resistivity price is above 15 ohms.m. Referring to Islami et al (2018) who conducted the study in Siak Kecil, the low resistivity value was below 10 Ohm.m indicating the presence of sea water in
the groundwater aquifer [6, 7, 8]. While the resistivity value above 70 ohm.m is a freshwater aquifer where the pores are filled with fresh water.

The L1 survey shows that the presence of sea water has reached a distance of 1 km from the shore. However, from the L2 track which is approximately 2.5 km from the coast, it can be seen that the aquifer is still protected from sea water intrusion. From the results of modeling 2 The dimensions of both L1 and L2 trajectories, can be predicted that the intrusion zone of sea water and fresh water is between L1 and L2. On the map, Figure 2 shows that the data L1 and L2 are taken alongside the large drainage. This means that water sources in shallow aquifers at L1 and L2 are also provided by the drainage. Both the results of modeling 2-dimensional geoelectric resistivity can be used as a reference to model 1 Dimensional data. For 1D tracks on L3, L4, L5, L6, L7 and L8. 1 Dimensional modeling data can be seen in the attachment.

In Figure 4.4 it can be seen that resistivity in the zone of 1 km from the coast, shallow aquifer resistivity is less than 10 ohms.m. Resistivity below 10 ohms. is interpreted as a zone of aquifer contaminated by seawater intrusion. However, on the L5 and L8 trajectories, in the shallow aquifer it can be seen that the resistivity is greater than 15 ohms. The price of this resistivity indicates that aquifers are filled with water which avoids sea water intrusion.

From the 2 Dimension and 1 Dimension survey, a geographical indication map for groundwater can be made in shallow aquifers in Dumai City. Figure 3.4 is a map of geographical indications for shallow aquifers in the research area, Dumai City. The map shows that there is an intrusion zone boundary with sea water content greater than 50% with seawater intrusion smaller than 50% (broken blue light line). While the limit of sea water intrusion is less than 50% with shallow aquifer zones that still contain fresh water is indicated by thick lines of light blue.

Figure 3. Geographical Indication Map of Shallow Aquifer in Dumai City

Figure 4 shows the cross section of the city dumai taken from the position L3 towards L4 and L5. This cross section is based on 1 Dimensional data calibrated from 2D data. The total distance from the
beach to L5 is around 6 km. It is seen that sea water intrusion has reached between L3 and L4. Whereas from the position between L3 and L4 to L5 the sea water has not intrusion in the shallow aquifer zone. However for deep aquifers, there is no indication of sea water intrusion.

Figure 4. L3-L4-L5 cross section

4. Conclusion
Based on the results of the study using the geoelectric method which is supported by geological data in the form of subsurface diology data, there is an intrusion zone boundary of sea water content greater than 50% with seawater intrusion smaller than 50% (broken blue light line). While the limit of sea water intrusion is less than 50% with shallow aquifer zones that still contain fresh water is indicated by thick lines of light blue.

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