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RESEARCH ARTICLE

Saltwater Intrusion Zone Mapping on Shallow Groundwater Aquifer in Selat Baru, Bengkalis Island, Indonesia

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Abstract

Saltwater intrusion becomes a common problem in coastal area. Northern coast of Bengkalis Island in Riau, Indonesia that contiguously to Malacca Strait is experiencing the problem particularly in Selat Baru area which considered as developing area and most of the people live close to the sea. Dug well is the main source of groundwater that had been used by the population in Selat Baru and as the increasing of land occupation, the demand of clean water is rising up followed by the number of dug well. A study of groundwater monitoring was conducted to identify the zone of saltwater intrusion. Field observation had done by measuring the water level and physical parameters of groundwater such as taste, pH, electrical conductivity (EC) and total dissolved solid (TDS) from 110 existing dug wells. Some conus feature had found from groundwater elevation map which indicated lower water level caused by excessive groundwater pumping. Generally, pH shows values from 6-8 that was still in range of water quality standard, but there are 20 wells (18%) that have pH below the water quality standard (slightly acidic water). Similar pattern had been observed from Electrical Conductivity (EC) and Total Dissolved Solid (TDS) map, higher value of EC and TDS was dominant in the northern part of study area and lower value in the south. Groundwater taste map also revealed the identical condition with EC and TDS map which dominated by brackish and saline water in the northern part. Therefore, the study area had been divided into two zones of groundwater saline water zone possibly caused by the saltwater intrusion in the northern part and freshwater zone from the center to the southern part.

Keywords: Coastal groundwater, groundwater quality monitoring, saltwater intrusion, groundwater physical parameters

1. Introduction

Groundwater is an essential and valuable water resource in many developing countries (Taufiq et al., 2018), the number of societies facing water shortages is increasing as the level of the groundwater table decreases as a consequence of excessive usage and the level of pollution of surface and groundwater resources increases due to environmental impacts. For this reason, there have been many studies on water quality in various parts of the world ((Gültekin et al., 2013); (Srivastva et al., 1988); (Baykal et al., 2000); (Mladenov et al., 2007); (Jaji et al., 2007); (Tayfur et al., 2013)). There are many benefits of groundwater for the survival of living beings. Present land use activities had large contribution for the change of water quality (Karanam et al., 2019). For humans the groundwater used to meet daily needs. Intensive irrigated agriculture substantially modifies the hydrological cycle and often has major environmental impacts (Foster et al., 2018). During recent decades, the agricultural exploitation of water has been strongly reinforced, causing an over-pumping of the groundwater resources accompanied by an intrusion of seawater (Chabaane et al., 2018).

Groundwater is the main source of drinking water for the people of Indonesia (Sapari et al., 2017). Saltwater intrusion became an important issue in coastal region because it can affect the freshwater quality in surrounding areas (Putra et al., 2017). Climate change-induced sea level rise on multiobjective saltwater intrusion management strategies in coastal aquifers (Kumar and Bithin, 2018) (Hamed et al., 2018). The salinity of water resources is an important problem that the world population suffers. This salinity has been studied intensively during the past decades, particularly in coastal aquifers (Bahir et al., 2018).

In environmental management, at first the human relationship with the environment running in a spirit of harmony that humans become an integral part of nature so that its behavior in tune and in harmony with the rhythms of nature and nature conservation in these conditions can be maintained (Suhartono et al., 2015). The use of Natural Resources was massive and uncontrolled and ignore the environmental equilibrium will result in a variety of negative effects will be felt in relatively quick time in both the acute and the condition of chronic conditions in the long term. Environmental damage in coastal areas triggered by ecological conditions of coastal areas that can meet the economic needs of human beings through some important activities such as industry, fisheries and services

2. Study Area

Selat Baru is a small area located in the northern coast of Bengkalis Island, Riau, Indonesia and contiguously to Malacca Strait. The Strait of Malacca is located between the east coast of Sumatra Island in Indonesia and the west coast of Peninsular Malaysia, and is linked with the Strait of Singapore at its south-east end ((Thia-eng et al., 2000); (Yuskar et al., 2018)). The study area was found to have brackish water in its river owing to a certain amount of salt water mixing ((Putra et al., 2017); (Putra and Yuskar, 2016)). The study was initiated from the result of water quality analysis in the western area of Bantan Tua, Jangkanng and Deluk village which adjacent directly to Selat Baru Village (Fig. 1).

The people of Selat Baru area, use groundwater for domestic purpose. They normally get their water supply from the shallow aquifer through traditional hand-dug wells as well as from the surrounding rivers. Even though, there is no official report about saltwater intrusion but it is very important to have proper planning and management of the groundwater exploitation in the coastal area of north Bengkalis island especially Selat Baru Village. The effect of an excessive withdrawal, especially during dry season, must be taken into account in order to avoid risk of saltwater intrusion into the groundwater aquifers (Samsudin et al., 1997).

Stratigraphy of the study area (Fig.2) are composed of rocks that include surface deposits which are Young Superficial Deposit (Qh), and Older Superficial Deposit (Qp) (Cameron, 1983). Young Superficial Deposit consists of clays, silts, clean gravel, vegetation rafts, peat swamps and Older Superficial Deposits consist of clays, silts, clayey gravels, vegetation rafts (Yuskar et al., 2018).

3. Methodology

The research had been conducted by measuring 110 dug wells in Selat Baru beach and the surrounding area. Shallow groundwater depth measured using manual and simple tools such as rope, stone and tape rule. Elevation and coordinate of each dug well position had been acquired using GPS. The physical parameters of water samples measured in the field are color, taste, temperature, pH, electrical conductivity (EC) and total dissolved solid (TDS). Those parameters divined using YSI Pro-1030 Water Quality Instrument.

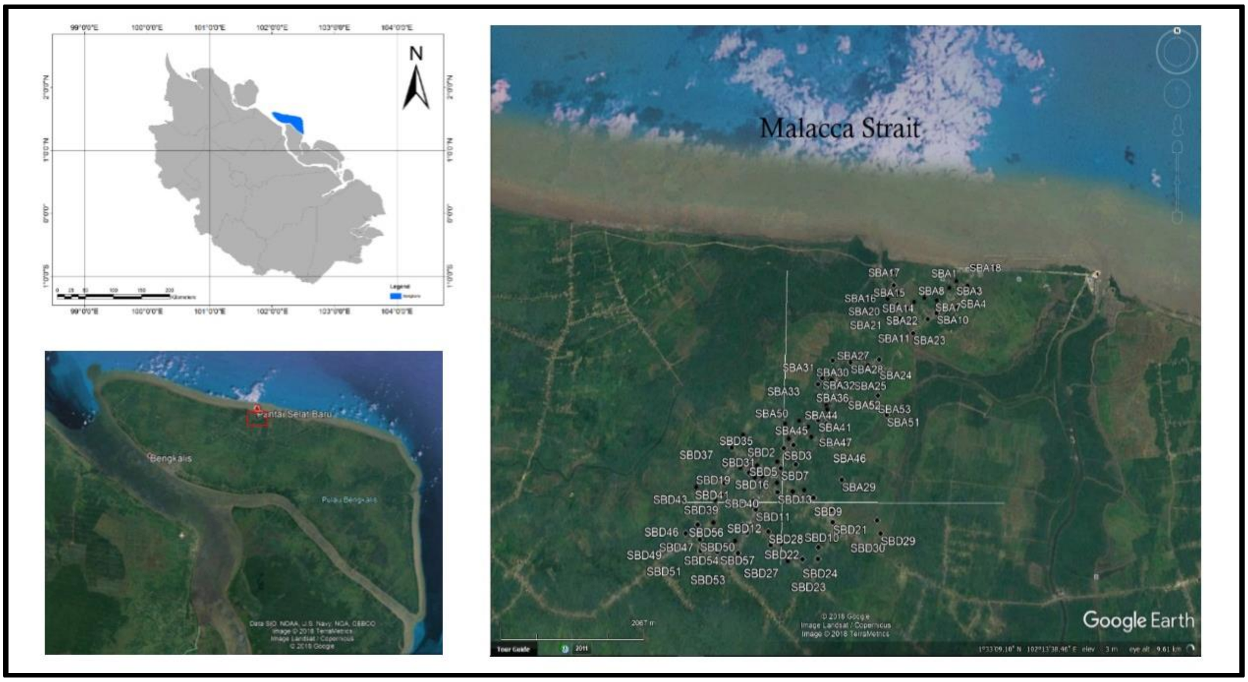

Fig. 1. Location of study area, Selat Baru Area and Surrounding Bengkalis Island Riau – Indonesia (Source: Google Earth 2018).

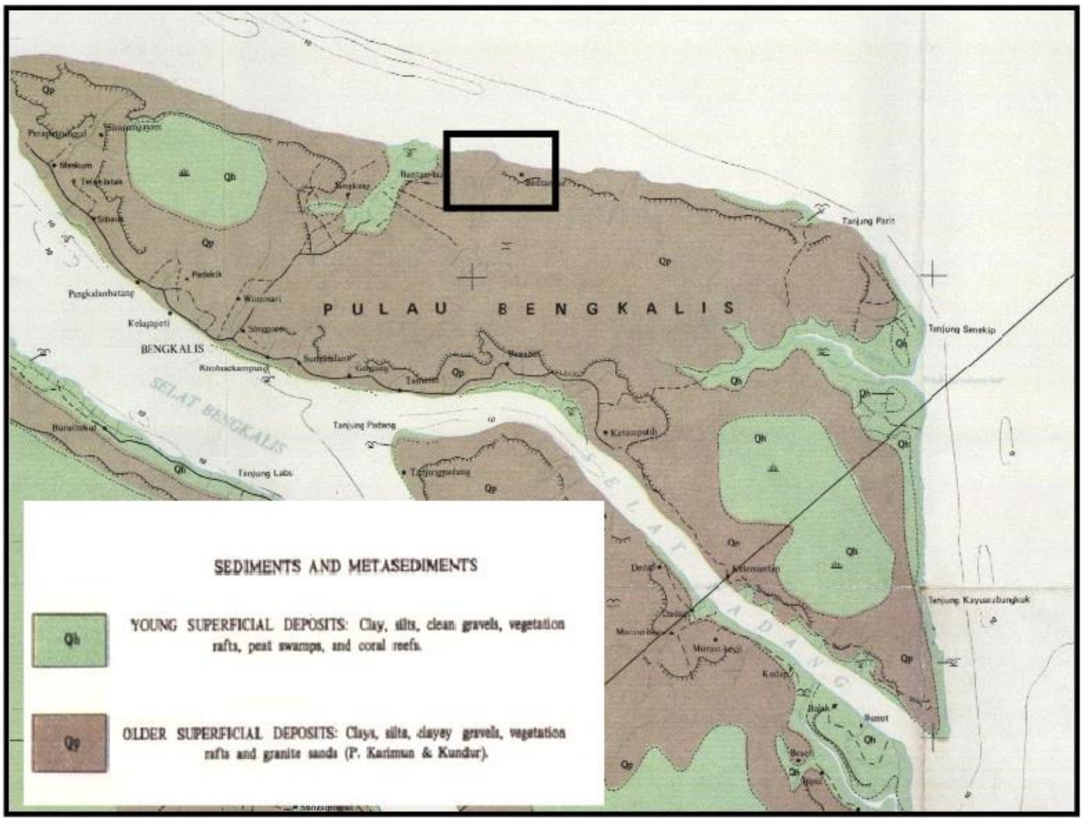

Fig. 2. Regional geological map of study area.

4. Result and Discussion

The data of each dug well being processed to produce shallow groundwater isopach map (Fig. 3), EC and TDS map (Fig. 4 & 5) and groundwater taste map (Fig. 6). Physical parameters such as temperature, pH, EC, and TDS had been used as a comparison to water quality assessment.

4.1 Groundwater Contour Map

Groundwater contour isopach map had been produced from the measuring the elevation of groundwater level in each well. Groundwater elevation is in range from 0.5-13.35 m.a.s.l. Groundwater elevation map shows some conus feature (A, B, D, D and E) that indicating deeper water level possibility caused by the excessive use of groundwater (Fig. 3).

4.2 pH and Temperature

In general, pH condition of groundwater is in normal value, in range of 6-8 and average 6.84. Only 20 wells (18%) that have pH value below the water quality standard (slightly acidic type of water).

The temperature of groundwater also shows the normal value with average 27.26°C and in range of 25.7-30.6°C which meet the values of water quality standard.

4.3 Electrical Conductivity (EC) and Total Dissolved Solid (TDS)

EC and TDS values show similar pattern (Fig.4 and 5), dominated by higher in the northern part of the study area and lower in the south. EC has average value of 1500.3µS/m and in range of 125.8-11485µS/m while TDS has average value of 947.93mg/L and in range of 76.5-7214mg/L. Those value represented by the taste of groundwater that more saline in the northern wells.

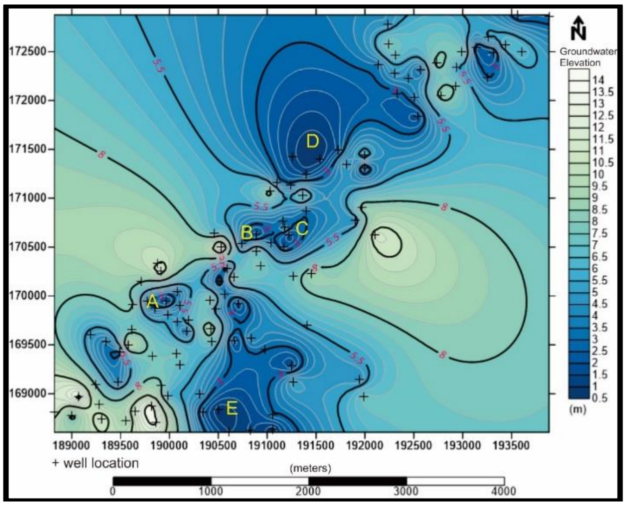

Fig. 3. Groundwater elevation map shows the occurrence of some conus features that indicated by dark blue color (A, B, C, D and E).

From the map, freshwater was shown by bright and dark green color (TDS 0-2000mg/L; EC 0-1000µS/m) and brackish water shown yellow and brown color (TDS 2000-4000mg/L; EC 1000-7000 µS/m), and saline water shown by blue color (TDS >4000mgl/L; EC >7000 µS/m).

4.4 Groundwater Taste Map

Groundwater taste map shows the majority of water in the research are is freshwater (Fig. 6). However, in the northern area, the groundwater taste had become more saline towards the coastline. In total, 24 wells had brackish taste water (21.8%), four wells had salty taste water (3.6%) and the remaining 82 wells had tasteless water (74.6%). Several wells in the central part of the study area around the conus A and E (SBD 10, 32 and 33) have brackish water and proven by the EC and TDS value of the water (consecutively 3993µS/m & 2517mg/L; 4449µS/m & 2752mg/L; 1594µS/m & 1002mg/L), those areas interpreted as the area that suffered from intrusion event due to excessive use of groundwater.

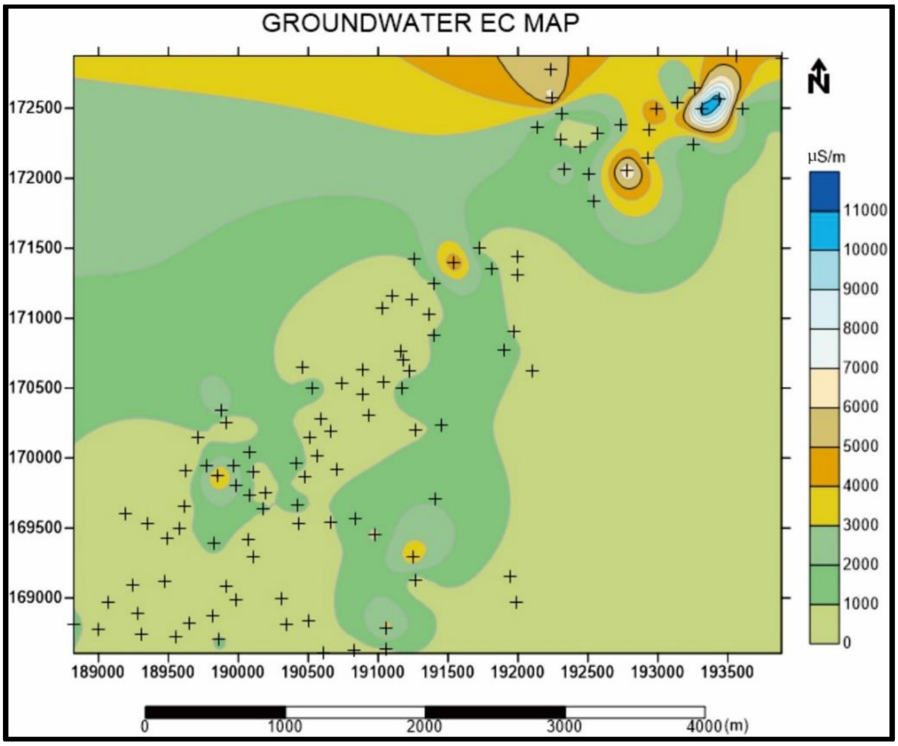

Fig. 4. Groundwater EC map that shown higher value in the northern part and lower value in southern part with several locations in central part have high value.

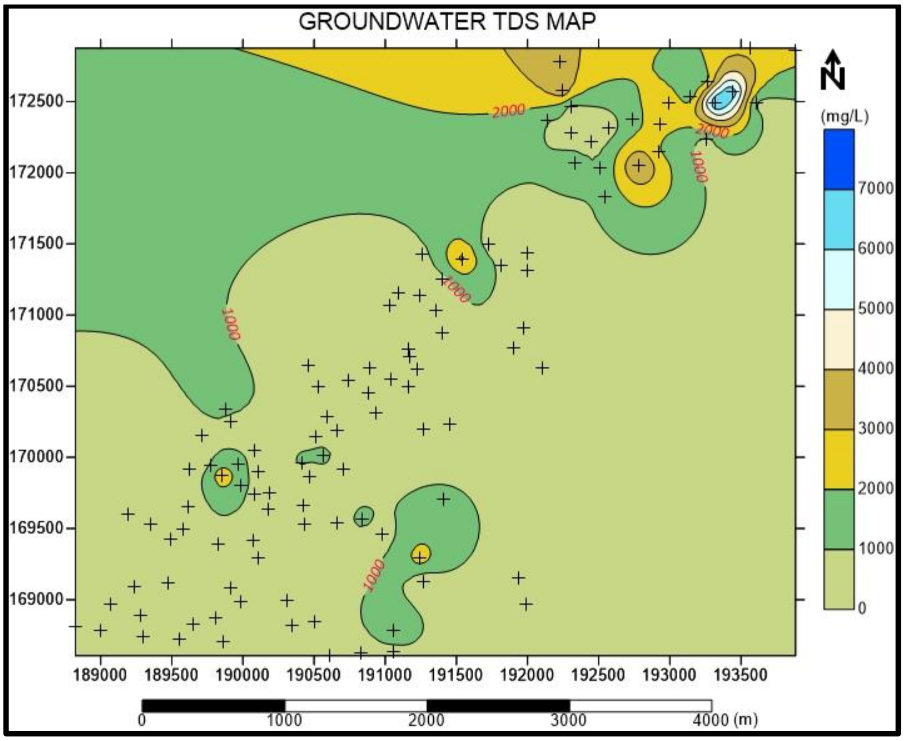

Fig. 5. Groundwater TDS map that shown similar pattern to groundwater EC map.

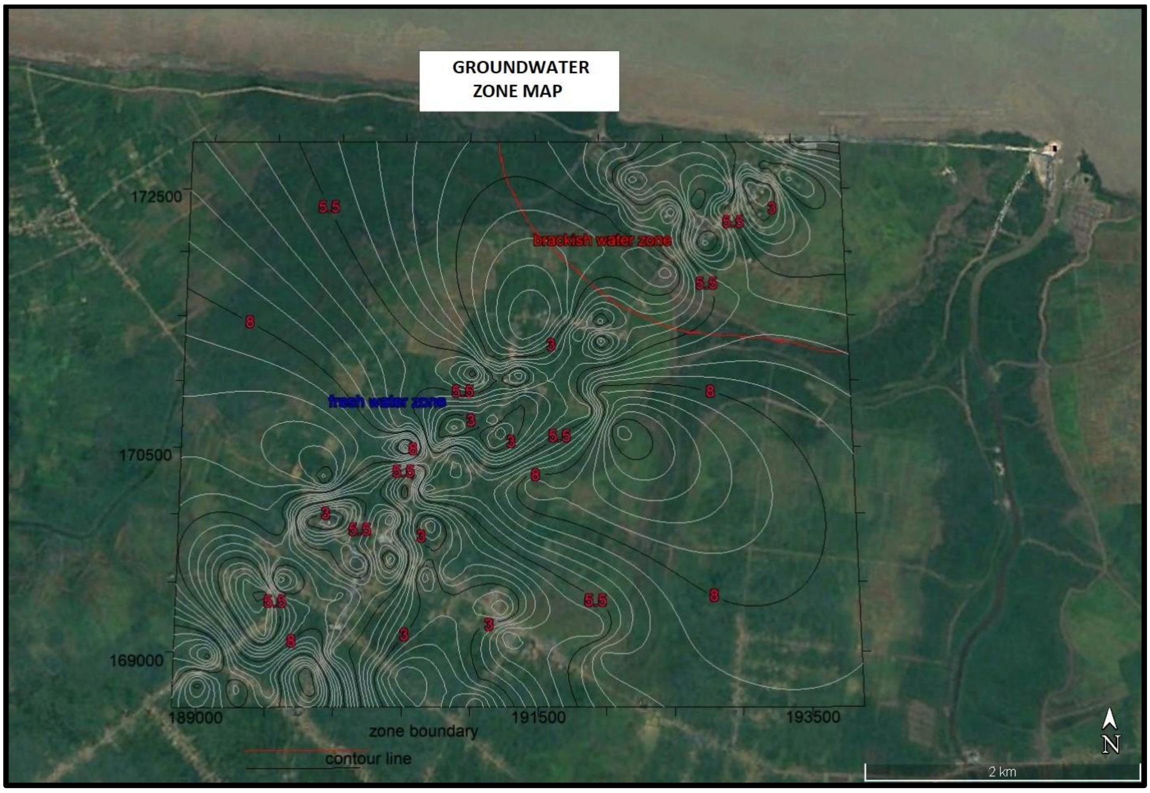

Fig. 6. Groundwater taste map that divided the groundwater zone into two, brackish water zone in the north and freshwater zone in the south.

5. Conclusion

In conclusion, the study area was divided into two zones of groundwater, brackish water zone possibly caused by the saltwater intrusion in the northern part and freshwater zone from the center to the southern part. Some wells in the southern part had higher EC-TDS value and located in the conus feature regions; this might be a result of saltwater intrusion that reached those areas. However, advance study needs to be carried out to ensure the impact of saltwater intrusion to the groundwater and to determine the subsurface saltwater-freshwater boundary in study area.

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