# Evaluation of groundwater usage in relationship to groundwater vulnerability to sea water intrusion in Cilacap Coastal

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**Abstract**. Besides being able to cause land subsidence, excessive groundwater use in coastal areas can also cause to sea water intrusion. The purpose of this study is to evaluate the use of groundwater in the study area in relation to its vulnerability to sea water intrusion. Because groundwater in the study area is used for domestic, industry and livestock purposes, the water use that is taken into account is the use of water for the three sectors. The amount of water used for domestic purposes is calculated based on the population and the amount of water needed of each person per day. The amount of water use for industry is calculated based on the number of industrial employees and water usage of each employee per day. Water use for livestock is calculated based on the number of livestock and water use of each livestock per day. The results of this water usage calculation are then linked to the criteria for groundwater vulnerability to sea water intrusion and the depth of the interface. Observing the relationship between groundwater usage and the vulnerability of groundwater to sea water intrusion and the depth of its interface, Tegal Kamulyan, Cilacap and Sidakaya villages, all of which are located in South Cilacap District, need attention. The three village are classified as moderate vulnerability to sea water intrusion and shallow interface depth, but their water usage is quite high. For this reason, it is necessary to make efforts to find other water sources for domestic, industry and livestock requirement other than groundwater.

Keywords: groundwater, sea water intrusion, Cilacap

## 1 Introduction

The larger the population requires more and more facilities and infrastructure, one of which is the availability of water sources. Because groundwater is still the main source of water for domestic and industrial needs, groundwater extraction will also be even greater. Without being balanced with an equivalent recharge, the increased usage of groundwater often causes a decrease in the groundwater level. Meanwhile, on the other hand, a lot of open land as infiltration areas has been converted into residential areas [1-2].

Coastal aquifers have an important role in meeting the needs of fresh water for the community [3]. Even in some countries, aquifers in coastal areas supply fresh water for industrial, agricultural, and drinking water for the community [4-5]. Likewise, in several Mediterranean regions with low rainfall, groundwater in coastal areas is the main supply for household needs. Therefore, the existence of aquifers in coastal areas has an important role for both humans and the environment.

Population growth in this area encourages increased fulfillment of fresh water needs [6]. However, if groundwater extraction exceeds the safe yield, the volume and surface of the groundwater will decrease, so that the hydrostatic pressure will weaken. In this situation, sea water can push and flow to the mainland and there is sea water intrusion. The boundary of freshwater and sea water on land is called an interface [7-10].

The interface area is a zone of water transition and diffusion between fresh and salt water, and salt water will be under fresh water [11-14] . If the pressure of fresh groundwater from the land against sea water is getting stronger, the interface will move towards the sea. However, if the groundwater's hydrostatic pressure weakens, sea water will push ashore and seawater intrusion occurs [15-17].

According to [18], it can be said that seawater intrusion has become a problem in cities located in coastal areas, because it causes changes in the type of groundwater chemistry or even the quality of its water. As a result, groundwater as the main source of drinking water for the majority of the population cannot be utilized because it tastes salty.

Among the other southern coastal areas of the Java Island, Cilacap is the most developed area [19]. Urban development is often identified with increasing population and settlements. In relation to water use, population growth results in increased use of water for daily life. Because groundwater is still the main source of water for domestic and industrial needs, groundwater extraction through dug wells is also increasing. Without being balanced with an equivalent additive, the increased use of groundwater often causes the groundwater level to fall and even in coastal areas it can cause sea water intrusion.

## 2 Methodology

In this research, the calculated water usage is the usage of water for domestic, industrial and animal husbandry purposes, because the three sectors make use of groundwater. The use of water for domestic needs is determined according to the size of the population and the amount of water needed per person per day. According to Mangku Sitepoe [in 20] , water demand in big cities is generally more than 150 liters/person/day, in medium cities 80-150 liters/person/day, districts cities 60-80 liters/person/days and villages ranging from 30-60 liters/person/day. Based on these criteria, because North Cilacap, Central Cilacap and South Cilacap are considered medium cities, the water usage is determined to be between 120 liters/person/day.

Industrial water use is calculated based on the number of industrial employees and water usage of each employee per day [21]. The standard of water requirement for industrial employees is 500 liters/employee/day.

Water use for livestock is calculated based on the number of livestock and water usage of livestock in each day, where the types of livestock that are calculated using water are cattle-buffalo-horse (big livestock), sheep (small livestock) and poultry. Standard water requirements for big livestock are 40 liters/livestock/day, small livestock 5 liters/livestock/day and poultry 0.6 liter/livestock/day [22].

The results of this water usage calculation are then linked to the criteria for groundwater vulnerability to sea water intrusion and the depth of the interface from Purnama's research results [23] (Figure 1). Quantitative descriptive analysis is used to give an explanation of the relationship between these three aspects.

## 3 Result and discussion

### 3.1 Location, boundary and area

This research was carried out in a coastal area that was formerly known as the Administrative City of Cilacap, which is astronomically located at 108°04'30 "-109°30'15" East Longitude and 07°00'20 "- 07°45'12" South Latitude. Administratively it covers North Cilacap District, Central Cilacap District and South Cilacap District, which are now part of the Cilacap Regency. The administrative boundaries of the research area are Jeruklegi District (north), Kesugihan District (east), Indian Ocean (south) and Donan River (west).

The research area has an area of 50.18 km$^2$, with details of North Cilacap covering 18.84 km$^2$, Central Cilacap covering an area of 22.15 km$^2$ and South Cilacap covering an area of 9.19 km$^2$. Judging from the topography, the research area is a sloping lowland.

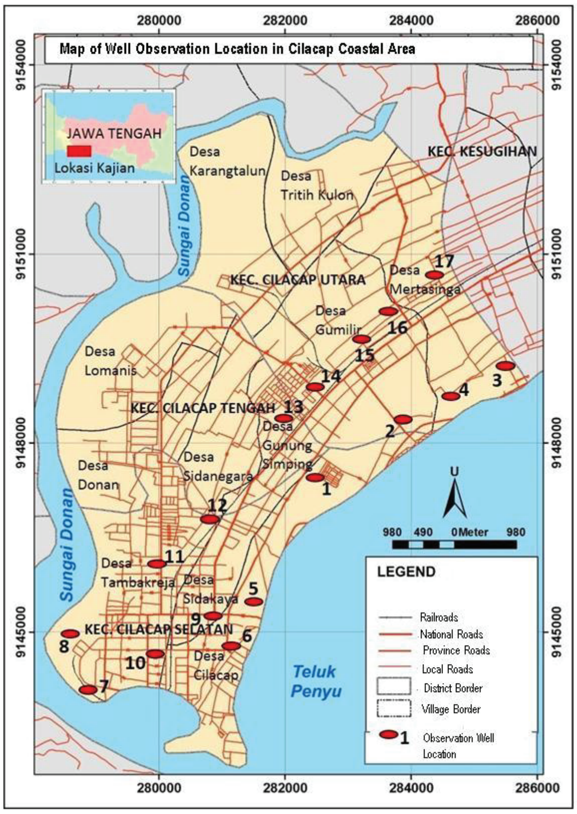


**Fig. 1.** Location of interface measurement [23]

### 3.2 Climate

To see climate patterns, climate classification is used. Among climate variables, rainfall is the most variable, so that climate classifications are often based on patterns and distribution of rainfall. Climate classification based on the distribution of monthly rainfall has been carried out in various ways, including the Schmidt-Ferguson System which is based on the calculation of the average wet and dry months year after year.

Based on the climatic division of Schmidt-Ferguson, the research area has a climate of B, which is a wet type with an average annual rainfall of 3,379 mm. The lowest average monthly rainfall of 136 mm occurs in August and the highest average monthly rainfall of 385 mm occurs in January. The other types are divided by Koppen. In the Koppen classification, beside from using rainfall data, the division of climate types is also based on air temperature. According to Koppen, climate is divided into five main climate types, i.e. climate type A or tropical rain climate, climate type B or dry climate, climate type C or temperate climate, climate type D or snowfall climate and climate type E or polar climate. Furthermore, climate type A is further divided into Af type or humid tropical, Am type or tropical rain and type Aw or tropical savanna. Based on the division of climate types from Koppen, the climate type on the coast of Cilacap is Af, which is a humid tropical climate, with the lowest average monthly temperature of 25.4°C occurring in August and the highest average monthly temperature of 27.4°C occurring in April.

### 3.3 Geology

Pay attention to its geological conditions, the research area is located in the coastal alluvial plain, river alluvial plain and swamp alluvial plain which are quaternary in age. The coastal alluvial plain is in the form of off-shore material with a material thickness of between 2 to 8 meters. River alluvial plains in the form of river alluvial deposits (silt, sand and gravel) are found in valleys, while alluvial plains of swamps in the form of clay, silt and sand are found in the Tritih and North Mertasinga areas.

Observing the stratigraphy, in the study area and its surroundings there are 3 rock units, namely coastal alluvium rock units, rivers and valleys, tuff marl rock units and tuff sandstone units. (Wongsosentono, 1974). The coastal alluvium units, rivers and valleys are exposed in the foothills of the Serayu Delta. The coastal alluvium forms an arc-shaped coastal embankment. Between one embankment and another embankment, it is separated by plains with clay, silt and silt material.

The alluvium of rivers and valleys in the form of fine-grained deposits is found in areas far from the river, while those in the form of coarse-grained deposits are found near rivers. The tuff marl rock units are scattered in the Jeruklegi and Tritih areas with material in the form of marl with an insertion of silt and sand, while the tuff sandstone units are composed of alternating sandstones with tuffs.

### 3.4 Geohydrology

Based on 3 cross sections of lithology drilled by the Directorate of Geology in 1970, groundwater in the study area is found in unconfined aquifers with sand material found up to a depth of 14-18 meters from the ground level. Under this layer of sand is a layer of clay.

Taking into account the material that makes up the aquifer, in terms of the porosity value, it is classified as large, namely between 39% to 42%, while the specific yield of aquifer is between 3 to 28%. Looking to the permeability value, it is classified as fast with a value of 2.5 to 45 m/day.

### 3.5 Population, industry and water usage

Based on data from North Cilacap in Number of 2019, Central Cilacap in Number of 2019 and South Cilacap in Number of 2019, the total population in the study area is 198,765 people. South Cilacap has the highest population of 83,329 people, followed by North Cilacap with 81,524 people and the lowest is Central Cilacap with 33,912 people.

Looking to Table 1, the total water demand for domestic usage in the study area is 23,851,800 liters/day. South Cilacap has the largest domestic usage namely 9,999,480 liters/day, followed by North Cilacap with 9,782,880 liters/day and Central Cilacap with 4,069,440 liters/day

**Table 1.** Total population, number of industries and water usage

| District/Village | Population (people) | Number of Industry Employees | | | | Water Usage (liters/day) |
|---|---|---|---|---|---|---|
| | | Large | Medium | Small | Home Industry | |
| **North Cilacap** | | | | | | |
| Kebon Manis | 9,864 | 0 | 0 | 90 | 81 | 1,633,680 |
| Gumilir | 17,389 | 0 | 0 | 161 | 352 | 2,343,180 |
| Mertasinga | 19,073 | 0 | 62 | 83 | 430 | 2,545,260 |
| Tritih Kulon | 22,325 | 0 | 0 | 63 | 575 | 2,997,500 |
| Karang Talun | 12,873 | 672 | 0 | 27 | 253 | 2,020,760 |
| **Central Cilacap** | | | | | | |
| Kutawaru | 10,341 | 0 | 0 | 218 | 266 | 1,482,920 |
| Lomanis | 1,505 | 1,855 | 0 | 32 | 33 | 1,140,600 |
| Donan | 6,144 | 0 | 0 | 186 | 363 | 1,011,780 |
| Sidanegara | 9,433 | 0 | 0 | 257 | 134 | 1,327,460 |
| Gunung Simping | 6,489 | 0 | 0 | 102 | 44 | 851,680 |
| **South Cilacap** | | | | | | |
| Tambakreja | 22,343 | 781 | 0 | 65 | 62 | 3,150,160 |
| Tegalreja | 12.301 | 0 | 0 | 295 | 200 | 1,723,620 |
| Sidakaya | 11,015 | 0 | 0 | 32 | 124 | 1,399,800 |
| Cilacap | 18,903 | 0 | 105 | 41 | 161 | 2,341,360 |
| Tegal Kamulyan | 18,767 | 1,094 | 32 | 125 | 145 | 2,877,540 |

Source : North Cilacap, Central Cilacap and South Cilacap in Number of 2019

Based on the scale of its activities, industry can be divided into four types, namely large industry, medium industry, small industry and home industry. The largest number of large industries is in South Cilacap, namely 4 industries with 1,875 employees, while in Central Cilacap and Sputh Cilacap, they have 2 and 1 large industries, respectively. For medium industry, South Cilacap also has the highest number of medium industries, namely 4 industries with 137 employees, while for small industries and home industries it is evenly distributed in the research area.

Based on the number of employees, the largest usage of water for industry is in Central Cilacap, amounting to 1,745,000 liters/day. The usage of water for industry in

South Cilacap is 1,631,000 liters/day and in North Cilacap is 1,424,500 liters/day.

### 3.6 Number of livestock and its water usage

In the research area, it turns out that there are also many livestock businesses, both large livestock, small livestock and poultry. The types of big and small livestock that are cultivated by the population include dairy cows, ordinary cows, buffalo, horses, goats and sheep, while the types of poultry that are cultivated are village chickens, purebred chickens, ducks and manila ducks.

The usage of water for livestock in the study area is 48,164 liters/day. The highest water usage was found in North Cilacap with 28,920 liters/day, followed by North Cilacap with 10,929 liters/day and Central Cilacap with 8,315 liters/day. Details of the number of livestock and water use for livestock are shown in Table 2.

**Table 2.** Number of livestock and water usage

| District/Village | Number of Livestock | | | Water Usage (liters/day) |
|---|---|---|---|---|
| | Big Livestock | Small Livestock | Poultry | |
| **North Cilacap** | | | | |
| Kebon Manis | 45 | 44 | 4368 | 4,701 |
| Gumilir | 52 | 61 | 4199 | 4,904 |
| Mertasinga | 62 | 72 | 8908 | 8,185 |
| Tritih Kulon | 73 | 61 | 5457 | 6,499 |
| Karang Talun | 41 | 48 | 4985 | 4,631 |
| **Central Cilacap** | | | | |
| Kutawaru | 65 | 253 | 780 | 4,333 |
| Lomanis | 7 | 58 | 283 | 730 |
| Donan | 34 | 84 | 307 | 1,964 |
| Sidanegara | 12 | 31 | 223 | 769 |
| Gunung Simping | 4 | 45 | 223 | 519 |
| **South Cilacap** | | | | |
| Tambakreja | 33 | 361 | 1798 | 4,203 |
| Tegalreja | 25 | 0 | 717 | 1,430 |
| Sidakaya | 0 | 81 | 816 | 895 |
| Cilacap | 0 | 154 | 1750 | 1,820 |
| Tegal Kamulyan | 0 | 184 | 2769 | 2,581 |

Source : [24] and calculation result

### 3.7 Evaluation of groundwater usage to sea water intrusion

Based on the accumulation of the three sectors, the highest water usage was in the North Cilacap of 11,569,300 liters/day, followed by South Cilacap at 11,492,480 liters/day and the least was in the Central Cilacap of 5,14,440 liters/day (Table 3). Observing the relationship between water usage and the vulnerability of groundwater to seawater intrusion and the depth of its interface, Tegal Kamulyan, Cilacap and Sidakaya villages, which are located in South Cilacap, need attention. Tegal Kamulyan Village is classified as moderate vulnerability with an interface depth of 39.20 to 63.58 meters, but its water usage is quite high, reaching 2,880,121 liters/day. Likewise in the Cilacap and Sidakaya Villages. Cilacap Village is classified as moderate vulnerability with an interface depth of 26.68 meters from the ground level, but the usage of groundwater reaches 2,343,180 liters/day. For Sidakaya Village, it is classified as moderate vulnerability with an interface depth of 57.12 meters from the ground level and the amount of water usage 1,400,695 liters/day. In these three village it is necessary to reduce the use of groundwater.

**Table 3.** Water Usage, groundwater vulnerability to sea water intrusion and interface depth

| District/Village | Category of Groundwater Vulnerability to Sea Water Intrusion | The Depth of Interface (m) | Water Usage (liters/day) |
|---|---|---|---|
| **North Cilacap** | | | |
| Kebon Manis | Low | 87.78 | 1,638,381 |
| Gumilir | Low | 129.74 | 2,348,084 |
| Mertasinga | Far from shore is low | 86.54 to 110.23 | 2,553,445 |
| | Close from shore is moderate | 64.12 to 72.28 | |

| | | | |
|---|---|---|---|
| Tritih Kulon | Not a coastal area | Not calculated | 3,003,999 |
| Karang Talun | Not a coastal area | | 2,025,391 |
| **Central Cilacap** | | | |
| Kutawaru | Not a coastal area | Not calculated | 1,487,253 |
| Lomanis | Not a coastal area | Not calculated | 1,140,600 |
| Donan | Not a coastal area | Not calculated | 1,013,744 |
| Sidanegara | Low | 95.11 | 1,328,229 |
| Gunung Simping | Moderate | 86.12 | 852,199 |
| **South Cilacap** | | | |
| Tambakreja | Low | 78.62 to 101.19 | 3,154,363 |
| Tegalreja | Low | 44.52 | 1,725,050 |
| Sidakaya | Low | 57.12 | 1,400,695 |
| Cilacap | Moderate | 26.68 | 2,343,180 |
| Tegal Kamulyan | Moderate | 39.20 to 63.58 | 2,880,121 |

Source : [23] and calculation result

## 4 Conclusion

Observing the relationship between water use and the vulnerability of groundwater to sea water intrusion and the depth of its interface, Tegal Kamulyan, Cilacap and Sidakaya villages, which are located in South Cilacap District, need attention. Because the three urban villages are classified moderate vulnerability to sea water intrusion, the interface depth is quite shallow but the water usage is quite high. For this reason, it is necessary to make efforts to find other water sources for domestic, industrial and livestock demand other than those from groundwater.

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