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Evaluation of groundwater availability to meet domestic water needs in Karangrejo Village, Petanahan District, Kebumen Regency

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Abstract
Groundwater plays a crucial role in fulfilling domestic water demands in Karangrejo Village, Petanahan District, Kebumen Regency. As the second-largest populated village in Petanahan in 2023 and bordered by the coastline, Karangrejo's groundwater availability is influenced by hydrogeological conditions. This study aims to determine groundwater flow patterns, assess water quality, estimate static and dynamic groundwater availability, and calculate domestic water demand. Methods used include groundwater level measurement, EM-VLF-VHF geophysical surveying, pumping tests, and domestic water-use assessment. The results show that groundwater flows from recharge zones in the central and partly northern areas toward discharge zones in the north and south. Groundwater availability reaches 5.54 billion L/year (static) and 362 million L/year (dynamic). Water quality indicates freshwater conditions based on temperature, electrical conductivity (EC), and Total Dissolved Solids (TDS) values. Domestic demand amounts to 98 million L/year, indicating a surplus condition. These findings demonstrate that the coastal aquifer in Karangrejo is capable of fulfilling local water demands and highlight the importance of aquifer characterization for sustainable groundwater management.

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Introduction

Water is an essential element in fulfilling the vital needs of living beings. Therefore, the water used must be free from pathogens and toxic substances. However, sources of drinking water that meet quality standards are increasingly diminishing due to human activities, both directly and indirectly. Meeting human water needs can be achieved by utilizing groundwater, surface water, or rainwater (Dewi, 2016). Groundwater is the most widely used because it has advantages compared to other sources, such as better quality and relatively low levels of pollution. The availability of groundwater is influenced by several factors, such as the area of the recharge zone, the size of the aquifer, and the amount of rainfall in the region (Cahyadi, 2019; Todd & Mays, 2005).

Groundwater is water that is stored in layers of soil or rock below the ground's surface (Widyasari et al., 2022). It is utilised through methods of excavation or drilling to extract available water. Secara global, sebagian besar air yang tersedia di Bumi adalah air asin, dengan proporsi mencapai 94%, dan air tawar hanya mencakup 6% (Triatmodjo, 2008). Of the total freshwater, 95% is groundwater, 3.5% is surface water, and the remaining 1.5% is soil moisture. The Ministry of Public Works and Housing (2019) states that the potential groundwater in Indonesia is estimated to be 712 billion m^3/year and is distributed across 421 groundwater basins.

The movement and flow patterns of groundwater can cause minerals in rocks to dissolve, thereby influencing the chemical composition of groundwater. Todd (1980) berpendapat bahwa litologi, struktur geologi, dan stratigrafi adalah faktor utama yang memengaruhi pembentukan airtanah dan akuifer. Therefore, groundwater in each region has different characteristics. This creates three types of groundwater with different compositions, namely fresh water, brackish water, and salt water (Indrayati & Setyaningsih, 2016). This provides motivation for research into groundwater, given its tendency to deteriorate over time.

Karangrejo Village is one of the villages located in Petanahan Subdistrict, Kebumen Regency. The village borders the coastline directly, which increases the risk of groundwater contamination. The Kebumen Regency Central Statistics Agency (2024) reports that Karangrejo Village had a population of 5,007 in 2023, making it the village with the second-largest population in Petanahan Subdistrict. The high population directly impacts the increasing demand for water. Water demand levels in each region can vary because they depend on several factors, such as geographic location, specific seasons or times of year, and the social conditions of the community.

Increasing water demand often leads to excessive groundwater exploitation. Without proper management, groundwater extraction may exceed its natural availability, causing a decline in groundwater reserves and threatening future water security. This condition can also trigger environmental problems such as seawater intrusion, land subsidence, and deterioration of groundwater quality. Therefore, sustainable water resource management is essential to ensure ecosystem balance and meet community needs. Accordingly, this study aims to: (1) identify groundwater flow patterns in Karangrejo Village; (2) estimate static and dynamic groundwater availability; (3) assess well water quality; and (4) determine domestic water demand. The study applies aquifer characterization through geophysical methods and hydrogeological analysis to provide a comprehensive understanding of groundwater conditions in the coastal environment.

Method

The Study Area

The research site is located in Karangrejo Village, Petanahan Subdistrict, Kebumen Regency. Geographically, it lies at 7°44'50"–7°46'20" S and 109°33'40"–109°34'40" E. To the north, the village borders Kewangunan Village; to the south, it borders the Indian Ocean; to the west, it borders Puring Subdistrict; and to the east, it borders Munggu Village. Geologically, Karangrejo Village is situated on the southern coast of Kebumen, composed of alluvial material, with characteristic landforms including back swamps, swales, and sandbars (Fig 1). This area is also part of the Kebumen–Purworejo Groundwater Basin (CAT), which, according to Setiadi (2003), has an unconfined aquifer with a discharge of approximately 130 million m³/year.

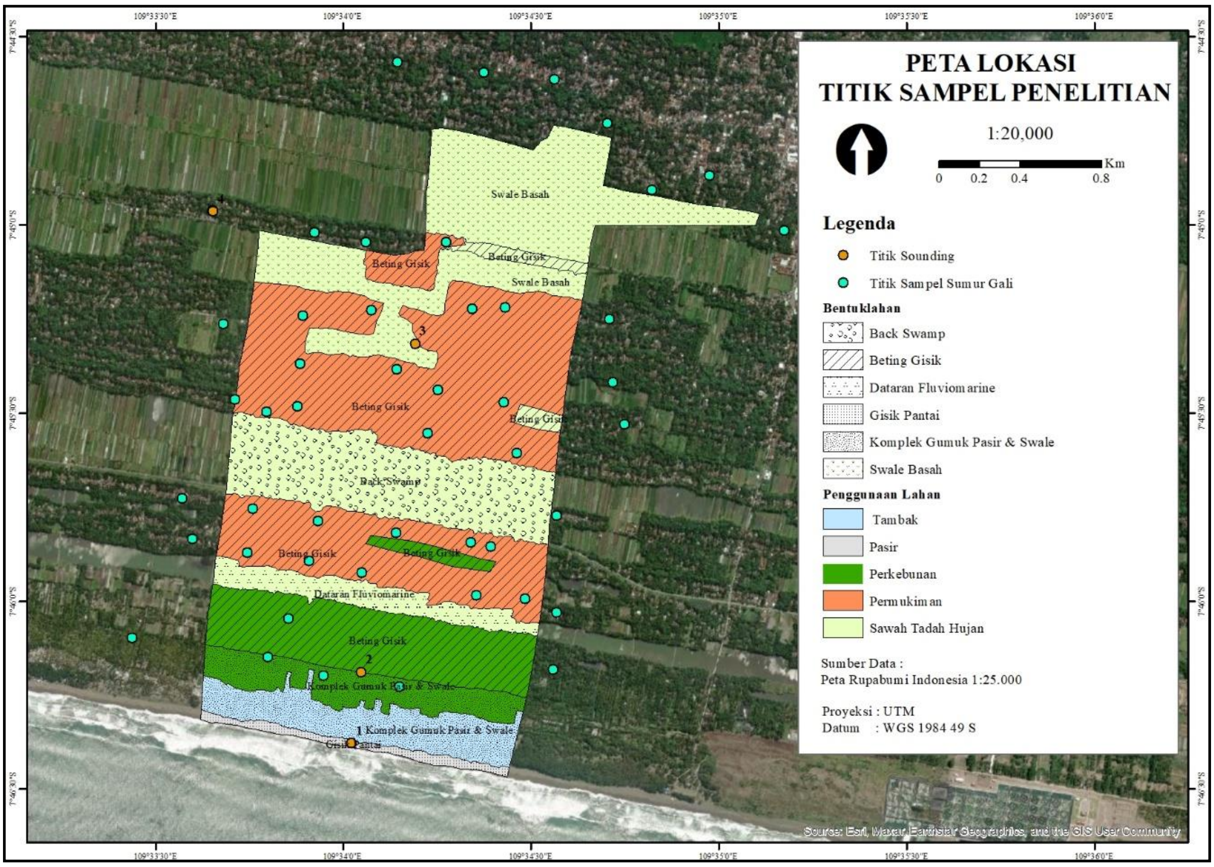

Fig 1. Map of Sample Locations

Data Collection and Analysis

This study estimates groundwater availability for meeting domestic needs in Karangrejo Village. Field data collected include groundwater level (GWL) data, water quality data, aquifer characteristics data obtained through EM-VLF-VHF geophysical measurements, hydraulic conductivity data from pumping tests, and domestic water consumption data gathered through direct interviews with residents.

Groundwater level (GWL) measurements were conducted at 48 dug well sampling points distributed throughout Karangrejo Village, concurrently with water quality checks using field instruments. The collected GWL data was used to create flow nets in the study area. Linear interpolation of the GWL was performed using the three-point method to manually generate groundwater contour lines. The groundwater contour map was used to determine groundwater flow direction by drawing lines perpendicular to the contour lines. This flow direction pattern was used to identify recharge and discharge zones.

Groundwater availability is estimated using two approaches: the static method and the dynamic method. According to Santosa & Adji (2014), the static method is a method for calculating groundwater that assumes the water is at rest. Static estimates of groundwater availability are calculated based on aquifer material characteristics, such as thickness and specific yield. Aquifer material characterization is performed using the Electromagnetic Very Low Frequency–Very High

Frequency (EM-VLF-VHF) geophysical method. This method utilizes reflected electromagnetic waves at each change in rock composition captured by sensors (Febriarta and Purnama, 2020), and the measurement results are used as the basis for interpreting aquifer materials. Subsequently, static groundwater availability is estimated using the Todd & Mays (2005) approach as follows:

$$Vat = A \times D \times sy \quad (1)$$

Notes:
Vat : groundwater availability (m³/year)
A : aquifer cross-sectional area (m)
D : aquifer thickness (m)
Sy : specific yield (%)

The dynamic method for calculating groundwater availability is an approach that assesses groundwater potential based on water flow and discharge within an aquifer system. This approach considers the parameters of hydraulic conductivity (K) and hydraulic gradient (I). Hydraulic conductivity is obtained through a pumping test using the Shallow Dug Well Recovery Test (Slug Test) method. According to Cahyadi et al. (2015), the slug test is conducted by pumping water through the installation pipe until the groundwater level reaches a certain height, then recording changes in the water level over time until a steady-state condition is reached. This slug test uses the Theis Recovery approach based on the principle of groundwater level recovery (Residual Drawdown). The hydraulic conductivity value is calculated using the Bouwer & Rice (1976) formula:

$$K = \frac{rc^2 ln(\frac{Re}{rw})}{2d} \times \frac{1}{t} \times ln\frac{So}{St} \quad (2)$$

$$Ln\frac{Re}{rw} = [\frac{1,1}{ln(\frac{b}{rw})} + \frac{A + B\ ln\ [(D-b)/rw]}{(\frac{d}{rw})}]\text{-}1 \quad (3)$$

Notes:
K : hydraulic conductivity
rc : radius of the impermeable section of the well (m)
Re : radius of the influence circle (m)
rw : radius of the permeable section of the well (m)
d : height of the permeable well wall (m)
D : distance between the water table and the impermeable layer (m)
A and B : results from the graph showing the relationship between A and B
T : time (seconds)
So : difference between the initial and final water table levels during pumping
St : difference between the initial water table level and the water table level at time t seconds after pumping stops (m)

The hydraulic gradient is obtained from a flownet analysis, which measures changes in groundwater level elevation over a specific distance based on the TMA contours. Once the values of K and I are obtained, the dynamic groundwater availability is calculated using Darcy's equation (Fetter, 1994):

$$Q = K \times A \times I \quad (4)$$

Notes:

Q : total groundwater discharge (m^3/day)
K : hydraulic conductivity
A : aquifer cross-sectional area ( )
I : hydraulic gradient

Determining domestic groundwater needs is done by collecting data on population size, per capita water consumption, and daily water usage patterns through direct interviews with the community. The data obtained is used to calculate daily and annual groundwater needs. The calculation of daily groundwater needs per person can be done using the following formula.

$$Q_{f(hari)} = \frac{Water\ consumption\ \ (liters/day)}{Number\ of\ People(orang)} \quad (5)$$

The total domestic water demand for a given area can be calculated using the following formula.

$$Q_{f(tahun)} = 365 \times Q_{f(hari)} \times Population$$

Result

Groundwater Flow Patterns

An analysis of groundwater flow patterns in Karangrejo Village was conducted to determine the groundwater potential in the study area through an analysis of recharge and discharge zones. Naturally, groundwater flows toward lower elevations under the force of gravity (Fitts, 2002). Another factor influencing groundwater flow is the lithological composition of Karangrejo Village, which consists of coastal sedimentary deposits containing loose sand and fine sediments. These materials have high permeability, allowing groundwater to flow more rapidly (Okto et al., 2023).

The GWL in Karangrejo Village varies within a range of 2.75–15.04 meters, measured during the rainy season. The GWL values at each of these points were connected to form GWL contour lines, also known as flownets, which can be used for groundwater flow analysis. Based on the created flownets, it was found that areas with high GWL are predominantly located in the central part and parts of the northern side, while low GWL is predominantly found in parts of the northern and southern sides of the study area (Fig 2). This distribution of TMA is influenced by the topographic conditions of the study area, where the southern part of the study area has a lower elevation than the northern part (Fan et al., 2007). Table 1 shows the Groundwater Level (GWL) in Karangrejo Village at 48 dug well sampling points.

The delineation of recharge and discharge zones can be performed based on the existing flownet maps. Areas with high TMA values constitute recharge zones, while areas with low TMA values fall within discharge zones. The dominant recharge zones are located in the central part and parts of the northern side, with the highest TMA reaching 14 meters. Discharge areas are located in parts of the northern and southern sides of the study area, with the lowest TMA at 4 meters. Groundwater flow patterns in Karangrejo Village move in all directions from the recharge areas. This indicates that groundwater flow movement is largely controlled by the elevation within the study area.

These conditions are associated with the landforms in the study area. The recharge area is associated with beach ridge landforms. These developed landforms, such as old beach ridges, have relatively flat topography, so the most common land use is residential areas. The discharge area is associated with swale and back swamp landforms, which have relatively lower elevations compared to beach ridges.

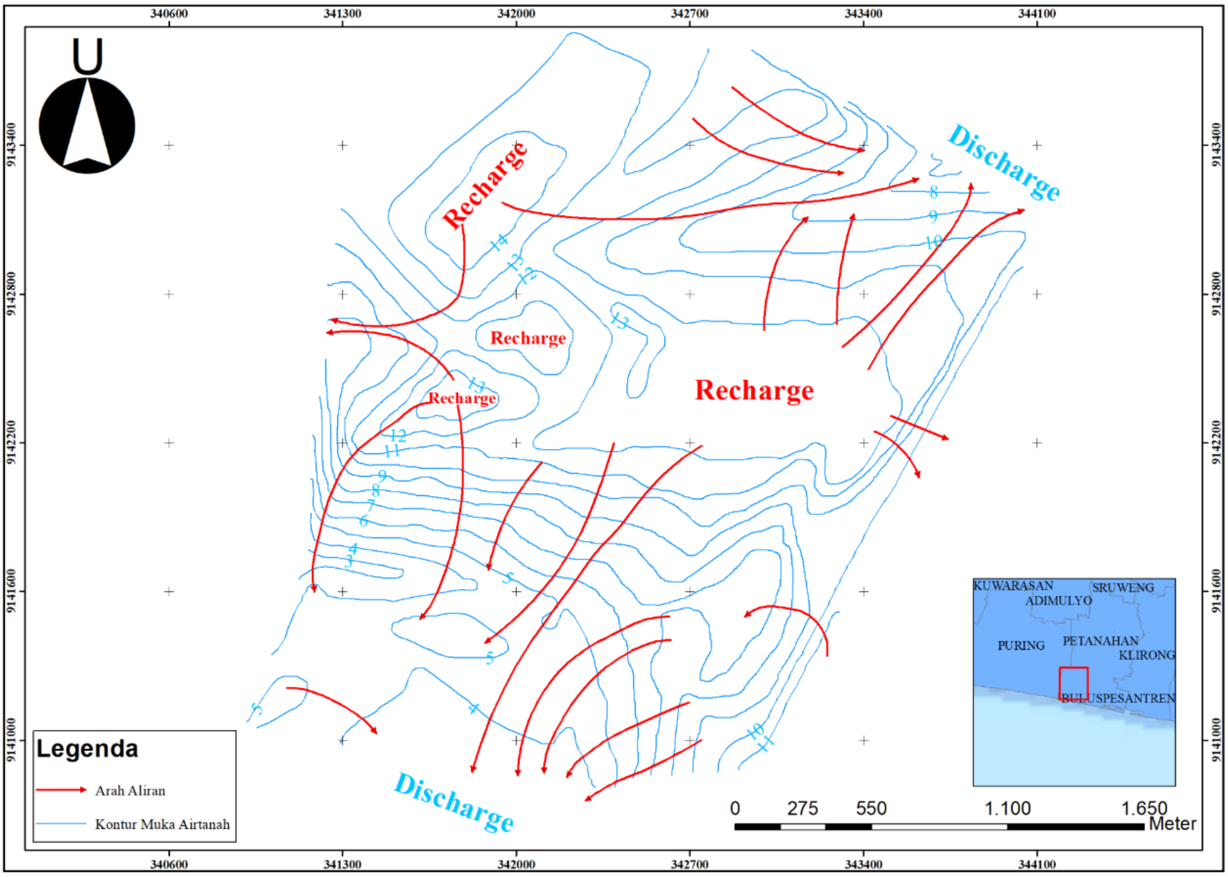

Fig 2. Flownets Map of Karangrejo Village

A swale is a depression between two sand dunes. However, the swale landforms found in the study area are depressions between two sandbars. Groundwater flows toward these swale-like depressions, where it accumulates, making it easy to find at shallow depths. The most common land use is agricultural land, as in the study area, where swales and back swamps are utilized as rain-fed rice field.

Estimated Groundwater Availability

Estimates of static groundwater availability can be calculated once the characteristics of the aquifer in Karangrejo Village are known, which include several parameters such as aquifer thickness, constituent materials, aquifer area, and hydraulic conductivity (Iskandar & Adji, 2017). The aquifer thickness in this study was determined using the Electromagnetic Very Low Frequency - Very High Frequency (EM-VLF-VHF) geophysical method. The results indicate that the aquifer thickness in Karangrejo Village varies, with an average of 48.8 m. This value indicates a saturated zone from the groundwater table to the impermeable layer, thus characterizing the groundwater reservoir in Karangrejo Village. Table 2 shows the aquifer thickness in Karangrejo Village.

Another parameter used in calculating static groundwater availability is hydraulic conductivity (K). The K value is used to determine the composition of the aquifer and to calculate the specific yield. Hydraulic conductivity (K) is the ability of aquifer material to transmit water (Prambandini, 2016).

Table 1. Groundwater Level in Karangrejo Village

Nomor Sumur	(X)	(Y)	TMA (m)	Nomor Sumur	(X)	(Y)	TMA (m)
1	343729	9143322	6,65	25	341714	9142185	11,10
2	341294	9143144	12,00	26	342664	9141502	7,63
3	341795	9143036	15,04	27	341771	9141427	5,82
4	342047	9142992	12,60	28	341469	9141468	4,93
5	342968	9143792	11,10	29	341202	9141534	4,93
6	343227	9143579	12,40	30	342033	9141371	4,98
7	343445	9143253	8,260	31	342594	9141263	7,09
8	342440	9142994	10,48	32	342832	9141246	6,95
9	342073	9142659	10,06	33	342986	9141181	8,80
10	341727	9142396	14,07	34	342983	9141656	5,41
11	341409	9142220	11,85	35	342564	9141521	6,84
12	341350	9142590	8,35	36	342199	9141567	5,02
13	341739	9142629	11,35	37	341815	9141625	3,92
14	342201	9142370	11,60	38	341496	9141683	2,85
15	342729	9142673	12,10	39	341149	9141732	2,75
16	343241	9142618	12,55	40	341672	9141144	3,24
17	342568	9142665	13,22	41	342217	9140812	3,51
18	342402	9142268	12,90	42	341574	9140957	3,23
19	342723	9142209	12,25	43	341845	9140868	3,65
20	343258	9142309	12,97	44	342970	9140902	11,43
21	343314	9142103	12,95	45	340908	9141047	5,05
22	342789	9141960	10,80	46	342620	9143823	12,70
23	342352	9142057	10,60	47	342199	9143874	13,00
24	341564	9142160	10,85	48	344093	9143056	9,90

Source: (Field data, 2025)

Table 2. Aquifer Thickness in Karangrejo Village

Sounding Point	Thickness of Saturated-Impermeable Zone (m)	*Depth to Water Table* (m)	Aquifer Thickness (m)
1	61,20	0	61,20
2	37,80	1,11	36,69
3	54,00	0,87	53,13
4	45,00	0,52	44,48
Average (m)			48,88

The K value in this study was determined from pumping tests conducted at three wells. The average K value in Karangrejo Village was 12.7 m/day, indicating that the aquifer material consists of medium-grained sand. Based on Todd's classification (1980), medium-grained sand has a Specific Yield of 28%. Meanwhile, the aquifer area corresponds to the total area of Karangrejo Village, which is 4.05 km².

The calculation of static groundwater volume was performed by multiplying the thickness of the aquifer by the area of the Karangrejo Village aquifer, resulting in an aquifer volume of 197,964,000 m³. Based on its specific yield, the volume of groundwater that can be yielded by the medium-grained sand material is 5,542,922,000 liters per year. This indicates that Karangrejo Village has relatively high groundwater potential, with 5.5 billion liters of water stored in the aquifer annually. However, this value does not fully represent the actual groundwater conditions. According to Iskandar & Adji (2017), static groundwater availability assumes that groundwater is stationary and contained within a reservoir, whereas in reality, groundwater is constantly moving due to recharge and subsequent replenishment.

Groundwater availability in Karangrejo Village can also be estimated using groundwater discharge through calculations of dynamic groundwater potential. Groundwater flowing at a certain velocity is considered to have dynamic properties, so calculations of groundwater availability are based on Darcy's Law. Groundwater discharge is calculated based on the parameters of hydraulic conductivity (K), hydraulic gradient (I), and aquifer cross-sectional area (A). The hydraulic gradient values are obtained from segments of the flownet map that include recharge and discharge areas. According to Saputra (2016), soil conditions on slopes allow groundwater to move within the aquifer. The discharge values resulting from calculations in recharge and discharge segments differ significantly because recharge areas generally have a denser contour pattern. Areas with a dense contour pattern can be identified as steep regions, indicating high groundwater movement. Results of Dynamic Groundwater Discharge Calculations for 4 Flownet Segments are shown in Table 3. Meanwhile results of dynamic groundwater discharge calculations 362.283.487.

Karangrejo Village is part of the Kebumen-Purworejo groundwater basin system (CAT), which is characterized by an unconfined aquifer. The unconfined aquifer in the Kebumen-Purworejo CAT has a discharge of 130 million m³/year (Setiadi, 2003). Calculations of the dynamic groundwater discharge for Karangrejo Village indicate an average groundwater discharge of 992.56 m³/day or 362,283,487 liters/year. According to Soetrisno's (1983) classification, a groundwater discharge rate exceeding 10 liters per second or 864 m³/year falls into the category of high-productivity aquifers with extensive distribution through intergranular spaces. This material aligns with the classifications by Todd & Mays (2005), Singhal & Gupta (2010), and Fetter (2014), indicating that the average hydraulic conductivity across the four Flownet segments is 10.88 m/day, placing it in the category of medium-grained sandstone. The aquifer is composed of alluvial material in the southern coastal region of Kebumen Regency (Purnama, 2017).

Table 3. Results of Dynamic Groundwater Discharge Calculations for 4 Flownet Segments

Segment	Q (m3/day)
1	1783,60
2	1044,47
3	724,38
4	417,78
Average Q (m3/day)	992,56

Well Water Quality

Groundwater quality testing was conducted directly in the field for the following parameters: temperature, pH, total dissolved solids (TDS), and electrical conductivity (EC). Water quality samples were collected from 48 dug wells distributed across two landforms: Beting Gisik and the Sand Dune and Swale Complex. The results of the water quality testing were evaluated against the drinking water quality standards set out in Regulation of the Minister of Health of the Republic of Indonesia No. 2 of 2023 on the Implementation of Government Regulation No. 66 of 2014 concerning Environmental Health. The standards apply to water used for drinking, cooking, washing, eating and drinking utensils, bathing, washing food ingredients intended for consumption, sanitation, and religious rituals.

All well water samples tested were clear, odorless, and tasteless, with temperatures ranging from 28.2 to 31.2°C, meeting quality standards (Fig 3). The pH test results ranged from 6.45 to 7.81. There were 2 wells with pH values of 6.45 and 6.46, respectively, which were slightly below the drinking water quality standard for pH, namely 6.5–8.5 (Fig 4). A pH below 6.5 (acidic) can increase the corrosivity of metal objects, cause an unpleasant taste, and render certain chemicals toxic, posing health risks (Sutrisno, 2006). pH quality can be influenced by various factors, including rainwater seeping into the ground and becoming groundwater. Test results for water quality for the DHL parameter ranged from 100–600 µS/cm, with most falling within 200–400 µS/cm (Fig 5). Wells with.

DHL values >400 µS/cm were found only on alluvial fan landforms associated with residential areas, particularly at Well 37, which recorded the highest DHL value of 603 µS/cm. All samples have DHL values classified as freshwater because they are below 1500 µS/cm. Fig 7 shows a strong correlation between DHL and TDS. The high correlation coefficient of 81.49% indicates that variations in DHL can largely explain variations in TDS values.

This implies that the higher the water's electrical conductivity, the higher the total dissolved solids content. Although most data points follow a linear trend, a few deviate slightly from the regression line. These deviations may be caused by other factors, such as the presence of specific ions that affect only one parameter.

Table 4. Groundwater Quality in Karangrejo Village

Number	T(˚C)	pH	DHL (µS/cm)	TDS (mg/l)	Number	T (˚C)	pH	DHL (µS/cm)	TDS (mg/l)
1	29,2	7,51	478	234	25	28,8	6,90	270	182
2	28,0	6,72	101	66.2	26	30,2	7,51	237	112
3	28,2	6,45	458	308	27	30,3	7,79	248	115
4	30,0	6,95	258	170	28	30,0	7,80	387	188
5	28,6	6,46	291	196	29	30,5	7,60	430	200
6	28,3	6,52	260	171	30	30,2	7,66	320	155
7	29,3	7,59	206	96.7	31	30,4	7,57	247	116
8	28,2	6,58	412	278	32	30,6	7,84	384	187
9	28,4	6,58	443	284	33	30,3	7,81	183	87,3
10	28,5	6,52	335	225	34	29,7	7,63	246	118
11	28,0	6,75	400	250	35	29,8	7,46	220	104
12	28,7	7,11	305	202	36	29,6	7,90	157	74,4
13	28,2	7,18	279	188	37	30,4	7,95	603	290
14	28,8	6,50	449	295	38	29,8	7,74	326	157
15	29,6	6,71	354	235	39	29,3	7,55	264	127
16	28,2	7,42	312	209	40	30,0	8,20	208	98,9
17	29,9	6,65	338	227	41	30,7	8,17	228	108
18	28,4	7,29	435	291	42	31,2	8,13	270	130
19	28,4	6,87	265	173	43	30,3	8,06	247	119
20	28,8	7,81	216	141	44	30,5	8,02	171	81,3
21	28,2	7,16	331	221	45	30,1	8,51	339	162
22	28,4	7,25	345	231	46	28,4	6,64	350	233
23	28,0	7,35	220	145	47	27,9	6,76	193	129
24	28,4	6,76	406	270	48	29,3	7,86	124	64,2

Source: (Field data, 2025)

Fig 3. Graph of Groundwater Temperature in Karangrejo Village

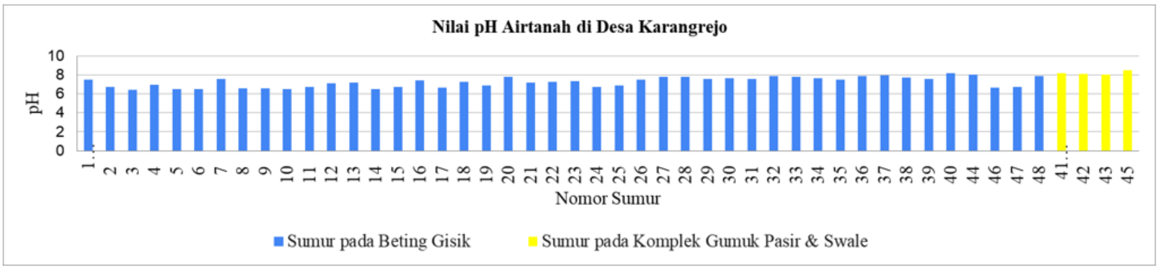

Fig 4. Graph of Groundwater pH Levels in Karangrejo Village

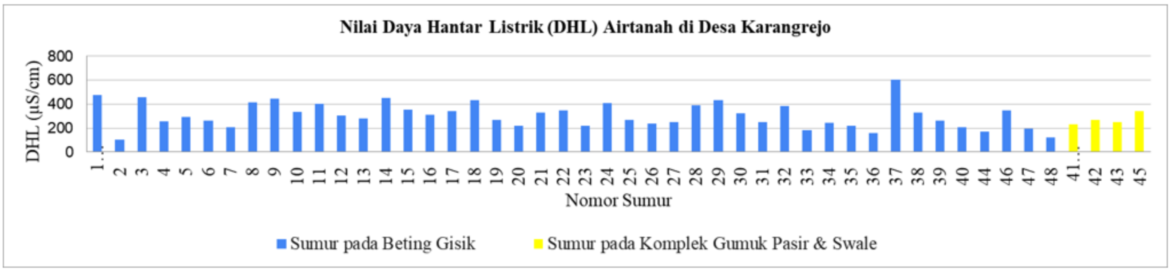

Fig 5. Graph of Ground-Level DHL Values in Karangrejo Village

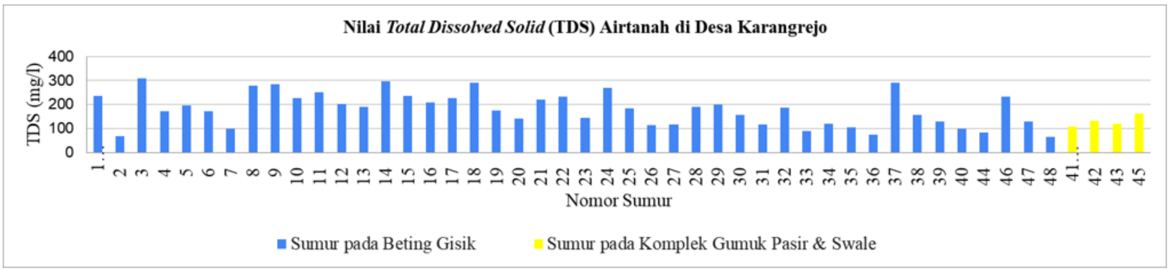

Fig 6. Graph of Groundwater TDS Levels in Karangrejo Village

Domestic Water Needs

Fundamental groundwater issues in a region are often linked to over-extraction and quality degradation due to pollution. Interview results indicate that the residents of Karangrejo Village still rely heavily on groundwater to meet most of their domestic needs. This situation makes the area vulnerable to significant drops in groundwater levels during the dry season, over-extraction, and seawater intrusion, which can degrade groundwater quality. Therefore, calculating domestic water needs and household-level groundwater consumption patterns is crucial for planning sustainable groundwater resource management.

Rajeevan & Mishra (2020) note that variations in domestic groundwater consumption are influenced by several factors beyond population size, including household size, the highest level of education, household access to groundwater, frequency of use, income, and the number of children in the family. Thus, calculating groundwater needs and comparing them with minimum requirements can provide an accurate picture of actual conditions on the ground and serve as the basis for developing optimal groundwater conservation strategies.

An increase in population will lead to higher water demand (Yudistira and Adji, 2013). According to BPS (2024), the population of Karangrejo Village in 2023 was 5,005, resulting in a total domestic water demand of 97,992,602.49 liters/year and a per capita water demand of 53.64 liters/day. According to SNI 19-6728.1-2002, the standard clean water requirement for rural residents is 60 liters/day, so the domestic water demand in Karangrejo Village is considered low. Results of domestic water demand calculations shown in Table 5.

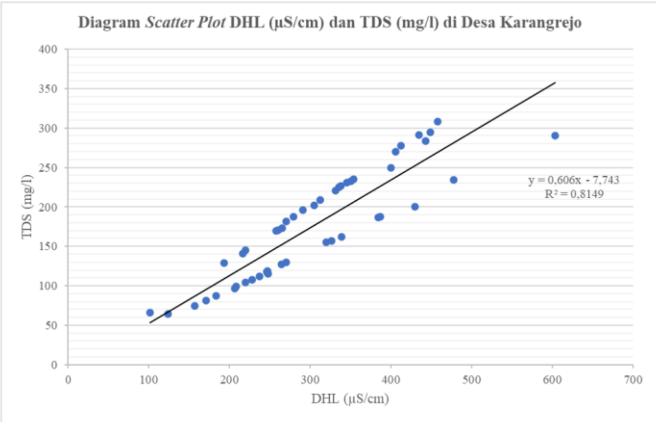

Fig 7. Scatter plot of DHL (µS/cm) and TDS (mg/L) in Karangrejo Village

Table 5. Results of Domestic Water Demand Calculations

Domestic Use	Bathing	Toilet	Laundry	Dishwashin g	Drinking and Cooking	othe	Total (L/day)
Total	1.386,50	791,25	1.427,67	699,00	164,00	58,70	4.613,12
average/KK	419,17	239,22	431,62	211,33	49,58	17,75	177,43
Per capita	126,73	72,32	130,49	63,89	14,99	5,17	53,64
Total Domestic Water Demand in Karangrejo Village (L/year)							97.992.602,49

The low domestic water demand in Karangrejo Village may be attributed to the residents' lifestyle and daily activities. People in rural areas generally lead simpler lifestyles, so they tend to use fewer household appliances that require large amounts of water compared to urban residents. Additionally, water resources in Karangrejo Village are used primarily for basic needs rather than secondary needs. The primary needs requiring the most water, in order, are washing clothes, bathing, using the toilet, and washing dishes.

The water balance is a representation of the relationship between water availability and demand in a given area, analyzed through a balance sheet to determine water surpluses or deficits (Triatmodjo, 2008). The results of the static water balance calculation indicate a surplus of 5,444,999,398 L/year, and the dynamic water balance calculation indicates a surplus of

264,290,885 L/year. The surplus conditions in both of these approaches indicate that groundwater availability in Karangrejo Village has been sufficient to meet the needs of the local community. This indicates optimal and sustainable fulfillment of water needs.

The difference in results between static and dynamic methods stems from the underlying assumptions used. The static method assumes that groundwater is at rest, whereas the dynamic method accounts for groundwater movement within the aquifer (Iskandar & Adji, 2017). In reality, groundwater is dynamic, and the aquifer will recharge when recharge occurs. The static water balance can serve as an early indicator in water resource management because it assumes that groundwater volume remains constant over time, thereby helping to anticipate the risk of overexploitation (Iskandar & Adji, 2017). A surplus in the static water balance indicates that the groundwater reserves, or aquifers, in this region are sufficient to meet long-term needs. On the other hand, a surplus in dynamic water balance reflects that the contribution from rainfall and surface runoff is substantial enough to maintain annual water discharge, thereby adequately meeting the daily needs of the community.

Over time, human use of groundwater tends to increase, but its availability remains relatively constant. The rapid population growth in Karangrejo Village can directly affect groundwater availability, potentially leading to water shortages. Additionally, the predominance of agricultural activities in Karangrejo Village underscores the need to prevent further increases in the water balance deficit in this area. One measure is the construction of a reservoir or retention pond in Karangrejo Village to channel rainwater to the baseflow (Nirwana et al., 2024). Educating farmers on selecting crop varieties suitable for the local climate is also a crucial step in preparing for the possibility of prolonged droughts.

Conclusion

The village of Karangrejo has a groundwater flow pattern from the recharge zone in the central part toward the discharge zones in the north and south. The groundwater availability is quite substantial, amounting to 5,542,992,000 liters/year using the static method and 362,283,487 liters/year using the dynamic method. The community's domestic water demand is 97,992,602 liters/year, indicating a groundwater surplus in this area. The groundwater is classified as freshwater based on temperature, pH, DHL, and TDS parameters. However, this study has limitations in interpreting aquifer materials, as it relies solely on the EM-VLF-VHF method; therefore, the aquifer characteristics have not been described in detail. Therefore, further research is recommended to analyze the aquifer material in greater detail.

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Author Contribution

Author Contributions: Conceptualization, Methodology, Data Curation, Formal Analysis, Visualization, and Writing—Original Draft Preparation, all authors; Investigation, D.K. Wijaya, A.K. Setyanigsih, A.A. Sakiyo, A.N. Fauziah, D.N. Rahmawati, F.B. Aufal, H. Firdaus, M.P.B. Setyawan, M.H.A.C. Saputra, M. Elviana, W. Handayani, and W.N. Hidayah; Writing—Review and Editing, D.K. Wijaya, T.N. Adji; Supervision, T.N. Adji. All authors have read and agreed to the published version of the manuscript.

Data Availabilty

All data generated or analyzed during this study are presented in the tables and figures within this article

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