



Optimization Of Groundwater Well Debit Capacity Based On Step Drowdown Test To Support The Sustainability Of Groundwater Utilization In Biromaru Area, Sigi District, Central Sulawesi Province

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Abstract. Groundwater in the Sigi region of Central Sulawesi is used to meet the increasing needs of the community. The limited availability of groundwater caused by the earthquake in 2018 resulted in many wells in the area not produce optimally, while the community relies heavily on well water for the needs of the plantation business. Hydrogeological research in Sigi aims to determine the parameters of the aquifer and evaluate the performance of Wells. The method used is pumping test method in the form of step drowing test. Well test results showed an average transmissivity of $111.89 \text{ m}^2 / \text{day}[1]$ and storativity obtained an average value of 0.0095. The well condition is considered good with aquifer loss coefficient B values of 0.00501. Low well loss values $C=0.000005$ In the tests carried out, a small average value of $B = 1.2 \times 10^{-3}$ was obtained, so it can be concluded that the decrease in water level due to the linear loss factor is very small, this indicates that there is enough groundwater reserve in the aquifer but it should also be reviewed that this small decrease is due to the production capacity of the water flow in the well. The C value of 6×10^{-4} indicates that the decline that occurs around the well wall occurs slowly and the entry of aquifer constituent materials into the well that can cause damage to the well pump does not occur.

Keywords: Aquifer; Hydrogeological; Pumping Test; Transmissivity

1 Introduction

Population increases year by year, the need of clean water also increases. However, groundwater reserves are limited and the recharge period is long, so it is necessary to limit the amount of groundwater withdrawal and ensure that the groundwater treatment capacity is not excessive. Pumped groundwater must be available regularly to fulfill the people's groundwater needs.

Sigi area in Central Sulawesi is an attractive location for hydrogeological research as it offers interesting potential for studying hydrogeology under real field conditions. Groundwater wells are an important source of water in the Sigi area because of the limited availability of water in the PDAM and the quality of groundwater in the Sigi area is generally good and safe for consumption. Groundwater wells in the Sigi area can also be utilized for household, agricultural and livestock needs. Because the Sigi area has good groundwater quality and is suitable for consumption, it is therefore necessary to maintain the quality of groundwater so that it is not polluted by waste and use groundwater in moderation and not excessively[1].

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Groundwater utilization is generally done by drilling wells. Increasing groundwater utilization through groundwater drilling can directly impact the decrease in groundwater quantity so to maintain the sustainability of groundwater utilization it is very important to maintain the sustainability of groundwater utilization, it is very important to know the ability of the aquifer to produce groundwater. To determine the water production capability of wells in an aquifer, it is necessary to test wells along with surface geological data[2].

Regionally, the research area is included in the Review Geological Map of Palu Sheet published by the Geological Research and Development Center by Rab. Sukamto (1993), where based on the Geological Map of Palu Sheet, it is known that the lithological formation of the research area consists of Metamorphic Complex (Km), Tinombo Formation (Tts), Molasa Celebes Sarasin/ (Tmc), Alluvium and Coastal Deposits (Qal), and Intrusive Rocks[3].

Pumping tests can test groundwater discharge and identify a well's ability to produce groundwater. ability to produce groundwater. In addition, this test is used to investigate the of the aquifer. The pumping test pumps groundwater from a borehole with a certain discharge and observes the groundwater level drop during pumping. Pumping groundwater from a borehole with a certain discharge, observing the groundwater level drop during pumping and observing the recovery of the water level after the pump is turned off according to an interval of time interval. Pumping tests can be divided into two: well testing and aquifer testing[4], [5], [6], [7], [8].

This research aims to analyze the quantity of groundwater wells by conducting pumping tests with the step drawdown method. This research is worth doing because it supports the sustainability of green economy. Conservation of groundwater for irrigation helps increase the production of agricultural products in the long term and sustainably.

1.1 Step Drawdown Test

The step-drawdown pumping test, sometimes also called the step discharge or well performance test, is a widely used method for determining the maximum allowable pumping rate of a water well [9]. The well is pumped sequentially at several points, usually three to six points, increasing the pumping rate. In the ideal case, the drawdown becomes constant at the end of each step before the rate is increased. The main purpose of pumping with this method is to determine well type capacity, production capability well and determine the optimum discharge of the well production. Measurements were made by measuring the initial groundwater level from the casing lip well casing lip to serve as the starting point or benchmark for the next measurement[10]. Step drawdown test is a single well test (first practiced by Jacob in 1947) where the well is pumped at a low and constant production rate until the drawdown in the wellbore stabilizes. The pumping rate is increased to a higher constant production rate and the borehole is pumped until the drawdown stabilizes again. This process should be repeated for at least three steps, and all steps should be of equal duration (e.g., 30 minutes to 2 hours).

One of the main objectives of the step drawdown test is to estimate well efficiency in actual field situations. This method measures well performance criteria, such as well-loss coefficient and well efficiency, and provides an estimate of the maximum yield (optimal pumping rate) under various water level conditions. Compared to other pumping tests, the stages of this method tend to be short, relatively simple and inexpensive. In the step draw down method, the abstraction rate from the well is increased in steps (minimum of three). The process consists of pumping the well in [11]the well in increments of discharge (Q), and then measuring the transient change in the water level (drawdown) at each step until the drawdown stabilizes. Referring to Jacob's formula[9], the drawdown of a full-through well can be expressed (ignoring the well loss component) as:

$$S_w = B(r_{ew},t)Q + CQ^2 \quad (1)$$

Therefore, Rorabaugh (1953)[12] suggested that Jacob's equation is

$$S_w = BQ + CQ^p \quad (2)$$

Is the turbulence exponent, and the value of p ranges from 1.5 to 3.5 depending on the value of Q. However, as suggested by Jacob, a value of p of 2 is acceptable [13]. Again: $B(r_{ew},t) = B_1(r_{ew},t) + B_2$, $B_1(r_{ew},t)$ and $B_2 =$ linear aquifer coefficient and borehole loss coefficient, $C =$ nonlinear borehole loss coefficient, $B(r_{ew},t) Q =$ linear loss, $B_1(r_{ew},t)Q =$ aquifer loss, $B_2Q =$ linear well loss, turbulence loss (nonlinear well loss) $= CQ^2$, total well loss = linear well loss + nonlinear well loss = $B_2Q + CQ^2$. In this study, we used the Hantush-Bierschenk method to determine the loss coefficient.

1.2 Hantush-Bierschenk Method

By applying the superposition principle to Jacob's equation, [13] expressed the drawdown $S_w(n)$ in the well during the nth step of the stepwise drawdown test as:

$$S_{w(n)} = \sum_{i=1}^n \Delta Q_i B(r_{ew}, t - t_i) + CQ_n^2 \quad (3)$$

Where, $\Delta Q_i = Q_i - Q_{i-1} =$ increase in discharge starting at time t_i ; $Q_i =$ constant discharge during the i-th step that precedes the n-th step. Total increase in debit

$$\sum_{i=1}^n \Delta S_w(i) = S_{w(n)} B(r_{ew}, \Delta t) Q_n + CQ_n^2 \quad (4)$$

$$\frac{S_w(n)}{Q_n} = B(r_{ew}, \Delta t) + CQ_n \quad (5)$$

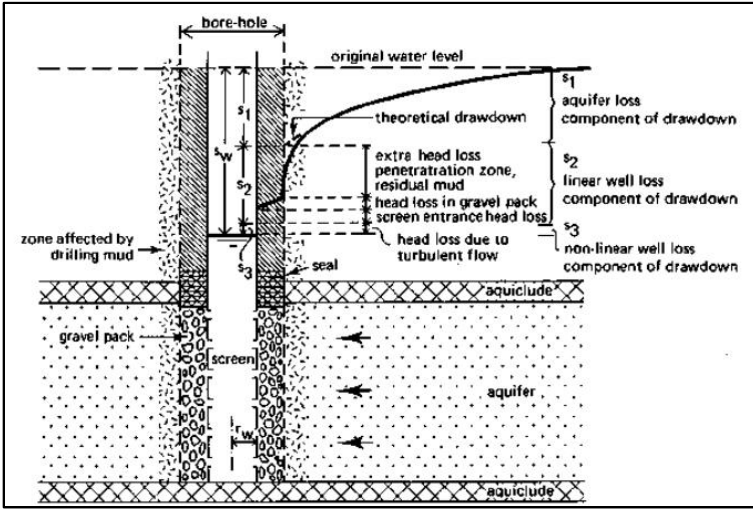


Fig. 1. Image Various head losses in a pumped well

- S¹ is the free aquifer drawdown component
- S² is the linear free aquifer component
- S³ is the nonlinear free aquifer component.

Efficiency (E_p) is considered as the ratio of water level loss due to laminar flow (BQ) to the total water level loss due to laminar and turbulent flow (S_w). An E_w value of 70% has been considered satisfactory by Kresic[12] and has been demonstrated in appropriate and well-developed designs. When E_p=100%, the well loss term has identified values as CQ² = zero. The well type capacity (S_c) is the amount of water that can be produced per drawdown in the well. The quantity of water is considered as the specific capacity (S_c), and is calculated per unit drawdown in the well. The yield per unit drawdown has been represented by a stable pumping rate.

1.3 Research Location

Geographically, Sigi Regency is located at 0° 57' 0" - 0° 58' 0" South latitude and 119° 54' 0" - 119° 55' 0" East longitude. Administratively the research location is located in Lolu village, Sigi Biromaru sub-district, Sigi district, Central Sulawesi with a distance of ± 12 km, passing the trans road ± 30 minutes using motorbike.

Table 1. Coordinate of well location in Lolu village Sigi Biromaru regency

Well Description	E (Longitude)	S(altitude)	Elevation
1	119° 54'42"	0° 57'42"	54
2	119° 54'04"	0° 57'48"	73
3	119° 54'32"	0° 57'33"	80
4	119° 54'18"	0° 57'45"	65
5	119° 54'08"	0° 57'23"	60

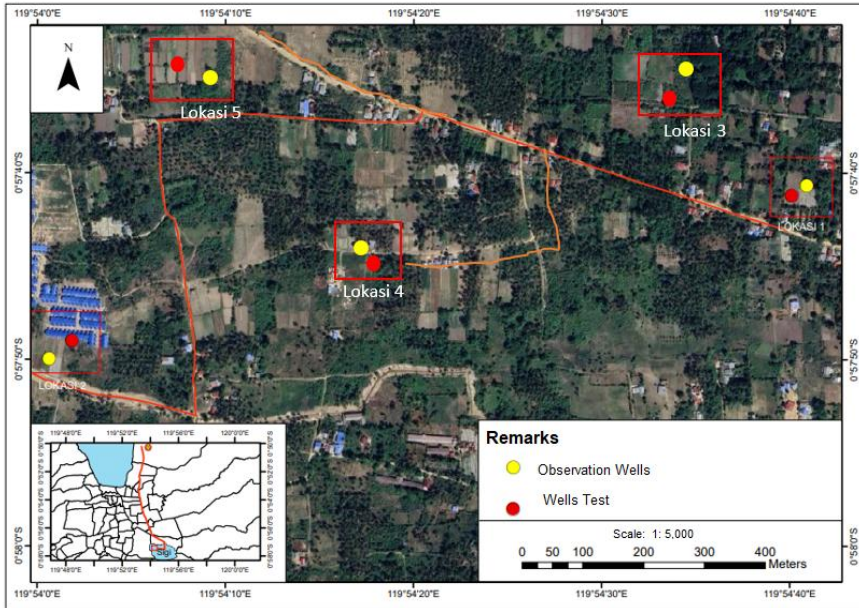


Fig. 2. research location map

2. Method

The study was conducted by pumping well water using the step drawdown method. This method is carried out with a gradual discharge and measures the decrease in water level for each stage of discharge. In the borehole well, a large-powered pump was installed about 5 m³/hour. The water released from the well using this pump is then channeled to a place far from the observation well so as not to seep into the aquifer being studied. into the aquifer being studied.

The pump was turned on continuously even though the water discharge that was released varied. For each water discharge (Q), the water level drop (S_w) was recorded periodically. A graph of the relationship between Q and S_w was made to the following was recorded determine the optimum Q and optimum S_w . These parameters indicate the optimum discharge and optimum discharge and optimum drawdown of the borehole. The data acquisition process was carried out by assembling the pumping test equipment including pump, water discharge meter, water level, stopwatch, and a series of pipes according to the research needs.

The results of this process then obtained discharge data and water level decline which were then recorded and processed and presented in graphs using Ms. Excel. Presented in a graph using Ms. Excel. The final stage of the research was interpretation of the graphs from the Q and S_w observation data to determine the optimum Q and optimum S_w of the borehole. S_w optimum of the borehole.

3. Results And Discussion

3.1 Neuman Method Result Data

Calculation results of aquifer characteristics with neuman method in wells 1-5

Table 2. Calculation results of neuman method

Wells	T	S	Sy	T.rec
1	24,35	$5,08 \times 10^{-6}$	$5,0 \times 10^{-5}$	24,124
2	18,57	$4,00 \times 10^{-3}$	$5,4 \times 10^{-4}$	24,764
3	25,47	$1,25 \times 10^{-5}$	$5,0 \times 10^{-5}$	24,124
4	17,68	$3,40 \times 10^{-2}$	$5,4 \times 10^{-4}$	24,764
5	25,02	$1,17 \times 10^{-3}$	$5,0 \times 10^{-5}$	24,65

Based on the calculation of transmissivity (T) and Storativity (S), the maximum value of well 3 is 25,47 m²/day while in well 4 the maximum Storativity is $3,40 \times 10^{-2}$. Based on the value of the transmissivity, the aquifer in the study area is classified as class 2 or classified as highland the well is suitable for domestic use because it is classified as good, but not suitable for irrigation.

3.2 Results of Step Drowdown Data Processing of Hantush-Bierschenk Method

Table 3. Calculation results of the Hantush-Bierschenk method (well 1)

Step	Qn (l/s)	Qn (m ³ /d)	ΔSw (cm)	Swn (cm)	Swn/Qn (d/cm ²)
Step 1	1.2	103.68	0.6	0.6	0.0057866
Step 2	2.8	241.92	0.8	1.4	0.00578703
Step 3	3.7	319.68	0.5	1.9	0.0059434
Step 4	4.4	380.16	0.9	2.8	0.0073653

Table 4. Calculation results of the Hantush-Bierschenk method (well 2)

Step	Qn (l/s)	Qn (m ³ /d)	ΔSw (cm)	Swn (cm)	Swn/Qn (d/cm ²)
Step 1	1,2	103,7	1	1	0,00964320
Step 2	2,6	224,64	4	5	0,02225783
Step 3	3,6	311,04	5	10	0,03215020
Step 4	4,8	414,72	8,5	18,5	0,04460841

Table 5. Calculation results of the Hantush-Bierschenk method (well 3)

Step	Qn (l/s)	Qn (m ³ /d)	ΔSw (cm)	Swn (cm)	Swn/Qn (d/cm ²)
Step 1	1.2	103.68	0.3	2.3	0.022183642
Step 2	2.8	241.92	0.9	3.2	0.013227513
Step 3	3.7	319.68	0.6	3.8	0.011886887
Step 4	4.4	380.16	0.9	4.7	0.012363215

Table 6. Calculation results of the Hantush-Bierschenk method (well 4)

Step	Qn (m ³ /d)	ΔSw (m)	Swn (m)	Swn/Qn (d/m ²)
Step 1	123.6	0.4	0.4	3.24x10 ⁻³
Step 2	132.2	0.05	0.45	3.25x10 ⁻³
Step 3	180.6	0.24	0.69	3.27x10 ⁻³
Step 4	197.9	0.1	0.79	3.29x10 ⁻³

Table 7. Calculation results of the Hantush-Bierschenk method (well 5)

Step	Qn (l/s)	Qn (m ³ /d)	ΔSw (cm)	Swn (cm)	Swn/Qn (d/cm ²)
Step 1	1.2	103.68	2.3	2.3	0.02218
Step 2	2.8	241.92	7.2	9.5	0.03927
Step 3	3.7	319.68	6	15.5	0.04849
Step 4	4.4	380.16	7	22.5	0.05919

Table 8. Calculation results of efficiency

Debit	Well 1		Well 2		Well 3		Well 4		Well 5		Efficiency			
	B	C	B	C	B	C	B	C	B	C				
10	0.0050 1 5	0.00000 99,01	0.002 9	0.000 1	74,36	0,0246 5	0,0000 4	98,40	0,00208 9	0,00001 4	95,41	0,0081 9	0,0001 1	89,01
20	0.0050 1 5	0.00000 98,04	0.002 9	0.000 1	59,18	0,0246 5	0,0000 4	96,86	0,00208 9	0,00001 4	91,23	0,0081 9	0,0001 1	80,20
30	0.0050 1 5	0.00000 97,09	0.002 9	0.000 1	49,15	0,0246 5	0,0000 4	95,36	0,00208 9	0,00001 4	87,39	0,0081 9	0,0001 1	72,97
90	0.0050 1 5	0.00000 91,76	0.002 9	0.000 1	24,37	0,0246 5	0,0000 4	87,26	0,00208 9	0,00001 4	69,80	0,0081 9	0,0001 1	47,37
260	0.0050 1 5	0.00000 79,40	0.002 9	0.000 1	10,03	0,0246 5	0,0000 4	70,33	0,00208 9	0,00001 4	44,44	0,0081 9	0,0001 1	23,75
420	0.0050 1 5	0.00000 70,46	0.002 9	0.000 1	6,46	0,0246 5	0,0000 4	59,47	0,00208 9	0,00001 4	33,12	0,0081 9	0,0001 1	16,17

Based on the results of calculations using the hantush method, these wells are suitable for daily use because they are classified as good. The well loss coefficient (C) is a constant loss coefficient that depends on the radius, construction and condition of the wells. The calculation results obtained C value is 0.00001. According to Walton 1970[14], the classification of well conditions based on the coefficient of well loss (C), the condition of the well is said to be good if the value of the coefficient of well loss (C) <0.5. The large C value obtained indicates that the well under review is in good condition, so repair opportunities have not been prioritized. Therefore, a well with a high productivity value is a well with a high aquifer loss coefficient (B) and a low well loss coefficient (C).

The causes of well inefficiency are well design factors, including well area/distance, poor distribution between wells, well length that does not reach the lower limit of the aquifer (inefficient) and construction factors including inadequate construction[10].

Based on the test, it can be said that each well has a different discharge capacity to produce groundwater so that through this research it can be known how much influence water withdrawal in one well has on other wells, which can help in making

decisions for fair and sustainable water use. By knowing the characteristics of the existing discharge capacity, farmers and managers can adjust their irrigation strategies, both in terms of irrigation time and irrigation technology used, so that they are more effective and efficient[15].

3.3 Evaluation of Sustainability of Groundwater Utilization

Groundwater in the study area is still available and accessible for daily needs, especially for agriculture. The existence of a fairly wide and shallow aquifer guarantees water stability throughout the year. These aquifers act like natural reservoirs, storing rainwater that seeps into the ground and releasing it slowly through dug wells. Even in the dry season, when rain is scarce, these wells are able to provide sufficient water for irrigation needs[4].

To maximize the use of groundwater, farmers are expected not to over-pump according to the yield capacity of the wells to ensure that every drop of water is used wisely, going straight to the plant roots without being wasted. Regulating the use of water pumps to not exceed the recommended withdrawal limit also includes proper scheduling, adjusting the time and amount of water used based on the specific needs of the crop[16].

Communities are critical in maintaining groundwater availability. Policies that support sustainable water supply practices, subsidies for modern pumping technologies, and education programs for farmers help ensure efficient and sustainable use of groundwater. In addition, cooperation between farmers, scientists and governments ensures that groundwater resources are safeguarded for future generations[17].

4. Conclusions

Based on the results of hydrogeological research on groundwater debit capacity by pumping test method in wells, it can be concluded that groundwater contained in the study area is at a depth of ± 15 to 20 meters and the type of layer that can act as an aquifer is sandstone. With the effectiveness of the pumping test method, it proved effective in evaluating the wells' production capacity and aquifer hydraulic parameters. Meanwhile, the Hantush Bierchenk analysis methods succeeded in providing an accurate estimate of the linier loss $(B) = 0,000501$ and Aquifer Loss $(C) = 0,0000005$. Debit values of all wells have a difference of $5 \text{ m}^3/\text{day}$. This is due to the difference in time / hour when measurements are made so that the efficiency of each well is different so that the more night measuring the water level will be higher. And can also be influenced by the pumping capacity of the engine because the engine capacity of well 1 reaches $420 \text{ m}^3/\text{day}$ has an optimum debit value of 70,46% while the other wells 2 reach $20 \text{ m}^3/\text{day}$ has an optimum debit value of 59,18 % it turns out that the optimum value can also affect the capacity value of the pump machine.

Factors that affect the production capacity of a well include transmissivity, storativity, and well loss coefficient. It can be concluded that the wells in this region are quite efficient and efficient compared to wells in other regions. However, the optimal production capacity of wells in the Sigi region is higher than wells in other regions. This is determined by the hydrogeologic characteristics of the aquifer, such as: B.

Influenced by transmissivity and storativity, as well as the loss factor of each well. These findings can be taken into consideration in the management and sustainable utilization of groundwater in the Sigi region.

Pumping test results show that well performance in the Sigi area varies significantly. Some wells show high production capacity with fast recovery time, while others show limitations in production discharge. The pumping test method used in this study proved effective in evaluating the production capacity and hydraulic parameters of wells. The data obtained from these tests provide a clear picture of well performance and the condition of the aquifer in question.

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