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Estimation Of Aquifer Parameters Using Pumping Tests Of Kavalapur Area, Miraj Taluka, Sangli District, Maharashtra, India

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ABSTRACT

Groundwater condition of the area depends on the aquifer parameters such as Storativity, Transmissibility and Coefficient of permeability. Geological formation of an area controls the porosity and permeability. These aquifer parameters are important for excavation and design of dug-wells. Applicability of results from laboratory results has limitations while in-situ, pumping tests gives the representative aquifer parameters. The aquifer yield can be estimated through a pumping test. In this method, water is withdrawn from the well by adjusting pumping rate to maintain a constant water level in the well. This established an equilibrium condition where the percolation rate into the well matches the pumping rate. Test results include recording drawdown in both the pumping well and observatory wells. Utilizing the Thiems and Dupuits equilibrium formula for unconfined aquifer conditions, the coefficient of permeability (k) and Transmissibility (T) can be computed. The fractured and weathered basalt behaves as a good aquifer whereas massive basalt doesn't. The value of Radius of influence in the study area is 140m. The paper ends with compressive results of hydraulic parameters, which may be helpful in the outlook of sustainable groundwater resource in the region.

Keywords: Pumping test, aquifer parameters, groundwater resource.

INTRODUCTION

Effective management of groundwater resources depends on a clear scientific understanding of aquifer characteristics, especially its hydraulic behaviour and overall yield. Among the various methods used to assess aquifer performance, the pumping test—widely known as an aquifer performance test (APT) is considered one of the most reliable. In this method, water is withdrawn from a well at a controlled and usually high discharge rate, while the response of the water level is carefully monitored in both the pumping well and nearby observation wells. The discharge rate is regulated so that the water level in the pumping well remains nearly constant, creating a condition of hydraulic equilibrium in which the inflow of groundwater matches the rate of pumping. Such tests are generally carried out during the summer or dry period, when groundwater levels are at their lowest. Conducting the test during this season helps in obtaining a more accurate estimate of the aquifer's true potential. The recorded drawdown values from the pumping and observation wells form the basis for calculating key hydraulic parameters of unconfined aquifers, including the coefficient of permeability (K), transmissivity (T), and specific yield (Sy).

Under steady-state conditions in unconfined aquifers, Thiem's equation (1906) and the assumptions proposed by Dupuit (1863) are commonly applied. These principles simplify the interpretation of groundwater movement by treating the flow as predominantly horizontal. Using these concepts, the observed drawdown can be analysed to determine the coefficient of permeability, which describes how easily water moves through the aquifer material, and the discharge capacity or well yield, which indicates the volume of groundwater that can be supplied per unit time without causing excessive drawdown. Overall, this approach offers a thorough assessment of aquifer behaviour and provides essential information for judging groundwater availability, well performance, and sustainable extraction limits. Pumping-test analysis therefore plays a crucial role in guiding groundwater management and planning, especially in areas where water resources are under increasing pressure.

STUDY AREA

The present study focuses on a region located in Miraj taluka of Sangli district, Maharashtra. The area falls within the Survey of India toposheet 47 L/9 and is geographically bounded between 16°53′07″ N to 16°57′07″ N latitude and 74°33′45″ E to 74°37′30″ E longitude. The total extent of the study area is approximately 57 km^2. This region represents a typical semi-arid landscape of southern Maharashtra, where groundwater forms an important source for domestic, agricultural, and small-scale industrial use. The defined geographic coordinates ensure precise mapping and analysis, supporting the assessment of aquifer characteristics and groundwater behaviour within the selected region.

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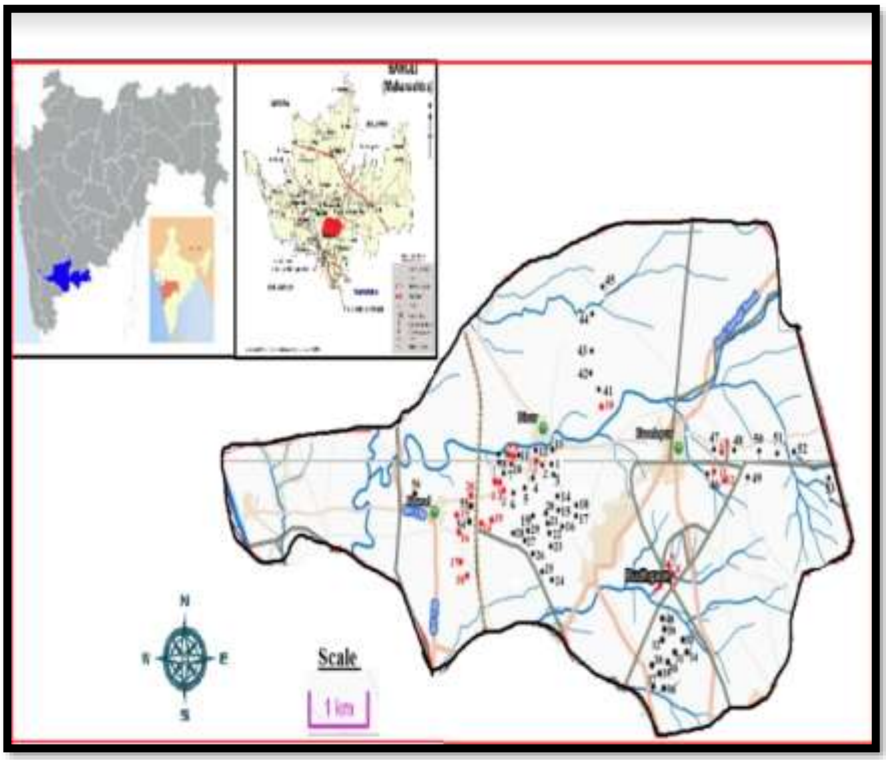

Fig No: Location Map of Study Area

METHODOLOGY

The pumping test was conducted using one main pumping dug well (Kv1) and two observation wells, designated as Kv2 and Kv3. Water levels were recorded systematically in all three wells throughout the test duration to capture the response of the aquifer to controlled pumping. The observed drawdown data were then used to estimate key hydraulic parameters under unconfined aquifer conditions. For this purpose, two standard analytical approaches—Thiem's method and Dupuit's method were applied. Both methods rely on steady-state assumptions and provide a means to determine the coefficient of permeability and discharge characteristics of the aquifer. The combined application of these procedures ensures a reliable assessment of aquifer behaviour and well performance in the study area.

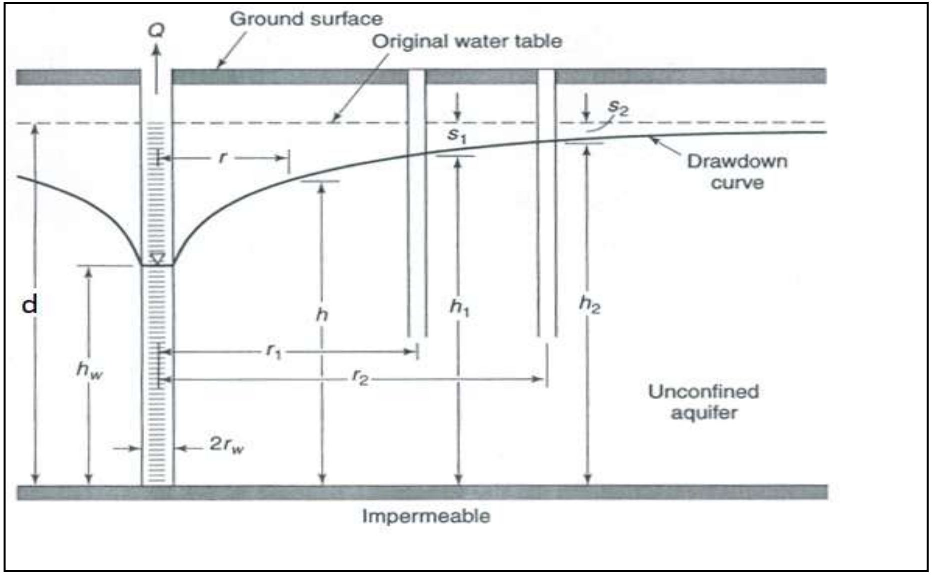

Fig No 2. Unconfined aquifer cases

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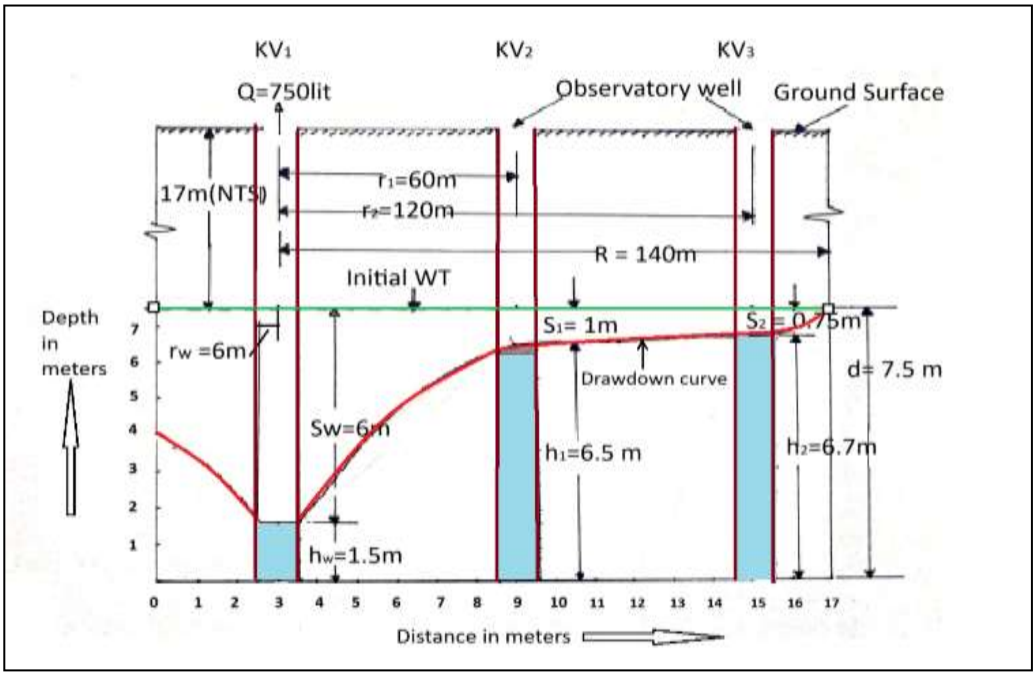

Fig No 3. Unconfined aquifer case study

- **Where:**
- **Q** – Discharge rate from the pumping well
- **d** – Saturated thickness of the aquifer
- **R** – Radius of the cone of depression
- **r_w** – Radius of the pumping well
- **h_w** – Saturated thickness of the aquifer below the equilibrium water table
- **k** – Coefficient of permeability of the aquifer
- $\mathbf{h_1}$ – Water-table height in the first observation well
- $\mathbf{h_2}$ – Water-table height in the second observation well
- $\mathbf{s_1}$ – Drawdown recorded in the first observation well
- $\mathbf{s_2}$ – Drawdown recorded in the second observation well
- $\mathbf{r_1}$ – Distance of the first observation well from the pumping well
- $\mathbf{r_2}$ – Distance of the second observation well from the pumping well

1. Thiem's Formula for Unconfined Aquifers

For steady-state flow towards a well in an unconfined aquifer, Thiem's equation is expressed as:

$$K = \frac{Q \ln\left(\frac{r_2}{r_1}\right)}{\pi(h_2^2 - h_1^2)}$$

or in terms of discharge:

$$Q = \frac{\pi K(h_2^2 - h_1^2)}{2.3 \log_{10}\left(\frac{r_2}{r_1}\right)}$$

The coefficient of transmissibility is given by:

$$T = Kd$$

where d is the saturated thickness of the aquifer.
Using transmissibility, the discharge may also be written as:

$$Q = \frac{2\pi T(s_1 - s_2)}{\log_{10}\left(\frac{r_2}{r_1}\right)}$$

A pumping test was conducted to estimate the permeability and transmissibility of the aquifer located in the northern part of Kavalapur. For this purpose, three dug wells—KV1 as the pumping well and KV2 and KV3 as the observation wells—were selected. All three wells have an approximate depth of 24.5 m. Continuous pumping was carried out from KV1 for a duration of eight hours, during which steady-state conditions were achieved. The observation wells, situated at distances of 60 m (KV2) and 120 m (KV3) from the pumping well, registered drawdowns of 1.00 m and 0.75 m respectively. In KV1, the water level dropped from its initial static level of 17.0 m to 23.0 m during pumping, resulting in a drawdown of 6.0 m. The radius of influence determined after eight hours of pumping was approximately 140 m. Following the cessation of pumping, the water level in KV1 recovered to its original level within 12 hours. Drawdown curves for all wells were plotted (Fig. X), and the measured parameters—including s_1, s_2, h_w, h_1, h_2, r_1, r_2, d, and Q—were compiled from field observations and are presented in the accompanying data table.

Table no. 1: Wells spatial locations

	Well no.	Well depth (m)	Water table	Time (hr)	Depleted water table(m)
Pumping well	Kv$_1$	24.5	17.00	8	6.0
Observatory well	Kv$_2$	23.0	17.00	8	1.0
Observatory well	Kv$_3$	23.5	17.00	8	0.75

Pumpingrate,$Q = 750 \text{ L/min} = 750/1000 \ \text{m}^3/\text{min} = 0.0125 \text{ m}^3/\text{s}$.

(Important: earlier you wrote 1.25 cm/s — that was a unit error. Q is a volume flow (m^3/s), not a velocity in cm/s.)

- $r_1 = 60$ m
- $r_2 = 120$ m
- $h_1 = 6.50$ m
- $h_2 = 6.75$ m
- Radius of influence $R = 140$ m
- Well radius $r_w = 6$ m
- Saturated thickness $d = 7.5$ m
- Saturated head below equilibrium $h_w = 1.5$ m

1. Thiem's formula (unconfined steady state)

$$K = \frac{Q \ln (r_2/r_1)}{\pi (h_2^2 - h_1^2)}$$

Calculate intermediate values:

$$\ln (r_2/r_1) = \ln (120/60) = \ln\ 2 = 0.693147$$
$$h_2^2 - h_1^2 = 6.75^2 - 6.5^2 = 45.5625 - 42.25 = 3.3125\text{m}^2$$

Denominator $= \pi \times 3.3125 = 10.4012\ \text{m}^2$(approx.)

Now compute K:

$$K = \frac{0.0125 \times 0.693147}{\pi \times 3.3125} = \frac{0.0086643}{10.4012} = 0.000832587 \text{ m/s}$$

Convert to commonly used units:

- $K = 0.0008326 \text{ m/s} = 0.08326 \text{ cm/s}$.

2. Dupuit formula (unconfined steady state)

One applicable form is:

$$K = \frac{2.3\, Q \log_{10}(R/r_w)}{\pi (d^2 - h_w^2)}$$

Calculate intermediate values:

$$\log_{10}(R/r_w) = \log_{10}(140/6) = \log_{10}(23.3333) = 1.367976$$
$$d^2 - h_w^2 = 7.5^2 - 1.5^2 = 56.25 - 2.25 = 54.00\text{m}^2$$

Denominator $= \pi \times 54.00 = 169.646\ \text{m}^2$(approx.)

Now compute K:

$$K = \frac{2.3 \times 0.0125 \times 1.367976}{\pi \times 54} = \frac{0.039326}{169.646} = 0.000231832 \text{ m/s}$$

Convert units:

- $K = 0.00023183 \text{ m/s} = 0.023183 \text{ cm/s}$.

3. Transmissibility $T = K \cdot d$

You can compute Tusing either K(Thiem or Dupuit). I show both:

Using Dupuit K:

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$T = 0.000231832\ \mathrm{m/s} \times 7.5\ \mathrm{m} = 0.0017387\ \mathrm{m^2/s}$.
Convert to $\mathrm{m^2/day}$: $0.0017387 \times 86400 = 150.227\ \mathrm{m^2/day}$.

- Using Thiem K:

$T = 0.000832587\ \mathrm{m/s} \times 7.5 = 0.0062444\ \mathrm{m^2/s}$.
Convert to $\mathrm{m^2/day}$: $0.0062444 \times 86400 = 539.516\ \mathrm{m^2/day}$.

4. RESULTS

Radius of Influence of Cone of Depression

When groundwater is pumped from a well, the surrounding water table declines, forming a characteristic *cone of depression*. The horizontal distance from the pumping well to the point where this decline becomes insignificant is termed the **radius of influence (R)**. Within this radius, groundwater moves toward the well under the hydraulic gradient generated by pumping. The magnitude of the radius of influence depends on several hydrogeological factors, including the aquifer's permeability and transmissibility, the saturated thickness, and both the pumping rate and duration. Higher pumping rates or prolonged pumping tend to enlarge the cone of depression and extend its radius. Understanding and estimating the radius of influence is vital for interpreting aquifer behavior, evaluating potential well interference, determining sustainable pumping limits, and planning long-term groundwater extraction. This concept is widely discussed in standard groundwater literature, including Todd and Mays (2005), Driscoll (1986), and Freeze and Cherry (1979), who emphasize its importance in pumping-test analysis and well-field design.

Case studies

1. Pandurang E. Gurav's Well

The dug well owned by Pandurang E. Gurav has a diameter of 10 meters and a depth of 25 meters, operated using a 3 HP pump. The well irrigates approximately 8 acres of agricultural land and has no additional supporting irrigation scheme. The initial water level was observed at 14.82 meters, which declined to 13.56 meters after one hour of pumping. The radius of influence of the resulting cone of depression was found to be 160 meters, indicating a significant lateral response of the aquifer to pumping.

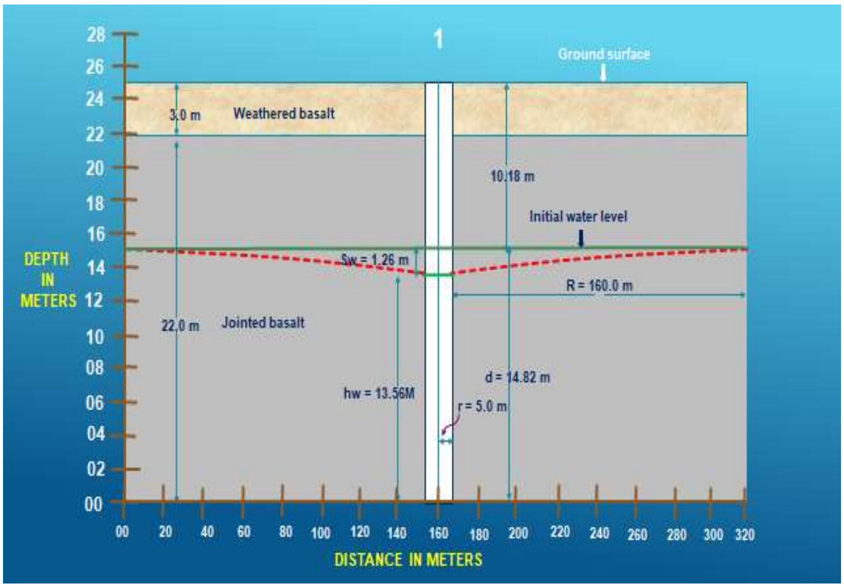

Fig No 4. Hydrogeological Cross-Sections Showing Cone of Depression and Radius of Influence case study 1

2. Gajanan S. Bandgar's Well

The well belonging to Gajanan S. Bandgar has a diameter of 11 meters and a depth of 19 meters, equipped with a 5 HP pump. It serves an irrigated area of 5 acres without the support of any additional scheme. The initial water level of 8.51 meters declined to 7.88 meters after one hour. The measured radius of influence was 16.26 meters, suggesting a relatively limited spread of drawdown in comparison to other wells in the study.

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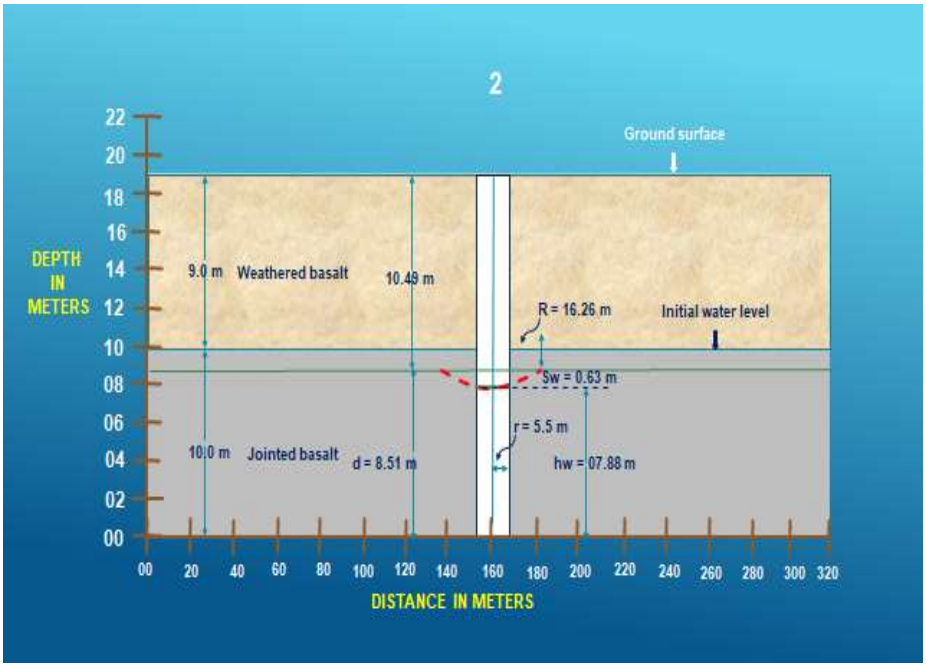

Fig No 5. Hydrogeological Cross-Sections Showing Cone of Depression and Radius of Influence case study 2

3. Jairam B. Patil's Well

Jairam B. Patil's dug well has a diameter of 10 meters and a depth of 16 meters, operated by a 3 HP pump and supporting an irrigation area of 4 acres. The water level dropped from 9.44 meters to 8.40 meters after one hour of pumping. The corresponding radius of influence was calculated as 40.27 meters, indicating moderate aquifer responsiveness to pumping.

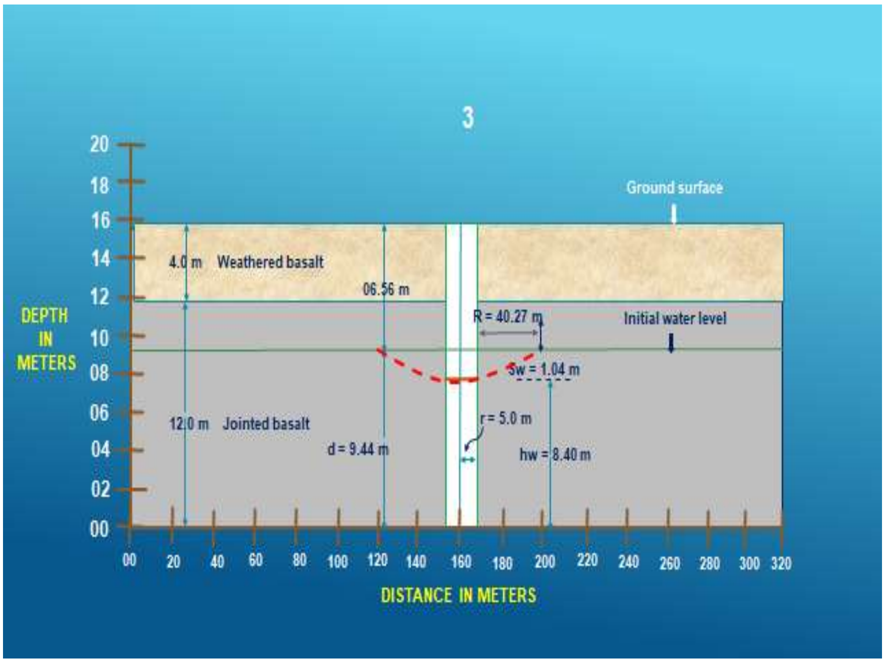

Fig No 6. Hydrogeological Cross-Sections Showing Cone of Depression and Radius of Influence case study 3

4. Ananda Bandgar's Well

The dug well of Ananda Bandgar is 9 meters in diameter and 16 meters deep, operated using a 3 HP pump. It irrigates around 2 acres of land. The initial water table at 8.0 meters dropped to 7.0 meters after one hour of continuous pumping. The radius of influence, estimated at 22.54 meters, reflects a modest extent of groundwater movement around the well.

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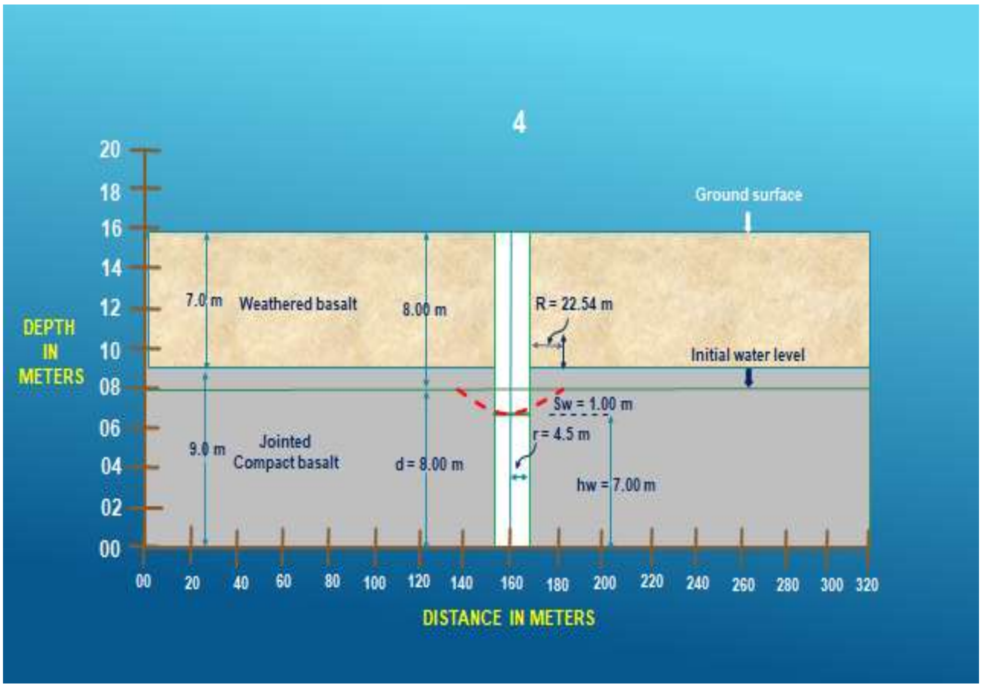

Fig No 7. Hydrogeological Cross-Sections Showing Cone of Depression and Radius of Influence case study 4

5. Ramjan A. Mulani's Well

Ramjan A. Mulani's dug well has a diameter of 11 meters and depth of 17 meters, operated by a 5 HP pump and supporting irrigation over 5 acres. The initial water level of 5.36 meters declined to 5.04 meters after one hour of pumping. Field observations indicated that the well nearly ran dry, and the radius of influence was measured at only 9.55 meters, the smallest among all case studies and indicative of low local aquifer storage

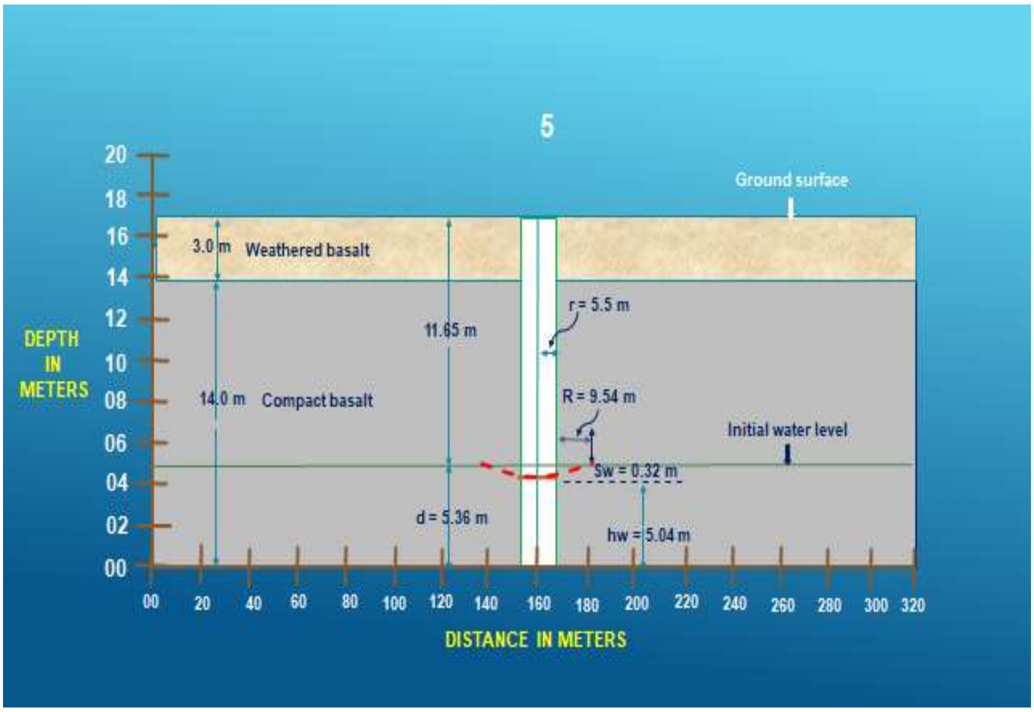

Fig No 8. Hydrogeological Cross-Sections Showing Cone of Depression and Radius of Influence case study 5

5. Ramjan A. Mulani's Well

Ramjan A. Mulani's dug well has a diameter of 11 meters and depth of 17 meters, operated by a 5 HP pump and supporting irrigation over 5 acres. The initial water level of 5.36 meters declined to 5.04 meters after one hour of pumping. Field observations indicated that the well nearly ran dry, and the radius of influence was measured at only 9.55 meters, the smallest among all case studies and indicative of low local aquifer

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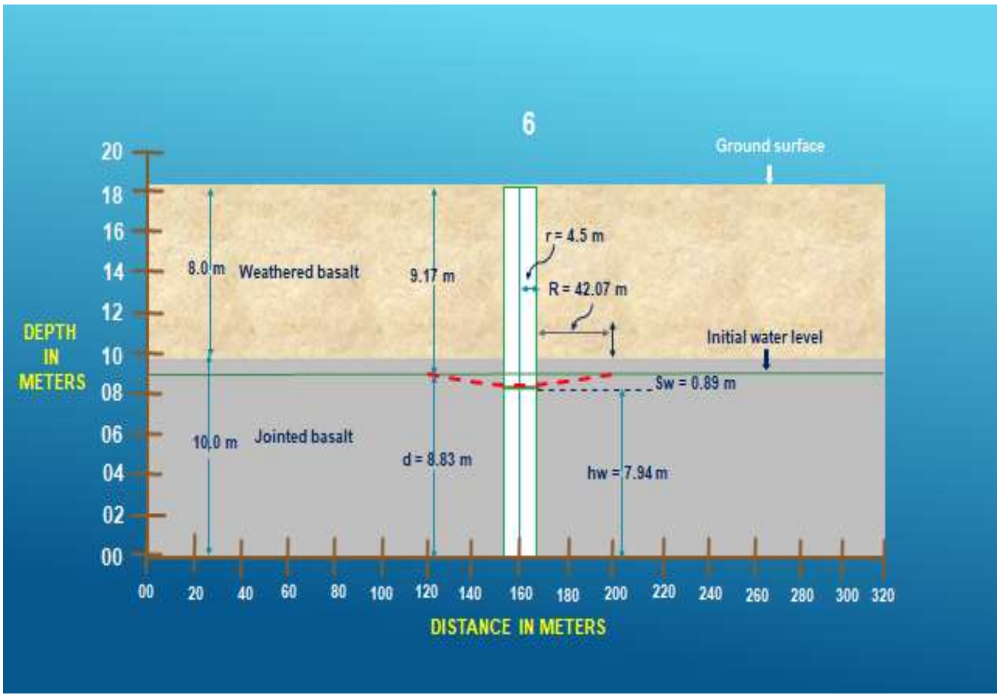

Fig No 9. Hydrogeological Cross-Sections Showing Cone of Depression and Radius of Influence case study 6

6. Rangrao L. Patil's Well

Rangrao L. Patil's dug well is 9 meters in diameter and 18 meters deep, operated by a 3 HP pump. It provides irrigation for 4 acres of land. The water level dropped from 8.83 meters to 7.90 meters after one hour of pumping. The resulting radius of influence was 42.07 meters, suggesting a relatively wider spread of drawdown within the aquifer.

Table no. 2: Comparative Hydrogeological Parameters of Six Dug Wells in the Study Area

Sr. No.	Parameter	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
1	Radius of Dug Well (m)	5	5.5	5	4.5	5.5	4.5
2	Depth of Dug Well (m)	25	19	16	16	17	18
3	Pump Capacity (HP)	3	5	3	3	5	3
4	Discharge (m^3/s)	0.32	0.3	0.28	0.28	0.2	0.21
5	Thickness of Saturated Aquifer below Equilibrium ($h_{(w)}$) (m)	13.56	7.88	8.4	7.09	5.04	7.94
6	$Sw = d - h_{(w)}$ (m)	1.26	0.63	1.04	0.91	0.32	0.89
7	Radius of Influence (R) (m)	160	16.26	40.27	22.54	9.55	42.07

CONCLUSION

The pumping test carried out at wells KV1, KV2, and KV3 provides valuable insight into the hydraulic behaviour of the unconfined aquifer in the study area. The test results show that the **radius of influence** generated by continuous pumping from KV1 for eight hours extended to approximately **140 meters**, indicating a moderate lateral spread of the cone of depression in the basaltic formation. During pumping, the water level in the pumping well KV1 declined by **6 meters**, while the saturated thickness (hw) was reduced to **1.5 meters**, and the observation wells KV2 and KV3 recorded drawdowns of **1.0 meter** and **0.75 meter**, respectively. Using these field measurements, the **coefficient of permeability (K)** was calculated through both Thiem's and Dupuit's steady-state equations. Thiem's method yielded a value of **1.10 cm/s**, whereas Dupuit's method produced **0.02318 cm/s**. Although both methods use the same dataset, the difference in results arises from the underlying assumptions: Thiem's equation assumes fully radial horizontal flow and uses the squared water-table terms, making it sensitive to small changes in head; Dupuit's method incorporates the radius of influence and is more suitable for unconfined aquifers with gently sloping water tables. For basaltic terrains, where hydraulic conductivity typically ranges around **0.01 cm/s**, the Dupuit-derived value aligns more closely with standard values and is therefore considered more realistic for the present site.

When comparing the **radius of influence** values of all six wells in the extended case study, noticeable variations are observed. Wells with larger radii exhibit wider cones of depression, meaning that

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their pumping activity influences groundwater levels over broader distances and has a higher likelihood of affecting neighbouring wells. In contrast, wells with smaller radii experience more localized drawdown zones, making them more vulnerable to rapid water-level decline and localized depletion. These differences highlight the heterogeneous nature of the basaltic aquifer system, where weathered and jointed zones create variable permeability conditions across short distances. Overall, the findings emphasize the importance of well-specific hydrogeological assessment for sustainable groundwater management, appropriate pump selection, and minimizing well interference in basaltic regions.

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