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Evaluation of Groundwater Potential of Islamabad Area using Logs Data of Test Holes Drilled by OGDC

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ABSTRACT

Several natural gamma and resistance logs data of test holes located in different sectors of Islamabad have been used to evaluate and interpret the subsurface water bearing lithologies which can be used to construct tubewells. Previous studies and quoted values of the hydraulic conductivities were used . Work carried out dealt with the evaluation of aquifer thickness, screen lengths, transmissivity (T), and theoretical discharge (Q). Results show significant increase in discharge with slight increase in hydraulic conductivity, while changes in thickness produce no significant change in discharge. Maximum theoretical discharge is obtained for tube-well T/W -H1, while a minimum discharge is found for tubewell T/W - G3. Screen lengths are also proposed for all tubewells. Aquifers in Islamabad area are formed in Lei Conglomerate of Middle Pleistocene age.

INTRODUCTION

Shortage of water supply to different sectors of Islamabad was drastically observed in 1994. To overcome this shortage, an extensive drilling program was carried out jointly by Capital Development Authority (CDA) and Oil and Gas Development Corporation (OGDC) under a special directive of Prime Minister secretariat. OGDC drilled ten test holes, later converted to tubewells, in different sectors using exploratory drill machines. The maximum depth of drilling penetrated up to a depth of 107 meters. Gamma Ray (GR) logs in nine and Resistance logs in four wells were carried out to examine the aquifer hydraulic characteristics, thickness, and possible lithologic correlation. A DesignCad 2D software was used to digitize log on convenient vertical and horizontal scale to be used for lithologic correlation. However, lithologic correlation has been constructed for tubewells of sectors H-8 and F-9 Park. The main lithologies interpreted from these logs are clay, boulder, gravel and interbedded clay and gravel. Boulder and gravel, belonging to Lei Conglomerate, form suitable aquifers. These aquifers have been delineated from gamma counts of natural gamma ray logs and from resistance of materials of the resistance logs. Aquifers exist in series of stratified confined form which are dissected by clayey lenses. For each tube-well, screen lengths have been designed for different water bearing segments. From the Hydraulic conductivities (K) and Aquifer Thicknesses (b), Transmissivities have been calculated. These parameters are used to evaluate discharge for individual aquifer in each well using Darcy's Law. The total discharge for each well is calculated by summing up the individual discharge from each aquifer in that well. This has provided the distribution of groundwater potential for each sector. During the computation work, it is observed that Q is highly dependent upon K. A slight change in hydraulic conductivity values results in a significant variability in discharge Q. However , Q is not much influenced by the aquifer thickness or the screen length.

LOCATION OF RECENTLY CONSTRUCTED TUBEWELLS

Figure 1 shows the location of recently constructed tubewells in Islamabad. They are located within the green belts of different sectors, such as F-6/1, F-8/4, F-9 Park, G-8/1, G-9/3, H-8 and H-9. Geophysical natural gamma log of nine wells, penetrating to the bottom, were used for making qualitative as well as quantitative interpretation in terms of aquifer hydraulic characteristic, groundwater potential and approximate discharge from an individual well. In addition, resistance log of wells were utilize to examine the subsurface lithologies in conjection with the natural gamma log.

HYDROGEOLOGY OF ISLAMABAD WATERSHED

Drainage pattern of the study area includes rivers, perennial canals and intermittent streams, and hill torrents during the streamy periods. Soan River and its tributaries drain the northern Potwar plateau in River Indus whereas southern Potwar plateau is drained by River Kanshi and Kahan. Major perennial streams are Kurang River, Gumrah Khas, etc. Perennial and intermittent streams emerging out from Margalla Hills are, Kanitwali Kas, Tanawali Kas, Bedarwali Kas and Nala Lei.

Runoff rate is very high in this area, due to rough topography and high relief. During rainy season water drains at very high velocity through streams, along the Margalla hills, and bring detrital material , like gravel and sand. Softer formations of sandstone are subjected to considerable amount of erosion.Due to high runoff rate and compact rock present in the study area, percolation rate is very low. Therefore existence of good potential aquifers are quite seldom. Alternate means of supplying water to residents of Islamabad is dependent upon Rawal and Simly Dams.

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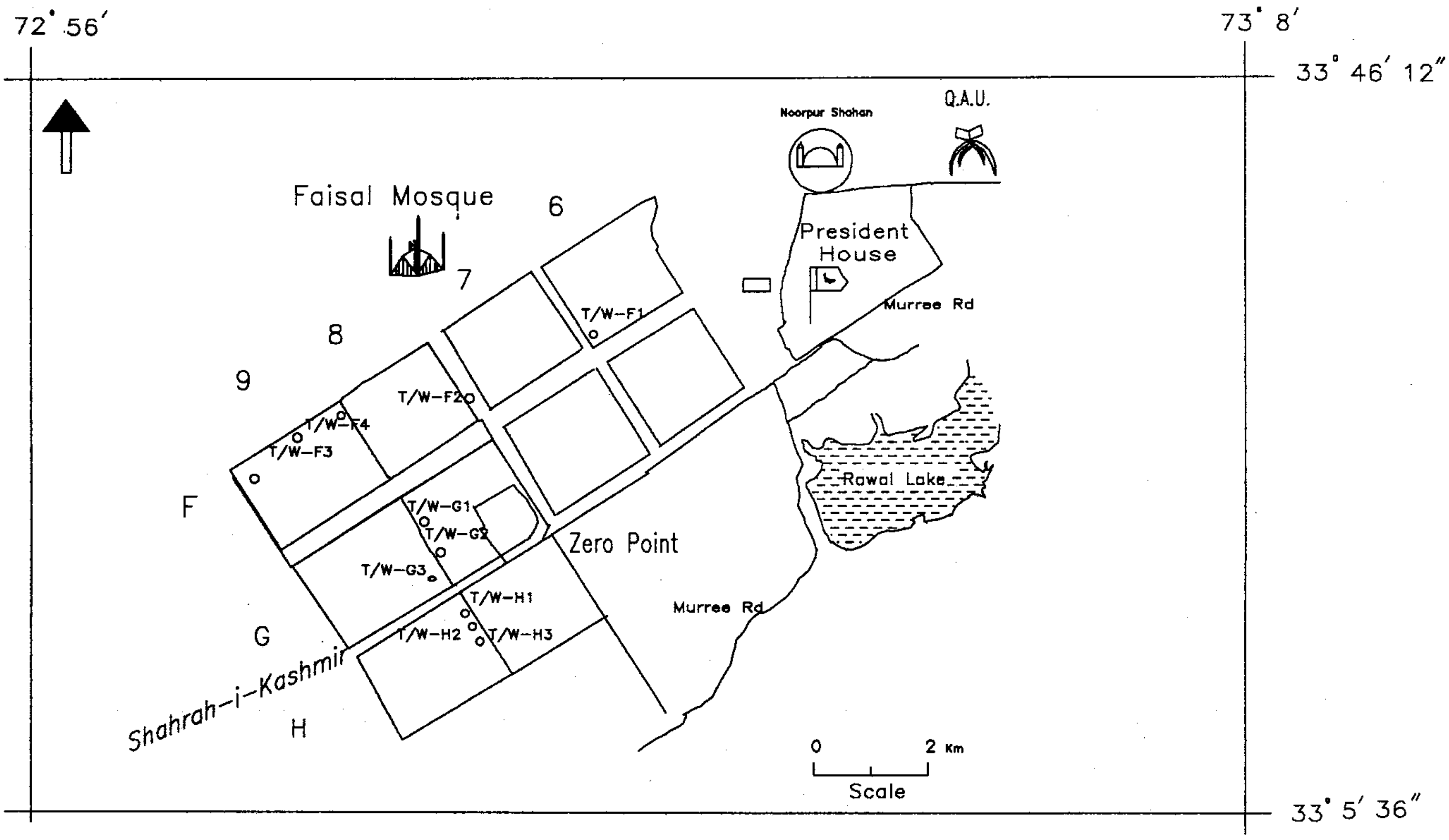

Figure 1- Location map of tubewells.

QUALITATIVE INTERPRETATION

Interpretation of digitized geophysical well logs are performed by examining variations in horizontal deflection of logs graphic expressed in units of counts per second (cps) for natural gamma and ohms for units of resistance logs. Materials with higher radioactivity exhibit higher values of cps e.g. clays, as they have higher percentage of potassium-40 (K-40) in their composition (TNO, 1976). Materials with lower radioactivity exhibit lower cps values e.g. gravel and boulders, composed of limestone of Lei Conglomerates. Limestone has very low radioactivity thus producing very small horizontal deflection on logs. Only those beds were recorded by gamma logs whose thicknesses were more than twice the radius of investigation at full amplitude (Keys an MacCary, 1971).

Interpretation technique is entirely reversed while dealing with resistance logs. On the resistance log gravel and boulder are indicated by a very high value of resistance, and clays by almost a straight line of low resistance. The ranges of different lithologies obtained from the natural gamma logs and resistance logs are given in table 1.

Table 1. Gamma counts and resistance for subsurface lithologies of Islamabad green belt area.

Subsurface Lithologies	Gamma Count (cps)	Resistance (ohms)
Clay	25-50	200-250
Gravel & Clay	20-35	250-300
Gravel	10-25	300-400
Boulder	2-15	400-500

Qualitative interpretation results obtained from geophysical logs of different sectors have been summarized in table 2.

LITHOLOGIC CORRELATION

Interpretative results formed a strong data base to make subsurface lithologic correlation for sectors having adequate geological information and number of wells. At least three wells based lithologic information with appropriate spacing is considered to be effective for correlation. Hence sectors H-9 and F-9 are chosen and for brevity, lithologic correlation of only sector H-8 has been presented.

Tubewells T/W-H1, T/W-H2, and T/W-H3 lie in sector H-8 with northeast orientation. Lithologic interpretation of T/W-H1, T/W-H2 and T/W-H3, is shown in Figure 2 and Figure 3. These tubewells have been spread over an approximate distance of 780 meters with equal spacing. Lithologic information obtained from geophysical logs of these tubewells have been correlated.

Aquifers are composed mainly of gravel and boulder belonging to Lei Conglomerate. Correlated portion exhibits largely the presence of boulder of large areal extent and thickness with intercalation of three clayey beds. The boulder bed deposited almost horizontally is a major aquifer in sector H-8. However due to larger thickness, partially penetrated tubewells have been sunk in the fractured portion of boulder for extraction of groundwater.

Table 2. Qualitative interpretation results obtained from geophysical logs of different sectors.

SECTOR	TUBEWELL	DESCRIPTION
F-6/1	T/W-F1	105 m deep, aquifer composed of gravel(1)* and boulder (3). Clay and interbedded clay and gravel layers are present.
F-8/4	T/W-F2	105m deep, aquifer composed of boulders(5). Clay and interbedded clay and gravel layers are present.
F-9 PARK	T/W-F3	75 m deep, aquifer comprised of boulder (1) and gravel (2).Clay layers are also present and some thin gravel layers are also present.
	T/W-F4	105 m deep, aquifer composed of gravel(1) and boulder (1). Clay with very thin gravel layers is present.
G-8/1	T/W-G1	105 m deep, aquifer composed of boulder(4) and gravel (1). Clay, interbedded clay and gravel, and gravel layers are present.
G-8/1 & G-9/3	T/W-G2	105 m deep, aquifer composed of gravel(1) and boulder (2). Clay, interbedded clay and gravel, thin gravel , and boulder layers are present.
G-8/1 & G-9/4	T/W-G3	107 m deep, aquifer composed of boulder(1). Clay with few thin gravel, boulder, and interbedded gravel and clay layers are present.
H-8	T/W-H1	105 m deep, aquifer comprised of gravel(2) and boulder (4). Clay, and interbedded clay and gravel layers are present.
	T/W-H2	106 m deep, aquifer comprised of boulder (4). Some clay, and interbedded gravel and clay layers are present.
	T/W-H3	105 m deep, aquifer comprised of boulder (5). Thick clay, few thin gravel layers, and interbedded gravel and clay layers are present.

* No of aquifers

Figure 4 shows the lithologic correlation among T/W-H1, T/W-H2, and T/W-H3.

QUANTITATIVE INTERPRETATION

Quantitative interpretation entails evaluation of aquifer transmissivity, thickness, and theoretical discharge of wells. Subsurface lithologies comprised of boulder and gravel form the aquifer under confining condition. In addition, mixture of clay with gravel/boulder are commonly observed lithologic features.

The values of hydraulic conductivties (K) were obtained from previous studies (JICA, 1988) and quoted values as ready references given in books (Fetter, 1988 & Todd, 1980).

Known discharge of pre-existing tubewells have been extensively used to readjust values of hydraulic conductivities of the aquifers. By several trial and error approaches refined values have been evaluated and used to compute the theoretical discharges close to actual one. Refined values of hydraulic conductivities are given in Table 3.

K values were multiplied with the aquifer thickness b (here referred to screen lengths) to get transmissivities for different water bearing formations.

Hence $T = Kb$ .... eq. 1

Where b is aquifer thickness

and K is the hydraulic conductivity.

Darcy's law is used to evaluate theoretical discharges for each individual aquifer of a well. It states that

$Q = - K A\, dh/dl$ .... eq. 2

Negative sign here shows the flow of water from higher head to lower head.

Where Q is expressed in L3 / T (Length3 / Time)

A is area of the aquifer

and dh/dl is the hydraulic gradient.

Darcy's law is further expressed in flow terms to compute the theoretical discharges.

$A = WL$

where $L = b$ is the aquifer thickness

and w is width of the aquifer.

Hence $A = Wb$ .... eq. 3

Substituting values of A from eq 3 in eq 2

$Q = - K b W\, dh/dl$

$T = K b$

Table 3. Hydraulic conductivities.

MATERIAL	HYDRAULIC CONDUCTIVITY m/hr	HYDRAULIC CONDUCTIVITY m/day
Gravel	3.15	75.6
Boulder	0.53	12.7

Hence Q = T W dh/dh.. eq. 4

Equation 4 is another form of Darcy's Law used to evaluate discharges of all the aquifers. While calculating discharges the hydraulic gradient is assumed to be 0.01 which suits best for Islamabad aquifers. The width and areal extent are dependent upon the aquifer thickness e.g. a boulder aquifer whose thickness is less than 10 meters may have a width of 200 meters, whereas for thickness greater than 10 meters may have a width of 250 meters. Therefore, for an aquifer composed of gravel, an average width of 150 meter is taken.

Calculated discharges for these aquifers mainly depends on the hydraulic conductivity (K). For instance, gravel aquifer having similar thickness as that of a boulder aquifer will give more discharge.

A complete design of tubewells have also been outlined for various sectors. Screens are made of a number of metals and alloys (brass and stainless steel), plastics, concrete, asbestos-cements, fiber glass-reinforced epoxy, coated base metal, and wood. Nonferrous metals, plastics, and alloys are used to avoid corrosion and encrustation (Todd, 1988). Wood screens are usually made of bamboo (Sharma, 1987).

In Pakistan the type of screens commonly used are, brass filter, stainless steel, punched screens, and plastic screens.

In this study stainless steel screens are proposed. Entire aquifer thicknesses of the wells are not utilized due to economic reasons. Hence, a minimum of 60 feet stainless steel filter has been used in these aquifers. Table 4 shows the results of quantitative analysis. Actual thicknesses and screen length, transmissivity, and discharge are shown in Figure 5, Figure 6 and Figure 7, respectively.

Discharges obtained from individual tubewell of each sector are summed up to get the total discharge for that sector, which is given in Table 5 and shown in Figure 8 as Pie chart.

Table 5. Total discharge for different sectors of Islamabad.

NO	SECTOR	DISCHARGE gal/hr
1	H-8.	38648
2	F-9	17917
3	G-8	16946
4	F-6/1	11316
5	F-8/4	8621
6	G-9	1363

RESULTS AND DISCUSSION

The outcome of the sectoral yield assessment indicates that the aquifers of sector H-8 are the best, aquifers of F-9 Park, sectors F-6/1 and G-8 are moderate, and the aquifers of sectors G-9 and F-8/4 are poor. Discharge for individual tubewells are shown in Figure 7.

Table 4. Quantitative interpretation for tubewells located at Islamabad.

SECTORS	TUBE-WELLS	# OF SCREENS	ACTUAL THICKNESS (m)	SCREEN LENGTH (m)	TRANSMISSIVITY (m^3/hr)	DISCHARGE (gal/hr)
F-6/1	T/W-F1	4	28	27.97	24.24	11316
F-8/4	T/W-F2	5	40.5	29.25	15.499	8621
F-9 PARK	T/W-F3	3	9.5	9.75	14.723	6263
	T/W-F4	2	13.5	12.71	28.76	11654
G-8/1	T/W-G1	5	23	21.91	21.16	9665
G-8/1 & G-9/3	T/W-G2	3	14	13.39	13.39	7281
G-8/1 & G-9/4	T/W-G3	1	5	4.87	9.75	1363
H-8	T/W-H1	6	29.7	26.97	36.533	15757
	T/W-H2	5	52.5	34.12	20.649	11970
	T/W-H3	4	68	34.12	18.074	10921

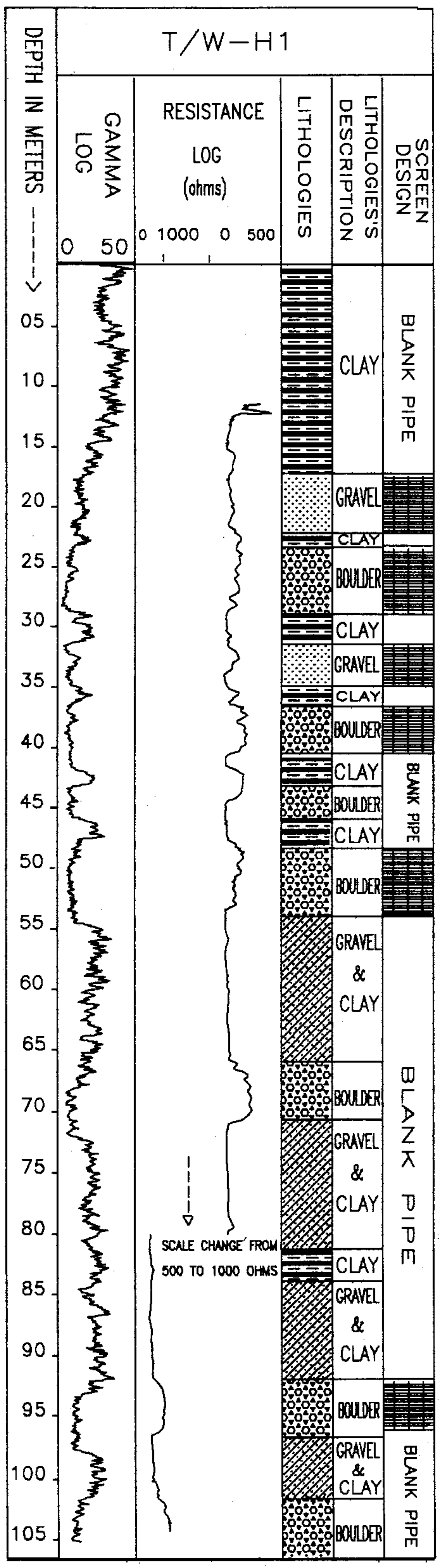

Figure 2- Lithologic interpretation for T/W-H1.

Proportional discharges for all the sectors are expressed as percentage and shown as a Pie chart in figure 8.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Following conclusions have been drawn from the interpretation of natural gamma and resistance logs of different sectors of Islamabad.

1). Aquifers delineated in these sectors are termed, stratified confined aquifers which are placed in series, dissected by clayey lenses. Aquifers with greater thicknesses exist in sector H-8 with maximum composite thickness of 112 feet encountered in T/W-H3.

2). In general, theoretical discharge of the tubewells lies between 1360 gal/hr and 15700 gal/hr (0.05 cusec to 0.6 cusec). Tubewells whose discharge lie between 11300 gal/hr to 15700 gal/hr are considered the best, whose discharge fall between 9600 gal/hr to 10900 gal/hr are considered as moderate, and whose discharge fall between 6200 gal/hr and 8600 gal/hr are considered as poor.

3). Among the investigated sectors, a maximum discharge of 38700 gal/hr has been estimated from the theoretical calculations for three tubewells in sector H-8. Likewise, a minimum discharge of 1360 gal/hr has been estimated in sector G-9.

4). Discharge of a tubewell is dependent upon the hydraulic conductivity (K) of the subsurface lithologies. Discharge increases considerably with a slight increase in the hydraulic conductivity. However, changes in the aquifer thickness (b) shows no significant change in the discharge of tubewells.

5). Transmissivities evaluated for aquifers, fall in the range of 1.4 m2/hr to 15.36 m2/hr. Good aquifers have transmissivities ranging between 10.98 m2/hr to 15.36 m2/hr, moderate aquifers with transmissivities between 7.74 m2/hr and 10.335 m2/hr, and poor aquifers with transmissivities between 1.4 m2/hr to 4.87 m2/hr.

Recommendations

Following recommendations have been made on the basis of outcome of this study.

1). Additional tubewells should be installed in sector H-8 keeping in view the cone of interference effects, and the remaining portion of the aquifer which has not been used in the previously constructed tube-wells.

2). Other logs such as sonic , resistivity or SP, density and normal resistivity , should also be used in conjection with natural gamma and resistance logs. This would in turn provide rapid interpretations and better results.

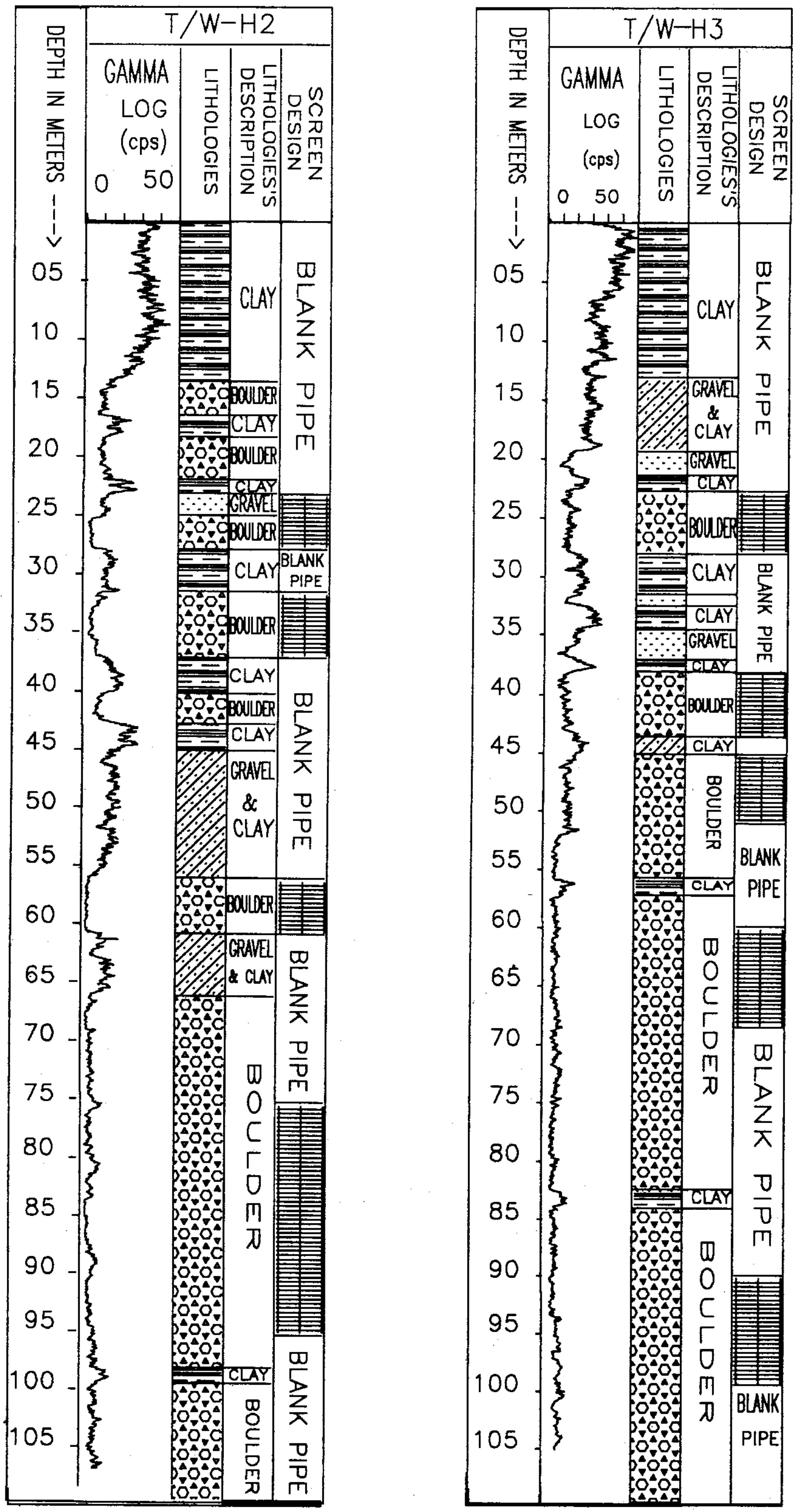

Figure 3- Lithologic interpretation for T/W-H2 and T/W-H3

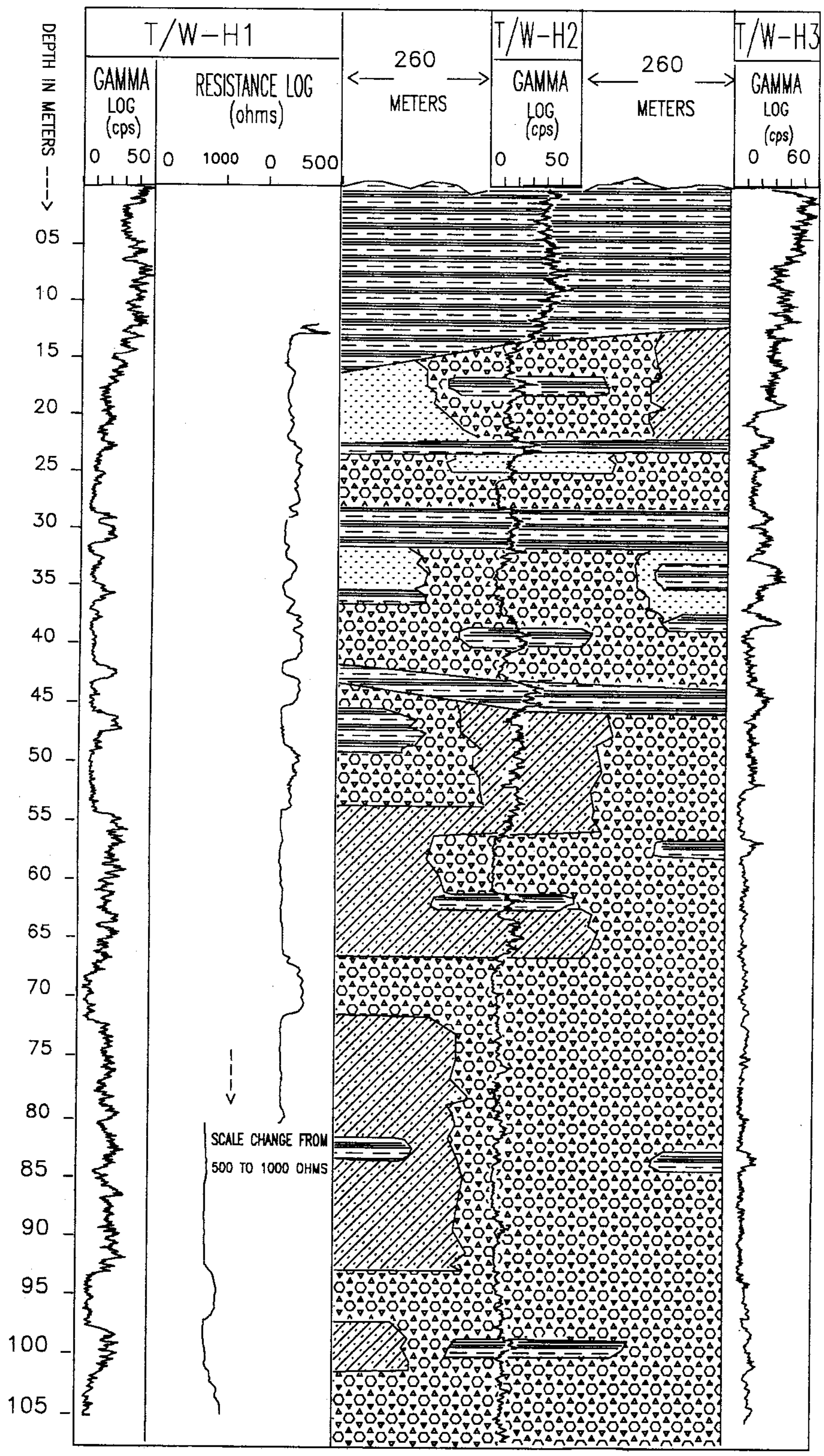

Figure 4- Lithologic correlation for the tubewells of sector H-8.

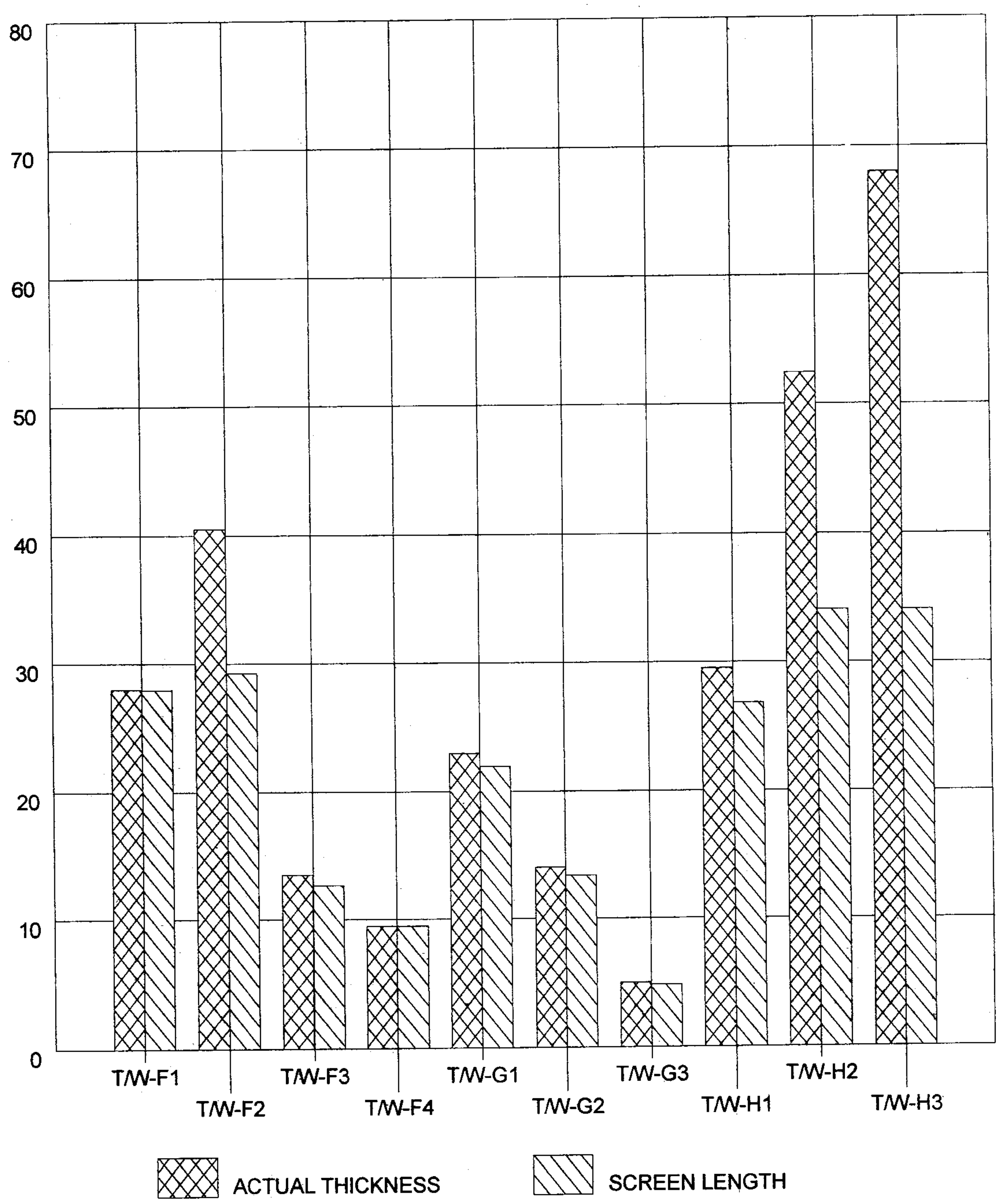

Figure 5- Actual aquifer length and screen lengths for tubewells.

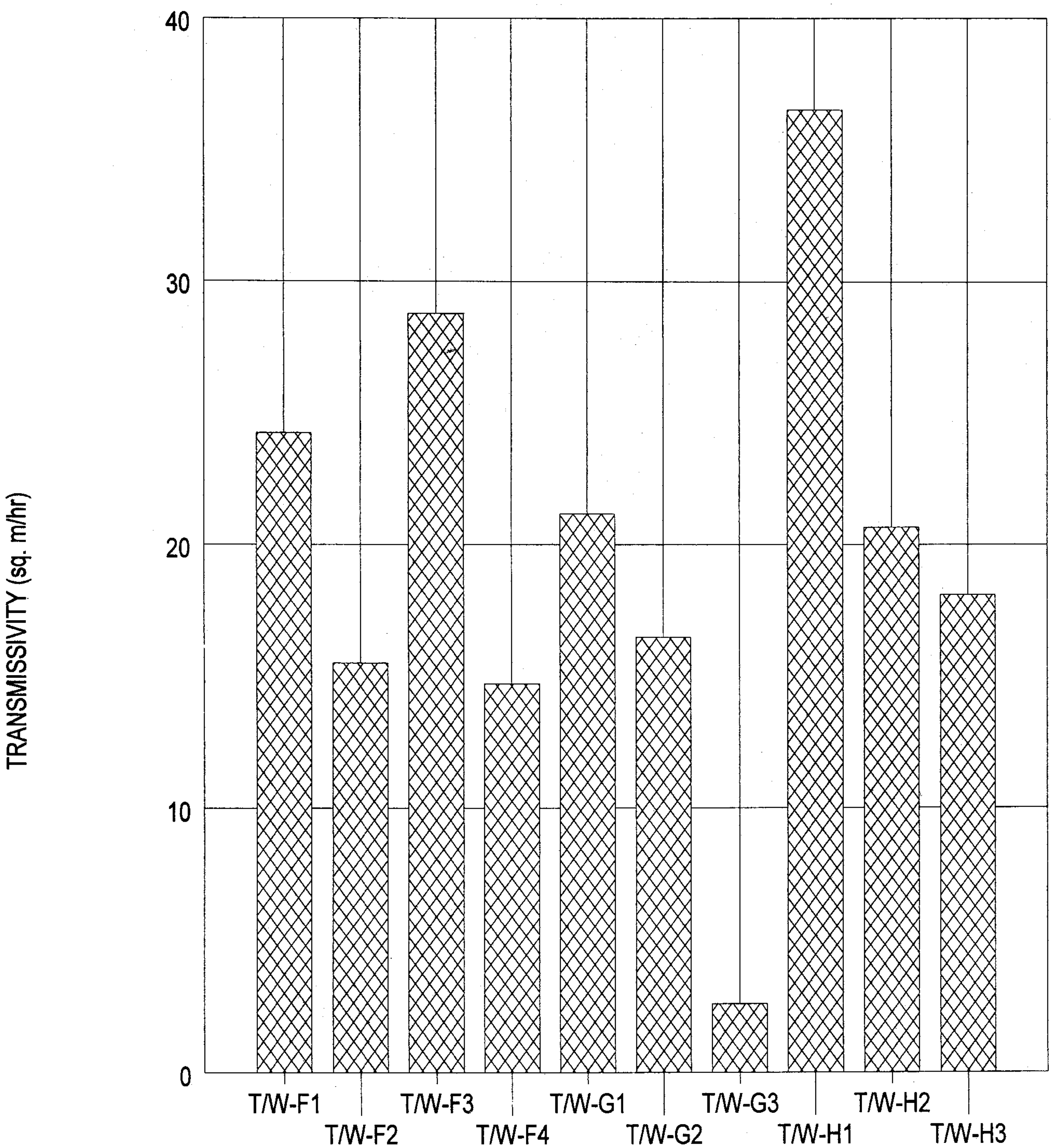

Figure 6- Transmissivity for different tubewells.

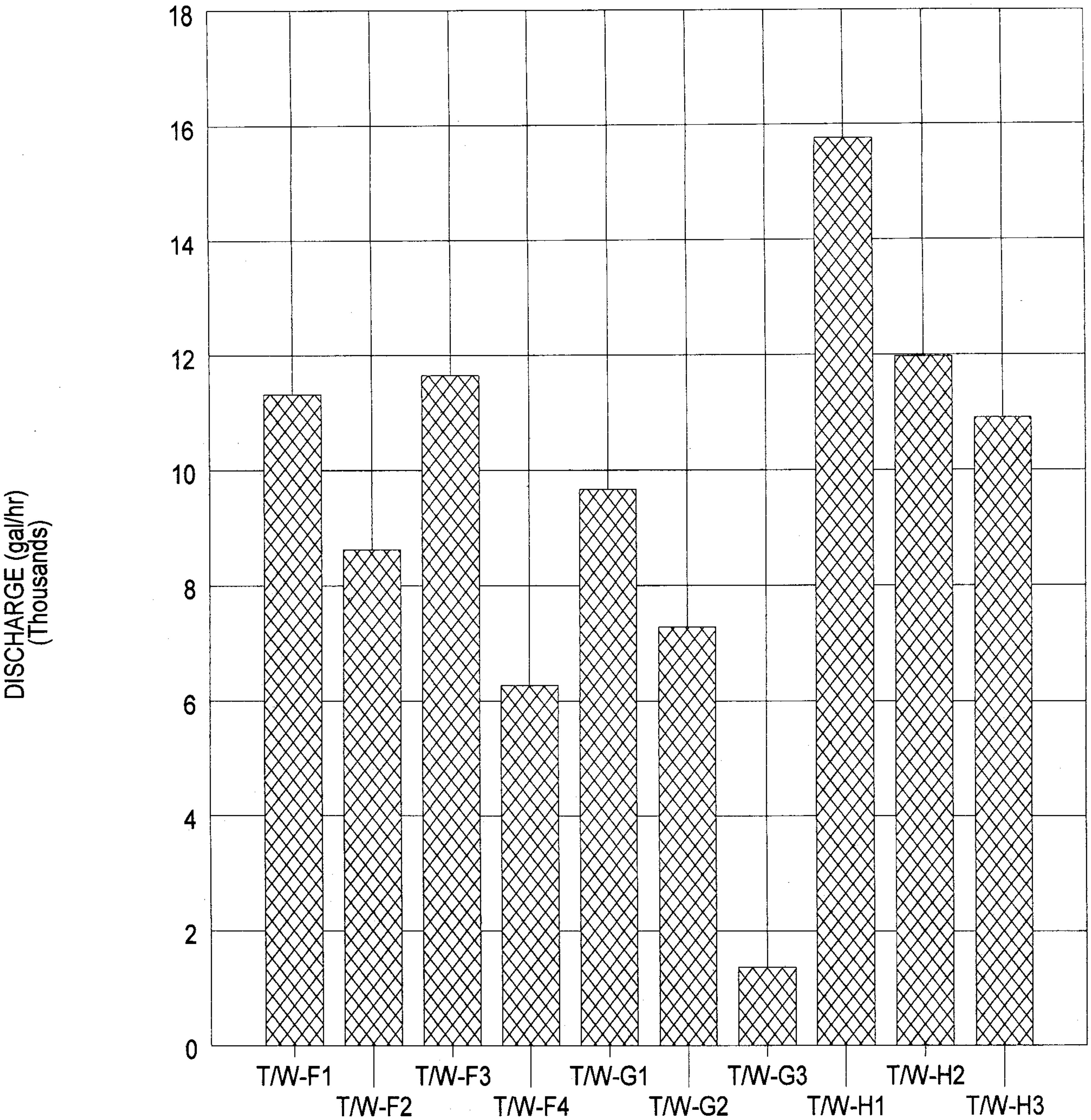

Figure 7- Discharge for different tubewells.

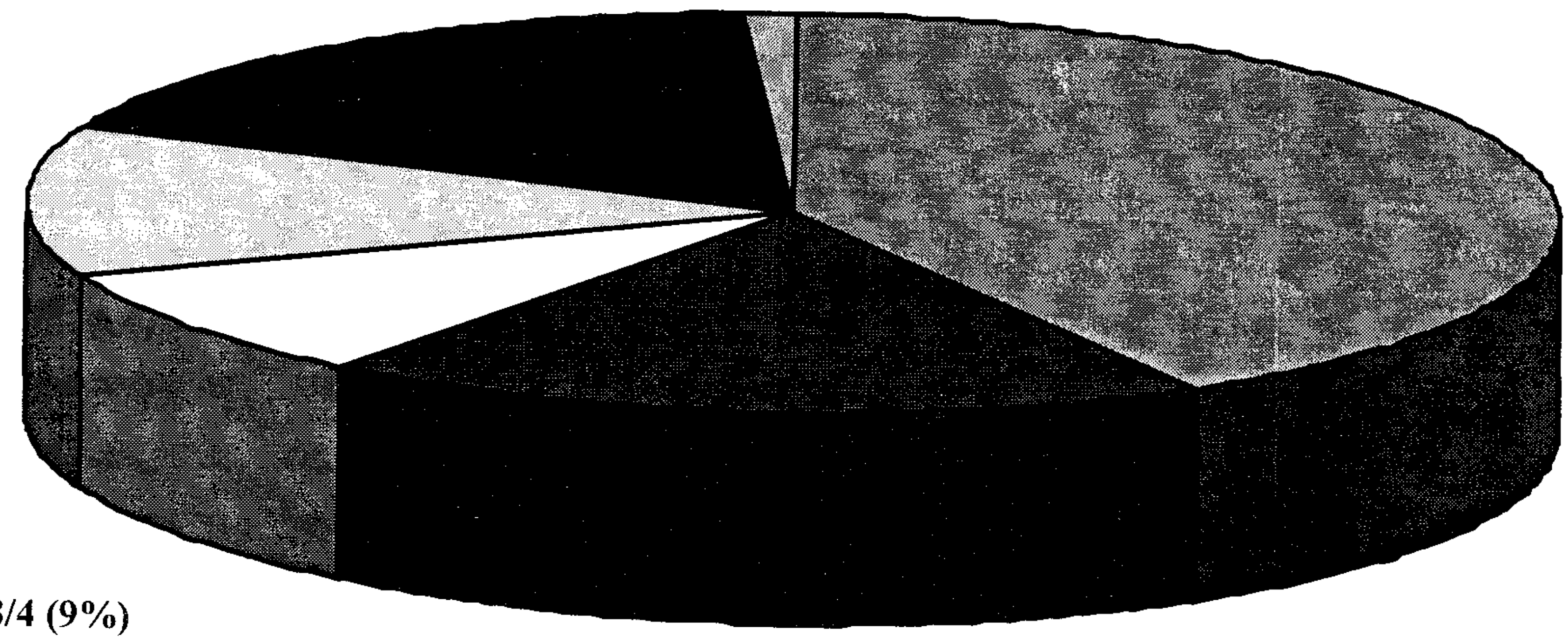

Figure 8- Pie chart showing proportional discharge for all sectors.

3) Stainless steel screens are recommended for their durability and long term trouble free services.

4). Pumping test should be performed to get accurate values of hydraulic characteristics of the subsurface lithologies.

5). Screens should be placed in aquifers lying below a minimum depth of 13 meters, so as to avoid risk of ground water pollution.

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