

# Application of Geographical Information System (GIS) for Aquifer Parameters Investigation: A case study of Peshawar district, Pakistan

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**Abstract** - This study was conducted to investigate aquifer parameters in district Peshawar. For this purpose 30 sites were selected, where tube wells were available. The global positioning system (GPS) was used for taking spatial data of these locations. The tube wells test data and verticals electrical sounding (VES) data were used to find the aquifer parameters on the selected locations. Analysis and mapping of aquifer data were accomplished, using geographical information system (Arc GIS 10.2.2) software. The results indicated that the aquifer parameters determined from vertical electrical sounding (VES) method are close to the results of field method. This study shows that vertical electrical sounding (VES) method can be used to estimates the aquifer's parameters. This method reduces extra expenditures for pumping tests and offers an alternate approach for estimating the hydraulic parameters of an aquifer.

**Key Words:** groundwater, aquifer, aquifer parameters, vertical electrical sounding, Geographical information system

## 1. INTRODUCTION

Groundwater resources are becoming valuable with increase in human population. Aquifer is responsible for storing the fresh water, which is the most valuable underground source of water supply, when there is low rainfall [1]. Groundwater occurs, below the surface within the zone of saturation in geological formation called aquifers. The role of groundwater resources is vital due to the directly dependent for drinking purposes of more than 30% of the world population [2]. Management of groundwater is the key factor to preserve these valuable resources. The aquifer parameters quantification is very important in addressing the hydrogeological issues as low or high yield for the management of groundwater resources. Aquifer parameters indicates the aquifer behaviour, that it is suitable for demanded water supply or not

## 2. DATA AND METHODOLOGY

District Peshawar, headquarter of Khyber Pakhtunkhwa, geographically lies between longitudes 71° 22' 0" - 71° 42' 0" East and latitudes .c33° 44' 0" - 34° 15' 0" North. The area of district Peshawar is 1,257 km<sup>2</sup> and approximately 358 m

elevated above mean sea level. The climate condition of the district is extreme. The district Peshawar mean monthly temperature ranges from minimum 2.60 °C in January to maximum 42.70 °C in June [3]. According to Peshawar district census report 1998, the rural population is 51.31% while urban population is 48.68% of the total population of the district. The main sources of drinking water are open wells, tube wells, hand pumps, ponds and tanks [4]. The district Peshawar agriculture is mostly dependent on canal irrigation extracted from Warsak dam, and tube well irrigation is also a source existing in some elevated area. The area under canal irrigation in rural is about 73 % while other sources irrigated the reaming area containing ravine, river, spring stream and tube wells [5]. The district Peshawar location and surrounding districts maps are shown in Fig. 1 and Fig. 2 respectively. The study sites map and water table map of the project area prepared by GIS software are shown in Fig. 3 and Fig. 4 respectively. Digital elevation model of the project area is shown in Fig. 5.

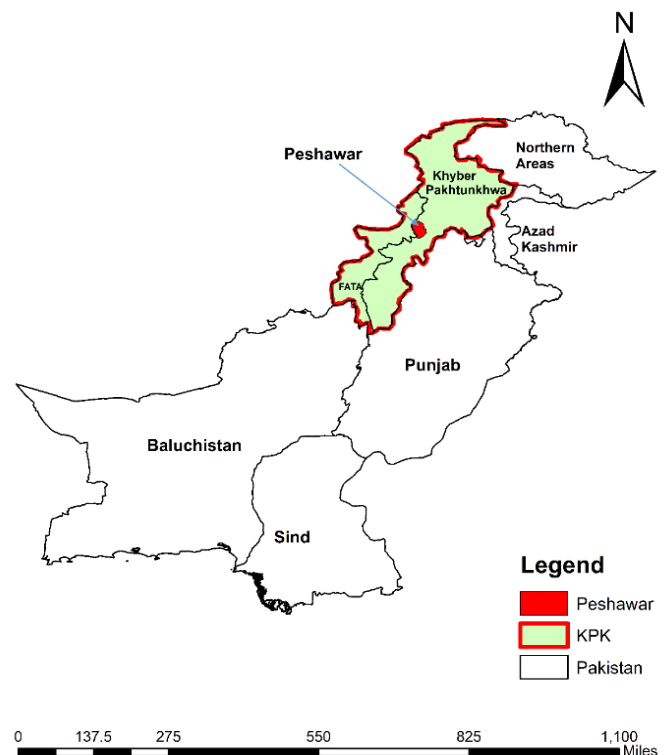


Fig -1: District Peshawar location map.

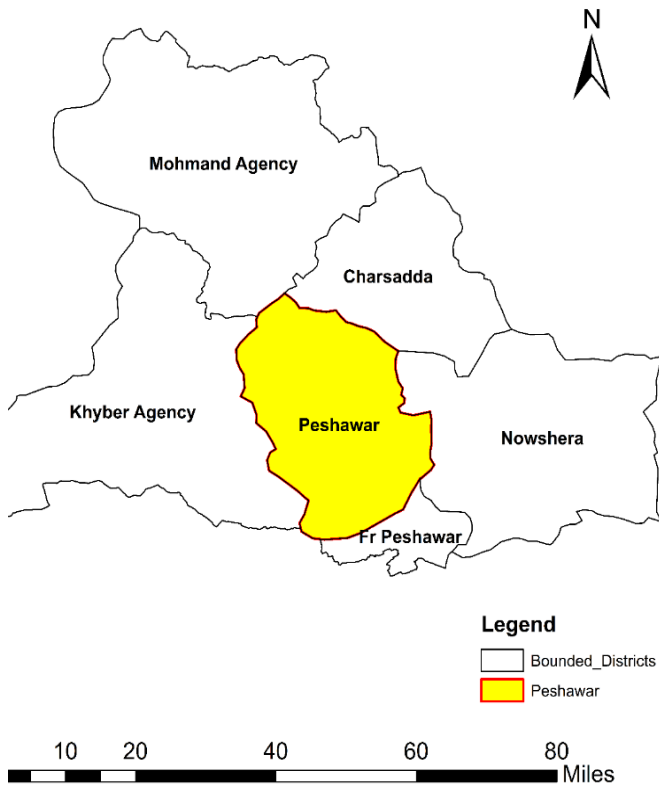


Fig -2: District Peshawar with adjacent districts.

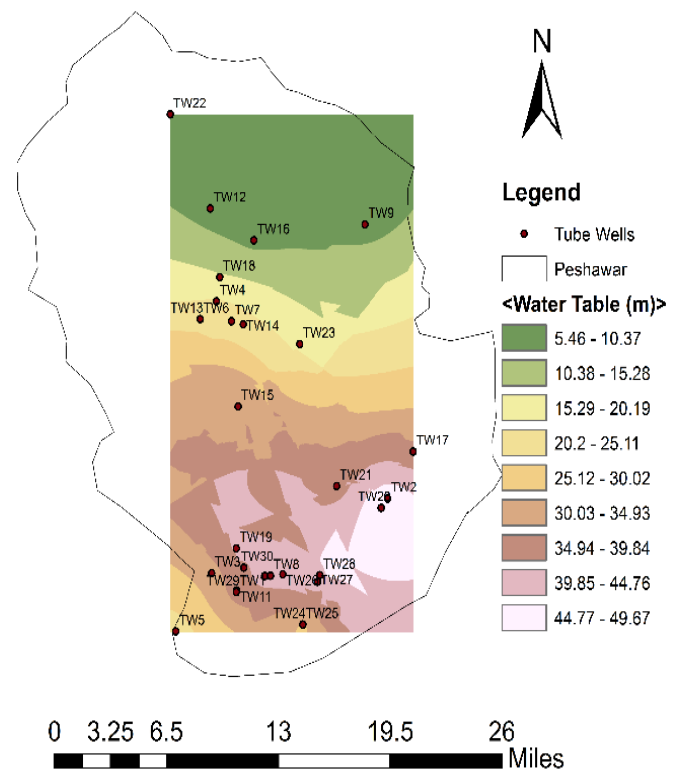


Fig -4: District Peshawar, project area water table map.

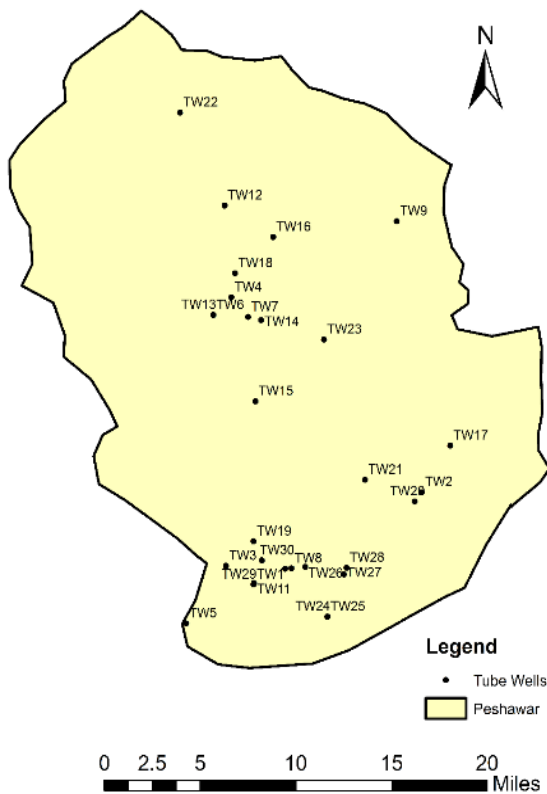


Fig -3: District Peshawar with study sites.

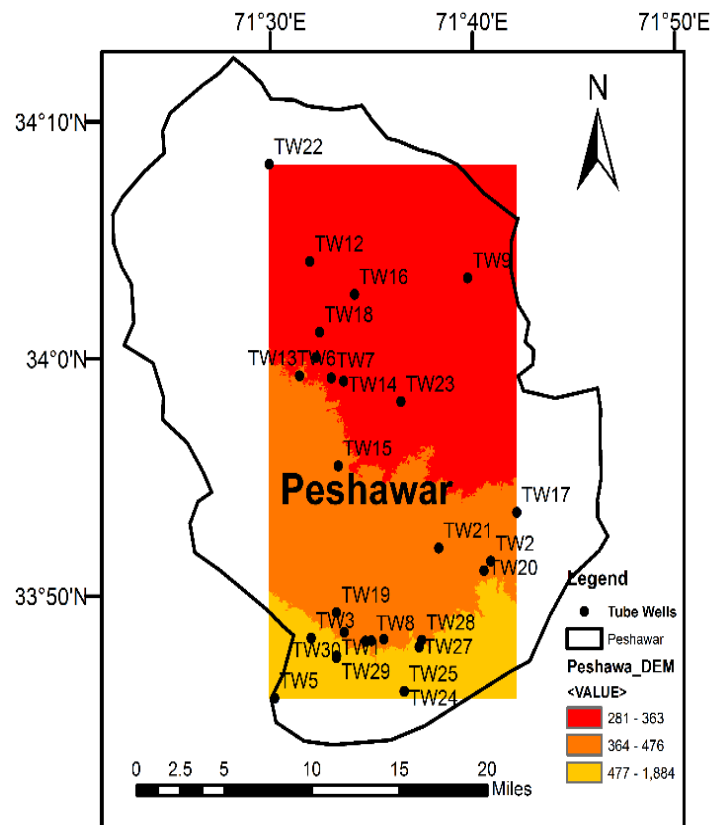


Fig -5: District Peshawar, project area DEM.

## 2.1 Data Analysis

The data for this study were collected from government departments of water sector, the data included the pump/tube well test data and vertical electrical sounding data. The collected data were analysed using Micro Soft Excel 2013 and Arc GIS 10.2.2 Software. The tube well test data and vertical electrical sounding (VES) data were used to find aquifer parameters, hydraulic conductivity and transmissivity.

## 2.2 Method I

In this method, pump/ tube well test data were used of each location, as a single well, observation wells were not available so the radius of cone of depression was selected in the range of 150 – 300 m [6]. Using Dupuit’s equation to find hydraulic conductivity of aquifer for each tube well location.

According to Dupuit’s equation

$$K = \frac{1.36 Q}{(H^2 - h_0^2)} * \log_{10} \frac{R}{r} \tag{1}$$

K=hydraulic conductivity (m/day),

Q= Discharge in (m<sup>3</sup>/day),

H= the aquifer thickness calculated from the impervious layer to the initial water level (m),

h<sub>0</sub>= depth to final water table after drawdown measured from the impermeable layer (m),

R= radius of cone of depression (m),

r = well radius (m)

Aquifer transmissivity was calculated by the hydraulic conductivity and the aquifer thickness (saturated). Therefore using the estimated hydraulic conductivity from Dupuit’s equation, to find transmissivity of the aquifer by “(2)”.

$$T = K * b \tag{2}$$

## 2.3 Method-II

In this method vertical electrical sounding data were used, the aquifer’s resistivity measurement are instinctively attractive for hydraulic conductivity estimation due to the fundamental relation between electrical conductivity and hydraulic conductivity; both of these properties depends on porosity, grain size and its packing configuration [7].

According to Archie Equation

$$\rho = a \rho_w \varphi^{-m} \tag{3}$$

$\rho$ =electrical resistivity of the formation (ohm-m),

a= electrical tortuosity parameter, for saturated sand

$\rho_w$ =resistivity of ground water (ohm-m) =1/EC<sub>w</sub>

$\varphi$  = porosity of aquifer

m= cementation factor

The second relationship between intrinsic permeability, grain size and porosity is given by [8].

$$k_f = \frac{d^2 * \varphi^3}{180 (1-\varphi)^2} \tag{4}$$

Where

$k_f$ = intrinsic permeability (m<sup>2</sup>)

d= median diameter of grain (m)

The third relation between hydraulic conductivity and intrinsic permeability is given by [9].

$$K = \frac{\delta_w g}{\mu} k_f \tag{5}$$

Where

K= hydraulic conductivity (m/sec),  $\delta_w$ = water density (1000 kg/m<sup>3</sup>), g= acceleration due to gravity (9.81 m/s<sup>2</sup>),

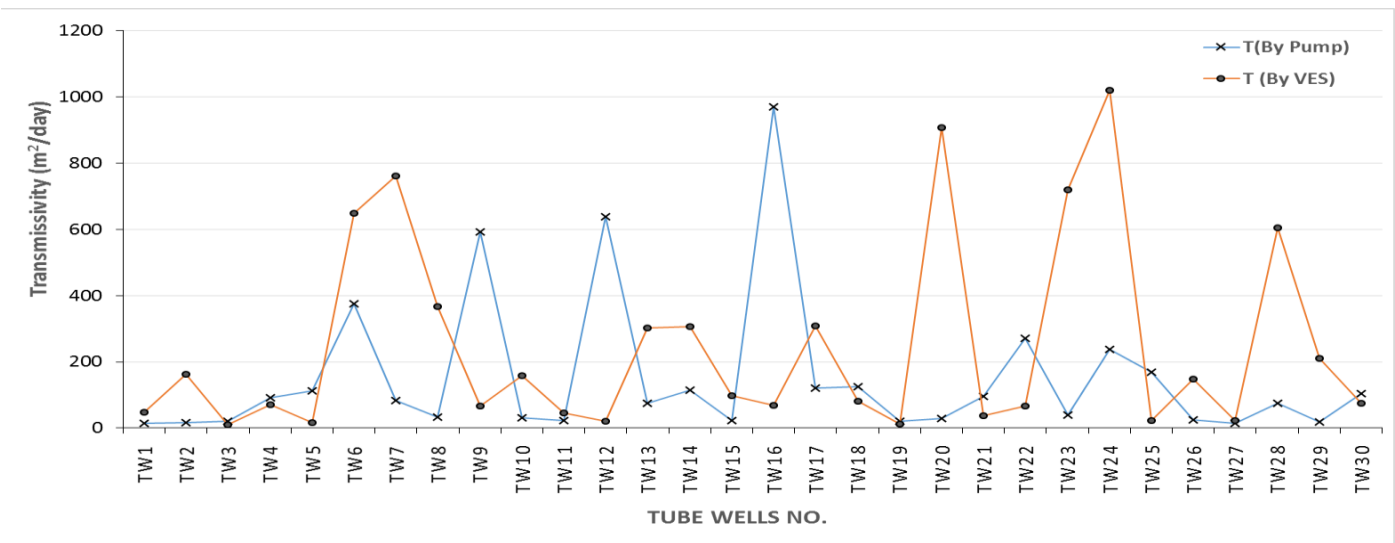
$\mu$ = water dynamic viscosity (0.0014 kg/m-s).

The vertical electrical sounding (VES) data of each location were used, to estimate the porosity of aquifer by “(3)”, using literature values of respective parameters for an unconsolidated gravel-sand. The values of electrical tortuosity parameter “a”, for saturated sand was selected from [10], the value of cementation factor was selected from [11] and ground water resistivity  $\rho_w=1/EC_w$  were used. Equation (4) was used to determine intrinsic permeability  $k_f$  from grain size (d) and porosity ( $\varphi$ ) was given by [8]. (d)=d<sub>50</sub> size in meter, median diameter of grain which was taken from grain size distribution curve. Equation (5) was used to determine hydraulic conductivity of the aquifer by putting  $k_f$  intrinsic permeability,  $\delta_w$  density of water, g acceleration due to gravity and  $\mu$  viscosity of water. Estimated hydraulic conductivity from vertical electrical sounding VES data were used for transmissivity of the aquifer by “(2)”

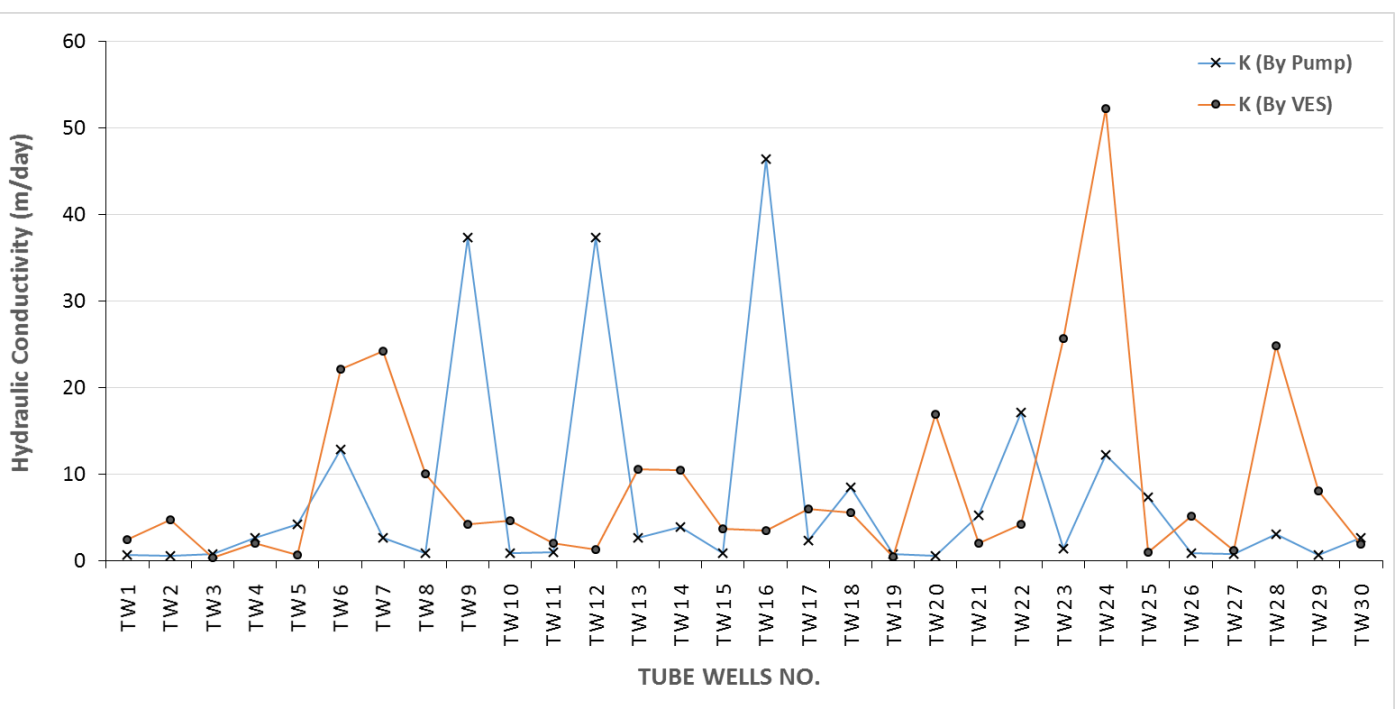
**Table -1:** Calculated Aquifer Parameters by two methods

Aquifer Parameters	Lowest	Highest	Mean
Hydraulic Conductivity (K) using Tube wells test data (m/day)	0.58	46.45	8.639
Transmissivity (T) using Tube wells test data (m <sup>2</sup> /day)	15.48	970.40	173.713

Aquifer Parameters	Lowest	Highest	Mean
Hydraulic Conductivity (K) using VES data, (m/day)	0.327	52.25	9.598
Transmissivity (T) using VES data, (m <sup>2</sup> /day)	9.83	1019.24	262.391



**Fig -6:** District Peshawar with study sites



**Fig -7:** District Peshawar with study sites

### 3. RESULTS AND DISCUSSION

The collected data were managed in Micro Soft Excel 2013 and GIS 10.2.2 software for analysis to investigate the aquifer parameters. In first method, tube well test data were used to find the aquifer parameters, as hydraulic conductivity and transmissivity at all points. In second method, vertical electrical sounding data at all points were used to find the aquifer parameters. The lowest, highest and mean values of aquifer parameters are shown in Table.1. The result of aquifer parameters obtained using tube well test data and vertical electrical sounding data are shown in Fig. 6 and Fig. 7. Geographical information system Arc GIS 10.2.2 was used to analyze the results obtained from tube well test data and vertical electrical sounding data and hence produced a regional map of the aquifer parameters. The hydraulic conductivity and transmissivity maps from tube well data and vertical electrical sounding data were obtained using Arc GIS 10.2.2 software, are shown in Fig. 8, Fig. 9, Fig. 10 and Fig. 11.

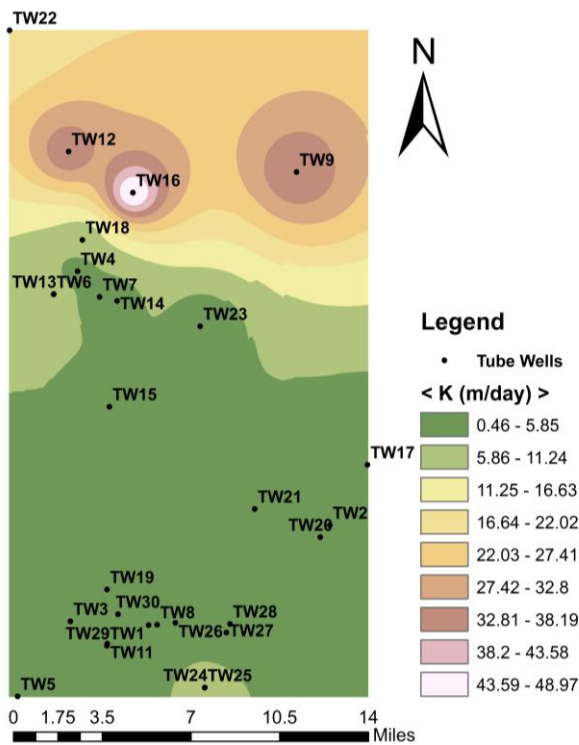


Fig -8: GIS's map showing Hydraulic conductivity from tube well test data

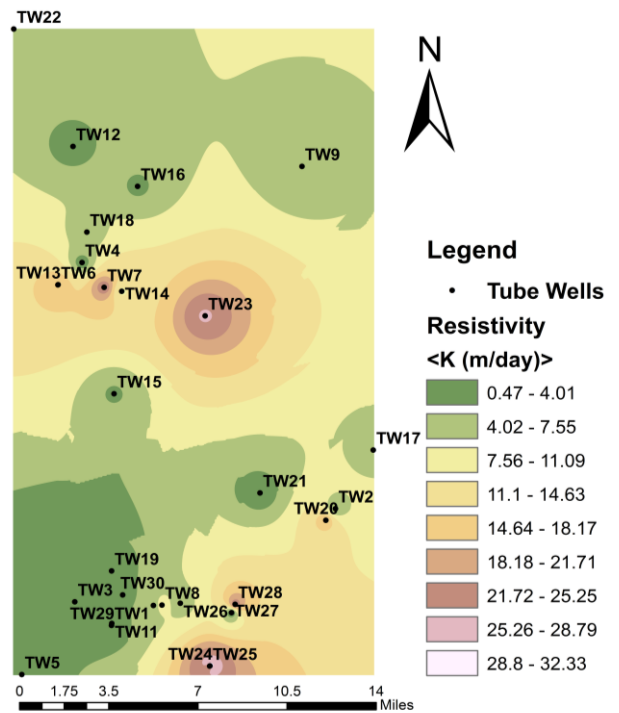


Fig -9: GIS's map showing Hydraulic conductivity from VES data

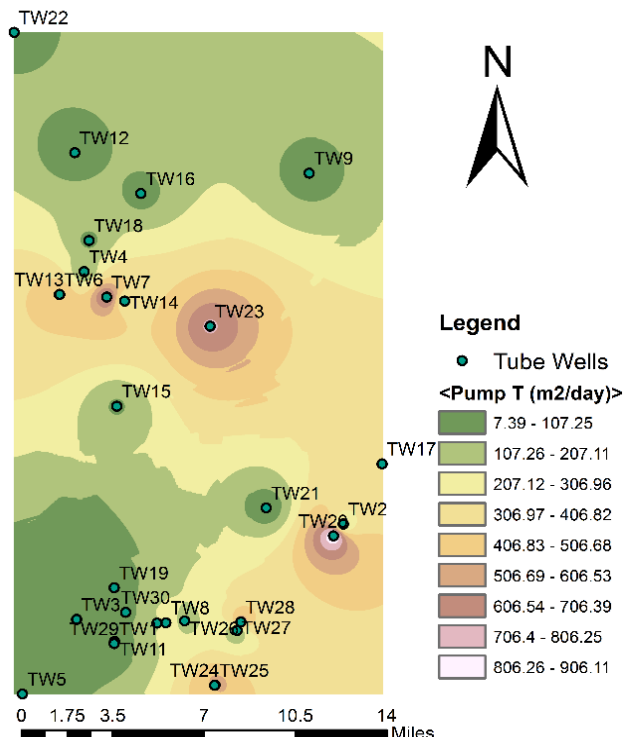


Fig -10: GIS's map showing Transmissivity from tube well test data.



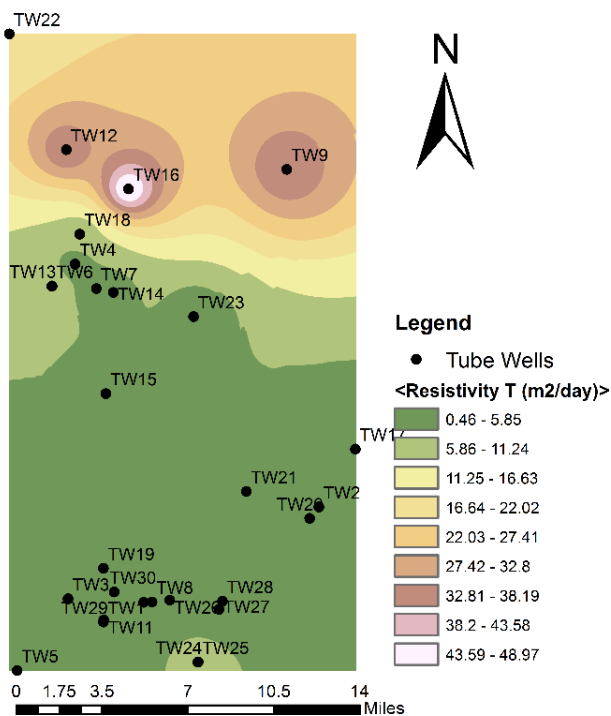


Fig -11: GIS's map showing Transmissivity from VES data

#### 4. Conclusion

The study was conducted to investigate the aquifer parameters in district Peshawar using two different methods; one is direct method (tube well test) and the other is indirect method (vertical electrical sounding). For best planning, analysis and management of the data, Microsoft Excel and ArcGIS software have been used in this study. It is observed that the mean value of hydraulic conductivity and transmissivity obtained from tube wells test data were 8.639 m/day and 173.713 m<sup>2</sup>/day respectively, and from vertical electrical sounding data, the mean value of hydraulic conductivity and transmissivity were 9.598 m/day and 262.391 m<sup>2</sup>/day respectively. The mean values obtained from two methods indicates the close correlation, therefore, vertical electrical sounding data can be used for determination of aquifer parameters. ArcGIS software was used for analysis and presented the results in the most well-organized and progressive form of mapping. The maps prepared from the global positioning system (GPS) data and aquifer parameters data provide very basic type of information about aquifer parameters of district Peshawar. These maps show the concentration intensities for parameters throughout the project area, which is not imaginable through other means.

#### References

[1] B.L. Morris, A.R.L. Lawrence, P.J.C. Chilton, B. Adams, R.C. Calow, and B.A. Klinck, "Groundwater and its susceptibility to degradation: a global assessment of the

problem and options for management", vol. 3, United Nations Environment Programme, 2003

[2] R. Connor, "The United Nations world water development report 2015 water for a sustainable world", vol. 1, UNESCO, 2015

[3] Ali, Arshad, and Khan, Taj, "Analysis of climate data of Khyber Pakhtunkhwa, Pakistan". International Research Journal of Engineering and Technology (IRJET), Volume 3, Issue (2), 2018, 4266-4282, 2018

[4] GOP (Government of Pakistan), "Statistics division, Peshawar district census report 1998", 2000.

[5] GOP (Government of Pakistan), "Statistics division, NWFP mouza statistics, agricultural census organization 2008", 2009.

[6] J. Dupuit, "Theoretical and practical studies about the movement of water in open channels and through permeable terrains. (In French.) 2nd ed. Dunod, Paris, 1863.

[7] G.E. Archie, "The electrical resistivity logs as an aid in determining some reservoir characteristics. transactions of the American Institute of Mining and Metallurgical Engineers / Petroleum, Division, 146: 1942, 54-62

[8] J. Kozeny, "The water in soil, groundwater movement. In: Kozeny, J. Hydraulics. Springer, Vienna, 1953, pp. 380-445. (In German),

[9] M.K. Hubert, "The theory of groundwater motions. Journal of Geology 48, 1940, 785-944

[10] W.O. Winsauer, "Resistivity of brine-saturated sands in relation to pore geometry. AAPG Bull. vol 36, issue (2) 1952, 253-277

[11] J.H. Doveton, "Log analysis of subsurface geology concepts and computer methods: Wiley Interscience, New York, 1986, 273 p