Qualitative and Quantitative Demarcation; and Impact of Groundwater on Farming Community

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Abstract: **Water being the vital source of life makes it the leading consumed entity around the world and Pakistan is no exception. Moreover, the ever-increasing consumer base in Pakistan, both in the domestic and commercial terms, put this already scant resource more susceptible to variation in both quality and quantity. In Pakistan, the primary source of water remains the Indus river complimented by groundwater. Though, long bouts of droughts have rendered people more dependent upon groundwater whose continuous pumping deteriorates the aquifer characteristics rendering the soil above infertile. In our study, we assess the groundwater strata by utilizing the electrical resistivity survey technique through analyzing eleven nodal points under the head of command area of Tando Allahyar-II distributory. The main purpose of the study was to demarcate the aquifer characteristics both qualitatively and quantitatively. The Electrical Resistivity Survey with standard Schlumberger electrode configuration was adopted with maximum exploration depth of 150 m. The data was recorded using ABEM Terrameter SAS 4000. Analysis of data was achieved through 1X1D software and the demarcation has been done through ArcGIS. Through the results, it can be inferred that the fresh water is present from ground level to 50m below the earth surface followed by marginal fresh water at 50m to 75m and marginal saline water is located at 75m to 170m.**

Keywords: **Electrical Resistivity Survey, Groundwater, Interpex IX1D, Terrameter SAS 4000.**

I. INTRODUCTION

Agriculture sector being the largest contributor to the Pakistan's GDP with 24 percent share and employment provider with 42 percent share is also the biggest beneficiary of the groundwater [1]. Pakistan lies in the semi-arid region to full arid regions and suffers from high seasonal variation in temperature, droughts and rainfall [2]. Per capita availability of water has also gone down from 5104 m^3 in 1950 to 935 m^3 in 2018. As a consequence, Pakistan only benefits from cultivable area of 22.07 million hectares form 34.89 million hectares total agricultural area (Pakistan bureau of Statistics 2018) [3]. This tend is in unison with the world where the annual groundwater extraction had reached 982 km^3 in 2010 (Benejam et al., 2010). In most of the countries around the world there has been a growing focus on the groundwater extraction and utilization for the domestic,

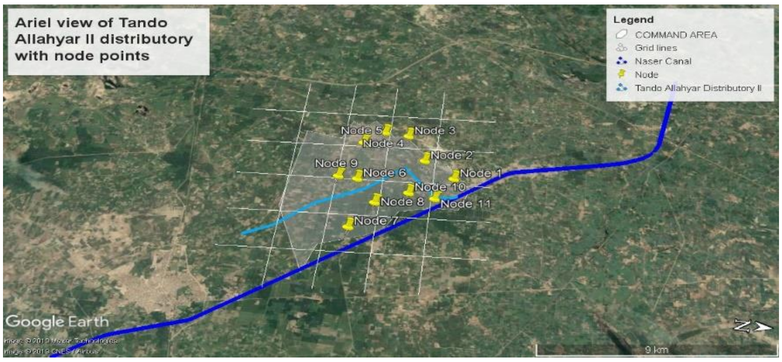


Figure 1 Ariel view of Tando Allahyar II distributory with nodes point shown

industrial and agricultural purposes. This growing trend demands for the safe and reliable supply of groundwater all around the year. From the last two decades, improvements in the microprocessors and numerical modelling methods brings new opportunities in which Geophysics has proved to be a harbinger for the development of new techniques for effective groundwater quality evaluation and subsurface mapping [4]. Furthermore, groundwater has also helped, usually the tail end farmers, to maximize their farms output and has sustain their socio-economic development [5].

II. MATERIALS & METHODS

A. Study Area

Tando Allahyar-II distributary is taken as the study area. This distributary is off-taking from Naseer canal at 33 RD. It passes from Tando Allahyar district.

Tando Allahyar is a district in Sindh, Pakistan located 36 km from Hyderabad city with GPS coordinates 25° 27′ 25″ N, 68° 43′ 17″ W. The N 120 highway connects Hyderabad and Tando Allahyar with each other. Details of parameters of the distributory is given in **Table 1** and coordinates of nodal points is given in **Table 2**. As the command area of the whole distributory is very large and it was not feasible to complete the whole survey within stipulated time and resources, so for this purpose the whole command area is divided into two section, namely; Head section and Tail section. We have carried out our work on the head section only. Furthermore, the whole command area was divided into a regular grid network with spacing 2km x 2km and Electrical Resistivity Survey was carried out on 11 selected nodes with each node lie in a grid.

Table 1. Basic parameters of Tando Allahyar distributory.

S.NO	Description	Tando Allahyar II distributory
1	Pareent Canal	Naseer Canal
2	District	Tando Allahyar
3	Length of Distributory	74 RD (14 miles)
4	Design Discharge (Cusec)	61.83
5	GCA	15,400 acres
6	CCA	14,464 acres
7	No. of Watercourse	33
8	Major Crops	Maize, rice, sugarcane, cotton bajra, wheat, grain, gram, barseen and mango plantations.

Table 2. Coordinates of Nodal points

S.NO	NODE	Coordinates of Nodes	
		Latitude	Longitude
1	NODE 1	25.557087	68.647586
2	NODE 2	25.547356	68.638989
3	NODE 3	25.541029	68.632324
4	NODE 4	25.528782	68.630789
5	NODE 5	25.522254	68.63218
6	NODE 6	25.520985	68.643244
7	NODE 7	25.510491	68.64576
8	NODE 8	25.522131	68.661297
9	NODE 9	25.527773	68.653109
10	NODE 10	25.53675	68.647351
11	NODE 11	25.548199	68.651691

B. Groundwater

Groundwater is the water that exists in the saturated zones beneath the earth surface [6]. The upper surface of the zone is termed as water table. Groundwater remain present inside the pores and fracture spaces created naturally or artificially in the earth material exhibiting the behaviour of a sponge. The groundwater present inside the earth surface moves slowly at the rate of 7-60 centimetre per day and if that water can be extracted out in a useful amount then the rock material is called *aquifer* (USGS). With the brewing climate changes and exacerbating pumping rates of the tube wells, groundwater scarcity has starts taking toll on the environment worldwide. To hold these adverse effects, it is high time to adopt optimized as well as sustainable groundwater management procedures [7].

C. Groundwater quality

The problem in Pakistan is not the development of groundwater but the unsustainable management with which it is being extracted. The shortfall of water which has increased from 49.71 BCM in the year 2000 to 133 BCM in year 2013 (PWP, 2000) puts enormous pressure on this resource. Moreover, not all the water that has been extracted out can be used for irrigation and domestic use. The quality of water can be compromised if the recharge rate of the aquifer exceeds the withdrawn rate especially during drought seasons. Excessive pumping of water may lead to the deterioration of its quality. There are mainly two reasons for that, firstly, the intrusion of saline water into the pumping water that is located below the fresh water and, secondly, due to the heavy reliance of the tail end farmers where water availability is scarce [8].

D. Electrical Resistivity Survey (ERS)

Rapid development in the exploitation and extraction of groundwater had led to many new innovations in the study of geophysical properties of aquifer. The issue looked by the designers is to locate the precise area of the groundwater in the subsurface zone. Geophysical is the use of material science that review the earth by taking the estimations at or close to the surface of earth [9]. Geophysical techniques are broadly connected in geotechnical and geo-natural examinations and is considered as the most appropriate strategy in the investigation of groundwater. Geophysical has had a critical influence in such examinations and aided in further advancement of overhauled strategies and systems for progressively dependable outcomes and furthermore in growing the extent of the methods [10].

Electrical Resistivity Method (ERM) is a piece of geophysical strategies which is presently utilized in the primary phases of the investigation of the groundwater. Electrical Resistivity Method (ERM) has been utilized for a long time to decide the degree of the layered media in the subsurface just as for the mapping of the current aquifer. Electrical Resistivity Method (ERM) is adequately utilized in the groundwater investigation tests due to simplicity of treatment of the gear, straightforward strategy and systems and non-destructive nature of the test [11].

E. Terrameter SAS 4000 and Schlumberger Array

Terrameter SAS 4000 is the equipment which measures potential difference or resistivity of the subsoil by inducing current in the ground. The SAS abbreviates for Signal Averaging System, it is actually a technique whereby successive readings are averaged continuously. The equipment SAS 4000 can operate on several modes i.e. self-potential, resistivity and induced polarization. Its main feature is its ability to read four channels concurrently. This gives four times quicker results when measuring resistivity, voltage and potential. Terrameter can send out controlled and continuous current signals with strength of up to 1000 milli Ampere (mA) and a voltage of 400 volts (V). Terrameter results are reliable as it consists of a battery powered, with deep penetration resistivity meter with an output adequate for an electrode separation of 200m in a good survey terrain. The current/ voltage ratio is calculated and displayed automatically in ohms or milli ohms on the screen of Terrameter [12]. During our research we have used Schlumberger array. The Schlumberger array is made by arranging the four electrodes in collinear position. The outer two electrode of the both sides acts as current electrode and the inner two electrodes from the two sides act as potential electrodes [13]. The potential electrodes are situated inside the current electrodes and at a small distance typically one fifth the spacing between the current electrodes. As the survey proceeds, the current electrodes are moves further outside keeping the potential electrodes in the same position until the observed voltages become too small to measure. The benefit of using Schlumberger array is that less number of electrodes are to be moved during sounding and the cable required for the potential electrodes is less. Moreover, Schlumberger sounding is less time consuming, greater probing depth and gives better resolution than Wenner array. The disadvantages are that the instrument required need to be very sensitive and long current cables are required and the array may be difficult to set out in the field if proper coordination is not maintained. Safety issues can also arise due to high voltage current. Therefore, Schlumberger array is also known to be labour intensive.

F. Procedure of Electrical resistivity survey by Terrameter SAS 4000

Electrical resistivity method is simplest method for measuring resistivity in Geophysics. A potential field is formed in the field by inducing electric current through two electrodes. Another two electrodes are inserted in the ground to measure potential. As the distance between the two current electrodes is increased so the depth of investigation. Now, considering the electrodes A and B as the current electrodes and M and N as potential electrodes (inserted between A and B). The potential difference will be measured between the M and N electrodes. Furthermore, as for now, we know current (I) and potential difference (V) the apparent resistivity can be measured by using "(1)," as given below

$$\rho = K\frac{V}{I} \quad (1)$$

Where K is the geometric factor of the electrode arrangement in case of Schlumberger electrode configuration, which is given by "(2),"

$$K = \frac{\pi(\frac{AB}{2})^2-(\frac{MN}{2})^2}{MN} \quad (2)$$

The procedure is repeated at all the nodal points with the distance between the current increased up to 200m. The final readings are analysed through Interpex IX1D software.

Figure 2 Terrameter with current and potential wires attached [14]

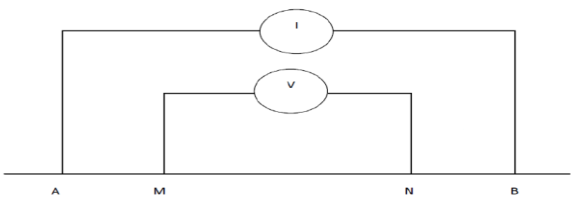


Figure 3 Schlumberger array and apparent resistivity diagram

G. ERS Data Evaluation Using IX1D Software

All Schlumberger sounding bends were handled and modelled utilizing Interpex IX1D program, which uses interpretation methods dependent on the Barnes Layer Model (Bhoi, 2012) [15]. Forward displaying and the automated inversion procedures were utilized reciprocally to deliver best fit curves that concur with quantitative translation [16]. Forward displaying was utilized widely since the inversion method could just yield best fits at shorter anode separating where the measured data seem smooth. At longer separating where most curves and cusp are noticeable, automated inversion procedure yielded questionable depth models which surpassed expected depths esteems underneath each sounding station [17].

III. RESULTS AND DISCUSSIONS

A. IX1D data interpretation

The results of electrical resistivity survey of the eleven node points show a wide change in the resistivity of the soil material. In most of the cases the value decreases as the depth of investigation increased giving an early indication that the saline water is present as moves down further. This data was analysed through computer aided software IX1D. the models thus generated confirms the ERS findings and pronounce the existence of fresh water at top and marginal saline water in the lower layers of the strata. The models of 11 node points are given in **Fig. 4 (a)** and **(b)**.

B. Groundwater demarcation using ArcGIS

The resistivities data acquired through the ERS is now been converted to the respective Electro Conductive (EC) values. For the mapping purpose, the investigation depth of 150m is now divided into five layers, layer one extends from 0m to 25m, layer two extends from 25m to 50m, layer three extends from 50m to 75m, layer four extends from 75m to 100m and layer five extends from 100m to 150m. The groundwater is classified into four classes as fresh water, marginal fresh water, marginal saline water and saline with EC values of less than 1.5 ds/m, 1.5-2.5 ds/m, 2.6-4 ds/m and greater than 4 dc/m respectively. The demarcation achieved at various layers is present in **Fig. 5**. The area covered under different quality water is presented in **Fig. 6**.

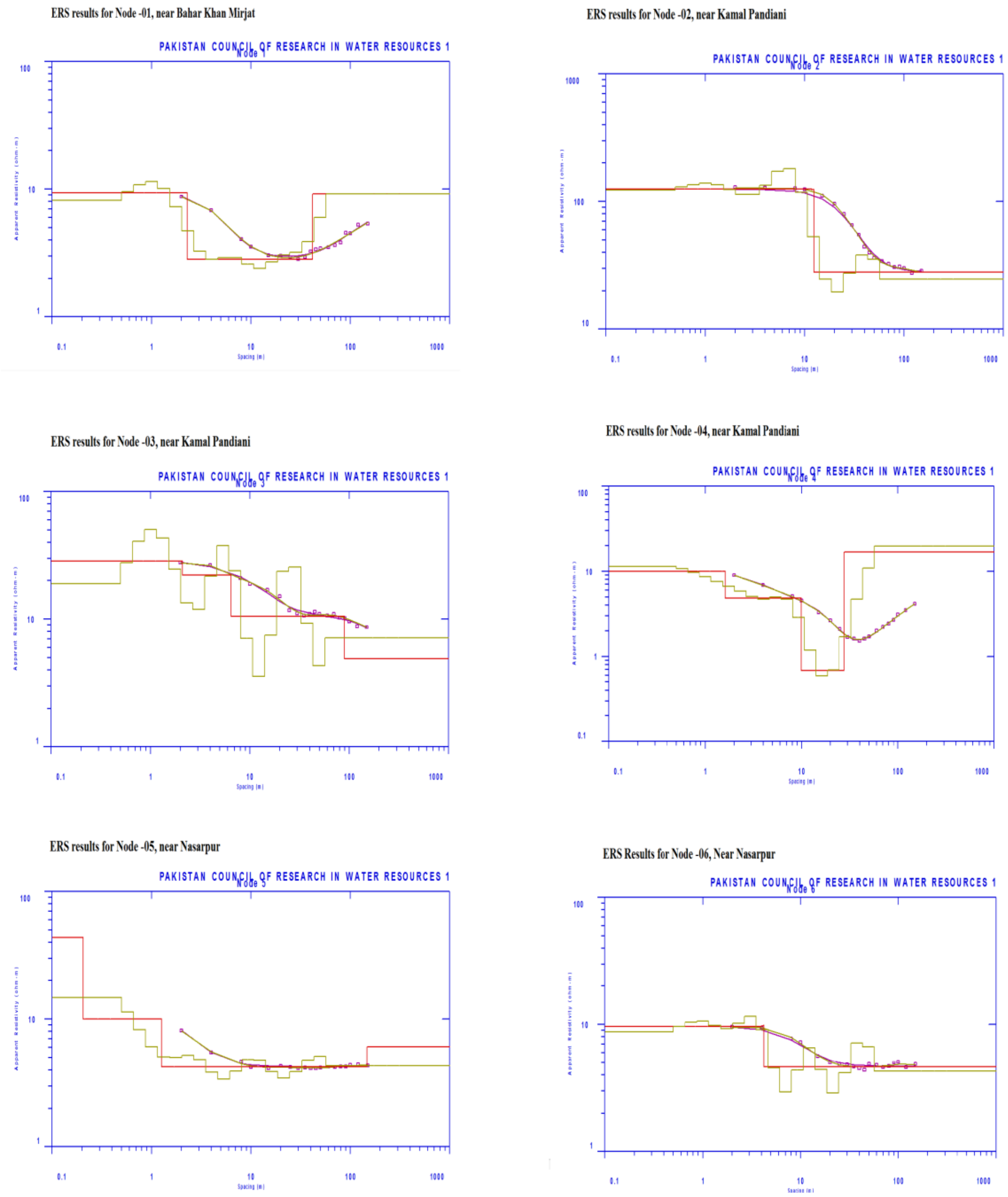
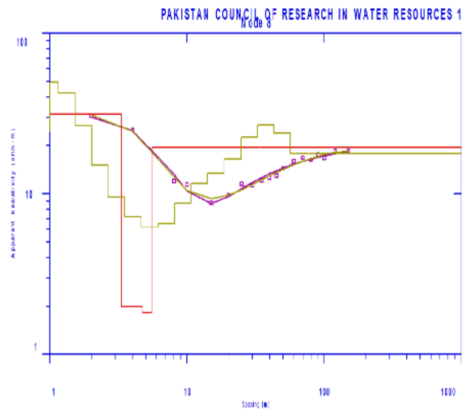
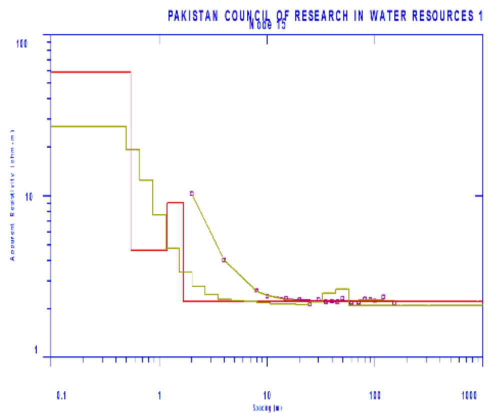


Fig. 4(a). IX1D data model for nodes 1-6

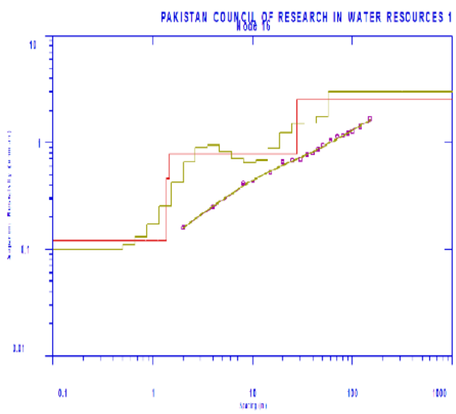
ERS results for Node -07, near Mahi Jha



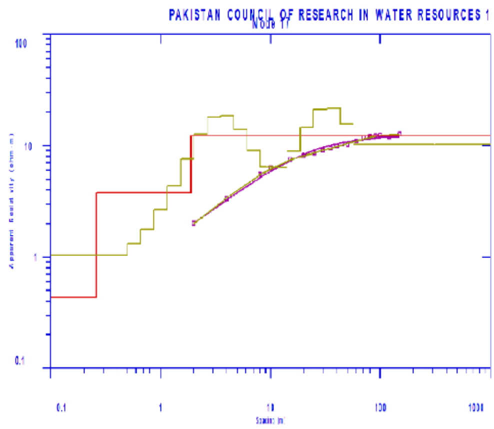
ERS results for Node -08, near Haji Khaman Nizamani



ERS Results for Node -09, Near Haji Khaman Nizamani



ERS results for Node -10, near Haji Khaman Nizamani



ERS results for Node -11, near Bahar Khan Mirjat

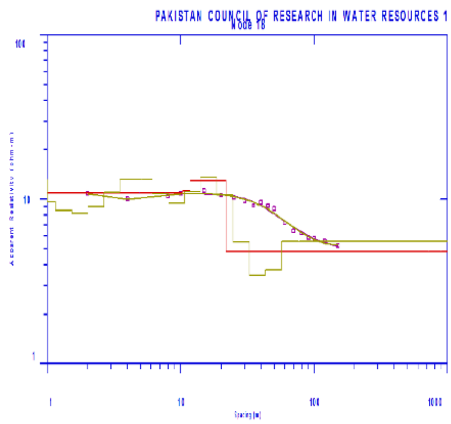


Figure 4(b). IX1D data model for nodes 7-11

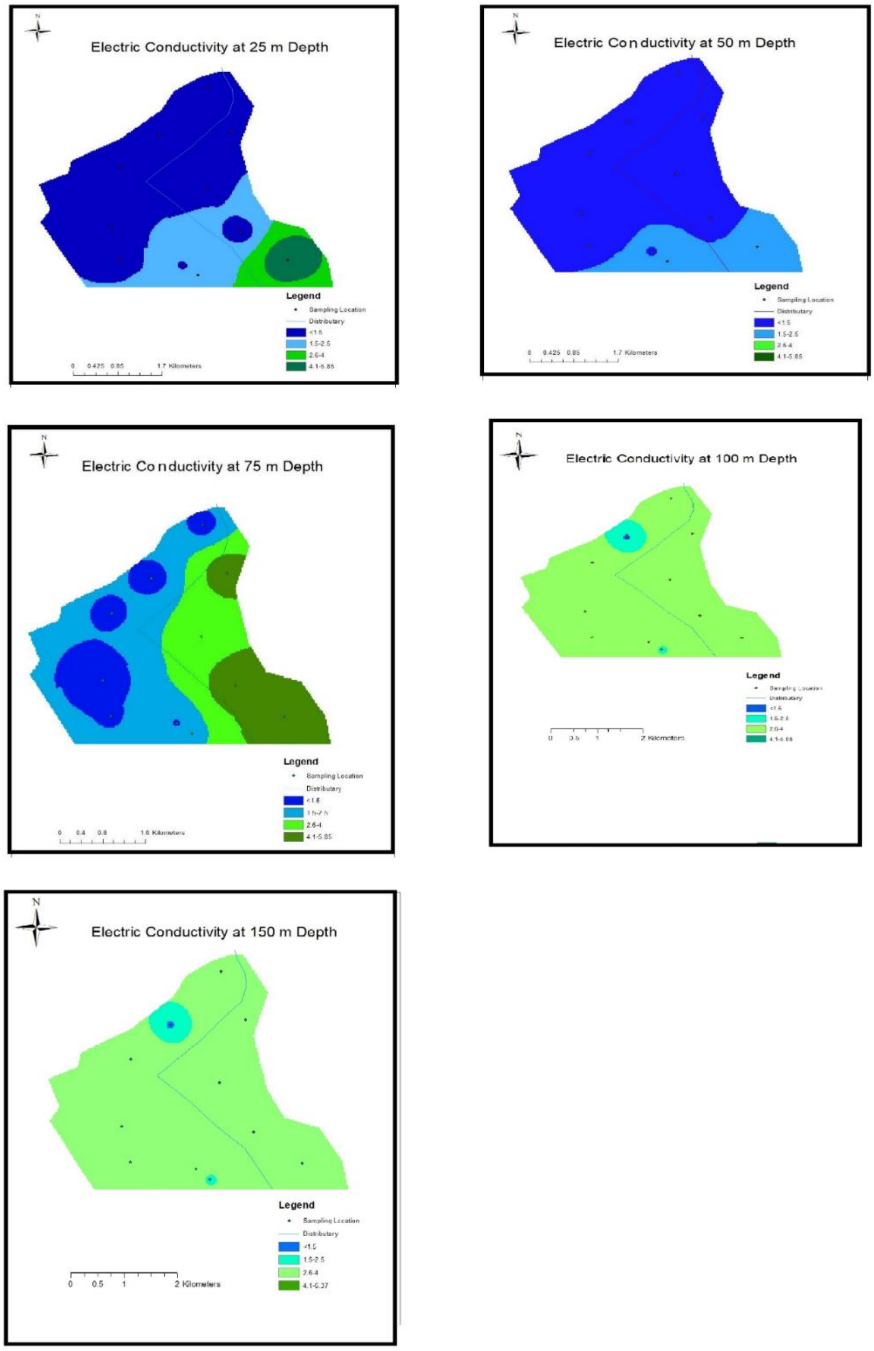


Figure 5. Layer wise demarcation of groundwater through ArcGIS

At 25m				
S. No	Groundwater Quality		Area	
	EC (ds/m)	Description	(KM2)	(%)
1	<1.5	Fresh	13.77	53.6
2	1.5-2.5	Marginal Fresh	9.27	36.1
3	2.6-4	Marginal Saline	1.59	6.2
4	>4	Saline	1.05	4.1
		Total	25.7	100

At 50m				
S. No	Groundwater Quality		Area	
	EC (ds/m)	Description	(KM2)	(%)
1	<1.5	Fresh	17.91	69.7
2	1.5-2.5	Marginal Fresh	7.78	30.3
3	2.6-4	Marginal Saline	0	0
4	>4	Saline	0	0
		Total	25.7	100

At 75m				
S. No	Groundwater Quality		Area	
	EC (ds/m)	Description	(KM2)	(%)
1	<1.5	Fresh	7.29	28.4
2	1.5-2.5	Marginal Fresh	5.34	20.8
3	2.6-4	Marginal Saline	6.86	26.7
4	>4	Saline	6.19	24.1
		Total	25.7	100

At 100m				
S. No	Groundwater Quality		Area	
	EC (ds/m)	Description	(KM2)	(%)
1	<1.5	Fresh	0.7	2.7237
2	1.5-2.5	Marginal Fresh	0.19	0.7393
3	2.6-4	Marginal Saline	22.91	89.144
4	>4	Saline	1.9	7.3929
		Total	25.7	100

At 150m				
S. No	Groundwater Quality		Area	
	EC (ds/m)	Description	(KM2)	(%)
1	<1.5	Fresh	1.78	6.9261
2	1.5-2.5	Marginal Fresh	2.1	8.1712
3	2.6-4	Marginal Saline	20.62	80.233
4	>4	Saline	1.2	4.6693
		Total	25.7	100

Figure 6. Different area's computed at different layers

3.3 Quantum of groundwater under different categories

Using the results of ArcGIS, we have classified groundwater into four categories and furthermore, we can now find the quantum of groundwater for these categories. For this purpose refer to **Fig. 3.5**.

Quantum of fresh ground water			
Depth (m)	Area (Km2)	Porosity	VOL (BCM)
25	13.77	0.32	0.0749088
50	17.91	0.32	0.14328
75	7.29	0.32	0.05832
100	0.7	0.32	0.0056
150	1.78	0.32	0.02848
		Total	0.3105888

Quantum of Marginal fresh ground water			
Depth (m)	Area (Km2)	Porosity	VOL (BCM)
25	9.27	0.32	0.0504288
50	7.78	0.32	0.06224
75	5.34	0.32	0.04272
100	0.19	0.32	0.00152
150	2.1	0.32	0.0336
		Total	0.1905088

Quantum of Marginal saline ground water			
Depth (m)	Area (Km2)	Porosity	VOL (BCM)
25	1.59	0.32	0.0086496
50	0	0.32	0
75	6.86	0.32	0.05488
100	22.91	0.32	0.18328
150	20.62	0.32	0.32992
		Total	0.5767296

Quantum of saline ground water			
Depth (m)	Area (Km2)	Porosity	VOL (BCM)
25	1.05	0.32	0.005712
50	0	0.32	0
75	6.19	0.32	0.04952
100	1.9	0.32	0.0152
150	1.2	0.32	0.0192
		Total	0.089632

Figure 7. Quantum of different water qualities

IV. CONCLUSION

The survey and analyses of the command area of the Tando Allahyar II distributory command area at the head shows that the fresh water is abundantly available in the top layers i.e. from ground level to 50m below followed by an increases in marginal fresh water at 50m to 75m and then the quality of water changes to marginal saline water at a depth of 75m to 150m. So, it can be concluded that as the depth increase the quality of water changes from fresh to marginal saline water. Though marginal saline groundwater can be used for irrigation water but its consumption by local populace can not recommended. Moreover, there is emerging threat that if the groundwater pumping remains continuous and unchecked there can damages to the delicate balance between the different layers of groundwater.

V. ACKNOWLEDGMENTS

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