Int. J. Econ. Environ. Geol. Vol. 8 (3) 26-31, 2017
Journal home page: www.econ-environ-geol.org

Open Access
ISSN: 2223-957X

Geoelectrical Survey for the Exploration of Ground Water using Vertical Electrical Sounding: A Case Study of Androt District Rawlakot, Azad Jammu & Kashmir

Mehboob ur Rashid[1*], Sohail Anwar[1], Syed Ali Abbas[2], Waqas Ahmad[3]

[1]Geoscience Advance Research Laboratory Islamabad, Geological Survey of Pakistan
[2]Geophysics Division, Geological Survey of Pakistan, Quetta
[3]National Centre of Excellence in Geology, University of Peshawar

*Email: mehboobgeo@yahoo.com

Received: *1March, 2017* ***Accepted:*** *18 August, 2017*

Abstract: Vertical Electrical Sounding (VES) method has been widely used to depict the subsurface lithology, thickness and structure based on resistivity of layered media with the ultimate objective of evaluating groundwater potential. In this investigation, VES was used to outline subsurface geology to produce a 2D subsurface resistivity model based on the resistivity contrast of layered rocks, for evaluating the accessibility of groundwater in the Siwaliks group of Androt District Rawlakot, Azad Jammu and Kashmir (AJ&K). The Schlumberger electrode configuration was used with spacing arrangement of current electrode (AB/2) going from 1.5 to 250 meters and potential electrode (MN) 1 to 50 meters. The VES data was qualitatively analyzed by using iteration software (IPI2win) which showed that the area is composed of clay, shale, fractured sandstone with intercalation of clay based on resistivity contrast. At depth of 40m-100m along VES indicates good prospects for ground water potential, associated with sandstone beds of Siwaliks group. The resistivity depth section maps at potential depth of 30m, 40m, 60m and 80m are prepared for the demarcation of potential reservoir beds at various depth. The interpreted sounding curves are interpreted qualitatively and pseudo section, Resistivity section and geological log are prepared based on resistivity contrast which shows agreement with geology and hydrological condition of the area. The favorable reservoir rock as an aquifer demarcated in the study area is fractured sandstone with intercalation of clay beds, with apparent resistivity range of 80Ωm to 100Ωm and thickness of 20m to 50m at different sites. The apparent resistivity sections revealed that the North East (NE) and North West (NW) regions are comparatively good potential reservoir for ground water.

Keywords: Vertical electrical sounding, ground water, resistivity, IPI2win.

Introduction

Groundwater is the largest accessible reserves of fresh water and is widely utilized as a hotspot for drinking water (Zektser and Lorne, 2004). More than 50% of all population depends on groundwater as a source of drinking (Loague et al., 1998), in rural level the figure is even higher. Hydro geological and geophysical examinations are regularly performed to assess the groundwater capability of any region. Such studies are useful to gather quick and practical information of distributed subsurface hydrogeology (Arshad et al., 2007; Huang et al., 2011; Kearey et al., 2002). The utilization of geophysical procedures for both groundwater mapping and water quality evaluation has extended significantly in the course of recent decade due to fast advancement in electronic innovation and improvement of numerical display arrangements (Metwaly et al., 2010; Ndlovu et al., 2010). Albeit different hydro-geophysical procedures are practically in practice, Vertical Electrical Sounding (VES) is a mainstream strategy in light of its ease to understand its operation and productivity in zones with highly differentiating resistivity (Martinelli, 1978; Maury and Balaji, 2014; Telford et al., 1990). Geoelectrical techniques are especially reasonable for groundwater resource mapping due to cost effective, instant and reliable as it contemplates on the grounds hydro geologic properties such as porosity and permeability, which can be related to electrical resistivity values (Ademilua et al., 2014). Geoelectrical strategies are basically concerned with the estimation of electrical resistivities of subsurface materials, which portrayed the underground topography, structures and the related aquifer potential (Dahlin, 1996; Van Overmeeren, 1989).

In the current study VES are performed to assess the ground water capability in Rawalpindi group rocks of Androt area, and to demarcate the potential depth and strata having potential of ground water reserves in the study area.

Study area

The study area is located in Rawlakot District Poonch, Muzaffarabad Division, Azad Jammu and Kashmir, a part of Hazara Kashmir syntaxes that lies in sub-Himalayan domain (Thakur et al., 2010) (Fig. 1). The area lies between Longitudes 73° 43′ 50″ to 73° 50′ 00″ east and Latitudes 33° 48′ 20″ to 33° 53′ 00″ north covering parts of Survey of Pakistan toposheet Nos: 43 G/9 located at a distance of 30km from rawlakot city. The area is having steep, rugged and undulating landscape with an average elevation of about 1500 meters above sea level. The climate is sub humid tropical type with average annual precipitation of about 1800 millimeters. Rainfall mostly occurs in monsoon season with total precipitation of 700mm having peak period in July and September. The area is having cold winter and hot summer, the temperature fluctuates about 16°C and 26°C in summer while in winter the temperature drop to 7°C and 1°C respectively (Nadeem, 2015). The Rawlakot Nallah is the main source of recharge in the area, which originates from Pir Panjal range in the occupied Jammu and Kashmir, flows along the south eastern boundary of the Rawlakot District. The main lithological units exposed are Kamlial Formation of Middle to Early Miocene which dominantly having purple gray to dark red medium to coarse bedded sandstone with intercalation of purple red mudstone to conglomerate underlain by Murree Formation of early Miocene age (Fig. 1). The Siwalik group; Chinji and Nagri formations of late to middle Miocene are also exposed in the vicinity (Shah, 2009). These formations consist of Himalayan molasses deposits, which are sandstones, sediments of clay and unconsolidated sands. While the alluvial deposits, of Holocene age consist of unconsolidated clay, silt, sand and gravel. The top soil is mostly clayey in composition having thickness of 1.5-2 m due to which the infiltration capacity is poor, which halts the vertical flow of water in recharging the aquifer.

Materials and Methods

The Geoelectrical acquisition system used in current investigation are; TSQ-3 Transmitter and RDC-10 receiver of Scintrex Canada aided by generator, stainless steel electrode and potential porous pots. The vertical electrical sounding (VES) with Schlumberger electrode configuration having spacing arrangement of current electrode (AB/2) going from 1.5m to 250m and potential electrode (MN) from 1m to 50m was used for data acquisition to unwrap the nature and subsurface lithology underlying the points (Dahlin, 1996). Ojelabi et al., 2002 ; Atakpo and Ayolabi, 2009 have shown that this configuration has a high penetrating depth per unit current electrode spacing, thereby yielding maximum information on subsurface geology and suitable for ground water exploration and basement complex. In Schlumberger configuration four electrodes with 2 current (AB) and 2 potential (MN)) are placed along a straight line on the earth surface. For any linear, symmetric array of AMNB electrodes, equation for resistivity can be written as:

$$\rho = k\left(\frac{\Delta V}{I}\right)$$

Where, ΔV is the potential difference across the potential electrodes and I is the current applied and k is the Geometric Factor and is given by.

$$k = \pi \frac{(AB/2)^2 - (MN/2)^2}{MN}$$

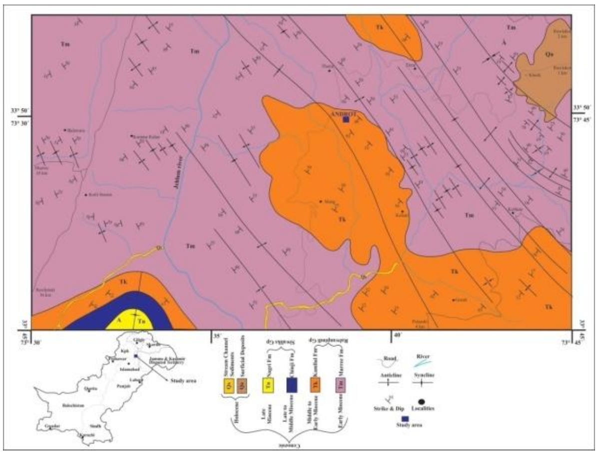

Fig.1 Regional tectonic map of and location of the study area (modified after Walliullah et al., 2004).

Results and Discussion

From the 1D-layered model generated using IPI2win resistivity software; the resistivities associated with each layer were derived together with corresponding thicknesses (Rao et al., 2014). From the analysis of resistivity curves, it was shown that the underlying lithology is of sedimentary in composition, which fit well with the geology of the area. Four lithological units are mainly identified based on the resistivity contrast of different geological materials (Fig. 2), these are shale, clay, clayey shale and clayey sandstone (S.St). The sounding curves are qualitatively and quantitatively analyzed and interpreted using inverse and forward modeling computer iteration software IPI2win to delineate true resistivity, thickness, depth and type of the subsurface layers (Fig: 3). The thickness, depth and corresponding resistivity of different layers interpreted from sounding curves are summarized in Table 1. Pseudo section, resistivity cross section and statistical distribution curves are also prepared using iteration software to trend the change in resistivity and its nature across the profile. Spatial model of apparent resistivity at (AB/2) 30 m, 40 m, 60 m and 80 m depth were prepared using surfer 11.

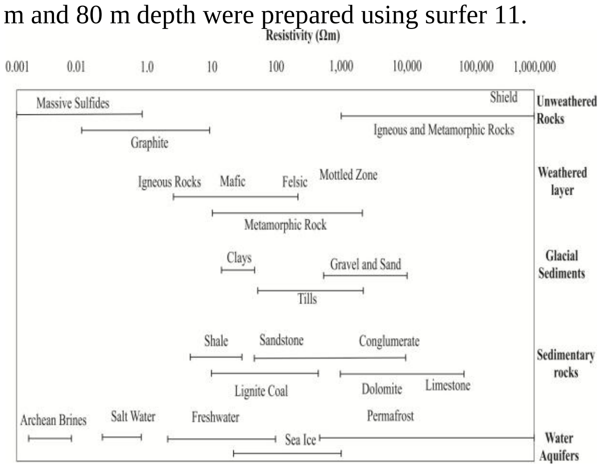

Fig. 2 Approximate resistivity values of common rocks (Telford et al., 1990).

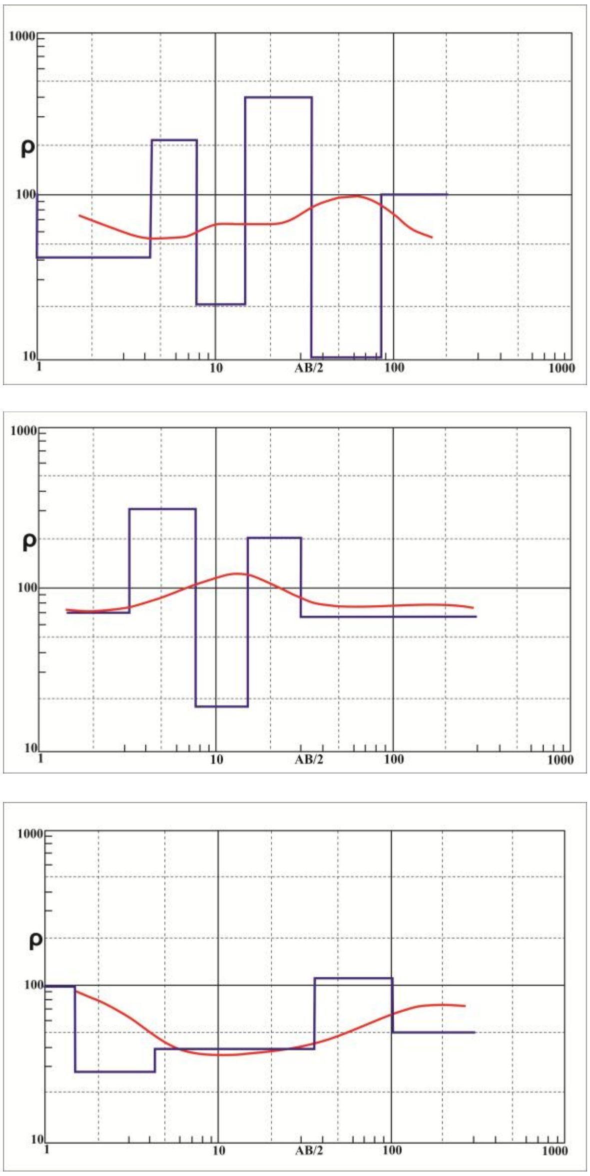

Fig. 3 Numerical modelling of Schlumberger VES data of the study area using IPI2WIN software.

Geoelectrical Cross section

A geoelectrical lithological section has been prepared from the resistivity curves derived from computer iteration software of the study to a depth of 250 m to compare the resistivity and lithology (Fig. 4). The resistivity is in agreement with the geology characterizing ground water potential in fractured weathered clayey sandstone layer based on resistivity value but will be confirmed after drilling. The resistivity of the top soil ranges in 90 Ωm, which is mostly unsaturated with composition of clayey sand. The 2^{nd} layer is characterized by sandstone layer, where resistivity value fluctuate b/w 30-40 Ωm with thickness of 3m-32 m predominantly composed of shale. The last layer having potential of ground water is characterized by fractured clayey sandstone where resistivity value followed a gentle slope with value of 120 Ωm with thickness of 70 m. The last layer is shaley in composition with resistivity of 50 Ωm.

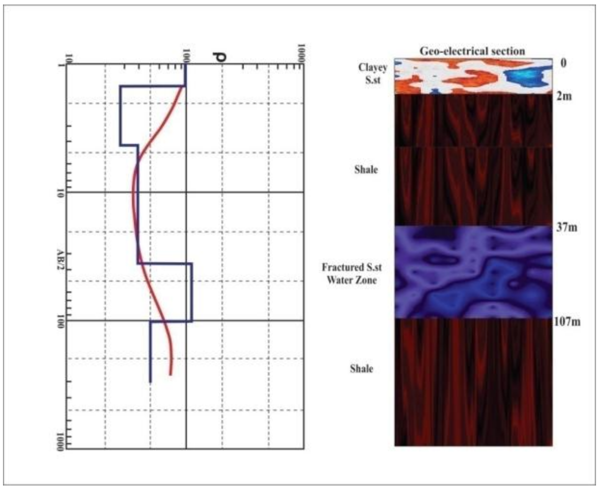

Fig. 4 Geoelectrical lithological section of sounding curve VES-03 in the study area.

Pseudo Section

Pseudo sections have been generated for the VES01-03 using IPI2 win software in order to depict the variety of resistivity over the focuses considered in a profile. The resistivity section shows a linear change in resistivity with depth (Fig. 5). The high resistivity values are recorded at the centre of the section with maximum value of 90-100 Ωm, sandwich in between layer of low resistivity of 70-75 Ωm. This low resistivity peculiarity augments assist showing loose strata such as shale and clay at the top to a depth of 3 m, as the resistivity value continuously decrease downward from 3m clayey content increases along VES-01 and 03. A zone of clayey weathered sandstone is encountered by VES-02 at a depth of 10 m having thickness of 20 m, showing aquifer holding water as a reservoir. The resistivity value of 35 Ωm-45Ωm inferred as shaley soil (SS), 45Ωm-55Ωm shaley-clayey soil (CSS), 55Ωm-70Ωm clayey soil (CS) and 70 Ωm-100Ω m inferred as clayey sandstone (CS.st) and is a probable good aquifer.

Resistivity Section

Resistivity section is prepared for the same profiles for which the pseudo section is prepared. It is clearly evident that resistivity value varies with depth in a periodic manner (Fig. 6). Along west side of the resistivity section along VES-01 a decrease value of resistivity is observed ranges between 100 Ωm- 37Ωm from top to 15m, beyond from that depth 15m to 35m, characterized by high resistivity value of 270-350 Ωm is demarcated. With further increase in depth the resistivity values drop to 50-70 Ωm to a depth of 60m, characterized by further increase to 100-150 Ωm to a depth of 105 m. At the centre of the section at VES-02, a resistivity increase is recorded from at a depth Range of 25m- 45m with value of 270 Ωm-350 Ωm and deciphered as sandstone beds, followed by a decrease vale of 100 Ωm-190 Ωm to a depth of 100 m and as interpreted as thick bed of mixed clay and sandstone beds. Along east side of resistivity section along VES-

03 a decrease value of resistivity is recorded from top to a depth of 35 m having value of 10 Ωm-30 Ωm and interpreted as shale beds,. With increase in depth the resistivity value ranges from 100 Ωm-140 Ωm to a depth of 100 m and interpreted as thick mixed clay sandstone bed. At a depth of 100 m with resistivity value of 70 Ωm-100Ωm interpreted as clayey shale beds. The resistivity trend generally increases in resistivity which shows the presence of sandstone beds at greater depth. The water reservoir is mostly concentrated at the resistivity value of 140 Ωm to 350 Ωm showing the mixed clayey sandstone to fractured sandstone beds having good porosity and permeability and probable good reservoir encountered at the depth of 20m along VES-01, 25 m at VES-02 and 35m at VES-03 of the resistivity section.

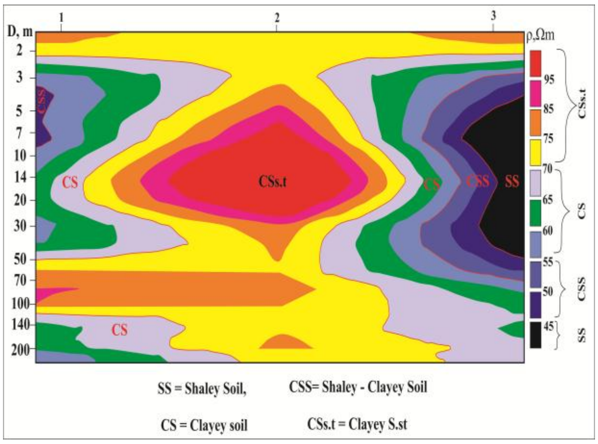

Fig. 5 Pseudo section of VES01 to VES03.

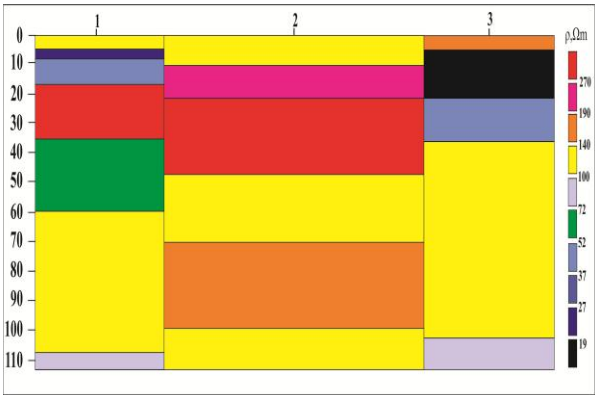

Fig. 6 Resistivity cross section of VES01 to VES03.

Statistical Distribution Curve

Statistical distribution curve (SDC) is generated by IPI2 win, which compares with all the resistivity value for VES to decipher the trend of resistivity with changing AB/2 (Fig. 7). From SDC, it is inferred that at a depth (AB/2) 0 m-3m, the trend is steep downward with resistivity value of 75Ωm-60Ωm showing presence of clayey shale as a top soil. As the depth increase the SDC shows a linear horizontal trend to a depth of 3m-9m with resistivity value of 55Ωm, and inferred as shale lithology. At a depth range of 9m - 30m, the SDC curve follows a dome shaped trend showing linear increase and decrease trend, where resistivity value change between 55Ωm -70Ωm showing clay to shale lithology. A steep upward trend is observed at a depth range of 40m-100m, where resistivity value rises from 55Ωm to 90 Ωm showing the presence of clayey sandstone and is inferred good reservoir for ground water. With further increase in depth from 100m the resistivity shows a gentle downward trend with resistivity value drop to 65Ωm to at depth of 250 m and is interpreted as mixed clay to shaley lithology. From SDC, it is inferred that the area is dominantly composed of clayey shale as a top soil followed by shale and beyond from the depth of 40m the sandstone content increases from clayey sand to sand with depth. The trend of SDC curve is in agreement with the pseudo section (Fig. 5), resistivity cross section (Fig. 6) and geology of the area.

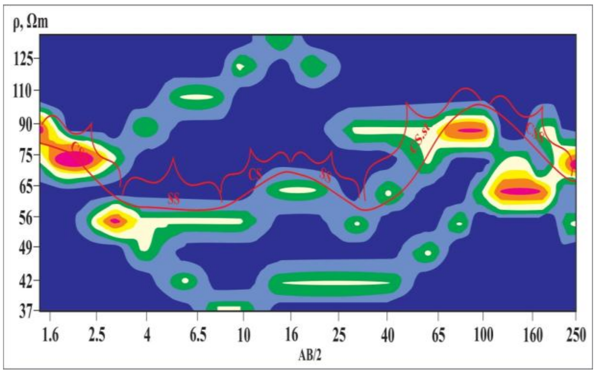

Fig.7 Statistical distribution curve of Androt area.

Spatial model of apparent resistivity

Based on the resistivity distribution of subsurface layers and change of resistivity value with depth, the spatial distributions of resistivity are modeled with various depths of (AB/2) 30 m, 40 m, 60 m, and 80 m maps are prepared using surfer 11.

The apparent resistivity value for (AB/2) 30 m and 40 m depth shows the resistivity range of 42 Ωm to78 Ωm. The maximum resistivity observed at the uppermost NW side of the section with a value of 68Ωm -78Ωm, a lowest resistivity value of 42 -55Ωm observed at the SE and SW area of the section, while resistivity of intermediate value is observed along middle NE and NW portion with a value of 52Ωm-62Ωm (Fig. 7). It is inferred that the uppermost NW side is having fractured sandstone lithology with intercalation of clay, while the SE and SW side is predominantly composed of shale to clayey in composition.

The apparent resistivity section at 60 m and 80 m depth shows moderate to high resistivity, with resistivity values ranges from 59Ωm to 85Ωm (Fig. 8). The minimal resistivity value is observed in lowermost SW side of the section with value ranges from 59 Ωm-64 Ωm shows the presence of clayey-shale beds. The maximum resistivity value is noted along NE side of the section with a value of 78Ωm-85Ωm which shows the presence of sandy to clayey lithology.

From analysis of the depth section, it is inferred that with increase in depth there is increase in resistivity value and increase in sandstone content. The apparent resistivity shows that maximum resistivity NE side and NW side showing presence loose fractured sandstone with intercalation of clay sandstone bed at a depth of 30m to 80m and having potential of ground water. The results are in confirmation and agreement with the geology of the area.

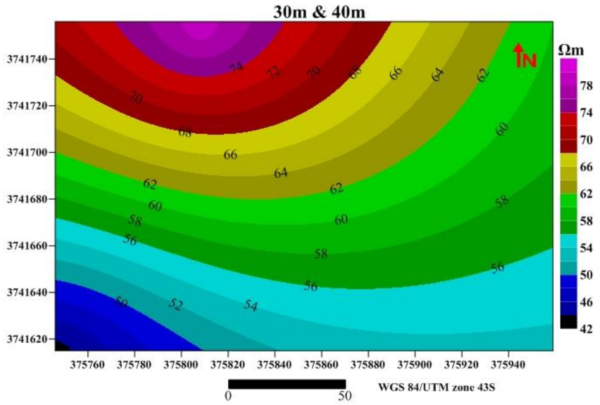

Fig. 8 Spatial distribution of apparent resistivity at (AB/2) 30 m and 40 m.

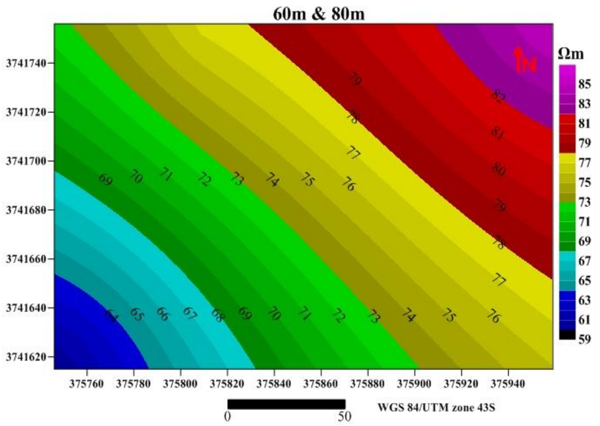

Fig. 9 Spatial distribution of apparent resistivity at (AB/2) 60m and 80 m.

Table 1 Summary of VES analysis.

VES N0	Layer	ρ (Ωm)	Thickness (m)	Depth (m)
1	**Shale**	40	1.5	3
	Clayey S.st	120	5	8
	Shale	20	7	15
	Clayey S.st	302	20	35
	Shale	10	60	95
	Clayey Soil	100		
2	**Shaley Clayey soil**	70	4	
	Clayey S.st	320	5	9
	Shale	18	8	17
	Clayey S.st	206	13	30
	Shaley Clayey Shale	67		
3	**Clayey Soil**	90	2	
	Shale	30	3	5
	Clayey Shale	40	32	37
	Weathered S.st	120	70	107
	Clayey Shale	50		

Conclusion

On the basis of VES results and prevailing knowledge about the geology of the study are, it is concluded that:

- The area mainly composed of four basic geological units that are, fractured sandstone, clayey-shale, clay and shale beds.
- The shale is having low resistivity value of 10 Ωm to 45 Ωm and clay resistivity varies between 50 Ωm to 70 Ωm and having potential of water content but due to less permeability of shale and clay, these zone are not productive.
- Porous and fractured sandstones are the main zone for water accumulation and productive zone inferred from the app. resistivity value of 80 Ωm to 100 Ωm and may prove comparatively better aquifer but will be proved only after test drilling.
- The productive zones in the study area as a reservoir along which drilling may be carried out are sandstone with clay intercalation along which drilling is recommended to a depth range of 25m - 35m.
- The presence of clay intercalation halted the extraction of water due to its poor permeability and recharge will be the main concern after extended drought period.
- However, lateral extent of the aquifer and recharge will remain the main consideration even if the productivity at the particular site is proved. It is recommended to do deep drilling up to 80 m to puncture the entire fracture sandstone zone for good recharge and permeability.
- The outcome from this study is useful for technical groundwater management as they obviously distinguished reasonable borehole locations for long haul groundwater prospecting.

Acknowledgement

Authors are very grateful to Dr. Imran Ahmad Khan, Director General Geological Survey of Pakistan and Federal Ministry of Petroleum and Natural Resources for financial assistance to carry out this work. Authors are also thankful to Secretariat Department of AJ&K for providing facilities during field work. They are also grateful to Geophysical Assistant Mr. Zahid Sarfaraz for assisting in the field work. Finally, t authors also thankful to all members of Geophysics Division, Geological Survey of Pakistan, Quetta for their valuable suggestions and support to carry out this work.

References

Ademilua, O L., Ojo, O F., Eluwole, A B., Ademilua, O B. (2014). Geophysical survey for groundwater resource appraissal in a basement complex terrain for agricultural purposes; Case Study of ABUAD Teaching and Research Farm Ado Ekiti Southwest Nigeria. *Global Journal of Science Frontier*

Research, **14**(5), 1-14.

Arshad, M., Cheema, J., Ahmed, S. (2007). Determination of lithology and groundwater quality using electrical resistivity survey. *International Journal of Agriculture and Biology*, **9**(1), 143-146.

Atakpo, E A., Ayolabi, E A. (2009). Evaluation of aquifer vulnerability and the protective capacity in some oil producing communities of western Niger Delta. *The Environmentalist*, **29**(3), 310-317.

Dahlin, T. (1996). 2D Resistivity surveying for environmental and engineering applications. *First break*, **14**(7), 275-283.

Huang, Y P., Kung, W J., Lee, C.H. (2011). Estimating aquifer transmissivity in a basin based on stream hydrograph records using an analytical approach. *Environmental Earth Sciences*, **63**(3), 461-468.

Kearey, P., Brooks, M., Hill, I. (2002). *An Introduction to Geophysical Exploration.* 3rd edition, Blackwell Boston, London, 272 pages.

Loague, K., Abrams, R H., Davis, S N., Nguyen, A., Stewart, I T. (1998). A case study simulation of DBCP groundwater contamination in Fresno County California and transport in the saturated subsurface. *Journal of Contaminant Hydrology*, **29**(2), 137-163.

Martinelli, E. (1978). Groundwater exploration by geoelectrical methods in Southern Africa. *Bulliten of Engineering Geology*, **15**(1), 113-124.

Maury, S., Balaji, S. (2014). Geoelectrical method in the investigation of groundwater resource and related issues in Ophiolite and Flysch formations of Port Blair, Andaman Island, India. *Environmental Earth Sciences*, **71**(1), 183-199.

Metwaly, M., El-Qady, G., Massoud, U., El-Kenawy, A., Matsushima, J., Al-Arifi, N. (2010). Integrated geoelectrical survey for groundwater and shallow subsurface evaluation: Case study at Siliy in spring, El-Fayoum, Egypt. *International Journal of Earth Sciences*, **99**(6), 1427-1436.

Nadeem, F. (2015). Pakistan Monsoon 2015 Rainfall. *CDPC Technical Report*, 2/2015, 4.

Ndlovu, S., Mpofu, V., Manatsa, D., Muchuweni, E. (2010). Mapping groundwater aquifers using dowsing, slingram electromagnetic suvey method and vertical electrical sounding jointly in the granite rock formation: A case of Matshetshe rural area in Zimbabwe. *Journal of Sustainable Development in Africa*, **12**, 199-208.

Ojelabi, E., Badmus, B., Salau, A. (2002). Comparative analysis of Wenner and Schlumberger methods of geoelectric sounding in subsurface delineation and groundwater exploration-A case study. *Geological Society of India*, **60**(6), 623-628.

Shah, S M I. (2009). *Stratigraphy of Pakistan*. 22nd edition, Geological Survey of Pakistan Publication Directorate, Quetta Pakistan, 381pages.

Telford, W M., Geldart, L P., Sheriff, R E. (1990). *Applied geophysics*. 2nd edition, Cambridge University Press, Cambridge, UK, 770 pages.

Thakur, V., Jayangondaperumal, R., Malik, M. (2010). Redefining Medlicott–Wadia's main boundary fault from Jhelum to Yamuna: An active fault strand of the main boundary thrust in northwest Himalaya. *Tectonophysics*, **489**(1), 29-42.

Van Overmeeren, R. (1989). Aquifer boundaries explored by geoelectrical measurements in the coastal plain of Yemen: A case of equivalence. *Geophysics*, **54**(1), 38-48.

Venkata Rao, G., Kalpana, P., Rao, R S. (2014). Groundwater investigation using geophysical methods-A case study of Pydibhimavaram Industrial area. *International Journal of Research in Engineering and Technology*, **3**, 13-17.

Walliullah., Nasir, S., Hussain, A., Akhtar, S S. (2004). Geological map of Thorar Area District Rawlakot AJK and part of Rawalpindi district Pakistan 43G/9. *Geological Survey of Pakistan Publication Directorate Quetta*, **19**, 1-1.

Zektser, I S., Lorne, E. (2004). *Groundwater resources of the world and their Use*. 6th edition, Unesco place de Fontenoy Paris, France, 342 pages.