

Mapping subsurface groundwater contamination zones using electrical resistivity methods in Osmania university campus, Hyderabad, Telangana state, India

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Abstract

An investigation has been laid of the groundwater potentials and contamination studies of Osmania University campus area, Hyderabad using Hydrogeological and Geoelectrical surveys. Hydrogeological investigations from data of 35 observation wells form the campus, the depth to the water table varies from 4 to 20m and study area, while the direction of groundwater flow is towards the N-S and NW-SE. The average depth water table is 8.5m below the surface. 103 Vertical Electrical Soundings were conducted with maximum electrode spacing of 150m, the results reveals that substantial lowering electrical resistivity signatures, broadly indicating the zones contamination and groundwater.

Keywords: Vertical Electrical sounding, contamination, electrical resistivity

Introduction

The Osmania University campus (O.U) located in Hyderabad city. After about ninety seven years of existence, the university has yet to be connected to a municipal water sources. Recent growth in students, new departments and staff populations has imposed significant on the existing inadequate water sources, based on groundwater abstraction from boreholes in the Osmania University campus. The focus was to delineate the area in to hydrogeological zones in order to increase the number of bore holes in the area.

Groundwater occurrence in the hard rock terrain can be vary irregular due to abrupt discontinuity in lithology, thickness and electrical properties of the over burden and weathered bed rock (Udaya Laxmi and Ramadass 2009 [1]. Consequently groundwater exploration within such a geological setting needs broad geophysical data sets effectively characterise the hydrogeological zones and to enhance successful identification wells and quality of water.

Electrical methods such as the Electrical Resistivity Profiling, Vertical Electrical Soundings (VES), Electromagnetic (EM) and the Induced Potential (IP) have found favour in geological studies (Kelly and Mares, 1993 [2]. The theory and field practice of electrical methods is well documented by Koefed (1979) [3], Parasnis (1973) [4], and among others. The interpretation of resistivity data and its applications to geological studies has been given in detail by Zohdy (1964 [5], 1965 [6] and 1975 [7]. Many researchers have employed electrical methods of prospecting comprise a wide variety of techniques which utilize different electrical properties and their related phenomena to

distinguish between different geological formations or to delineate structures (G. Udaya Laxmi and G. Ramadass, 2013 [8]. Subsurface characteristics are deduced from measured electrical properties of the earth such as resistivity. Though several geophysical methods are applicable for weathered zone studies under various geological conditions, the electrical methods are especially suited; they can quickly and cheaply demarcate the weathered zones and determine the extent of layers strata. The basic methodology of the electrical method rests on the fact that the resistivity of saturated soil is variable, depending upon on the layers resistivity and the properties of the geological formations for geological studies (Patangay *et al.*, 2002 [9], Ebrahim *et al.*, 1990 [10], De Lima *et al.*, 1995 [11]. In the present investigation, Vertical Electrical Soundings (VES) were carried out in the hard rock terrain of Osmania University campus, Hyderabad to delineate structural configuration and hydrogeological conditions at depth variance contaminated groundwater zones and its quality.

Study Area and Topography

The study area selected for surface geophysical surveys in the O.U campus (78° 31' 00"E Longitude to 78° 32' 30" E Longitude and 17° 23' 48" N Latitude to 17° 25' 42" N Latitude) area has on approximate 6.58 sq.kms (1627.32 acres) and lies in Hyderabad metro politon city (SOI toposheet no. 56 K/11/N-W). The topography of the O.U campus area can be treated as undulating with a gradual relief towards N-E. The maximum elevation observed is 535m and minimum elevation is 503m with the mean sea level (Figure: 1).

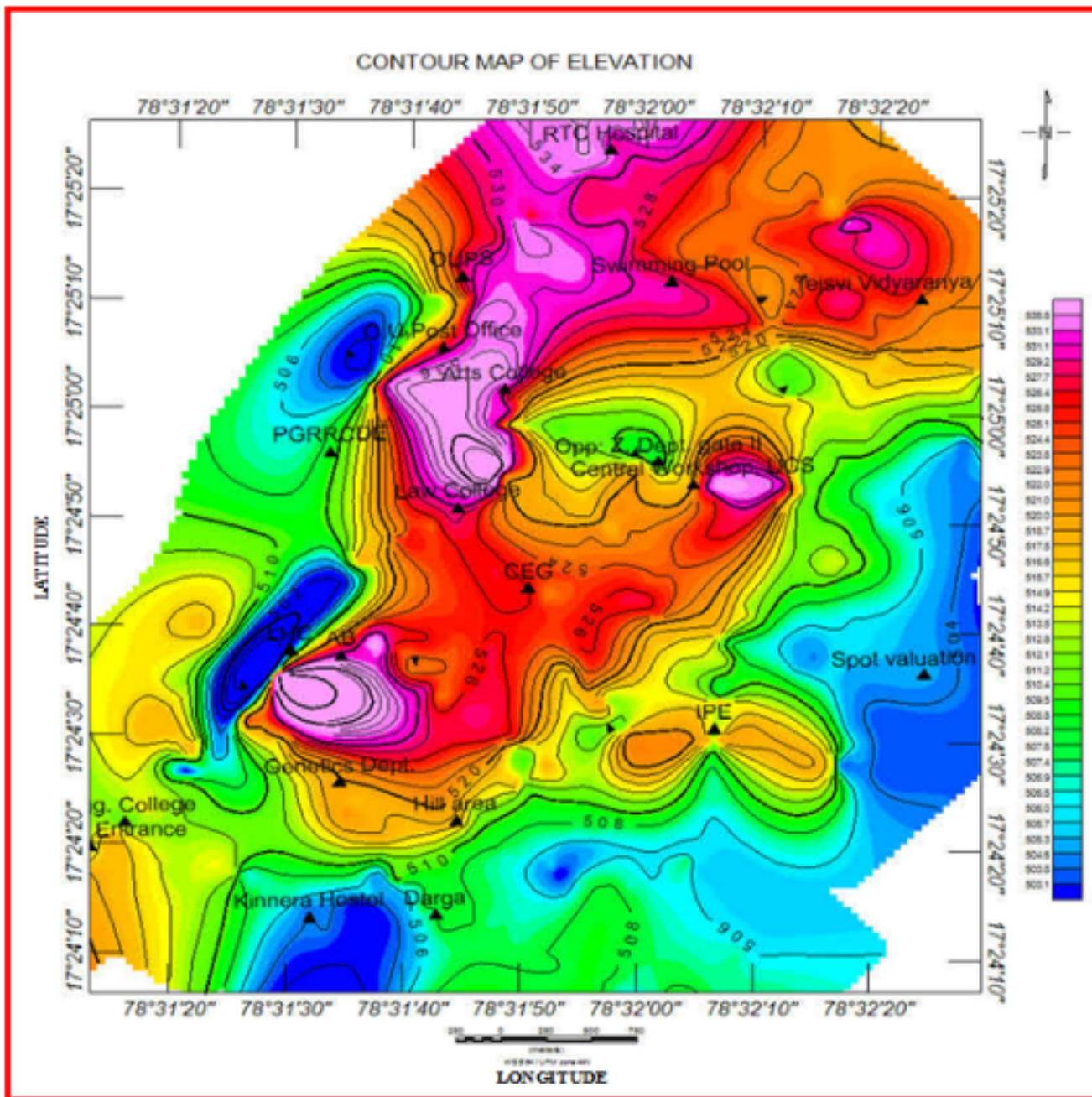


Fig 1: Contour map of elevation of study area Osmania University (Contour Interval 1.5 m)

Most of the major construction of the University are on the ridges. The area in general gently slopes approximately from north to south. Present the area under the University construction is approximately 6.58 sqkms (1627.32 acres).

Drainage

The drainage is mostly dendritic which is characteristic of the granitic country and becomes radial at some places. The general

trend of the drainage is towards the south joining the musri river. There is nallah running parallel to the road leading to Elegugutta hill, which takes many turns and finally attains north-south trend. There are three tanks in the area–Mohini Cheruvu, Landscape Garden tank and Ramanthapur Cheruvu (Figure: 2). The last one falls outside the university area, which was once part of it

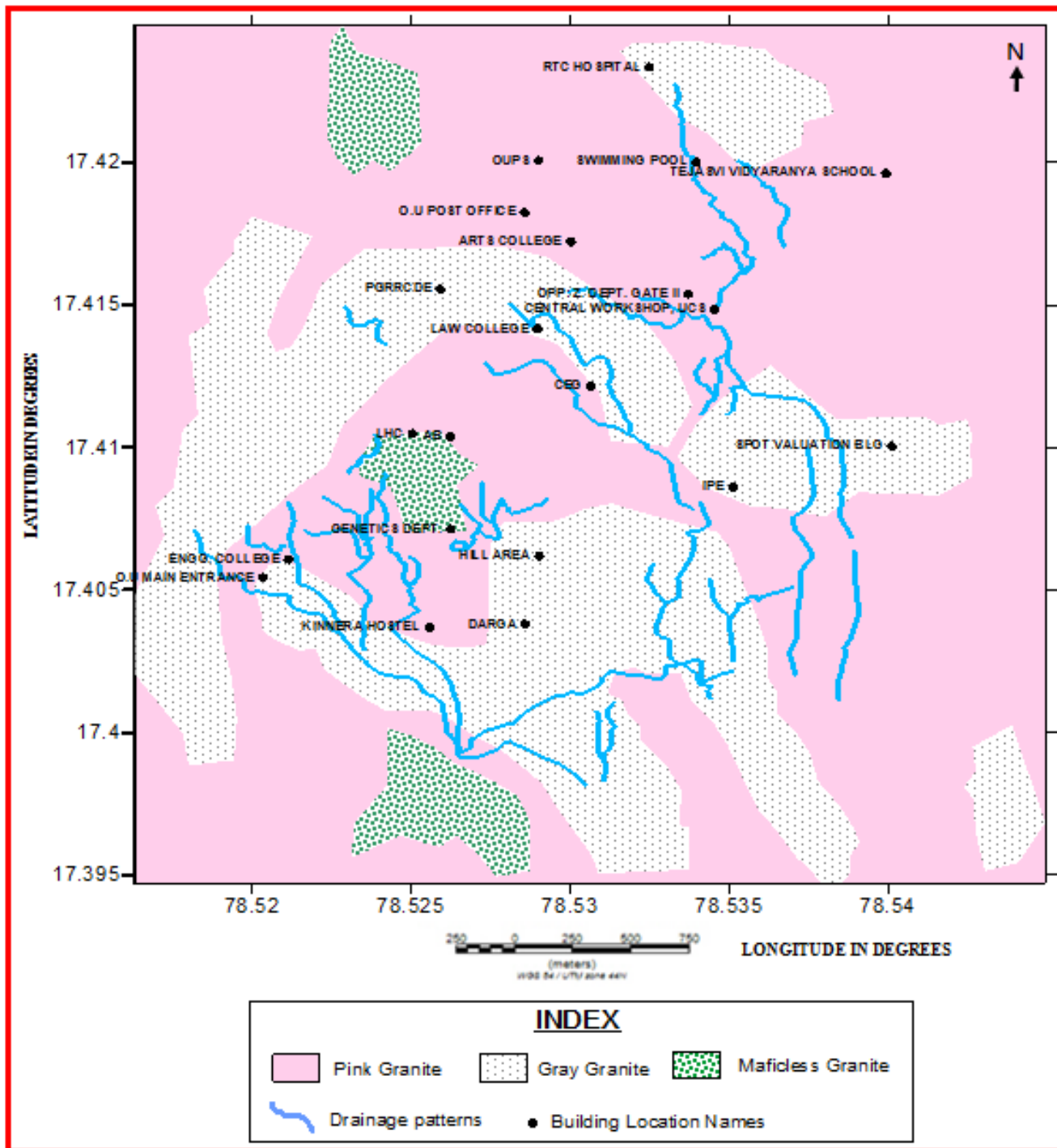


Fig 2: Drainage Patterns and Geology of the Study area

The Landscape Garden tank was formed due to the construction of a small dam like bund which is in a valley across the nallah. The tanks total area extent is about 1/2 sq.km. Under normal rainfall, the tank gets overflowed. However, due to the continuous drought for the last few years it does not contain much water. Of the three tanks, the major one is Mohini Cheruvu which gets filled with most of the University's run off water.

Geology of the Hyderabad

Hyderabad is centrally located on the top of the Deccan Plateau, presently is one of the fastest growing cities of India. The Hyderabad Urban Agglomeration (HUA) is the sixth largest in

India and is spread over an area of 778 sq. kms. The area has undulating topography with elevation ranging from 503 to 563 m amsl. The main geomorphic units are residual Hills, pediment inselbergs, Pedi plains and valley fills. Hyderabad forms part of the Pre-Cambrian peninsular shield and is underlain by the Archaean crystalline complex, comprising of granites intruded by dolerite dykes. A thin veneer of alluvium of recent age occurs along the Musi River. Granites exhibit structural features such as fractures, joints, faults and fissures. In case of Soils, most of the soils are of red lateritic, yellow sandy clay loams and alluvial black soils. The thickness of the soil cover ranges from 0.5m to 2.0m.

Geology of the Area

The Osmania University campus (78°31'00"E Longitude to 78°32'30"E Longitude and 17°23'48" N Latitude to 17°25'42" N Latitude) is situated in an area of approximately 6.58 sq kms. (1627.32 acres) (Figure: 3) in a granitic terrain. Here three types of granites exist—pink, grey and the leucogranites (Balakrishana and Rao, 1961 [12]; Sitaramayya, 1968 [13], 1971 [14] and some

pegmatite patches traversed by narrow white apatite veins, which intersect each other randomly. The granitic host rocks are intruded at places with doleritic dykes. The general geological section consists of a surficial soil layer underlain by weathered rock, which is in turn followed by the fractured rock at a few places. The basement, occurring at an average depth of 15 m consists of hard impervious granite.

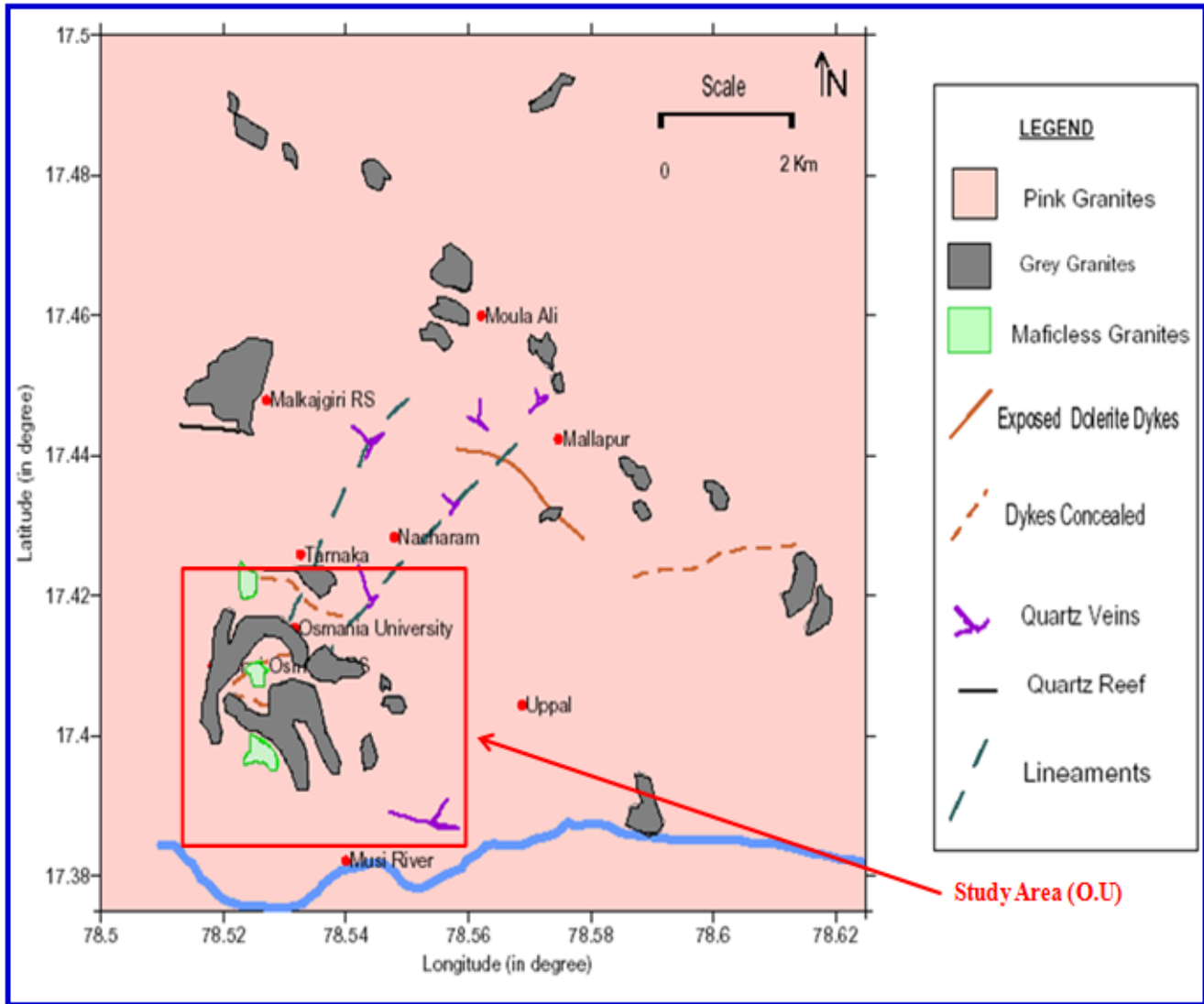


Fig 3: Geology Map of the Study Area (After G. Udayalaxmi, 2009 [1])

Hydrogeology

The occurrence, origin and distribution of groundwater are controlled by the type and nature of geologic formations (Figure: 4). Few tasks in hydrogeology are more difficult than

locating drilling sites for water wells in igneous and metamorphic rocks as these rocks do not contain primary porosity and permeability and hence is poor water-bearing formations.



Fig 4: Hydrogeology of Hyderabad (source: Central Groundwater Board)

In hard rock areas like the present granitic terrain, geomorphology, structure and weathering are the most important factors that control groundwater. Discharge areas which are normally low lying areas are believed to contain much more groundwater than recharge areas which normally coincide with ridges. This may be due to less subsurface runoff, influent seepage from upland areas, weak structural planes and thick weathered mantle. The analysis of drainage network in the area also suggests suitable locations for exploitation of groundwater.

Weathered disintegrated material and the fractured/jointed granitic rocks of the region are the repositories for groundwater

accumulation. Greater the thickness of the weathered rock, greater the potentials for tapping groundwater. Similarly, greater the density of fractures/joints and greater the potential of subsurface water.

As is well known weathering process in a granitic area which penetrates deep causes joints, faults and other fractures because of the weight of the overlying material, and openings at great depths are large enough to supply water to wells. The narrow fractures which are more or less parallel to the surface in sheet structure which is the common feature to a granitic terrain are important sources of water.

Hydrated minerals in the weathered rock at the surface will form loose aggregates which have porosities in excess of 35%. The porosity decreases with depth to zones in which the original rock-forming minerals are only partly altered indicating the absence of chemical weathering. In general the greatest permeability is found within partly decomposed rock below the zone of abundant clay-size material.

Groundwater Levels

It is observed that in general the depth to water levels ranged between 5 and 20 m but on an average it is around 12 m. The general depth to water level during pre-monsoon period varies from 5 m to 20 m bgl (Below Ground Level), whereas, during post monsoon periods, it varies from 2 m to 15 m bgl.

Considering the limited potential of hard rock aquifers, reduced recharge and that the resource is being tapped from deeper depths, there is possibility of degradation of groundwater beyond recoverable level in future due to rapid urbanization in Hyderabad (Figure: 5). Groundwater needs to be carefully managed if its use is to be sustained for future generations. Management is required to avoid serious degradation and there needs to be increased awareness of groundwater at the planning stage, to ensure equity for all stakeholders and most important of all to match water quality to end use (thereby maintaining the best quality for potable use). Although groundwater is not easily contaminated, once this occurs it is difficult to remediate, and in the developing world, such remediation may prove practically impossible.

In the Osmania University campus, there are about 56 bore wells and 4 dug wells (Table: 1). Groundwater occurs under water table conditions in the weathered formation with depths ranging between 15-25m. Groundwater also occurs under semi-confined to confined conditions in the subsurface fractured rocks. However, it is very difficult to differentiate or demarcate between the two zones as the boundary is gradational and there is no clear contact. The maximum depth of existing bore wells range up to 1000 feet and the invariable basement is struck in all the bore wells. The thickness of the water-bearing weathered/fractured rock is between 10 to 30m. The dug well is up to a maximum depth of 14 meters and a minimum depth of meters. Maximum depth of the water table is 7meters and

minimum depth is 1m which is subjected to variation due to rainfall drought and withdrawal

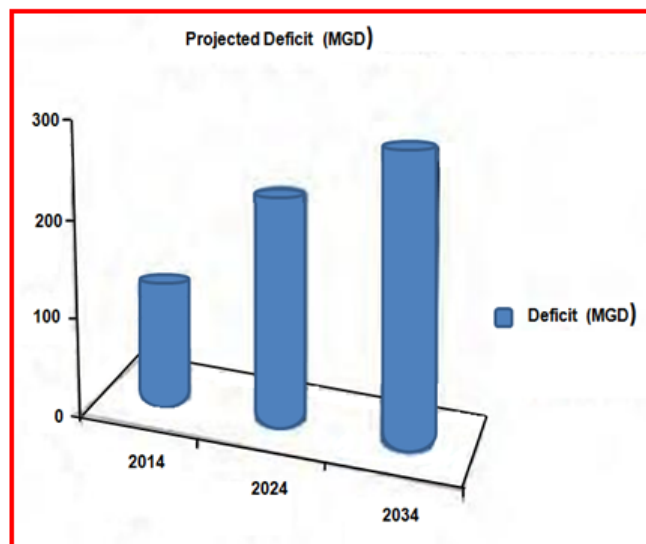


Fig 5: Projected Water Deficit of Hyderabad

Hydrogeological investigations in study area – Osmania University and surrounding regions – consisted of water level monitoring in selected observation well. Observations were made over a total of 105 wells in the region during March 2012. The reduced levels of observation wells with respect to mean sea level and water levels in meters above mean sea level (amsl) for November 2014 (the post monsoon season).

The large variation in depth to water table (1-30 m) is attributable to variations in the thickness of the weathered zone, variable intensity of weathering and also the extensive withdrawal rates prevalent in the region. The heavy withdrawal from the fractured aquifer is considered to have induced large leakage from the upper aquifers.

The groundwater level contours (Figure: 2.3(b) for the above period show that the direction of groundwater flow is towards the SE and SW in the study area.

Table 1: Reduced level of Observation Wells and Groundwater levels (m-amsl) in Study Area (BW: Bore well; OW: Open well; DTW: Depth of Water Table; RL: Reduced Level)

	Bore well	Location	Latitude	Longitude	Total Depth (m)	DTW (m)	RL (m-amsl)	WL (m-amsl)
1	BW	At Auditorium Road	17.4137	78.5304	27.40	0.50	518.00	517.50
2	BW	At 'B' Blocks	17.4060	78.5186	24.40	20.00	515.00	495
3	BW	At Biochemistry Dept.	17.4178	78.5320	32.00	12.00	525.00	513
4	BW	At Botanical Garden	17.4153	78.5316	21.60	8.00	523.00	515
5	BW	At Electronics & Comm. Engg. Dept.	17.4071	78.5197	30.00	9.00	512.00	503
6	BW	At Examination Branch	17.4113	78.5258	18.00	2.00	533.00	531
7	BW	At Ganga Hostel	17.4081	78.5222	14.50	4.00	515.00	511
8	BW	At Ladies Hostel	17.4110	78.5230	10.00	7.00	519.00	512
9	BW	At Menial Quarters	17.4154	78.5217	36.60	12.00	519.00	507
10	BW	At Narmada Hostel	17.4206	78.5337	30.50	7.00	523.00	516
11	OW	At OUB-4	17.4125	78.5229	19.00	13.00	524.00	511
12	OW	At Sadik Ali Open Well	17.4136	78.5225	22.50	9.72	519.00	509.28
13	BW	At Swimming Pool	17.4216	78.5317	26.50	8.00	525.00	517
14	OW	B.Ed College	17.4227	78.5287	20.00	9.00	534.00	525
15	BW	Back side of Diamond Jubilee Library	17.4058	78.5210	22.00	9.00	512.00	503

16	BW	Back side of Mech. Engg.	17.4018	78.5240	56.00	15.00	502.00	487
17	BW	Back side of Microbiology	17.4053	78.5257	20.00	6.00	507.00	501
18	BW	Behind New Spot Valuation Building	17.4091	78.5405	15.00	9.00	503.00	494
19	BW	ECH (II) Back side	17.4072	78.5220	19.55	10.00	507.00	497
20	BW	Genetics	17.4052	78.5248	21.00	6.00	506.00	500
21	BW	In Landscape Garden	17.4144	78.5289	14.00	6.00	525.00	519
22	OW	Manchineela Bavi	17.4151	78.5362	4.00	0.40	512.00	511.60
23	BW	Near ASRC	17.4075	78.5320	24.60	6.00	512.00	506
24	BW	Near Nursery Garden	17.4030	78.5261	16.00	9.00	503.00	494
25	BW	Near O.U 'B' Hostel	17.4092	78.5423	---	9.00	504.00	495
26	BW	Near Tennis Court	17.4219	78.5339	32.00	8.00	525.00	517
27	BW	Near Thermal Engineering lab	17.4046	78.5222	57.00	8.44	506.00	497.56
28	BW	New Ladies Hostel	17.4115	78.5228	24.00	9.00	522.00	513
29	BW	Old Diary Behind to NCC	17.4115	78.5394	24.85	8.00	507.00	499
30	BW	Old Diary Form	17.4101	78.5392	19.00	10.00	506.00	496
31	BW	Opposite Manjeera Hostel	17.4234	78.5313	28.50	8.00	528.00	520
32	BW	Opposite Navigation Electronics	17.4076	78.5204	22.00	8.00	509.00	501
33	BW	Opposite R-15 at Angad bazar	17.4187	78.5386	26.00	9.00	515.00	506
34	BW	OUB-29	17.4118	78.5203	15.00	9.00	516.00	507

(Continued Table: 1)

35	OW	OUB-7	17.4190	78.5350	25.00	11.00	518.00	507
36	BW	At D Hostel before main entrance	17.41275	78.52825	10.00	6.70	525	518.30
37	BW	CHW-I Lawn (Ladies Hostel)	17.41156	78.52256	169.6	6.5	516	509.50
38	BW	Opposite portico (Ladies Hostel)	17.41078	78.52314	121.2	6.8	517	510.20
39	BW	Engg. Girls Hostel (Tech.) (Ladies Hostel)	17.40992	78.52236	121.2	10	518	508
40	BW	Near Septic Tank Opposite Darga	17.40944	78.53675	151.5	12	510	498
41	BW	Maneru Hostel (Near IPE)	17.40983	78.53469	151.5	13	513	500
42	BW	Geography	17.41175	78.53069	136.3	9	520	511
43	BW	VC Lodge junction	17.41031	78.52744	106	6.5	520	513.50
44	BW	Near Camp-6 open well	17.41194	78.52153	136.3	10	517	507
45	BW	Near Hi-Tech Hostel	17.40800	78.52275	90.9	12	521	509
46	BW	Near Yellamma Temple	17.40972	78.52322	172.1	7	513	506
47	BW	Science & Humanities (Nursery Garden)	17.40833	78.52081	90.9	6.5	516	509.5
48	BW	Biomedical Engineering	17.40842	78.52061	90.9	8	517	509
49	BW	Non Teaching Home	17.41100	78.52083	151.5	7.5	532	524.5
50	BW	Physical Education Department	17.41175	78.53611	196.9	7	520	513
51	BW	C Hostel near gate	17.42131	78.53133	195.4	6.5	506	499.50
52	BW	Geophysics Department	17.41094	78.53550	171.2	7	518	511
53	BW	Administrative Building	17.40972	78.52394	178.7	9	517	508
54	BW	Near R/36 Quarter Opp. Teachers Flats	17.41969	78.53853	121.2	8.5	520	511.50
55	BW	A Ground	17.42147	78.53244	30.3	7	515	508
56	BW	Near B Mess back side	17.42178	78.53003	121.2	6.5	523	516.5

Geophysical Database

A total of 103 vertical electrical soundings (VES), Schlumberger configuration with maximum AB/2 spacing of 150m were carried out with N-S and E-W azimuth at selected locations covering the entire area in the field seasons during the period 2011-2014 (Figure: 6).

The resistivity sounding curves obtained from the study area vary of a 3-layers A and H types which are characterizing of the basement complex terrain. The H type is the most dominant curve type in the study area with particularly curve of 46% similarly, A type 26%. 4 - layers HA, HK and KH type with percentage curve of 22%, 1% and 5% respectively. It is observed that the dominant type of curves is the A type followed by the H type. Occasionally, wherever fracture and

multilayer zones present four layers (Figure: 7(a) and (b)) type of curves observed. The frequency of the VES curve type shown in the table: 2 and a few typical VES curves are shown in Figure: 8.

Table 2: VES Curve Type Frequency in the Study Area

Curve Type	Frequency
A	26
H	46
HA	22
HK	1
KH	5

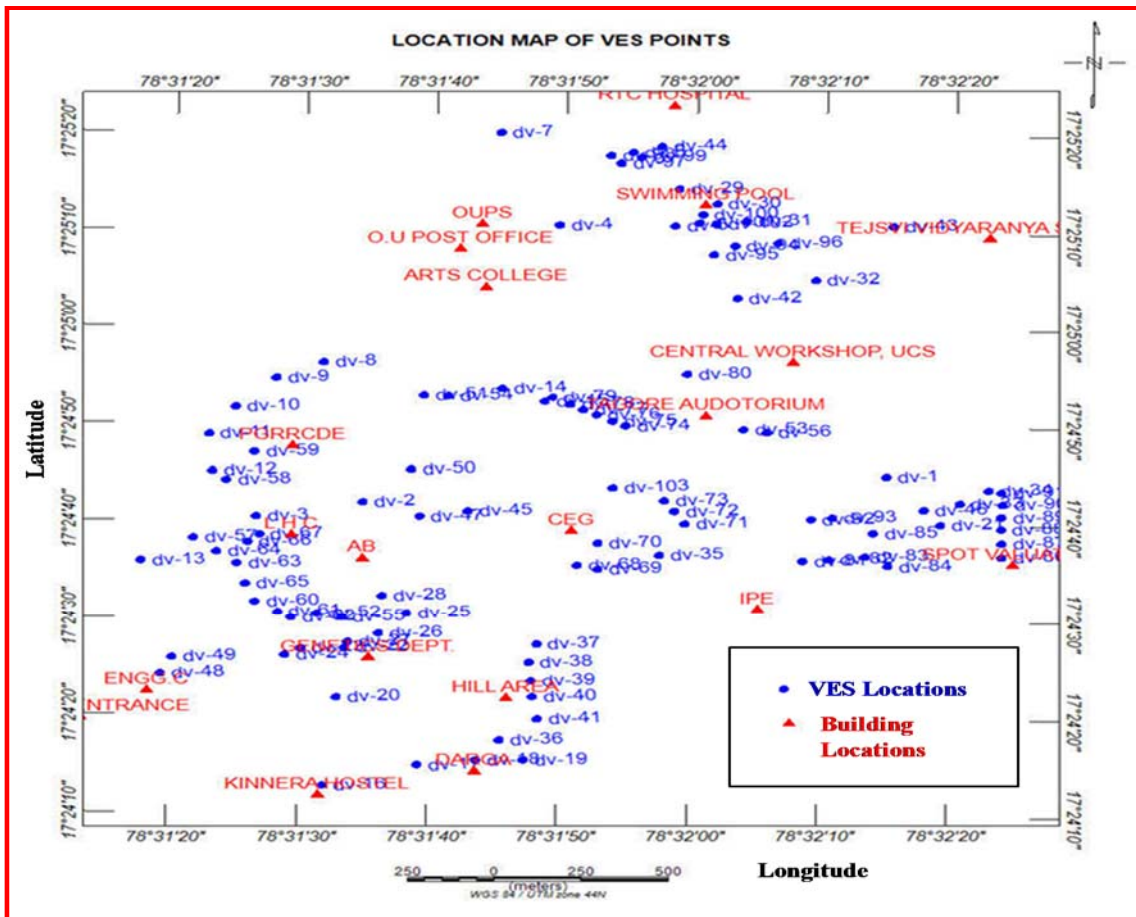


Fig 6: Map of Locations of Vertical Electrical Sounding (VES) Points Carried out in the O.U Study Area.

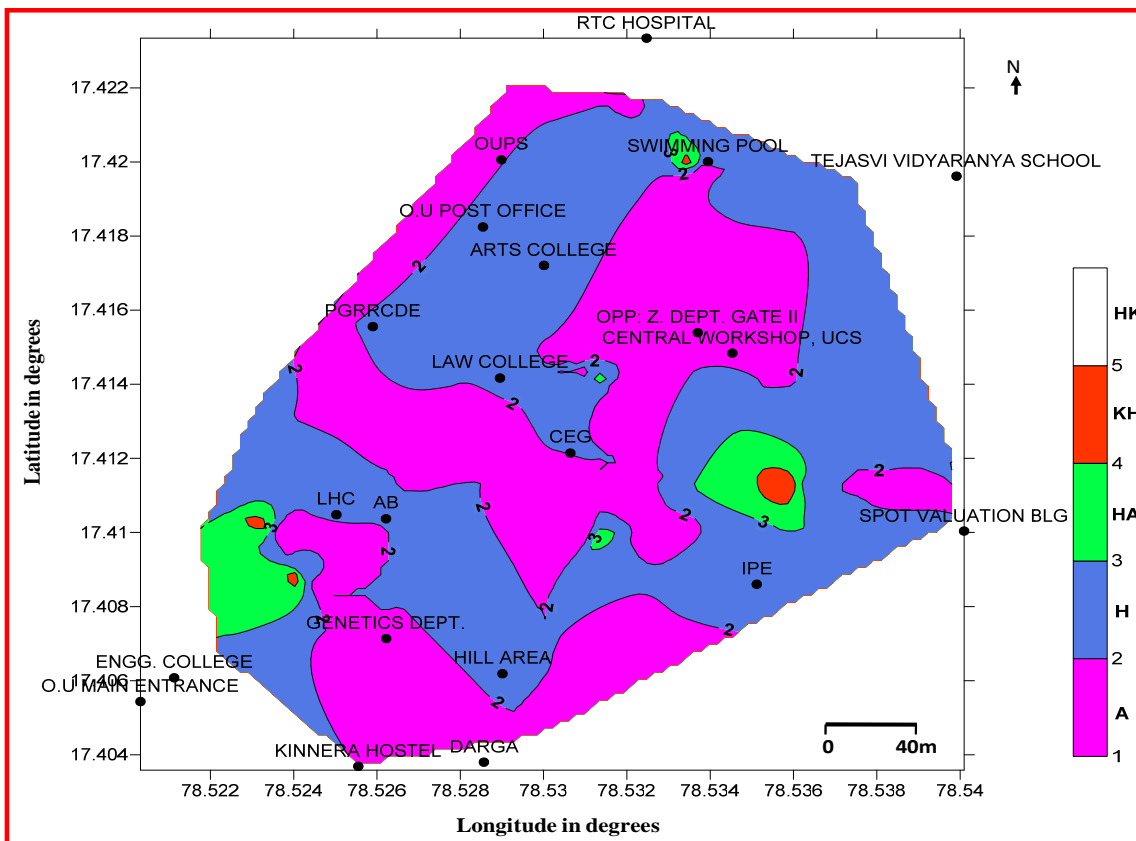


Fig7: (a) Contour Map of the VES Curve Types in the Study Area (Contour Interval 1)

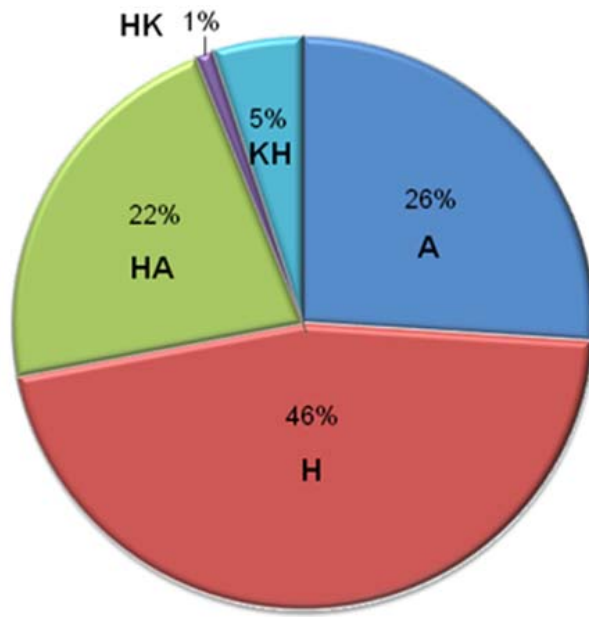
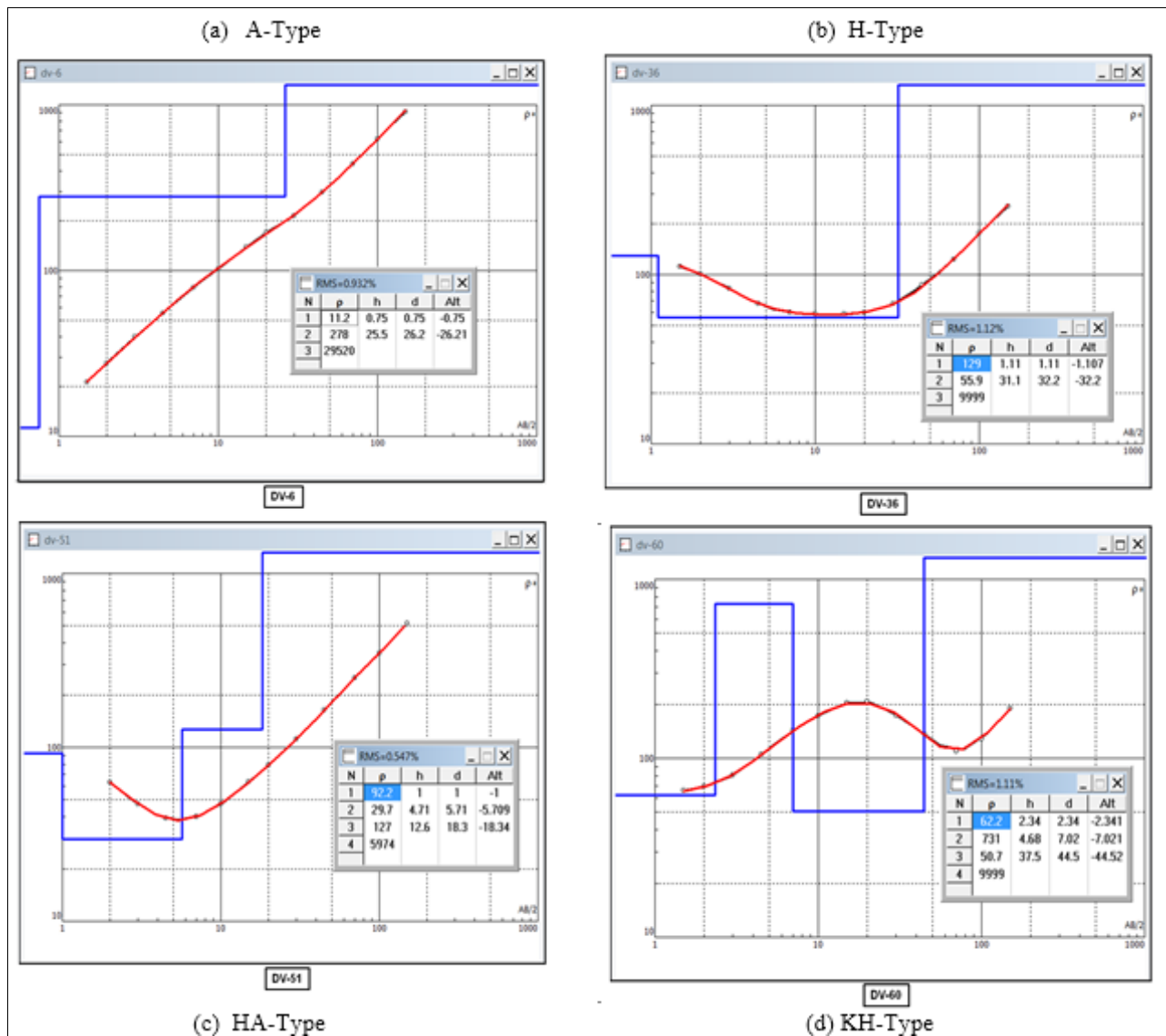


Fig 7: (b) Distribution of Curve Type in the Study Area



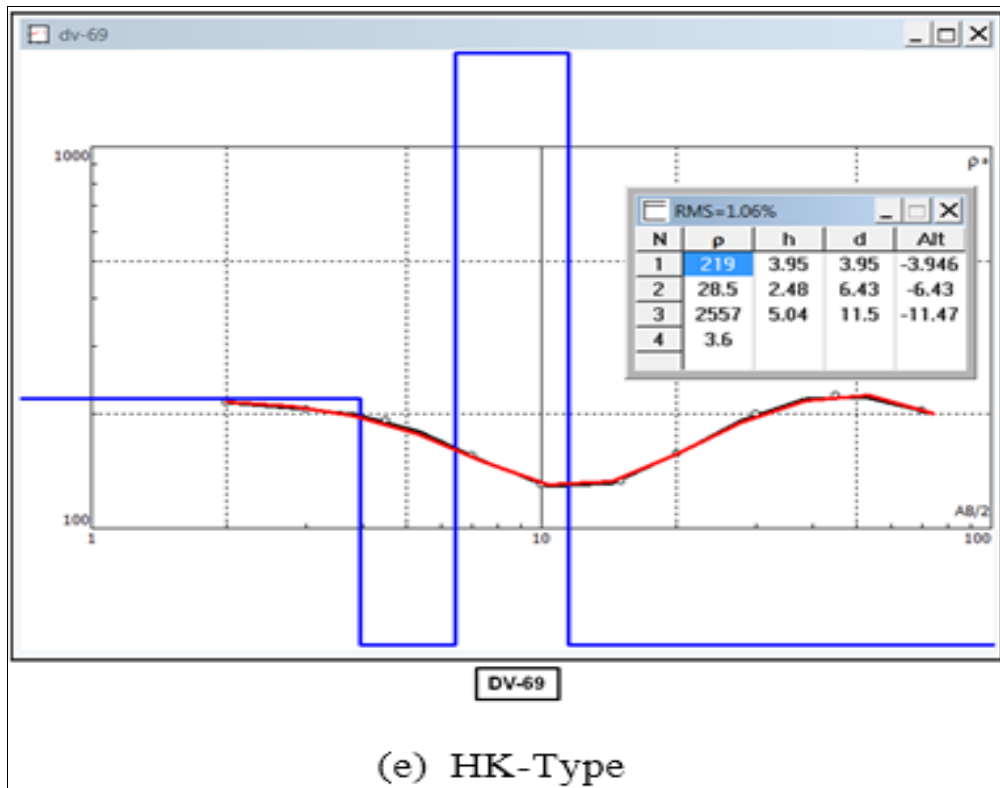


Fig 8: Some Typical Interpreted VES Curves in the Study Area. [(a) A-type, (b) H-type, (c) HA-type, (d) KH-type and (e) HK-type].

Qualitative Analysis

Maps contoured at an interval of 10Ωm for AB/2 separation of 20m and 45m, (Figure: 9 a & b) respectively. These maps show the lateral and vertical distribution of resistivity. The distributions of high > 40Ωm and low resistivity zone are similar to all the five AB/2 separations. Figure: 9 (a & b) reveals significant resistivity lows < 20Ωm attributable with groundwater contamination in AB/2 with 20m

separation map and low resistivity zone is essentially similar at all five AB/2 separations, whereas high resistivities are dispersive throughout the study region. The vertical extents of resistivity low values are apparent resistivity up to AB/2 of 45m separation, resistivity lows are observed at 5 places in the area PGRRCDE, north of Tagore Auditorium, in front of CEG and southern part of the study region.

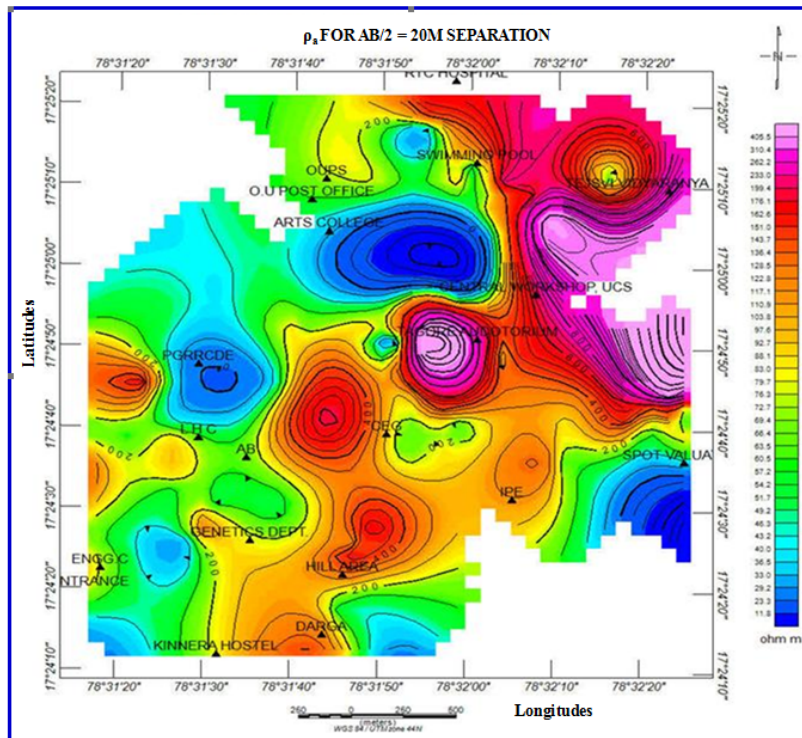


Fig 9: (a) Contour Maps of ρ_a with AB/2 Separation of (a) 20m and (b) 45m in the Study Area (Contour Interval 10 Ωm)

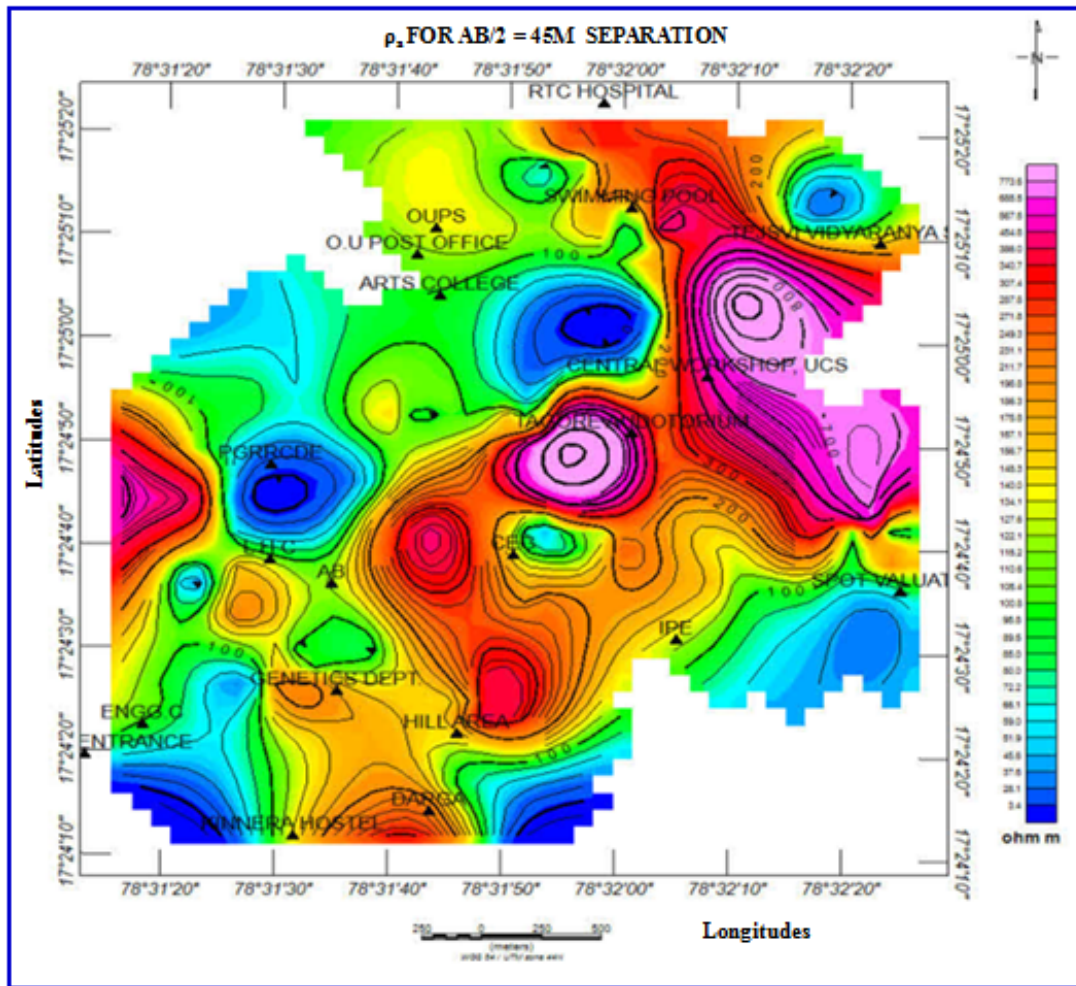


Fig 9: (b) Continued (Contour Interval 10Ωm)

The broad low resistivity may be attributed to clay formations. The low resistivity zones are less pronounced in the contour map corresponding to AB/2 with 150m in probably a reflection of the lower limit of the pollution/contamination. In the northeastern part of the study region resistivity high values trending NW-SE directions in all AB/2 maps (Figure: 9 a & b). In the central part of the study area also observed high resistivity values are indicative of by exposed basement (crystalline rock). This zone is not derived by groundwater. It is also apparent that width and vertical extent of the low resistivity zone are diminishing by AB/2 separation of 20m and 45m.

Summary and Conclusions

The geoelectrical investigations (VES) are surface to lateral litho variations are thus useful to delineate resistivity lows represents which are contaminated zones in the study area. The resistivity values AB/2 of 20 and 45 separations, the resistivities less than 25 Ω m polluted/contaminated zones and further extended the horizontal and vertical variation in the electrical characteristics of the subsurface and the resistivity range from 42 to 60 Ωm shown as potential zones. Hydrological investigations consisted of well data of 35 observation wells in study area O.U campus. The depth to the water table varied from 0.4-20m in study area O.U campus, while the direction of groundwater flow is towards the SE and SW, the average depth to the water table is 8.5m below the surface. Aquifer parameter Transmissivity values of 30-190 m²/day for the study area.

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