DISCUSSION

HYDROGEOLOGICAL INVESTIGATIONS IN NAMAGIRIPETTAI AREA, NAMAKKAL DISTRICT, TAMIL NADU by P.N. Ballukraya. Jour. Geol. Soc. India, v.58, no.3, Sept. 2001, pp.239-249

(1)

N. Lakshmi Narayana, Geohouse, H.No.2-4-38/C/2, Road No.2, Adarsh Nagar, Nagole, Hyderabad - 500 068 comments:

1. Based on the information furnished under hydrogeology it is noted that (a) water-bearing joints occur up to a depth of 300 m below ground level, (b) the average depth of agricultural borewells at present is 198 m, (c) a few borewells drilled in 1999 are as deep as 350 m, etc. Based on the availability of detailed hydrogeological information of the area it is clear that the targeted depth ranges from 200 m to 350 m. While conducting soundings (VES) employing Schlumberger electrode array it is expected that the current electrode (AB) separation to be three to five times more than the targeted depth i.e., in the present case (AB) a minimum of 600 m to 1000 m or more. Surprisingly in this very important project, the current electrode (AB) separations were extended generally up to 300 m and to a maximum of 500 m.
2. Based on the geological and structural information furnished, it is clear that "northeast and southwest trending joints are dominant and a majority of lineaments retained and marked (Fig.1) here seem to be approximately parallel to the strike direction of the dominant joints". To avoid the variation in resistivity measurements due to the formation anisotropy, lineaments, joints etc., instead of keeping the current electrode spread along north-south it should have been in northeast-southwest direction (except in the southeast corner of the area (Fig.1) where it could be in southeast-northwest direction). Any radial soundings/profiling conducted in the area to assess the axis/direction of anisotropy?
3. The VES curves indicate a four-layered sub-surface in the area, corresponding to the topsoil, weathered rock, fractured rock and basement. From Table 1, 13 VES curves were interpreted for 5 layers. Then how this relatively high resistive fourth layer i.e., resistivity of 430, 500, 1170, 2500, 1400, 378, 540, 1450, 198, 162, 304, 480 and 6026 (all in Ohm-m) at sounding location VES - 34, 36, 38, 41, 47, 52, 55, 61, 73, 82, 86, 87 and 90 respectively is accounted when in the same VES locations the third layer resistivity is 105, 140, 220, 120, 93, 57, 35, 126, 44, 32, 210, 232 and 264 (all in Ohm-m)? If the third and fourth layers are interpreted for the "fractured zone", how the variation in resistivity as low as 32 Ohm-m (third layer at VES-82) and high of 6026 Ohm-m (fourth layer at VES-90) could be grouped into one geoelectric layer termed as 'fractured rock'?
4. The topsoil resistivity is ranging from as low as 4 Ohm-m to 350 Ohm-m (Table 1). The top soil resistivity is less than 10 Ohm-m at 7 locations; 10-20 Ohm-m at 20 VES locations; more than 100 Ohm-m at 23 locations and in the remaining locations it is in the range of 20-100 Ohm-m. How this variation in resistivity is accounted for the topsoil.
5. While doing soundings (VES) in hard rock area, for better interpretation it is necessary to extend the current electrodes till the attainment of infinity or 45° line or S-line in the sounding curves. In the present study, the VES curves have recorded the reflection of basement or infinity for the separation of AB/2 to 250 or 150 m. Though the VES interpreted results (Table 1) confirms the recording of high resistivity basement in all the soundings, presentation of a few sounding curves with the interpreted model would have helped in a better understanding the nature of sub surface particularly where the topsoil is as low as 4 Ohm-m.
6. From the interpreted results (Table 1), the depth to high resistive geoelectric layer (interpreted as basement) is ranging from as low as 3 m (VES-80) to 99.3 m (VES-47). While the groundwater potential zone is expected in the depth range of 200 m to 350 m, how can the sounding results recorded in the study area are supportive particularly when the depth interpreted (Table 1) is in the range of 3-10 m at 6 locations: 10-20 m at 14 locations; 20-50 m at 46 locations and 50-99.3 m at 24 locations?

7. Based on the apparent resistivity sections (Figs.3A and 3B) and geoelectric sections (Figs. 4A and 4C) drawn from two north-south profiles, several conclusions were drawn on the lateral variation and in particular about the presence of lineaments. This shows that the expected axis of anisotropy is parallel to north-south direction.
8. The data on the soundings considered for preparing geoelectric sections (Fig. 4A and C) were also considered for the apparent resistivity sections (Figs.3A and B). But, the structural features brought out from the apparent resistivity sections and its corresponding geoelectric sections (Figs.3A and B; 4A and C) appears to be different and not matching.
9. The interpreted sounding results (Table 1) presented in the form of geoelectric sections (Figs.4A, B, C, and D) do not match. For instance

   - The results of VES-34 shown in Figs.4B and C
   - The results of VES-27 shown in in Figs.4C and D
   - VES-3, 31 and 6 are three layered cases as per Table 1 but are shown as four layered cases in geoelectrical sections (Figs.4A, C and D)
   - VES-18 is interpreted as two layered (Table 1) but presented as four layered (Fig.4C)
   - VES-40 is interpreted as 4 layered (Table 1) but presented as three layered

10. The spatial distribution pattern of apparent resistivity values at AB/2=100 m in the area is shown in Fig.5A and concluded that "the map however, does not indicate any specific linear pattern in the distribution of apparent resistivity, as one would expect in the area of lineament – controlled hydrogeology". What is the basis adopted to fix AB/2 at 100 m? From Fig.4A to D it appears that the thickness of soil+weathered zone is uniform. But there is a significant variation in the thickness of fractured rock. Is the AB/2=100 m penetration aimed to reflect the fractured rock?
11. The spatial distribution of the resistivity of the fractured rock layer is shown in Fig.5B and concluded that "there is no perceptible linear pattern indicative of lineaments controlled hydrogeology". The resistivity of the fractured rock is varying from as low as 32 Ohm-m (at VES-82) to as high as 6026 Ohm-m (at VES-90). The thickness of the fractured rock is varying from 7.5 m (at VES-40) to 88 m (at VES-47). The contour map indicating the thickness of fractured rock would have contributed significant information on the possible groundwater potential zones of greater depths.
12. From the hydrogeological data of the study area, it is observed that the weathered rock layer is not productive. In this situation instead of total longitudinal conductance (as calculated in the present study) the longitudinal conductance of fractured rock layer i.e., S3=h3/R3 would have been more appropriate (since high thickness of h3 and lower values of R3 will result for the higher values of S3) for locating the groundwater potential zones in the fractured rock layer. The total longitudinal conductance 'S' calculated in this paper is >0.5 at VES-1 (0.68); 7 (0.59); 13 (0.54); 42 (0.52); 47 (0.92); 49 (0.62); 51 (0.61); 52 (0.54); 53 (0.65); 54 (0.85); 55 (0.55); 56 (0.97); 73 (0.98); 78 (0.50) and 82 (0.66). But the longitudinal conductance of 'fractured rock layer' is >0.5 only at two sounding locations i.e., at VES-47 (0.58) and 56 (0.69).
13. Based on the merged data map (Fig.6) of the area, it has been concluded that "all the three geoelectric parameters i.e., resistivity less than 300 Ohm-m for the fractured layers, S value more than 0.5 and depth to the bedrock at more than 50 m are favourable values at two locations". The points to be clarified are:

   - How the total longitudinal conductance S (S1+S2+S3 and +S4 in five layered cases) was considered instead of S3 (longitudinal conductance of fractured rock, S3+S4 in five layered cases) alone?
   - At the favourable zone indicated in the northeastern corner of the study area (Fig.6) the basement depth is ranging from 50 m to 99.3 m when the targeted depth is from 200 to 350 m.
   - Table 1 indicates that all the three geoelectric parameters have favourable values at 8 locations i.e., VES-7, 42, 47, 52, 55, 56, 73 and 82 but are not reflected in merged data map (Fig.6). Out of these locations (1) VES-42 is in the northeastern corner of the area whereas VES-47 is near to the lineament, (2) VES-7, 52, 55 and 56 are in the central part of the area amidst many lineaments and (3) VES-73 and 82 are in the northwestern part of the area where VES-73 is near to the lineament. All these 8 locations are associated with high yielding wells.
   - Had the longitudinal conductance of 'fractured rock layer' been considered (instead of the total longitudinal conductance as considered in the paper), all the three geoelectric parameters would have shown favourable values at VES-47, 56 and 73. Even the merged data map (Fig.6) reveals that VES-47 and 73 are near to the lineament and VES-56 at the intersection points of lineaments. All the three locations have high yielding wells.

14. The targeted depth of information in delineating/ mapping the groundwater potential zones is around 200 m to 350 m. The depth of information obtained in the soundings ranges from 3 m to 99.3 m only. Then how the author can justify his statements which reads that
    - the geoelectrical parameters could not also be correlated with groundwater availability in the area and this is essentially because of the nature of hard rock hydrogeology, particularly under over-exploited conditions, where most of groundwater comes from the highly resistive bedrock layer.
    - The study also shows that the deep water-bearing horizons are not indicated in the VES curves and therefore location of sites for construction of borewells in such areas (where these zones are to be found only below 120-150 m) is difficult.
15. The magnetic survey along the profiles (across the targeted lineaments, joints, faults etc., delineated based on the remote sensing studies) would have helped to map the targeted features.

P.N. Ballukraya, Department of Applied Geology, University of Madras, Guindy Campus, Chennai - 600 025 replies:

I wish to thank Dr. N. Lakshmi Narayana for his comments. It is indeed gratifying that he has taken the trouble of going through the paper in depth. Following are the item-wise replies to his observations/comments.

1. It is true that the targeted depth is 200-350 m and under ideal conditions the electrode separation, AB should have been about 600-1000 m. However, in the present investigation this was not possible due to certain field constraints. In any case, test soundings near existing borewells showed that the producing zones were largely confined to the highly resistive bedrock layer. Once this layer (45° slope) is obtained in the VES curves, further expansion of AB may not provide any further information about greater depths. Hence, no need to have such large electrode separations in this area.
2. Normally electrode azimuth is kept parallel to the foliation trend of the country rock. But, due to field constraints, the azimuth was kept north-south. Since there is bound to be anisotropy caused by the rock structure, all the soundings were uniformly recorded near north-south azimuths, so that the effect of at least one variable is removed from the data.
3. The variation in the absolute values of resistivity of the fractured rock layer could be due to the degree of fracturing, extent of weathering along these fractures, quality of groundwater, etc. Some rationalization has been used in relating geoelectric layers with lithology.
4. The variation in resistivity of topsoil (1 layer) may be due to soil type, clay and moisture content present in it.
5. As already stated, majority of VES curves have attained 45° slope and any further expansion of AB separations would not have given any additional information about deeper horizons. Since interpreted results of all the soundings were furnished, it was opined not necessary to provide field curves.
6. The water-bearing fractures present in the high-resistivity geoelectric layers may not possibly be identified from the VES curve interpretation since they cannot significantly contribute to the measured signal.
7. North-south profiles were drawn not because of the axis of anisotropy but due to most of the lineaments in the area cutting along those lines.
8. Apparent resistivity sections and geoelectric sections need not be identical. A VES curve with low apparent resistivity value may have a high-resistivity geoelectric layer. For example, VES-6 shows a low apparent resistivity value of 112 Ohm-m at AB/2=100 m while it indicates infinite high resistivity layer at a depth of only 3.6 m.
9. I thank N. Lakshmi Narayana for pointing out some errors that crept in, while drawing the geoelectric sections. However, the depth to bedrock marked is correct. In a few cases where the sounding indicated lesser or more geoelectric layers than the neighbhouring soundings, some smoothening of the section has been done.
10. All the apparent resistivity contour maps drawn for various AB separations showed essentially the same spatial pattern. The 100 m separation figure was selected with a consideration that the first producing zone in borewells is generally around this depth.
11. There is of course a wide variation in both thickness and resistivity of the fractured rock layer. N. Lakshmi Narayana suggests that the fractured rock thickness by itself could have contributed more significant information. The depth to bedrock map in Fig.5D also includes the thickness of fractured rock.
12. The S_3 (h_3/ρ_3) map could have been drawn instead of S_1 map. But since most water producing zones are in the high resistivity layer below it, even S_3 map may not have indicated better groundwater potential zone.

Further, from Table 1, even if S_3 maps were to be prepared, the spatial pattern would still have been the same (except for the values).

13. The pattern of S3 distribution (not absolute value) is similar to that of S value.

    No information regarding water-bearing horizons at 300 m is likely to be obtained by increasing the electrode separation since these fractures are in the highly resistive geoelectric layers.

    Data merged map has been prepared using contours drawn with the help of a computer software. The two zones (not VES locations) where all the favourable conditions coincide are seen in the area of VES 47 and 56. No doubt all the three parameters have favourable values at several VES locations as pointed out by N. Lakshmi Narayana but they do not form a spatial pattern. However, it is incorrect to say that all the 8 locations are associated with high yielding wells and that the groundwater potential shall be high when all the three parameters are favourable. For example, the nearest borewell to the VES-7 site is very low-yielding. Similar is the case in other seven locations pointed out by N. Lakshmi Narayana, or for that matter in the entire area. VES-56 is quite some distance away from the junction of lineaments. There are several low-yielding borewells around this location as well.

    Several high yielding wells are located near VES 40-43 area. However, in this instance only VES-42 has all the three parameters favourable. Only VES-40 and 41 have low resistivity fractured rock layers while 40, 41 and 43 have all low S values. This indicate that the well yields are not really related to the geoelectrical parameters in this area.

14. As noted earlier, since water-producing fractures are found mostly in the highly resistive bedrock (geoelectric layer with 45° slope) and the fact that they could not be identified from VES curves shows that there is no need to expand the AB separation further. The fractures are very thin, generally less than a metre thick, and their contribution to the total signal will be insignificant. They do not give rise to enough resistivity contrast for them to be reflected in the VES curve. Thus, the geoelectric parameters used in this study do not necessarily indicate potential groundwater zone. The two conclusions made in the paper are hence justified.

15. I agree with N. Lakshmi Narayana that magnetic surveys will be an additional tool in mapping geological structures.

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K.S. Subramanian, Plot 283, 17th East Street, Kamraj Nagar, Chennai - 600 041 comments:

Dr. Ballukraya's interesting article (September, 2001) lucidly reviews the painstaking studies carried out in the Namakkal District, Tamil Nadu, where the groundwater level in the Precambrian terrain is sinking steadily like the setting Sun. He has observed (page 247) that '... there is no apparent concentration of high-yielding wells along these linear features' and '... this lack of relationship indicates that lineaments may not control the availability of groundwater in a hard rock area'. It is not clear whether the lineaments represent linear structural features like faults and fractures, which are known to influence the groundwater regime. Or are they just linear features of unknown identity without any structural significance? Analysis as to whether the lineaments are structural features or otherwise has taken a back seat.

P.N. Ballukraya, Department of Applied Geology, University of Madras, Guindy Campus, Chennai - 600 025 replies:

I thank Sri K.S. Subramanian for his comments. He has commented on the possible nature of the linear features that were interpreted from satellite imagery and further mapped in the area. The study area is located in a tectonically disturbed terrain. These lineaments are probably the fracture zones or faults. The possibility of these linear features being unknown identities cannot be ruled out. The confirmation of smaller lineaments on ground is a difficult task. Linear features representing ridges and dykes have not been included in the study.