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Restoration of Minor Irrigation Tank Using Geophysical Methods in Deccan Traps – A Case Study in Sawangi, Amravati District, Maharashtra

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Abstract: *In watershed areas the groundwater management can be solved by building irrigation tanks to sustain from drought and improve crop yield. The minor irrigation tanks can also supply water for drinking purpose. When the tank is full to its capacity during the rainy season, it should be able to supply water both for irrigation and drinking purposes even during the dry season. Any leakages in the subsurface of the tank would result in seepage of water into the ground and the tank would be dry during the summer months. An attempt has been made to identify the leakages in a minor irrigation tank using geophysical methods, which would enable to study not only the leakages but also the flow direction of the leakages along fractures or joints in the tank. This can lead to improved sustainability of the minor irrigation tank during the dry seasons. A detailed geophysical investigation has been carried out on minor irrigation tank located in village Sawangi, Warud taluka, District Amaravti, Maharashtra, India. In this area a large number of minor irrigation tanks have been constructed for groundwater management. One tank located in the area with a storage capacity is 521 Mm3 and water spread area is 37 ha has been chosen for the present study. The average normal rainfall of this area is 710 mm. During the rainy season when the rainfall in the area is normal or above normal the tank attains a full capacity. Subsurface leakages were observed in this tank and it was found that water was draining and the tank was not able to sustain its capacity during the summer months. The leakages were detected in the upstream direction and the downstream direction of the tank. Geophysical studies using Electrical resistivity, Self-potential and VLF EM surveys were carried out to detect the leakages. The fractures zones were identified to be oriented in NW-SE direction in the massive basalt formations and accordingly measures were taken to plug the leakages. This paper presents the applicability using geophysical studies for detection of leakages in minor irrigation tank with a case study.*

Keywords-*Deccan trap, Gradient Resistivity Profiling, Hydrogeology, Sawangi Tank, Self-potential, Tank Leakage, VLF EM*

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I. INTRODUCTION

The Sawangi Minor Irrigation tank (SMI) constructed across a major north-south stream in the village Sawangi, Warud taluka, District Amaravti, Maharashtra, India (Figure 1). The Sawangi Minor irrigation tank is located due South-East at about 2.5 km distance from the Village Sawangi. The tank is spread over an area of about 1014.64 ha and lies between the coordinates 21°29'31” E and 78°21'44” N and the elevation is about 400 MSL. The area falls in the SE quadrant of Survey of India Toposheet No 55 K/6, 55 K/7 (1:50,000 scale).

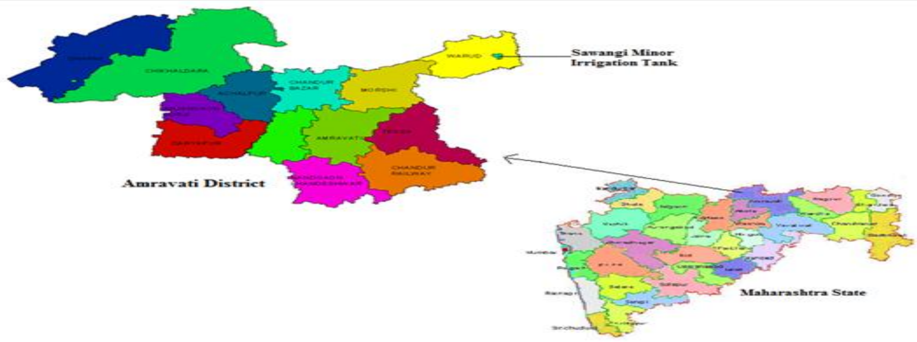

Figure 1 Sawangi Minor Irrigation Tank, Warud Taluka, District Amaravti, Maharashtra, India

The north of the tank is the upstream direction while the southern side is the downstream direction. The SMI tank is an earth filled embankment without a core. The embankment is composed of silty clay with an average thickness of 10 m above the basalt rock in the Deccan Trap region. The SMI tank was constructed in East-West direction over a length of 750 m and width of 45 m. The head regulator of SMI tank is situated in the Eastern part at 120 m and there is an outlet in the Western part. Storage capacity and water-spread area of the tank are 521 mm^3, and 37 ha respectively. The tank is situated in the Deccan Basalt area and the topography is near flat with gentle slope in the southern direction. The area receives rainfall during southwest monsoon. The average rainfall this area is 710 mm. The maximum temperature during summer reaches a maximum of about 460 C and the minimum temperature during winter is about 5^0 to 9^0 C [1-3].

The Sawangi area is drained by second and third order major streams, which are seasonal and are tributaries of Wardha River. The flow of the stream is from north to south direction. Drainage pattern is dendritic to sub-dendritic (Figure 2). The map prepared based on the satellite pictures (Figure 3) two lineaments were observed, which are along the drainage from north to south. The lineament in the NW side is about 1 km in length and the other SE side lineament is about 350 m in length.

This tank developed leakages in the month of December 2013 (Census Report code No 53, Watershed No WR-1). The water in the tank was seeping into the ground and completely drained the water from the tank. There are about 14 dug wells in situated around a radius of 2-3 km of the tank on the downstream side. All the dug wells were seasonal and 8 of them are perennial that could sustain throughout the year.

The dry condition of the tank led to severe water shortage in the area both for drinking and irrigation purpose. To solve the problem electrical resistivity, Self-Potential (SP) and VLF EM surveys were carried out in the Sawangi Minor Irrigation tank in order to assess the source of the leakage in the tank. The zone of leakage was identified from the geophysical data and is presented in this paper.

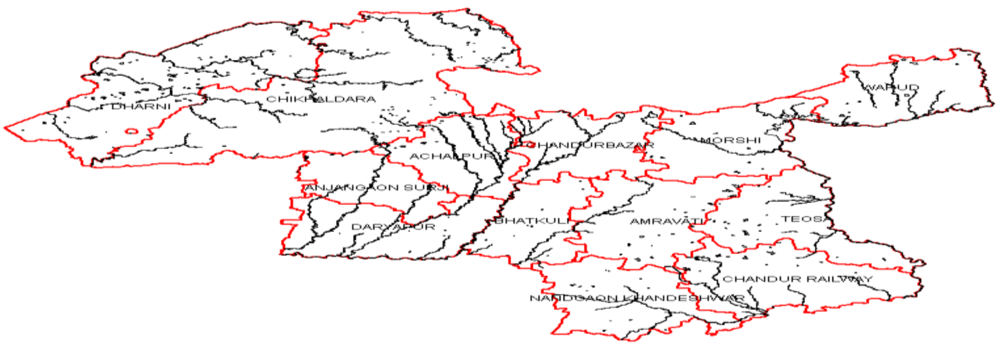

Figure 2 Drainage Map showing Dendritic to Sub-Dendritic patterns for Amravati District, Maharashtra, India

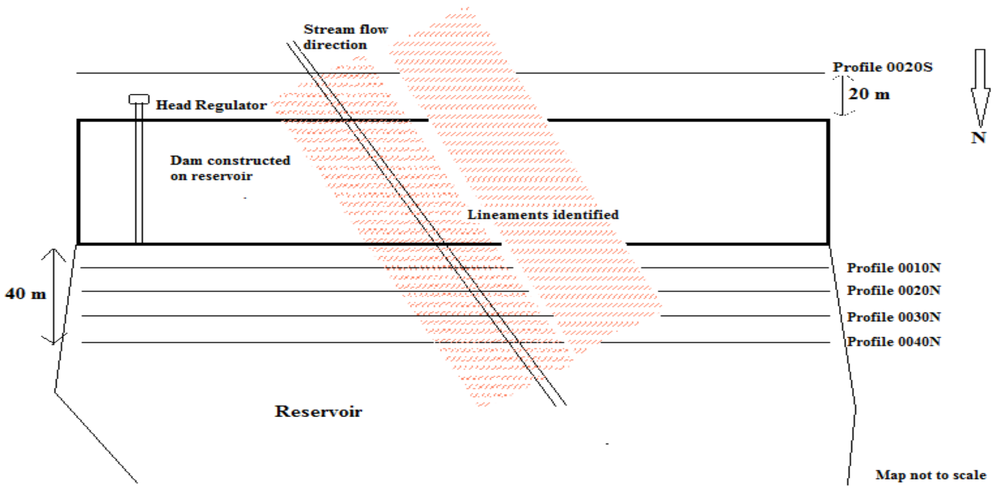

Figure 3 Geophysical Survey Profile layouts for Sawangi Minor Irrigation Tank and the identified lineaments

II. GEOLOGY AND HYDEROGEOLOGY

The area lies in the Deccan Trap region formed due to the fissure type volcanic eruption activity during upper cretaceous to lower Eocene in age [4-11]. Rock samples were collected and the strata along the various dug well situated in the area were identified. On the basis of the well sections the geological succession was identified.

During the field investigations 6 Wells were examined for collecting information pertaining to hydrogeology, subsurface geology of the study area The aquifers of the study area is weathered vesicular basalt in eastern part while jointed massive basalt in western part of the tank. The average well depth range is 15 to 18 m. The pre-monsoon water level ranges from 12 to 15 m and post monsoon water level is 6 to 8 m. The annual fluctuation is between 6 to 7 m. All wells are perennial in downstream of the tank. The average yield range of well is 36 kiloliters/day (kL/d) in summer and yield range is 108 kL/d in winter.

III. GEOPHYSICAL SUVEYS

Geo-electrical resistivity surveys help decipher both lateral and depth variations of resistivity covered by different geological formations [12]. The Very Low Frequency (VLF) electromagnetic method [13] proved as fast and easy tool for locating fractures zones [14-16].

Electrical resistivity, Self-Potential and VLF EM surveys were conducted to locate leakages in the tank. Surveys were carried out using McOHM Resistivity meter and VLF-EM WADI Instruments.

The McOHM Resistivity meter manufactured by OYO Corporation, Japan is a digital stacking type with the transmitter and receiver completely housed in a case and is controlled by 8-bit CPU. The maximum voltage output of the transmitter is 400 V (peak-to-peak) at a current output of 200 mA. The source is a 12 V external battery through an effective power boosting circuit. The SP surveys were also conducted using Cu-$CuSO_4$ porous pot electrodes.

The VLF EM WADI equipment manufactured by ABEM, Sweden measures the real and imaginary components of the polarization ellipse. It is automatically tuned to the optimally strong VLF EM transmitter in the survey area in the frequency range of 15 to 30 KHz. The interpretation is carried out using the RAMAG Software provided by ABEM, Sweden.

Resistivity Profiles were conducted with Gradient Resistivity Profiling (GRP) method with Current and Potential electrodes separation of 300 and 20 m respectively and observation interval of 10 m. Self-Potential measurements were taken with the observation interval of 10 m. Figure 3 shows the layout map of GRP, SP and VLF Surveys were conducted along five profiles 0010S, 0010N, 0020N, 0030N and 0040N in the upstream and downstream of the SMI tank area. The length of each profile was 750 m and the measurements were taken from east to west. The northern profiles (0010N to 0040N) were 10 m from the dam and spaced at 10 m interval. The southern profile (0010S) was 10 m from the dam of the reservoir.

The GRP, SP and VLF EM plots for the five profiles are shown in Figures 4-8. Along these profiles high resistivity zones in the GRP data, low Self-Potential in the SP surveys and low current density values in the VLF-EM pseudo depth sections [17] represent the locations of compact basalt, which is the hard rock area. The low resistivity in GRP, high Self-Potential in SP and high current density observations in VLF-EM represent the weak zones that represent fractured or weathered basalts along which water leakage was occurring in the SMI tank.

The results of the GRP, SP and VLF-EM data along five profiles 0010S, 0010N, 0020N, 0030N and 0040N (Figures 4-8) are categorized as compact basalt and weathered or fractured basalt and are presented in Table 1. From Table 1 the weathered or fractured basalt region in all the profiles for GRP, SP and VLF is observed to be beyond 400 m towards east along the SWI tank. Hence, based on the integrated interpretation of the GRP, SP and VLF-EM data the lineament zone causing the leakage in the SWI tank has been marked beyond 400 m (Figure 3).

	Weathered or Fractured Basalt			**Compact Basalt**		
Profile	**GRP Profile Resistivity distance(m)/ Ohm m**	**SP Profile distance(m) /mv**	**VLF EM current distance(m) /density%**	**GRP Profile Resistivity distance(m)/ Ohm m**	**SP Profile distance(m) /mv**	**VLF EM current distance(m) /density%**
0010S	400-480 m 100 to 110 ohm m	300-350 m 0 to -300 mv	400-480 m -10 to -20%	0-150 m 20 to 60 ohm m 500-750 m 10 to 40 ohm m	0-200 m 0 to 150 mv 500-750 m -50 to 50 mv	0-200 m 0 to 15% 520-750 m 0 to15%
0010N	400-750 m 30 to 65 ohm m	400-680 m -30 to 75 mv	400-750 m 10 to 30%0-	0-300 m 10 to 50 ohm m	0-300 m -75 to 50 mv	300 m -5 to 10%
0020N	400-650 m 30 to 65 ohm	400-650 m -50 to 50 mv	400-750 m -20 to 0%	0-400 m 20 to 50 ohm m	50-400 m -150 to 100 mv	0-400 m 0 to 25%

	m					
0030N	450-700 m 10 to 60 Ohm m	350-600 m -125 to 40 mv	400-750 m 10 to 30%	0-400 m 20 to 100 ohm m	0-250 m -50 to 50 mv	0-400 m -10 to 10%
0040N	400-750 m 40 to 80 ohm m	400-750 m -50 to 50 mv	400-750 m -20 to 0%	0-400 m 10 to 50 ohm m	0-400 m -200 to 100 mv	0-400 m 0 to 30%

Table 1: Hard compact Basalt and fractured or weathered Basalt zones identified on each of the five profiles from geophysical data

IV. CONCLUSIONS

Based on the observations from the VLF-EM, GRP and SP profiles (Figures 4-8) the weathered or fractured basalt is between 400 to 750 m along the respective profiles in the NE-SW direction (Figure 3).

Compact Basalt is observed towards east direction before 400 m along all profiles. The weak zones has been observed and interpreted to be along 400 to 600 m along the profiles, through which the leakage is occurring. From the integrated observations of the resistivity, SP and VLF-EM the orientation of the weak zone (Figure 3) parallel to the stream was identified for the structural engineers to act to solve the problem of leakage in the MI tank.

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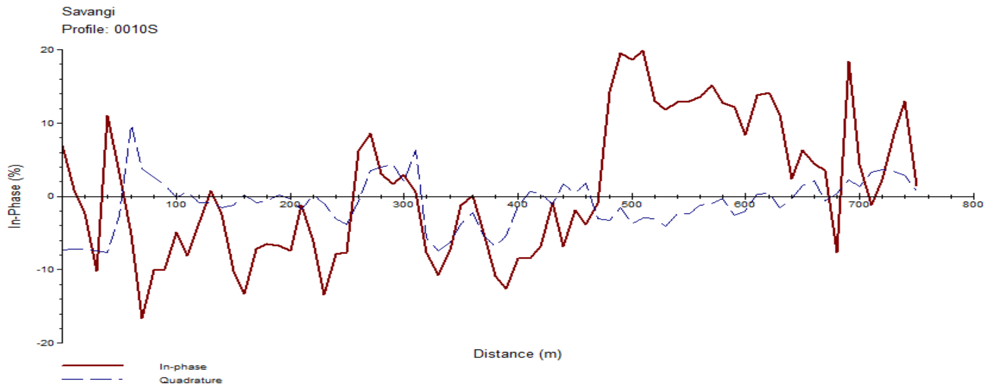

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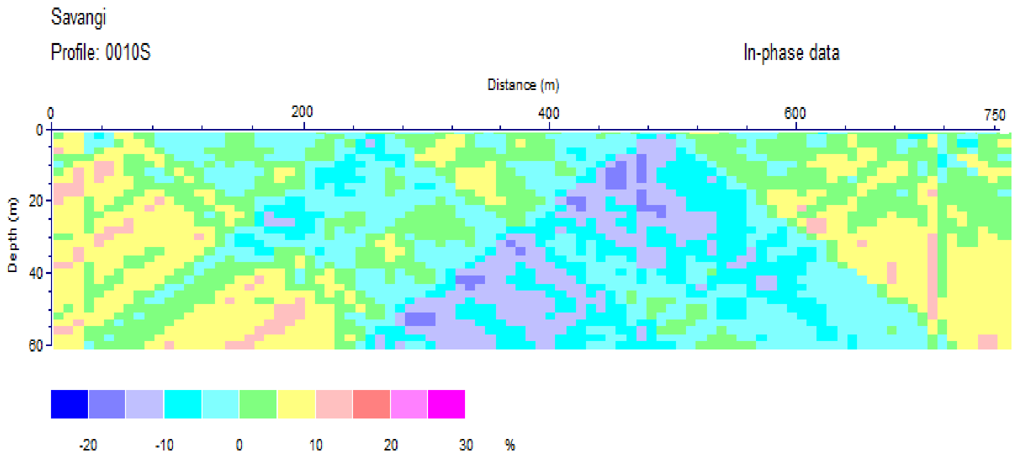

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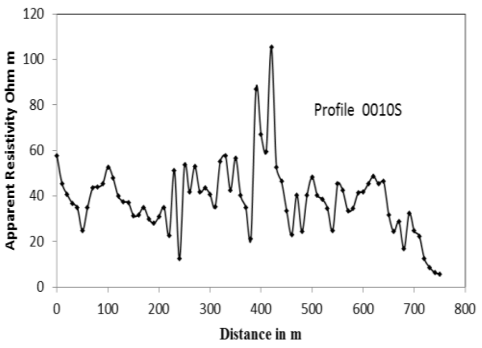

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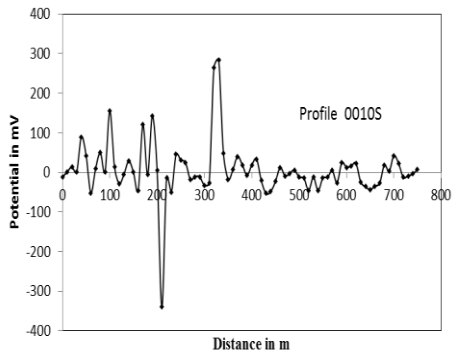

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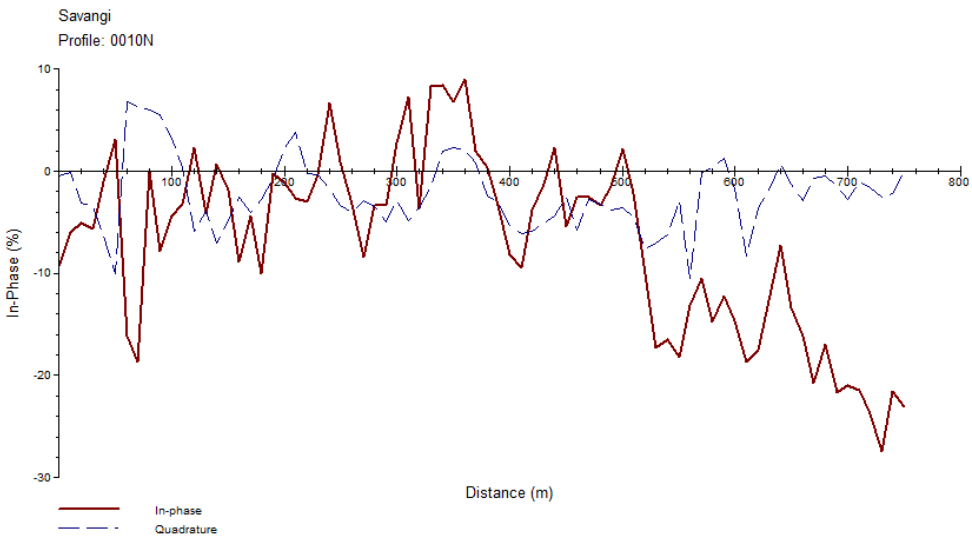
Figure 4: Profile 0010S from west to east, SWI Tank (a) VLF-EM Real and Imaginary components (b) VLF-EM Pseudo-Depth Section (c) GRP Profile (d) S.P. Profile



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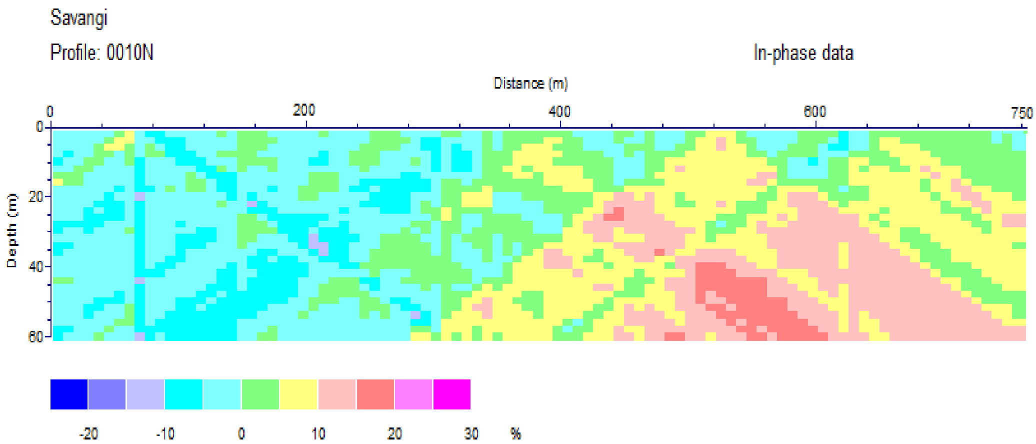

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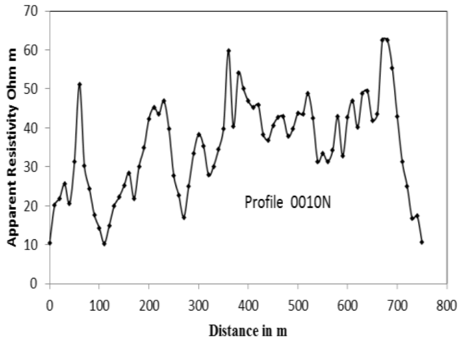

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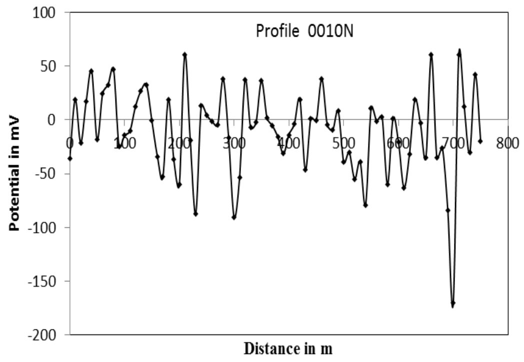

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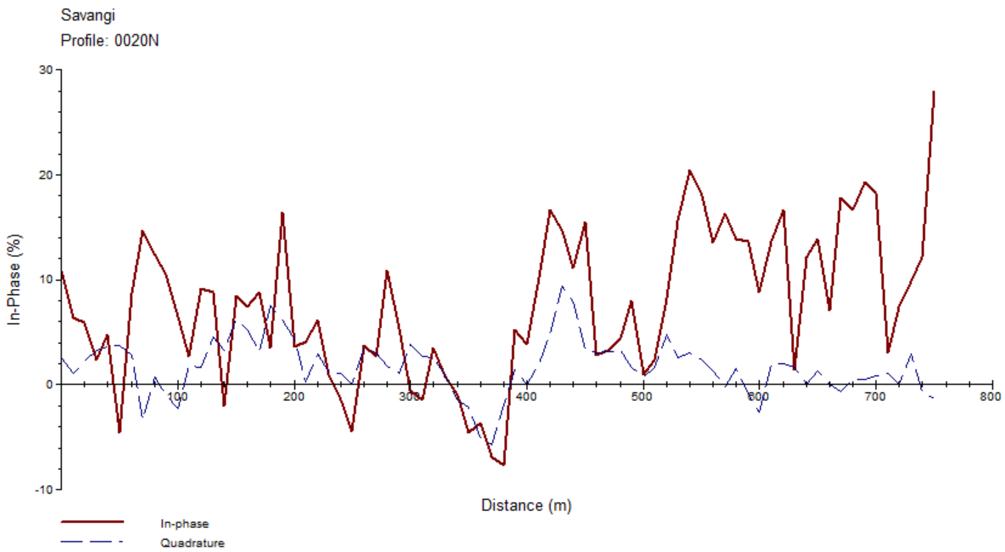
Figure 5: Profile 0010N from west to east, SWI Tank (a) VLF-EM Real and Imaginary components (b) VLF-EM Pseudo-Depth Section (c) GRP Profile (d) S.P. Profile



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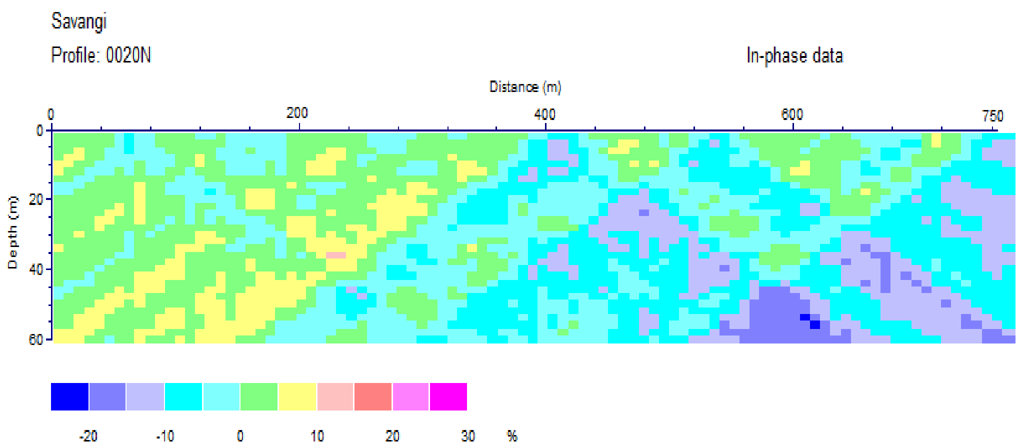

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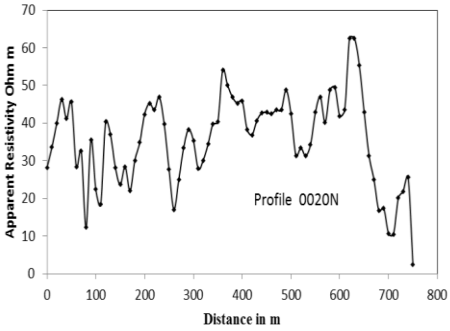

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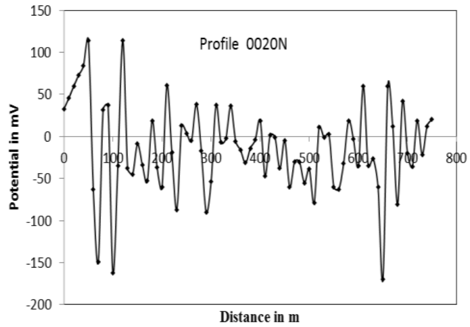
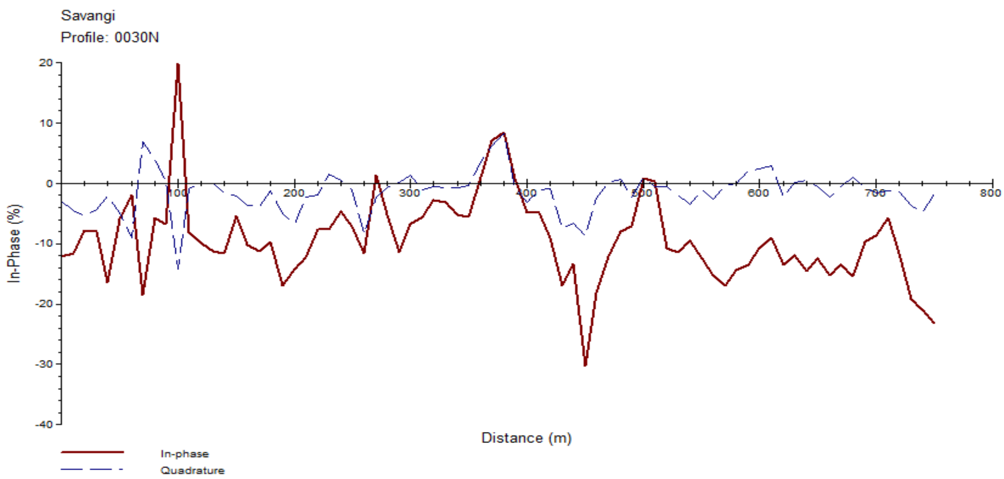


(d)

Figure 6: Profile 0020N from west to east, SWI Tank (a) VLF-EM Real and Imaginary components (b) VLF-EM Pseudo-Depth Section (c) GRP Profile (d) S.P. Profile



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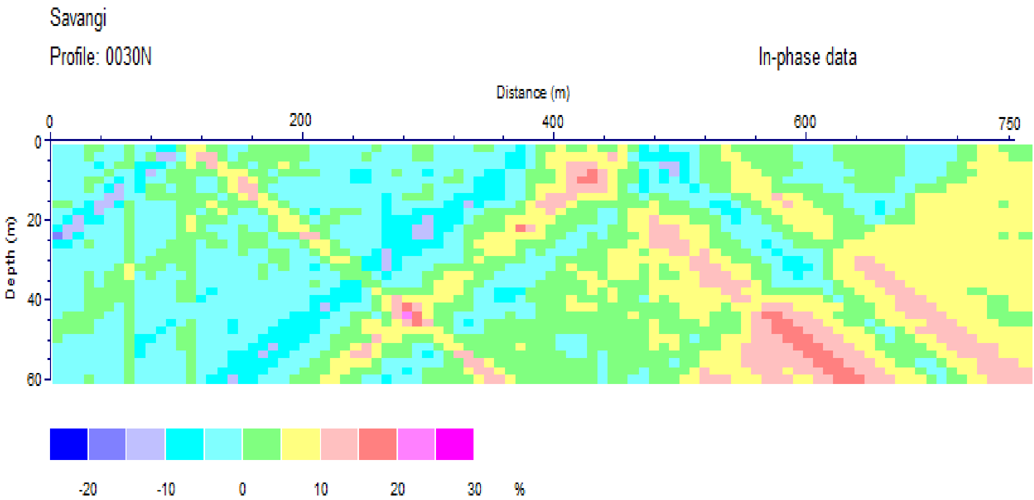

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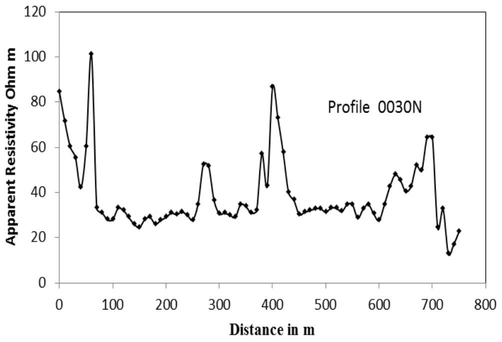

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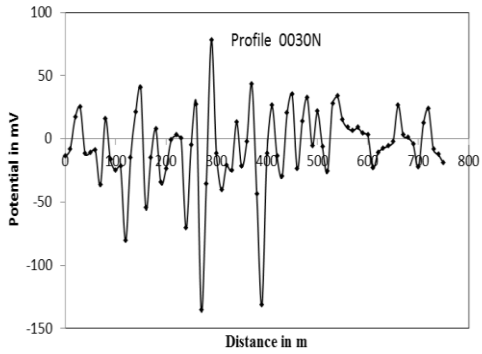

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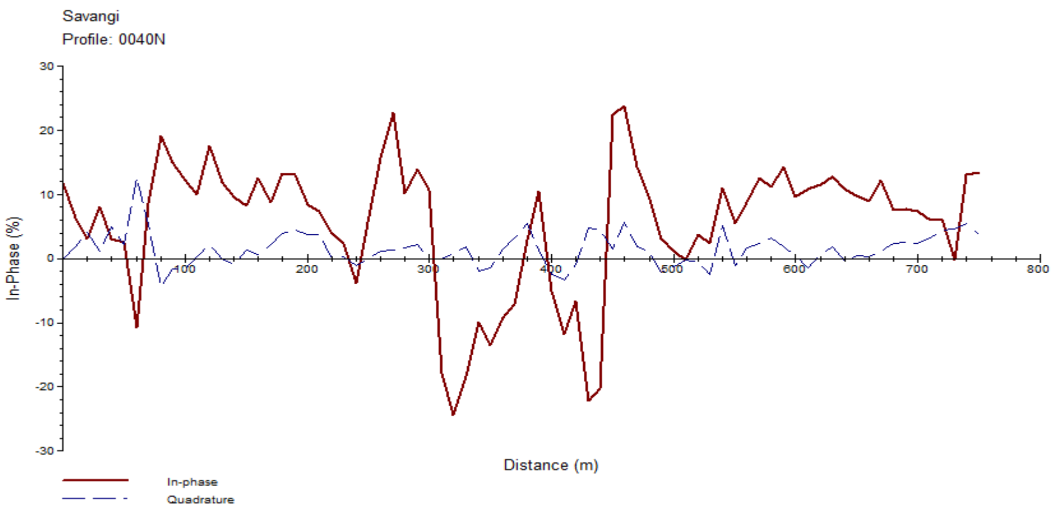
Figure 7: Profile 0030N from west to east, SWI Tank (a) VLF-EM Real and Imaginary components (b) VLF-EM Pseudo-Depth Section (c) GRP Profile (d) S.P. Profile



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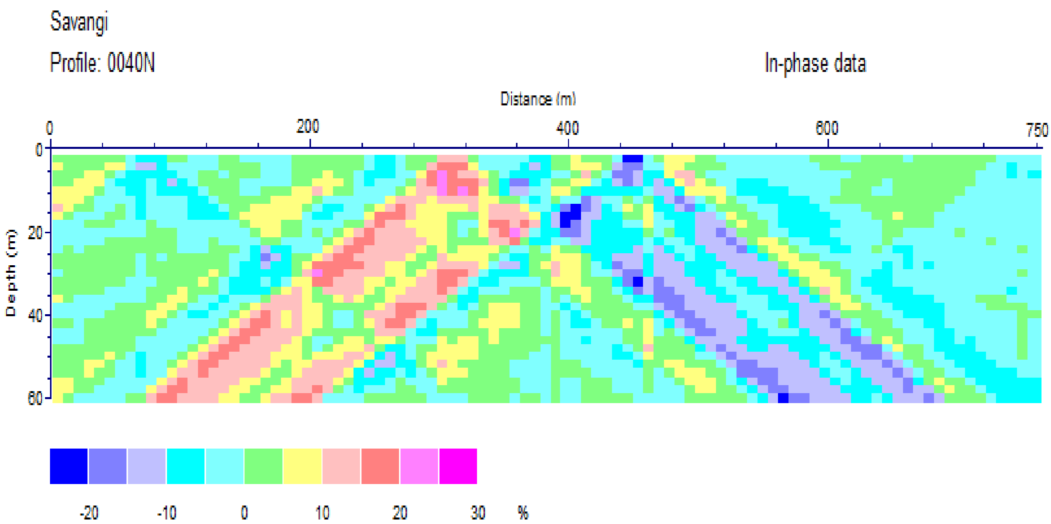

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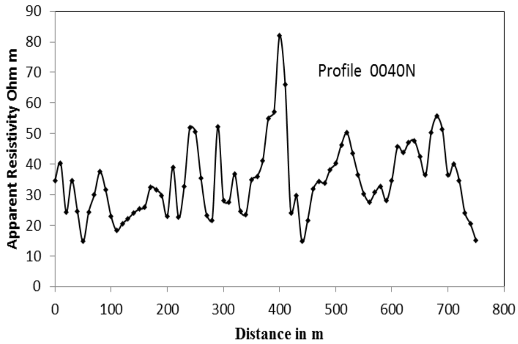

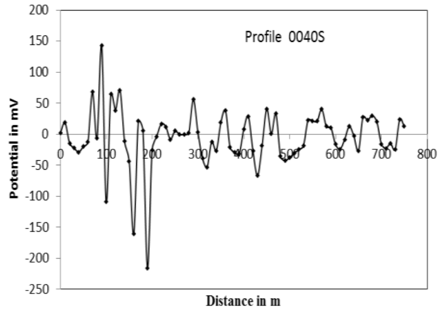

(c) **(d)**

Figure 8: Profile 0040N from west to east, SWI Tank (a) VLF-EM Real and Imaginary components (b) VLF-EM Pseudo-Depth Section (c) GRP Profile (d) S.P. Profile

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