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ASSESSMENT OF SOIL COLLAPSE AND SUBSURFACE FEATURES USING INTEGRATED GEOPHYSICAL METHODS IN BISMAYAH PUMPING STATION, SOUTHEAST BAGHDAD, IRAQ

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ABSTRACT

The Bismayah pumping station was exposed to differential subsidence in the near surface soil due to the dewatering process. The geophysical surveys via ground penetrating radar (GPR) and electrical resistivity imaging (ERI) were used to assess the subsidence in subsurface soils. Four profiles of ERI using Wenner-Schlumberger array and four lines of GPR using antenna 250 MHz were implemented around the pumping station. The results show many underground features that are interpreted as concrete slabs of the storm and sewage tanks. These features reflect high resistivity values on the ERT profiles and high amplitude reflections on the GPR lines. Moreover, the results revealed the existence of pipe leakage on the northern side of the station, which in turn showed a very distinctive shape and low resistivity values. However, the results do not present any evidence of the existence of soil subsidence in the area around the station area.

Keywords: Bismayah pumping station; ERI; GPR; Integrated geophysical methods.

1 INTRODUCTION

Ground (soil) collapse is a well-known issue that occurs frequently around the world, especially in urban and agricultural industries. It depends on several manmade and natural conditions. Ground collapse related to manmade conditions occurs in areas with mining and drilling processes. The buried artifacts, dewatering and extraction methods, and time are factors associated with soil collapse. The natural collapse usually occurs due to the karstification effect, over pumping of aquifers, and swelling of soils [1, 2, 3, 4 and 5]. Today, geophysical methods, such as Electrical Resistivity Tomography (ERT) and Ground-Penetrating Radar (GPR), can provide crucial information for investigating and tracing soil collapse. The advantage of a geophysical survey is that it enables information to be obtained for large volumes of ground that cannot be investigated by direct methods because of the costs involved. The applications of geophysics in the characterization of contaminated land, and the distribution and migration of pollutants in the ground and groundwater, are still developing, but with great potential. These are still insufficiently or inappropriately used in engineering and the newer capabilities are not appreciated [6]. Geophysical tools are designed to measure specific parameters and are generally used to measure spatial variation in these specific parameters within a study area of interest. GPR survey instruments are used to measure spatial variations in the travel times and magnitudes of pulsed EM radiation that has been reflected from subsurface features (generally geologic boundaries) of interest. For an electrical resistivity measurement, the current (I) is induced between pair of electrodes (C1, C2). Then the potential difference (ΔV) between another pair of electrodes P1 and P2 are measured and apparent resistivity (ρ) is then calculated. If the current electrode spacing is expanded about a central location, a resistivity–depth sounding can be generated. If the array is expanded and moved along the surface, a 2-D or 3-D resistivity–depth variation model can be estimated. If external constraints are available, resistivity–depth models can be transformed into geologic models [7]. Ismail and Saad used GPR to identify ground subsidence and detect voids [8]. The method was successful in detecting areas of subsidence at depths of

4 meters. Karim et al. conducted GPR surveys using various antennas (250, 500, 800, and 1000 MHz) along multiple traverses at various sites to determine pavement thicknesses and bridge damage [9]. Rekapalli and Sarma used different electrode arrays that differ significantly in geological structure and resistivity range [10]. The present study aims to use the Integrated of the GPR and ERI geophysical techniques to map subsurface features and assess the soil collapse in the area around the Bismayah pumping station.

2 SITE DESCRIPTION

The current study area is located in southeastern Baghdad city, where the location of the investigated site is achieved around the Bismaiya pumping station (Fig. 1). The study area is about 100×120 m^2 and extends underground 14 meters in-depth. Bismayah pumping station was built in an area suffering from the problem of the rising water table, and this may affect the foundations of buildings. Dewatering was used to reduce the effect of this problem. During the dewatering, some of the soil grains may be washed out with water and may cause many voids in the soil. Therefore, the foundations of the pumping station in this site have been subjected to subsidence impact due to the process of withdrawal of water outside the station and beneath the foundations as a result of the removal of the fine grains towards the wells of the withdrawal. This process caused the collapse of the soil under the raft foundation at a depth of 4 m (Fig. 2). Geologically, most deposits in the Baghdad area are secondary soils (residual soils) derived from the above regions, transported from place to place, and accumulated as a result of sedimentation. Besides, Baghdad soil strata are affected by river course changes leading to coarse silt deposits and giving different depositional stratigraphy every few meters. Thus, Baghdad strata are erratic and somewhat nonhomogeneous with a shallow water table. In general, this soil is alkaline with low permeability [11]. As revealed by drilling boreholes at 30 m depth, the soil section differentiates two main subsoil layers (Fig. 3). The following is a summary of the subsoil section: Brown clay makes up the top layer (from 0.5 m to 18 m depth) with a water table of 1.9 m, while gray sand makes up the second layer, which extended from 18 to 30 m.

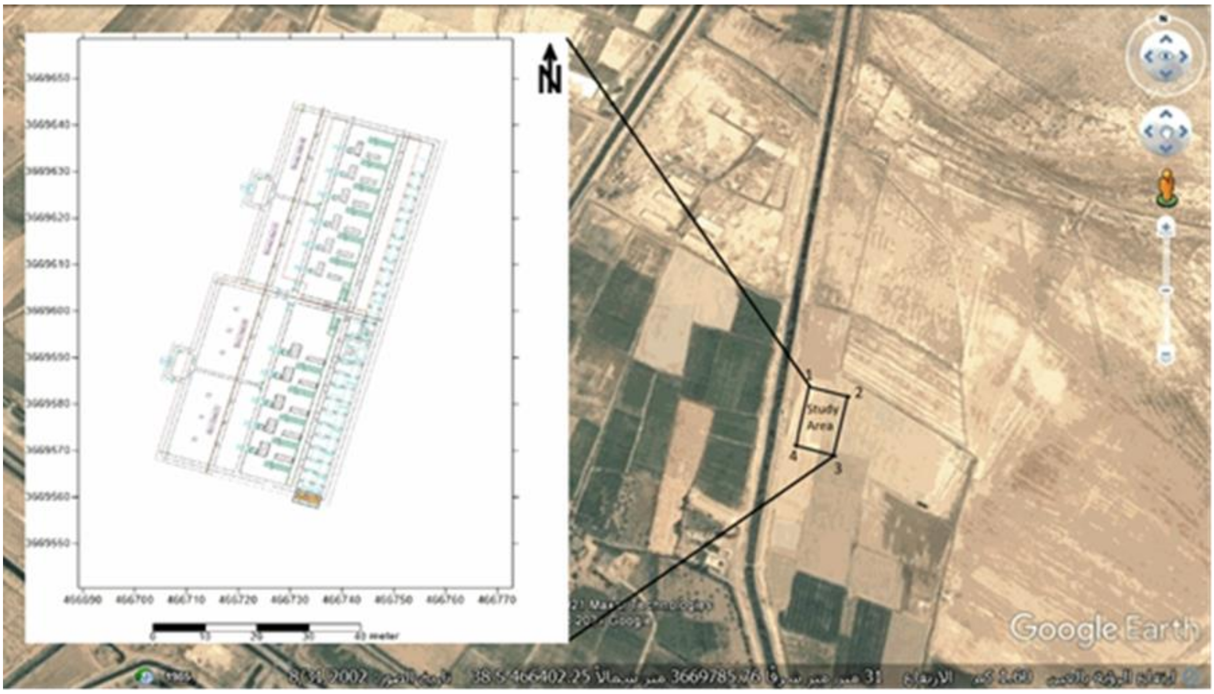

Figure 1. *Aero-map of Bismayah site, the black rectangle represents the location of Bismayah pumping station (google.com/maps)*

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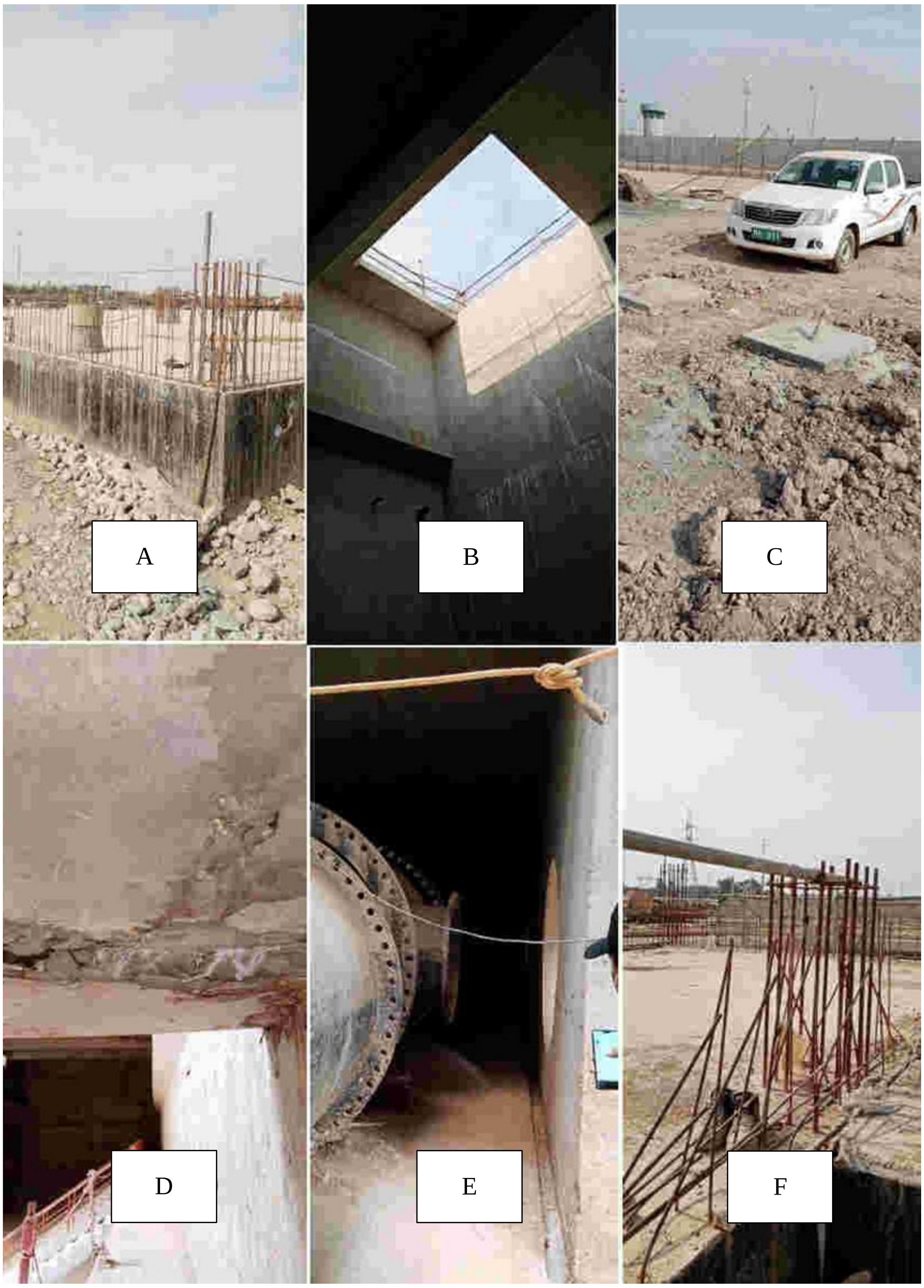

Figure 2. *Pumping station after being exposed to the subsidence due to water withdrawal outside the station and below the foundations. A) The outside view of the pumping station site; B) The inner side view of the pumping station; C) The withdrawal of water below the foundations of the pumping station; D) Fractures in the skeleton of the pumping station; E) Pipes damaged due to soil subsidence; F) Joints due to soil subsidence (Photo: Al-saady, 2020)*

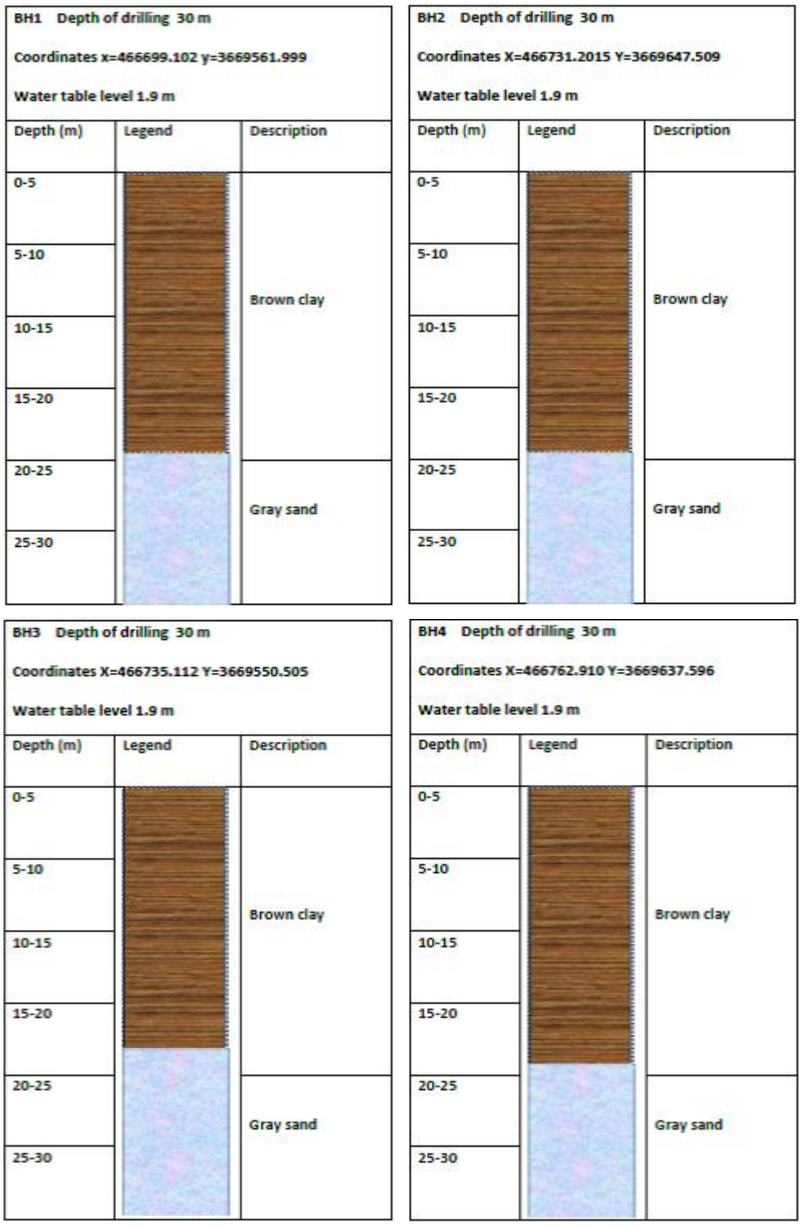

Figure 3. *Stratigraphic column for the existed for Borehole within the Bismayah pumping station site [12]*

3 APPLICATIONS OF GEOPHYSICAL SURVEY

An integration between ERT with GPR profiles was used in the same positions to survey the area (which is about 100×120 square meters) outside the station. The survey was done with four profiles for each technique. The SYSCAL Pro resistivity meter was used to collect the resistivity measurements around the Bismayah pumping station utilizing the Wenner-Schlumberger electrode array. Two ERT profiles have 120 m in length (labeled BS1, and BS2) while the two others (labeled BS3, and BS4) have 100 m in length. All of them are characterized by an initial a-spacing of 1m between every two electrodes and an n-factor of1-4a n-factor. The GPR scanned paths were carried out along 4 lines (labeled Line1, Line2, Line3, and Line4) outside the station using the LMX200 GPR device with a 250 MHz antenna (Figs. 4 and 5).

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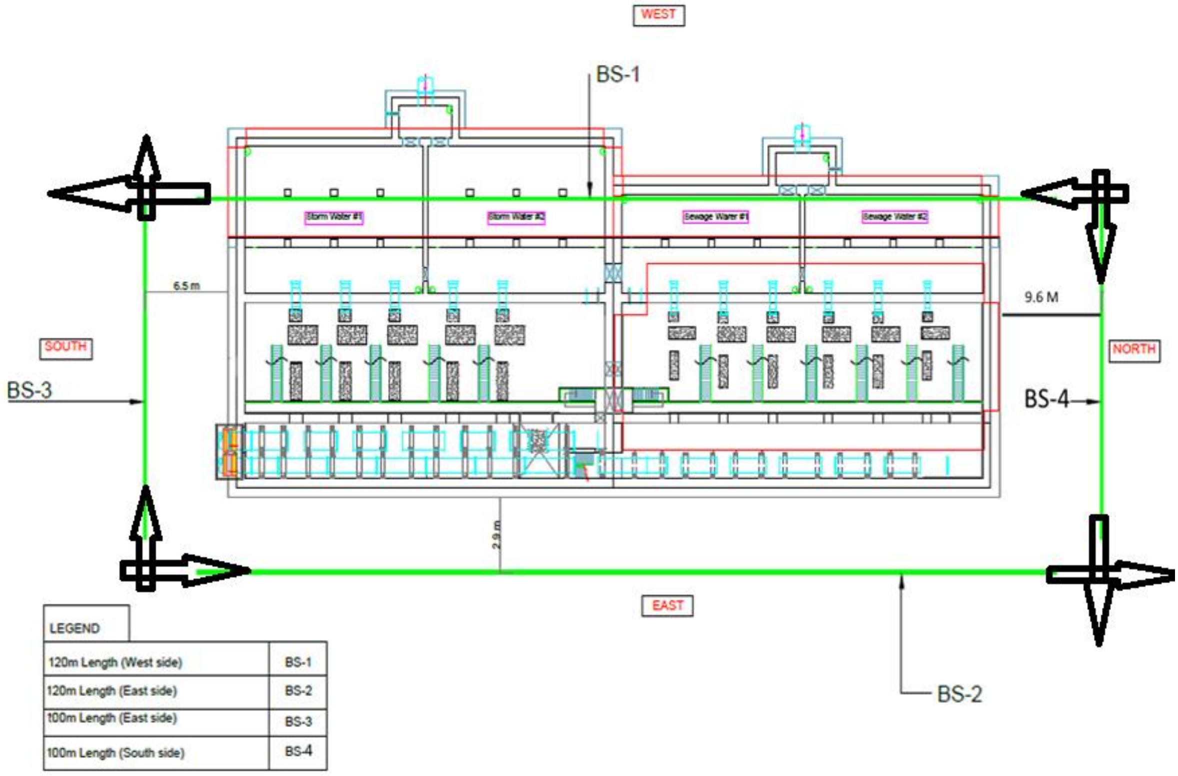

Figure 4. *Locations of the geophysical survey: ERI profiles, around the Bismayah pumping station. The head of the arrows refers to the direction of the profiles*

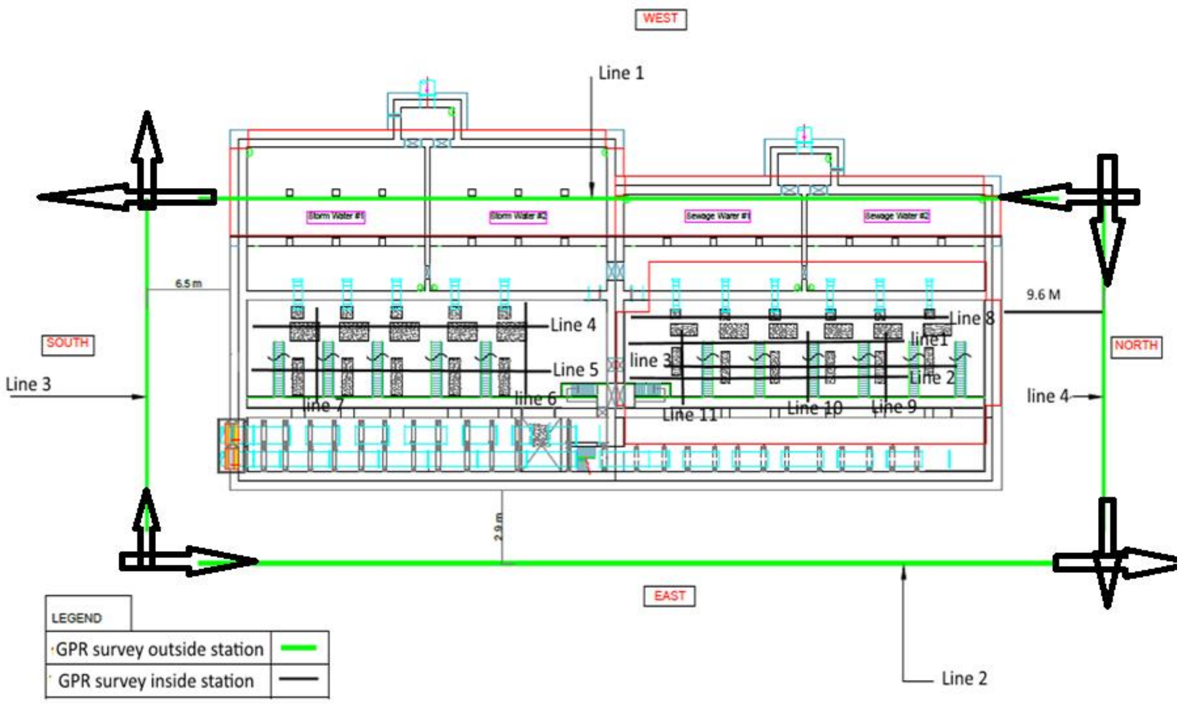

Figure 5. *Locations of the geophysical survey: GPR lines within and around the Bismayah pumping station. The head of the arrows refers to the direction of the lines*

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4 RESULTS AND DISCUSSIONS

The processing and interpretation of 2D resistivity data were performed using the RES2DINV program. The GPR data processing and interpretation were achieved by applying for the ReflexW program. The inverse model of the ERT profile BS1 shows distinctive high resistivity values of 15 Ωm to more than 50 Ωm, which may represent a concrete slab of the storm and sewage tanks. Based on this inverse model, the thickness of this slab varies between 4 m to 8 m and occurs at a depth of 2 m. The low resistivity values that range between 0.5 Ωm to about 12 Ωm are interpreted as clay deposits (Figure 5). Furthermore, at a distance of 5m and a depth of 2m, the features of low resistivity values (1–3 Ωm) may interpret as grouted material. On the other hand, GPR Line1, which was conducted in the same location as the BS1, presents many reflections that may correspond with some resistivity features of the ERT inverse model. For example, the reflectors at a depth of more than 2m may correspond with high resistivity values of the concrete slabs (tanks) (Fig. 6).

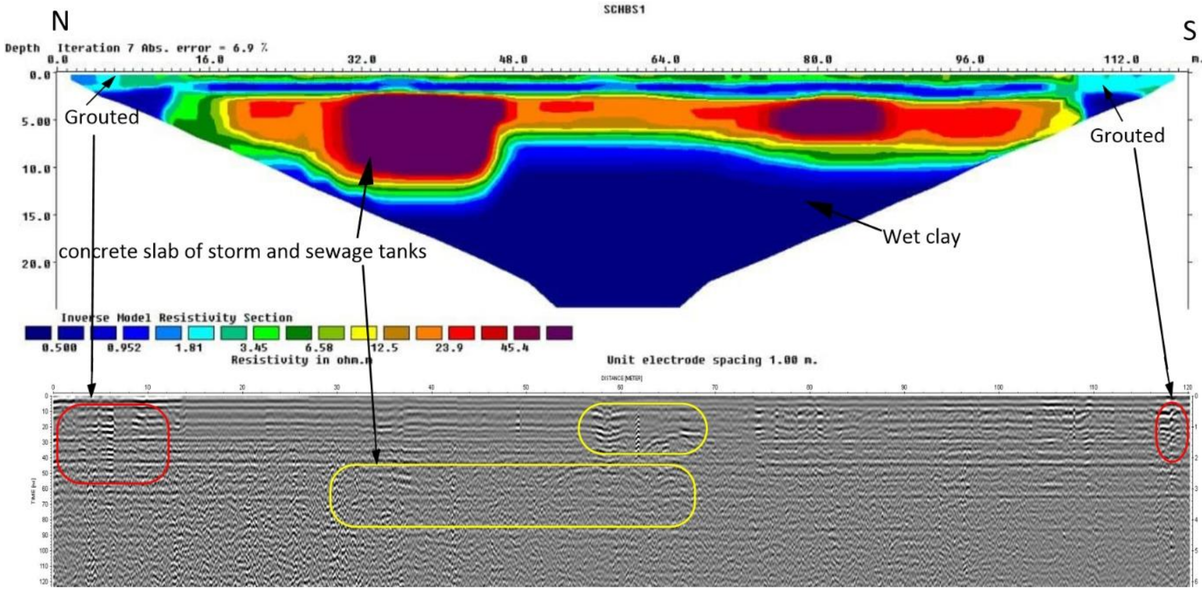

Figure 6. *Electrical resistivity profile in site BS1 array and GPR Line1*

The inverse model of the ERT profile BS2 shows distinctive high relative resistivity values of 15 Ωm to more than 50 Ωm at electrode 110 and a depth of half meter, which may represent a concrete material. This high resistivity anomaly is corresponding to the high reflection on the conceding GPR Line2. Also, the Inverse model shows relatively high resistivity values of 10 Ωm to 20 Ωm at electrodes 82 to 110 and a depth of about 5m that interpret as concrete material (gallery pipe). The low resistivity of about 0.5 Ωm to 4 Ωm is interpreted as a clay layer. While for the GPR survey, the reflectors in the GPR Line2 at a distance of 4m, 36m, and a depth of less than half a meter are interpreted as grouted material. The reflector at distance from 40m to 60m corresponds with very low resistivity values of the ERT profile BS2 and can interpret as grouted material. (Fig. 7).

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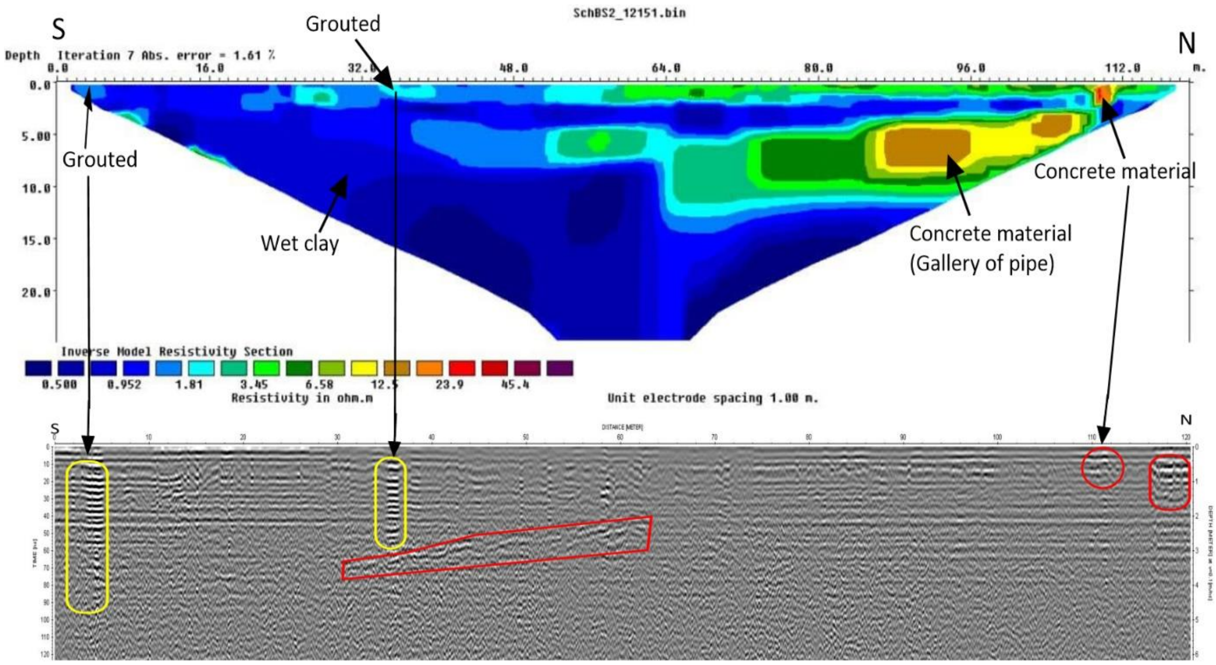

Figure 7. *Electrical resistivity profile BS2 and GPR Line2*

The inverse model of the ERT profile BS3 shows relative high resistivity values of 15 Ωm to more than 30 Ωm at electrodes 53 to 60 and a depth of 2 m, which may represent a concrete material. The low resistivity values of about 0.5 Ωm to 4 Ωm are interpreted as wet clay, while for the GPR Line3, the reflector at a distance of 45 m corresponds with very low resistivity values and can interpret as grouted material. The reflector at a distance of 60 m and depth of less than 1m corresponds with relatively high resistivity values, which are interpreted as concrete material. The reflector at a distance of 63 m corresponds with very low resistivity values and can interpret as a pipe (Fig. 8).

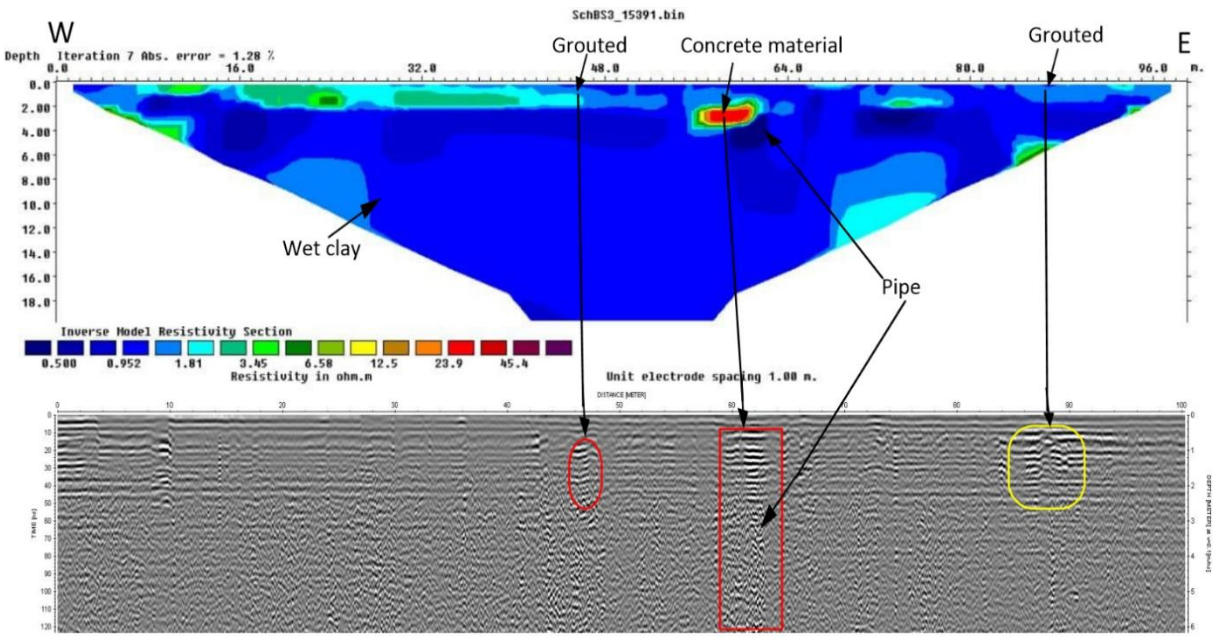

Figure 8. *Electrical resistivity profile BS3 and GPR Line3*

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The inverse model of the ERT profile BS4 shows relative high resistivity values of 15 Ωm to more than 30 Ωm at electrodes 90 and depth 4 m, which may represent a concrete material. The Inverse model shows low resistivity values of about 0.5 Ωm to 4 Ωm which are interpreted as a ca lay layer. A distinctive low resistivity anomaly of 0.5 Ωm to 1 Ωm below electrode 30 is corresponding to the GPR high amplitude reflection at the same location. This anomaly is interpreted as leakage from a pipe. This leakage may cause a failure in the sediments around the station. The reflector at distance from 45m to 60 m corresponds with very low resistivity values and can interpret as grouted material. The reflector at a distance of 90 m and depth of less than half a meter corresponds with relatively low resistivity values interpreted as pipe or manhole. (Fig. 9).

The results of the ERT inverse models and the GPR lines do not indicate any subsidence in the soil. This means that the subsidence has occurred below the station's foundations only and does not extend further out the station. Therefore, an intensive geophysical survey should be done on the side of the station to precisely trace this subsidence for applying further treatment to prevent any failure that may occur to the station in the future.

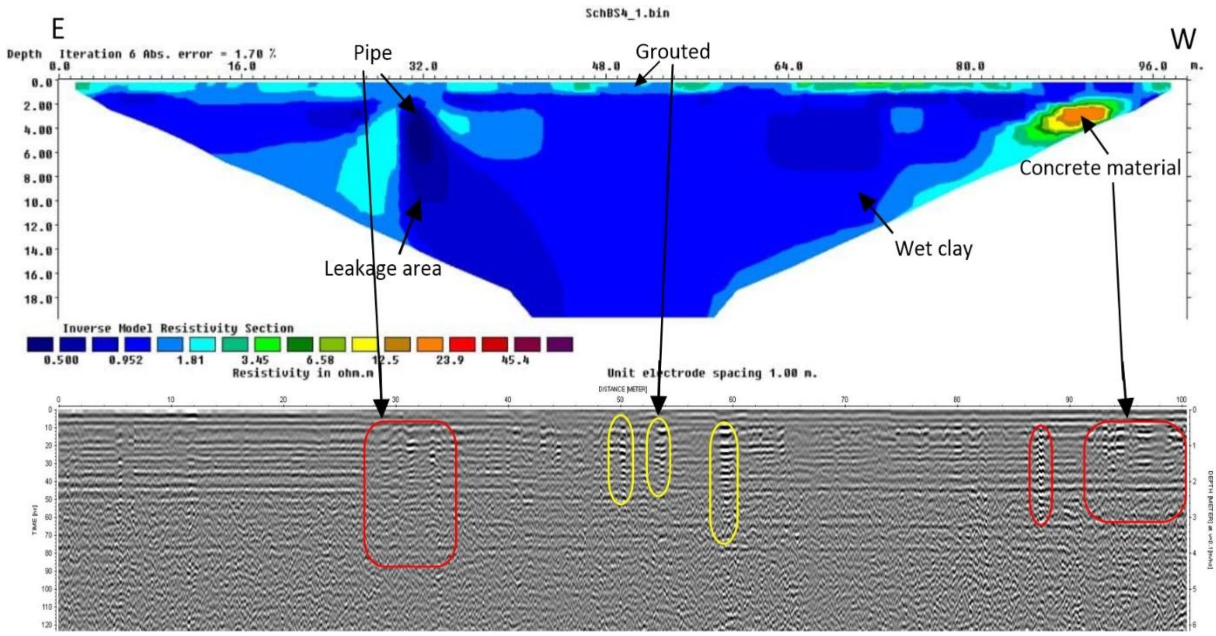

__Figure 9.__ Electrical resistivity profile BS4 and GPR Line4

5 CONCLUSIONS

The area around the Bismaiya pumping station is investigated for tracing any soil subsidence as well as to delineate the underground features. The results show many underground features that are interpreted as a concrete slab of the storm and sewage tanks. These features reflect relatively high resistivity values on the ERT profiles and high amplitude reflections on the GPR lines. Moreover, the results revealed the existence of pipe leakage on the northern side of the station, which in turn showed a very distinctive shape and low resistivity values on the ERT profile (BS4). This leakage may cause a failure in the sediments around the station. However, the results do not present any evidence of the existence of soil subsidence in the area around the station area. An extensive geophysical survey is recommended to trace this soil subsidence beneath the station's foundations to determine the locations of this subsidence.

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