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COMBINED GEOPHYSICAL METHODS FOR CAVITY DETECTION IN HIGHLY INHOMOGENEOUS MATERIAL OVER KARSTIC BASEMENT. A CASE HISTORY

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Introduction

Sometimes the need for an immediate action for applying a geophysical investigation is of vital importance particularly in cases where remedial measures are necessary to be conducted soon after the termination of field surveys. An example is given in this paper for an off-river reservoir at an elevation of approximately 80m above sea level, few hundred meters from the coastline, in the southwestern part of the Chania prefecture, in Crete island, Greece. The reservoir was under construction, partly by excavation and partly by filling the depressions, when the authors were called to investigate the reservoir area. They were faced with a sizeable subsidence in the form of an almost perfect cylindrical cavity having a diameter of 10 m and a height of 9 m, downstream of the embankment. The surface material is highly inhomogeneous and basically is composed of brown silty sand, gravel of very variable composition and huge blocks of rock. This overburden layer lies above a karstic breccia formation which is easily eroded due to the solution of gypsum present in the initial composition of breccias and extends up to sea level. In such a geologic environment subsidence phenomena are prone to be developed due to weathering factors that continuously enlarge the cavities by the downward flow of meteoric water and widening the existing karstic openings in the basement, as it has been shown in the past (Sowers 1984 and Newton 1984).

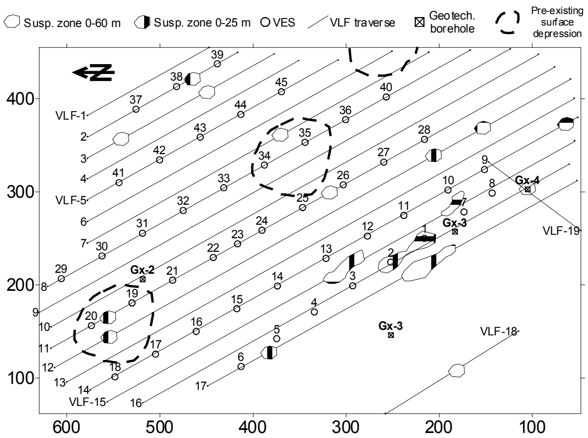
Geophysical surveys

The choice of applying an appropriate geophysical method had to fulfil two basic prerequisites: a) to be a potential one to detect and outline probable subsurface cavities and weak zones and b) to be simple and fast to obtain reliable results in a short time.

The D.C. geoelectrical method was first chosen to detect any large subsurface cavities extended up to sea level (AB=300 m). A number of 50 geoelectrical soundings were carried out in the reservoir area covering a grid of 500 X 300 m extent. To investigate the presence of conductive zones laterally and at depth, the VLF method was first tested over known subsurface structures (cavities filled will air or loose material). VLF measurements were conducted by a Wadi instrument of ABEM. The use of VLF-R technique that might give better results (Ogilvy et. al. 1991) was not available by the time the authors asked to conduct the geophysical investigation.

Geoelectrical investigation

The wide range of resistivity values reflects the inhomogeneity structure of the reservoir area. High resistivity values at shallow depths do not necessarily correspond to the presence of free-air or filled with loose material cavities, but more often to the presence of large blocks of rock scattered inside the overburden layer. For deeper structures where the resolution is lower, the presence of high resistivity zones of substantial extent (fig. 2) will probably correspond to large sinkholes that are poorly filled with loose material. The orientation of such large features aligns with the location of surface depressions which pre-existed on ground surface before the excavation takes place (fig. 1).



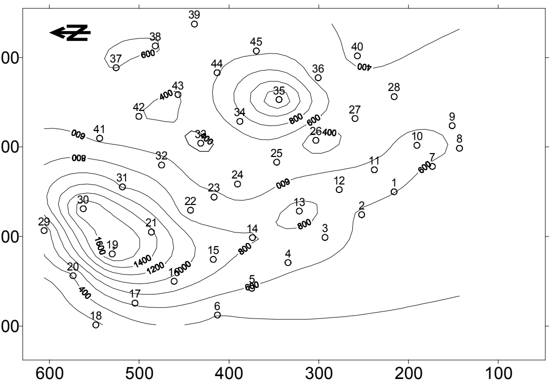
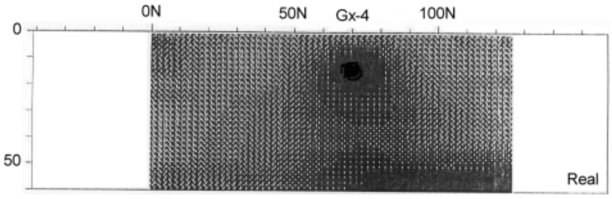


Fig. 1: Reservoir area and sites of VES and VLF traverses. It is also shown “suspected” zones for cavities and locations of pre-existing surface depressions.

Fig. 2: Resistivity distribution at 70 m depth.

VLF- Electromagnetic measurements

Although VLF method is not in favor for detecting subsurface cavities, however it was tested here, as a fast method, to detect any large vertical conductive zones. The results were unexpectedly positive as it is shown in figures 3 and 4. Figure 3 represents a VLF pseudosection (profile VLF-19) of equivalent current density of the Real component across borehole Gx-4, showing the existence of a near surface cavity filled with loose weathering material that extends to deeper depths. Figure 4 represents a VLF pseudosection (profile VLF-18) which runs above the subsided cylindrical body (filled by earth material shortly after the cavity was formed) showing that a loose conductive material is spread out laterally (40m width) and at depth reaching sea level. The reservoir area was covered by a number of equal spaced profiles every 50m (at 5m step interval) and anomaly zones were extended to over 60 m depth. Subsequent drilling and the occurrence of minor cavities in the reservoir floor, long after the submission of geophysical results, showed that there is a good agreement in most cases.



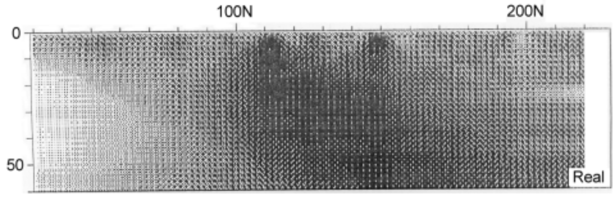


Fig. 3: Pseudosection, VLF-19 along with the location of borehole Gx-4.

Fig. 4: Pseudosection, VLF-18. At distance about 115N a sizeable subsidence was formed during the reservoir construction.

Conclusions

The detection of large subsurface cavities (filled or not with loose material) could be accomplished by utilizing the VLF method under favorable circumstances (i.e. presence of conductive material or water flow through the wall of cavity) for relatively shallow investigations. D.C. geoelectrical method has limited use for detecting surface cavities in such highly inhomogeneous environment. In contrast, resistivity values corresponding to deeper depths can give valuable information for the presence of large morphological features (sinkholes etc.).