Introduction. Geophysical techniques are frequently used to investigate the subsoil to identify buried structures placed at different depth non invasively saving time and money. Among all geophysical techniques, ground penetrating radar (GPR) and electrical resistivity tomographies (ERTs) are the most used, often in tandem with magnetometric and electromagnetic surveys. During last years there has been an increasing interest for geophysical acquisition in lacustrine and marine context; in particular for resistivity acquisitions due their capability to investigate very conductive scenarios without problem of attenuation as unlucky happens for GPR signal. The advantages of the geophysical approach are constituted in provide good information to detect buried target without necessity of excavations; however the methods often suffers of great limitations in resolution and depth of investigation caused by signal attenuation phenomenon and low physical contrasts occurring between existing structures and surrounding environment. Non-conventional ERTs are made for off-shore application in many fields of the research to achieve different objectives as characterization of geological formations (Rucker et al., 2011), characterization of geological stratigraphy (Colombero et al., 2014), analysis of submarine archaeological sites (Passaro, 2010; Simyrdanis et al., 2015).

GPR and ERTs are less effective when are applied in humid or water saturated scenarios and for these reasons an experimental activity has been performed at the Hydrogeosite laboratory. The test has been performed with GPR acquisitions con water in tandem with ERTs realized with different electrodes arrays. In particular ERTs are carried out with 3D-loop shaped acquisitions and 2D surveys made both directly on the water surface both under water. This paper presents the preliminary results obtained with GPR and ERT surveys at an archaeological test site to detect subsurface anomalous bodies.

Experimental set-up. The experiments are realized at the Hydrogeosite CNR-IMAA laboratory in Marsico Nuovo (PZ) in a concrete pool of 252 m$^3$ (12 x 7 x 3 m) filled with silica sand (average diameter equal to 0.09 mm, very fine sand), a porosity of about 45 ÷ 50% and hydraulic conductivity in the order of $10^{-5}$ m/s. The pool is equipped with seventeen wells and a hydraulic system to simulate variation of variation of groundwater level. In an limited area of the pool with size of 6 x 4 m was reproduced an archaeological roman site with structures placed at a depth reaching about 1-1.50 m from the ground surface. An accurate reconstruction of a roman archaeological site buried site was simulated with ancient burials, paved road and stone wall as showed in Fig. 1. Several papers are yet published for this study cases where traditional

---

Fig. 1 – Plan of the test site at “Hydrogeosite” laboratory in MarsicoNuovo (PZ-Basilicata) with indication of the buried structures.
GPR and ERT acquisitions are carried out in tandem to improve results for archaeological research (Capozzoli et al., 2015; Perciante et al., 2015).

The presence of structures with shape and size well-known allowed us to use the site for other geophysical experiences, in particular to test the capability of GPR and ERT in water saturated soil, improve the protocol of acquisition and enhance the quality of the data.

Geophysical surveys are performed with a GPR System SIR-3000 (GSSI-Instruments) and a Syscal Pro Switch 96 (Iris Instruments) georesistivimeter with the water table placed at different heights. For each position of the water table GPR and ERT acquisitions are made and results are compared and analysed. GPR data are processed with ReflexW software with linear and basic operations. ERTs are inverted with ERTLab software (Geostudi Astier) through a finite element inversion algorithm to solve the forward modelling problem (Morelli and LaBrecque, 1996).

The geophysical plan of investigation was performed in accordance with the following steps:

1. 3D loop-shaped acquisitions with both current and potential electrodes distributed along all the site surface as showed in Fig. 2. The test site was investigated with the water table placed at the depth of respectively 1.50, 1.00 and 0.20 m;
2. 2D ERT parallel profiles along two characteristic transects characterized by the presence of the most significant structures. Surveys are made with cables realized in laboratory using brass electrodes coupled to unbending pipes and positioned under water directly on the ground surface (submerged electrodes) or in floating mode (floating electrodes);
3. 2D GPR profiles along the same lines examined with 2D ERT with a depth of the water level above the ground surface of 0.15 m. The same conditions are adopted in the second step characterized by a similar scenario. The 400 MHz antenna was coupled to the acquisition system and mounted on a floating element.

Results. In the first step, 3D ERTs based on loop-shaped grid of 96 steel electrodes applied according the Wenner Schlumberger and Dipole-Dipole arrays are achieved. Generally, it seems that the better results are obtainable with Wenner Schlumberger mode allowing us to very easily individuate some archaeological remains, especially in drier conditions. While, in wetter conditions, the background electrical resistivity values are very similar to archaeological remains ones and therefore it was not possible to clearly individuate most of remains.

However, promising results are obtained in the second step of the research when only bi-dimensional ERTs along two characteristic transects are acquired. As it was expected very low resistivity values are measured with all the arrays due to the conductive environment; but some electrical anomalies could be associated to the geometry of the buried structures. In Fig. 3 the graves placed at a depth greater than 50 cm show a resistive behaviour with respect of
the surrounding soil. The resistive anomalies at the top corners of the ERT are related to the concrete walls of the pool and a pvc drainage ring. Finally GPR radargrams have allowed to identify the top of the buried structures and results are well comparable with those obtained with 2D ERTs.

**Conclusions.** The growing interest in underwater geophysics, as witnessed by numerous archaeological campaigns carried out in the Mediterranean region in marine and lacustrine environments involves a challenge of great importance for archaeogeophysical discipline. Through a careful use of geophysical techniques it is possible support underwater research to identify and analyse undiscovered structures placed under water or located near rivers and sea. A multi methodological approach based on the use of electric and electromagnetic techniques have showed the possibility to individuate remains in the subsoil. In this way the capability of geophysics, limited cause problems of resolution, depth of investigation and sensitivity related to each adopted technique, can be overcome or reduced. The experiments realized in controlled conditions, where geophysical measurements are acquired also in an underwater scenario, showed us the abilities of the GPR and ERTs to support a remote research performed mainly in lacustrine conditions. Good results are, indeed, obtained with 2D profiles, while 3D survey with loop-shaped grid require new efforts to individuate more effective array.

**References**


Perciante F., Capozzoli L., Caputi A., De Martino G., Giampaolo V., Luongo R., Rizzo E., Geophysical investigation for an analogue labscale archaeological site 1st International Conference on Metrology for Archaeology Benevento, Italy, October 22-23, 2015


Fig. 3 – 2D ERT (Wenner-Schlumberger) acquired in the presence of graves with floating electrodes in array.