DETECTION OF LEAKS IN BURIED PLASTIC WATER DISTRIBUTION PIPES IN URBAN PLACES - A CASE STUDY

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ABSTRACT

The nondestructive evaluation of leaks on buried tanks, drums and pipes is of interest for a variety of engineering and environmental applications. There is a limited arsenal of tools available for leakage detections. However, the diversity of techniques shows that each has advantages and shortcomings. Geophysical techniques are faster and cheaper generally than excavation and have the advantage that they are safer in hazardous environments.

Testing and studying several pipe detection tools such as, pulsed induction methods, magnetic locators, EM locators, resistivity methods, acoustic techniques and GPR method, we concluded that, Ground Penetration Radar is the most effective and accurate method to pinpoint buried pipeline leaks without digging.

An extensive work using ground-penetrating radar was carried out at the central road of town Kilkis (N. Greece), in order to locate areas of possible water leakages from distribution pipes.

INTRODUCTION

The necessity of controlling the water use in order to cover the human activities is increasing. In many places in Greece and especially in Evia isl. (C.Greece) and the prefecture of Kilkis (N.Greece), the percentage of water loss due to leakages from water pipes is high. To reduce water loss, the operators of distribution system, requested the application of systematic programs to locate leaks and repair broken pipes.

We should note that part of the old metallic water pipes network of urban area of Kilkis, has been replaced by either plastic or concrete tubes. The use of magnetic and acoustic locators or GPR equipment normally indicates possible leaks. The first two methods are especially useful in detecting valves and junction boxes associated with metal lines, since these are generally undetectable with other detection methods. Cast-iron or steel pipe laid end to end will produce a strong signal to the magnetic locators at each joint – even if the pipes are welded together – since these devices are most sensitive at the ends of magnetic objects. For plastic pipes, however, the effectiveness of the preferred equipments is not well studied. This has prompted an extensive investigation of the potential of alternative non-magnetic/acoustic methods for leak detection in plastic pipes. Ground-penetrating radar has been identified as the most applicable method in such problems.

GPR could accurately identify buried pipeline leaks without any excavation. The potential of ground penetrating radar for leak detection is independent of the pipe type, e.g., metallic or plastic. The leaking substances can be detectable at the source by the radar via the changes in the surrounding soil's electrical parameters. Specifically, GPR could in principle define the underground voids created by the leaking water, since saturation of water slows down the radar wave that gives a deeper appearance of the energy. A handful of papers have recently been written, reporting results of GPR's effectiveness (Hunaidi et al., 1998, Annan et al., 1992, Annan, 1994,2002, Daniels, 1989, Davis et al., 1989, Topp et al., 1980, Yarovoy et al. 2000, Zhang et al., 1992). Over the last 20 years, several important tests have been conducted mapping controlled releases of fluids in test pits using the same method (Sneddon, et. al., 2000, Carlson, 1993, Farmer et al., 1988, Graf, 1990, Griebenow et al., 1988, Jackson et al. 1997, Hennigar, 1993, Hough, 1988, Mears, 1993, Turner, 1991). These confirm GPR's sensitivity to subtle changes in soil moisture. In our work, we tested GPR in more realistic conditions where a pipe is actually leaking and the exact location of leak was in need of detection. Closing the short review in GPR method, we should make clear that there are some limitations/peculiarities on the use of method. In fact, GPR has difficulty in highly conductive clay and silty soils. Sometimes clutter from other objects can obscure pipes. And most commonly, subtleties in processing and interpretation mean that less skilled investigator may fail to detect pipes that would otherwise be clearly resolved.

An extensive leak detection survey using the pulseEKKO 1000 system was carried out in this work to reduce the uncaused loss of water. The survey was performed in the urban area of Kilkis (N.Greece) and all the measured sections were taken over a grid as presented in figure 1.

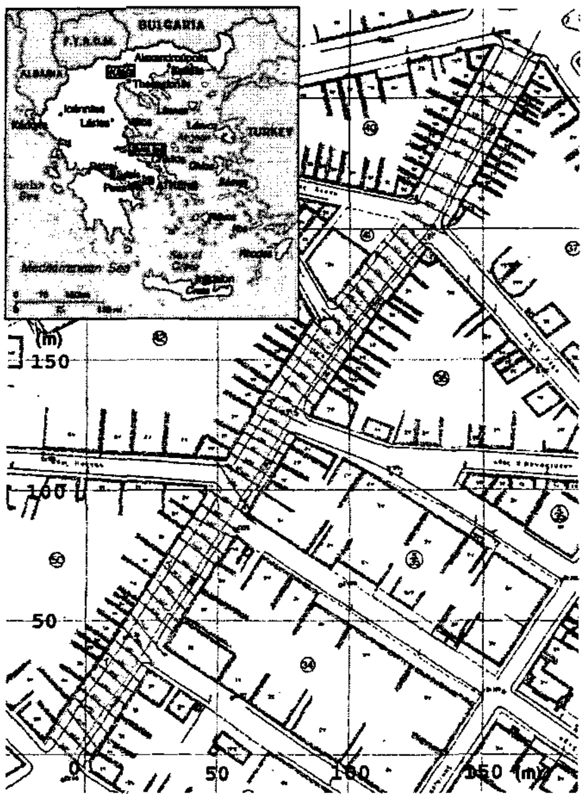

Figure 1. Location map and town planning sketch of the actual part of the city of Kilkis were the survey took place. The lines that are crossing 21st June str indicate the locations of the GPR profiles.

DATA ACQUSITION – PROCESSING

Measurements were performed using the pulseEKKO 1000 radar system manufactured by Sensors and Software Inc. and equipped with 225 MHz antennas. The pulseEKKO 1000 system is of the shielded type, which makes it ideal for use in "noisy" urban environments. GPR lines were acquired over areas where the pipe was supposed to have leaked and areas where no leaks were suspected. The water table across the site was uniform and significantly below the horizon within which the pipe was buried. It was anticipated therefore that any change in moisture content due to the leaking pipe would be seen as a disruption in the GPR record or specific reflection events.

Indications of high noise content were observed in the data. Metallic plates at the top of the asphalt were the sources of noise in many cases (figure 2). Along each profile, the measurements were carried out at regular spatial intervals of 0.1 m. The space interval between adjacent profiles was between 4 and 10 m. 330 meters long part of the city's main road was covered by 59 GPR profiles (figure 1), while a 330-meter long parallel profile was also measured. A total of 1350 meters of GPR measurements were conducted for the present study.

The GPR data were processed using the software provided by Sensors & Software (Annan, 1994). The traces were edited wherever necessary. Editing essentially used to remove bad traces. We performed removal of the low frequency inductive component known as "wow". A user defined gain function has been applied to compensate for losses of energy ($A_{gain}=3\sqrt[3]{A_{orig}}$), where A_{gain} is the gained amplitude. This formula was applied in order to have scaled amplitude comparison of our profiles. Low pass filtering was applied afterwards, in order to remove the high frequency component from the data.

DATA ANALYSIS

The results of each survey profile are in the form of cross sections in two-way travel times. These sections are converted to depth sections using standard velocity for propagation of electromagnetic waves through ground materials. Previous work in the area gave an average velocity of 0.07 m/ns for the upper ground surface (Stampolidis, 2002). Thus, we used this velocity for our depth conversion. We approximated that the maximum penetration depth of the radar signal was between 1.5 to 2.5 meters. At deeper horizons the data is not reliable because it is governed by noise. The interpretation of the radar data is usually directed by the existence of some features such as hyperbolic reflections, irregularities in largely uniform reflection patterns and changes in frequency signal (lowers the frequency and focuses the beam width due to the water saturation) (Hunaidi and Giammou, 1998).

Some of the major features of our survey are presented in the following figures. A series of hyperbolic reflections were identified in all the profiles. Those reflections were attributed to service cables, water and drainage pipes. Point reflector (pipe) seen near the eastern part of the resulted image as presented in profile kil43 (figure 2) and is believed to be plastic water pipe, because of the dual hyperbolic response which is typical of water filed plastic water pipe. We could also define on the top of each image the different response pattern between pavement and asphalt. A noisy signal due to the existence of a metallic plate at the surface (cover of a junction box) can be seen on the right part of figure 2. Large hyperbolic reflections on the edges of the resulted image are effects (dashed line in figures 2, 3), which related with underground constructions (bargain basements) on the vicinity of the measured profiles. Velocity adoption to these reflections gave a value of about 0.3 m/ns, which correspond to air filed chambers.

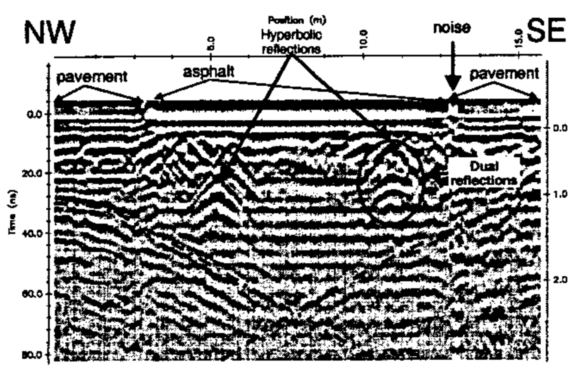

Figure 2. GPR profile kil43.

A successful example of water leak detection is given in figure 3. An unexpected attenuation of the energy of the signal was observed (dashed oval curve) at the left part of the profile. A cut at the hyperbolic reflection on the left side of the image is clear. This pattern was interpreted as the effect of water saturation due to broken drainage pipe, which passes closely. An actual water leak was observed in situ at bargain basements in this area.

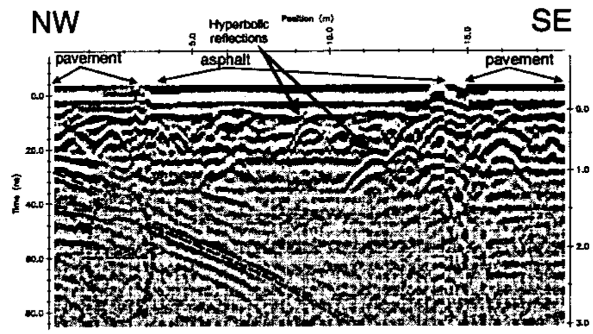

Figure 3. GPR profile kil31.

Another example of water leakage detection is shown in figure 4. We can observe a lowering of signals frequency, seen as deepening of reflection horizons and signal weakening in the area surrounded by a dashed oval curve. The strong hyperbolic reflection to the right is due to a metal plate at the surface, which covers an underground syringe. The distinctive reflection pattern over pavement and asphalt is also visible in this profile. Profile kil1 (figure4) is located at the northern part of the study area (figure 1). The cross section point with profile kil66, which runs parallel to the road, is indicated on the image.

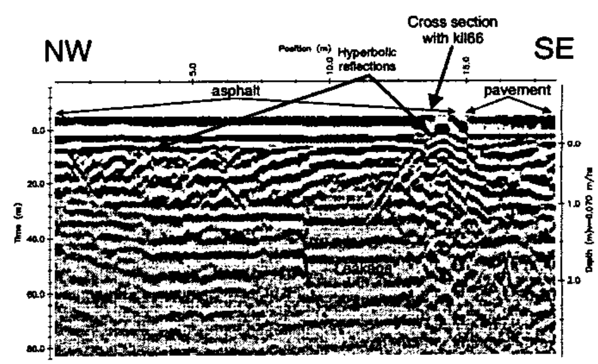

Figure 4. GPR profile kil1.

The interpretation of profile kil66 (figure 5) is shown a possible leak area northern from cross section with profile kil1. Here, the water saturation caused signal diffusion and abrupt termination of horizontal reflections (dashed oval area). The large hyperbolic reflection is coincident with that of profile kil1.

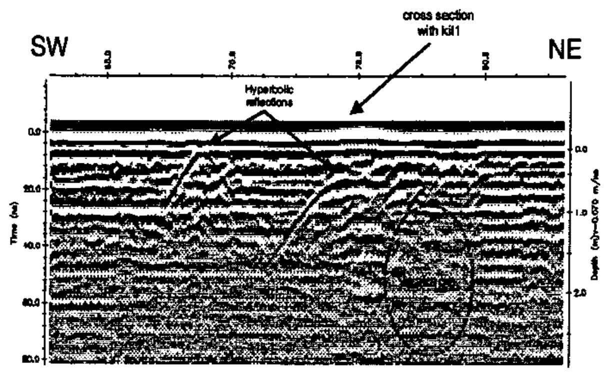

Figure 5. GPR profile kil66.

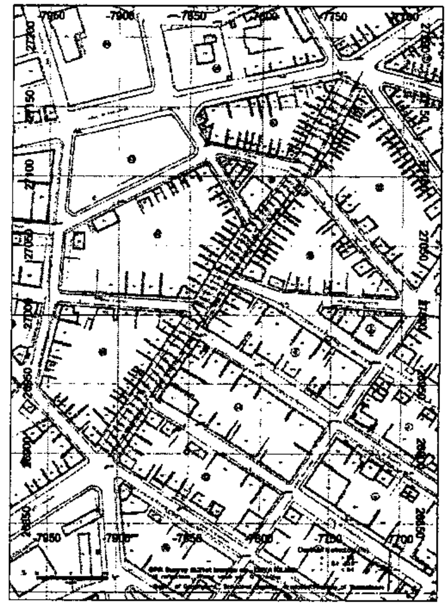

Figure 6. Town-planning sketch with locations of point reflectors.

Figure 6 shows the locations of the determined hyperbolic reflections on the town-planning sketch. Two group of points (point reflectors shown as dots in figure 6) could be detected, one on the left and the other on the right side of the road. The left group was attributed to sewerage network, which lies at depth and service cables (telephone, power lines) that were detected at lower depths. The point reflectors on the right side of the road are related with the water supply pipes. The extracted results as produced by GPR survey, are in a good agreement with the planning and the information as offered by the local authorities.

Four regions with possible leakage were finally suggested and presented by black rectangles in figure 7. The uppermost and the lowermost areas are related directly with major nodes of the distribution water and sewerage pipes, respectively. The central possible leakage area is coincidence with the observed leakage at basements of adjacent buildings as shown in figure 7. Our study also revealed five more areas of possible leakages with local occurrence. These areas are isolated cases in contradiction with the above four suggested areas where leakages are detected in the same distance in continuous profiles.

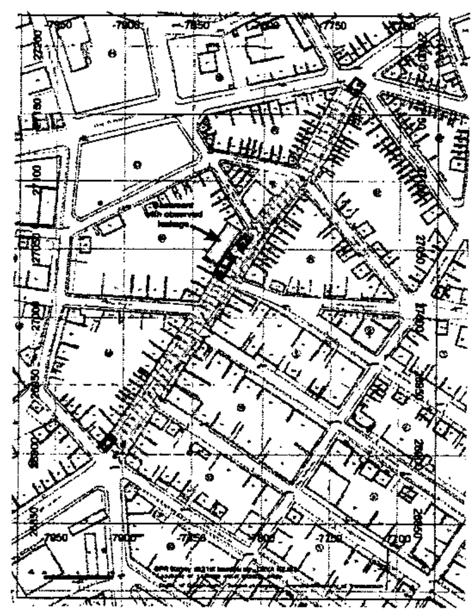

Figure 7. Town-planning sketch with locations of possible leakage areas.

CONCLUSION

Based on the GPR survey performed in this study, we confirmed the applicability of this method on the exact detection of several types of pipes. We have also recognized some reflection patterns, which attributed to water leakage areas and confirmed by in situ observations. Thus, we conclude that GPR method is a promising tool for leakages detection.

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