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Stakeholder needs for ground penetrating radar utility location

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ABSTRACT

In the UK alone there are millions of miles of underground utilities with often inaccurate, incomplete, or non-existent location records that cause significant health and safety problems for maintenance personnel, together with the potential for large, unnecessary, social and financial costs for their upkeep and repair. This has led to increasing use of Ground Penetrating Radar (GPR) for utility location, but without detailed consideration of the degree of location accuracy required by stakeholders — i.e. all those directly involved in streetworks ranging from utility owners to contractors and surveyors and government departments. In order to ensure that stakeholder requirements are incorporated into a major new UK study, entitled Mapping the Underworld, a questionnaire has been used to determine the current and future utility location accuracy requirements. The resulting data indicate that stakeholders generally require location tolerances better than 100 mm at depths usually extending down to 3 m, and more occasionally to 5 m, below surface level, providing significant challenges to GPR if their needs are to be met in all ground conditions. As well as providing much useful data on stakeholder needs, these data are also providing a methodology for assessment of GPR utility location in terms of the factor most important to them — the degree to which the equipment provides location within their own accuracy requirements.

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1. Introduction

For both utility location surveyors, and their clients, a dichotomy of interests exists between desires for significant accuracy of location and the knowledge that current equipment and practices are often incapable of meeting them. This does not, however, mean that there is a conflict between the interests of these two parties. Indeed, both can benefit from high levels of accuracy, the client through the ability to maintain high quality utility location records, and the surveyors through the opportunity to ensure client confidence relating to utility survey efficacy. Both can also benefit through reducing safety risks and cost risks in commissioning construction projects, and through reduction of the utility industry's direct construction costs associated with street works which, in the UK alone, is estimated to be around £1.5 billion per year (McMahon et al., 2005).

However, one fundamental question has remained largely unanswered — what do stakeholders require from geophysical utility location? Without an answer to this question, advances in GPR utility location risk being inappropriate, or inadequate, in terms of the parameters which stakeholders require and need to have confidence are being achieved. In order to avoid these pitfalls, the Mapping the Underworld team (MTU – a multi-disciplinary research project, combining expertise from a number of UK universities – see Rogers et al., 2006) has recently completed a stakeholder engagement exercise involving a questionnaire (see www.mappingtheunderworld.ac.uk/questionnaire.html) requesting of stakeholders their accuracy requirements, the depths within which they require those accuracies to remain valid and their comments on how geophysical utility location, and in particular GPR as the dominant technology for current location surveys — could be improved. This has proved a successful exercise and provides a unique insight into the needs and perspectives of a wide and representative range of utility location stakeholders. In total, eighty-five valid responses were received and the data they provide are detailed in this paper. Although it is not possible to give details of the response rate, as some canvassing was undertaken at major conferences thus preventing knowledge of the total number of stakeholders asked to complete the questionnaire, the large number of responses received was gratifying and shows the importance that the industrial stakeholders attach to the issue.

Considering the scale of the problems associated with locating buried utilities, only limited information is available on the needs of stakeholders. Prior to the MTU questionnaire, UK utility industry stakeholders were interviewed to provide details on their requirements in relation to industry practices for capturing, recording and

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sharing underground asset information (NUAG, 2006). Crucially, that survey questioned stakeholders as to whether existing code of practice requirements for location recording accuracy (±300 mm for measurement data, and ±500 mm for records) should be updated in the future, with respondents indicating that they should be and, in some cases, it was identified that standards within utility related organisations were already more restrictive than the existing codes.

Also, during operation of the MTU questionnaire, another highly significant survey was undertaken by the European Union funded ORFEUS ('Optimising Radar to Find Every Utility under the Street') project, which sought data for the specific purpose of developing a specification for significantly improved GPR equipment (see Thomas, 2007). This work included many aspects of the operational requirements of GPR equipment including accuracy requirements, resolution of two features and types of surface beneath which utilities must be detected. Therefore, there are currently three significant sources of survey data available on the requirements of utility stakeholders, each covering different aspects of the utility location problem. The specific virtue of the MTU survey, as reported in this paper, is that it provides a base of data for both location accuracy and the depths within which those requirements should remain valid.

A novel presentation of the data allows consideration of depth and accuracy requirements in a manner that is directly linked to the needs of stakeholders, ensuring that their views are central to data interpretation. These data are presented as a satisfaction score on the *y*-axis of graphs, representing the percentage of stakeholders who would be satisfied by the corresponding depth or accuracy value shown on the *x*-axis. This allows consideration of the efficacy of GPR equipment in terms of their locational accuracy, weighted against stakeholder perspectives, and suggests a methodology that would allow location equipment performance to be judged against the percentage of stakeholders who would be satisfied by the accuracy achieved (see Thomas et al., 2007). The methodology firstly shifts the accuracy emphasis from arbitrary tolerances towards what stakeholders actually require and, secondly, provides a means of monitoring the extent to which equipment advances achieve these ideals.

2. Demographics

As can be seen from Fig. 1, responses were received from a wide variety of utility location sectors, thereby covering the major stakeholder groups that have an interest in the MTU project. The significant size of four groups (government, contractors, utility providers and utility surveyors) ensures that the largest sectors responsible for streetworks and utility maintenance are properly represented. The responses included within 'other' were a trade association, an equipment manufacturer, a survey equipment sales organisation and two students. However, it should be noted that the information on organisation type does not allow differentiation between those organisations involved in traditional trench excavation and trenchless utility installations, nor between plant-based and manual excavation.

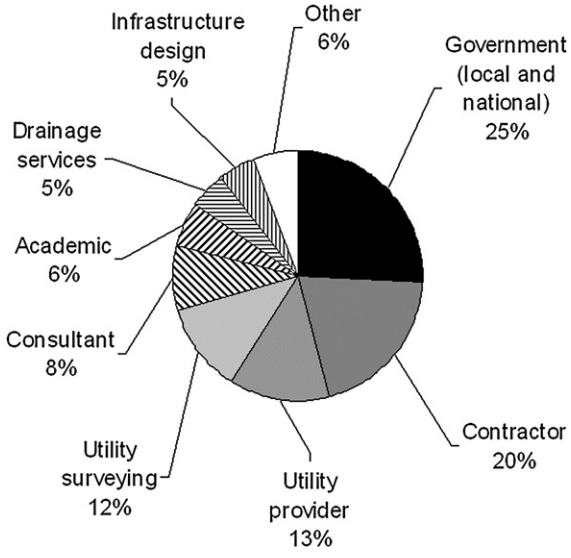

Fig. 1. Respondents by industry sector.

3. Importance of specific issues

In order to confirm the validity of research into the geophysical location of utilities, respondents were requested to rate four questions on a scale of 'very important', important', 'not important', and 'no opinion'. The four questions related to the importance of accurate determination of utility depth, accurate detection of utilities, accurate location of critical utilities (defined as those that pose significant health and safety problems if damaged) and understanding potential errors.

The results of these questions are shown in Fig. 2 and indicate that all four issues are of great importance to stakeholders. Of highest priority is the need to accurately locate utilities that pose significant health and safety issues, highlighting the importance of utility location as a form of risk minimisation.

Of slightly lower priority are accurate detection and understanding potential errors. That these two factors are shown to be of equal importance is significant in that both affect the confidence of stakeholders in location equipment — i.e. errors in detection, and the level of accuracy obtained, both degrade the usefulness of location survey data. Accurate depth assessment was given lowest priority by stakeholders, potentially because once plan location has been established within an acceptable tolerance, hand digging is often undertaken before excavation approaches the expected utility depth. However, it can be seen later in this paper that stakeholders are also slightly more restrictive in their accuracy requirements for depth than plan location.

4. Depth requirements

All GPR signals suffer from attenuation, that is they lose energy with increasing distance from the transmitter (see Thomas et al., 2006a, Santamarina et al., 2001). Also, the strength of transmitted signals is often limited by legislation to reduce interference to other devices (Chignell, 2004, Olhoeft, 2002). These two main factors can limit the depth range within which a signal reflected from a utility will be above the minimum sensitivity of the receiving equipment — i.e. the greater the attenuation, the lower the likelihood of the equipment being able to distinguish the utility from background noise. Therefore, an understanding is required of the depth ranges within which location equipment must operate.

Stakeholders were asked to provide details of the minimum depth of interest, as well as maximum depths relating to 'normal' and 'rarer' scenarios. Results for the minimum depth are depicted in Fig. 3a from which it can be seen that the majority of stakeholders favour minimum depths close to surface level — for instance, to satisfy 68% of stakeholders, the minimum depth at which a target can be detected must be no greater than 100 mm. Maximum depth requirements are depicted in Fig. 3b, illustrating that a 'normal' depth is anywhere between surface level and approximately 3 m deep, with 'rarer' scenarios requiring maximum depths extending to at least 5 m. In Fig. 3c, the rate of change in satisfaction is plotted against maximum depths up to 5 m deep, which indicates that stakeholders tend to round their required depths approximately to the nearest 0.5 m at shallow depths and to the nearest 1 m for depths of 2 m and greater, as illustrated by the pronounced peaks in the graph.

In the UK most utilities should be installed in the first metre below surface level (NJUG, 2003), and variations in placement depth and

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