DETECTION OF FLUID LEAKAGE USING GROUND PENETRATING RADAR

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A thesis submitted in fulfillment of the
requirements for the award of the degree of
Master of Science (Geomatic Engineering)

Faculty of Geoinformation and Real Estate
Universiti Teknologi Malaysia

JANUARY 2015

To my beloved:

Mum, Sabariah Binti Bujang

Dad, Yusup Bin Bujang.

Siblings:

Shah Rezza

Nur Zalikha

Nasrullah

Fakhrullah

Thank you for love, best wishes and blessing in my study.

ACKNOWLEDGMENT

Alhamdulillah, my gratitude to Allah Almighty for enabling me to study a small portion of His magnificent creation. My appreciation to all those who gave me the possibility to successfully accomplish my task in this study and it is a pleasure to thank everyone especially to my family members for their constant prayers, love, moral support, and everything.

I have met many people whom I remain extremely grateful, sharing their knowledge and help me either direct or indirect during this study. Firstly, my deepest gratitude to my supervisor, Dr Zulkarnaini Bin Mat Amin, for the encouragement, guidance and motivation from the initial to the final level of this study. He has been providing space and freedom for me to venture in this study.

A special thanks to UKK staff, especially En Fahmi, who taught me to handle the equipment in proper way and giving assistance during the pipe leakage simulation. To Civil engineering Geotechnical lab assistant, En Zulkifli, who supervised me in soil compaction procedure which is added in this thesis writing. Lastly, my sincere appreciation to all my friends who have assisted various occasions especially during the observation.

ABSTRACT

The reliability of Ground Penetrating Radar (GPR) is a new positional technology for underground utility especially in the water supply distribution. Thus, water supply distribution system has to be maintained in order to prevent shortage of water supply in an area. This study emphasized on the detection of fluid leakage using GPR. Several tests such as soil compaction, GPR calibration and two experiments are performed. Soil compaction is conducted to clarify the maximum dry density (MDD) of sand. Sand is used in this study because sand produces small dielectric constant in reflecting the GPR signal. The study involved GPR calibration at National Institute of Land and Survey (INSTUN) test base area. GPR calibration is performed to make sure that the equipment is in good condition. Next, the pipe leakage simulation is conducted at the selected site. The experiment is directed on good and broken pipe condition. Consequently, result of GPR calibration and data on GPR are processed using Reflex 2D software. Feasibility study on different types of pipe condition images proved the extraction of features is complimentary to visual inspection. In this study, the spatial distribution of the contaminated soil or different dielectric permittivity of the soil is analyzed by interpreting the GPR image based on GPR reflection coefficients. As a conclusion, the development of underground infrastructure especially in water supply management in this study is expected to work well in order to help many sectors not only for country development but also for authority well-being and academic purposes. Throughout this study, Geomatics profession has contribute in providing valuable evidence on fluid leaks location and mapping the network.

ABSTRAK

Radar Penusukan Tanah (GPR) adalah teknologi baru dalam penentududukan utility bawah taah terutama dalam pengagihan bekalan air. Oleh itu, system pengagihan bekalan air perlu dipantau untuk mengelak kekurangan air di suatu kawasan. Kajian ini menekankan pengesanan kebocoran cecair menggunakan GPR. Beberapa ujian akan dijalankan seperti pemendapan tanah, kalibrasi alat dan dua experiment berdasarkan kebocoran paip. Ujian pemadatan tanah diadakan untuk mengenalpasti takat tertinggi ketumpatan pasir. Pasir digunakan dalam kajian ini kerana pasir mempunyai daya dielektik yang kecil dalam memantul balik isyarat GPR. Kajian ini juga mengadakan pengkalibrasian alat di INSTUN. Kalibrasi alat dilakukan untuk memastikan alat berkeadaan baik. Setelah itu, simulasi kebocoran paip dilakukan di tempat yang ditetapkan. Experimen ini dilakukan menggunakan paip berkeadaan baik dan pecah. Data kalibrasi alat dan experimen akan diproses menggunakan pemprosesan Reflex 2D. Di samping itu, pengenalpastian anomali dalam data mentah dilakukan melalui pemeriksaan visual. Analisis akan dilakukan setelah pengesanan kebocoran cecair dalam tanah dengan penafsiran imej GPR berdasarkan pekali pantulan GPR. Kesimpulannya, pembangunan infrastruktur bawah tanah terutamanuya pengurusan bekalan air dalam kajian ini kajian ini diharap boleh dilakukan dengan baik untuk membantu banyak sektor bukan sahaja untuk pembangunan infrastruktur bawah tanah Negara tetapi juga untuk tujuan akademik. Melalui kajian ini, ahli geomatik boleh menyumbang dalam memberi ketepatan lokasi pengensanan kebocoran air.

TABLE OF CONTENTS

CHAPTER 2 LITERATURE REVIEW

CHAPTER 3 RESEARCH METHODOLOGY

CHAPTER 4 PERFORMANCE OF GPR AND ANALYSIS

CHAPTER 5 CONCLUSION AND RECOMMENDATION

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Numerous activities are undertaken particularly in construction and provision of underground infrastructure nowadays. These activities required precise and reliable monitoring service especially on water distribution system. The most practical domestic device of underground infrastructure is that by detecting water leakage in the distribution system. According to Hasnul and Normayasuria (2009), old and dilapidated asbestos cement (AC) pipes contributes to major physical loses of water leakage. Non-revenue Water (NRW) is an indicator used by National Water Services Commission (Suruhanjaya Perkhidmatan Air Negara) (SPAN) to reflect the performance of water supply in Malaysia. The estimated level of NRW in 2010 was 18% in Penang to 55% in Pahang (http://www.span.gov.my).

Recently in The Star Online article published on Sunday, February 16, 2014 mentioned the Petaling Jaya folk have experienced a dry taps which is due to the pipe burst within the area. Thus, some precaution should be done for well-being of life applications. Furthermore, Malaysia is a country which experience monsoon season throughout the year with high density of rainfall catalyzing the risk of landslides to certainly tragedy. Therefore, more significant scientific studies are necessary in order to monitor the vicinity of buried utilities for general public and environment safety but also the network itself.

In addition, on March 17, 2014, the Mass Rapid Transit (MRT) project has cost up by another millions which is due to utility damage. The most significant effect from the previous damage towards Malaysia gives problem not only to water supply but also in transportation. This destructive damage had generated a killing wave and swept everything along its path as our country development problem. It propagated across nearly RM172 millions where it affected the Selangor area.

Besides the destruction effects, there are several identified minor malfunction within underground pipe cable which are mostly generate electromagnetic wave for the time being. Although the underground utility is just a minor breakdown, it is still necessary to take an action before it becomes a serious matter to the country. Moreover, Malaysia is also bare to other disasters such as heavy rain during the monsoon season. The high density of water leakage in the pipe or drain is vastly catalyzing the risk to inevitably disaster. Based on all the highlighted disaster events mentioned above, Malaysia undoubtedly requires a competent and dynamic system which is capable to induce underground displacement in long term. This water supply management damage did not occur silently but with precursors.

This study is emphasizing on the detection of fluid leakage using GPR, (Model: IDS-DUO). The architecture of GPR will be provided in Chapter 2. The concept and parameter of GPR will be discussed in this Chapter. Meanwhile, the research methodology of the study will be explained in Chapter 3 which embraces every important constraint for GPR parameter. Next, the performance of GPR which comprise the processing, results and analysis provided from the survey will be discussed in Chapter 4. Besides, the result of soil compaction and GPR calibration will also be discussed in this Chapter. Finally, the summary and concluding remarks will be presented in Chapter 5. The outcome from this study is expected to provide reliable GPR service in support of utility mapping in Malaysia.

1.2 Problem Statement

The problem statements in this study are as the following:

a) GPR services across different geographic region

- On 30th September 2013, an outdated utility maps for underground utility such as MRT had triggered a destructive of water cuts in Selangor which claimed approximately big amount of money. This tragedy shows that Malaysia is vulnerable to many disasters that also disrupt other services. There are many pipe leakage detectors available in market, the agencies or department related to water distribution does not aware with GPR capability. Therefore, in order to enhance the accuracy, integrity, reliability and availability, the needs and requirements for GPR is important for various applications. GPR services can be found in many countries with majority of GPR system developer and service provider are operating across different regions. Hence, the study and understanding of the behavior could improve the GPR services in an area.

b) GPR as a requirement for sufficient utility management application and sustainable development.

- The issue of utility base map remains very important in national development policy. Country development could be easily being managed through the base map as the guideline. Other damages could be reduced too. Nonetheless, the common practice in underground utility still uses conventional techniques, which is limited in term of specific equipment and rate of data processing. Hence, the agency such as Licensed Land Surveyor (LLS) could utilize GPR potential especially in fluid leakage detection.

- The reliable GPR service in detecting water leakage during an observation without any digging on ground has offer a huge contribution to the country for numerous purposes especially for economic growth. Water content in the

sediment would causes dielectric properties changes. Move toward of using the new technology, GPR, may accomplish the development of the region. Thus, it is a need to maintain the underground infrastructure monitoring system for authorities' welfare and the network itself.

- According to 10th Malaysia plan (2011-2015), the quality of life for Malaysians improved through better access to healthcare, public transport, electricity and water. Measures were also being taken to create a caring society and promote community well-being. Economic development which is based on sustainability principles should ensure that the environment and natural resources are preserved so that growth will not come at a cost to future generations. Consequently, the existence of GPR technology in underground maintenance especially in fluid leakage detection could be carried out effectively.

c) Research-based on underground services

- A research need to be carried out in underground services specifically in water supply management in Malaysia. The expectation of this study is to provide faster and sufficient requirement for water leakage solution. Additionally, underground study is a new topic of scientific study especially for higher learning institution based on GPR.

- Even though the purpose of GPR is to locate the utility, the knowledge and understanding to handle GPR is importantly needed to obtain worthy information. By knowing the limitation and strength of the equipment, user will follow the effective technique to obtained respectable result.

1.3 Objectives of the Study

The aim of this study is to detect fluid leakage using ground penetrating radar. The aims have embarked to the following objectives:

a) To retrieve the soil moisture contains.
b) To evaluate the performance of GPR in water leakage detecting.
c) To differentiate images between pipe in good condition and pipe leakage.

1.4 Scope of the Study

Malaysia is exposed to various types of deformation events including underground utility damage. All these deformation incidents have miscellaneous displacement behaviours and a diversity of frequency in the movement occurrence. Thus, the scopes of this study only focuses on pipe water leakage detection through GPR and the details are described as follow:

a) The assessment for GPR service

- To monitor on the stability data transfer and availability of the system. The equipment used in this study is IDS Detector Duo Ground Penetrating Radar. The equipment is checked and tested at INSTUN to ensure that it is in good condition. The bouncing wave reflected back during observation would shows that the equipment is capable to detect different material planted in ground.

- To analyze the precision of electromagnetic wave transmitting through sand. GPR have dual frequency which capture images in shallow and deeper depth. Different frequency works for different purposes. This study is using sand as sand has lower dielectric constant.

b) Experiment conducted

- An infrastructure of the pipe leakage simulation is designed with a suitable dimension. The simulation of pipe leakage is conducted at the selected site with estimated coordinate of 1°33' 56.6"N, 103° 39' 22.8"E through Google Map (2014). The design, location and detailed of the pipe leakage simulation could be referred in Chapter 3.

- Two different tests were conducted with respect to types of pipes, which are good and broken pipes. The first test consists of decent water stream in a good pipe while final tests consist of water leak stimulation in a broken pipe. The changes of the different dielectric permittivity of the soil and images obtained during both testing would be analyzed in Chapter 4.

c) Processing Software

- The Reflex 2D software is used to process the GPR data by allowing an easy import, presentation, processing and investigation of two dimensional (2D). It is used to remove the unnecessary conditional and filter the image. In this study, the processing includes the identification of anomalies in the raw data and the feature is courtesy to visual inspection.

- Interpretation of GPR image. Comparison of between dry soil and contaminated soil. Based on the electromagnetic frequency vectors, the trend of the object's image is directly visualised on screen during the field. Therefore, the spatial distribution of the soil with different pipe conditions would give dissimilar dielectric permittivity

1.5 Significant of the Study

The interpretation of GPR image is an awaiting action to enable the nation to benefit from its uses. Thus, there are several essential purposes of the study as below:

a) Enlightening GPR application in Malaysia

- Accurate evidence regarding on what lies beneath the surface is required in planning the installation of new utilities and excavation of present utilities. Underground utility mapping presents a new method for land surveyors to approach their proficiency in positioning technology. Thus, the use of GPR has emerged as a viable technology to detect all the material contained underneath earth surface easily without extensive digging.

b) Improving time period to analyze the GPR result

- Many users could get the benefit from the GPR by providing precaution if any underground damage occurred especially in detecting water leakage. The problematic area could be mark directly during survey using GPR. The design of electromagnetic wave is formed through GPR screen in realtime with its components: data collecting, data processing and modelling. Through the combinations of those components, the Reflex 2D software is expected to provide the analysis sooner than the current timing. Finally, GPR would anticipate the non-destructive methods and helps to locate early leaks that would also prevent further damages.

c) To support authorities, academics and researchers

- The result based on GPR reflection coefficients could be used for academic and scientific study especially for higher learning institution. Moreover, the new method in underground positioning technology would help user to know the important of GPR. It also benefits the authorities, in several aspects such

as providing alternate alerting services, risk anticipating, updated record and safety of water supply network.

1.6 Chronology of the Study

The operational framework is an important role in planning and implementing a system to achieve the aims and objectives of the study. Thus, the operational framework is portrayed in five phases and detailed of the tasks are described shortly. The execution method to tackle this study was elaborated in Chapter 3. The operational framework design is illustrated in Figure 1.1.

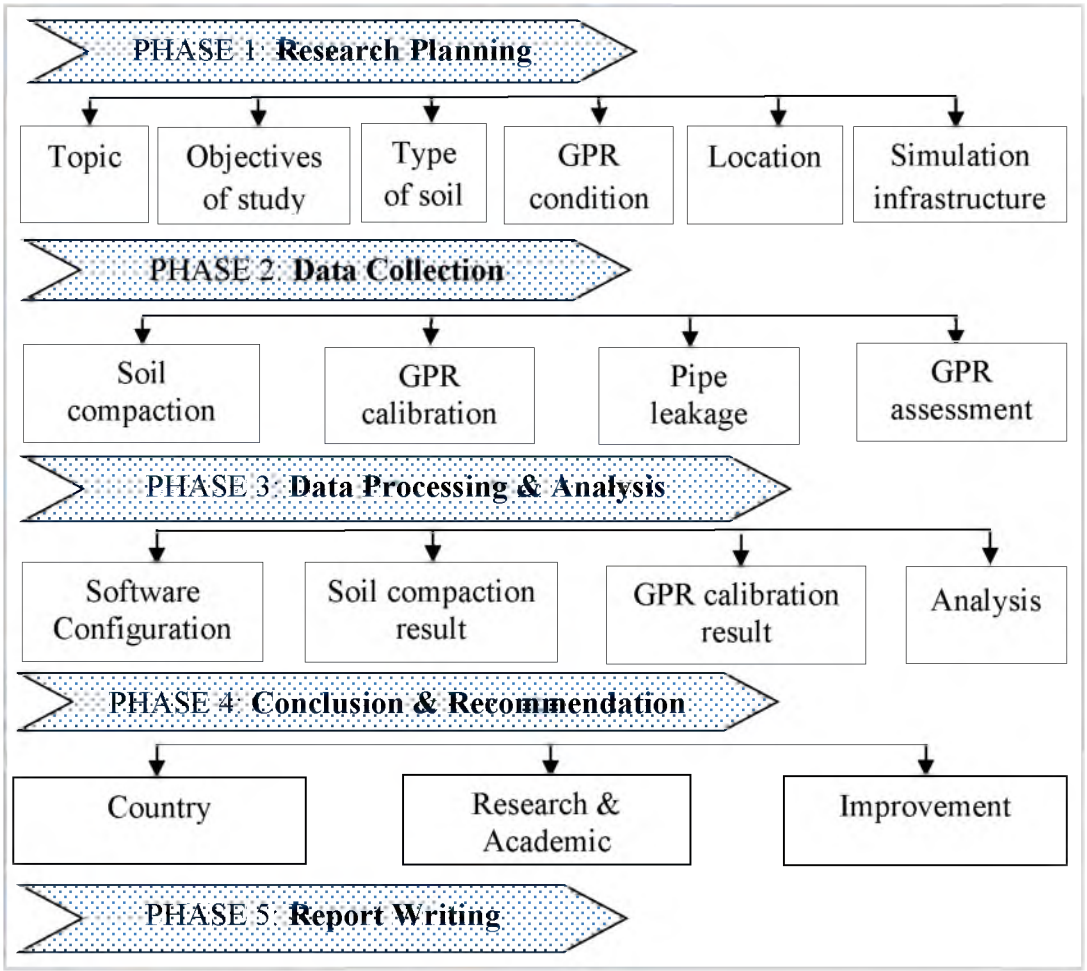

Figure 1.1: Operational Framework Design

Phase 1: Research Planning

a) Understanding of the important concept and study topic
b) Planning of the study objectives accomplishment
c) Selection of type of soil used in the study
d) GPR checking and testing
e) Selection of site survey
f) Designing of pipe leakage simulation infrastructure

Phase 2: Data collection

a) Soil compaction
b) GPR calibration
c) Pipe leakage simulation at the selected site survey
d) Assess GPR performance on dry and contaminated soil

Phase 3: Data Processing & Analysis

a) Software configuration to process the collected data
b) Result of soil compaction
c) Result of GPR calibration
d) Feasibility study on different types of pipe condition images

Phase 4: Conclusion & Recommendation

a) Benefits to country, safety of authority and network
b) For academic purposes.
c) Recommendation and approaches in some part or area to improve this study

Phase 5: Report Writing

e) Final study dissertation

1.7 Thesis Outline

The thesis consists of five chapters and described briefly as follows:

Chapter 1: This study is emphasizing on the detection of fluid leakage using ground penetrating radar. Malaysia has a big problem regarding the underground utility arrangement causing many underground disasters especially in water supply management. Therefore, this Chapter has stated it objectives in order to overcome the problem and discuss concisely about the study significant. The scope of study is used as a guideline in order to achieve the aims of this study. Besides, the chronology of each experiment's operational framework is defined to ensure that the procedure would works well.

Chapter 2: This chapter reviews some of the theory and concept of GPR as electromagnetic and radio frequency instrument. There are four major issues that are frequently referred to and discussed in this study as follow: 1) Subsurface utilities detector, 2) Review of other method used to detect pipe leakage, 3) GPR parameter and survey application, 4) GPR processing workstation, 5) Soil compaction, 6) Reflex 2D. All issues discussed here are used to highlight the expenditure of GPR in this study.

Chapter 3: This chapter focuses on the operational framework of each experiment starting from research planning. Several tests such as soil compaction is performed to clarify the maximum dry density (MDD) of sand as sand is used in this study. The testing infrastructure system and equipment needed in this survey were also being reviewed. Then, test on GPR calibration is done at National Institute of Land and Survey (INSTUN). Next, the details of testing procedure will be briefly described in this subtopic, which involve dry and contaminated soil. Last but not least, Reflex 2D software was used to process and filter the data obtained. In order to verify the performance of GPR signal transfer through type of soils use and its' contain, a data analysis would be elaborated further in Chapter 4.

Chapter 4: In this chapter, all the results are discussed including data processing and analysis. The analysis in the chapter also includes, soil compaction, GPR calibration and the two experiments. Soil compaction is an essential to configure the MMD of the sand. Meanwhile, GPR calibration was performed to ensure that the equipment is in good condition. The outcome from this study is expected to provide reliable GPR service in support of utility mapping in Malaysia. Thus, the experiments are demonstrated in order to examine the performance of GPR. Firstly, the experiment is design by scanning the good pipe condition. Next, the GPR scanning for contaminated soil by the broken pipe. The result and analysis is very important to ensure that the objectives are achieved. Therefore, evidence in this study is useful to detect underground utility by surveyor.

Chapter 5: This chapter summary the research finding, draws some conclusions, and suggests recommendation for future study. Throughout this study, the performance of GPR algorithms has been analyzed by simulation process. From the analysis section in Chapter 4, the data from GPR is consequently shows the effects of fluid leakage in pipe. Throughout this study, there are many improvement or approaches need to be made in order to investigate more on the use of GPR in detecting underground utility as GPR is a new technology used especially in Malaysia. The reviews of other method used to detect pipe leakage in Chapter 2 could help researchers to explore more in this study. It can be conclude that, the development of underground infrastructure in this study is optimisms to work well in order to help improving the water supply management. Moreover, this study is expected to help in the development of the country but also for authority well-being and academic purposes.

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