FORENSIC INVESTIGATION USING GROUND PENETRATING RADAR (GPR)

NOORAZLIZA BINTI SUDAR

A project report submitted is partial 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

DEDICATION

I dedicated this study to my beloved papa and mama

En. Sudar bin Sitra & Pn. Fatimah binti Ehwan

Thank you for always being supportive and always pray for me

To all *my family* members & my *Meor*,

Thank you for the blessing

ACKNOWLEDGEMENT

In the name of Allah, the Most Gracious and the Most Merciful. Alhamdullilah, all priases to Allah for the strenghts and His blessing in completing this thesis. First of all, special thanks goes to my supervisor, Dr. Zulkarnaini bin Mat Amin for invaluable help of good comments and suggestions to the succes of this study

My sincere thanks also goes to ASP Nizam from Crime Scene Investigation Department of Royal Police Malaysia for the assistance and guidance of forensic investigation. A special thanks to UTM guards, and Osha Department of UTM for supplied the simulation objects. Not forgotten lab technician, En. Fahmi for being willing to share his knowledge and help in fieldwork.

Thanks to all my friends, for their kindness and moral support during my study and willing to help me in finished my fieldwork. Thanks to my family and special thanks to Meor for support and encouragement.

Last but not least, to my beloved parents; Mr. Sudar bin Sitra and Mrs. Fatimah binti Ehwan for their endless love, prayers and support. To those who indirectly contributed in this study, your kindnes means a lot to me.

Thank You.

ABSTRACT

Controlled forensic using GPR has been successful used by law enforcement agencies from other countries to locate graves and forensic evidence. However, in Malaysia, forensic agencies are still using cadaver dogs in order to determine the clandestine graves. The purpose of this study was to determine the applicability of GPR in detecting controlled graves for Malaysia environment. The objectives for this study included what the different images radar between four burial scenarios (e.g naked object, wrapped object, metal object, and wrapped object in 0.5m) in a month monitoring, comparing GPR imagery between 250 MHz and 750 MHz antenna and to analyze all the images. Data and images were collected on controlled graves containing three graves at one meter and 0.5 meter; naked object, wrapped object, metal object and wrapped object under 0.5 m. the data then were processed by using Reflex2DQuick. Duo frequencies were used to detect the location and depth of the simulation object which are 250 MHz and 750 MHz. The electromagnetic wave velocity is decrease with the depth together. In terms of antenna performance, 250 MHz data generally provided high resolution image for earlier week. Over time, the 750 MHz data provided the higher detail resulted. GPR can be one of the best techniques to determine clandestine graves and this study found that it suited with Malaysia environment.

ABSTRAK

Kawalan forensic yang menggunakan alat GPR telah jayanya digunakan oleh pihak agensi undang-undang dari luar negara dalam menentukan lokasi kubur dan pengumpulan bukti forensik. Walaubagaimanapun, di Malaysia, pihak agensi forensik masih lagi menggunakan anjing pengesan untuk mengenalpasti kubur yang tidak diketahui. Tujuan kajian ini adalah untuk menentukan kebolehan alat GPR dalam mengesan kubur bagi situasi di Malaysia. Objektif kajian ini pula termasuk apakah perbezaan imej radar antara empat situasi kubur (cth: objek terdedah, objek yang dibalut, objek metal, objek yang dibalut pada kedalaman 0.5m) dalam satu bulan perhatian, membezakan imej GPR antara 250 MHz frekuensi dan 750 MHz antena frekuensi, dan menganalisa semua imej tersebut. Data dan imej-imej diperoleh daripada empat kubur yang ditetapkan iaitu tiga kubur pada satu meter dan satu kubur pada 0.5 meter; objek yang terdedah, objek yang dibalut, objek metal, dan objek yang dibalut pada kedalaman 0.5 m. Data-data tersebut kemudiannya diproses menggunakan Reflex2DQuick. Duo frekuensi digunakan untuk mengenalpasti lokasi dan kedalaman bagi objek simulasi iaitu 250 MHz dan 7550 MHz. Velociti bagi signal elektromagnetik adalah semakin berkurangan dan begitu juga dengan kedalaman. Bagi prestasi antena pula, data yang diperoleh oleh 250 MHz antena adalah beresolusi tinggi untuk minggu terawal. Dari masa ke semasa, 750 MHz antena menyediakan data yang hasilnya lebih terperinci. GPR adalah salah satu teknik yang berkesan untuk menentukan kubur yang tidak diketahui dan kajian ini mendapati bahawa GPR adalah sesuai digunakan di Malaysia.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 Background of the study

During crime investigations to detect clandestine graves, some agencies involved such as law enforcement agencies, coroners, medical examiners, and police department request forensic investigators to aid them in searches for bodies or skeletal remains (France et al. 1992; Schultz *et al*. 2006; Schultz 2007, 2008). The problem that law enforcement agencies are faced from time to time is to locate, detect and recovering the buried bodies in clandestine graves. In Malaysia, Crime Scene Investigation Department of Royal Police Malaysia is using cadaver dogs to identify the location of the crime area. This technique cannot locate the exactly object under hard ground and narrow the area of target.

The Ground Penetrating Radar (GPR) is a non-destructive tool which has been accepted for forensic investigation. This instrument is operated by scanning the

underground features and locating the subsurface utilities by penetrating the image display in digital format which easier to analyze and interpreted the underground data.

In earliest inception, GPR were used to natural geologist material and it used the method of radio waves to probe the ground. Use of radio waves to sound the earth was contemplated for decades before results were obtained in the 1950s (El said. 1956; Waite and Schmidt, 1961)

The most important parameter is the frequency of the electromagnetic wave which is used to determine the good image resolution of GPR and to achieve the best study area. The high frequency will come out the accurate information but the depth of the study is short. For the lower frequency, antenna will penetrate deeper into the ground. However, because the wavelength is longer, the response is less detailed as in Figure 1.1.

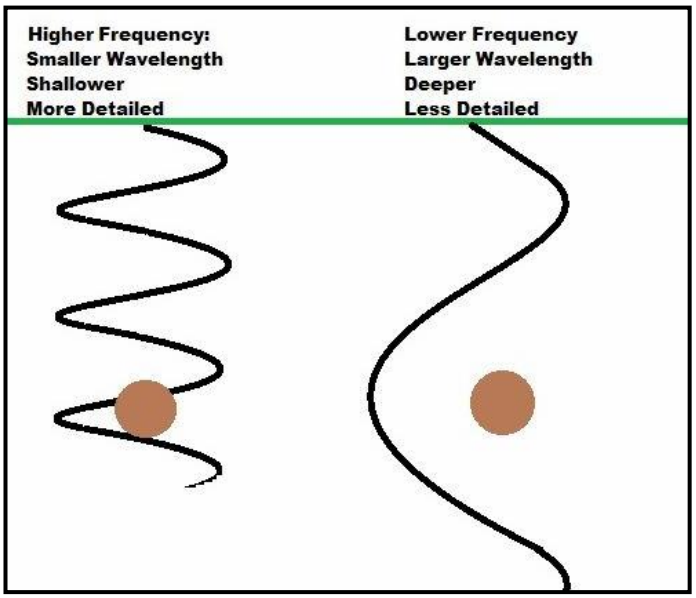

Figure 1.1: GPR antenna frequency
(http://gprtrainingcourses.com)

Currently, GPR is one of geophysical option for the grave detection. Archeologists usually used this kind of instrument at their site area where is containing burials. Therefore, they need to document the location of unmarked graves and with this technology also has proven as useful technique to identify the areas that have the unmarked graves.

Forensic geophysics also can used this technique to study the localization and mapping the buried objects instead of the elements beneath the soil. There are many geophysical techniques for the forensic investigation to detect the underground material or buried objects in large area which have different dimensions (from weapons or metallic barrels to human burials and bunkers). This kind of method have the possibility to aid the search and recovery the targets because it is non-destructively and can investigate in a short time in large areas where suspect, illegal burial or forensic target is hidden in the subsoil. Usually, there is always a contrast in physical properties between the target and the material that buried under soil, so it may help to define precisely the concealing place of the search and recovery target.

GPR has being broadly accepted in forensic investigation since it is increasingly known as one of the geophysical search methods. This is because the GPR is non-invasive and possible for the investigation of the search and recovery without disturbing or destruction to evidence. In particular, GPR has become popular in geophysical option especially for grave detection (Vaughn 1986; Bevan 1991; King *et al*, 1993; Nobes 1999; Davis *et al.* 2000; Conyers 2006; Jones 2008). As example, in Utah, the police department helped to search a suspected burial site for missing person with using GPR. There is no other information about the clandestine grave but the detectives working for that case believed that the missing person may have been buried somewhere around the residence. So the technician on site was mobilized quickly to the site area and scan using GPR. In Florida, at least 81 boys died. Their remains lie in unmarked graves

spread over the shuttered campus of the Florida Reform School for Boys. So, the forensic teams working in collaboration with USF archaeologist have begun to use ground-penetrating radar in the search as in Figure 1.2.

Figure 1.2: Detecting unmarked burial in Florida (http://blogs.plos.org/neuroanthropology, 2012)

Meanwhile, in Malaysia, no technique has been used to detect the burial objects under the soil unless our forensic teams use cadaver dog (see Figure 1.3) to determine the location of area that containing the object buried underground (Personal Communication with ASP Nizam, 2014). It may be the responsible party may not yet know the effectiveness of GPR equipment in identifying object buried underground. With this advent of this study, can be share with respective party about the use of GPR tool in detecting objects buried underground. The police and forensics should use the latest methods as technology is increasingly sophisticated. GPR has the ability detect with accurate and faster method than others.

Figure 1.3:Cadaver dog used for search and recovery
(http://www.rmp.gov.my, 2010)

The police dog unit (K9) will train dogs to find corpses submerged underwater or buried underground as part of its upgrades and facelift. Some 30 sniffer dogs which were purchased in December were also shown to the public. The canines from Germany and the Czech Republic are believed to have been bought for RM30,000 each. Unfortunately, cadaver dog only can define objects in soft ground and the dogs cannot detect or hardly detect objects buried under hard ground. With using GPR instruments, K9 team can detect the burial object in a short time and in large area either in soft ground or hard ground.

1.2 Statement of problem

GPR can assist in identifying the underground utilities objects in a short time compared to other techniques such as excavation and water blasting. Information generated by these devices is in the form radar image that contains a hyperbolic shape and it shows the depth of detected objects as well. The instrument is influenced by many factors in order to transmit the signal and depth. The factors that affect the GPR are (Doolittle and Collins, 1995):

i. Porosity and water saturation level
ii. The amount and type of soil in solution
iii. The amount and type if clay
iv. Scattering

GPR has been utilized in forensic investigation and has become well known method because has been used in some high profile case histories. With this techniques also can greatly assist police detectives and investigators or forensic team to pinpoint the suspicious areas and thus saving the unnecessary excavation and time.

To define the good GPR survey results, the area or ground should not been disturbed by anything either the heavy vehicle or by digging which can compress the soil and will affect the reflections.

This study was conducted and monitored to systematically assess the changing geophysical response of simulated burial objects for a month and was monitored for every week. Graves containing monkey carcasses and metal object were defined in this

study as an unrecorded burial and have been excavated and dug about 1m depth and 0.5m below ground level. This should be noted that geophysical results will vary depending upon the period of buried. The discover grave are usually rectangular in planview, and it is just large enough to deposit the object before being backfill with excavated soil and associate surface debris. There are four scenarios for this study:

i. Naked burial
ii. Wrapped burial
iii. Metal objects
iv. Wrapped burial (0.5 m depth)

The aims of this one month geophysical monitoring study of different period of time clandestine burials will answer some questions posed by forensics search teams such as:

i. Could GPR surveys successful locate the simulated clandestine burials
ii. How long were surveys detect the unmarked graves
iii. When should a geophysical survey using GPR take action
iv. How about the processing technique
v. What images will come out from the processing

These questions by forensic search teams listed above will be answered after the survey has been taken throughout monitoring the graves every week in a month.

1.3 Objectives of study

The objectives of this study are:

i. To evaluate the image radar between the clandestine burial within first day of the burial till a month.
ii. To define the comparison between four scenarios of the simulated burial.
iii. To analysis the image after the processing in order to identify the location and the depth of the buried objects.

1.4 Scope of Work

This study involves the simulation of clandestine graves by developing a rectangular box with 1m depth below ground-level. The simulation process are conducted at the Faculty of University Technology Malaysia (refer Figure 1.4). To execute this study, several factors should be given attentions, which are:

i. Designed and construct the simulate grave area

- The study area is at open area near the UTM gate to Senai Highway (see Figure 1.4). The dimension rectangular box for the survey areas for this simulation graves are 1.9 m x 0.8 m and depth 1.0 m for three graves and one 0.5m as in Figure 1.5

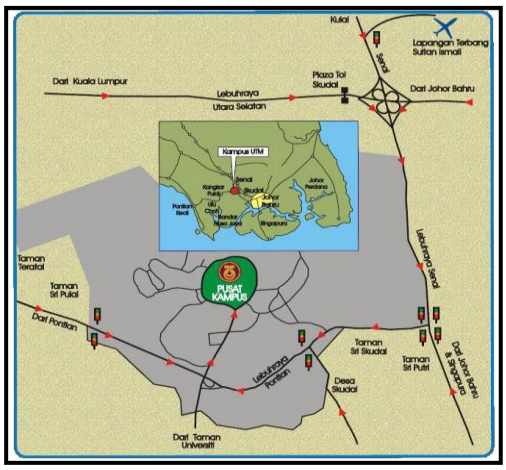

Figure 1.4: Case study area

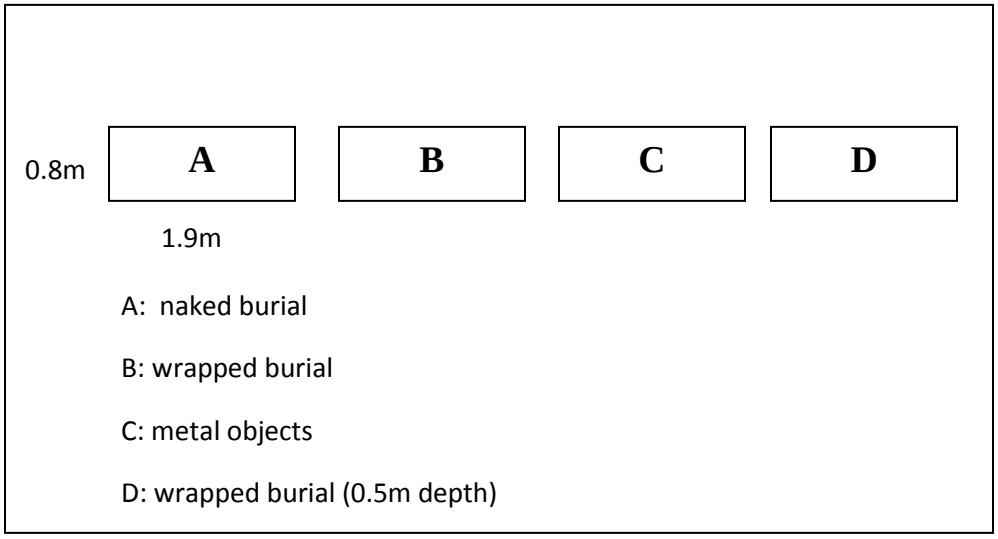

Figure 1.5: The dimension of rectangular box for simulation grave

ii. The type of soil that used in this study

- For this study, the soil type that used is clay because the forensic team said that usually the crime scene happened in oil palm and plantation which is containing clay. See figure 1.6.

Figure 1.6: The simulation area and type of soil that used in this study

iii. The instrument (GPR) and software

- GPR was used in order to detect the burial object underground (see Figure 17) and as for software, Utilities Detector Duo System was applied to identify and interpret the real time result of the targets and type of the data structure which have been buried. These real time images were displayed on the screen of the tough book. For the processing step, Reflex2DQuick software was used in order to analyze the image and define the type of data.

Figure 1.7: Ground Penetrating Radar

iv. The comparison of time period in a month (monitor every week) between the simulation object

- The several of period were done to analyze and compare the images that have been process between 1st weeks until 4th weeks of the month.

1.5 Significance of Study

The benefits of this study that are expected as following:

i. Guidelines for police to investigate in searching for died bodies
ii. Results from the literature study is expected to give a clear picture of guidelines for carrying out the investigation on a buried bodies as defined by the policeman, and forensic investigation
iii. In addition, the study of these works can be used for any parties that requires and as a reference for the management of their plans for the future.
iv. Having extensive knowledge about the procedure in order to detect buried object with using GPR. Results and analysis can be used to produce and improve the quality of the production of the image of GPR.

1.6 Methodology

The research methodology is the process to achieve the objective or the aim of the study. A methodology should be emphasized and should not be taken lightly. According to Wikipedia methodology is defined as a guideline system for solving a problem, with specific components phases, tasks, methods, techniques and tools". The methodology is a process, a set of tools for research and retrieval, as well as an art of performing a scientific paper (Adam and Schvaneveldt, 1985). Generally, the study is started from the problem until the data acquisition and analysis of such data. This method uses 5 phases methodology (Figure 1.8):

i. First phase: preliminary study

Which is including objectives, problem statement, significance of study and scope of the study.

ii. Second phase: literature review

Which should be obtained from the reading of books and search on the internet that relating to the study.

iii. Third phase: data collection

Divided into 2; primary data is do the observation to soils and find out the properties of the soil, do the simulation of objects that are buried and analyze images obtained from GPR tool. Secondary data were reviewed from educational materials and books for reference.

iv. Fourth phase: result and analysis.

Result obtained from measurements made and the analysis will come out from the results.

v. Fifth phase: conclusion and recommendations.

Conclusion involves the entire phase and whether the objectives of the study achieve or not. Recommendations are needed to improve and extend this study.

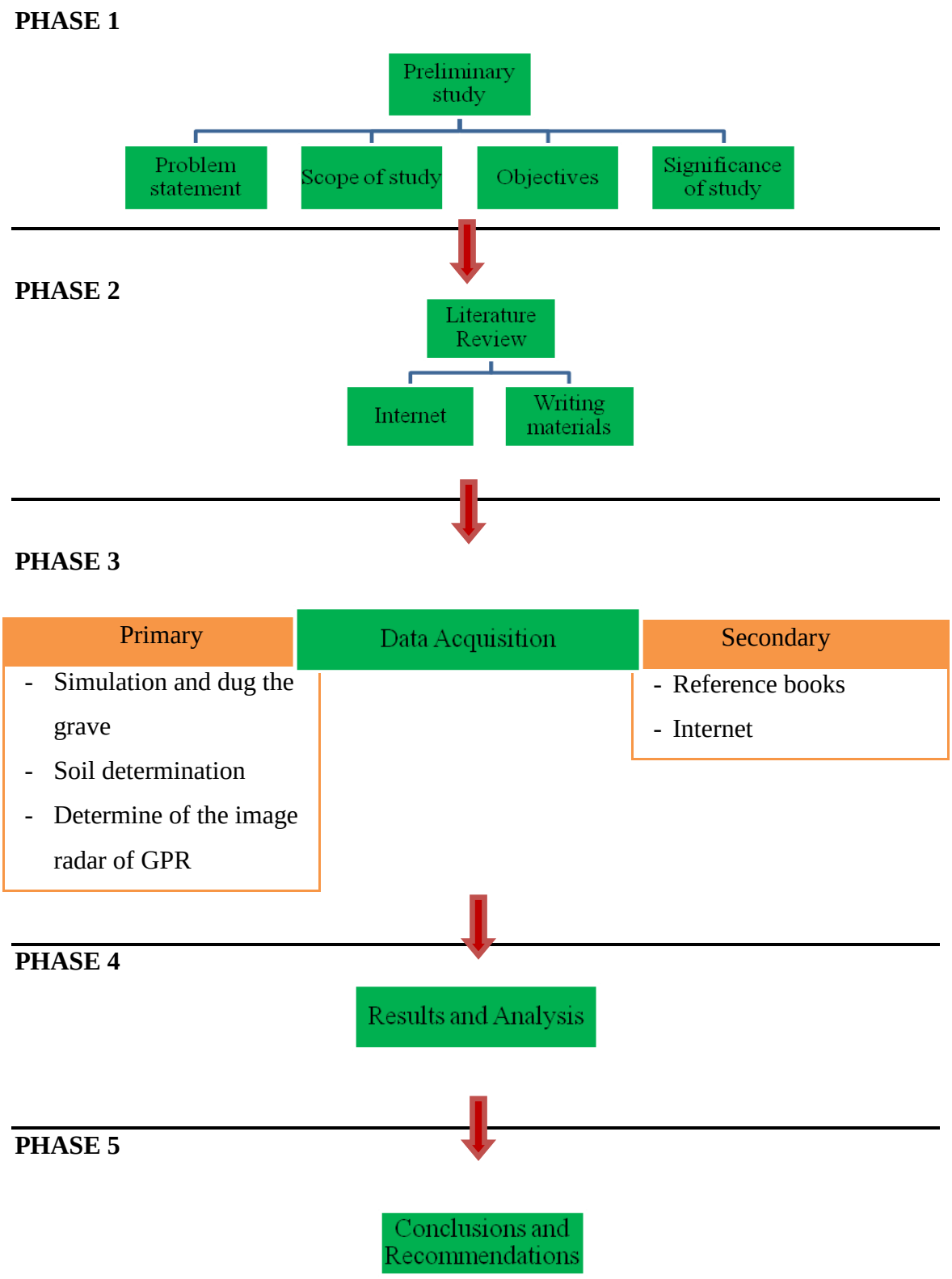

Figure 1.8: Flow chart

REFERENCES

Alexandre Novo, Henrique Lorenzo, Fernando I. Rial, Mercedes Solla. (2009). *3D GPR in Forensics: Finding a Clandestine Grave in a Mountainous Environment*. University of Vigo

ASP Nizam (Police Officer), Personal Communication, September 19, 2014

Brenton L. Crawford, Peter G. Betts, Laurent Aillères. (2009). *An Aeromagnetic Approach to Revealing Buried Basement Structures and Their Role in The Proterozoic Evolution of the Wernecke Inlier, Yukon Territory, Canada*. Monash University.

Conyers LB, and Lucius JE. (1996). *Velocity analysis in archaeological ground-penetrating radar studies.* Archaeological Prospection.

Conyers LB. (2004). *Ground-Penetrating Radar for Archaeology*. Walnut Creek, CA: AltaMira Press.

Conyers LB. (2006). *Ground-penetrating radar techniques to discover and map historic graves.* Historical Archaeology

David J. Daniels. (2007). *Ground Penetrating Radar, 2nd Edition, Volume 1*. The Institute of Engineering and Technology, London, United Kingdom.

Doolittle, J.A., Minzenmayer, F.E., Waltman, S.W., Benham, E.C. (2002). *Ground penetrating radar soil suitability map of the conterminous United States.* In: *Ninth International Conference on Ground Penetrating Radar, Proceedings of SPIE*. 30 April to 2 May 2002. University of California, Santa Barbara, California, pp. 7-12.

Doolittle JA, and Bellantoni NF. (2009). *The search for graves with ground-penetrating radar in Connecticut.* Journal of Archaeological Science.

Dupras TL, Schultz JJ, Wheeler SM, and Williams LJ. (2006). *Forensic Recovery of Human Remains: Archaeological Approaches.* Boca Raton Fl: CRC Press, Taylor and Francis Group.

France DL, Griffin TJ, Swanburg JG, Lindemann JW, Davenport GC, Trammell V, Armbrust CT, Kondratieff B, Nelson A, Castellano K and others. (1992). *A multidisciplinary approach to the detection of clandestine graves.*

Hammon WS III, McMechan George, Zeng Xiaoxian. (2000). Forensic GPR: *Finite-difference Simulation of Responses from Buried Human Remains.*

J.A. Doolittle, F.E. Minzenmayer, S.W. Waltma, E.C. Benham, J.W. Tuttle, S.D. Peaslee (2007). *Ground Penetrating Radar Soil Suitability Map of the Conterminous United State*.

Jeffrey J. Daniels. (2000). *Ground Penetrating Radar Fundamentals.* The Ohio State University.

J.J. Schultz, *Detecting Buried Remains in Florida Using Ground-Penetrating Radar*, (2012). PhD Dissertation, UMI

Joanna Mae Fletcher. (2005). *Monitoring Shallow Controlled Graves Containing Small Cadavers using Ground Penetrating Radar.*

Kazunori Takahashi, Holger Preetz and Jan Ige. (2009). *Soil Characterisation And Performance of Demining Sensors.*

Miller P.S. (1996). *Disturbance In The Soil: Finding Buried Bodies and Other Evidence Using Ground Penetrating Radar*. J. Forensic Sci.

Mohammad Zulhimi bin Che Abdullah. (2014). *Determination of Dielectric Constant of Soil Using Ground Penetrating Radar (GPR).* Universiti Teknologi Malaysia

Noraini binti Zul-Kornain. (2014). *Mapping of Soil Characteristics Using Ground Penetration Radar (GPR).* Degree Thesis. Universiti Teknologi Malaysia

Remke L. van Da. (2001). *Causes of Ground-Penetrating Radar Reflections in Sediment.* Faculty of Earth Science, Vrije Universiteit

Schultz JJ, Collins ME, Falsetti AB. (2006). *Sequential Monitoring of Burials Containing Large Pig Cadavers Using Ground-Penetrating Radar.*

Schultz JJ. (2007). *Using Ground-Penetrating Radar to Locate Clandestine Graves of Homicide Victims: Forming Forensic Archaeology Partnerships with Law Enforcement*

Schultz JJ. (2008). *Sequential Monitoring of Burials Containing Small Pig Cadavers Using Ground Penetrating Radar.*

Schultz JJ, (2012). Phd. *Detecting Buried Remain Using Ground Penetrating Radar*

Strongman KB. (1992). *Forensic applications of ground penetrating radar.* In: Pilon J, editor. Ground penetrating radar. Ottawa: Geological Survey of Canada.

Vaughan CJ. (1986). *Ground-Penetrating Radar Surveys Used in Archaeological Investigations.*