Current Condition of the Holy Kadhimiya Shrine Surveying Using a GPR / Original Article

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الوضع الحالي لصحن الامام الكاظم الشريف مسح باستخدام الرادار المخترق للأرض

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Abstract

This study describes the extensive survey of the Holy Kadhimiya Shrine in Baghdad, Iraq, carried out with the use of a non-invasive geophysical instrument called Ground Penetrating Radar (GPR) to assess the conditions of subsurface and the condition of the infrastructure in the site. The total area of the shrine is 19,575 m² that was systematically studied with the help of internal measures, satellite imagery and radar profiling. The frequency antennas used for the GPR survey were the 250 MHz, 500 MHz, and 800 MHz which have a penetration depth of 1-15 m. Specialized software packages (Ground Vision, Reexplore and Object Mapper) were used for data processing to ensure the correct interpretation of the subsurface anomalies. The results were as follows: (1) The precise topographic surveys allowed a reliable matching by radar; (2) Water and sewage pipelines were located near the main gates; especially rain water drainage lines were interpreted as remains of an ancient tomb; and (3) No unusual geological formations were detected, except for historical brick layers which do not affect stability of soil. In conclusion the research conducted could conclude that overall GPR is effective instrument for investigating heritage sites, including the engineering and archaeological applications. Aerial photographs taken using radar imaging have been helpful in gaining an understanding of the area; it is recommended that further geotechnical validation work be undertaken by collecting soil samples to determine bearing capacity and to feed into plans for future restoration or development. The application of geophysical methods together with traditional survey is an integrated survey method to preserve and manage cultural landmarks that can also be adopted as a model for other studies in historic urban environment.

Keywords: GPR, Kadhimiya, Surveying, Subsurface utility

المستخلص

تصف هذه الدراسة المسح الشامل للمرقد الكاظمي الشريف في بغداد، العراق، والذي تم إجراؤه باستخدام جهاز جيوفيزيائي غير تدميري تسمى الرادار المخترق الأرضي (GPR) لتقييم الظروف تحت السطح وحالة البنية التحتية في الموقع. تبلغ المساحة الإجمالية للضريح الشريف 19.575 مترًا مربعًا، وقد تمت دراستها بشكل منهجي بمساعدة القياسات الداخلية وصور الأقمار الصناعية والتصوير الراداري. وكانت هوائيات التردد المستخدمة في مسح GPR هي 250 ميجا هرتز و500 ميجا هرتز و800 ميجا هرتز والتي يبلغ عمق اختراقها 1-15 مترًا. تم استخدام حزم البرامج المتخصصة (Ground Vision وReexplore وObject Mapper) لمعالجة البيانات لضمان التفسير الصحيح للشذوذات الموجودة تحت السطح. وكانت النتائج على النحو التالي: (1) أتاحت المسوحات الطبوغرافية الدقيقة مطابقة موثوقة بواسطة الرادار؛ (2) وجود خطوط أنابيب المياه والصرف الصحي بالقرب من البوابات الرئيسية؛ وخاصةً خطوط تصريف مياه الأمطار تم تفسيرها على أنها بقايا مقبرة قديمة؛ (3) لم يتم اكتشاف أي تكوينات جيولوجية غير عادية، باستثناء طبقات الطوب التاريخية التي لا تؤثر على استقرار التربة. في الختام، يمكن أن يخلص البحث الذي تم إجراؤه إلى أن GPR بشكل عام هو أداة فعالة لدراسة المواقع التراثية، بما في ذلك التطبيقات الهندسية والأثرية. الصور الملتقطة باستخدام التصوير الراداري ساعدت في فهم المنطقة. يوصى بإجراء المزيد من أعمال التحقق الجيوتقنية من خلال جمع عينات التربة لتحديد قدرة التحمل وإدخالها في خطط الترميم أو التطوير المستقبلية. ويعتبر تطبيق الأساليب الجيوفيزيائية مع المسح التقليدي أسلوباً مسحياً متكاملاً للحفاظ على المعالم الثقافية وإدارتها، كما يمكن اعتماده كنموذج لدراسات أخرى في البيئة الحضرية التاريخية.

الكلمات المفتاحية: GPR، الكاظمية، المساحة، البنى التحتية

1. Introduction

The total area of the shrine, including the courtyard and mosque, is 19,575 square meters. It is rectangular in shape, measuring 140 meters by 135 meters. The shrine building is square, with each side measuring 60 meters, and has a total area of 3,600 square meters. The shrine building connects to the mosque on its northern side, while the eastern, southern, and western sides form the courtyard, which is divided into: The courtyard of Bab al-Murad (the eastern section), The courtyard of Bab al-Qibla (the southern section) and the courtyard of Quraish (the western section).

The courtyard is surrounded on all four sides by a wall approximately ten meters high. Internally, it is divided into two levels. The first level contains rooms and porticoes, while the second level is an open wall, divided into arched openings and ribs, precisely in the shape of the porticoes. There are sixty-three porticoes leading to rows that were originally intended to receive visitors, replacing the former hotels. Another section was designated for teaching religious sciences. Sixty-three rooms are connected to the porticoes, in addition to fourteen rooms connected to the entrances, bringing the total to seventy-six rooms. One of the porticoes on the eastern side of the wall contains two entrances for the restrooms, one for men and one for women, and one of its rooms was designated as a library.[1]

There are three main gates, uniform in design and size: Bab al-Murad on the eastern side, Bab al-Qibla on the southern side and Bab Sahib al-Zaman on the western side. Each gate is 5.10 meters high and four meters wide. Their facades are decorated inside and out with marble tiles. Opposite each gate is a portico bearing its name. There are also five medium-sized gates distributed along the four walls of the courtyard: two in the north, two in the south, and one in the east. There are two small gates, one in the northeastern corner of the courtyard and the other in the southwestern corner of the western wall of the courtyard.

2. Data Collection:

One of the most important aspects of any consultancy study is collecting data about the study area. The larger the dataset, the better the projections. The data collected for the Kadhimiya Shrine in particular, and the city of Kadhimiya in general, varied between satellite imagery, topographic maps, sectional maps, and infrastructure maps.[2,3]

2.1 Satellite Imagery

A collection of satellite images covering the entire study area was prepared from various sources with a resolution of 60 cm, as shown in the Figures (1) and (2) below. These images, taken at different times, were collected to identify changes that have occurred in the study area in recent years.

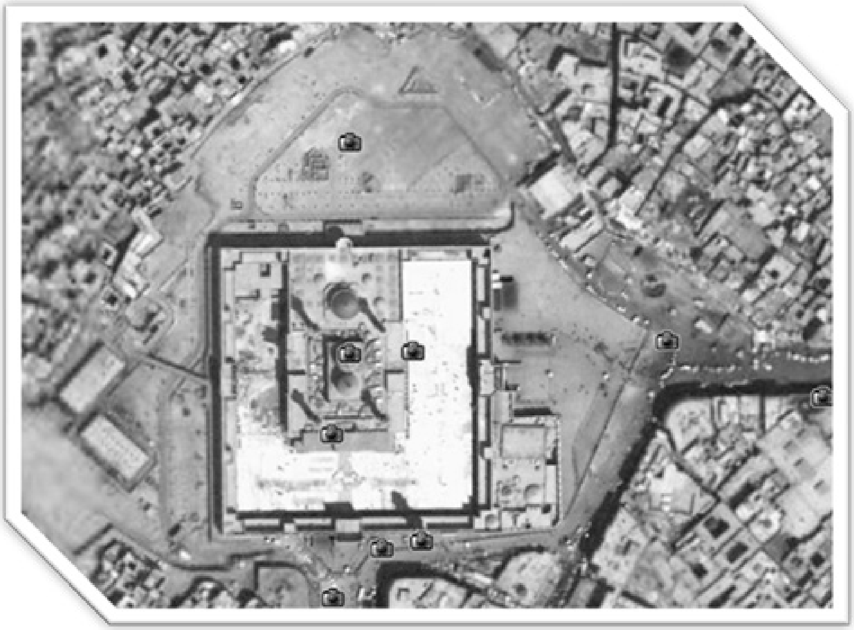


Figure (1): satellite images covering area of the shrine

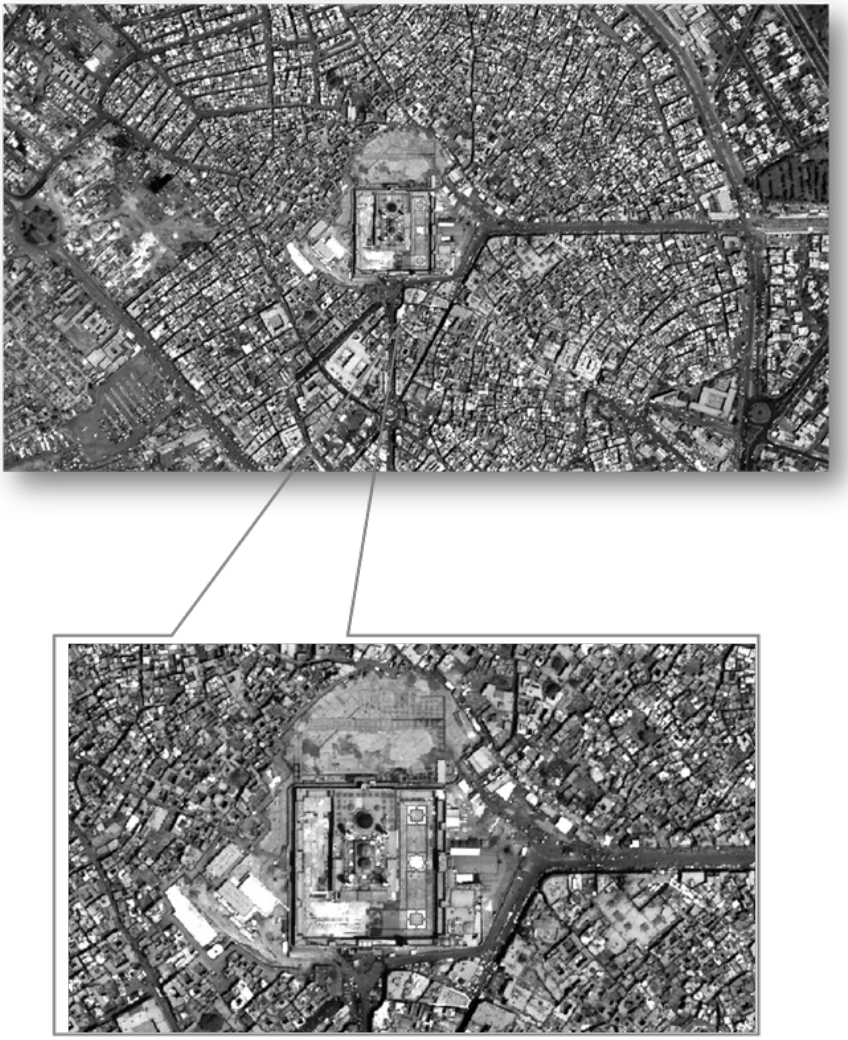


Figure (2): satellite images covering the entire study

2.2 Use of a GPR Device

Ground penetrating radar (GPR) is a nondestructive surveying method which is continuous, fast and has been applied to many applications for mapping subsurface conditions.[4] There are numerous applications that are suitable for the evaluation of highway systems. GPR is essentially a subsurface “anomaly” detector; therefore, it will provide a profile of the underground changes as a consequence of contrasts in the electromagnetic conductivity of the materials at interfaces [5] within the ground and obtain a realistic image of the infrastructure of the Holy Kadhimiya Shrine. The GPR equipment currently used by University of Technology is summarized in Table (1). This equipment consists of data collection system (MALA geoscience), data collection and analysis software packages (Ground Vision, Object mapper, and RadExplorer), 3 ground-coupled shielded antennas (250 MHz, 500 MHz, 800 MHz, shown in Table (2). Table (1) lists the approximate depths for penetration that each of these antennas gives. Overall, the depth of penetration decreases as the speed of transmission of the antenna increases.[6] In addition, a wheel cart for GPR data collection, including an independent power source, GPS data collection, electronic DMI device and camera for the project.

Table (1): GPR equipment currently used by University of Technology

Data collection unit	ProEx Control Unit
Collection software	GroundVision 2
Processing software	RadExplorer, Object mapper
Antenna / depth of penetration	250 MHz / 8-15 m 500MHz / 3.5-8 m 800 MHz / 1-3 m

Table (2): Antenna Technical Specification

Antenna	Dimensions	Applications
250 MHz	0.74 x 0.44 x 0.16 m – Weight: 7.85 kg	Utility detection, Underground Storage Tank and void detection.
500MHz	0.50 x 0.30 x 0.16 m – Weight: 5.0 kg	Utility detection, road and pavement surveys
800 MHz	0.38 x 0.20 x 0.12 m – Weight: 2.6 kg	Road/ pavement surveys and concrete/ structural investigations.

3. Methodology and approach

The field surveys consist Phase One: Internal measurements of the Holy Courtyard and Phase Two: Processing and analysis. Phase One: Internal Measurements of the Holy Courtyard

This section includes surveying all the flooring within the Holy Courtyard, including buildings, roofs, corridors, etc. see Figure (3).

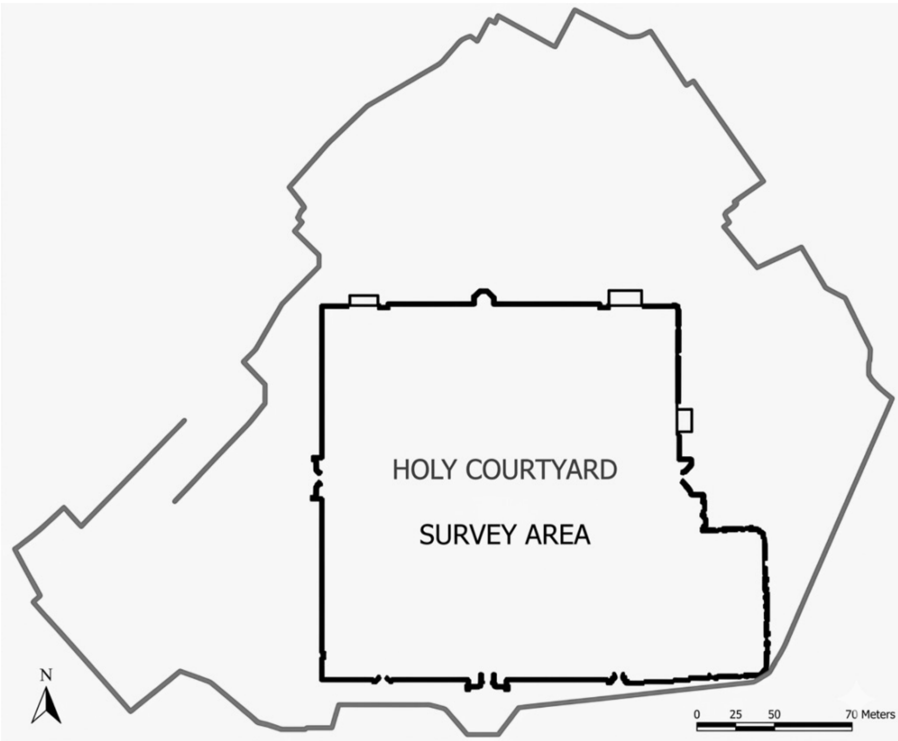


Figure (3): Internal Measurements of the Holy Courtyard

4. Processing and Analysis

During this phase, several programs specific to the GPR device were used for processing and analysis, including Rad Explorer. These are some samples of ground-penetrating radar images of the Holy Kadhimiya Shrine. The basis of GPR is to probe the ground with short pulses of electromagnetic energy. One-dimensional electromagnetic wave propagation theory is used to analyse the reflected images of these pulses. The amplitude and arrival time of these pulses are reflected back to the antenna and related to the electrical conductivity (or dielectric constant) of the material layers Figure (4). For the interfaces, a certain amount of energy is reflected, depending on the dielectric contrast of the material, a certain amount is absorbed. The above-mentioned peaks in amplitude (in the order they are observed) are the antenna end reflection (A0), the surface (pavement) reflection (A1) and the base reflection (A2), respectively. Time interval (t1) between peaks A1 and A2 is the 2-way travel time through the pavement layer. The thickness of the pavement layer (h) as shown in Figure (4), can be calculated as:

$$h = v\,\Delta t / 2 \qquad (1)$$

where v = propagation velocity through each layer and Δt = t2-t1

The propagation velocity is related to the electromagnetic behavior of the asphalt layer:

$$v = c / \sqrt{\varepsilon} \qquad (2)$$

where ε = dielectric constant of asphalt layer

c = speed of light in air = 0.30 m/ns

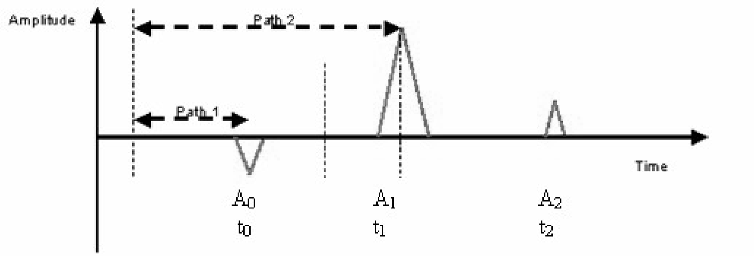
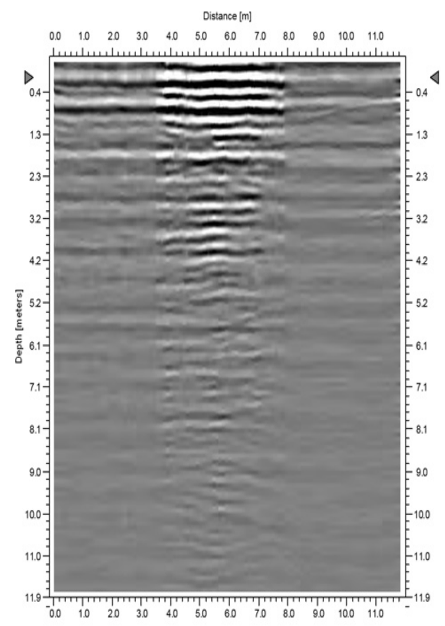
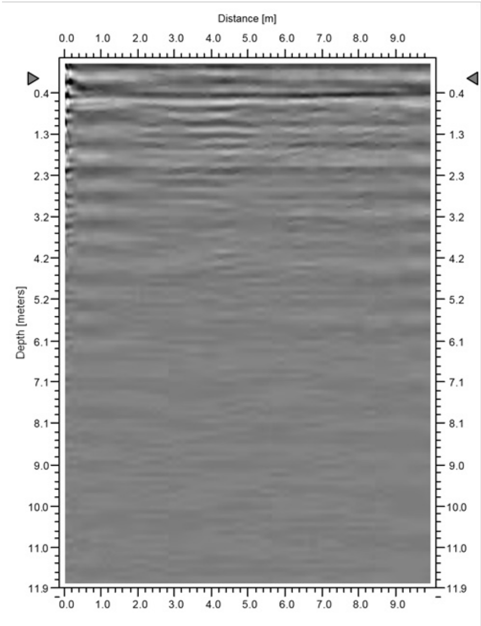


Figure (4): Typical Amplitude Time History from GPR Antenna [7]

5. Results and discussion

The use of Ground Penetrating Radar (GPR) on the Holy Kadhimiya Shrine site provided important results not only from the engineering point of view, but also for the historical aspects of the subsurface features. Combined with topographic surveys and satellite imagery, the use of radar was able to present a detailed overview of the current state of the shrine, as well as some indications of its history. One of the most significant discoveries was the identification of pipelines of water and sewerage, particularly the rain water drainage pipes which are positioned in front of the main gates of the courtyard. The radar profiles could easily be seen these networks in the radar profiles because they depended on the differences in soil and pipe dielectrics. The detection is a testament to the real-world applications of GPR in infrastructure management, enabling non-destructive mapping of critical infrastructure. This is especially useful if excavation will be limited in heritage sites. The results provide a foundation for future maintenance planning and preventive measures to safeguard the shrine's structural integrity as shown in Figures (5) and (6).





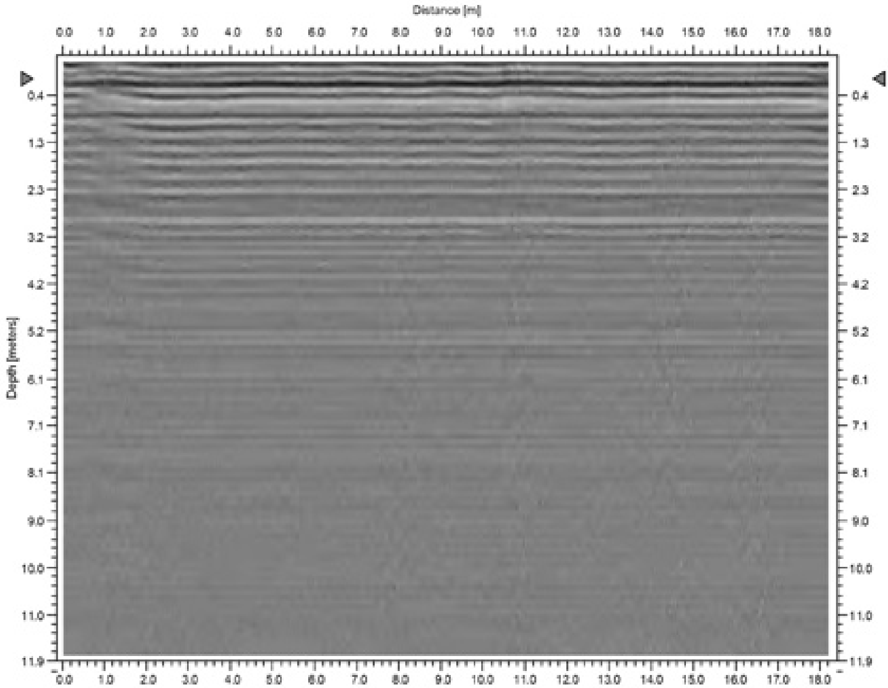


Figure (5): Typical Amplitude results from GPR Antenna

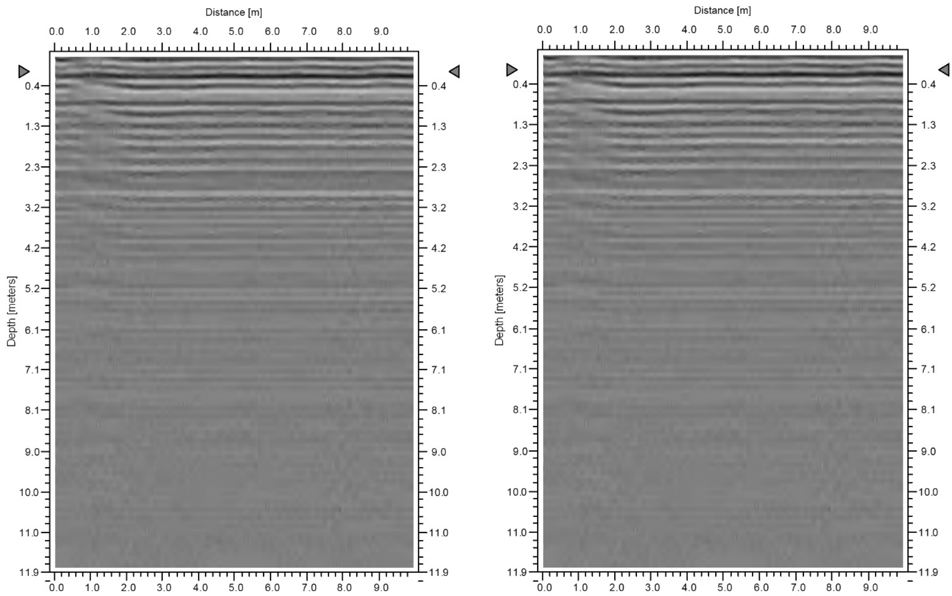


Figure (6): Typical Amplitude results from GPR Antenna border site

The results show the potential of GPR as a non-invasive method for heritage site investigation. It can be used in the detection of utilities, historic features and subsurface layers without excavation, making it especially appropriate for religious and cultural sites. Typically, a drainage line and soil layers are identified from an engineering standpoint, which aids in infrastructure maintenance and risk assessment. An archaeological point of view, the identifying of the remains of ancient tombs adds to the understanding of the history of the shrine. The combination of GPR data with satellite imagery and topographic surveys is a multi-layered data set that increases the confidence of the interpretations. This multi-disciplinary approach can be used to attain both engineering and cultural heritage goals, and serves as a model for studies in other historical sites.

6. Conclusions

Based on the scientific principles followed in using radar data and determining depths and foreign objects underground, the following can be concluded:

1- The topographic survey required for radar matching was highly accurate and met the requirements of radar analysis.

2- Water and sewage lines, especially rainwater drainage lines, were identified in front of the main gates of the courtyard.

3- There are simple brick structures in the courtyard facing the Al-Jawadain Mosque, measuring 10x10 meters, which represent the remains of an ancient tomb.

4- The radar did not indicate any unusual geological structure in the vertical basins surrounding the courtyard, except for layers of brick dating back to earlier periods that do not affect the soil composition from a geological perspective.

5- For the purpose of accurate geotechnical matching, we recommend taking soil samples (test pits) at a rate of 4 to 6 pits that represent the general soil profile in order to determine the soil bearing capacity.

7. References

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