Role of ground penetrating radar in buried utility damage prevention

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Modern society's critical dependence on the uninterrupted availability of telecommunications, power distribution, water/sewer networks and transportation systems has made damage prevention a greater priority. Greater awareness of the costs of repair, service disruption liabilities, not to mention compensations for injury or death, have created a strong demand for more effective methods of detecting buried infrastructure.

What is the goal of damage prevention?

Damage prevention focuses on mitigating the risk of endangering lives and the loss of money. Adherence to best practices and use of the latest recognized methods can substantially ameliorate both.

a. First, define the nature of the risk. What is the potential for injury or death and what, if any, potential costs can be accommodated?

b. Next, define the costs of mitigating the risks. What are the costs of using systematic damage prevention methods to reduce the risk?

c. After following best-practice damage prevention, what residual risk remains?

d. How will the residual risk be managed? Should one use insurance, attempt to contract away the liability, or just ignore it?

Proactive damage prevention for subsurface construction incorporates the following elements:

a. Exploit all knowledge of land use history including old records, photographs, drawings and even people's memories (eye witness accounts).

b. Investigate and classify direct observations of above-round indicators such as poles, pipes, monuments, caps, etc.

c. Utilize subsurface detection systems to map all detectable underground objects.

d. Employ systematic site marking and labeling.

e. Use invasive testing and careful excavation methods.

f. Compile and/or update drawings and database records with field locates and intrusive testing findings.

g. Educate all contractors and workers about the marking system conventions, excavation procedures and risk factors.

This discussion focuses on point (c) above, the technologies that 'sense' the presence of subsurface objects using phenomena that obey the basic laws of physics. There are no magic solutions – only sound science, adherence to proper procedure and intelligent use of the observations.

Sensing technologies

Most sensing technologies use electric and magnetic fields or acoustic signals to detect the presence of underground objects. All technologies depend on the signals interacting with the buried objects in a manner that uniquely determines the presence and position of a buried object. Further, the operator must be provided with a simple, systematic means for marking the position of the detected object.

Three technologies are most frequently used for locating buried utilities and similar structures:

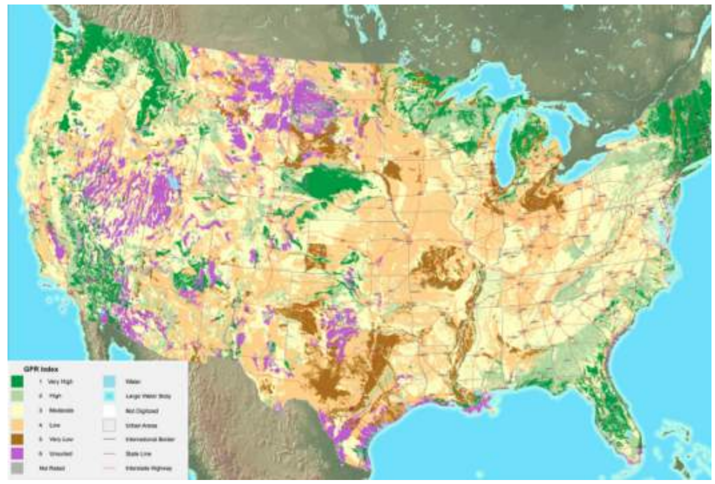
1. The most common is the traditional pipe and cable locator which detects magnetic fields associated with electric current flow on a buried pipe or cable. Logically, this requires a metallic structure or tracer wire to carry the electric current.

2. Magnetometers are occasionally used to detect

magnetic fields from buried ferrous objects. Unfortunately, few buried utilities are composed of ferrous material.

3. Ground Penetrating Radar (GPR) uses radio waves to image the subsurface. GPRs contain a transmitter which directs radio waves into the ground. Subsurface objects are detected by sensing the radio waves reflected from the object.

Since GPR is a relatively new technique for subsurface sensing of utilities, further discussion on its use and limitations is warranted.



Benefits & pitfalls in using GPR

GPR has many advantages; it can detect both metallic and non-metallic objects as well as sense previously disturbed soil. Being non-invasive and self-contained, GPR does not require physical connection to the buried object. In good conditions, GPR can "see" objects that are 1 to 5 meters below surface, establish lateral positions within centimeters and determine depths with accuracies to better than a few percent. A major benefit, as well as pitfall, is that GPR senses any object with differing electrical properties in the subsurface. The benefit is that unanticipated hazards can be detected; the pitfall is that GPR detects objects of no importance for buried utility locating.

To detect an object, a GPR system needs to pass over the object and the object must return a detectable signal. Since radio waves are strongly absorbed by soils and rocks, there is a limit to how deep the GPR signal will penetrate. How deep a target is buried before it becomes undetectable is very site-dependent. Typically, heavy clay soils absorb energy rapidly and penetration depth can be less that one meter whereas penetration in sandy soils can be much greater. A GPR soil suitability map such as the one available in the USA (Figure 1) can help define how effective GPR might be in a given location. These maps should only be used as a general guide because GPR penetration can change quite a bit over a small area if the local soils are variable.

Object recognition requires the use of the human eye to identify the characteristic pattern in reflected waves displayed on a computer screen. While recognition technology is improving, nothing surpasses the experienced human eye as the most powerful pattern recognition method. Modern GPRs are constantly improving data presentation so the complex GPR signals are more readily interpreted by novice operators.

Some objects are not detectable because some soils will absorb all the GPR radio waves so there is no visible return signal. Other objects provide no contrast with the surrounding soil; they are so similar to the soil properties that a reflected signal is undetectable. In both cases, the target is invisible (like a stealth aircraft). Objects also cannot be detected if GPR signals are scattered away or masked by stronger responses from other features (tree roots, rocks, construction debris, overlying reinforced concrete, etc.) in the ground.

Currently, GPR operates at three levels depending on the requirements of the investigation.

1. The most common mode is the locate-and-mark approach depicted in Figure 2. The GPR sensor moves over the ground. When an object is sensed, the operator backs up, positions the sensors directly over the target, and marks the ground with paint or flagging.

2. The next level of operation is to follow the same

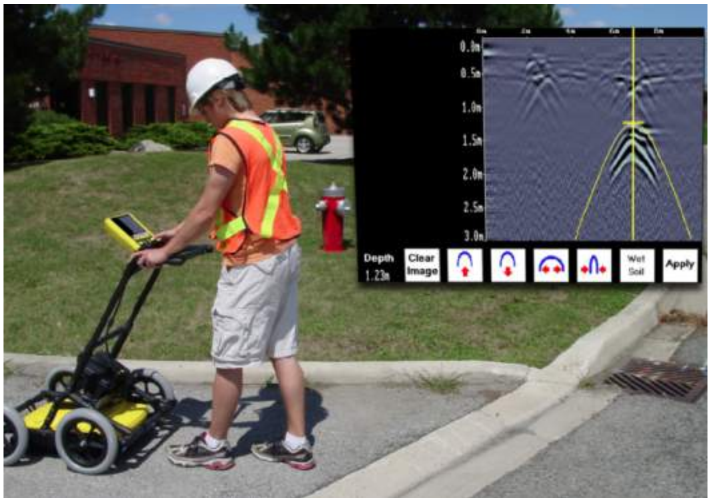


Figure 2. When an object is sensed, the operator backs up, positions the sensor directly over the target, and then marks the ground with paint or flagging.

procedure as (a) but then log the spatial coordinates of the detected object with GPS or other electronic positioning to update maps and records.

3. The most advanced use of GPR is to scan an area and transform the recorded image into a 3D image (Figure 3), much like the medical imaging produced by CAT and MRI scanners.

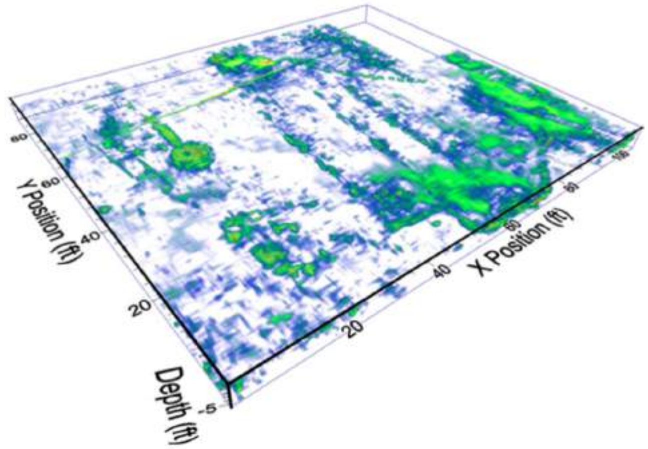


Figure 3. Example of 3D image

The locate-and-mark approach provides the most cost effective use of GPR and works best in simple situations. In complex, congested sites, the more advanced scanning method is often the only way to unscramble the subsurface structure.

Best practices for damage prevention

Best practice damage prevention combines all the sensing technologies and their associated workflows along with the systematic use of historical records. Further, diligent field staff should note all visual clues and combine the entire information for a complete understanding of the site.

In instances where only a singe type of buried structure has to be located, the selection and use of the simplest, most suitable technology may reduce time and cost. Having alternate technology solutions available addresses those situations when a simple problem proves to be more challenging and complex.

How dependable is technology? Technology will not do everything and the current techniques have physical limitations which cannot be overcome. There will always be some buried objects that are not detectable. Believing otherwise is a fallacy. Combining all the sensing technologies with experienced personnel enhances the probability of success.

Why use any subsurface mapping technology?

If there is no danger to human safety and the cost of any damage is small, there is no reason to use any subsurface mapping technology. In fact, the cost of a site investigation may be more than the cost of damage repair. Unfortunately, even the most innocuous site may contain buried objects that are not readily apparent. Well documented cases of construction projects encountering buried pipelines, electrical lines or other major communications links in seemingly open farm fields demonstrate the need for vigilance.

Ultimately you must answer the following questions:

a. What are the consequences of not being proactive on damage prevention?

b. Can I and my company live with the consequences?