Target / Method Comparison Matrix

Target	Geophysical Method	Benefits	Limitations
Voids, sinkholes, abandoned mines' karst	GPR	Shallow voids only Data recorded quickly and displayed on screen in during field acquisition Antenna frequency changed quickly to either enhance resolution or penetration	Success is very site specific Depends on a contrast in dielectric properties between the target and host Any metal features may hinder survey
	Resistivity	Quite successful at imaging large shallow voids Voids have a high resistivity	Best suited for finding shallow voids, 20 to 30 m depending on geology and void size A 12 m deep void would require 24 m spacing between electrodes (Wenner Array). A total array length of 72 m
	Seismic Refraction	Rapid to apply in the field Seismic refraction records are displayed on the instrument allowing potential fractures to be recognized during the field survey	This method is indirect as it detects fractures and not voids Voids may be detected if they are not too far beneath the bedrock Fractures may not be related to a void and have some other origin
	Shear-wave Seismic Reflection	Success depends on the frequency of shear waves in the ground If high frequencies can be generated, small voids can be detected	Shear wave reflection is labor intensive Requires extensive processing Few sources exist for shear wave propagation
	Crosshole Tomography	Tomography provides a high-resolution 2D or 3D volumetric image between two boreholes Can image the entire length of the borehole No diminishing returns with depth	Tomography is data intensive Specialized 3D software is required for true 3D imaging Artifacts can be present due to limited ray coverage near image boundaries

Target / Method Comparison Matrix			
Target	**Geophysical Method**	**Benefits**	**Limitations**
Clay	GPR	Can image the top clay layer only Data recorded quickly and displayed on screen in during field acquisition Antenna frequency changed quickly to either enhance resolution or penetration	Can not image layers underlying a clay layer Success is very site specific Depends on a contrast in dielectric properties between the target and host Any metal features may hinder survey
	EM	Conductivity recorded with EM31 and EM34 rather quickly Depth of investigation can be chosen by using the different modes of data acquisition Maximum depth of investigation (vertical dipole mode) Near surface material (horizontal dipole)	Clay is electrically conductive, areas of high conductivity have a reasonable chance that they contain clay Cannot estimate the amount of clay from conductivity measurements alone Measurements influenced by metal either above or below ground
	Resistivity	Automated systems record a large amount of data allowing detailed interpretations	Difficult to implant electrodes in hard ground May need to saturate electrodes with water to enhance electrical contact with the ground Power lines, fences, and other metal features may provide false anomalies
Determination of depth to bedrock	GPR	Fast Survey method Easily substitute antennas if the penetration depth is insufficient	Success is dependent on site conditions Depends on sufficient contrast in dielectric properties of the target compared to the host Sufficient penetration depth to reach target Clay layers and metal objects mask response from underlying features Reflections from surface features such as buildings and power lines affect the unshielded antennas

Target / Method Comparison Matrix			
Target	**Geophysical Method**	**Benefits**	**Limitations**
	Seismic Refraction	Effectively maps depth of bedrock Provides fairly detailed lateral variations in depth Seismic refraction more appropriate for bedrock at shallow depths	Successively deeper layers must have higher velocities than the shallower refractor The water table in close proximity to the bedrock may obscure the bedrock arrivals which results in a false interpretation of the bedrock depth Traffic noise may obscure the refractions from the bedrock. Larger energy sources may be used to correct this problem.
	Seismic Reflection	Reflection requires a let intense energy source for a given depth than refraction Images greater depths than refraction Seismic reflection more appropriate for bedrock depths greater than 30 m	Labor intensive data acquisition Expensive Requires extensive processing
	Resistivity	Resistivity works when the layers are more or less resistive Simple field procedures Soundings to 50 m can be conducted in less than an hour	Difficult to use in asphalt or concrete at the electrodes must be coupled with the ground Water may be poured on the electrodes to improve the contact between the ground and the electrode Current electrode spacing must be 3 times the depth of penetration. If bedrock is 15 m than electrode spacing must be 45 m. Grounded metal objects near the electrodes may influence the data Lateral variations in resistivity may affect the accuracy of the depth interpretation

Target / Method Comparison Matrix			
Target	**Geophysical Method**	**Benefits**	**Limitations**
	TDEM	Efficient method for investigating the vertical distribution of ground resistivity Requires less work than resistivity and provides more accurate precise depth estimates More efficient at depths greater than 50 m No electrodes planted in the ground	Better suited to mapping conductive rather than resistive layers, however, can map depths to resistive layers Cultural features (power lines, fences, bridges reinforced with metal) strongly influence the data recording and may prohibit the use of this method in some areas
	FDEM	Quick method for mapping bedrock topography	Bedrock layer must be thick enough to have a significant influence on the conductivity readings Bedrock must be more conductive or resistive than the overburden Any metal either above or below the ground surface will influence the data

Target / Method Comparison Matrix			
Target	**Geophysical Method**	**Benefits**	**Limitations**
	SASW	Non invasive and non destructive A larger volume of the subsurface can be sampled than in borehole methods	The depth of penetration is determined by the longest wavelengths that can be generated by the source, measured accurately in the field, and resolved in the modeling Noisy data must be smoothed and contains less resolution Whether a particular layer can be resolved depends on its depth and velocity contrast Cultural noise (traffic, rotating machinery) may limit the signal to noise ratio at low frequencies
Determination of fractures in bedrock	FDEM	Easy data collection in the vertical dipole mode	
	GPR	Easy data collection Results can be viewed in the field as the data is collected Easily substitute antennas if the penetration depth is insufficient	Success is dependent on site conditions Depends on sufficient contrast in dielectric properties of the target compared to the host Sufficient penetration depth to reach target Clay layers and metal objects mask response from underlying features Reflections from surface features such as buildings and power lines affect the unshielded antennas

Target / Method Comparison Matrix			
Target	**Geophysical Method**	**Benefits**	**Limitations**
	Seismic Refraction	Field recording is quite fast and the data can be viewed on the recorder screen as the survey progresses	Bedrock velocity must exceed the velocity of overburden The water table near the bedrock may produce refractions
	Seismic Reflection-Shear Wave	Good resolution if the seismic source can produce high frequencies	Labor intensive field work Requires extensive processing
	Resistivity	An automated resistivity system provides more data and allows for a better interpretation Little data processing is required	A resistivity contrast with the host rock must exist at the fracture zone Fracture zones have a higher porosity than unfractured rock and contain more moisture resulting in a lower resistivity than unfractured rock Difficult to implant electrodes in hard ground, concrete or asphalt Metallic cultural features will influence the data if they are in close proximity to the electrode array
Determination of faults	Seismic Reflection	Can map faults without significant physical property differences on either side Can penetrate to depths greater than 100 m	Other methods may be cheaper to use to map shallower faults.
Determination of Lithology	Seismic Refraction	A good method to obtain the velocity of rocks	Each successively deeper refractors must have a higher velocity than the preceding one Errors in depth estimates are possible if a lower velocity layer underlies a higher velocity layer Water table in close proximity may obscure bedrock refractions Traffic noise may obscure refractions from the bedrock

Target / Method Comparison Matrix			
Target	**Geophysical Method**	**Benefits**	**Limitations**
	Seismic Reflection	Provides a pictorial section that resembles the subsurface layers Layer velocities do not need to successively increase with depth Suited to depths great than 10 to 20 m	Labor intensive data acquisition Expensive Significant processing required Local vibrational noise will reduce the signal to noise ratio making the section less definitive
	TDEM	More efficient than resistivity Good at defining conductive layers	Limited to 4 or 5 layers Less effective at defining resistive layers Resistive layers must be thick to resolve with thickness increasing with depth Metallic cultural features may prohibit recording interpretable data
	Resistivity	Automated systems record more data than simple systems Three dimensional surveys may be recorded and interpreted	Difficult to implant electrodes into hard ground Water must be poured over electrodes in dry areas to improve the electrical contact between the ground and soil
	Magnetic	Simple and efficient to record in the field	Cannot record data if diurnal fluctuations in the Earth's magnetic field are large Not recommended in areas containing magnetite Due to acquisition difficulties
Shallow Sands and Gravel Deposits	Resistivity	Resistivity soundings prove an efficient and effective method of measuring resistivity to about 30 m Little processing is required for automated systems, however bad data points may be removed	Labor intensive since four electrodes must be inserted into the ground for every resistivity reading A sounding curve may have 15 measured resistivities Water must be poured over electrodes in dry areas to improve the electrical contact between the ground and soil Metallic cultural features influences the data

Target / Method Comparison Matrix			
Target	**Geophysical Method**	**Benefits**	**Limitations**
	FDEM	The EM31 and EM34 are efficient methods for mapping lateral changes in conductivity	Metallic cultural features interfere with geologic targets in the survey area because they both generate secondary electromagnetic fields making data interpretation difficult
	TDEM	Efficient method for mapping the vertical distribution of resistivity Good at mapping conductive layers	Less effective at defining resistive layers Method assumes that the layers are homogeneous and horizontal Metallic cultural features influence the data
	Seismic Refraction	Can map sand and gravel if the base has a higher velocity Provides reasonable accurate depth estimates	Each successive refractor must have a higher velocity The water table in close proximity to the deposit may obscure the refractor Traffic noise may obscure the refractions, may need larger impact sources or repeating the process at a common shot point for data stacking
	GPR	Easy to use Provides an image as the survey progresses Good for defining the extent of deposits	Success is very site specific Must have contrast in dielectric properties between the target and the host Slow compared to EM31 and EM34 methods Not good for exploring new areas
Subsurface Utilities	Magnetic	Magnetic locators are simple to operate and provide a field signal when an anomaly is detected	Only responds to ferromagnetic metals Cannot detect aluminum, copper, stainless steele, plastic, clay, or concrete pipes
	Electromagnetic	Electromagnetic instruments are simple to use and provide anomaly indications while the survey is being conducted	Depth of utility Size of utility (amount of metal) Proximity to other surface metal, buried metal, power lines

Target / Method Comparison Matrix

Target	Geophysical Method	Benefits	Limitations
		EM31 is simple to use, allows a field read out, and can find utilities to a depth of 3 m	Instrument produces secondary electromagnetic fields The instrument is quite long and might be difficult to use in confined areas
		EM61 is excellent for locating metal in the top 2 meters of the ground surface Can use the handheld EM61 in confined areas	The instrument produces secondary electromagnetic fields less of a problem than the EM31 EM61 difficult to maneuver in confined areas
	GPR	Rapid technique for locating utilities Data viewed in the field Locations marked immediately on the ground	Success is very site specific Depends on a dielectric contrast between the host and target Depth penetration limited Cannot be used in clays
Underground Storage Tanks	Magnetic	Simple method for detecting metallic underground storage tanks Anomalies can be marked on the ground at the time of the survey	The underground storage tank must be constructed of ferromagnetic metal Surface metallic objects may be difficult to distinguish from subsurface objects Should not record data during large diurnal fluctuations in the Earth’s magnetic field
	Electromagnetic	Provides a good method for locating underground storage tanks Data can be downloaded and plotted to provide a record of the survey	Local metal influences the EM31, EM61, and GEM2 instruments

Target / Method Comparison Matrix

Target	Geophysical Method	Benefits	Limitations
	GPR	Easy to survey and provide results in the field Antenna can be substituted easily in the field to achieve greater resolution or depth penetration Sufficient dielectric contrast is provided between the host rock and the UST USTs buried with their tops just a meter or so beneath the surface	Success is site specific Overlying clay and metallic objects may mask underlying USTs
Contaminant Plumes	Electromagnetic	EM31 and EM34 instruments are easy to use Efficient way to find the lateral extent of a plume Provide efficient field surveys Approximate anomaly locations can be observed during the field survey	Requires a conductivity contrast Surface metallic cultural features influence the data EM34 more expensive to use than the EM31
	Resistivity	Soundings are used to find the vertical extent of a contaminant plume	Requires a resistivity contrast between the plume and the host material
	GPR	Easy to conduct Field image available during surveying Antennas can be easily interchanged for better resolution or greater depth penetration	Success is site specific Contrast in dielectric properties between target and overburden Power lines may influence unshielded antennas
UXO	Magnetic	Easy to use Provides anomalies near surface and those buried at some depth depending on size	Detects only ferromagnetic ordnance Cannot detect aluminum, copper, stainless steel Cannot detect data when the diurnal fluctuations on the Earth’s magnetic field are large Usually not possible to determine the length or diameter of the anomaly

Target / Method Comparison Matrix			
Target	**Geophysical Method**	**Benefits**	**Limitations**
	Electromagnetic	Reliably detects buried UXO Not influenced by magnetic field fluctuations	The location of the source of the anomaly is diluted slightly by the areas of the transmitter and receiver coils Exploration depths with EM61 are limited to 3 m
	GPR	Can detect both metal and plastic UXO	Electromagnetic field could potentially detonate ordnance with electric fuses, prohibits use in areas with fuses Magnetic and Electromagnetic are preferred methods for UXO Success is site specific Cannot be used in clay soils May not be able to distinguish between cobbles and UXO