Summary of 12 Commonly Used Geophysical Surveying Methods

Geophysical Method	Measured Parameter(s)	Physical Property or Properties	Physical Property Model (Geotechnical Application)	Typical Site Model (Geotechnical Applications)	Strength	Weakness
Shallow seismic refraction	Travel times of refracted seismic energy (p- or s-wave)	Acoustic velocity (function of elastic moduli and density)	Acoustic velocity–depth model often with interpreted layer boundaries	Geologic profile	●2-D or 3-D structural images of the subsurface ● Shear and/or compressional wave velocities can be measured ● Interpretations, if constrained, can be remarkably accurate ● Reconnaissance tool, used to optimally locate exploratory boreholes ● Cost-effective means of establishing control between boreholes	● lateral and vertical velocity variations within a layer are difficult to image using conventional processing techniques ● doesn't work well in "acoustically" noisy areas ● all you ever end up with is an interpretation ● interpretations are non-unique ● ground truth is needed to constrain interpretations
Shallow seismic reflection	Travel times and amplitudes of reflected seismic energy (p- or s-wave)	Density and acoustic velocity (acoustic velocity is a function of elastic moduli and density)	Acoustic velocity–depth model often with interpreted layer boundaries	Geologic profile	● Shear and/or compressional wave velocities can be measured ● Responds to changes in acoustic impedance ● Depth of investigation (shallow-deep; 50 ft - 20,000 ft) ● Limited resolution (layer thickness >10 ft) ● Very reliable 2-D and 3-D geologic models can be generated (if constrained)	●Geophones need to be coupled to the earth ● Depth of investigation (shallow-deep; 50 ft - 20,000 ft) ● Limited resolution (layer thickness >10 ft) ● Interpretations are non-unique ● External constraints are required ● Relatively slow and expensive ● Processing requires considerable expertise ● Doesn't work well in "acoustically" noisy areas
Cross-hole seismic tomography	Travel times and amplitudes of seismic energy (p- or s-wave)	Density and acoustic velocity (acoustic velocity is a function of elastic moduli and density)	Model depicting spatial variations in acoustic velocity	Geologic profile	●Tool measures inter-borehole P-wave or S-wave velocities ●Average velocities are calculated over relatively short distances (10-15 ft) ●Generates "most accurate" 1-D velocity profiles ●Ground truth is acquired (borehole)	●Recorded energy may be refracted (as opposed to direct) ●Tool is invasive ●Borehole deviation data are required ●Relatively expensive (cost of borehole)

Multichannel analyses of surface waves (MASW)	Travel times of surface waves energy generated using an active source (e.g., sledge hammer)	Acoustic velocity (function of elastic moduli and density)	Acoustic (shear-wave) velocity–depth model often with interpreted layer boundaries	Geologic profile	● sensors (geophones) do not need to be coupled to the ground ● data can be acquired relatively quickly ● tool can be used in areas inaccessible to drill rigs (paved roadways, beneath bridges, on steep slopes, etc.) ● works well in acoustically noisy areas ● output is 1-D or 2-D shear wave velocity profile of subsurface ● interpretations, if constrained, can be remarkably accurate ● depths of investigation typically 120 ft ● reconnaissance tool, used to optimally locate exploratory boreholes ● cost-effective means of establishing control between boreholes	● depth penetration typically <120 ft ● thin layers may be "invisible" ● lateral and vertical averaging occurs as data is acquired using sensor arrays spread over distances on the order of 100+ ft ● hence, tool may not work well in areas where depth-to-bedrock and/or physical properties of soil vary significantly over relatively short distances
Refraction micro- tremor (ReMi)	Travel times of passive surface waves energy	Acoustic velocity (function of elastic moduli and density)	Acoustic (shear-wave) velocity–depth model often with interpreted layer boundaries	Geologic profile	●uses ambient noise as seismic source ●determines shear wave velocity	●depth limited to <300 feet
Ground- penetrating radar (GPR)	Travel times and amplitudes of reflected pulsed EM energy	Dielectric constant, magnetic permeability, conductivity and EM velocity	EM velocity/depth model with interpreted layer boundaries	Geologic profile	●Tool does not need to be coupled to earth ●Relatively rapid data acquisition ●Moderate to very high resolution (relative to other methods; decreases with depth) ●Very reliable 2-D and 3-D geologic models can be generated (if constrained)	●Limited depth of investigation (<30 m) ●EM radiation does not penetrate moist clays ●Post-acquisition processing may be required ●Interpretations are non-unique ●External constraints are required
Electro- magnetics (EM)	Response to natural–induced EM energy	Electrical conductivity and inductivity	Conductivity–depth model often with interpreted layer boundaries	Geologic–hydrologic profile	●Do not need to be coupled to earth; data can be acquired rapidly and inexpensively ●Multiple tools available (simple to sophisticated) ●1-D, 2-D or 3-D conductivity images of subsurface ●Interpretations, if constrained, can be remarkably accurate	●resolution diminishes with depth ● cultural features can create problems (metal fences, buried pipelines, electric power lines, etc.) ● all you ever end up with is an interpretation ● interpretations are non-unique ● ground truth is needed to constrain interpretations

Electrical resistivity	Potential differences in response to induced current	Electrical resistivity	Resistivity–depth model often with interpreted layer boundaries	Geologic–hydrologic profile	●1-D, 2-D or 3-D geologic/hydrologic images of the subsurface ● interpretations, if constrained, can be remarkably accurate ● reconnaissance tool used to optimally locate exploratory boreholes ● cost-effective means of establishing control between boreholes ● acquisition is relatively straightforward ● processing is automated ● interpretation is generally relatively straightforward (if constrained)	●relatively slow, as electrodes must be coupled to ground surface ● coupling can be a problem (rock or dry sand) ● limited depth penetration (relative to EM) ● resolution diminishes with depth ● cultural features can create problems (metal fences, buried pipelines, electric power lines, etc.) ● interpretations are non-unique ● ground truth is needed to constrain interpretations
Induced polarization (IP)	Polarization voltages or frequency dependent ground resistance	Electrical capacitivity	Capacitivity–depth model	Model depicting spatial variations in clay content (or metallic mineralization)	Can be acquired simultaneously with resistivity data (otherwise expensive)	External constraints are required
Self potential (SP)	Natural electrical potential differences	Natural electric potentials	Model depicting spatial variations in natural electric potential of the subsurface	Hydrologic model (seepage through dam, levee, or fractured bedrock, etc.)	●SP tool measures natural potential differences ●Only geophysical tool that responds directly to flowing water!! ●One or two person crew ●Relatively rapid and inexpensive ●Also responds to natural oxidization/ reduction	●Qualitative interpretations ●Interpretations are non-unique ●Anomalies (undesired signal or noise) can be due corroding metal ●Shallow depth of investigation ●Ore body must straddle water table
Magnetics	Spatial variations in the strength of the geomagnetic field	Magnetic susceptibility and remnant magnetization	Model depicting spatial variations in magnetic susceptibility of subsurface	Geologic profile or map (location of faults, variable depth to bedrock, etc.)	●Magnetometers respond to the presence and concentration of magnetically-susceptible material (almost exclusively man-made iron-based materials or magnetite); ●Data can be acquired rapidly and inexpensively (1-person crew); ●Data are usually interpreted qualitatively and therefore require minimal post-acquisition processing; ●Precise surveying is not required	●Magnetometers respond to presence and concentration of magnetically-susceptible material only
Gravity	Spatial variations in the strength of gravitational field of the Earth	Bulk density	Model depicting spatial variations in the density of the subsurface often with interpreted layer boundaries	Geologic profile or map (location of voids, variable depth to bedrock, mapping mines)	●Data can be acquired anywhere gravimeter can be placed and survey data acquired; ●Model (depth, shape, size, density) of target can often be generated	●Gravimeters respond to density variations – only; ●Very precise surveying control is required so that elevation and latitude corrections can be applied