THE TOWN OF TICONDEROGA

VETERAN'S ROAD CULVERT REPLACEMENT
OVER FIVE MILE CREEK
PIN 1761.09, D036296

AMENDMENT NO. 2

May 25, 2021 LETTING DATE

(Issued May 18, 2021)

NOTICE TO PROSPECTIVE BIDDERS

This Amendment No. 2 is issued to all bidders and is to be inserted into, and shall become part of, the Contract Documents.

This Amendment serves as an addition to the Bid Proposal, dated April 2021 prepared by Greenman-Pedersen, Inc.

Delete the following items:

Item No.	Unit	Quantity		Contract Proposal Page
None				

Change the ESTIMATE QUANTITIES for the following items:

Item No.	Unit	Existing Quantity	New Quantity
None			

Project Manual page deletions/additions/replacements are summarized in the following table:

Old Page	New Page	Description of Changes
3	3A2	Added GPR Report to Supplemental Information
None	231-258	Added GPR Report

Plan sheet deletions/additions/replacements are summarized in the following table:

Old Sheet	New Sheet	Drawing #	Description of Changes
None			

Additional items addressed in this amendment:

ITEM #1:

Contractor Question: Are there boring logs and rock core information for this project?

No. Borings were not completed on this project due to the interference of the overhead utilities at the time. Ground penetrating radar was used to map the rock elevations at the project site. The Ground Penetrating Radar and Seismic Refraction Geophysical Investigation Report has been added to the Project Manual under supplemental information.

PLEASE BE GOVERNED ACCORDINGLY WHEN SUBMITTING BIDS

Please email the signed Amendment No. 2 to skern@gpinet.com at Greenman-Pedersen, Inc and include a printed copy in your bid package as acknowledgement.

I hereby certify that Amendment No. 2 has been received and that the contents of said Amendment are reflected in the price bid for this contract.

____________________________________ ___________________
Authorized Signature Date

Company Name: ____

Address: ____

____

TABLE OF CONTENTS

Veteran's Road Culvert Replacement over Five Mile Creek
Town of Ticonderoga, Essex County, New York
D036296, PIN 1761.09

GROUND PENETRATING RADAR AND SEISMIC REFRACTION GEOPHYSICAL INVESTIGATION

VETERANS FARM ROAD

OVER

FIVE MILE RIVER

TICONDEROGA, NEW YORK

Prepared for

GREENMAN-PEDERSON, INC.

MAY 2020

NDT CORPORATION
Concrete & Geophysical Testing

NDT CORPORATION
153 Clinton Road, Sterling, MA 01564
Main: 978-563-1327 | Fax: 978-563-1340
eMail: Info@NDTCorporation.com

May 11, 2020

Ms. Sheri Kern, P.E.
Structural Engineer
Greenman-Pederson Incorporated (GPI)
80 Wolf Road, Suite 300
Albany, New York 12205

Subject: Proposal for Nondestructive/Geophysical Testing to locate the approximate bedrock elevations at a bridge located on Veterans Road crossing Five Mile River in Ticonderoga, NY

Dear Ms. Kern:

NDT Corporation conducted a Ground Penetrating Radar (GPR) and seismic refraction survey at the above referenced location to determine depth to rock/subsurface profile for a bridge replacement project. The fieldwork was conducted on May 5th, 2020 by NDT Corporation.

We thank you for the opportunity to perform this work and look forward to being of service to you in the future. If you have any questions or require additional information, call the undersigned at 978-573-1327.

Sincerely,

NDT Corporation
William Horne

William Horne

TABLE OF CONTENTS

1.0 INTRODUCTION AND PURPOSE:

NDT Corporation (NDT) conducted a Ground Penetrating Radar (GPR) and seismic refraction survey at Bridge No. 02128; Veterans Road crossing Five Mile River in Ticonderoga, NY to determine depth to rock/subsurface profile for a bridge replacement project. The fieldwork was conducted on May 5th, 2020 by NDT. NDT conducted this geophysical investigation to assist Greenman-Pederson, Inc. (GPI) in their effort to design a new 3-sided culvert on site.

2.0 LOCATION AND SURVEY CONTROL

The general location of the project area for Bridge No. 02128; Veterans Road crossing Five Mile River in Ticonderoga, NY is shown in Figure 1. Seismic data was collected along 2 lines of coverage on the north side of the road; designated Line 1 west side of culvert (sta. 110 to 10) and Line 2 eastside of culvert (-10 to -110) and stationed by NDT -110 to 110. The centerline of the northern face of the bridge was used as our 0+00 station. GPR data was collected along the north (File 1) and south side (File 2) of the road in the grassy area between the roadway and the guardrails. Additional GPR data (File 3 and 4) were collected near the northwestern wing wall. Figure 2 shows the Seismic and GPR lines of coverage, red lines indicate seismic data, green lines indicate GPR data. GPR data collection was limited due to access and limited penetration on site.

All depth measurements were referenced to the top of road/asphalt elevation (Elev. 316), which is related to the Elevation Plot provided by GPI.

3.0 METHODS OF INVESTIGATION

3.1 SEISMIC REFRACTION:

Seismic refraction data was acquired with a 12-channel system with 5- and 10-foot geophone spacing, and seismic energy generated approximately every 50 feet with a sledgehammer. Seismic Refraction utilizes the natural energy transmitting properties of the soils and rocks and is based on the principle that the velocity at which seismic waves travel through the earth is a function of the physical properties (elastic moduli and Poisson's ratio) of the materials. Refracted compressional wave data are used to evaluate material types and thickness, profile top of bedrock, and to determine the approximate depth to layer interfaces. A more complete discussion of the seismic refraction survey method is included in Appendix 1.

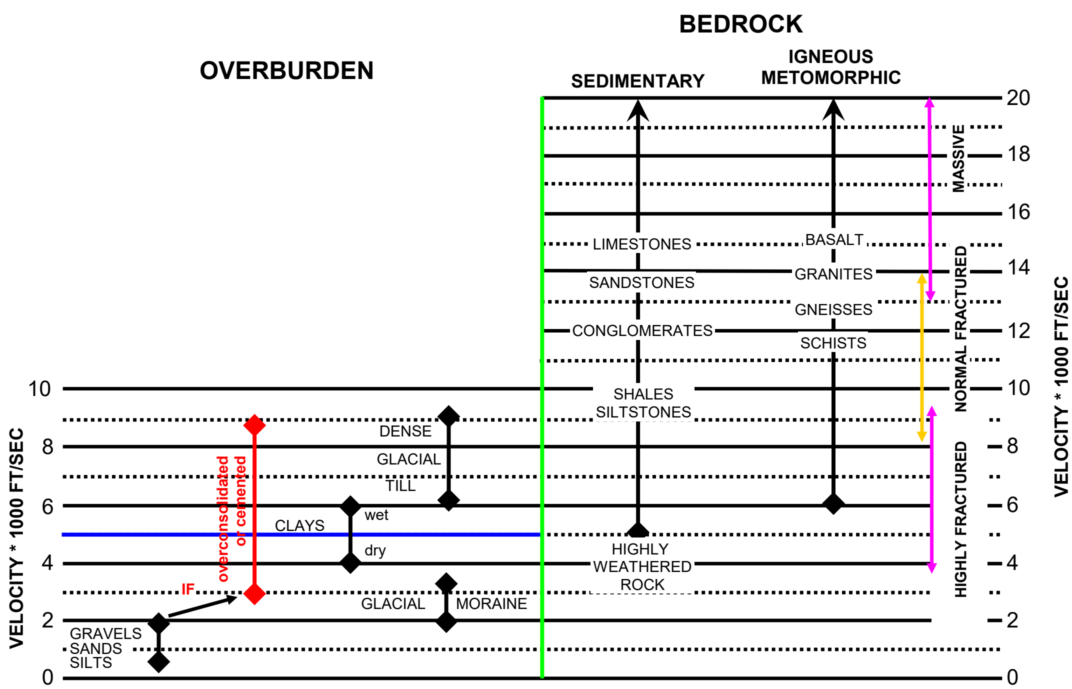
The seismic refraction data were interpreted using the critical distance method. Delayed bedrock wave arrivals were used to more accurately portray the bedrock surface between critical distance depth calculations. The delayed arrivals at individual geophone locations are an indicator of variability in the rock surface. Delayed arrivals indicate thicker overburden over the bedrock. Variations of 3+/- feet are not accurately profiled, particularly in shallow (less than 10 feet deep) bedrock areas.

Overburden with a 1,000-1,500+/- ft/sec velocity is consistent with normally consolidated soils/sands/fill material typical of natural soils, fluvial deposits, and/or construction fill. Till with a 2,600+/- ft/sec velocity value is consistent with unstratified glacial drift or ground moraine. These tills are typically deposited by receding glaciers consisting of an admixture of clays, sands and gravels with occasional and sometimes frequent boulders associated with an ablation till.

Overburden and till layers with “dry” velocities of less than 5,000 ft/sec are indistinguishable when saturated and assume the velocity of water 5,000+/- ft/sec when saturated.

Till with velocities between 6,000 to 8,000 ft/sec is consistent with an over-consolidated basil till. These tills consist of sands, gravel, and rocks/boulders which were deposited as the glaciers advanced. Subjected to the full weight and pressure of the glaciers these tills are very dense and are associated with split-spoon sampling of 30-50 blows per foot.

Bedrock velocities of less than 10,000 ft/sec are indicative of highly weathered and/or fractured rock typical of sedimentary and low-grade metamorphic rocks such as shales, silt stones and schists. Bedrock with a velocity of 10,000 to 15,000 ft/sec is indicative of competent bedrock that will require drilling and blasting for removal. This velocity range is typical of competent sedimentary and metamorphic rocks such as sandstones, limestones, schists, and gneisses. Bedrock velocities greater than 15,000 ft/sec are indicative of massive bedrock typical in metamorphic and igneous rocks such as gneisses, granites, and basalts.



3.2 Ground Penetrating Radar:

GPR data were acquired using a digital system coupled with a 200 & 400 MHz antenna. The 200 MHz antenna is high resolution which can have an approximate depth of investigation of 12 to 15 feet along the survey area. The 400 MHz antenna is high resolution which can have an approximate depth of investigation of 8 to 12 feet along the survey area. The actual depth of investigation is dependent on the soil types and moisture conditions. Depths of GPR investigation are usually deeper in dry sands and gravels than in moist silts and clays. The GPR method uses a pulsed electromagnetic signal that is transmitted to and reflected by a target back to the point of transmission. The electromagnetic wave transmission and reflection is dependent on the dielectric constant and conductivity (electrical) properties of the material(s) being investigated.

GPR reflectors are controlled by changes in moisture content, and electrical properties of soil/rock layers. When soil, till, and/or rock layers have differing moisture contents or electrical properties at these interfaces the GPR signal is reflected back at different rates/intensity. When layers have similar moisture/electrical properties it is possible there will be no change in signal reflection. Water/saltwater is highly conductive there for a water table will often reflect a high percentage of the GPR signal limiting the depth of penetration to this layer. Data penetration was limited to 7+/- feet at this site.

GPR signals are reflected by changes in materials, typically due to change in electrical/conductivity properties and/or moisture content, and the matrix of the material. Typically, construction fill and soils (when undisturbed) have a dry/well drained layered homogenous matrix which shows as smooth horizontal banding in GPR data. Ablation tills typically contain clays which retain moisture and are often comprised of sand/gravel/clay layers often with boulders included in the matrix. GPR data for tills are typically more reflective than fill and soils and the boulders are depicted by randomly spaced hyperbolas throughout the layer. Rock reflectors are often characterized as a change in material dependent on the conductivity of the rock type or an increased moisture layer; typically fracturing and an irregular surface are indicators of top of rock reflectors. A detailed discussion of the GPR Survey Method is included in Appendix 2.

4.0 RESULTS:

Seismic velocities in general consisted of a top, overburden layer with a velocity range of 1,000-1,500+/- ft. /sec (approximately 7-12+/- feet across the survey area). The river surface was measured to be 9.5 feet (approx. Elev. 305) below the road surface. The overburden and till/water saturated layers are underlain by bedrock with a velocity of approximately 10,000-12,000 ft. /sec.

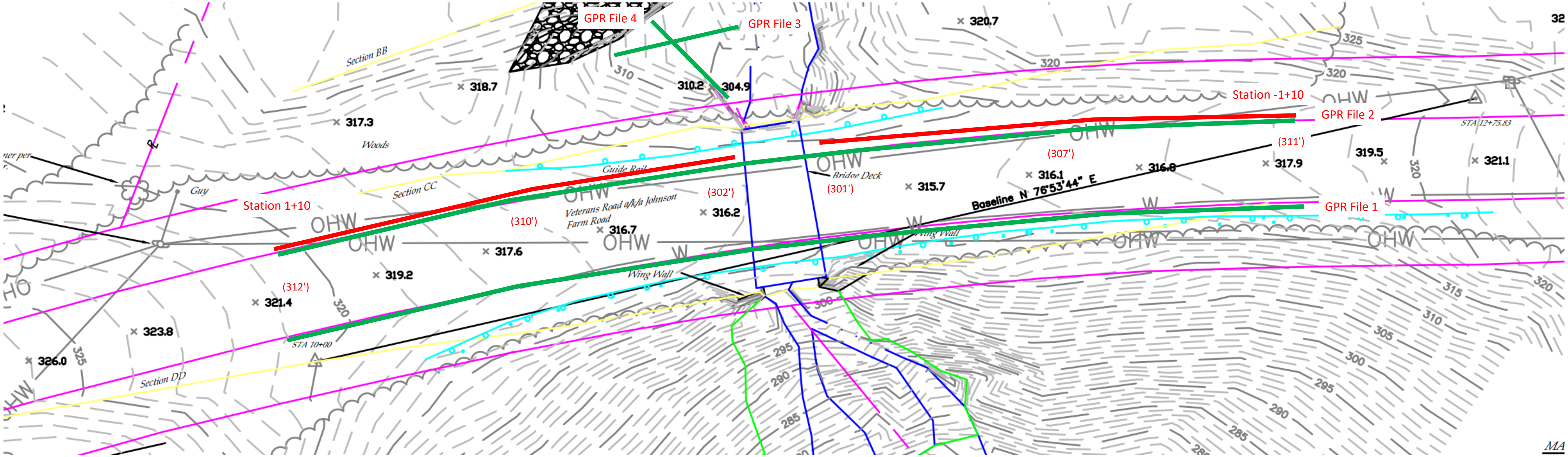
Overburden, with a 1,000-1,500 +/- ft. /sec velocity, are consistent with normally consolidated soils/sands/fill material typical of natural soils, fluvial deposits, and/or construction fill. These tills consist of an admixture of clays, sands and gravels with occasional and sometimes frequent boulders associated with an ablation till.

Top of bedrock surface shown on Figure 3 is an average rock surface, localized high and low areas exist. Definition of high and low areas is a function of the seismic spread length, number of "shots" taken, geophone spacing, velocity contrast, and the irregularity of the rock surface. Variations of 5+/- feet are not accurately profiled. The seismic profile in Figure 3 shows smooth changes in the rock surface data, which indicates that there is a high probability that vertical 3+/- foot changes are present.

The GPR signal penetration was limited to 7-7.5 feet. GPR data from File 1 and File 2 along the road surface did not detect a top of rock interface due to loss of signal penetration. GPR Files 3 and 4 collected on the north side of the culvert near the stream bed below the road surface from the wingwall north are shown on Figures 4 and 5. Each GPR record is annotated with dashed lines depicting change in material interfaces. The change in materials which are indicative of top of rock are shown as a dashed white line. Both records in this area indicate the bedrock to be 1-2.5' deep.

FIGURES

Non Destructive Geophysical Testing Vetrans Road Bridge Ticonderoga, NY Prepared for Greenman-Pederson, Inc. by NDT Corporation	Area of Investigation	
	May 2020	Figure 1



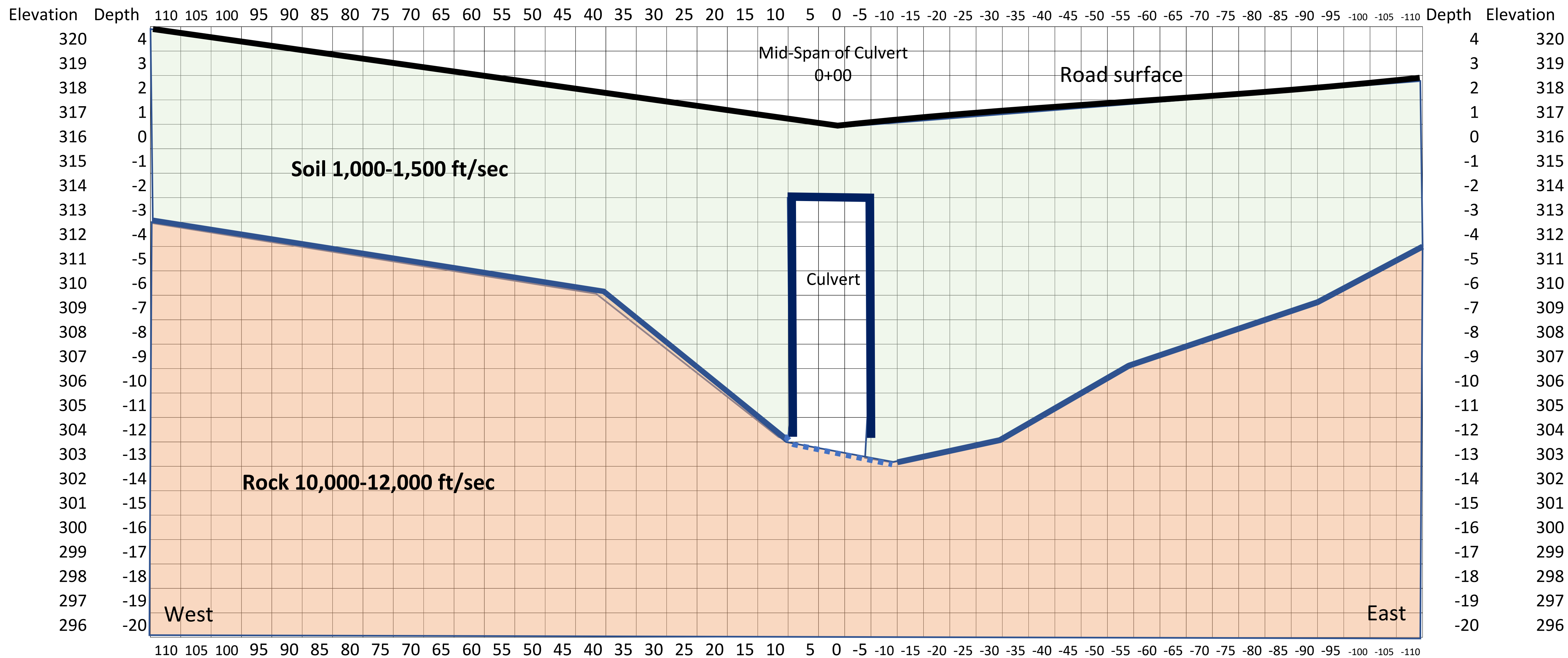
GPR lines of Coverage with both the 200MHz and 400 MHz antennas

Seismic Refraction lines of coverage

(312') Depth of Rock Elevation estimated from the GPR and Seismic refraction data

N

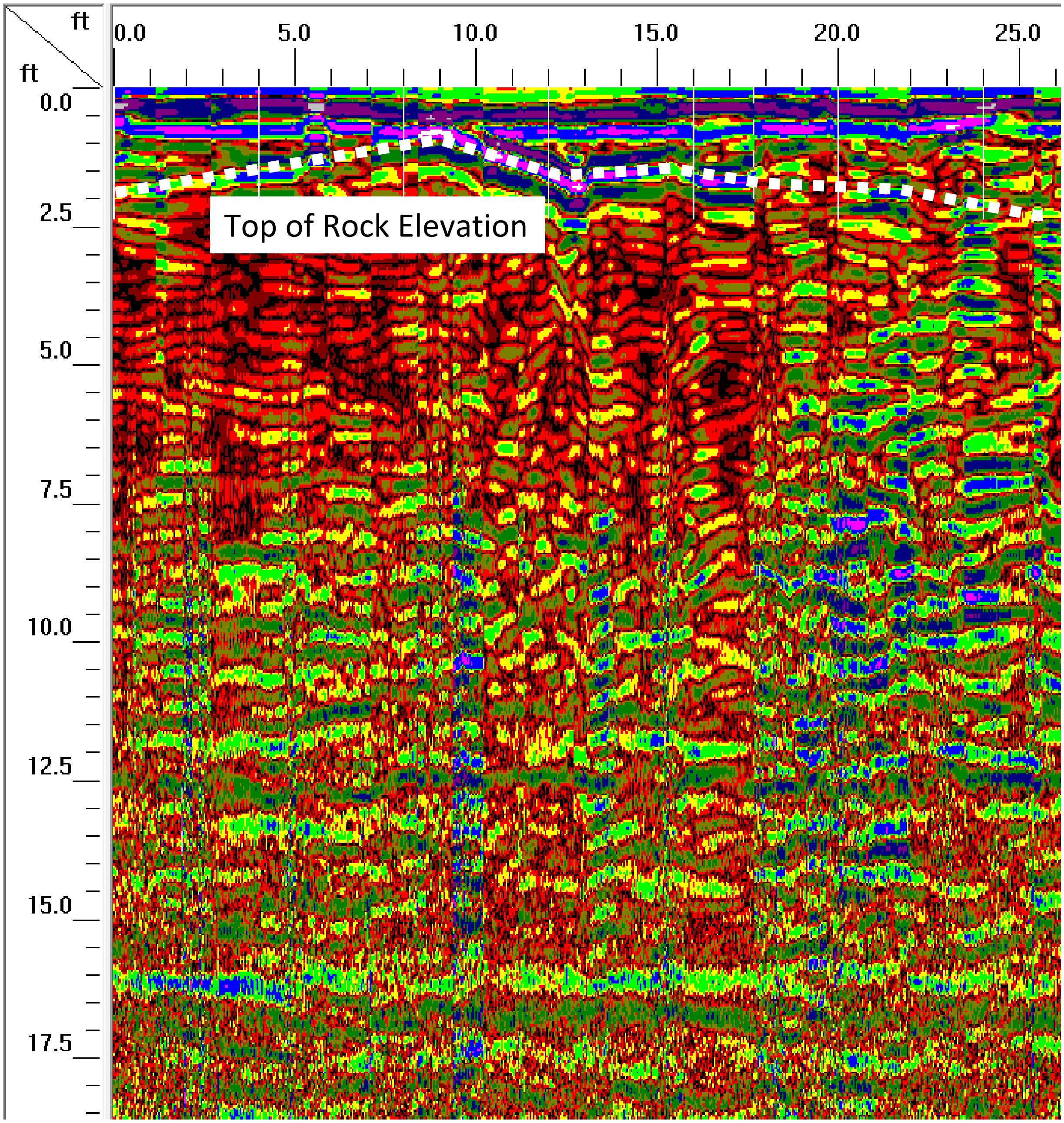
Non Destructive Geophysical Testing Vetrans Road Bridge Ticonderoga, NY Prepared for Greenman-Pederson, Inc. by NDT Corporation	Lines of Coverage	
	May 2020	Figure 2



Seismic Refration Profile North Edge of Road

Non Destructive Geophysical Testing Vetrans Road Bridge Ticonderoga, NY Prepared for Greenman-Pederson, Inc. by NDT Corporation	Seismic Refraction Profile Results	
	May 2020	Figure 3

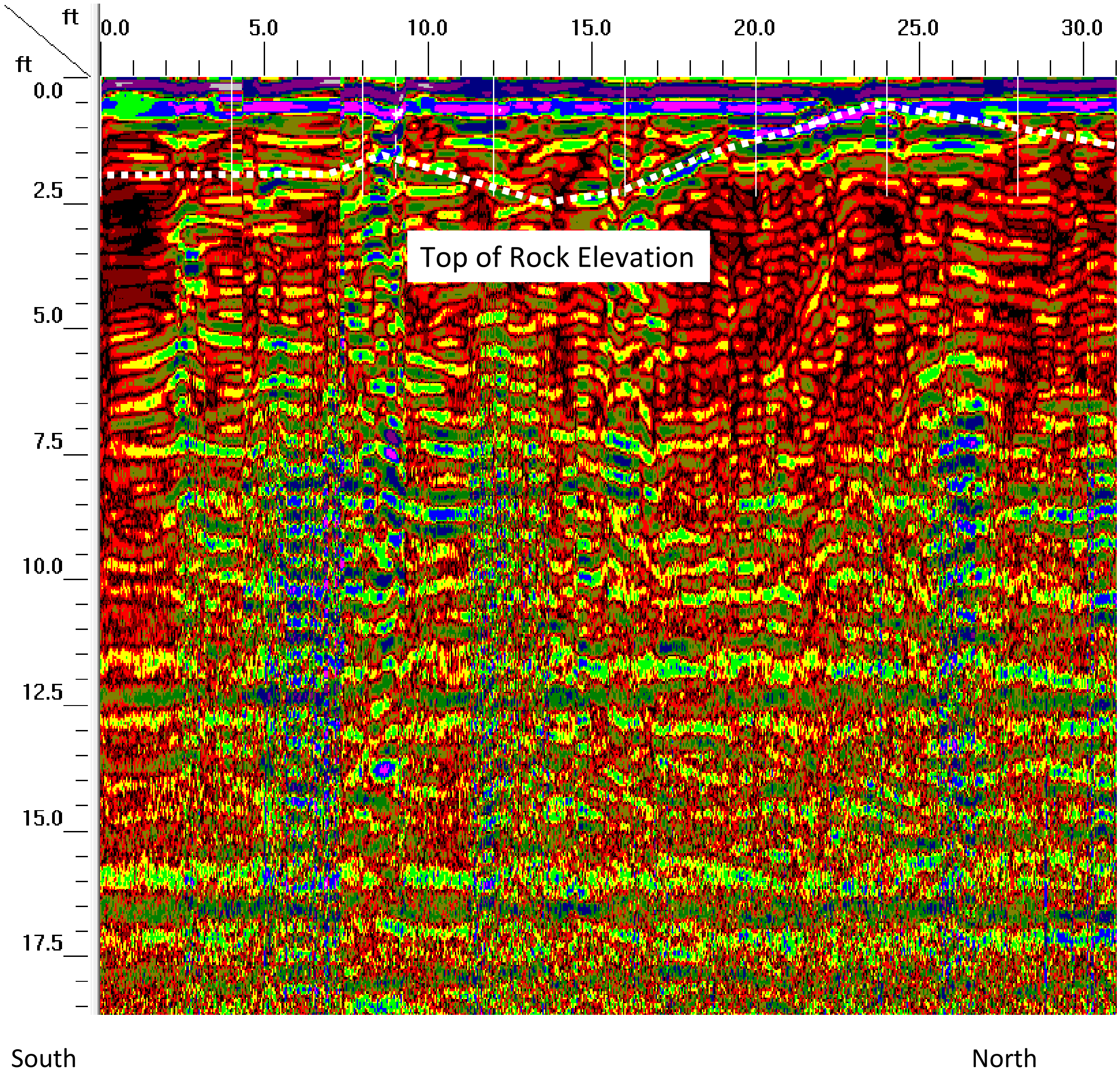
GPR Line 3



West East

Non Destructive Geophysical Testing Vetrans Road Bridge Ticonderoga, NY Prepared for Greenman-Pederson, Inc. by NDT Corporation	Annotated GPR Line 3 Collected West to East	
	May 2020	Figure 4

GPR Line 4



Non Destructive Geophysical Testing Vetrans Road Bridge Ticonderoga, NY Prepared for Greenman-Pederson, Inc. by NDT Corporation	Annotated GPR Line 4 Collected South to North	
	May 2020	Figure 5

APPENDIX 1

SEISMIC REFRACTION

APPENDIX: SEISMIC REFRACTION

OVERVIEW

Seismic exploration methods utilize the natural energy transmitting properties of the soils and rocks and are based on the principle that the velocity at which seismic waves travel through the earth is a function of the physical properties (elastic moduli and Poisson's ratio) of the materials. Energy is generated at the ends and at the center of the seismic spread. The geophone/hydrophone is in direct contact with the earth/water and converts the earth's motion resulting from the energy generation into electric signals with a voltage proportional to the particle velocity of the ground motion. The field operator can amplify and filter the seismic signals to minimize background noise. Data are recorded on magnetic disk and can be printed in the field. Interpretations are based on the time required for a seismic wave to travel form a source to a series of geophones/hydrophones located at specific intervals along the ground surface. The resultant seismic velocities are used for:

* Material identification.
* Stratigraphic correlation.
* Depth determinations.
* Calculation of elastic moduli values and Poison's ratio.

A variety of seismic wave types, differing in resultant particle motion, are generated by a near surface seismic energy source. The two types of seismic waves for seismic exploration are the compressional (P) wave and the shear (S) wave. Particle motion resulting from a (P-wave) is an oscillation, consisting of alternating compression and dilatation, orientated parallel to the direction of propagation. An S-wave causes particle motion transverse to the direction of propagation. The P-wave travels with a higher velocity of the two waves and is of greater importance for seismic surveying. The following discussions are concerned principally with P-waves.

Possible seismic wave paths include a direct wave path, a reflected wave path or a refracted wave path. These wave paths are illustrated in FIGURE A1. The different paths result in different travel times, so that the recorded seismic waveform will theoretically show three distinct wave arrivals. The direct and refracted wave paths are important to seismic refraction exploration while the reflected wave path is important for seismic reflection studies.

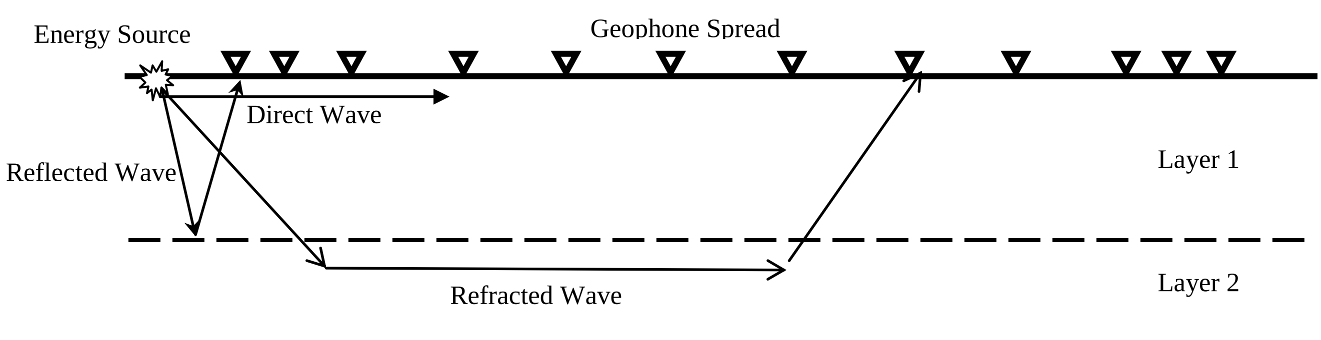


FIGURE A1:
SEISMIC WAVE PATHS FOR DIRECT WAVE, REFLECTED WAVE AND REFRACTED WAVE ILLUSTRATING EFFECTS OF A BOUNDARY BETWEEN MATERIALS WITH DIFFERENT ELASTIC PROPERTIES

Seismic waves incident on the interface between materials of different elastic properties at what is termed the critical angle are refracted and travel along the top of the lower layer. The critical angle is a function of the seismic velocities of the two materials. These same waves are then refracted back to the surface at the same angle. The recorded arrival times of these refracted waves, because they depend on the properties and geometry of the subsurface, can be analyzed to produce a vertical profile of the subsurface. Information such as the number, thickness and depths of stratigraphic layers, as well as clues to the composition of these units can be ascertained.

The first arrivals at the geophones/hydrophones located near the energy source are direct waves that travel through the near surface. At greater distances, the first arrival is a refracted wave. Lower layers typically are higher velocity materials, therefore the refracted wave will overtake both the direct wave and the reflected wave, because of the time gained travelling through the higher velocity material compensates for the longer wave path. Depth computations are based on the ratio of the layer velocities and the distance from the energy source to the point where refracted wave arrivals over take direct arrivals.

Although not the usual case, a constraint on refraction theory is that material velocities ideally should increase with depth. If a velocity inversion exists, i.e. where a higher velocity layer overlies a low velocity layer, depths and seismic velocities can be calculated but the uncertainty in calculations is increased unless borehole data are available.

APPLICATIONS

Seismic refraction technique is an accurate and effective method for determining the thickness of subsurface geologic layers. Applications for engineering design, assessment, and remediation as well as ground water and hydrogeologic studies include:

* Continuous profiling of subsurface layers including the bedrock surface
* Water-table depth determinations
* Mapping and general identification of significant stratigraphic layers
* Detection of sinkholes and cavities
* Detection of bedrock fracture zones
* Detection of filled-in areas
* Elastic moduli and Poisson’s ratio values for subsurface layers

Seismic refraction investigations are particularly useful because seismic velocities can be used for material identification. FIGURE A2 presents a guide to material identification based on P-wave seismic velocities. In rocks and compacted overburden material, the seismic waves travel from grain to grain so that the measured seismic velocity value is a direct function of the solid material. In porous or fractured rock and most overburden materials the seismic waves travel partly or wholly though the fluid between the grains.

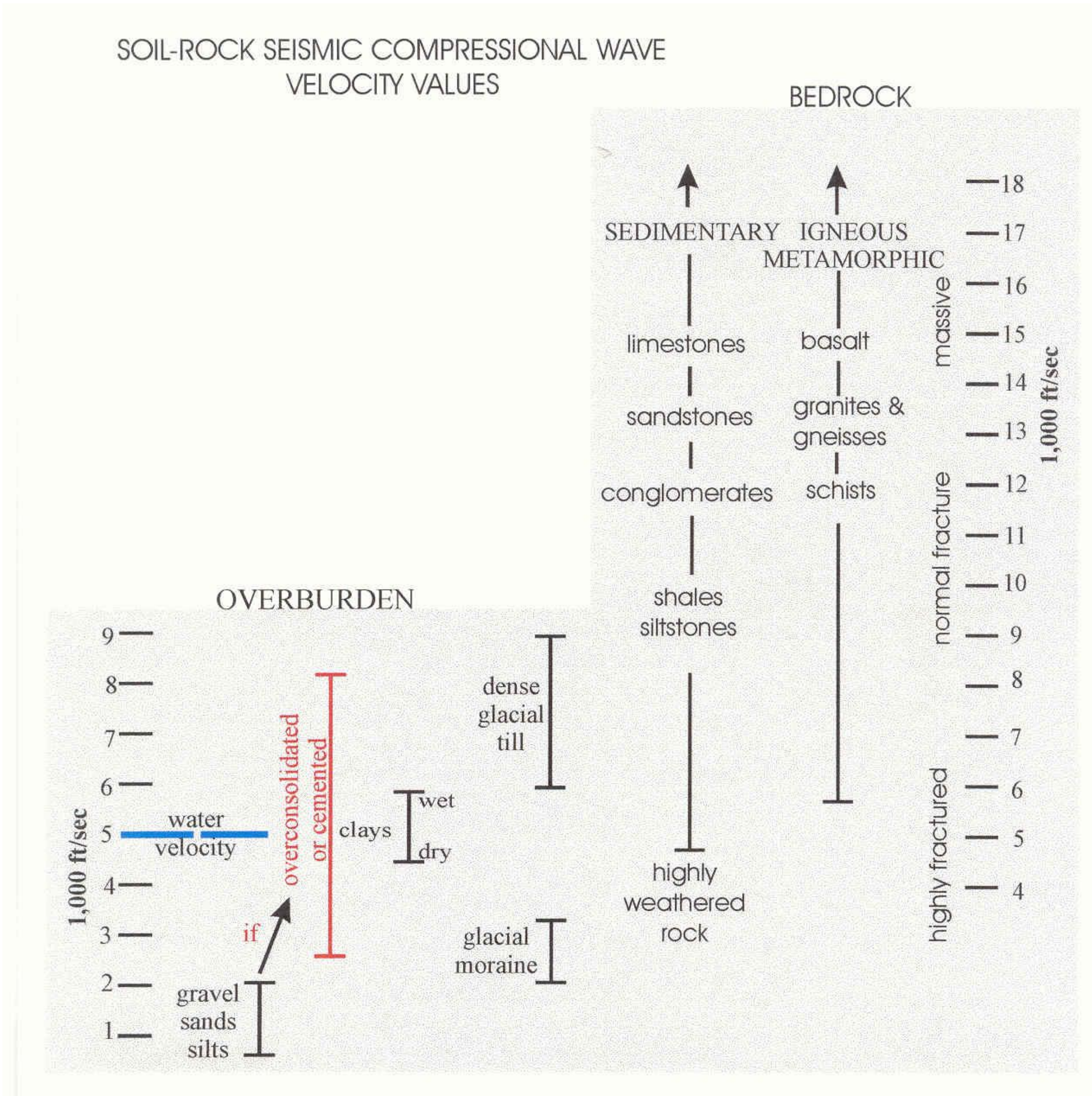


FIGURE A2:
GUIDE TO MATERIAL IDENTIFICATION BY P-WAVE VELOCITY

Seismic compressional wave velocities in unconsolidated deposits are significantly affected by water saturation. The seismic velocity values of unsaturated overburden materials such gravels, sands and silts generally fall in the range of 1,000 to 2,000 ft/sec. When these materials are water saturated, that is when the space between individual grains are 100% filled with water, the seismic velocities range from 4,800 to 5,100 ft/sec, equivalent to the compressional P-wave velocity of sound in water. This is because the seismic wave assumes the velocity of the faster medium, that of water. Even a small decrease in the saturation level will substantially lower the measured P-wave velocity of the material. Because of this velocity contrast between saturated and unsaturated materials, the water table acts as a strong refractor.

Seismic investigations over unconsolidated deposits are used to map stratigraphic discontinuities and to unravel the gross stratigraphy of the subsurface. These can be vertically as in the case of a dense till layer beneath a layer of saturated material or horizontally as in the case of the boundaries of a fill material. Often these boundaries represent significant hydrologic boundaries, such as those between aquifers and aquicludes.

A common use of seismic refraction is the determination of the thickness of a saturated layer in unconsolidated sediments and the depth to relatively impermeable bedrock or dense glacial till. Continuous subsurface profiles and even contour maps of the top of a particular horizon or layer of interest can be developed from a suite of seismic refraction data.

Bedrock velocities FIGURE A2 vary over a broad range depending on variables, which include:

* Rock type
* Density
* Degree of jointing/fracturing
* Degree of weathering

Fracturing and weathering generally reduce seismic velocity values in bedrock. Low velocity zones in seismic data must be evaluated carefully to determine if they are due to overburden conditions or fractured/weathered or perhaps even faulted bedrock.

EQUIPMENT:

The basic equipment necessary to conduct a seismic refraction investigation consists of:

* Energy source
* Seismometers (Geophones/Hydrophones)
* Seismic cables
* Seismograph

Energy sources used for seismic surveys are categorized as either non-explosive or explosive. The energy for a non-explosive seismic signal can be provided by one of the following:

* Sledge Hammer (very shallow penetration)
* Weight Drop
* Seisgun
* Airgun
* Sparker
* Vibrators (for reflection surveys)

Explosive sources can be categorized as:

* Dynamite
* Primers
* Blasting Agents

Choice of energy source is dependent on site conditions, depth of investigation, and seismic technique chosen as well as local restrictions. Explosive sources may be prohibited in urban areas where non-explosive sources can be routinely used. Deeper investigations usually require a larger energy source: therefore, explosives may be required for sufficient penetration.

Geophones/Hydrophones are sensitive vibration detectors, which convert ground motion to an electric voltage for recording the seismic wave arrivals. Seismic cables, which link the geophones/hydrophones and seismograph are generally fabricated with pre-measured locations for the geophones/hydrophones and shot point definitions.

The seismograph can be single channel or multi-channel, although, multi-channel seismographs (12 to 24 channels) are preferred and necessary for all but the simplest of very shallow surveys. The seismograph, amplifies (increases the voltage output of the geophones), conditions/filters the data, and produces analog and digital archives of the data. The analog archive is in the form of a thermal print of the data, which can be printed directly after acquisition in the field. The digital archive is stored on magnetic disk and can be used for subsequent computer processing and enable more extensive and detailed interpretation of seismic data.

ACQUISITION CONSIDERATIONS:

Several concerns arise before data collection, which must be addressed before of any seismic survey:

* Geophone spacing and Spread length
* Energy Source (discussed above)
* On-site utilities and cultural features (buildings, high tension lines, buried utilities, etc.)
* Vibration generating activities
* Geology
* Topography

To acquire seismic refraction data, a specific number of geophones are spaced at regular intervals along a straight line on the ground surface; this line is commonly referred to as a seismic spread. The length of spread determines the depth of penetration; a longer spread is required for a greater depth of penetration. Spread length should be approximately three to five times the required depth of penetration. Required resolution will control the number of geophones in each spread and the distance between each geophone. Closer spacings and more geophones usually result in more detail and greater resolution.

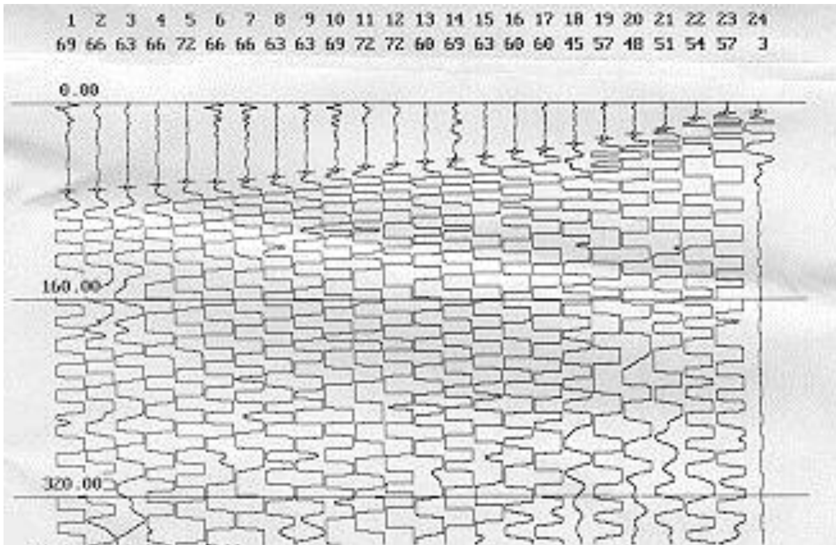
Cultural effects such as vibration generating activities, on-site utilities, and building affect where data can be acquired, and where lines/spreads are located. High volume traffic areas may require nighttime acquisition. If the survey is to be conducted near a building where vibration-sensitive manufacturing is conducted, data acquisition may be constrained to particular time intervals and appropriate energy sources must be used. Over head and buried utilities must be located an avoided, for both safety and induced electrical noise concerns. Since the seismic method measures ground vibration, it is inherently sensitive to noise from a variety of sources such as traffic, wind, rain etc. Signal Enhancement, such as record stacking, accomplished by adding a number of seismic signals from a repeated source, causes the seismic signal to "grow" out of the noise level, permitting operation in noisier environments and at greater source to phone spacings.

Knowledge of site geology can be used to determine the energy source. Some geologic materials, such as loose, unsaturated alluvium, do not transmit seismic energy as well and a powerful energy source may be required. Geologic conditions also dictate whether or not drilled shotholes are required. Site geology can also dictate the positioning of seismic lines/spreads. Where a bedrock depression of a feature is suspected, seismic lines should be orientated perpendicular to the suspected trend of the feature. Seismic cross profiles may be necessary to confirm depths to a particular refracting horizon.

The topography of a site dictates whether or not surveyed elevations are required. If possible, refraction profile lines should be positioned along level topography. For highly variable topography, a continuous elevation profile may be required to ensure sufficiently accurate cross-sections and to permit the use of time corrections in the interpretation of the refraction data.

DATA PRESENTATION AND INTERPETATION:

Interpretation of seismic refraction data involves solving a number of mathematical equations with the refraction data as it is presented on a travel-time versus distance chart. Seismic refraction data FIGURE A3 can be processed by plotting the "First Arrival" travel times at each geophone location. The preferred format of data presentation is a graph (Travel Time Plot) illustrated in FIGURE A4, in which travel time in milliseconds is plotted against source-receiver distance. From such a chart, the velocities of each layer can be obtained directly from the increase slope of each straight-line segment. Using the velocities the critical angle of refraction for each boundary can be calculated using Snell's Law. Then, utilizing these velocities, and angles and the recorded distances to crossover points (where line segments cross); the depths and thickness of each layer can be calculated using simple geometric relationships.



Shot point is 0.00

Channel	1	Phone location	195.00	Arrival time	71.3	msec
Channel	2	Phone location	190.00	Arrival time	70.3	msec
Channel	3	Phone location	185.00	Arrival time	68.5	msec
Channel	4	Phone location	175.00	Arrival time	66.3	msec
Channel	5	Phone location	165.00	Arrival time	63.0	msec
Channel	6	Phone location	155.00	Arrival time	63.0	msec
Channel	7	Phone location	145.00	Arrival time	62.0	msec
Channel	8	Phone location	135.00	Arrival time	59.0	msec
Channel	9	Phone location	125.00	Arrival time	56.8	msec
Channel	10	Phone location	115.00	Arrival time	54.8	msec
Channel	11	Phone location	110.00	Arrival time	51.5	msec
Channel	12	Phone location	105.00	Arrival time	49.3	msec
Channel	13	Phone location	95.00	Arrival time	47.3	msec
Channel	14	Phone location	90.00	Arrival time	46.0	msec
Channel	15	Phone location	85.00	Arrival time	43.0	msec
Channel	16	Phone location	75.00	Arrival time	39.0	msec
Channel	17	Phone location	65.00	Arrival time	37.0	msec
Channel	18	Phone location	55.00	Arrival time	33.0	msec
Channel	19	Phone location	45.00	Arrival time	28.0	msec
Channel	20	Phone location	35.00	Arrival time	25.0	msec
Channel	21	Phone location	25.00	Arrival time	20.0	msec
Channel	22	Phone location	15.00	Arrival time	12.0	msec
Channel	23	Phone location	10.00	Arrival time	8.0	msec
Channel	24	Phone location	5.00	Arrival time	7.0	msec

FIGURE A3:
TYPICAL 24 CHANNEL ANALOG SEISMIC REFRACTION RECORD, WITH FIRST ARRIVAL TIMES

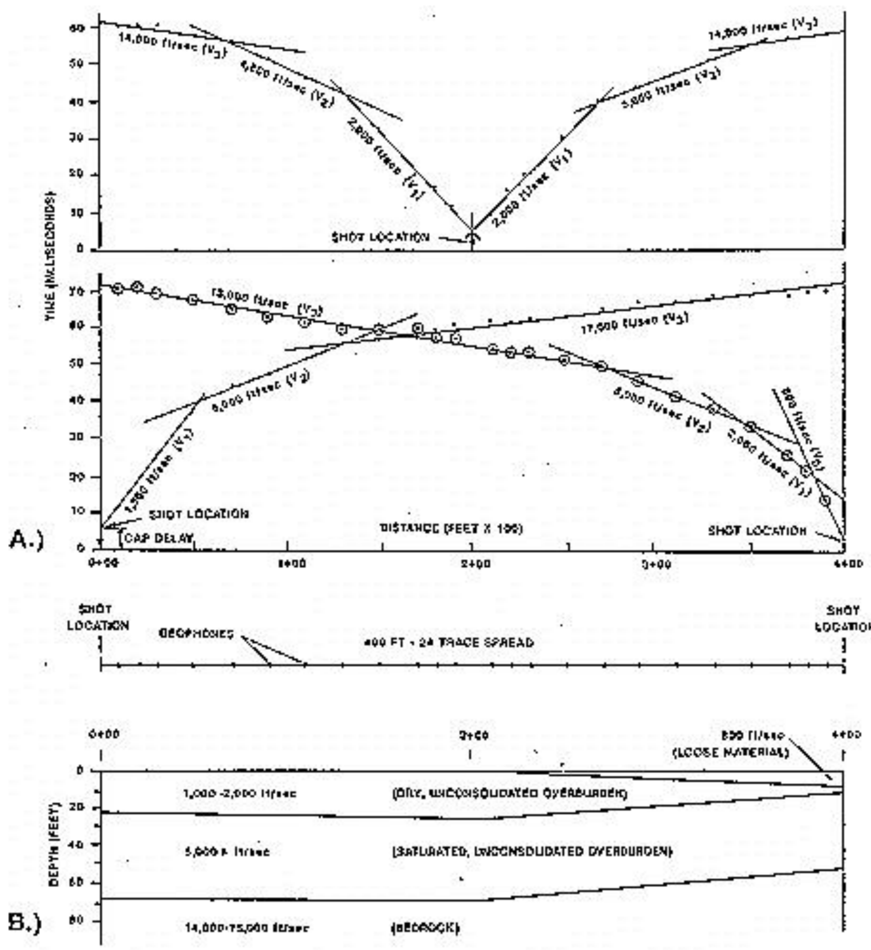


FIGURE A4:
A: TRAVEL-TIME PLOTS; UPPER PLOT IS A CENTER SHOT, LOWER PLOT IS TWO END SHOTS
B: RESULTING PROFILE OF SUBSURFACE MATERIALS SHOWING INTERFACE BETWEEN DIFFERENT SEISMIC VELOCITY LAYERS

The results of any seismic survey, refraction or reflection are usually presented in profile form showing elevations of seismic horizons/layers. Data acquired on a grid basis can be contoured and used to construct isopach maps. Seismic velocities and therefore, generalized material identifications should be presented on refraction profiles along with any test borings used for correlation to establish confidence in the overall subsurface data, both seismic and borings.

Where profiles indicate dipping boundaries, calculation of dips, true depths and true velocities involve more complicated equations. Further more, corrections for differing elevations and varying thicknesses of weathered zones must often be made. Fracturing and weathering generally reduce seismic velocity values in bedrock. Consequently, travel-time plots with late arrivals must be evaluated carefully to determine if the late arrival times (slower velocities) are due to overburden conditions or fractured/weathered bedrock.

Very thin layers or low velocity zones often complicate the travel-time chart as well. Although not the usual case, one constraint on refraction theory is that material velocities ideally should increase with depth. If a velocity inversion exists, i.e. where a higher velocity layer overlies a low velocity layer, depths and seismic velocities can be calculated but the uncertainty in calculations is increased unless borehole velocity data are available.

ADVANTAGES AND LIMITATIONS:

The seismic refraction technique, when properly employed, is the most accurate of the geophysical methods for determining subsurface layering and materials. It is extremely effective in that as much as 2,000 linear feet or more of profiling can be acquired in a field day. The resulting profiles can be used to minimize drilling and place drilling at locations where borehole information will be maximized resulting in cost-effective exploration. A standard drilling program runs the risk of missing key locations due to drillhole spacing. This risk is substantially reduced when refraction is used.

In summary, the advantages and limitations of the seismic techniques are:

Advantages:

* Material identification
* Subsurface data over broader areas at less cost than drilling
* Relatively accurate depth determination
* Correlation between drillholes
* Preliminary results available almost immediately
* Rapid data processing

Limitations:

* As depth of interest and geophone spacing increases, resolution decreases
* Thin layers may be undetected
* Velocity inversions may add uncertainty to calculations
* Susceptible to noise interference in urban areas, which require use of grounded cables and equipment, signal enhancement and alternative energy sources.

APPENDIX 2

GPR METHOD OF INVESTIGATION

APPENDIX: GROUND PENETRATING RADAR

Ground Penetrating Radar (GPR) is an electrical geophysical method for evaluating subsurface conditions by transmitting high frequency electromagnetic waves into the ground and detecting the energy reflected back to the surface. Electromagnetic signals are transmitted from the antenna (transmitter and receiver) at ground surface and reflected back to the antenna from interfaces with differing electrical (dielectric constant and conductivity) properties. The greater the contrast in the electrical properties between two materials, the more energy that is reflected to the surface and the more defined results are.

GPR SYSTEM:

GPR systems consist of: Control unit (pulse transmitter, digital recorder, data storage, monitor); and an antenna(s) and survey wheel.

The GPR control unit is a computer which controls data acquisition parameters, such as sampling rate, range, gain control, filtering, etc. The Control Unit also visually displays the data, digitally archives the data, and allows for play back of the data.

Coaxial cable connects the control unit to the antenna. The antenna(s) are sealed and shielded in fiberglass housing.. Selection of the antenna is dictated by the requirements of the survey. For high resolution, near-surface data, a high frequency antenna is used; for deeper penetration investigation, a lower frequency antenna is used. Typically the 100 to 400 MHz antennas are used for geologic surveys; 400 to 900MHz are used for utility, near surface voiding settlement, foundation, etc surveys while the 900 to 1500 MHz are used for concrete reinforcing assessment.

APPLICATIONS

Ground Penetrating Radar (GPR) can be used to locate underground pipes, buried drums, foundations, voids in rock and concrete, soil settlement, determine stratigraphy, depth to water table, buried artifacts, filled excavations, and locate voids/settlement behind walls and under floor slabs, etc. GPR is also a good tool for evaluating concrete structures such as bridges, walls, beams, ceilings, etc where the GPR can locate rebar and conduits, quantify rebar spacing, cover variability over reinforcing, and concrete thickness.

GPR reflections typically occur at subsurface discontinuities such as:

- Buried metal objects (utilities, tanks, reinforcing)
- Open and water filled voids
- Water table
- Soil stratification
- Seepage paths
- Bedrock fractures

DETPH OF PENETRATION AND LIMITATIONS

The depth of penetration of GPR is site specific, limited by the attenuation of the electromagnetic energy. Signal attenuation is controlled by four different mechanisms:

- Scattering: energy losses due to scattering occur when signals are dispersed in random directions, away from the receiving antenna, by closely spaced rebar or large irregular shaped objects, such as boulders or tree stumps.
- High conductivity layers: the greater the conductivity values of materials at a site, the more signal attenuation or less penetration. (Mineral content, high moisture content, water table, metal plates, etc.)

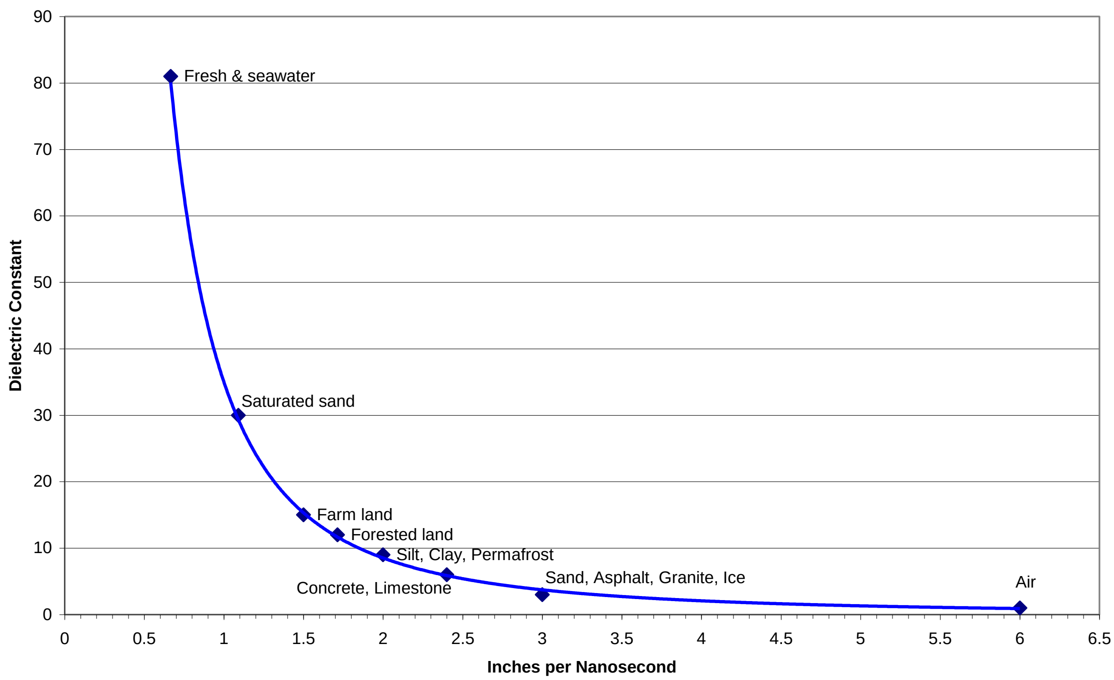
Signal penetration is also dependent on the frequency of the antenna. High frequency antennas have shallow penetration and high resolution. Low frequency antennas have greater depths of penetration, but the resolution of small and near surface targets is reduced. Listed below are antenna frequency, approximate depths of penetration and typical application. (Depths of penetration are in ideal conditions if a highly conductive layer, such as a brackish water table, steel plate, etc., is present all antennas will be limited to the depth of this layer.)

1500 and 1600 MHz	+/-2 feet	Asphalt/Concrete thickness Wire mesh/rebar/conduit location Voiding within and behind structures
900 MHz	3-5 feet	Concrete thickness Rebar and utility location Voiding within and behind structures
400 MHz	10-15 feet	Concrete/Masonry thickness Utility location Soil settlement/sinkhole development Geologic and Environmental mapping Archaeological Surveys
200 MHz	25-30	Soil settlement/sinkhole development

		Geologic and Environmental mapping Archaeological Surveys
100 MHz	+/-50	Soil settlement/sinkhole development Geologic and Environmental mapping Archaeological Surveys

Depth of investigation can be estimated using material dielectric constants and the diagram shown below. Typically 2 inches per nanosecond can be used as an average signal velocity for most materials and sites. When available an onsite depth calibration can be conducted to determine the electrical properties (speed of the signal) of the materials at the site. Depth calibrations typically consist of collecting GPR data over a metal target with a known depth. Known utilities, and buried metal plates are good targets for calibrations. GPR surveys can be very effective when coupled with other geophysical surveys and/or ground truth methods to verify, correlate and extrapolate GPR results. GPR surveys are a fast and cost effective method to collect data over large or obstructed sites, and isolate anomalies and areas where borings or other methods can be focused for the best interest of a project.

Material Velocity - Dielectric Constant

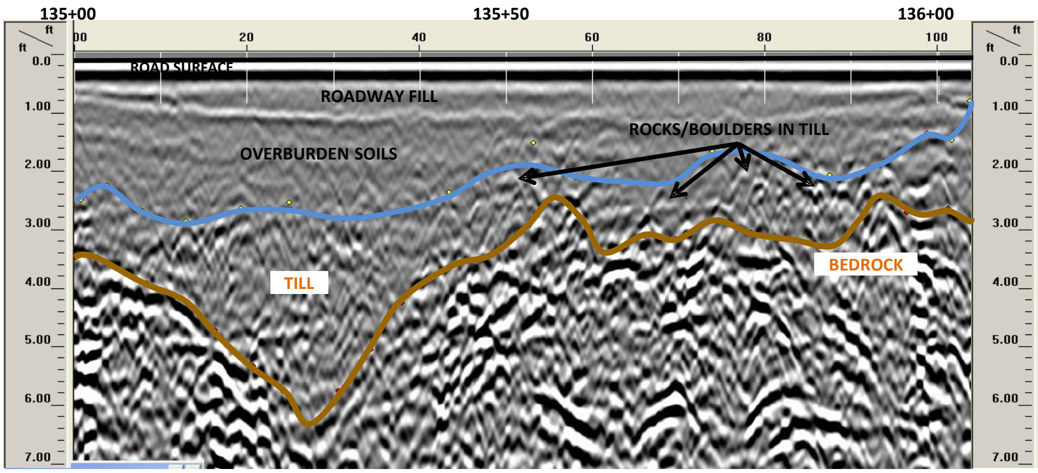


ACQUISITION AND INTERPRETATION:

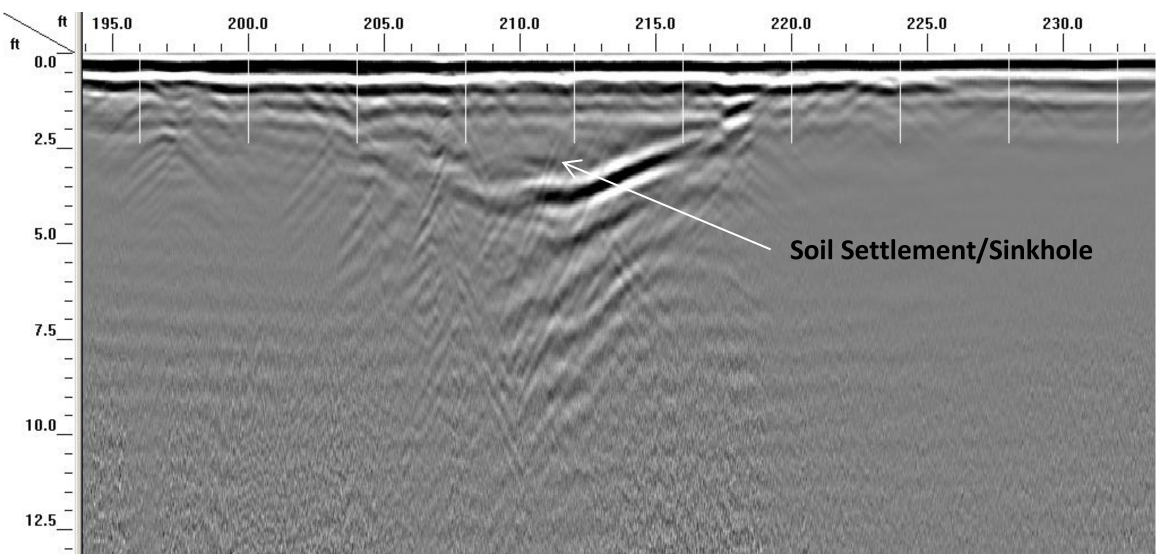
Radar data are typically acquired at a slow walking speed along a grid pattern of survey lines or a series of parallel lines. Data is displayed on LCD screen for field verification and quality control of results and digitally saved. Calibrated measuring wheels are used to automatically added footage/station markers to the digital data. The saved data can be printed or post processed.

Interpretation of GPR data is subjective. GPR results should be verified with borings or test pits. GPR lines indicate a cross-section in time/depth along a survey line.

Natural soils or fill placed in lifts during construction retain moisture between material interfaces and typically have horizontal or near horizontal bedding planes. These conditions cause a change in conductivity which shows as continuous reflective layers on GPR data. The strength of a reflected signal and/or the continuity of the reflector across the record may be indicative of a stratigraphic contact, water table, top of rock, back of wall/slab.



Locations where GPR data indicate theses horizontal bedding planes/layers are sloping, draped or disturbed can be indication of soil settlement, trenching and/or voiding. Areas where GPR data is less reflective, indicating fine soil materials (clays and silts) have been washed or eroded away or areas that are more reflective, indicating loose soil conditions where moisture has accumulated are also indicative of and associated with settlement, sinkholes, and voiding.



Often point targets, such as reinforcing, buried utilities, boulders, create a distinctive parabolic feature on GPR records. Point targets trending perpendicular to the direction of the line of coverage are detected, therefore to detect longitudinal reinforcing a transverse line of data would be collected and to detect transverse reinforcing, a longitudinal line of data would be collected. Plotting point targets of similar signal strength, depth, and shape located along the grid of GPR lines give the trend and location of individual utilities and/or reinforcing.