HILLIS-CARNES
ENGINEERING ASSOCIATES

Geophysical Exploration Services
500 N. Plum Street
Lancaster, Pennsylvania
HCEA Job No. H19107

Prepared for:

C.S. Davidson, Inc.
315 W. James Street, Suite 102
Lancaster, Pennsylvania 17603

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September 12, 2019

Mr. Evan Laub
C.S. Davidson, Inc.
315 W. James Street, Suite 102
Lancaster, PA 17603

Re: Geophysical Exploration
500 Block N. Plum Street
Lancaster, Pennsylvania
HCEA Project Number: H19107

Dear Mr. Laub,

Pursuant to your request, Hillis-Carnes Engineering Associates, Inc. (HCEA) is pleased to submit this summary letter for the geophysical exploration within the 500 block of North Plum Street, Lancaster, Pennsylvania (Site).

This report explains the survey procedures and describes the general site conditions in addition to the subsurface conditions encountered.

Project Description

The Site consists of ten row houses (referral addresses: 521, 523, 525, 527, 529, 531, 533, 535, 537 and 539) along the northeastern side of North Plum Street. Each house has an accompanying yard to the rear of the main dwelling and several properties also include garages and/or concrete parking spaces. The properties are bordered to the rear by a private alleyway that runs approximately parallel to N. Plum Street. A depression, reportedly known to collect and retain stormwater is present within the middle of the private alleyway, approximately near the #531 residence, where the alleyway is intersected by Burrowes Avenue entering from the northeast. It is our understanding that residents of the 500 Block have reported the depression increasing in diameter and depth over the past several years. In addition to the noted depression, structural disturbance was noted to the properties within the 500 Block, particularly the dwellings within the central portion of the block.

General Geology of the Project Site

According to the information on the Pennsylvania Department of Conservation and Natural Resources website, the project site is located within the carbonate rocks of the Lancaster area where the predominate the strike of bedrock trends in a northeast-southwest orientation with a southward dip. The site is primarily located within the mapped stratigraphic boundary of the Conestoga Limestone (map symbol OCc) of Ordovician and Cambrian ages just south of the stratigraphic boundary for the Ledger Dolomite (map symbol Cl) of Cambrian age. These formations are further described on the next page.

Conestoga Limestone (OCc) of Ordovician and Cambrian Age

The Limestone is described as a "The Conestoga Formation consists of medium-gray, impure limestone with black, graphitic shale partings. It is conglomeratic at the base. In Chester County, it includes micaceous limestone, phyllite, and alternating dolomite and limestone. The total thickness is at least 300 feet (Geyer and Wilshusen, 1982)."

Ledger Dolomite (Cl) of Cambrian Age

This formation is described as "Formation is a light-gray, locally mottled, massive, pure, coarsely crystalline dolomite that is siliceous in the middle part. The beds, which are moderately well developed and massive, weather to rust-stained, granular, cherty layers. It is approximately 2,00 feet thick."

In-situ decomposition of limestone materials typically produces surficial layers of residual soil of significant variable thicknesses. Localized concentrations of bedding planes, fractures, or other discontinuities often result in decomposition extending deeper within the subsurface profiles. Ridges and lenses of rock that are relatively resistant to decomposition form pinnacles of unweathered bedrock that can extend nearly up to the ground surface. The localized decomposition and rock pinnacles all combine to form a highly irregular rock surface. Occasionally, solution cavities develop below or within the rock surface. The cavities are sometimes left open or are filled with soft, reworked residual materials.

Based on the aforementioned-site conditions, HCEA was requested by C.S. Davidson, Inc. to provide a subsurface investigation within the 500 Block of North Plum Street to gain an understanding of the subsurface conditions present at the Site. As such, HCEA conducted limited geophysical surveys, utilizing Microgravity (MG) and Ground Penetrating Radar (GPR) techniques. This report discusses the results of these surveys, and the subsequent recommendations regarding the additional areas of concerns delineated. The MG and GPR results are attached in the Appendix (Figures 2 through 14) of this report.

Microgravity Survey

Microgravity testing measures the minute changes in the earth's gravitational field (measured in micro gals) caused by the changes in density of the soil and rock. Micro-gravity is a geophysical exploration method that can aid in detecting underground openings, caves, etc. in urban areas or obstructed areas. Another advantage for occupied sites is that this geophysical method can function when placed on concrete and inside buildings because, unlike Electrical Resistivity geophysics, micro-gravity does not require cables and steel pins to be placed in the ground. The results can be displayed in colorized contour maps based upon the microgal levels. Micro-gravity results are in color where the green and blue areas represent potentially soft/loose/saturated soils while the bright oranges and red colors represent relatively denser objects, such as rock or relatively denser materials. The gravity instrument used for the micro-gravity surveys is the Scintrex CG-6. The CG-6 uses the fused quartz spring system. The gravitational force on the proof-mass is balanced by a spring, and an electrostatic restoring force. The inherent strength and excellent elastic properties of

fused quartz, together with the limit stops around the proof-mass, permit the instrument to be operated without clamping. Additional protection is provided by a durable shock mount system. Before data is collected, readings at a base station were collected at the beginning and end of each day. Mini base stations were collected at two-hour intervals. The base station readings were used to calculate instrument drift. Data was collected on a grid consisting of 5-foot centers within the central four properties (527, 529, 531, and 533) and 10-foot centers elsewhere, where accessible, within the remaining properties located in the 500 block of North Plum St. Additionally, data points were obtained in basements where access was allowed or within accessible areas based on tenant permissions.

The gravity data was corrected for latitude, elevation, topography, and tides to detect anomalies caused by the subsurface density contrasts. The gravity corrections used to process the data are the Tide Corrected Gravity, the Instrument Drift Correction, the Latitude correction, the Free-Air Correction, and the Bouguer Correction. Each gravity line was interpreted using GM-SYS after the corrections were made. GM-SYS is a 2 ¾-dimensional model that computes the subsurface to theoretical gravity responses. GM-SYS uses Inman-style ridge regression for inversion calculations which are nonlinear least square approaches for obtaining the model which best fits the observed data.

The model is performed by inputting layers of different densities which the model uses to compute subsurface conditions. The density used for the clayey materials was 2.2 g/cm^3. A polynomial body representing the voids associated with rubble debris used a density from about 1 g/cm^3. A polynomial body representing the dolomite used a density of 2.7 g/cm^3. The model profiles present three curves. The points are the raw data, the black line is the modeled fit to the data, and the red line is the error line in which the best result is when the red line is flat. The plot is the modeled subsurface cross-section based upon the model curve fit. The contours of the microgravity data were generated by computer using Golden Software's Surfer for Windows TOPO®. The Kriging algorithm was used for grid interpolation.

Microgravity Survey Results

Based on the microgravity image provided within the Appendix, the results indicated that two primary clustered areas of concern (anomalies) exist, as referenced as Anomaly 1 and Anomaly 2. Anomaly 1 area is located within the general area of the existing foundations of townhouse units 525, 527, and 529. Whereas, Anomaly 2 is located within the backyards of the townhouse units (#521, 523, 525, and 527) and extending into the rear alley behind the backyards of the referenced units. Please refer to Figure 2 in the Appendix for the location of these referenced anomalies.

While further investigation is needed to further clarify the structural constituents of the microgravitational anomalies, based on the survey and the structural conditions of the residences relative to Anomaly 1, the foundations may have been influenced by a bedrock fracture(s). As within Karst topography areas, fractures are known to facilitate soils migrating further into the subsurface thus producing relatively weaker soils underneath the foundations of the residences in that location. It should also be noted that, bedrock fracture(s) may be influencing the illustrated gravitational lows within Anomaly 2. The carbonate rocks that underly the Site have undergone several compressional tectonic events throughout their history, each likely producing fractures

within the rocks that, under deleterious hydrogeologic conditions, have the potential to destabilize the soils above them, leading to surficial subsidence.

Ground Penetration Radar (GPR) Survey

As part of a relatively shallow subsurface exploration in areas between the data points, HCEA performed a GPR survey, within accessible areas, utilizing a NOGGIN™ SmartCart with a 250MHZ antenna, manufactured by Sensors and Software. The NOGGIN™ emits an electromagnetic pulse into the ground and records the "echoes" and then builds an image from the data collected. The GPR NOGGIN™ SmartCart allows the user to view in real time utilizing the Digital Video Logger (DVL) while conducting the field survey.

GPR testing is well suited to conduct surveys in mediums such as rock, dense soils, sand, and gravels; as the electromagnetic pulses can penetrate these media types to deeper depths. However, limitations of the equipment include, but are not limited to, surveying clayey and/or saturated soils; which tend to attenuate the electromagnetic pulses and significantly limit the depth of the survey. Also, surveying areas with excessive buried utilities or structural steel reinforcing, as these objects may obstruct the overall depth and image capabilities of the system.

This GPR survey was conducted utilizing the two-dimensional (2-D) survey method operating in the NOGGIN™ GPR system. The effective depth of the GPR survey ranged between approximately 6.0 and 8.0 $\pm$ feet below the current site elevations. The survey lines were field located and laid-out relative to the best fit scenario based on-site restrictions and geometry.

GPR scanning of the Site was performed with singular survey lines numbered 0 through 14. Line locations were chosen to gain a representative understanding of the subsurface conditions within the alleyway and yards of the N. 500 block. At some locations, saturated subsurface conditions resulted in increased signal attenuation, thus limiting the GPR resolution and effective depth of investigation. These scans provided 2-Dimensional graphs of the GPR echoes within the surveyed areas. Please refer to the attached GPR Line Survey Location in the Appendix (Figures 3-14) for the survey locations and resulting images.

Ground Penetrating Radar Results

Based upon the GPR data, at locations not covered by bituminous asphalt and/or concrete, approximately, the top two feet of the surface appears to consist of a "topsoil" horizon. Beneath this layer, a strong reflector is not generally observed until 5.5 to 6.5 feet below the existing site grades. This reflector may represent a change in subsurface materials. The materials represented between 2 and 5.5 to 6.5 feet produce a generally non-reflective GPR signature, suggesting a relatively homogenous composition of the materials. A possible interpretation is that the reflector at 5.5 to 6.5 feet represents the contact between fill material (above) placed at the time of primary construction of the residences and undisturbed/natural soil contact zone. Where the scans were performed in areas where concrete and bituminous asphalt were present, the scans indicated that these layers were approximately up to one foot in thickness. Multiple possible utility lines at varying depths are observed, particularly in the front of the residences.

Recommendations

When comparing the geophysical surveys relative to the existing structural distress present with the structures (units #525, 527, and 529), it is our opinion, that a subsurface geologic condition exists which appears to be facilitating structural disturbances to the aforementioned addresses as well as the surrounding areas. Consequently, these subsurface issues will need to be evaluated and remediated in order to mitigate the likelihood of further structural disturbances to those residences. Therefore, HCEA recommends that Anomalies 1 and 2, where accessible, be further evaluated by performing Standard Penetration testing at locations designated by our office.

The primary purpose for this additional exploration will be to ascertain the composition and relative competency of the deeper subsurface structure and to confirm the assumptions made within our report. Additionally, this additional work with further evaluate the remedial work options such as inverted rock filters in the yards, to collecting data for potential compaction grouting within the structures; as well as assessing potential associated costs and inherent risks associated with each option.

Remarks

This report has been prepared for the exclusive use of C.S. Davidson, Inc. and their representatives in accordance with generally accepted geotechnical engineering practice. No other warranty, either expressed or implied, is made.

The analyses and recommendations contained in this report are based on the data obtained from limited MG and GPR surveying at the data point locations discussed within this report. Additionally, should be noted that there may be undulations within the profiles that have been melded into the data reduction of the geophysical data and findings presented on the profiles shall be considered as an extrapolation of such data. They do not necessarily reflect strata variations that may exist between the data point locations.

Should you have any questions concerning this Summary, please do not hesitate to contact our office. We appreciate being the geotechnical consultant on this project.

Respectfully submitted,

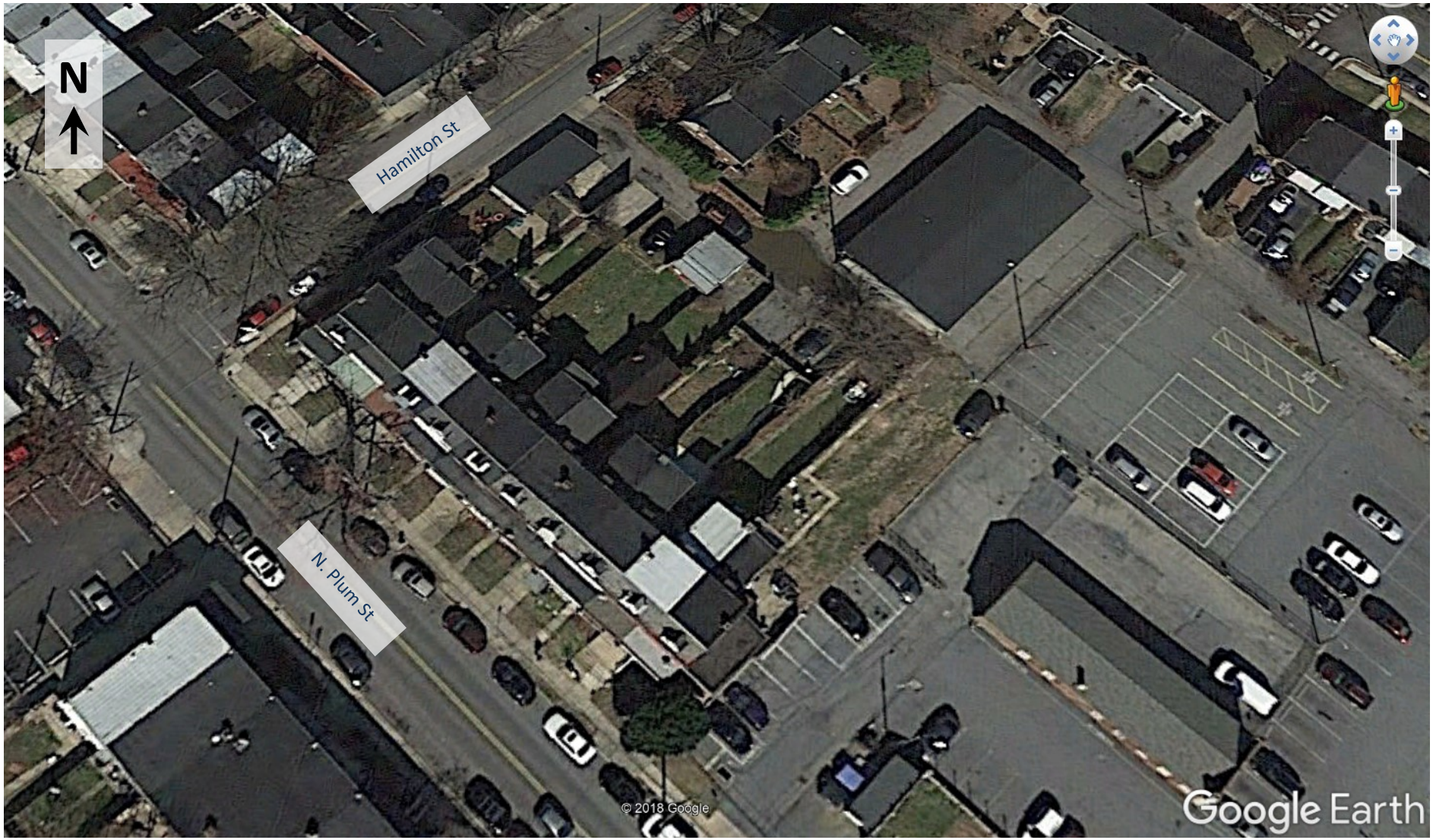
Hillis-Carnes Engineering Associates, Inc.

Samuel Michalak
Project Geologist

Cindy S. Shepeck
Branch Manager

Appendix

- **Site Location Plan (Figure 1)**
- **Microgravity Test Survey (Figure 2)**
- **GPR Test Results (Figures 3 to 15)**



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Site Location Plan

500 Block N. Plum St.

Lancaster, Pennsylvania

HCEA Project No.: HI9107

Figure - 1

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MICROGRAVITY TEST AREA

500 BLOCK N. PLUM ST.

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FIGURE - 2

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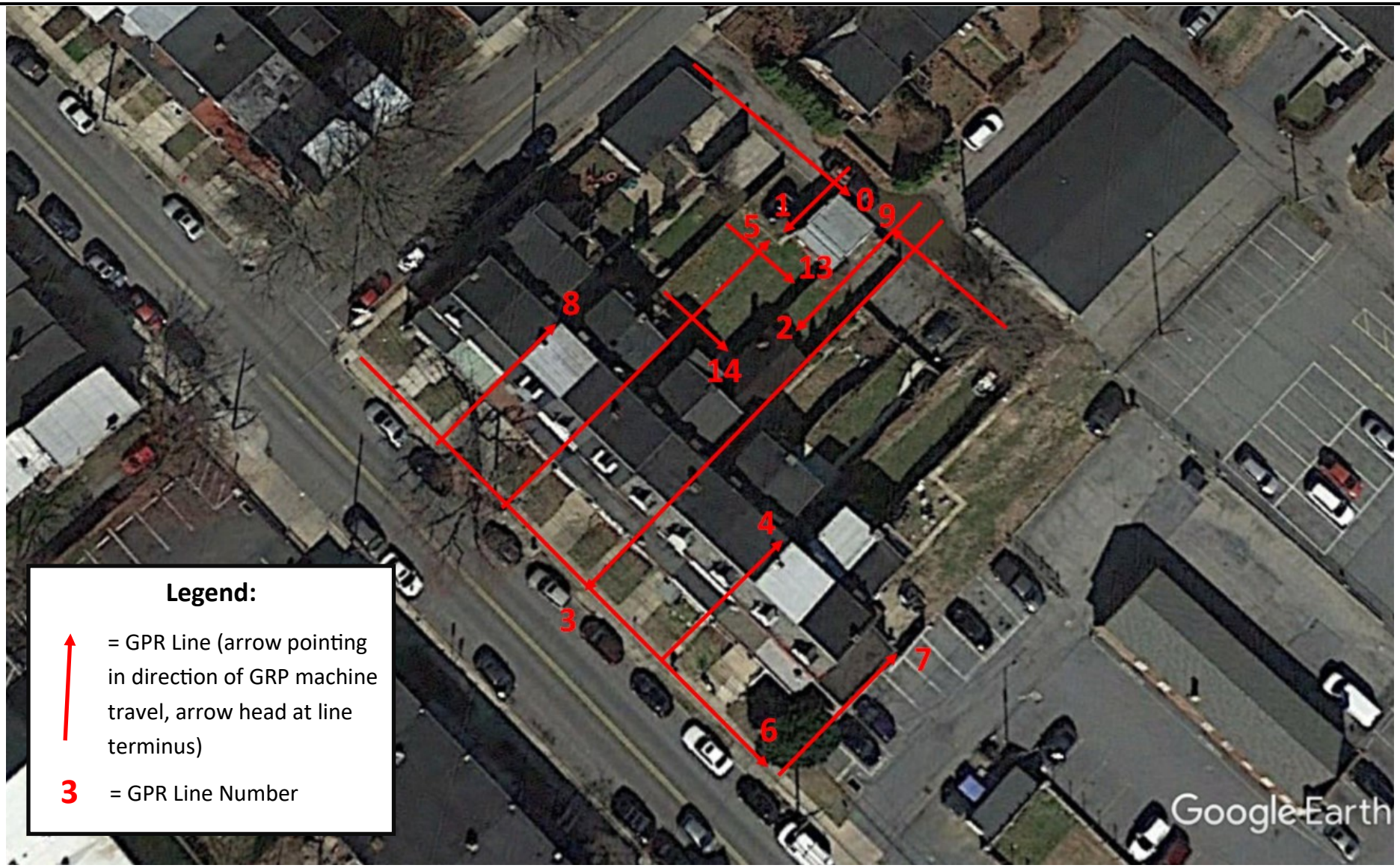

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GROUND PENETRATING RADAR TEST AREA

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FIGURE - 3

10228 Governor Lane Boulevard

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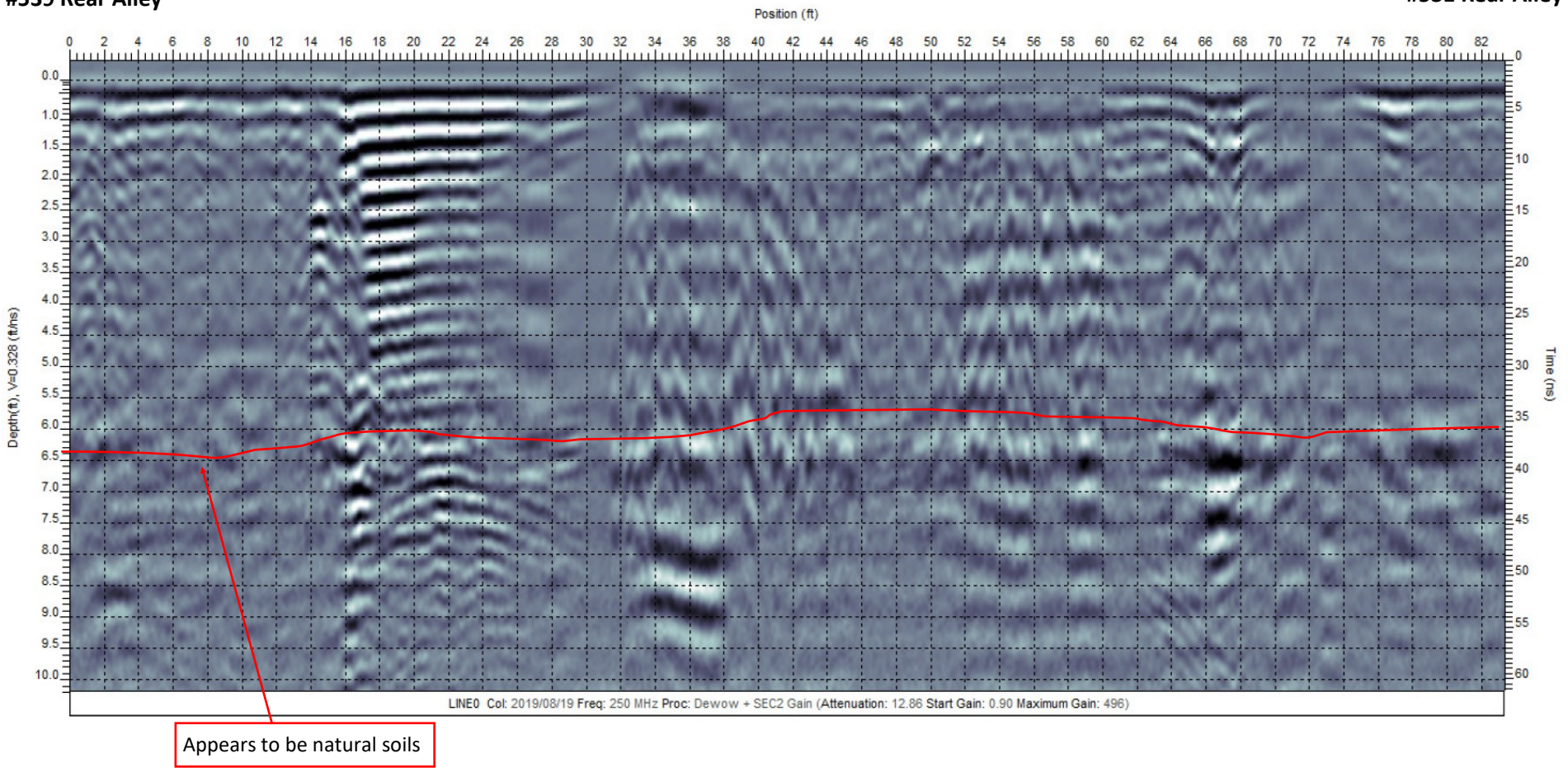
Survey Line 0

#539 Rear Alley

#531 Rear Alley



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GROUND PENETRATING RADAR TEST LINES

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FIGURE - 4

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Survey Line 1

#533 Rear Alley

#533 Parking

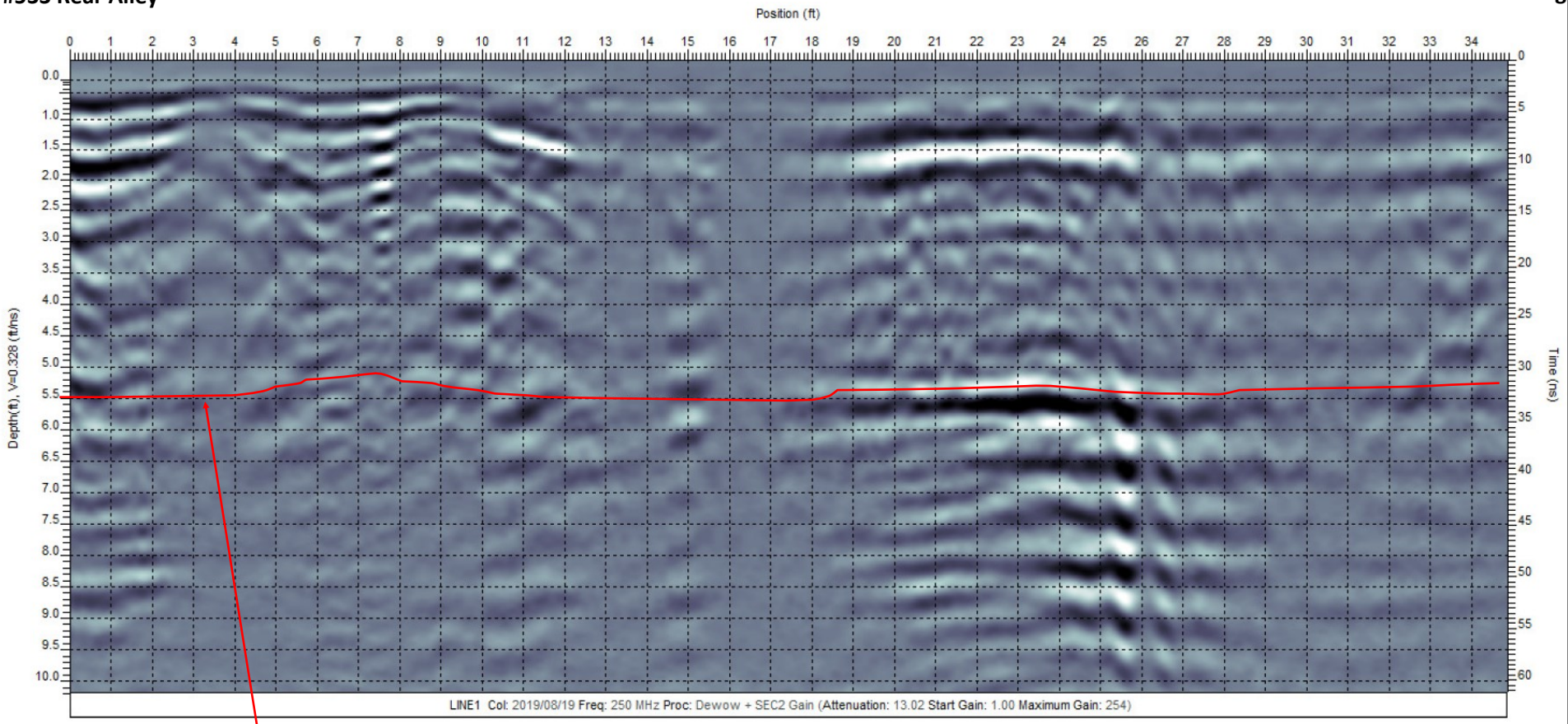

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FIGURE - 5

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Survey Line 2

#529 Rear Alley

#529 Rear Yard

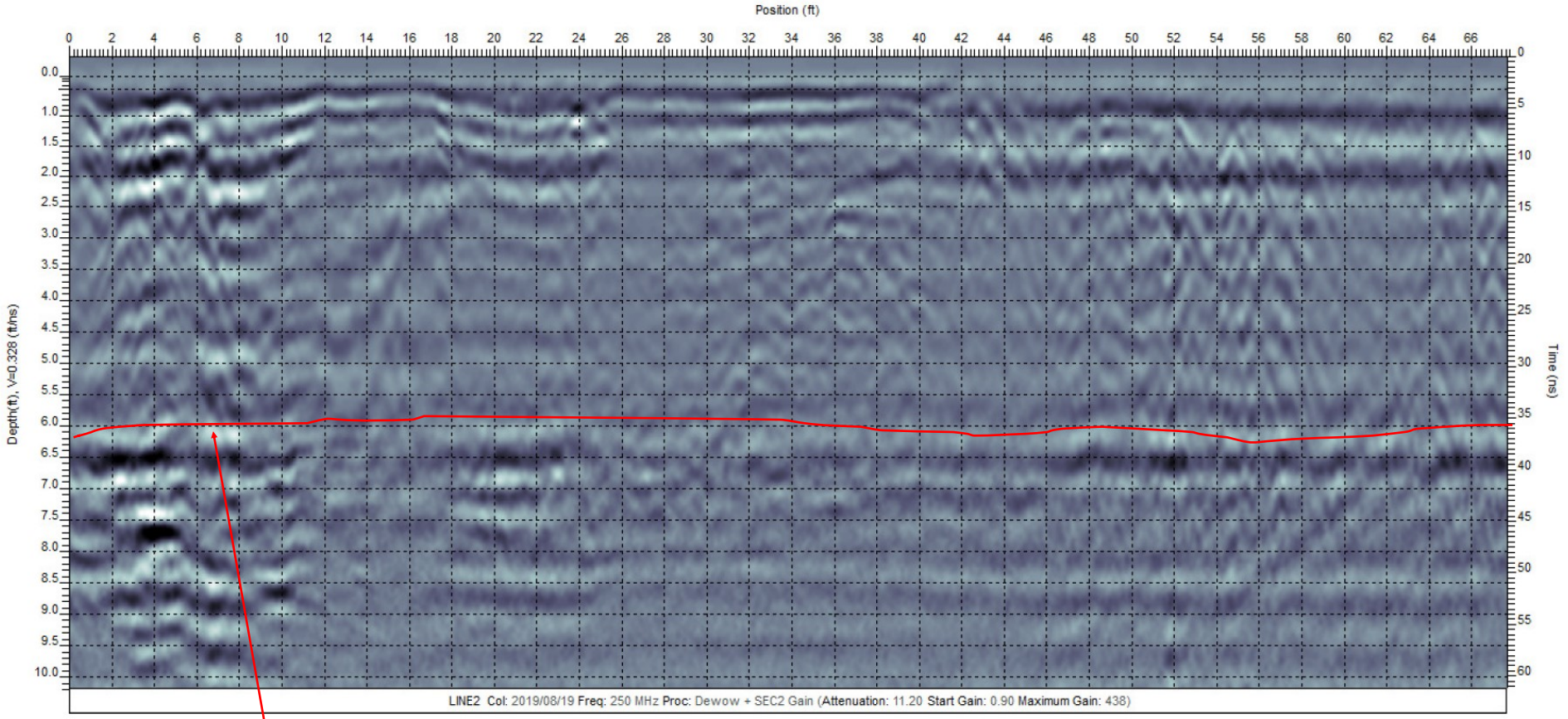

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FIGURE - 6

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Survey Line 3

#527-529 Rear Alley **#527-529 Front Sidewalk**

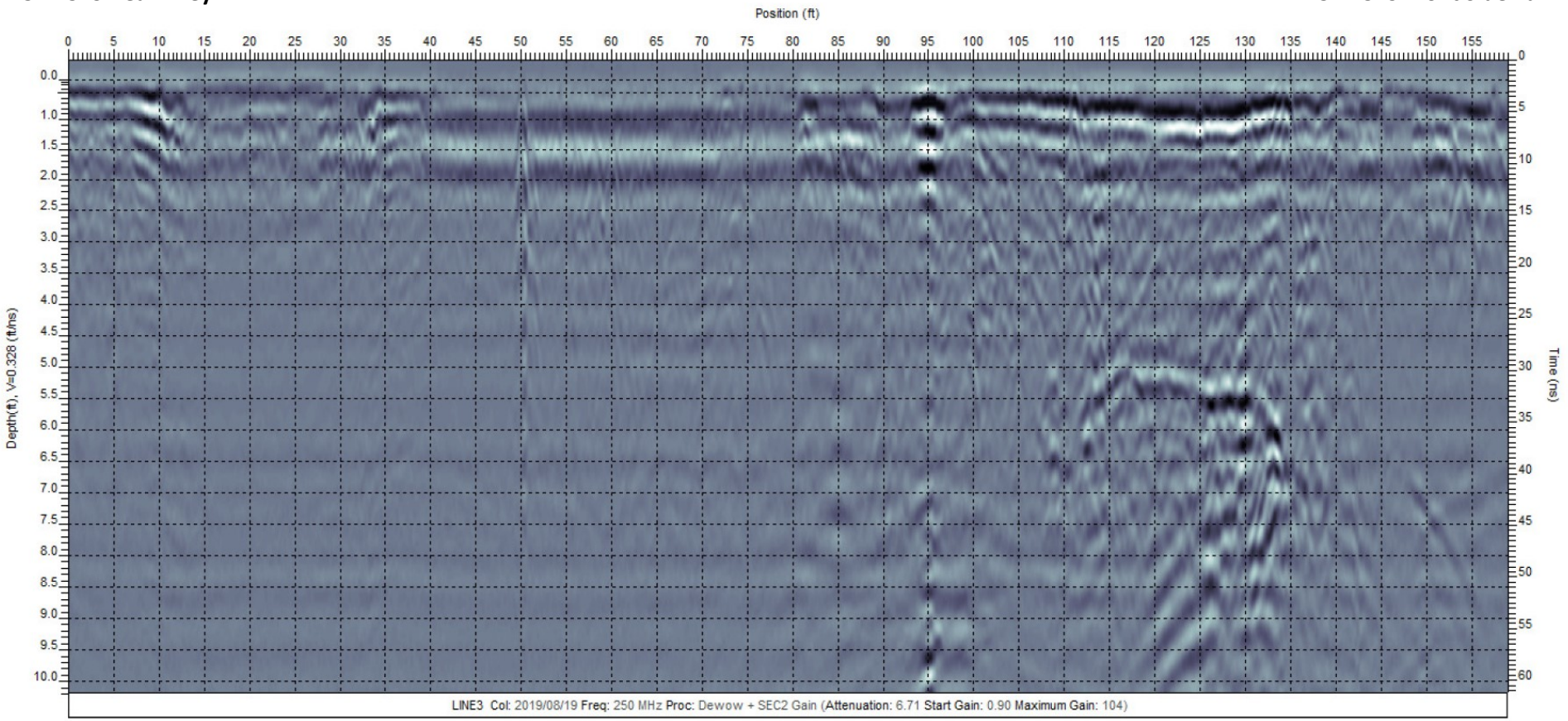

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FIGURE - 7

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Survey Line 4

#523-525 Front Sidewalk

#523-525 Rear Yard

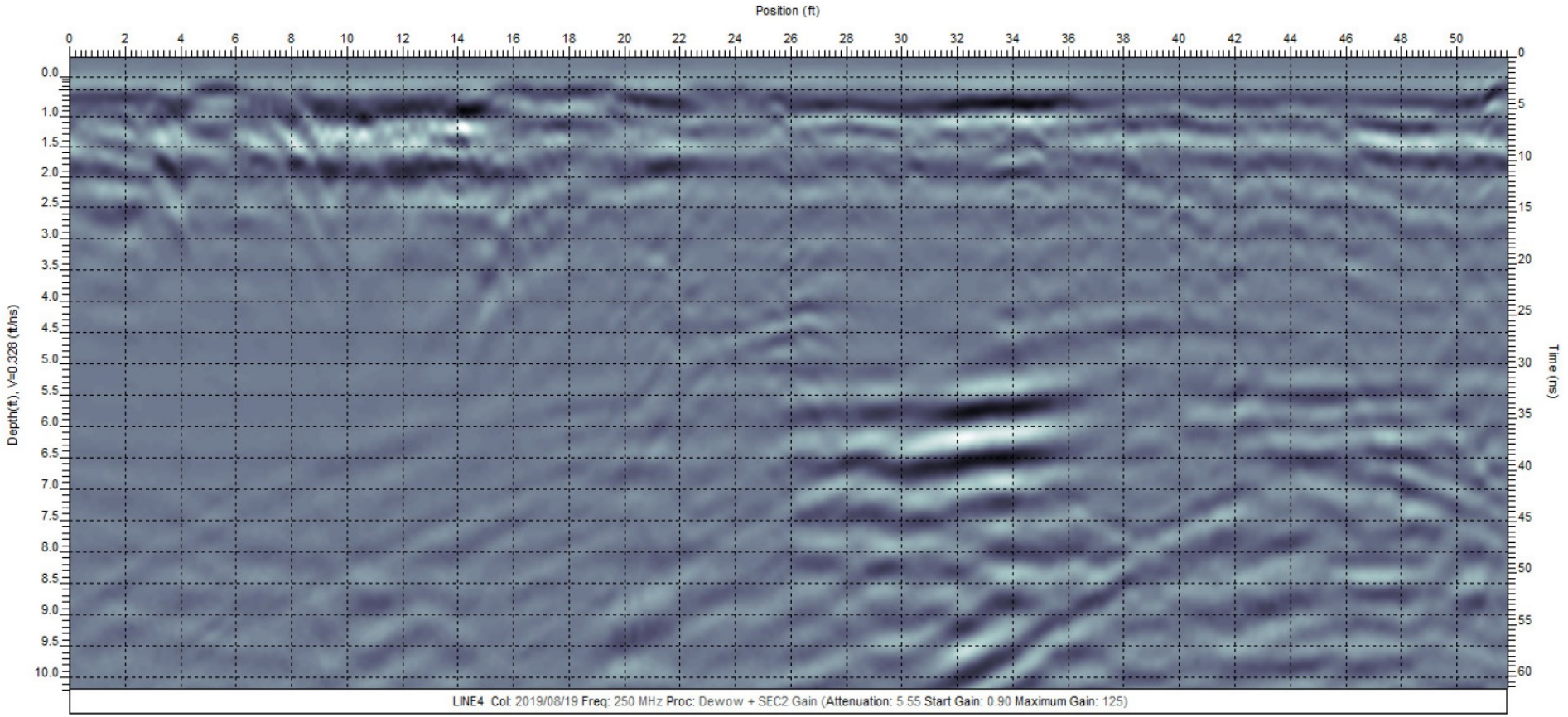

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FIGURE - 8

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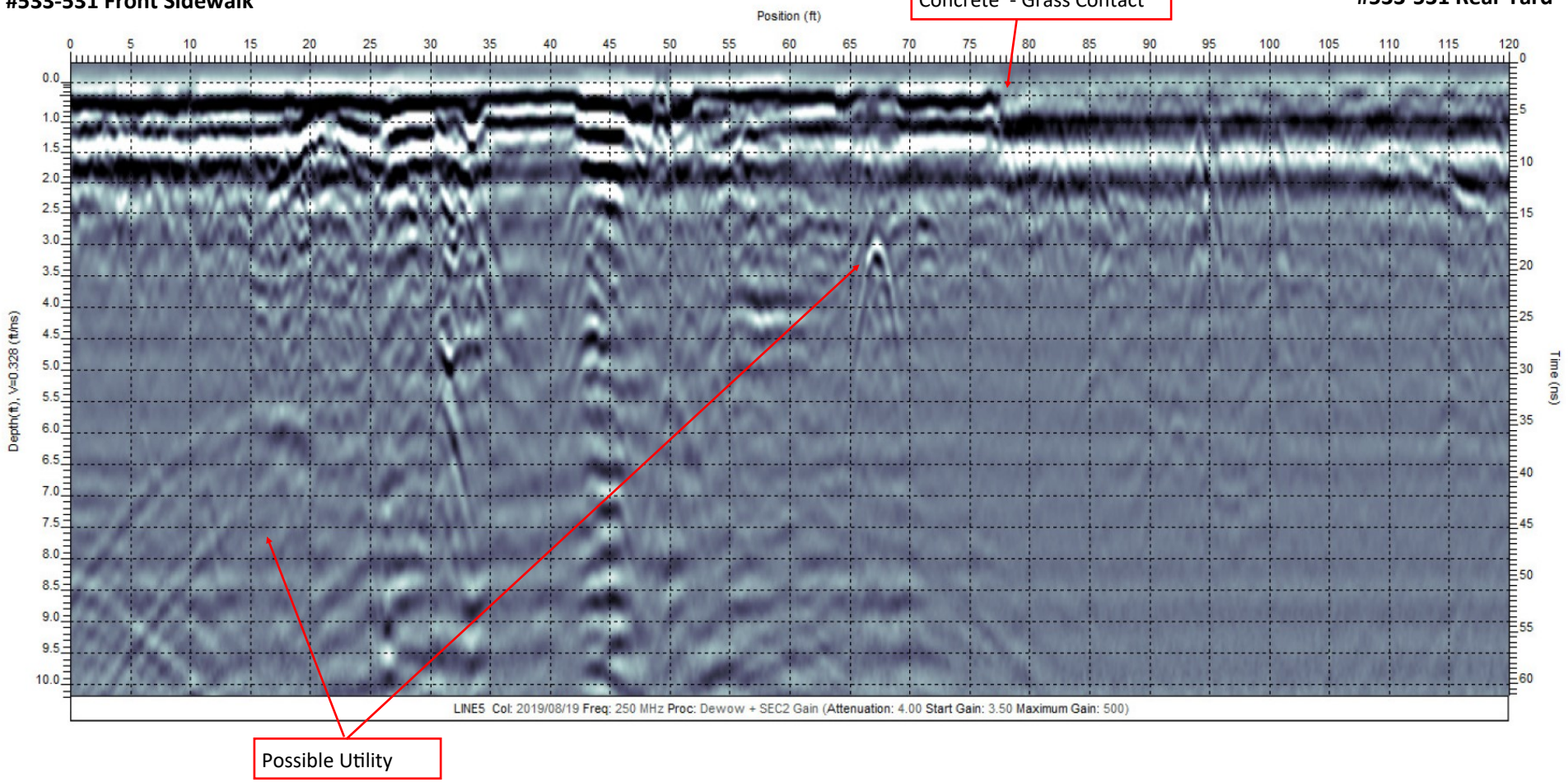
Survey Line 5

#533-531 Front Sidewalk

#533-531 Rear Yard



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GROUND PENETRATING RADAR TEST LINES

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FIGURE - 9

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Survey Line 6

#539 Front Sidewalk

#521 Front Sidewalk

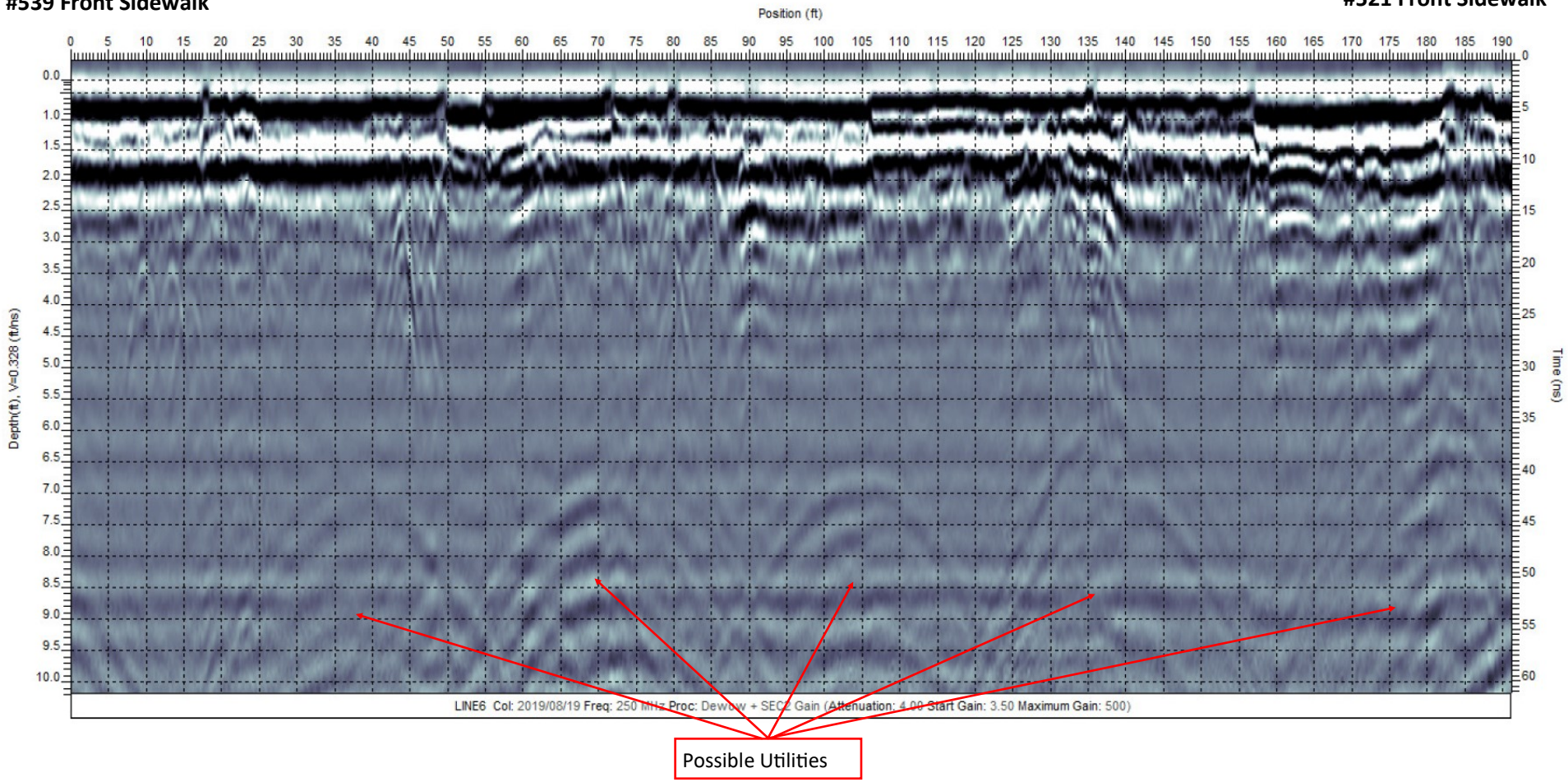

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FIGURE - 10

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Survey Line 7

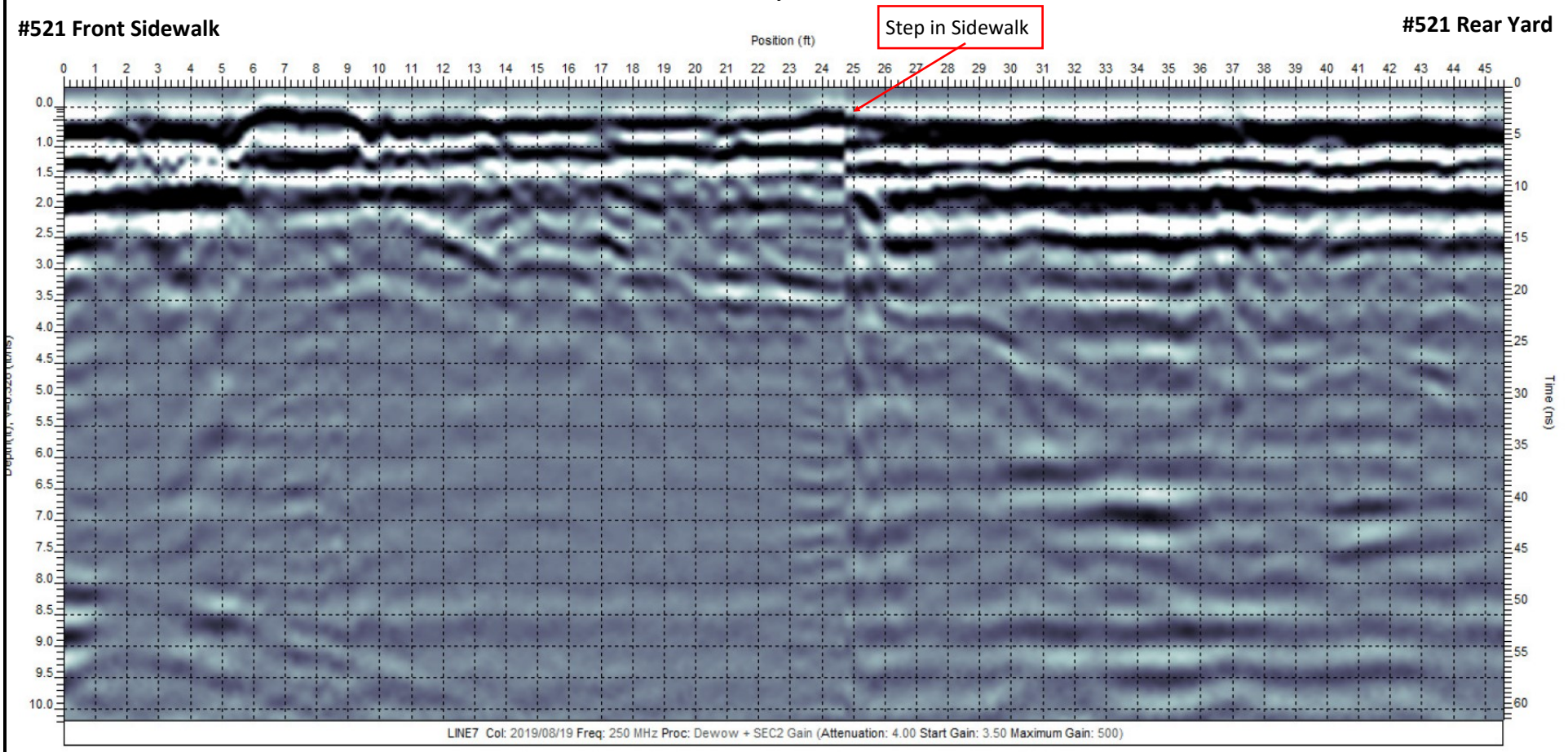

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FIGURE - 11

10228 Governor Lane Boulevard

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Survey Line 8

#537-535 Front Sidewalk

#537-535 Rear Yard

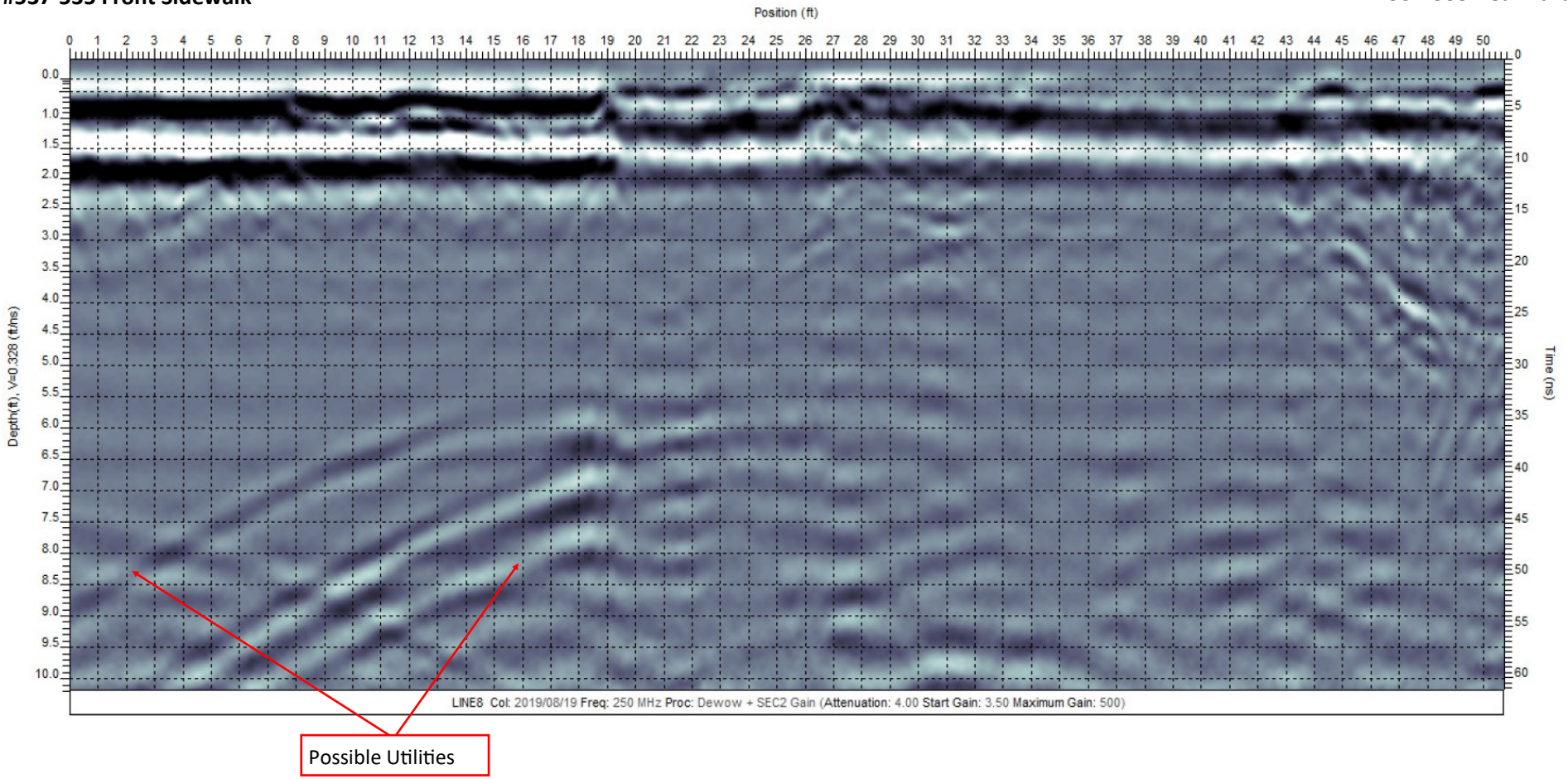

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FIGURE - 12

10228 Governor Lane Boulevard

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Survey Line 9

#523 Rear Alley

#529 Rear Alley

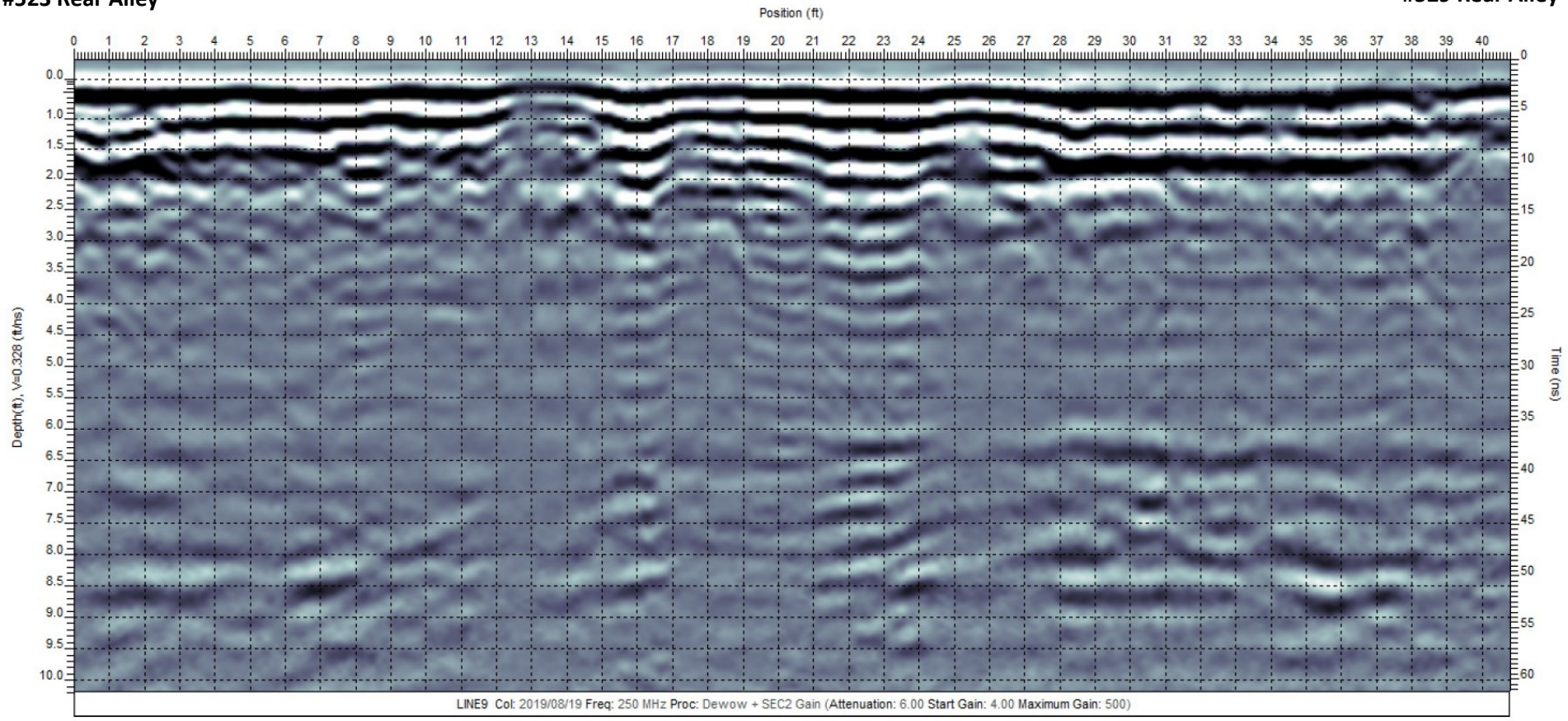

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FIGURE - 13

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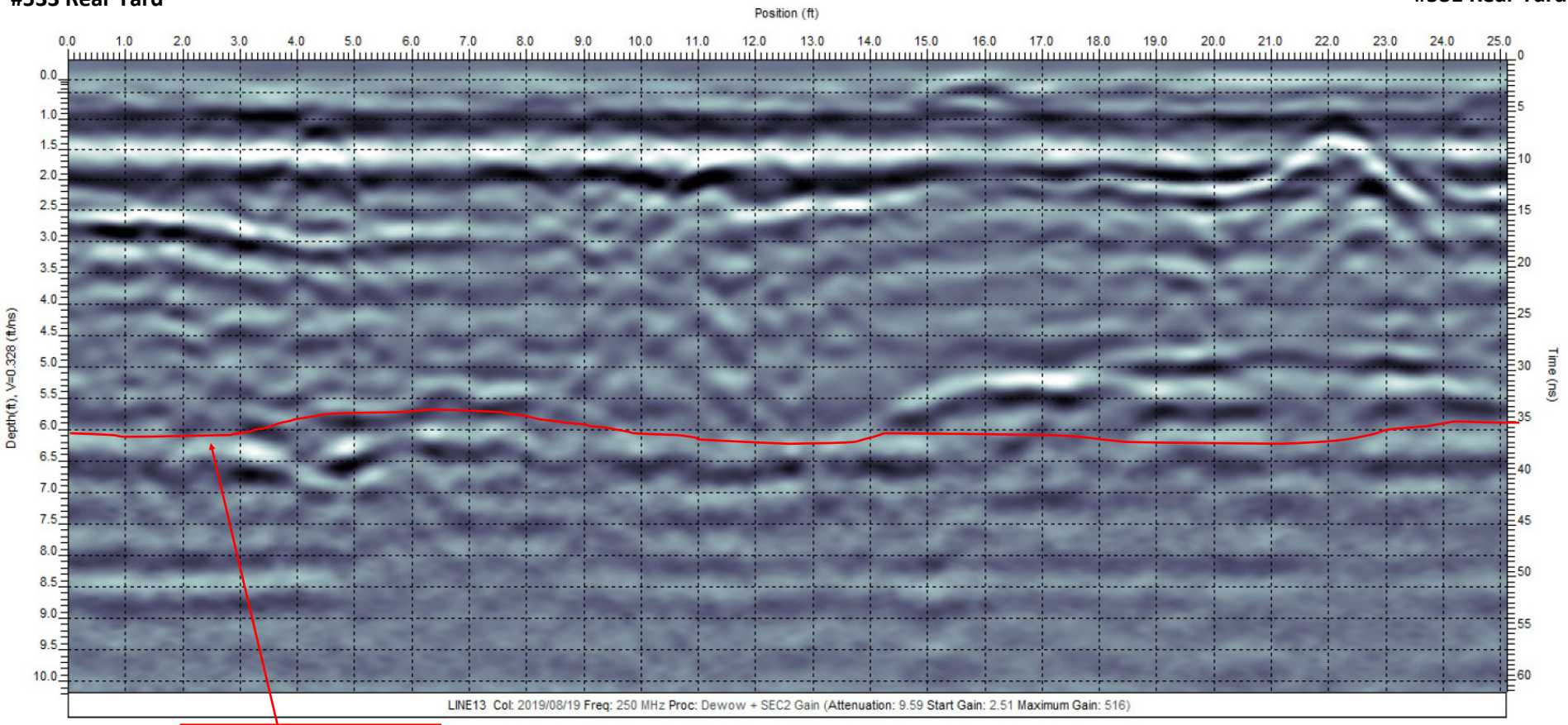
Survey Line 13

#533 Rear Yard

#531 Rear Yard



Appears to be natural soils

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FIGURE - 14

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Survey Line 14

#533 Rear Yard

#531 Rear Yard

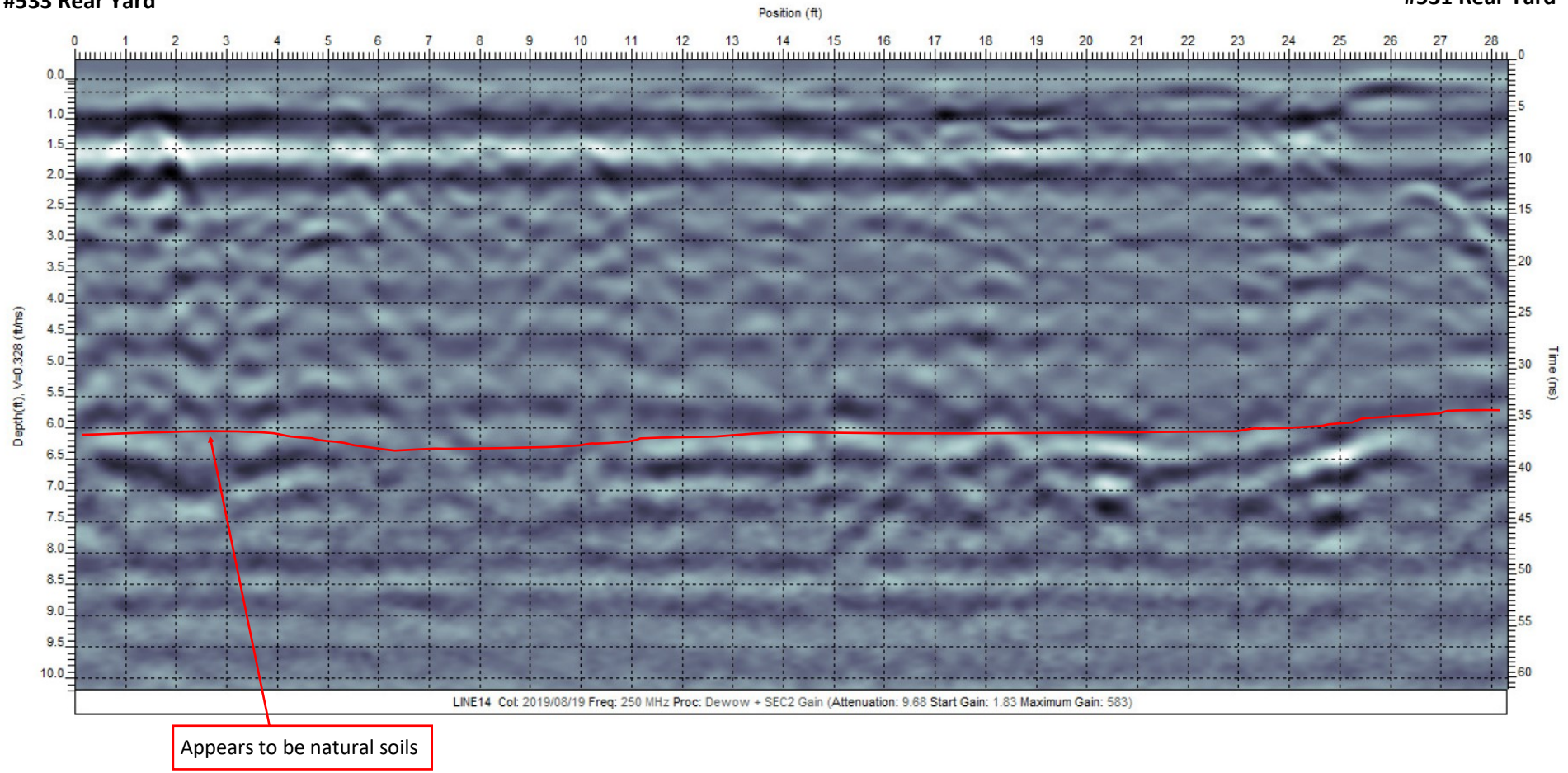

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FIGURE - 15

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