Geophysical Survey
Proposed Barn, Cottages, Driveway, and Septic Field
14558 Chapel Lane
Leesburg, Virginia

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19th April 2021

FES Project No. 21144

Table of Contents

List of Figures

List of Appendices

1.0 Introduction

Forrest Environmental Services, Inc. (FES) performed a geophysical survey for the proposed barn, six cottages, driveway, and septic field located on 14558 Chapel Lane in Leesburg, Virginia on the 8th January 2021 and 16th April 2021 (Figure 1). The survey consisted of an electric resistivity (ER) survey to locate potential voids and caverns that may develop into sinkholes.

Eight ER lines were conducted at the proposed barn, cottages, driveway, and septic field. The ER survey covered approximately an area of 3,000 linear feet and approximately 7,700 soundings were collected for a total of eight ER lines. The electrode spacing (dipole size) was 3-meter (10 feet) and used 35 to 70 electrodes. The ER total distance of the ER lines was approximately 335 feet to 700 feet during data collection. FES placed marked wooded stakes with orange ribbon at each end of the ER lines within the property.

The site is located the western Piedmont physiographic province of Virginia. The western Piedmont Province bedrock is predominantly Triassic and Jurassic strata within the Mesozoic Culpeper basin that are in contact with the eastern limb of the Blue Ridge anticlinorium along a major normal fault. Sedimentary and igneous rocks of the Culpeper basin accumulated during Mesozoic continental rifting that resulted in the opening of the Atlantic Ocean.

The site is geology consists of the Leesburg Limestone of the Triassic Newark Super Group. The Leesburg Limestone conglomerate intertongues with the sandstone and siltstone of the other members and forms a complex map pattern. The Leesburg Member is a carbonate conglomerate composed of subangular to subrounded boulders, cobbles, and pebbles of limestone and dolomite in a reddish-brown sandy siltstone matrix. Large, isolated outcrops are well exposed along the Route 15 corridor north of Leesburg. The source of the carbonate clasts includes the limestone and dolomite of the Tomstown Formation and Frederick Limestone that are presently restricted to Furnace Mountain and north of the Potomac River in Frederick County, Maryland. The conglomerate is interpreted to be debris-flow deposits on alluvial fans.

The Loudoun County online mapping system indicates no sinkholes are located within 1,000 from the barn, cottages, driveway, and septic field. No limestone bedrock outcrops/float or sinkholes were observed in field during the geophysical survey within the survey area. The closest water body is a stream located approximately 500 feet southwest of the barn, cottages, driveway, and septic field. The closest geologic feature is a fault located approximately 500 feet south of the proposed barn, cottages, driveway, and septic field. These features appear not to influence the proposed barn, cottages, driveway, and septic field.

Topographically, the site slopes downhill mostly to the east. The site generally consisted a grassed yard. Survey locations and physical features are shown in Figure 2.

Details of the geophysical survey are described in the following sections.

Photo 1 - ER Line 5

2.0 Equipment and Procedures

The geophysical survey instrument used during this survey was an earth resistivity meter that maps the resistivity changes in the earth. Resistivity is a fundamental parameter of the material that describes how easily the material can transmit electrical current. High values of resistivity imply that the material is very resistant to the flow of electricity, and low values of resistivity imply that the material transmits electrical current very easily.

The primary factors affecting the resistivity of earth materials are porosity, water saturation, clay content, and ionic strength of the pore water. The minerals making up soil and rock generally do not readily conduct electric current. Most of the current flow takes place through the material's pore water in which the resistivity decreases with increasing porosity and water saturation. Clay minerals are conductive because of the availability of free ions in the sheet structure of the clay particles in which resistivity decreases with increasing clay content. Similarly, higher salinity in groundwater makes the water more conductive to electrical current and resistivity decreases. Hard competent bedrock, such as limestone or granite, generally has a high resistivity in the absence of fracture or other permeable features.

The geophysical survey instrument used during this survey was a Sting R8 earth resistivity meter (Sting) connected to a Swift automatic electrode system (Swift). The Sting measures the electrical resistivity of the earth and the Swift automates the resistivity measurement process using the multi-electrode system.

The Swift was connected to the Sting and SMART electrodes to optimize survey efficiency by gathering maximum information with a minimum of electrodes. Each SMART electrode is numbered by a computer chip located within the electrode. The Swift selects which electrodes to employ as the current and receiver. For example for this ER survey, the first sounding uses electrodes 1 and 2 as the transmitter and electrodes 3 and 4 as the receiver. The next sounding uses electrodes 2 and 3 as the transmitter and electrodes 4 and 5 as the receiver. The Swift also uses redundancies in the data set to reduce the effects of lateral heterogeneities in the earth and to calculate uncertainties in the data. The survey was conducted automatically using the Sting/Swift dipole-dipole array system.

The earth resistivity meter works by introducing a measured current into the earth through two electrodes; the resultant voltage is then measured across two different electrodes. At the low currents used, the voltage is proportional to the current. The resistivity meter calculates the voltage/current ratio or resistance in ohms. The resistance is then converted to resistivity using an algorithm which is a function of the electrode array configuration. Measured differences in the electrical resistivity of various earth materials are then used to map the geology and character of the soil and rock materials. For example, clays generally have low resistivities and limestones have high resistivities.

A contact resistance test was conducted before the Sting/Swift dipole-dipole survey commenced. The contact resistance test ensures the stake has good contact with the ground. The Sting produces a current between the first two stakes and measures the voltage. The instrument measures the resistance between the first and second stakes and the ground. The contact resistance is also checked for the measurements consistent for all of the 35 to 70 electrodes.

The Swift cable resistance checks the voltage difference signal between two electrodes. Four leads of the Swift cable using two electrodes send a current through a 1 ohm resistor in the Swift box. The test is checked before the first ER survey and after the last ER line for each day.

The Swift switch relays test is performed to check the Swift cable is continuous and the relays in the electrodes are working properly. A current is sent through each lead in the Swift cable to make sure the relays are functioning properly and there is no leakage between leads, and to test the relays for sticking. The test is checked before the first ER survey and after the last ER line for each day.

The depth of investigation by Sting is a function of the total distance of the electrode layout and was from 335 feet to 700 feet for the eight ER lines. The Sting has an effective analysis depth of approximately 60 feet to 140 feet to using a 3-meter electrode spacing. This depth is considered sufficient to locate voids and caverns that may develop into sinkholes at the 14558 Chapel Lane site.

3.0 Interpretation Methods

The ER data was converted into a resistivity depth model using Rapid 2D resistivity inversion model and the least-squares method (RES2DINV). Soundings from each line were modeled to produce the measured apparent resistivity pseudo-sections. The model calculated the apparent resistivity pseudo-sections using finite-difference forward modeling. The least-squares optimization technique was used for the inversion routine that calculated the modeled resistivity section. The profiles include cross-sections that consist of the inverse model resistivity cross-section. The horizontal and vertical scales are in feet.

The cross-section is the inverse model resistivity pseudo-section. The ER data was converted into a resistivity depth model (RES2DINV) using a resistivity inversion model by the least-squares method and is topographically corrected. The ground surface elevations were determined by interpolating between contours from a USGS topography quadrangle. RES2DINV confirms the model reliability by calculating the modeled data into empirical data or the calculated resistivity pseudo-section. The difference between the measured and calculated data is the root mean square percent error. The modeled calculated mean root square error averaged approximately 10 rms error which is considered accurate.

Low resistive materials can be caused by certain conductive soils such as clay. High resistive materials are caused generally by bedrock, sand, wood, and air. Low ER values represent the thickening overburden. Lower ER anomalies are generally found at saturated or semi-saturated sinkholes, or fractures in the rock.

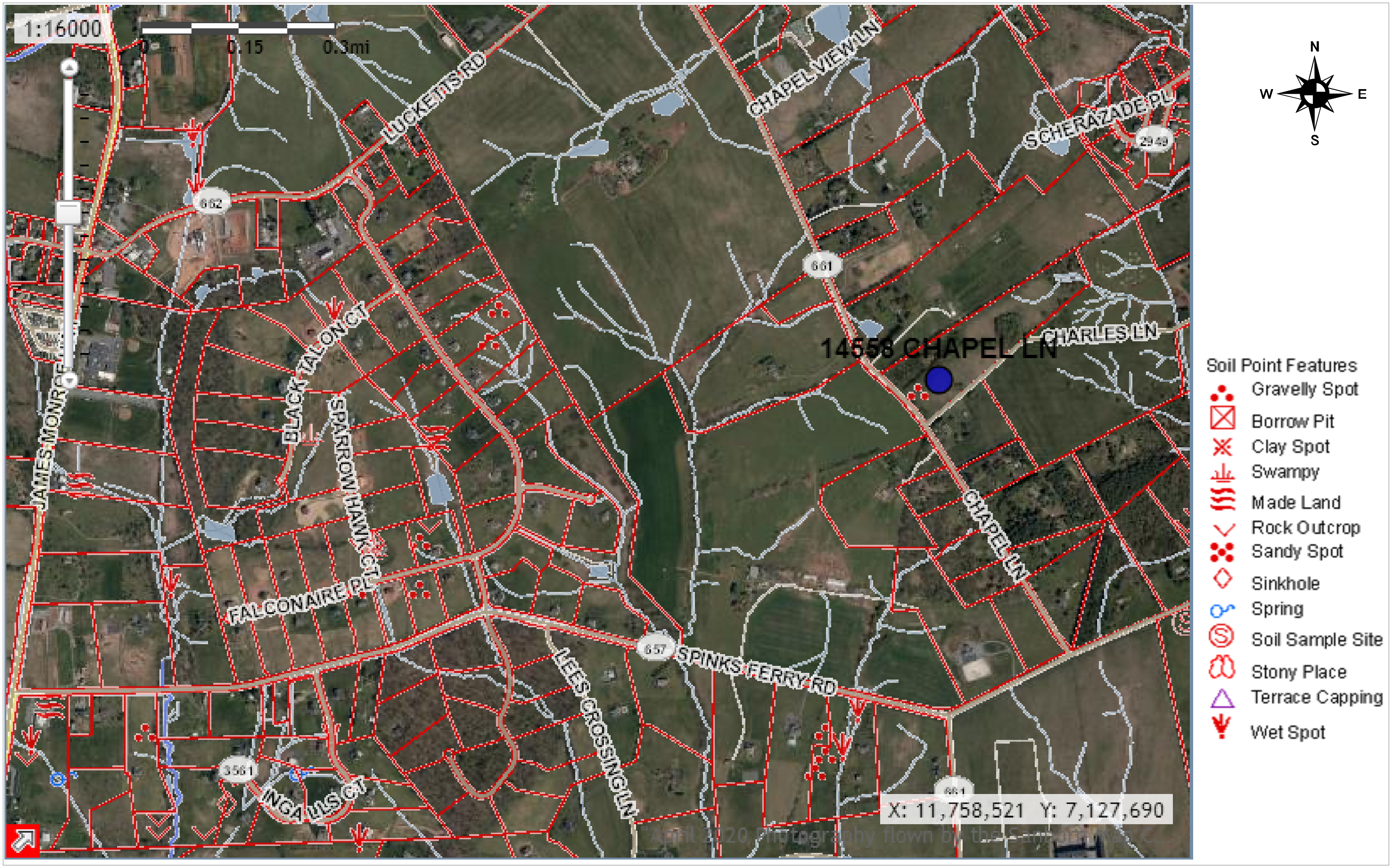
Typical resistivities of the overburden (clay) are 100 ohm meters (blue). Limestone resistivities typically range from 500 (green) to 5,000 (red) ohm meters. The siltstone resistivity resistivities typically range from 100 (blue) to 500 (green) ohm meters. Saturated zone void resistivities typically measure approximately less than 50 ohm meters (dark blue), and less dense or soft zone areas that can cause lower blow counts during split-spoon sampling typically measure approximately 1,000 ohm meters (yellow). Air-filled voids typically measure greater than 3,500 ohm meters (red).

4.0 Survey Results

The objective of the ER survey was to locate suspected voids and caverns that may develop into sinkholes. ER cross-sections are provided in Appendix A. The horizontal scale is in feet. The vertical scale is in feet above sea level. The ER survey at the proposed patio and pool indicates the geology from the subsurface resistivity are within the Balls Bluff Siltstone.

ER lines 1 through 8 indicated depth to limestone is approximately 60 feet to 70 feet below ground surface. The geophysical survey indicated no karst features within the survey area.

FES does not recommend a geotechnical report because the geophysical survey indicated no karst features within the proposed barn, cottages, driveway, and septic field. The geophysical survey indicated no groundwater-threatening karst-related structures beneath the proposed barn, cottages, driveway, and septic field and has an insignificant risk in collapse or groundwater contamination.



Forrest Environmental Services, Inc. Oak Hill, Virginia (703) 648-9090 www.fesinc.net	DATE January 2021	SCALE shown	TITLE ***Geophysical Anomaly Map Proposed Barn, Cottages, and Driveway 14558 Chapel Lane Leesburg, Virginia***
	DRAWN BY	APPROVED BY	
	JOB NO. 20241	DWG. NO./ REV. NO. S14558F2	CLIENT Soles — FIGURE 1

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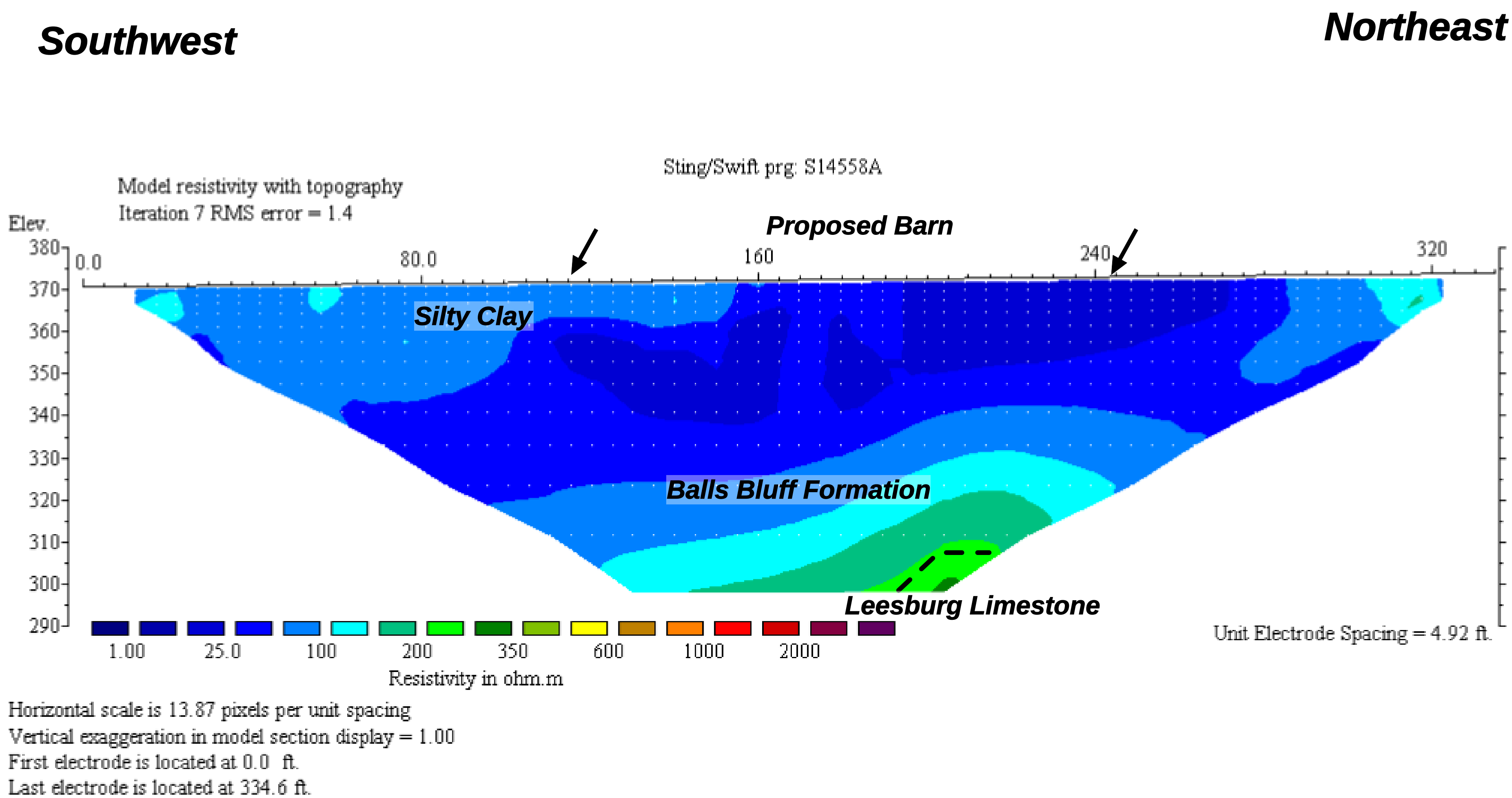
www.fesinc.net

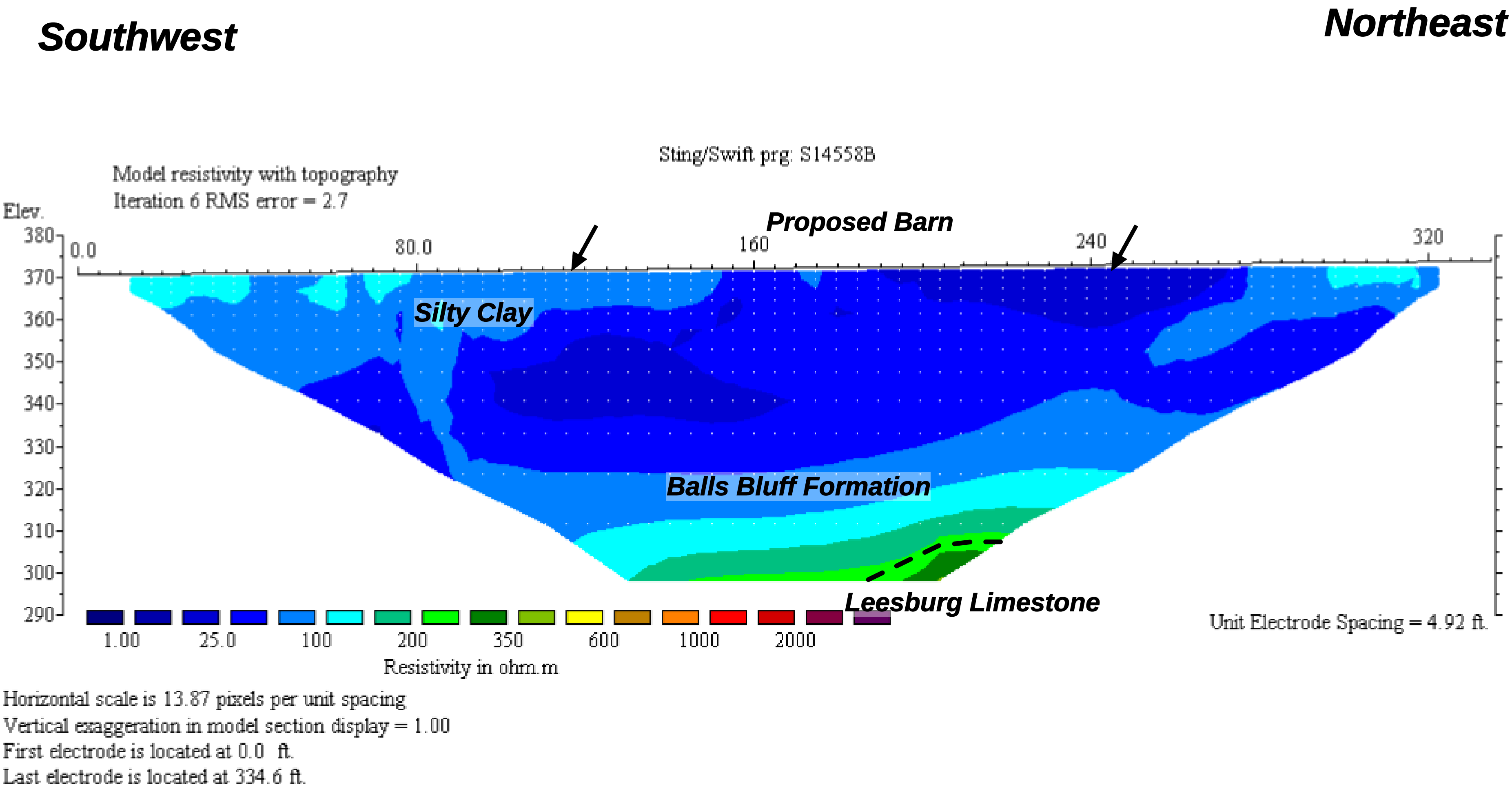
DATE April 2021	SCALE 1 inch ~ 200 ft	TITLE	**Geophysical Site Map** **Proposed Barn, Cottages, Driveway, and Septic Field** **14558 Chapel Lane** **Leesburg, Virginia**
DRAWN BY	APPROVED BY		
JOB NO. 21144	DWG. NO./ REV. NO. S14558F2	CLIENT Soles	FIGURE 2

Appendix A

ER Cross-Sections
1 through 8



Forrest Environmental Services, Inc. Oak Hill, Virginia (703) 648-9090 www.fesinc.net	DATE January 2021	SCALE shown	TITLE **ER Line 1 Proposed Barn, Cottages, and Driveway 14558 Chapel Lane Leesburg, Virginia**	
	DRAWN BY	APPROVED BY		
	JOB NO. 20241	DWG. NO./ REV. NO. S14558-1	CLIENT Soles	FIGURE



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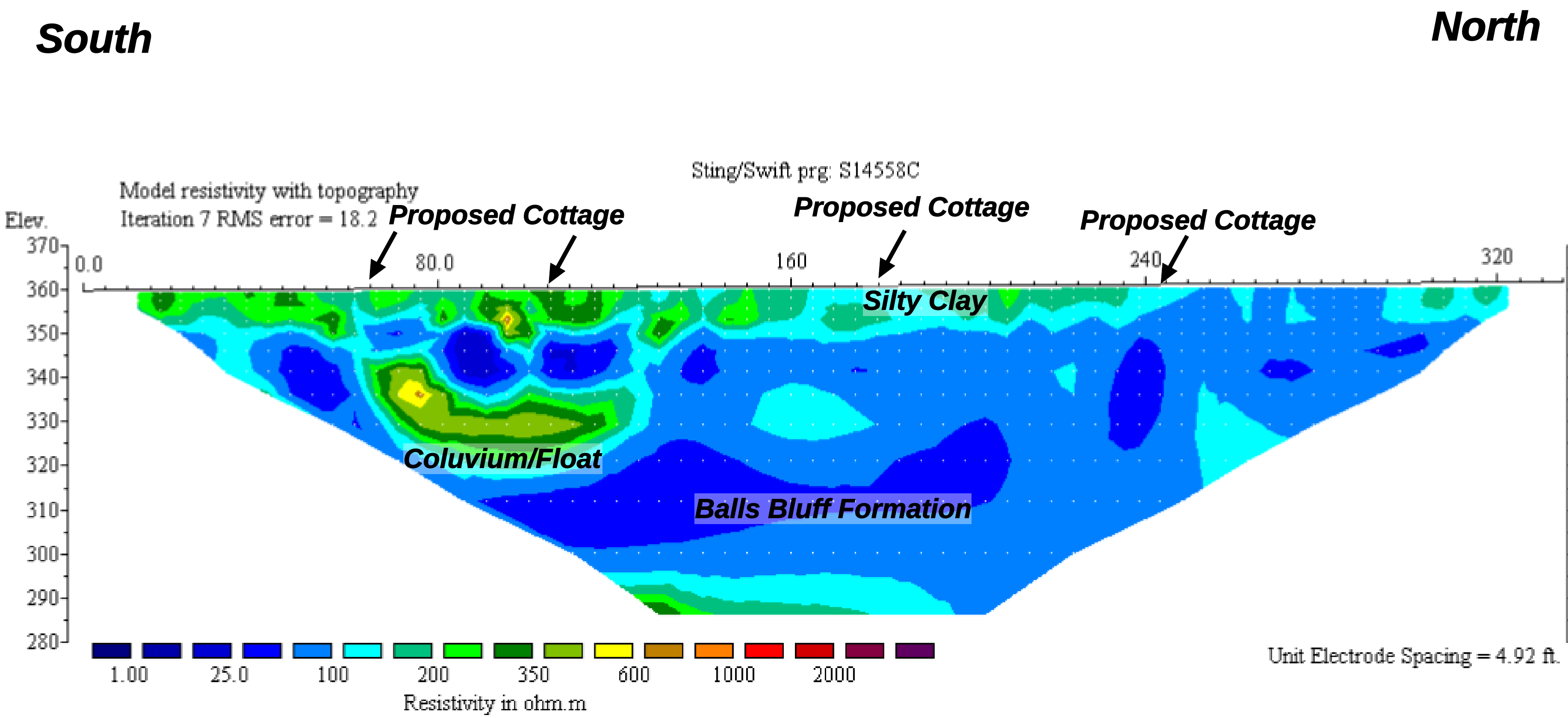
DATE January 2021	SCALE shown	TITLE ***ER Line 2 / Proposed Barn, Cottages, and Driveway / 14558 Chapel Lane / Leesburg, Virginia***	
DRAWN BY	APPROVED BY		
JOB NO. 20241	DWG. NO./REV. NO. S14558-2	CLIENT Soles	FIGURE



Horizontal scale is 13.87 pixels per unit spacing
Vertical exaggeration in model section display = 1.00
First electrode is located at 0.0 ft.
Last electrode is located at 334.6 ft.

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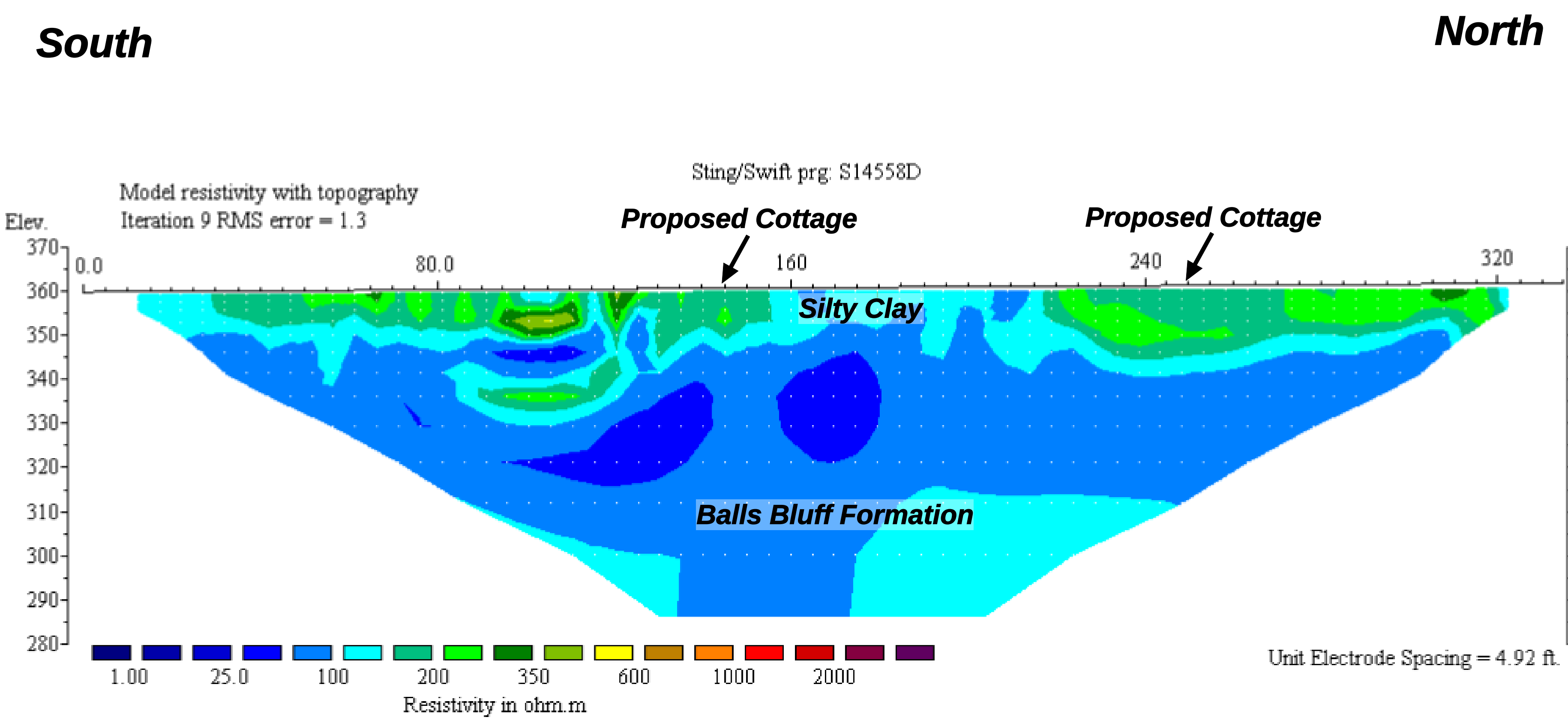
DATE	SCALE	TITLE
January 2021	shown	***ER Line 3*** ***Proposed Barn, Cottages, and Driveway*** ***14558 Chapel Lane*** ***Leesburg, Virginia***
DRAWN BY	APPROVED BY	
JOB NO. 20241	DWG. NO./ REV. NO. S14558-3	CLIENT Soles — FIGURE



Horizontal scale is 13.87 pixels per unit spacing
Vertical exaggeration in model section display = 1.00
First electrode is located at 0.0 ft.
Last electrode is located at 334.6 ft.

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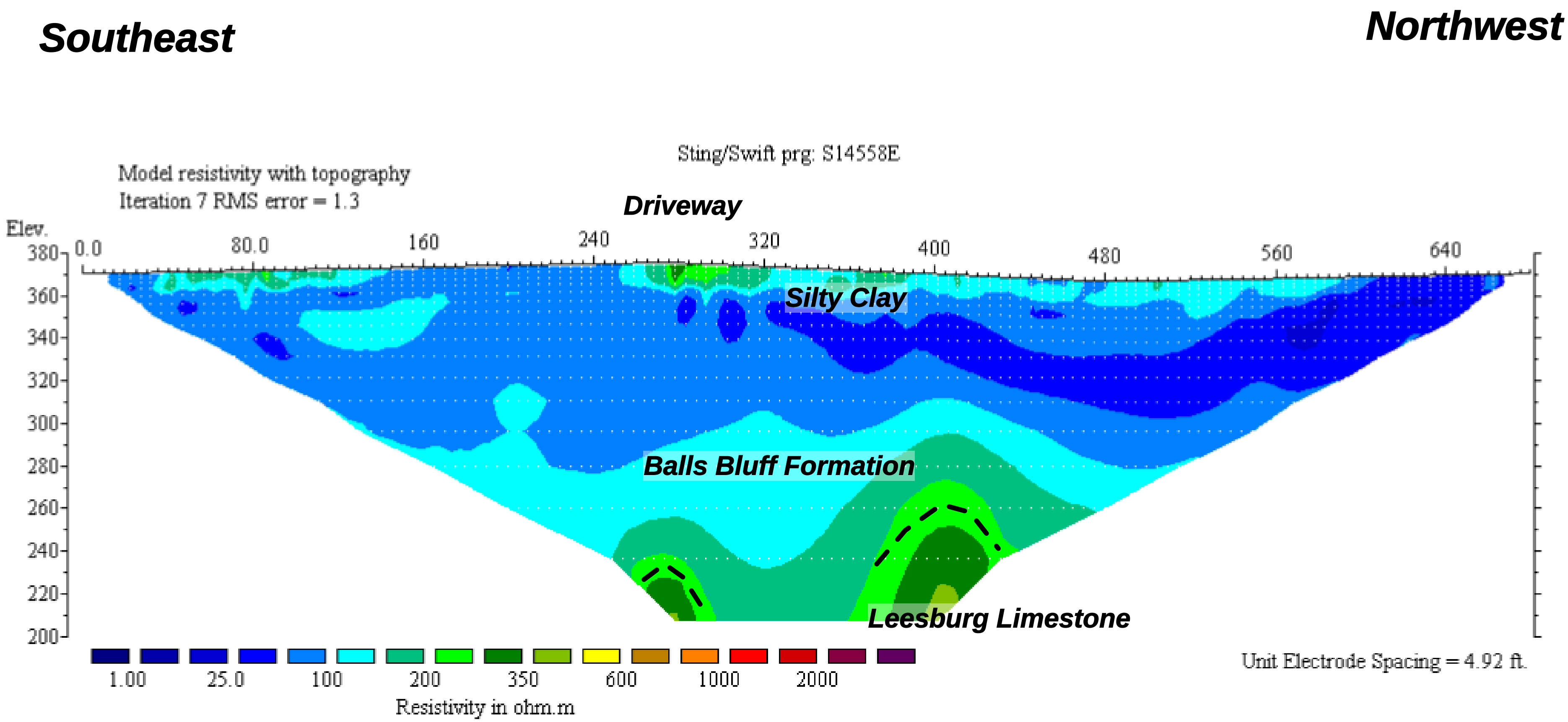
DATE January 2021	SCALE shown	TITLE ***ER Line 4 Proposed Barn, Cottages, and Driveway 14558 Chapel Lane Leesburg, Virginia***	
DRAWN BY	APPROVED BY		
JOB NO. 20241	DWG. NO./ REV. NO. S14558-4	CLIENT Soles	FIGURE



Horizontal scale is 6.83 pixels per unit spacing
Vertical exaggeration in model section display = 1.00
First electrode is located at 0.0 ft.
Last electrode is located at 679.1 ft.

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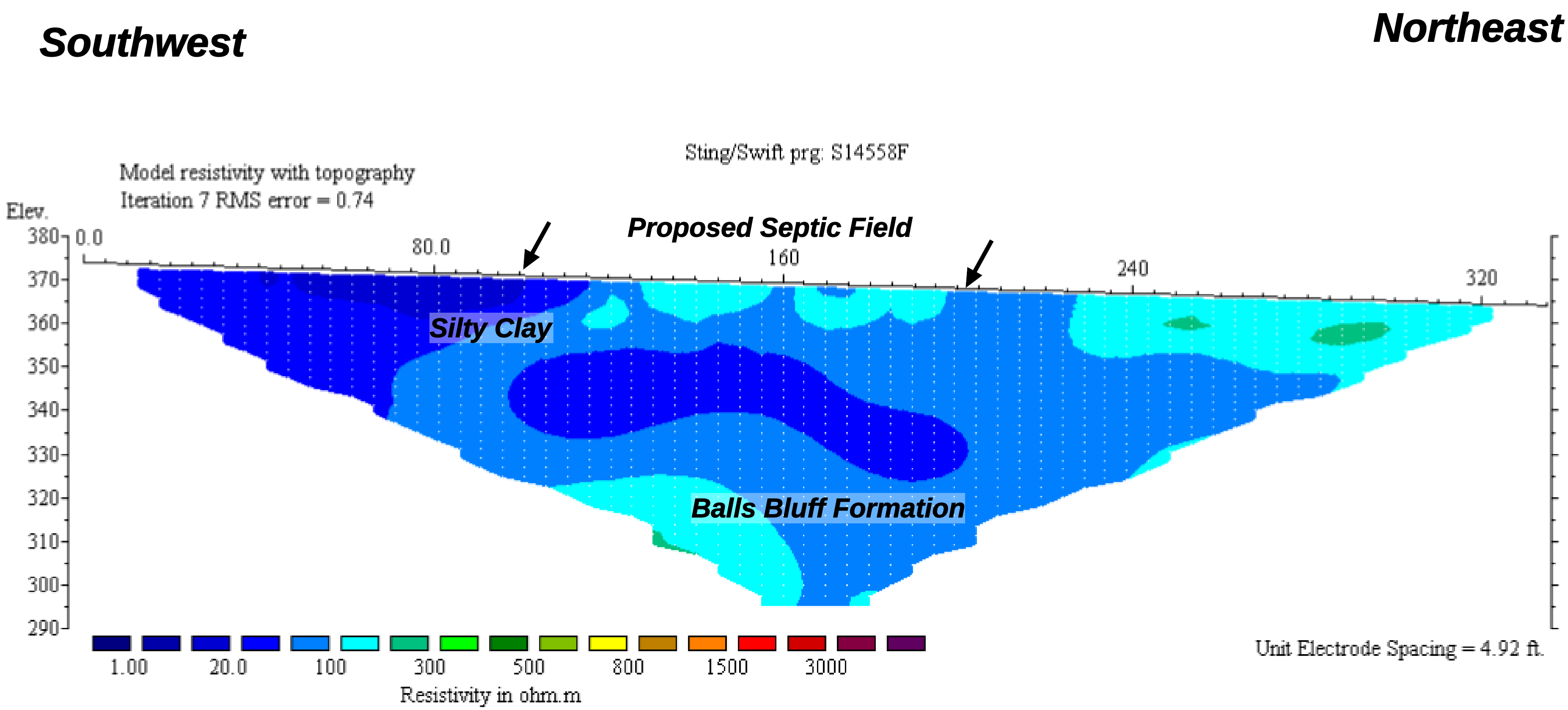
DATE January 2021	SCALE shown	TITLE *ER Line 5 Proposed Barn, Cottages, and Driveway 14558 Chapel Lane Leesburg, Virginia*
DRAWN BY	APPROVED BY	
JOB NO. 20241	DWG. NO./ REV. NO. S14558-5	CLIENT Soles / FIGURE



Horizontal scale is 13.87 pixels per unit spacing
Vertical exaggeration in model section display = 1.00
First electrode is located at 0.0 ft.
Last electrode is located at 334.6 ft.

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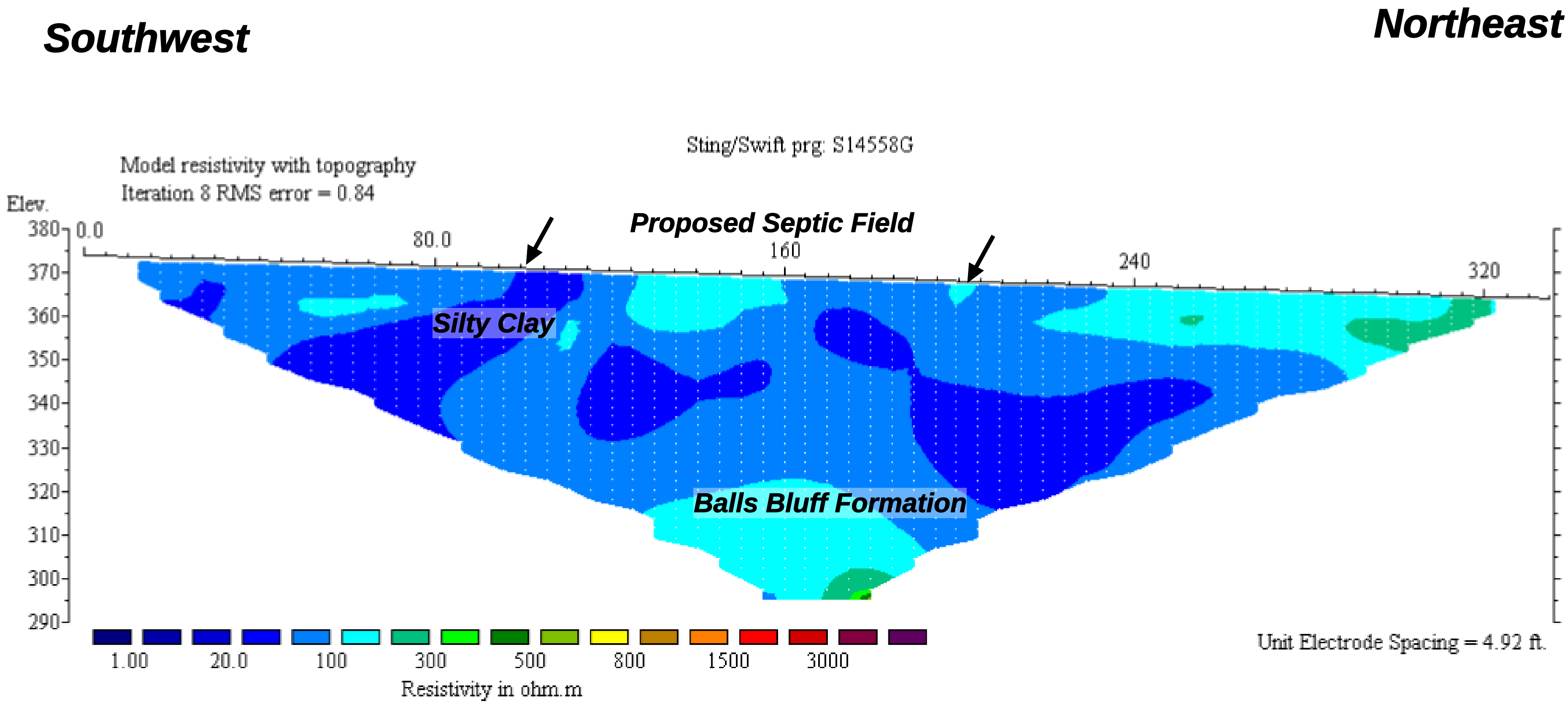
DATE April 2021	SCALE shown	TITLE ***ER Line 6 Proposed Septic Field 14558 Chapel Lane Leesburg, Virginia***
DRAWN BY	APPROVED BY	
JOB NO. 21144	DWG. NO./ REV. NO. S14558-6	CLIENT Soles / FIGURE



Horizontal scale is 13.87 pixels per unit spacing
Vertical exaggeration in model section display = 1.00
First electrode is located at 0.0 ft.
Last electrode is located at 334.6 ft.

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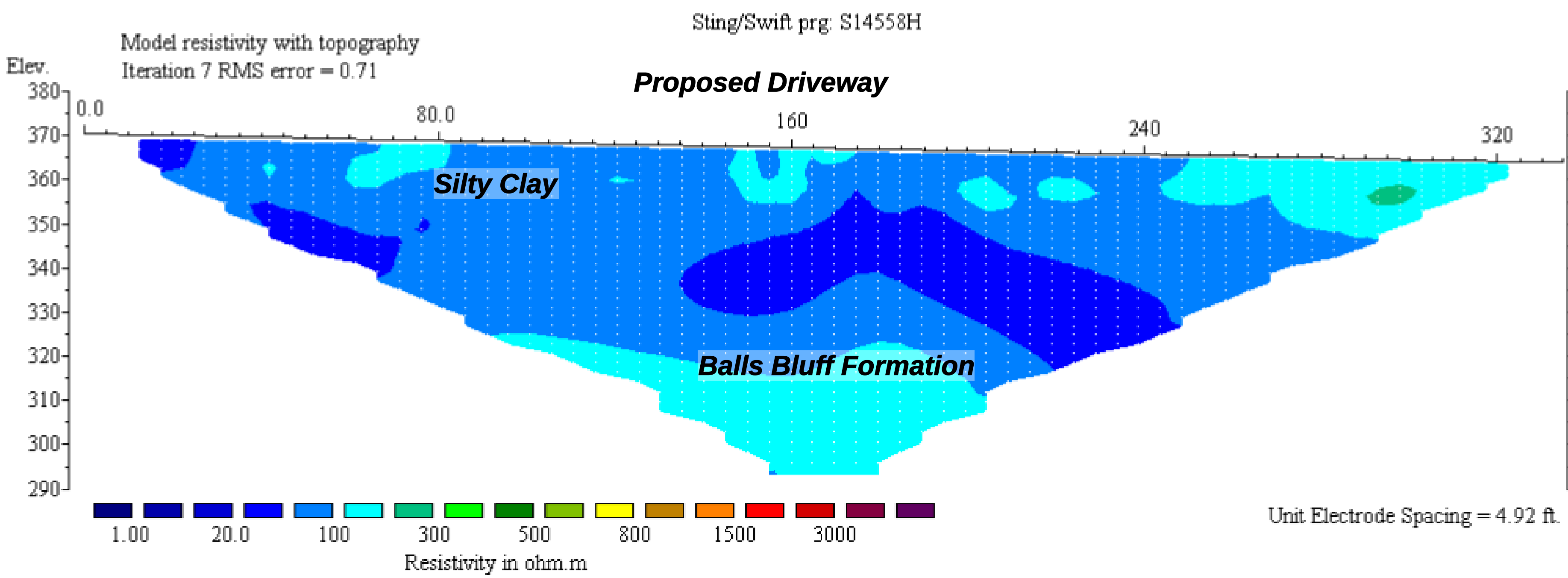
DATE: April 2021	SCALE: shown	TITLE: ***ER Line 7 Proposed Septic Field 14558 Chapel Lane Leesburg, Virginia***
DRAWN BY:	APPROVED BY:	
JOB NO. 21144	DWG. NO./ REV. NO. S14558-7	CLIENT: Soles
		FIGURE:

Southwest **Northeast**



Horizontal scale is 13.87 pixels per unit spacing
Vertical exaggeration in model section display = 1.00
First electrode is located at 0.0 ft.
Last electrode is located at 334.6 ft.

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DATE April 2021	SCALE shown	TITLE ***ER Line 8 Proposed Driveway 14558 Chapel Lane Leesburg, Virginia***
DRAWN BY	APPROVED BY	
JOB NO. 21144	DWG. NO./ REV. NO. S14558-8	CLIENT Soles — FIGURE