Figure 1  Interpreted anomalies from geophysical surveys of the Josiah Henson Special Park, 2012.

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Overview
As part of the Time Team America, Series 2 television program, ground based geophysical surveys were completed to help map the archaeological features and landscape of the Josiah Henson Special Park (JHSP) and adjacent property.

Magnetic gradient, conductivity, resistance, and ground penetrating radar (GPR) data were collected August 13-15, 2012. The Time Team America challenge at the JHSP was to (1) identify potential structures and landscape features that related to the period 1800-1830 when Josiah Henson lived on the Riley Plantation and to (2) attempt to retrieve artifacts that link Josiah Henson to the Riley plantation.

In the three days of geophysical surveys a number of anomalies identified the location of possible structures and landscape features on the JHSP, and adjacent properties. Ground-truthing of some of these features confirmed structures, but diagnostic artifacts date to the period post 1830, after the time of Josiah Henson. Excavation in the log cabin section of the Riley Plantation House identified 5 historic floor surfaces, one potentially dating to the period of Josiah Henson.

Introduction
Sub-surface geophysical survey methods and 3D laser scanning of existing environments provide cost-effective means for capturing archaeological information for site recording, investigation, and management. Using non-invasive sub-surface and surface mapping methods can document the basic structure and layout of site. These methods can guide placement of excavation units and contribute to site impact strategies when dealing with upgrade of site infrastructure (such as utilities and landscape management); thus providing cost savings while reducing destructive impact upon important archaeological remains.

These survey methods can provide primary information on site settlement patterns. The continued application and development of broad area coverage for archaeological assessment has begun to introduce an alternative perspective into regional, or landscape archaeology (David and Payne 1997; Kvamme 2003, Crutchley and Crow 2009). Because geophysical surveys are able to cover large areas in comparison to the limited extent of archaeological excavations, the information they provide introduces a new component to the concept of the archaeological landscape. Broad area geophysical surveys provide information on the structure and organization of a site enabling the study of spatial patterns and relationships relevant to research questions. In addition to the large-scale perspective of the site, geophysical survey results also provide a high-resolution focus on individual site features.

Geophysical surveys measure different subsurface properties at regular intervals across broad areas. Contrasting properties in a relatively homogeneous soil can identify buried objects or features such as foundations, compacted earthen surfaces, pits, stone walls, middens, hearths and any number of archaeological features. The different physical properties of the features, measured either in contrast to their surrounding matrix, or as recorded at the surface are referred to as ‘anomalies’ until they are able to be ground-truthed through excavation or other methods such as soil coring.
Different geophysical methods are sensitive to specific properties, such as magnetic fields, or the flow of an electrical current in the earth. Employing a combination of methods over a survey area can help provide information as to the nature, or material, of an anomaly thus providing insight to site interpretation. Mapping the distribution of anomalies over a large area can help in the recognition of anomalies generated through cultural activities revealing the spatial distribution and association with site features (Kvamme 2003).

Geophysical surveys can provide important information for help in site planning and preservation. These non-invasive methods can help establish priorities and identify areas for further invasive investigations, or for preservation and management. They are a fast and cost-effective method for gaining insight to what is buried beneath the ground. Geophysical survey results can be spatially integrated with other data relevant to archaeological investigations to provide a comprehensive record of the site environment, both below, and above ground.

Geophysical surveys were conducted over the JHSP property as well as in the two yards adjacent (to the west) to the JHSP. Figure 1 shows the areas for each of the geophysical surveys as part of this project.

Figure 2 Geophysical survey areas: magnetic gradient is dark grey and conductivity is light grey.
Individual survey areas can be seen in Figure 3. Some of the surveys have breaks in them where the survey area was inaccessible due to dense ground cover and trees.

Figure 3 Geophysical survey area coverage for conductivity/magnetic susceptibility (EM), A; resistance, B; magnetic gradient, C; and GPR, D.

**Geophysical Methods, Principles, and Results**

**Conductivity / Magnetic Susceptibility**

Electromagnetic (EM) induction instrumentation uses a near surface transmitter coil to emit radio frequency electromagnetic waves into the subsurface. Objects in the subsurface respond by generating eddy currents, producing a secondary electromagnetic field (Figure 4). This secondary electromagnetic field is proportional to conductivity and detected by a receiver coil on the instrument and recorded by an attached data logger (Bevan 1983; Clay 2006).
Figure 4 Electromagnetic induction diagram.

The Geonics Limited EM38B was used in the survey (Figure 5) and allows for simultaneous collection of both quadrature-phase (electromagnetic conductivity) and in-phase (magnetic susceptibility) components. Electromagnetic conductivity measures the “ability of the soil to conduct an electric current” (Clay 2006) and is recorded in siemens (mS/m). Theoretically, electromagnetic conductivity is the inverse of resistivity although methods for recording each are completely different (voltage, sample spacing, soil, volume, sensitivity to metals) and results may not match entirely. The transmission of the quadrature-phase component of the induced electromagnetic field signal is related to the mineral and chemical composition of the soil. Soils high in clay and/or saline composition will produce higher conductivity measurements, whereas soils composed of sand and/or silt will produce a lower conductivity measurement (Clay 2006). Levels of soil moisture also have a dramatic impact on conductivity measurements where increased moisture will cause higher conductivity readings (Clay 2006).

Magnetic susceptibility measures “a material’s ability to be magnetized” (Dalan 2006). It is different from magnetic gradiometry in that susceptibility is an active measurement recorded in the presence of an induced magnetic field. The transmission of the in-phase component of the induced electromagnetic field is based on the presence of a magnetic topsoil matrix being greater in magnetism than proximate soil matrix or materials. The increase in magnetism in topsoil is the result of pedogenesis enhancement from hematite, magnetite and maghemite minerals. Additionally, changes to the magnetic composition of the soil can be caused by human activity, such as fire or the movement of magnetically rich topsoil (Dalan 2006).

Both quadrature phase and in phase readings were simultaneously collected for each station, relating to conductivity and magnetic susceptibility properties respectively. This specification results in a maximum depth sensitivity of about 1 m for the conductivity. For the magnetic susceptibility, the penetration is significantly shallower.
Conductivity survey data sampling:
- 2 samples per meter
- 0.5 meter transect spacing
- Parallel data collection method (all transects travel grid south to north)

The EM data were processed using Geoplot 3.0. Null values were added in a text editor so that grid lengths and widths were in multiples of 10 meters and these were used to create a single composite data set.

Data processing methods include a despike operation and a 3X3 low pass, as well as the addition of a 10 X 10 high pass filter to a second version. The magnetic susceptibility data was processed in a similar fashion, without the creation of the second high pass filtered version.

Figure 5 Bryan Haley with the EM38 conductivity meter.

**Electrical Resistance**

Resistance survey is designed to measure the electrical resistance of the earth in order to provide information on the subsurface structure. The electrical properties of the earth are recorded as a function of depth and / or horizontal distance. An electrical current is introduced into the earth through electrodes and the resulting potential distribution is sampled at the ground surface. The measured apparent resistivity provides information on the magnitude and distribution of the electrical resistivities in the volume of the sampled subsurface (Griffiths and King 1981).
An electric current is caused by the flow of charged particles and is measured in amperes (amps). Amperage expresses the amount of charge that passes any point in a circuit in one second. A measurement of the ground resistivity is made by passing an electrical current into the ground through an electrode acting as the current source (Figure 6). A second electrode, or current sink, enables the electrical current to exit from the ground completing the circuit. The current flows into the earth in all directions from the source electrode.

![Figure 6](image)

**Figure 6** The flow of current from a single current source and resulting potential distribution.

The most common electrode configurations are linear arrays that contain two current electrodes (A and B) that are the current source and sink of equal strength, and two potential electrodes (M and N) that measure the difference in potential between two points (Figure 7).

![Figure 7](image)

**Figure 7** A general four electrode array.

If the ground is inhomogeneous and a fixed electrode array is moved or the electrode spacing is varied during survey, the calculated resistivity will vary for each measurement. The resistivity of the earth can vary greatly depending on the composition and structure of the material and ground water saturation. Not only does resistivity vary with rock formations, it also varies from deposit to deposit and on a macro scale within individual deposits depending upon their structure. Resistivity values can vary greatly due to the unconsolidated nature of near-surface materials. The principles provided for basic rock formations can be followed when considering the structure of the near surface and resistivity mapping for archaeological applications (Griffiths and King 1981).
The nature of the archaeological features, the mineral content and compaction of soils in which they are buried, and the saturation levels of the subsurface all affect earth resistivity. The saturation of the subsurface is dependent on rainfall, soil composition and compaction and subsequent percolation rates, evaporation rates, and water take-up through the roots of vegetation. Weather and geological conditions impact on the effectiveness of resistivity surveys in archaeological applications and dictate careful consideration of resulting data (Clark 1996).

A number of electrode arrays are used in resistivity surveys. The array, or configuration, refers to the arrangement of electrodes. Linear arrays, which are used more commonly, consist of two current electrodes (A and B) and two potential electrodes (M and N). The twin-electrode array is the most popular for archaeological surveys. Due to the relative speed of data collection, the benefits of the resulting survey include a high lateral resolution and depth of investigation relative to the spacing of the mobile electrodes (Apparao et al. 1969; Apparao and Roy 1971). The basic twin electrode array used in archaeological applications can be seen in Figure 8 where single current (A) and potential (M) electrodes are set with a fixed distance (a) with the second pair of electrodes (B and N) are placed at a distance 30 times the spacing (a) of the primary electrodes (A and M) and fixed separation distance (a) the same as the mobile probe spacing.

![Figure 8 The Twin-electrode array commonly used in archaeology.](image)

The depth of investigation can be defined as the depth at which a thin horizontal layer makes the maximum contribution to the total measured signal at the surface (Barker 1989; Evjen 1938; Roy and Apparao 1971; Roy 1972). The separation distance and positions of the current and potential electrodes fundamentally contribute to calculating the most accurate depth estimation. The depth of investigation of electrode arrays should be the depth with which a measurement of apparent resistivity is best associated. Although there is no single depth of investigation, a single value is more useful to have as a reference. The most practically useful value is the median depth (Edwards 1966; Barker 1989). The median depth is defined as the depth from below which and from above which 50% of the signal originates.
The Geoscan RM15 resistivity meter was used for survey in the area of interest (Figure 9). Data were collected every 0.5 m along transects spaced every 1 m apart. Post processing was performed in Geoplot and final resistance maps are rectified into the project GIS. Resistance data are displayed in this report.

Magnetometry

Magnetometers are passive instruments that measure the magnetic field strength at a specific location on the surface of the Earth. The Earth's magnetic field varies depending on location relative to the Earth’s equator and can be visualized as a large bar magnet that is tilted 11 degrees from the axis of rotation (Heimmer and Devore 1995). Over a small area and in homogeneous soils, the magnetic field is expected to be uniform (Weymouth 1986). A subsurface target can be detected with magnetic survey as a deviation from this background field reading. The resultant anomaly often has a dipolar form aligned with the dip and direction of the Earth's field (Figure 10). The most common unit of measure is the nanoTesla (nT).

The magnetic signal of a target is composed of two parameters: induced and remnant magnetism (Reynolds 1997). A magnetometer measures the remnant magnetism of a target, which is permanent and may be caused by the presence of highly magnetic rock compounds or thermal alterations to soils which have high iron content (Heimmer and Devore 1995). Magnetization caused by thermal alteration
is called thermoremanence and it occurs at maximum expression at temperatures above about 600 degrees Celsius, but there is some effect at any elevated temperature (Aitken 1964).

Figure 10 The magnetic anomaly produced by a kiln is aligned to the dip and direction of the Earth’s magnetic field (From Clark 1996).

Induced magnetism is only visible in the presence of magnetizing field. However, the Earth serves as a constant magnetizing agent and, therefore, it can be sensed by a magnetometer. The induced magnetism is generally referred to as magnetic susceptibility. Magnetic susceptibility is greater in the topsoil and soils that are organically rich, but often produces relatively subtle anomalies (Clark 1996). Therefore, excavations that rearrange the topsoil are sometimes evident in magnetic surveys, but these are rather weak in strength. The Geonics EM38B can better measure the induced magnetism of the ground.

Magnetic anomalies produced by archaeological targets are often much weaker than signals produced by other sources, usually between 1 nT and 100 nT (Aitken 1961). However, anomalies produced by historic period targets are usually much greater than this range. Archaeological objects that may produce magnetic anomalies include fireplaces, furnaces, burnt clay floors, hearths, kilns, daub, bricks, and walls composed of magnetically anomalous rocks such as basalt (Aitken 1964; Hasek 1999).

Another type of targets visible magnetically are ferrous, or iron containing materials (Aitken 1964). Archaeological targets such as historic nails can sometimes be mapped using magnetometers. However, more recent ferrous objects, such as power lines, cars, buried pipes, and surface trash, can easily obscure archaeological targets (Heimmer and De Vore 1995).

Some advantages to the use of fluxgate instruments are their relative insensitivity to steep magnetic gradients and their speed of acquisition is better (Reynolds 1997). Fluxgate instruments have become the workhorse for archaeological geophysical survey in Britain and the United States (Clark 1996).

The magnetic gradiometer was developed in the 1990s and uses two sensor heads. The primary advantage of a gradiometer system is that no correction for diurnal drift is necessary (Reynolds 1997, Bevan 1998). In addition, they are much less affected by nearby objects with steep magnetic gradients, such as large masses iron (Bevan 1998). Also, gradiometers tend to emphasize shallow anomalies, a
benefit for archaeological survey. One disadvantage is that the accuracy is dependent on a consistent orientation of the sensors (Bevan 1998, Hasek 1999).

Interpretation of magnetic imagery begins by identifying anomalies, which may have strong high and low amplitude values (Bevan 1998). Next, metal objects can be identified from the shape and amplitude. Anomalies with strong, narrowly spaced dipoles or strong monopoles are usually produced by ferrous metal objects. If targets are relatively large and the amplitude is not extreme, the shape may be approximated in the magnetic imagery (Bevan 1998).

Little information about the depth of a target is obtained with magnetic survey. In some cases, the half-width rule can be used to estimate target depth. The half-width rule depends on the amplitude drop off for readings over a target and assumes a simple and regular target shape (Bevan 1998). However, except for buried iron targets, this technique is often not useful for archaeological targets.

The Bartington 601 fluxgate gradiometer was used for the magnetic survey at the JHSP (Figure 11).

Magnetometry survey parameters were:
- 0.125 m sample rate
- 0.5 meter transect spacing
- Zig-zag data collection method (survey grid SW corner to grid NE corner)

The magnetic survey data were processed using Geoplot 3.0. Processing techniques included de-spiking, grid/transect mean zeroing, 3 x 3 low pass and 10 x 10 high pass filtering. Once processed, data were interpolated along the x axis.
Ground Penetrating Radar

GPR can provide high resolution records of boundaries between subsurface features with contrasting dielectric properties. A standard method for detecting buried archaeological features, GPR is able to collect large amounts of data, covering moderate areas, over a short period of time. GPR is a geophysical technique that can produce a three dimensional image of the subsurface and provide accurate depth estimates and information concerning the nature of buried features.

GPR maps the form of contrasting electrical properties (dielectric permittivity and conductivity) of the subsurface and records information on the amplitude, phase and time of electromagnetic energy reflected from subsurface features. The results are presented as 2D vertical profiles in the earth. The stronger the contrast between the electrical properties of two materials, the stronger the reflected signal in the GPR profile will be. Because the electromagnetic radar wave is transmitted from an antenna on the surface, reflects off of sub-surface interfaces, and is recorded back at a receiving antenna on the ground surface, surveys are ineffective in highly conductive materials.

The GPR surveys were conducted with a SIR3000 GPR unit and a 400 MHz antenna (Figure 12). The 400 MHz antenna is a relatively high frequency antenna with the ability to penetrate to approximately 2-3 m in well drained loamy soils. While this antenna can penetrate to that depth, the system can be set to target the upper meter of the earth depending on the estimated depth of buried archaeological features. In the case of surveys at the JHSP, we focused on the near surface while allowing for possible excavated pits (privy, basement, etc.) to be identified as well.

Figure 11 Duncan McKinnon with the Bartington 601 dual array fluxgate gradiometer.

Figure 12 SIR 3000 GPR unit with the 400 MHz antenna.
**Geophysical Data Interpretations**

All of the geophysical survey results were imported to a project GIS using ArcMap 10.1. Data are rectified\(^1\) into the GIS project and polygon files are created to identify and map interpreted anomalies. Data results are presented below with and without interpretations. This is done so that the client may look at the data and consider what they may see based upon their viewpoint and expertise.

**1927 Aerial Photograph**

Numerous historic documents were included in the research leading up to the geophysical surveys at the JHSP. The most relevant to the goals of the geophysical surveys, identifying possible out-buildings related to the Riley Plantation house during the period of Josiah Henson’s life there (1800-1830) is an aerial photograph dating to 1927. The Riley Plantation house can be seen in this photo with additional structures thought to be associated with the Riley property\(^2\). The largest of these buildings is thought to be a barn, or similar type of structure.

\(^1\) Please note that spatial reference was difficult as the local site survey was not tied into global reference, thus rectification of the Time Team America survey data is based on the local grid as well as aerial photographs.

\(^2\) based on oral communications with site contacts.
Modern day occupation has impacted this 1927 landscape as can be seen in Figure 14.
The information from the 1927 aerial photograph is a good starting point for both targeting areas of interest to survey with various geophysical survey methods and for testing the effectiveness of the survey methods over known structures. The geophysical surveys targeted the visible out-buildings in the 1927 aerial photograph as well as the land adjacent to the Riley Plantation house (Figure 15).
The sub-surface nature of the survey area at the JHSP is mixed with areas of intense disruption, and areas that appear relatively undisturbed. The four geophysical survey data sets that are available for analysis all reveal different information in regard to the subsurface as a result of the physical properties to which they are sensitive (Figure 16). Interpretations of the entire JHSP project area focus on large busy (or noisy) anomalies in the data (such as in the potential location of the barn as dictated by the 1927 aerial photograph), alignments or clustering of single point anomalies, and geometric patterns defined by contrasting ground properties. It is important to keep in mind the modern features that geophysical surveys can map such as different soil types or depositions, utilities, tree roots, animal burrows, and buried irrigation systems.

In this area, the magnetometry survey results reveal the most information regarding buried features and give the best indication of the potential past activity on this site. Conductivity and magnetic susceptibility complement some of the magnetic anomalies, suggesting perhaps ‘activity’ or work areas that may have been associated with a structure. It is interesting to note that resistance survey does not identify all of the same ‘features’ as magnetic survey does, but contributes additional areas of interest for investigation. GPR was the least revealing of the geophysical survey methods. While it clearly
mapped a pipe leading out from the Riley Plantation house; it did not map the remains of the barn feature (1927 aerial photo and magnetic survey), nor did it define any specific anomalies suggestive of structures or features such as a privy or well. That said however, there are a lot of anomalies in the GPR data (below) which would need to be further investigated to interpret as archaeological or perhaps geological or pedogenic in nature.

The interpretations below are annotated for magnetic gradient, conductivity, magnetic susceptibility, resistance, and GPR with single anomalies identified as well as some with ‘areas of interest’ (AOI) drawn around clusters of anomalies or areas of contrasting properties. While not all of the anomalies in each data set are annotated, the author focused on annotating the anomalies that most likely reflect a possible historic/archaeological source. This does not rule out the possibility that anomalies that are not annotated here could also be of importance. These interpretations are meant as a guide for site archaeologists to gain a certain perspective on the buried nature of the site to enable more focused excavations and perhaps development of ground-truthing soil coring surveys. Site archaeologists should also examine the clear data images and images with interpretations included to see if they may have a different perspective on the data and are able to extract even more relevant interpretations (the author is available for further discussion and development of site interpretations).

Figure 16 Final interpretation of all geophysical surveys at the JHSP, overlain on magnetic gradient survey data.
Magnetic Gradient Interpretation

Due to the nature of magnetometry survey, the resulting data is very busy (Figure 17). Magnetic survey will map historic and modern activity as well as any ferrous debris. Many times the development of urban neighborhoods may have a significant impact on the historic landscape introducing areas of fill, trash, and modern debris. In the magnetic data areas of high activity suggest a concentration of ferrous and/or burned materials. There are many point anomalies as well in this data, some of which can be attributed to ferrous material (typically with a dipole oriented North-South or a single strong anomaly with a ‘halo’ type effect of monopole). The dipole oriented North-South is typical of ferrous materials, which may include historic (and modern!) artifacts such as horse shoes or nails. Other single point anomalies that have a different dipolar orientation, or that appear as a monopole, may represent other types of features such as pits, or more subtle features that have contrasting magnetic properties to the background material.

Figure 17 Magnetic gradient survey results for the JHSP.

Figure 18 shows the interpreted magnetic data. The interpretations focus on attempting to identify landscape or structural features that relate to the period of Josiah Henson’s occupation of the site. The red annotations identify individual anomalies, patterns in the data, and concentrations of magnetic
contrasts. The areas of interest identified with pink polygons identify areas of interest that are suggested by more background or clustering patterns in the data. Some possible anomalies may not be annotated, to do so would produce a confusing map, interpretations suggest areas of highest likelihood of features of interest. However, all data are delivered to site archaeologists in the form of a project GIS and they are encouraged to continue examining all of these data in ongoing investigations.

Figure 18 Interpreted magnetic gradient survey results for the JHSP.

Overlaying the features from the 1927 aerial photo contribute significantly to the interpretation of the magnetic data as can be seen in Figure 19. In the western section of the survey the strong magnetic anomaly (1) overlaps with one of the structures of the 1927 aerial photograph. Subsequent excavations identified this feature as a possible burned barn. Iron artifacts and burned beams were located in this area. The ground-truthing in this area provides good insight to what may be present in other areas of the survey area with similar magnetic signatures such as area (2).

Another area of interest for investigation is at (3) where four point anomalies appear confined in a single area (this AOI extends beyond these four point anomalies north to the barn feature). This is similar to the signature of two point anomalies at (4). Of additional interest in this section of the survey area is the line of single point anomalies that is just to the west of the ‘barn’ feature, these may reflect features
such as post holes, or even nails that might reflect a fence (5). Another probable fence alignment is apparent in the data at (6) within the JHSP property. Another single anomaly alingment may suggest an additional fence, but the spacing between these anomalies is larger than the other two (7).

It is interesting to note that one of the AOIs (8) alignes perfectly with the road as mapped in the 1927 aerial photo, this might suggest disturbance directly related to the road, or road construction; possible activity/structures related to the road; or more recent activity such as landscaping to reduce the visual / topographical effect of the road.

The limestone block ‘wall’ that appeared in excavation units prior to the arrival of Time Team America can be seen clearly on the JHSP property between two excavation units (9).

Modern disturbance can be seen adjacent to the Riley Plantation house and a possible modern utility (10)(this should be checked) in the eastern most part of the survey area. A known excavation is located at (11) and is not annotated in the magnetic data interpretations.

Figure 19 Magnetic gradient survey data with interpretations and overlain features from the 1927 aerial photograph.
Resistance

The resistance survey provides some good information as to what remains buried in the earth (Figure 20). Keep in mind that this method measures the resistance of the ground and what is buried in it to an electrical current. Thus, features like walls (piles of rock), pits, and ditches may be mapped. Disturbance from tree root systems (less compact soil) can also be mapped along with other modern landscape related features.

![Resistance survey results for JHSP.](image)

Interpretation of the resistance survey results (Figure 21) with the overlain 1927 aerial photograph features identify some of the same features as the magnetic survey such as the ‘barn’ feature (1) and the possible limestone ‘wall’ (2). This survey also reveals complementary information to what may be additional structures, concentrations of rubble, or perhaps highly compact surfaces (3).
Figure 21 Resistance survey results with overlain interpretations.
The resistance anomalies that suggest possible structures cluster to the western half of the survey area. It is important to note that a number of these anomalies are adjacent to the ‘wooded’ area that divides the two back yards in this area. Investigation of these anomalies would need to rule out impact of tree root system and modern landscaping features. However, based upon the resistance and magnetic surveys it is possible, should these anomalies prove to be structures, that this area may be cluster of out-buildings that could relate to the Rile Plantation house property. Additional anomalies appear in the eastern section of the survey area within the JHSP boundary and should be investigated to rule out modern utility, tree/shrub, or landscape feature. Feature (4) located near the early 20th century BBQ grill may be of archaeological nature, but its close vicinity to the BBQ as well as the trees/ground cover in this area would need to be ruled out as contributing to the high resistance anomaly.

**Conductivity & Magnetic Susceptibility**
The conductivity (Figure 22) and magnetic susceptibility (Figure 23) surveys identified the same ‘barn’ feature as the magnetic and resistance data did, but with slightly different signatures (Figure 24, (1)).

![Figure 22 Conductivity survey results for the JHSP.](image)
Figure 23  Magnetic susceptibility survey results for the JHSP.
Additional areas of activity are identified in both of the electromagnetic induction (EM) methods that match the areas of possible features identified in the magnetic gradient and resistance surveys (2). The conductivity data appear to show the impact of modern day activity on the JHSP property (3) with a slightly higher conductivity value extending from the concrete slab area, through the area of the excavations to the southeastern side of the survey area that leads to the now cleared asphalt pad. (4) - coincides with a modern garden feature, also in the magnetic gradient data.

**Ground Penetrating Radar**

The GPR survey was the least effective method for mapping sub-surface features (Figure 25). GPR records data in profiles, or vertical traces into the earth, thus can record approximate depth to features. The project GIS contains 23 plans of the GPR data, approximately 0.10 m thick, every 0.5 m (so they overlap). The automated depth conversion based on signal velocity should be given +/- at least 0.15-0.20m error\(^3\). GPR identified a number of anomalies, some of which cluster in the area of the known

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\(^3\) If desired, future in-field depth conversions can be done with existing data, but the shallow nature of the archaeological features may not demand this fine-tuning.
‘barn’

Additionally, GPR identified possible anomalies in the middle section of the survey area (2) that may relate to structures. Other anomalies in the middle of the survey area may relate to landscaping activity, tree root systems, rodent burrows, or archaeological features (3). More anomalies appear in the JHSP property boundary (4), but it is not possible to clearly interpret whether they are archaeological in nature. A pipe is identified coming from the house (5), and the GPR clearly mapped the location of the earlier archaeological excavation (6), now backfilled.

Figure 25  Ground penetrating radar survey results at a depth of approximately 0.20 – 0.35m for the JHSP.

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4 From the 1927 aerial photo as well as from excavation and other geophysical survey methods.
Airborne LiDAR Principles and Results

Airborne LiDAR, or light detection and ranging, measures the height of the ground surface and any features (i.e. trees, buildings) that may be on it and provides high definition and accurate models of the landscape to a resolution of 1 m to 0.5 m in archaeological applications. LiDAR uses a pulsed laser beam that scans from side to side as a plane flies at a low altitude over the survey area. 20,000 to 100,000 points per second build the ground model. In post-processing the first returns can be removed from the data providing a ‘bare earth’ model (or Digital Terrain Model, DTM) that accurately represents the ground surface.

The airborne LiDAR data were acquired by the NRAC, West Virginia University. NRAC operates an OPTECH ALTM-3100C airborne laser (small-footprint) mapping system. The system integrates a laser altimeter, a high-end Applanix Pos/AV Inertial Measurement Unit (IMU), also called an Inertial Navigation System (INS), and a dual frequency NovAtel GPS receiver. This integrated system is capable of 100 kHz operation at an operating height of 1,100 meters (3,609 feet). LiDAR technology offers fast,
real-time collection of three-dimensional points that are employed in the creation of Digital Elevation Models (DEMs), Digital Terrain Models (DTM), landscape feature extraction, forest stand structure analysis, as well as many other research applications.

Data were collected in multiple, low altitude acquisition passes over the core area of the Dillard site (Figure 11) to yield ground LiDAR point densities of 15-20 per square meter (vertical accuracy of 15 cm or better). Integrated data have a vertical error of 15 cm or less at the 95% confidence level for areas of open terrain and moderate slopes of 10 degrees or less (based off manufacturer’s specifications). Data are recorded in the applicable Universal Transverse Mercator (UTM) zone, NAD83 datum (CORS96) while heights are orthometric, referenced to the North American Vertical Datum of 1988 (NAVD88) using GEOID09.

While the resulting ‘bare earth’ model from the LiDAR flight of the JHSP provides an excellent model of the landscape, the urban nature of the site with significant modern impact on the landscape makes it difficult to interpret archaeological (and landscape) features from the period of Josiah Henson’s occupation. However, further examination by site archaeologists may reveal information relevant to investigations.
Figure 27 LiDAR Hillshade of the Bethesda neighborhood surrounding the JHSP.

Figure 28 LiDAR Hillshade of the immediate area of the JHSP.
Figure 29  Hillshade of the immediate area of the JHSP with modern parcels and building footings.
Conclusions and Recommendations
The combination of geophysical survey techniques used at the JHSP provides a wealth of information and suggests the location of numerous possible structures and potential archaeological features. Further investigations might include doing a thorough ground-truthing of a sampling of geophysical anomalies to better understand what they were mapping. Depending on site resources, repeating the EM survey (conductivity and magnetic susceptibility) at a higher sample density might reveal more subtle changes of soil that might lead to further interpretation of the archaeological nature of the site and location of structures such as the slave quarters where subtle soil property changes may be the only remaining evidence.
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Time Team America
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5 Noel Broadbent, Smithsonian Institute is the other co-PI and Dave Davis from OPB is the project PI.
6 Thanks to Duncan and Bryan for all of their hard work in and out of the field with data collection, processing, interpretation and contributing to this report.


