

Atop Gallows Hill: Magnetic Susceptibility in Archaeological Reconnaissance

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Thank you for believing in me.

# Atop Gallows Hill: Magnetic Susceptibility in Archaeological Reconnaissance

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## Abstract

This thesis synthesizes documentary evidence with two major sets of geophysical data in a comparative study between a potential subsurface archaeological feature, tentatively identified as the possible remains of a colonial palisade, and an experimental palisade trench.

In 2013 a geophysical survey was undertaken at the Lunenburg Academy National Historic Site, Lunenburg, Nova Scotia. This survey revealed several anomalies, including one that may indicate the 18<sup>th</sup> century palisade line. In an effort to better understand this feature an interdisciplinary methodology was employed. The background study included a review of historic material on the construction and life span of British era palisades. It was enlightened with environmental and remote sensing data to identify the archaeological potential of Gallows Hill and to provide a framework for the interpretation of geophysical responses from the experimental research component. The objectives of the experimental research were to generate a susceptibility response for an earth filled trench of known dimensions, comparable to British North American palisades, and contribute to a literature on the accuracy of the EM38B inphase component as a non-invasive remote sensing technology, for detecting subtle features.

The origin of the linear magnetic susceptibility anomaly on Gallows Hill remains unknown, although geophysical surveys conducted for this thesis confirmed its existence and mapped it at a higher resolution than the 2013 survey. The results of the experimental research component do not support the conclusions drawn regarding the tentative identification of the linear anomaly as the palisade. In this case, it appears that traditional archaeological excavation may be the best method for determining the nature and significance of the linear anomaly. Excavation would inform the geophysical survey results, providing insight into the response of the EM38B to the trench feature, contributing to discussion on the effect of tightening magnetic susceptibility transect spacing for detecting features in archaeological mapping.

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## INTRODUCTION

The primary objective of this thesis is to demonstrate the utility of the Geonics Limited EM38B electromagnetic induction meter, which measures ground conductivity and susceptibility, as an archaeological reconnaissance tool for detecting shallow trench and wood features, such as the remains of an 18<sup>th</sup> century palisade. This approach constitutes a non-invasive effort to identify 18<sup>th</sup> century colonial archaeological features, providing an alternative to more traditional archaeology approaches such as excavation.

Across the world, methods are being developed to refine and test magnetic susceptibility (Clark 2003; Clay 2006; Campana & Salvatore 2009; Dalan 2006; Dalan & Banerjee 1998; English Heritage 2008; Gaffney & Gator 2006). The effectiveness of the EM38B on stone features has been clearly demonstrated in the European context. The predominance of wooden construction materials in North America, however, has resulted in comparatively few in-depth studies of the instrument's ability to detect these more subtle archaeological features (Clark 2003:11). While efforts have been made by local archaeologists in Nova Scotia to demonstrate the value of the EM38B as an archaeological research tool, there is room for more work to be done (Fowler 2006; McNeill 2012; McNeill & Fowler 2013; Ferguson 1990).

In the fall of 2013, Saint Mary's University archaeology students carried out geophysical and landscape surveys on the Lunenburg Academy grounds in an effort to locate traces of subsurface archaeological features with an EM38B (Fowler 2014; Fraser *et al.* 2013). The Lunenburg Academy is located on Gallows Hill, at the northwest edge

of the town of Lunenburg, in Lunenburg County, Nova Scotia (Figure 1), which provides a natural vantage point for guarding the town proper and overlooking the land beyond the peninsula. The survey revealed several anomalies that were considered to exhibit archaeological potential (Figure 2). Of particular interest was a faint line extending north–south over the entire length of the western quadrant. This anomaly appeared to correspond with the limited historical information available, which described the palisade that once encompassed the town of Lunenburg (J. Fowler, personal communication, May, 2014).



Figure 1: Area 1: Site location map (North at top). The Gallows Hill survey area, indicated by the blue ellipse. SOURCE: Detail of Energy, Mines and Resources Canada 1:10,000 NTS map, “Lunenburg”.

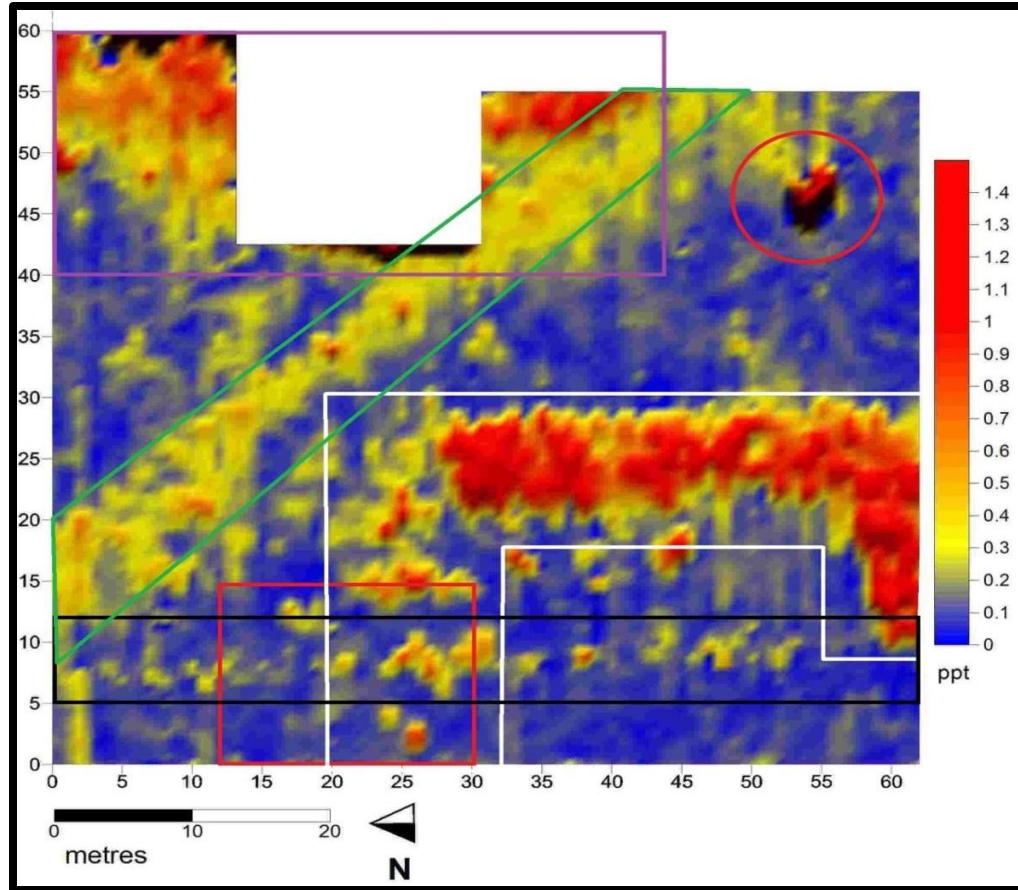


Figure 2: Lunenburg Gallows Hill Magnetic Susceptibility Orthographic Presentation, with the 2014 survey area shown with a red rectangle. Feature A is indicated with a black rectangle, Feature B is indicated by the white polygon, Feature C is indicated with a green trapezoid, Feature D is indicated with a red ellipse, and Feature E is indicated with a purple rectangle. SOURCE: Adapted from Fowler 2014.

An examination of the susceptibility results for the 2013 survey, collected at 1m transect intervals, reveals four subsurface features. As indicated on Figure 2, Feature E is an extended zone of high magnetic susceptibility, caused by the existing building, gravel driveway, and metal scaffolding, which abut the survey lines. The high susceptibility response to the southeast of the grid is interference from a lamp post (Feature D). Research has shown that the linear anomaly (Feature C) extending southeast–northwest direction is the remains of an historic road alignment (Town of Lunenburg, 1977). Dwarfing the surrounding anomalies is Feature B, an area of extremely high susceptibility that suggests the presence of a buried archaeological feature, probably a



stone structure. Feature B includes the scattered anomalies trending west from this feature, where one of the walls may have been dispersed, over time, downhill. Finally, Feature A is a very faint, but distinct linear feature extending north–south across the survey area, from (0, 7) to (60, 8). Feature A may correspond to the line of the 18<sup>th</sup> century palisade. This anomaly appears to abut the large feature described above (Feature B), enclosing that structure. Fowler has suggested that the two features are contemporary (2014:9).

In order to investigate the accuracy and value of the EM38B relative susceptibility component in archaeological mapping, this project generated electromagnetic susceptibility data from two areas. In expanding on the 2013 geophysical survey results, a more highly resolved data set was gathered from Gallows Hill (Area 1). The second area is the Eisener family property (Area 2) in Italy Cross, Lunenburg County, Nova Scotia (Figure 3).

To test the capacity of the EM38B to detect trench features, we excavated a new palisade trench at Area 2 using known 18<sup>th</sup> century British palisade dimensions. The experimental trench was subsequently backfilled and subjected to three additional geophysical surveys at 1m, 0.50m, and 0.25m transect intervals. Before digging the test trench, we conducted a preliminary geophysical survey of the study area at 1m transect intervals in order to obtain baseline data for the existing terrain. This test trench was located on terrain similar to Gallows Hill but situated at Italy Cross, approximately 35km to the west.

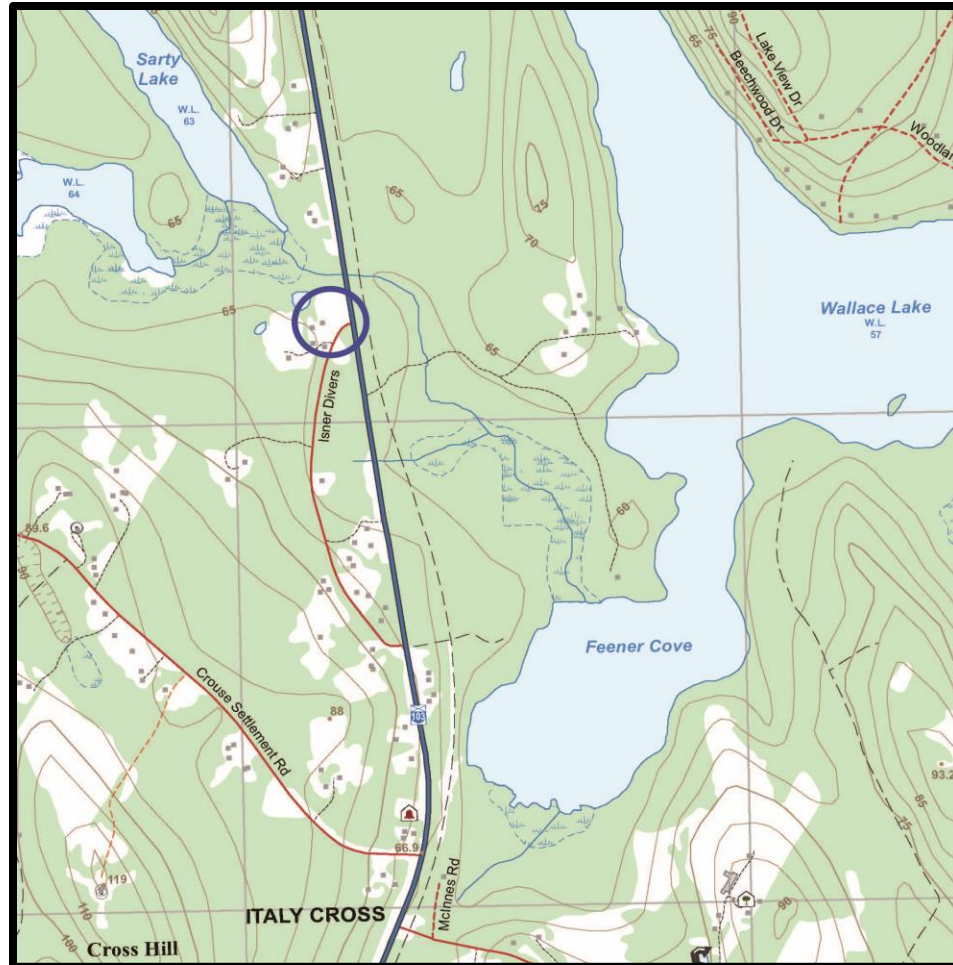


Figure 3: Area 2: Site location map (North at top). The Eisener Property survey area, indicated by the blue ellipse. SOURCE: Detail of Energy, Mines and Resources Canada 1:10,000 NTS map, "Italy Cross".

This was necessary because test excavation on Gallows Hill (an area of known archaeological resources) would have necessitated a separate Heritage Research Permit, as well as a labor-intensive archaeological excavation that would have exceeded the scope of this investigation.

This research has generated a total of seven sets of data from two study areas, exploring the effects of tightening interline spacing on data resolution and demonstrating the effectiveness of EM38B susceptibility surveys in detecting shallow trench and wood



Figure 4: Allison Fraser and Dr. Jonathan Fowler gather data for the 2013 geophysical survey of the Lunenburg Academy's west lawn. SOURCE: Henry Cary.

features in the archaeological record. The project was conducted under a Category B Heritage Research Permit (A2014NS108), issued by the Special Places Program, Nova Scotia Department of Communities, Culture, and Heritage to the researcher of this thesis (Appendix A). In expanding on the 2013 survey, this thesis presents an effort to determine the nature of the linear anomaly (Feature A) on Gallows Hill (is it a palisade?) with modern non-invasive archaeological field methods.

In the absence of archaeological excavation, documentary evidence gathered to establish a historical narrative of Gallows Hill was brought together with the new geophysical data to interpret the anomalies in the survey results. Based on the limited amount of cartographic evidence pertaining to early Lunenburg, supplemented by the historical record, a rough timeline of the structures on Gallows Hill was constructed. British authorities selected an area known to the Mi'kmaq as Milnigetjg (Mirliguèche), meaning 'hilly', as the site for the town of Lunenburg for its natural harbour and

defensible location on a peninsula, which could be easily enclosed by a palisade (Pacifique 1934:290). Gallows Hill boasts a commanding view of the peninsula and the valley approach, protecting the town from landward attacks. A firsthand account by Lieutenant Colonel Charles Lawrence on the construction of fortifications atop Gallows Hill in 1753 provides definitive evidence that a palisade was built crossing the crest of Gallows Hill (Harvey 1953). The palisade stretched from Lunenburg Harbour to Back Harbour and was bounded by a small blockhouse at each end of the wall. Two blockhouses, a small fort, and a pentagonal fort with barracks (enclosed by a star shaped fence [DesBrisay 1895:33]) sat atop the hill. Historical mapping also highlights these defenses. A blueprint of the fortifications dated to ca. 1770 (Anon.), shows in detail the placement of these features across the neck of the peninsula (Figure 5).

Construction of the town defenses on Gallows Hill began June 9<sup>th</sup>, 1753 (Harvey 1953:4). Based on Lawrence's reports, it appears that he was anticipating Native and French attacks. Therefore, the western defenses were immediately put in place to secure the peninsula from the mainland (Harvey 1953:20). The palisade was an important feature in the success of the old town, because it allowed the community to safely access the neighbouring common land for construction materials and for grazing, as long as the settlers remained within its protective reach. After the 'Treaty of Peace and Friendship' in 1760, military activity decreased and a local militia was stationed in Lunenburg (Hewitt n.d.:25; Brymner 1905). The need for these defenses diminished once the 'Treaty of Paris' brought the Seven Years' War to an end in 1763. In time, the palisade line faded from memory.

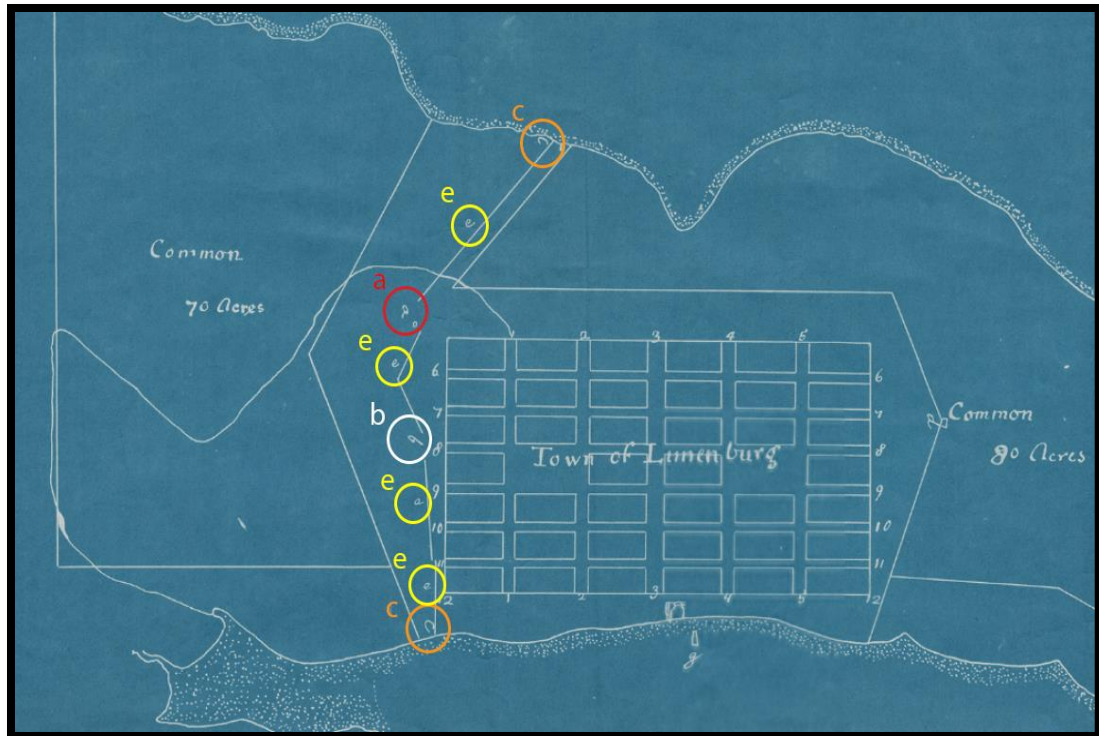


Figure 5: Lunenburg ca. 1770 (North at top). SOURCE: Map Collection, Nova Scotia Archives, Halifax F/239-1770.

Indicated on this map and labeled in the legend are the western defenses:

- a: A pentagon fort with a blockhouse and barracks
- b: A tetragon fort and blockhouse
- c: c: Two small blockhouses
- e: e: e: picket lines on the west side of town

The American Revolution brought a new sea-based threat to Lunenburg in 1782 and attention was given wholly to fortifying the two eastern fortifications of the town (Booth 1785). An 1820 map of the Town (Great Britain Army Royal Engineers) suggests that the western fortifications were no longer standing by this date. Similar to Lunenburg, defenses at Halifax and Louisbourg are reported to have fallen into disrepair within 10 years of construction. As the settlements grew, attention was increasingly directed to the ocean approaches (Young 1980:43; Johnston 2007:10). Being outside of the town plot, there appears to be no available records referring to any official reuse of the land until 1894, at which time it became home to the Lunenburg Academy.

## THEORY

### 2.1 Geophysics

Magnetic susceptibility is a property of all materials that indicates the degree to which the material itself can be magnetized in response to a temporary, external magnetic influence. Determining variations in soil susceptibility within an archeological study area can often identify the nature and scope of subsurface, anthropogenic generated features. Many factors influence the strength of the soil susceptibility. The higher the susceptibility, the greater the concentration of iron oxides. Soil magnetism is a proxy for the presence or absence of archaeological features, defined as “the ease with which a material can be magnetized” (Dalan & Bevan 2002:8). Apparent magnetic susceptibility is the weighted average of the magnetism of iron oxide minerals collected in the field (Dalan & Bevan 2002:784). The response to the induced temporary magnetization (i.e. from the EM38B) is measured as the “ratio of intensity of the induced field to that of the magnetizing field” (Clark 2003:99). Mafic rocks generate a strong susceptibility response because of the high magnetite content (Clark 2003:99–101; McNeill 2013:1–3). The utility of the EM38B has been demonstrated in Kings County, Nova Scotia, where the use of mafic rocks as the preferred building material at archaeological sites has drawn local geophysical attention (Fowler 2006; Fowler 2014).

It has been shown that enhancement of magnetic susceptibility over archaeological sites is not always predictable and is strongly dependent on individual site conditions

(Linford 1994 and Weston 2002 [Aspinall 2008:26]). Topsoil naturally accumulates a greater amount of iron-oxide minerals than the substrate beneath it. The presence of hematite, maghemite, and magnetite in the soil makes it possible to use electromagnetic sensing technology to detect archaeological sites (Aspinall 2008:23; McNeill 2013:1). Hematite is the most commonly occurring mineral in the soil. It exists naturally in an oxidized state, which has a weak magnetic susceptibility. Through the process of reduction and re-oxidization the magnetic states of this mineral can be enormously enhanced as it is chemically converted to the highly magnetic state of maghemite, and then to magnetite (Clark 2003:99–102; McNeill 2013:1–3; Aspinall 2008:22–26).

It has been demonstrated that anthropogenically influenced topsoil has a high concentration of iron oxides that lead to enhanced magnetic susceptibility. Activity such as a concentration or removal of topsoil, or long exposure to low burning fires (the La Borgne effect) often magnetically enhances these minerals (McNeill 2013:5; Aspinall 2008:23). In an environment with decayed wooden posts, bacteria have been found that enhance soil magnetism by converting the naturally occurring hematite into magnetite crystals (Fassbinder *et al.* 1990 [Aspinall 2008:25]). Subsequent to the process of decay, features receive further magnetic enhancement through pedogenesis (soil formation) (Aspinall 2008:24–25; Dalan & Banerjee 1998: 3; Kvamme 2003:441; McNeill 2013:2–3). Originally suggested by Le Borgne (1965), the oxidation/reduction cycle is stimulated through periodic wetting and drying of the soil (Dalan & Banerjee 1998:4). Ultrafine grained magnetite accumulates during this process, magnetically enhancing the soil. If a pit or ditch is filled with magnetically enhanced soil it will create a contrast to the surrounding soil susceptibility, generating a surface response (Dalan & Banerjee 1998).

There are two types of electromagnetic induction meters, which have been used worldwide in reading measurements of susceptibility: the Slingram apparatus, which has two separate magnetic dipoles, and the Barrington Ltd. coincident loop apparatus, which is the preferred instrument utilized by British archaeologists in topsoil susceptibility surveys (Benech & Marmet 1999:32). The EM38B is an example of an inductive, conductivity/susceptibility Slingram apparatus, which simultaneously measures the electrical conductivity and the apparent magnetic susceptibility of terrain. The EM38B was originally designed to measure soil conductivity with the quadrature component and to detect soil salinity and ground water contamination (Clay 2006:82; McNeill 2013:1). Over the years the usefulness of the susceptibility component has increasingly been demonstrated in archaeological mapping.

An electrical current is generated in the transmitter coil producing a primary magnetic field in the earth and receiver coil, allowing the measurement of the quad-phase secondary magnetic field as a function of soil conductivity (Figure 6). Furthermore, the induced magnetic field acts on iron-oxide minerals in the soil to align them with the primary magnetic field from the transmitter coil, generating a smaller secondary inphase magnetic response (McNeill 2013:1). The strength of the secondary field is compared to the primary field, which is proportional to the magnetic susceptibility of subsurface features. The influence of the quad-phase response generated by the electrical conductivity is expressed as apparent conductivity (McNeill 2013:10; Dalan 2008:3). The ratio of the secondary field to the primary field, is calibrated in parts per thousand (susceptibility- inphase response) or, milisiemens per meter (conductivity- quad phase response) (Gaffney & Gator 2006:42). Carrying the instrument just above the landscape



allows variations in local susceptibility to be directly measured, providing the EM38B with greater spatial resolution between anomalies than magnetometers (McNeill 2013:11).

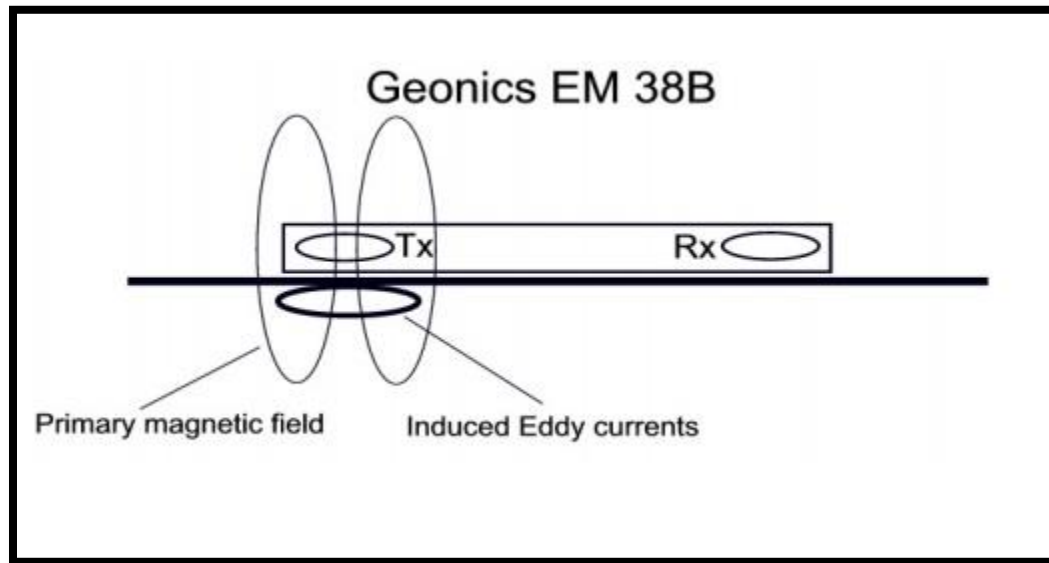


Figure 6: The EM38B generating primary and induced magnetic fields, where Tx represents the transmitter coil and Rx represents the receiver coil. SOURCE: McNeill 2013.

The distance of separation and orientation of the two magnetic dipoles determine the depth of investigation. As demonstrated by Tabbagh, when comparing horizontal versus vertical orientation as a control of the depth of investigation, perpendicular coil arrangement allows for the greatest extent to be measured (1986:191). Subsequent research has confirmed that the instrument performs best when operated in vertical dipole mode. This orientation generates the most valuable information for archaeological surveys as it is able to effectively measure the inphase susceptibility to a depth of 0.5m to 1.0m and quad phase to a depth of 1–1.5m (Benech & Marmet 1999:32; Clay 2006:83; Dalan & Bevan 2002:799; Dalan 2006:177; Dalan 2008:4; English Heritage 2008:36).

The limited maximum investigation depth is ideally suited to detecting near surface features and changes in topsoil susceptibility. Thin horizontal layers of material

immediately beneath the surface generate a variation in vertical susceptibility. As depth of measurement decreases, magnetic response strength increases, until it peaks at a depth of 0.2m (McNeill 2013:8). At the Cahokia Mounds State Historic Site the magnetic footprint of a significantly disturbed feature was revealed in a susceptibility survey (Dalan 1991; Dalan 2008:7). Two core samples taken from this site demonstrated higher values at the surface that decreased with depth and stabilized at the subsoil, showing that magnetic susceptibility can be useful in detecting archaeological resources in the subsoil to a certain depth (Dalan 2006:162).

The gentle slope of decay in susceptibility readings can cause the induced magnetic field to contribute to the inphase measurements and lead to erroneous interpretation of the results. In a study that obtained confirmation of laboratory conclusions over an experimental test site, Benech and Marmet demonstrated that the rate of decay of the response was least pronounced in the EM38B than in the other induction meters. Thus it is less sensitive to the superficial effects of surface anomalies and conductivity levels (1999:39). It is a function of the design to differentiate the ground magnetic susceptibility with the conductivity of the artificial field, thereby allowing more concise measurements of subtle near surface features (McNeill 2013:5).

Magnetic noise is a detrimental parameter that impacts the collection and interpretation of data. It can have a significant influence on the readings of all types of geophysical survey instruments. Some instruments are more susceptible to this effect than others. The signal-to-noise ratio is used to measure the ratio of the intended electric/magnetic signal to the background noise (Aspinall 2008:77). This measurement can be then used to determine the quality of the final reading. Magnetic noise has been

categorized by Aspinall according to the origin of the interference (2008:78). Operator noise is generally the result of a novice user, and can be alleviated or minimized through conscientious field practice. This includes the reaction of the operator to the obstacles presented by vegetation and topography, and an operational noise, which can be rectified by removing the presence of ferrous objects around the instrument while it is in operation. More random aspects of human error are harder to control, such as inconsistent gait, poor surveying posture, and consistently maintaining a close distance between the instrument and the ground. Coherent instrument noise is another variable on signal interference. Some instruments are prone to drift from the initial baseline and need to be readjusted from time to time (Aspinall 2008:79). The EM38B is vulnerable to temperature change during the surveying period, particularly when being used to gather inphase data. The instrument is designed to correct for thermal drift. Nonetheless, good surveying methodology dictates that the instrument be raised to a height of approximately 1.50m for roughly 5 seconds at the beginning and end of each survey line. This secures a true zero reading to help correct for sensor drift during data processing (Dalan 2008:4).

The geologic signal-to-noise ratio, of which the geological makeup of the subsoil is a direct factor, is an important control for spatial resolution in data quality (Aspinall 2008:79). Most geophysical anomalies of archaeological interest measure above 0.2 parts per thousand (ppt.), however, if the background noise level for the survey area is lower than the 0.2ppt. signal level, then anomalous areas with greater susceptibility will be reflected in the contour map as extremely warm colours. If the prevailing magnetic activity (i.e. background noise) of a site is high, then the definition of the archaeological feature will be muted (McNeill 2013:30). Overhead power cables can have a slight

overall effect on the survey data, as the interfering signal can influence the zero levels during equipment setup. Other variables, such as wire fencing, underground power cables, vehicles, buildings, and pipelines, can affect survey results and create false anomalies (Gaffney & Gator 2006:81–83). Therefore, knowing the details of the survey area in advance of data collection can significantly improve data processing and results.

Use of the EM38B is only appropriate under the right environmental conditions and is restricted to open areas, as ground cover interferes with the operation of the instrument. Reliable results depend highly on the subsurface geology (McNeill 1980; Dalan 2006; Gaffney & Gator 2006:78). Anything that may result in instrument buffeting (including wind) will increase noise levels and generate respective errors. As the instrument needs to be dragged near the surface, vegetation must be cut and cleared before gathering the data (Gaffney & Gator 2006:80). Well soiled areas produce the best results, as rock can interfere with magnetic susceptibility levels, as can discarded metal objects (Scollar 1990:9–25).

Soil stratigraphy that has been disturbed by anthropogenic movement, mixing, or deposition tend to be softer, more porous, and more or less, conductive or magnetic than the undisturbed stratigraphy. Cultural earthworks destroy the natural stratigraphy and cohesion of the soil; affecting density, porosity, and permeability, which can alter the electrical properties. If there is a greater concentration of topsoil in the feature, a high magnetic response will be detected, whereas loading with subsoil will result in lower magnetism than the surrounding undisturbed soil (Dalan 2008:7). Moreover, the structure of the soil has effects on the surface vegetation colour and water retention (Scollar 1990:37).

## 2.2 Aerial Photography

As technology improves, archaeological aerial photographs are increasingly being applied as a terrestrial remote sensing tool. Among other ground features, this research methodology is dependent upon crop growth, which is a response to soil conditions, that provide a rare vantage point of a survey area for detecting archaeological features that have been removed from the landscape (Heywood *et al.*, 2006:56). Crop marks can be a useful tool in archaeological research when photographed from the air. Backfilled ditches are better conductors of water to the vegetation above and encourage vegetation growth known as positive crop marks. Buried stone features restrict the supply of water, negatively affecting growth and create negative crop marks (Scollar 1990:50–52; Aston 1997:17). The utility of this type of terrestrial remote sensing is determined by variables such as the time of year and time of day. (Heywood *et al.*, 2006:57).

The angle at which the aerial photograph is taken is important in determining the spatial resolution of the image and later interpretation. Oblique images (bird's-eye-view) are the most useful when looking at archaeological resources because they are more adept at picking up shadows and contours (Aston 1997:17; Heywood *et al.*, 2006:57). These images are highly complementary to the analysis of geophysical results and the application of GIS landscape archaeology techniques (Heywood *et al.*, 2006:57; English Heritage 2008:49). The extent of aerial photographs taken for archaeological purposes is much greater in Great Britain than in North America, however, the catalogues that do

exist in North America are often not taken at the right time of year for features to be revealed by the surface vegetation (Kvamme 2003:454).

There is a bank of aerial photographs dating from the early 20<sup>th</sup> century at the National Air Photo Library in Ottawa, which were originally taken for the purpose of land surveying. Locally, these images are purchased by the Nova Scotia Department of Natural Resources (DNR) from the Federal Geographic Data Service, GeoNOVA, and consist of the most up to date images. They are organized by provincial box number, and those pertaining to this study fall in 21A 7 (Lunenburg) and 21A 8 (Italy Cross). Three hundred dpi (dots per inch) scans are available from the DNR library for free, and high resolution 600 dpi and 1800 dpi scans can be ordered from the NAL or GeoNOVA directly.

## METHODOLOGY

To investigate the accuracy and value of the EM38B relative susceptibility component in archaeological mapping, this thesis generated a comparative geophysical data set for Area 1 to evaluate the archaeological potential of Gallows Hill. To achieve these goals, the research methodology consisted of the following components: background study, archaeological mapping; experimental research component; and, data processing.

### 3.1 Background Study

The objectives of the background study were to determine the archaeological potential of geophysical anomalies and establish a timeline of British occupation within the study area from documentary evidence. The background study includes a review of archaeological and/or historic research undertaken on the construction and life span of British era palisades, an examination of archival documents and sources relating to historic activities within the study area, and a review of relevant secondary source literature that may provide insight for the survey data gathered.

Research was focused on the location and identification of the palisade wall and other architectural features considered to exhibit high potential for subsurface archaeological remains. The research included an audit of relevant historical documents and records, such as available military records, historic maps, local and/or regional

histories, and other archival sources (Appendix B). A cursory review of palisades in archaeological literature was conducted in order to determine the nature of archaeological remains that might influence an electromagnetic susceptibility response. Topographic and geological maps and aerial photographs were consulted in order to identify landscape features that correlate with the documentary and geophysical data (Appendix B) (e.g. geomorphological features, cultural disturbance, crop growth, and soil moisture content). The historical and cultural information was integrated with the environmental and remote sensing data to identify the potential of archaeological features within the study area and to provide a framework for the interpretation of responses from the experimental research component.

### 3.2 Archaeological Mapping

The objectives of the archaeological mapping were threefold. The first aim was to conduct a non-invasive archaeological investigation of the study areas. The second was to determine the nature of the geophysical anomaly in Area 1, tentatively identified as the potential remains of the Gallows Hill palisade, through background research. The third objective was to document the utility and accuracy of the EM38B susceptibility component as an archaeological research method in the detection of shallow trench and wood features.

In order to achieve comprehensive coverage of the survey areas, the archaeological mapping included the collection of seven highly resolved data sets (Table 1) that explore the effects of tightening interline spacing in identifying subsurface features or other signs



of occupation. Particular attention was paid to the linear anomaly in the 2013 survey results, which had the potential to be the palisade wall. The survey grid of Area 1 was anchored over this anomaly and the experimental research component was designed to test the susceptibility component over an experimental trench feature (Figure 7).

**Table 1:** Electromagnetic Surveys Gathered

Study Area	Significance	Planar dimensions (m x m)	Interline Spacing
Area 1	Area survey	18x15	1m
			0.5m
			0.25m
Area 2	Preliminary area survey	15x15	1m
	Post-trench area survey		1m
	Post-trench sub-grid	6x5	0.5m
	survey		0.25m

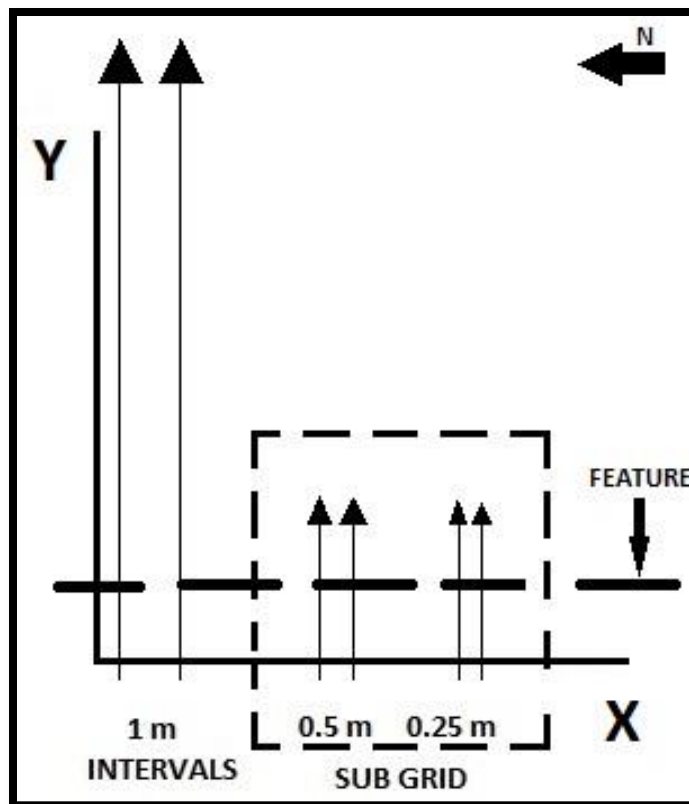


Figure 7: Hypothetical survey methodology, showing transect alignment and interline spacing within the survey areas.

## Area 1

The Area 1 data were gathered on November 9<sup>th</sup> 2014 (Figure 8). For the 2013 survey a 60x60m grid had been established in relation to the rear wall of the Academy building.



Figure 8: 2011 aerial photograph of Area 1 (North at top). The red polygon indicates the Lunenburg Academy property. The 2013 survey grids have been overlain and the present study area is indicated by a red square within the overlain image. SOURCE: Centre of Geographic Sciences 2011314-154; survey grid diagram adapted from Fowler 2014.

Encompassing most of the western lawn of the Academy property, the survey grid was divided into three sub-grids, A, B, C to accommodate the large area. The strongest response from the anomaly in the 2013 results was in the western quadrant of the former grid B. Gathering data over this entire 60x60m area was unnecessary, as our focus was the linear anomaly. Therefore, our new survey grid was established within the relevant portion of the original grid B (Figure 9).

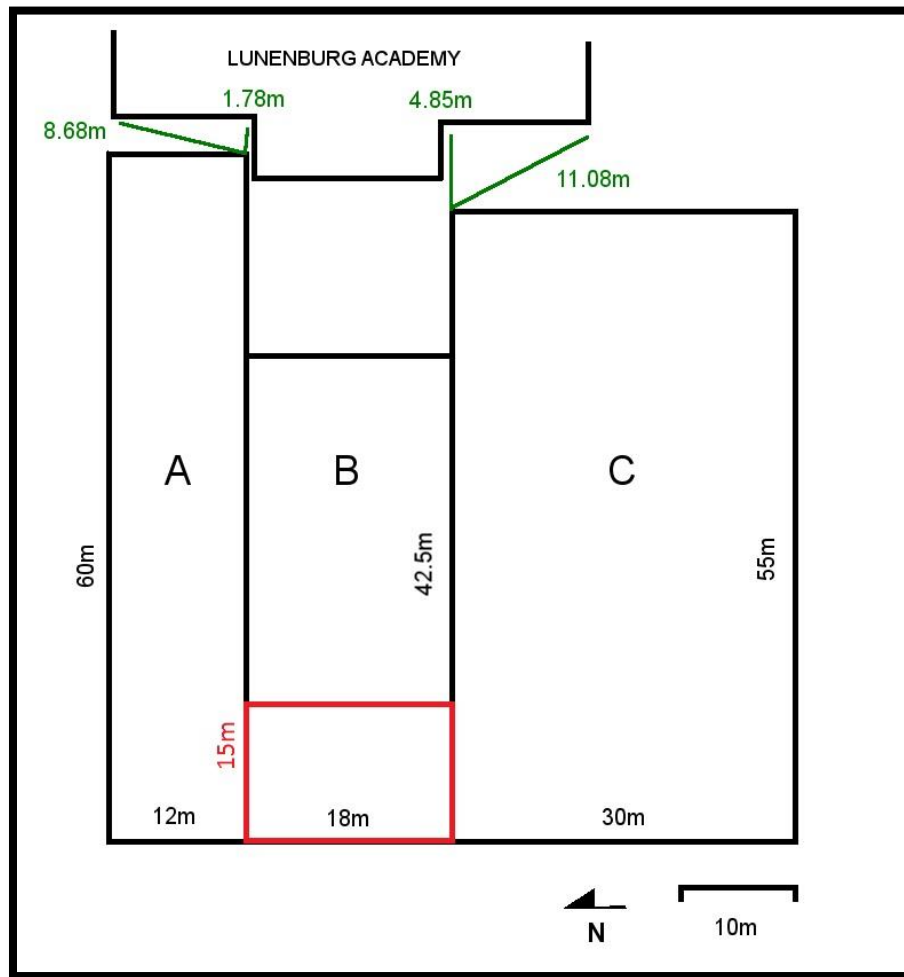


Figure 9: Plan of the 2013/2014 survey grids in relation to the Lunenburg Academy Building. SOURCE: Adapted from Fowler 2014.

The 2014 survey crew consisted of 6 members: Allison Fraser, Jonathan Fowler, Sara Beanlands, Katie Cottreau-Robins, Jeff Turner, and Robyn Baschynski. While on

site we experienced an average temperature of 11.5°C and average relative humidity of 82.71% (Environment Canada 2014). These conditions were similar to those during the 2013 survey.

The methodology employed within each study area was standard. Each grid was established with 100m tapes to encompass known geophysical features (Area 1), and the corners were anchored with plastic pegs at Area 2. The survey grids were oriented on a magnetic north axis with the start line at the northwest corner of the survey grids. Once the instrument was calibrated in vertical dipole mode, the data was gathered in parallel transects oriented east-west.

## Area 2

The second set of data collected at Area 2 was gathered on November 21<sup>st</sup>, 2014, with Allison Fraser and Nicolas Parsons as the field crew (Figure 10). The day was an average temperature of (1.35°C) and an average relative humidity of (59.5%) (Environment Canada 2014). It was not necessary for all three of the interval surveys to encompass the entire grid as the purpose was to gain detailed survey results of the trench feature, and one area survey of the 15x15m grid was gathered at 1m interline spacing. Following this, a 6x5m sub-grid was established with a cushion of 2 metres on each side of the trench. The sub-grid was anchored to the original grid on the X-axis from 2 to 8m and along the Y-axis at 10 to 15m. Within this sub-grid, two electromagnetic surveys were gathered at 0.50m and 0.25m interline spacing.



Figure 10: 2011 aerial photograph of Area2 (North at top). The study area is outlined in a red polygon. SOURCE: Centre of Geographic Sciences 2011308-044.

### 3.3 Experimental Research Component

The archaeological mapping also included an experimental research component to better understand the anomaly in the Area 1 survey results and to provide a control for exploring the limits of susceptibility data gathered over similar trench features. The objectives of the experimental research were to generate a susceptibility response for an earth filled trench of known dimensions, comparable to British era North American palisades, and contribute to a literature on the accuracy of the EM38B inphase component

in archaeological mapping and non-invasive remote sensing technology, for detecting subtle features.

A comprehensive search within Lunenburg County to secure a comparable study area was informed by geologic and topographic mapping, and a review of historic and modern aerial photographs. The strategy for excavation was developed through a range of geophysical theory and examination of geologic data and historical archeological documentation, including, palisade dimensions, proximity to ferrous objects or objects that generate an electromagnetic field, subsoil and bedrock type, presence of near surface anomalous objects, and regional location. Four of the data sets were gathered in Area 2 and included a preliminary area survey at 1m interline spacing to identify the lowest area of magnetic response to assist in selecting the site for the experimental trench.

An experimental trench was excavated as a method of testing the sensitivity of the EM38B inphase component on the subtle disturbance of earth features in the organic magnetic field (Figure 11). The trench was dug, backfilled, and subjected to several electromagnetic susceptibility surveys under the assumption that, by altering the stratigraphy, the susceptibility could be disturbed and generate an anomalous response in the readings. In an effort to determine the identity of the Gallows Hill linear anomaly as military architecture, the experimental trench was designed with the known dimensions of an 18<sup>th</sup> century North American palisade trench. If an anomaly was generated by the experimental trench, it could be compared with the Area 1 linear anomaly. Very little electromagnetic susceptibility research has been conducted on such features.

Archaeological reference to decomposed palisade features *in situ* on the North American landscape was important reference material for this research component.



Figure 11: Ground breaking research; executing the experimental trench at Area 2. Camera facing south, the measuring tape demonstrates 1m length. October 29th, 2014.

The utility of the EM38B depends on the environmental conditions of the site. To ensure accurate results between the study areas National Soil Database (NSDB) and Provincial Geological Survey maps were consulted to understand the geologic variables. The underlying geological conditions of both sites are similar enough to maintain consistency in the readings: sandy loam subsoil with glacial till, well drained, and the same bedrock type (Table 2). Sitting at the base of a hill, Area 2 has relatively flat topography, whereas Area 1 is classified as a part of the “Wolfville loam-drumlin phase” (NSDB 1957); a minor detail for the survey conditions.

Area 2 is cleared land that was used as a horse paddock from at least the 1970s until recently (W. Eisener, personal communication, October, 2014). The study area is located less than 30 metres from the Trans-Canada Highway 103. Power lines once crossed the south east corner of the study area, before the Highway was constructed in the 1940s.

There is a wide, shallow hole in the eastern quadrant of the survey grid where a

**Table 2:** Geologic conditions of the study areas. SOURCE: NDSB 1957 & 1966; Keppie 2000.

	Gallows Hill	Eisener property
Soil Type	Wolfville loam-drumlin phase	Bridgewater sandy loam
Description of surface and subsoil	Dark brown loam over yellowish red loam or sandy clay loam	Light brown sandy loam over yellowish brown or olive brown sandy loam; salty
Parent Material	Reddish brown sandy clay loam till; firm	Olive sandy loam till; firm and very salty
Topography and drainage	Undulating to drumlin relief; well rained; internal drainage moderately rapid to moderately slow	Gently undulating to undulating, well drained; internal drainage moderately rapid
Underlying geology	Meguma Group - Halifax Formation: slope-outer shelf slate, siltstone, minor sandstone and Fe-Mn nodules (in places metamorphosed to schist)	

wooden telephone pole once stood until it was subsequently removed after being damaged by a tractor (W. Eisener, personal communication, October, 2014). There is another shallow, but wider, hole of unknown origin to the north of the grid. Scattered across the southern portion of the study area are patches of exposed bedrock, the largest of which is within the western limit of the survey grid.

For the experimental trench, an area was cleared of vegetation and a 15x15m area grid oriented to magnetic north was dug. The data for the preliminary area survey was gathered in the afternoon of October 29<sup>th</sup>, 2014: the day had an average temperature of (15.48°C) and an average relative humidity of (95.6%) (Environment Canada 2014). These were ideal conditions for operating the EM38B as it is sensitive to atmospheric constraints. The field crew for this survey consisted of three members: Allison Fraser, Brittany Houghton, and Duncan McNeill. For the purposes of this preliminary survey,



one data set with transect intervals of 1m interline spacing was sufficient. Once the preliminary survey was completed the results were examined, line by line, in the field on the Allegro logger. An area of low relative susceptibility was selected in the northwestern quadrant for the experimental palisade trench (Figure 12).

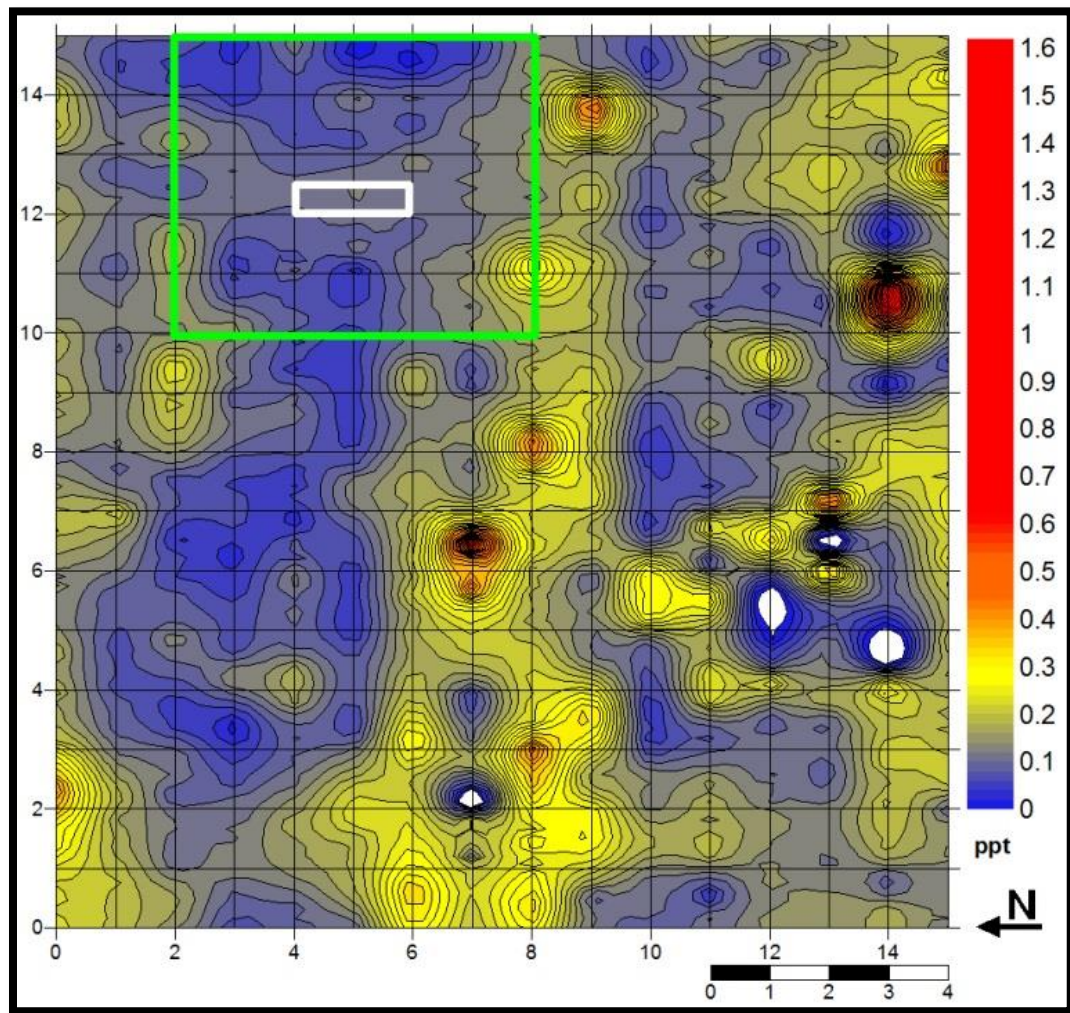


Figure 12: The preliminary 1m transect interval survey results showing the area selected for the sub-grid (green rectangle) and the trench area is indicated by a white rectangle.

The experimental trench was oriented north-south to ensure the closest possible comparative susceptibility data set to Area 1. The trench was anchored to the main grid at (4, 12) to (6, 12), and (4, 12.5) to (6, 12.5). The dimensions were 50cm wide, 50cm deep, and 1m in length, derived from the average measurements of 18<sup>th</sup> century British palisade

trenches in the archaeological record (Young 1980:38–50cm wide, 50–76cm deep; Babits & Gandulla: 30–121cm deep, 45–60cm wide). The field crew included: Allison Fraser, Brittany Houghton, and Maxime Tardy. The corners of the grid were marked with plastic pegs so that the dimensions could be preserved for the second data set to be collected. Once excavated, details about the trench were recorded with lot summary forms. The plough zone followed a 6-10cm sod layer; there was a consistent A horizon of dark brown sandy-loam (5YR3/2), with no mottling. This stratum was of medium-hard compaction, with small and medium glacial till inclusions, on average 25cm in diameter with a few larger size rocks. There was no change in the soil stratigraphy and no B horizon was reached.

### 3.4 Geophysical Data Processing

The archaeological mapping included processing the data and 2D plotting as contour maps to visualize and analyze the susceptibility results (Appendix C). The data were recorded and evaluated in the field with an Allegro data logger and transferred to a computer for further refinement. Using Geonics Limited Dat38BW (2002, version 2.3) profile handling program, the survey geometry was adjusted, corrected for thermal drift, further refined for data analysis, and converted for 2D and 3D plotting. Using the point Kriging method, each data set was plotted as a colour contour map in the Golden Software Incorporated (2008) Surfer 8 surface mapping program.

## RESULTS

The following research details, documents and literature from the historic and/or archival record of the Gallows Hill/Lunenburg area. Maps of Lunenburg from 1753–1879 gathered from the Nova Scotia Archives provided the basis for the architectural history of Area 1. Aerial photographs supplemented the limited number of archival documents or secondary sources that mention the western defenses. This dearth of documented information is also noted by archivist D.C. Harvey in a letter that reads in part: “There do not seem to be any plans or reports in the Dominion Archives showing the appearance of these blockhouses, and only one that gives a rough idea of their location [see Walter 1755]” (Harvey n.d.).

### 4.1 Background Research

Preliminary title searches at the Land Registration Office and historic land grants from the Nova Scotia Archives yielded no clues as to the use of the property prior to the construction of the Academy in 1894. Military, government, and similar archival documents provide the greatest insight into past activity on Gallows Hill. The journal and letters of Lieutenant Colonel Charles Lawrence, in particular, provided detailed information regarding the town defenses.

As part of an aggressive British military strategy to eradicate the French hold on Acadia, and weaken the Mi’kmaw and Acadian presence, the British constructed Fort

Edward (Pisiquid), Fort Vieux Logis (Grand-Pré), and Fort Lawrence (Beaubassin) (Johnston 2007; Bell 1961; Plank 2001; Young 1980). In response to the increased British naval and military presence, the French increased the number of warships in the North American theater, and created an alliance with Native Americans (Johnston 2007:10). Louisbourg was returned to the French in the 1748, Treaty of Aix-la-Chapelle (Johnston 2007::32). In response to this treaty, the British established Halifax and Lunenburg, and populated them with “foreign Protestants”, primarily composed of German, French, and Swiss settlers (Harvey 1953:IV). Chebucto Bay (Halifax), which had similar geographic characteristics to Lunenburg, was established in June 1749. The defenses of Chebucto Bay (Halifax) were better documented than Lunenburg. Both settlements would have required similar defenses.

Under the joint leadership and guidance of Governor Peregrine Hopson and Lieutenant Colonel Charles Lawrence, the town of Lunenburg was established in June of 1753 with approximately 1,453 “foreign Protestants” (Harvey 1953:IV). Lunenburg was picked for its good harbour, cleared land, and better soil coverage than nearby places on the coast (Bell 1961:404). The site offered a major advantage of being on a 6,000 acre peninsula that could be easily enclosed by a palisade (Bell 1961:431). According to Bell, the Acadian presence had diminished to 8 families by 1745(1961:430). In 1753 only the man “Old Labrador” and his Native-Acadian family were left of the former population of Mirliguèche (DesBrisay 1895:18). Previous inhabitants had cleared a 300-400 acre tract of land at the neck of the peninsula, which Lawrence and the surveyor Captain Charles Morris designated this as common land (Harvey 1953:IV, 19). “A True Copy of a A [sic] Plan of the Town of Lunenburg Garden Lotts [sic] and Commons adjoining” (W.S.

Morris n.d.) illustrates the area chosen for the Gallows Hill fortifications in relation to the town plot (Figure 13).

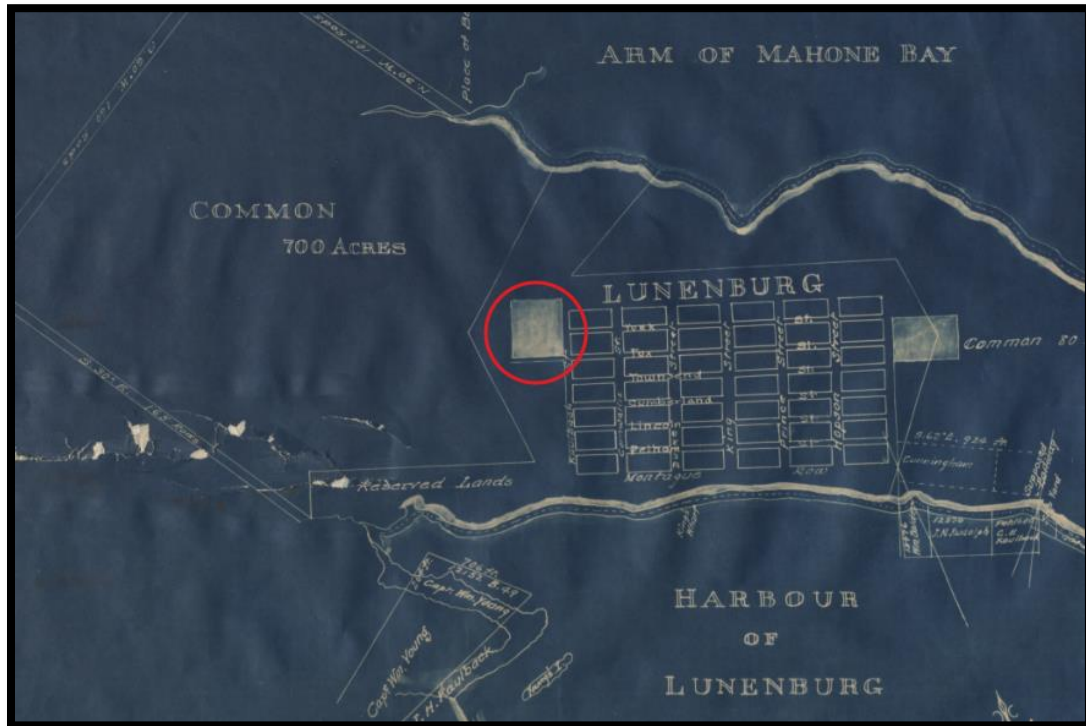


Figure 8: Detail of “A True Copy of a A [sic] Plan of the Town of Lunenburg Garden Lotts [sic] and Commons adjoining” (W.S. Morris .n.d.) (North at top) illustrates the town layout as planned under the supervision of Governor Hopson before the settlers arrived. The Gallows Hill fortification area is indicated with a red ellipse. SOURCE: Nova Scotia Archives V7/239-1753.

When the first group of settlers arrived on June 8<sup>th</sup>, a guard was stationed on Gallows Hill to monitor the fresh water brook at the head of Back Harbour and the cleared land leading to the forest (Harvey 1953:4). On different occasions, in letters to the Lords of Trade, Governor Hopson expresses concern over the French and Native alliance (Bell 1961:414; Harvey 1953:14). Having received a report on May 29<sup>th</sup> 1753 that a party of Mi’kmaq warriors intended to raid the settlement that June (Brymner 1894:192), fortifying the settlement became a priority. Documents referenced by Harvey, state that initially two blockhouses were constructed in June 1753 on Gallows Hill and Blockhouse Hill; the former having been replaced soon after by a pentagonal fort (n.d.:file #1). The

decision was made to run the palisade from Back Harbour east up the side of Gallows Hill, across the western face and back down the south side to Lunenburg Harbour (Bell 1961:420).

The town blockhouses were completed by June 15<sup>th</sup> and Lawrence immediately commissioned men to commence with “digging the trench and cutting ye pickets for ye line of defense” (Bell 1961:423; Harvey 1953:4, 16, 23). He estimated that with the distance measured “upwards of 3,000 pickets... will be sufficient for ye line from water to water” (Harvey 1953:23). In a letter to Governor Hopson on June 16<sup>th</sup>, Lawrence indicates that metal spikes were used to secure the pickets of the palisade line: “140 lb. at least of spike nails, 5 ½ inches in length, are wanted for securing ye picketing, since without them it is impossible... that it can stand” (Harvey 1953:20).

By July 7<sup>th</sup>, the palisade was nearly complete; however, Lawrence considered the distance between the main blockhouse on the brow of the hill and the end of the palisade at each harbour was too great. As a result, Lawrence constructed a small fort at the water on either end of the palisade to better secure those points (Harvey 1953:24). Confirmed by Lawrence in a letter to Hopson dated August 8<sup>th</sup>, 1753, the palisade had been completed (Harvey 1953:40). A “Memo Of Blockhouses, etc., 1753” describes the complete western defenses: Garrison blockhouse, on Gallows Hill; a blockhouse by the burial ground; a blockhouse on back of shore below Labroane’s [sic] [Labrador’s?] garden; a blockhouse on the Back Harbour, opposite Mason’s [sic]; and a picket fence from Fort to Fort, from Front (Lunenburg) Harbour to Back Harbour (DesBrisay 1895:31). Within the first year and a half of the settlement the crude blockhouse was

replaced by a pentagonal fort and barracks surrounded by “around 100’sq of pickets” (DesBrisay 1895:33; Bell 1961:428).

The first known illustration of these fortifications is “A plan of Lunenburg Harbour Nova Scotia” (Walter 1755) (Figure 14). This map shows the town plot, enclosed by a fence and five adjoining bastions. Two of these bastions appear to overlook the valley west of Gallows Hill, one to the north brow and one to the south brow. No forts are depicted at Gallows Hill on the Doroti Mango 1767 “Plan of the Township of New Dublin, Lunenburg, and Chester”; however, this plan does acknowledge Battery/Fergusons Point. Now well known as Battery Point, Mango makes a distinction between the names, indicating a recent change and the beginning of major efforts to permanently fortify the east side of the settlement. When this map was redrawn by William McKay in 1834 the fort on Blockhouse Hill was the only extant fortification and is the only fort indicated on the map (Cuthbertson 2002:52).



Figure 14: Detail of “A plan of Lunenburg Harbour” (Walter 1755) (North at top). Labrador’s farm is shown in relative to the palisade that encloses the town. SOURCE: Nova Scotia Archives V7/ F/239-1755.

There were no troops stationed at Lunenburg in the first few months of settlement, only a militia. Colonel Monkton was dispatched with 200 soldiers to quell an insurrection among the settlers in December of 1753, and they appear to have returned to Halifax shortly after the situation was brought under control (Hewitt n.d.:25). A 1755 military document referenced by Hewitt describes the growing danger outside of the palisade, as well as the unrest within, resulting in an additional 120 English soldiers being stationed at Lunenburg in the spring of 1755 (n.d.:25). In 1756, at the culmination of hostilities surrounding the Seven Years War, 152 soldiers were garrisoned at Lunenburg. The 1760 “Treaty of Peace and Friendship” between Great Britain and Mi’kmaq alleviated the threat of Native aggression and regular troops were subsequently withdrawn to Halifax and a local militia was established in their place (AANDC 2010).

The most detailed illustration of the fortifications is a ca. 1770 map (Anon.) (Figure 5). This map is unique in depicting a tetragonal fort and blockhouse on the south brow of Gallows Hill. There is little context for this map and it cannot be known for certain if it accurately describes the western fortifications as they were in ca. 1770, or if it is showing what was erected in the 1750s. Moreover, this may reflect only the planned fortifications rather than what was constructed. Lawrence, who oversaw the completion of the fortifications before returning to Halifax in September of 1753, recommended an additional fort on the hill but records nothing of its construction. The accuracy with which the legend depicts the other defenses supports the existence of a “tetragon fort and blockhouse”. The “King's Bay and Lunenberg [sic]” map (DesBarres 1776) (Figure 15) indicates Fort Boscawen and a fort on Gallows Hill, but nothing at all on Blockhouse Hill. Fort Boscawen and the fort on Gallows Hill seem to have been far more substantial



in 1776 than Blockhouse Hill and were notable landmarks from the harbour. The initial structure at Blockhouse Hill was not improved upon until it was brought to the attention of the Board of Ordnance in 1782 by American Privateers.



Figure 15: Detail of “King’s Bay and Lunenburg” (DesBarres 1776) (North at top) appears to show forts on Gallows Hill and Blockhouse Hill, indicated by red ellipses. SOURCE: Nova Scotia Archives Atlantic Neptune S35 N 34.

At the time of the 1782 ‘Sack of Lunenburg’—a result of hostilities toward the British during the American Revolution—the military at Lunenburg was lax. The Americans surprised the garrison at Blockhouse Hill who had no nearby source to call for reinforcements, and the blockhouse itself was destroyed (McCreath & Leefe 1982:300; Anonymous, n.d.; Russell 1977; Hewitt n.d.:26). Lieutenant William Booth visited the Town in 1785 to assess the damage caused by the American Privateers. Booth reports that the Blockhouse Hill fortifications are in need of repair, but makes no mention of the

state of the fortifications on Gallows Hill, suggesting that by 1785 they no longer played a prominent role in the protection of Lunenburg.

Often, place names tell a lot about the history of a site (Aston 1997:18). Originally known as Barrack Hill, it became the site of public executions during the late 18<sup>th</sup> century, thus earning the name Gallows Hill. There is only one known reference to these executions, that being “the Boutiler brothers” who were hanged there for murder in 1791 (Hewitt n.d.:144). After Confederation, public executions were made private. It would be useful to know how long public executions persisted in Lunenburg into the 19<sup>th</sup> century, as it might better define a period of existence for the gallows.

As part of an effort to protect British interests in Nova Scotia during the French Revolution, Blockhouse Hill and Fort Boscawen were rebuilt in 1793 (Hewitt n.d.:26; Cuthbertson 2002:40). According to Hewitt, when the War of 1812 was declared, some of the early fortifications had become unnecessary and “disappeared” (might this be a reference to those on Gallows Hill?), while others were in need of significant renovations (n.d.:26). Young and Hewitt discuss the improvements and additions made to the existing fortifications; it appears that Gallows Hill was not a part of these renovations (1980:27; n.d.:51). In addition to these accounts, no meaningful military architecture was addressed in the 1810-1834 issues of the “Report of state and strength of Forts and Batteries” (Great Britain Royal Engineers).

It is not clear if the buildings on Gallows Hill decayed *in situ*, or if the materials were intentionally removed and repurposed for military or civilian use elsewhere. If the western fortifications had been decaying since the 1780s as the historical record indicates, or the 1790s, by 1810 there might have been little structural remains. An 1820

map of “Lunenburg Harbour” (Great Britain Army Royal Engineers) (Figure 16) clearly indicates two functioning forts; one on Blockhouse Hill and one on Battery Point. Had there been ruins extant at Gallows Hill when the map was drawn, it is likely that these would have been included (Garry Schutlak, personal communication, October, 2014).

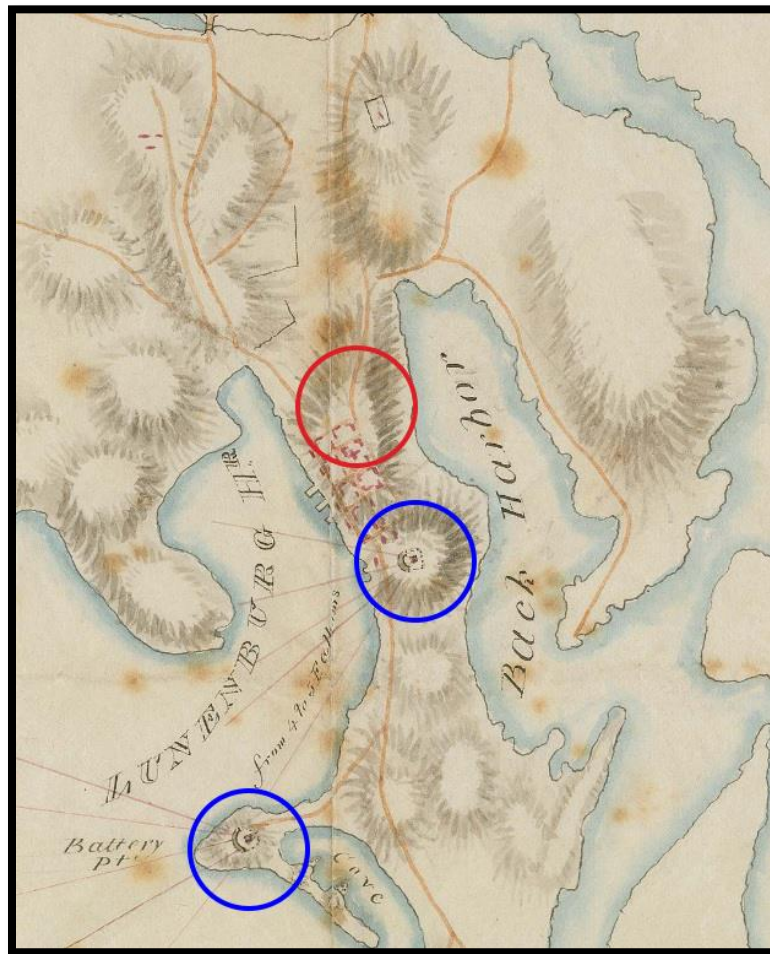


Figure 16: Detail of “Lunenburg Harbour” (Great Britain Army Royal Engineers 1820) (North at top) appears to show fortifications at Battery Point, Blockhouse Hill (indicated with blue ellipses) but none on Gallows Hill (indicated by a red ellipse). SOURCE: Nova Scotia Archives HG REO O.11.

This 1824 “Chart of part of the coast of Nova Scotia” (Bayfield) (Figure 17), appears to be the first map to illustrate Gallows Hill devoid of architecture. There is a suspicious cluster of buildings on a rise between the town plot and the head of Back Harbour. One of the structures appears to be the same as the symbol used for the Battery Point Fort.

Although features on the land are not depicted with detail by Bayfield, this may represent a new phase of development on Gallows Hill.



Figure 17: Detail of “Chart of part of the coast of Nova Scotia” (Bayfield 1824) (North at top), potentially showing a cluster of buildings to the north of the town plot (indicated by a red ellipse) Gallows Hill. SOURCE: Nova Scotia Archives Vol 3 Chart no 343 p66.

A detailed 1885 map of Lunenburg by A.F. Church (Figure 18), suggests that Gallows Hill remained devoid of structures into the late 19<sup>th</sup> century, and shows that although almost 100 years had passed since the fortifications became redundant, their memory survived, through the name ‘Barrack Hill’. It is important to note that buildings on maps by A.F. Church were often depicted with bias toward those who were his

subscribers or sponsors, and it is possible that this situation applied to Gallows Hill. The 1890 “Bird's Eye View of Lunenburg, Mahone Bay and Ritcey's Cove” (Anon.) (Figure 19) captured Gallows Hill in the background and depicts a barren hill top. It is likely that this illustrates the state of the hill, free of standing architecture, until the construction of the Academy in 1894.

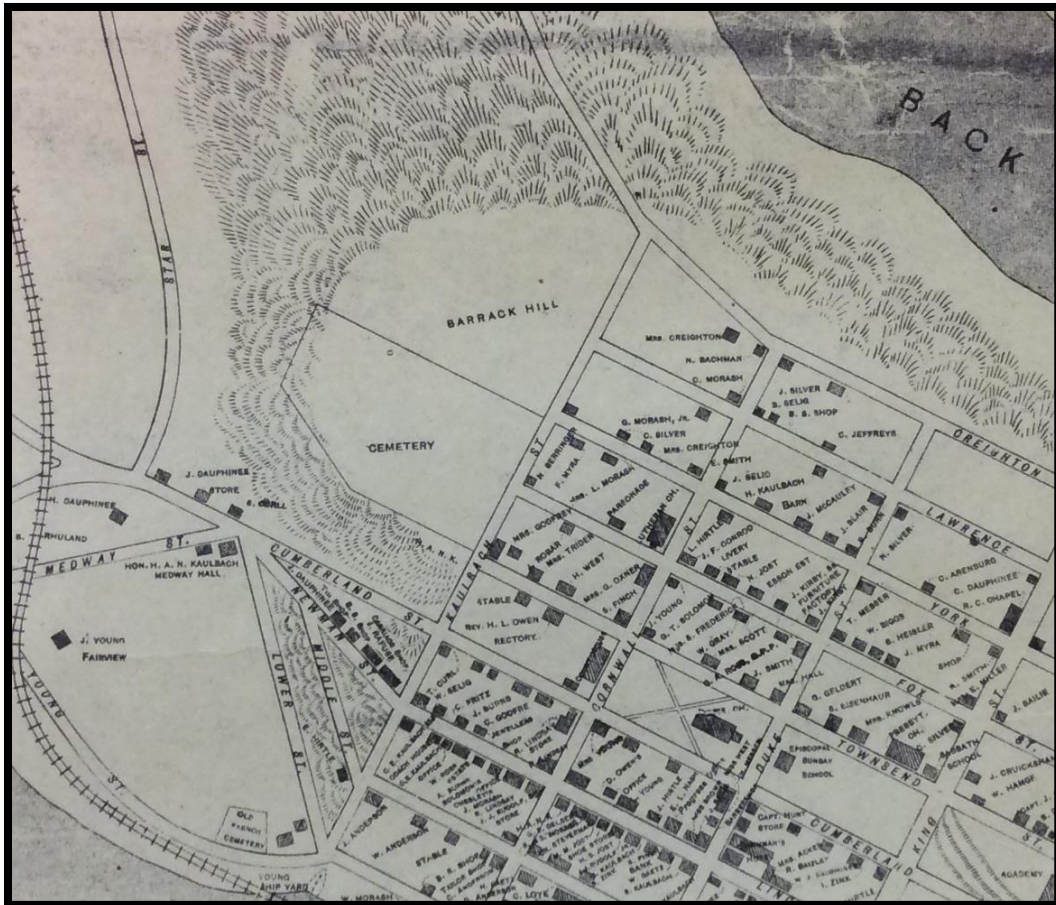


Figure 18: Detail of “Lunenburg Town” (Church 1885) (North at top), no structures are depicted atop Gallows Hill. SOURCE: Nova Scotia Archives A.F. Church Maps.

In 1893, the first Lunenburg Academy near the town parade was destroyed by fire (Hewitt n.d.:131; Parish & Hall 1993:62). New government mandates required that a school the size of the new academy have  $1 \frac{5}{8}$  acres of land associated with the grounds

(Cary 2013:11). The School Superintendent, MacKay, proposed Gallows Hill as a spacious site with good “elevation, drainage, and pure air” (Parish & Hall 1993:63).

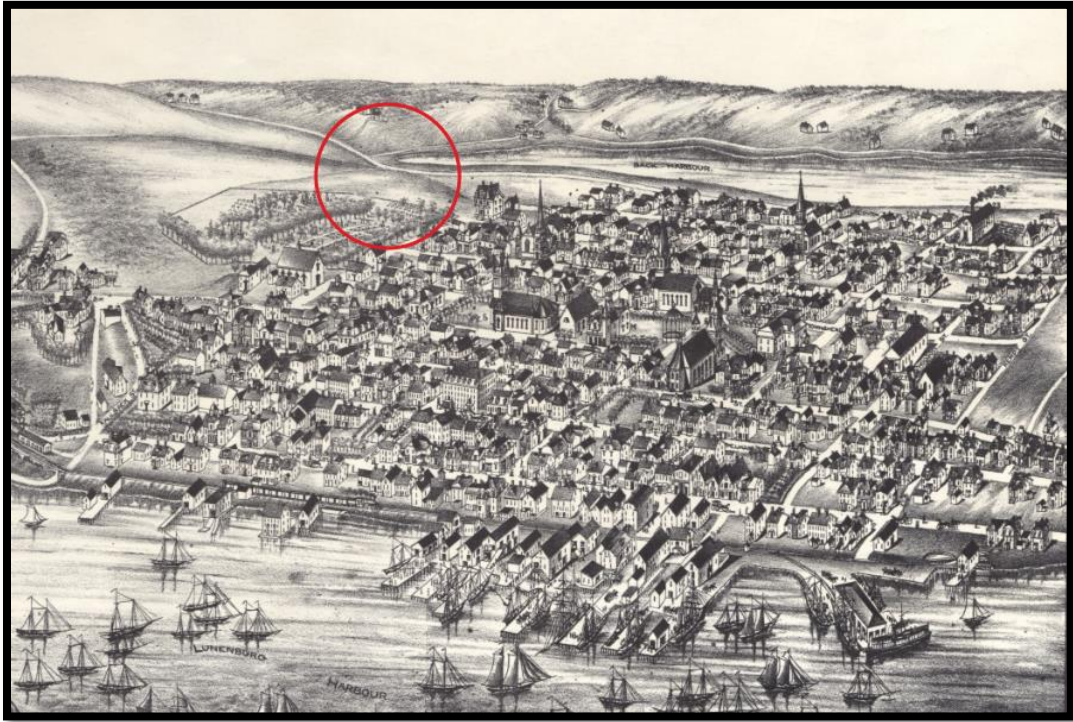


Figure 19: Detail of “Bird's Eye View of Lunenburg, Mahone Bay and Ritcey's Cove” (Anon. 1890) (North at top), also shows no structures atop Gallows Hill (the area indicated by a red ellipse). SOURCE: Nova Scotia Archivers NSA Map Collection 3.1.1.

Construction began in 1894 after the building tender was awarded to Harry H. Mott of St. John New Brunswick (Parish & Hall 1993:63; Cary 2013:11). A “Plan of Proposed School Lot at Lunenburg” (Ross 1894) shows the crest of Gallows Hill free of standing architecture at the time prior to the construction of the Lunenburg Academy (Figure 20).

It appears that, over time, the hill was the location of several military structures, a gallows, and the Academy that stands to this day. Although it does not give detail about the precise location of features on Gallows Hill, this narrative can help to narrow down the number, and possible identities, of anomalies in the geophysical survey results. The historical record concerning the construction of the Lunenburg Academy is readily

unavailable because most of these documents are located in the Archives of New Brunswick.

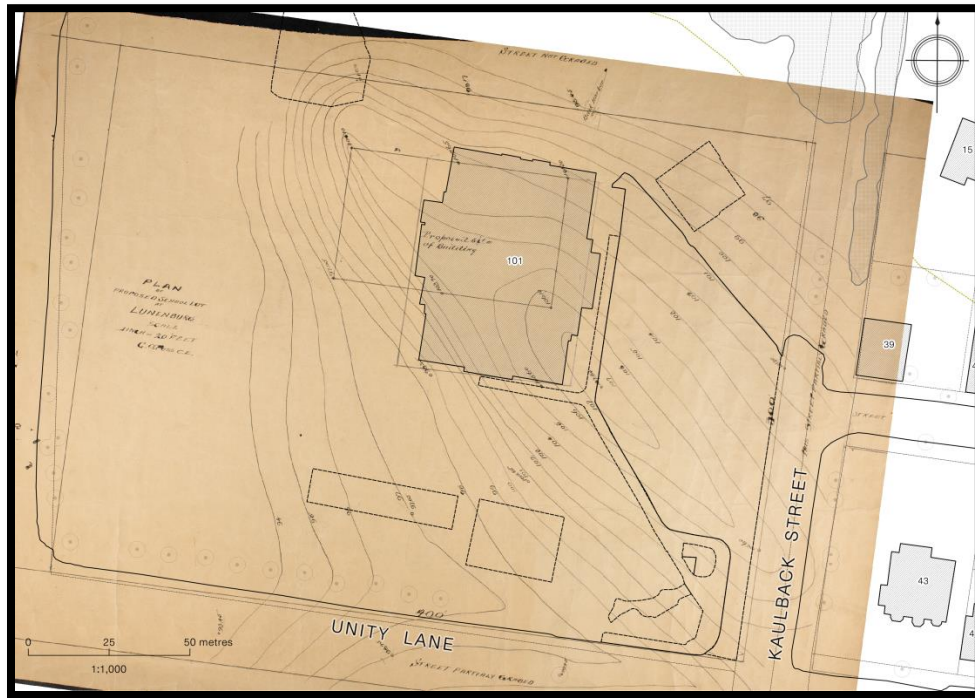


Figure 20: Detail of “Plan of Proposed School Lot at Lunenburg” (Ross 1894) (North at top), overlain on contemporary GIS mapping by H. Cary. SOURCE: Courtesy of H. Cary (NBA Mott Collection Acc. 164).

These may provide a basis for further investigation into the land records, allowing research backwards from the most recent known use of the property, eliminating any other possible structures.

#### 4.2 Historical Research

With the history of British occupation on Gallows Hill now outlined, we turn to the archaeological research and historical records of mid-18<sup>th</sup> century British military architecture to better inform the data interpretation and the experimental research

component. The sources describe British palisades as preserved in the archaeological record, providing insight into their materials, manner of construction, and dissolution.

As preliminary security measures, blockhouses and palisades served as expedient means of defense in times of war, often playing a minor role in the permanent defenses of a settlement (Young 1980:39). In Halifax for example, the first defenses were bastions, with barracks for 100 men, joined by a palisade encompassing the new settlement. Thirty feet of woods were cleared in front of the wall and labourers stacked the felled trees horizontally in front of it for extra reinforcement (Akins 1895:18; Young 1980:24). As the settlement expanded, these early fortifications became redundant and three peninsular blockhouses were built between the Northwest Arm and the Bedford Basin to serve the long term defensive needs of Halifax (Young 1980:24). In 1763, after the Treaty of Paris ended the Seven Years' War, upkeep of the defensive works at Halifax was abandoned until 1775 when pressure from the American Revolution created need to fortify the naval yard (Young 1980:43). After the threat of the revolution had passed the defenses were allowed to fall into disrepair until, 1795 when the defenses were renovated (Young 1980:45). This was also the case at Fort Anne, where the initial 1740s palisade was expanded upon in 1778, as need for protection grew with the settlement. Facing war in 1793, the defenses were strengthened and again expanded (Dunn 2004:222–228).

There is an obvious cycle of disrepair and reconstruction of temporary fortifications in time of need, which is reflected at Lunenburg. Batteries, blockhouses, and redoubts were never as strong as they should have been due to a constant turnover in military engineers and a failure to effectively maintain them, as the Board of Ordnance sought the least expensive and most cost effective construction methods available (Young 1980:39).



Although ideal designs were being drafted in Great Britain, the engineering principles used to construct European fortifications had to be adapted to the local conditions (Babits & Gandulla 2013:21). For instance, topography was a variable that was often encountered during construction and adapted for during the building process. Over a large piece of land several blockhouses could be joined together with pickets, or as demonstrated with the Lunenburg palisade, additional posts were incorporated, if the initial design underestimated the area to be protected (Young 1980:39). Construction materials also varied greatly from the stone used in Europe. Timber and earth were usually the primary building materials for the first phase of fortifications. Both were replaced eventually with stone, as required (Babits & Gandulla 2013:247).

Most repairs made to fortifications in North America were cheap and considered temporary, as government officials were only interested in effectively maintaining defenses, not improving them (Johnson 2007:50). In Nova Scotia, letters from Lieutenant General Edward Cornwallis indicated that fortifications with earthworks or wooden material deteriorated quickly and needed regular maintenance (Bell 1961:340). The short term quality of wood and earthen defenses is well demonstrated at archaeological excavations internationally. For instance, the palisade at Fort Umrevinsky in Russia, which was subject to a similarly harsh climate as that of colonial Nova Scotia, required major repair every 5–10 years and minor repairs were carried out every 29 years (Borodovsky & Gorokhov 2008:77). This pattern is also demonstrated in several New Brunswick examples. The small stockade built at Fort Howe (1777), Fort Fredrick (1758), and the Fort George picket line (1758), had all succumbed to decay and were almost in complete ruins by the War of 1812 (Young 1980:46).

The synthesis of the archival documents, historical research, and archaeological excavation provide context for the interpretation of the geophysical surveys conducted in this thesis, and better inform conclusions regarding the linear anomaly at Area 1. Direct historic reference and evidence from contemporary archaeological excavations aid in the understanding of construction and the nature of mid-18<sup>th</sup> century British palisades. The historical record of Gallows Hill alone cannot positively identify the subsurface anomalies at Area 1, or accurately inform the experimental research component. In an effort to provide context to the geophysical survey results, within the historical record, aerial photographs of Area 1 and Area 2 were collected. Photographs of Area 2 were consulted to inform the methodology of the experimental trench and inform the interpretation on the data sets gathered there.

#### 4.3 Aerial Photograph Interpretation

The large National and Provincial database of publically available imagery includes images from the 1930s to 2011. While the National and Provincial image series sources often overlap in coverage, there are also gaps in both. An exhaustive list of the Department of Natural Resources catalogue of the study areas has been compiled in Appendix B. Several of these images and two from the National Air Photo Library are applied to the interpretation of this data. Of particular interest are the 1976, 1992, and 2001 aerial photographs, which appear to show subsurface features at Area 1. The aerial photograph analysis of Area 2 revealed no significant features. This was an ideal situation as no features would interfere with the test trench results.

### Area 1

The earliest available image of Gallows Hill is from 1945. This black and white image shows a cleared landscape surrounding the Academy building. A row of broad trees delimits the western extent of the property; in 2015 only a few trees remain in this line. The next image was taken in the fall of 1976 (Figure 21).



Figure 21: 1976 aerial photograph of Area 1 (North at top), showing a very faint, light green crop mark within the study area, indicated by the red ellipse. SOURCE: Department of Natural Resources Air Photo Library 76327-165 (1976).

There is minimal landscaping over the area and Feature C from the survey results is clearly visible crossing the area diagonally from northeast to southwest. Along the western boundary of the property, just east of the row of trees is a very subtle, negative crop mark. This appears as a pale linear feature, particularly visible toward the north of the lawn and, seemingly, abutted by the gravel road.

Two positive crop marks are visible in a 1992 aerial photograph of Gallows Hill (Figure 22). Apparently taken over the summer months, this image shows a large, undefined, area

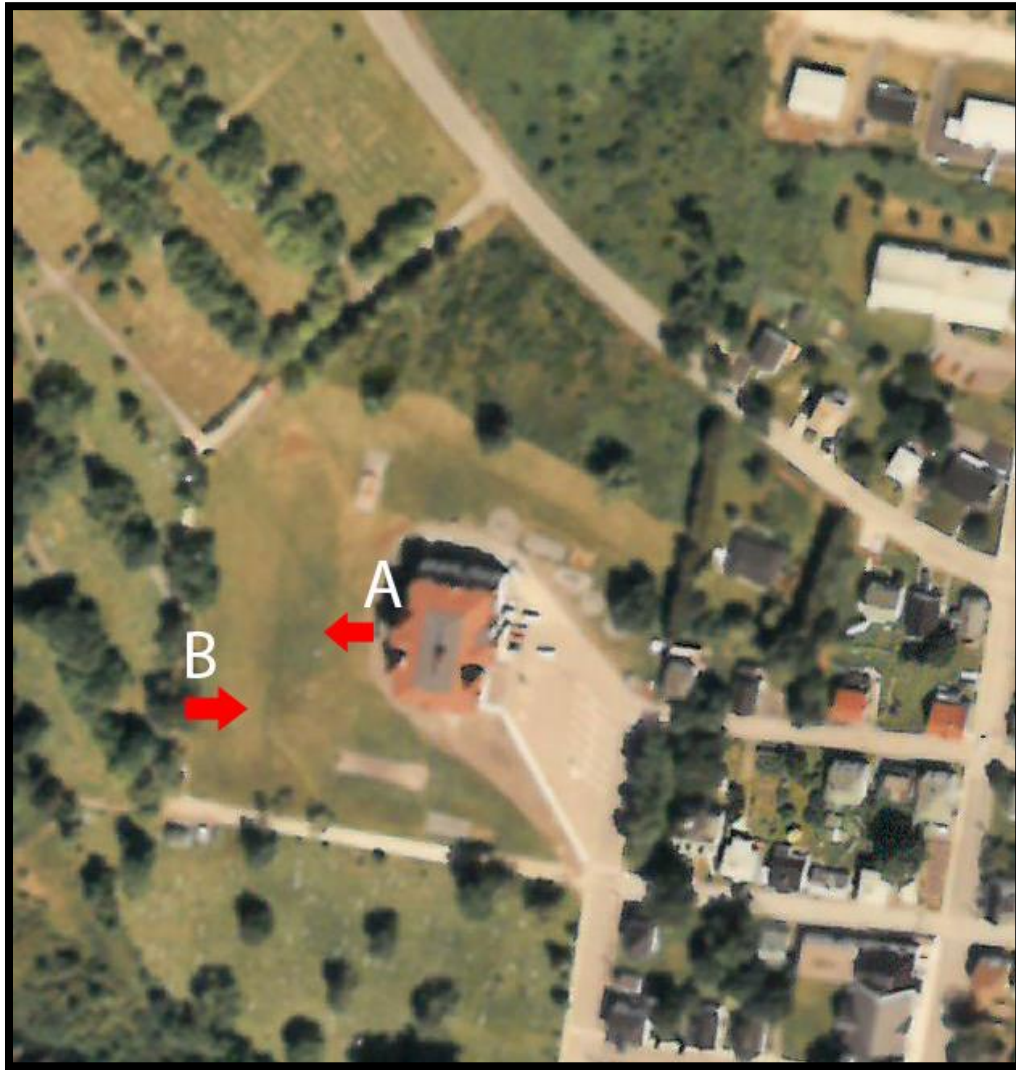


Figure 22: 1992 aerial photograph of Area 1 (North at top), showing an indistinct green Feature (A) and a faint, dark green, linear shaped positive crop mark (Feature B); indicated by red arrows. SOURCE: Department of Natural Resources Air Photo Library 92335-178 (1992).

of dark crop growth on the western lawn (Feature A) suggesting greater moisture retention in the soil. There is an obvious narrow linear anomaly (Feature B) extending north–south. This linear feature lays to the east of our Area 1 survey grid and appears to align with Feature A. The 2001 Gallows Hill photograph (Figure 23) shows an anomalous zone of light crop growth in the vicinity of Area 1 and may be an artifact of the subsurface features passing through the survey grid.



Figure 23: 2001 aerial photograph of the Academy property on top of Gallows Hill (North at top), showing an anomalous light green feature within Area 1, indicated by the red ellipse. SOURCE: Department of Natural Resources Air Photo Library 01312-260 (2001).

## Area 2

The earliest available image of the Eisener property is also a 1945 black and white image (Figure 24). What will become 'Isner diversion' is the main Trunk Road and the Trans-Canada Highway 103 is under construction. The image is significant because at this time the house had not been built and the lot was still forested. A small power line cut paralleling the Trunk Road crosses the southwest corner of the study area. Between 1955 and 1976 the land was cleared and the house that presently stands on the property was built. In the 2001 photograph a fence has been built, delineating the paddock area that contains the present study area. The site remains the same in 2015, and does not appear to have undergone any significant impact form anthropogenic alterations that may interfere with the geophysical survey results.



Figure 24: Aerial photographs of Area 2 (North at top):1945 (black and white) and 2011 (colour) showing 21st century development of the study area (indicated by a red ellipse). SOURCE: Department of Natural Resources Air Photo Library 8808-89 (1945), Centre of Geographic Services 2011308-044 (2011).

#### 4.4 Geophysical Survey Results:

##### Area 1 (Gallows Hill)

##### *Magnetic susceptibility*

##### 1m transect interval survey

The EM38B has proven effective for representing the faint linear anomaly from the 2013 survey (Feature A). This study has revealed a clear picture of the subsurface activity, illustrating four prominent features on the contour map (Figure 25). The object of this study is the central area of activity oriented north–south, which crosses the grid diagonally (Feature A).

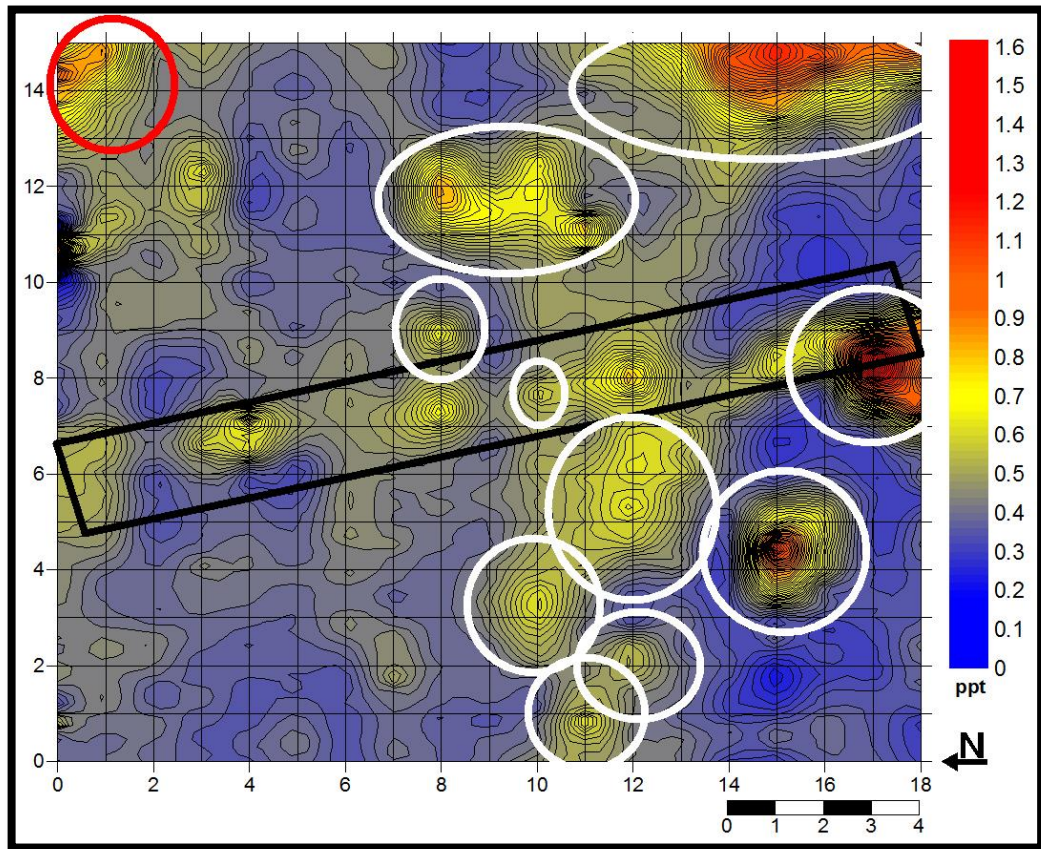


Figure 25: 1m interval inphase (magnetic susceptibility) results for Area 1, displayed as a contour map. Feature A is indicated with a black rectangle, Feature B components are indicated with white ellipses, and Feature C is indicated in red.

This feature appears to be a chain of susceptibility spikes between 0.5 and 0.9ppt., extending across the entire width of the grid from (0, 6) to (18, 9). Within these coordinates there appear to be at least 4 individual spikes in the data, each measuring roughly 50cm wide. Unfortunately, a distinct cluster of medium to high susceptibility anomalies trending east–west (Feature B), are dispersed across the southern quadrant of the grid from (7.5, 13) to (13, 13) with outlying scatter at (0.5, 15.5), (4.5, 15), (17.5, 8), and (12.5, 15) to (15, 13). A small area of high susceptibility (Feature C) is exhibited in the far northeast corner of the grid at (0, 13) to (2, 15): research has shown this feature to be an out of use grave road.

*Magnetic susceptibility*

0.50m 0.25m fine transect interval survey

The 0.50m and 0.25m transect interval surveys for Area 1 retain and enhance the four major anomalies in the 1m transect results (Figures 26 & 27). In tightening the interline spacing, the magnetic susceptibility of the existing Feature A anomaly has heightened and enhanced more subtle ones. With the 0.25m transect interval results the detail within Feature A more than doubles, showing at least 8 spikes of susceptibility. The more highly resolved data sets better illustrate the feature, which now appears as a line of many subtle susceptibility points. Feature B has been enhanced as well, further obscuring the view of Feature A. What appear in the 1m, and 0.50m maps as individual scatter have coalesced into a more or less homogenous east–west trending anomaly with a few scattered outliers in the 0.25m survey data. With more fine transect intervals the entire southeastern quadrant of the grid, between roughly (0, 11) and (6, 15), is overtaken



by an area of high magnetic susceptibility (Feature C), which dissipates to the northeast and southwest.

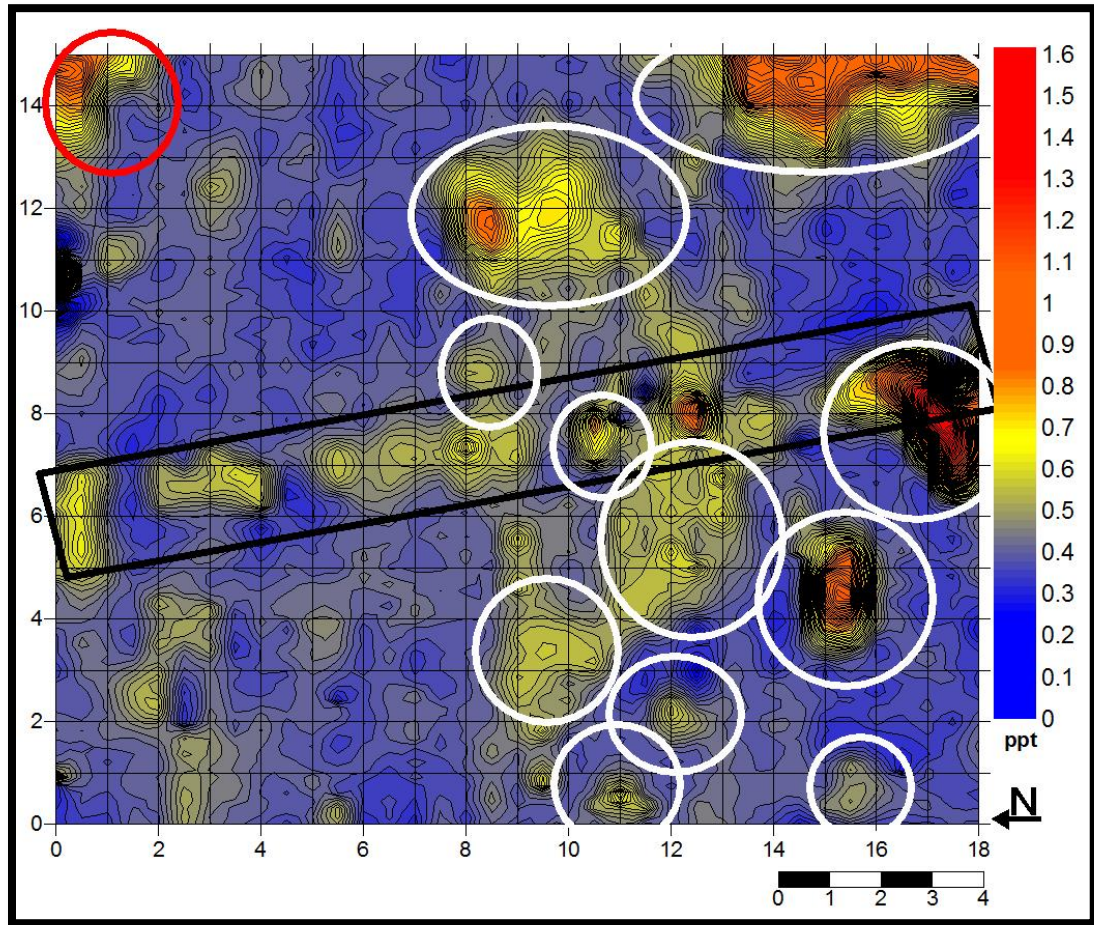


Figure 26: 0.50m interval inphase (magnetic susceptibility) results for Area 1, displayed as a contour map. Feature A is indicated with a black rectangle, Feature B components are indicated with white ellipses, and Feature C is indicated in red.

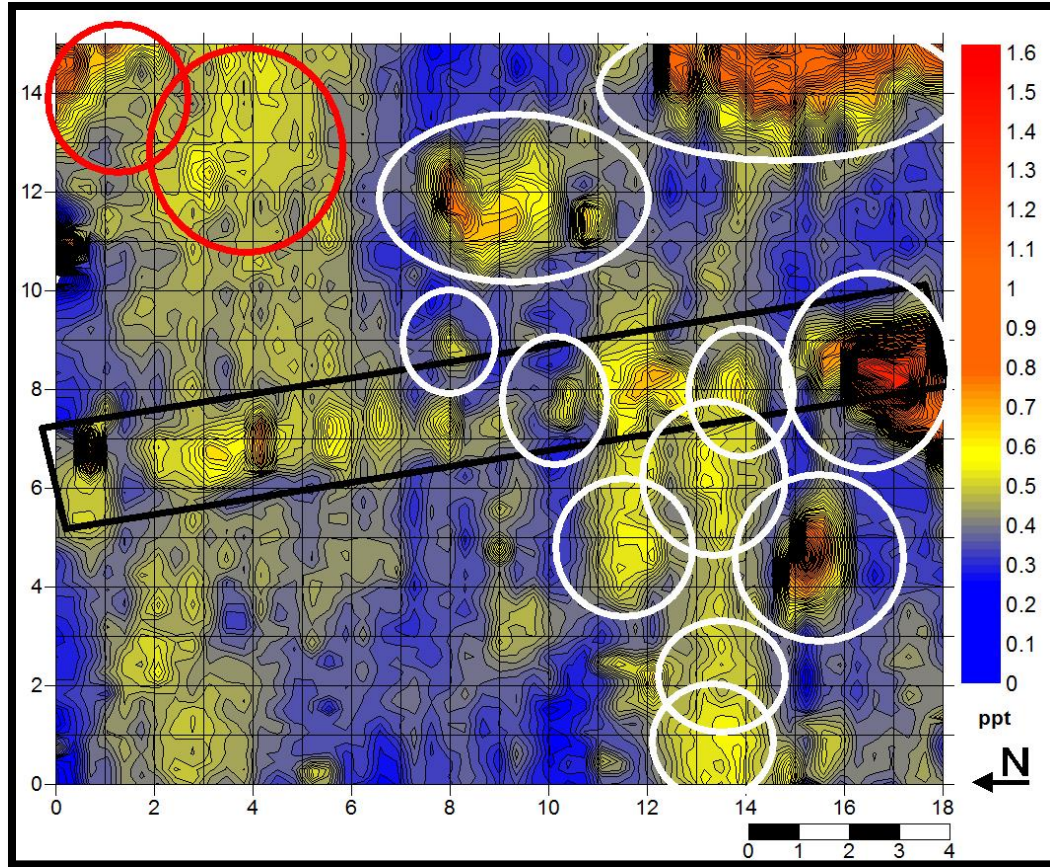


Figure 27: 0.25m fine interval inphase (magnetic susceptibility) results for Area 1, displayed as a contour map. Feature A is indicated with a black rectangle, Feature B components are indicated with white ellipses, and Feature C is indicated in red.

### Area 2 (Eisener Property)

#### *Magnetic susceptibility*

1m transect interval preliminary area survey

The inphase response for the Area 2 preliminary survey (Figure 28) is active with most areas emitting a susceptibility measurement over 0.4ppt. A central area of activity oriented east–west dominates the grid (Feature A). A scatter of anomalies in this group (6, 4) to (9, 4), (7, 6.5), (8, 8.25), (13, 7), and (8, 11), between 0.4 and 0.7ppt., is interference from near-surface bedrock. A significant spike in the susceptibility measurements lies to the southwest of the grid (Feature B), which may be a horse shoe, as

this was a paddock. Two areas of high response (Feature C) correspond to two large depressions in the surface of the survey area. In the north quadrant a shallow and wide hole has caused the anomaly at (2, 9), and toward the northeast edge of the grid a hole with a smaller diameter and about the same depth corresponds to the anomaly at (9, 14).

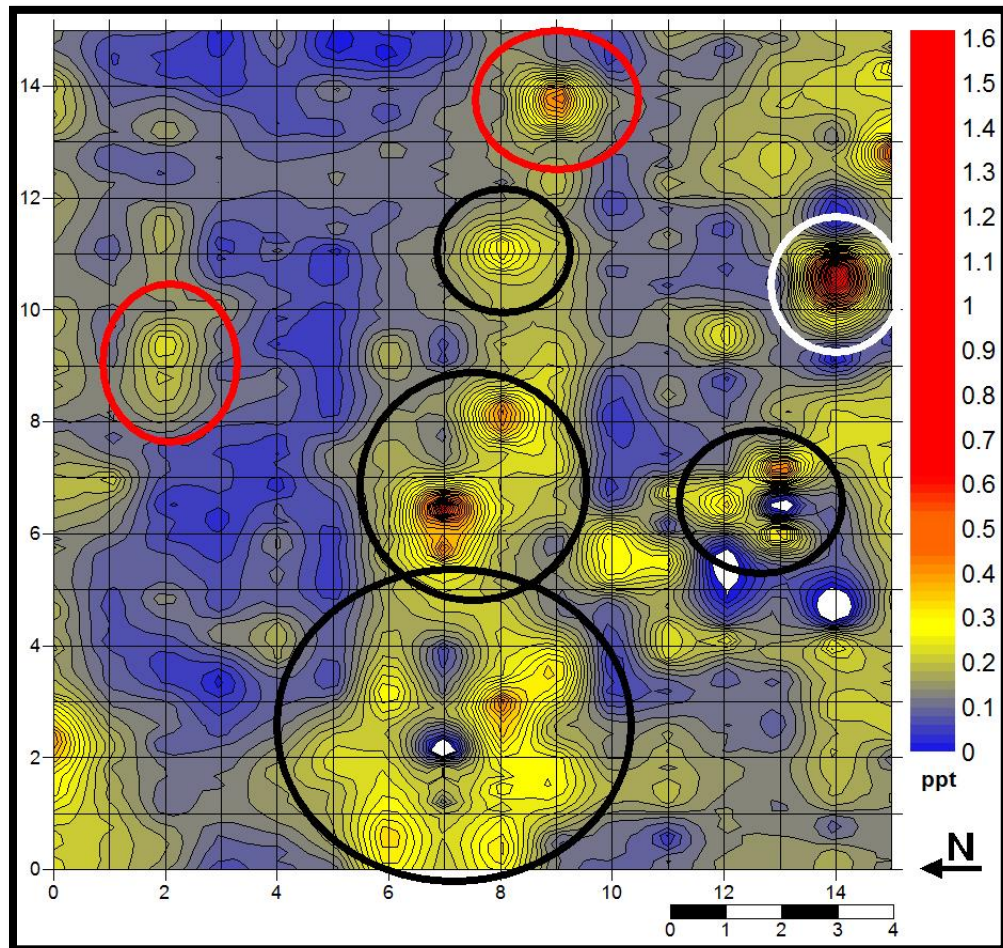


Figure 28: 1m interval preliminary inphase (magnetic susceptibility) results for Area 2, displayed as a contour map. Feature A components are indicated by the black ellipses, Feature B is indicated with a white ellipse, and Feature C components are indicated in red.

*Magnetic susceptibility*  
1m post trench area survey

The inphase response for the Area 2 survey gathered subsequent to digging the experimental trench appears identical to the preliminary survey results, detecting the

same four features (Figure 29). The dominating central area of activity generated by the near-surface bedrock is present, trending east–west on the grid (Feature A).

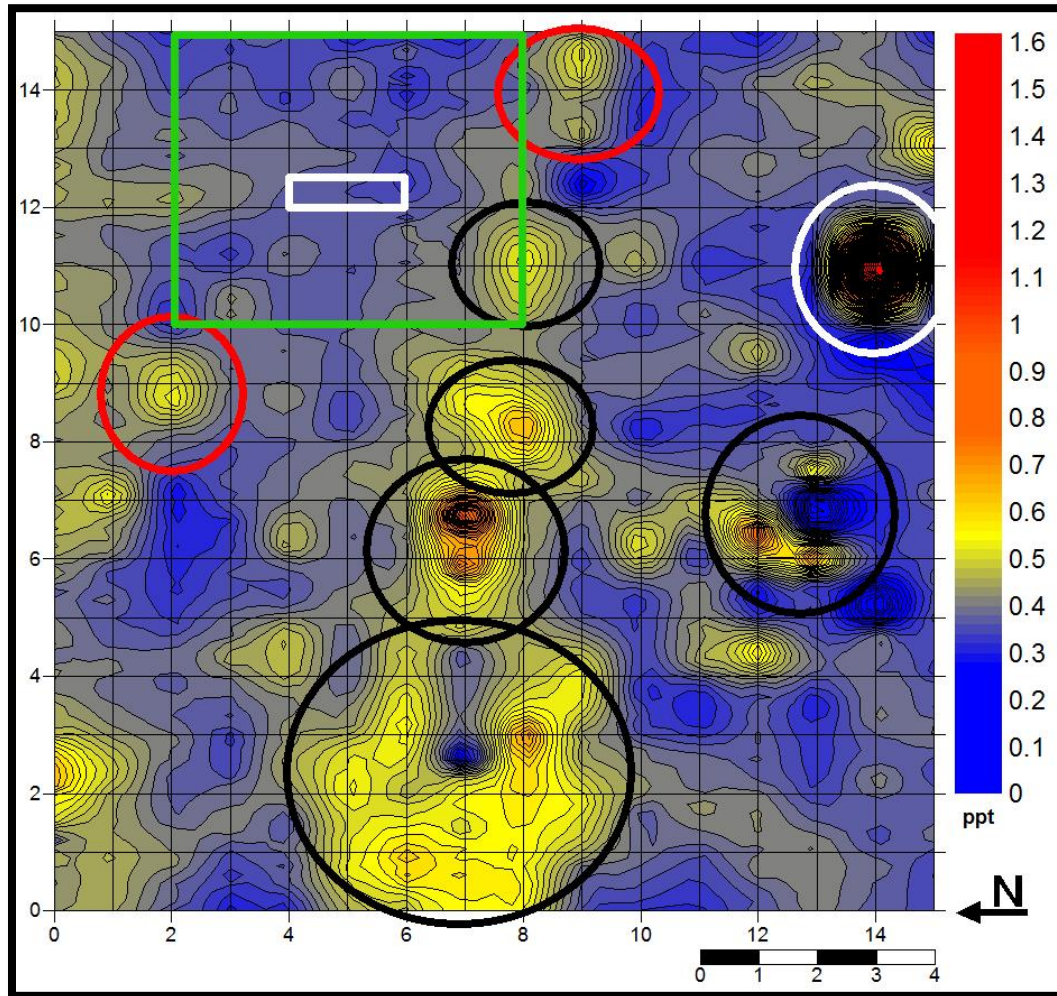


Figure 29: 1m interval post trench inphase (magnetic susceptibility) results for Area 2, displayed as a contour map. The sub-grid is indicated by the green rectangle and the area of the trench by a white rectangle. Feature A components are indicated by the black ellipses, Feature B is indicated with a white ellipse, and Feature C components are indicated in red.

The high response to the southwest of the grid (Feature B) is likely from a ferrous object, and the medium susceptibility responses of Feature C are present. There is continuity of anomalies between these two surveys, but the new data set does not appear to have detected any magnetic response from the experimental trench. Instead, this region provides uniform, distinctly low, susceptibility measurements. Had the trench generated a

disturbance in the stratigraphy of the subsoil organic susceptibility, or the iron-oxide rich top soil, then an anomaly would be indicated on the contour map.

*Magnetic susceptibility*  
0.50m fine interval post trench survey

The overall result of the fine transect interval surveys appears to be an enhancement of subtle anomalies in the 1m transect results. In the 0.50m transect contour map (Figure 30) these anomalies have been indicated by white ellipses (Feature A), where the magnetic response for many of these anomalies has been heightened.

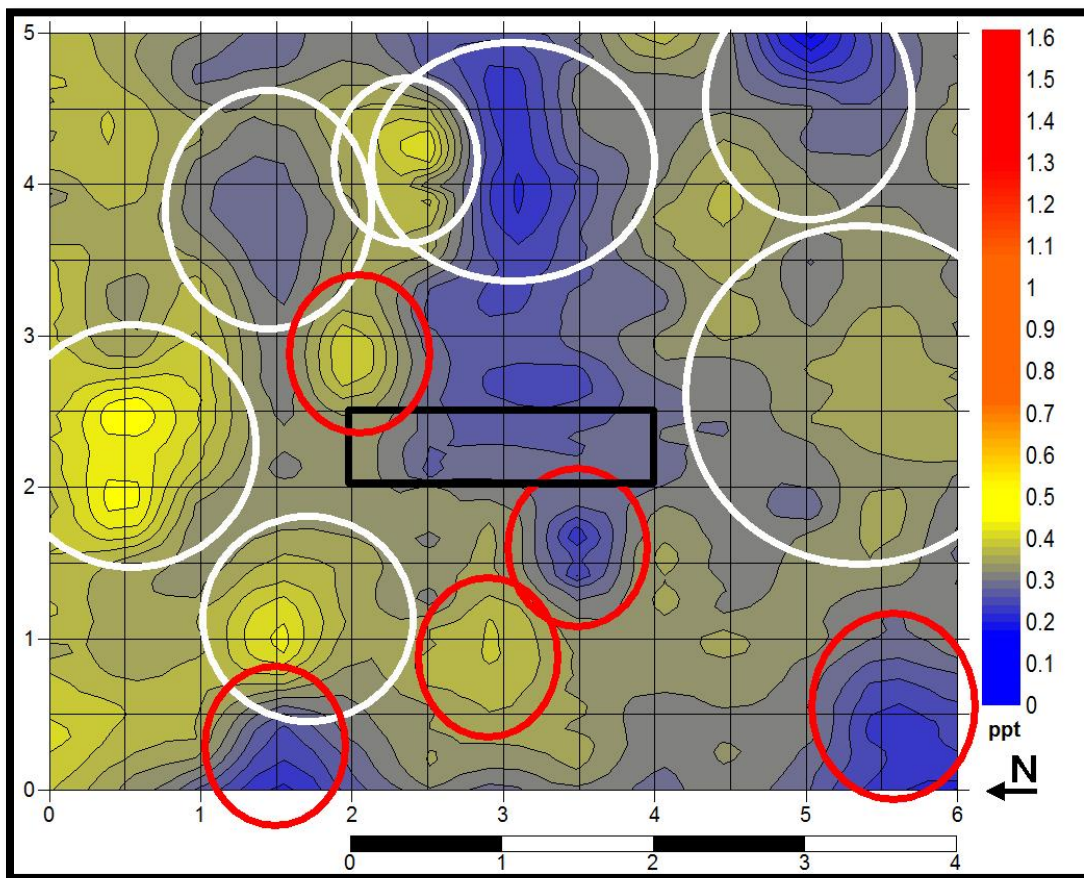


Figure 30: 0.50m fine interval post trench inphase (magnetic susceptibility) results for Area 2, displayed as a contour map. Feature A components are indicated by white ellipses, Feature B components are indicated with red ellipses and the physical location of the experimental trench is delineated as a black rectangle.

Others appear to have generated a lower response than indicated with the 1m transect contour map. New anomalies also appear in this contour map, and have been grouped together as Feature B. These new anomalies are a result of tightening the interline spacing and gathering stronger readings over an anomaly that the coarse interval survey was not able to detect. Of these, the most interesting is an area of low susceptibility in the southwest corner of the grid; this appears to be a response from exposed bedrock bordering that corner of the sub-grid. Within this chaos of anomalies lies an area with minimal magnetic noise and low susceptibility, the black rectangle in the contour map highlights the physical location of the trench feature. As the transect intervals were tightened no variation in susceptibility was detected in the readings over the trench.

#### *Magnetic susceptibility*

##### 0.25m fine interval post trench survey

Within the 0.25m transect survey an overall higher magnetic response permeates the grid, enhancing and linking individual points into anomalous zones of high susceptibility (Figure 31). Again, the susceptibility values of several anomalies are lower than the previous two post-trench contour maps, this is a result of tightening the interline spacing. The response of the entire southern quadrant of the grid has been heightened as the magnetic noise from Feature A and one of the Feature C anomalies in the 1m transect contour map have been enhanced by the tightening of the survey transects. Near-surface bedrock is present in the southwest corner of the sub-grid is the cause of the particularly low anomaly at (5.5, 0.75) and the anomalous zone of high response from (5, 2) to (6, 4) (Feature B). When examining the area within the black rectangle, tightening the transect

intervals has heightened the overall susceptibility of the area, but no distinct anomaly has appeared that can be related to the experimental trench.

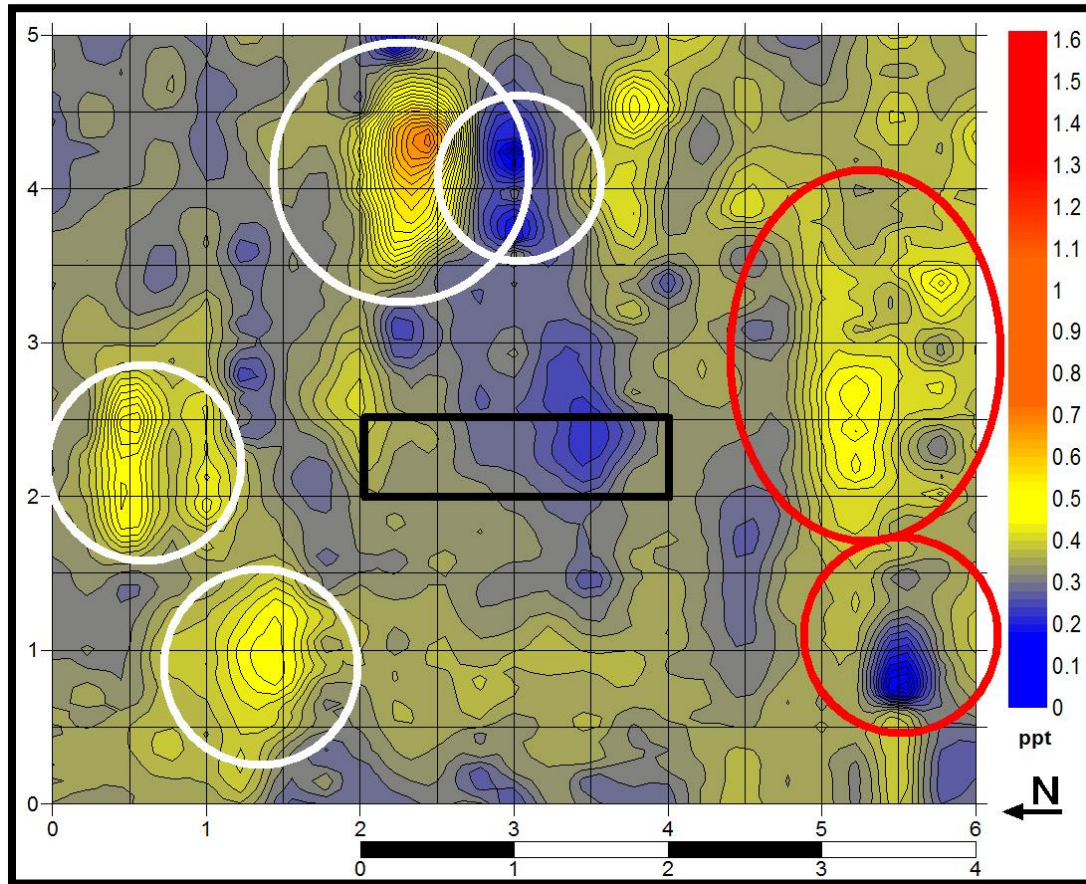


Figure 31: 0.25m fine interval post trench inphase (magnetic susceptibility) results Area 2, displayed as a contour map. Feature A components are indicated by white ellipses, Feature B components are indicated with red ellipses and the physical location of the experimental trench is delineated as a black rectangle.

## DISCUSSION

This project synthesized documentary evidence and geophysical data to determine the nature of the linear anomaly in Area 1, and to investigate the accuracy and value of the Geonics Ltd., EM38B relative susceptibility component in archaeological mapping. Although there are gaps in this narrative, the historical and archival research has contributed to a better understanding of the nature of the mid-18<sup>th</sup> century military architecture and subsequent use of Gallows Hill. To compensate for the absence of archaeological excavation to conclusively identify the anomalies identified in the Area 1 geophysical survey results, an experimental research component provided a comparative geophysical data set. The experimental research generated a susceptibility response for an earth filled trench of known dimensions, comparable to British era North American palisades. Documenting the effects of tightening transect interval spacing in detecting shallow trench and wood features.

The results of the geophysical surveys are somewhat mixed. The study did not determine whether the linear anomaly at Area 1 was a trench feature, however, the research was able to confirm the presence of the anomaly and provide useful insight into the effects of varied interline spacing. This research raised further concerns regarding the utility of the EM38B in detecting subtle earth features through the susceptibility component, and the composition of the subsurface feature producing the linear anomaly at Area 1. Although a review of available historical documentation has demonstrated that Area 1 is considered to exhibit high archaeological potential, the geophysical data



collected could not confirm the nature and/or significance of the linear feature. Future archaeological excavation would provide greater insight into the application of the EM38B as a technology for archaeological research. As Mick Aston has stated, “although an earthwork may appear to be a certain type of site, it is almost impossible to know for certain... without excavation” (1997:14).

### 5.1 Assessment of Results

Although the geophysical anomalies could not be identified, there is evidence to suggest that they are related to the mid-18<sup>th</sup> century military presence on Gallows Hill. There does not seem to be any other significant architecture on the hill that could account for the anomalies in the geophysical data.

Based on the historical research, the western defenses of Gallows Hill became redundant within 30 years of their construction. After the 1760 Treaty of Peace and Friendship, the defenses were no longer important and ceased to be mentioned in the historical record. This redundancy is mirrored at Halifax and Louisbourg, where in just a 10 year period the defenses are reported to have fallen into disrepair (Young 1980; Johnston 2007). Archaeological evidence shows that in most cases early British forts had expedient, upright log palisades that were erected as the first line of defense. These were continually repaired until they became redundant and were repurposed and/or decayed. If threat on the settlement persisted they were replaced by more sturdy building techniques (Babits & Gandulla 2013:119).

The historical evidence suggests that Gallows Hill was abandoned for all defensive purposes early in the history of Lunenburg. References related to the ‘Sack of Lunenburg’ (1782), during the American Revolution, make no mention of Gallows Hill. The 1791 reference to a public execution is the last known use of the property. Being outside of the town plot, there are no known records referring to any official reuse of the land until, over a century later, it became home to the Lunenburg Academy.

Two cartographic sources serve as the primary documentary evidence supporting the military connection to the anomalies in the geophysical results. Although lacking in detail, the Walter 1755 map (Figure 14) indicates the palisade enclosing the settlement, with a north and south bastion connecting the span across the crest of Gallows Hill. There is no reference to indicate the exact location of these posts; however, they appear to match the placement of a blockhouse and fort depicted on the more detailed ca. 1770 map (Anon.) (Figure 5). This map indicates the general location of a tetragon fort with a blockhouse toward the south brow of the hill. It seems possible that the anomalies in the survey results, if not the palisade, may be connected with this structure.

The mid-18<sup>th</sup> century standard measurements used in British Nova Scotian palisade construction tentatively identify the palisade trench in the results of the Area 1 surveys. As cited in Bell, the post logs were 15cm in diameter providing an approximate size of the post holes that would be contained by the palisade trench (1961:345). The components of the subsurface feature appear to be near the surface, within range of the 0.2m optimal depth of investigation for the EM38B, as they are drawn out with the finer transect intervals. According to the document cited by Bell, the depth of posts depended on the distance that the logs extend above ground, and the standard height of a log was

304 cm (1961:345). This information alone cannot aid in understanding the realistic dimensions of a palisade trench, however the specific dimensions of other contemporary palisades have been recorded through archaeological excavation.

Excavated palisades demonstrate that trench depth is shallow and has the potential to generate a signal in the magnetic susceptibility, supporting the interpretation at Area 1. The original depth below surface of the palisade trench at the Fort Dobbs (North Carolina) location was 30cm, and 18cm of erosion has brought the existing depth of the post mold bottoms to 12cm (Babits & Gandulla 2013:93). The excavations at the Fort Loudoun (Tennessee) location revealed individual post molds in a 45–76cm deep trench (Babits & Gandulla 2013:163). The archaeological record also preserves evidence of construction style that may aid in explaining the appearance of the anomaly: post logs were inserted individually into a linear ditch, and were reinforced with split logs inserted side by side, or small 7–12cm posts to fill gaps between the larger logs (Babits & Gandulla 2013:92,163). This construction method is demonstrated at the Fort Umrevinsky location, where an induction sounding survey (resistivity) was undertaken in 2002 prior to archaeological excavation. The survey was successful in detecting what subsequent excavation revealed to be halved post logs, 50cm in diameter inserted 87cm into the palisade trench (Borodovsky & Gorokhov 2008:74). Pieces of the palisade logs and fragments of earthen defense works were uncovered just below the topsoil layer (see Figure 4, Borodovsky & Gorokhov 2008:72). In this case, it was possible, through non-invasive methodology, to successfully delineate the site and reveal details about the layout of the palisade and earthen walls without extensive excavation (Borodovsky & Gorokhov 2008:73).

The appearance of Feature A as individual points of susceptibility, regularly spaced and aligned, may be explained by the method of construction used to join the posts of the palisade. The contrast between the higher points and the apparently more subtle responses may be explained through artificial magnetic enrichment. Often, pieces of posts are preserved in the palisade trench, suggesting that as the decayed pickets were pulled from the trench, fragments of large splinters remained behind (Borodovsky & Gorokhov 2008:74; Babits & Gandulla 2013:92). It is possible that organic material is preserved in the Lunenburg palisade trench and has become chemically magnetized, generating a slight magnetic response in the susceptibility (see p.10 above).

Tightening the interline spacing produced new points of susceptibility between the existing high points in the 1m interval survey. The initial high points read between 0.6-0.8ppt. The responses elicited in the 0.50m and 0.25m interval surveys appear to be more subtle, generating a reading between 0.4-0.6ppt. As the data becomes more highly refined, Feature A becomes more pronounced. An aura of susceptibility appears to link together the components of the anomaly, muting the spatial resolution of gaps between individual points in the data. This is most likely an artefact of data processing. The point Kriging gridding method selected in Surfer 8 is designed to assign point value based on that of other nearby points, which surround a common grid node (Golden Software n.d.). By design, as more data points are gathered the Kriging method is more likely to find trends within the data, linking high points rather than displaying isolated peaks.

Interestingly however, the experimental trench susceptibility survey results from the Eisener property appear to show no variation between the preliminary area survey and the subsequent data sets. The experimental trench was excavated to a depth of 0.50m below

the surface, without encountering different stratigraphic layers. In typical Nova Scotian soil conditions, there is a change in the soil lots, from the A horizon (topsoil layer) to the less magnetically enriched B horizon (subsoil layer) within a relatively shallow depth. This is a direct factor in the variation of susceptibility with depth. It is also possible that the infilled trench did not generate a magnetic response strong enough for the EM38B susceptibility component to detect. The study area is highly magnetically active as a result of near-surface bedrock and a large component of glacial till in the immediate subsoil. The near-surface noise levels reflect this activity clearly, as chaotic feedback displayed in the contour maps. The prevailing signal-to-noise ratio may have prevented the recovery of any subtle response generated by the experimental trench.

Technical issues due to the logging equipment were experienced in both study areas and left a noticeable impression on the survey readings, potentially skewing the response of the experimental trench. Where sampling was interrupted due to power failure of the data logger, the reading levels for the remaining portion of the affected survey line dropped dramatically (Figure 32). The data logger used in this thesis was several years old and began to experience power failure at 2.5m into the Area 1, 0.50m transect interval data set. In an attempt to conserve power, the logger was turned off after each transect. In Area 2 power failure persisted with increasing frequency during the collection of the 0.50m and 0.25m data sets, generating a number of false anomalies in the respective survey geometry. Although the anomalies generated can be edited out of the survey results by artificially raising the values to equal the surrounding levels of magnetic susceptibility, there may still be an underlying effect on the readings that skew the

presentation of the subsurface features within these areas, particularly if they are very subtle.

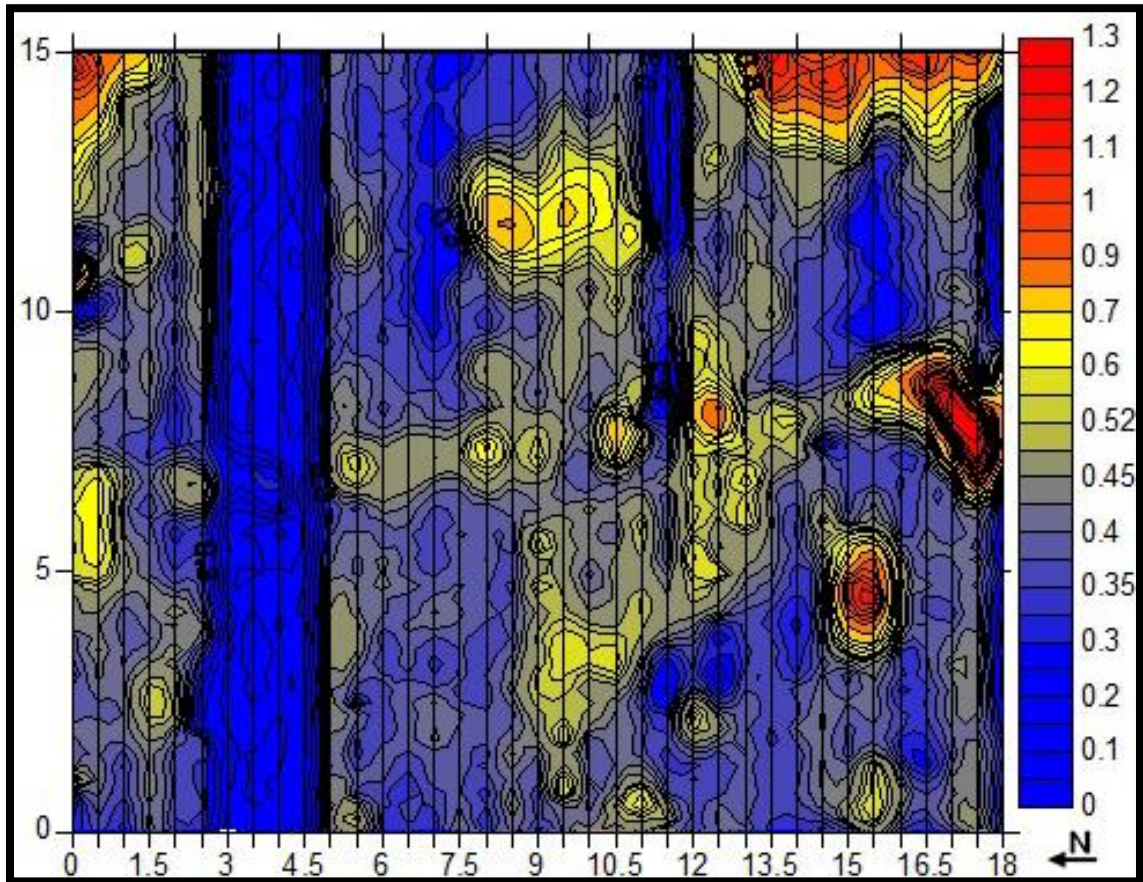


Figure 32: 0.50m susceptibility survey from Gallows Hill. Vibrant blue in data represents lines affected by the data logging issues.

To overcome this issue, data was gathered with a quickened pace and ambient zero levels were measured for a shorter period than is recommended. The adaptation of this methodology had an interesting effect on the subsequent data collected. Despite efforts to conserve the battery, the data logger shut down repeatedly within a single transect. When this occurred the recording needed to be backtracked slightly to capture the last few readings that the data logger did not sample. This approach distorted the spatial resolution of the anomalies, as evident when comparing the Area 2 plotted sub-grid data to the

greater area survey contour maps. Anomalies that are enhanced by the finer interval surveys are slightly out of place from their location on the 1m interval contour maps.

A separate issue was encountered with the overall zero levels in the Area 2, 0.50m and 0.25m data sets. In the 1m post trench survey the ambient temperature of the instrument was higher as it had just been transported to the site in a heated vehicle; however, when collection for the sub-grid was initiated the instrument had time to adjust to the field conditions. The day was much cooler than previous survey days and the difference in the atmospheric conditions were reflected in the survey geometry with lower overall zero levels. This required subsequent adjusting during data handling. It is worth noting the distinction between the data handling process and image processing (Gaffney & Gator 2006:103). While the latter involves only refinement to the visual presentation of the survey data in plotting programs, the former requires precise adjustments to the raw data profiles to attain the optimal representation of the survey results. There are often tradeoffs between these two stages to obtain the most accurate visual representation of the data. This was the case with the Area 2 sub-grid data. This process can be time consuming, and in pursuit of perfection, easy to “lose sight of the original data” (Gaffney & Gator 2006:102). Over-manipulation can mute existing anomalies and generate false anomalies. Processing should go no further than removing all known errors to present a coherent data set for interpretation.

The aerial photographs collected to aid in the interpretation of the Area 1 geophysical contour maps did identify a few intriguing features on Gallows Hill, however, nothing substantial was found that can be associated with the linear anomaly. The 1976 photograph is the most revealing in the collection. In this photograph, a

rectilinear area of poor crop growth extends north-south, just north of the Area 1 grid, and it is possible that this may be related to the linear anomaly in the geophysical surveys. This is highly speculative, however, as the photograph is not of sufficient resolution to accurately determine if these features align, or, coincidentally, overlap with Feature A in the geophysical survey data. The 1992 photograph presents an interesting array of crop marks to the east of Area 1. Although these features are outside of the study area, they are more coincident with the ca. 1770 (Anon.) map of the fortifications. The most recent 2011 images have served as base maps for some interesting synthesis with the historical maps gathered and contour maps produced in this project. Figure 33



Figure 33: Gallows Hill 1 m. interval inphase (magnetic susceptibility) survey results displayed as a contour map, and a detail of the ca. 1770 town plan, overlaid together on a 2011 aerial photograph of Gallows Hill. The geophysical survey grid does not pair with the fortifications detailed on the ca. 1770 map (North at top). SOURCE: Centre of Geographic Sciences 2011314-154 (2011) and Map Collection, Nova Scotia Archives, Halifax F/239-1770.



attempts to consolidate the 2011 aerial photograph with the ca. 1770 (Anon.) map and a contour map of the survey area, to potentially delineate the path of the palisade and associated fortifications atop Gallows Hill, putting the geophysical surveys in context with the greater area.

## CONCLUSION

In conclusion, the origin of the linear magnetic susceptibility anomaly on Gallows Hill remains unknown, although our surveys did confirm its existence and mapped it at a higher resolution than the 2013 survey. Background research has demonstrated, within reasonable doubt, that the anomalies in the geophysical survey results are related to mid-18<sup>th</sup> century British military activity. The results of the experimental research component do not support the hypothesis that magnetic susceptibility can be used to identify the linear anomaly as the palisade. It would be interesting to see a future investigation into the conductivity component of Area 2, to determine if the experimental trench generated a conductive response in the data. In this case, it appears that traditional archaeological excavation may be the best method for identifying this subtle subsurface feature.

This research contributes to the ongoing demonstration within the archaeogeophysical community of advancing investigation methodology, and informing site examination, by utilizing dynamic technological developments. The surveys gathered at coarse and fine transect intervals explored the effects of tightening interline spacing on data resolution. They also demonstrated the effectiveness of EM38B susceptibility surveys in detecting shallow trench and possible wood features in the archaeological record. Had the historical record on the use of Gallows Hill, been more complete, it is reasonable that the conclusions pertaining to the identity of the features revealed in the geophysical surveys would have been more precise. The geophysical research

methodology employed at Area 1 has been executed in such a way as to permit further targeted investigations, and future excavations.

Moving forward, it is reasonable to expect that subsurface military activity may be detected with further geophysical surveys. There is still a portion of the hill top to be surveyed. Expanding the 2013 survey area will delineate the linear anomaly, provide context within the greater subsurface geography on the crest of Gallows Hill, and define areas of archaeological potential to facilitate future excavation. Excavation of the linear anomaly could inform the geophysical survey results from Area 2, and might explain the response of the EM38B to the trench feature. This future work could further contribute to discussions on the value of the EM38B and the effects of tightening transect spacing for detecting features in archaeological mapping.

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APPENDIX A HERITAGE RESEARCH PERMIT



Heritage Research Permit  
(Archaeology)

Special Places Protection Act 1989

(Original becomes Permit when approved by  
Communities, Culture and Heritage)

Office Use Only  
Permit Number:  
A2014NS108

*Greyed out fields will be made publicly available. Please choose your project name accordingly*

Surname <b>FENSE</b>	First Name <b>ALISON</b>
Project Name <b>ADON GALLOWAY HILL: GEOSPATIAL SURVEY IN ARCHAEOLOGICAL RECONNAISSANCE</b>	
Name of Organization <b>SAINT MARY'S UNIVERSITY (STUDENT)</b>	
Representing (if applicable)	
Permit Start Date <b>NOVEMBER 3, 2014</b>	Permit End Date <b>DECEMBER 31, 2014</b>
General Location: <b>TOWN OF LUNenburg, LUNenburg COUNTY, NOVA SCOTIA</b>	
Specific Location: <i>(cite Borden numbers and UTM designations where appropriate and as described separately in accordance with the attached Project Description. Please refer to the appropriate Archaeological Heritage Research Permit Guidelines for the appropriate Project Description format)</i>	
Permit Category: Please choose one <input type="checkbox"/> Category A – Archaeological Reconnaissance <input checked="" type="checkbox"/> Category B – Archaeological Research <input type="checkbox"/> Category C – Archaeological Resource Impact Assessment <input type="checkbox"/> I certify that I am familiar with the provisions of the Special Places Protection Act of Nova Scotia and that I have read, understand and will abide by the terms and conditions listed in the Heritage Research Permit Guidelines for the above noted category.	
Signature of applicant 	Date <b>14/10/28</b>
Approved by Executive Director 	Date <b>14/11/4</b>

## APPENDIX B BACKGROUND RESEARCH

**Table 1:** Historical Archival Evidence

Date	Title	Author	Source	Reference no.	Notes
1753	“A True Copy of a A [sic] Plan of the Town of Lunenburg Garden Lotts [sic] and Commons adjoining”	Morris	Primary	V7/239-1753	Area for fortifications
1753	Journal and letters of Colonel Charles Lawrence	Lawrence (Harvey)	Primary		Fortifications constructed
1755	“A plan of Lunenburg Harbour, Nova Scotia”	Walter	Map	V7/ F/239-1755	Bastions on Gallows Hill
1758	Lunenburg then and now	Cuthbertson	Secondary		Protect settlers from native attacks outside walls
1760	History of the town of Lunenburg	Hewitt	Secondary	F5249/ L96/ H61	Military presence dropped to local militia
1767	“Plan of the Township of New Dublin, Lunenburg, Chester”	Doroti	Map	F230- c.1767/ No. 10394	No depiction of forts- focus on Lots
1834	“Plan of the Township of New Dublin, Lunenburg, Chester”	McKay	Map	V7/230-1834	Representation of forts vs. Mango
1770	“Lunenburg”, 20 <sup>th</sup> century blue print	Anonymous	Map	F/239-1770	Detailed fortifications
1776	Atlantic Neptune: “Kings Bay and Lunenburg Harbour”	DesBarres	Map	Atlantic Neptune S35 N34	Gallows Hill and Battery Point have forts- none at Blockhouse Hill
1782	Raid during the American Revolution	Anonymous	Primary	RG1/ Vol223/ Doc22	Only mention of fort on Blockhouse Hill
		McCreath & Leefe Cuthbertson	Secondary		

1785	Description of Lunenburg. Journal on a tour with General Campbell	Hewitt Russell Lt. Booth	Primary	F90/ N85/ AR2R 1933	Blockhouse Hill state disrepair of after the 1782 attack - nothing concerning Gallows Hill
1791	History of the town of Lunenburg	Hewitt	Secondary		Hanging on Gallows Hill
1793		Hewitt Cuthbertson	Secondary		French revolution - Blockhouse Hill and Fort Boscawen
1810-1834	Reports of state and strength of forts and batteries	Great Britain Royal Engineers	Primary	MG12/ RE52-53/ 1810-1817, 1834	Gallows Hill fort not included
1820	Lunenburg Harbour	Great Britain Army Royal Engineers	Map	HG REO O.11	No ruins on Gallows Hill vs. nearby forts
1824	Chart of the coast of Nova Scotia	Bayfield	Map	Great Britain Hydrographic Office, Chart No. 343	New cluster of buildings
1867	Dominion day events	Cuthbertson	Secondary		Rifle practice on Gallows Hill
1885	Lunenburg Town	Church	Map	A.F. Church Maps	Cleared land - "Barracks Hill"
1890	Bird's Eye View of Lunenburg, Mahone Bay and Ritcey's Cove	Anonymous	Map	NSA Map Collection 3.1.1	Cleared land
1894	"Plan of Proposed School Lot at Lunenburg"	Ross (Cary)	Map	NBA: Mott Collection Acc. 164	Overlain on contemporary GIS mapping
1893-1895	A Walk through Old Lunenburg	Parish & Hall	Secondary	F5249/ L926	First Academy fire 1893 New Academy - opened Nov. 7 1895 - Design: H.H. Mott - Decision of location - Description of Academy: 1896 Education review (not pertinent)

**Table 2:** Various Maps

Date	Title	Source	Reference no.
2013	1:10,000 NTS map, "Lunenburg"	GeoNet Technologies Inc.	N/A
2013	1:10,000 NTS map, "Italy Cross"	GeoNet Technologies Inc.	N/A
1977	Buildings built prior 1880	Town of Lunenburg	F/239-1977
2000	Geological map of Nova Scotia	J.D. Keppie (compiler) Department of Natural resources, Minerals and Energy Branch	N/A
1785	Lunenburg Division into town plots	Anonymous	F 239-1785
1977	Map of water pipes and sewers	Town of Lunenburg Municipal Services	F239-1977
1994	Old Town Lunenburg Map of the inscribed property	United Nations Educational, Scientific and Cultural Organization	N/A
1957	Soil map of Lunenburg County	Experimental Farms Service. Provincial Department of Agriculture	N/A
1966	Soil Map of Kings County	Soil Research Institute, Research Branch. Canada Department of Agriculture.	N/A

**Table 3:** An exhaustive list of all images available from the DNR Air Photo Library, recorded November 2014.

Location	Date	Reel no.	Photograph no.	Line no.	Scale	Significance	Notes
Lunenburg	2011-08-31	2011314	154	0-11	1:12,500	Recent image of property	Obtained-DNR
Lunenburg	2011-08-31	2011314	154	0-11	1:12,500	1800 dpi	Obtained-COGS
Eisener Property	2011-08-18	2011308	044	005	1:12,500	1800 dpi	Obtained-COGS
Eisener Property	2011-08-18	2011308	044	005	1:12,500	Recent image of property	Obtained-DNR
Lunenburg	2001-08-26	01312	260	15-1	1:10,000		Obtained-DNR
Eisener Property	2001-09-02	01322	92	7-1	1:10,000	Paddock extant	Obtained-DNR
Lunenburg	1992-07-16	92335	178	42	1:10,000	Crop mark	Obtained-DNR
Eisener Property	1992	92354	120	34	1:10,000	N/A	No significant features
Lunenburg	1986	86318	210	N/A	1:10,000	N/A	Missing
Lunenburg	1986	87001	126	27E	1:40,000	N/A	Scale too great for detail
Eisener Property	1986	87001	215	25E	1:40,000	N/A	Scale too great for detail
Lunenburg	1976-09-25	76327	166	42	1:10,000	Crop mark	Obtained-DNR
Eisener Property	1976	76311	30	34	1:10,000	House constructed	Not obtained
Lunenburg	1955	14724	130	4418	1:15,840	N/A	No significant features
Eisener Property	1955	14709	187	4413	1:15,840	No structure	Obtained-DNR
Lunenburg	1945	9006	7	45	1:15,840	Barren field	Obtained-DNR
Eisener Property	1945	8808	89	40	1:15,840	Area forested	Obtained-DNR
Lunenburg	1931	3521	105	N/A	N/A	N/A	Missing
Eisener Property	1931	3767	101-102	N/A	N/A	N/A	Missing

## APPENDIX C DATA PROCESSING

1. Convert file format from .P38 logger file to .B38 processing file; .B38 file can now be formatted in Dat38BW.

At this point several housekeeping issues with the data can be performed:

- Add EM38B profile file.

During this study it was necessary to merge two .B38 files in order to have all survey lines in one file; this is solved by adding one profile (or more) to the more complete set of profiles.

- Reverse line order; this will reorder the lines in descending order.

The Area 1 preliminary survey commenced at the end of the X-axis, on 18, not at the origin with the Y-axis. For consistency, this methodology was followed for the subsequent 3 sets of data collected at Area 2. The order of profiles in DAT38BW is by default labeled to display profiles in ascending order, beginning with line 0. In this case, the survey lines needed to be reversed to reflect the field methodology and the origin aligns with the true origin of the grid.

2. Adjust scale to X-axis metres to station increments; condense survey line.  
The scales of the survey lines usually appear much greater in the profile view than the Y-axis of the survey grid. This is because readings are collected at 10 per second and the data logger assumes that the surveyor is walking at roughly 1 metre a second. The Y-axis for the data display in Dat38BW is relative to the survey grid X-axis; the transect is displayed in the profile horizontally. Each profile must be compressed to represent the accurate stations to metres gathered in the field.

- With the lines condensed, position them to zero; move the condensed survey line together and apart until the first and final FIDs corresponds with the stations collected.

3. Adjust display parameters.  
Once the profiles are representative of the distance of the survey line, the display parameters should be adjusted to show a corresponding 'stations to metre' scale to the Y-axis. The scale should be reduced to slightly greater than the extent of the Y-axis on the survey grid to incorporate the ambient susceptibility levels collected at either end of the line.

- Major and minor axis marks can also be selected; it is beneficial to match the labels with the fiducial points for reference. The scale has been reduced so that the first and last FID roughly aligns with the beginning and end of the data collected.

4. Position markers; adjust FIDs to Y-axis.  
This step refines the position of the FIDs so that they are right on the metre marks, for better spatial resolution in the projected data. Reflecting the guideline used in the



methodology, the FID markers should be adjusted to every 5 metres on the Y-axis along the data profile, so that the first FID, representative of 0 on the Y-axis, is at 0 on the data profile as well (Figure 1). The remaining FIDs should be positioned accordingly, so that the final point on the Y-axis and end of the data corresponds. With these aligned, there should be excess data at the beginning and end of the survey lines, this is representative of the zeroed data discussed in the methodology section.

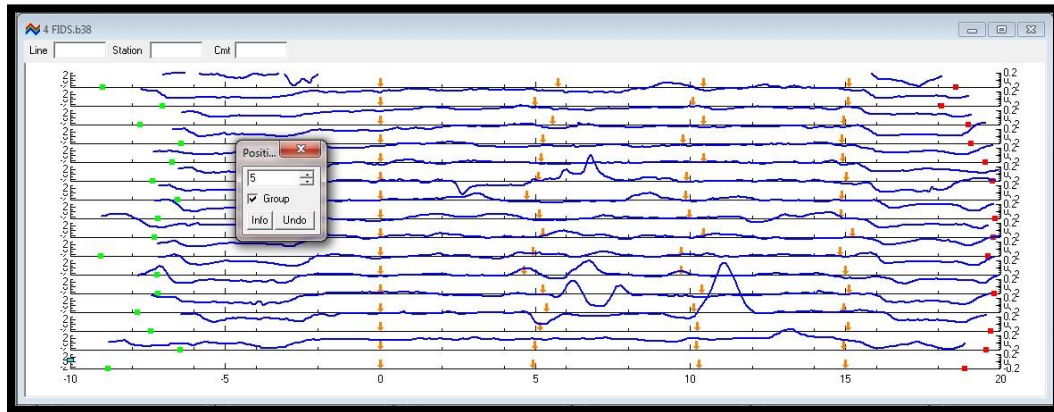


Figure 1: Inphase results for Area 2 1m interval survey displayed in DAT38BW software by Geonics Ltd.

5. Edit survey geometry; zero lines with inphase grid.
 

Display the inphase grid. A line will be drawn across the profile window displaying a 0 level, which the inphase values collected, can be aligned with.

  - Using the ambient data collected at the beginning and ends of the survey lines adjust their values up or down until they rest at the inphase grid 0. Initially, it may be best to shift the entire data set, when an entire data set is particularly high or low due to errors. This option also allows for an entire individual line to be shifted separate from the rest of the data set, in the event that there is an outlier.
6. Edit survey geometry; correct linear drift.
 

Often fine tuning is necessary after the data set has been adjusted to align with the inphase grid. The line ends may drift independently, higher or lower than the rest of the data set. This issue is greatest toward the final section of a survey grid where they may have drifted up from the initial values, due to thermal drift. The program allows either end of a line to be independently raised or lowered, in order to correct for thermal drift and other variables that may cause errors in the data. Fine increments allow for precise positioning of a line on the inphase grid. It helps to do this in small sections selecting a few lines at a time so that each profile is large enough to see the details in the zero level and the inphase grid.
7. Format .b38 to .XYZ for Surfer8 plotting.
 

At this time the data should be converted to a .XYZ file to visualize the remaining refinement necessary in the contouring program.

- When doing this, the orientation of the survey lines must correspond to the direction in the field. For example, this project was west to east, so the orientation projected by DAT38BW will be north–south.
8. Grid .XYZ profile data in Surfer 8.  
The .XYZ file format is converted into a 3 dimensional grid with X, Y, and Z data columns. When gridding the file, a properties window is displayed, edit the grid line geometry of the X and Y axis respective to grid dimensions. This will format the scale appropriately to the dimensions of the survey grid and cleanly remove the excess data being used to zero the profiles in the DAT38BW program, so the extremely low susceptibility values do not interfere with the colour scale in the contour map.
  9. Create contour map.  
Upon opening the Surfer program, the user is presented with a new plot document. Once the .XYZ file has been formatted as a .grd file, it can be applied to a contour map. Select the new contour map option, and choose recently created .grd file. The map appears without any colour detail with contours represented as black circles on a white map (Figure 2).

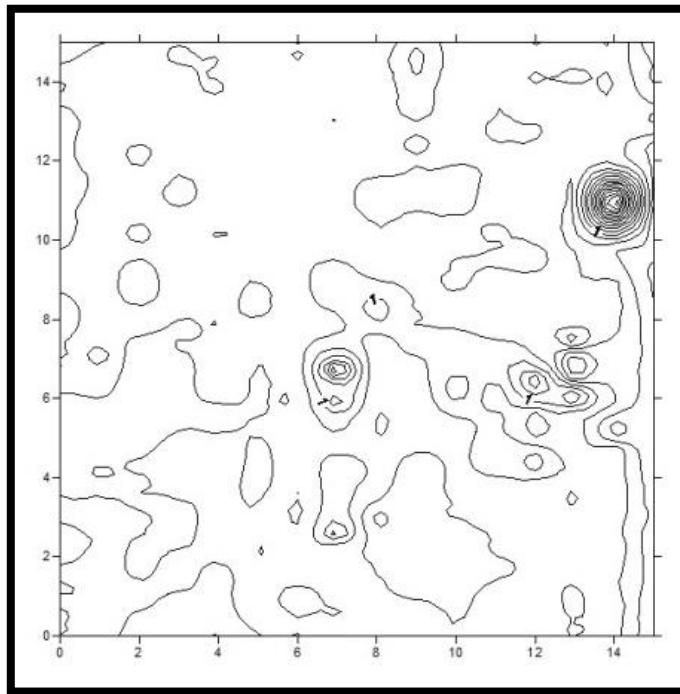


Figure 2: Inphase results for Area 2 1m interval survey preliminary processing stages, displayed in Surfer 8, Golden software.

10. Adjust colour scale.  
By double clicking on the map, the contour properties display window appears; under the general tab ensure that 'fill contours' is selected.

- Depending on the survey parameters, some surveys require adjustment to the contour levels to enhance or mute the magnetic responses. Under the levels tab change the level interval by selecting the column heading ‘level’ and enter in the desired frequency.
  
  - To edit the colour scale, select the column heading ‘fill’; change the foreground colour. The colour spectrum is a function of the number of colours selected and can be adjusted by adding or removing ‘nodes’ on the colour spectrum. In this study, blue was selected to represent the lowest values, red the most extreme, and yellow was selected as the mid-range value. Several nodes can be added across the spectrum, strengthening the colours as they fade into each other. To save time in the following steps, these settings can then be saved and loaded into future versions of this map through the properties window.
11. Refine data properties; repeat steps 5–10.
- From this point the user will switch between the Dat38BW and Surfer 8 programs to bring out the optimal responses from the survey data. This is done visually, by examining the contour map and returning to the profile handling stages to ‘shift data set’ or ‘correct linear drift’ as necessary to attain desired results. The user can expect to spend a significant amount of time between the two programs correcting the errors, although at some point it must be accepted that there are limitations to the data collected that cannot be altered in these programs.
- Once refined for interpretation, the data can be plotted in various visualization styles such as the 3D orthographic surface map presented in this study. Following the instructions in step 9 can be followed to create other varieties of maps with the refined data.