## Methodology:

### *Geophysical Survey Grids:*

The geophysical survey grids were established in two stages: 1. GPS positioning of 50m grids throughout the entire survey area, 2. 20 m grids were surveyed in with a total station based on 50m pegs.

100m, 50m, and 20 m grid co-ordinates were created in ArcGIS, loaded to the GPS data card and established in the field. Easy grid re-location was essential due to the nature of the survey and the survey area itself. As a working farm, machinery tended to disturb grid markers and the survey crew had to be flexible where they worked due to crop and irrigation schedules.


**Figure 6 Leica 500 GPS unit used to establish grid control. Rover unit (l), differential remote unit (r).**

### *Equipment:*

Two FM256 fluxgate gradiometers were used individually and in tandem for the magnetometry survey. Data were collected with a sampling interval of 0.125 m along transects spaced at 0.5m apart. Post processing software for data analysis and interpretation included: Geoplot 3.0, Surfer 8, and ArcGIS 8.3.

A RM15 resistance meter was used with twin probe separation of 0.5 m. Data were collected with a sampling interval of 0.5m along 1m spaced transects. Post processing software for data analysis and interpretation included: Geoplot 3.0, Surfer 8, and ArcGIS 8.3.

A SIR3000 GPR unit with a 400 MHz and survey wheel was used for this survey. 70 scans were collected per meter along 1m spaced transects. Post processing software for data analysis and interpretation included: RADAN 5.0.0.6, Erdas Imagine 6.0, and ArcGIS 8.3. GPR data settings were established in each survey area to best suit unique site values and goals.

### *Data collection and processing:*
Data were collected with resistance, magnetometry and GPR were downloaded and backed up daily. All data underwent basic processing and imaging daily to ensure

continued work was as effective as possible.  The majority of the geophysical data were compiled, processed and interpreted during February-March 2004.  Magnetic and resistance data underwent typical data processing in Geoplot including:  edge matching (between resistance grids), clipping, de-spiking, periodic defect filters, high and low pass filters, and interpolation to enable easy input into the GIS.  The GIS contains the results from the magnetic and resistance surveys in individual layers that include:  regular clipping and despiking, low pass filtering (LPF) with neighbourhoods of 1, 2, and 3 and a high pass filter with a neighbourhood of 10 x 10.  Only one sample of this data is provided in this report (LPF of 2).  All the data contained in the GIS an be viewed in the ArcIMS site.

The GPR data were very clear (having vertical high and low pass filters adjusted in the field before data collection) and needed little processing.  Initial examination of the data included additional vertical and horizontal filtering, migration, hilbert transform, and other processes.  Once the correct processing techniques were determined for the most effective display of data, all data were compiled into 3D cubes.  The GPR data were then viewed in the 3D cubes with time slices (z-axis, horizontal plan views of the survey area) and with intersecting axes x and y.  A selection of time slices was exported from RADAN to represent each survey area in the GIS.

### *Geophysical Techniques:*

*Resistance*

A RM15 resistance meter was used with twin probe separation of 0.5 m. Data were collected with a sampling interval of 0.5m along 1m spaced transects. Post processing software for data analysis and interpretation included: Geoplot 3.0, Surfer 8, and ArcGIS 8.3.

Resistance survey measures the change in the resistance of the earth. The “Twin Probe” array is used in this case where a current and potential probe are paired on a roving frame that measures the variation in resistance across a grid. A second pair of current and potential probes is fixed at a certain distance from the area being surveyed. With a fixed separation distance of 0.5 m, the roving probes map an effective volume of resistance to a depth of approximately 0.75 m, measured in Ohms.

Resistance effectively looks at the saturation level of the materials in the survey area, thus is sensitive to soil compaction, soil type, geological features and objects that may be buried with in the soil. Resistance survey can map features that include pits, trenches, foundations, compacted or disturbed surfaces, and changes in soil type. (Clark 1996)

**Figure 7 RM15 resistance meter with 0.5 m spaced probes used in the ALSF Focus area.**

*Magnetometry*

Two FM256 fluxgate gradiometers were used individually and in tandem for the magnetometry survey. Data were collected with a sampling interval of 0.125 m along transects spaced at 0.5m apart. Post processing software for data analysis and interpretation included Geoplot 3.0, Surfer 8, and ArcGIS 8.3.

Magnetic survey measures the variation of the magnetic fields of the earth and buried features across a site. Different soils and features can be mapped through their contrasting magnetic values. Examples of features that can be detected through this process include ferrous materials, soil affected by human occupation (rubbish pits and middens with organic materials), fired materials such as kilns and hearths, tiles, bricks, and concentrations of ceramics. Differences in soil type or soil perturbation are also detected through magnetic survey enabling identification of ditches, pits, foundations, graves and other excavated features. (Clark 1996)

**Figure 8 FM256 fluxgate gradiometer used in the ALSF Focus area.**

When interpreting data for archaeological purposes we look at the gradient of the magnetic field that best reveals archaeological features. Magnetometry collects two total fields from two separate magnetometer sensors in the FM256. These sensors measure the total magnetic field at their respective distance above the earth. The gradient is calculated from the two total fields and effectively removes broader scale background noise. This background noise includes larger geological trends and diurnal effects.

Magnetometry data are collected as a series of regularly spaced points along a grid. Typical data collection for this survey is 4 – 8 points per meter with 0.5 to 1 m spaced transect lines. Data are viewed, processed and interpreted in a plan view map that represents the variation of the magnetic field values across the survey area.

*Ground Penetrating Radar*

Geophysical equipment used included the SIR3000 ground penetrating radar unit with a 400 MHz antenna and survey wheel. 70 scans were collected per meter along 1m spaced transects. Post processing software for data analysis and interpretation included RADAN 5.0.0.6, Erdas Imagine 6.0, and ArcGIS 8.3. GPR data settings were established in each survey area to best suit unique site values and goals.

**Figure 9 SIR3000 ground penetrating radar unit with a 400 MHz antenna.**

GPR maps the form of contrasting electrical properties (dielectric permitivity and conductivity) of a soil or other materials below the ground surface. The stronger the difference between the electrical properties of two materials, the stronger the reflected signal in the GPR profile. The conductivity of soils and buried features has the primary control on the attenuation, or loss, of the GPR signal that impacts the effectiveness of GPR survey. Though a highly conductive material will attenuate the GPR signal, it can also be an effective mapping tool contributing information to the nature of the subsurface and features within it. (Daniels 1996, Conyers and Goodman 1997)

GPR records information on the amplitude, phase and time related to the capture and induction properties of the antenna in addition to the energy propagation, scattering and reflection off of subsurface features. Unlike resistance or other archaeological-based geophysical methods, GPR data are collected as 2D vertical profiles into the earth. The 2D profiles are made up of a number of traces (or scans) at a particular location (x, y) that record the response of sub-surface properties to the radar's electromagnetic wave at discrete points at a particular time (or depth) in the earth. The horizontal axis represents surface distance along the transect with the vertical axis recording time (often referred to as two-way travel time.) The time is recorded in nanoseconds (ns). Time can be easily converted to depth in two ways: the first is by having a known dielectric permitivity value for the material in the survey area, the second through having a known depth to a feature that appears in the radar profile. The more accurate of these two methods is the latter but this requires digging or coring. It must be kept in mind that earth properties are not constant and can change drastically over an area. Depth conversion should be checked at intervals across a site if possible.

When considering feature resolution, differences are best viewed based on a relative scale. The outline of features may be identified at the lowest resolution and individual features such as bones and artefacts within for example, a grave, may be imaged at the highest resolution (to date, no conclusive research has been conducted that has positively imaged bones within a grave, although Watters and Hunter *in press* propose a method through which this may be possible). GPR is easily adaptable to these different scales because of its range of antenna frequencies. These frequencies range between 10 MHz and 1.5 GHz with the lowest frequencies used to map geological and environmental targets with a typical penetration of approximately 30 m. The highest frequency, 1.5 GHz, will effectively penetrate to about 1.5 – 2 m in basic, dry loamy soils but often much less, particularly in wet, clay-rich material. The deeper penetration achieved with lower frequency antennas provides a coarser resolution while the finest feature resolution is achieved with higher frequency antennas (but with a limited depth penetration). The most suitable antennas for archaeological feature location and detailed imaging are the 200, 400, 900, and 1500 MHz antennas. This group provides a range of depth and resolution flexibility.

*GPR Data Viewing and Imaging:*

GPR data are collected along a grid as vertical slices into the ground. Grid lines (transects) are collected in parallel lines typically spaced 0.5 to 1m apart. Due to the form of the beam of radar wave propagation into the earth, survey transects are most effective if oriented perpendicular to known archaeology. To record the most information on buried features, data can be collected orthogonally, or on a grid with perpendicular transects.

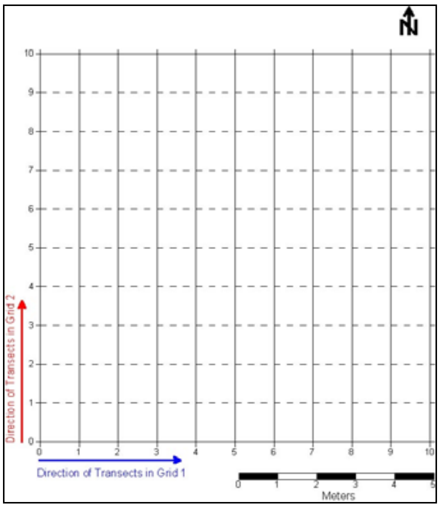


**Figure 10. Orthogonal grid display. All geophysical data are typically collected along grids for spatial accuracy. This image shows two overlapping grids perpendicular to each other, an optimal survey method for 3D imaging of GPR.**

Initial data review is conducted on these vertical profiles. Anomalies can be identified in individual profiles and are best defined and interpreted through time slicing.

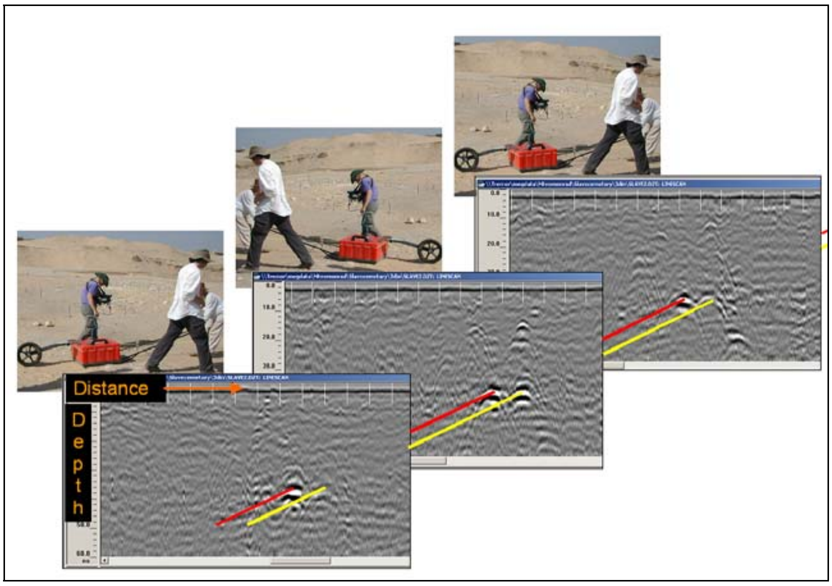


**Figure 11. GPR data are collected as vertical profiles into the earth. Vertical profiles can be stacked together to create a 3D cube of information for use in data imaging and analysis.**

Time slicing is when the vertical slices are stacked next to each other and interpolated to form a cube of data. This cube is then sliced on the horizontal plane to create plan views of the area. As GPR data records the nature of the subsurface to a certain depth, a number of time slices can be created that depict the nature of the subsurface at given depths. Further assistance in feature mapping can be achieved in displaying all three axes of the GPR cube x, y, and z. This helps define feature shape and volume.

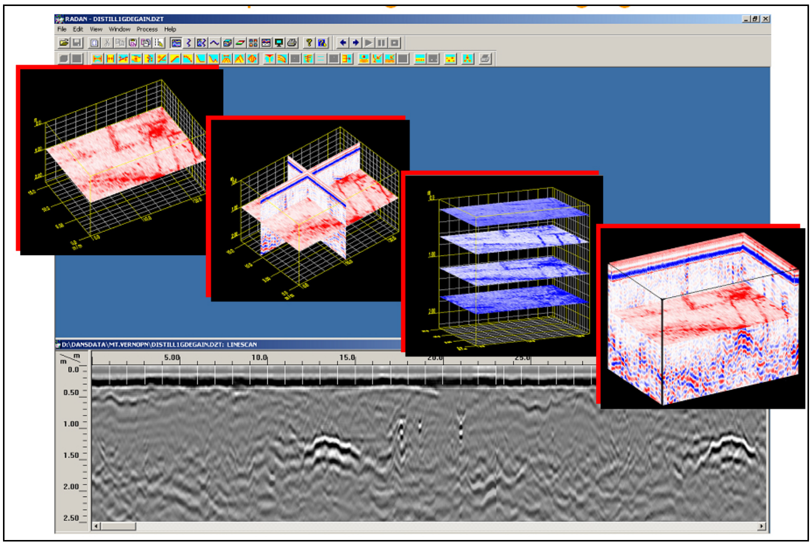

**Figure 12. GPR data can be displayed as 2D vertical profiles (greyscale at the bottom of the figure), or sliced along the x, y, and z axes.**

Each area surveyed with GPR during this project has been reviewed in both vertical profile and plan views. Each area is represented by a selection of plan views in the GIS that best represent the nature of the subsurface. Images included in this report are a single time-slice for each area that best represent the archaeology, but do not show all of the features. The images with interpretations include interpretations from every time slice in the GIS for an overall depiction of identified features. All of the GPR time slices can be viewed on the ALSF ArcIMS site.

One important issue to consider with the GPR survey results gain. Gain is the control for varying the amplification over the radar signal to compensate for variations in the signal strength. Though every effort was made to regulate gain values, periodically (with changing batteries and GPR system bugs) the gain values shifted. The result of a shift in gain values can be seen in some time slices with blocks of contrasting greyscale. Any regular (typically rectangular) greyscale contrast can be considered a gain shift and should be more or less ignored. In one or two survey areas, this contrast makes it difficult to see all the data clearly in report images, but has been thoroughly reviewed.

It must be stated that the depth to this point is assumed based on the input dielectric value for the area soils. Excavating down to a noticeable anomaly in a GPR profile then a measurement to that surface can be taken can do a depth calibration. A simple equation or software can quickly convert all data for appropriate depth.

***The depths in this report are not accurate and should not be held as so.***

***Area Coverage:***

Review of the grey literature for geophysical and archaeological investigations in the ALSF Study area shows that most archaeological investigations are conducted in the field based on the location of mapped crop marks. The geophysical survey for the ALSF Focus area was also based on the location of the crop marks. As with other work done this way, one of our primary goals is to establish whether we are able to map the crop marks and other archaeological features, and the process of mapping these features. Or alternatively proving that geophysical survey is not effective in mapping archaeological features in this environment. The ALSF Focus area geophysics project was allotted time and resources so that the area covered could go beyond typical commercial coverage (with limited time and budgets) in order to map more of the landscape of the Focus area than the isolated “postage stamp” areas more conventionally targeted.

The ALSF Focus area was divided into 5 separate sections based on existing field divisions. These areas were given names so that the ALSF project members, the landowner, the survey crew and the field geophysical crew would be able to communicate without any problems.