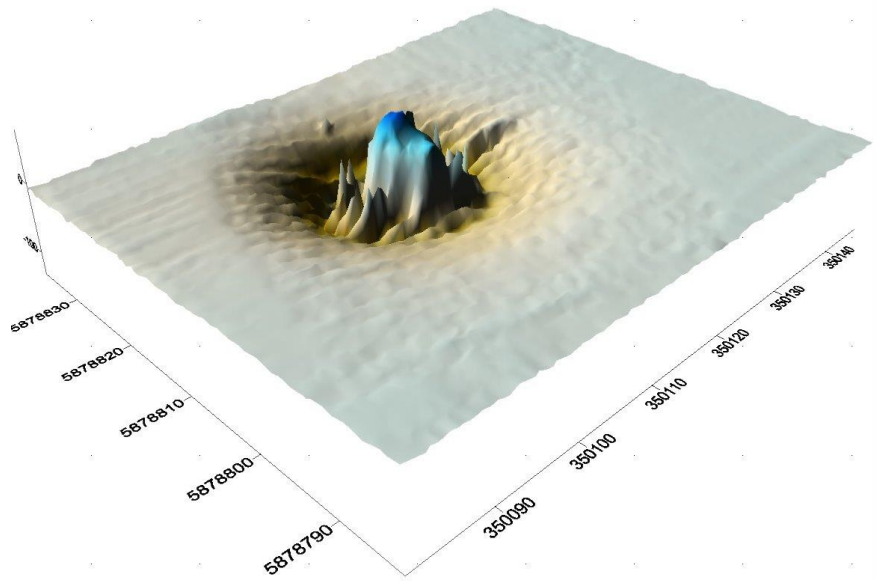# Abandoned Well Locating

A Comparative Study
of Subsurface Investigation
Technologies

Compiled by Howard Black, Warren Tessari

2016

Introduction

As of early June 2016, there were 69,153 oil and gas wells that had been sealed and abandoned but not reclaimed in Alberta, and 79,102 wells that were inactive for more than a year. These wells have attracted media attention recently due to the global downturn in the petroleum industry, heightened environmental awareness, and the difficulties land owners are facing as energy companies are hit with dwindling operational and remediation budgets.

Sometimes wells are evident on the surface due to structures such as well trees or pump jacks. Often, however, there are no remaining visible clues for the exact location of a well. Gaps in record keeping, accuracy issues with coordinates, and other complications can make locating hidden wells difficult and costly. This can add to the time and expense already associated with remediation, re-activation or re-purposing of the lease site.

Although the area may be narrowed down to a few hundred square meters based on available databases, there are obvious safety and cost benefits to non-destructively verifying a well's position prior to a ground disturbance or other work in the area.

There are a range of subsurface investigation options available for this type of work, each with its own strengths and weaknesses. The simplest tools such as metal detectors often provide too many false positives. Depending on the level of disturbance and the amount of foreign and natural objects obtaining clear results can be difficult even for powerful technology such as Ground-penetrating Radar (GPR).

Figure 1: An image from a Global News excerpt depicting the estimated amount of inactive oil and gas wells across the province of Alberta.

"There are almost 170,000 inactive wells across Alberta, based on license status counts." Hartshorn, M (October 28, 2015). Map: Alberta littered with inactive oil and gas wells. *Global News.* Retrieved from http://globalnews.ca

"Alberta faces growing backlog of abandoned oil and gas wells." Reith, T (July 14, 2015). Alberta faces growing backlog of abandoned oil and gas wells. *CBC News Edmonton.* Retrieved from http://cbcnews.ca

"The Saskatchewan government is proposing to have oil and gas workers who have lost their jobs clean up abandoned wells." The Canadian Press (Feb 8 2016). Saskatchewan proposes getting laid-off oil workers to clean up abandoned wells. *Financial Post.* Retrieved from http://business.financialpost.com
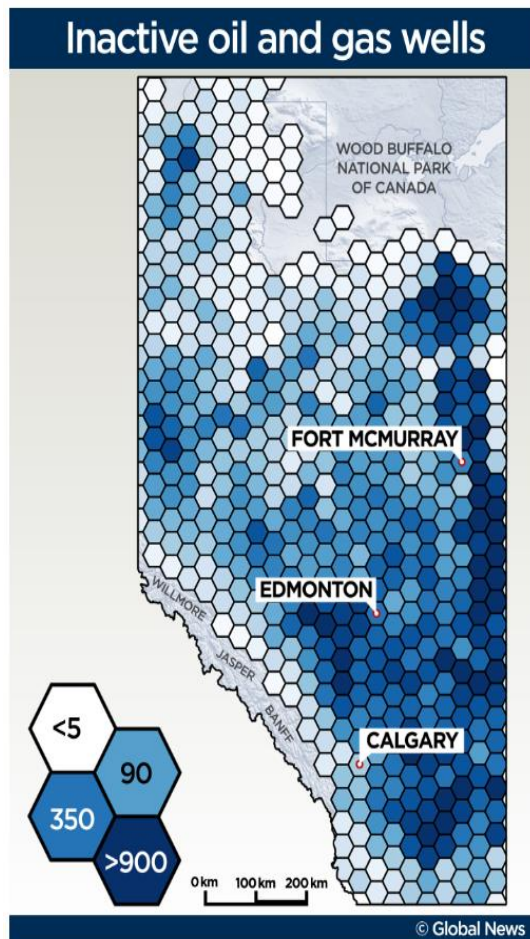
Study Overview

In this abandoned well study, Maverick Inspection Ltd. technicians compared the results obtained from employing a Magnetic Gradiometer, an Electromagnetic Conductivity Profiler, and a Ground-penetrating Radar system. Using a handheld consumer GPS system, the approximate location of a well was marked in a farmer's fallow field, and then a data gathering grid was constructed centered on the roughly-located coordinates. There was no surface indications of a well noted. The data from all three systems was collected and correlated via GPS positioning. Compilation and analysis software was used on a Maverick workstation to yield the clearest results for presentation.

This type of investigation falls comfortably within Maverick's scope of subsurface investigation services, including specialized utility locates, ground stability scans, clandestine grave exploration and other data gathering and analysis. Maverick typically provides this high level of information for clients ranging from energy companies to various contractors, engineers, geoscientists, property owners, law enforcement, First Nations, and others.

The study yielded excellent results with some very specific conclusions. First, every technology has advantages and limitations and will not be appropriate for all sites and in all situations. Therefore, equipment availability and operator experience for selecting the right method or combination of systems is critical. Second, the technician must have significant knowledge and experience to set up the investigation, gather the data, and use the additional tools and software to provide accurate and meaningful results. The equipment and methods are not appropriate for inexperienced operators. Third, due to the wide range of well locations, the crew must have the vehicles, tools, and training to safely and effectively access the sites and perform the work.

In the following sections, the equipment and methods are briefly discussed and compared, and samples of the resulting data are presented.

Figure 2: The image on the left shows plenty of surface indications of historical wells. The image to the right shows Howard Black of Maverick Inspection Ltd. marking the approximate recorded location of the abandoned well chosen for this study. These two images are from different locations in the same field.

Technology and Methodology Summary

1. Ground-penetrating Radar (GPR)

For this application, Sensors & Software's Noggin 250MHz system was chosen from Maverick's available selection of antenna wavelengths. Mavericks' GPR equipment ranges in frequency from 50MHz to 1.6GHz and has a broad complement of deployment options, makes, models, and manufacturers. The system and methodology is tailored to each application for a virtually limitless array of approaches within this discipline.

GPR uses electromagnetic pulses at a select frequency range to image subsurface changes in dielectric properties in the time domain. The frequency of operation is determined by the selected antenna, which is chosen based upon the size, orientation, composition and depth of the target to be identified. As with all technology, GPR has limitations. For example, conductive soil types, such as clay and silts, have a large impact on the ability of GPR to obtain images of the subsurface, and this can greatly limit its potential in certain areas.

Due to the operating principles and manner of which the data is displayed, GPR is capable of providing an very detailed image of the subsurface including exact depths and orientations of certain objects. The information contained within the data provided by GPR (radargrams) can be challenging to interpret for intermediate or novice users of the technology. Therefore projects of certain complexity require a skilled operator, normally with many years of experience.

Figure 3: Howard Black and Matt Etherington configure the RTK GPS to one of Maverick's GPR systems to provide positional data. The wavelength of radar system, deployment platform, and data gathering method was chosen based on the site and suspected targets.

For this type of work, data is gathered at a slow to moderate walking pace with centimeter level positioning accuracies being provided by an RTK GPS. For this specific survey, lines were required in a double axis grid with spacing of 0.5 meters. A certain level of real-time interpretations can be obtained with only moderate impact on data collection time, however more advanced methods used in post-processing are often able to provide an even higher level of detail in a more accurate manner. Although this technology provides vastly more information of the subsurface when compared to other subsurface investigation techniques, the data review and post processing can be relatively time consuming. It is normally expected that a ratio of 2 hours data review and processing are required to every 1 hour of data collection.
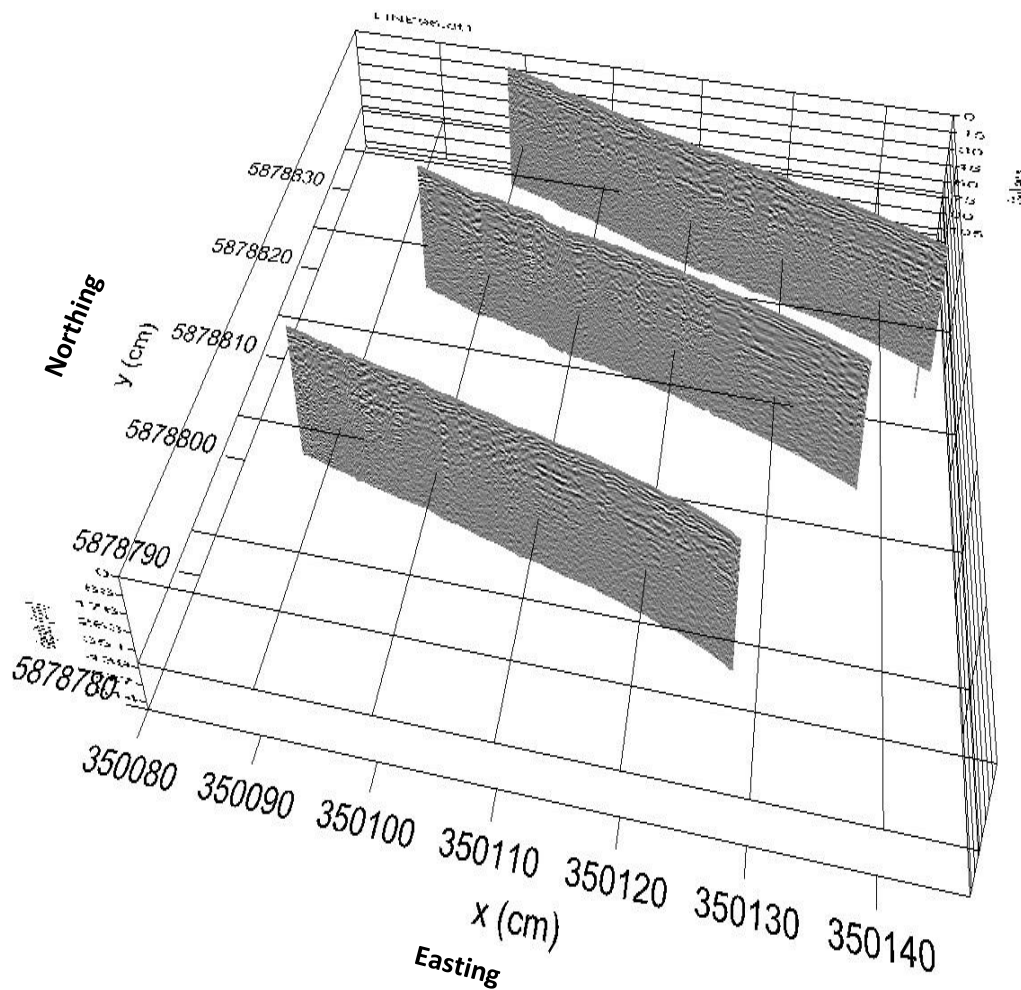

Figure 4: A typical example of GPR data plotted for analysis and review.

2. Electromagnetic Conductivity Profiling

For this portion of the study, the GEM2 Electromagnetic Conductivity Profiler was chosen. This system uses a series of precisely wound coils to generate and measure electro-magnetic fields in the frequency domain of multiple frequencies simultaneously. The unit is able to provide information of a qualitative (in-phase and quadrature) and quantitative (apparent conductivity) nature. Because the results are not based upon the material in question containing some type of metallic content, the GEM2 is able to map subsurface features that result in any change of dielectric properties. This technology is also subject to interference. For instance, highly conductive layers of the local lithology can have an impact on the overall data quality.

The data collection with the GEM2 is limited to a slow to moderate walking pace to ensure highest possible data quality in a single axis grid with spacing of 1-2 meters. The results are recoded with the capability of including RTK level GPS positions, providing centimeter level accuracy. The unit allows for some level of real-time interpretations with limited to no impact on data collection time. The post processing and analyzing of the data upon completion of the collection can be done in a relatively quick manner with time equal to approximately the required time for data collection.

Figure 5: Advantages of the GEM2 include the moderate data-gathering pace, some real-time interpretation, and relatively quick post-processing and analysis of data.

MAVERICK
INSPECTION LTD.

3. Magnetic Gradiometry

The GSM19WG Magnetic Gradiometer uses the Overhauser Effect to measure changes in the local magnetic field strength related to changes in the subsurface. As the name suggests it measures the vertical magnetic gradient by having two sensors mounted at separate heights. This allows for the unit to have a very fine localized resolution while removing the effect of diurnal drift and solar activities on the local magnetic datum. The conductivity of the host soils has no impact on the quality of the data produced providing a distinct advantage over the other technologies utilized.

Since the unit works on properties of magnetics and is capable of collecting DGPS, it is ideal for localizing metallic or semi-metallic anomalies to sub-meter positioning accuracy. Centimeter level accuracies are not capable with this unit due to the interference from the RTK GPS on the measurement technique. However the unit is largely affected by objects at the surface such as cars, metal fences and structures. This limits the sites where it can be effectively deployed.

The data from this particular unit can be gathered at a brisk walking pace with no corruption or negative impact on the quality of the data in a single axis grid with spacing of 1-2 meters. The processing and analyzation of the data can be completed in a fraction of the time required to collect the data, however the ability to conduct real-time interpretations is limited.


Figure 6: Howard Black collecting Mag data in the open field. Magnetic Gradiometry data can be gathered and analyzed relatively quickly, however real-time interpretations are limited and metallic objects or debris can have a negative effect on the results.

Abandoned Well Data Comparison

As briefly described earlier in this document, all three technologies gathered data related to different site conditions and features due to the type of data they were collecting. In this instance, the Magnetic Gradiometer appeared to pinpoint the location of the well in the clearest manner. This data shows a clear, singular target with little to no additional targets or signal noise noted.
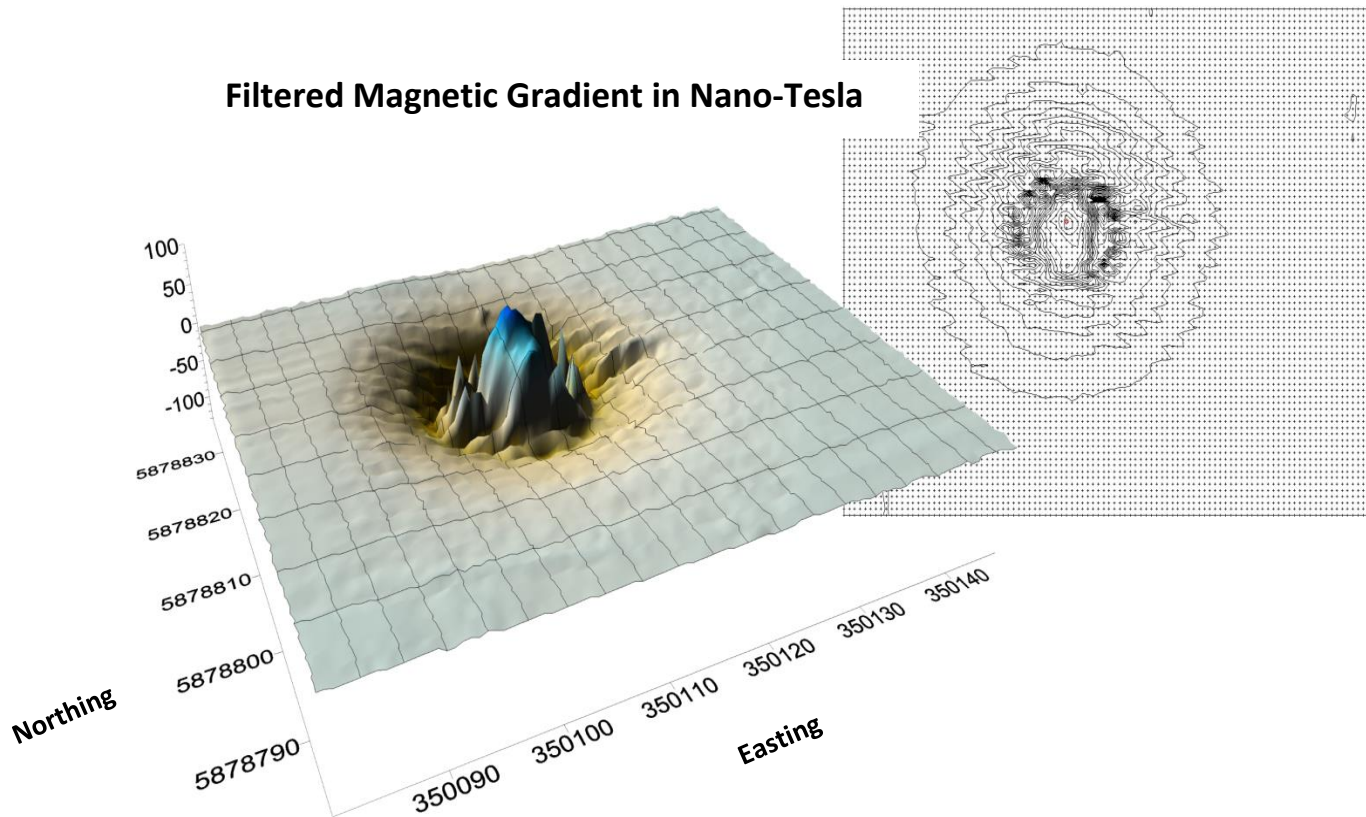

Figure 7: After software post-processing and analysis, this data from the GSM19WG Magnetic Gradiometer appears to show the clearest target with the least interference.

It is important to reiterate that these results are specific to this particular site and ground/target parameters. Although the Magnetic Gradiometer was the best approach for locating this abandoned well, it may not be appropriate for other sites and targets.

In addition to the strong signature associated with the most likely well location, there is a noticeable lack of other targets. This indicates that there are likely few other significant metallic targets in the immediate area.

In contrast, the GPR data provided the least subsurface information in this scenario, even after extensive software post-processing. This was surprising, since the area was relatively smooth with no noticeable above grade interference. Also, this farmland was cleared of tree roots and shallow boulders, so false positives were also not a significant concern. It is likely, however, that soil conditions were not favorable for signal penetration. Factors such as moisture, soil pH, and clay content can all vary the attenuation of the system's subsurface radio waves.
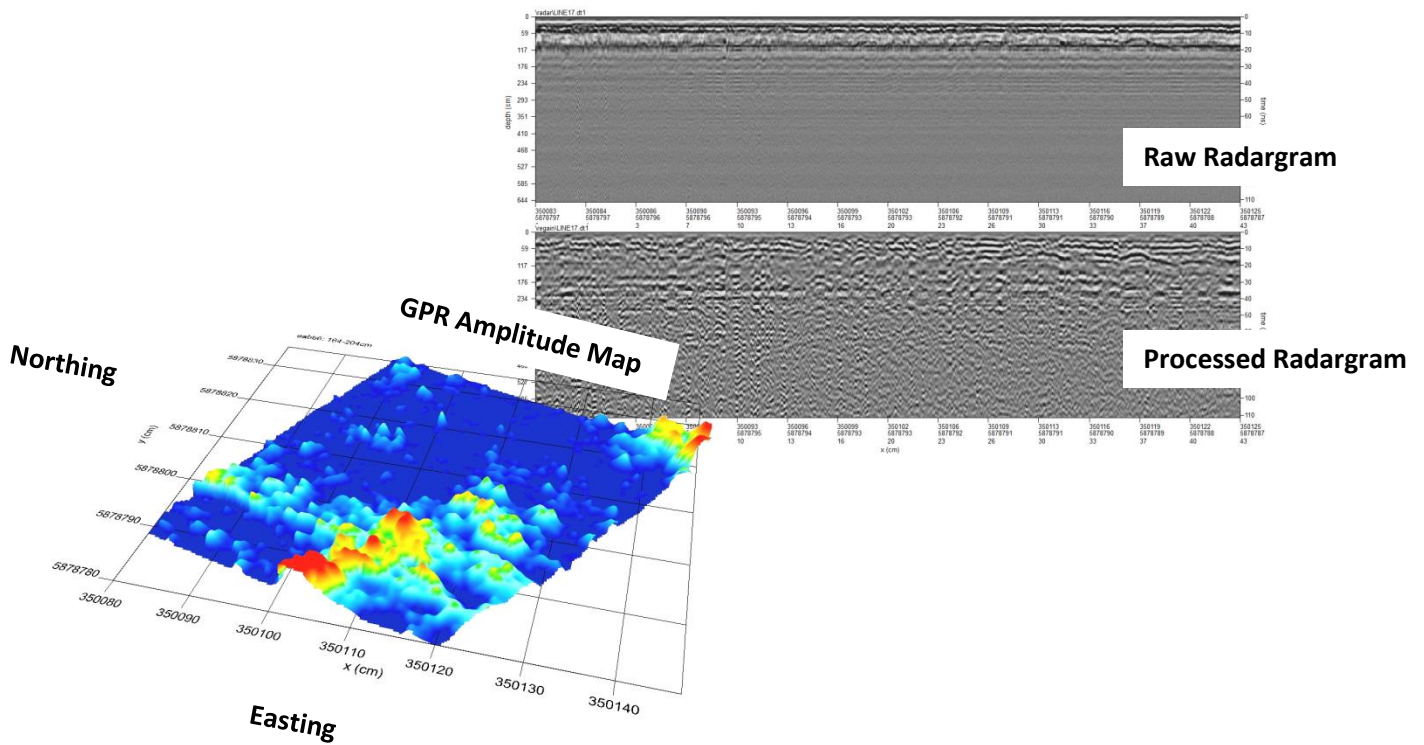
Figure 8: No strong targets were noted in the GPR data in this instance, likely due to radio signal attenuation caused by soil conditions.

In Northern Alberta, there are many areas were clay layers are known to interfere with the collection and interpretation of subsurface radar data. In addition, drilling muds, fluids, and other sources of contamination could have an effect on the signal's ability to travel through the matrix.

The GEM2 Electromagnetic Conductivity Profiler seemed to provide more information than GPR technology. On its own, the data was not as clear or obvious as Magnetic Gradiometry, however the area of highest conductivity does correspond with the GSM19WG results.

The wider area indicated in blue in this in Figure 7 representation may indicate a subsurface feature such as a contamination plume, a change in moisture content, or other factors. In this particular case expanding the area of investigation may have yielded a clearer image of the anomaly and allowed for further interpretations as to the cause.
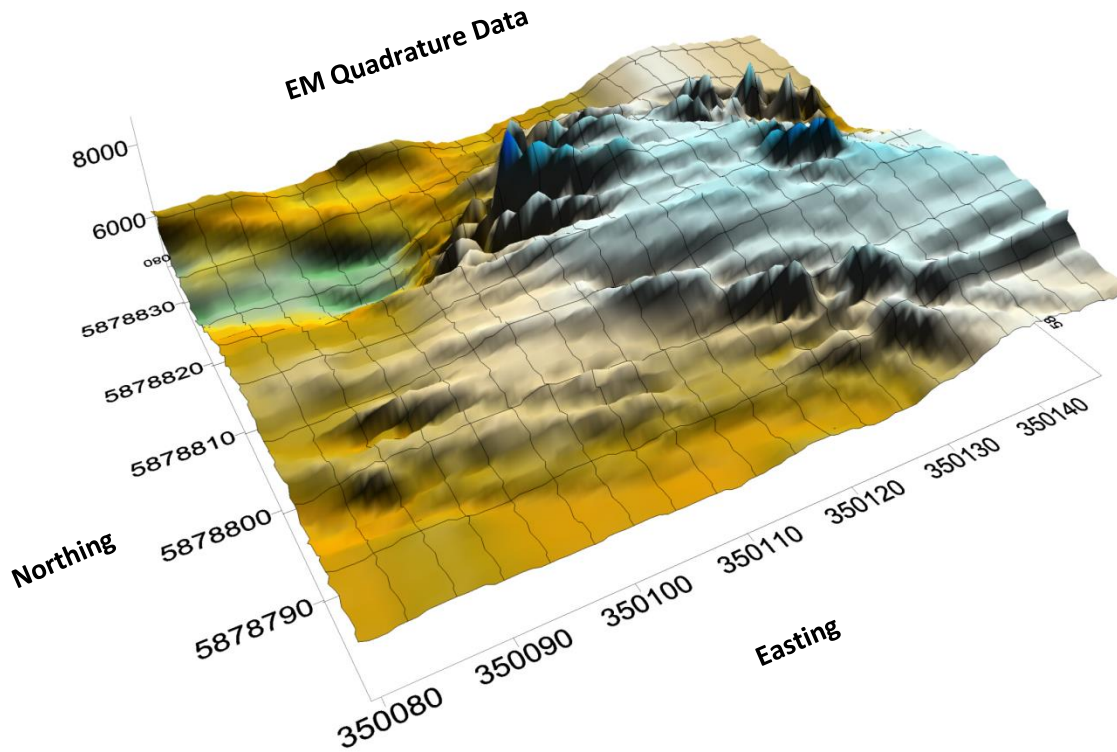

Figure 9: The EM Profiler results indicated a larger area of higher conductivity, and the peak within this area corresponded to the target also noted in the Magnetic Gradiometry data.

Conclusions

At this site, under these conditions, Magnetic Gradiometry appeared to yield the best results. There is no reason to suspect that this would be the case for all well locations, especially given the diverse well histories, terrain, and subsurface conditions across Western Canada.

Of the other two technologies, Electromagnetic Conductivity Profiling was the next best option for indicating the well location at this site. Although Maverick has had success locating abandoned wells with Ground-penetrating Radar in the past, in this situation it was not effective.

Destructive testing such as boreholes and sampling, or physically exposing the located well, was not within the scope of this study. Between the three technologies, enough data was gathered that the technicians were confident with the clarity and repeatability of the results.

Although factors such as site access, safety considerations, and travel to remote locations have to be taken into account, it was demonstrated that a crew of technicians can gather enough data with multiple systems in a single site visit to an abandoned well site. Armed with sufficient experience, knowledge, and equipment options, pinpointing these well locations can be both effective and affordable.

For this study, a standard 4x4 truck was sufficient for site access. Depending on weather, the age and condition of roads, and other challenges additional vehicles or tools may be required to perform the work in a safe and timely fashion.

Figure 10: For this scenario, a 4x4 truck from Maverick's fleet was sufficient for site access. In more remote or difficult to access locations, Maverick typically deploys a tracked side-by-side or Centaur offroad vehicle.

Acknowledgements

Several individuals from Maverick Inspection Ltd. were involved in the data gathering portion of this technology comparison. These include the following personnel:

- Howard Black, GPR Supervisor
- Matthew Etherington, Utility Locate Supervisor
- Steven Toner, Operations Manager
- Warren Tessari, R&D Team Lead
- Rex, Howard's Constant Canine Companion

Howard Black selected the systems and methodologies, and he performed the software post-processing and analysis for all three technologies.

Terraplus 25
GEOPHYSICAL EQUIPMENT SUPPLIER

> For more information regarding Maverick Inspection Ltd.'s services including available technology, inspection applications, news, and case studies, please visit:
>
> **www.maverickinspection.com**

Figure 11:(From Left) Matthew Etherington (inset) Howard Black, Steven Toner, Warren Tessari, and Rex (inset) at the end of a very windy day on the Alberta prairies.