The special demands on airborne geophysics of engineering projects

Greg Hodges
Sander Geophysics, Ottawa, Canada

Abstract. Airborne geophysics can be very useful in many engineering projects, but geophysicists need to learn to understand and address the needs of the engineering problem. Geophysicists have to design surveys and predict results for never-been-done applications with very little prior information or experience. It is essential to educate the engineers on what geophysics can do and what the limits are, show how geophysics should be properly integrated into the project. Finally, geophysicists must provide data and interpretation in formats and measurements most useful to the project, with proper confidence factors provided for the interpreted results.

1. Introduction
The application of airborne geophysics to engineering problems has been growing over the last 25 years. These developments grew on a solid foundation of 75 years of successful applications to exploration. However, the styles and needs of engineers are different from those of explorers, and for engineering, geophysicists have to learn new ways of analyzing, presenting, and delivering their results. Unlike exploration, where clients are often geophysicists or at least geologists familiar with geophysics, engineering clients may be geotechnical or civil engineers with little knowledge of geophysics and its use and possibly no understanding of geology.

2. Deep learning inversion method
Geophysicists looking at engineering projects may have to consider surveys for applications that have never been tried before, which means previous experience doesn’t exist, rock or soil properties may be unknown, and supporting geological information unavailable. Without this background information, careful planning is needed to determine what geophysical method, if any, will work for the problem. Extensive practical experience is needed to guide cautious use of standard geophysical properties to develop realistic models that will reliably predict how accurately the target will be detected – if at all. However, geology is endlessly complex and variable. Tabulated geophysical properties represent limited samples of the type of rocks or dirt. The actual rock properties can fall anywhere in a large range of values, may be affected by unpredictable factors (like saturation), and can vary greatly within apparently-uniform rock units. The models used have to be interpreted carefully, with suitable, significant allowances for errors in the assumptions made. The contrast between target and host geology and the strength of the geophysical signal predicted by the model have to be enough to provide a significant margin for errors before predictions of success can be trusted.

3. Education
Resource exploration is a high risk venture, and all those who engage in exploration generally accept and understand these risks. Engineering, on the other hand, is based on minimizing risk wherever
possible because, of course, lives may depend on the developments and construction. Geophysical interpretations, whether for exploration or engineering, involve uncertainty because of the volume of geology sampled, the complexity of geology compared to our models, the uncertainty of rock properties, and the ambiguity of interpretation from data to rock properties to geology.

Engineers expect measurements, like overburden depth or soil compaction parameters, to be precise, definitive, and unambiguous. Geophysics can rarely provide that kind of accuracy and confidence, so the key to using geophysics for engineering problems is education. The geophysicists need to educate themselves about the specific needs of the engineers, the geology and conditions for the survey. They need to understand clearly what the engineers hope to get from the geophysical data.

Once the geophysicists understand the engineering problem, they need to educate the engineers on what can be accomplished with geophysics, what possible pitfalls there may be, what level of accuracy will be achieved, and how the results could vary depending on the difference between the model parameters and the actual measured geology. This will not be easy. Engineers want direct measurements with tried-and-trusted techniques. To propose a never-before-tried geophysical method will require the geophysicist to gain the engineer’s confidence by demonstrating a clear understanding of the problem and needs, confidence in the geophysical model, the ability to describe these to a non-geoscientist in an understandable way – and a certain amount of salesmanship.

4. Integrating Geophysics
It is unrealistic to hope, in most cases, that geophysics could replace other, more direct methods, like drilling, trenching, or penetrometers. In many cases, geophysics will be most effective if it is designed to complement other methods of gathering data. Geophysicists need to understand the other options engineers might have to get information, and how geophysics can be integrated to enhance or complement these other data sets. For certain you will never convince engineers to replace their methods with geophysics – and you’d be making a mistake if you do!

For example, drilling and airborne EM are highly complementary. Drilling and cone penetrometers are standard tools of soil and civil engineers to measure overburden thickness and character. Drilling samples the soil directly and provides a direct measure of thickness, but it is expensive and invasive. Drilling tells nothing about conditions even one metre from the hole. The drill can be easily fooled by,
for example, a large boulder in the soil. The interpretation of geophysical measurements to provide geology, on the other hand is much more ambiguous, but the sample volume is much greater and coverage can be continuous. When drilling and geophysics are planned and used together the drilling provides precise, point measurements, and the geophysics provides the “fill” in-between the drill locations, particularly if the drill information is used to “calibrate” the geophysics to reduce the ambiguity. The final data are better, and with good planning the costs are less.

To be useful to the engineers, geophysicists must try to convert their measurements to the measurements that the engineers need: thickness, or competence, for example. Caterpillar (the bulldozer people) have produced graphs that relate seismic velocity to “rippability”, which defines whether material can be “ripped” with a bulldozer or must be blasted: an important parameter to estimate excavation cost. In some instances, geophysicists can create a useful conversion from, say, conductivity to rippability. Salinity is another good example: hydrologists do not want to know the conductivity (in mS/m) of the ground water; they want to know the salinity or total dissolved solids in ppm. Geophysicists need to be able to provide that conversion from measured conductivity – with proper advice on accuracy and the assumptions made in the conversion.

In some cases, geophysics can provide the actual rock property needed. When designing cathodic protection for pipelines or lightning protection for power lines, engineers need to know conductivity near the structures, which only geophysics can provide as an in-situ measurement.

In all cases, geophysicists need to provide a confidence factor, preferably as an error range on measurements, although it is often possible only to give a qualitative answer, perhaps a percent confidence.

5. Conclusion

Geophysical surveys can provide information that can be very useful to engineering projects, but the surveys have to be conducted with a full understanding of the type of information and confidence needed by engineers, and with full understanding between the geophysicists and engineers of what can be accomplished, and what geological conditions might limit the accuracy of the results. The geophysicists are often required to predict results from models with very little reliable information, so the modelling report must properly assess and communicate the uncertainty that comes from that. Geophysical surveys sometimes provide exactly the earth property needed – like conductivity – but more often the measurements need to be converted to the earth property or measurement that the engineers need. Only someone with full understanding of the geophysical principles and measurement can make these conversions accurately, and with accurate assessment of reliability.