GPR technology
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January 2008

Subsurface Views

Sensors & Software Inc.

Factors that affect the practical use of GPS

GPR & GPS revisited

Previous newsletters have discussed the use of global positioning systems (GPS) with GPR (EKKO_Update, April 2004) and the accuracy of moderately-priced differential GPS (Oct 2004). We advised that an understanding of the true accuracy of the GPS, and the conditions necessary to provide that level of accuracy, were needed before blindly relying on the GPS results.

In this newsletter we provide an overview of the capabilities of various GPS configurations (Table 1). We explore accuracy as well as other factors that affect the practical use of GPS for GPR surveys.

GPS Accuracy

Table 1 shows the quantitative relative accuracies of various GPS. The accuracy shown is relative to the local coordinate system. Absolute accuracy is somewhat less, depending on the known precision of the base station location.

It comes as no surprise that the most accurate GPS's are the most expensive. This does not mean that the most expensive systems are always required. Lower priced GPS may be perfectly adequate, depending on the type of survey being conducted.

Figure 1 - page 2 graphically displays the accuracies of four of the GPS's listed in Table 1. In all cases the GPS data were

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From our customer files:

Blackbeard's secrets

The Marcus Hook Plank Log House in southeastern Pennsylvania is an excellent example of early 18th century vernacular architecture in the Delaware Valley

Noggin plus 250 SmartCart was used to survey the Marcus Hook Plank Log House.

but it may hold other secrets. Local folklore claims that the Plank House was once the home of a mistress of Blackbeard, the notorious English pirate who sailed the Caribbean Sea and western Atlantic during the early 18th century, a period referred to as the "Golden Age of Piracy".

This legend recently came to life again when the current owner, while remodeling the kitchen area for his wife, began recovering artifacts including many pieces of old plates and hundreds of bones.

Another myth claims that underground tunnels connect the house to St. Martin's Church and down to the Delaware River. The tunnels are supposed by some to have been used by pirates to hide their plunder.

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In This Issue

GPR & GPS revisited *(continued from page 1)*

Dual frequency WAAS mode

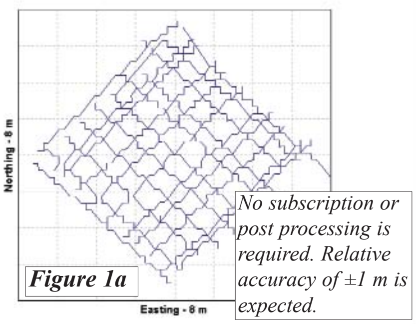

Figure 1a

No subscription or post processing is required. Relative accuracy of ±1 m is expected.

Subscription satellite based correction service

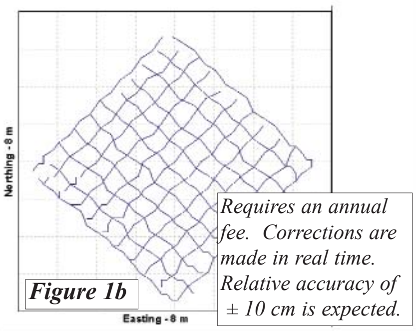

Figure 1b

Requires an annual fee. Corrections are made in real time. Relative accuracy of ± 10 cm is expected.

Post processing with remote reference station

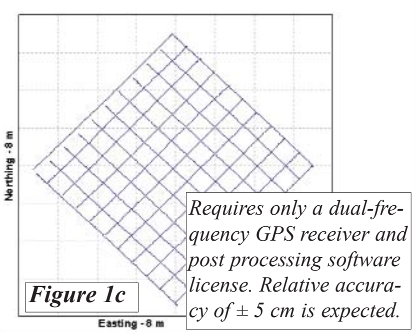

Figure 1c

Requires only a dual-frequency GPS receiver and post processing software license. Relative accuracy of ± 5 cm is expected.

Post processing using local reference station

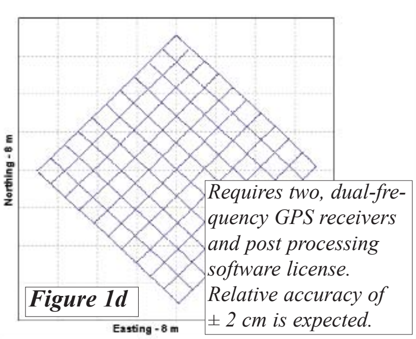

Figure 1d

Requires two, dual-frequency GPS receivers and post processing software license. Relative accuracy of ± 2 cm is expected.

collected on a standard 5 m by 5 m grid with 0.5 m line spacing in an area with a wide open sky.

The least accurate Differential GPS's (WAAS mode, Figure 1a) provide trace positioning suitable for larger scale geological surveys with GPR antenna frequencies less than 200 MHz. These GPS's are also used in ice profiling and snow depth surveys (Figure 2a) where high-precision positional data are not usually required.

The medium accuracy GPS's (Figure 1b and 1c) are suitable for surveys with GPR antenna frequencies up to 250 MHz surveys. Archaeology, forensics and utility locating (Figure 2b) fall in this category.

Differential GPS receivers with post-processing using a local reference station and Real-Time Kinematic (RTK) systems can provide sufficiently accurate positioning for GPR grids and line data. The most accurate of these GPS methods (Figure 1d) can provide individual trace positioning suitable for bridge deck surveys with 1000 MHz GPR systems (Figure 2c).

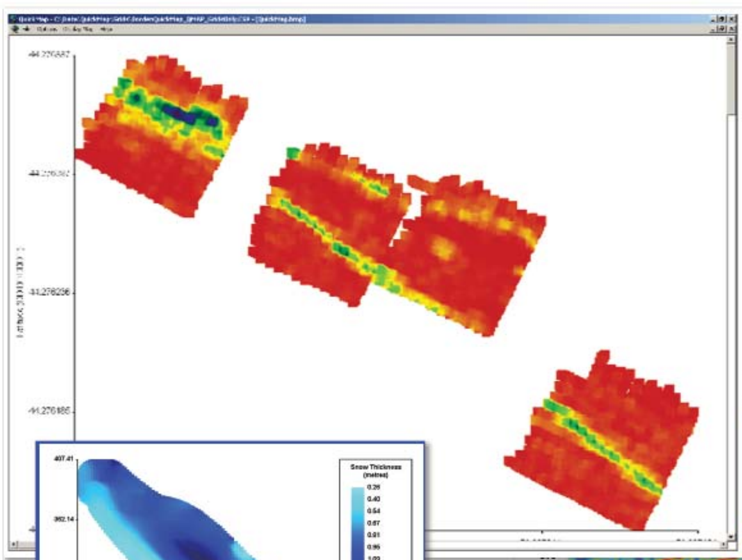

Figure 2b: *Depth slice maps showing utilities require the 10cm accuracy from systems with subscription-based corrections or post-processing with a remote reference station.*

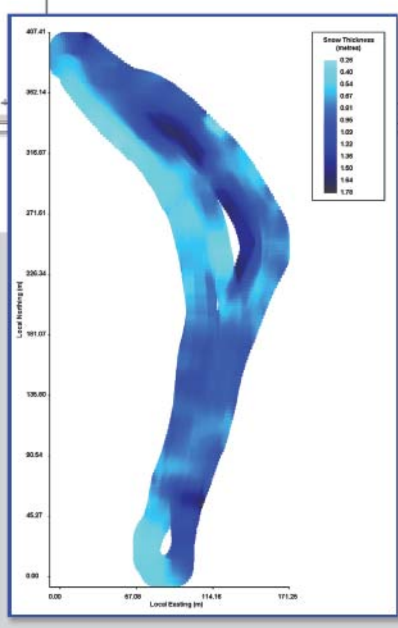

Figure 2a: *Snow depth data using a WAAS mode GPS with about 1m accuracy.*

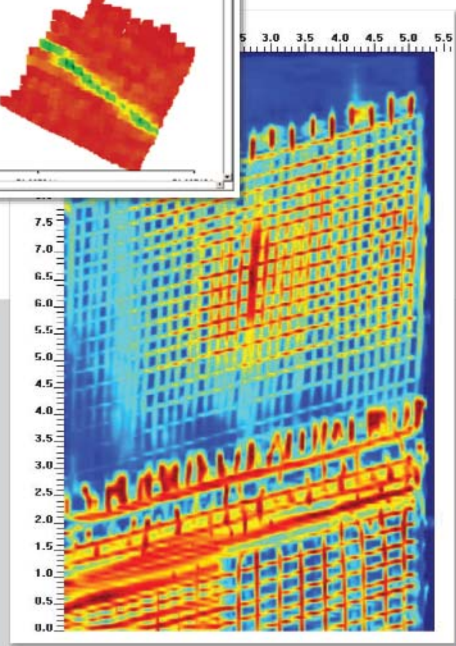

Figure 2c: *Depth slice maps showing structural members in a concrete bridge deck require the 2cm accuracy from post-processing with a local reference station or real-time kinematic (RTK) systems.*

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System	Expected Relative Accuracy	Warm up Time (min)	Reliability (signal reacquire time)	Typical Update Rate (Hz)	Latency Time (sec)	User Input	Price Range (US$)	Suitable GPR Frequency	Suitable GPR Application
WAAS Mode	± 1 m	<5	Excellent	1	~1.0	Minimal	$500 - $3000	< 200 MHz	Geology, Ice Profiling, Snow Depth
Dual Frequency WAAS Mode	± 1 m	<5	Excellent	5	~1.0	Minimal	$5000 - $10000	< 200 MHz	Geology, Ice Profiling, Snow Depth
Subscription based satellite correction service	± 10 cm	30	Poor	5	Variable for a given receiver (~1.0)	Minimal	$10000 + $1400 /year subscription fee	Up to 250 MHz	Utility Locating, Archaeology, Forensics
Post processing with remote reference stations	± 5 cm (Absolute ± 20 cm)	5 - 10	Good	10	~0.1	Requires knowledge of post processing software	$10000 - $15000	Up to 500 MHz	Utility Locating, Archaeology, Forensics
Post processing with local reference stations	± 2 cm (Absolute ± 10 cm)	5 - 10	Very good	10 - 20	~0.1	Requires knowledge of post processing software and local reference location	$20000 - $25000	Up to 1000 MHz	Structure Assessment
Real-Time Kinematic (RTK)	± 2 cm	5 - 10	Excellent	10 - 20	Unknown	Requires known local reference location	$25000 - $30000	Up to 1000 MHz	Structure Assessment

Table1: *Conclusions are based on testing that Sensors & Software conducted with various GPS on mobile platforms. It describes our experience with these systems so in some cases it may conflict with individual manufacturer's claims. This information is intended as a basic guide and not an exhaustive study. GPR practitioners considering adding GPS to their GPR system are encouraged to diligently assess available systems and carefully select the GPS most suited to the GPR surveys they conduct.*

Other factors affecting GPS use for GPR surveys

1) Warm Up Time is the time required to obtain the most accurate data. This can vary from a few seconds to 30 minutes.

2) Signal Recovery is related to Warm Up Time. All systems are prone to temporary loss of GPS signal. The time to reacquire that signal varies from seconds to up to 30 minutes. Obviously, long wait times for signal recovery are frustrating and impractical on moving platforms.

3) Update Rate is how often the GPS position is updated. This varies from once per second to 5-20 times per second. If the update rate is once a second, the position of a given GPR trace can be incorrect by up to the distance traveled in that second. For this reason, it is important to choose a GPS with an update rate that reflects the survey speed. For high-accuracy GPS receivers used at walking speed, an update rate of at least 5 Hz is recommended. Clearly, higher speed towed systems require the fastest update rate.

4) Latency is the delay time from the position fix by the GPS to the acquisition of the position information by the data logger of the GPR system. This is usually only important on high speed GPR surveys (e.g. road surveys) if the distance between GPR traces (a.k.a. the step size) is comparable to the distance traveled during the latency time. Shorter latency times are better and a consistent latency time is critical for accurately correcting the data for this time delay.

5) Post Processing: Some GPS's require that corrections from base stations be applied to the raw GPS positions acquired during the survey. These corrections are typically available on the GPS manufacturer's website a few hours or up to a day after the survey. This time must be considered for generating accurate images and reports. As well, this step requires the user to learn the GPS manufacturer's correction software which, in our experience, can have a steep learning curve and may require software training for the most accurate corrections.

Summary

Our experience to date indicates:

- GPS accuracy increases with system cost and sophistication;
- Reliable GPS operations depends on clear skies unobstructed by buildings, trees and other structures;
- Latency and Update rate must be considered when operating GPS on mobile platforms;
- GPR applications demand differing levels of GPS accuracy;
- Accuracy of GPS is continuing to improve with use of dual frequency (L1 and L2) and integration with GLONASS (Russian) satellites.

Sensors & Software's application group are continuing to monitor GPS advances and will regularly report practical results obtained with combining GPR & GPS. ■

Recent Technical Papers

1. Using Ground Penetrating Radar as an Assessment Methodology in Roadway Rehabilitation
   By: Mark Popik, Dave Redman
   2006 ***ref 375***
2. Geomorphic constraints on listric thrust faulting: Implications for active deformation in the Mackenzie Basin, South Island, New Zealand
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   2007 ***ref 376***

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Blackbeard's secrets

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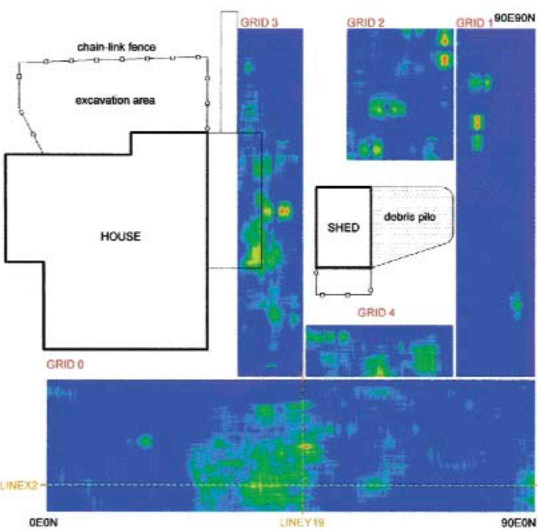

An anomalous area was located at the central portion of Grid 0.

NAEVA Geophysics conducted GPR surveys at the site in an attempt to delineate any anomalous features associated with the Marcus Hook Plank Log House. Five bi-directional (XY) grids, each with a line spacing of 2.5 feet (0.75 meters), were collected with a Noggin*plus* 250 SmartCart system. The grids covered a total area of 4800 square feet (about 450 square meters).

The grid data were processed and visualized as a series of 2 foot thick depth slices using the EKKO_Mapper software. An anomalous area was located at the central portion of Grid 0.

This anomaly may represent foundations of a garage or carriage house which is shown at this location on an early 20th century map. Everyone of course hopes that it is really a tunnel or buried treasure.

For more information go to www.bbplankhouse.com

Story and data images courtesy of NAEVA Geophysics. ■

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