Accuracy in Subdivisions

By Ron Mak, OLS, OLIP

Introduction

Not many surveyors are sending crews out to survey subdivisions these days without a total station, or even GPS. The benefits are obvious, but are you aware of the challenges? These instruments are significantly more accurate than the optical theodolites and chains of days not that long ago, but when used inappropriately, the results can be a poor reflection of their abilities.

Having worked in firms that have done a significant amount of subdivision and housing, I have checked the accuracy of many subdivisions within days of being registered. I have also pounded in my share of iron. Unfortunately it is not uncommon to find an area or two where the bars are 5 or more centimetres from the coordinates calculated from the plan. In the days of houses being designed to very close tolerances, 5 cm can be a real problem. This could be exacerbated in a future "Deferred Monumentation" subdivision where another firm may be laying out the house next door based on the exterior subdivision boundary 300 metres away. Having experienced and addressed the problem (as evident by my hairline), let me remind you of some of the fundamental principles, which need to be addressed.

5" Means What?

A 5" total station is accurate to 5", right? That works out to 2mm / 100m. But wait! That 5" is likely the DIN 18723 specification, which is a measure of *precision*, not *accuracy*. You might get this accuracy 2/3 of the time (one sigma) if your instrument is perfectly calibrated, perfectly set-up, and the angle is measured on both faces. (*Professional Surveyor*, November 2002 Vol. 22, No. 11 has a full explanation of this; it can be found in the archives at www.profsurv.com). In reality, you may only get a precision of 10" out of that total station, and then only 2/3 of the time.

Error Propagation

It's not uncommon for a crew to set the first few bars from control points that were established when working on the boundary survey. But these often get knocked out or hidden behind piles of dirt. The crew may then resort to setting up on a bar recently set (because they *know* it's going to be good - no chance for bulldozers to get close), and then checking to another bar set from the previous set-up. After setting many bars through many set-ups, a check is finally available to a bar on the exterior boundary, or another control point. Unfortunately, the check ends up being out by 10 cm. What the crew has forgotten is that errors propagate. In my experience, the errors can easily double through each set-up, so a 2 cm error can quickly grow to 10 cm after just 3 set-ups.

Redundancy Increases Boundary Accuracy

To establish coordinates on a point from two other known points, a distance and an angle is required. Two measurements are required to establish two unknowns (a Northing and Easting). If you measure a distance to the unknown point from a third known point, you have a redundant observation, which can be used to check the coordinates, or be used as part of an adjusted solution. You then have a redundancy of one. A closed loop traverse - no matter how large or how many points it has - has a redundancy of three: the last angle and distance, as well as the closing angle are all redundant observations. This is clearly not enough if you are going to be laying out 9 metre lots, which will all have

Calendar of Events

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July 6th to 8th, 2003

Survey & GIS Summit
Bridging the Gap 2003
San Diego, California
www.esri.com/events/survey/index.html

September 21st to 25th, 2003

Digital Earth - Information Resources for Global Sustainability
Brno, Czech Republic
http://digitalearth03.geogr.muni.cz

October 6th to 10th, 2003

4th International Conference on 3-D Digital Imaging and Modelling
Banff, Alberta
www.3dimconference.org

October 11th to 15th, 2003

URISA Annual Conference
Atlanta, Georgia
www.urisa.org

October 14th to 17th, 2003

25th Canadian Remote Sensing Symposium
Montreal, Québec
http://casi.ca/crsseng.pdf

October 16th to 18th, 2003

CIG - ACSG
96th Annual Conference
Calgary, Alberta
www.cig-acsg.ca

November 27th & 28th, 2003

AOLS Statutes and Professional Examinations
GTA, Ontario
www.aols.org

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houses with minimum side yards on a 40 ha site.

On a recent site where we had an exterior traverse with no cross ties or other extra redundant measurements, I initially closed and adjusted the traverse with a least squares package and appeared to have great results. The initial misclosure was only 8 cm (1:27,000) and the residuals were all very small - 4"/angle and less than 5mm per distance. But when I checked the adjusted coordinates against the coordinates obtained by GPS calibrated on one road, I still had a 12 cm error at the opposite end of the project! I then constrained the traverse with the observed coordinates obtained by GPS at the four main corners. Adding four coordinate pairs to the solution increased the redundancy from 3 to 11. Re-adjusting the traverse also gave small residuals and indicated no significant measurement blunders. What is the moral of the story? Always build adequate redundancy into your boundary survey and adjust the results with least squares. The days of the Compass Rule and the Crandall Method are over.

Boundary Models

Surveyors sometimes find themselves in a quandary: An observed bearing and distance is close enough to a previous survey to agree, but the digital model matches the actual measurement, and not the previous plan. How do you lay out ten 9-metre lots along a line 89.972 metres long? One workaround employed by some surveyors is to create a second point close to the observed location of each bar, which is used to model the boundary and then the subdivision inside. This technique has merits, but can cause significant errors in the field if the crew is only given the new "theoretic" coordinates for the bars. Don't forget the crew is going to set up on the bar - not on a theoretical point 14 mm away. And remember, that 14mm will quickly grow to significant errors in the field.

Inflexible Total Stations

Back in the days when subdivisions were barred using an optical theodolite and a chain, a crew would routinely compensate for small errors as they built up the subdivision in the field. Total Stations are almost incapable of distributing error, but their operating range far exceeds that of former technologies. While this can cause problems by propagating errors instead of mitigating them, proper field techniques can prevent runaway errors. Your crew should always work between previously established, checked and adjusted control points. Never allow them to backsight one control point and then turn 180° to set a SIB 200 metres away. If a control point needs to be established in the field and used the same day, the crew should know how to take redundant observations to/from the new point and calculate adjusted coordinates for it. Total stations with full resection/least squares programs can be very useful here, but make sure you know how the programs work. Some "free station" programs are nothing more than a distance/distance intersection. Of course, the field calculations should all be checked in the office.

GPS - Friend or Foe?

GPS has been a great tool for increasing accuracy on any large site, to the point where I can't imagine going back to using total stations alone. But two points separated by 1000 metres coordinated to 2 cm accuracy sounds great, until we see two points 10 metres apart with the same accuracy. We're not helping the crew with the total station when they check across a road from one GPS point to another and find a 3 cm difference. Here are some of the methods to get the most from using GPS.

- Be aware of the potential for multipath and other GPS errors. Back in the days when I was testing different RTK systems, it wasn't unusual for a system to give coordinates 0.5 metres away from the previous system's solution observed coordinates which were obtained moments before. Difficult GPS environments may give bad solutions.
- With RTK, take multiple observations on points at different times (at least 20 minutes apart) when there is different satellite geometry. Using different base stations will also add independence to the solutions. We regularly tie in all points on a site, then go through them all again in the same order to add redundancy and accuracy.
- Adjust your GPS data with traditional data. Don't rely solely on one or the other - let the technologies complement each other.
- Even if you use RTK, consider logging raw data so that you can post-process and adjust it later to tighten things up.

Conclusion

With today's tools, there is no reason why we can't consistently achieve the high accuracy needed today. But the tools are just that - tools. They need to be used properly by staff who have been trained to understand their abilities and limitations. Don't fall into the trap that total stations and GPS make your field crew's job easier. Sure - it's easier. But it's still just as easy to do it poorly.

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