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Understanding Global Positioning System Limitations: A Case Study of Mapping and Survey Grade GPS

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The Global Positioning System (GPS) is used to locate positions on Earth. The accuracy of a position derived by GPS depends on the GPS-receiver design, the satellite configurations at the time of data collection, local conditions which may interfere with signal reception, length of time spent on data collection, and the method of signal interpretation. GPS receivers are grouped into 3 general categories based on the previous criteria and additional data-recording capabilities. GPS receivers with low accuracy and relatively few features are considered recreational grade. Increased accuracy and data management features designed for advanced data collection characterize mapping grade. Survey-grade GPS receivers have the highest accuracies.

"The accuracy of a position computed by a GPS receiver is a function of the geometry of the GPS constellation visible at that moment in time" (Trimble 2001). The geometry of the satellite configuration is reported as the Position Dilution of Precision (PDOP) and is considered a measure of accuracy of the GPS data. This data may be represented as a horizontal precision.

This study compares mapping-grade GPS data to survey-grade GPS data to assess the accuracy of mapping-grade data. In addition, the reported horizontal precision is used to assess the quality of reported locations when the sample locations are near the reported horizontal accuracy of the data collector.

The study was conducted at Pine Tree Branch Station located in St. Francis County, Arkansas. The test site was an open field of approximately 92,000 m². The test plot was constructed on a 3.6 m grid with 480 staked corners. Initial grid construction was with tape measure. Two Trimble Model 4700 GPS receivers with Trimble Microcentered L1/L2 GPS antennas with ground planes (part number 33429-00) were positioned for data collection, one at 6 meters, the second at 29 meters away from the grid. A TopCon GTS-603AF Total Station survey instrument was positioned 7.6 meters away from the grid (Fig. 1). The Trimble GPS-data recorders recorded carrier-phase GPS data for approximately 6 hours. This data was post-processed for differential correction using the Online Positioning User Service (OPUS). Three base stations were used for differential correction: Memphis 2 CORS, 78,075 m from the site; Bloomfield CORS, 216,825 m from the site; and Memphis WAAS CORS, 88,851 m from the site.

A TopCon Total Station survey instrument was used to record relative positions of the 2 survey-grade GPS recorders and all stake positions (TopCon 2002). The total station data was imported into a Geographic Information System (GIS) and the two survey-grade GPS positions were used to assign coordinates to all stake positions.

Each stake location was also captured by 1 of 2 Trimble GeoExplorer 3 GPS-data recorders by 1 of 2 operators. Data masks were set within the GPS-data recorder to minimize positional errors. The settings used for this study were Position Dilution of Precision (PDOP): < 4; Signal to Noise Ratio (SNR): 6; and satellite elevation mask: 15°. Data was collected in the Universal Transverse Mercator (UTM) projection, Zone 15, North American Datum 1983 (NAD83). Positions were collected at one-second intervals with a goal of reaching at least 30 positions per stake. The positions were averaged together into a single location for each stake. All stake locations were captured in a single day.

GPS location data from the GeoExplorer 3s were post-processed in GPS Pathfinder Office for differential correction. The base station used for differential correction was a Trimble 12-Channel Community Base Station located at the Ground Water Institute, Memphis, TN.

GPS Pathfinder Office produces a horizontal precision based on a user-selectable confidence level. The precision is a function of the GPS receiver type, method used to collect point data (number of positions averaged), distance to the base station used for differential correction, the PDOP, and other reference variances (Trimble 2001). The horizontal precisions were calculated at the 68% confidence level, the default value for the software. Corrected data were imported into a GIS for analysis.

The data were analyzed for positional agreement between the mapping- and survey-grade GPS. The mapping-grade data were also analyzed using reported 68% horizontal precision circles. The precision circles were tested for intersection with the correct survey-grade location, overlap with adjacent survey-grade locations, and overlap with adjacent mapping-grade locations. The horizontal precision estimates were also tested against the RMS-positional error in SPSS statistical software to determine the best-fit model.

The RMS error from the survey-grade GPS positions as reported by the OPUS solution was 0.025 m. The distance between the Total Station position and the furthest survey-grade GPS position was 118.5 m. Reported accuracy for the GTS-603AF Total Station is ±2 mm + 2 ppm (Topcon 2004). Therefore, expected accuracy for the stake locations was 0.027 m. The final grid measurements between stake locations were a mean distance of 3.689 m with a standard deviation of 0.179 m.

Stake locations collected with the GeoExplorer 3 GPS recorders were reported in 100ths of a meter from the origin
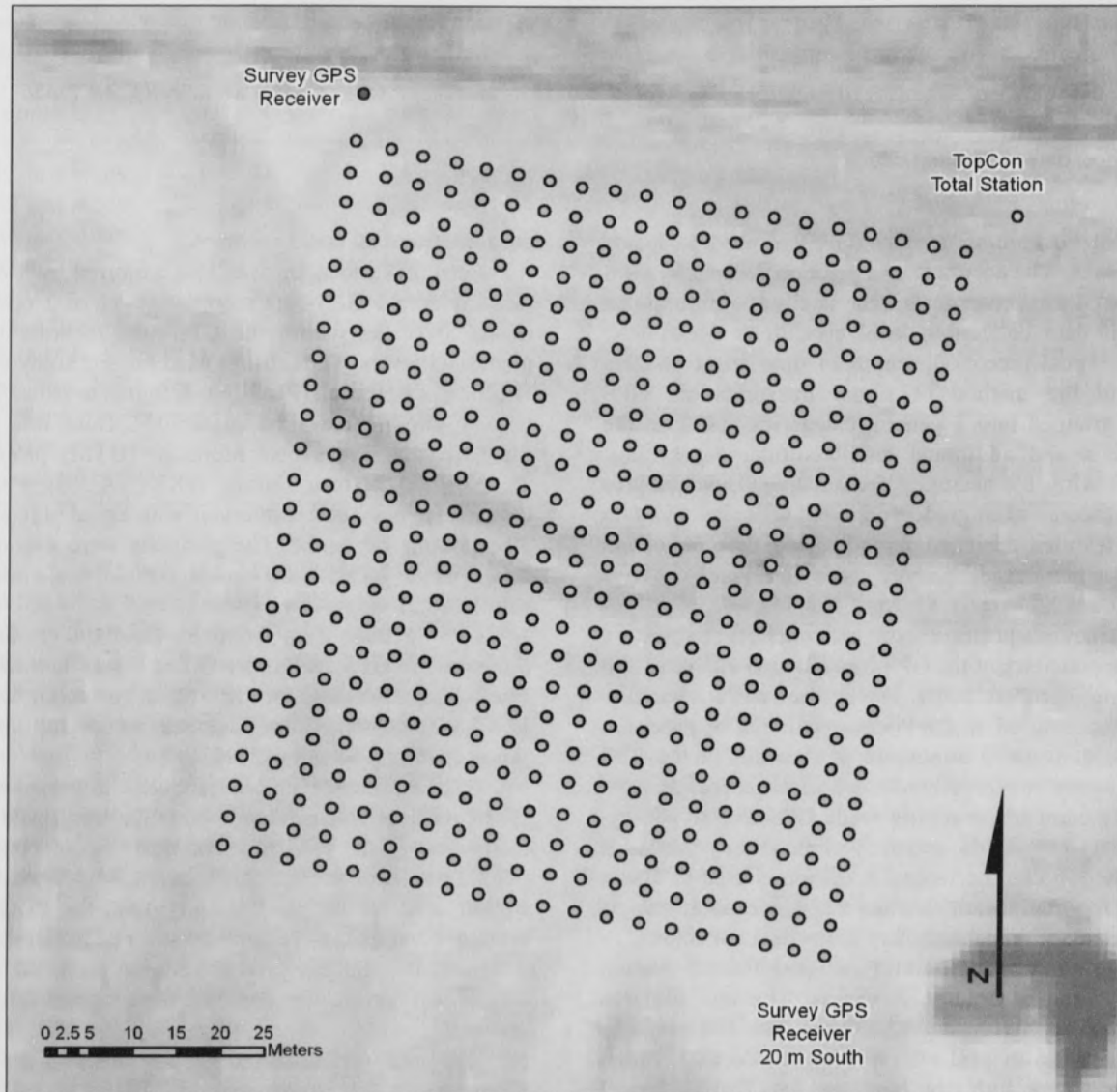
Fig. 1. Relative positions of survey GPS receivers, TopCon Total Station, and stake locations.

of the projection (UTM Zone 15, NAD83). The 68% horizontal precisions averaged 2.48 m with a standard deviation of 0.53 m. The RMS error between the mapping- and survey-grade locations averaged 0.80 m with a standard deviation of 0.53 m. The straight-line distances between the mapping and survey grade locations averaged 0.99 m with a standard deviation of 0.76 m.

The intersection between the mapping-grade GPS-precision circles and nearby GPS locations resulted in an average of 1.41 GPS locations observed in each precision circle with a standard deviation of 0.74 and a maximum of 8. The intersection between the mapping-grade GPS-precision circles and the survey locations resulted in an average of 1.4 survey-grade locations

in each precision circle with a standard deviation of 0.66 and a maximum of 5. No statistical relationship was found between the 68% horizontal-precision and RMS-positional error.

The results show that the accuracy of the GeoExplorer 3 mapping-grade GPS recorder can be much better than specification. Average RMS-positional error in this study was below 1 m. However, no relationship was found between the 68% horizontal-precision estimates generated by GPS Pathfinder Office and the RMS error between the mapping-grade and survey-grade locations. This shows that while the reported GPS horizontal precision may be high (a low value), the accuracy of that position is unknown (Fig. 2).

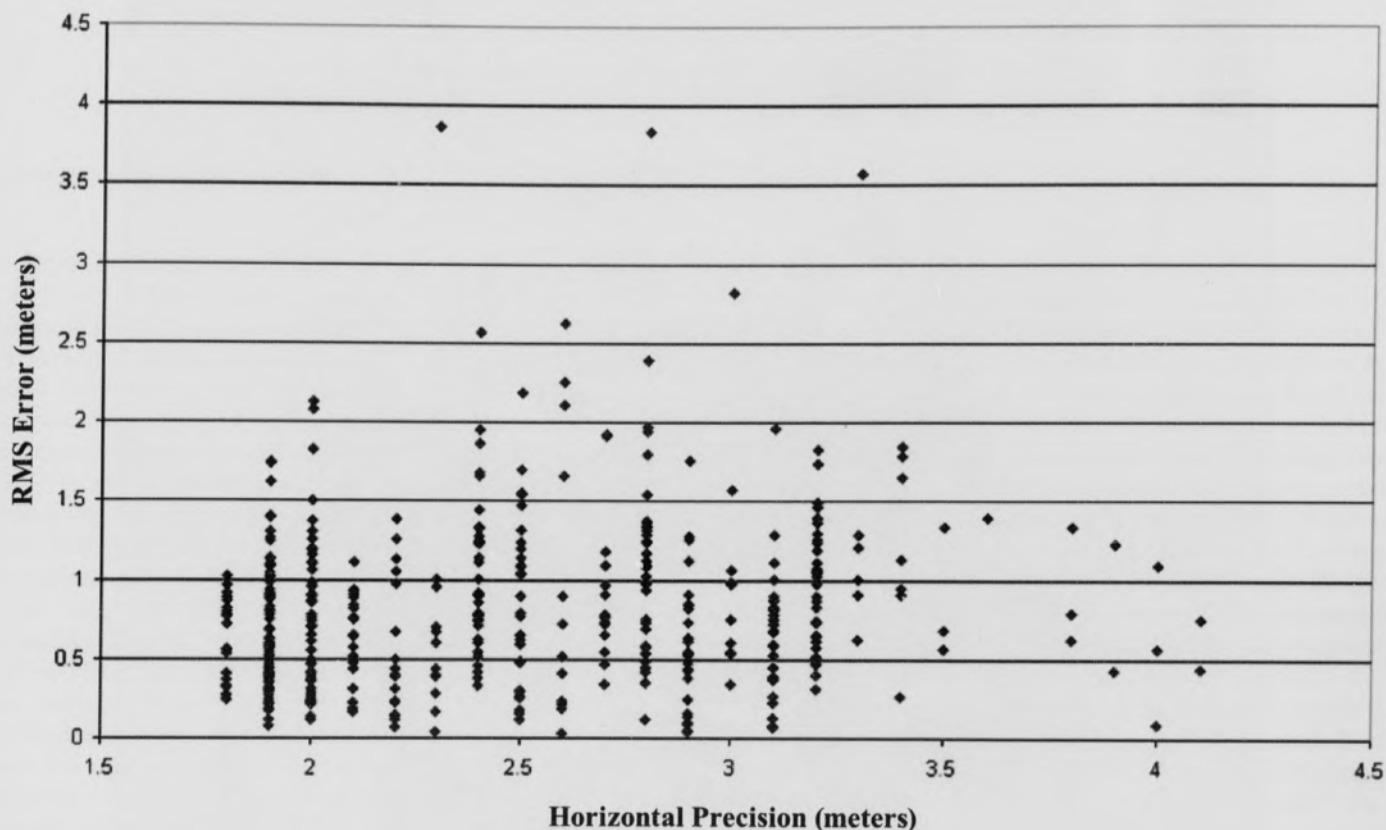The spacing of the test grid was within the accuracy

Fig. 2. Sixty-eight percent horizontal precision circle radius versus RMS error between survey location and mapping grade GPS location for stakes.

specifications for the GeoExplorer 3 GPS recorder. The precision circles captured the true location (survey grade data) in 66.46% of the data. However, more than one true location was captured in the precision circle in 32.92% of the data. In 3 of the mapping-grade GPS locations, the true location was not captured in the precision circle (Fig. 3).

It is useful to compare the precision circles to the reported locations when the grid spacing is within the horizontal accuracy of the GPS equipment. The horizontal-precision circles captured more than 1 GPS location 31.46% of the time. In all of the data, there was only one location where the precision circle did not overlap one or more precision circles for nearby locations. Because the precision circles represent the 68% probability of the location being within the circle, overlapping precision circles suggests that the locations with overlapping precision circles are indistinguishable.

This work demonstrates the high accuracy of mapping-grade GPS-data recorders when they are used in ideal conditions with proper procedures. However, it should be noted that the reported horizontal precisions represent a probability of a location being within the precision circle, and there is no relationship between the reported precision and the RMS error between the mapping-grade GPS location and the location derived by survey techniques. Using the reported precision as a measure of accuracy should be done with caution. This work also demonstrates the importance of horizontal spacing in experimental design when GPS is to be used to locate objects. To prevent uncertainty in feature location, the distance between adjacent features should be at least twice the maximum expected accuracy of the equipment used to identify locations.
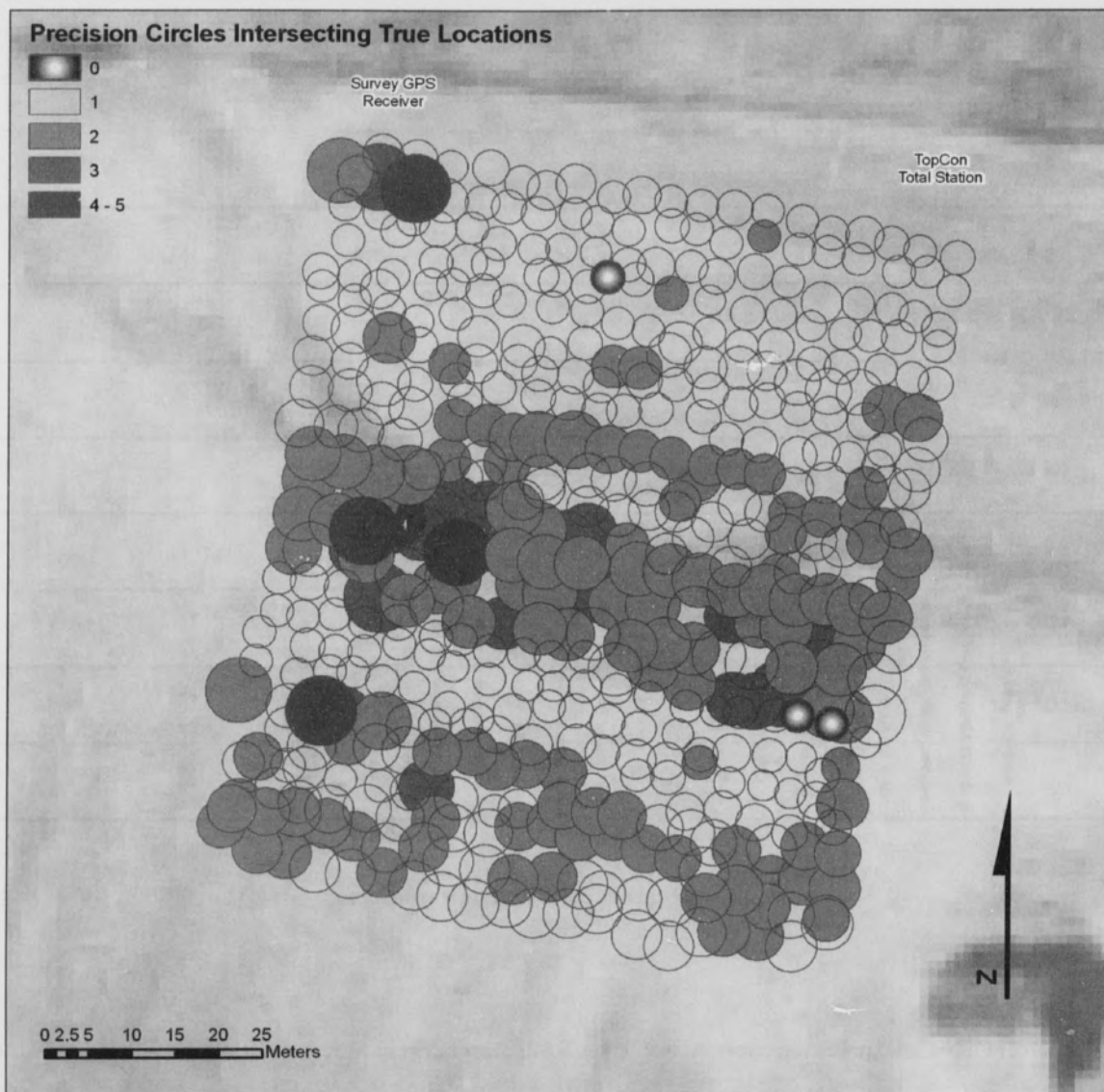
Fig. 3. Intersection of 68% precision circles and survey location. Hollow circles indicate precision circles which intersect survey location. Bullseye shading indicates circles which did not intersect any survey location. Gray circles indicate circles which intersect more than 1 survey location.

Literature Cited

Trimble Navigation Limited Mapping & GIS Division. 2001. GeoExplorer 3 Operation Guide ver 1.20. Sunnyvale, CA. 628 p. Available at: www.trimble.com. Accessed 2006 March.

Topcon 2002. GTS-600/GTS-600C series Electronic Total Station brochure. Item # 5310731. Available at: www.topcon.com. Accessed 2006 March.