WETLANDS, Vol. 15, No. 1, March 1995, pp. 31–36

LOCATING DELINEATED WETLAND BOUNDARIES IN COASTAL SOUTH CAROLINA USING GLOBAL POSITIONING SYSTEMS

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Abstract: A six-channel Global Positioning System was used to locate eleven points on wetland boundary lines. The latitude and longitude of these points were compared to locations obtained by a second order ground survey. Operating criteria and tree foliage coverage varied over a 19-month period of data collection (February 1992 to October 1993). Canopy coverage levels sampled within a hurricane impacted area, did not increase horizontal position error as much as percent of readings that had only 3 satellite (2D) coverage. If at least 60 readings were made at each point and more than 50% of the total readings had 4 satellite (3D) coverage, the average horizontal distance error was 3m. Beginning in June 1993, with appropriate adjustments in data collection and data manipulation, 5-m accuracy was obtained 95% of the time regardless of time of year, level of canopy coverage, or height of antenna. These accuracies seem to be sufficient for boundary surveys of delineated wetlands for routine regulatory purposes. Criteria for data collection should be specified so that the accuracy of the data can be evaluated.

Key Words: wetland maps, operator criteria, location accuracy

INTRODUCTION

Location of wetland boundaries for regulatory purposes is usually a two-step process. First, soils, vegetation, and hydrology are examined and a boundary line is flagged between the wetlands and uplands. Second, the flagged boundary is surveyed by a registered land surveyor. This process is not only time-consuming, but it is expensive to the landowner, may require a higher degree of accuracy for boundary-line location purposes than is necessary for routine needs, and has the potential to slow down regulatory decisions. Global Positioning System (GPS) receivers have been widely used for locating points, boundary lines, environmental applications, and a host of other uses (Gerlack and Jasumback 1989, Bergstrom and Jasumback 1990, Larson and Jasumback 1990, Peterson 1990, Evans et al. 1992, Kruczynski and Jasumback 1993, August et al. 1994), but their use for routine wetland boundary surveys has not been widely accepted by regulatory agencies. The advantages of GPS are obvious: a wetland delineator may locate boundary points and survey them immediately or quickly survey key points on a flagged boundary line with GPS before leaving the site.

Specific accuracy of GPS may vary with time of day, among days, number of satellites within a certain zenith, number of satellites used for a computation, number of readings with three satellites (2D) or four satellites (3D), geometry of satellite constellation, how data are corrected for height above ellipsoid (HAE), and interferences such as earth bounce, presence and

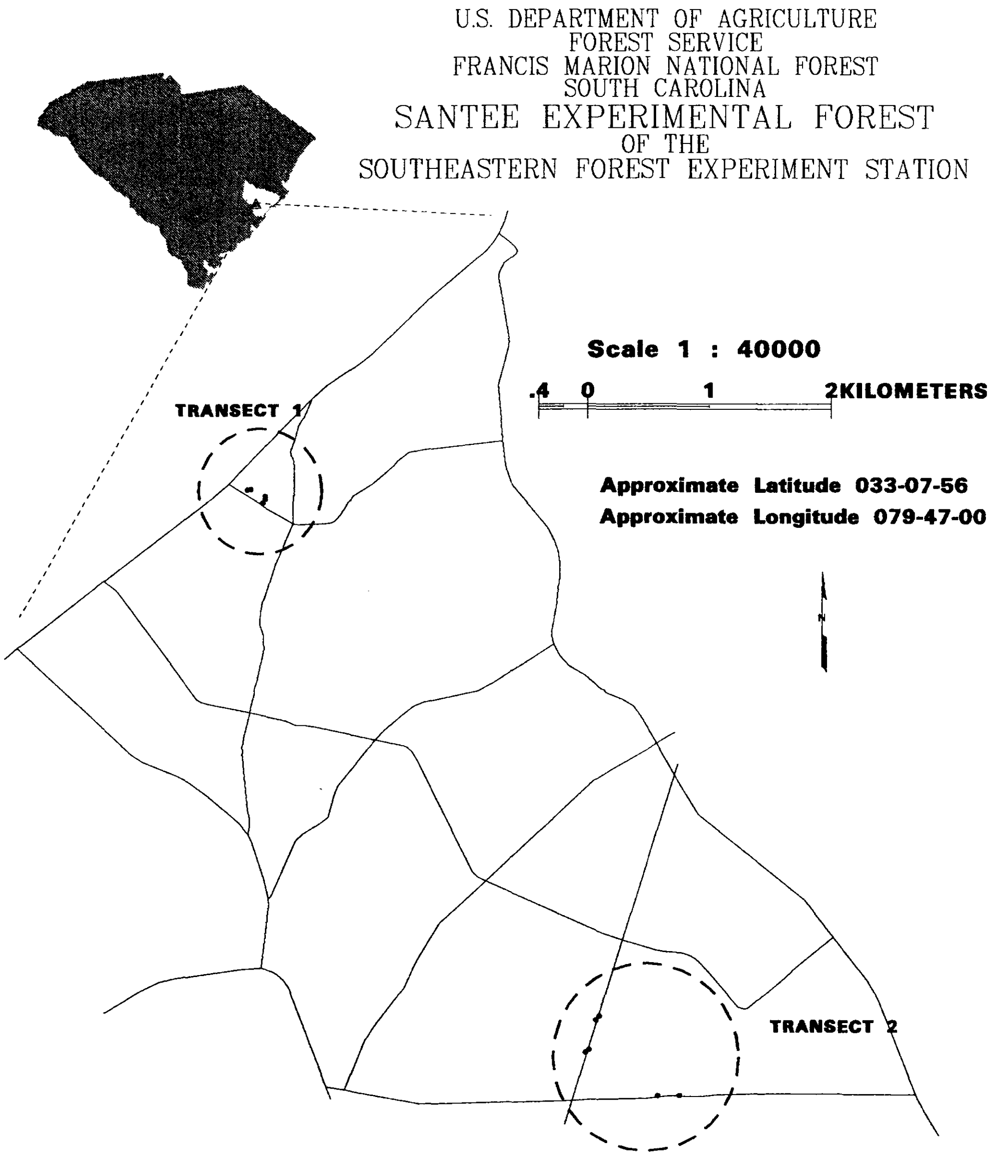

Figure 1. Wetland boundaries surveyed on the Santee Experimental Forest in coastal South Carolina.

density of tree canopies, height of antenna above ground, antenna motion, and distance from base correction station. Although manufacturer's manuals and the references cited above provide guidance for collection of GPS data, data collection and correction are still not a turn-key job. Careful mission planning and post-processing of field data are necessary to minimize errors in point or boundary locations (August et al. 1994).

The General Reference Manual (Trimble Navigation, Ltd. 1992) recommends collecting one hundred eighty 3D readings at each point. Frequently, under adverse field conditions, fewer readings may be collected and/or other recommended criteria may not be met. The question is: How far from ideal collection criteria can one deviate and still obtain reliable data? The objective of this study was to determine the effect of failure to meet desired operating criteria on degree of horizontal error of location. GPS data were collected on eleven points over a 19-month period, where one or more ideal collection criteria were not achieved, and evaluated to determine degree of horizontal error of location.

METHODS

Site

All field work was conducted on wetland boundary lines within the U.S. Forest Service, Southeastern Forest Experiment Station, Santee Experimental Forest in Berkeley County, SC (approximate latitude 033-07-56

Table 1. Specific operator criteria for five collection dates.

		Readings		Antenna			
Year	Month	Interval (sec)	Time (min)	Height Above Ground (m)	Motion Rotation* (S or R)	PDOP Switch** Position	Satellites Number in Operation
92	February	1	3	0	S	6	16
92	June	1	3	0	S	6	16
93	June	1	3	0	S	6	24
93	August	3	1	2	R	6	24
93	October	1	***	2	S	M	25

* S = antenna held stationary and R = antenna rotated in circle about 1 m diameter to try to maintain 3D readings.
** 8 is default for either 2D or 3D readings and M = set manually to read 3D fixes only.
*** Kept recording until 180 3D readings had been made.

and longitude 079-47-00; Figure 1). To test the accuracy of point location by GPS, a second order Class II survey (per Bossler 1984) was conducted on eleven delineated points on the wetland boundaries (Figure 1). The first five points (Traverse 1) were tied into a South Carolina State Geodetic Survey (SCGS) triangulation station, and the second survey of six points (Traverse 2) was tied into a USDA Forest Service second order geodetic control station established by GPS survey grade equipment. GPS survey grade instruments are carrier-phased and typically have accuracies of 1 cm but require mathematically intense computations. They are also sensitive to signal blockage and user motion. In contrast, the Pathfinder instrument used in this study was a code-phased instrument and typically has accuracies of 5 m and are mobile and less sensitive to user motion (Kruczynski and Jasumback 1993). All locations were by latitude and longitude. Both surveys were traversed and closed with a ratio of closure of 1:66,658 or better.

Equipment and Operations

A Trimble Pathfinder Pro GPS Receiver (upgraded to six channels) was used to determine the coordinates of the wetland delineated points at five different times during a 19-month period. Instrument settings during collection period were a) Elevation Mask 15 to limit lowest angle of satellite acceptance to 15 degrees, b) Signal Level Mask 6 to minimize signal to noise ratio, c) PDOP Mask 8 to control the geometry of satellite constellations (the lower the reading the better the geometry, but low readings may limit times when data can be collected), and d) PDOP Switch 6 to allow reception of 2D or 3D readings except when in the Manual mode (see Table 1).

All points on both Traverses were surveyed by GPS in February of 1992 (prior to leaf-out), June of 1992 and 1993, August of 1993 (full leaf-out), and October of 1993 (partial leaf-fall) using collection criteria shown in Table 1.

GPS Data Manipulation Methods

The data were downloaded from a field polycorder into a personal computer with GPS Pathfinder Professional, Release 2.3 software, for processing point determination. The Geodetic Datum selection was Lat/Lon. Each data set was corrected to lessen Selective Availability degradation by using a correction file obtained from the Community Base Station at Columbia, SC, a distance of about 120 km. The corrected data for each point were averaged into a single descriptor as the point coordinates.

Initially, data were collected without regard to the number of 2D readings, since the primary interest was horizontal location errors. It was later found that 2D data also needed to be corrected for height above ellipsoid (HAE) to minimize horizontal errors. With 2D readings, one satellite measurement (altitude) is replaced with a fixed measurement, and if the fixed altitude is incorrect, horizonal distance may be off by two times or more of the altitude error.

Two approaches were used to correct for HAE. As per Trimble recommendations, each file was placed into the editor, and all 2D points were filtered out. Statistics were run on the individual files to obtain a mean HAE. The original file was 2D-corrected using the mean HAE for that site, and the adjusted file was averaged to obtain a point latitude and longitude. Mean HAE corrections are only valid if a large number of observations have been taken. Since a number of our points had less than the desired number of observations, an additional correction method was sought. A fixed-18m HAE value was recommended by Matthew Wellslager of the South Carolina Geodetic Survey (pers. comm.) as an acceptable standard for 2D corrections in the topographic area of this study. This value was

Table 2. Distance from GPS locations to survey points (m) by correction method, total number readings per point (#), and percent of reading that were 2D.

	GPS*	Correction Method: Base	HAE	−18 m	Recordings: #	% 2D
Traverse 1						
February 1992	1	7.8	9.1	8.5	124	94
	2	4.2	1.4	6.7	115	83
	3	4.5	6.7	3.8	146	23
	4	2.8	4.5	4.0	191	58
	5	1.5	1.8	1.5	167	78
Mean		4.2	4.7	4.9	149	67
SD		2.4	3.3	2.7	31	28
June 1992	1	0.6	0.6	0.7	178	2
	2	30.9	30.9	9.1	196	100
	3	30.3	30.3	8.4	191	100
	4	31.4	31.4	9.2	190	100
	5	7.5	3.5	4.2	192	53
Mean		20.1	19.3	6.3	189	71
SD		14.9	15.8	3.7	7	44
Traverse 2						
February 1992	15	3.0	3.0	8.1	90	100
	16	1.4	1.4	3.8	130	100
	20	14.9	14.9	8.6	176	100
	21	0.4	0.6	1.0	168	28
	28	18.9	18.9	16.1	197	100
	29	5.8	5.9	9.8	198	75
Mean		7.4	7.5	7.9	160	84
SD		7.6	7.5	5.2	42	29
June 1993	15	1.4	1.9	1.0	189	49
	16	1.9	1.8	1.7	36	19
	20	3.6	2.7	3.1	213	16
	21	1.9	2.9	1.5	172	18
	28	5.3	5.3	5.3	179	0
	29	4.4	4.6	4.3	179	98
Mean		3.1	3.2	2.8	161	33
SD		1.6	1.4	1.7	63	35

* GPS = GPS location number; Base = corrected by base station only; HAE = corrected for mean height above ellipsoid; −18 m = height corrected by a constant of −18 m; # = total number recordings at each point; and % 2D = percent of recording that had 2D fixes (i.e., only three satellites).

Table 3. Distance from GPS locations (m) to survey locations by collection date, HAE correction method, number of recordings, and % 2D recordings.

	August 1993					October 1993		
	Correction Method			Recordings		Correction Method	Recordings	
GPS*	Base	HAE	−18 m	#	% 2D	Base	#	% 2D
Traverse 1								
1	2.7	1.5	2.0	54	7	1.0	185	0
2	4.9	5.0	5.0	94	13	1.9	180	0
3	1.5	1.5	1.5	40	0	3.2	185	0
4	7.8	6.5	4.1	57	96	5.2	185	0
5	1.7	1.7	1.7	61	0	3.8	183	0
Mean	3.7	3.2	2.9	61	23	3.0	184	0
SD**	2.6	2.3	1.6	20	41	1.6	2	0
Traverse 2								
15	5.9	5.9	4.2	19	42	5.2	185	0
16	2.2	2.4	4.0	57	56	2.1	187	0
20	3.7	1.7	3.0	93	20	5.3	184	0
21	1.9	0.9	0.6	79	39	4.1	182	0
28	0.6	0.6	0.6	72	0	2.6	183	0
29	3.6	3.6	3.6	47	0	1.9	181	0
Mean	3.0	2.5	3.4	61	26	3.5	184	0
SD	1.8	2.0	1.5	26	23	1.5	2	0

* GPS = GPS location number; Base = corrected by base station only; HAE = corrected for mean height above ellipsoid; −18 m = height corrected by a constant of −18 m; # = total number recordings at each point; and % 2D = percent of recording that had 2D fixes (i.e., only three satellites). ** SD = standard deviation.

based on experience and the general flat topography of the area (generally less than 2m change). Therefore, all files containing 2D values were also corrected using-18m HAE. Inverse computations were made by U.S. Coast and Geodetic Survey Software program GEODIREC and were based on NAD-83. Horizontal distances between points were determined by computer.

Cover Index

A Kodak 35mm Funsaver Panoramic Camera with extra wide prints was placed on the ground over each point and photographs taken in two cardinal directions. After developing, the prints were matched together at the center and a dot area grid with the scale of 1:62,000 was used to evaluate canopy cover along each photograph. A total of 320 dots were used in each estimate, and cover indices were computed as a percent for foliage, stem, and total.

RESULTS AND DISCUSSION

Horizontal distance of GPS location from surveyed location of the eleven points varied from 0.4m to 31.4m for the 1992 readings (Table 2). The largest errors during this time period (31.4m) occurred in June 1992, when 100% of the GPS readings for a given location were 2D. A regression of distance error versus percent 2D readings for 1992 showed a positive and significant increase in error with percent 2D readings ($r = 0.6$, $p = 0.01$). This indicated that as the percent of readings with 2D fixes increased, so did the error of location. There were no correlations between distance errors and percent stem indices for the February readings or with percent cover indices for the June readings.

The method of correcting location for 2D readings only influenced mean error of location in June 1992 when foliage was on the trees and the percent of 2D reading was excessively high (Table 2). The fixed-18m HAE correction reduced the average error of Traverse 1 from 20.1 m to 6.3 m (Table 2). Note that in June of 1993, the error of location was not significantly influenced by the 2D correction method when only one location had greater than 50% 2D readings (Table 2). Also, in August 1993, the method of correcting for 2D readings had no significant influence upon the error of location (again %2D readings were much lower; Table 3). These results indicate that the fixed-18m correction was reasonable for the area.

If the percent of 2D readings was generally less than 50%, base station corrections seemed to be sufficient for location corrections. There were no correlations between the August error distances and percent cover indices for these locations.

With base station correction only, error of location averaged 3.7 m ± 1.8 m for Traverse 1 and averaged 3.0 m ± 1.8 m for Traverse 2 in August 1993. Hence, 95% of the time Traverse locations were within 5.5 m of the survey location. These accuracies were very close to 5.3-m accuracy in October 1993 when the leaves were off and all criteria for obtaining the most accurate data were met. These results are comparable to the 5-m accuracy reported by Jasumback (1993) under dense tree canopies and better than the 6-m accuracy reported by August et al. (1994) under ideal conditions. However, August et al. (1994) used a three-channel GPS receiver, which limited the number of satellites that they could monitor.

The number of GPS recordings at each point varied from 90 to 213, except when readings were limited by recordings at three-second intervals for three minutes in August 1993 (Table 3). Best control of number of recordings was achieved by recording at one-second intervals until the operator counted 180 beeps (Table 3). This was cumbersome and required intense concentration by the operator. Such stringent criteria probably would not be easily achieved during inclement weather, detract from the ease, speed, and attractiveness of using GPS for routine wetland boundary-line surveying, and did not significantly improve accuracy.

The cover index for the eleven points varied from 95–17% index for total coverage and 72–0% stem coverage (data not shown). Under the conditions tested, the interference from the canopy seemed to have a minor effect on GPS location accuracy. Canopy cover only seemed to be important when percent of 2D readings was very high, antenna was on the ground, and the vegetation was in full leaf (June 1992). This work was conducted in an area impacted by Hurricane Hugo, and the canopy had considerably less foliage and canopy stratification than fully stocked stands normally have in the coastal plain of South Carolina. Jasumback (1993) reported that canopy interference increased the length of time required to obtain desired number of readings (120) under a dense stand of mature hardwoods in Indiana but did not affect the accuracy. Their average horizontal position error was 3.7m, similar to 3.0m-to-3.5m accuracy in this study.

CONCLUSIONS AND RECOMMENDATIONS

Horizontal position errors averaged about 3m per traverse and 5-m accuracy was achieved 95% of the time using the criteria employed from June 93 through October 93 under a moderate range of forest canopy conditions. Canopy cover only seemed to be a problem when the percent of 2D reading was very high. In general, no differences were evident in correction methods for 2D readings except when the percentage of 2D readings was high (greater than 50%) and foliage was on the trees and shrubs. Although the manufacturer recommended obtaining 180 readings at each location point, the same accuracy was achieved with an average of 60 readings at each location provided that the percent of 2D readings was generally less than 50% of the total number of readings (Table 3). Rigorously holding to 180 readings and accepting no 2D readings in October 1993 did not improve the accuracy over readings in June and August of 1993 with lesser restrictions on data acquisition.

The GPS method seems to be suitable for surveying of wetland boundary lines for routine regulatory purposes and other uses where 5-m accuracy is acceptable. Exceptions to this methodology for surveying wetland boundaries would occur where property values are very high, a controversy exists, or legal questions arise. Use of the GPS method for routine wetland boundary surveys should expedite the process for both the wetland delineator and regulatory personnel and decrease the costs to the landowner. However, we recommend that wetland boundary surveys by GPS be accompanied by data so that the accuracy of equipment and methodology may be evaluated. Minimum criteria should specify

a) type and limitations of GPS equipment used, since there is a a host of equipment available on the market, some of which have better performance qualities than others;
b) location of and distance to base station (Jasumback 1993);
c) number of readings for each point location (minimum of 60 but 180 preferred with no 2D);

d) if 2D fixes are accepted, the number at each location must be less than 50% of the total number of readings;
e) during the growing season, estimates of percent crown cover at each location point should be quantified;
f) height of antenna above ground indicated; and
g) time of day readings were taken (although not reported in these data, we found that readings very late in the day were associated with large errors).

ACKNOWLEDGMENTS

This research was supported in part by a cooperative agreement with the USDA, Forest Service, Southeastern Forest Experiment Station, Charleston, SC.

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Manuscript received 10 January 1994; revision received 15 July 1994; accepted 24 October 1994.