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# All Topo Maps: GPS - Accuracy & Datum Concerns

A customer recently called with this *All Topo Maps: GPS* tool accuracy complaint:

## Customer's Question:

> "The *All Topo Maps: GPS* Tool does not work! I physically occupied a NGS horizontal control point (see http://www.ngs.noaa.gov/datasheet.html) at our local airport, set my GPS (a Garmin 35LP) on top of the X scribed on the stainless steel cap. The *All Topo Maps: GPS* reported position is:
>
> ```
> N 33 17 20.7 W 95 53 53.1
> ```
>
> The enumerated NGS position is:
>
> ```
> N 33 17 21.0593 W 95 53 54.2151
> ```
>
> Another mapping program, using the same GPS at the same position, much more accurately reports the 'true' position. All Topo Maps obviously do not work! When will you fix the GPS tool?"

## Answer: Datum Shift

This is a classic Datum shift question. The All Topo Maps: GPS tool is not broken, the user has mixed coordinates from multiple datums.

The NGS reported position is expressed in NAD83 datumed coordinates. *All Topo Maps: Texas* expresses coordinates in NAD27 datums (every Texas quadrangle is NAD27 datumed and we want our bombsight cursor to report the same coordinates that are printed on the maps.)

The *All Topo Maps: GPS* tool receives the GPS position in WGS84 datum over the serial interface link from the GPS receiver. All Topo Maps (and the GPS) use the 'Molodensky Datum Transformation' to convert the received WGS84 coordinate to a NAD27 coordinate and report a NAD27 position (see http://www.colorado.edu/geography/gcraft/notes/datum/datum_f.html for information).

It is worth mentioning that the Molodensky Datum Transformation is an approximation, but it does quickly generate conversions that are close enough for consumer GPS work. A more accurate conversion is provided by the CORPSCON program (download from http://crunch.tec.army.mil/software/corpscon/corpscon.html ).

Let's closely look at the original NGS coordinate, the transformations and the observed GPS position for this coordinate set:

| | |
|---|---|
| NGS NAD83 coordinate | N 33 17 21.0593 W 95 53 54.2151 |
| NAD27 converted by Molodensky | N 33 17 20.5500 W 95 53 53.27000 |
| NAD27 converted by Corpscon | N 33 17 20.6587 W 95 53 53.33877 |
| Observed GPS coordinate | N 33 17 20.7 W 95 53 53.1 |

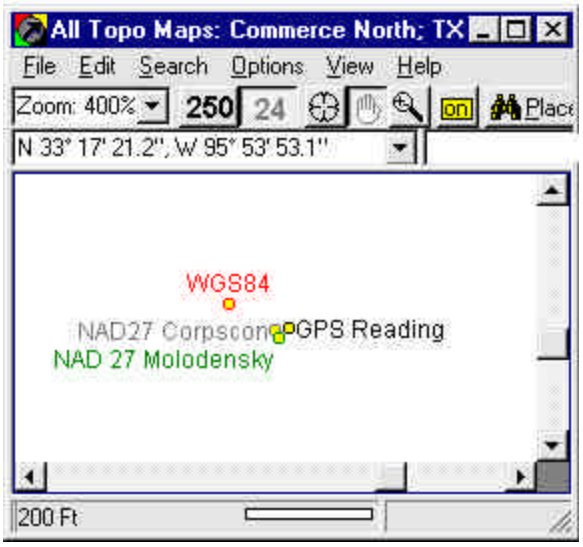
The difference between the NAD83 coordinate and the Corpscon converted NAD27 coordina is 84.7 feet.

The difference between the Molodensky NAD27 coordinate and the Corpscon NAD27 coordinate is 12.4 feet.

The GPS reading reported by All Topo Maps: Texas is within 20.93 feet of the Molodensky NAD27 value and 20.7 feet of the Corpscon NAD27 coordinate.

20 feet (6.1 meters) is about 1.6 pixels in the All Topo Maps image database!

Here is an image showing the relationship of these points:




This screen shot of All Topo Maps was generated with this annotation set:

<P 3>
N 33 17 21.0593 W 95 53 54.21510; WGS84 <P N> <F Red> <S Red>
N 33 17 20.65867 W 95 53 53.33877; <P W> NAD27 Corpscon <F Blue> <S Blue>

N 33 17 20.5500 W 95 53 53.27000; NAD 27 Molodensky <P SW> <F Green> <S Green>
N 33 17 20.7 W 95 53 53.1; GPS Reading <P E> <F Black> <S Black>

## Additional Inaccuracies

In this case we are lucky to have a very accurate horizontal coordinate point available from the NGS database. (The point was used as a survey base for a public airport.) Typically All Topo Map users are snapping locations from features found on the topographic maps. How accurately might we expect to recover these points?

The base USGS Quadrangles are produced in accordance with the 'National Map Accuracy Standards'. From these standards (see http://rockyweb.cr.usgs.gov/nmpstds/acrodocs/nmas/NMAS647.PDF ) we find:

> **1. Horizontal accuracy.** For maps on publication scales larger than 1:20,000, not more than 10 percent of the points tested shall be in error by more than 1/30 inch, measured on the publication scale; for maps on publication scales of 1:20,000 or smaller, 1/50 inch. These limits of accuracy shall apply in all cases to positions of well-defined points only. Well-defined points are those that are easily visible or recoverable on the ground, such as the following: monuments or markers, such as bench marks, property boundary monuments; intersections of roads, railroads, etc.; corners of large buildings or structures (or center points of small buildings); etc. In general what is well defined will be determined by what is plottable on the scale of the map within 1/100 inch. Thus while the intersection of two road or property lines meeting at right angles would come within a sensible interpretation, identification of the intersection of such lines meeting at an acute angle would obviously not be practicable within 1/100 inch. Similarly, features not identifiable upon the ground within close limits are not to be considered as test points within the limits quoted, even though their positions may be scaled closely upon the map. In this class would come timber lines, soil boundaries, etc.

At 1:24,000 scale, 1 inch equals 2,000 feet, so:

1/30 inch = 66.6 feet
1/50 inch = 40.0 feet
1/100 inch = 20.0 feet

Depending upon how you interpret the official statement, we expect map coordinates to be within 40-67 feet 90% of the time! (No indication of standard deviation is implied so 10% of the points could be ?...)

In addition to the base map inaccuracy, the DRGs (Digital Raster Graphics) that All Topo Maps are based upon, are rubber-sheet transformed to UTM projection. This mathematical transformation is based upon control points manually snapped onto the map surface. Additional errors are introduced with each step.

To the mapping errors, datum conversion errors, cursor positioning errors, map georeferancing errors, we also must add the GPS 'Estimated Position Error' (see EPE, commonly displayed on the Satellite Constellation display page) which is based upon the 'Dilution of Precision' (DOP is a measure of the number of satellites and quality of satellite positions.)

## Summary

Hopefully, the realities of geodetic coordinates and GPS accuracy will not shatter your expectations of consumer GPS receivers and their applications. The GPS's ability to accurately pinpoint your location, on the face of the planet or in the sky, is one of the most amazing feats of technology contrived during the 21st century.

Happy and safe mapping!

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