Baseline Accuracy Assessments of Garmin Recreational GPS Receivers

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INTRODUCTION

There has been considerable discussion concerning the applicability of low end or recreational receivers for mapping or GIS data collection purposes. However there has been little effort to determine the baseline accuracy and performance of this type of receiver under optimal observing conditions. By understanding the receiver capability under optimum conditions then one has a benchmark against which they can interpret the receiver operation under field conditions.

This report will discuss the results of a study on Garmin recreational GPS systems.

TEST PURPOSE

This test had two purposes. The first was to determine the baseline autonomous horizontal accuracy of several types of Garmin recreational GPS receivers under optimal observing conditions. The second purpose of this testing was to determine the ability of these receivers to track the satellites that transmit the WAAS real time differential corrector, apply this corrector, and then determine the baseline horizontal accuracy of the resulting positions.

PROCEDURE

While data files have been collected and periodically analyzed for several years, the files used in this report were collected in August and September of 2003.

Four different Garmin GPS receivers were used. These were the Etrex Legend, Etrex Venture, GPS 76, and GPS V. All receivers were updated to use the most current firmware available at the time.

Tripods were set up and leveled over two points that had been surveyed in using Trimble 4700 and 5700 survey level GPS receivers and tied to the Wyoming HARN and the National CORS networks. Point accuracies are on the order of 2 cm in latitude, longitude, and HAE. The points were located so that receivers would have a clear and unobstructed view of the sky in all directions.

A small ground plane was attached to each tripod and leveled over the reference point. Several GPS receivers were then attached to the ground plane and placed so that the internal antennas did not obstruct each other and had a clear view of the sky. It is estimated that the horizontal locations of the receiver antennas were within 6 cm of the reference coordinates.

During a given observation receivers were either enabled to receive and utilize the WAAS corrector or set in the autonomous mode and not permitted to use WAAS.

Receivers were set to store a track log point every 15 seconds and were run until the internal batteries were depleted. This typically yielded seven to eight hours of data. Files were collected at different times of the day to ensure that all satellite constellations were covered. During the test one receiver was connected to an external battery. Two files, one with WAAS enabled and one autonomous, were collected that were more than 30 hours in length.

After collection the data was downloaded from the receivers and analyzed using MS EXCEL. The horizontal RMS (63%) and 2dRMS(95%) statistics were calculated for the entire files as well as the radial difference from truth on a measurement by measurement basis.

RESULTS

Table 1 shows the results for the receivers with the WAAS corrector disabled and Table 2 shows the results for the WAAS enabled receivers.

TABLE 1 Autonomous Accuracies (WAAS off)

	Legend	GPSV	Legend (33 hours)
RMS (m)	5.44	5.52	4.91
2dRMS (m)	9.41	9.55	8.50

TABLE 2 WAAS Accuracies

	Venture	Venture	GPS76	Legend (31 hours)	Venture
RMS (m)	3.75	4.53	6.28	4.29	4.59
2dRMS (m)	6.49	7.84	10.87	7.42	7.94

These tables show a general consistency for all cases and receivers. In general the autonomous accuracy is approximately 5.5 m (RMS) and 9.5 m (2dRMS). The 33 hour file collected with a Legend receiver show slightly lower values than the shorter files. This could be due to using the entire file instead of truncating the file at 24 hours.

The files collected with the WAAS corrector enabled also show a general consistency for all files, with the exception of the GPS76. In general the RMS value is approximately 4.5 m and the 2dRMS is 7.78 m for all receivers.

The results for GPS 76 were more consistent with autonomous positioning than for the WAAS corrected positioning. The testing has been repeated with several other Garmin 76 receivers and the results have been the same. This particular receiver does not track the WAAS signal and apply it consistently when in a static mode. The accuracy of this receiver is also less than other receivers in the autonomous mode.

Interestingly the overall accuracies of the autonomous versus WAAS enabled cases only differ by a 1.5 meter for the 2dRMS value. Manufacturer specifications state that the

accuracy should less than 3 meters 95% of the time. This result suggests that the WAAS corrector is not being received or applied consistently. It could be argued that the corrector broadcast was not available or the satellite was not visible. A Trimble GeoXT was used as a check during this test and it was able to track the WAAS broadcast and apply it without problem. Other files that have been collected since this time have shown the same behavior.

With the exception of the West Coast, the Atlantic Ocean Region – West (AOR-W) Inmarsat 3f4 satellite located over northern Brazil provides the WAAS satellite coverage for the United States. For the Cheyenne, WY area the satellite is located at an azimuth 117^{o} and elevation 18^{o}. This sky location is visible from the test site. However as one moves west or north the satellite will appear lower in the sky in the same general direction. As one travels easterly or southerly AOR-W will be higher in the sky. For much of the western United States AOR-W could prove difficult to track and use under more adverse conditions.

The Pacific Ocean Region (POR) Inmarsat 3f3 satellite is located just west of the International Date Line. Along the West Coast this satellite is at an azimuth of 250^{o} and an elevation of 14^{o} to 15^{o}. To the east this satellite lies below 10^{o}. In Cheyenne POR is approximately 1^{o} and so is only visible under extremely good conditions from the ground. For most users in the western United States this satellite will not be useful as a source of the WAAS corrections due to its low elevation in the sky.

Figures 1 through 8 show the horizontal radial differences from truth on a measurement by measurement basis for each file.

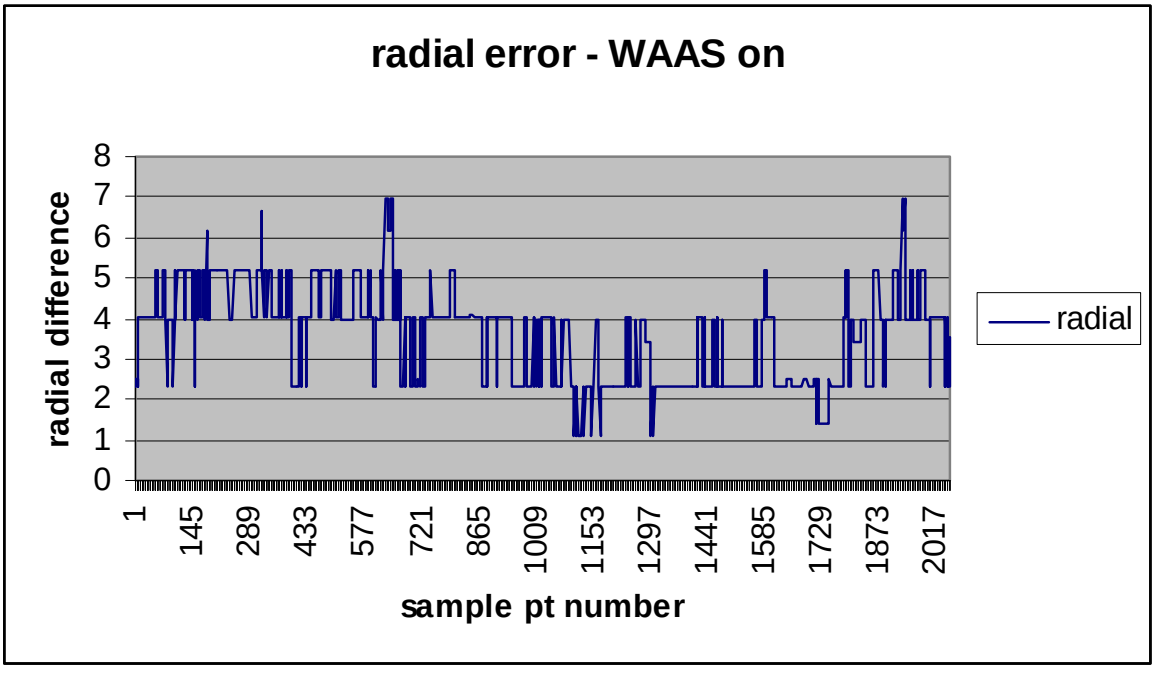

Figure 1: Etrex Venture 08 14 03

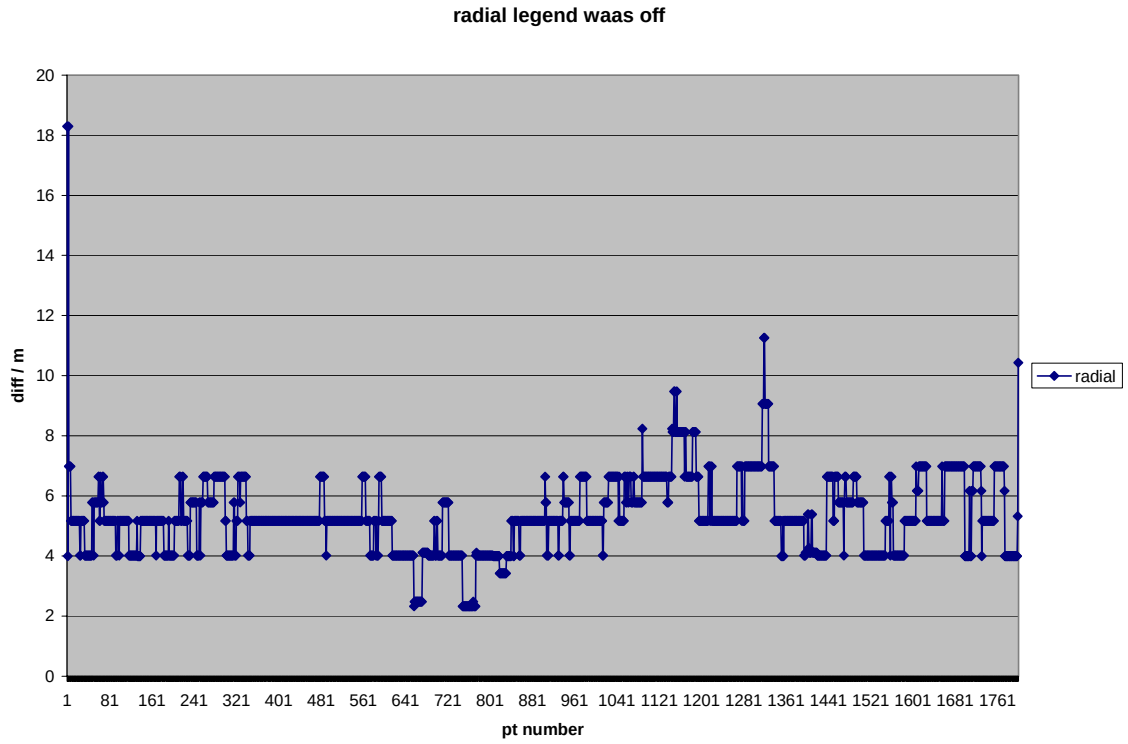

Figure 2: Etrex Legend WAAS Off 08 16 03

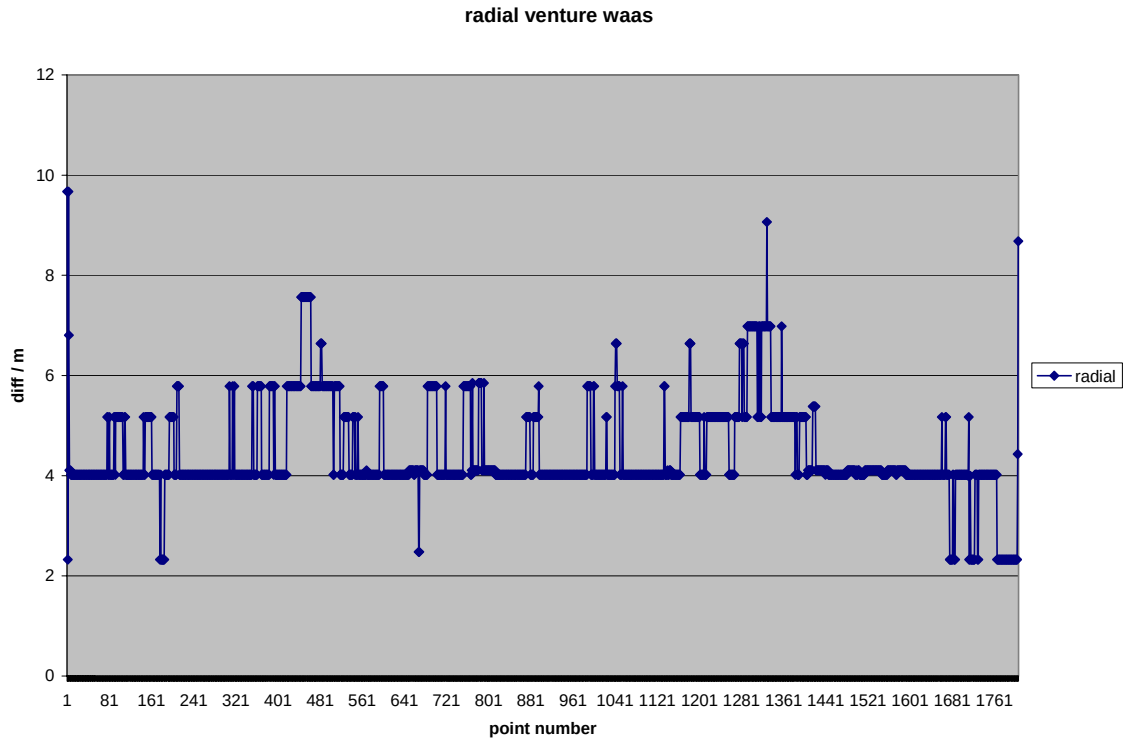

Figure 3: Etrex Venture WAAS 08 16 03

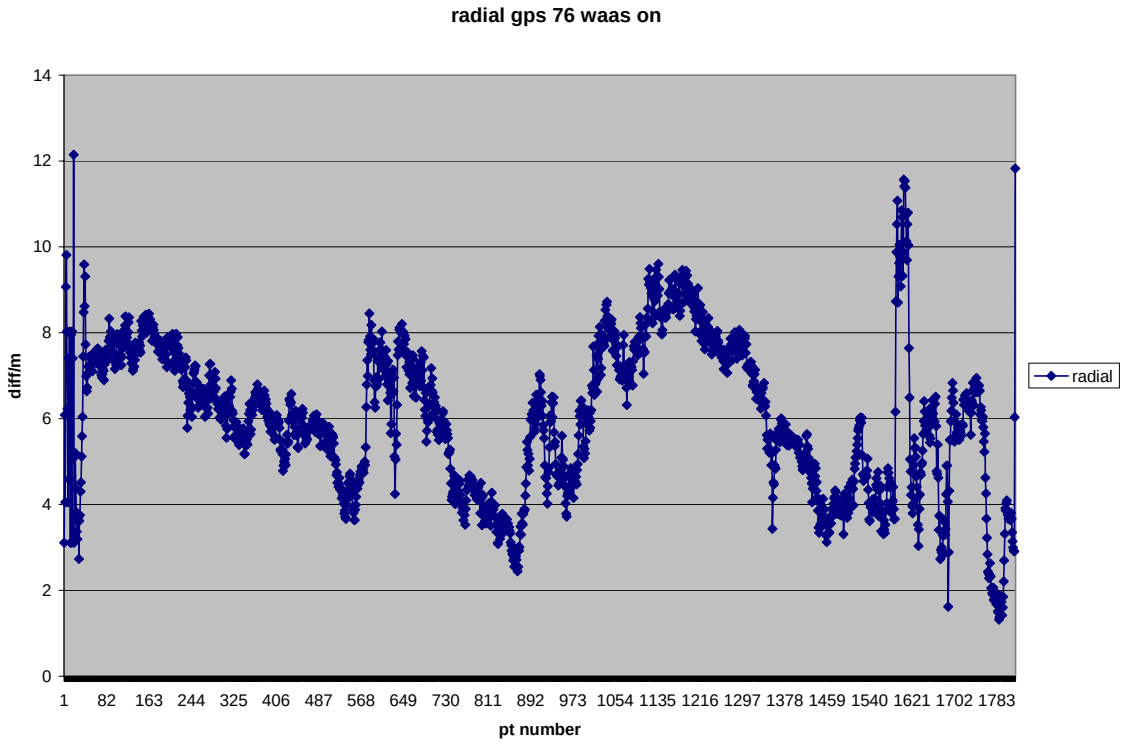

Figure 4: GPS 76 WAAS 08 16 03

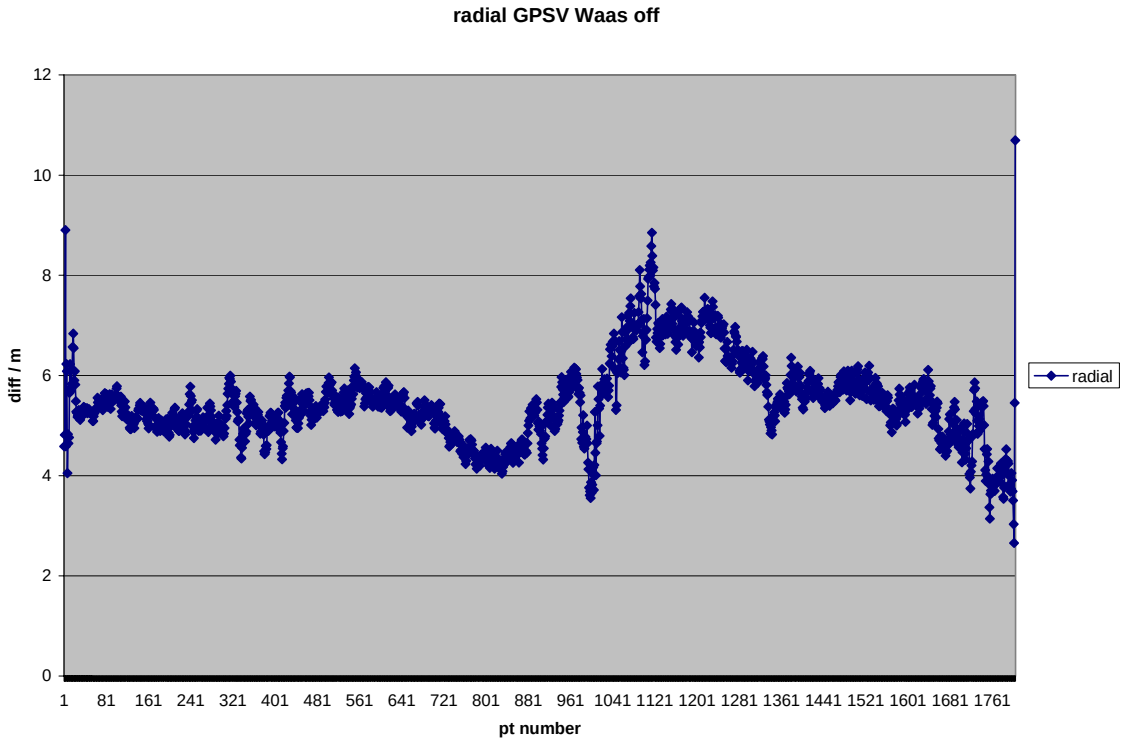

Figure 5: GPS V 08 16 03

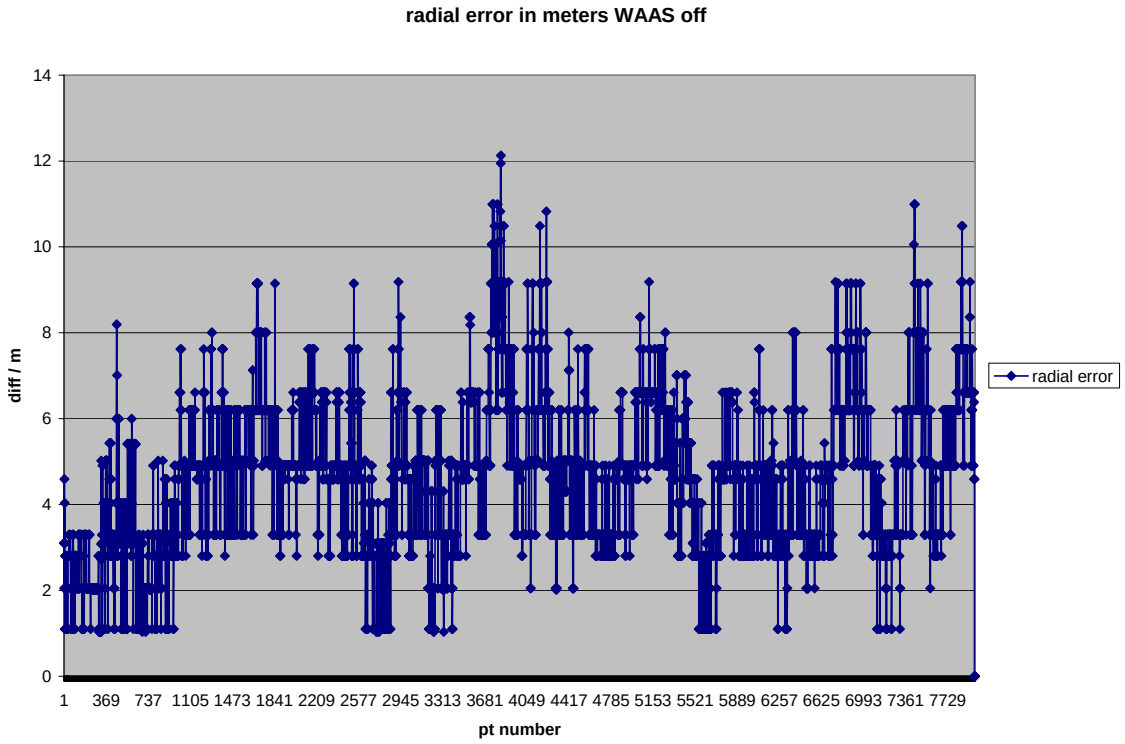

Figure 6: Legend WAAS off 09 14 03

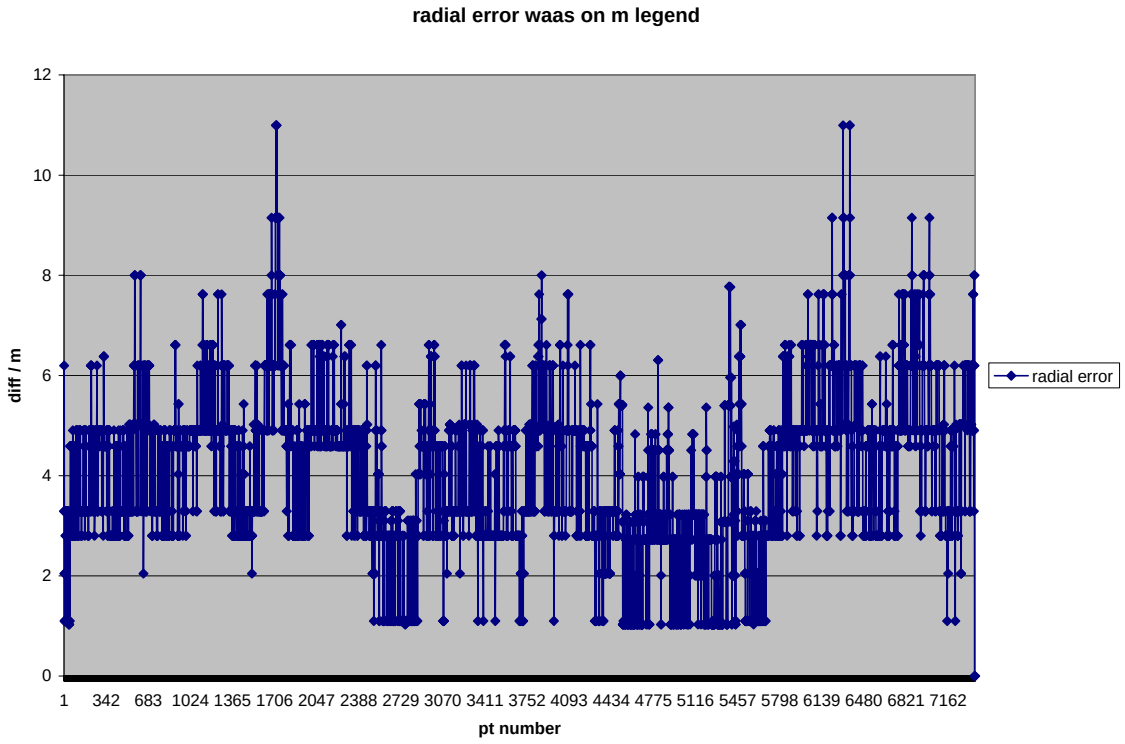

Figure 7: Legend WAAS on 09 17 03

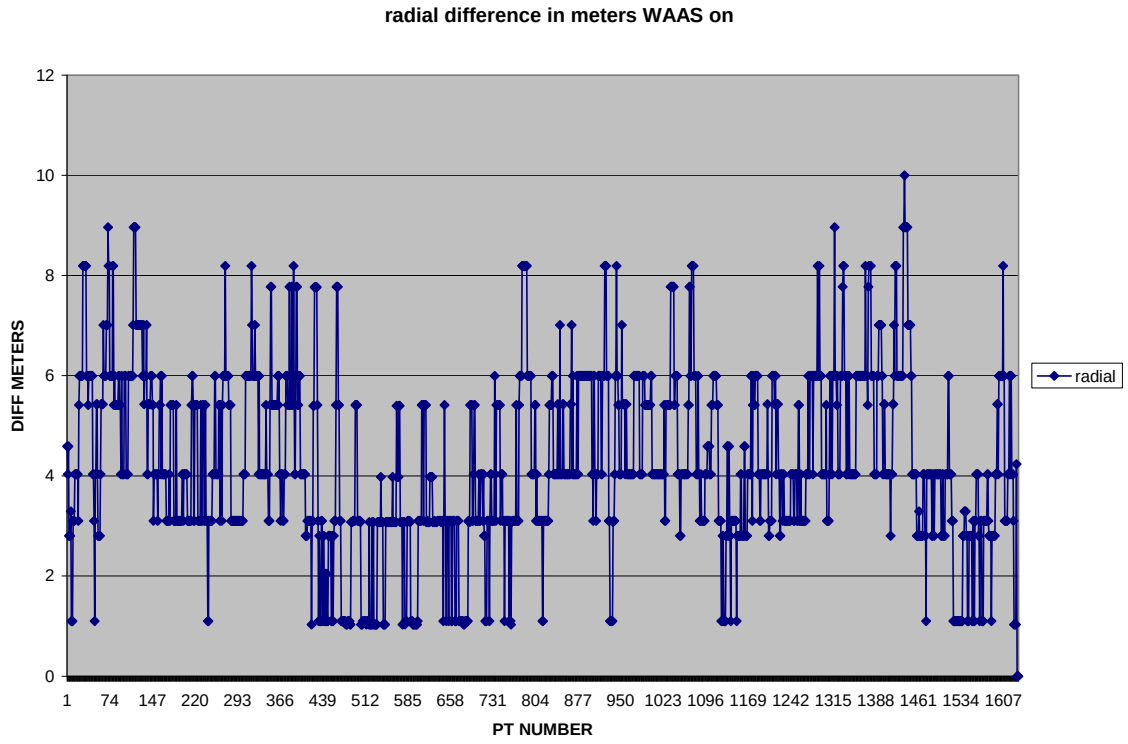

Figure 8: Venture WAAS 09 14 03

These figures are interesting in that they show there is strong short term correlation between differences and that there is very little difference between the autonomous and WAAS enabled files. For the Legend and Venture receivers a value of approximately 4 meters for the radial difference is very prevalent though there can be short variations where the radial error can rapidly change from 1 meter to 10 to 12 meters. A check of the raw data shows that same position can be repeated for several measurement cycles. This suggests some type of filtering is present in the receiver firmware. However inquiries to Garmin have not been able to confirm this. The GPSV and Map76 receivers show smaller variation between measurements but the same possible short term correlation between positions.

CONCLUSIONS

These tests were run under optimal observing conditions and help establish baseline accuracies for this type of receiver. Actual performance under field conditions will be less than reported here.

There is very little difference between the autonomous and WAAS enabled cases. The WAAS enabled accuracies seen in this study differ markedly from the manufacturer specifications at best and will vary by receiver type. This type of receiver does not appear to consistently track and apply the WAAS corrector signal.

Even though the RMS (63% confidence level) accuracy value is probably the best indicator of the receiver accuracy, most positioning standards require positions be reported at a 2dRMS (95% confidence level). It could be conservatively stated that at best these types of receivers are accurate to 8m to10 m at 95% confidence.

This set of tests has concentrated on Garmin recreational receivers. Tests that have been run on other brands of recreational receivers have yielded similar results.