WAAS Technical Report
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DR#1: C&V Source Switch Caused WAAS Service Outage
GPS Week/Day: Week 1321 Day 4 (5/5/2005)

Discussion:

A failure of the ZLA C&V at time 374745 of GPS Week 1321 caused a source selection switch (from ZLA to ZDC) resulting in a 1-second gap in both AOR-W and POR GEO transmissions at time 374746. This gap was immediately followed by four Type 0 messages. As designated in the MOPS, the effect of a Type 0 alert upon a user is that all data is cleared and must be reacquired by the receiver, a process that can take up to 5 minutes before an LPV operation can be resumed. WAAS LPV coverage at 100% availability and NPA coverage at both 99.9% and 100% availability were both at 0% for GPS Week 1321 Day 4.

The transition of the ZLA C&V from 'Normal' to 'Faulted' was the result of a delay in the transmission of acknowledgements from the safety processor to the corrections processor. Due to the timing of this fault, ZLA did not send out its WAAS user message to the GUS for that second. Each WAAS user message that is sent by a C&V is validated by the other C&V (ZDC), so when ZDC received no message from the newly faulted ZLA, it sent out a Type 0 alert. The GUS, which had just switched to the backup source (ZDC), received this alert and broadcast it.

The following outputs from daily O&M analysis show the time of a C&V mode transition at ZLA from 'Normal' to 'Faulted' (Table 1.1). Source selection switches followed at all GUS sites (Table 1.2).

Table 1.1 - ZLA C&V Mode Transitions

Time of Week	Site	Previous Mode	New Mode
374745	**ZLA-CP2**	**Normal**	**Faulted**
374746	**ZLA-CP1**	**Normal**	**Faulted**
375554	ZLA-CP1	Maintenance	Verification
375555	ZLA-CP2	Maintenance	Verification
375612	ZLA-CP1	Verification	Maintenance
375613	ZLA-CP2	Verification	Maintenance
377465	ZLA-CP1	Maintenance	Verification
377466	ZLA-CP2	Maintenance	Verification
379957	ZLA-CP1	Verification	Normal
379958	ZLA-CP2	Verification	Normal

Table 1.2 - Resulting Source selection switch (bold)

Time of Week	GUS	C&V Source	GUS Mode
345600	Brewster	ZLA	Backup
345600	Santa Paula-B	ZLA	Primary
345600	Santa Paula-A	ZLA	Backup
345600	Clarksburg	ZLA	Primary
374745	**Clarksburg**	**ZDC**	Primary
374746	**Santa Paula-B**	**ZDC**	Primary
374747	**Brewster**	**ZDC**	Backup
374747	**Santa Paula-A**	**ZDC**	Backup

Real-time data processing of the WAAS message stream is performed on a daily basis and a detailed output of WAAS message types is shown below (Tables 1.3 and 1.4) for both AOR-W and POR at the time of the failure. Each table shows that a Type 0 alert (four consecutive Type 0 messages) was issued at the time of the failure. It should be noted that when a Type 0 alert is issued, all parameters of the WAAS system are reset and must be reacquired by a user before service is restored. Consequently, service was interrupted as a direct result of WAAS issuing this Type 0 alert.

Table 1.3 - Real-time WAAS AOR-W GEO Messages

Time	Msg Type	Preamble	Status	Receiver ID	GEO	IODP/Band#	IODF/Block#
374743	25	9a	1	b92	122	2	-
374744	6	c6	1	b92	122	-	-
374745	6	53	1	78c3	122	-	-
374748	**0**	53	1	77c2	122	0	0
374749	**0**	9a	1	77c2	122	0	0
374750	**0**	c6	1	b92	122	0	0
374751	**0**	53	1	b92	122	0	0
374752	3	9a	1	7ac3	122	2	0
374753	24	c6	1	b92	122	2	1

Table 1.4 - Real-time WAAS POR GEO Messages

Time	Msg Type	Preamble	Status	Receiver ID	GEO	IODP/Band#	IODF/Block#
374743	25	9a	1	2d91	134	2	-
374744	6	c6	1	2d91	134	-	-
374745	6	53	1	2d91	134	-	-
374748	**0**	53	1	83c2	134	0	0
374749	**0**	9a	1	83c3	134	0	0
374750	**0**	c6	1	83c3	134	0	0
374751	**0**	53	1	1c81	134	0	0
374752	3	9a	1	6cc3	134	2	0
374753	24	c6	1	1c81	134	2	1

This interruption of service can be observed very clearly by inspecting the following plots. Figures 1.1 and 1.2 are taken from daily coverage processing. The first (Fig 1.1) shows the complete loss of 100% LPV service over CONUS for this day while Figure 1.2 shows the complete loss of both 99.9% and 100% NPA service over the NPA service volume.

Fig. 1.1 – LPV Coverage, 5/5/2005

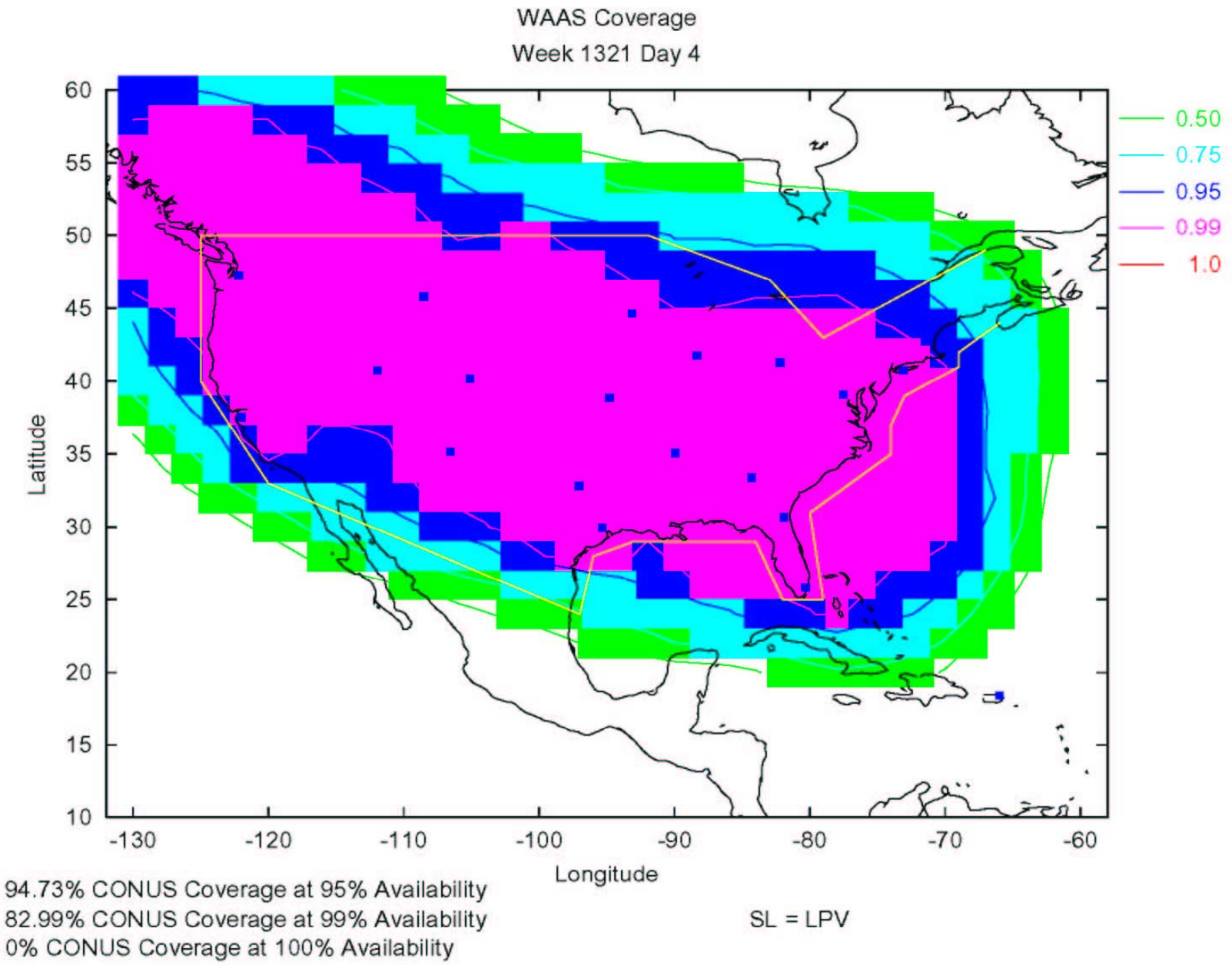
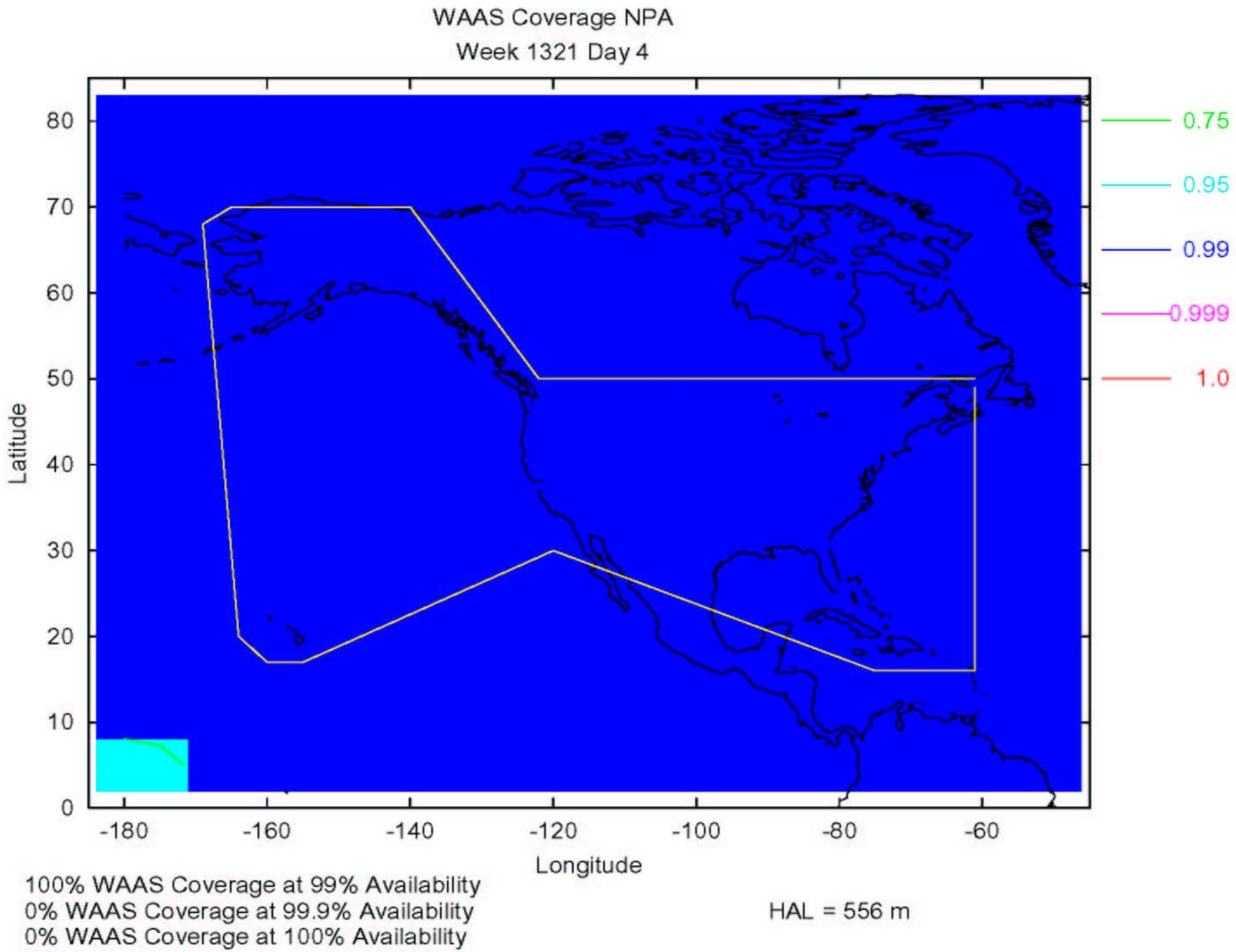


Fig 1.2 – NPA Coverage, 5/5/2005



The effect of this event on the availability of service over the CONUS and NPA service volumes can be more directly correlated to this event by observing Figures 1.5 and 1.6. These plots show the instantaneous coverage over the course of the day with 30 second sampling. At the time the Type 0 alert was issued, GPS time of week 374748, both LPV and NPA service levels are entirely unavailable over both the CONUS and NPA service volumes respectively.

Fig. 1.3 – % of CONUS Service Volume Available for LPV, 30 second sampling

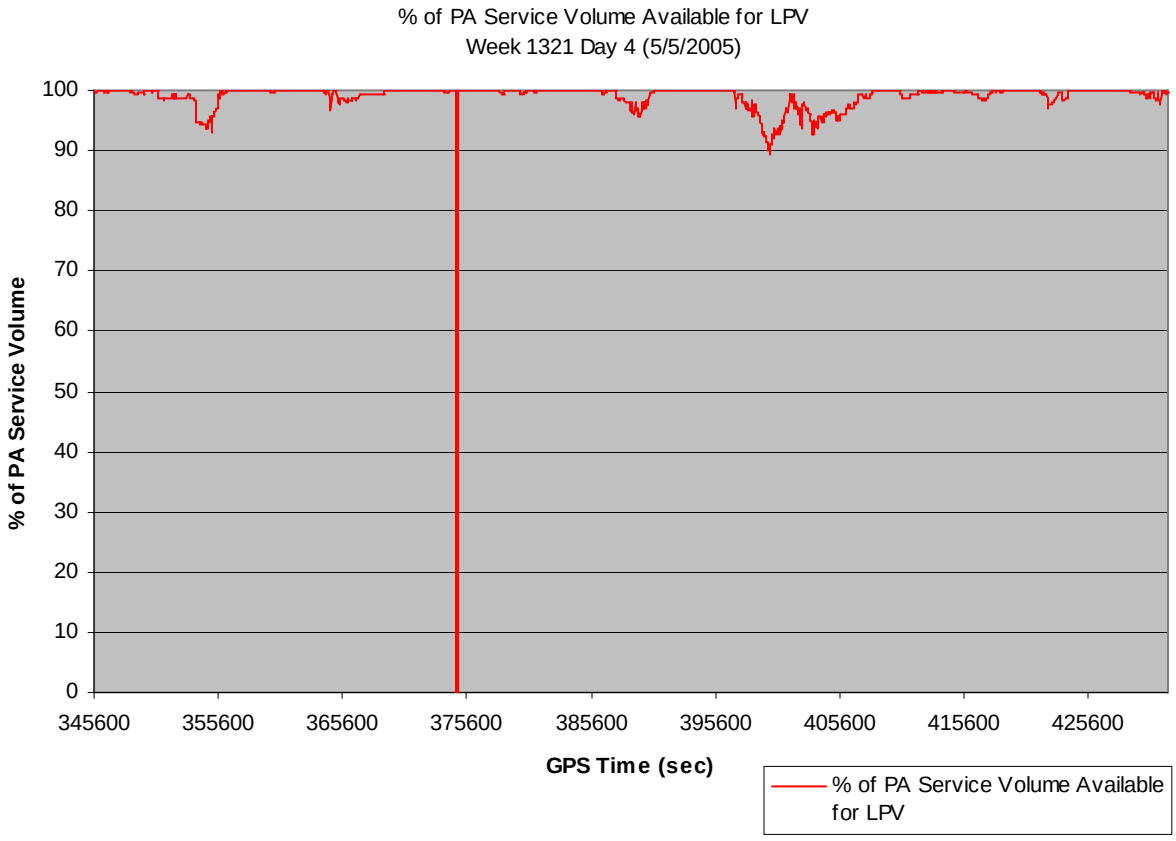
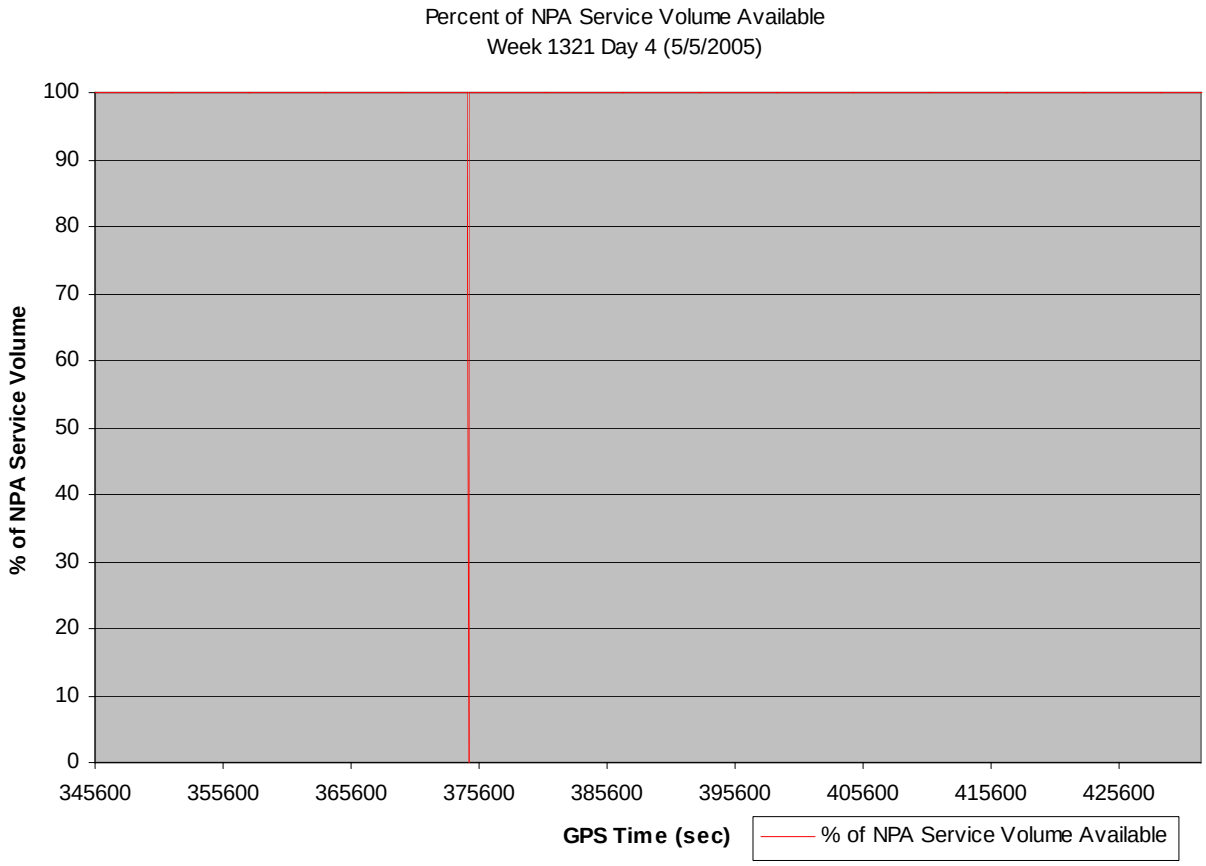


Fig 1.4 - % of NPA Service Volume Available for NPA, 30 second sampling



The loss of service availability also becomes more evident from a user perspective. The following plots represent data taken from WAAS reference stations. Figure 1.5 was created from data collected at the Washington DC reference station. Figure 1.6 is from Kansas City and Figure 1.7 is taken from Los Angeles. The effects of the Type 0 alert resulting from the C&V failure are clearly evident on the plots at the time the alert was issued, GPS time of week 374748. An obvious spike in position errors and protection levels can be seen across all plots.

Figure 1.5 - Vertical and Horizontal Error/Protection Level plots from Washington DC WRS

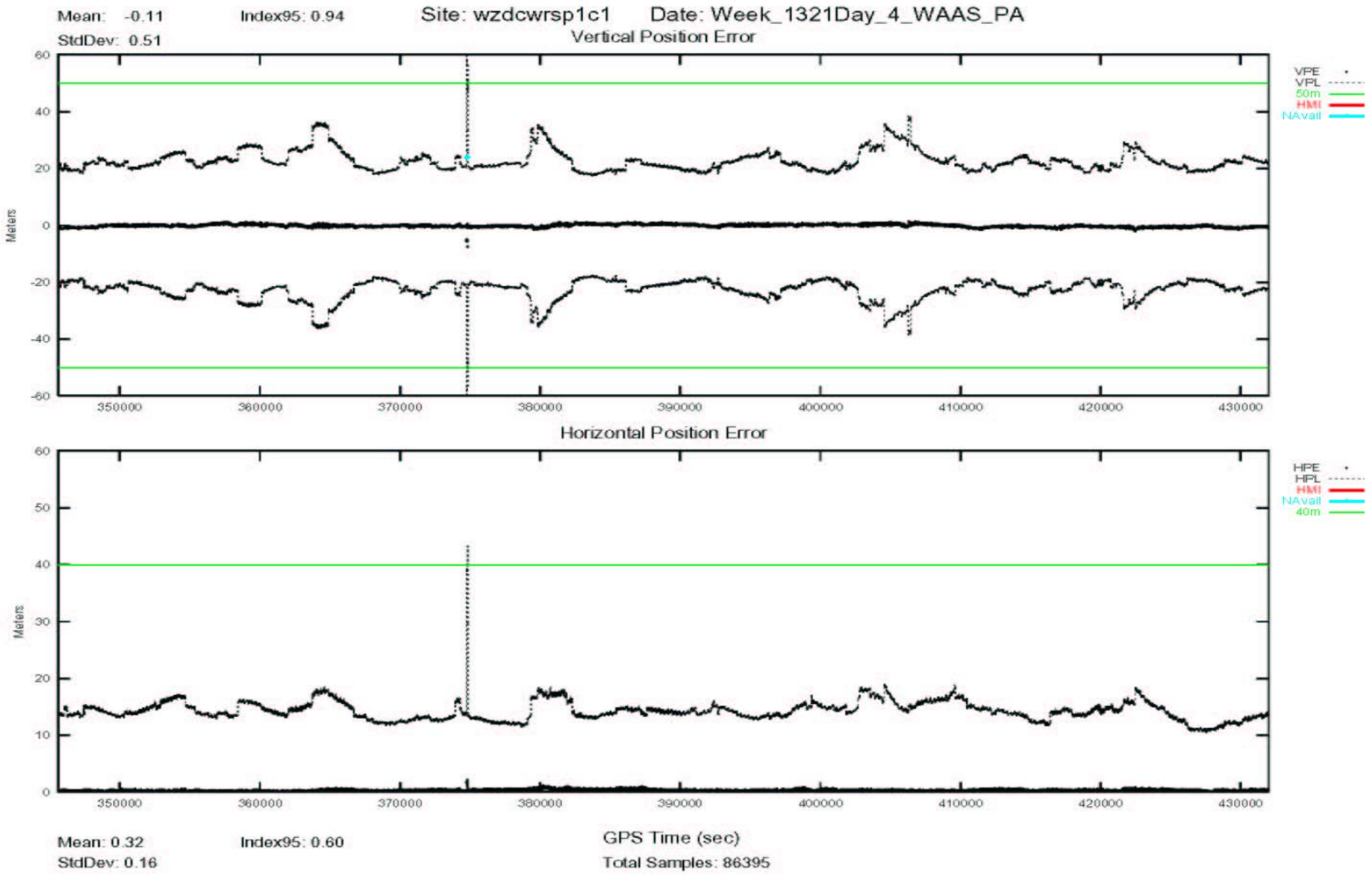


Figure 1.6 - Vertical and Horizontal Error/Protection Level plots from Kansas City WRS

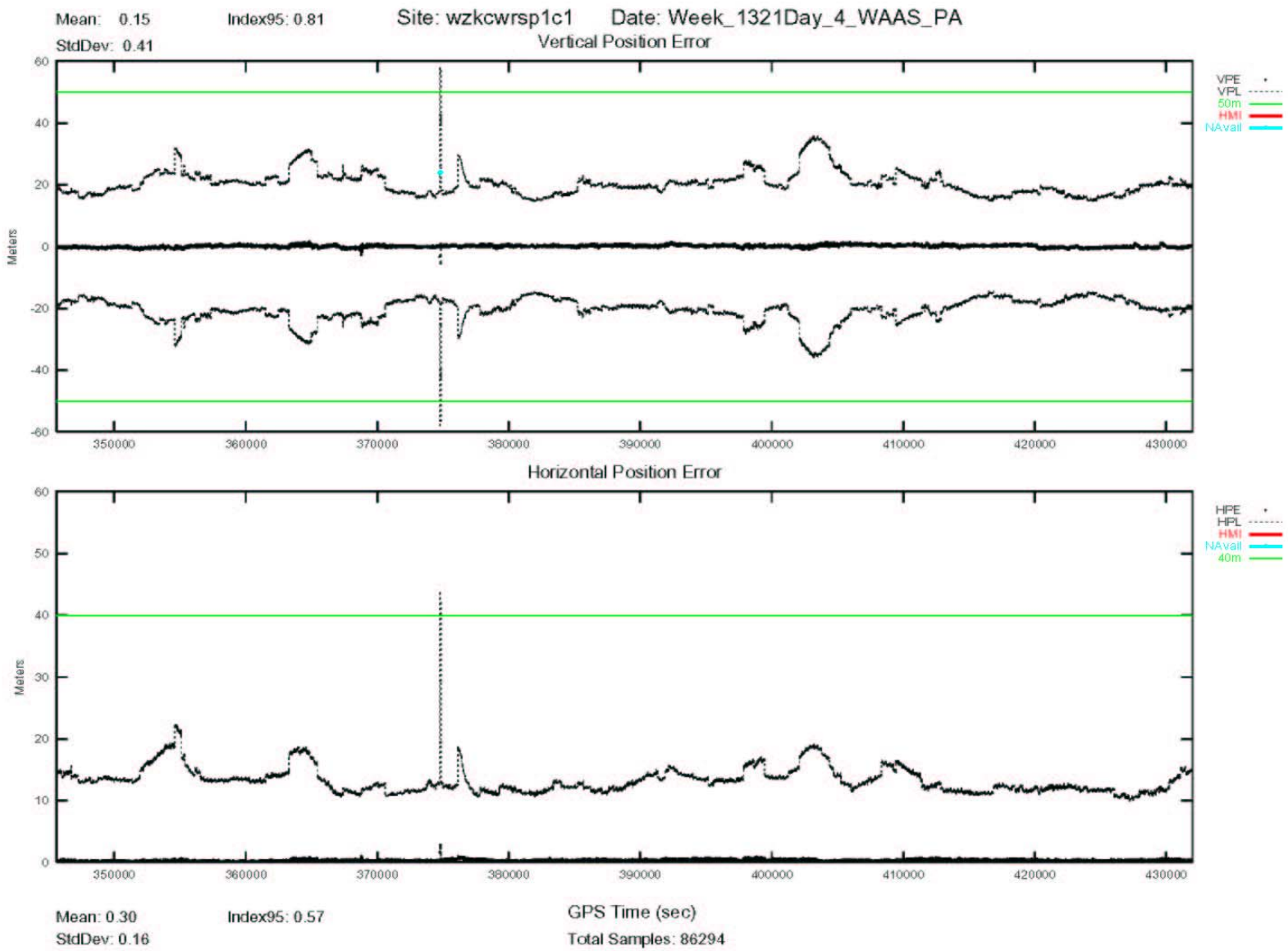
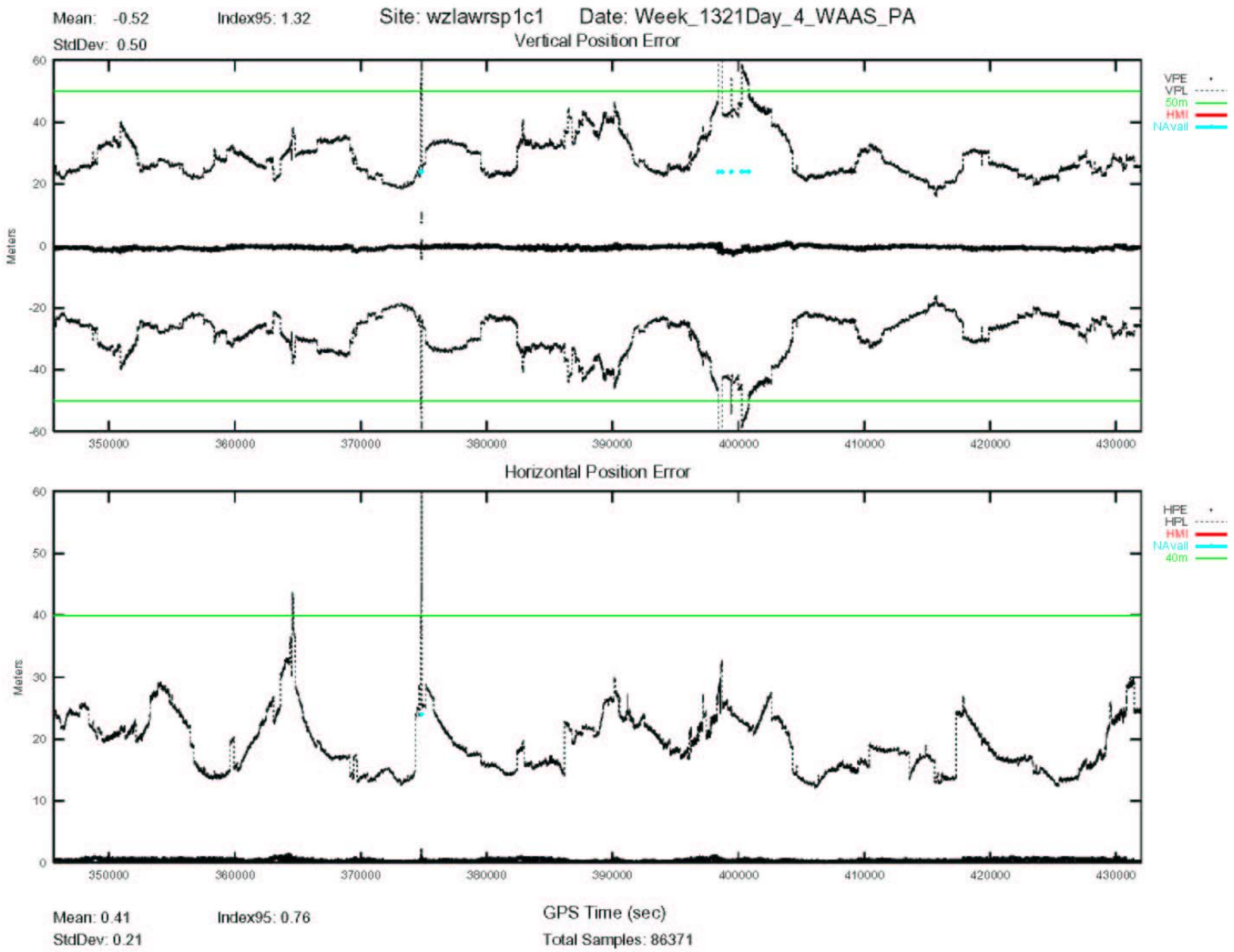


Figure 1.5 - Vertical and Horizontal Error/Protection Level plots from Los Angeles WRS



Conclusion:

Design specifications indicate that a subsystem failure such as this should be handled smoothly by WAAS without a loss of availability. GUS hardware and software is designed to constantly receive WAAS correction data from two sources simultaneously and provide a seamless transition between the two in the event of a failure.

Such a seamless transition did not follow the failure of the ZLA C&V corrections processor that occurred on May 5th, 2005. A delay in the transmission of acknowledgments from the safety processor to the corrections processor occurred and it was this delay that faulted the C&V. The timing of the fault was such that the affected C&V could not send its WAAS user message for that second and the other C&V responded with a Type 0 alert. This reset all WAAS message timing and ultimately disrupted both PA and NPA service availability.