

Radar Rainfall Analysis
September 2004 Summary Report

Prepared for 3 Rivers Wet Weather Demonstration Program
October 11th, 2004

Vieux & Associates, Inc.

3 Rivers
Wet Weather
Demonstration Program



Improving our region's water quality



GIS ■ Hydrology
Radar Rainfall

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Overview

The following rainfall event analyses are performed in support of the 3 Rivers Wet Weather Demonstration Program (3RWWDP). Two events were processed for September 2004. Both events met the storm definition criteria (for any given hour at least 50% of all working gauges must have an accumulation of 0.05 inches) and were processed using Level II NEXRAD data from KPBZ. Event 1 (9/8/04) was split into two parts for optimum calibration. The calibration statistics for each event are listed in Table 1 along with the radar and resolution used for analysis. All radar data was processed into 15-minute increments. Rain gauge data was provided by 3RWWDP in 15-minute increments. Gauge/grid network shapefiles were provided by 3RWWDP as well. Sampling the radar over the gauges/grid network was achieved using software developed at Vieux & Associates, Inc.

Level II NEXRAD data is the native resolution of the radar measurements with a polar coordinate system of 1 degree by 1-km. Due to proximity to the radar, KPBZ Level II data resolution over Allegheny County is approximately 1-km². The events were resampled to a 1-km² Cartesian grid provided by 3RWWDP.

Methodology

Based on climatology of the National Weather Service (NWS) gauge located at the Pittsburgh International Airport, Allegheny County receives an average of 3.21 inches of rainfall (30-year average from 1971-2000) during the month of September. September is on average the fifth wettest month of the year for the Pittsburgh area. The maximum daily rainfall amount for the month of September is 5.95 inches recorded on September 17th, 2004, which is the wettest day on record and broke the previous record of 3.60 inches set on September 8th, 2004. The wettest September and fourth wettest month on record occurred in 1945 with 10.08 inches. The driest September and eighth driest month on record occurred in 1985 with 0.28 inches. The Pittsburgh NWS gauge received 10.06 inches during September, which is the second wettest September and fifth wettest month on record. Based on preliminary data (WS Form F-6), the year to date rainfall total is 48.27 inches (normal year to date is 29.72 inches). Figure 1 shows the average accumulation year-to-date versus year-to-date accumulations in 2004. Figure 2 shows the monthly average versus monthly accumulations for 2004.

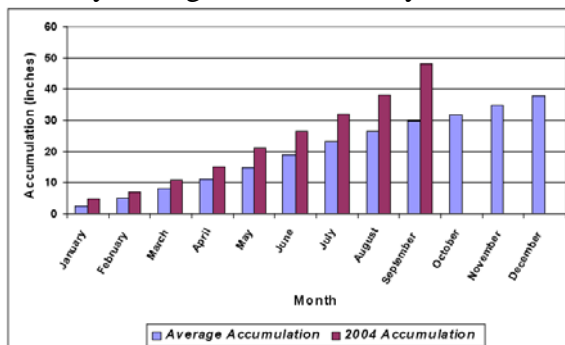


Figure 1 Comparison of average and 2004 year-to-date accumulations.

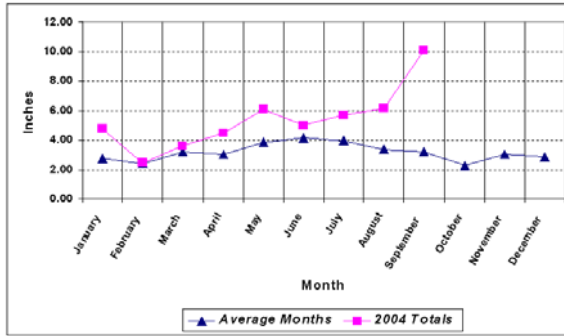


Figure 2 Average versus monthly accumulations for 2004.

Results

Table 2 shows the bias for each event along with the calibrated average difference and relative dispersion, respectively. The bias is the sum of the gauges divided by the sum of the sampled radar values over the gauges. Several gauges had incomplete or missing data for a portion of the month. Carnegie (Loc6) and Flaugherty Run (Loc32) were not available for processing during Event 2. Flaugherty Run (Loc21) was removed from analysis for both events since it is located within the cone-of-silence of KPBZ. The gauge network was analyzed to identify and remove outliers.

Table 1 Storm events and bias statistics

Event #	Radar	Data Level	Event Date	Gauges Used	Bias	AD (%)	CAD (%)	RD (%)
1A	KPBZ	II	9/8/04	11 of 33	0.494	108.8	14.1	16.5
1B	KPBZ	II	9/8/04	30 of 33	1.176	14.8	5.5	7.0
2	KPBZ	II	9/17/04	28 of 31	0.976	7.7	7.8	9.2

Cumulative Distribution Plots (CDPs) were produced for each event (see Appendix). No discernible clogging issues were observed during either event. Examination of the CDPs revealed a potential synchronization issue. The CDPs for Mayview (Loc5) appear to lag behind the radar estimates by 15 minutes during both events. Any gauge having potential clogging or synchronization issues observed during Event 2 (Loc5) could benefit by inspection since that problem may still be occurring at present.

Event 1: 9/8/04

The event of September 7-9th, 2004 was characterized by moderate to strong showers and thunderstorms in association with the remnants of Hurricane Frances moving northwards along the Appalachians interacting with a cold front approaching from the west. As the north-south oriented cold front began to stall across the Upper Ohio Valley during the afternoon of the 7th, isolated thunderstorms developed along the front over central Allegheny County by 9/7/04 16:00 EDT. This activity moved slowly to the east before diminishing by 9/7/04 20:30 EDT with the lack of daytime heating. By 9/8/04 5:30 EDT, the northern edge of the precipitation shield from Frances began to move into southern Allegheny County. As the center of Frances continued to approach from the south, showers became more widespread over Allegheny County throughout the afternoon of

the 8th with most of the activity occurring between 9/8/04 12:00 – 20:00 EDT. Rainfall ended over Allegheny County by 9/9/04 8:00 EDT as the remnants of Frances moved north of the region bringing drier air in its wake. Most of Allegheny County received at least 3 inches with locally higher amounts between 5 – 6 inches. The NWS gauge received 3.60 inches (WS Form F-6) on the 8th, which broke the previous daily record of 3.57” set on August 21st, 1888.

The analysis period was from 9/7/04 15:00 EDT to 9/9/04 11:00 EDT (9/7/04 19:00 UTC to 9/9/04 15:00 UTC). This event was split into 2 parts (A and B) at 9/7/04 21:00 EDT (9/8/04 1:00 UTC) for optimal calibration. Gauges Loc1, Loc2, Loc4, Loc5, Loc6, Loc15, Loc17, Loc18, Loc22, Loc23, Loc25, Loc26, Loc27, Loc29 and Loc30 did not record any precipitation during the first portion of the event and were removed from analysis. Gauges Loc11, Loc32 and Loc33 were discarded from analysis during the first portion of the event since their gauge storm total estimates were less than 0.10 inches. Gauges Loc8, Loc9 and Loc24 were identified as outliers during the first portion of the event and were thus discarded. Gauges Loc12 and Loc13 were identified as outliers during the second portion of the event and were thus discarded.

The tropical Z-R relationship was used to convert radar reflectivity to rainfall rate. Tables 2 and 3 summarize the results for each RG pair during both portions of the event, where G_i is the gauge estimate, R_i is the non-adjusted radar estimate, R_i^* is the adjusted radar estimate, Diff* (in) is the difference in inches between the gauge and adjusted radar estimate, and Diff* (%) is the percent difference between the gauge and adjusted radar estimate. The shaded rows in Tables 2 and 3 differentiate the gauges used for final adjustment of the radar during both portions of the event. Figures 3 and 4 show the scatter plot of the remaining calibrated RG pairs during both portions of the event.

Table 2 Summary of individual RG pairs for Event 1A

Gauge Name	MAP_ID	G_i	R_i	R_i^*	Diff* (in)	Diff* (%)
Univ of Pittsburgh	Loc9	0.12	1.30	0.64	-0.52	-436.5
AC Health Dept Bldg	Loc8	0.44	1.79	0.88	-0.44	-100.7
Castle Shannon	Loc16	0.78	2.45	1.21	-0.43	-55.2
Hampton Munic Bldg	Loc31	0.22	0.56	0.28	-0.06	-25.1
Baldwin	Loc12	0.12	0.27	0.13	-0.01	-10.2
Shaler Munic Bldg	Loc3	1.51	3.15	1.56	-0.05	-3.1
Gateway Engineers Bldg	Loc7	0.40	0.82	0.40	0.00	-0.9
Gascola Eq Facility	Loc20	1.89	3.73	1.84	0.05	2.5
U.A.J.S.A. Creighton	Loc32	0.04	0.08	0.04	0.00	4.0
PWSA-Highland Park	Loc10	0.20	0.37	0.18	0.02	7.9
Sandy Creek Eq Facility	Loc19	0.87	1.59	0.78	0.09	9.9
Churchill Munic Bldg	Loc14	2.23	4.06	2.00	0.23	10.2
Plum Munic Bldg	Loc28	0.37	0.64	0.32	0.05	14.8
M-59 Access Shaft	Loc13	0.77	1.32	0.65	0.12	15.1
Richland Twp	Loc33	0.02	0.03	0.01	0.01	28.9
Lewis Run Pump Station	Loc24	0.13	0.13	0.07	0.06	50.0
M-46 Access Shaft	Loc11	0.01	0.00	0.00	0.01	79.8

Highland Country Club	Loc1	0.00	0.00	0.00	0.00	---
ALCOSAN WWTP Lab	Loc2	0.00	0.00	0.00	0.00	---
Kennedy Twp PS	Loc4	0.00	0.00	0.00	0.00	---
Mayview PS	Loc5	0.00	0.04	0.02	-0.02	---
Carnegie Transit Time	Loc6	0.00	0.05	0.03	-0.03	---
Trafford Maint Bldg	Loc15	0.00	0.00	0.00	0.00	---
Chartiers Pump Station	Loc17	0.00	0.01	0.00	0.00	---
Oakdale Pump Station	Loc18	0.00	0.00	0.00	0.00	---
Flaugherty Run	Loc21	0.00	0.02	0.01	-0.01	---
North Fayette TWP	Loc22	0.00	0.00	0.00	0.00	---
Clinton Munic Bldg	Loc23	0.00	0.00	0.00	0.00	---
White Oak Public Works Bldg	Loc25	0.00	0.00	0.00	0.00	---
Elizabeth TWP Munic Bldg	Loc26	0.00	0.00	0.00	0.00	---
Marshall Twp	Loc27	0.00	0.00	0.00	0.00	---
Bell Acres Munic Bldg	Loc29	0.00	0.00	0.00	0.00	---
McCandless Twn Hall	Loc30	0.00	0.00	0.00	0.00	---

Table 3 Summary of individual RG pairs for Event 1B

Gauge Name	MAP_ID	G _i	R _i	R _i [*]	Diff* (in)	Diff* (%)
M-59 Access Shaft	Loc13	2.41	2.57	3.03	-0.62	-25.6
Kennedy Twp PS	Loc4	4.20	4.17	4.91	-0.71	-16.9
Clinton Munic Bldg	Loc23	4.08	4.00	4.71	-0.63	-15.4
Bell Acres Munic Bldg	Loc29	3.82	3.68	4.32	-0.50	-13.2
Elizabeth TWP Munic Bldg	Loc26	2.45	2.27	2.67	-0.22	-9.1
M-46 Access Shaft	Loc11	2.98	2.72	3.20	-0.22	-7.3
White Oak Public Works Bldg	Loc25	2.78	2.47	2.90	-0.12	-4.4
ALCOSAN WWTP Lab	Loc2	4.06	3.60	4.24	-0.18	-4.3
North Fayette TWP	Loc22	3.93	3.48	4.10	-0.17	-4.2
Richland Twp	Loc33	4.04	3.56	4.19	-0.15	-3.6
Chartiers Pump Station	Loc17	3.77	3.31	3.89	-0.12	-3.2
Oakdale Pump Station	Loc18	3.93	3.40	3.99	-0.06	-1.6
U.A.J.S.A. Creighton	Loc32	3.30	2.85	3.35	-0.05	-1.5
Shaler Munic Bldg	Loc3	3.88	3.33	3.91	-0.03	-0.9
Churchill Munic Bldg	Loc14	2.98	2.52	2.97	0.01	0.3
AC Health Dept Bldg	Loc8	3.50	2.95	3.47	0.03	0.8
Plum Munic Bldg	Loc28	3.16	2.66	3.12	0.04	1.1
Highland Country Club	Loc1	4.15	3.48	4.10	0.05	1.3
Gascola Eq Facility	Loc20	2.99	2.49	2.93	0.06	2.0
Sandy Creek Eq Facility	Loc19	3.36	2.80	3.29	0.07	2.0
McCandless Twn Hall	Loc30	3.78	3.13	3.68	0.10	2.7
Trafford Maint Bldg	Loc15	2.77	2.29	2.69	0.08	2.8
Gateway Engineers Bldg	Loc7	4.49	3.67	4.32	0.17	3.8
Univ of Pittsburgh	Loc9	3.69	2.99	3.52	0.17	4.6
Lewis Run Pump Station	Loc24	3.39	2.72	3.20	0.19	5.6
Carnegie Transit Time	Loc6	4.43	3.50	4.12	0.31	7.0

Mayview PS	Loc5	4.13	3.24	3.81	0.32	7.8
PWSA-Highland Park	Loc10	3.57	2.79	3.29	0.28	8.0
Castle Shannon	Loc16	4.32	3.36	3.95	0.37	8.7
Hampton Munic Bldg	Loc31	4.22	3.24	3.81	0.41	9.8
Marshall Twp	Loc27	4.10	3.07	3.61	0.49	11.8
Baldwin	Loc12	4.38	3.02	3.55	0.83	18.9
Flaugherty Run	Loc21	4.42	2.60	3.06	1.36	30.9

Table 4 shows the Intensity Depth Frequency (IDF) maximum values for the 1-km² grid network.

Table 4 Intensity duration frequency analyses for Event 1

Duration	Depth (in)	Pixel	Time (EDT)	Frequency
15 minute	1.12	160141	9/7/2004 18:30	> 10 year
30 minute	1.79	160141	9/7/2004 18:45	> 25 year
1 hour	2.82	160141	9/7/2004 19:00	> 100 year
2 hour	2.88	160141	9/7/2004 19:30	> 50 year
3 hour	2.88	160141	9/7/2004 19:30	> 25 year
6 hour	3.60	124127	9/8/2004 21:00	> 25 year
12 hour	5.26	124127	9/8/2004 23:00	> 100 year
24 hour	5.89	124127	9/9/2004 4:15	> 100 year

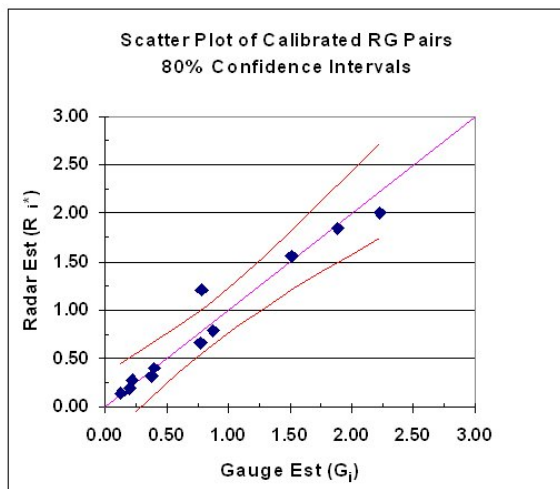


Figure 3 Scatter plot of calibrated RG pairs for Event 1A

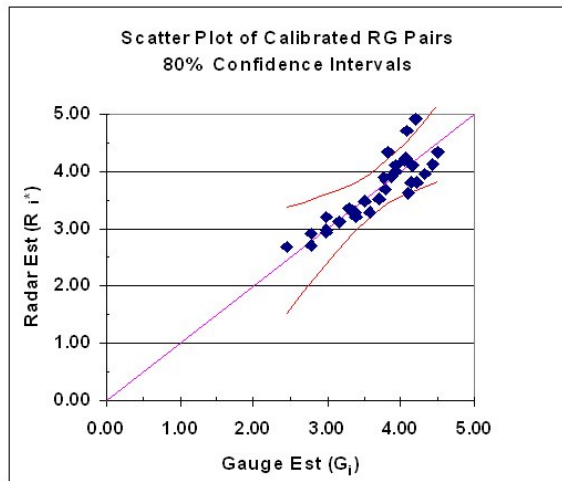


Figure 4 Scatter plot of calibrated RG pairs for Event 1B

Event 2: 9/17/04

The event of September 17-18th, 2004 was characterized by an extended period of moderate to strong showers in association with the remnants of Hurricane Ivan moving up the Appalachians. As the system moved northward, it began to merge with a northeast-southwest oriented cold front that had stalled over the Upper Ohio Valley. Light showers began to move across Allegheny County by 9/17/04 4:00 EDT as abundant tropical moisture was transported northward along the front. As the remnants of Hurricane Ivan approached Allegheny County from the south, showers increased in both coverage and intensity through 9/17/04 17:00 EDT. Rainfall ended over Allegheny County by 9/18/04 1:00 EDT as the cold front slowly pushed through the area from west to east. Over half of Allegheny County received at least 5.5 inches with higher amounts approaching 8 inches in western portions of the county. The NWS gauge received 5.95 inches (WS Form F-6) on the 17th, which broke the previous daily record of 3.60" set on September 8th, 2004.

The analysis period was from 9/16/04 20:00 EDT to 9/18/04 4:00 EDT (9/17/04 0:00 UTC to 9/18/04 8:00 UTC). Gauges Loc17, Loc25 and Loc28 were identified as outliers and were thus discarded. The tropical Z-R relationship was used to convert radar reflectivity to rainfall rate. Table 5 summarizes the results for each RG pair, where G_i is the gauge estimate, R_i is the non-adjusted radar estimate, R_i^* is the adjusted radar estimate, Diff* (in) is the difference in inches between the gauge and adjusted radar estimate, and Diff* (%) is the percent difference between the gauge and adjusted radar estimate. The shaded rows in Table 5 identify the gauges used for final adjustment of the radar. Figure 5 show the scatter plots of the remaining calibrated RG pairs.

Table 5 Summary of individual RG pairs for Event 2

Gauge Name	MAP_ID	G_i	R_i	R_i^*	Diff* (in)	Diff* (%)
Chartiers Pump Station	Loc17	6.69	8.95	8.74	-2.05	-30.7
AC Health Dept Bldg	Loc8	5.82	7.19	7.02	-1.20	-20.6
Highland Country Club	Loc1	5.88	7.03	6.86	-0.98	-16.7
Oakdale Pump Station	Loc18	6.67	7.93	7.74	-1.07	-16.1

Clinton Munic Bldg	Loc23	5.81	6.67	6.51	-0.70	-12.1
Gateway Engineers Bldg	Loc7	6.17	6.87	6.71	-0.54	-8.8
Univ of Pittsburgh	Loc9	6.66	7.38	7.21	-0.55	-8.2
ALCOSAN WWTP Lab	Loc2	5.89	6.48	6.32	-0.43	-7.4
Kennedy Twp PS	Loc4	7.01	7.56	7.38	-0.37	-5.3
M-59 Access Shaft	Loc13	4.96	5.30	5.18	-0.22	-4.4
North Fayette TWP	Loc22	6.71	7.08	6.92	-0.21	-3.1
Bell Acres Munic Bldg	Loc29	4.80	5.03	4.92	-0.12	-2.4
Baldwin	Loc12	6.68	6.84	6.68	0.00	0.0
Mayview PS	Loc5	5.83	5.81	5.67	0.16	2.7
PWSA-Highland Park	Loc10	6.26	6.22	6.07	0.19	3.0
Hampton Munic Bldg	Loc31	5.73	5.66	5.53	0.20	3.6
Sandy Creek Eq Facility	Loc19	5.35	5.27	5.15	0.20	3.8
McCandless Twn Hall	Loc30	5.43	5.35	5.22	0.21	3.8
Gascola Eq Facility	Loc20	5.17	5.06	4.94	0.23	4.5
Shaler Munic Bldg	Loc3	6.37	6.18	6.03	0.34	5.3
U.A.J.S.A. Creighton	Loc32	5.56	5.30	5.17	0.39	7.0
Trafford Maint Bldg	Loc15	5.19	4.92	4.80	0.39	7.5
Castle Shannon	Loc16	5.82	5.50	5.37	0.45	7.7
Richland Twp	Loc33	5.96	5.61	5.48	0.48	8.0
Churchill Munic Bldg	Loc14	5.56	5.18	5.06	0.50	9.0
Marshall Twp	Loc27	5.10	4.71	4.60	0.50	9.8
Elizabeth TWP Munic Bldg	Loc26	4.60	4.15	4.05	0.55	11.9
Lewis Run Pump Station	Loc24	5.97	5.32	5.20	0.77	12.9
M-46 Access Shaft	Loc11	6.03	5.31	5.18	0.85	14.0
White Oak Public Works Bldg	Loc25	5.34	4.21	4.11	1.23	23.1
Plum Munic Bldg	Loc28	6.15	4.75	4.64	1.51	24.6

Table 6 shows the Intensity Depth Frequency (IDF) maximum values for the 1-km² grid network.

Table 6 Intensity duration frequency analyses for Event 2

Duration	Depth (in)	Pixel	Time (EDT)	Frequency
15 minute	1.96	134146	9/17/2004 13:30	> 100 year
30 minute	2.33	134146	9/17/2004 13:45	> 100 year
1 hour	2.81	134146	9/17/2004 14:15	> 100 year
2 hour	3.71	134146	9/17/2004 14:45	> 100 year
3 hour	4.49	134146	9/17/2004 15:45	> 100 year
6 hour	6.08	135147	9/17/2004 17:30	> 100 year
12 hour	7.56	135147	9/17/2004 22:00	> 100 year
24 hour	8.67	135147	9/18/2004 0:00	> 100 year

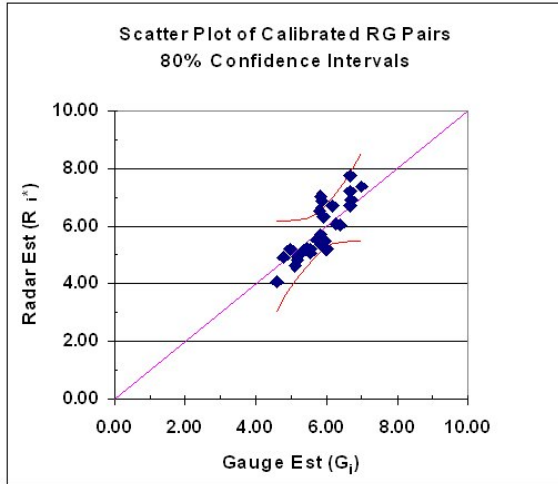


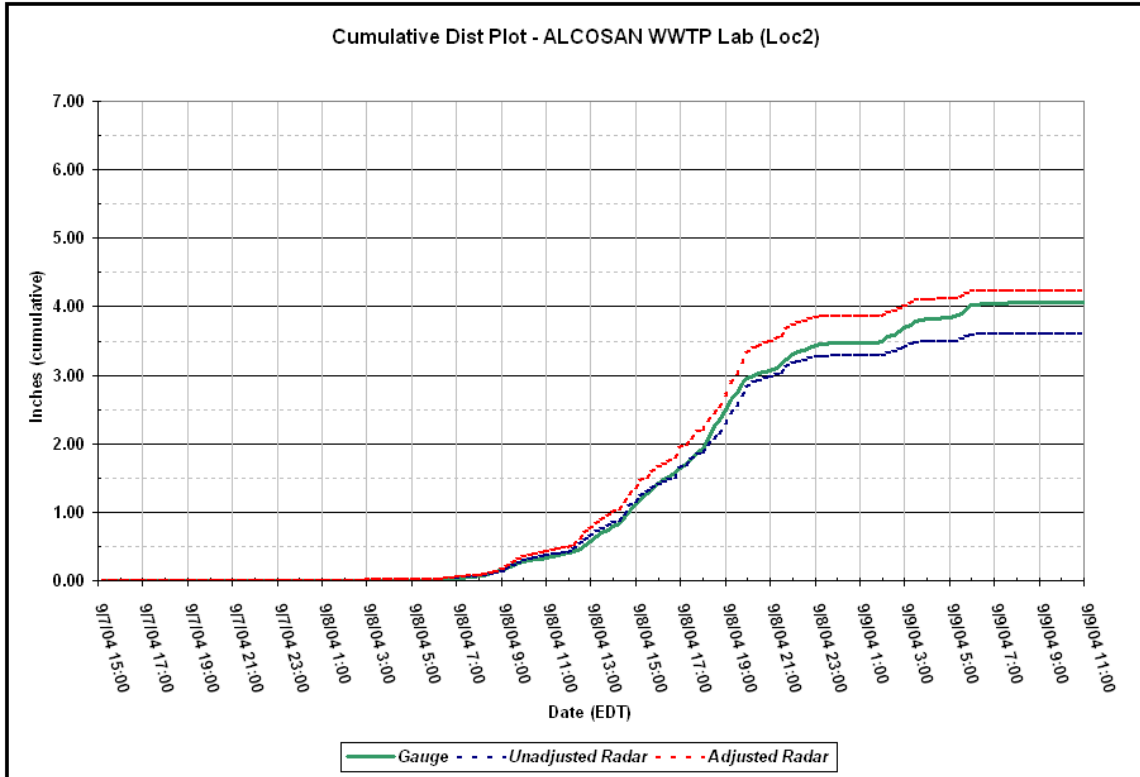
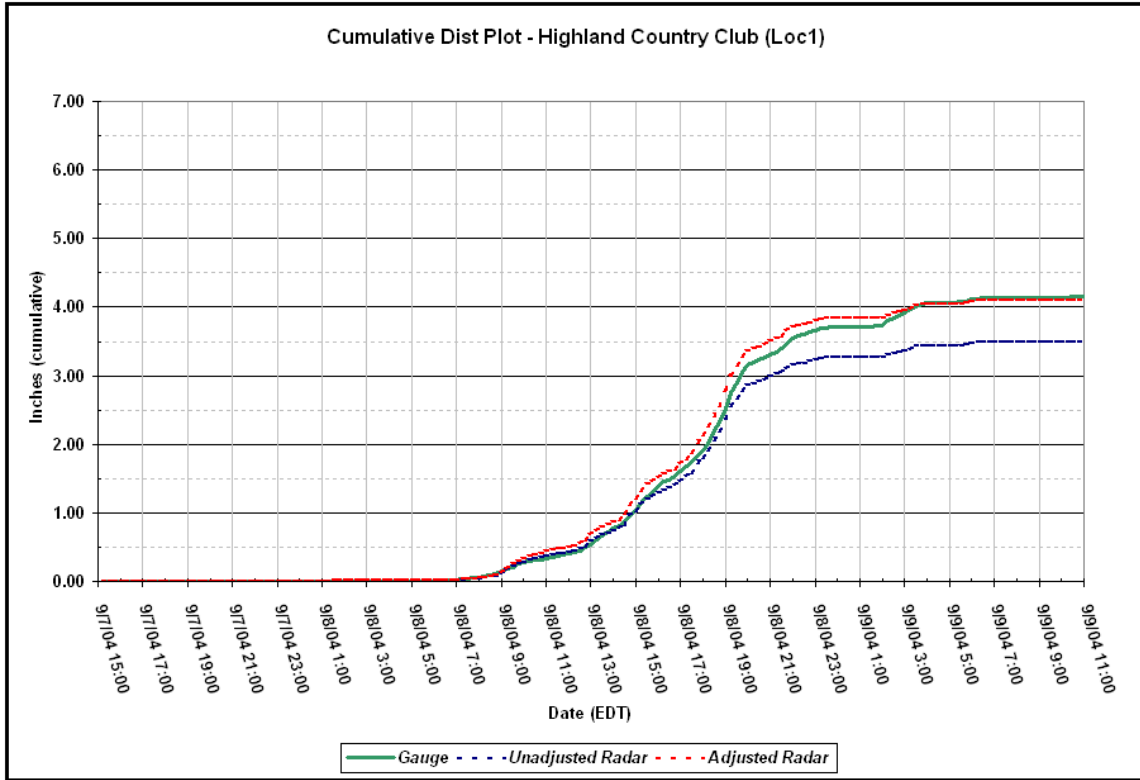
Figure 5 Scatter plot of calibrated RG pairs for Event 2

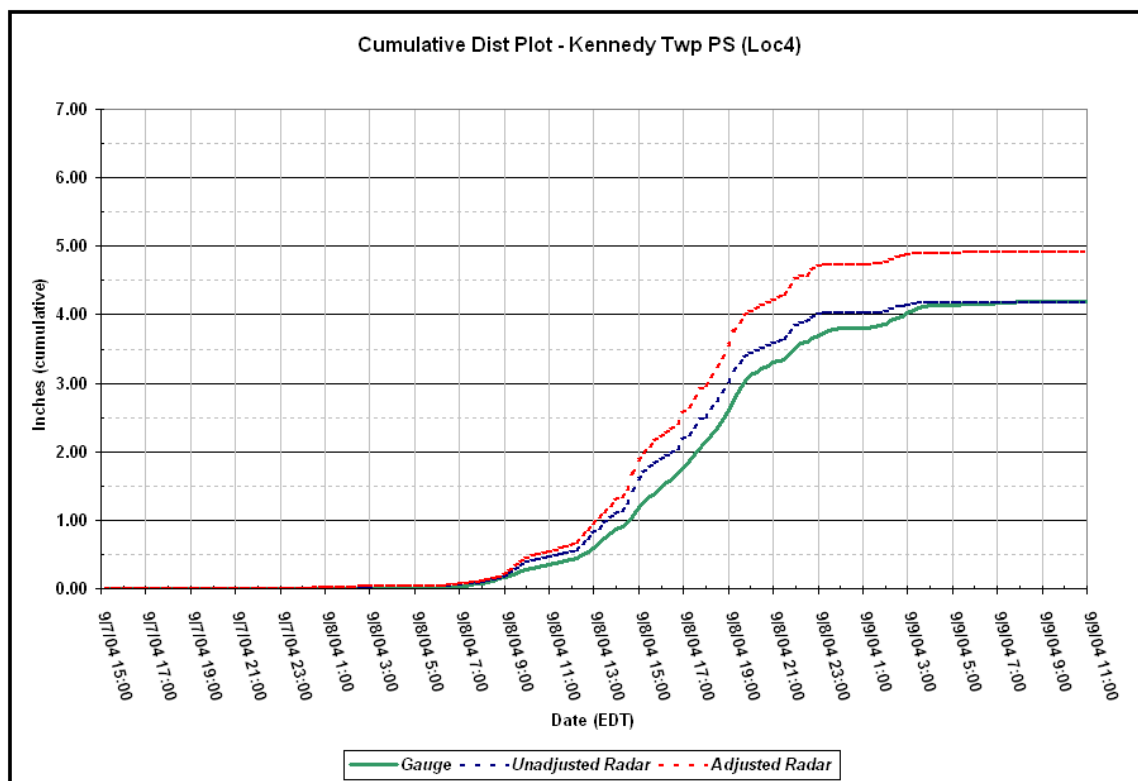
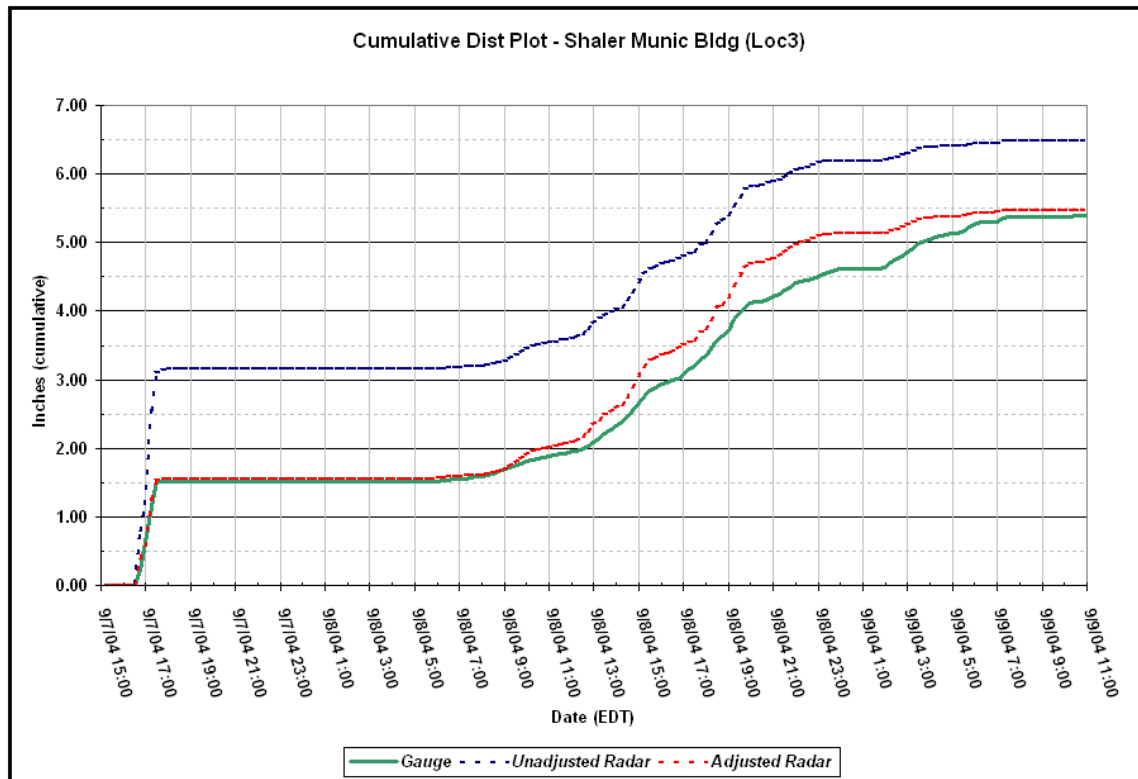
Appendices

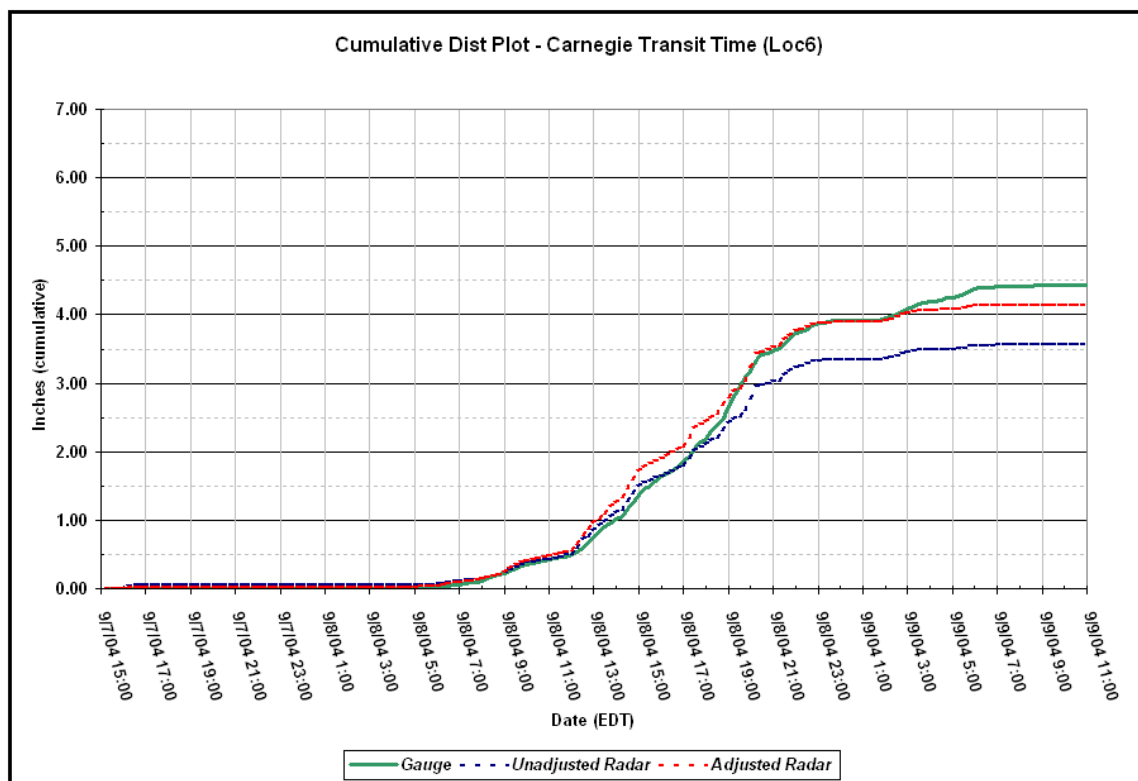
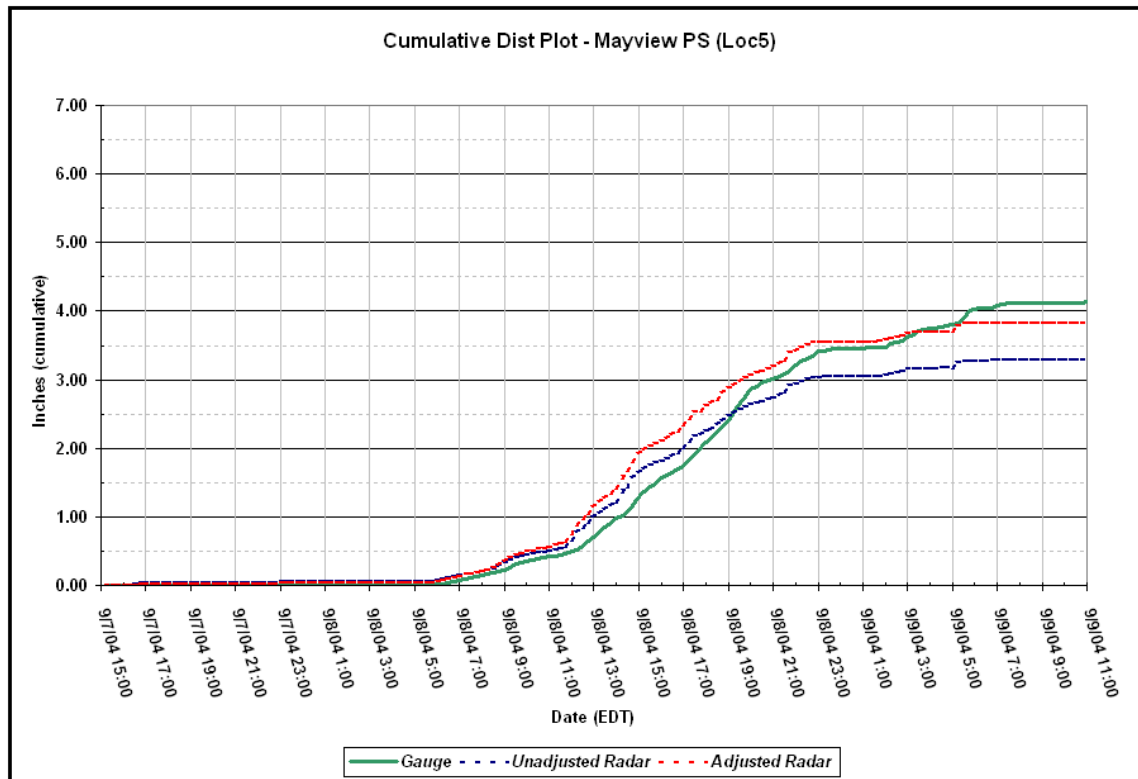
Appendix A – Event 1 (9/8/04) CDPs

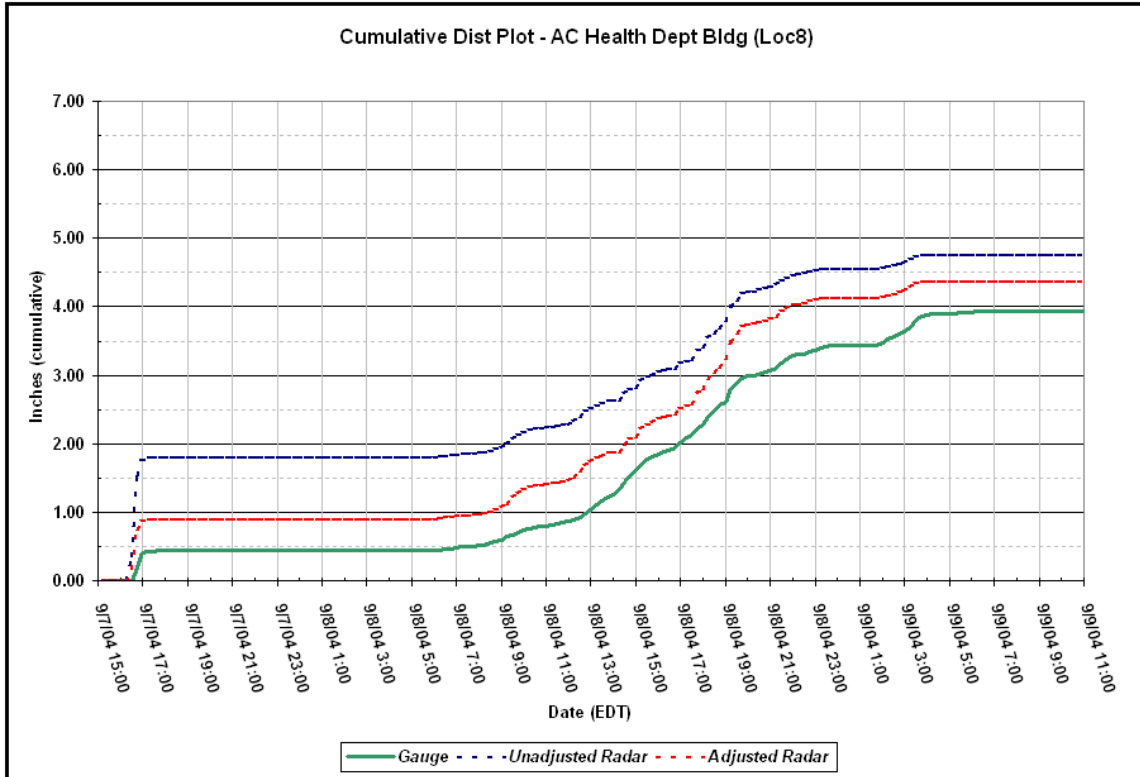
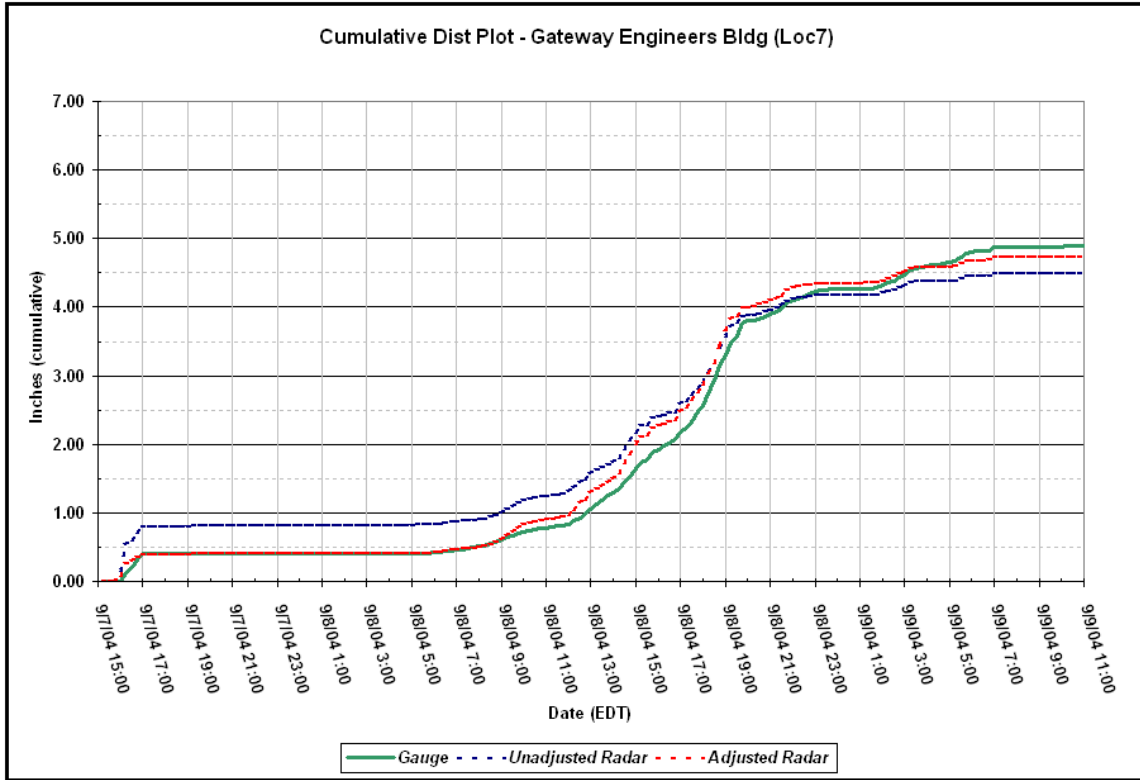
Appendix B – Event 2 (9/17/04) CDPs

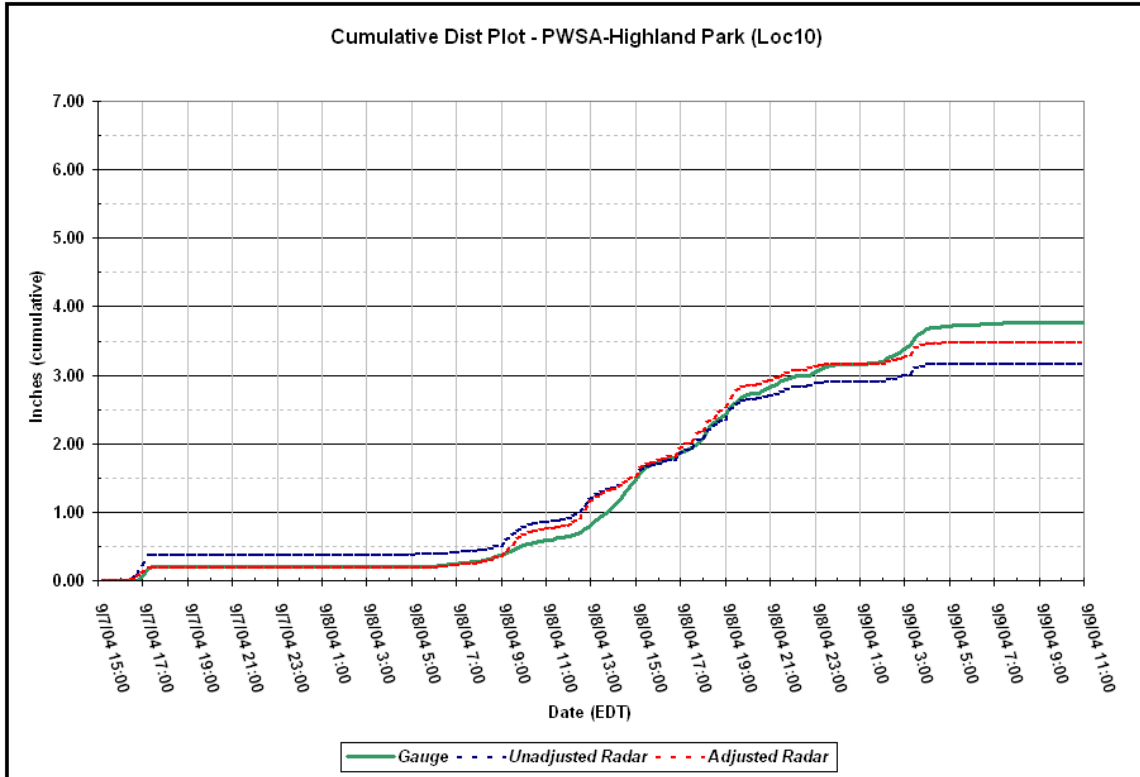
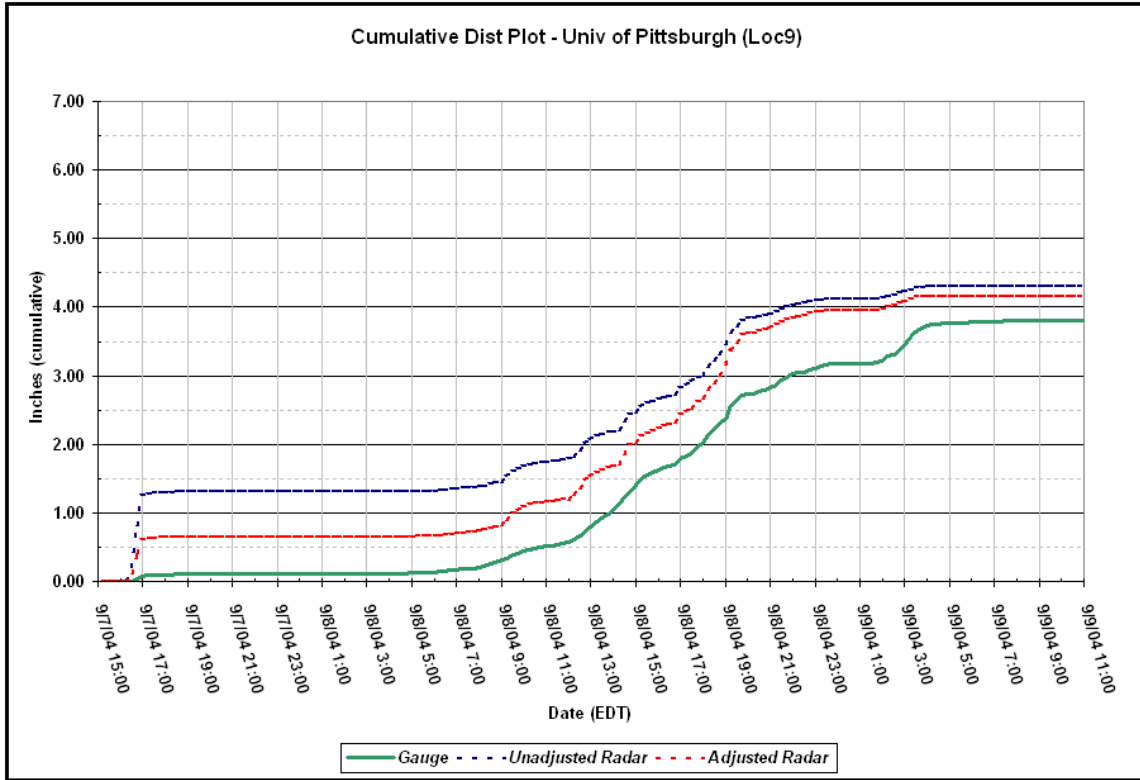
Appendix A - Event 1 (9/8/04) CDPs

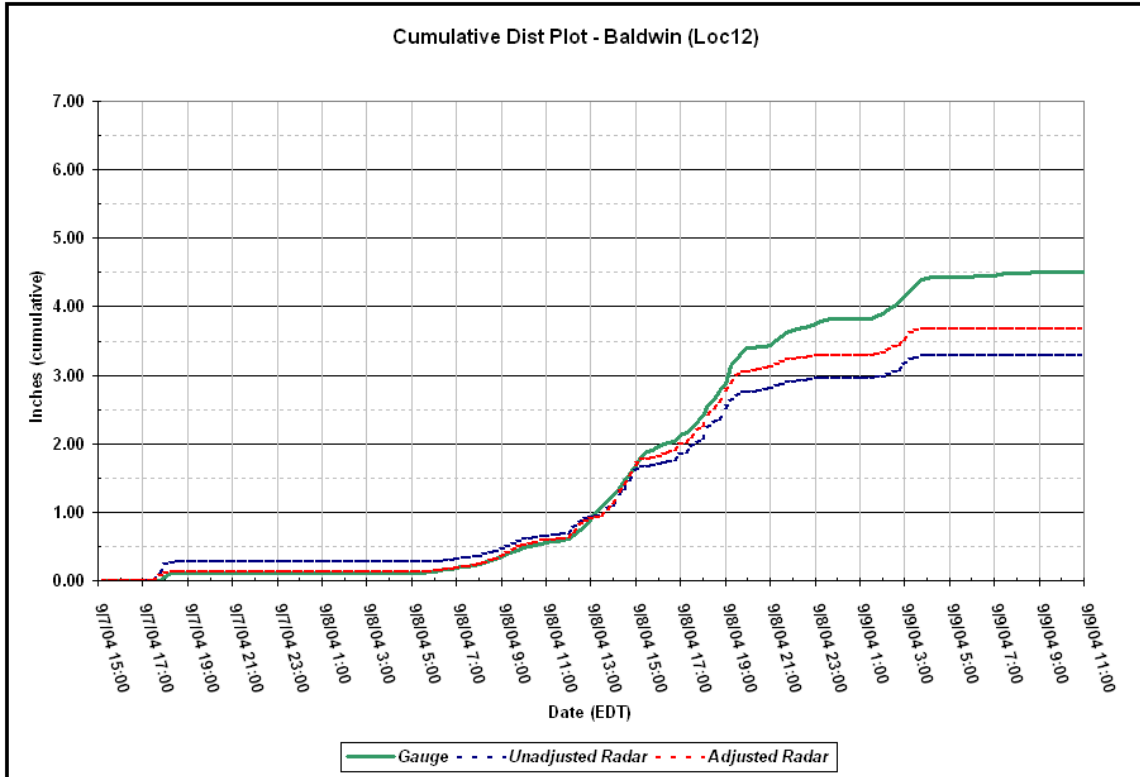
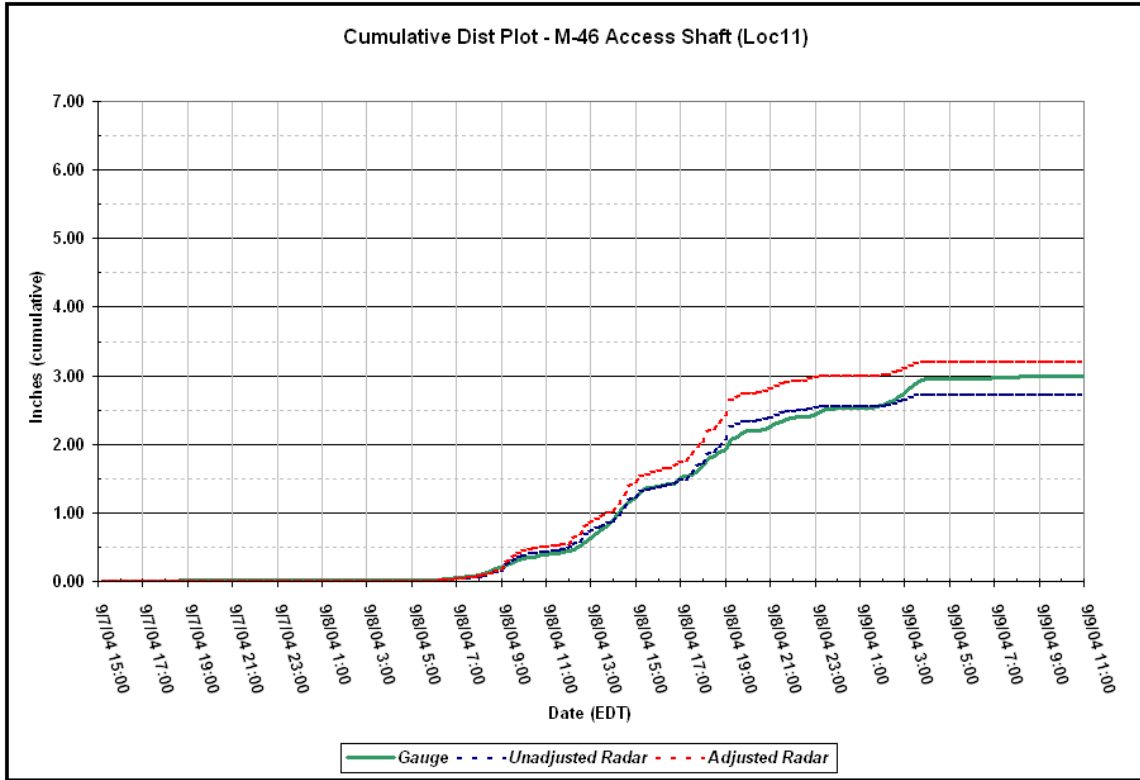


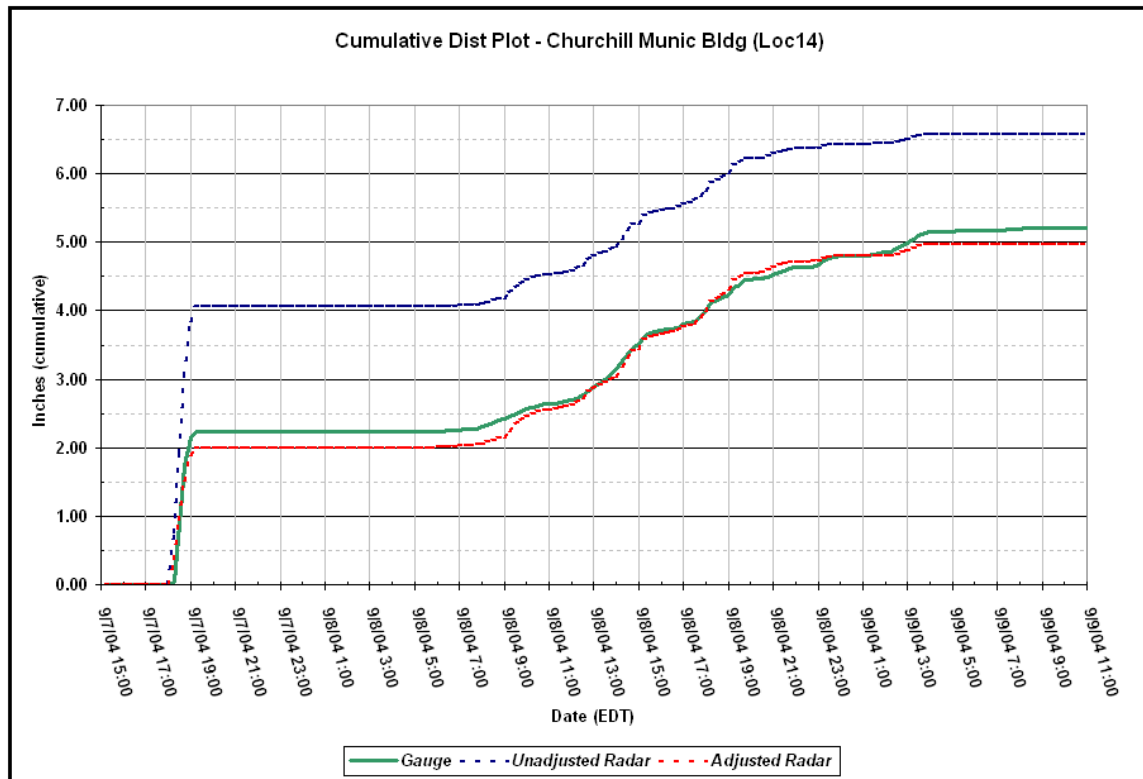
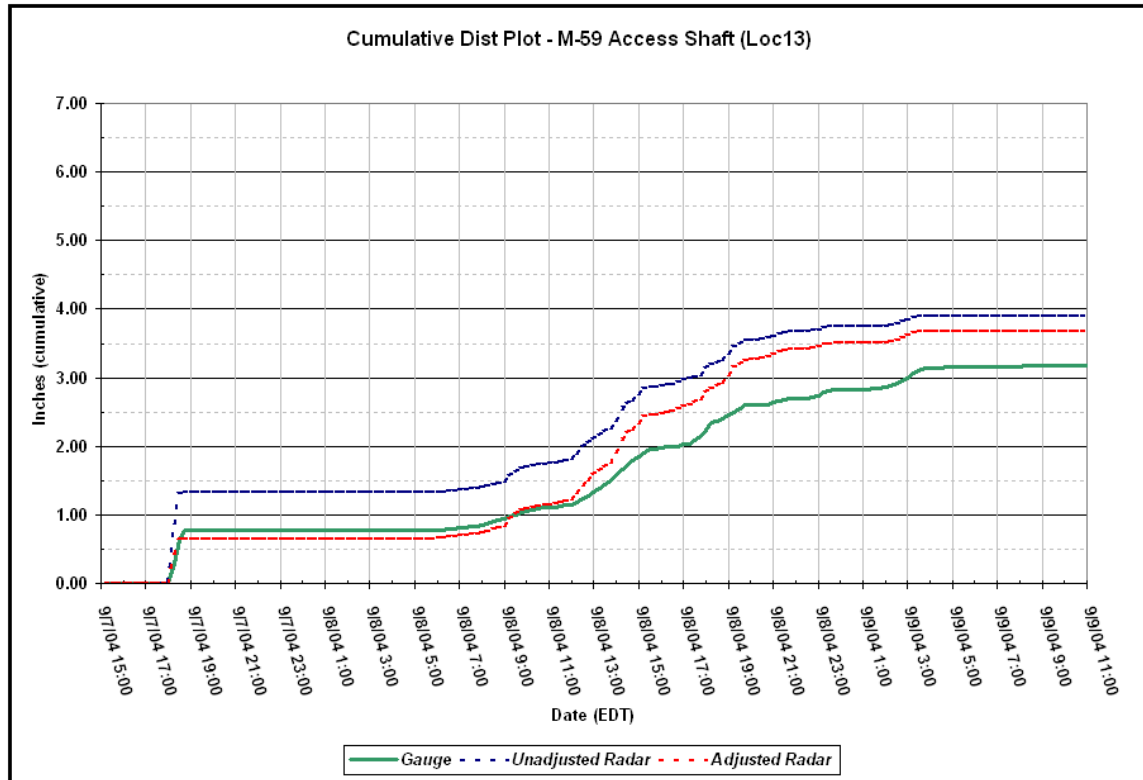


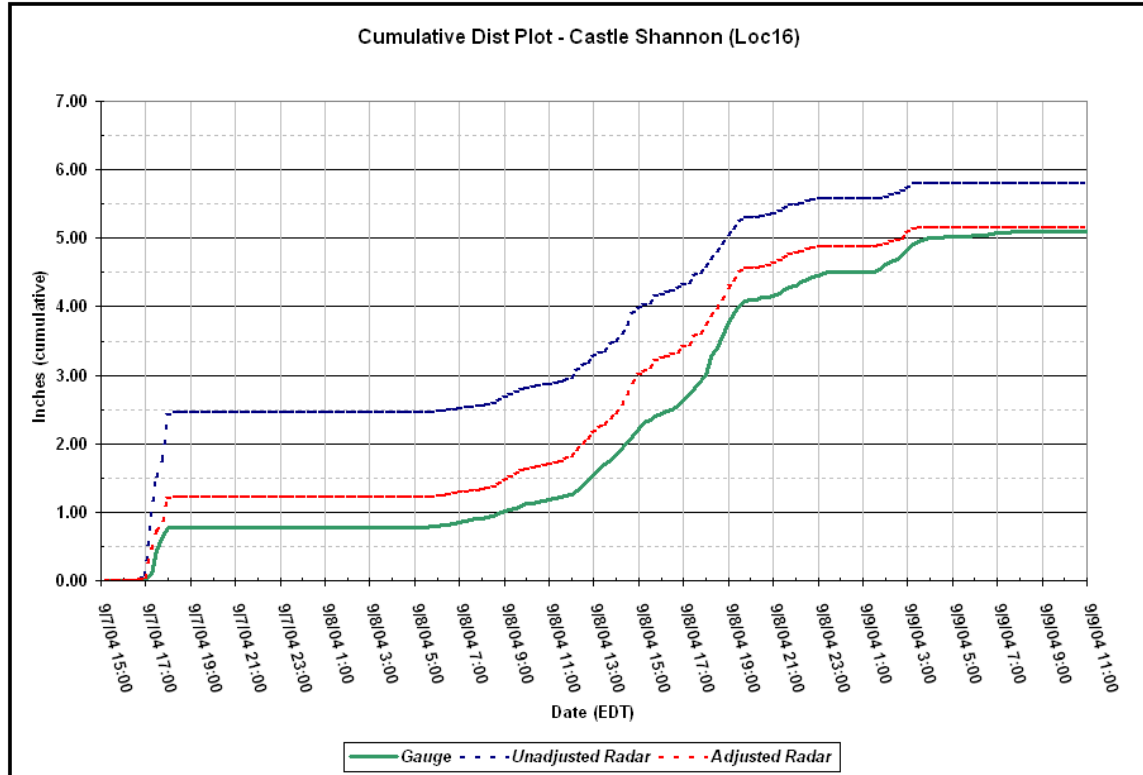
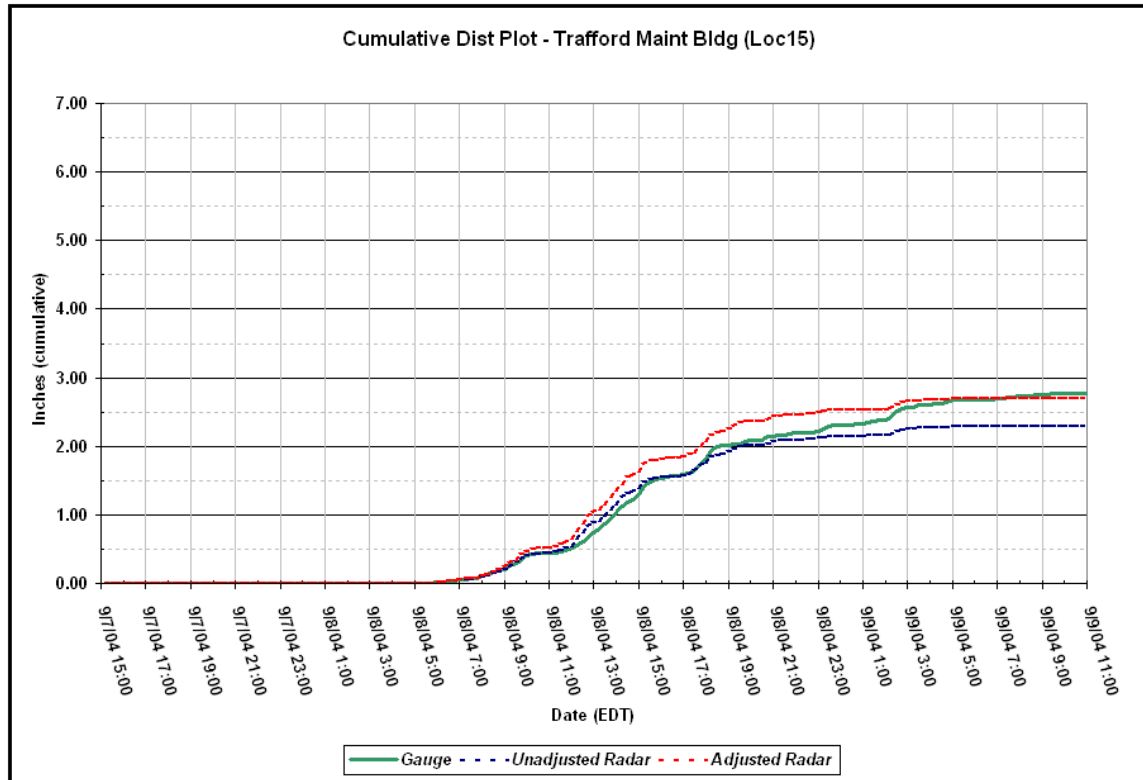


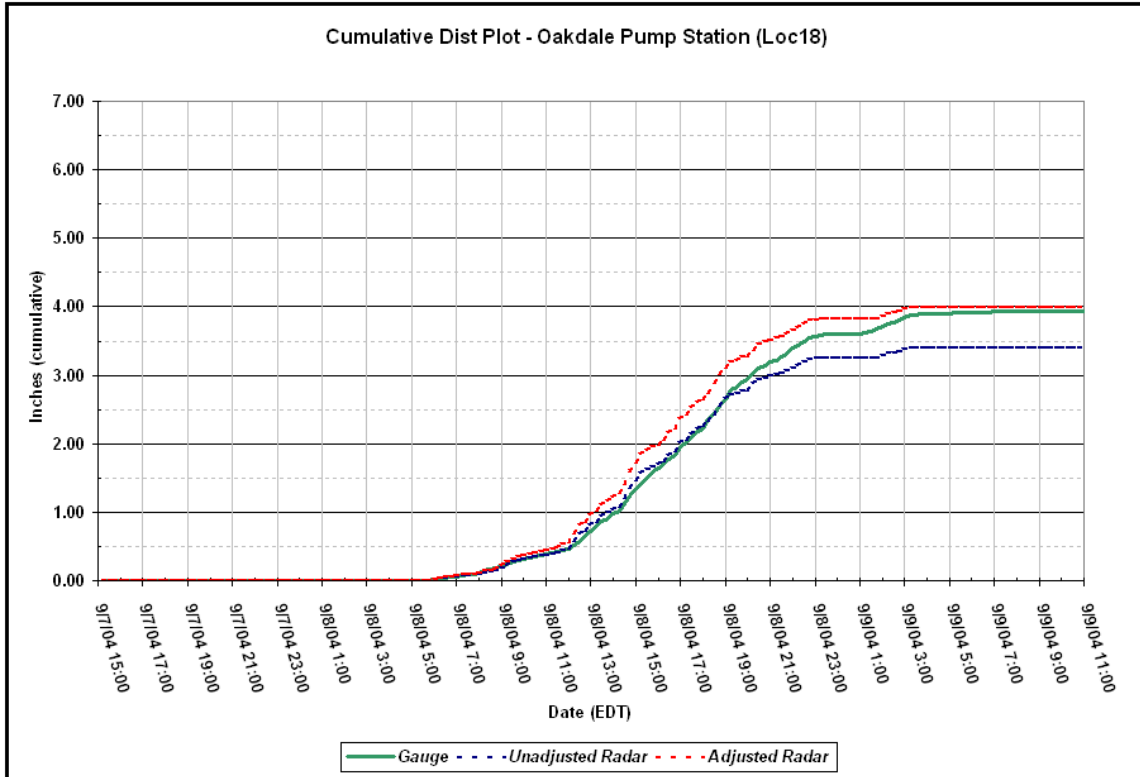
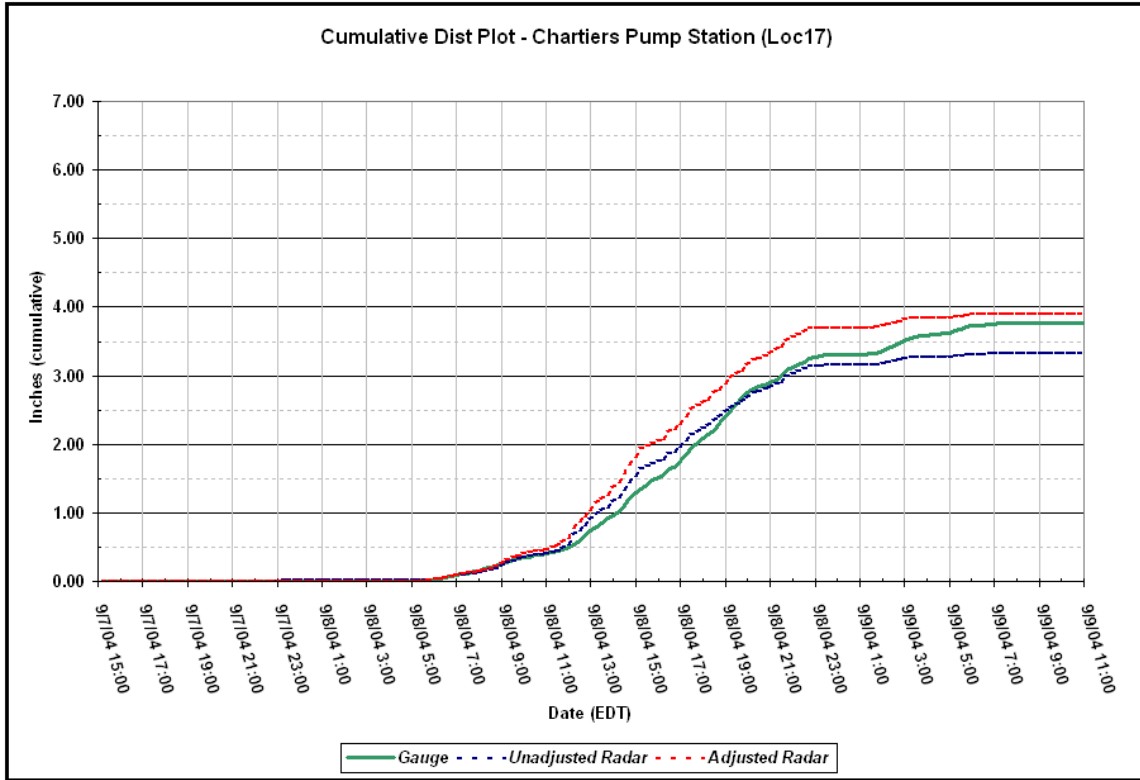


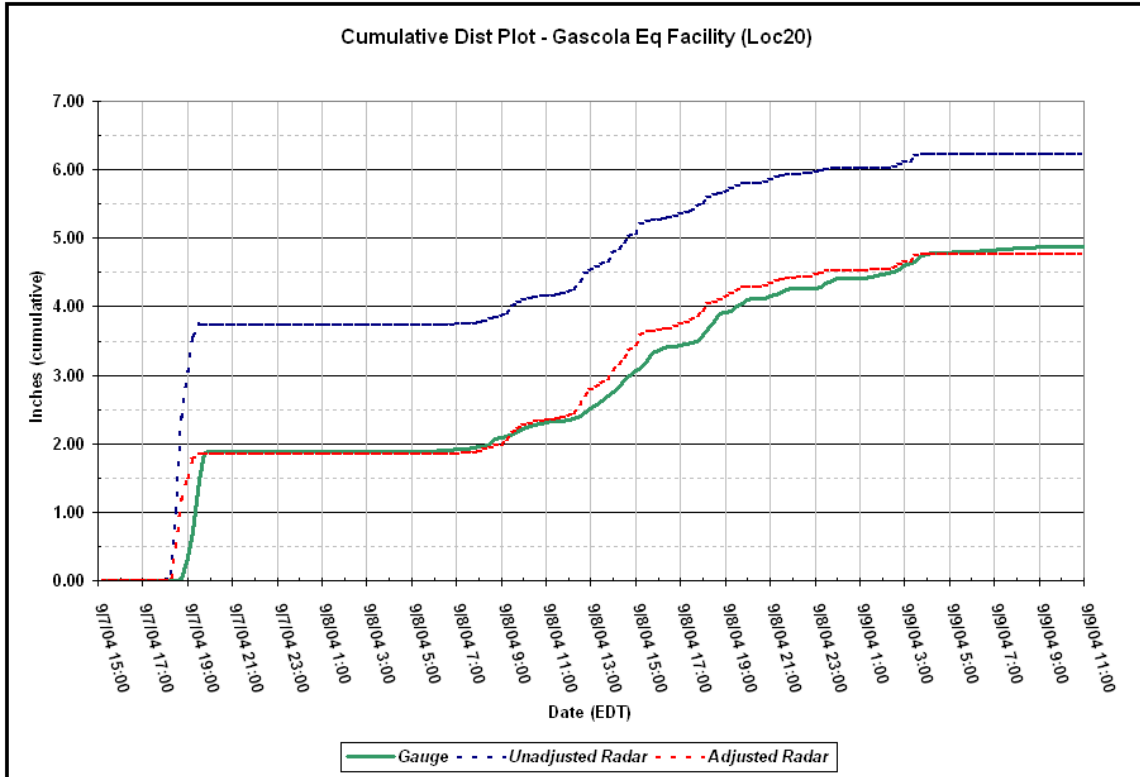
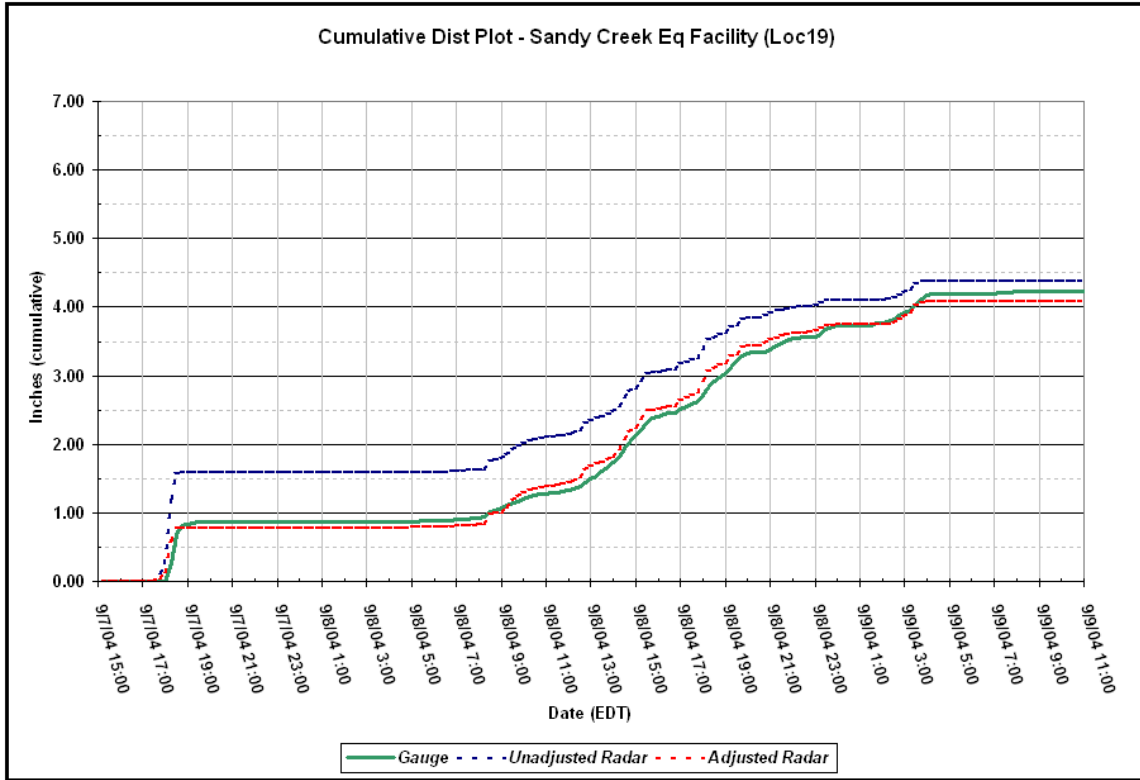


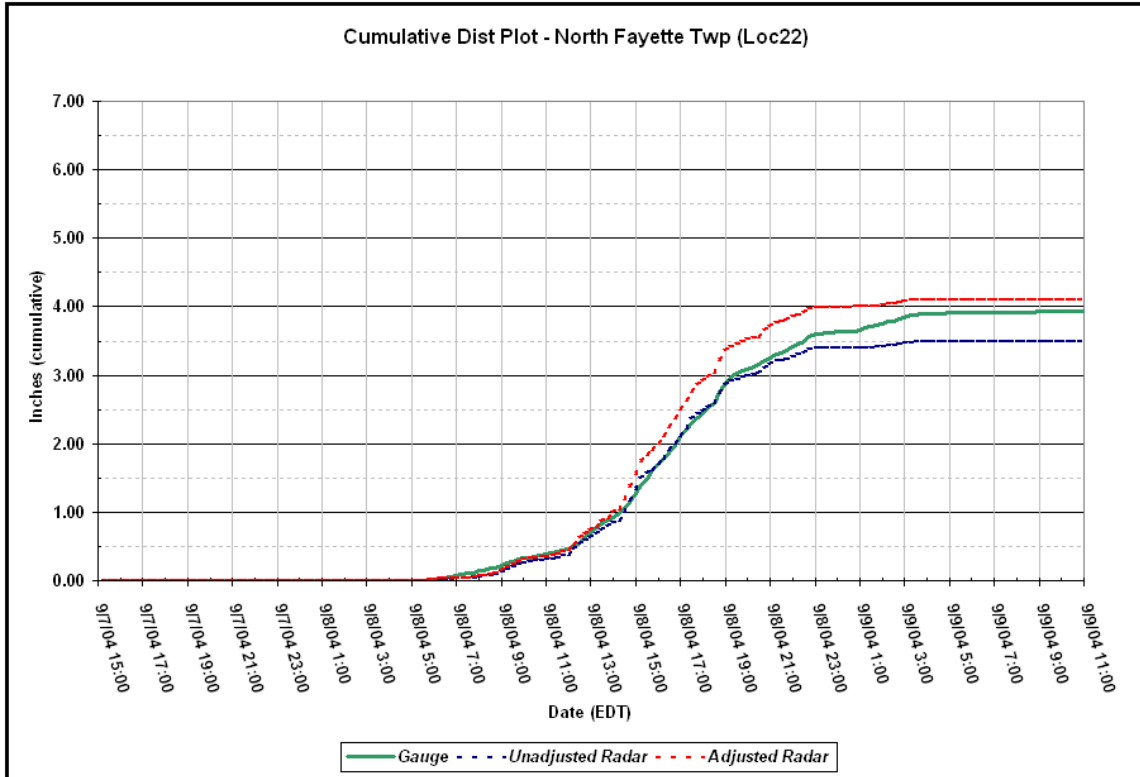
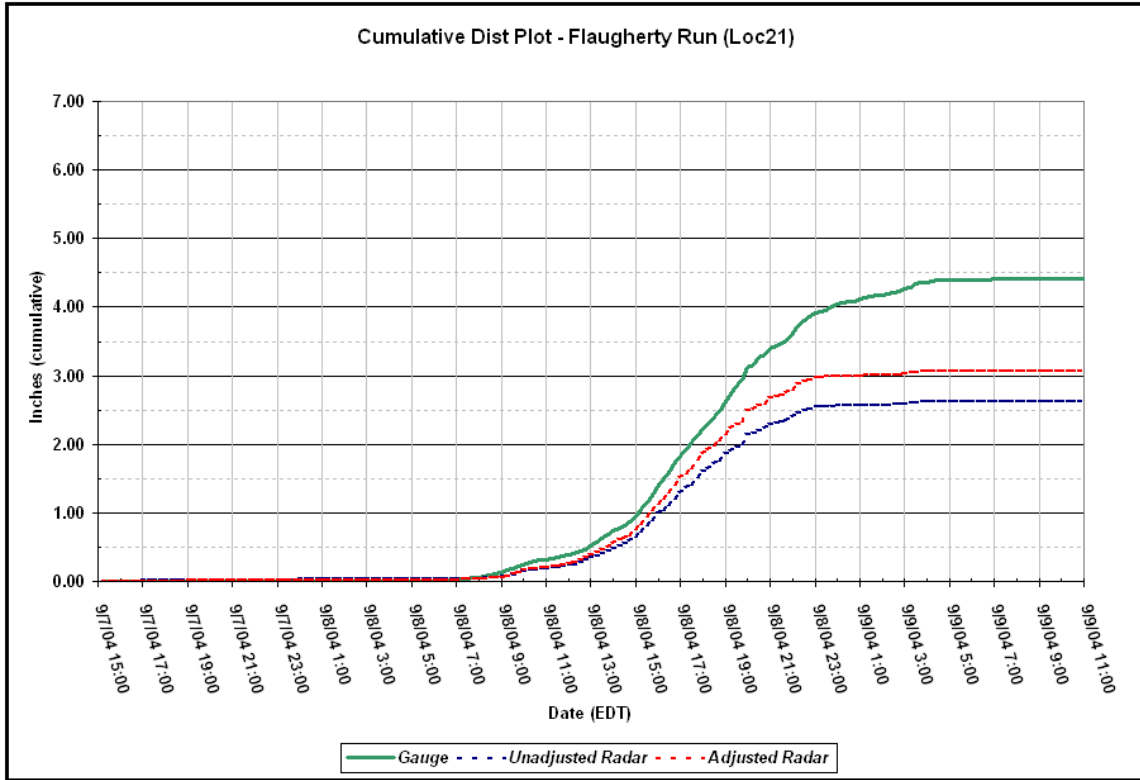


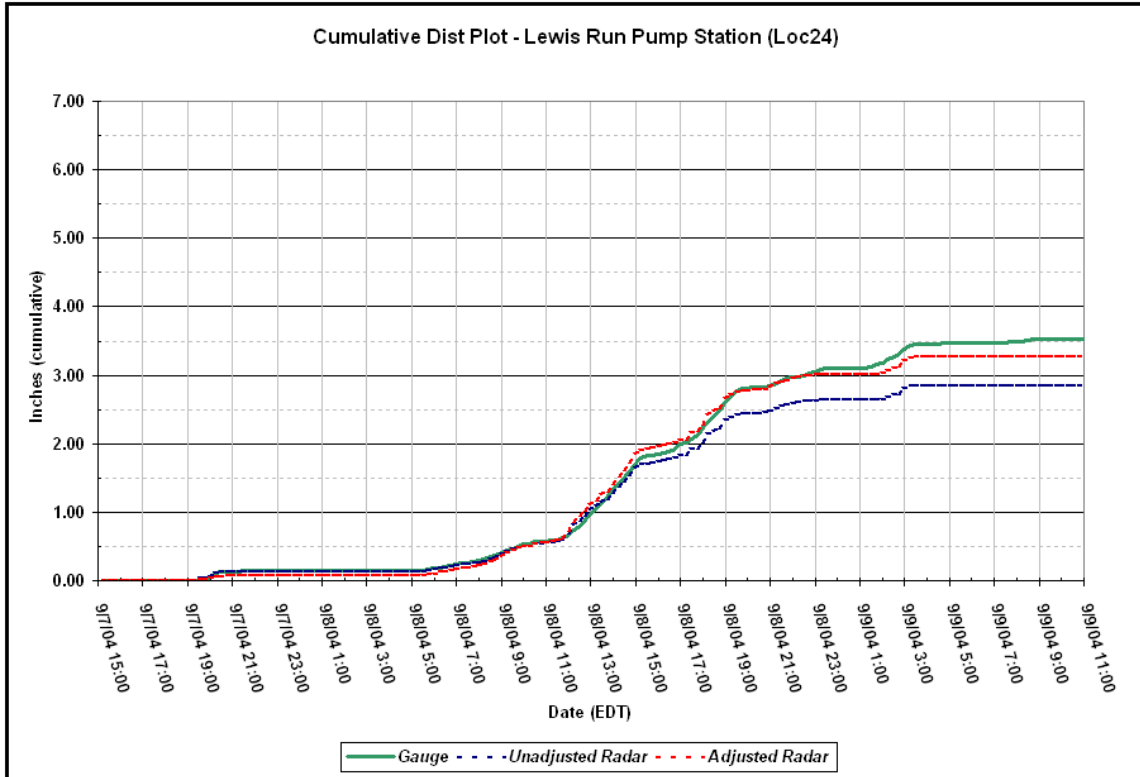
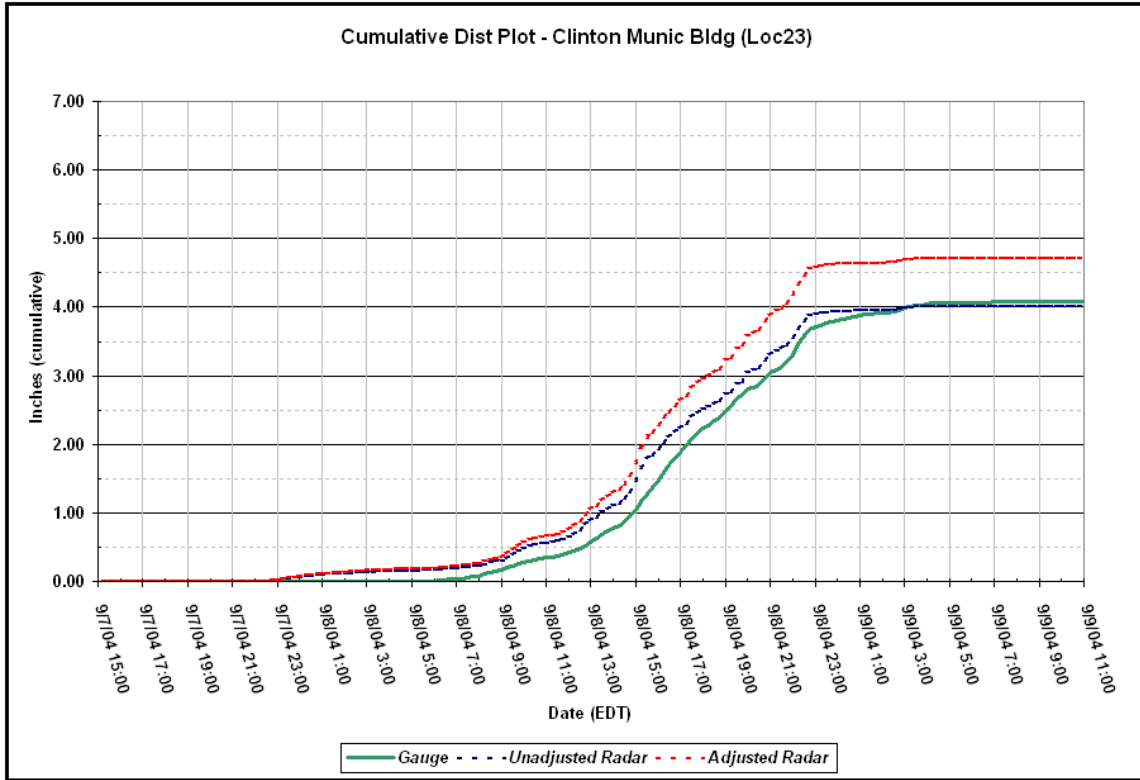


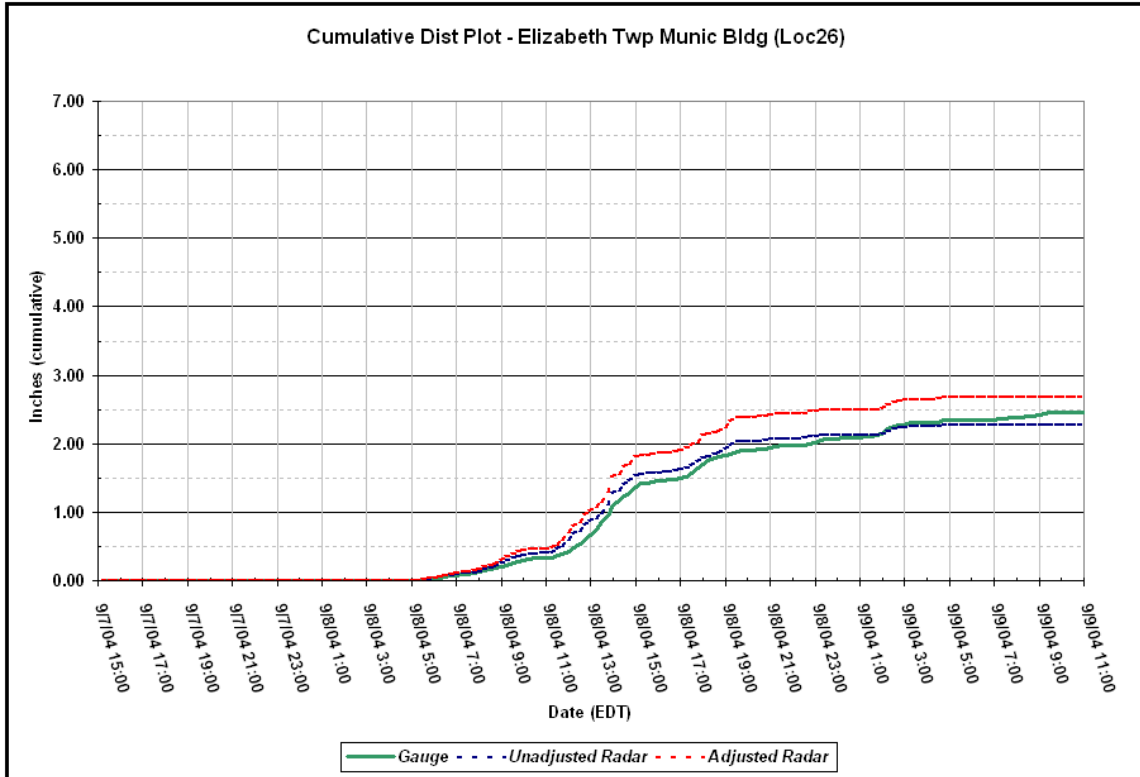
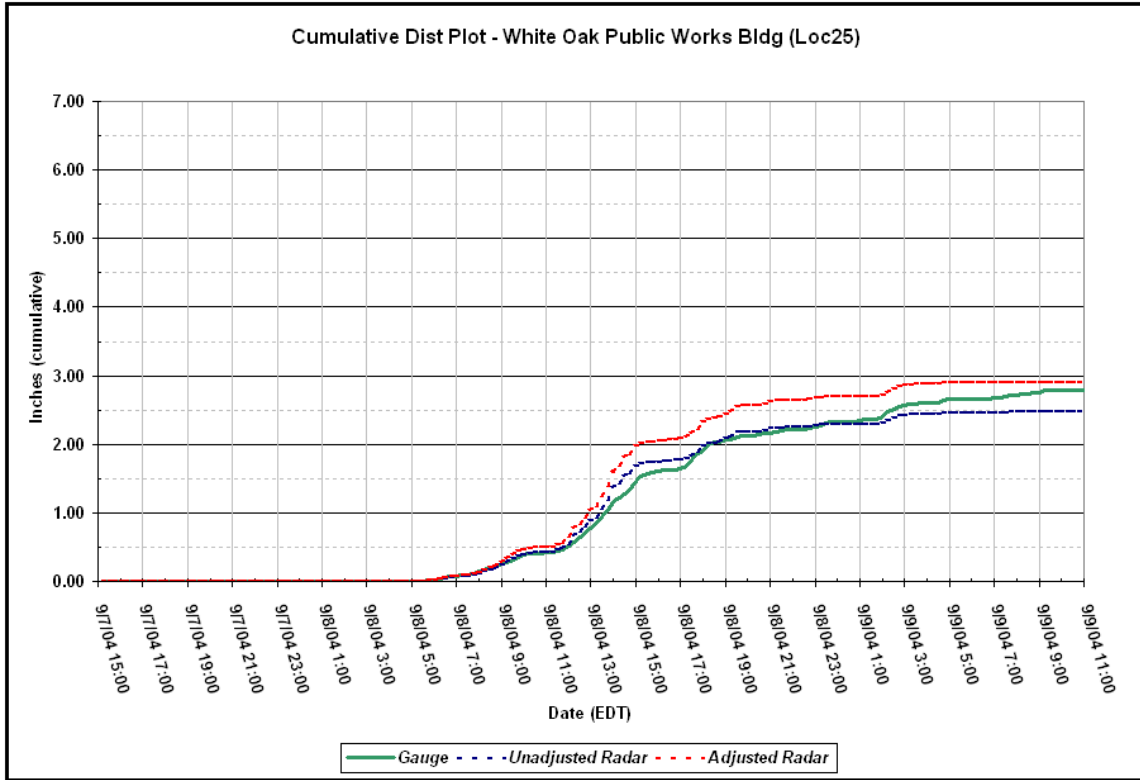


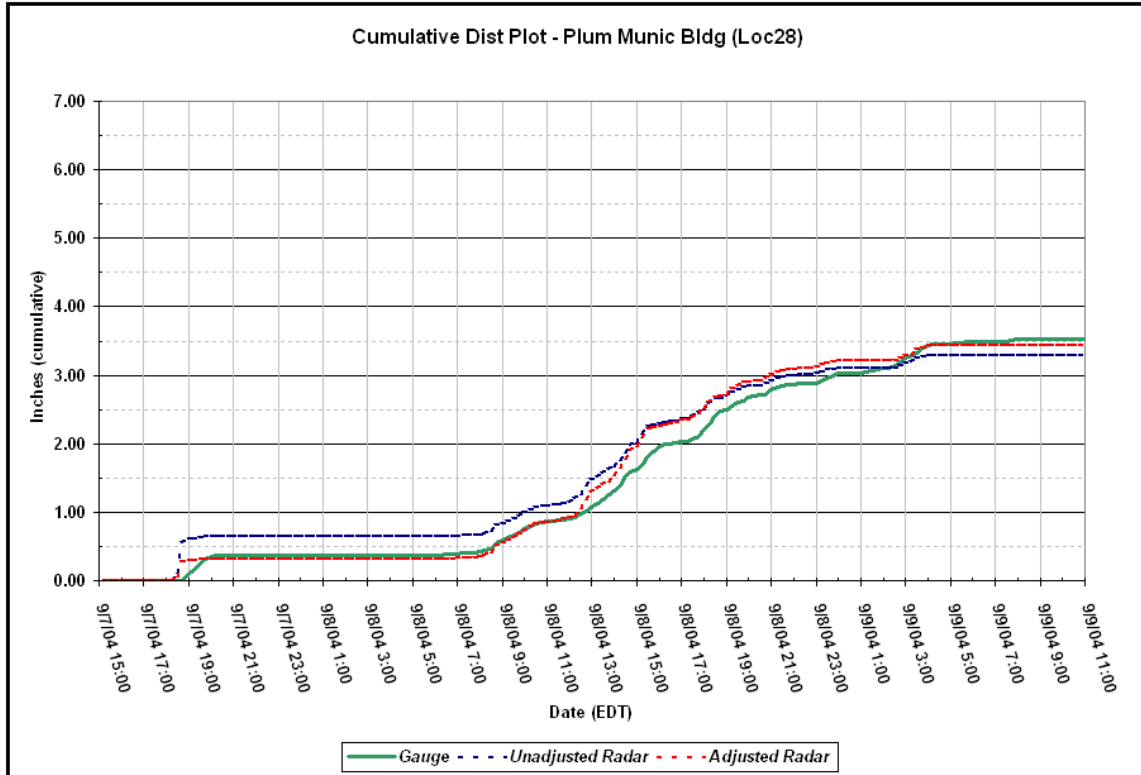
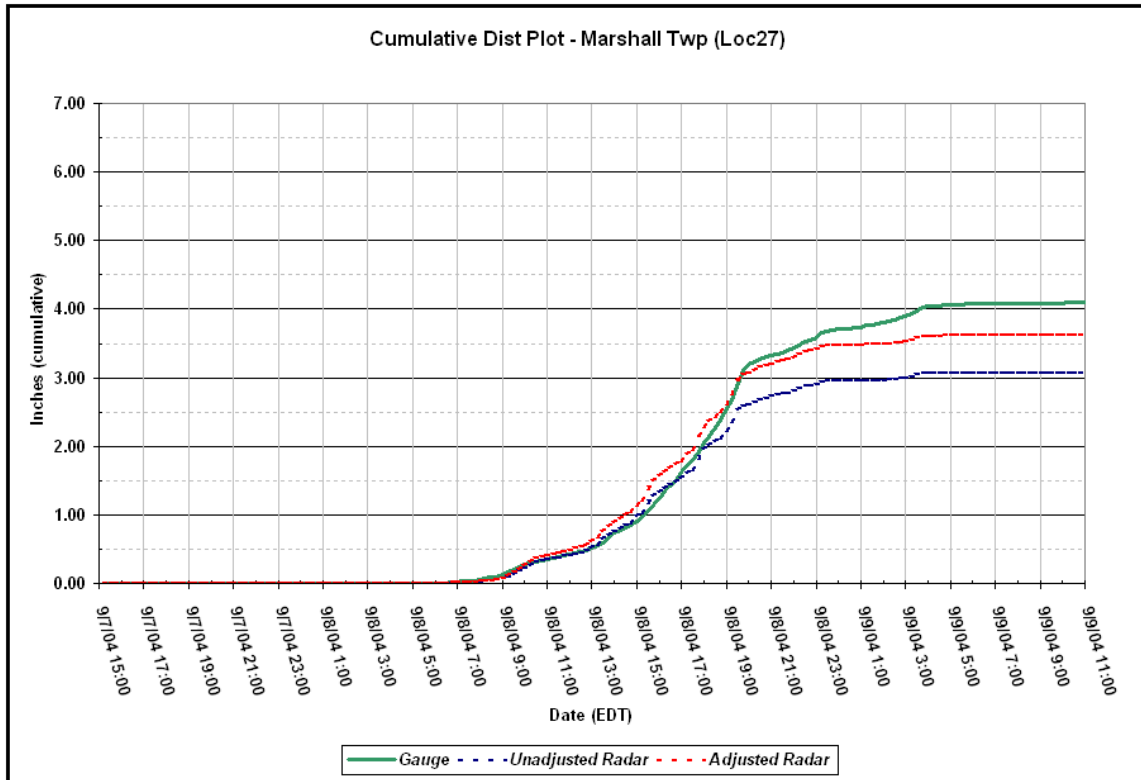


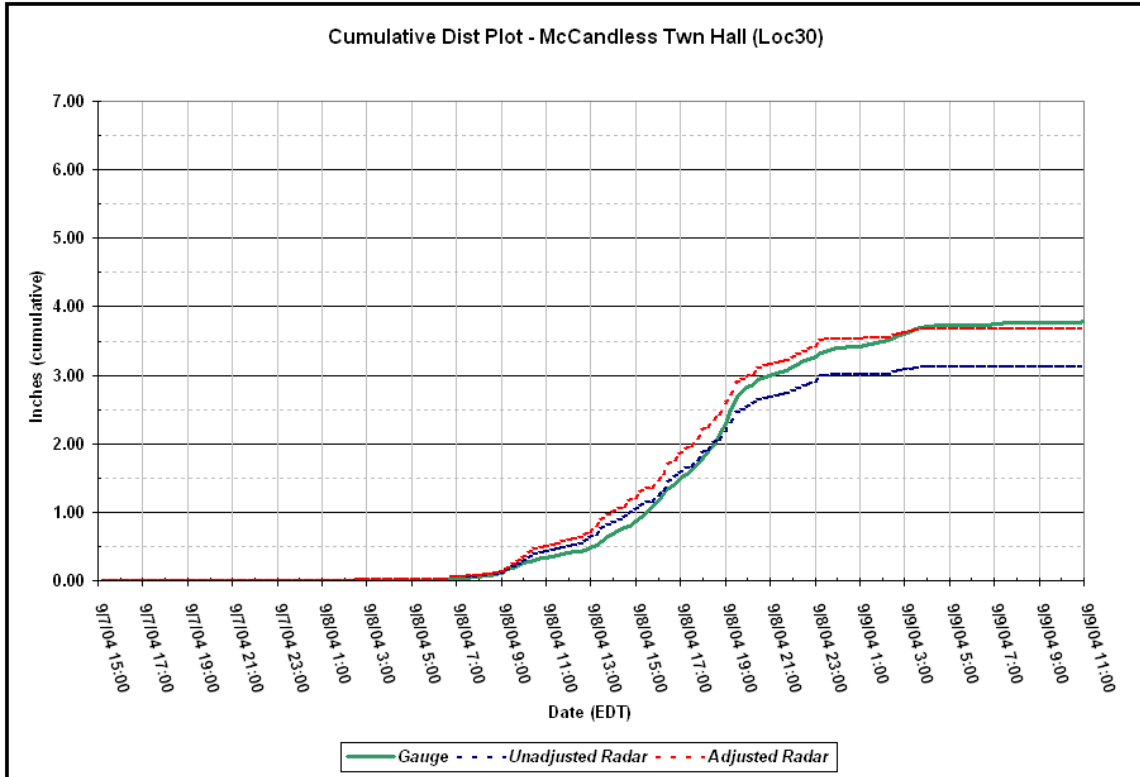
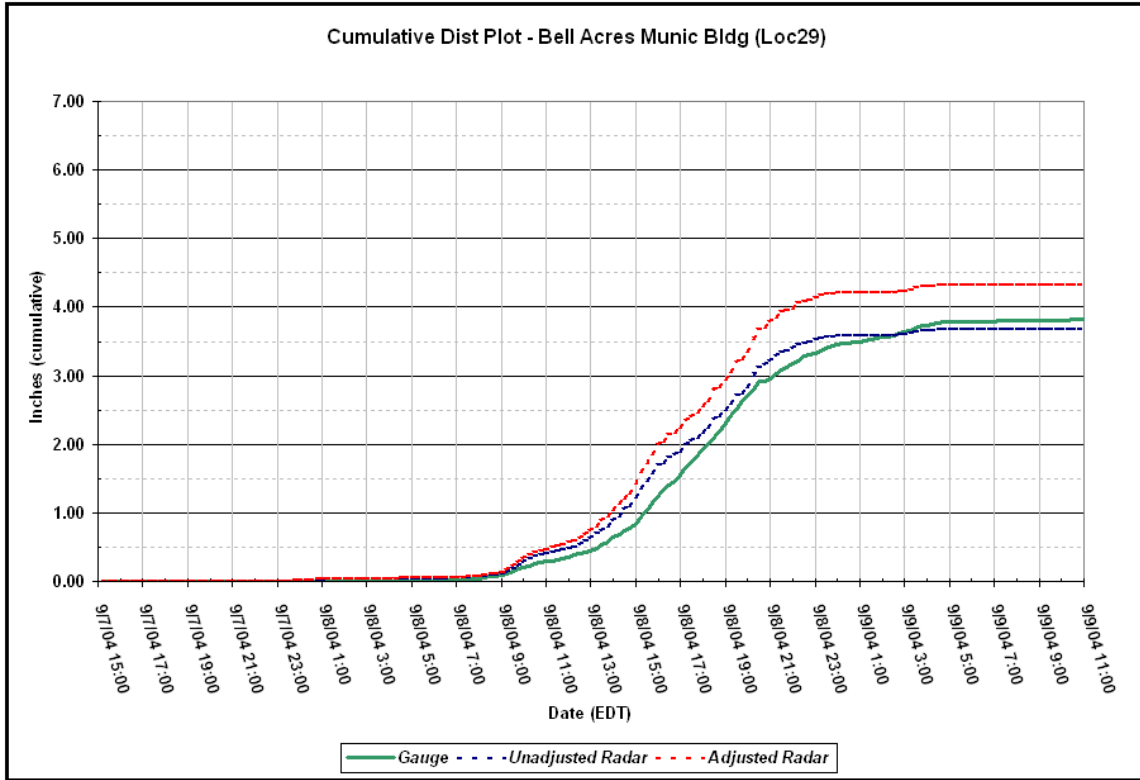


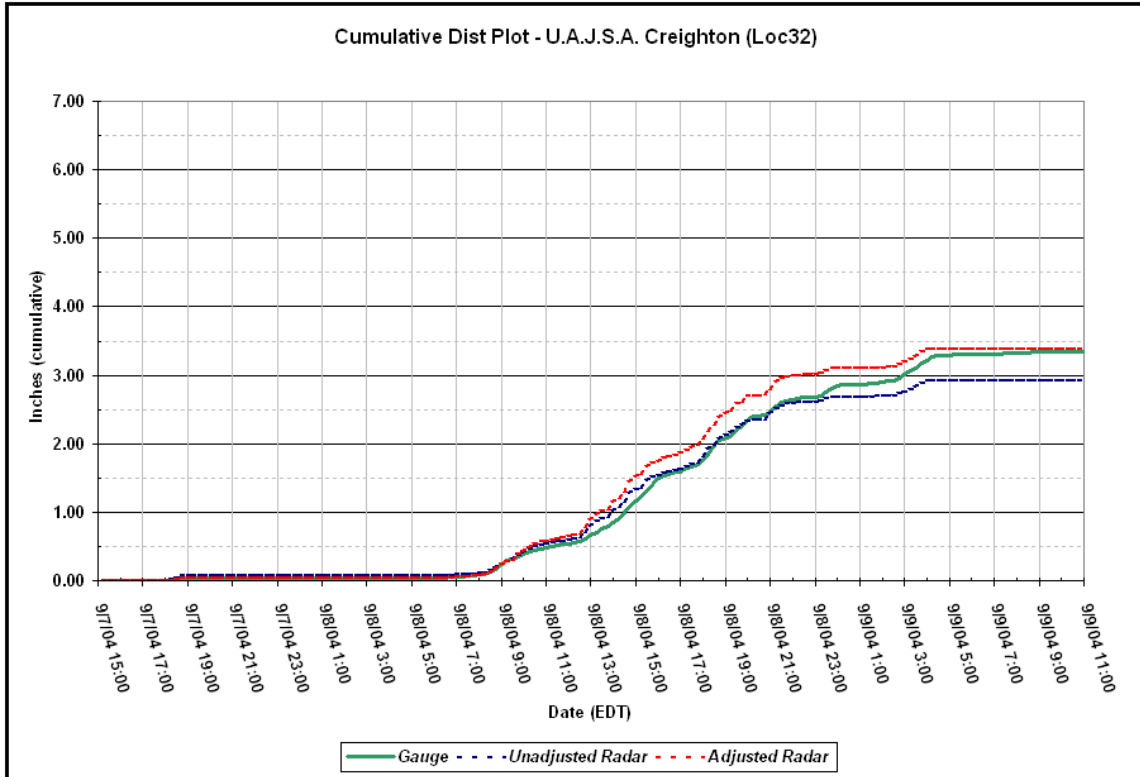
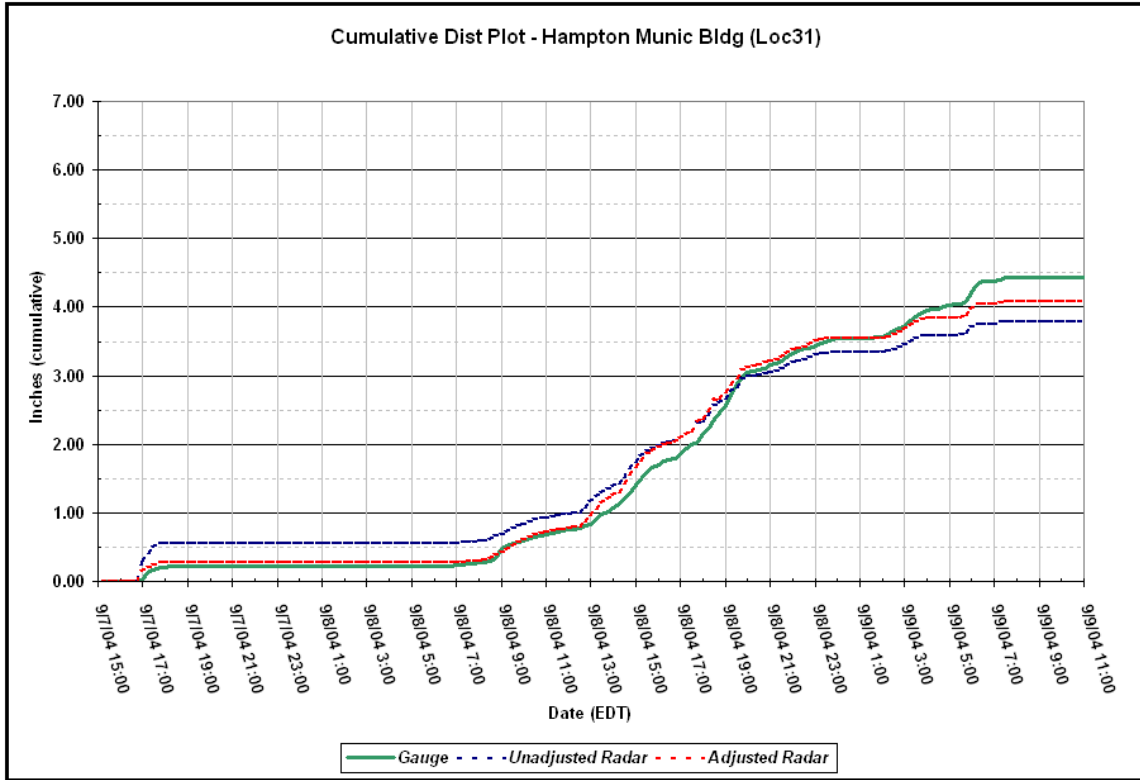


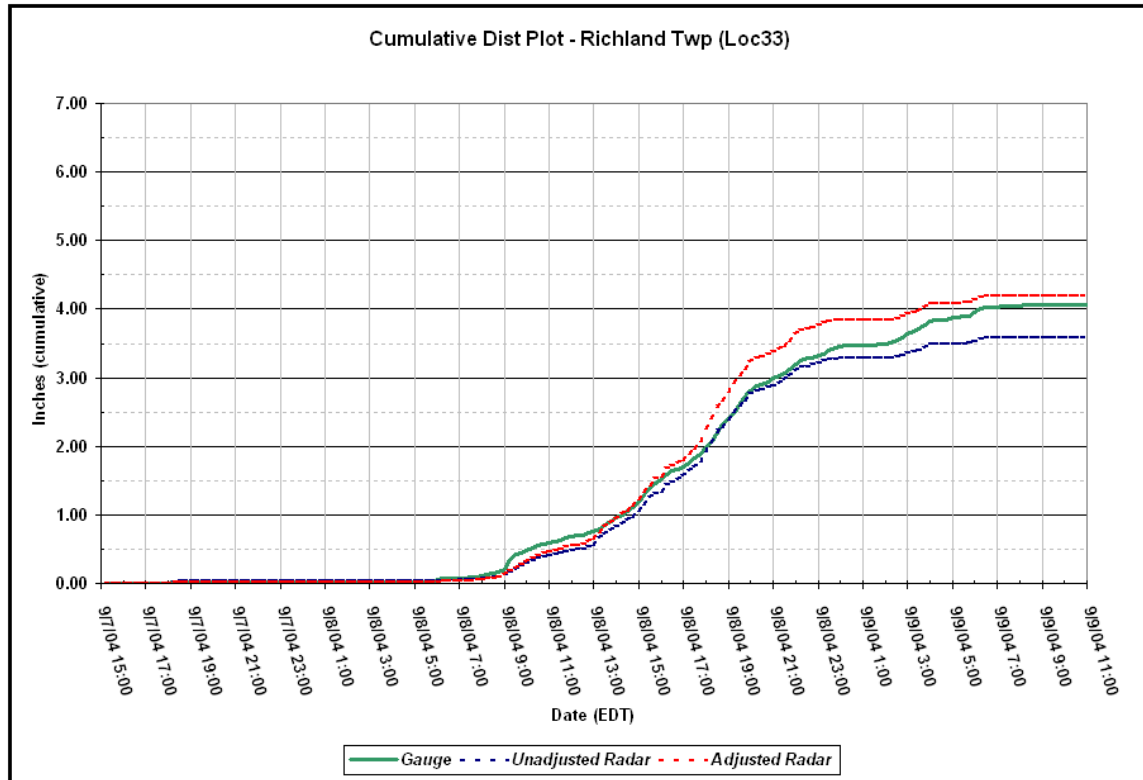












Appendix B - Event 2 (9/17/04) CDPs

