

Radar Rainfall Analysis

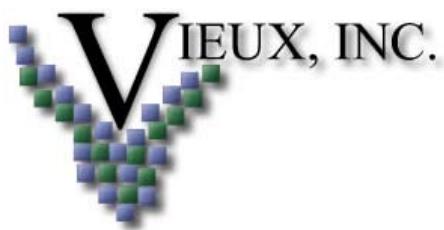
April 2015 Summary Report



Improving our region's water quality

Prepared for 3 Rivers Wet Weather

June 3rd, 2015



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Glossary

Average Difference (AD) – Average of the absolute percentage differences between the rain gauge data and uncalibrated radar data sampled over the gauges.

Bias Correction Factor – Bias is a systematic error that can be corrected through calibration. The correction factor is the sum of the gauges divided by the sum of the sampled radar values over the gauges.

Calibrated Average Difference (CAD) – Average of the absolute percentage differences between the rain gauges and local bias calibrated radar data sampled over the gauges.

Cumulative Distribution Plot (CDP) – A graph depicting the accumulation of a rain gauge and the unadjusted/adjusted radar over that gauge.

Decibels of Reflectance (dBZ) – The logarithmic scale for measuring radar reflectivity factor or a measure of reflectivity of a radar signal off a remote object.

Gauge Adjusted Radar Rainfall (GARR) – Bias corrected radar rainfall through comparison with rain gauges.

KCCX – Federal Communications Commission (FCC) call sign for the NEXRAD near State College, PA.

KPBZ – Federal Communications Commission (FCC) call sign for the NEXRAD near Pittsburgh, PA.

Level II – The Level II radar products are the highest resolution, and consist of the base data that includes reflectivity measured in decibels of reflectance (dBZ) among Doppler velocity and spectrum width.

Level III – The Level III radar products are derivative products from Level II, and consist of horizontal and vertical reflectivity among other products.

Local Bias (LB) – An approach to adjusting radar rainfall that uses the ratio of gauge to radar accumulations from surrounding gauges, with the closest gauge having the most weight.

Minimum Storm Total Threshold (MSTT) – A check used to remove radar/gauge pairs whose cumulative radar and/or gauge values for a given event period were below 0.05 inches.

Next Generation RADAR (NEXRAD) – A network of S-band (10.5-cm wavelength) radars operated by the National Weather Service.

Radio Detection and Ranging (RADAR) – An electronic instrument used for the detection and ranging of distant objects of such composition that they scatter or reflect radio energy.

Radar-Gauge (RG) – A pair of rainfall accumulations measured by the rain gauge and the radar rainfall accumulation sampled above the gauge.

Z-R relationship – An empirical relationship between radar reflectivity factor Z ($\text{mm}^6 \text{ m}^{-3}$) and rain rate R (mm hr^{-1}). Radar reflectivity factor is dependent on the rain drop size distribution. [$Z = aR^b$, where a and b are empirically derived constants]

- **Convective** – generally used for convective (i.e. thunderstorms) rainfall [$Z = 300R^{1.4}$]
- **Eastern U.S. Cool Stratiform** – generally used for cool season, non-convective rainfall that occurs east of the Continental Divide [$Z = 130R^{2.0}$]

Overview

Vieux processes radar and rain gauge data for 3 Rivers Wet Weather (3RWW). During each month, radar and rain gauge data are quality controlled (QC). To produce QC gauge-adjusted radar rainfall (GARR), both radar and rain gauge data are reviewed manually to remove inconsistent data. Only rainfall events that qualified for gauge-adjustment of the radar are included in this report.

Radar data used in production of GARR is produced by the National Weather Service (NWS) Next Generation Radar (NEXRAD) system. NEXRAD Level II radar data are often referred to as Base Data and contain the full spatial/temporal/data resolution data from the radar. Level II radar data measures reflectivity in decibels of reflectance (dBZ), and at a spatial resolution of 0.5-degree by 0.25-km every 4 – 10 minutes with a data resolution of 0.5 dBZ amounting to 256 data levels of data. Level III Q1 radar data have the same data and temporal resolution, but a reduced spatial resolution of 1-degree by 1-km.

The primary radar data source used to process this period was Level II NEXRAD data from KPBZ located near Pittsburgh, PA. The succession of data used gives priority to Level II followed by Level III products. If KPBZ Level II NEXRAD data are unavailable, then KPBZ Level III Q1 is substituted. If no radar data are available from KPBZ, then Level II NEXRAD data from KCCX (State College, PA) are used. In the event that all radar sources are unavailable or if the radar provides insufficient rainfall information, then a gauge-only product that spatially distributes point rainfall estimates is used. All radar data were processed into fifteen-minute increments.

Because the radar measures reflectivity in polar coordinates centered on the radar installation, the 1-degree azimuth increases in width as range increases from the radar. Range resolution of the Level II radar data is 1-km and is measured out to 230 km from the radar. Due to the proximity of KPBZ to the study area, the polar coordinates defining horizontal resolution over Allegheny County range from 0.1 – 0.9 km, whereas KCCX ranges from 2.5 – 3.6 km. The radar data represented in these polar coordinates are sampled through spatial averaging into a Cartesian grid of uniform resolution, i.e. 1x1 km. An advantage of the Cartesian grid is that one radar can be substituted for the other without changing the grid resolution, as would be necessary if polar coordinates were used for output of rainfall information at 1x1 km spatial resolution. The Cartesian grid used was defined by a 1-km² grid domain shapefile containing 2313 1-km² pixels covering the study area.

Rain gauge data from as many as 38 gauges were used to adjust the radar. 3RWW provided rain data in 15-minute increments for 33 stations. In addition, rain gauge data were obtained from three United States Geological Survey (USGS) stations and two NWS Automated Surface Observing System (ASOS) stations. Figure 1 depicts the spatial distribution of the rain gauge network, KPBZ NEXRAD and 1-km² pixels. For the gauges shown in Figure 1, the ID, name and source of each gauge is listed in Table 1. Radar data review, preparation and sampling the radar over the gauges and 1-km² pixels were achieved using software developed at Vieux, Inc.

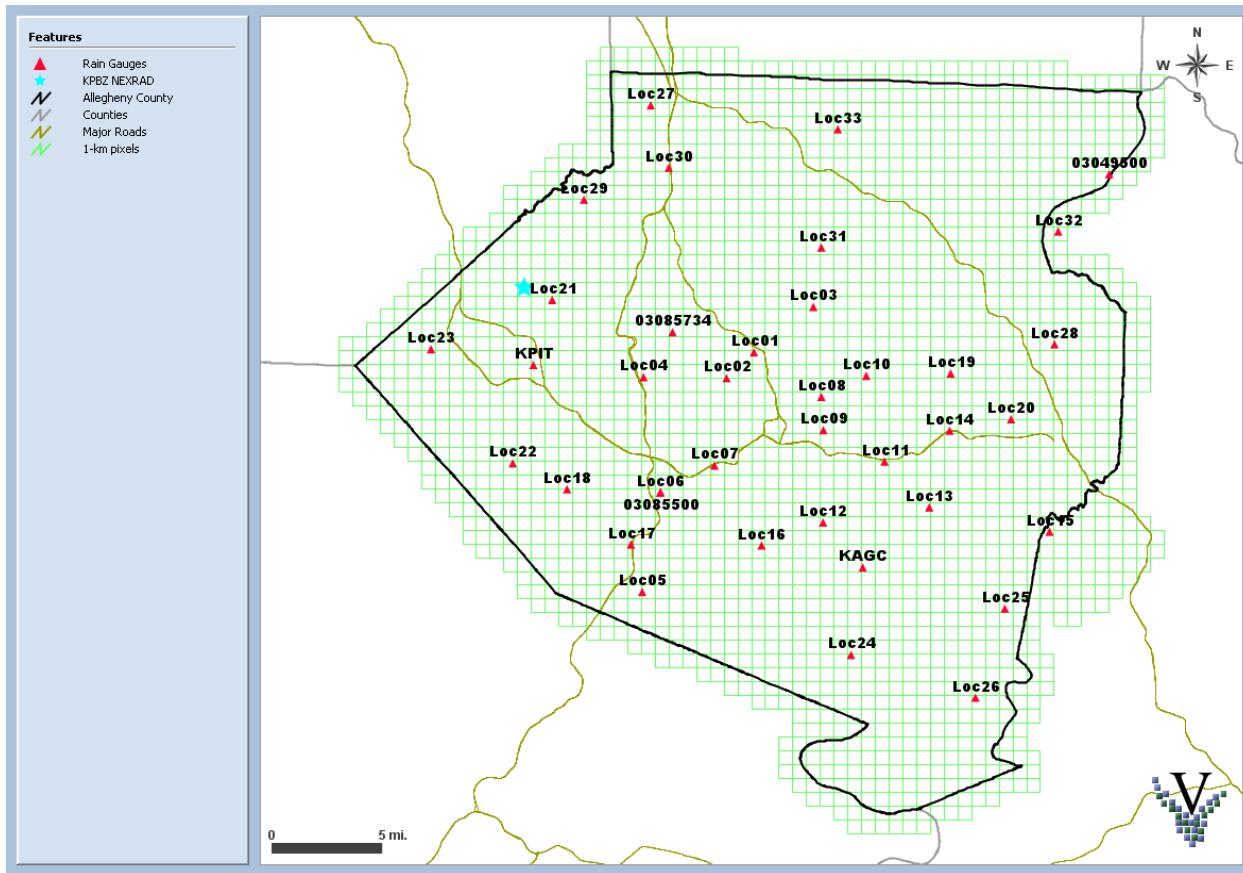


Figure 1. Spatial Distribution of the Rain Gauge Network, KPBZ NEXRAD and 1-km² Pixels

Table 1. Rain Gauge ID, Name and Source

Gauge ID	Gauge Name	Source
Loc01	PWSA-Montana St.	3RWW
Loc02	ALCOSAN WWTP Lab	3RWW
Loc03	Shaler Munic Bldg	3RWW
Loc04	Kennedy Twp PS	3RWW
Loc05	Upper St. Clair	3RWW
Loc06	Carnegie Transit Time	3RWW
Loc07	Greentree Munic Bldg	3RWW
Loc08	AC Health Dept Bldg	3RWW
Loc09	Univ of Pittsburgh	3RWW
Loc10	PWSA-Highland Park	3RWW
Loc11	M-46 Access Shaft	3RWW
Loc12	Baldwin	3RWW
Loc13	M-59 Access Shaft	3RWW
Loc14	Churchill Munic Bldg	3RWW

Gauge ID	Gauge Name	Source
Loc15	Trafford Maint Bldg	3RWW
Loc16	Castle Shannon	3RWW
Loc17	Chartiers Pump Station	3RWW
Loc18	Oakdale Pump Station	3RWW
Loc19	Sandy Creek Eq Facility	3RWW
Loc20	Gascola Eq Facility	3RWW
Loc21	Moon TWP	3RWW
Loc22	North Fayette TWP	3RWW
Loc23	Clinton Munic Bldg	3RWW
Loc24	Jefferson Hills	3RWW
Loc25	White Oak Public Works Bldg	3RWW
Loc26	Elizabeth TWP Municipal Bldg	3RWW
Loc27	Marshall TWP	3RWW
Loc28	Plum Municipal Bldg	3RWW
Loc29	Bell Acres Munic Bldg	3RWW
Loc30	McCandless Twn Hall	3RWW
Loc31	Hampton Municipal Bldg	3RWW
Loc32	Arnold	3RWW
Loc33	Richland TWP	3RWW
KAGC	Pittsburgh Allegheny Cty	NWS - ASOS
KPIT	Greater Pittsburgh Int'l	NWS - ASOS
03049500	Allegheny River at Natrona	USGS
03085500	Chartiers Creek at Carnegie	USGS
03085734	Ohio River at Emsworth Dam Lower Pool at Emsworth	USGS

The 38 rain gauges and the two NWS NEXRAD radars are used to produce gauge-adjusted radar rainfall (GARR). The methodology used in production of the GARR and the dataset metadata are described in the following sections.

Methodology

Statistical control of the data makes radar rainfall measurements more accurate. By statistical comparison between the radar and rain gauge accumulations during a calibration interval, statistical outliers may be identified. Radar data is enhanced by correcting it for systematic errors called bias, which helps improve the accuracy of the rainfall product. The bias correction factors are multiplicative factors applied to the radar that enhances the accuracy of the radar rainfall for any accumulation period. By adjusting the radar data with rain gauge data, better maps of rainfall are produced than either sensor system could produce alone. Qualified rainfall events are defined based on a storm event definition where, for any given hour, at least 50% of all working 3RWW gauges have an accumulation of 0.05 inches.

In the production of GARR, radar rainfall is bias corrected through comparison with rain gauge accumulations. To the extent possible, individual gauges are combined to cover the target area for use in bias adjustment. The method of adjustment depends on the hydrologic application and the spatial extent of the area of interest. The local bias (LB) approach to adjusting the radar rainfall uses the ratio of gauge to radar accumulations from surrounding gauges with the closest gauge having the most weight. The LB approach distributes the variation of bias over the region, and is computed and applied within each event period.

The LB uses the ratio between the sum of each gauge divided by the sum of the sampled radar values over each gauge. Gauge and radar accumulations were computed for each event period. A minimum storm total threshold (MSTT) check was used to remove radar/gauge (RG) pairs whose R or G cumulative values for a given event period were below a chosen threshold (i.e. 0.05 inches for this study). The remaining RG pairs were then checked for statistical outliers. Those RG pairs with individual bias (G/R) or average difference ($((G-R)/G)$) values greater than two standard deviations from the mean were then excluded from being used to adjust the radar.

After RG pairs have been removed on an event basis by either the MSTT or outlier check, the individual biases of the remaining RG pairs are then distributed spatially over the analysis area using the LB weighted distance method. The resulting LB value over each radar bin is the multiplicative factor that adjusts the radar. For example, a bias of 1.5 can be interpreted as a 33% underestimation by the radar. The statistical measures reported are 1) average difference (AD) and 2) calibrated average difference (CAD). Both of these statistical measures are expressed as an absolute percentage about the mean of G/R accumulations for each event period. The 1-km² pixels are then filtered spatially from the final adjusted radar bins using an area-averaged technique.

After bias correction, though generally small, differences between rain gauge and radar rainfall accumulations still exist due to sampling differences or local meteorological conditions among other reasons. A major reason for departures is that radar collects data by averaging reflectivity over a 1-degree by 1-km sample volume, while rain gauges measure at a point. Another source of difference is that radar measures above the ground, while rain gauges measure close to the ground. Further, updrafts and downdrafts during storms can decrease or increase rain rates, respectively. However, radar cannot detect local wind effects, while rain gauges can be affected. Differences between the radar data and the rain gauge data are also affected by precipitation processes associated with the type of storm, which also are affected by the season of the year.

Metadata

Data accompanying this document provides a continuous rainfall record of all 2313 1-km² pixels for all events. The data is provided in CSV format. The data file documentation follows:

CSV metadata:

- Single CSV file for each 1-km² pixel in 15-minute intervals.
- Comma-delimited text file, first five columns represent the month, day, year, hour and minute, respectively.
- The sixth and last column represents the rainfall depth in inches.
- Data values represent 15-min accumulation (inches) at end of interval.
- Time zone is in Eastern local time (e.g. EST/EDT).
- The 1-km² pixel ID is contained in the filename.

Gauge-Adjusted Radar Rainfall (GARR)

GARR was processed continuously at fifteen-minute increments for each qualified rainfall event. Thirteen rainfall events were identified as having met the storm definition during April 2015. The GARR statistics for each event are listed in Table 2. Eleven of the events were split into multiple sub-event periods to improve gauge-adjustment of the radar, resulting in a total of thirty-five event and sub-event periods. The events that were split into multiple periods are shown in the **Event#** column with the letter "a", "b", "c", etc. appended to the event number (e.g., E1a, E1b, E1c). The **Source** column shows what rainfall source was used to produce GARR for each event or sub-event period. The listed **Event Date** shown in Table 2 corresponds to the day or portion of the day when most of the rainfall occurred for that GARR event period. All thirteen rainfall events are discussed in more detail in the following Events section.

The **Bias** value shown in Table 2 is the sum of the gauges divided by the sum of the sampled radar values over the gauges. Those rain events with the lowest CAD values shown in Table 2 represent the best agreement between GARR and gauge values for all radar/gauge pairs used to adjust the radar. On average, lower values of CAD imply higher statistical confidence in the reliability of the dataset. Typically, stratiform rainfall events (i.e., low spatial variability) have lower CAD values than convective rainfall events (i.e., high spatial variability). Based on all thirty-five event and sub-event periods, the event CAD averaged 3.5%, indicating that the mean GARR agrees with the mean gauge accumulation to within $\pm 1.8\%$.

Table 2. Storm Events and GARR Statistics

Event #	Source	Event Date	Gauges Used (38)	Avg. Depth (in)	Bias	AD (%)	CAD (%)
E1a	KPBZ LII	2015-04-02	31	0.081	1.061	10.3	3.3
E1b	KPBZ LII	2015-04-02	5	0.026	0.845	23.3	0.0
E1c	KPBZ LII	2015-04-02	12	0.074	1.539	30.5	3.5
E1d	KPBZ LII	2015-04-02	24	0.114	1.501	30.1	4.4
E2a	KPBZ LII	2015-04-03	30	0.182	1.649	38.5	4.4
E2b	KPBZ LII	2015-04-03	19	0.048	0.941	22.7	5.8
E3a	KPBZ LII	2015-04-07	11	0.071	1.551	31.2	4.8
E3b	KPBZ LII	2015-04-07	33	0.264	2.289	57.0	2.2
E4a	KPBZ LII	2015-04-08 AM	11	0.071	2.079	50.5	2.6
E4b	KPBZ LII	2015-04-08 AM	10	0.059	1.701	39.8	3.0
E4c	KPBZ LII	2015-04-08 AM	32	0.231	2.137	53.0	4.3
E5	KPBZ LII	2015-04-08 PM	22	0.115	1.175	13.7	2.4
E6	KPBZ LII	2015-04-09 AM	30	0.121	1.159	13.8	1.8
E7a	KPBZ LII	2015-04-09 PM	29	0.349	1.175	15.4	4.1
E7b	KPBZ LII	2015-04-09 PM	31	0.104	1.147	12.9	3.0
E7c	KPBZ LII	2015-04-09 PM	13	0.090	0.960	15.7	6.2
E8a	KPBZ LII	2015-04-10	9	0.029	0.961	29.9	0.6
E8b	KPBZ LII	2015-04-10	31	0.122	1.094	18.2	5.5

Event #	Source	Event Date	Gauges Used (38)	Avg. Depth (in)	Bias	AD (%)	CAD (%)
<u>E8c</u>	KPBZ LII	2015-04-10	32	0.156	1.354	25.2	2.1
<u>E8d</u>	KPBZ LII	2015-04-10	20	0.105	1.162	16.3	2.6
<u>E9a</u>	KPBZ LII	2015-04-13	15	0.046	1.060	11.1	6.2
<u>E9b</u>	KPBZ LII	2015-04-13	27	0.127	1.615	36.5	2.7
<u>E10a</u>	KPBZ LII	2015-04-16	5	0.054	1.035	15.4	2.8
<u>E10b</u>	KPBZ LII	2015-04-16	24	0.134	1.505	35.0	2.5
<u>E10c</u>	KPBZ LII	2015-04-16	7	0.050	1.223	23.5	1.2
<u>E11a</u>	KPBZ LII	2015-04-19	8	0.048	0.785	27.4	0.2
<u>E11b</u>	KPBZ LII	2015-04-19	30	0.139	1.827	44.8	2.5
<u>E11c</u>	KPBZ LII	2015-04-19	28	0.202	2.701	62.6	2.8
<u>E11d</u>	KPBZ LII	2015-04-19	12	0.082	1.798	43.3	2.3
<u>E11e</u>	KPBZ LII	2015-04-19	15	0.080	1.576	35.2	4.1
<u>E12a</u>	KPBZ LII	2015-04-22	34	0.119	1.022	29.7	7.7
<u>E12b</u>	KPBZ LII	2015-04-22	33	0.164	1.285	31.8	5.2
<u>E13a</u>	KPBZ LII	2015-04-30	5	0.030	0.900	27.1	7.2
<u>E13b</u>	KPBZ LII	2015-04-30	31	0.280	1.587	40.9	5.1
<u>E13c</u>	KPBZ LII	2015-04-30	31	0.325	1.693	41.1	3.6

Statistical review of the data can provide an indication of data quality. Depending on the quality of the radar and gauge data, CAD values for individual events less than 10% are considered excellent, 10 - 20% are considered good, and 20 - 30% are considered fair. However, CAD may not serve as a reliable indicator of data quality when abrupt changes in bias occur within the analysis period, particularly when compensating over- and under-estimation results due to using an assumed Z-R relationship throughout the period while atmospheric conditions merit different Z-R coefficients. The effects from abrupt changes in Z-R are mitigated by splitting the event periods.

Rain gauges were analyzed to identify those that were not consistent with the radar or surrounding gauges. Cumulative Distribution Plots (CDPs) at each gauge location showing gauge, unadjusted radar and GARR values were produced for each rainfall event and are presented in Appendices B - N. CDPs are useful for visualizing rain gauge performance. Figure 2 shows the rainfall accumulation at the Clinton Munic Bldg (Loc23) gauge during the 2015-04-08 event as measured by the gauge (green), unadjusted radar (blue), and gauge-adjusted radar (red). Rain gauges that are not performing consistently with the radar or surrounding gauges have characteristics such as clogs, synchronization or other mechanical/transmission malfunctions that can be visually identified in the CDP graph.

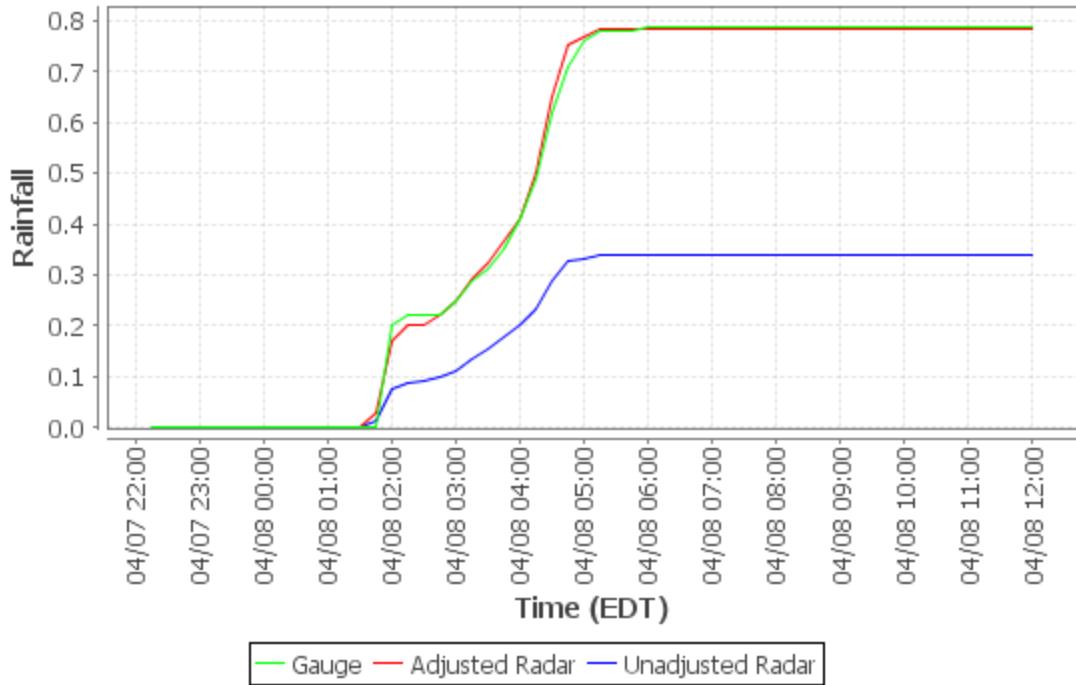


Figure 2. CDP Showing Rain Gauge Versus Unadjusted Radar Versus GARR

Reasons for not using gauges in rainfall analysis include clogs, significant under- or over-reporting of rainfall, gauges that stop reporting during rainfall, or a combination of these reasons. A list of possible reasons for not using a gauge based on CDP analysis is shown in Table 3. Those gauges that were excluded from analysis are shown in [Appendix A](#). Additional gauges were not used to adjust the radar for a given event or sub-event period if they did not meet the statistical criteria outlined in the Methodology section.

Table 3. List of Possible Reasons for Exclusion of Rain Gauges

Reason	Explanation
Clog (C)	Gauge appeared to be clogged
Zero (Z)	Gauge did not report any rainfall while radar rainfall estimates reported significant rainfall
Stop (S)	Gauge appeared to stop reporting rainfall while radar rainfall estimates reported significant rainfall
Over (O)	Gauge appeared to significantly over-report rainfall as compared to radar rainfall estimates and surrounding gauges (e.g. anomalously high rainfall values caused by field calibration, data transmission error, or switch malfunctions)
Under (U)	Gauge appeared to significantly under-report as compared to radar rainfall estimates and surrounding Gauges (e.g. half-tipper)
Sync (SY)	Gauge appeared to be reporting out-of-sync with the radar rainfall estimates
Frozen/Melt (F/M)	Gauge not reporting properly due to frozen or melting precipitation
Other (T)	Combination of multiple reasons

Reason	Explanation
No Data (ND)	Gauge reported "no data" for a significant amount of time

A synopsis for each event is described below in terms of the specific processing protocol applied to each event period as well as specific GARR information.

Events

Event 1: 2015-04-02

The event of April 2nd, 2015 was characterized by multiple waves of light to moderate showers and thunderstorms in association with a weak upper level system moving northeast out of the Central Mississippi Valley towards the Great Lakes Region. The first wave of scattered showers and thunderstorms developed along the eastern and southeastern periphery of the system over the Lower Ohio Valley during the early morning hours of the 2nd. As this activity tracked northeast into the Upper Ohio Valley, additional storms developed further west across portions of Illinois, Indiana and Ohio. The first two waves of rainfall traversed Allegheny County between 4/2/15 12:00 – 15:30 EDT. Another round of light to moderate showers moved east-northeast through the county between 4/2/15 16:30 – 20:00 EDT. The last wave of rainfall, consisting of light to moderate showers and thunderstorms, tracked mostly across northern Allegheny County between 4/2/15 20:30 – 22:30 EDT. Highest rainfall amounts ranging between 0.40 – 0.60 inches were located across the northern and northwestern quarter of Allegheny County with generally decreasing amounts towards the south, where as much as 0.10 inches occurred.

The analysis period was from 2015-04-02 11:00 EDT to 2015-04-03 01:00 EDT. The event was then split into four sub-event periods at 2015-04-02 14:00 EDT, 2015-04-02 16:00 EDT and 2015-04-02 20:30 EDT to improve gauge adjustment of the radar. The gauges listed in [Appendix A](#) were not used to adjust the radar due to inconsistencies between the gauge and the radar or surrounding gauges, or they did not have data available for this event. Gauges Loc12, Loc24, Loc25 and Loc26 did not meet statistical criteria for gauge-adjustment of the radar and were not used to adjust the radar during Event 1a. Gauges Loc01, Loc02, Loc03, Loc04, Loc05, Loc06, Loc07, Loc08, Loc09, Loc10, Loc11, Loc13, Loc15, Loc16, Loc17, Loc18, Loc19, Loc20, Loc21, Loc23, Loc24, Loc25, Loc26, Loc27, Loc29, Loc30, Loc32, Loc33, KAGC, KPIT, 03049500 and 03085734 did not meet statistical criteria for gauge-adjustment of the radar and were not used to adjust the radar during Event 1b. Gauges Loc01, Loc05, Loc06, Loc07, Loc08, Loc09, Loc11, Loc12, Loc13, Loc14, Loc15, Loc16, Loc17, Loc18, Loc20, Loc21, Loc22, Loc24, Loc25, Loc26, Loc29, Loc30, Loc31 and KAGC did not meet statistical criteria for gauge-adjustment of the radar and were not used to adjust the radar during Event 1c. Gauges Loc05, Loc06, Loc07, Loc12, Loc13, Loc15, Loc17, Loc18, Loc24, Loc25, Loc26 and KAGC did not meet statistical criteria for gauge-adjustment of the radar and were not used to adjust the radar during Event 1d.

A convective Z-R relationship was used to convert radar reflectivity to rainfall rates. Table 4 shows the mean bias and average depth of the event along with the AD and CAD, respectively. Tables 5 - 8 summarize the results for each RG pair used for final radar adjustment, where G_i is the gauge estimate, R_i is the non-adjusted radar estimate, R_i^* is the GARR estimate, and Diff* (%) is the percent difference between the gauge and GARR estimate. Figures 3 - 6 show the

scatter plots of the gauge-adjusted RG pairs. Figure 7 depicts the GARR storm total over the 1-km² pixels. The GARR amounts for the 2313 1-km² pixels range from 0.1 - 0.6 inches with a mean of 0.3 inches. Table 9 shows the Depth Duration Frequency (DDF) maximum values for the 1-km² pixels.

Table 4. GARR Statistics for Event 1

Event #	Radar	Event Date	Gauges Used (38)	Avg. Depth (in)	Bias	AD (%)	CAD (%)
E1a	KPBZ LII	2015-04-02	31	0.081	1.061	10.3	3.3
E1b	KPBZ LII	2015-04-02	5	0.026	0.845	23.3	0.0
E1c	KPBZ LII	2015-04-02	12	0.074	1.539	30.5	3.5
E1d	KPBZ LII	2015-04-02	24	0.114	1.501	30.1	4.4

Table 5. Summary of Individual RG Pairs for Event 1a

Gauge ID	Name	G _i (in)	R _i (in)	R _i * (in)	Diff* (in)	Diff* (%)
Loc14	Churchill Munic Bldg	0.05	0.06	0.06	-0.01	-20.0
Loc08	AC Health Dept Bldg	0.08	0.07	0.09	-0.01	-12.5
03085734	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.08	0.08	0.08	0.00	0.0
KAGC	Pittsburgh Allegheny Cty	0.09	0.07	0.09	0.00	0.0
KPIT	Greater Pittsburgh Int'l	0.09	0.09	0.09	0.00	0.0
Loc02	ALCOSAN WWTP Lab	0.08	0.08	0.08	0.00	0.0
Loc03	Shaler Munic Bldg	0.09	0.09	0.09	0.00	0.0
Loc04	Kennedy Twp PS	0.07	0.07	0.07	0.00	0.0
Loc05	Upper St. Clair	0.07	0.07	0.07	0.00	0.0
Loc06	Carnegie Transit Time	0.11	0.10	0.11	0.00	0.0
Loc07	Greentree Munic Bldg	0.09	0.08	0.09	0.00	0.0
Loc13	M-59 Access Shaft	0.07	0.07	0.07	0.00	0.0
Loc15	Trafford Maint Bldg	0.06	0.06	0.06	0.00	0.0
Loc16	Castle Shannon	0.06	0.07	0.06	0.00	0.0
Loc17	Chartiers Pump Station	0.10	0.09	0.10	0.00	0.0
Loc18	Oakdale Pump Station	0.09	0.08	0.09	0.00	0.0
Loc19	Sandy Creek Eq Facility	0.06	0.06	0.06	0.00	0.0
Loc20	Gascola Eq Facility	0.07	0.07	0.07	0.00	0.0
Loc21	Moon TWP	0.12	0.13	0.12	0.00	0.0
Loc23	Clinton Munic Bldg	0.10	0.10	0.10	0.00	0.0
Loc27	Marshall TWP	0.08	0.08	0.08	0.00	0.0
Loc28	Plum Municipal Bldg	0.07	0.06	0.07	0.00	0.0

Gauge ID	Name	G_i (in)	R_i (in)	R_i^* (in)	Diff* (in)	Diff* (%)
Loc29	Bell Acres Munic Bldg	0.10	0.10	0.10	0.00	0.0
Loc30	McCandless Twn Hall	0.10	0.11	0.10	0.00	0.0
Loc31	Hampton Municipal Bldg	0.06	0.07	0.06	0.00	0.0
Loc32	Arnold	0.08	0.08	0.08	0.00	0.0
Loc33	Richland TWP	0.09	0.08	0.09	0.00	0.0
Loc22	North Fayette TWP	0.12	0.09	0.11	0.01	8.3
Loc09	Univ of Pittsburgh	0.09	0.07	0.08	0.01	11.1
Loc10	PWSA-Highland Park	0.08	0.06	0.07	0.01	12.5
Loc11	M-46 Access Shaft	0.08	0.06	0.07	0.01	12.5

Table 6. Summary of Individual RG Pairs for Event 1b

Gauge ID	Name	G_i (in)	R_i (in)	R_i^* (in)	Diff* (in)	Diff* (%)
Loc12	Baldwin	0.06	0.07	0.06	0.00	0.0
Loc14	Churchill Munic Bldg	0.05	0.08	0.05	0.00	0.0
Loc22	North Fayette TWP	0.05	0.05	0.05	0.00	0.0
Loc28	Plum Municipal Bldg	0.10	0.14	0.10	0.00	0.0
Loc31	Hampton Municipal Bldg	0.10	0.09	0.10	0.00	0.0

Table 7. Summary of Individual RG Pairs for Event 1c

Gauge ID	Name	G_i (in)	R_i (in)	R_i^* (in)	Diff* (in)	Diff* (%)
03085734	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.08	0.06	0.09	-0.01	-12.5
KPIT	Greater Pittsburgh Int'l	0.17	0.09	0.17	0.00	0.0
Loc02	ALCOSAN WWTP Lab	0.07	0.06	0.07	0.00	0.0
Loc03	Shaler Munic Bldg	0.09	0.05	0.09	0.00	0.0
Loc10	PWSA-Highland Park	0.06	0.05	0.06	0.00	0.0
Loc19	Sandy Creek Eq Facility	0.06	0.05	0.06	0.00	0.0
Loc23	Clinton Munic Bldg	0.13	0.06	0.13	0.00	0.0
Loc27	Marshall TWP	0.11	0.07	0.11	0.00	0.0
Loc28	Plum Municipal Bldg	0.06	0.06	0.06	0.00	0.0
Loc32	Arnold	0.10	0.07	0.10	0.00	0.0
Loc33	Richland TWP	0.10	0.06	0.10	0.00	0.0
Loc04	Kennedy Twp PS	0.11	0.06	0.10	0.01	9.1

Table 8. Summary of Individual RG Pairs for Event 1d

Gauge ID	Name	G _i (in)	R _i (in)	R _i * (in)	Diff* (in)	Diff* (%)
Loc08	AC Health Dept Bldg	0.07	0.06	0.08	-0.01	-14.3
Loc10	PWSA-Highland Park	0.08	0.06	0.09	-0.01	-12.5
03085734	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.09	0.07	0.10	-0.01	-11.1
Loc31	Hampton Municipal Bldg	0.19	0.15	0.20	-0.01	-5.3
Loc27	Marshall TWP	0.27	0.17	0.28	-0.01	-3.7
03049500	Allegheny River at Natrona	0.20	0.15	0.20	0.00	0.0
KPIT	Greater Pittsburgh Int'l	0.09	0.06	0.09	0.00	0.0
Loc02	ALCOSAN WWTP Lab	0.07	0.06	0.07	0.00	0.0
Loc11	M-46 Access Shaft	0.09	0.06	0.09	0.00	0.0
Loc14	Churchill Munic Bldg	0.08	0.06	0.08	0.00	0.0
Loc16	Castle Shannon	0.06	0.05	0.06	0.00	0.0
Loc20	Gascola Eq Facility	0.08	0.07	0.08	0.00	0.0
Loc21	Moon TWP	0.15	0.11	0.15	0.00	0.0
Loc22	North Fayette TWP	0.08	0.05	0.08	0.00	0.0
Loc23	Clinton Munic Bldg	0.14	0.08	0.14	0.00	0.0
Loc28	Plum Municipal Bldg	0.09	0.07	0.09	0.00	0.0
Loc29	Bell Acres Munic Bldg	0.30	0.16	0.30	0.00	0.0
Loc32	Arnold	0.16	0.11	0.16	0.00	0.0
Loc33	Richland TWP	0.37	0.21	0.37	0.00	0.0
Loc30	McCandless Twn Hall	0.28	0.16	0.27	0.01	3.6
Loc03	Shaler Munic Bldg	0.13	0.09	0.12	0.01	7.7
Loc04	Kennedy Twp PS	0.11	0.06	0.10	0.01	9.1
Loc09	Univ of Pittsburgh	0.10	0.06	0.09	0.01	10.0
Loc19	Sandy Creek Eq Facility	0.09	0.06	0.08	0.01	11.1

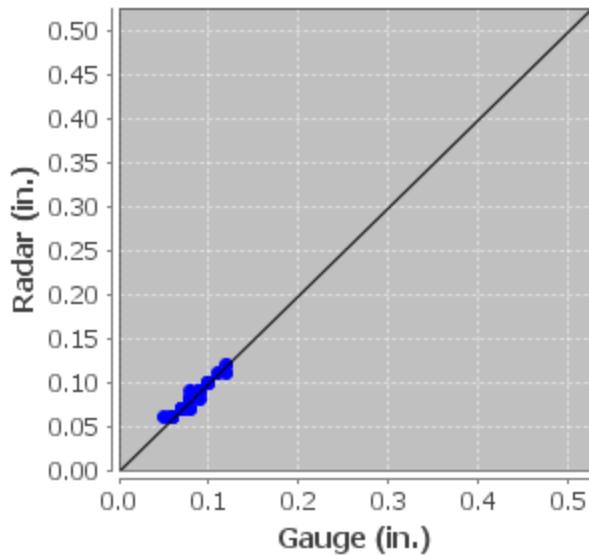


Figure 3. Scatter Plot of Gauge-Adjusted RG Pairs for Event 1a

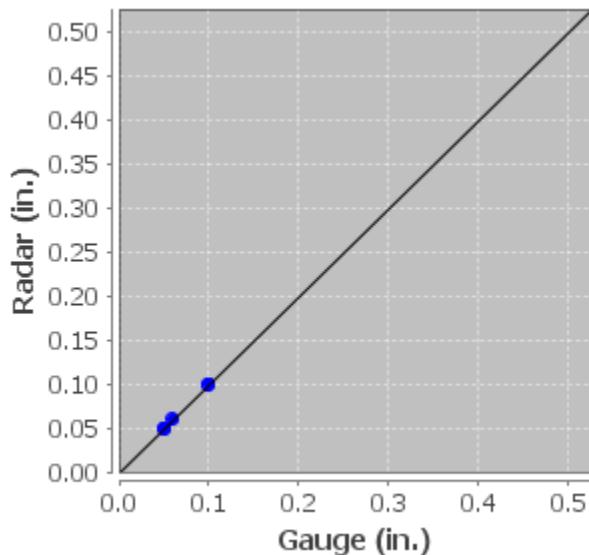


Figure 4. Scatter Plot of Gauge-Adjusted RG Pairs for Event 1b

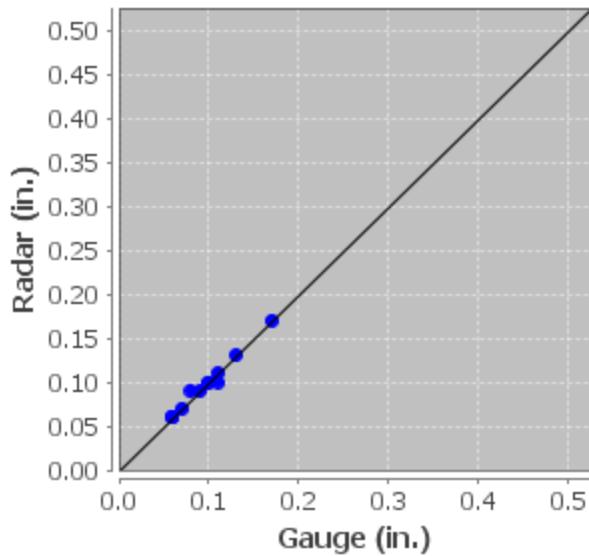


Figure 5. Scatter Plot of Gauge-Adjusted RG Pairs for Event 1c

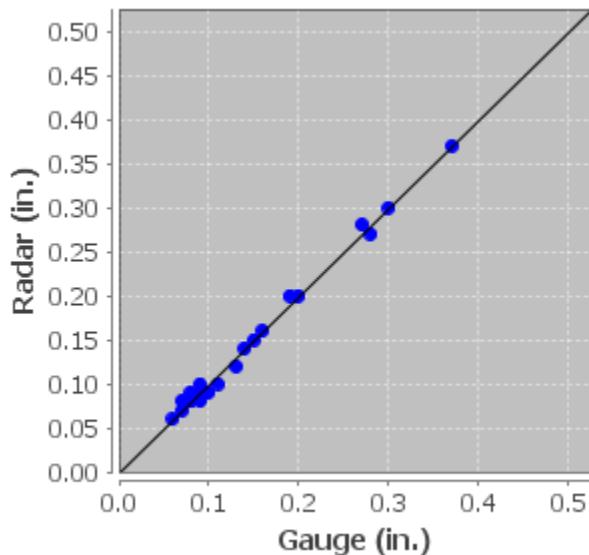


Figure 6. Scatter Plot of Gauge-Adjusted RG Pairs for Event 1d

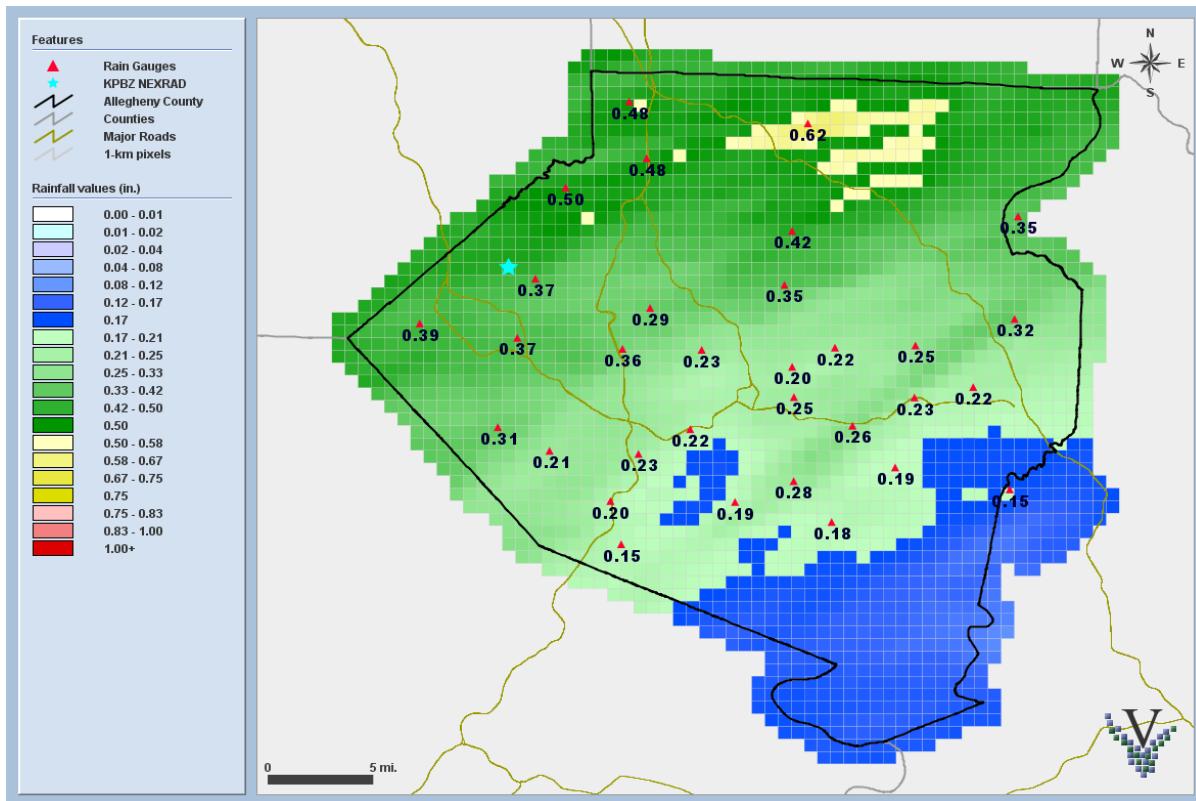


Figure 7. GARR Storm Total for Event 1

Table 9. Depth Duration Frequency Analyses for Event 1

Duration	Depth (in)	Pixel	Time (EDT)	Frequency
15 minutes	0.205	151117	2015-04-02 21:30	<1 yr.
30 minutes	0.307	151117	2015-04-02 21:30	<1 yr.
1 hour	0.400	151117	2015-04-02 22:00	<1 yr.
2 hour	0.403	151117	2015-04-02 22:15	<1 yr.
3 hour	0.411	151117	2015-04-02 22:00	<1 yr.
6 hour	0.497	151117	2015-04-02 22:15	<1 yr.
12 hour	0.628	151117	2015-04-02 23:00	<1 yr.

Event 2: 2015-04-03

The event of April 3 – 4th, 2015 was characterized by two main waves of light to moderate showers in association with a system moving northeast out of the Central Mississippi Valley through the Ohio Valley. A stationary boundary extending northeast of the system provided the lifting mechanism for a band of showers to develop along and behind the frontal boundary over the Lower Ohio Valley during the afternoon hours of the 3rd. This first wave of activity moved through Allegheny County between 4/3/15 19:30 EDT – 4/4/15 1:00 EDT. As the trailing upper level system moved east towards Upstate New York, another round of light showers tracked southeast across the county between 4/4/15 4:00 – 6:00 EDT. Rainfall totals were fairly uniform across Allegheny County with most areas receiving between 0.20 – 0.30 inches.

The analysis period was from 2015-04-03 18:00 EDT to 2015-04-04 08:00 EDT. The event was then split into two sub-event periods at 2015-04-04 03:00 EDT to improve gauge adjustment of the radar. The gauges listed in [Appendix A](#) were not used to adjust the radar due to inconsistencies between the gauge and the radar or surrounding gauges, or they did not have data available for this event. Gauge KPIT did not meet statistical criteria for gauge-adjustment of the radar and was not used to adjust the radar during Event 2a. Gauges Loc02, Loc05, Loc14, Loc15, Loc17, Loc18, Loc19, Loc20, Loc24, Loc26, Loc27, Loc28, Loc32 and Loc33 did not meet statistical criteria for gauge-adjustment of the radar and were not used to adjust the radar during Event 2b.

The Eastern U.S. cool season stratiform Z-R relationship was used to convert radar reflectivity to rainfall rates. Table 10 shows the mean bias and average depth of the event along with the AD and CAD, respectively. Tables 11 - 12 summarize the results for each RG pair used for final radar adjustment, where G_i is the gauge estimate, R_i is the non-adjusted radar estimate, R_i^* is the GARR estimate, and Diff* (%) is the percent difference between the gauge and GARR estimate. Figures 8 - 9 show the scatter plots of the gauge-adjusted RG pairs. Figure 10 depicts the GARR storm total over the 1-km² pixels. The GARR amounts for the 2313 1-km² pixels range from 0.1 - 0.3 inches with a mean of 0.2 inches. Table 13 shows the Depth Duration Frequency (DDF) maximum values for the 1-km² pixels.

Table 10. GARR Statistics for Event 2

Event #	Radar	Event Date	Gauges Used (38)	Avg. Depth (in)	Bias	AD (%)	CAD (%)
E2a	KPBZ LII	2015-04-03	30	0.182	1.649	38.5	4.4
E2b	KPBZ LII	2015-04-03	19	0.048	0.941	22.7	5.8

Table 11. Summary of Individual RG Pairs for Event 2a

Gauge ID	Name	G_i (in)	R_i (in)	R_i^* (in)	Diff* (in)	Diff* (%)
Loc06	Carnegie Transit Time	0.10	0.08	0.12	-0.02	-20.0
Loc02	ALCOSAN WWTP Lab	0.13	0.10	0.15	-0.02	-15.4
Loc19	Sandy Creek Eq Facility	0.13	0.10	0.15	-0.02	-15.4
Loc12	Baldwin	0.16	0.12	0.18	-0.02	-12.5

Gauge ID	Name	G_i (in)	R_i (in)	R_i^* (in)	Diff* (in)	Diff* (%)
Loc31	Hampton Municipal Bldg	0.15	0.11	0.16	-0.01	-6.7
Loc14	Churchill Munic Bldg	0.16	0.11	0.17	-0.01	-6.3
KAGC	Pittsburgh Allegheny Cty	0.19	0.12	0.19	0.00	0.0
Loc09	Univ of Pittsburgh	0.15	0.09	0.15	0.00	0.0
Loc15	Trafford Maint Bldg	0.24	0.13	0.24	0.00	0.0
Loc21	Moon TWP	0.17	0.11	0.17	0.00	0.0
Loc22	North Fayette TWP	0.18	0.10	0.18	0.00	0.0
Loc23	Clinton Munic Bldg	0.17	0.09	0.17	0.00	0.0
Loc24	Jefferson Hills	0.22	0.13	0.22	0.00	0.0
Loc25	White Oak Public Works Bldg	0.25	0.13	0.25	0.00	0.0
Loc26	Elizabeth TWP Municipal Bldg	0.19	0.10	0.19	0.00	0.0
Loc27	Marshall TWP	0.27	0.16	0.27	0.00	0.0
Loc28	Plum Municipal Bldg	0.17	0.10	0.17	0.00	0.0
Loc29	Bell Acres Munic Bldg	0.22	0.15	0.22	0.00	0.0
Loc30	McCandless Twn Hall	0.25	0.15	0.25	0.00	0.0
Loc32	Arnold	0.20	0.12	0.20	0.00	0.0
Loc11	M-46 Access Shaft	0.20	0.11	0.19	0.01	5.0
Loc16	Castle Shannon	0.19	0.12	0.18	0.01	5.3
Loc04	Kennedy Twp PS	0.18	0.10	0.17	0.01	5.6
Loc01	PWSA-Montana St.	0.17	0.11	0.16	0.01	5.9
Loc03	Shaler Munic Bldg	0.17	0.10	0.16	0.01	5.9
Loc10	PWSA-Highland Park	0.17	0.10	0.16	0.01	5.9
Loc17	Chartiers Pump Station	0.17	0.09	0.16	0.01	5.9
Loc07	Greentree Munic Bldg	0.15	0.08	0.14	0.01	6.7
Loc18	Oakdale Pump Station	0.14	0.07	0.13	0.01	7.1
Loc20	Gascola Eq Facility	0.21	0.11	0.19	0.02	9.5

Table 12. Summary of Individual RG Pairs for Event 2b

Gauge ID	Name	G_i (in)	R_i (in)	R_i^* (in)	Diff* (in)	Diff* (%)
Loc01	PWSA-Montana St.	0.05	0.08	0.06	-0.01	-20.0
Loc06	Carnegie Transit Time	0.05	0.08	0.06	-0.01	-20.0
Loc12	Baldwin	0.07	0.07	0.08	-0.01	-14.3
KPIT	Greater Pittsburgh Int'l	0.08	0.10	0.08	0.00	0.0
Loc03	Shaler Munic Bldg	0.09	0.08	0.09	0.00	0.0
Loc04	Kennedy Twp PS	0.10	0.10	0.10	0.00	0.0
Loc09	Univ of Pittsburgh	0.06	0.08	0.06	0.00	0.0

Gauge ID	Name	G_i (in)	R_i (in)	R_i^* (in)	Diff* (in)	Diff* (%)
Loc10	PWSA-Highland Park	0.05	0.06	0.05	0.00	0.0
Loc11	M-46 Access Shaft	0.07	0.06	0.07	0.00	0.0
Loc21	Moon TWP	0.09	0.10	0.09	0.00	0.0
Loc22	North Fayette TWP	0.06	0.07	0.06	0.00	0.0
Loc23	Clinton Munic Bldg	0.09	0.09	0.09	0.00	0.0
Loc25	White Oak Public Works Bldg	0.06	0.05	0.06	0.00	0.0
Loc29	Bell Acres Munic Bldg	0.06	0.09	0.06	0.00	0.0
Loc30	McCandless Twn Hall	0.07	0.10	0.07	0.00	0.0
Loc31	Hampton Municipal Bldg	0.09	0.07	0.09	0.00	0.0
KAGC	Pittsburgh Allegheny Cty	0.10	0.07	0.09	0.01	10.0
Loc07	Greentree Munic Bldg	0.09	0.09	0.08	0.01	11.1
Loc16	Castle Shannon	0.09	0.06	0.08	0.01	11.1

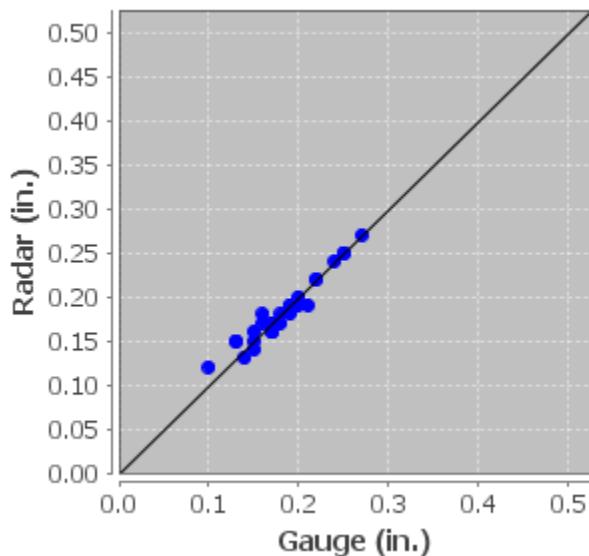


Figure 8. Scatter Plot of Gauge-Adjusted RG Pairs for Event 2a

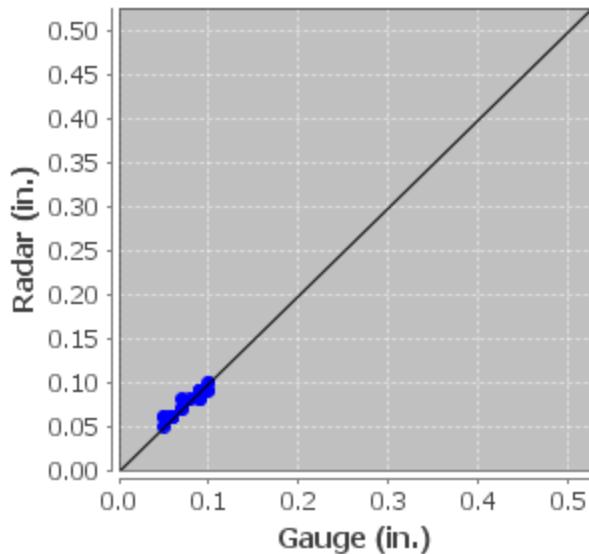


Figure 9. Scatter Plot of Gauge-Adjusted RG Pairs for Event 2b

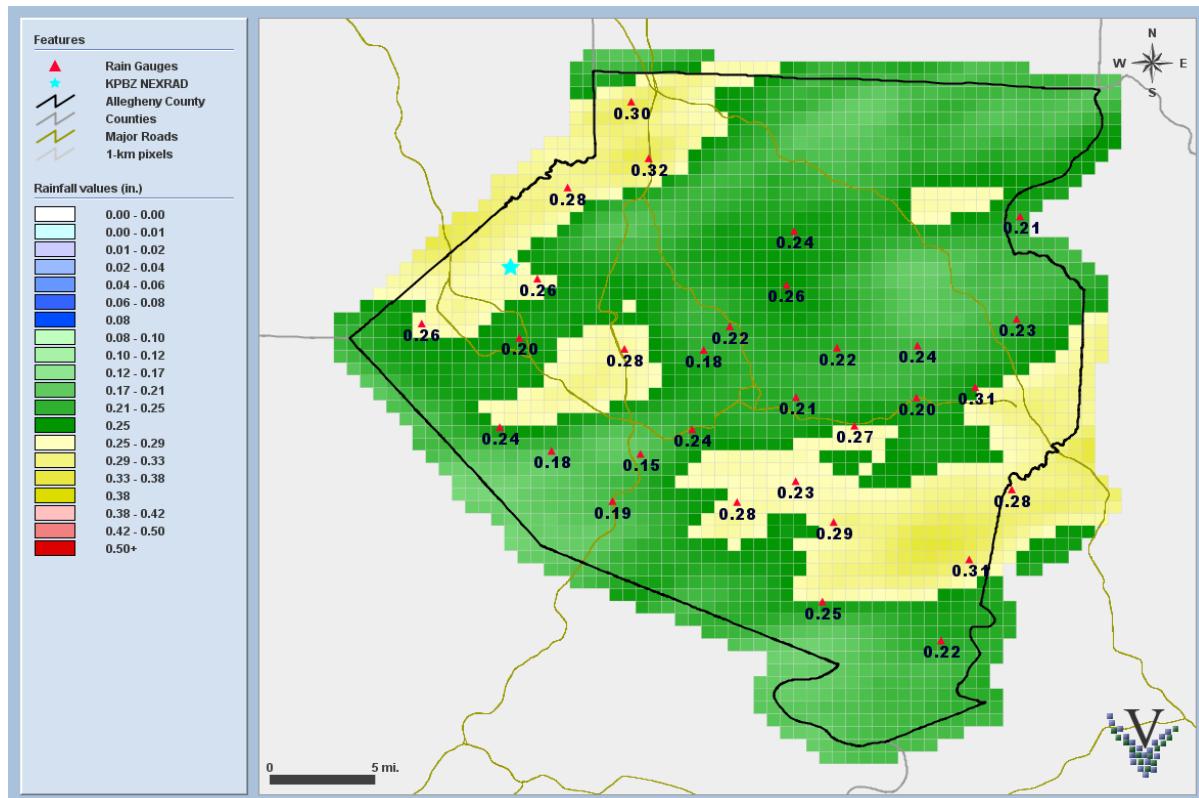


Figure 10. GARR Storm Total for Event 2

Table 13. Depth Duration Frequency Analyses for Event 2

Duration	Depth (in)	Pixel	Time (EDT)	Frequency
15 minutes	0.071	172138	2015-04-03 23:15	<1 yr.
30 minutes	0.109	161162	2015-04-03 22:30	<1 yr.
1 hour	0.180	164161	2015-04-03 23:00	<1 yr.
2 hour	0.235	174146	2015-04-04 00:00	<1 yr.
3 hour	0.262	161150	2015-04-04 00:30	<1 yr.
6 hour	0.279	138115	2015-04-04 00:45	<1 yr.
12 hour	0.343	160150	2015-04-04 06:00	<1 yr.

Event 3: 2015-04-07

The event of April 6 – 7th, 2015 was characterized by multiple waves of light to moderate showers in association with an east-west oriented stationary boundary extending from the Upper Midwest through the Lower Great Lakes Region. As the front sagged slowly towards the south, scattered light showers consistently developed on both sides of the boundary over the Ohio Valley during the afternoon and evening hours of the 6th. This activity moved east into Allegheny County by 4/6/15 16:00 EDT. Light scattered showers persisted across the county for the next several hours before starting to increase in intensity by 4/6/15 22:00 EDT. Further west, an area of scattered storms developed over portions of Indiana and Ohio during the early morning hours of the 7th. This activity weakened slightly as it moved into western Allegheny County by 4/7/15 10:00 EDT. Light to moderate showers tracked east through the entire county with the heaviest rainfall occurring across far southern portions of the county. Rainfall ended across the county by 4/7/15 12:00 EDT. Almost half of Allegheny County received at least 0.30 inches with higher amounts in excess of 0.75 inches located across southern portions of the county.

The analysis period was from 2015-04-06 14:00 EDT to 2015-04-07 14:00 EDT. The event was then split into two sub-event periods at 2015-04-07 09:30 EDT to improve gauge adjustment of the radar. The gauges listed in [Appendix A](#) were not used to adjust the radar due to inconsistencies between the gauge and the radar or surrounding gauges, or they did not have data available for this event. Gauges Loc01, Loc02, Loc03, Loc04, Loc06, Loc07, Loc08, Loc09, Loc10, Loc12, Loc13, Loc15, Loc19, Loc21, Loc22, Loc23, Loc27, Loc28, Loc29, Loc30, Loc31, Loc32, Loc33, KPIT and 03085734 did not meet statistical criteria for gauge-adjustment of the radar and were not used to adjust the radar during Event 3a. Gauges Loc01, Loc12 and Loc26 did not meet statistical criteria for gauge-adjustment of the radar and were not used to adjust the radar during Event 3b.

A convective Z-R relationship was used to convert radar reflectivity to rainfall rates. Table 14 shows the mean bias and average depth of the event along with the AD and CAD, respectively. Tables 15 - 16 summarize the results for each RG pair used for final radar adjustment, where G_i is the gauge estimate, R_i is the non-adjusted radar estimate, R_i^* is the GARR estimate, and Diff* (%) is the percent difference between the gauge and GARR estimate. Figures 11 - 12 show the scatter plots of the gauge-adjusted RG pairs. Figure 13 depicts the GARR storm total over the 1-km² pixels. The GARR amounts for the 2313 1-km² pixels range from 0.2 - 0.8 inches with a

mean of 0.3 inches. Table 17 shows the Depth Duration Frequency (DDF) maximum values for the 1-km² pixels.

Table 14. GARR Statistics for Event 3

Event #	Radar	Event Date	Gauges Used (38)	Avg. Depth (in)	Bias	AD (%)	CAD (%)
E3a	KPBZ LII	2015-04-07	11	0.071	1.551	31.2	4.8
E3b	KPBZ LII	2015-04-07	33	0.264	2.289	57.0	2.2

Table 15. Summary of Individual RG Pairs for Event 3a

Gauge ID	Name	G _i (in)	R _i (in)	R _i * (in)	Diff* (in)	Diff* (%)
Loc24	Jefferson Hills	0.07	0.07	0.08	-0.01	-14.3
Loc05	Upper St. Clair	0.22	0.12	0.23	-0.01	-4.5
Loc11	M-46 Access Shaft	0.06	0.05	0.06	0.00	0.0
Loc14	Churchill Munic Bldg	0.08	0.06	0.08	0.00	0.0
Loc16	Castle Shannon	0.11	0.06	0.11	0.00	0.0
Loc18	Oakdale Pump Station	0.10	0.05	0.10	0.00	0.0
Loc20	Gascola Eq Facility	0.09	0.06	0.09	0.00	0.0
Loc25	White Oak Public Works Bldg	0.11	0.08	0.11	0.00	0.0
Loc26	Elizabeth TWP Municipal Bldg	0.06	0.06	0.06	0.00	0.0
KAGC	Pittsburgh Allegheny Cty	0.13	0.08	0.12	0.01	7.7
Loc17	Chartiers Pump Station	0.15	0.06	0.13	0.02	13.3

Table 16. Summary of Individual RG Pairs for Event 3b

Gauge ID	Name	G _i (in)	R _i (in)	R _i * (in)	Diff* (in)	Diff* (%)
Loc13	M-59 Access Shaft	0.24	0.14	0.27	-0.03	-12.5
03085734	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.13	0.06	0.14	-0.01	-7.7
Loc10	PWSA-Highland Park	0.17	0.07	0.18	-0.01	-5.9
Loc06	Carnegie Transit Time	0.25	0.11	0.26	-0.01	-4.0
KAGC	Pittsburgh Allegheny Cty	0.32	0.18	0.33	-0.01	-3.1
Loc03	Shaler Munic Bldg	0.17	0.07	0.17	0.00	0.0
Loc04	Kennedy Twp PS	0.17	0.07	0.17	0.00	0.0
Loc05	Upper St. Clair	0.44	0.19	0.44	0.00	0.0
Loc08	AC Health Dept Bldg	0.18	0.07	0.18	0.00	0.0
Loc09	Univ of Pittsburgh	0.21	0.08	0.21	0.00	0.0

Gauge ID	Name	G _i (in)	R _i (in)	R _i * (in)	Diff* (in)	Diff* (%)
<u>Loc14</u>	Churchill Munic Bldg	0.20	0.08	0.20	0.00	0.0
<u>Loc15</u>	Trafford Maint Bldg	0.30	0.16	0.30	0.00	0.0
<u>Loc16</u>	Castle Shannon	0.30	0.14	0.30	0.00	0.0
<u>Loc17</u>	Chartiers Pump Station	0.27	0.12	0.27	0.00	0.0
<u>Loc18</u>	Oakdale Pump Station	0.24	0.11	0.24	0.00	0.0
<u>Loc19</u>	Sandy Creek Eq Facility	0.15	0.07	0.15	0.00	0.0
<u>Loc20</u>	Gascola Eq Facility	0.20	0.09	0.20	0.00	0.0
<u>Loc21</u>	Moon TWP	0.14	0.06	0.14	0.00	0.0
<u>Loc22</u>	North Fayette TWP	0.22	0.09	0.22	0.00	0.0
<u>Loc23</u>	Clinton Munic Bldg	0.20	0.07	0.20	0.00	0.0
<u>Loc25</u>	White Oak Public Works Bldg	0.40	0.19	0.40	0.00	0.0
<u>Loc27</u>	Marshall TWP	0.26	0.10	0.26	0.00	0.0
<u>Loc28</u>	Plum Municipal Bldg	0.15	0.06	0.15	0.00	0.0
<u>Loc29</u>	Bell Acres Munic Bldg	0.26	0.10	0.26	0.00	0.0
<u>Loc30</u>	McCandless Twn Hall	0.31	0.12	0.31	0.00	0.0
<u>Loc31</u>	Hampton Municipal Bldg	0.14	0.06	0.14	0.00	0.0
<u>Loc32</u>	Arnold	0.22	0.08	0.22	0.00	0.0
<u>Loc33</u>	Richland TWP	0.30	0.12	0.30	0.00	0.0
<u>Loc24</u>	Jefferson Hills	0.71	0.34	0.70	0.01	1.4
<u>Loc02</u>	ALCOSAN WWTP Lab	0.17	0.06	0.16	0.01	5.9
<u>KPIT</u>	Greater Pittsburgh Int'l	0.14	0.06	0.13	0.01	7.1
<u>Loc07</u>	Greentree Munic Bldg	0.26	0.10	0.24	0.02	7.7
<u>Loc11</u>	M-46 Access Shaft	0.28	0.10	0.25	0.03	10.7

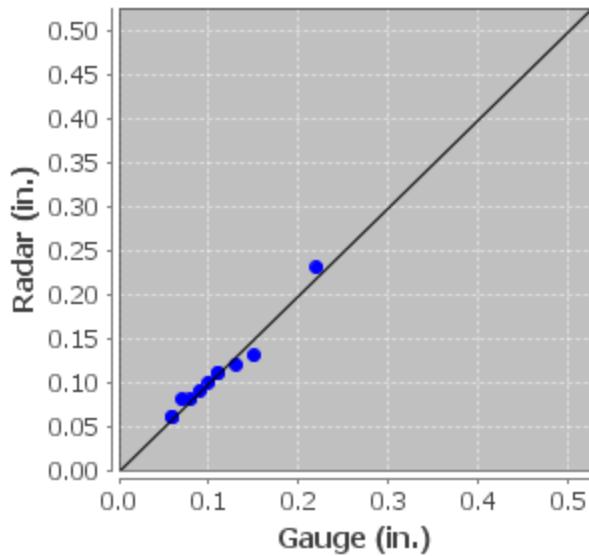


Figure 11. Scatter Plot of Gauge-Adjusted RG Pairs for Event 3a

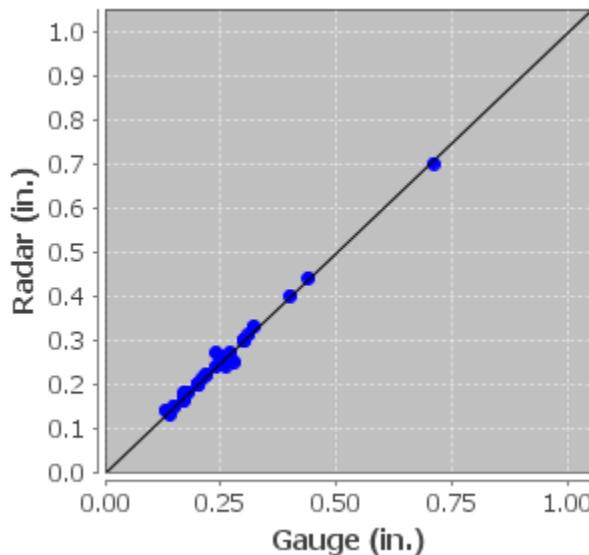


Figure 12. Scatter Plot of Gauge-Adjusted RG Pairs for Event 3b

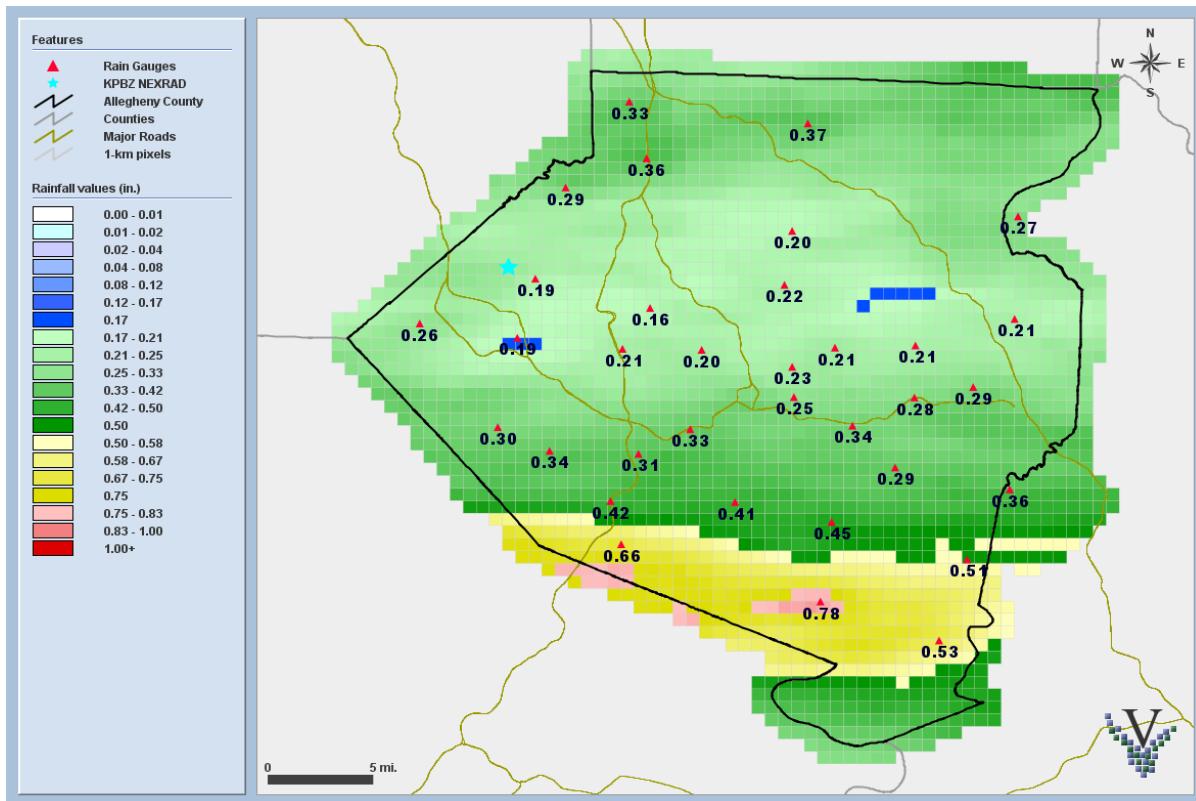


Figure 13. GARR Storm Total for Event 3

Table 17. Depth Duration Frequency Analyses for Event 3

Duration	Depth (in)	Pixel	Time (EDT)	Frequency
15 minutes	0.258	147155	2015-04-07 10:45	<1 yr.
30 minutes	0.431	151155	2015-04-07 11:00	<1 yr.
1 hour	0.630	151155	2015-04-07 11:30	<1 yr.
2 hour	0.729	151155	2015-04-07 11:45	<1 yr.
3 hour	0.729	151155	2015-04-07 11:45	<1 yr.
6 hour	0.729	151155	2015-04-07 11:45	<1 yr.
12 hour	0.747	151155	2015-04-07 11:45	<1 yr.
24 hour	0.798	151155	2015-04-07 14:00	<1 yr.

Event 4: 2015-04-08 AM

The first event of April 8th, 2015 was characterized by light to moderate showers and thunderstorms in association with a stalled frontal boundary bisecting the Ohio Valley from west to east. As moisture lifted over the front, scattered showers and thunderstorms developed across Ohio and West Virginia during the evening hours of the 7th. These storms moved slowly northeast into far western Allegheny County by 4/8/15 1:30 EDT, while also developing across the eastern half of the county as well. Mostly widespread rainfall with isolated heavier pockets of rain occurred over Allegheny County for the next few hours before tracking east of the county by 4/8/15 7:30 EDT. Over half of Allegheny County received at least 0.35 inches with higher amounts approaching an inch located across far west-central portions of the county.

The analysis period was from 2015-04-07 22:00 EDT to 2015-04-08 12:00 EDT. The event was then split into three sub-event periods at 2015-04-08 03:00 EDT and 2015-04-08 04:00 EDT to improve gauge adjustment of the radar. The gauges listed in [Appendix A](#) were not used to adjust the radar due to inconsistencies between the gauge and the radar or surrounding gauges, or they did not have data available for this event. Gauges Loc01, Loc02, Loc03, Loc05, Loc08, Loc09, Loc10, Loc11, Loc12, Loc13, Loc14, Loc15, Loc16, Loc17, Loc19, Loc20, Loc24, Loc25, Loc26, Loc28, Loc30, Loc31, Loc32, Loc33, KAGC and 03085734 did not meet statistical criteria for gauge-adjustment of the radar and were not used to adjust the radar during Event 4a. Gauges Loc01, Loc02, Loc03, Loc04, Loc08, Loc09, Loc10, Loc11, Loc12, Loc13, Loc14, Loc15, Loc16, Loc19, Loc20, Loc24, Loc25, Loc26, Loc27, Loc28, Loc29, Loc31, Loc32, KAGC, 03049500 and 03085734 did not meet statistical criteria for gauge-adjustment of the radar and were not used to adjust the radar during Event 4b. Gauges Loc11, Loc14, Loc17, Loc24 and Loc29 did not meet statistical criteria for gauge-adjustment of the radar and were not used to adjust the radar during Event 4c.

A convective Z-R relationship was used to convert radar reflectivity to rainfall rates. Table 18 shows the mean bias and average depth of the event along with the AD and CAD, respectively. Tables 19 - 21 summarize the results for each RG pair used for final radar adjustment, where G_i is the gauge estimate, R_i is the non-adjusted radar estimate, R_i^* is the GARR estimate, and Diff* (%) is the percent difference between the gauge and GARR estimate. Figures 14 - 16 show the scatter plots of the gauge-adjusted RG pairs. Figure 17 depicts the GARR storm total over the 1-km² pixels. The GARR amounts for the 2313 1-km² pixels range from 0.1 - 1.1 inches with a mean of 0.4 inches. Table 22 shows the Depth Duration Frequency (DDF) maximum values for the 1-km² pixels.

Table 18. GARR Statistics for Event 4

Event #	Radar	Event Date	Gauges Used (38)	Avg. Depth (in)	Bias	AD (%)	CAD (%)
E4a	KPBZ LII	2015-04-08 AM	11	0.071	2.079	50.5	2.6
E4b	KPBZ LII	2015-04-08 AM	10	0.059	1.701	39.8	3.0
E4c	KPBZ LII	2015-04-08 AM	32	0.231	2.137	53.0	4.3

Table 19. Summary of Individual RG Pairs for Event 4a

Gauge ID	Name	G_i (in)	R_i (in)	R_i^* (in)	Diff* (in)	Diff* (%)
Loc18	Oakdale Pump Station	0.08	0.05	0.09	-0.01	-12.5
03049500	Allegheny River at Natrona	0.11	0.05	0.11	0.00	0.0
KPIT	Greater Pittsburgh Int'l	0.18	0.08	0.18	0.00	0.0
Loc04	Kennedy Twp PS	0.12	0.06	0.12	0.00	0.0
Loc06	Carnegie Transit Time	0.15	0.07	0.15	0.00	0.0
Loc21	Moon TWP	0.22	0.09	0.22	0.00	0.0
Loc23	Clinton Munic Bldg	0.25	0.11	0.25	0.00	0.0
Loc27	Marshall TWP	0.11	0.07	0.11	0.00	0.0
Loc29	Bell Acres Munic Bldg	0.16	0.10	0.16	0.00	0.0
Loc22	North Fayette TWP	0.14	0.07	0.13	0.01	7.1
Loc07	Greentree Munic Bldg	0.13	0.05	0.12	0.01	7.7

Table 20. Summary of Individual RG Pairs for Event 4b

Gauge ID	Name	G_i (in)	R_i (in)	R_i^* (in)	Diff* (in)	Diff* (%)
Loc17	Chartiers Pump Station	0.09	0.06	0.10	-0.01	-11.1
KPIT	Greater Pittsburgh Int'l	0.07	0.05	0.07	0.00	0.0
Loc07	Greentree Munic Bldg	0.08	0.05	0.08	0.00	0.0
Loc21	Moon TWP	0.09	0.06	0.09	0.00	0.0
Loc22	North Fayette TWP	0.11	0.07	0.11	0.00	0.0
Loc23	Clinton Munic Bldg	0.16	0.09	0.16	0.00	0.0
Loc30	McCandless Twn Hall	0.11	0.05	0.11	0.00	0.0
Loc33	Richland TWP	0.13	0.07	0.13	0.00	0.0
Loc18	Oakdale Pump Station	0.11	0.06	0.10	0.01	9.1
Loc05	Upper St. Clair	0.10	0.05	0.09	0.01	10.0

Table 21. Summary of Individual RG Pairs for Event 4c

Gauge ID	Name	G_i (in)	R_i (in)	R_i^* (in)	Diff* (in)	Diff* (%)
Loc08	AC Health Dept Bldg	0.32	0.19	0.37	-0.05	-15.6
KAGC	Pittsburgh Allegheny Cty	0.21	0.12	0.23	-0.02	-9.5
Loc03	Shaler Munic Bldg	0.21	0.11	0.23	-0.02	-9.5
Loc18	Oakdale Pump Station	0.13	0.06	0.14	-0.01	-7.7
Loc07	Greentree Munic Bldg	0.14	0.08	0.15	-0.01	-7.1
Loc21	Moon TWP	0.31	0.18	0.33	-0.02	-6.5

Gauge ID	Name	G _i (in)	R _i (in)	R _i * (in)	Diff* (in)	Diff* (%)
Loc02	ALCOSAN WWTP Lab	0.35	0.17	0.37	-0.02	-5.7
Loc25	White Oak Public Works Bldg	0.19	0.12	0.20	-0.01	-5.3
Loc19	Sandy Creek Eq Facility	0.29	0.16	0.30	-0.01	-3.4
03085734	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.33	0.15	0.34	-0.01	-3.0
Loc05	Upper St. Clair	0.18	0.08	0.18	0.00	0.0
Loc15	Trafford Maint Bldg	0.48	0.25	0.48	0.00	0.0
Loc16	Castle Shannon	0.23	0.10	0.23	0.00	0.0
Loc20	Gascola Eq Facility	0.35	0.19	0.35	0.00	0.0
Loc23	Clinton Munic Bldg	0.38	0.14	0.38	0.00	0.0
Loc26	Elizabeth TWP Municipal Bldg	0.12	0.06	0.12	0.00	0.0
Loc27	Marshall TWP	0.35	0.13	0.35	0.00	0.0
Loc28	Plum Municipal Bldg	0.25	0.13	0.25	0.00	0.0
Loc30	McCandless Twn Hall	0.25	0.09	0.25	0.00	0.0
Loc32	Arnold	0.25	0.12	0.25	0.00	0.0
Loc33	Richland TWP	0.28	0.10	0.28	0.00	0.0
Loc09	Univ of Pittsburgh	0.39	0.20	0.38	0.01	2.6
Loc13	M-59 Access Shaft	0.38	0.16	0.37	0.01	2.6
Loc31	Hampton Municipal Bldg	0.27	0.13	0.26	0.01	3.7
Loc12	Baldwin	0.25	0.11	0.24	0.01	4.0
Loc04	Kennedy Twp PS	0.47	0.20	0.45	0.02	4.3
03049500	Allegheny River at Natrona	0.22	0.09	0.21	0.01	4.5
KPIT	Greater Pittsburgh Int'l	0.33	0.14	0.31	0.02	6.1
Loc22	North Fayette TWP	0.16	0.06	0.15	0.01	6.3
Loc06	Carnegie Transit Time	0.13	0.06	0.12	0.01	7.7
Loc10	PWSA-Highland Park	0.47	0.22	0.43	0.04	8.5
Loc01	PWSA-Montana St.	0.31	0.12	0.27	0.04	12.9

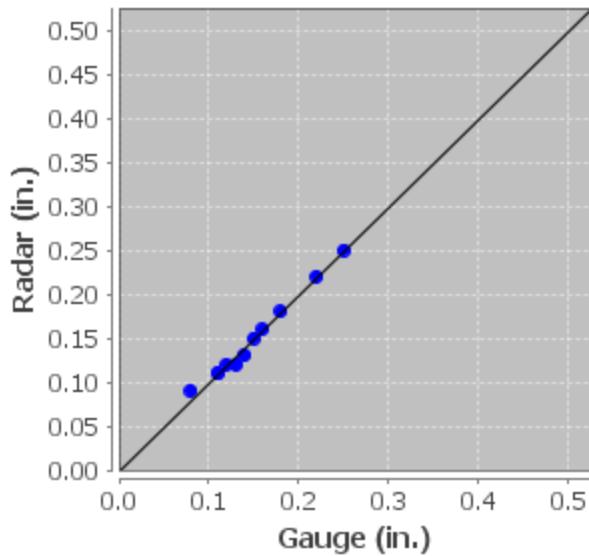


Figure 14. Scatter Plot of Gauge-Adjusted RG Pairs for Event 4a

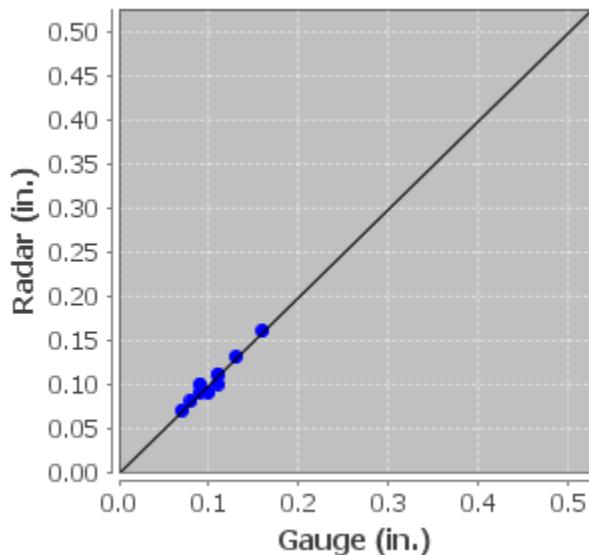


Figure 15. Scatter Plot of Gauge-Adjusted RG Pairs for Event 4b

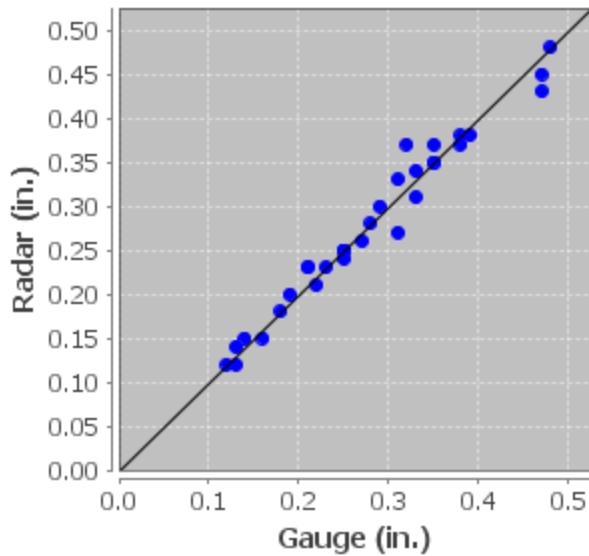


Figure 16. Scatter Plot of Gauge-Adjusted RG Pairs for Event 4c

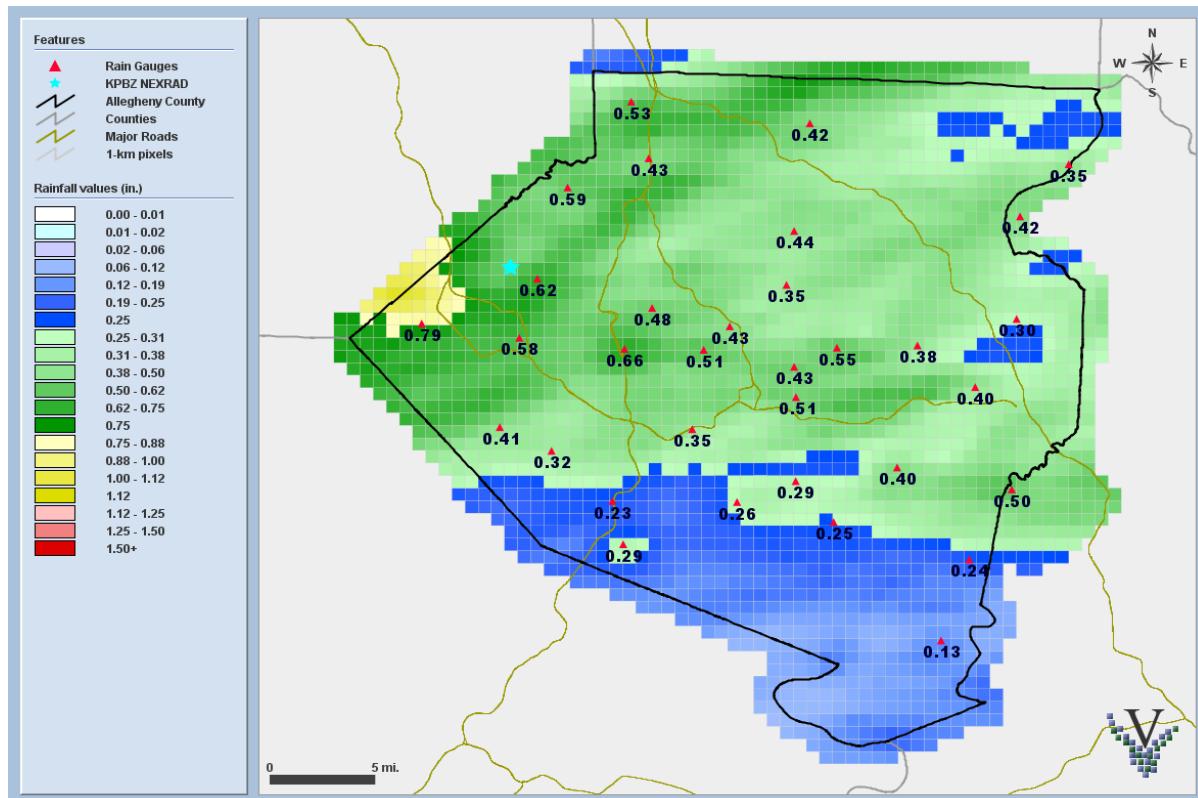


Figure 17. GARR Storm Total for Event 4

Table 22. Depth Duration Frequency Analyses for Event 4

Duration	Depth (in)	Pixel	Time (EDT)	Frequency
15 minutes	0.310	151113	2015-04-08 06:00	<1 yr.
30 minutes	0.471	120130	2015-04-08 04:30	<1 yr.
1 hour	0.631	119130	2015-04-08 04:45	<1 yr.
2 hour	0.804	119130	2015-04-08 04:45	<1 yr.
3 hour	1.002	120130	2015-04-08 04:45	<1 yr.
6 hour	1.058	119130	2015-04-08 05:15	<1 yr.
12 hour	1.058	119130	2015-04-08 10:00	<1 yr.

Event 5: 2015-04-08 PM

The second event of April 8th, 2015 was characterized by a brief period of light to moderate showers and thunderstorms in association with a weakening thunderstorm complex tracking east-southeast across the Ohio Valley. Scattered thunderstorms developed over northern Illinois coalesced into a thunderstorm complex during the early morning hours of the 8th. This activity moved quickly across Indiana and Ohio throughout the remainder of the morning hours. While the strongest storms were located along the southern extent of the thunderstorm complex entering West Virginia, the northern extent began to weaken as it tracked into eastern Ohio. The leading edge of rainfall moved into western Allegheny County by 4/8/15 15:30 EDT. Mostly widespread rainfall with embedded thunderstorms tracked northeast through Allegheny County as the weakening thunderstorm complex moved south-southeast of the county by 4/8/15 18:00 EDT. Highest rainfall amounts ranging between 0.40 – 0.50 inches were confined to a few small locations across central, far north-central and far northwestern Allegheny County, while much of southwestern, southern and far northeastern portions of the county received less than 0.10 inches.

The analysis period was from 2015-04-08 12:00 EDT to 2015-04-08 19:00 EDT. The gauges listed in [Appendix A](#) were not used to adjust the radar due to inconsistencies between the gauge and the radar or surrounding gauges, or they did not have data available for this event. Gauges Loc05, Loc06, Loc07, Loc09, Loc11, Loc12, Loc14, Loc15, Loc16, Loc17, Loc20, Loc24, Loc25 and Loc26 did not meet statistical criteria for gauge-adjustment of the radar and were not used to adjust the radar during Event 5.

A convective Z-R relationship was used to convert radar reflectivity to rainfall rates. Table 23 shows the mean bias and average depth of the event along with the AD and CAD, respectively. Table 24 summarizes the results for each RG pair used for final radar adjustment, where G_i is the gauge estimate, R_i is the non-adjusted radar estimate, R_i^* is the GARR estimate, Diff* (in) is the difference in inches between the gauge and GARR estimate, and Diff* (%) is the percent difference between the gauge and GARR estimate. Figure 18 shows the scatter plot of the gauge-adjusted RG pairs. Figure 19 depicts the GARR storm total over the 1-km² pixels. The GARR amounts for the 2313 1-km² pixels range from 0.0 - 0.5 inches with a mean of 0.1 inches. Table 25 shows the Depth Duration Frequency (DDF) maximum values for the 1-km² pixels.

Table 23. GARR Statistics for Event 5

Event #	Radar	Event Date	Gauges Used (38)	Avg. Depth (in)	Bias	AD (%)	CAD (%)
E5	KPBZ LII	2015-04-08 PM	22	0.115	1.175	13.7	2.4

Table 24. Summary of Individual RG Pairs for Event 5

Gauge ID	Name	G_i (in)	R_i (in)	R_i* (in)	Diff* (in)	Diff* (%)
<u>Loc01</u>	PWSA-Montana St.	0.12	0.11	0.13	-0.01	-8.3
<u>Loc31</u>	Hampton Municipal Bldg	0.20	0.17	0.21	-0.01	-5.0
<u>03049500</u>	Allegheny River at Natrona	0.10	0.08	0.10	0.00	0.0
<u>KAGC</u>	Pittsburgh Allegheny Cty	0.19	0.15	0.19	0.00	0.0
<u>KPIT</u>	Greater Pittsburgh Int'l	0.10	0.09	0.10	0.00	0.0
<u>Loc02</u>	ALCOSAN WWTP Lab	0.09	0.09	0.09	0.00	0.0
<u>Loc04</u>	Kennedy Twp PS	0.09	0.09	0.09	0.00	0.0
<u>Loc08</u>	AC Health Dept Bldg	0.45	0.36	0.45	0.00	0.0
<u>Loc10</u>	PWSA-Highland Park	0.28	0.22	0.28	0.00	0.0
<u>Loc13</u>	M-59 Access Shaft	0.10	0.09	0.10	0.00	0.0
<u>Loc18</u>	Oakdale Pump Station	0.06	0.05	0.06	0.00	0.0
<u>Loc19</u>	Sandy Creek Eq Facility	0.12	0.09	0.12	0.00	0.0
<u>Loc21</u>	Moon TWP	0.09	0.09	0.09	0.00	0.0
<u>Loc22</u>	North Fayette TWP	0.06	0.06	0.06	0.00	0.0
<u>Loc23</u>	Clinton Munic Bldg	0.09	0.09	0.09	0.00	0.0
<u>Loc27</u>	Marshall TWP	0.35	0.30	0.35	0.00	0.0
<u>Loc28</u>	Plum Municipal Bldg	0.21	0.16	0.21	0.00	0.0
<u>Loc29</u>	Bell Acres Munic Bldg	0.19	0.19	0.19	0.00	0.0
<u>Loc32</u>	Arnold	0.20	0.15	0.20	0.00	0.0
<u>Loc33</u>	Richland TWP	0.23	0.21	0.23	0.00	0.0
<u>Loc03</u>	Shaler Munic Bldg	0.23	0.17	0.22	0.01	4.3
<u>Loc30</u>	McCandless Twn Hall	0.19	0.15	0.18	0.01	5.3

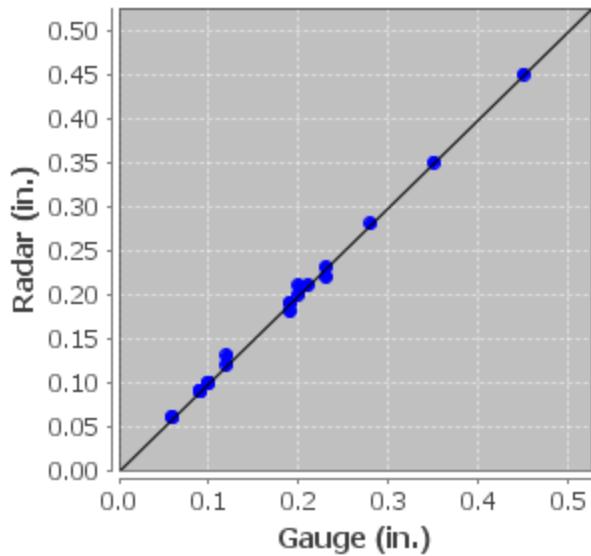


Figure 18. Scatter Plot of Gauge-Adjusted RG Pairs for Event 5

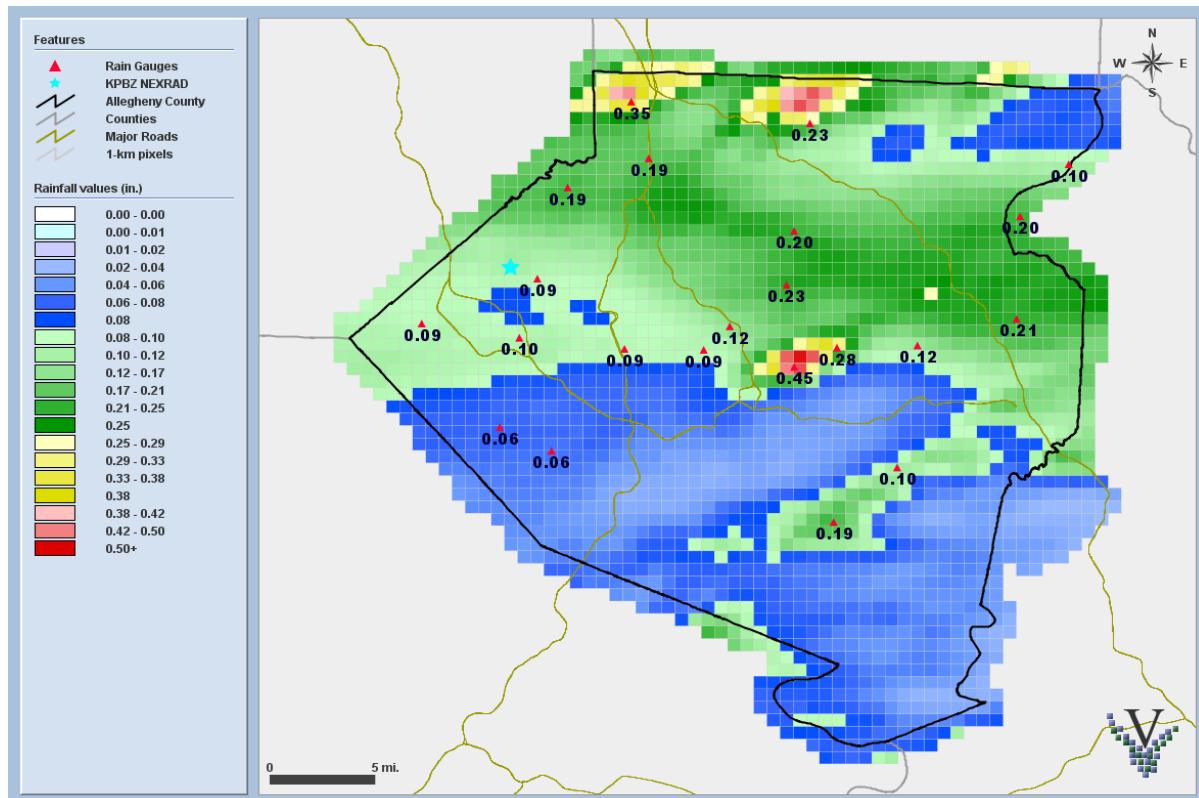


Figure 19. GARR Storm Total for Event 5

Table 25. Depth Duration Frequency Analyses for Event 5

Duration	Depth (in)	Pixel	Time (EDT)	Frequency
15 minutes	0.357	150115	2015-04-08 16:45	<1 yr.
30 minutes	0.422	150135	2015-04-08 17:15	<1 yr.
1 hour	0.464	150135	2015-04-08 17:15	<1 yr.
2 hour	0.493	150135	2015-04-08 17:30	<1 yr.
3 hour	0.493	150135	2015-04-08 17:30	<1 yr.
6 hour	0.493	150135	2015-04-08 18:00	<1 yr.

Event 6: 2015-04-09 AM

The first event of April 9th, 2015 was characterized by a brief period of light showers in association with a stalled frontal boundary stretching from northern Indiana and Ohio, then south into West Virginia. As moisture lifted north and northeast of the front, numerous showers and thunderstorms developed along and ahead of the front over Ohio and West Virginia during the early morning hours of the 9th. This activity weakened quickly as it moved east and northeast of the frontal boundary over cooler air. The leading edge of weakening widespread showers tracked into western Allegheny County by 4/9/15 7:30 EDT and moved east of the county by 4/9/15 9:30 EDT. Another wave of scattered light showers traversed Allegheny County between 4/9/15 10:30 – 13:30 EDT. Highest rainfall amounts approaching 0.30 inches were located across far southern Allegheny County with generally decreasing amounts towards the north and east.

The analysis period was from 2015-04-09 06:00 EDT to 2015-04-09 14:00 EDT. The gauges listed in [Appendix A](#) were not used to adjust the radar due to inconsistencies between the gauge and the radar or surrounding gauges, or they did not have data available for this event. Gauges Loc11, Loc14, Loc17, Loc19 and Loc28 did not meet statistical criteria for gauge-adjustment of the radar and were not used to adjust the radar during Event 6.

A convective Z-R relationship was used to convert radar reflectivity to rainfall rates. Table 26 shows the mean bias and average depth of the event along with the AD and CAD, respectively. Table 27 summarizes the results for each RG pair used for final radar adjustment, where G_i is the gauge estimate, R_i is the non-adjusted radar estimate, R_i^* is the GARR estimate, Diff* (in) is the difference in inches between the gauge and GARR estimate, and Diff* (%) is the percent difference between the gauge and GARR estimate. Figure 20 shows the scatter plot of the gauge-adjusted RG pairs. Figure 21 depicts the GARR storm total over the 1-km² pixels. The GARR amounts for the 2313 1-km² pixels range from 0.0 - 0.3 inches with a mean of 0.1 inches. Table 28 shows the Depth Duration Frequency (DDF) maximum values for the 1-km² pixels.

Table 26. GARR Statistics for Event 6

Event #	Radar	Event Date	Gauges Used (38)	Avg. Depth (in)	Bias	AD (%)	CAD (%)
E6	KPBZ LII	2015-04-09 AM	30	0.121	1.159	13.8	1.8

Table 27. Summary of Individual RG Pairs for Event 6

Gauge ID	Name	G _i (in)	R _i (in)	R _i * (in)	Diff* (in)	Diff* (%)
Loc09	Univ of Pittsburgh	0.07	0.07	0.08	-0.01	-14.3
KAGC	Pittsburgh Allegheny Cty	0.08	0.07	0.08	0.00	0.0
KPIT	Greater Pittsburgh Int'l	0.17	0.14	0.17	0.00	0.0
Loc01	PWSA-Montana St.	0.13	0.12	0.13	0.00	0.0
Loc02	ALCOSAN WWTP Lab	0.11	0.10	0.11	0.00	0.0
Loc03	Shaler Munic Bldg	0.14	0.12	0.14	0.00	0.0
Loc04	Kennedy Twp PS	0.14	0.12	0.14	0.00	0.0
Loc05	Upper St. Clair	0.17	0.14	0.17	0.00	0.0
Loc06	Carnegie Transit Time	0.08	0.07	0.08	0.00	0.0
Loc07	Greentree Munic Bldg	0.09	0.07	0.09	0.00	0.0
Loc08	AC Health Dept Bldg	0.09	0.07	0.09	0.00	0.0
Loc10	PWSA-Highland Park	0.08	0.06	0.08	0.00	0.0
Loc12	Baldwin	0.09	0.08	0.09	0.00	0.0
Loc13	M-59 Access Shaft	0.07	0.07	0.07	0.00	0.0
Loc15	Trafford Maint Bldg	0.09	0.07	0.09	0.00	0.0
Loc16	Castle Shannon	0.10	0.09	0.10	0.00	0.0
Loc18	Oakdale Pump Station	0.11	0.09	0.11	0.00	0.0
Loc20	Gascola Eq Facility	0.07	0.05	0.07	0.00	0.0
Loc21	Moon TWP	0.15	0.12	0.15	0.00	0.0
Loc22	North Fayette TWP	0.11	0.09	0.11	0.00	0.0
Loc23	Clinton Munic Bldg	0.16	0.13	0.16	0.00	0.0
Loc24	Jefferson Hills	0.18	0.15	0.18	0.00	0.0
Loc25	White Oak Public Works Bldg	0.13	0.11	0.13	0.00	0.0
Loc26	Elizabeth TWP Municipal Bldg	0.19	0.18	0.19	0.00	0.0
Loc27	Marshall TWP	0.14	0.13	0.14	0.00	0.0
Loc29	Bell Acres Munic Bldg	0.14	0.14	0.14	0.00	0.0
Loc30	McCandless Twn Hall	0.13	0.12	0.13	0.00	0.0
Loc31	Hampton Municipal Bldg	0.10	0.09	0.10	0.00	0.0
Loc32	Arnold	0.08	0.06	0.08	0.00	0.0
Loc33	Richland TWP	0.11	0.11	0.11	0.00	0.0

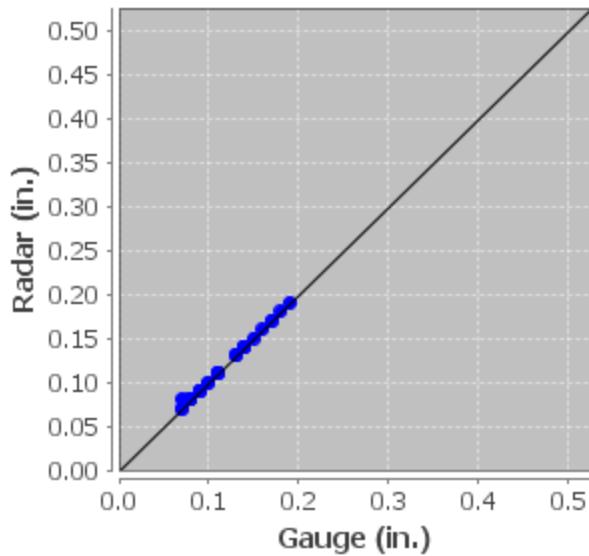


Figure 20. Scatter Plot of Gauge-Adjusted RG Pairs for Event 6

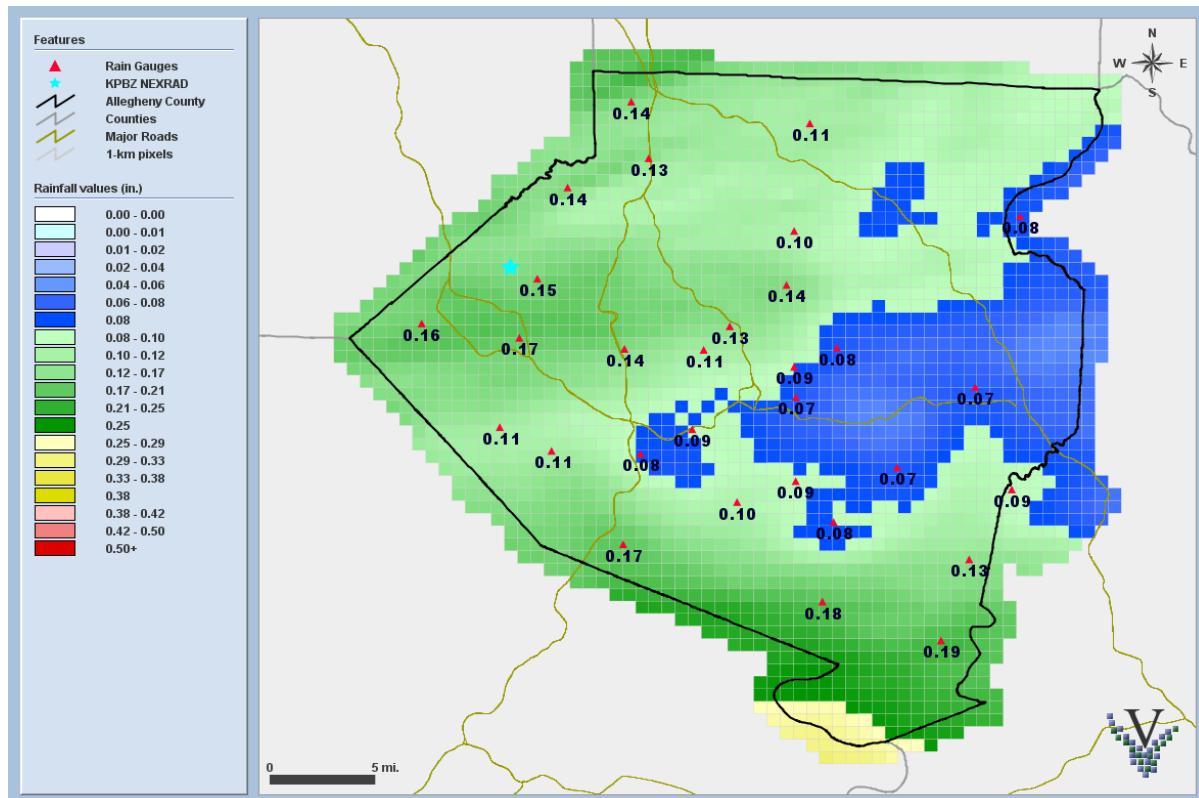


Figure 21. GARR Storm Total for Event 6

Table 28. Depth Duration Frequency Analyses for Event 6

Duration	Depth (in)	Pixel	Time (EDT)	Frequency
15 minutes	0.074	144156	2015-04-09 09:00	<1 yr.
30 minutes	0.146	150165	2015-04-09 09:00	<1 yr.
1 hour	0.214	155167	2015-04-09 09:15	<1 yr.
2 hour	0.230	152167	2015-04-09 09:15	<1 yr.
3 hour	0.283	152167	2015-04-09 11:15	<1 yr.
6 hour	0.304	152167	2015-04-09 12:00	<1 yr.

Event 7: 2015-04-09 PM

The second event of April 9th, 2015 was characterized by multiple waves of light to moderate to strong showers and thunderstorms in association with a warm front located near the northern state line of Indiana and Ohio and then curving south over the Ohio and Pennsylvania state line. Numerous showers and thunderstorms developed in the warm humid sector south and west of the warm front over much of the Lower Ohio Valley during the morning and afternoon hours of the 9th. This activity moved northeast into the Upper Ohio Valley, with the first wave of scattered light showers traversing Allegheny County between 4/9/15 14:30 – 15:30 EDT. A group of thunderstorms that coalesced into a thunderstorm complex over southern Ohio bringing light to moderate to strong storms across Allegheny County between 4/9/15 17:30 – 20:00 EDT. Starting at 4/9/15 21:00 EDT, scattered showers and thunderstorms continued to develop in and around Allegheny County and track northeast through the county before temporarily ending by 4/10/15 0:00 EDT. One last wave of light to moderate storms developed and tracked across the northern half of Allegheny County between 4/10/15 2:00 – 3:30 EDT. Almost half of Allegheny received at least 0.50 inches with higher amounts in excess of an inch located across east-central and far southwestern portions of the county.

The analysis period was from 2015-04-09 14:00 EDT to 2015-04-10 04:00 EDT. The event was then split into three sub-event periods at 2015-04-09 18:45 EDT and 2015-04-09 20:30 EDT to improve gauge adjustment of the radar. The gauges listed in [Appendix A](#) were not used to adjust the radar due to inconsistencies between the gauge and the radar or surrounding gauges, or they did not have data available for this event. Gauge Loc14 did not meet statistical criteria for gauge-adjustment of the radar and was not used to adjust the radar during Event 7a. Gauges Loc18 and Loc22 did not meet statistical criteria for gauge-adjustment of the radar and were not used to adjust the radar during Event 7b. Gauges Loc01, Loc02, Loc03, Loc04, Loc05, Loc10, Loc11, Loc12, Loc13, Loc15, Loc16, Loc18, Loc20, Loc21, Loc22, Loc23, Loc24, Loc25, Loc26, Loc31, KAGC, KPIT and 03085734 did not meet statistical criteria for gauge-adjustment of the radar and were not used to adjust the radar during Event 7c.

A convective Z-R relationship was used to convert radar reflectivity to rainfall rates. Table 29 shows the mean bias and average depth of the event along with the AD and CAD, respectively. Tables 30 - 32 summarize the results for each RG pair used for final radar adjustment, where G_i is the gauge estimate, R_i is the non-adjusted radar estimate, R_i^* is the GARR estimate, and Diff* (%) is the percent difference between the gauge and GARR estimate. Figures 22 - 24 show the scatter plots of the gauge-adjusted RG pairs. Figure 25 depicts the GARR storm total over the 1-

km² pixels. The GARR amounts for the 2313 1-km² pixels range from 0.2 - 1.1 inches with a mean of 0.5 inches. Table 33 shows the Depth Duration Frequency (DDF) maximum values for the 1-km² pixels.

Table 29. GARR Statistics for Event 7

Event #	Radar	Event Date	Gauges Used (38)	Avg. Depth (in)	Bias	AD (%)	CAD (%)
E7a	KPBZ LII	2015-04-09 PM	29	0.349	1.175	15.4	4.1
E7b	KPBZ LII	2015-04-09 PM	31	0.104	1.147	12.9	3.0
E7c	KPBZ LII	2015-04-09 PM	13	0.090	0.960	15.7	6.2

Table 30. Summary of Individual RG Pairs for Event 7a

Gauge ID	Name	G _i (in)	R _i (in)	R _i * (in)	Diff* (in)	Diff* (%)
Loc31	Hampton Municipal Bldg	0.21	0.21	0.25	-0.04	-19.0
Loc08	AC Health Dept Bldg	0.45	0.45	0.52	-0.07	-15.6
Loc13	M-59 Access Shaft	0.17	0.23	0.19	-0.02	-11.8
Loc20	Gascola Eq Facility	0.21	0.24	0.23	-0.02	-9.5
Loc18	Oakdale Pump Station	0.63	0.53	0.68	-0.05	-7.9
KAGC	Pittsburgh Allegheny Cty	0.18	0.22	0.19	-0.01	-5.6
Loc06	Carnegie Transit Time	0.39	0.37	0.40	-0.01	-2.6
Loc04	Kennedy Twp PS	0.51	0.39	0.51	0.00	0.0
Loc11	M-46 Access Shaft	0.27	0.26	0.27	0.00	0.0
Loc15	Trafford Maint Bldg	0.22	0.21	0.22	0.00	0.0
Loc17	Chartiers Pump Station	0.37	0.32	0.37	0.00	0.0
Loc21	Moon TWP	0.28	0.27	0.28	0.00	0.0
Loc23	Clinton Munic Bldg	0.41	0.38	0.41	0.00	0.0
Loc24	Jefferson Hills	0.25	0.28	0.25	0.00	0.0
Loc25	White Oak Public Works Bldg	0.23	0.22	0.23	0.00	0.0
Loc26	Elizabeth TWP Municipal Bldg	0.31	0.29	0.31	0.00	0.0
Loc27	Marshall TWP	0.33	0.25	0.33	0.00	0.0
Loc28	Plum Municipal Bldg	0.36	0.33	0.36	0.00	0.0
Loc29	Bell Acres Munic Bldg	0.39	0.31	0.39	0.00	0.0
Loc32	Arnold	0.48	0.42	0.48	0.00	0.0
Loc33	Richland TWP	0.44	0.36	0.44	0.00	0.0
Loc02	ALCOSAN WWTP Lab	0.62	0.46	0.61	0.01	1.6
Loc19	Sandy Creek Eq Facility	0.46	0.36	0.45	0.01	2.2
Loc30	McCandless Twn Hall	0.45	0.33	0.44	0.01	2.2
Loc16	Castle Shannon	0.25	0.20	0.24	0.01	4.0
Loc12	Baldwin	0.24	0.22	0.23	0.01	4.2

Gauge ID	Name	G _i (in)	R _i (in)	R _i * (in)	Diff* (in)	Diff* (%)
Loc22	North Fayette TWP	1.06	0.70	1.01	0.05	4.7
Loc03	Shaler Munic Bldg	0.63	0.45	0.60	0.03	4.8
Loc10	PWSA-Highland Park	0.58	0.41	0.52	0.06	10.3

Table 31. Summary of Individual RG Pairs for Event 7b

Gauge ID	Name	G _i (in)	R _i (in)	R _i * (in)	Diff* (in)	Diff* (%)
Loc02	ALCOSAN WWTP Lab	0.08	0.07	0.09	-0.01	-12.5
Loc11	M-46 Access Shaft	0.09	0.09	0.10	-0.01	-11.1
Loc12	Baldwin	0.09	0.09	0.10	-0.01	-11.1
Loc19	Sandy Creek Eq Facility	0.12	0.12	0.13	-0.01	-8.3
KAGC	Pittsburgh Allegheny Cty	0.10	0.09	0.10	0.00	0.0
Loc01	PWSA-Montana St.	0.10	0.08	0.10	0.00	0.0
Loc03	Shaler Munic Bldg	0.11	0.10	0.11	0.00	0.0
Loc04	Kennedy Twp PS	0.08	0.06	0.08	0.00	0.0
Loc07	Greentree Munic Bldg	0.09	0.08	0.09	0.00	0.0
Loc09	Univ of Pittsburgh	0.11	0.10	0.11	0.00	0.0
Loc10	PWSA-Highland Park	0.12	0.10	0.12	0.00	0.0
Loc15	Trafford Maint Bldg	0.12	0.11	0.12	0.00	0.0
Loc16	Castle Shannon	0.09	0.09	0.09	0.00	0.0
Loc17	Chartiers Pump Station	0.07	0.07	0.07	0.00	0.0
Loc20	Gascola Eq Facility	0.12	0.11	0.12	0.00	0.0
Loc21	Moon TWP	0.06	0.06	0.06	0.00	0.0
Loc23	Clinton Munic Bldg	0.06	0.06	0.06	0.00	0.0
Loc24	Jefferson Hills	0.10	0.08	0.10	0.00	0.0
Loc25	White Oak Public Works Bldg	0.10	0.09	0.10	0.00	0.0
Loc26	Elizabeth TWP Municipal Bldg	0.08	0.07	0.08	0.00	0.0
Loc27	Marshall TWP	0.10	0.08	0.10	0.00	0.0
Loc29	Bell Acres Munic Bldg	0.08	0.07	0.08	0.00	0.0
Loc30	McCandless Twn Hall	0.10	0.08	0.10	0.00	0.0
Loc31	Hampton Municipal Bldg	0.11	0.11	0.11	0.00	0.0
Loc32	Arnold	0.18	0.17	0.18	0.00	0.0
Loc33	Richland TWP	0.16	0.12	0.16	0.00	0.0
Loc28	Plum Municipal Bldg	0.18	0.13	0.17	0.01	5.6
Loc08	AC Health Dept Bldg	0.12	0.09	0.11	0.01	8.3
Loc13	M-59 Access Shaft	0.12	0.09	0.11	0.01	8.3
Loc14	Churchill Munic Bldg	0.12	0.10	0.11	0.01	8.3
Loc06	Carnegie Transit Time	0.09	0.07	0.08	0.01	11.1

Table 32. Summary of Individual RG Pairs for Event 7c

Gauge ID	Name	G _i (in)	R _i (in)	R _i * (in)	Diff* (in)	Diff* (%)
Loc14	Churchill Munic Bldg	0.20	0.33	0.23	-0.03	-15.0
Loc30	McCandless Twn Hall	0.10	0.11	0.11	-0.01	-10.0
Loc07	Greentree Munic Bldg	0.13	0.13	0.14	-0.01	-7.7
Loc17	Chartiers Pump Station	0.34	0.39	0.36	-0.02	-5.9
Loc09	Univ of Pittsburgh	0.32	0.36	0.33	-0.01	-3.1
Loc28	Plum Municipal Bldg	0.51	0.46	0.51	0.00	0.0
Loc29	Bell Acres Munic Bldg	0.08	0.09	0.08	0.00	0.0
Loc32	Arnold	0.10	0.08	0.10	0.00	0.0
Loc33	Richland TWP	0.17	0.16	0.17	0.00	0.0
Loc27	Marshall TWP	0.40	0.36	0.39	0.01	2.5
Loc19	Sandy Creek Eq Facility	0.34	0.40	0.32	0.02	5.9
Loc08	AC Health Dept Bldg	0.16	0.16	0.15	0.01	6.3
Loc06	Carnegie Transit Time	0.14	0.10	0.11	0.03	21.4

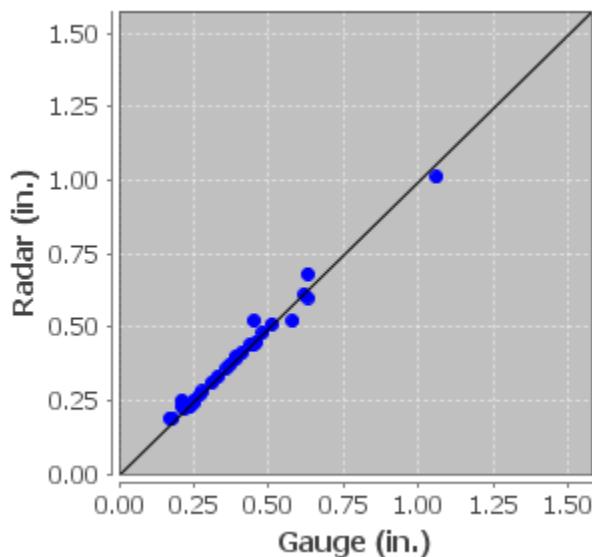


Figure 22. Scatter Plot of Gauge-Adjusted RG Pairs for Event 7a

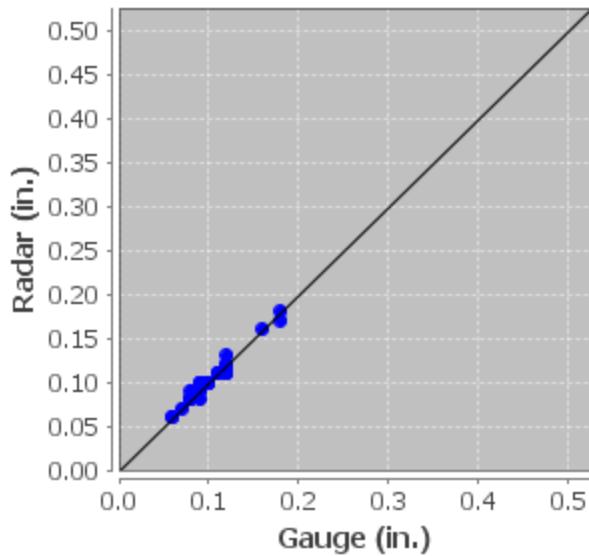


Figure 23. Scatter Plot of Gauge-Adjusted RG Pairs for Event 7b

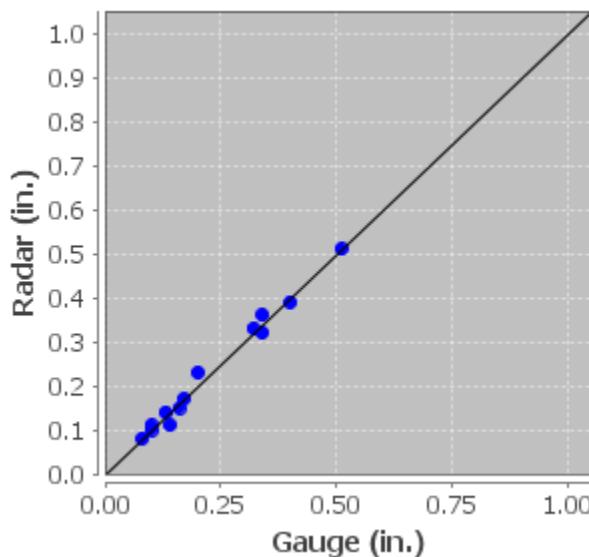


Figure 24. Scatter Plot of Gauge-Adjusted RG Pairs for Event 7c

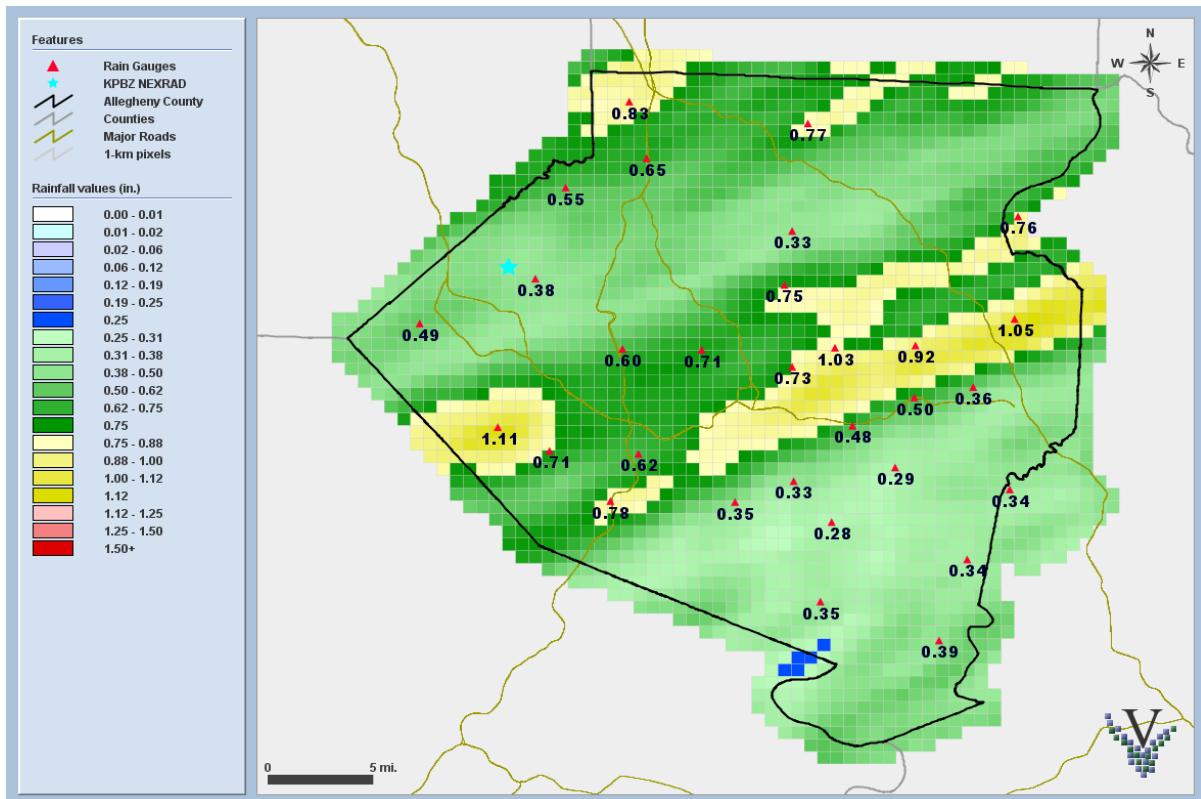


Figure 25. GARR Storm Total for Event 7

Table 33. Depth Duration Frequency Analyses for Event 7

Duration	Depth (in)	Pixel	Time (EDT)	Frequency
15 minutes	0.554	158128	2015-04-09 18:30	<1 yr.
30 minutes	0.873	127141	2015-04-09 18:15	1 yr.
1 hour	1.002	127141	2015-04-09 18:45	1 yr.
2 hour	1.086	127141	2015-04-09 19:15	<1 yr.
3 hour	1.089	127141	2015-04-09 19:30	<1 yr.
6 hour	1.109	168132	2015-04-09 23:45	<1 yr.
12 hour	1.120	168132	2015-04-10 02:00	<1 yr.

Event 8: 2015-04-10

The event of April 10th, 2015 was characterized by a steady period of light to moderate showers and thunderstorms in association with a system moving northeast across the Great Lakes Region. A cold front extending southwest of the system provided the lifting mechanism for numerous moderate to strong showers and thunderstorms to develop along and ahead of the front from the Upper Midwest through the Central Mississippi Valley into the Southern Plains during the afternoon and evening hours of the 9th. This band of activity weakened slightly and widened in coverage as it moved northeast through the Tennessee Valley and Lower Ohio Valley during the early morning hours of the 10th. Scattered light showers moved into southern and southwestern Allegheny County by 4/10/15 5:30 EDT. Rainfall coverage quickly increased across the county with widespread showers with embedded thunderstorms enveloping all of Allegheny County by 4/10/15 7:00 EDT. The showers began to taper off from west to east by 4/10/15 9:30 EDT. Additional scattered showers traversed Allegheny County through 4/10/15 13:00 EDT before ending shortly thereafter as the cold front pushed across the county. All of Allegheny County received at least 0.25 inches with higher amounts ranging between 0.60 – 0.70 inches located across southern portions of the county.

The analysis period was from 2015-04-10 04:00 EDT to 2015-04-10 15:00 EDT. The event was then split into four sub-event periods at 2015-04-10 06:30 EDT, 2015-04-10 07:30 EDT and 2015-04-10 08:45 EDT to improve gauge adjustment of the radar. The gauges listed in [Appendix A](#) were not used to adjust the radar due to inconsistencies between the gauge and the radar or surrounding gauges, or they did not have data available for this event. Gauges Loc01, Loc02, Loc03, Loc04, Loc06, Loc07, Loc08, Loc09, Loc10, Loc12, Loc13, Loc15, Loc17, Loc18, Loc19, Loc20, Loc21, Loc22, Loc25, Loc26, Loc27, Loc30, Loc31, Loc32, Loc33, KPIT, 03049500 and 03085734 did not meet statistical criteria for gauge-adjustment of the radar and were not used to adjust the radar during Event 8a. Gauges Loc11, Loc14 and Loc15 did not meet statistical criteria for gauge-adjustment of the radar and were not used to adjust the radar during Event 8b. Gauge Loc06 did not meet statistical criteria for gauge-adjustment of the radar and was not used to adjust the radar during Event 8c. Gauges Loc02, Loc03, Loc04, Loc06, Loc18, Loc21, Loc22, Loc23, Loc27, Loc29, Loc30, Loc31, Loc33 and KPIT did not meet statistical criteria for gauge-adjustment of the radar and were not used to adjust the radar during Event 8d.

A convective Z-R relationship was used to convert radar reflectivity to rainfall rates. Table 34 shows the mean bias and average depth of the event along with the AD and CAD, respectively. Tables 35 - 38 summarize the results for each RG pair used for final radar adjustment, where G_i is the gauge estimate, R_i is the non-adjusted radar estimate, R_i^* is the GARR estimate, and Diff* (%) is the percent difference between the gauge and GARR estimate. Figures 26 - 29 show the scatter plots of the gauge-adjusted RG pairs. Figure 30 depicts the GARR storm total over the 1-km² pixels. The GARR amounts for the 2313 1-km² pixels range from 0.3 - 0.7 inches with a mean of 0.4 inches. Table 39 shows the Depth Duration Frequency (DDF) maximum values for the 1-km² pixels.

Table 34. GARR Statistics for Event 8

Event #	Radar	Event Date	Gauges Used (38)	Avg. Depth (in)	Bias	AD (%)	CAD (%)
E8a	KPBZ LII	2015-04-10	9	0.029	0.961	29.9	0.6
E8b	KPBZ LII	2015-04-10	31	0.122	1.094	18.2	5.5
E8c	KPBZ LII	2015-04-10	32	0.156	1.354	25.2	2.1
E8d	KPBZ LII	2015-04-10	20	0.105	1.162	16.3	2.6

Table 35. Summary of Individual RG Pairs for Event 8a

Gauge ID	Name	G_i (in)	R_i (in)	R_i* (in)	Diff* (in)	Diff* (%)
<u>KAGC</u>	Pittsburgh Allegheny Cty	0.08	0.07	0.09	-0.01	-12.5
<u>Loc05</u>	Upper St. Clair	0.05	0.09	0.05	0.00	0.0
<u>Loc11</u>	M-46 Access Shaft	0.13	0.14	0.13	0.00	0.0
<u>Loc14</u>	Churchill Munic Bldg	0.13	0.14	0.13	0.00	0.0
<u>Loc16</u>	Castle Shannon	0.09	0.06	0.09	0.00	0.0
<u>Loc23</u>	Clinton Munic Bldg	0.05	0.06	0.05	0.00	0.0
<u>Loc24</u>	Jefferson Hills	0.09	0.06	0.09	0.00	0.0
<u>Loc28</u>	Plum Municipal Bldg	0.06	0.09	0.06	0.00	0.0
<u>Loc29</u>	Bell Acres Munic Bldg	0.11	0.12	0.11	0.00	0.0

Table 36. Summary of Individual RG Pairs for Event 8b

Gauge ID	Name	G_i (in)	R_i (in)	R_i* (in)	Diff* (in)	Diff* (%)
<u>Loc17</u>	Chartiers Pump Station	0.07	0.09	0.09	-0.02	-28.6
<u>Loc08</u>	AC Health Dept Bldg	0.10	0.13	0.12	-0.02	-20.0
<u>Loc19</u>	Sandy Creek Eq Facility	0.06	0.08	0.07	-0.01	-16.7
<u>KPIT</u>	Greater Pittsburgh Int'l	0.10	0.12	0.11	-0.01	-10.0
<u>Loc02</u>	ALCOSAN WWTP Lab	0.11	0.14	0.12	-0.01	-9.1
<u>Loc12</u>	Baldwin	0.14	0.12	0.15	-0.01	-7.1
<u>Loc30</u>	McCandless Twn Hall	0.20	0.18	0.21	-0.01	-5.0
<u>Loc22</u>	North Fayette TWP	0.24	0.21	0.25	-0.01	-4.2
<u>03049500</u>	Allegheny River at Natrona	0.12	0.13	0.12	0.00	0.0
<u>Loc06</u>	Carnegie Transit Time	0.10	0.11	0.10	0.00	0.0
<u>Loc07</u>	Greentree Munic Bldg	0.09	0.10	0.09	0.00	0.0
<u>Loc09</u>	Univ of Pittsburgh	0.09	0.10	0.09	0.00	0.0
<u>Loc20</u>	Gascola Eq Facility	0.07	0.06	0.07	0.00	0.0
<u>Loc21</u>	Moon TWP	0.10	0.09	0.10	0.00	0.0

Gauge ID	Name	G _i (in)	R _i (in)	R _i * (in)	Diff* (in)	Diff* (%)
Loc23	Clinton Munic Bldg	0.11	0.07	0.11	0.00	0.0
Loc24	Jefferson Hills	0.11	0.08	0.11	0.00	0.0
Loc25	White Oak Public Works Bldg	0.10	0.09	0.10	0.00	0.0
Loc26	Elizabeth TWP Municipal Bldg	0.05	0.06	0.05	0.00	0.0
Loc28	Plum Municipal Bldg	0.08	0.08	0.08	0.00	0.0
Loc29	Bell Acres Munic Bldg	0.15	0.13	0.15	0.00	0.0
Loc31	Hampton Municipal Bldg	0.15	0.13	0.15	0.00	0.0
Loc32	Arnold	0.10	0.12	0.10	0.00	0.0
Loc33	Richland TWP	0.16	0.14	0.16	0.00	0.0
Loc27	Marshall TWP	0.18	0.13	0.17	0.01	5.6
Loc04	Kennedy Twp PS	0.16	0.14	0.15	0.01	6.3
KAGC	Pittsburgh Allegheny Cty	0.14	0.10	0.13	0.01	7.1
Loc16	Castle Shannon	0.13	0.10	0.12	0.01	7.7
Loc13	M-59 Access Shaft	0.12	0.07	0.11	0.01	8.3
Loc05	Upper St. Clair	0.10	0.08	0.09	0.01	10.0
Loc18	Oakdale Pump Station	0.20	0.13	0.18	0.02	10.0
Loc10	PWSA-Highland Park	0.16	0.14	0.14	0.02	12.5

Table 37. Summary of Individual RG Pairs for Event 8c

Gauge ID	Name	G _i (in)	R _i (in)	R _i * (in)	Diff* (in)	Diff* (%)
Loc31	Hampton Municipal Bldg	0.11	0.09	0.12	-0.01	-9.1
Loc19	Sandy Creek Eq Facility	0.14	0.13	0.15	-0.01	-7.1
KAGC	Pittsburgh Allegheny Cty	0.16	0.14	0.17	-0.01	-6.3
Loc17	Chartiers Pump Station	0.18	0.14	0.19	-0.01	-5.6
KPIT	Greater Pittsburgh Int'l	0.11	0.09	0.11	0.00	0.0
Loc02	ALCOSAN WWTP Lab	0.15	0.10	0.15	0.00	0.0
Loc04	Kennedy Twp PS	0.13	0.09	0.13	0.00	0.0
Loc07	Greentree Munic Bldg	0.19	0.13	0.19	0.00	0.0
Loc08	AC Health Dept Bldg	0.17	0.11	0.17	0.00	0.0
Loc09	Univ of Pittsburgh	0.19	0.13	0.19	0.00	0.0
Loc10	PWSA-Highland Park	0.17	0.12	0.17	0.00	0.0
Loc11	M-46 Access Shaft	0.18	0.13	0.18	0.00	0.0
Loc12	Baldwin	0.17	0.13	0.17	0.00	0.0
Loc13	M-59 Access Shaft	0.17	0.13	0.17	0.00	0.0
Loc14	Churchill Munic Bldg	0.15	0.13	0.15	0.00	0.0
Loc15	Trafford Maint Bldg	0.16	0.15	0.16	0.00	0.0

Gauge ID	Name	G _i (in)	R _i (in)	R _i * (in)	Diff* (in)	Diff* (%)
Loc16	Castle Shannon	0.17	0.13	0.17	0.00	0.0
Loc20	Gascola Eq Facility	0.14	0.13	0.14	0.00	0.0
Loc22	North Fayette TWP	0.15	0.09	0.15	0.00	0.0
Loc23	Clinton Munic Bldg	0.24	0.14	0.24	0.00	0.0
Loc24	Jefferson Hills	0.17	0.14	0.17	0.00	0.0
Loc25	White Oak Public Works Bldg	0.16	0.13	0.16	0.00	0.0
Loc26	Elizabeth TWP Municipal Bldg	0.12	0.10	0.12	0.00	0.0
Loc27	Marshall TWP	0.18	0.12	0.18	0.00	0.0
Loc28	Plum Municipal Bldg	0.15	0.13	0.15	0.00	0.0
Loc29	Bell Acres Munic Bldg	0.20	0.12	0.20	0.00	0.0
Loc30	McCandless Twn Hall	0.17	0.11	0.17	0.00	0.0
Loc32	Arnold	0.13	0.10	0.13	0.00	0.0
Loc33	Richland TWP	0.15	0.10	0.15	0.00	0.0
Loc18	Oakdale Pump Station	0.21	0.12	0.20	0.01	4.8
Loc05	Upper St. Clair	0.20	0.14	0.19	0.01	5.0
Loc03	Shaler Munic Bldg	0.14	0.09	0.13	0.01	7.1

Table 38. Summary of Individual RG Pairs for Event 8d

Gauge ID	Name	G _i (in)	R _i (in)	R _i * (in)	Diff* (in)	Diff* (%)
Loc11	M-46 Access Shaft	0.11	0.10	0.12	-0.01	-9.1
Loc20	Gascola Eq Facility	0.12	0.12	0.13	-0.01	-8.3
KAGC	Pittsburgh Allegheny Cty	0.16	0.15	0.16	0.00	0.0
Loc05	Upper St. Clair	0.09	0.07	0.09	0.00	0.0
Loc07	Greentree Munic Bldg	0.07	0.06	0.07	0.00	0.0
Loc08	AC Health Dept Bldg	0.09	0.06	0.09	0.00	0.0
Loc09	Univ of Pittsburgh	0.11	0.08	0.11	0.00	0.0
Loc12	Baldwin	0.11	0.11	0.11	0.00	0.0
Loc13	M-59 Access Shaft	0.15	0.14	0.15	0.00	0.0
Loc15	Trafford Maint Bldg	0.23	0.22	0.23	0.00	0.0
Loc16	Castle Shannon	0.11	0.10	0.11	0.00	0.0
Loc17	Chartiers Pump Station	0.08	0.06	0.08	0.00	0.0
Loc19	Sandy Creek Eq Facility	0.12	0.09	0.12	0.00	0.0
Loc24	Jefferson Hills	0.24	0.20	0.24	0.00	0.0
Loc26	Elizabeth TWP Municipal Bldg	0.33	0.32	0.33	0.00	0.0
Loc28	Plum Municipal Bldg	0.13	0.12	0.13	0.00	0.0
Loc32	Arnold	0.10	0.07	0.10	0.00	0.0

Gauge ID	Name	G_i (in)	R_i (in)	R_i^* (in)	Diff* (in)	Diff* (%)
Loc25	White Oak Public Works Bldg	0.35	0.30	0.34	0.01	2.9
Loc14	Churchill Munic Bldg	0.13	0.10	0.12	0.01	7.7
Loc10	PWSA-Highland Park	0.10	0.07	0.09	0.01	10.0

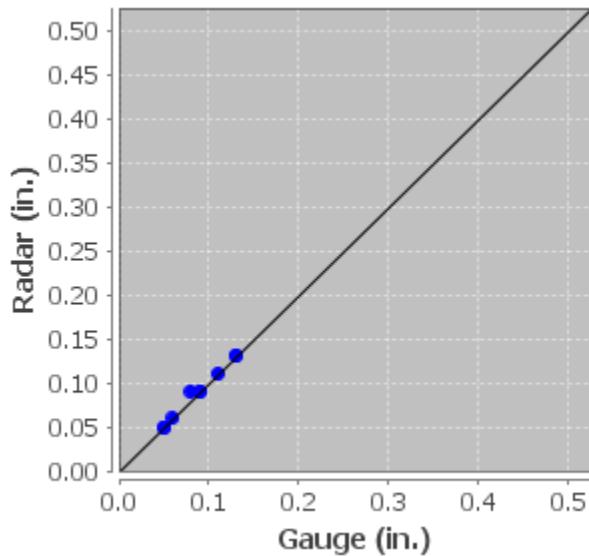


Figure 26. Scatter Plot of Gauge-Adjusted RG Pairs for Event 8a

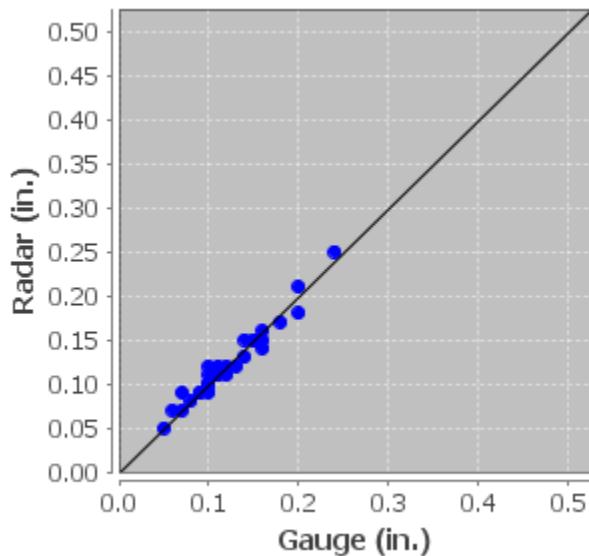


Figure 27. Scatter Plot of Gauge-Adjusted RG Pairs for Event 8b

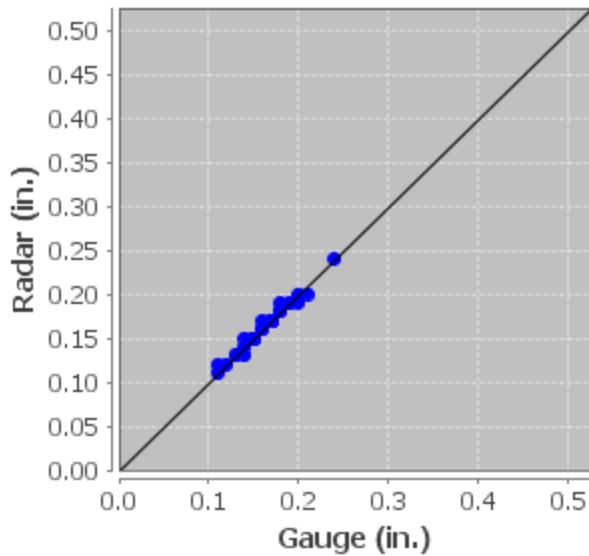


Figure 28. Scatter Plot of Gauge-Adjusted RG Pairs for Event 8c

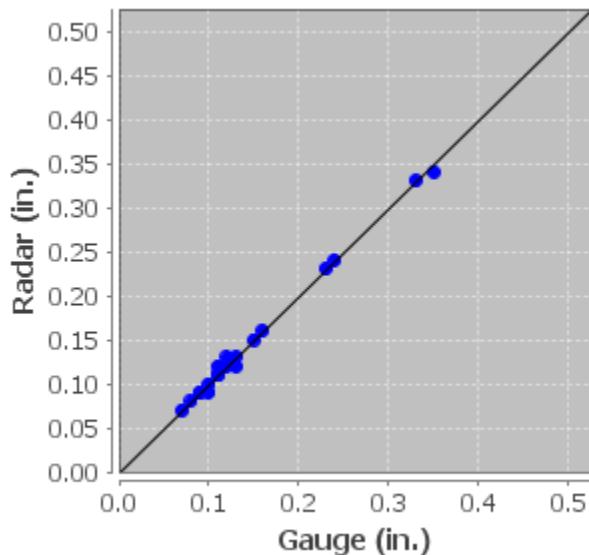


Figure 29. Scatter Plot of Gauge-Adjusted RG Pairs for Event 8d

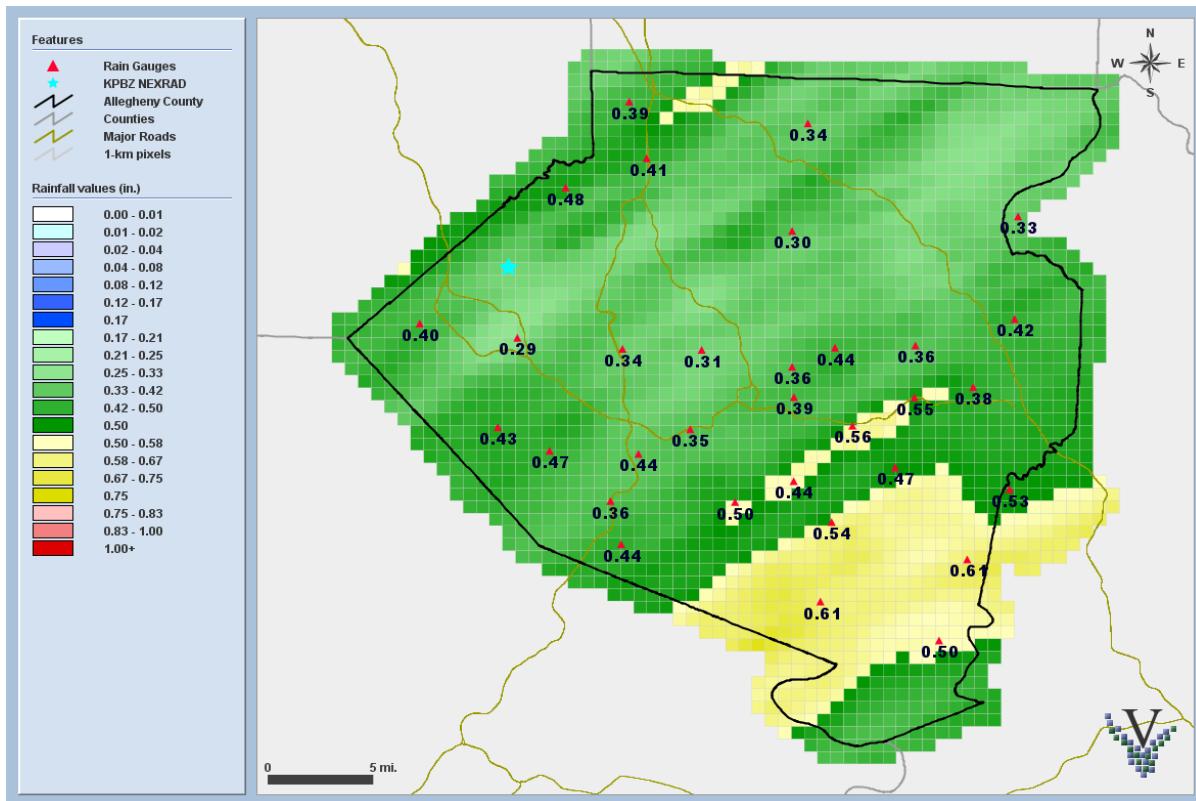


Figure 30. GARR Storm Total for Event 8

Table 39. Depth Duration Frequency Analyses for Event 8

Duration	Depth (in)	Pixel	Time (EDT)	Frequency
15 minutes	0.220	143114	2015-04-10 06:45	<1 yr.
30 minutes	0.254	142115	2015-04-10 06:45	<1 yr.
1 hour	0.340	143114	2015-04-10 07:15	<1 yr.
2 hour	0.460	143114	2015-04-10 08:30	<1 yr.
3 hour	0.538	142115	2015-04-10 09:00	<1 yr.
6 hour	0.710	147158	2015-04-10 11:15	<1 yr.

Event 9: 2015-04-13

The event of April 13 – 14th, 2015 was characterized by brief period of light to moderate showers in association with a system moving east across Hudson Bay. A cold front extending south into the Great Lakes Region and then southwest into the Central Mississippi Valley triggered a narrow band of showers and thunderstorms along and ahead of the front over Missouri, Illinois and Ohio during the early morning hours of the 13th. This activity moved northeast along the front as began to weaken in intensity as the front tracked across Ohio. Light showers entered southern and southwestern Allegheny County by 4/13/15 21:00 EDT. Widespread showers traversed the entire county between 4/13/15 23:30 EDT – 4/14/15 1:30 EDT as the cold front tracked through Allegheny County. Highest rainfall amounts ranging between 0.30 – 0.40 inches were located along a narrow band extending from southwestern to far east-central portions of Allegheny County while the northern and northwestern third of the county received generally less than 0.10 inches.

The analysis period was from 2015-04-13 19:00 EDT to 2015-04-14 07:00 EDT. The event was then split into two sub-event periods at 2015-04-13 23:00 EDT to improve gauge adjustment of the radar. The gauges listed in [Appendix A](#) were not used to adjust the radar due to inconsistencies between the gauge and the radar or surrounding gauges, or they did not have data available for this event. Gauges Loc01, Loc02, Loc03, Loc04, Loc13, Loc15, Loc21, Loc22, Loc23, Loc24, Loc25, Loc26, Loc27, Loc29, Loc30, Loc31, Loc32, Loc33, KPIT and 03049500 did not meet statistical criteria for gauge-adjustment of the radar and were not used to adjust the radar during Event 9a. Gauges Loc21, Loc27, Loc29, Loc30, Loc31, Loc33 and KPIT did not meet statistical criteria for gauge-adjustment of the radar and were not used to adjust the radar during Event 9b.

A convective Z-R relationship was used to convert radar reflectivity to rainfall rates. Table 40 shows the mean bias and average depth of the event along with the AD and CAD, respectively. Tables 41 - 42 summarize the results for each RG pair used for final radar adjustment, where G_i is the gauge estimate, R_i is the non-adjusted radar estimate, R_i^* is the GARR estimate, and Diff* (%) is the percent difference between the gauge and GARR estimate. Figures 31 - 32 show the scatter plots of the gauge-adjusted RG pairs. Figure 33 depicts the GARR storm total over the 1-km² pixels. The GARR amounts for the 2313 1-km² pixels range from 0.0 - 0.4 inches with a mean of 0.2 inches. Table 43 shows the Depth Duration Frequency (DDF) maximum values for the 1-km² pixels.

Table 40. GARR Statistics for Event 9

Event #	Radar	Event Date	Gauges Used (38)	Avg. Depth (in)	Bias	AD (%)	CAD (%)
E9a	KPBZ LII	2015-04-13	15	0.046	1.060	11.1	6.2
E9b	KPBZ LII	2015-04-13	27	0.127	1.615	36.5	2.7

Table 41. Summary of Individual RG Pairs for Event 9a

Gauge ID	Name	G _i (in)	R _i (in)	R _i * (in)	Diff* (in)	Diff* (%)
Loc06	Carnegie Transit Time	0.11	0.13	0.13	-0.02	-18.2
Loc14	Churchill Munic Bldg	0.08	0.10	0.09	-0.01	-12.5
Loc10	PWSA-Highland Park	0.09	0.10	0.10	-0.01	-11.1
Loc12	Baldwin	0.12	0.12	0.13	-0.01	-8.3
Loc05	Upper St. Clair	0.13	0.12	0.14	-0.01	-7.7
Loc11	M-46 Access Shaft	0.12	0.11	0.12	0.00	0.0
Loc16	Castle Shannon	0.14	0.13	0.14	0.00	0.0
Loc18	Oakdale Pump Station	0.11	0.10	0.11	0.00	0.0
Loc19	Sandy Creek Eq Facility	0.12	0.12	0.12	0.00	0.0
Loc20	Gascola Eq Facility	0.11	0.11	0.11	0.00	0.0
Loc28	Plum Municipal Bldg	0.12	0.11	0.12	0.00	0.0
Loc07	Greentree Munic Bldg	0.16	0.15	0.15	0.01	6.3
Loc09	Univ of Pittsburgh	0.16	0.14	0.15	0.01	6.3
Loc17	Chartiers Pump Station	0.18	0.14	0.16	0.02	11.1
KAGC	Pittsburgh Allegheny Cty	0.08	0.06	0.07	0.01	12.5

Table 42. Summary of Individual RG Pairs for Event 9b

Gauge ID	Name	G _i (in)	R _i (in)	R _i * (in)	Diff* (in)	Diff* (%)
Loc12	Baldwin	0.12	0.08	0.13	-0.01	-8.3
Loc13	M-59 Access Shaft	0.12	0.08	0.13	-0.01	-8.3
Loc19	Sandy Creek Eq Facility	0.22	0.14	0.23	-0.01	-4.5
Loc01	PWSA-Montana St.	0.12	0.08	0.12	0.00	0.0
Loc02	ALCOSAN WWTP Lab	0.12	0.08	0.12	0.00	0.0
Loc03	Shaler Munic Bldg	0.09	0.07	0.09	0.00	0.0
Loc04	Kennedy Twp PS	0.09	0.07	0.09	0.00	0.0
Loc05	Upper St. Clair	0.16	0.10	0.16	0.00	0.0
Loc06	Carnegie Transit Time	0.21	0.12	0.21	0.00	0.0
Loc07	Greentree Munic Bldg	0.25	0.15	0.25	0.00	0.0
Loc09	Univ of Pittsburgh	0.21	0.13	0.21	0.00	0.0
Loc10	PWSA-Highland Park	0.22	0.13	0.22	0.00	0.0
Loc14	Churchill Munic Bldg	0.20	0.12	0.20	0.00	0.0
Loc15	Trafford Maint Bldg	0.16	0.10	0.16	0.00	0.0
Loc17	Chartiers Pump Station	0.19	0.11	0.19	0.00	0.0
Loc18	Oakdale Pump Station	0.18	0.10	0.18	0.00	0.0
Loc22	North Fayette TWP	0.14	0.09	0.14	0.00	0.0

Gauge ID	Name	G_i (in)	R_i (in)	R_i^* (in)	Diff* (in)	Diff* (%)
Loc23	Clinton Munic Bldg	0.07	0.05	0.07	0.00	0.0
Loc24	Jefferson Hills	0.15	0.10	0.15	0.00	0.0
Loc25	White Oak Public Works Bldg	0.14	0.10	0.14	0.00	0.0
Loc26	Elizabeth TWP Municipal Bldg	0.20	0.13	0.20	0.00	0.0
Loc28	Plum Municipal Bldg	0.24	0.14	0.24	0.00	0.0
Loc32	Arnold	0.11	0.08	0.11	0.00	0.0
Loc20	Gascola Eq Facility	0.23	0.12	0.22	0.01	4.3
Loc11	M-46 Access Shaft	0.22	0.12	0.21	0.01	4.5
Loc16	Castle Shannon	0.17	0.09	0.16	0.01	5.9
KAGC	Pittsburgh Allegheny Cty	0.13	0.08	0.12	0.01	7.7

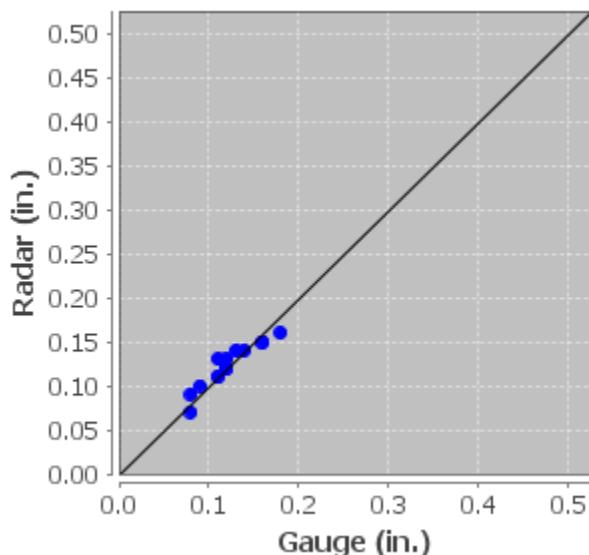


Figure 31. Scatter Plot of Gauge-Adjusted RG Pairs for Event 9a

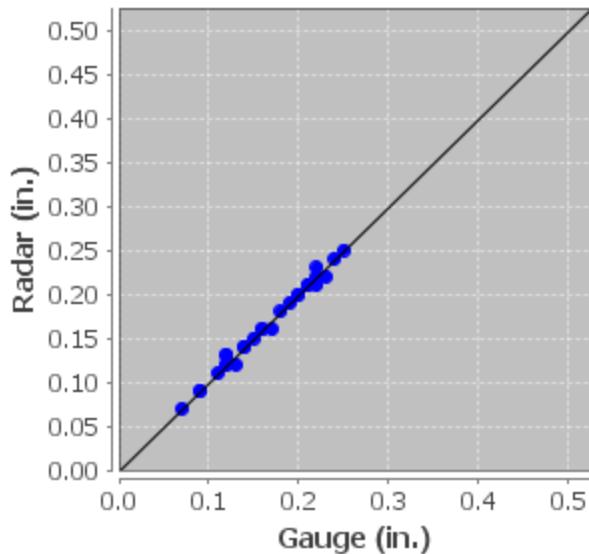


Figure 32. Scatter Plot of Gauge-Adjusted RG Pairs for Event 9b

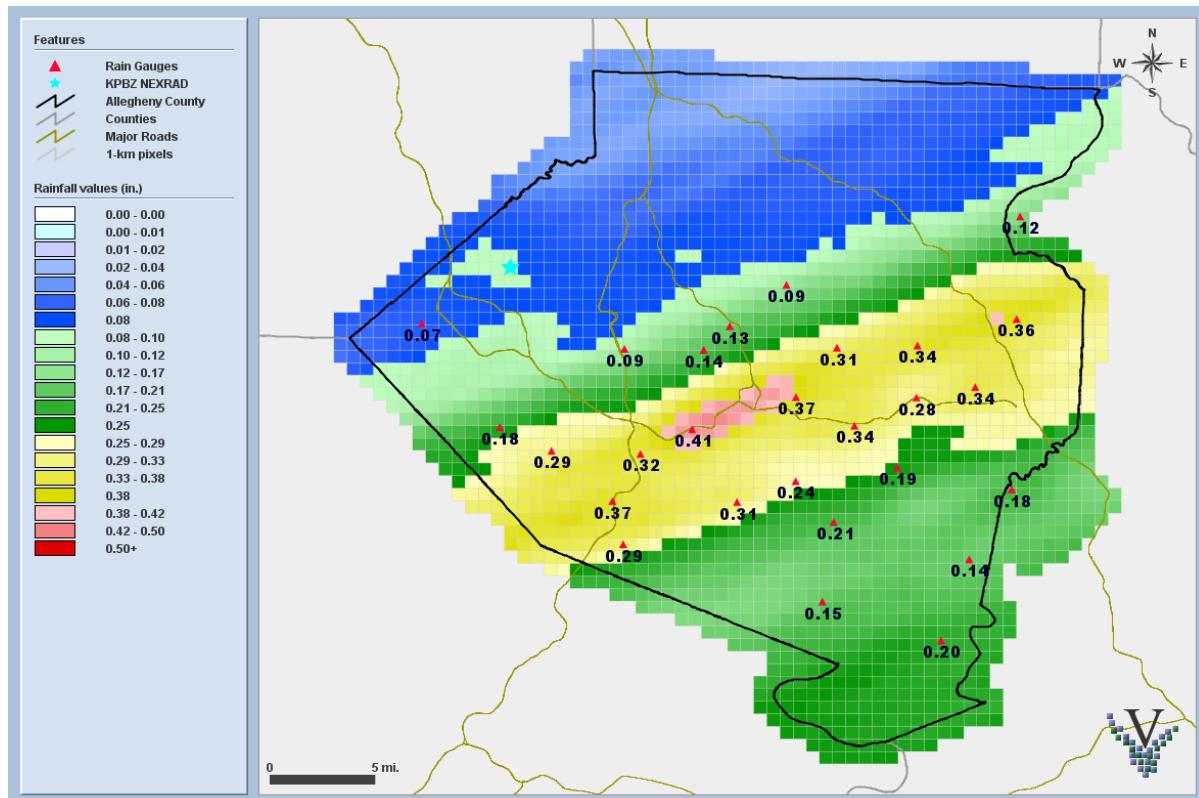


Figure 33. GARR Storm Total for Event 9

Table 43. Depth Duration Frequency Analyses for Event 9

Duration	Depth (in)	Pixel	Time (EDT)	Frequency
15 minutes	0.085	150162	2015-04-14 00:30	<1 yr.
30 minutes	0.151	148163	2015-04-14 00:30	<1 yr.
1 hour	0.209	143140	2015-04-14 00:30	<1 yr.
2 hour	0.277	143140	2015-04-14 00:30	<1 yr.
3 hour	0.373	143140	2015-04-14 00:30	<1 yr.
6 hour	0.414	143140	2015-04-14 01:00	<1 yr.
12 hour	0.414	143140	2015-04-14 07:00	<1 yr.

Event 10: 2015-04-16

The event of April 16th, 2015 was characterized by multiple waves of light to moderate showers in association with a weak upper level system moving northeast out of the Tennessee Valley through the Ohio Valley. An area of enhanced atmospheric lift located along the eastern and southeastern flank of the system produced scattered showers and thunderstorms across Kentucky, West Virginia and southern Ohio during the early morning hours of the 16th. This activity weakened in intensity as it tracked generally northeast into the Upper Ohio Valley. The leading edge of light showers moved north-northeast into southern Allegheny County by 4/16/15 11:00 EDT. Rainfall coverage and intensity gradually increased across the county through 4/16/15 14:00 EDT as the storms shifted towards the northeast. By 4/16/15 15:00 EDT, scattered showers began traversing Allegheny County and continued across the county through 4/16/15 19:00 EDT before ending shortly thereafter. More than half of Allegheny County received at least 0.25 inches with higher amounts in excess of 0.35 inches located across far north-central portions of the county.

The analysis period was from 2015-04-16 09:00 EDT to 2015-04-16 21:00 EDT. The event was then split into three sub-event periods at 2015-04-16 12:30 EDT and 2015-04-16 14:30 EDT to improve gauge adjustment of the radar. The gauges listed in [Appendix A](#) were not used to adjust the radar due to inconsistencies between the gauge and the radar or surrounding gauges, or they did not have data available for this event. Gauges Loc01, Loc03, Loc04, Loc05, Loc06, Loc08, Loc09, Loc10, Loc11, Loc12, Loc13, Loc14, Loc15, Loc17, Loc18, Loc19, Loc20, Loc21, Loc22, Loc23, Loc25, Loc26, Loc27, Loc28, Loc29, Loc30, Loc31, Loc32, Loc33, KPIT and 03049500 did not meet statistical criteria for gauge-adjustment of the radar and were not used to adjust the radar during Event 10a. Gauges Loc04, Loc06, Loc07, Loc15, Loc17, Loc18, Loc22, Loc23, Loc26 and KPIT did not meet statistical criteria for gauge-adjustment of the radar and were not used to adjust the radar during Event 10b. Gauges Loc01, Loc02, Loc04, Loc05, Loc06, Loc07, Loc09, Loc10, Loc11, Loc12, Loc13, Loc14, Loc15, Loc16, Loc17, Loc18, Loc19, Loc20, Loc21, Loc22, Loc23, Loc25, Loc26, Loc27, KAGC and KPIT did not meet statistical criteria for gauge-adjustment of the radar and were not used to adjust the radar during Event 10c.

The Eastern U.S. cool season stratiform Z-R relationship was used to convert radar reflectivity to rainfall rates. Table 44 shows the mean bias and average depth of the event along with the AD and CAD, respectively. Tables 45 - 47 summarize the results for each RG pair used for final radar adjustment, where G_i is the gauge estimate, R_i is the non-adjusted radar estimate, R_i^* is the

GARR estimate, and Diff* (%) is the percent difference between the gauge and GARR estimate. Figures 34 - 36 show the scatter plots of the gauge-adjusted RG pairs. Figure 37 depicts the GARR storm total over the 1-km² pixels. The GARR amounts for the 2313 1-km² pixels range from 0.1 - 0.4 inches with a mean of 0.2 inches. Table 48 shows the Depth Duration Frequency (DDF) maximum values for the 1-km² pixels.

Table 44. GARR Statistics for Event 10

Event #	Radar	Event Date	Gauges Used (38)	Avg. Depth (in)	Bias	AD (%)	CAD (%)
E10a	KPBZ LII	2015-04-16	5	0.054	1.035	15.4	2.8
E10b	KPBZ LII	2015-04-16	24	0.134	1.505	35.0	2.5
E10c	KPBZ LII	2015-04-16	7	0.050	1.223	23.5	1.2

Table 45. Summary of Individual RG Pairs for Event 10a

Gauge ID	Name	G _i (in)	R _i (in)	R _i * (in)	Diff* (in)	Diff* (%)
KAGC	Pittsburgh Allegheny Cty	0.08	0.08	0.08	0.00	0.0
Loc02	ALCOSAN WWTP Lab	0.12	0.10	0.12	0.00	0.0
Loc07	Greentree Munic Bldg	0.10	0.08	0.10	0.00	0.0
Loc16	Castle Shannon	0.05	0.06	0.05	0.00	0.0
Loc24	Jefferson Hills	0.08	0.09	0.08	0.00	0.0

Table 46. Summary of Individual RG Pairs for Event 10b

Gauge ID	Name	G _i (in)	R _i (in)	R _i * (in)	Diff* (in)	Diff* (%)
Loc02	ALCOSAN WWTP Lab	0.08	0.05	0.09	-0.01	-12.5
Loc14	Churchill Munic Bldg	0.21	0.17	0.23	-0.02	-9.5
KAGC	Pittsburgh Allegheny Cty	0.20	0.14	0.21	-0.01	-5.0
Loc20	Gascola Eq Facility	0.20	0.17	0.21	-0.01	-5.0
03085734	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.10	0.05	0.10	0.00	0.0
Loc01	PWSA-Montana St.	0.12	0.07	0.12	0.00	0.0
Loc03	Shaler Munic Bldg	0.15	0.08	0.15	0.00	0.0
Loc05	Upper St. Clair	0.09	0.06	0.09	0.00	0.0
Loc09	Univ of Pittsburgh	0.13	0.08	0.13	0.00	0.0
Loc10	PWSA-Highland Park	0.14	0.08	0.14	0.00	0.0
Loc12	Baldwin	0.18	0.12	0.18	0.00	0.0
Loc16	Castle Shannon	0.12	0.08	0.12	0.00	0.0
Loc21	Moon TWP	0.08	0.05	0.08	0.00	0.0

Gauge ID	Name	G _i (in)	R _i (in)	R _i * (in)	Diff* (in)	Diff* (%)
Loc25	White Oak Public Works Bldg	0.14	0.12	0.14	0.00	0.0
Loc27	Marshall TWP	0.11	0.06	0.11	0.00	0.0
Loc28	Plum Municipal Bldg	0.23	0.18	0.23	0.00	0.0
Loc29	Bell Acres Munic Bldg	0.10	0.06	0.10	0.00	0.0
Loc30	McCandless Twn Hall	0.10	0.05	0.10	0.00	0.0
Loc31	Hampton Municipal Bldg	0.15	0.09	0.15	0.00	0.0
Loc32	Arnold	0.23	0.18	0.23	0.00	0.0
Loc33	Richland TWP	0.18	0.10	0.18	0.00	0.0
Loc13	M-59 Access Shaft	0.26	0.16	0.25	0.01	3.8
Loc11	M-46 Access Shaft	0.22	0.14	0.21	0.01	4.5
Loc19	Sandy Creek Eq Facility	0.26	0.16	0.24	0.02	7.7

Table 47. Summary of Individual RG Pairs for Event 10c

Gauge ID	Name	G _i (in)	R _i (in)	R _i * (in)	Diff* (in)	Diff* (%)
Loc03	Shaler Munic Bldg	0.05	0.05	0.05	0.00	0.0
Loc28	Plum Municipal Bldg	0.05	0.06	0.05	0.00	0.0
Loc29	Bell Acres Munic Bldg	0.08	0.05	0.08	0.00	0.0
Loc30	McCandless Twn Hall	0.11	0.06	0.11	0.00	0.0
Loc31	Hampton Municipal Bldg	0.05	0.05	0.05	0.00	0.0
Loc32	Arnold	0.05	0.06	0.05	0.00	0.0
Loc33	Richland TWP	0.11	0.07	0.11	0.00	0.0

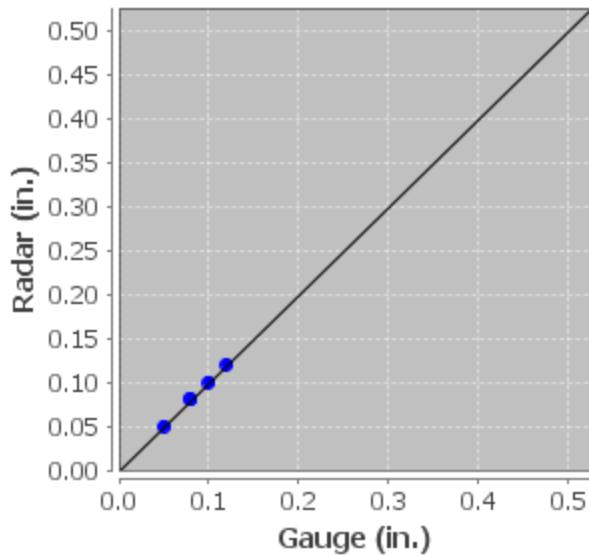


Figure 34. Scatter Plot of Gauge-Adjusted RG Pairs for Event 10a

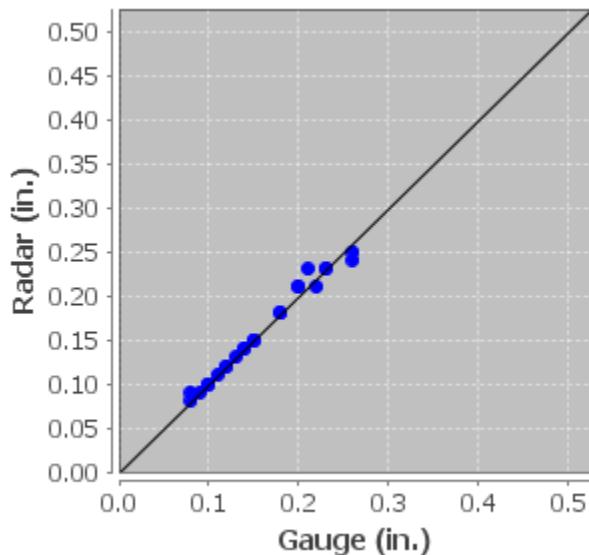


Figure 35. Scatter Plot of Gauge-Adjusted RG Pairs for Event 10b

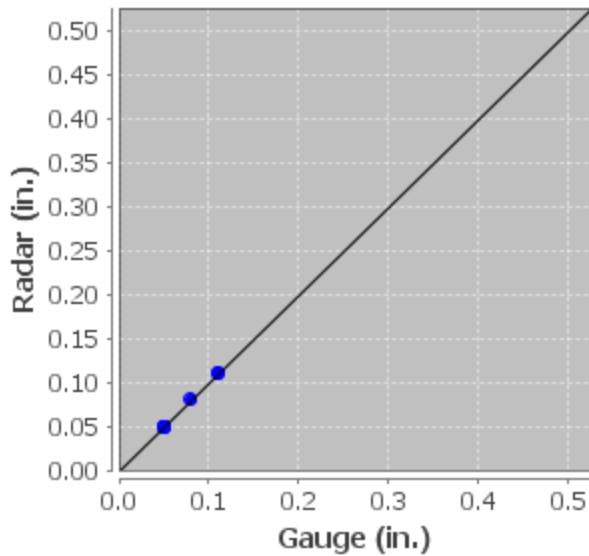


Figure 36. Scatter Plot of Gauge-Adjusted RG Pairs for Event 10c

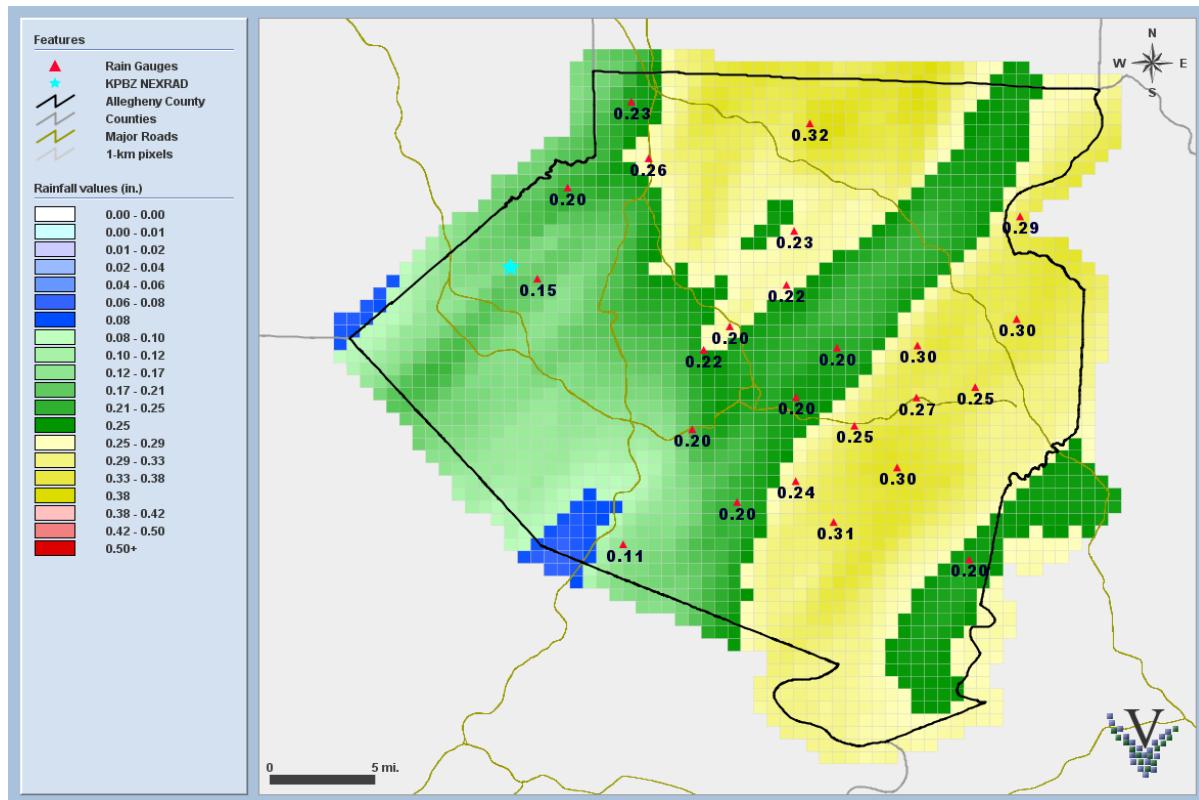


Figure 37. GARR Storm Total for Event 10

Table 48. Depth Duration Frequency Analyses for Event 10

Duration	Depth (in)	Pixel	Time (EDT)	Frequency
15 minutes	0.073	157143	2015-04-16 14:00	<1 yr.
30 minutes	0.121	158145	2015-04-16 14:00	<1 yr.
1 hour	0.196	157144	2015-04-16 14:00	<1 yr.
2 hour	0.257	161134	2015-04-16 14:30	<1 yr.
3 hour	0.310	170126	2015-04-16 14:45	<1 yr.
6 hour	0.355	152117	2015-04-16 17:00	<1 yr.
12 hour	0.370	152117	2015-04-16 21:00	<1 yr.

Event 11: 2015-04-19

The event of April 19 – 20th, 2015 was characterized by multiple waves of light to moderate showers in association with a system moving north-northeast out of the Tennessee Valley towards the Great Lakes Region. As Gulf moisture was lifted over a warm front extending southeast of the system, a large swatch of light to moderate showers with embedded thunderstorms developed over much of the Tennessee Valley, Carolinas and Lower Ohio Valley during the morning hours of the 19th. The activity spread northeast into the Upper Ohio Valley, with the leading edge of light showers reaching southwestern Allegheny County by 4/19/15 17:00 EDT. Multiple waves of light showers traversed the county for the next few hours, and increased in intensity after 4/19/15 22:30 EDT. The last main wave of light to moderate showers tracked northeast across the county between 4/20/15 3:00 – 4:30 EDT. Rainfall ended over Allegheny County by 4/20/15 7:00 EDT as the warm front pushed northeast of the area. All of Allegheny County received at least 0.30 inches with higher amounts in excess of 0.90 inches located across far northeastern portions of the county.

The analysis period was from 2015-04-19 15:00 EDT to 2015-04-20 08:00 EDT. The event was then split into five sub-event periods at 2015-04-19 19:00 EDT, 2015-04-19 22:00 EDT, 2015-04-20 01:00 EDT and 2015-04-20 03:00 EDT to improve gauge adjustment of the radar. The gauges listed in [Appendix A](#) were not used to adjust the radar due to inconsistencies between the gauge and the radar or surrounding gauges, or they did not have data available for this event. Gauges Loc01, Loc03, Loc04, Loc05, Loc06, Loc07, Loc09, Loc10, Loc11, Loc12, Loc13, Loc15, Loc16, Loc17, Loc18, Loc19, Loc20, Loc21, Loc22, Loc27, Loc31, Loc32, Loc33, KPIT and 03049500 did not meet statistical criteria for gauge-adjustment of the radar and were not used to adjust the radar during Event 11a. Gauges Loc10, Loc12 and Loc15 did not meet statistical criteria for gauge-adjustment of the radar and were not used to adjust the radar during Event 11b. Gauges Loc05, Loc06, Loc08, Loc17, Loc18 and Loc30 did not meet statistical criteria for gauge-adjustment of the radar and were not used to adjust the radar during Event 11c. Gauges Loc04, Loc05, Loc06, Loc07, Loc09, Loc10, Loc11, Loc14, Loc16, Loc17, Loc18, Loc19, Loc21, Loc22, Loc23, Loc27, Loc29, Loc30, KAGC, KPIT and 03085734 did not meet statistical criteria for gauge-adjustment of the radar and were not used to adjust the radar during Event 11d. Gauges Loc09, Loc10, Loc11, Loc12, Loc13, Loc14, Loc15, Loc16, Loc18, Loc19, Loc20, Loc22, Loc23, Loc25, Loc27, Loc32, KAGC and KPIT did not meet statistical criteria for gauge-adjustment of the radar and were not used to adjust the radar during Event 11e.

A convective Z-R relationship was used to convert radar reflectivity to rainfall rates. Table 49 shows the mean bias and average depth of the event along with the AD and CAD, respectively. Tables 50 - 54 summarize the results for each RG pair used for final radar adjustment, where G_i is the gauge estimate, R_i is the non-adjusted radar estimate, R_i^* is the GARR estimate, and Diff* (%) is the percent difference between the gauge and GARR estimate. Figures 38 - 42 show the scatter plots of the gauge-adjusted RG pairs. Figure 43 depicts the GARR storm total over the 1-km² pixels. The GARR amounts for the 2313 1-km² pixels range from 0.3 - 1.0 inches with a mean of 0.6 inches. Table 55 shows the Depth Duration Frequency (DDF) maximum values for the 1-km² pixels.

Table 49. GARR Statistics for Event 11

Event #	Radar	Event Date	Gauges Used (38)	Avg. Depth (in)	Bias	AD (%)	CAD (%)
E11a	KPBZ LII	2015-04-19	8	0.048	0.785	27.4	0.2
E11b	KPBZ LII	2015-04-19	30	0.139	1.827	44.8	2.5
E11c	KPBZ LII	2015-04-19	28	0.202	2.701	62.6	2.8
E11d	KPBZ LII	2015-04-19	12	0.082	1.798	43.3	2.3
E11e	KPBZ LII	2015-04-19	15	0.080	1.576	35.2	4.1

Table 50. Summary of Individual RG Pairs for Event 11a

Gauge ID	Name	G_i (in)	R_i (in)	R_i^* (in)	Diff* (in)	Diff* (%)
KAGC	Pittsburgh Allegheny Cty	0.05	0.06	0.05	0.00	0.0
Loc14	Churchill Munic Bldg	0.05	0.06	0.05	0.00	0.0
Loc23	Clinton Munic Bldg	0.05	0.06	0.05	0.00	0.0
Loc25	White Oak Public Works Bldg	0.05	0.06	0.05	0.00	0.0
Loc26	Elizabeth TWP Municipal Bldg	0.05	0.06	0.05	0.00	0.0
Loc28	Plum Municipal Bldg	0.05	0.07	0.05	0.00	0.0
Loc29	Bell Acres Munic Bldg	0.05	0.06	0.05	0.00	0.0
Loc30	McCandless Twn Hall	0.05	0.07	0.05	0.00	0.0

Table 51. Summary of Individual RG Pairs for Event 11b

Gauge ID	Name	G_i (in)	R_i (in)	R_i^* (in)	Diff* (in)	Diff* (%)
Loc13	M-59 Access Shaft	0.10	0.06	0.11	-0.01	-10.0
Loc07	Greentree Munic Bldg	0.14	0.08	0.15	-0.01	-7.1
Loc17	Chartiers Pump Station	0.15	0.09	0.16	-0.01	-6.7
KAGC	Pittsburgh Allegheny Cty	0.13	0.07	0.13	0.00	0.0
KPIT	Greater Pittsburgh Int'l	0.17	0.11	0.17	0.00	0.0
Loc01	PWSA-Montana St.	0.16	0.09	0.16	0.00	0.0

Gauge ID	Name	G _i (in)	R _i (in)	R _i * (in)	Diff* (in)	Diff* (%)
Loc03	Shaler Munic Bldg	0.14	0.08	0.14	0.00	0.0
Loc04	Kennedy Twp PS	0.19	0.11	0.19	0.00	0.0
Loc08	AC Health Dept Bldg	0.12	0.07	0.12	0.00	0.0
Loc09	Univ of Pittsburgh	0.11	0.06	0.11	0.00	0.0
Loc14	Churchill Munic Bldg	0.11	0.06	0.11	0.00	0.0
Loc16	Castle Shannon	0.12	0.06	0.12	0.00	0.0
Loc20	Gascola Eq Facility	0.10	0.06	0.10	0.00	0.0
Loc21	Moon TWP	0.18	0.12	0.18	0.00	0.0
Loc22	North Fayette TWP	0.17	0.10	0.17	0.00	0.0
Loc23	Clinton Munic Bldg	0.22	0.11	0.22	0.00	0.0
Loc25	White Oak Public Works Bldg	0.09	0.05	0.09	0.00	0.0
Loc26	Elizabeth TWP Municipal Bldg	0.09	0.06	0.09	0.00	0.0
Loc27	Marshall TWP	0.17	0.09	0.17	0.00	0.0
Loc28	Plum Municipal Bldg	0.09	0.05	0.09	0.00	0.0
Loc29	Bell Acres Munic Bldg	0.21	0.10	0.21	0.00	0.0
Loc30	McCandless Twn Hall	0.18	0.10	0.18	0.00	0.0
Loc31	Hampton Municipal Bldg	0.15	0.08	0.15	0.00	0.0
Loc32	Arnold	0.10	0.06	0.10	0.00	0.0
Loc33	Richland TWP	0.19	0.08	0.19	0.00	0.0
Loc18	Oakdale Pump Station	0.18	0.10	0.17	0.01	5.6
Loc06	Carnegie Transit Time	0.17	0.09	0.16	0.01	5.9
Loc05	Upper St. Clair	0.16	0.07	0.15	0.01	6.3
Loc19	Sandy Creek Eq Facility	0.12	0.06	0.11	0.01	8.3
Loc11	M-46 Access Shaft	0.11	0.06	0.10	0.01	9.1

Table 52. Summary of Individual RG Pairs for Event 11c

Gauge ID	Name	G _i (in)	R _i (in)	R _i * (in)	Diff* (in)	Diff* (%)
Loc09	Univ of Pittsburgh	0.14	0.07	0.16	-0.02	-14.3
03085734	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.15	0.06	0.16	-0.01	-6.7
Loc21	Moon TWP	0.15	0.07	0.16	-0.01	-6.7
Loc13	M-59 Access Shaft	0.17	0.07	0.18	-0.01	-5.9
Loc31	Hampton Municipal Bldg	0.21	0.10	0.22	-0.01	-4.8
Loc28	Plum Municipal Bldg	0.24	0.11	0.25	-0.01	-4.2
KAGC	Pittsburgh Allegheny Cty	0.18	0.06	0.18	0.00	0.0

Gauge ID	Name	G _i (in)	R _i (in)	R _i * (in)	Diff* (in)	Diff* (%)
KPIT	Greater Pittsburgh Int'l	0.14	0.06	0.14	0.00	0.0
Loc01	PWSA-Montana St.	0.18	0.07	0.18	0.00	0.0
Loc03	Shaler Munic Bldg	0.21	0.08	0.21	0.00	0.0
Loc07	Greentree Munic Bldg	0.16	0.05	0.16	0.00	0.0
Loc11	M-46 Access Shaft	0.16	0.06	0.16	0.00	0.0
Loc14	Churchill Munic Bldg	0.20	0.08	0.20	0.00	0.0
Loc15	Trafford Maint Bldg	0.26	0.10	0.26	0.00	0.0
Loc16	Castle Shannon	0.15	0.05	0.15	0.00	0.0
Loc19	Sandy Creek Eq Facility	0.20	0.08	0.20	0.00	0.0
Loc20	Gascola Eq Facility	0.23	0.09	0.23	0.00	0.0
Loc22	North Fayette TWP	0.14	0.05	0.14	0.00	0.0
Loc23	Clinton Munic Bldg	0.22	0.08	0.22	0.00	0.0
Loc25	White Oak Public Works Bldg	0.24	0.09	0.24	0.00	0.0
Loc26	Elizabeth TWP Municipal Bldg	0.23	0.08	0.23	0.00	0.0
Loc27	Marshall TWP	0.21	0.07	0.21	0.00	0.0
Loc29	Bell Acres Munic Bldg	0.24	0.07	0.24	0.00	0.0
Loc32	Arnold	0.31	0.10	0.31	0.00	0.0
Loc33	Richland TWP	0.32	0.10	0.32	0.00	0.0
Loc04	Kennedy Twp PS	0.19	0.06	0.18	0.01	5.3
Loc12	Baldwin	0.17	0.05	0.16	0.01	5.9
Loc10	PWSA-Highland Park	0.22	0.07	0.19	0.03	13.6

Table 53. Summary of Individual RG Pairs for Event 11d

Gauge ID	Name	G _i (in)	R _i (in)	R _i * (in)	Diff* (in)	Diff* (%)
Loc01	PWSA-Montana St.	0.10	0.06	0.11	-0.01	-10.0
Loc31	Hampton Municipal Bldg	0.12	0.07	0.13	-0.01	-8.3
Loc12	Baldwin	0.09	0.05	0.09	0.00	0.0
Loc13	M-59 Access Shaft	0.09	0.06	0.09	0.00	0.0
Loc15	Trafford Maint Bldg	0.13	0.07	0.13	0.00	0.0
Loc20	Gascola Eq Facility	0.12	0.08	0.12	0.00	0.0
Loc25	White Oak Public Works Bldg	0.10	0.07	0.10	0.00	0.0
Loc26	Elizabeth TWP Municipal Bldg	0.09	0.06	0.09	0.00	0.0
Loc28	Plum Municipal Bldg	0.12	0.08	0.12	0.00	0.0
Loc32	Arnold	0.14	0.06	0.14	0.00	0.0
Loc33	Richland TWP	0.13	0.05	0.13	0.00	0.0
Loc03	Shaler Munic Bldg	0.13	0.06	0.12	0.01	7.7

Table 54. Summary of Individual RG Pairs for Event 11e

Gauge ID	Name	G_i (in)	R_i (in)	R_i^* (in)	Diff* (in)	Diff* (%)
03085734	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.09	0.07	0.10	-0.01	-11.1
Loc05	Upper St. Clair	0.09	0.07	0.10	-0.01	-11.1
Loc07	Greentree Munic Bldg	0.09	0.05	0.10	-0.01	-11.1
Loc01	PWSA-Montana St.	0.11	0.07	0.11	0.00	0.0
Loc04	Kennedy Twp PS	0.11	0.07	0.11	0.00	0.0
Loc21	Moon TWP	0.08	0.06	0.08	0.00	0.0
Loc26	Elizabeth TWP Municipal Bldg	0.06	0.05	0.06	0.00	0.0
Loc28	Plum Municipal Bldg	0.10	0.05	0.10	0.00	0.0
Loc29	Bell Acres Munic Bldg	0.08	0.05	0.08	0.00	0.0
Loc30	McCandless Twn Hall	0.08	0.05	0.08	0.00	0.0
Loc31	Hampton Municipal Bldg	0.10	0.07	0.10	0.00	0.0
Loc33	Richland TWP	0.11	0.08	0.11	0.00	0.0
Loc06	Carnegie Transit Time	0.13	0.06	0.12	0.01	7.7
Loc17	Chartiers Pump Station	0.12	0.06	0.11	0.01	8.3
Loc03	Shaler Munic Bldg	0.10	0.05	0.09	0.01	10.0

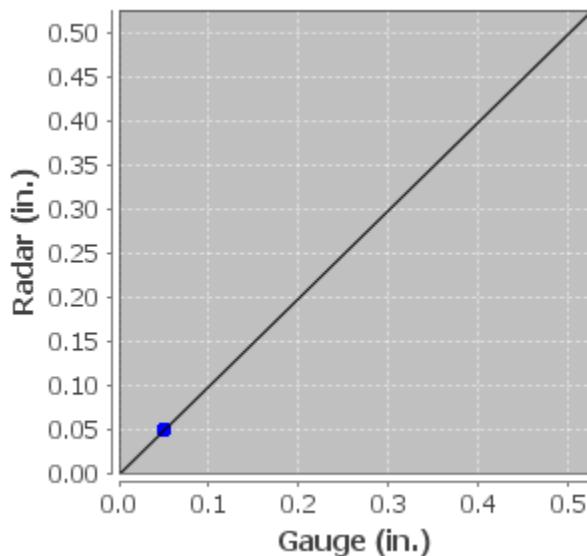


Figure 38. Scatter Plot of Gauge-Adjusted RG Pairs for Event 11a

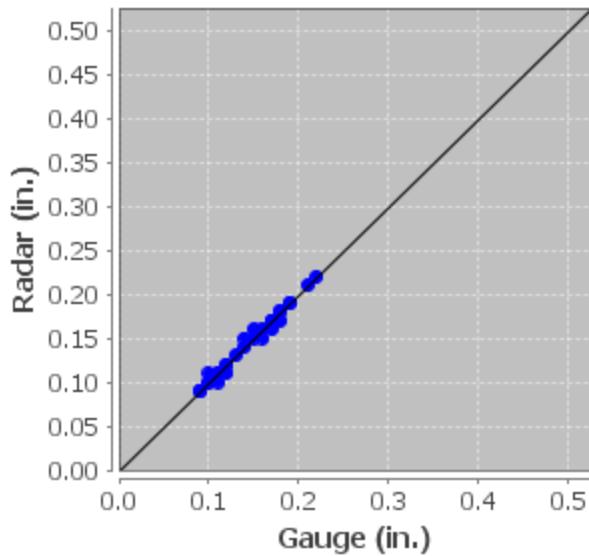


Figure 39. Scatter Plot of Gauge-Adjusted RG Pairs for Event 11b

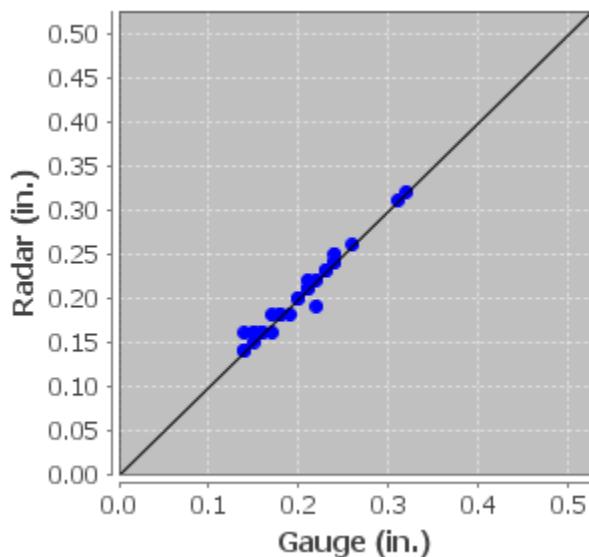


Figure 40. Scatter Plot of Gauge-Adjusted RG Pairs for Event 11c

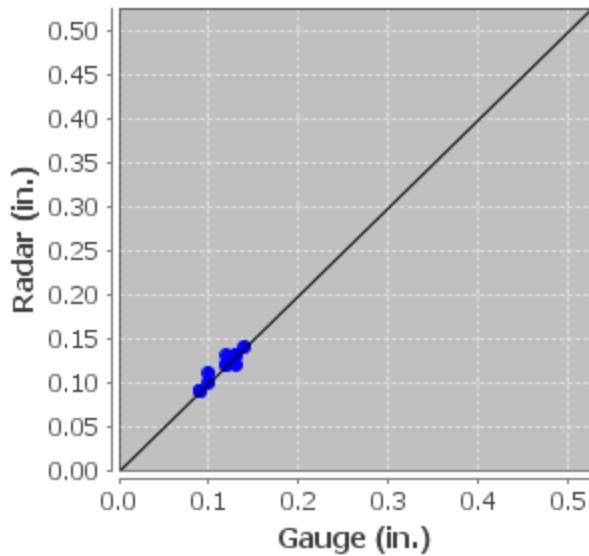


Figure 41. Scatter Plot of Gauge-Adjusted RG Pairs for Event 11d

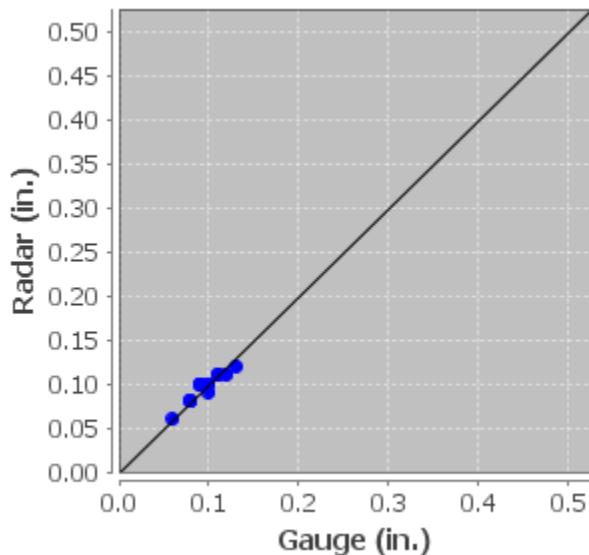


Figure 42. Scatter Plot of Gauge-Adjusted RG Pairs for Event 11e

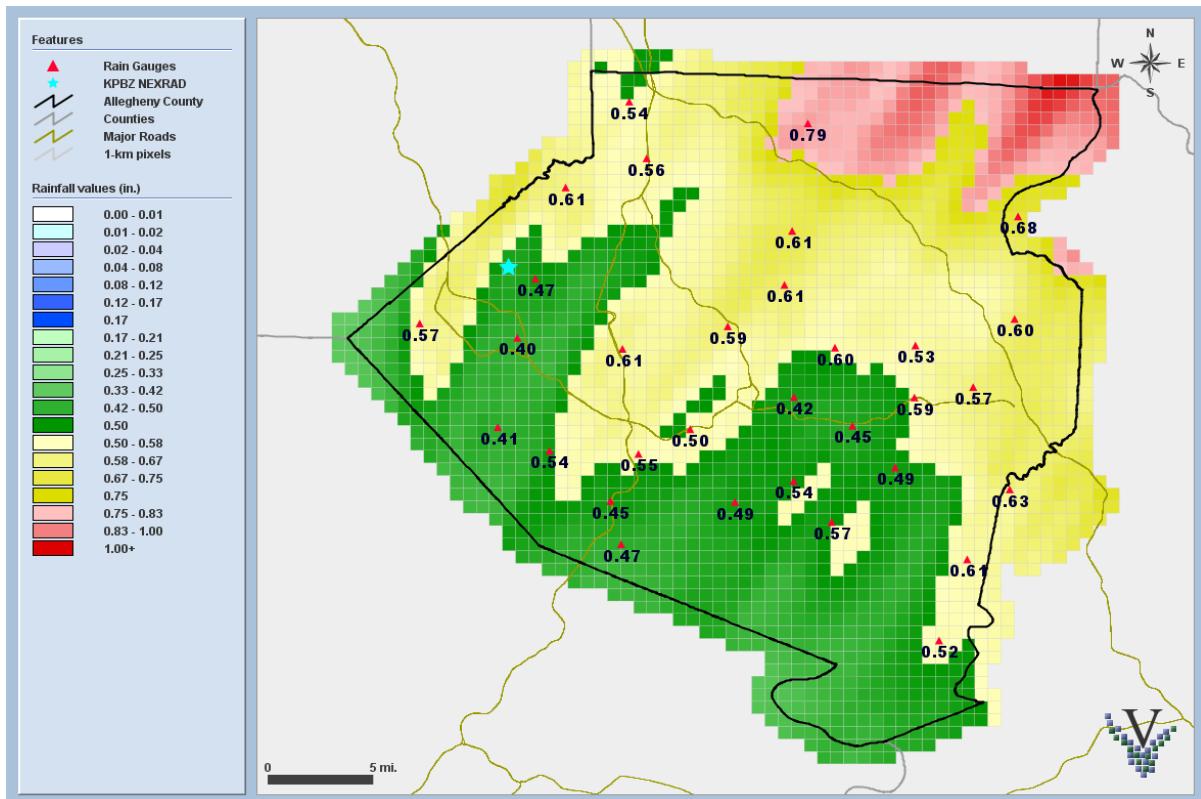


Figure 43. GARR Storm Total for Event 11

Table 55. Depth Duration Frequency Analyses for Event 11

Duration	Depth (in)	Pixel	Time (EDT)	Frequency
15 minutes	0.108	156119	2015-04-20 02:15	<1 yr.
30 minutes	0.146	123132	2015-04-19 23:15	<1 yr.
1 hour	0.236	128122	2015-04-19 23:45	<1 yr.
2 hour	0.332	168113	2015-04-20 00:45	<1 yr.
3 hour	0.446	159114	2015-04-20 02:30	<1 yr.
6 hour	0.760	170113	2015-04-20 02:45	<1 yr.
12 hour	0.983	170113	2015-04-20 04:30	<1 yr.

Event 12: 2015-04-22

The event of April 22nd, 2015 was characterized by a steady period of light showers in association with a system moving east out of the Lower Great Lakes Region towards New England. A cold front extending west-southwest of the system provided the lifting mechanism for a band of light showers to develop along and behind the front over portions of Ohio, Indiana and Illinois during the early morning hours of the 22nd. This activity moved northeast along the front as the front moved towards the southeast. Light showers moved into southern Allegheny County by 4/22/15 4:00 EDT and then spread further north across the rest of the county by 4/22/15 6:00 EDT. Mostly widespread showers persisted across Allegheny County for the next few hours before diminishing from west to east by 4/22/15 10:30 EDT as the cold front moved into the Mid-Atlantic States. Rainfall totals were fairly uniform across Allegheny County with most areas receiving between 0.25 – 0.35 inches.

The analysis period was from 2015-04-22 03:00 EDT to 2015-04-22 13:00 EDT. The event was then split into two sub-event periods at 2015-04-22 08:30 EDT to improve gauge adjustment of the radar. The gauges listed in [Appendix A](#) were not used to adjust the radar due to inconsistencies between the gauge and the radar or surrounding gauges, or they did not have data available for this event. Gauge Loc20 did not meet statistical criteria for gauge-adjustment of the radar and was not used to adjust the radar during Event 12a. Gauges Loc15 and Loc26 did not meet statistical criteria for gauge-adjustment of the radar and were not used to adjust the radar during Event 12b.

The Eastern U.S. cool season stratiform Z-R relationship was used to convert radar reflectivity to rainfall rates. Table 56 shows the mean bias and average depth of the event along with the AD and CAD, respectively. Tables 57 - 58 summarize the results for each RG pair used for final radar adjustment, where G_i is the gauge estimate, R_i is the non-adjusted radar estimate, R_i^* is the GARR estimate, and Diff* (%) is the percent difference between the gauge and GARR estimate. Figures 44 - 45 show the scatter plots of the gauge-adjusted RG pairs. Figure 46 depicts the GARR storm total over the 1-km² pixels. The GARR amounts for the 2313 1-km² pixels range from 0.2 - 0.4 inches with a mean of 0.3 inches. Table 59 shows the Depth Duration Frequency (DDF) maximum values for the 1-km² pixels.

Table 56. GARR Statistics for Event 12

Event #	Radar	Event Date	Gauges Used (38)	Avg. Depth (in)	Bias	AD (%)	CAD (%)
E12a	KPBZ LII	2015-04-22	34	0.119	1.022	29.7	7.7
E12b	KPBZ LII	2015-04-22	33	0.164	1.285	31.8	5.2

Table 57. Summary of Individual RG Pairs for Event 12a

Gauge ID	Name	G_i (in)	R_i (in)	R_i^* (in)	Diff* (in)	Diff* (%)
Loc13	M-59 Access Shaft	0.09	0.11	0.12	-0.03	-33.3
Loc02	ALCOSAN WWTP Lab	0.08	0.14	0.10	-0.02	-25.0
Loc12	Baldwin	0.12	0.15	0.15	-0.03	-25.0

Gauge ID	Name	G _i (in)	R _i (in)	R _i * (in)	Diff* (in)	Diff* (%)
Loc06	Carnegie Transit Time	0.09	0.15	0.11	-0.02	-22.2
Loc09	Univ of Pittsburgh	0.09	0.11	0.11	-0.02	-22.2
Loc19	Sandy Creek Eq Facility	0.08	0.08	0.09	-0.01	-12.5
Loc30	McCandless Twn Hall	0.13	0.16	0.14	-0.01	-7.7
03085734	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.10	0.16	0.10	0.00	0.0
KPIT	Greater Pittsburgh Int'l	0.12	0.12	0.12	0.00	0.0
Loc04	Kennedy Twp PS	0.10	0.15	0.10	0.00	0.0
Loc15	Trafford Maint Bldg	0.13	0.08	0.13	0.00	0.0
Loc18	Oakdale Pump Station	0.11	0.17	0.11	0.00	0.0
Loc21	Moon TWP	0.13	0.11	0.13	0.00	0.0
Loc22	North Fayette TWP	0.11	0.17	0.11	0.00	0.0
Loc23	Clinton Munic Bldg	0.14	0.14	0.14	0.00	0.0
Loc24	Jefferson Hills	0.13	0.10	0.13	0.00	0.0
Loc25	White Oak Public Works Bldg	0.15	0.09	0.15	0.00	0.0
Loc26	Elizabeth TWP Municipal Bldg	0.14	0.08	0.14	0.00	0.0
Loc28	Plum Municipal Bldg	0.14	0.07	0.14	0.00	0.0
Loc29	Bell Acres Munic Bldg	0.12	0.15	0.12	0.00	0.0
Loc31	Hampton Municipal Bldg	0.08	0.07	0.08	0.00	0.0
Loc32	Arnold	0.12	0.06	0.12	0.00	0.0
Loc33	Richland TWP	0.12	0.07	0.12	0.00	0.0
Loc16	Castle Shannon	0.17	0.16	0.16	0.01	5.9
Loc05	Upper St. Clair	0.16	0.16	0.15	0.01	6.3
Loc27	Marshall TWP	0.16	0.17	0.15	0.01	6.3
Loc17	Chartiers Pump Station	0.14	0.16	0.13	0.01	7.1
Loc10	PWSA-Highland Park	0.12	0.09	0.11	0.01	8.3
Loc01	PWSA-Montana St.	0.11	0.12	0.10	0.01	9.1
Loc07	Greentree Munic Bldg	0.11	0.14	0.10	0.01	9.1
Loc03	Shaler Munic Bldg	0.10	0.09	0.09	0.01	10.0
KAGC	Pittsburgh Allegheny Cty	0.17	0.12	0.15	0.02	11.8
Loc14	Churchill Munic Bldg	0.14	0.09	0.12	0.02	14.3
Loc11	M-46 Access Shaft	0.17	0.11	0.14	0.03	17.6

Table 58. Summary of Individual RG Pairs for Event 12b

Gauge ID	Name	G _i (in)	R _i (in)	R _i * (in)	Diff* (in)	Diff* (%)
Loc31	Hampton Municipal Bldg	0.10	0.14	0.12	-0.02	-20.0
KPIT	Greater Pittsburgh Int'l	0.12	0.18	0.14	-0.02	-16.7
Loc13	M-59 Access Shaft	0.15	0.10	0.17	-0.02	-13.3
Loc06	Carnegie Transit Time	0.16	0.13	0.18	-0.02	-12.5
03085734	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.15	0.17	0.16	-0.01	-6.7
Loc01	PWSA-Montana St.	0.16	0.16	0.17	-0.01	-6.3
Loc19	Sandy Creek Eq Facility	0.17	0.11	0.18	-0.01	-5.9
Loc12	Baldwin	0.18	0.12	0.19	-0.01	-5.6
Loc14	Churchill Munic Bldg	0.18	0.11	0.19	-0.01	-5.6
Loc09	Univ of Pittsburgh	0.20	0.13	0.21	-0.01	-5.0
KAGC	Pittsburgh Allegheny Cty	0.18	0.11	0.18	0.00	0.0
Loc04	Kennedy Twp PS	0.16	0.17	0.16	0.00	0.0
Loc10	PWSA-Highland Park	0.19	0.12	0.19	0.00	0.0
Loc18	Oakdale Pump Station	0.17	0.13	0.17	0.00	0.0
Loc23	Clinton Munic Bldg	0.12	0.16	0.12	0.00	0.0
Loc25	White Oak Public Works Bldg	0.18	0.10	0.18	0.00	0.0
Loc29	Bell Acres Munic Bldg	0.11	0.17	0.11	0.00	0.0
Loc30	McCandless Twn Hall	0.11	0.14	0.11	0.00	0.0
Loc32	Arnold	0.18	0.11	0.18	0.00	0.0
Loc33	Richland TWP	0.11	0.12	0.11	0.00	0.0
Loc24	Jefferson Hills	0.23	0.11	0.22	0.01	4.3
Loc28	Plum Municipal Bldg	0.22	0.09	0.21	0.01	4.5
Loc05	Upper St. Clair	0.21	0.12	0.20	0.01	4.8
Loc17	Chartiers Pump Station	0.21	0.13	0.20	0.01	4.8
Loc16	Castle Shannon	0.20	0.12	0.19	0.01	5.0
Loc20	Gascola Eq Facility	0.20	0.10	0.19	0.01	5.0
Loc07	Greentree Munic Bldg	0.19	0.13	0.18	0.01	5.3
Loc22	North Fayette TWP	0.19	0.14	0.18	0.01	5.3
Loc02	ALCOSAN WWTP Lab	0.18	0.15	0.17	0.01	5.6
Loc21	Moon TWP	0.15	0.18	0.14	0.01	6.7
Loc27	Marshall TWP	0.10	0.11	0.09	0.01	10.0
Loc03	Shaler Munic Bldg	0.19	0.15	0.17	0.02	10.5
Loc11	M-46 Access Shaft	0.25	0.12	0.22	0.03	12.0

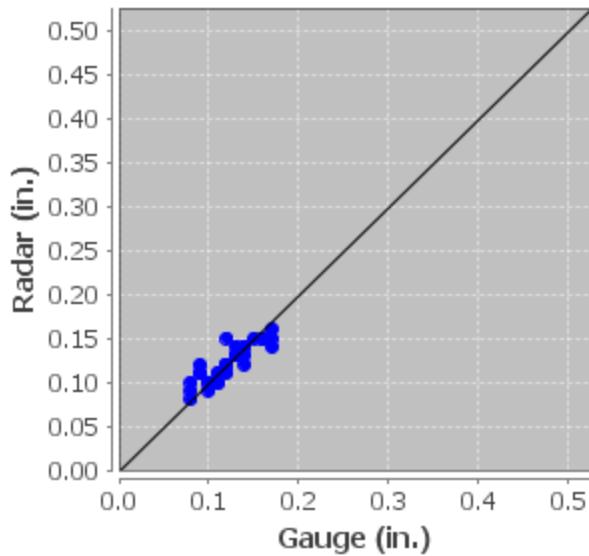


Figure 44. Scatter Plot of Gauge-Adjusted RG Pairs for Event 12a

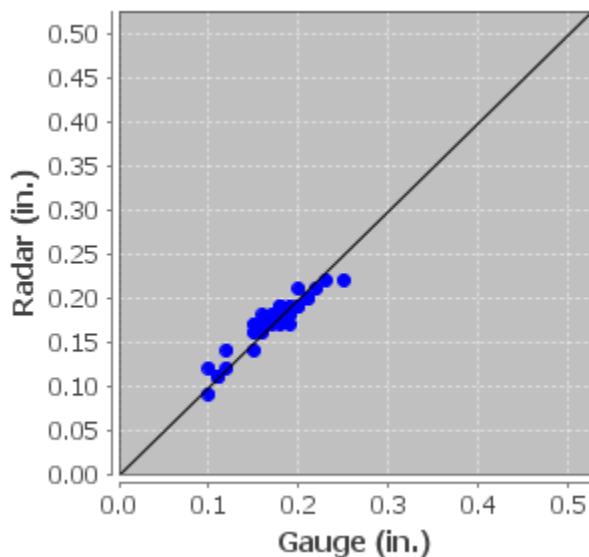


Figure 45. Scatter Plot of Gauge-Adjusted RG Pairs for Event 12b

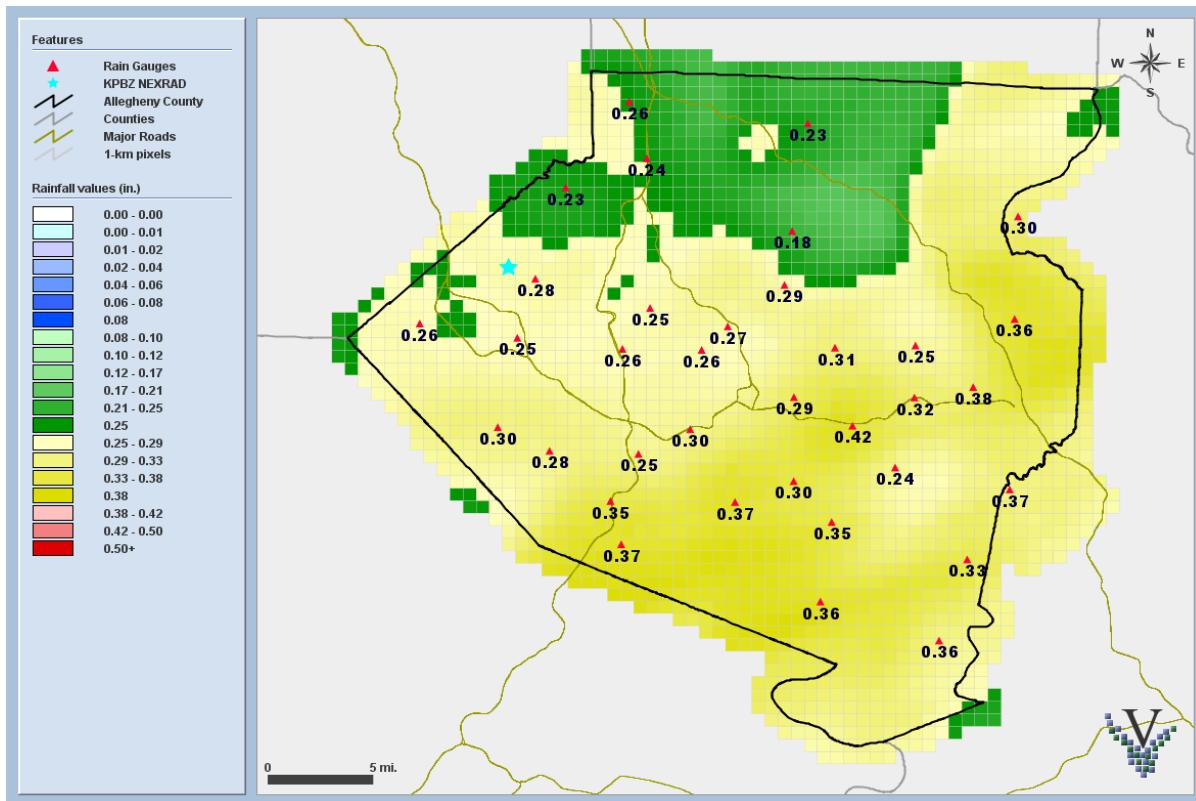


Figure 46. GARR Storm Total for Event 12

Table 59. Depth Duration Frequency Analyses for Event 12

Duration	Depth (in)	Pixel	Time (EDT)	Frequency
15 minutes	0.049	165130	2015-04-22 09:30	<1 yr.
30 minutes	0.084	134150	2015-04-22 09:15	<1 yr.
1 hour	0.139	153139	2015-04-22 09:45	<1 yr.
2 hour	0.224	153140	2015-04-22 10:30	<1 yr.
3 hour	0.289	147154	2015-04-22 10:30	<1 yr.
6 hour	0.357	164129	2015-04-22 10:45	<1 yr.

Event 13: 2015-04-30

The event of April 30th, 2015 was characterized by multiple waves of light to moderate to strong showers in association with an upper level system moving southeast out of the Great Lakes Region through the Lower Ohio Valley towards the Carolinas. A series of weak surface frontal boundaries combined with enhanced atmospheric lift aloft along the southern and eastern periphery of the upper level system triggered scattered showers and thunderstorms over a wide area of the Ohio Valley during the morning hours of the 30th. This activity rotated counter-clockwise around the system as it tracked towards the southeast. Rainfall began across far eastern Allegheny County by 4/30/15 13:00 EDT as a band of light showers moved towards the north-northwest. Scattered showers developed across central and western portions of the county by 4/30/15 14:00 EDT. Isolated moderate to strong showers developed across south-central and central Allegheny County between 4/30/15 18:30 – 20:00 EDT as the band of showers across eastern portions of the county increased in intensity, became more widespread and moved west across the entire county by 4/30/15 21:30 EDT. Shortly thereafter, these widespread showers tracked southwest across Allegheny County. Rainfall began to taper off from east to west over Allegheny County by 4/30/15 23:30 EDT as the upper level system traversed western Virginia. A few scattered light showers persisted across the county for the next few hours before ending by 5/1/15 4:00 EDT. Almost half of Allegheny County received at least 0.60 inches with locally higher amounts in excess of 1.25 inches.

The analysis period was from 2015-04-30 09:00 EDT to 2015-05-01 05:00 EDT. The event was then split into three sub-event periods at 2015-04-30 18:30 EDT and 2015-04-30 21:45 EDT to improve gauge adjustment of the radar. The gauges listed in [Appendix A](#) were not used to adjust the radar due to inconsistencies between the gauge and the radar or surrounding gauges, or they did not have data available for this event. Gauges Loc03, Loc04, Loc05, Loc06, Loc07, Loc08, Loc09, Loc10, Loc11, Loc12, Loc13, Loc14, Loc15, Loc16, Loc17, Loc18, Loc19, Loc20, Loc21, Loc22, Loc23, Loc24, Loc25, Loc26, Loc28, Loc29, Loc30, Loc31, Loc33, KAGC and KPIT did not meet statistical criteria for gauge-adjustment of the radar and were not used to adjust the radar during Event 13a. Gauges Loc06, Loc15, Loc22, Loc23 and Loc25 did not meet statistical criteria for gauge-adjustment of the radar and were not used to adjust the radar during Event 13b. Gauges Loc15, Loc24, Loc26, Loc28 and Loc31 did not meet statistical criteria for gauge-adjustment of the radar and were not used to adjust the radar during Event 13c.

A convective Z-R relationship was used to convert radar reflectivity to rainfall rates. Table 60 shows the mean bias and average depth of the event along with the AD and CAD, respectively. Tables 61 - 63 summarize the results for each RG pair used for final radar adjustment, where G_i is the gauge estimate, R_i is the non-adjusted radar estimate, R_i^* is the GARR estimate, and Diff* (%) is the percent difference between the gauge and GARR estimate. Figures 47 - 49 show the scatter plots of the gauge-adjusted RG pairs. Figure 50 depicts the GARR storm total over the 1-km² pixels. The GARR amounts for the 2313 1-km² pixels range from 0.3 - 1.9 inches with a mean of 0.6 inches. Table 64 shows the Depth Duration Frequency (DDF) maximum values for the 1-km² pixels.

Table 60. GARR Statistics for Event 13

Event #	Radar	Event Date	Gauges Used (38)	Avg. Depth (in)	Bias	AD (%)	CAD (%)
E13a	KPBZ LII	2015-04-30	5	0.030	0.900	27.1	7.2
E13b	KPBZ LII	2015-04-30	31	0.280	1.587	40.9	5.1
E13c	KPBZ LII	2015-04-30	31	0.325	1.693	41.1	3.6

Table 61. Summary of Individual RG Pairs for Event 13a

Gauge ID	Name	G_i (in)	R_i (in)	R_i* (in)	Diff* (in)	Diff* (%)
<u>Loc01</u>	PWSA-Montana St.	0.05	0.05	0.06	-0.01	-20.0
<u>03049500</u>	Allegheny River at Natrona	0.15	0.23	0.15	0.00	0.0
<u>Loc27</u>	Marshall TWP	0.08	0.06	0.08	0.00	0.0
<u>Loc02</u>	ALCOSAN WWTP Lab	0.11	0.08	0.10	0.01	9.1
<u>Loc32</u>	Arnold	0.11	0.13	0.10	0.01	9.1

Table 62. Summary of Individual RG Pairs for Event 13b

Gauge ID	Name	G_i (in)	R_i (in)	R_i* (in)	Diff* (in)	Diff* (%)
<u>Loc08</u>	AC Health Dept Bldg	0.60	0.47	0.68	-0.08	-13.3
<u>KAGC</u>	Pittsburgh Allegheny Cty	0.30	0.24	0.33	-0.03	-10.0
<u>Loc20</u>	Gascola Eq Facility	0.27	0.19	0.29	-0.02	-7.4
<u>Loc04</u>	Kennedy Twp PS	0.15	0.08	0.16	-0.01	-6.7
<u>Loc17</u>	Chartiers Pump Station	0.16	0.12	0.17	-0.01	-6.3
<u>Loc30</u>	McCandless Twn Hall	0.19	0.10	0.20	-0.01	-5.3
<u>Loc13</u>	M-59 Access Shaft	0.29	0.18	0.30	-0.01	-3.4
<u>Loc28</u>	Plum Municipal Bldg	0.35	0.26	0.36	-0.01	-2.9
<u>Loc03</u>	Shaler Munic Bldg	0.50	0.30	0.51	-0.01	-2.0
<u>03085734</u>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.18	0.08	0.18	0.00	0.0
<u>KPIT</u>	Greater Pittsburgh Int'l	0.10	0.06	0.10	0.00	0.0
<u>Loc07</u>	Greentree Munic Bldg	0.16	0.09	0.16	0.00	0.0
<u>Loc12</u>	Baldwin	0.40	0.27	0.40	0.00	0.0
<u>Loc16</u>	Castle Shannon	0.20	0.14	0.20	0.00	0.0
<u>Loc18</u>	Oakdale Pump Station	0.13	0.08	0.13	0.00	0.0
<u>Loc21</u>	Moon TWP	0.15	0.07	0.15	0.00	0.0
<u>Loc26</u>	Elizabeth TWP Municipal Bldg	0.35	0.43	0.35	0.00	0.0
<u>Loc29</u>	Bell Acres Munic Bldg	0.16	0.08	0.16	0.00	0.0

Gauge ID	Name	G_i (in)	R_i (in)	R_i^* (in)	Diff* (in)	Diff* (%)
Loc32	Arnold	0.37	0.19	0.37	0.00	0.0
Loc33	Richland TWP	0.34	0.14	0.34	0.00	0.0
Loc24	Jefferson Hills	0.66	0.42	0.65	0.01	1.5
Loc14	Churchill Munic Bldg	0.26	0.15	0.25	0.01	3.8
Loc05	Upper St. Clair	0.21	0.14	0.20	0.01	4.8
Loc27	Marshall TWP	0.17	0.08	0.16	0.01	5.9
Loc09	Univ of Pittsburgh	0.61	0.38	0.57	0.04	6.6
Loc10	PWSA-Highland Park	0.23	0.14	0.21	0.02	8.7
Loc31	Hampton Municipal Bldg	0.34	0.17	0.31	0.03	8.8
Loc19	Sandy Creek Eq Facility	0.21	0.11	0.19	0.02	9.5
Loc02	ALCOSAN WWTP Lab	0.19	0.08	0.17	0.02	10.5
Loc11	M-46 Access Shaft	0.26	0.14	0.23	0.03	11.5
Loc01	PWSA-Montana St.	0.22	0.10	0.18	0.04	18.2

Table 63. Summary of Individual RG Pairs for Event 13c

Gauge ID	Name	G_i (in)	R_i (in)	R_i^* (in)	Diff* (in)	Diff* (%)
Loc13	M-59 Access Shaft	0.23	0.17	0.26	-0.03	-13.0
KAGC	Pittsburgh Allegheny Cty	0.27	0.19	0.30	-0.03	-11.1
KPIT	Greater Pittsburgh Int'l	0.24	0.14	0.26	-0.02	-8.3
Loc20	Gascola Eq Facility	0.26	0.19	0.28	-0.02	-7.7
Loc16	Castle Shannon	0.29	0.17	0.30	-0.01	-3.4
Loc01	PWSA-Montana St.	0.35	0.22	0.36	-0.01	-2.9
Loc02	ALCOSAN WWTP Lab	0.35	0.23	0.36	-0.01	-2.9
Loc09	Univ of Pittsburgh	0.35	0.21	0.36	-0.01	-2.9
Loc06	Carnegie Transit Time	0.39	0.25	0.40	-0.01	-2.6
Loc10	PWSA-Highland Park	0.40	0.24	0.41	-0.01	-2.5
Loc30	McCandless Twn Hall	0.50	0.26	0.51	-0.01	-2.0
Loc05	Upper St. Clair	0.31	0.20	0.31	0.00	0.0
Loc07	Greentree Munic Bldg	0.43	0.27	0.43	0.00	0.0
Loc17	Chartiers Pump Station	0.36	0.22	0.36	0.00	0.0
Loc18	Oakdale Pump Station	0.49	0.28	0.49	0.00	0.0
Loc19	Sandy Creek Eq Facility	0.32	0.19	0.32	0.00	0.0
Loc23	Clinton Munic Bldg	0.33	0.14	0.33	0.00	0.0
Loc25	White Oak Public Works Bldg	0.28	0.32	0.28	0.00	0.0

Gauge ID	Name	G_i (in)	R_i (in)	R_i^* (in)	Diff* (in)	Diff* (%)
Loc29	Bell Acres Munic Bldg	0.44	0.24	0.44	0.00	0.0
Loc32	Arnold	0.24	0.16	0.24	0.00	0.0
Loc33	Richland TWP	0.43	0.23	0.43	0.00	0.0
Loc08	AC Health Dept Bldg	0.41	0.23	0.40	0.01	2.4
Loc22	North Fayette TWP	0.40	0.21	0.39	0.01	2.5
Loc04	Kennedy Twp PS	0.33	0.18	0.32	0.01	3.0
Loc03	Shaler Munic Bldg	0.26	0.14	0.25	0.01	3.8
03085734	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.23	0.13	0.22	0.01	4.3
Loc27	Marshall TWP	0.35	0.16	0.33	0.02	5.7
Loc21	Moon TWP	0.26	0.12	0.24	0.02	7.7
Loc14	Churchill Munic Bldg	0.25	0.14	0.23	0.02	8.0
Loc12	Baldwin	0.35	0.17	0.32	0.03	8.6
Loc11	M-46 Access Shaft	0.33	0.16	0.29	0.04	12.1

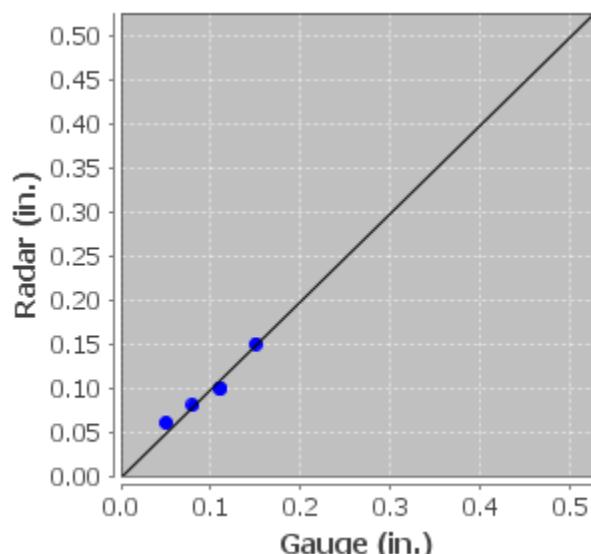


Figure 47. Scatter Plot of Gauge-Adjusted RG Pairs for Event 13a

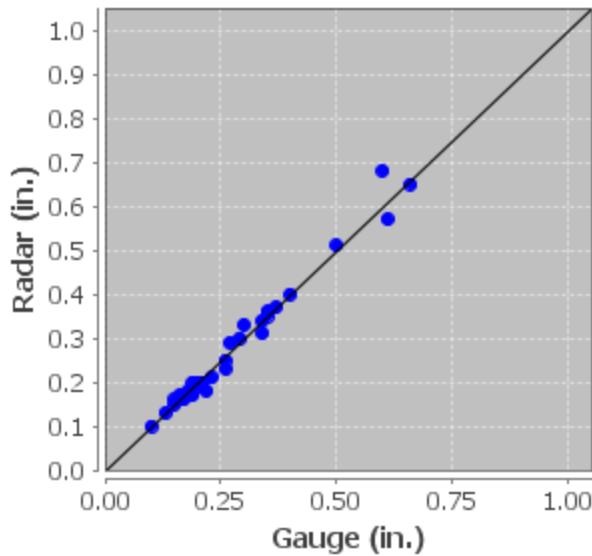


Figure 48. Scatter Plot of Gauge-Adjusted RG Pairs for Event 13b

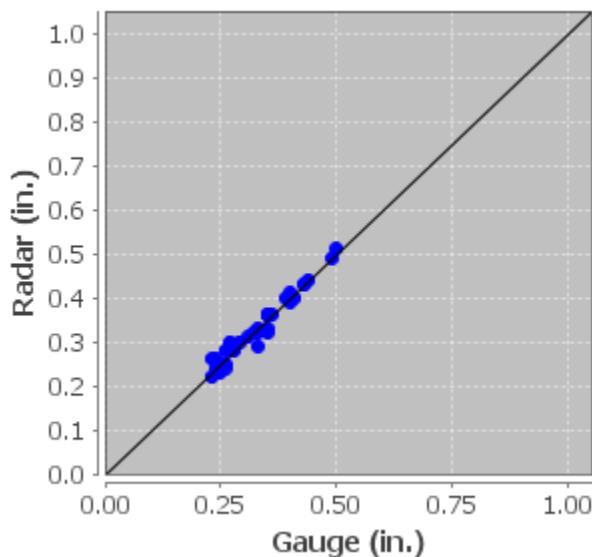


Figure 49. Scatter Plot of Gauge-Adjusted RG Pairs for Event 13c

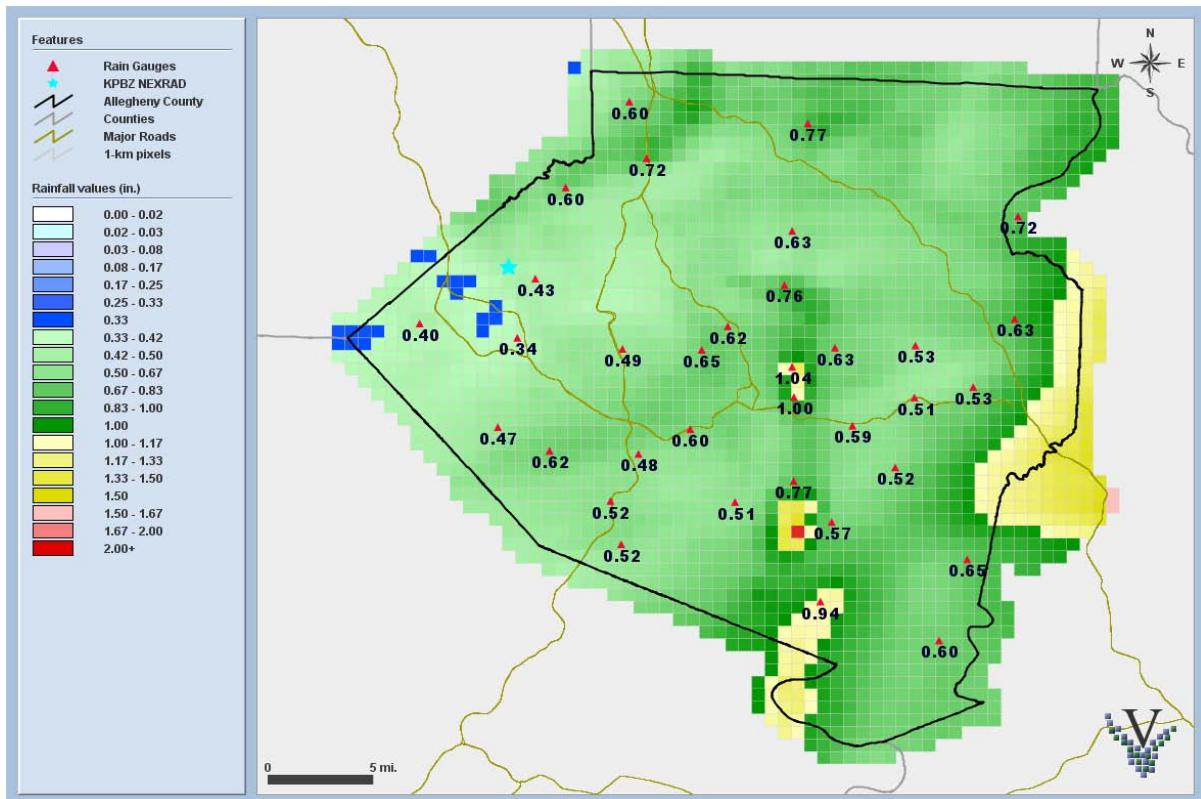


Figure 50. GARR Storm Total for Event 13

Table 64. Depth Duration Frequency Analyses for Event 13

Duration	Depth (in)	Pixel	Time (EDT)	Frequency
15 minutes	0.691	150149	2015-04-30 19:15	1 yr.
30 minutes	1.111	150149	2015-04-30 19:15	2 yr.
1 hour	1.239	150149	2015-04-30 19:45	2 yr.
2 hour	1.381	150149	2015-04-30 20:45	1 yr.
3 hour	1.576	150149	2015-04-30 21:45	1 yr.
6 hour	1.903	150149	2015-05-01 00:00	2 yr.
12 hour	1.916	150149	2015-05-01 00:00	1 yr.

Appendices

- [Appendix A](#) - Gauge Summary Table
- [Appendix B](#) - Event 1 (2015-04-02) CDPs
- [Appendix C](#) - Event 2 (2015-04-03) CDPs
- [Appendix D](#) - Event 3 (2015-04-07) CDPs
- [Appendix E](#) - Event 4 (2015-04-08 AM) CDPs
- [Appendix F](#) - Event 5 (2015-04-08 PM) CDPs
- [Appendix G](#) - Event 6 (2015-04-09 AM) CDPs
- [Appendix H](#) - Event 7 (2015-04-09 PM) CDPs
- [Appendix I](#) - Event 8 (2015-04-10) CDPs
- [Appendix J](#) - Event 9 (2015-04-13) CDPs
- [Appendix K](#) - Event 10 (2015-04-16) CDPs
- [Appendix L](#) - Event 11 (2015-04-19) CDPs
- [Appendix M](#) - Event 12 (2015-04-22) CDPs
- [Appendix N](#) - Event 13 (2015-04-30) CDPs

Appendix A - Gauge Summary Table

Reason	Explanation
Clog (C)	Gauge appeared to be clogged
Zero (Z)	Gauge did not report any rainfall while radar rainfall estimates reported significant rainfall
Stop (S)	Gauge appeared to stop reporting rainfall while radar rainfall estimates reported significant rainfall
Over (O)	Gauge appeared to significantly over-report rainfall as compared to radar rainfall estimates and surrounding gauges (e.g. anomalously high rainfall values caused by field calibration, data transmission error, or switch malfunctions)
Under (U)	Gauge appeared to significantly under-report as compared to radar rainfall estimates and surrounding Gauges (e.g. half-tipper)
Sync (SY)	Gauge appeared to be reporting out-of-sync with the radar rainfall estimates
Frozen/Melt (F/M)	Gauge not reporting properly due to frozen or melting precipitation
Other (T)	Combination of multiple reasons
No Data (ND)	Gauge reported "no data" for a significant amount of time

	<u>E1a</u>	<u>E1b</u>	<u>E1c</u>	<u>E1d</u>	<u>E2a</u>	<u>E2b</u>
Gauge	2015-04-02	2015-04-02	2015-04-02	2015-04-02	2015-04-03	2015-04-03
Loc01	U			U		
Loc02						
Loc03						
Loc04						
Loc05					U	
Loc06						
Loc07						
Loc08					U	U
Loc09						
Loc10						
Loc11						
Loc12						
Loc13					U	U
Loc14						
Loc15						
Loc16						
Loc17						
Loc18						
Loc19						
Loc20						
Loc21						
Loc22						
Loc23						
Loc24						
Loc25						
Loc26						
Loc27						
Loc28						

	<u>E1a</u>	<u>E1b</u>	<u>E1c</u>	<u>E1d</u>	<u>E2a</u>	<u>E2b</u>
Gauge	2015-04-02	2015-04-02	2015-04-02	2015-04-02	2015-04-03	2015-04-03
Loc29						
Loc30						
Loc31						
Loc32						
Loc33					O	
KAGC						
KPIT						
03049500	U		U		ND	ND
03085500	C	C	C	C	C	C
03085734					U	U

	<u>E3a</u>	<u>E3b</u>	<u>E4a</u>	<u>E4b</u>	<u>E4c</u>	<u>E5</u>
Gauge	2015-04-07	2015-04-07	2015-04-08 AM	2015-04-08 AM	2015-04-08 AM	2015-04-08 PM
Loc01						
Loc02						
Loc03						
Loc04						
Loc05						
Loc06				O		
Loc07						
Loc08						
Loc09						
Loc10						
Loc11						
Loc12						
Loc13						
Loc14						
Loc15						
Loc16						
Loc17						
Loc18						
Loc19						
Loc20						
Loc21						
Loc22						
Loc23						
Loc24						
Loc25						

	<u>E3a</u>	<u>E3b</u>	<u>E4a</u>	<u>E4b</u>	<u>E4c</u>	<u>E5</u>
Gauge	2015-04-07	2015-04-07	2015-04-08 AM	2015-04-08 AM	2015-04-08 AM	2015-04-08 PM
Loc26						
Loc27						
Loc28						
Loc29						
Loc30						
Loc31						
Loc32						
Loc33						
KAGC						
KPIT						
03049500	U	U				
03085500	C	C	C	C	C	C
03085734						Z

	<u>E6</u>	<u>E7a</u>	<u>E7b</u>	<u>E7c</u>	<u>E8a</u>	<u>E8b</u>
Gauge	2015-04-09 AM	2015-04-09 PM	2015-04-09 PM	2015-04-09 PM	2015-04-10	2015-04-10
Loc01		U				U
Loc02						
Loc03						O
Loc04						
Loc05		S	Z			
Loc06						
Loc07		O				
Loc08						
Loc09		O				
Loc10						
Loc11						
Loc12						
Loc13						
Loc14						
Loc15						
Loc16						
Loc17						
Loc18						
Loc19						
Loc20						
Loc21						
Loc22						
Loc23						
Loc24						
Loc25						

	<u>E6</u>	<u>E7a</u>	<u>E7b</u>	<u>E7c</u>	<u>E8a</u>	<u>E8b</u>
Gauge	2015-04-09 AM	2015-04-09 PM	2015-04-09 PM	2015-04-09 PM	2015-04-10	2015-04-10
Loc26						
Loc27						
Loc28						
Loc29						
Loc30						
Loc31						
Loc32						
Loc33						
KAGC						
KPIT		U	O			
03049500	U	U	U	U		
03085500	C	C	C	C	C	C
03085734	Z	Z	Z			Z

	<u>E8c</u>	<u>E8d</u>	<u>E9a</u>	<u>E9b</u>	<u>E10a</u>	<u>E10b</u>
Gauge	2015-04-10	2015-04-10	2015-04-13	2015-04-13	2015-04-16	2015-04-16
Loc01	U	U				
Loc02						
Loc03						
Loc04						
Loc05						
Loc06						
Loc07						
Loc08			Z	S		U
Loc09						
Loc10						
Loc11						
Loc12						
Loc13						
Loc14						
Loc15						
Loc16						
Loc17						
Loc18						
Loc19						
Loc20						
Loc21	O					
Loc22						
Loc23						
Loc24						C
Loc25						
Loc26						

	<u>E8c</u>	<u>E8d</u>	<u>E9a</u>	<u>E9b</u>	<u>E10a</u>	<u>E10b</u>
Gauge	2015-04-10	2015-04-10	2015-04-13	2015-04-13	2015-04-16	2015-04-16
Loc27						
Loc28						
Loc29						
Loc30						
Loc31						
Loc32						
Loc33						
KAGC						
KPIT						
03049500	U	U		U		U
03085500	C	C	C	C	C	C
03085734	Z	Z	ND	ND	Z	

	<u>E10c</u>	<u>E11a</u>	<u>E11b</u>	<u>E11c</u>	<u>E11d</u>	<u>E11e</u>
Gauge	2015-04-16	2015-04-19	2015-04-19	2015-04-19	2015-04-19	2015-04-19
Loc01						
Loc02		U	U	U	U	U
Loc03						
Loc04						
Loc05						
Loc06						
Loc07						
Loc08	Z	Z			Z	Z
Loc09						
Loc10						
Loc11						
Loc12						
Loc13						
Loc14						
Loc15						
Loc16						
Loc17						
Loc18						
Loc19						
Loc20						
Loc21						
Loc22						
Loc23						
Loc24	C	C	C	C	C	C
Loc25						
Loc26						

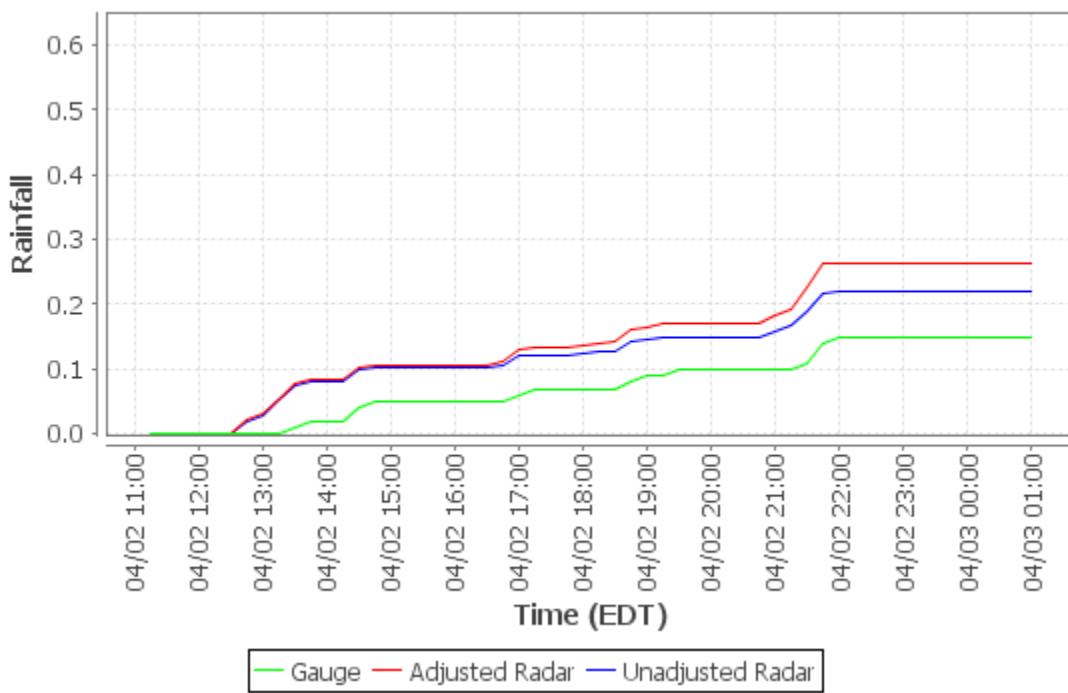
	<u>E10c</u>	<u>E11a</u>	<u>E11b</u>	<u>E11c</u>	<u>E11d</u>	<u>E11e</u>
Gauge	2015-04-16	2015-04-19	2015-04-19	2015-04-19	2015-04-19	2015-04-19
Loc27						
Loc28						
Loc29						
Loc30						
Loc31						
Loc32						
Loc33						
KAGC						
KPIT						
03049500	U		U	U	U	U
03085500	C	C	C	C	C	C
03085734	ND	ND	S			

	<u>E12a</u>	<u>E12b</u>	<u>E13a</u>	<u>E13b</u>	<u>E13c</u>
Gauge	2015-04-22	2015-04-22	2015-04-30	2015-04-30	2015-04-30
Loc01					
Loc02					
Loc03					
Loc04					
Loc05					
Loc06					
Loc07					
Loc08	S	U			
Loc09					
Loc10					
Loc11					
Loc12					
Loc13					
Loc14					
Loc15					
Loc16					
Loc17					
Loc18					
Loc19					
Loc20					
Loc21					
Loc22					
Loc23					
Loc24					
Loc25					
Loc26					

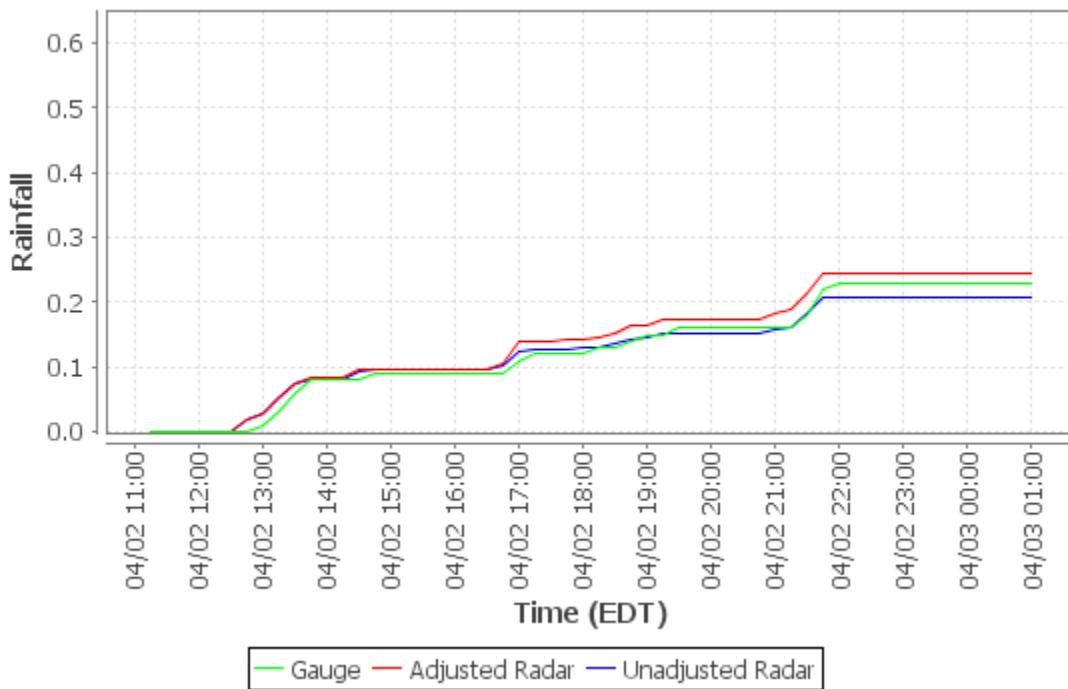
	<u>E12a</u>	<u>E12b</u>	<u>E13a</u>	<u>E13b</u>	<u>E13c</u>
Gauge	2015-04-22	2015-04-22	2015-04-30	2015-04-30	2015-04-30
Loc27					
Loc28					
Loc29					
Loc30					
Loc31					
Loc32					
Loc33					
KAGC					
KPIT					
03049500	U	U		U	U
03085500	C	C	C	C	C
03085734			ND		

Appendix B - Event 1 (2015-04-02) CDPs

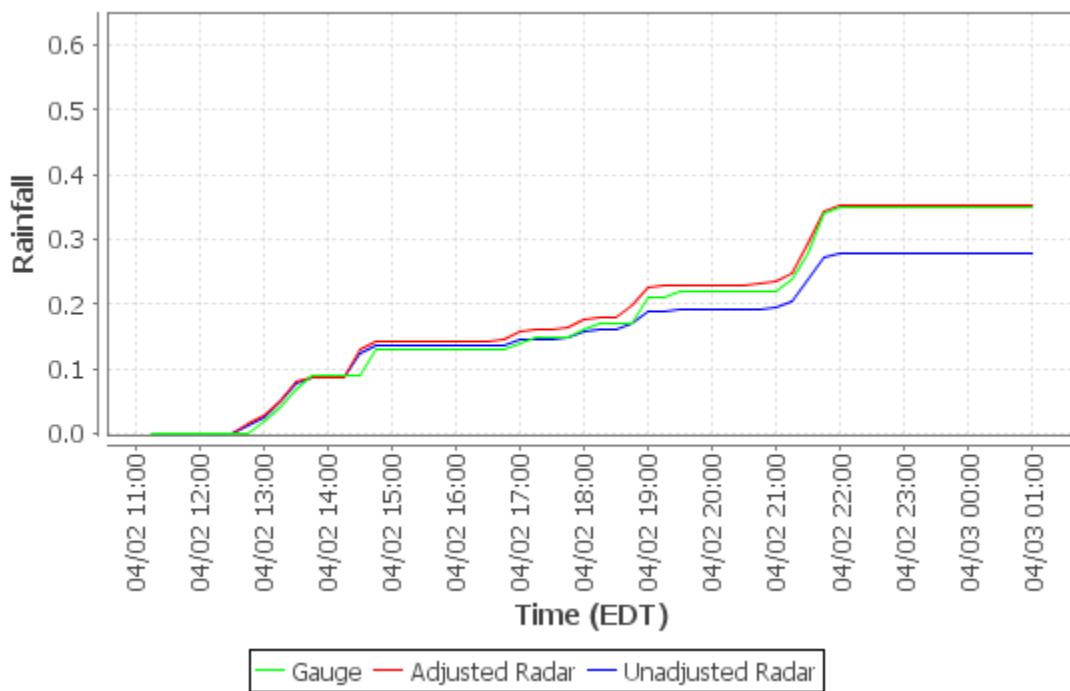
Cumulative Distribution Plot - PWSA-Montana St. (Loc01)



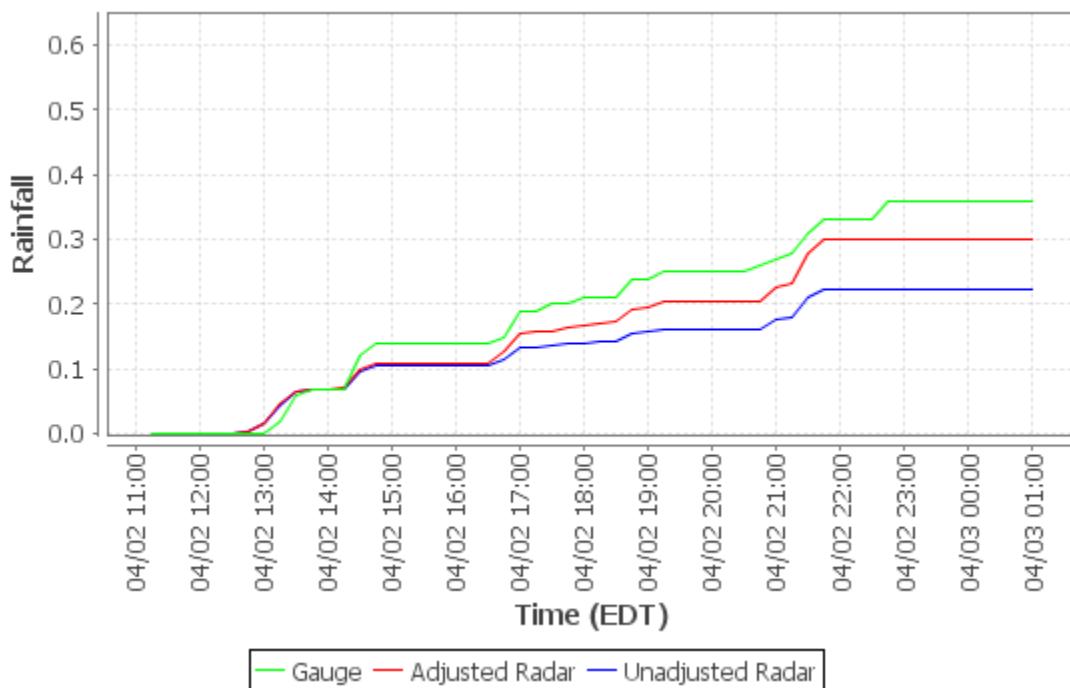
Cumulative Distribution Plot - ALCOSAN WWTP Lab (Loc02)



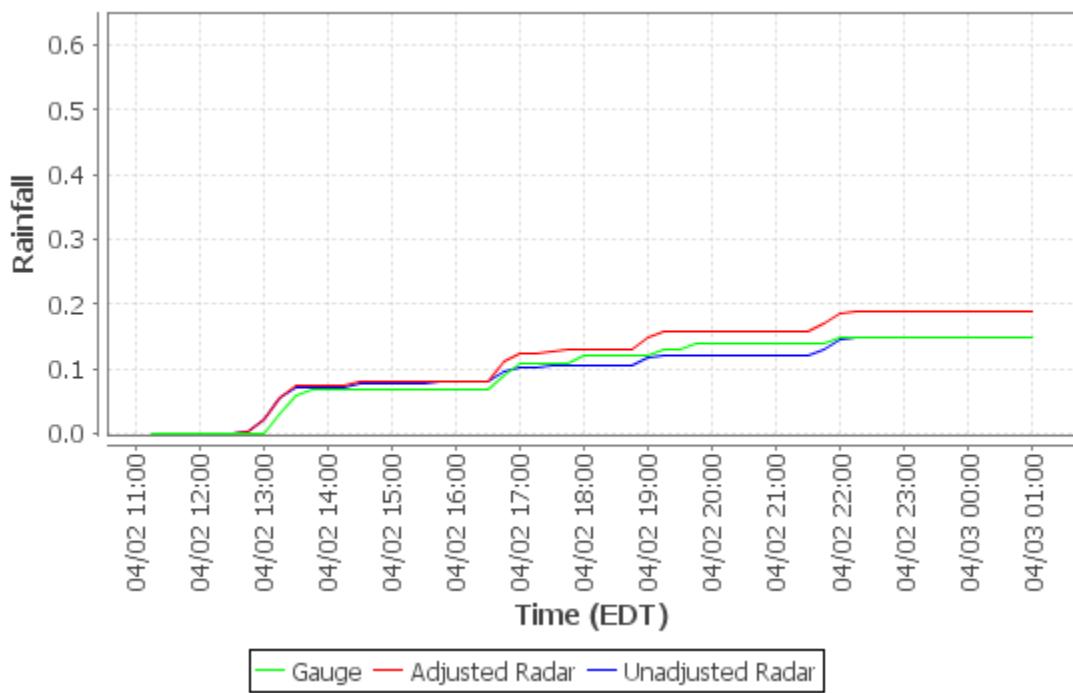
Cumulative Distribution Plot - Shaler Munic Bldg (Loc03)



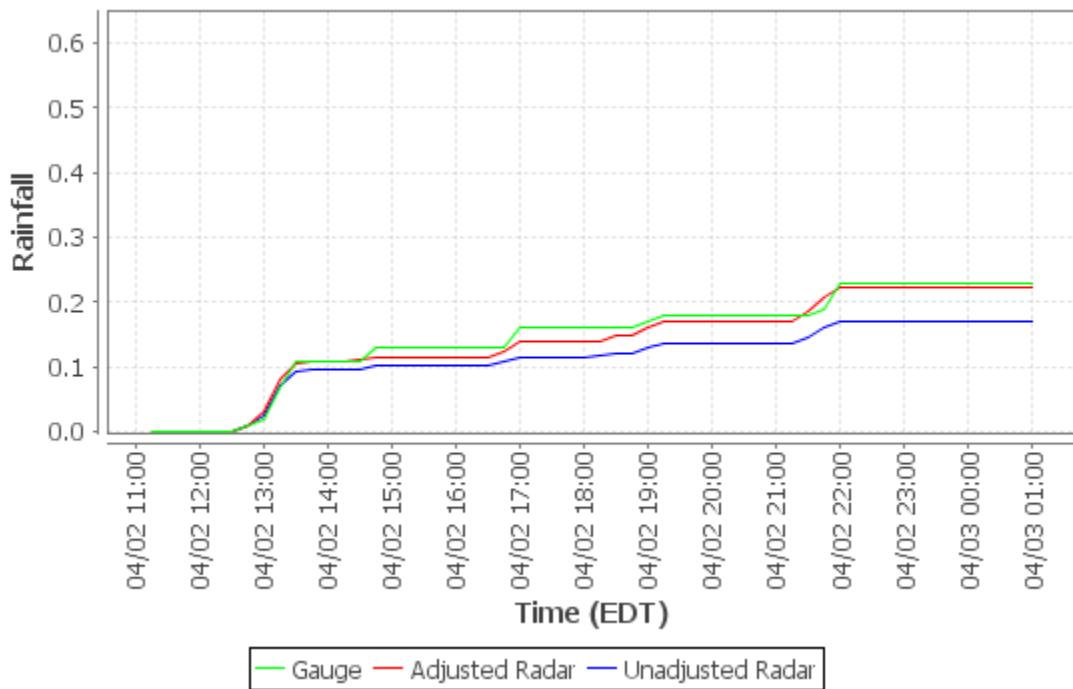
Cumulative Distribution Plot - Kennedy Twp PS (Loc04)



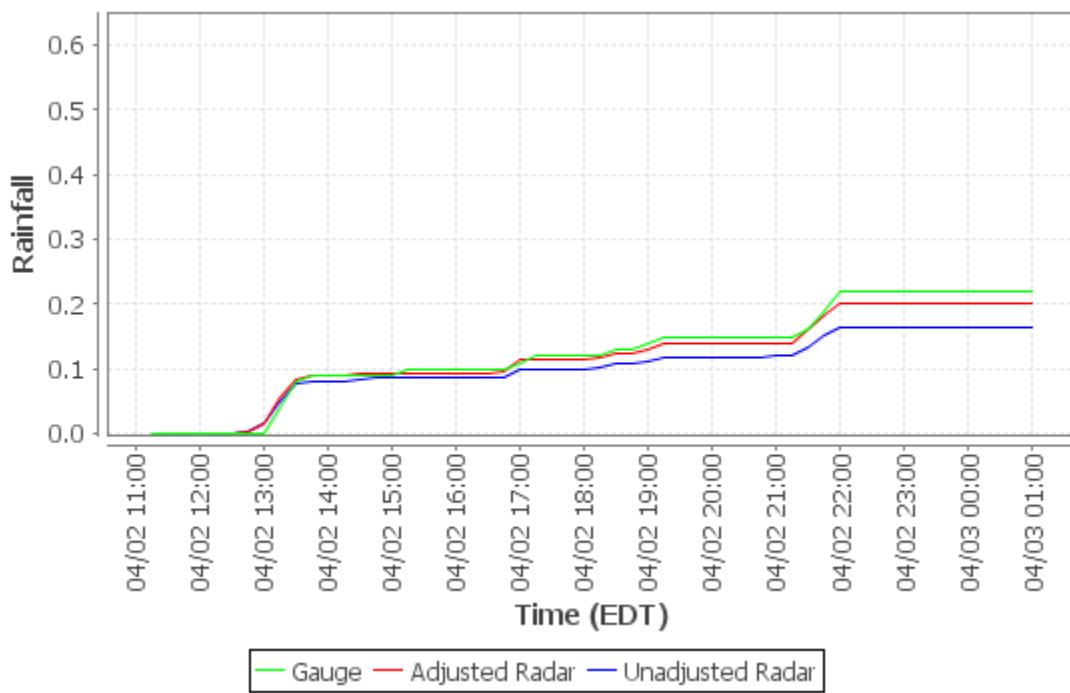
Cumulative Distribution Plot - Upper St. Clair (Loc05)



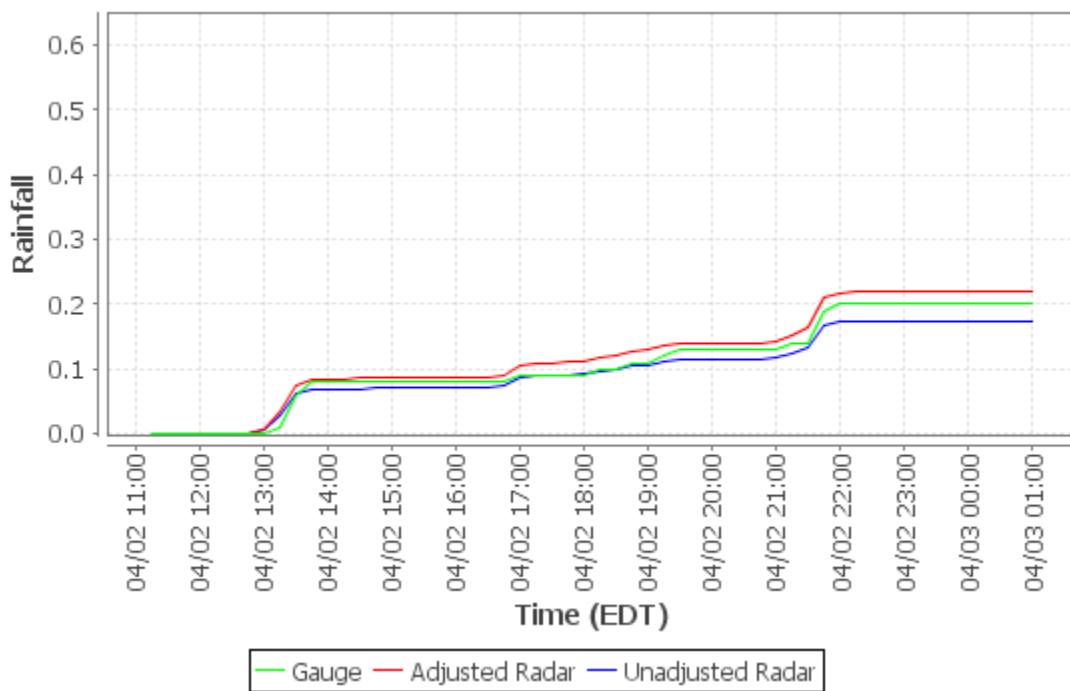
Cumulative Distribution Plot - Carnegie Transit Time (Loc06)



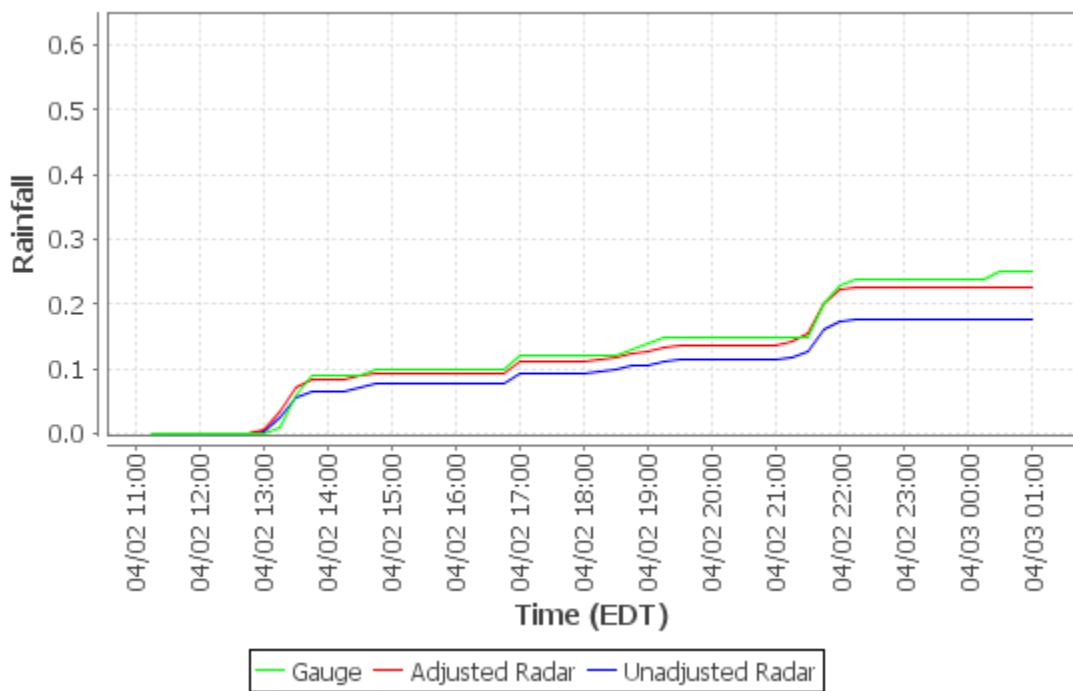
Cumulative Distribution Plot - Greentree Munic Bldg (Loc07)



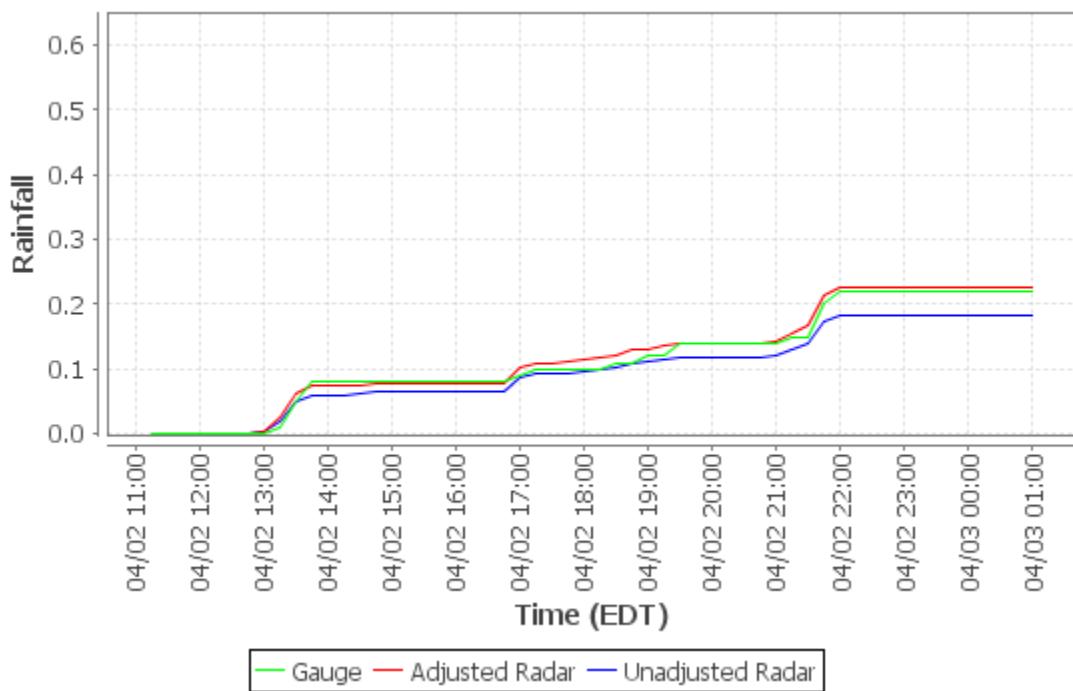
Cumulative Distribution Plot - AC Health Dept Bldg (Loc08)



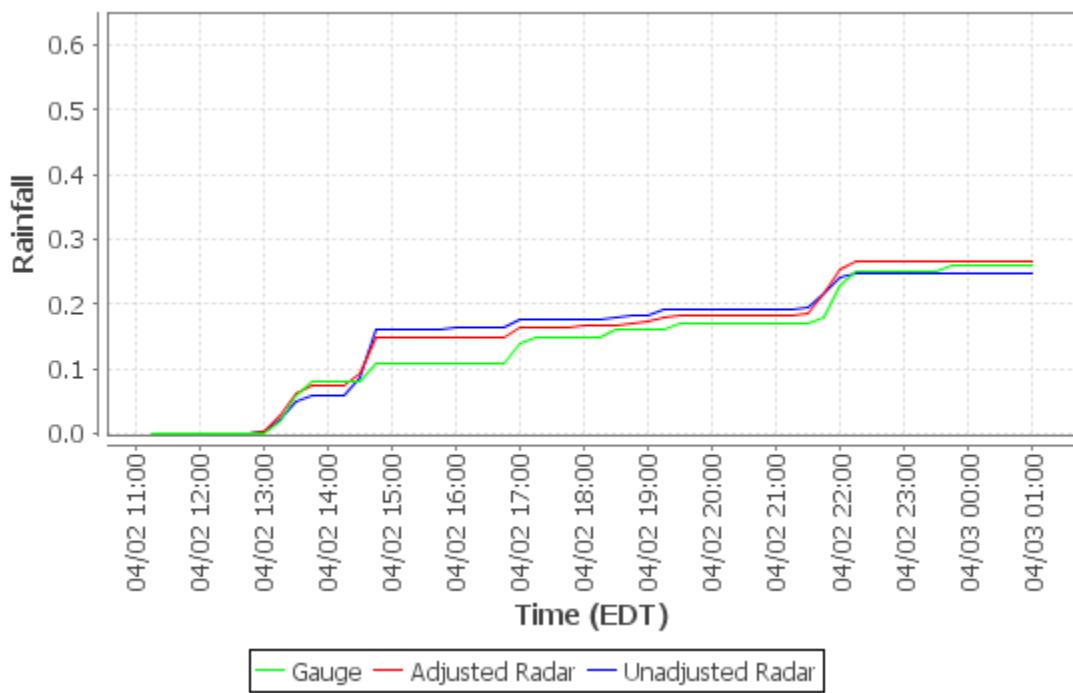
Cumulative Distribution Plot - Univ of Pittsburgh (Loc09)



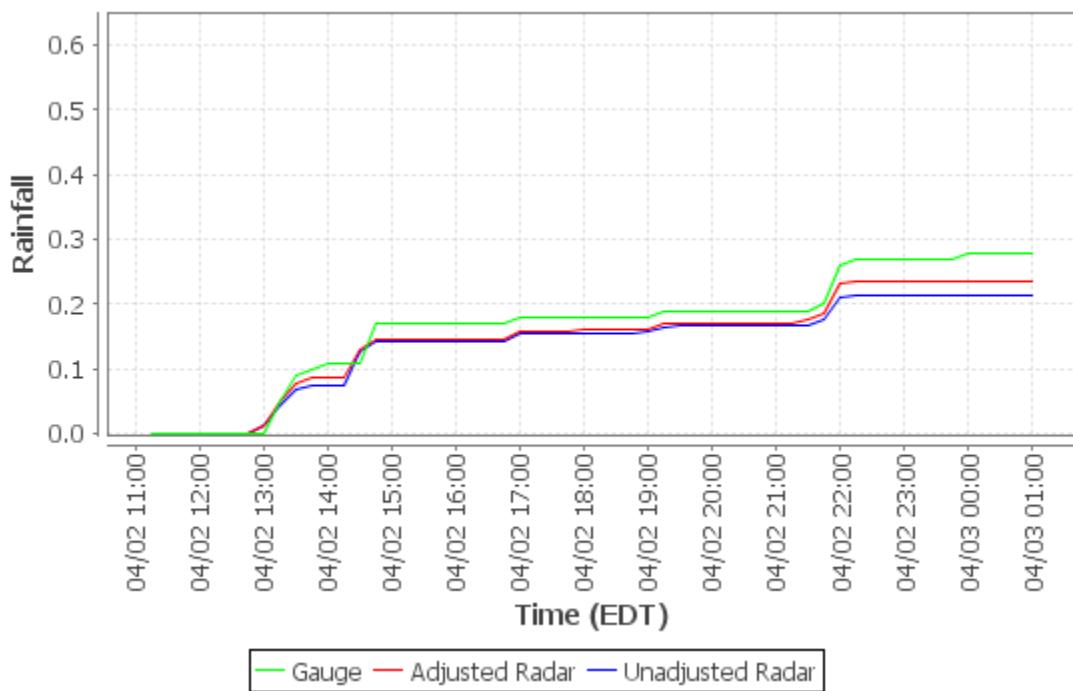
Cumulative Distribution Plot - PWSA-Highland Park (Loc10)



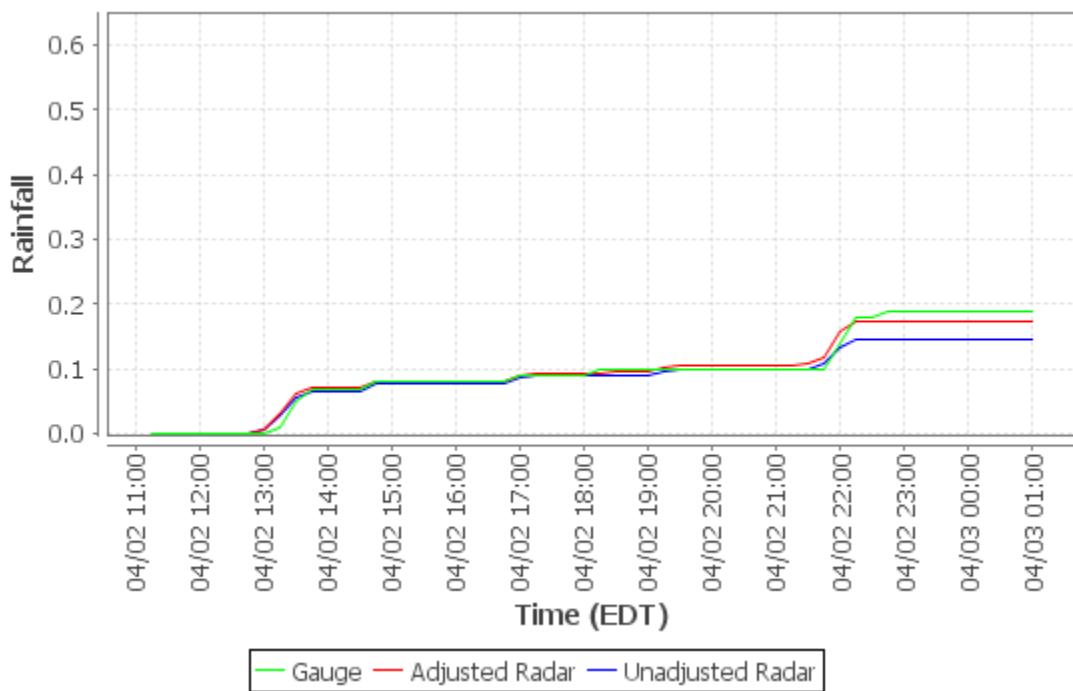
Cumulative Distribution Plot - M-46 Access Shaft (Loc11)



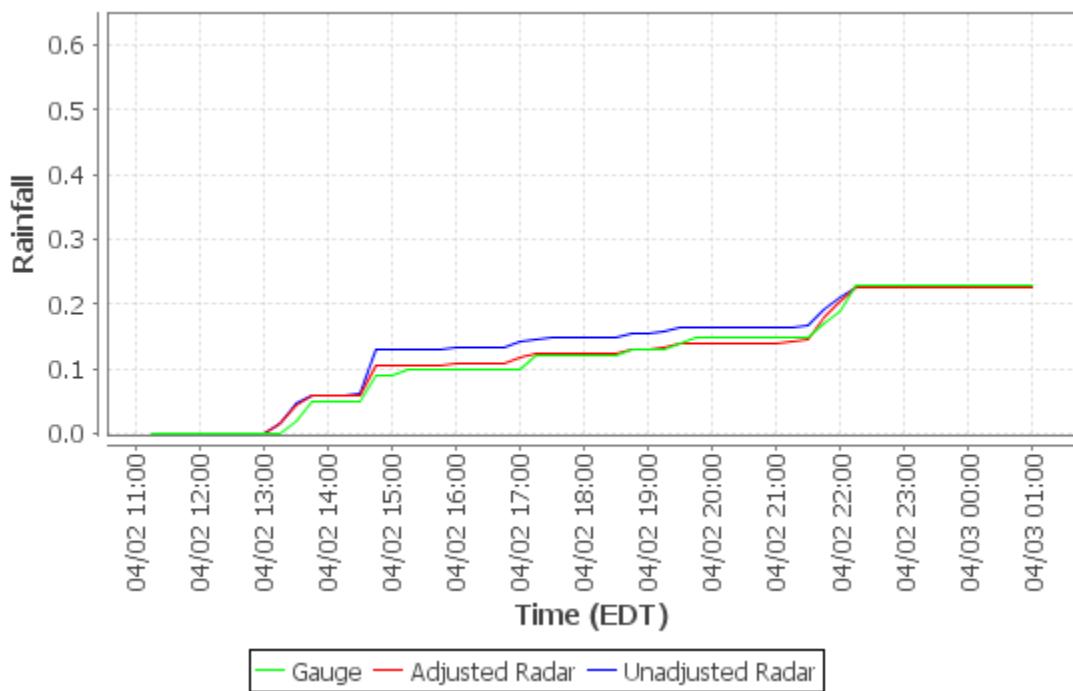
Cumulative Distribution Plot - Baldwin (Loc12)



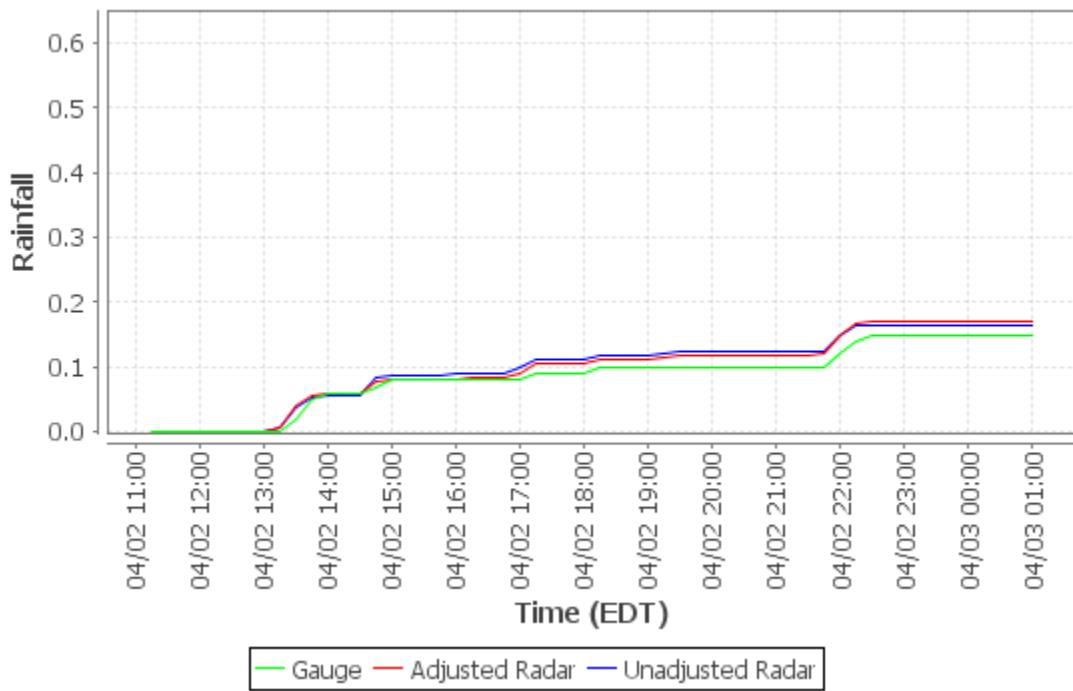
Cumulative Distribution Plot - M-59 Access Shaft (Loc13)



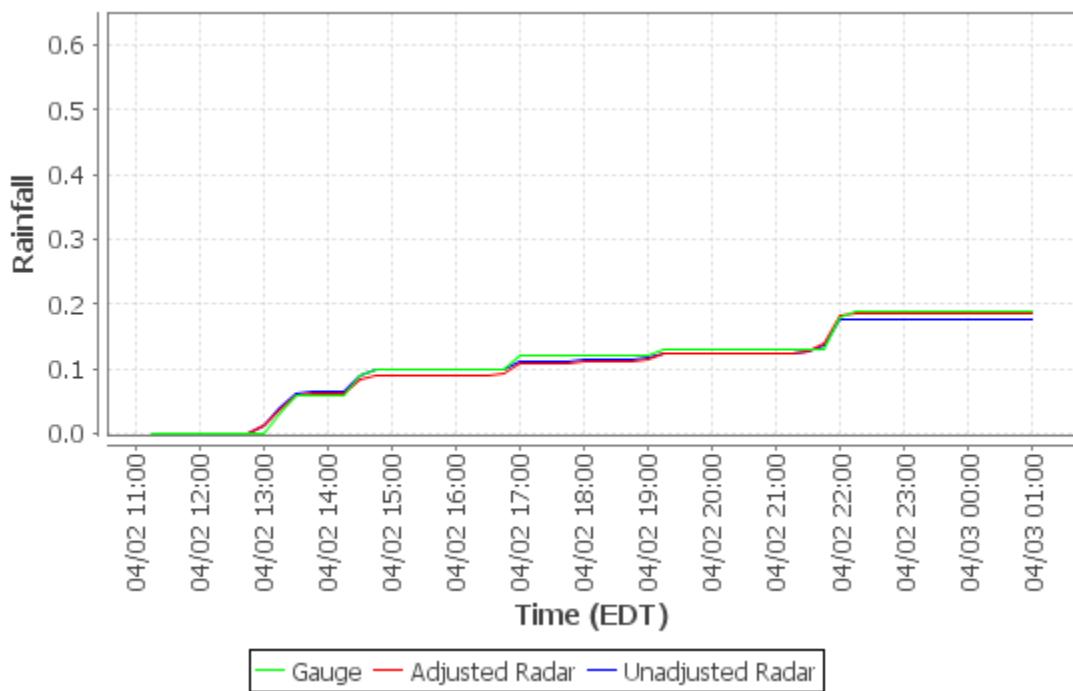
Cumulative Distribution Plot - Churchill Munic Bldg (Loc14)



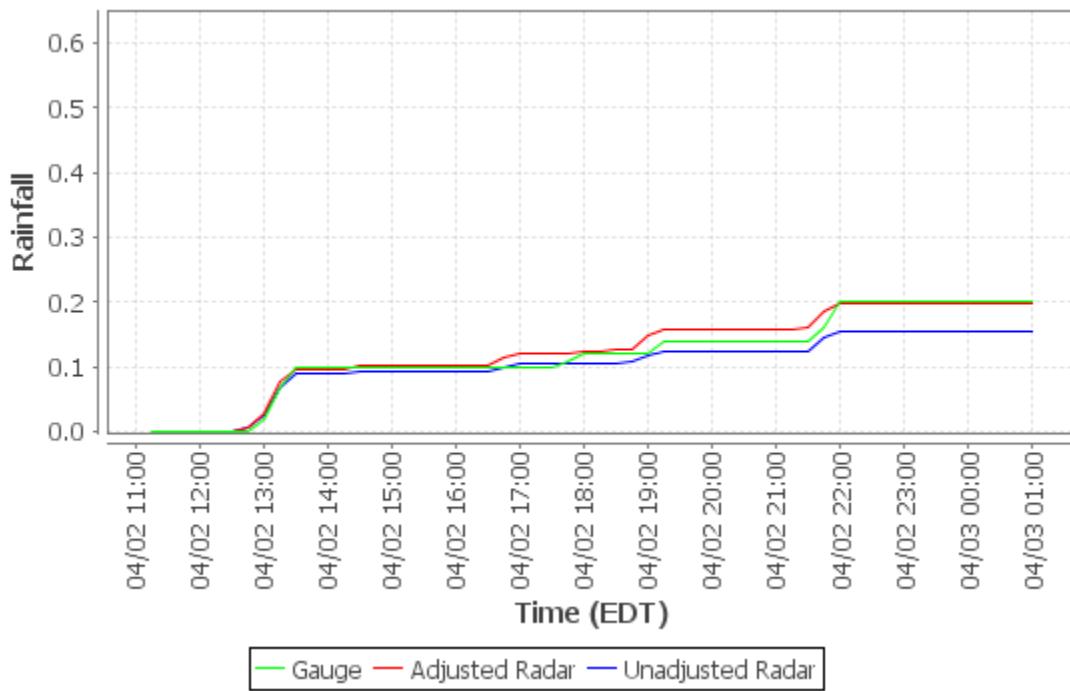
Cumulative Distribution Plot - Trafford Maint Bldg (Loc15)



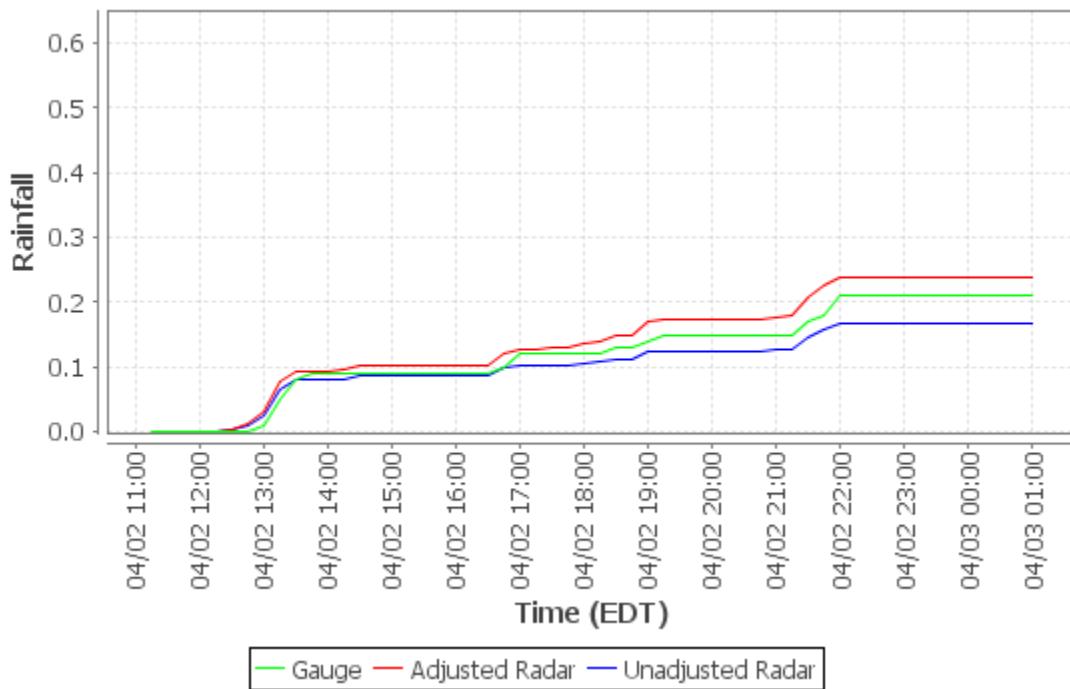
Cumulative Distribution Plot - Castle Shannon (Loc16)



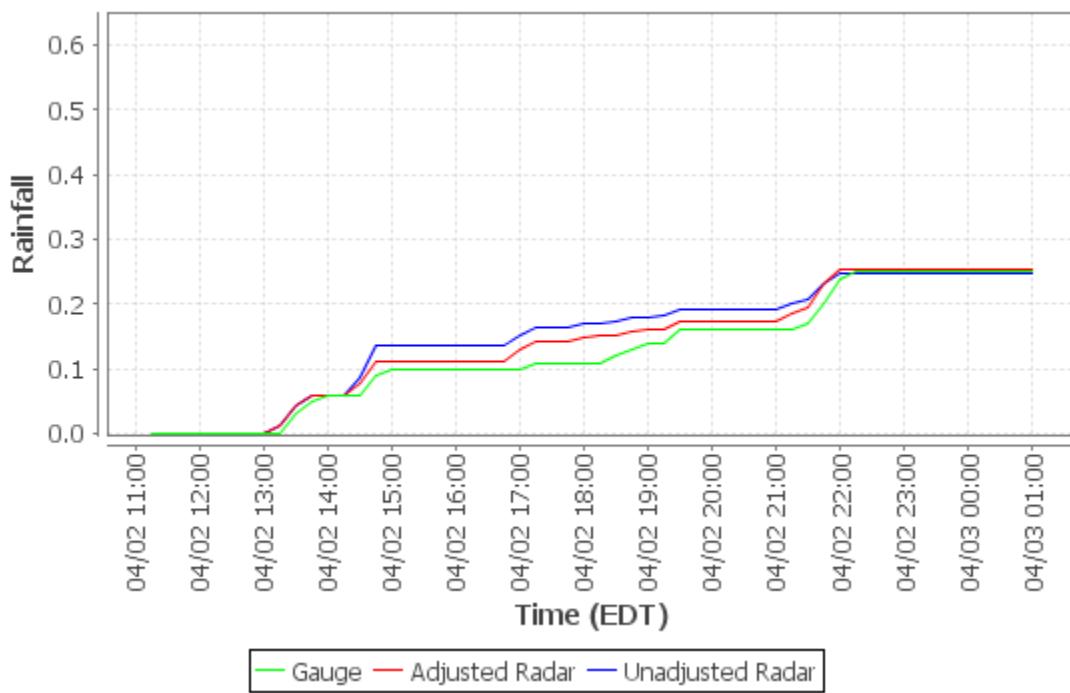
Cumulative Distribution Plot - Chartiers Pump Station (Loc17)



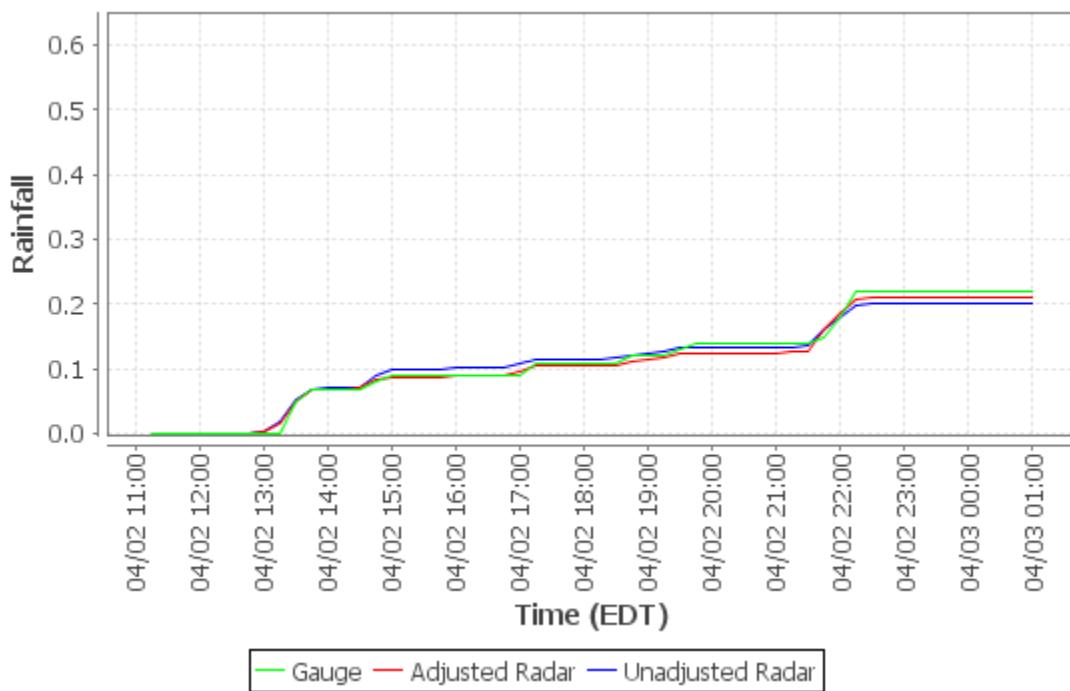
Cumulative Distribution Plot - Oakdale Pump Station (Loc18)



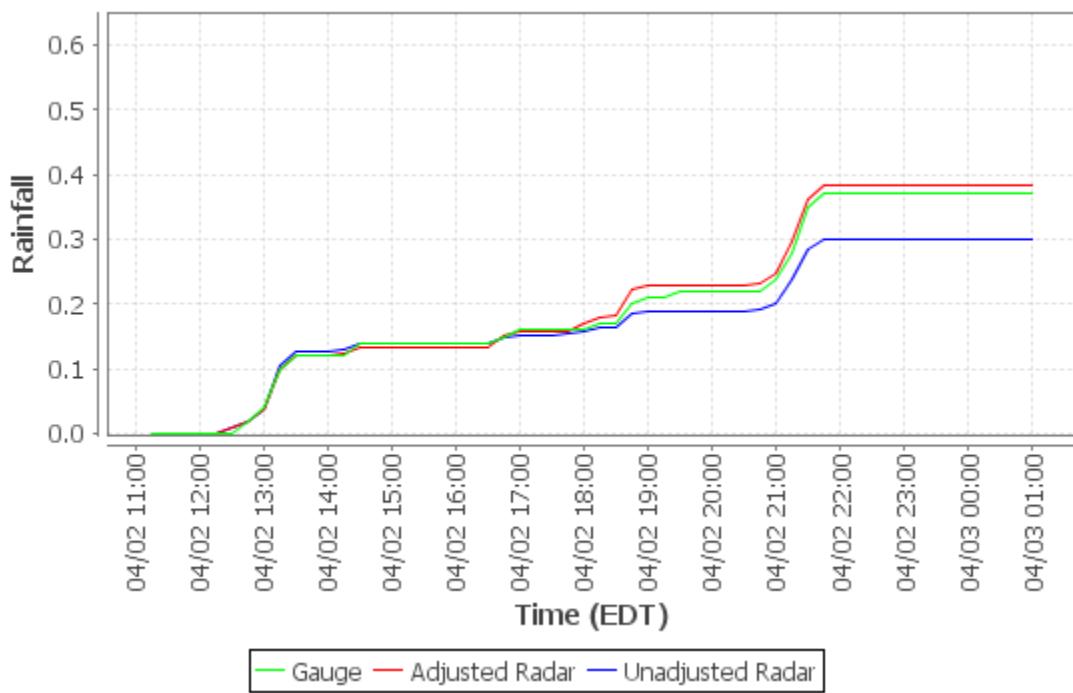
Cumulative Distribution Plot - Sandy Creek Eq Facility (Loc19)



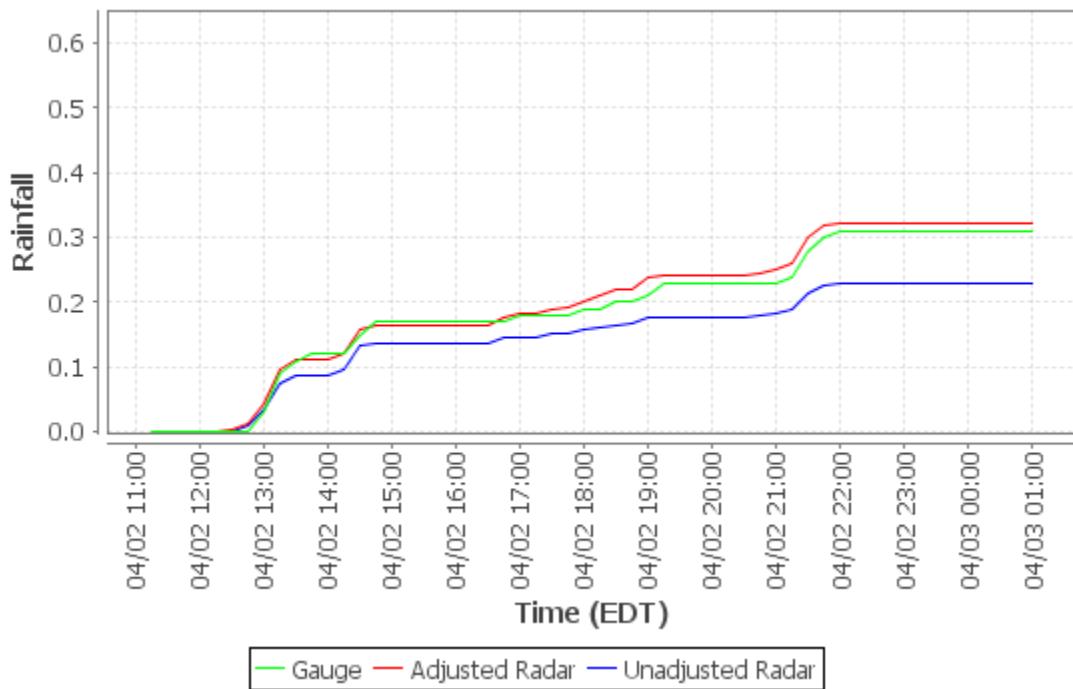
Cumulative Distribution Plot - Gascola Eq Facility (Loc20)



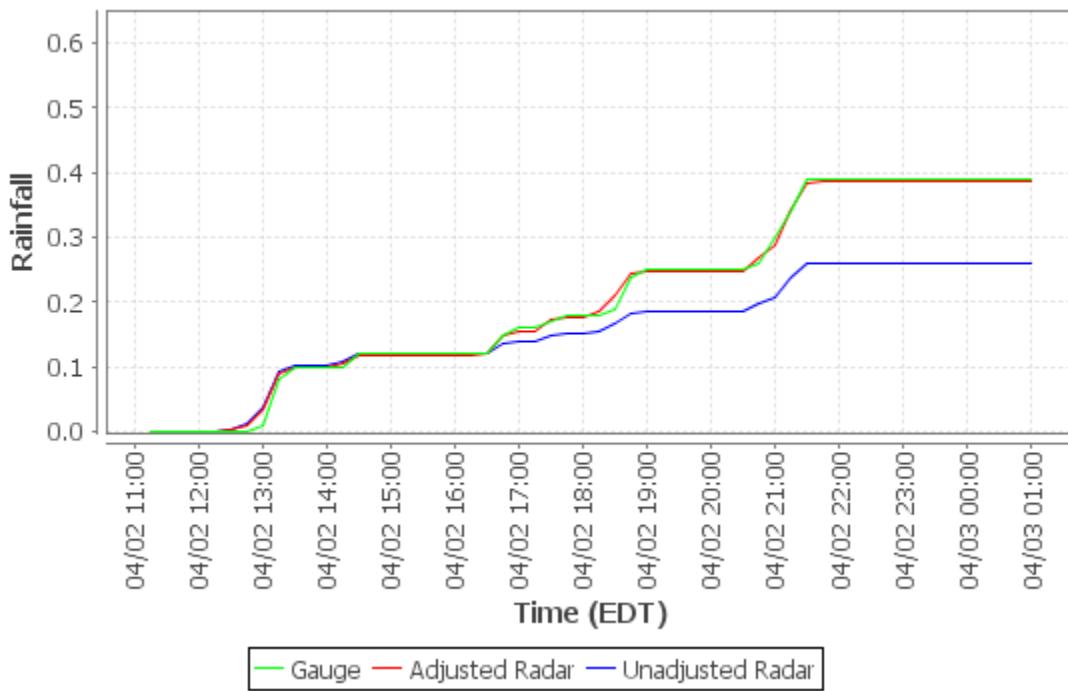
Cumulative Distribution Plot - Moon TWP (Loc21)



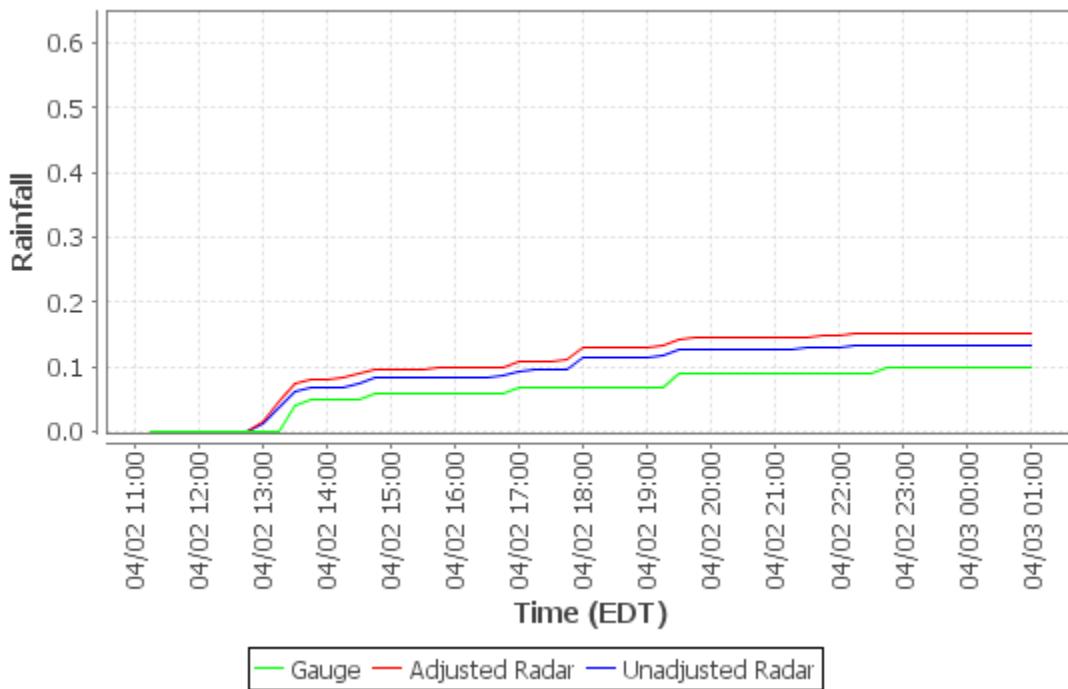
Cumulative Distribution Plot - North Fayette TWP (Loc22)



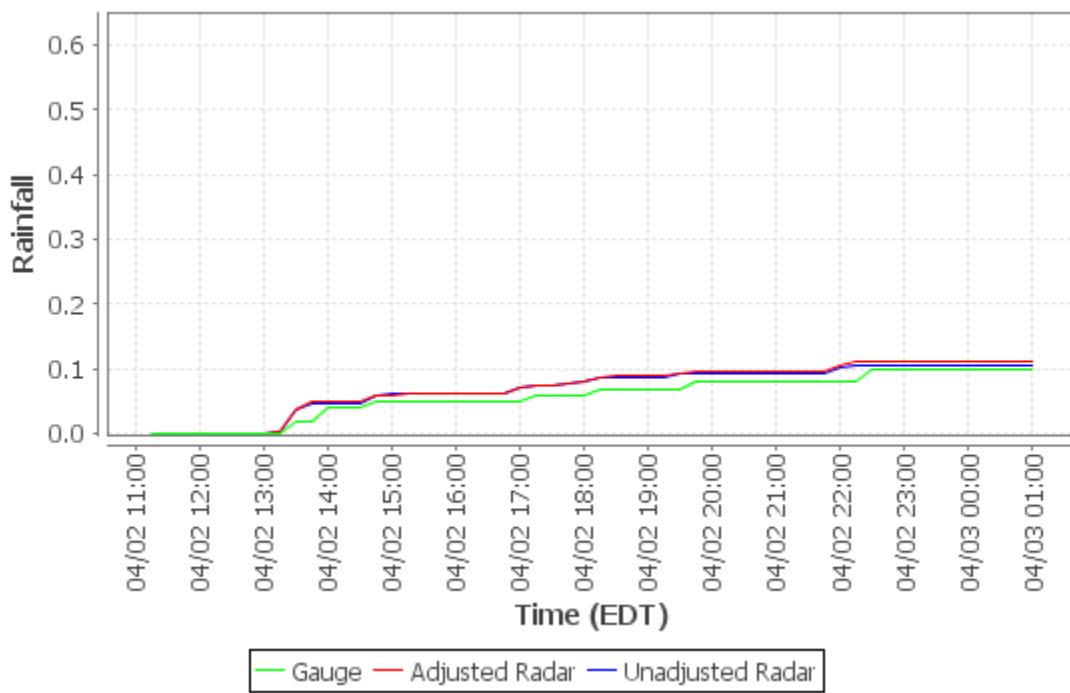
Cumulative Distribution Plot - Clinton Munic Bldg (Loc23)



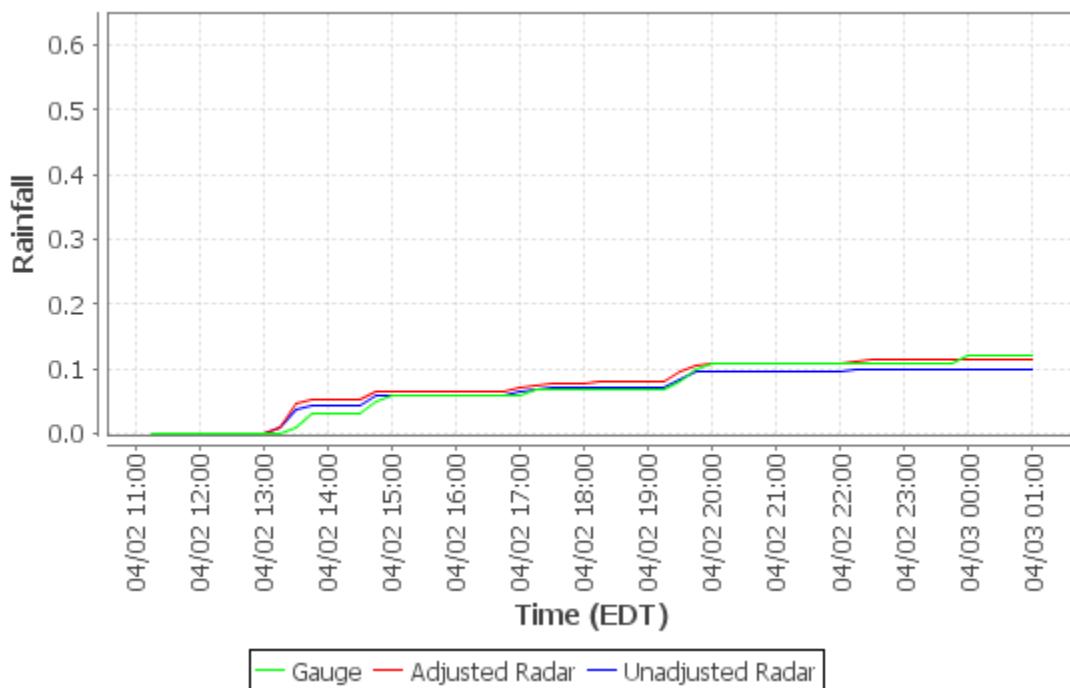
Cumulative Distribution Plot - Jefferson Hills (Loc24)



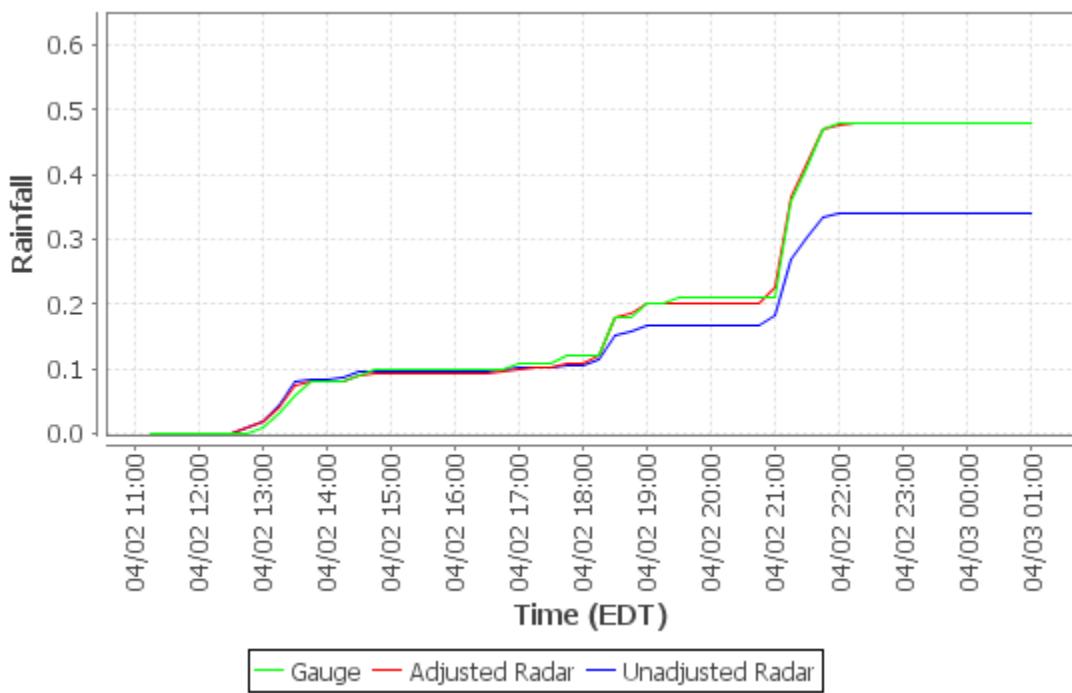
Cumulative Distribution Plot - White Oak Public Works Bldg (Loc25)



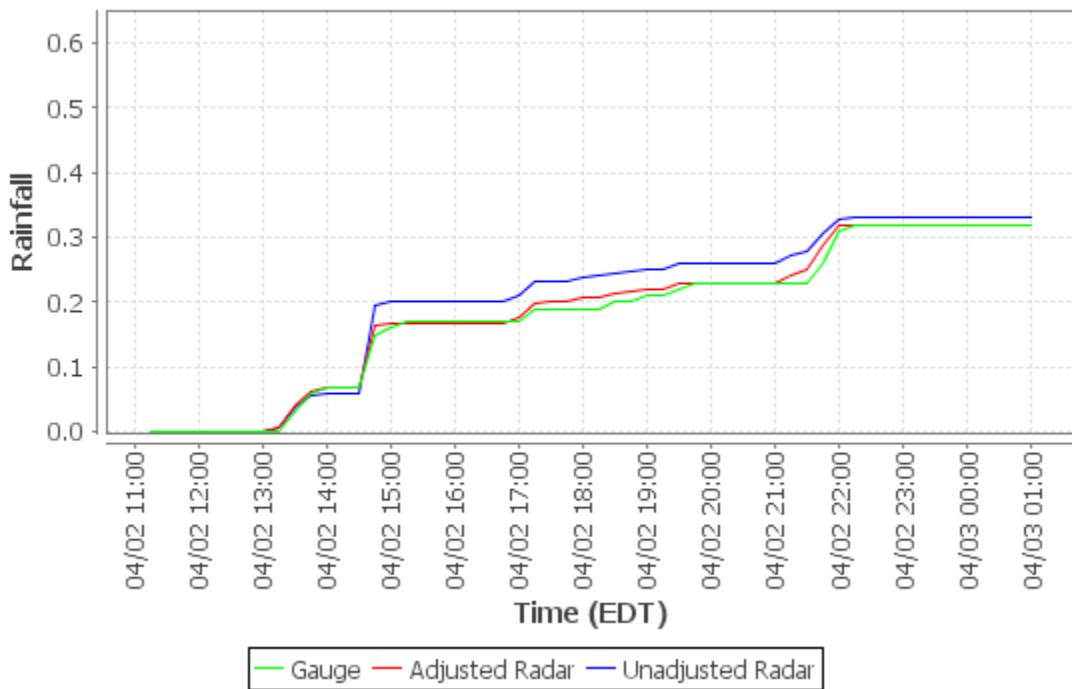
Cumulative Distribution Plot - Elizabeth TWP Municipal Bldg (Loc26)



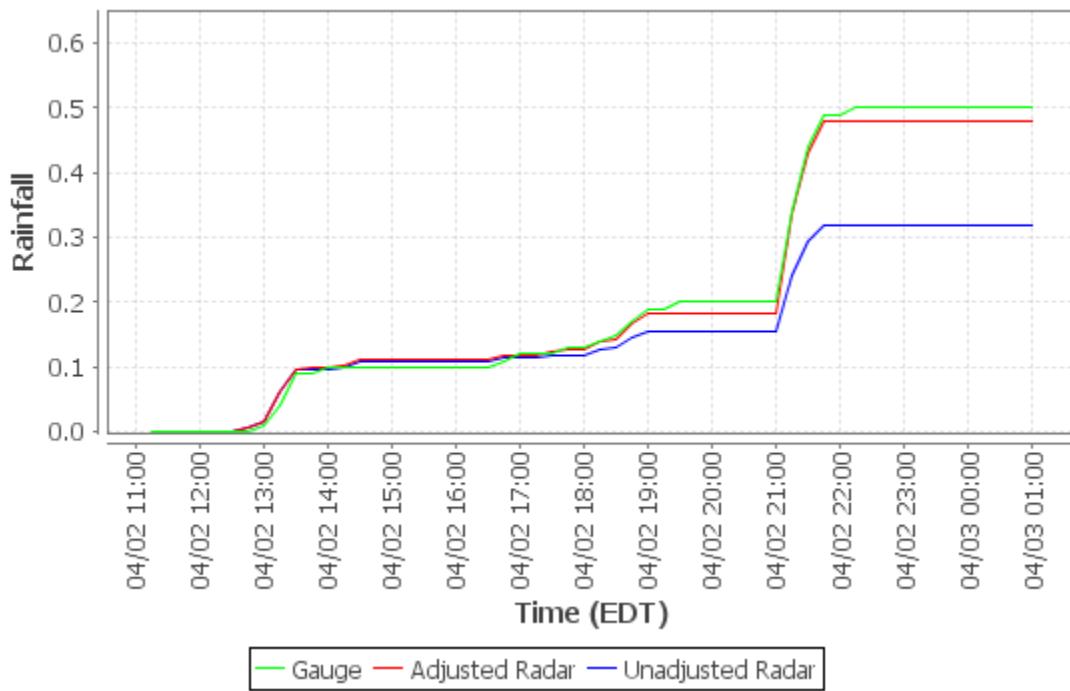
Cumulative Distribution Plot - Marshall TWP (Loc27)



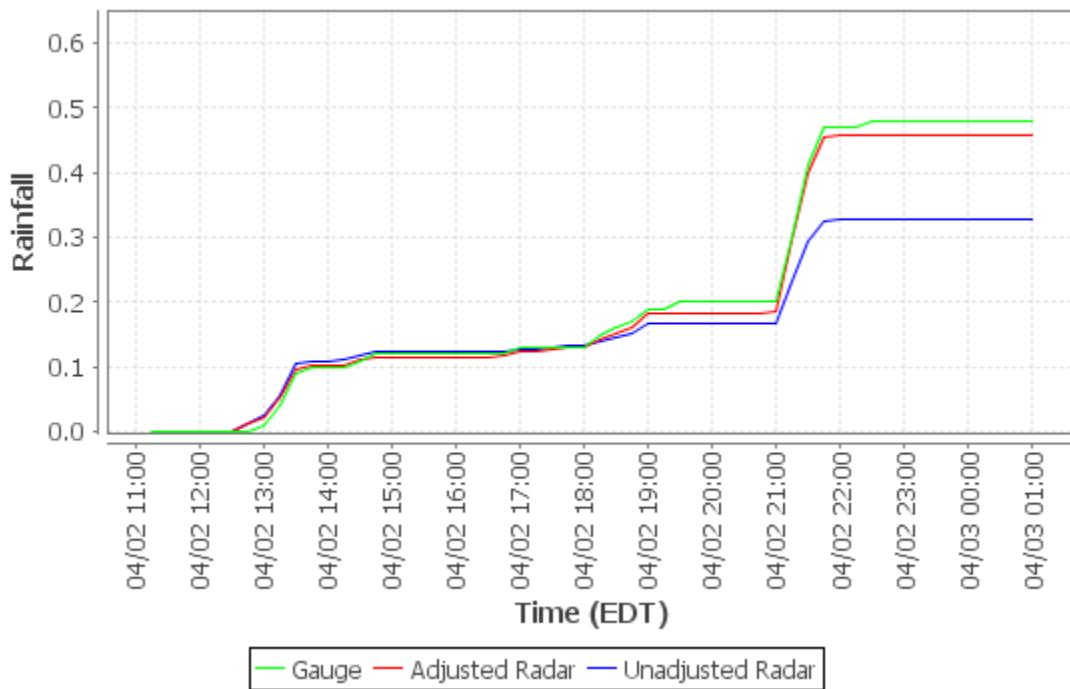
Cumulative Distribution Plot - Plum Municipal Bldg (Loc28)



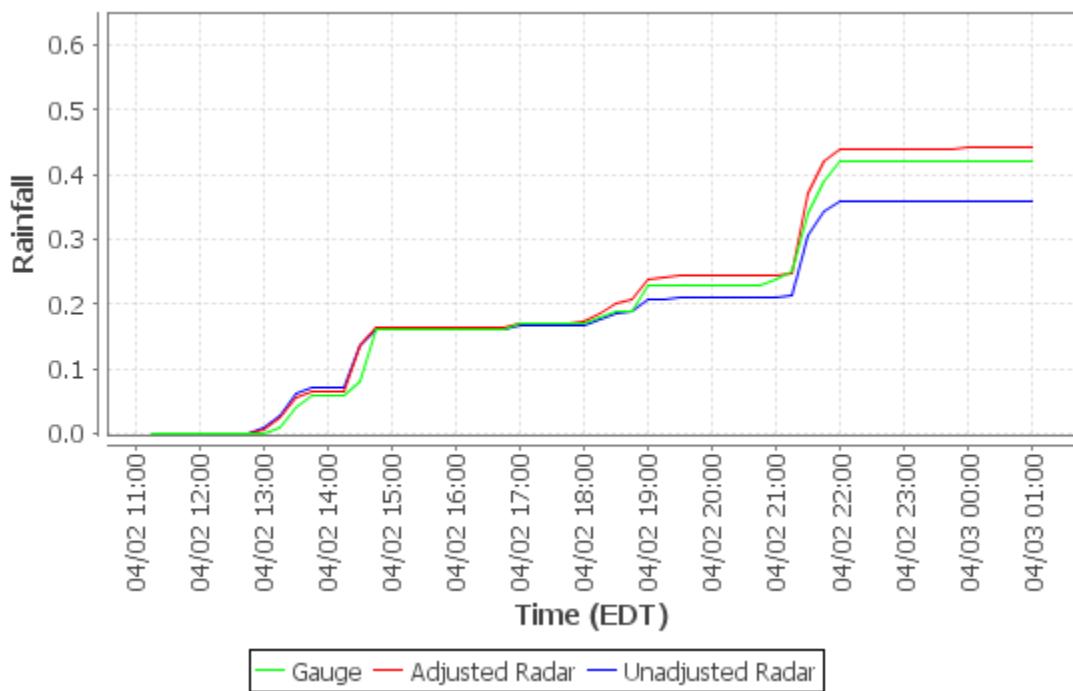
Cumulative Distribution Plot - Bell Acres Munic Bldg (Loc29)



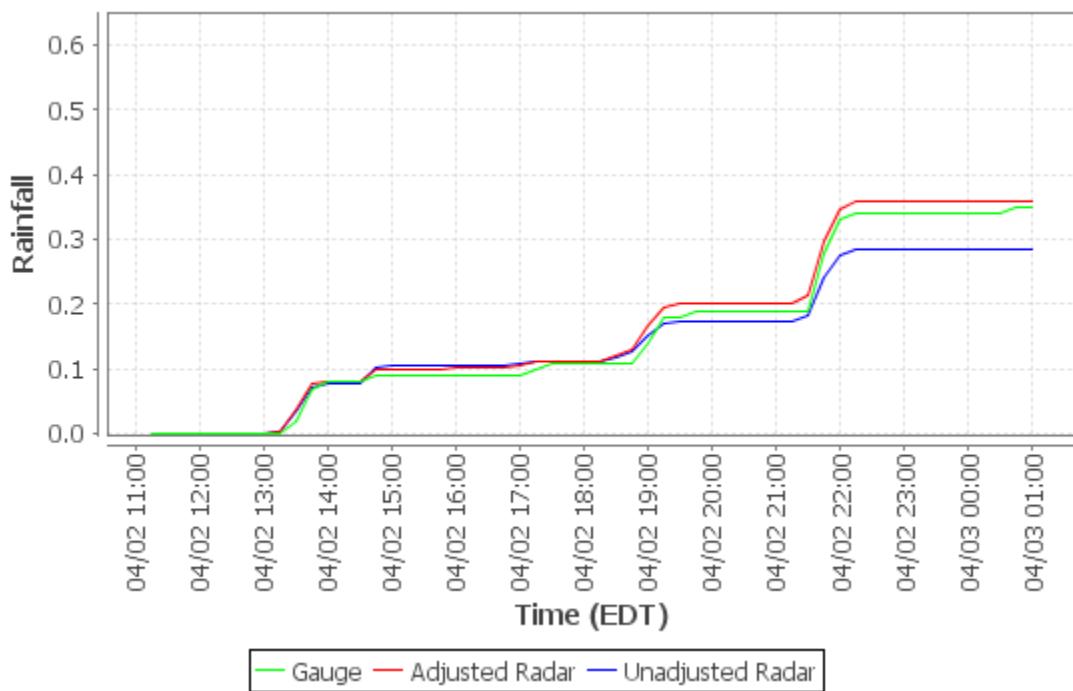
Cumulative Distribution Plot - McCandless Twn Hall (Loc30)



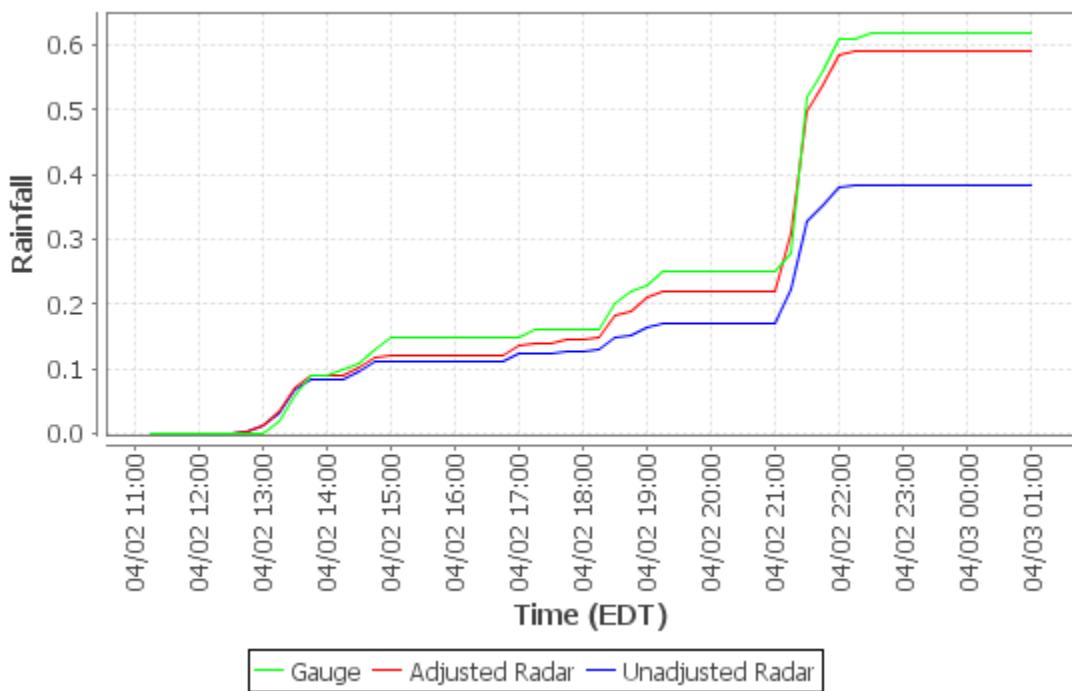
Cumulative Distribution Plot - Hampton Municipal Bldg (Loc31)



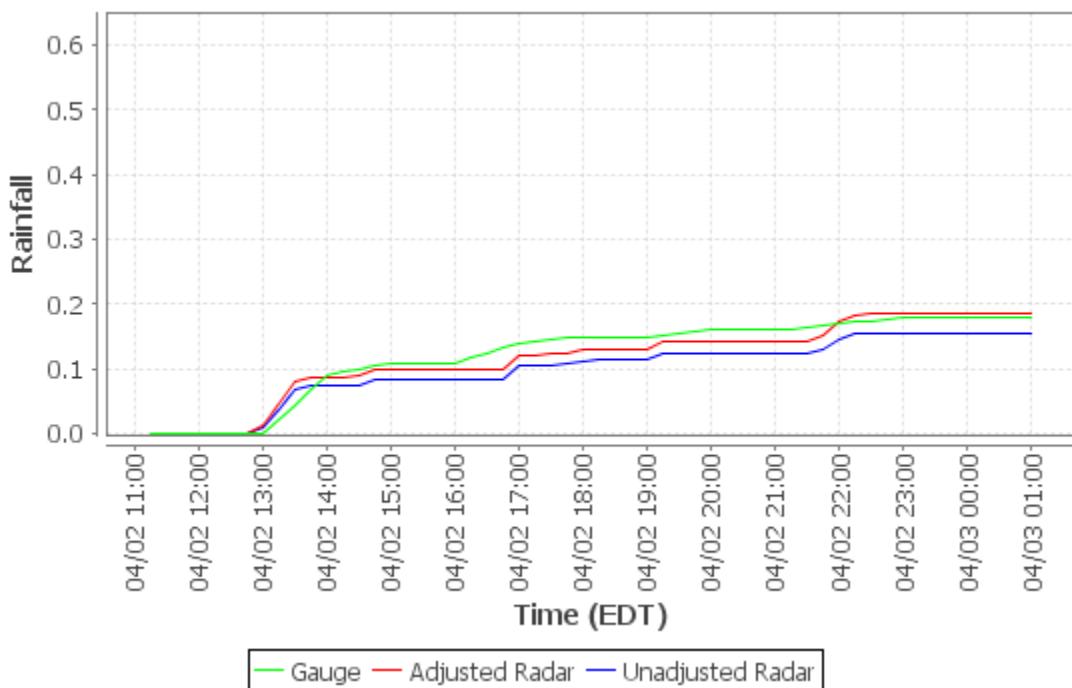
Cumulative Distribution Plot - Arnold (Loc32)



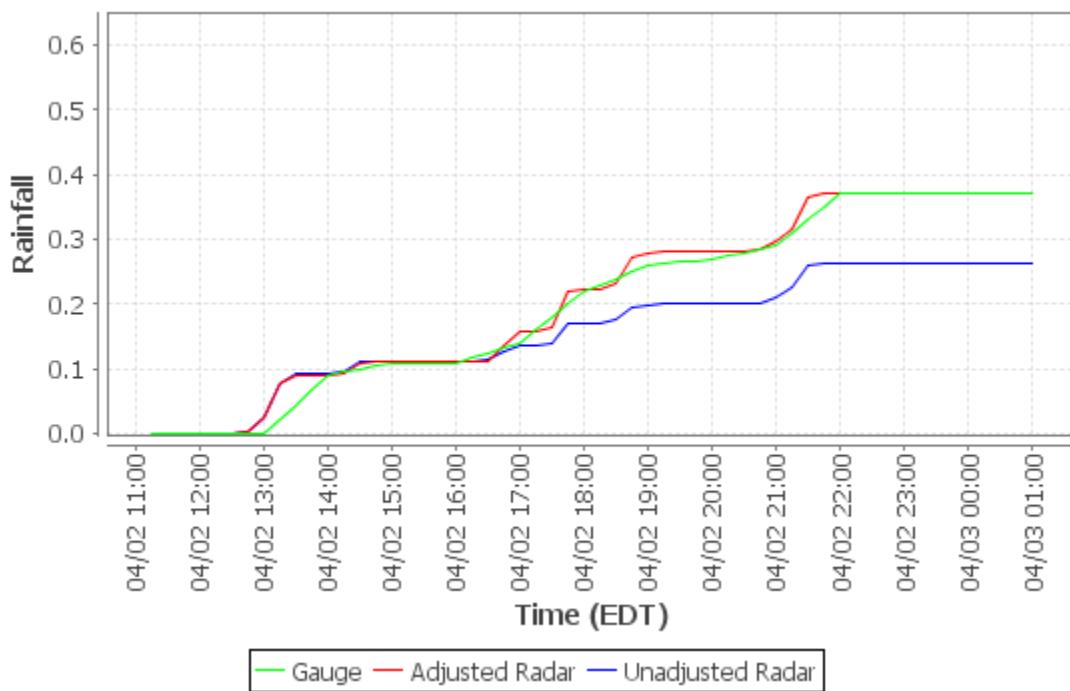
Cumulative Distribution Plot - Richland TWP (Loc33)



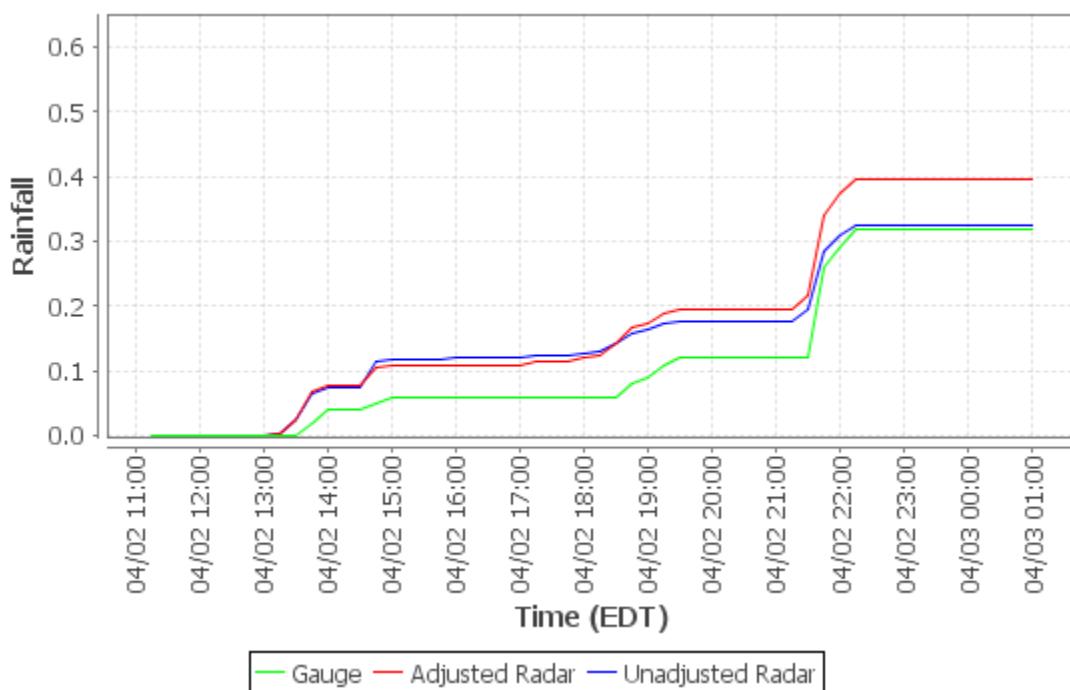
Cumulative Distribution Plot - Pittsburgh Allegheny Cty (KAGC)



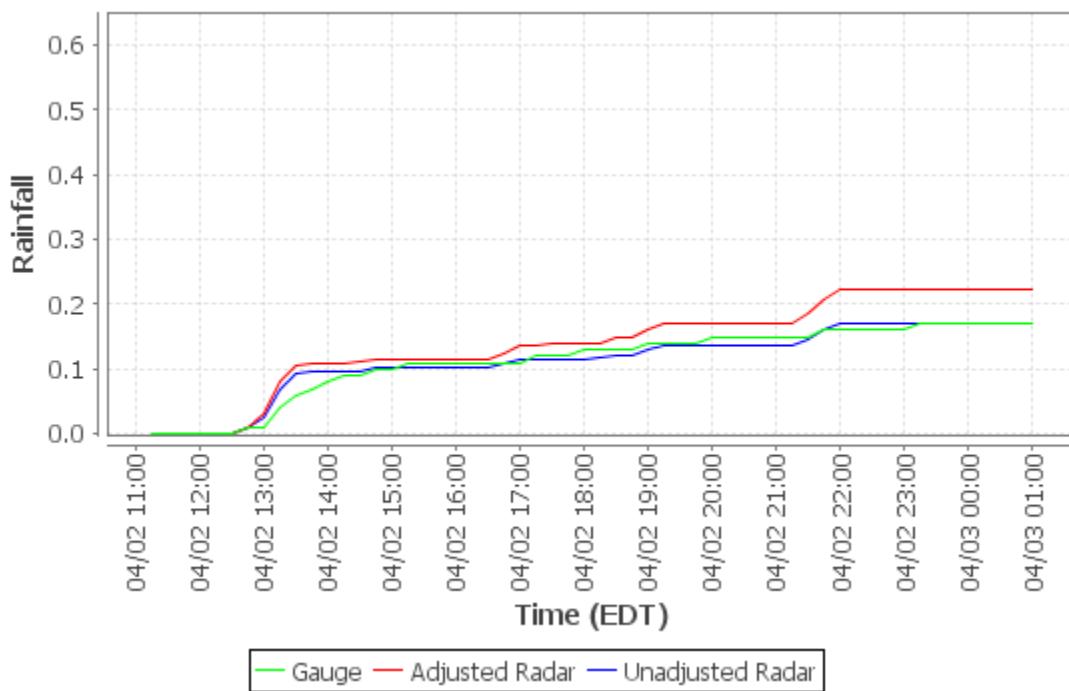
Cumulative Distribution Plot - Greater Pittsburgh Int'l (KPIT)



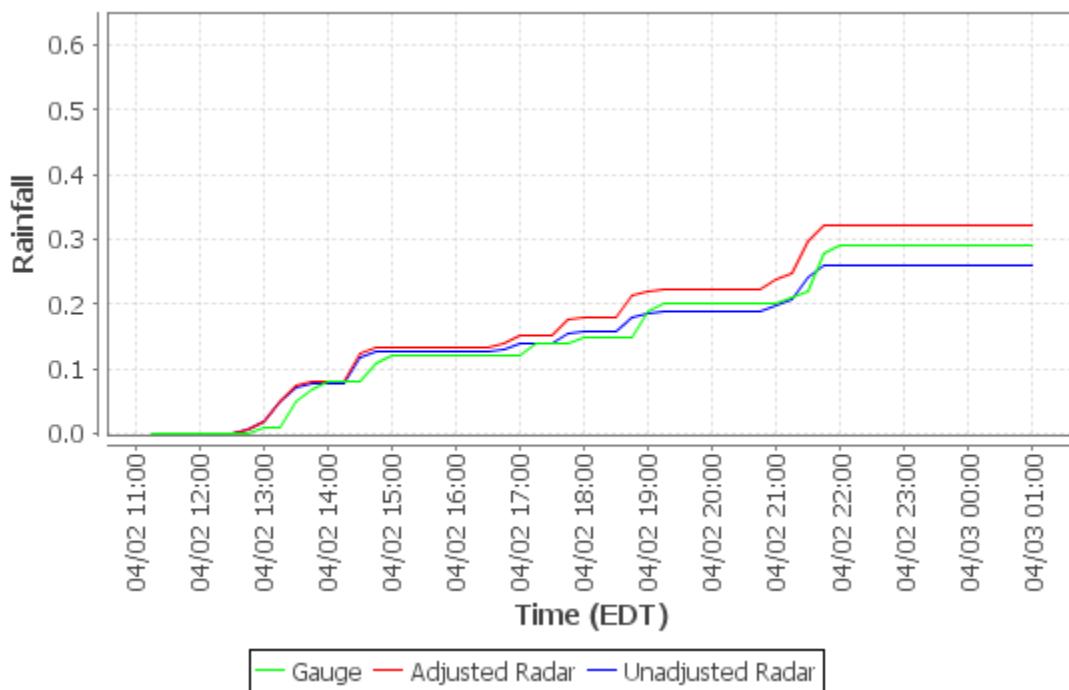
Cumulative Distribution Plot - Allegheny River at Natrona (03049500)



Cumulative Distribution Plot - Chartiers Creek at Carnegie (03085500)

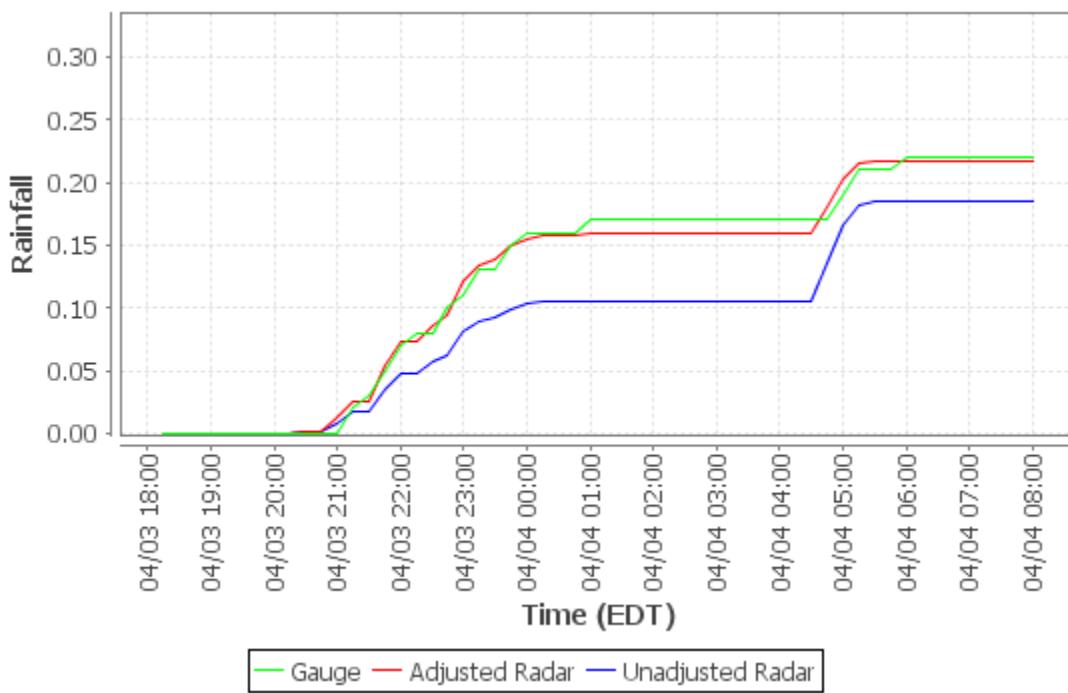


Cumulative Distribution Plot - Ohio River at Emsworth Dam Lower Pool at Emsworth (03085734)

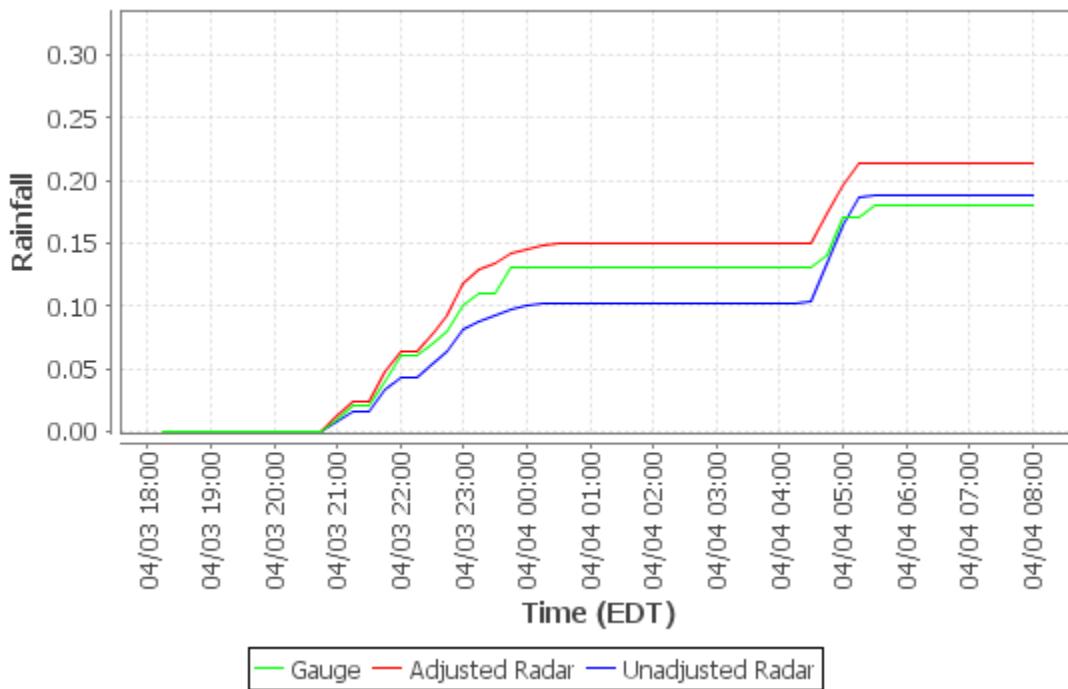


Appendix C - Event 2 (2015-04-03) CDPs

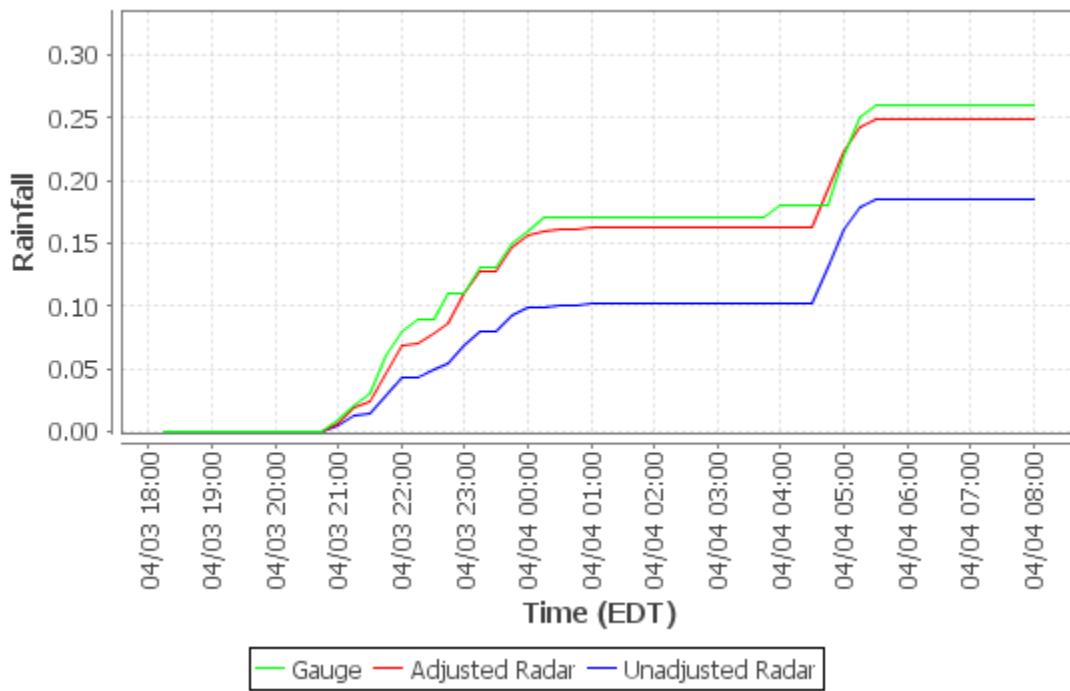
Cumulative Distribution Plot - PWSA-Montana St. (Loc01)



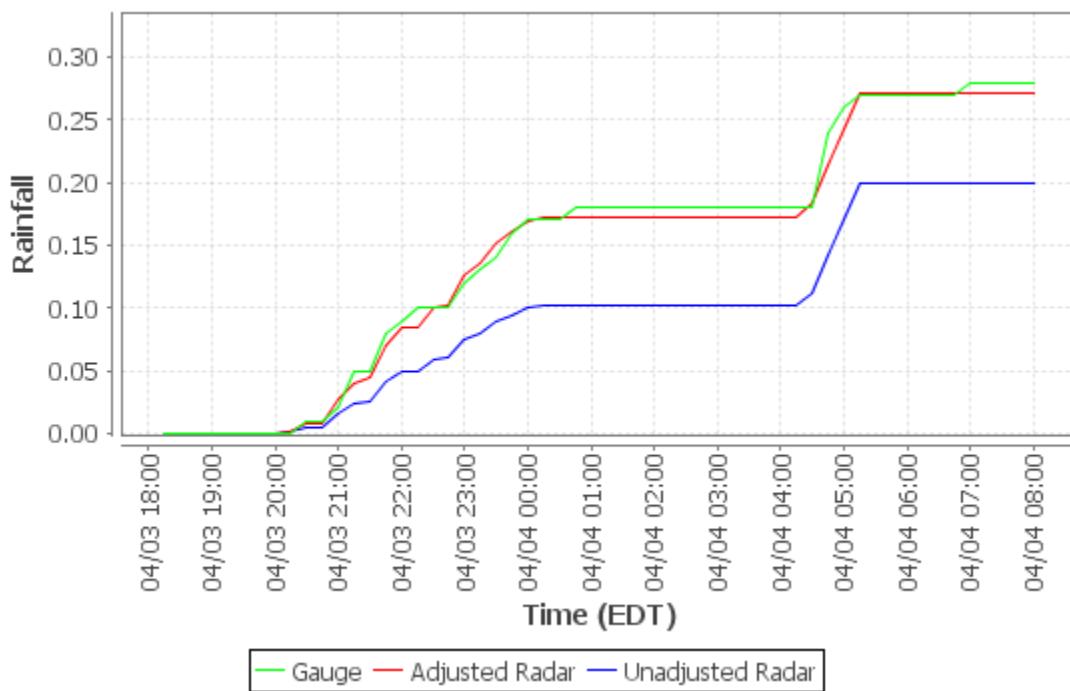
Cumulative Distribution Plot - ALCOSAN WWTP Lab (Loc02)



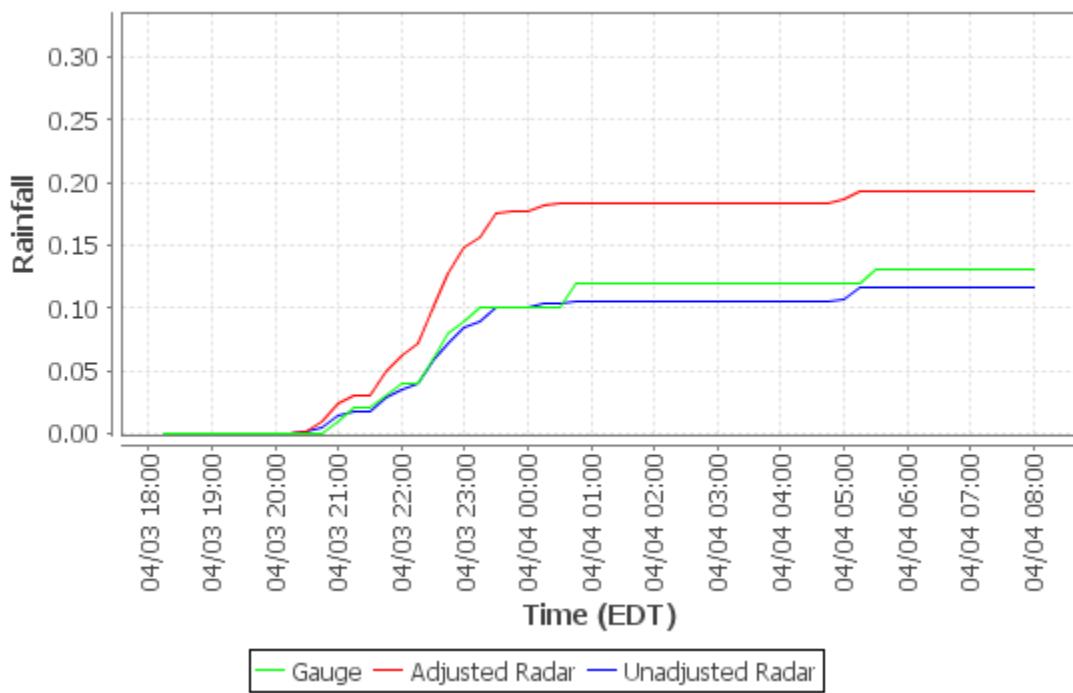
Cumulative Distribution Plot - Shaler Munic Bldg (Loc03)



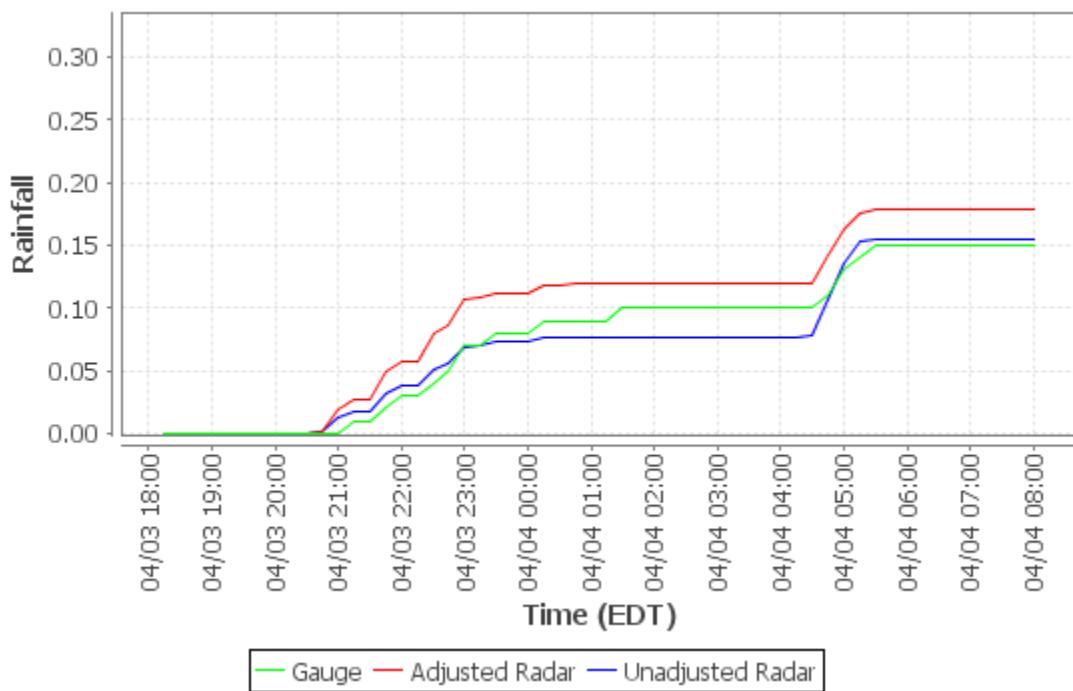
Cumulative Distribution Plot - Kennedy Twp PS (Loc04)



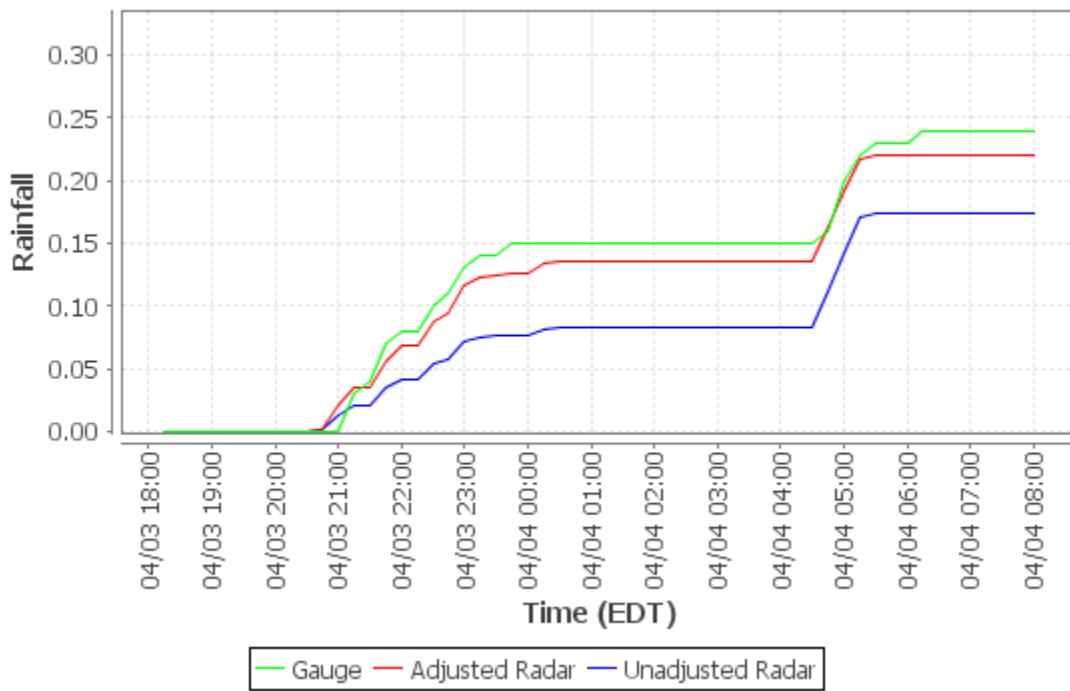
Cumulative Distribution Plot - Upper St. Clair (Loc05)



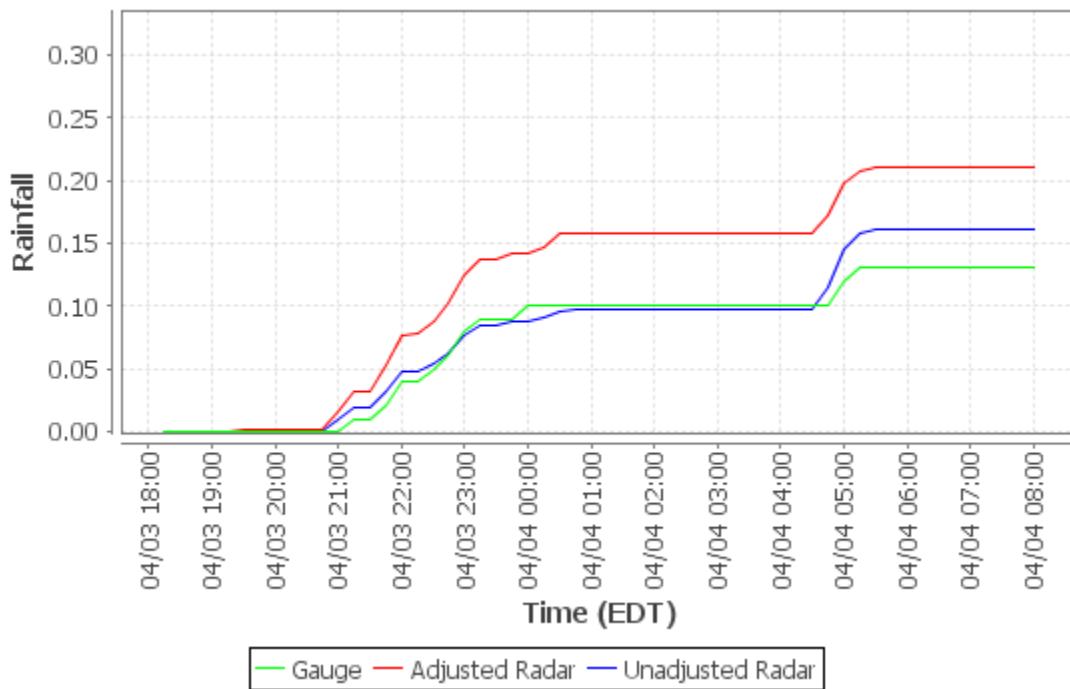
Cumulative Distribution Plot - Carnegie Transit Time (Loc06)



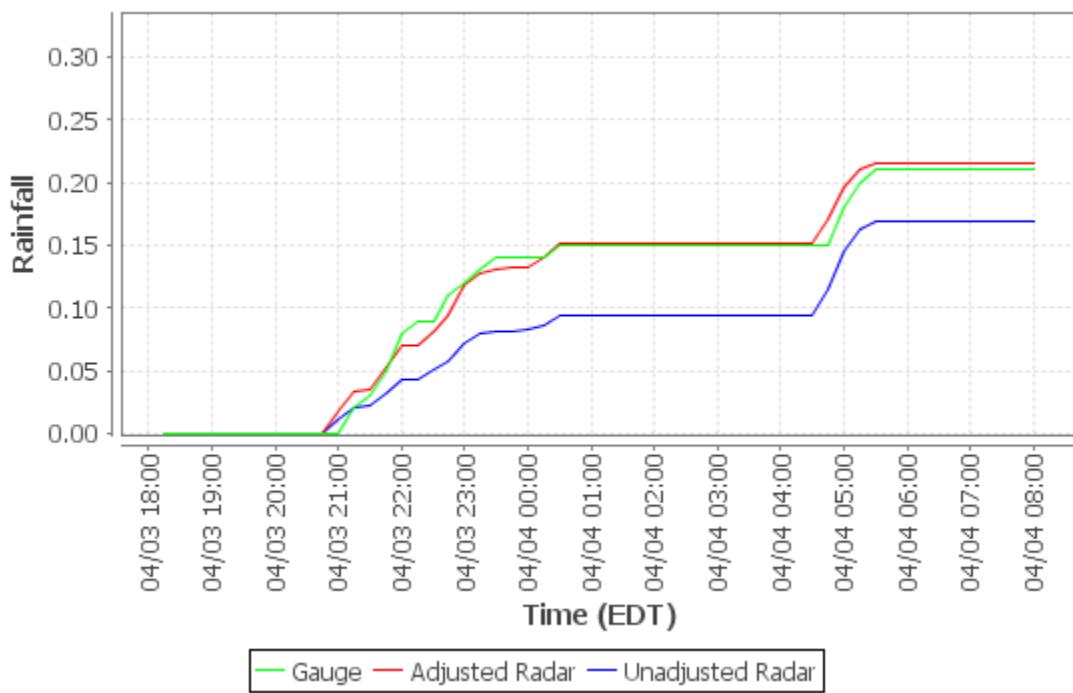
Cumulative Distribution Plot - Greentree Munic Bldg (Loc07)



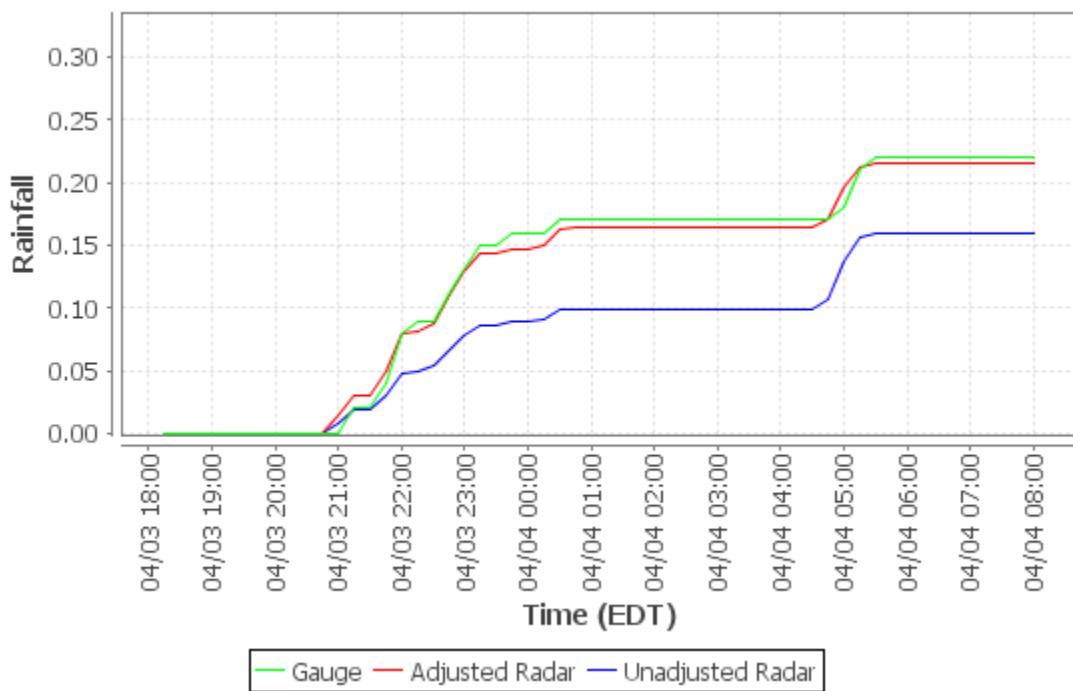
Cumulative Distribution Plot - AC Health Dept Bldg (Loc08)



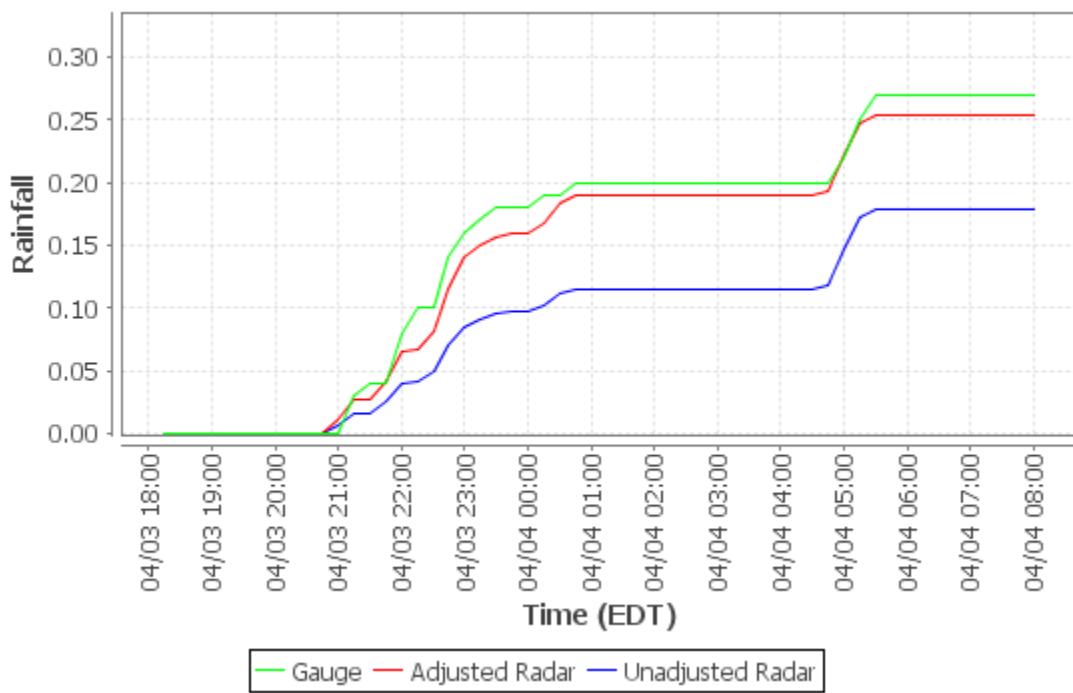
Cumulative Distribution Plot - Univ of Pittsburgh (Loc09)



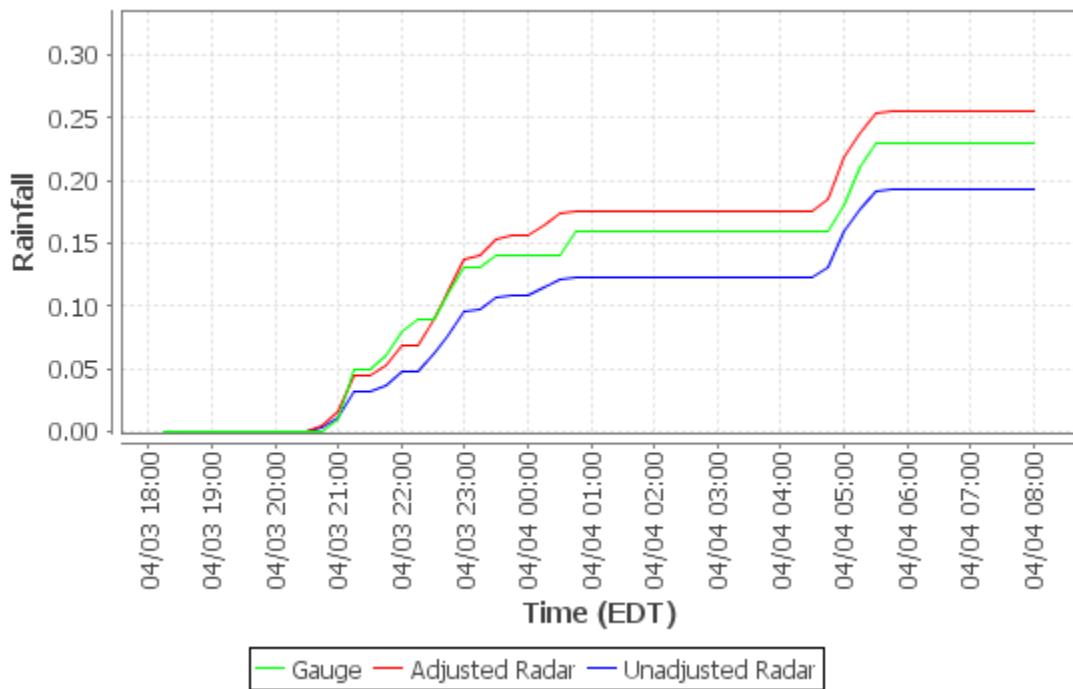
Cumulative Distribution Plot - PWSA-Highland Park (Loc10)



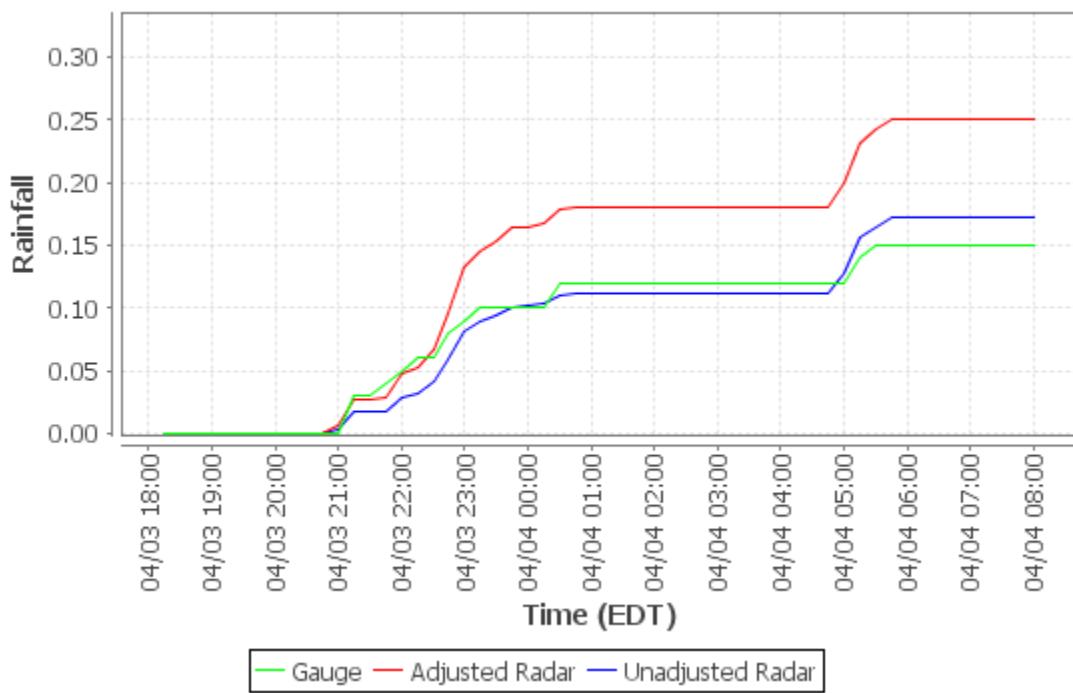
Cumulative Distribution Plot - M-46 Access Shaft (Loc11)



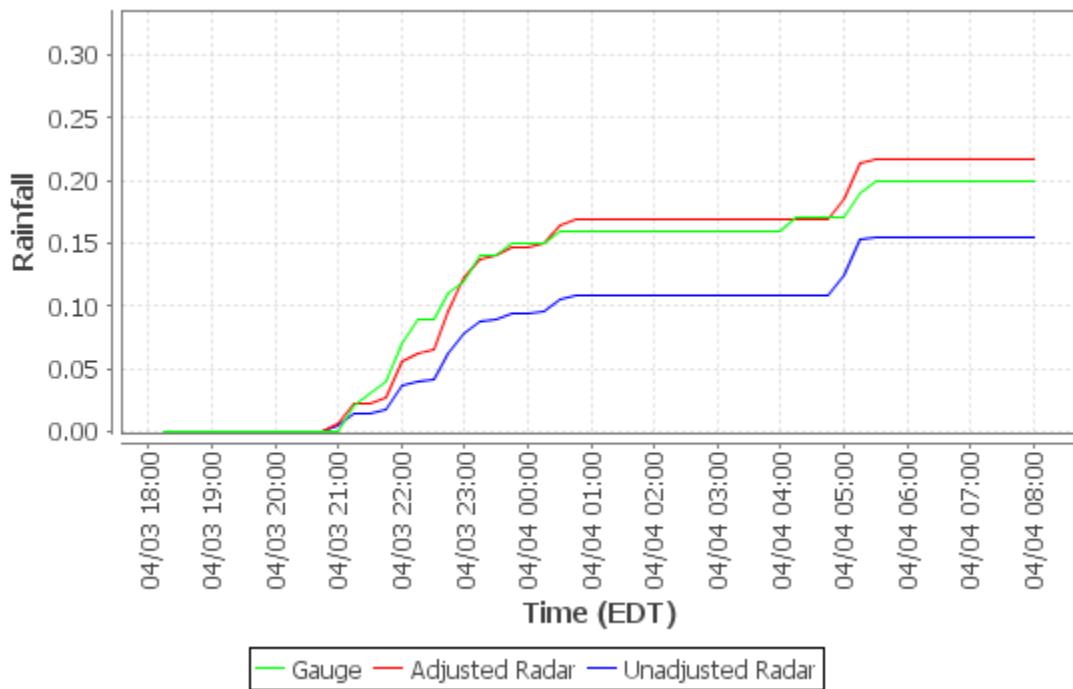
Cumulative Distribution Plot - Baldwin (Loc12)



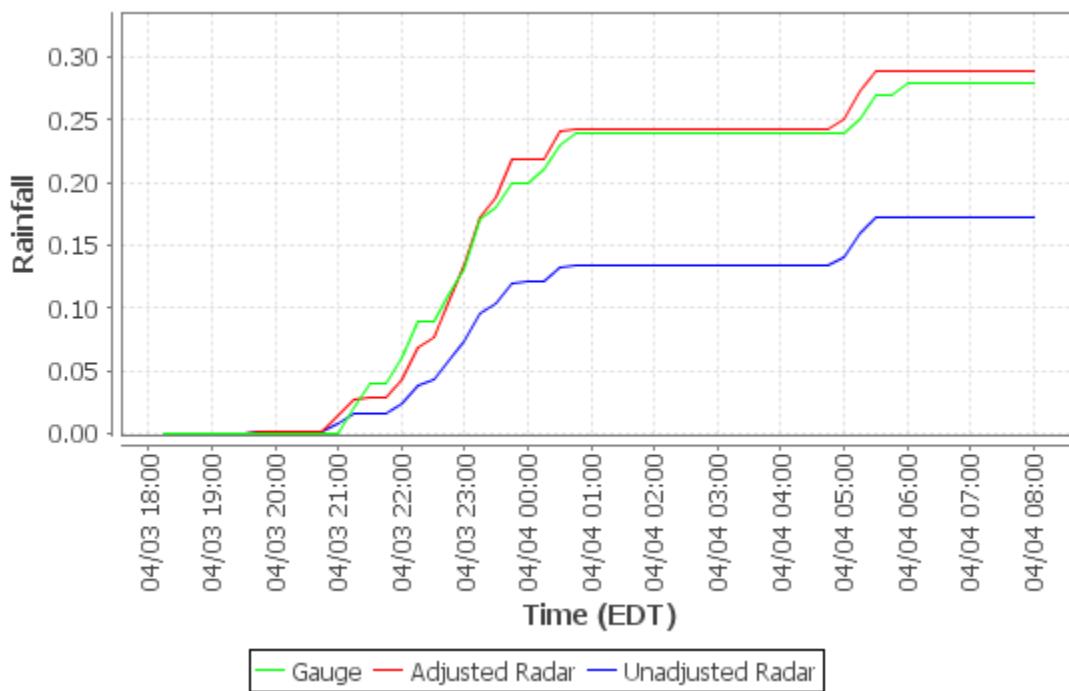
Cumulative Distribution Plot - M-59 Access Shaft (Loc13)



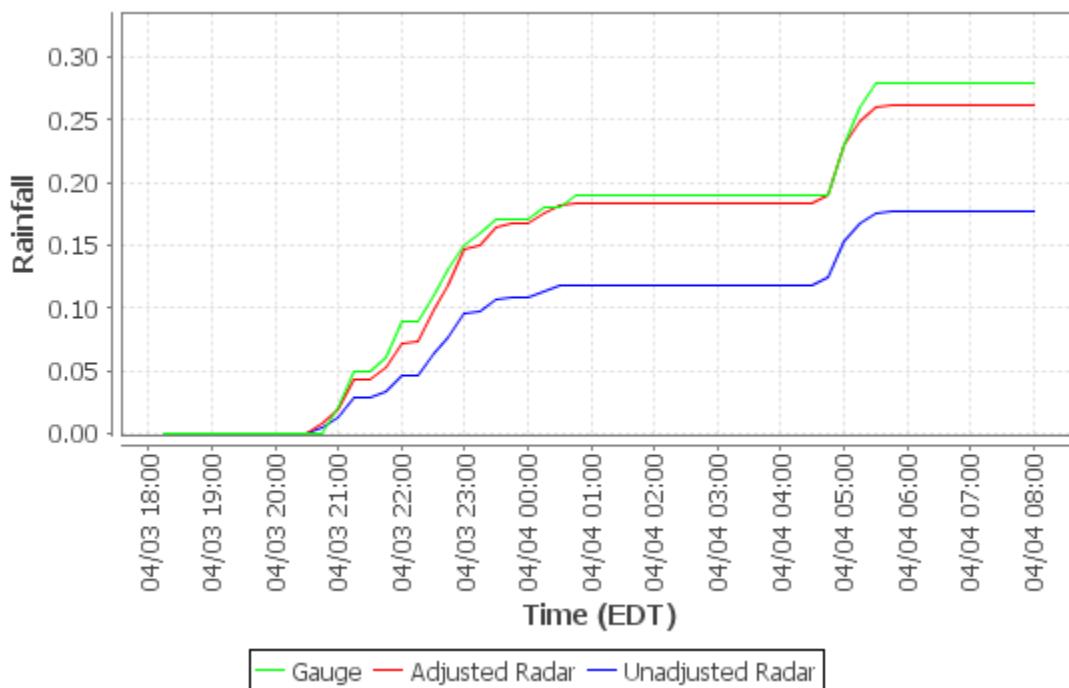
Cumulative Distribution Plot - Churchill Munic Bldg (Loc14)



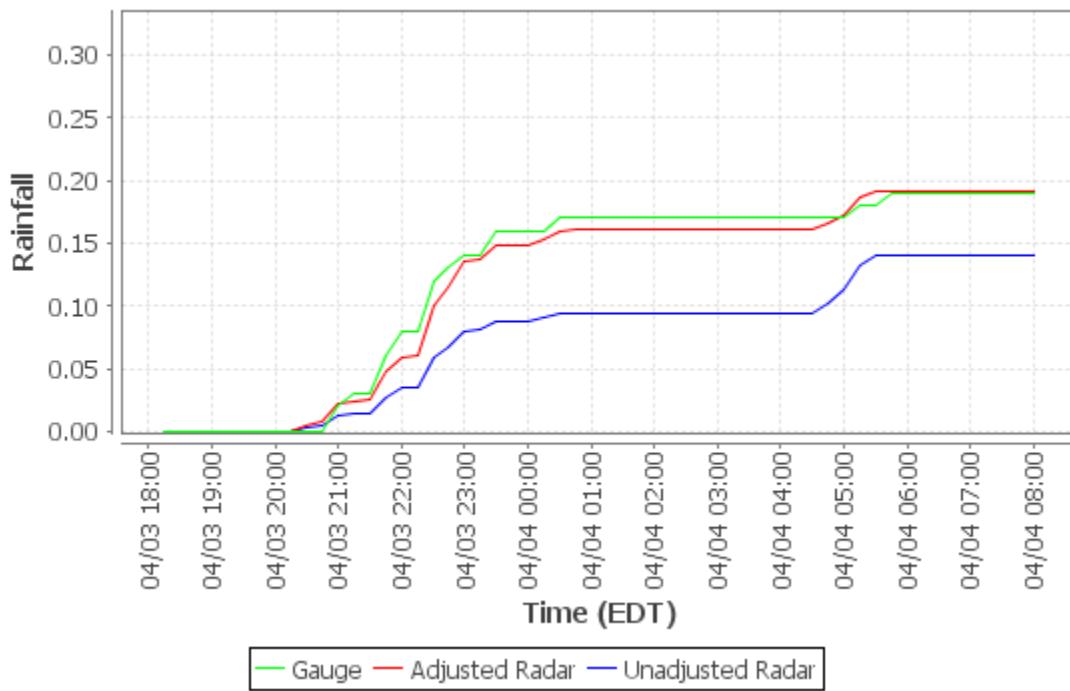
Cumulative Distribution Plot - Trafford Maint Bldg (Loc15)



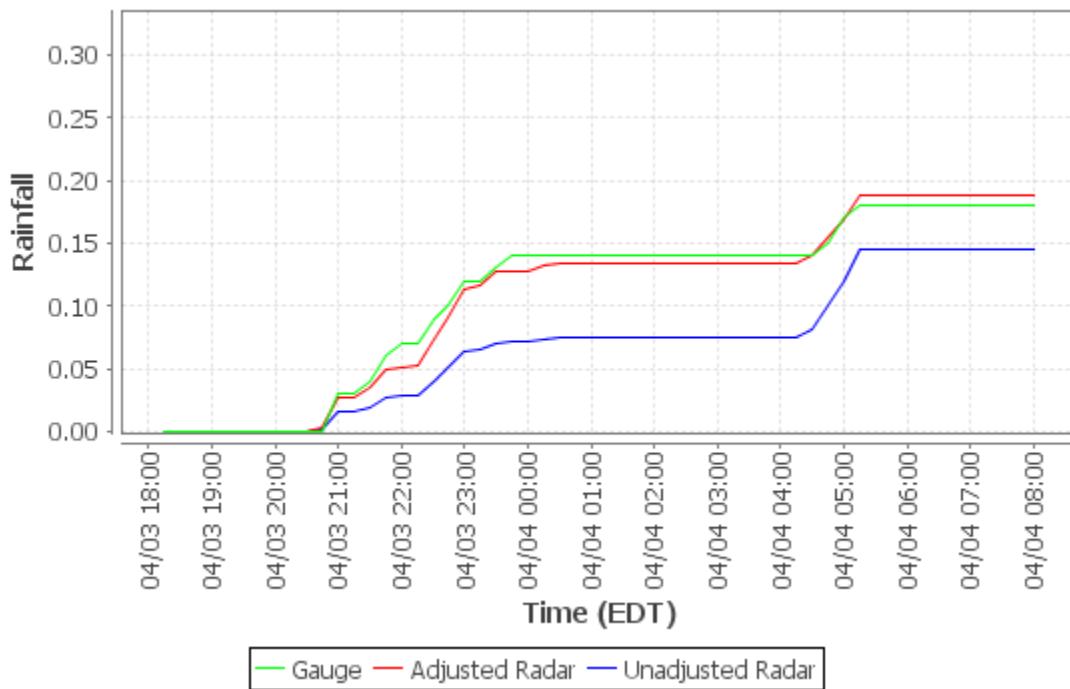
Cumulative Distribution Plot - Castle Shannon (Loc16)



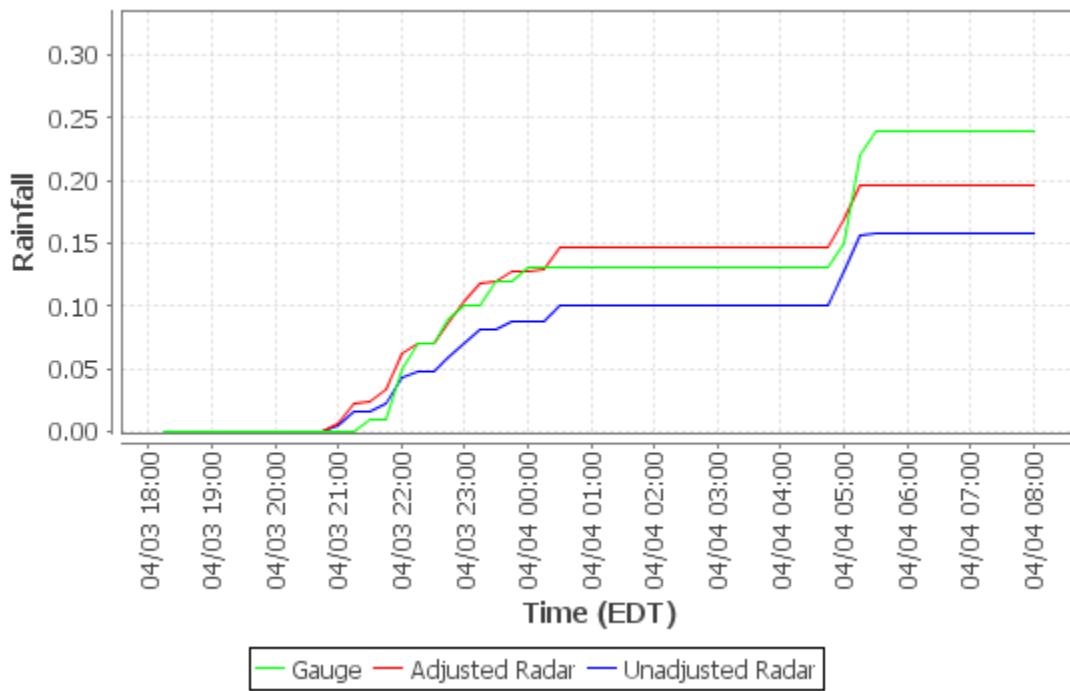
Cumulative Distribution Plot - Chartiers Pump Station (Loc17)



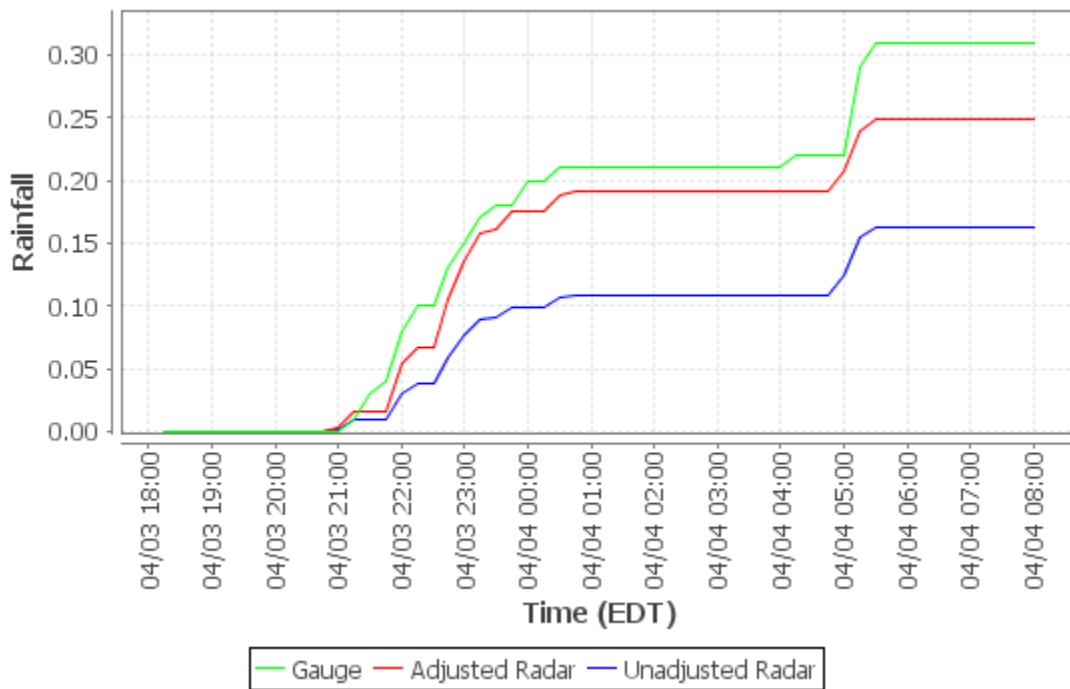
Cumulative Distribution Plot - Oakdale Pump Station (Loc18)



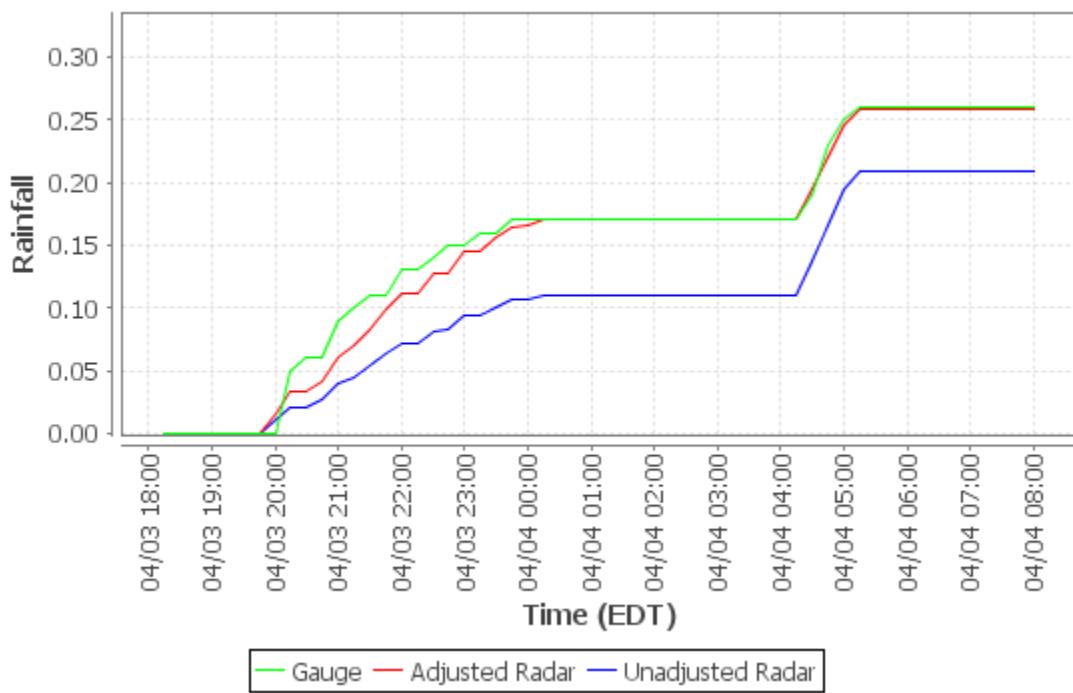
Cumulative Distribution Plot - Sandy Creek Eq Facility (Loc19)



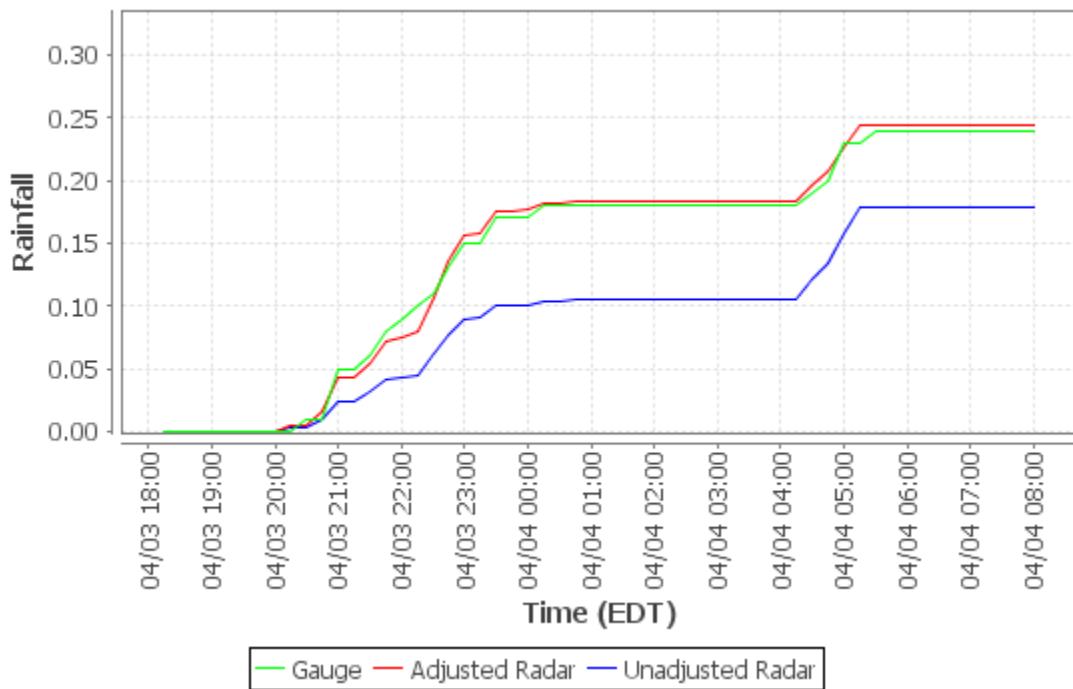
Cumulative Distribution Plot - Gascola Eq Facility (Loc20)



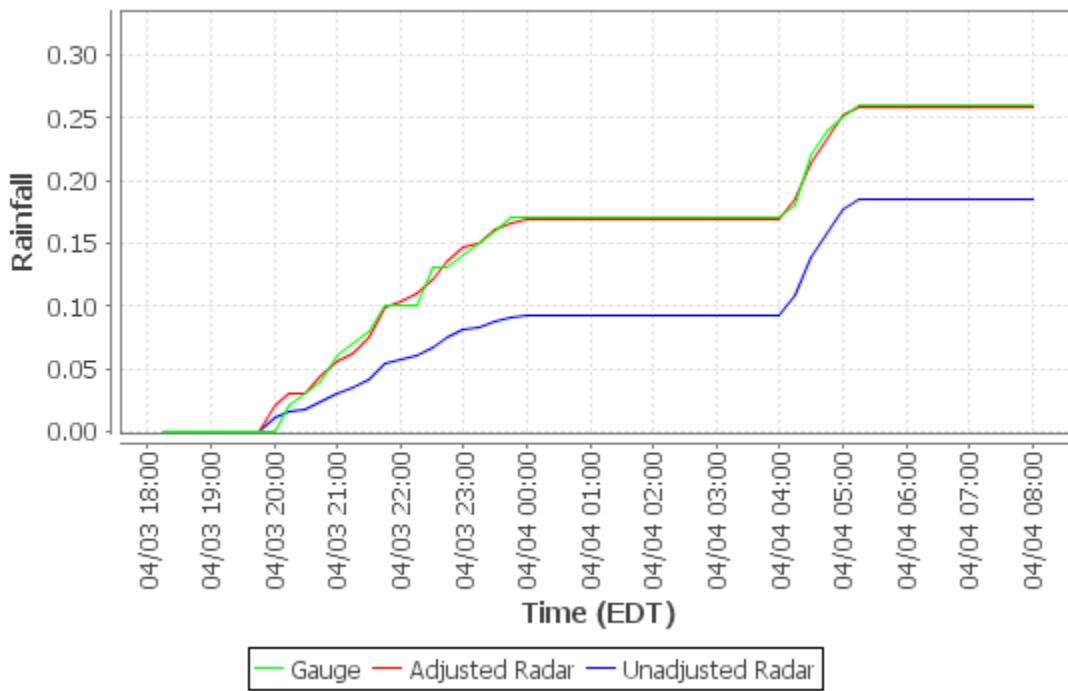
Cumulative Distribution Plot - Moon TWP (Loc21)



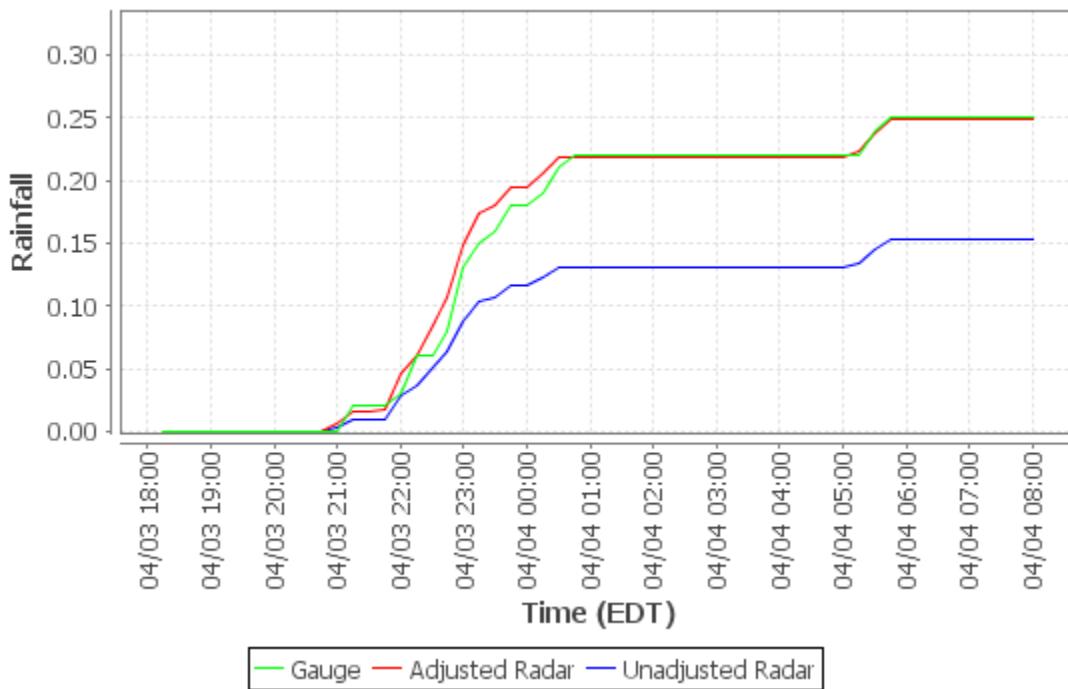
Cumulative Distribution Plot - North Fayette TWP (Loc22)



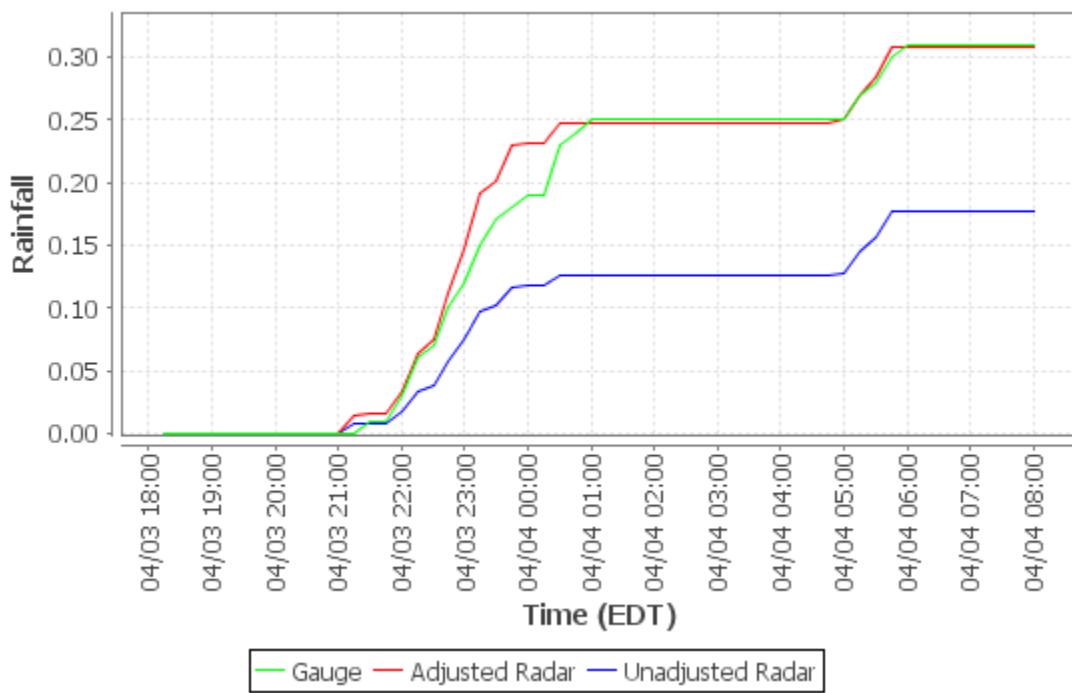
Cumulative Distribution Plot - Clinton Munic Bldg (Loc23)



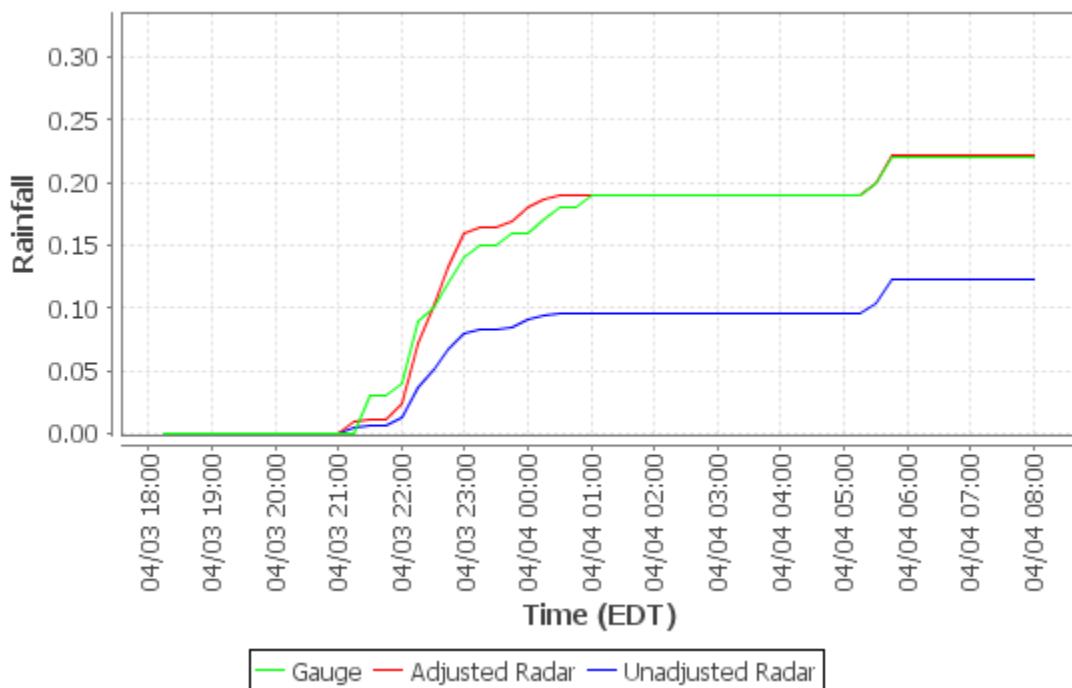
Cumulative Distribution Plot - Jefferson Hills (Loc24)



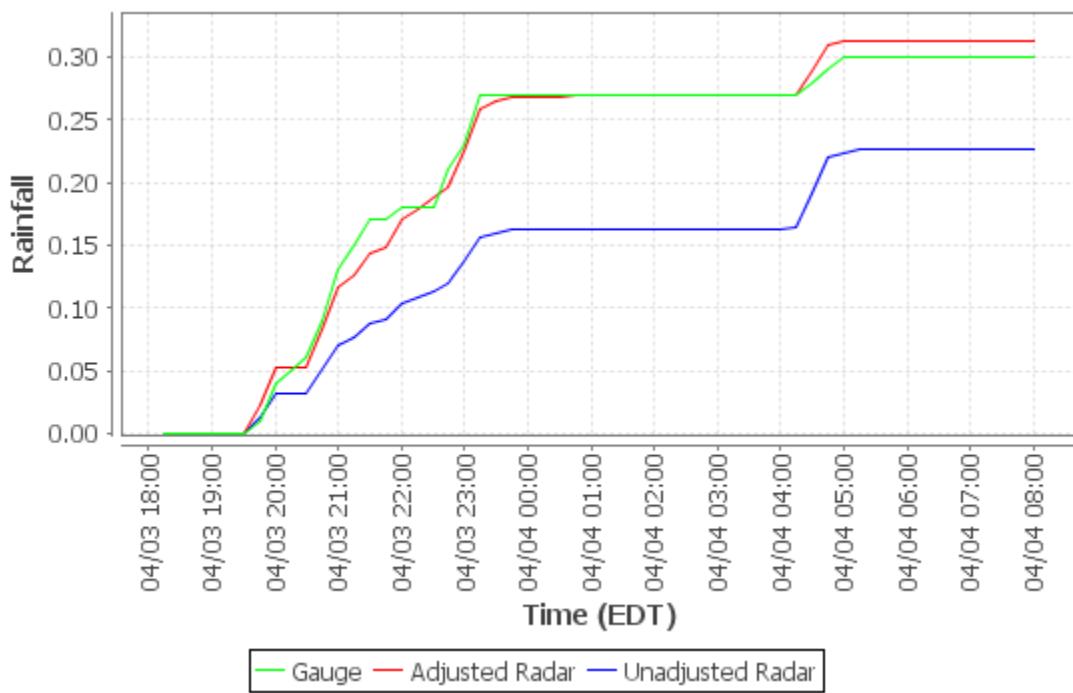
Cumulative Distribution Plot - White Oak Public Works Bldg (Loc25)



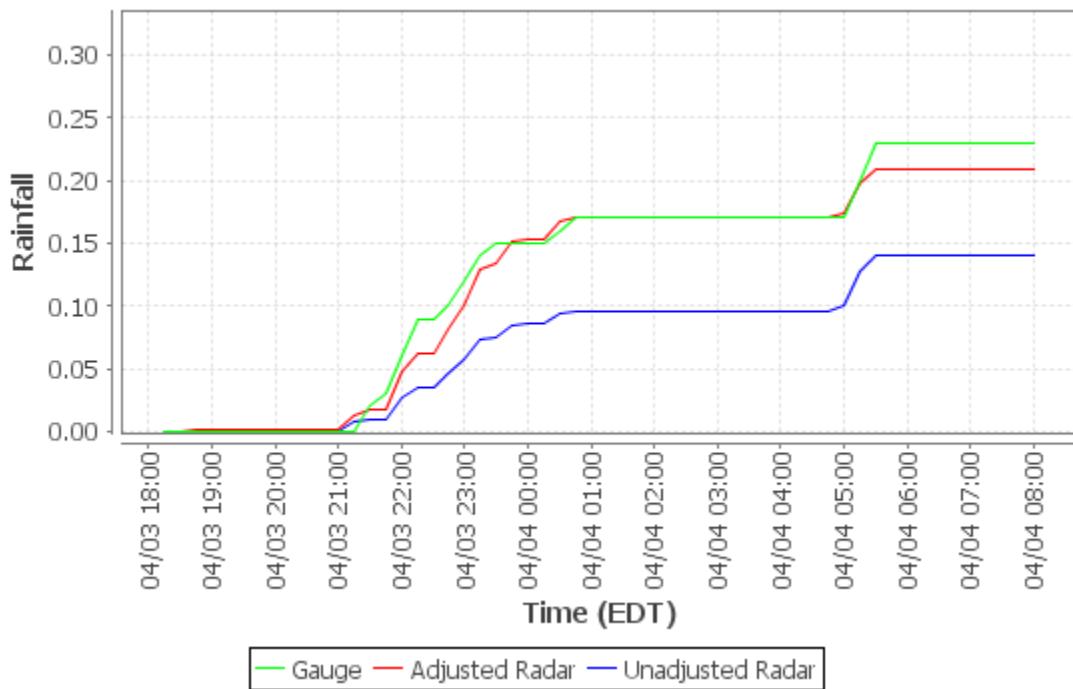
Cumulative Distribution Plot - Elizabeth TWP Municipal Bldg (Loc26)



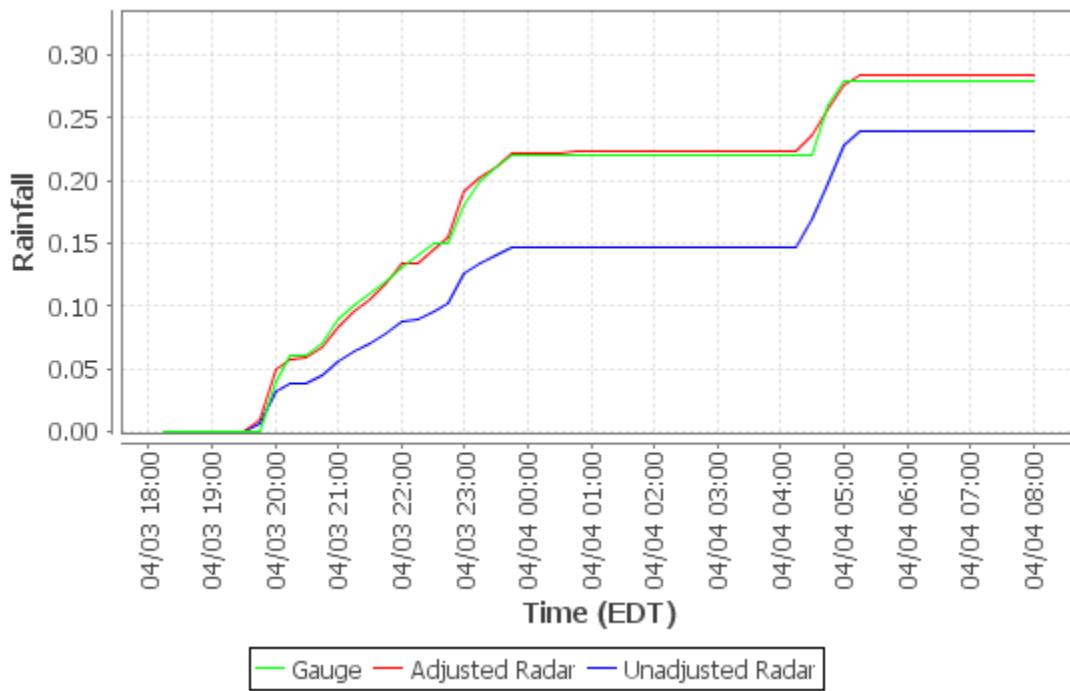
Cumulative Distribution Plot - Marshall TWP (Loc27)



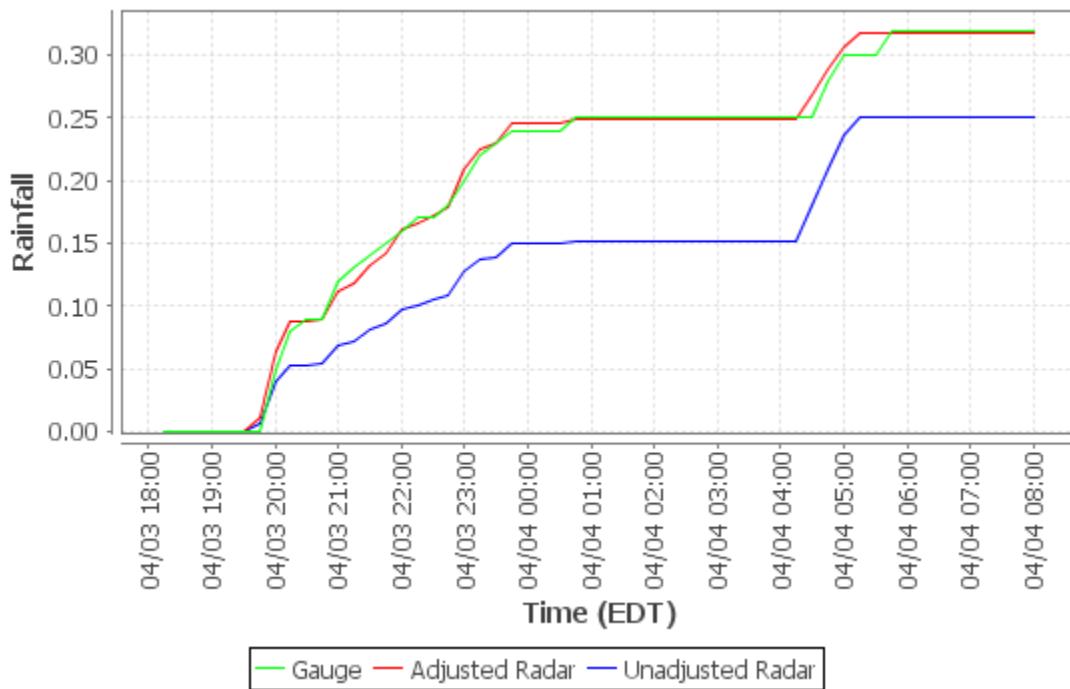
Cumulative Distribution Plot - Plum Municipal Bldg (Loc28)



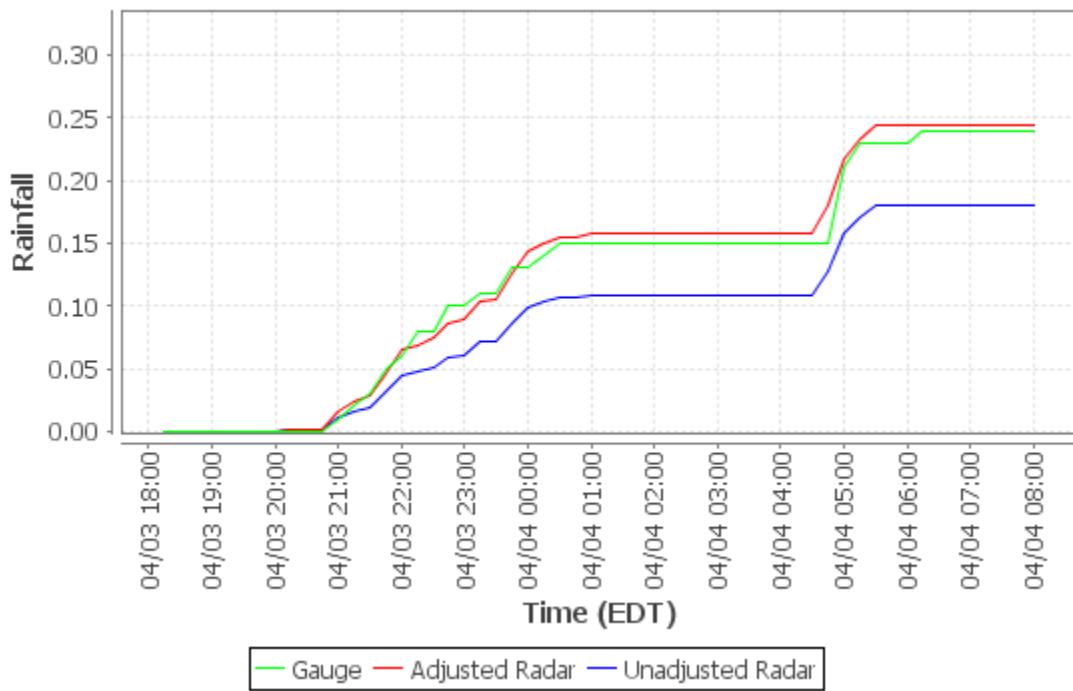
Cumulative Distribution Plot - Bell Acres Munic Bldg (Loc29)



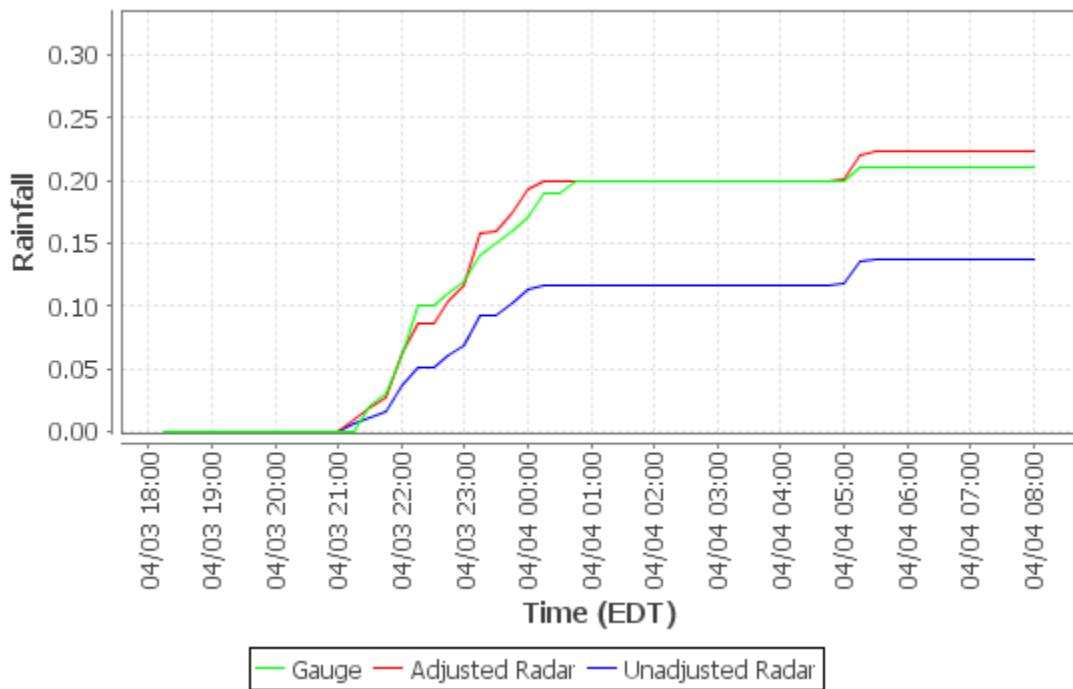
Cumulative Distribution Plot - McCandless Twn Hall (Loc30)



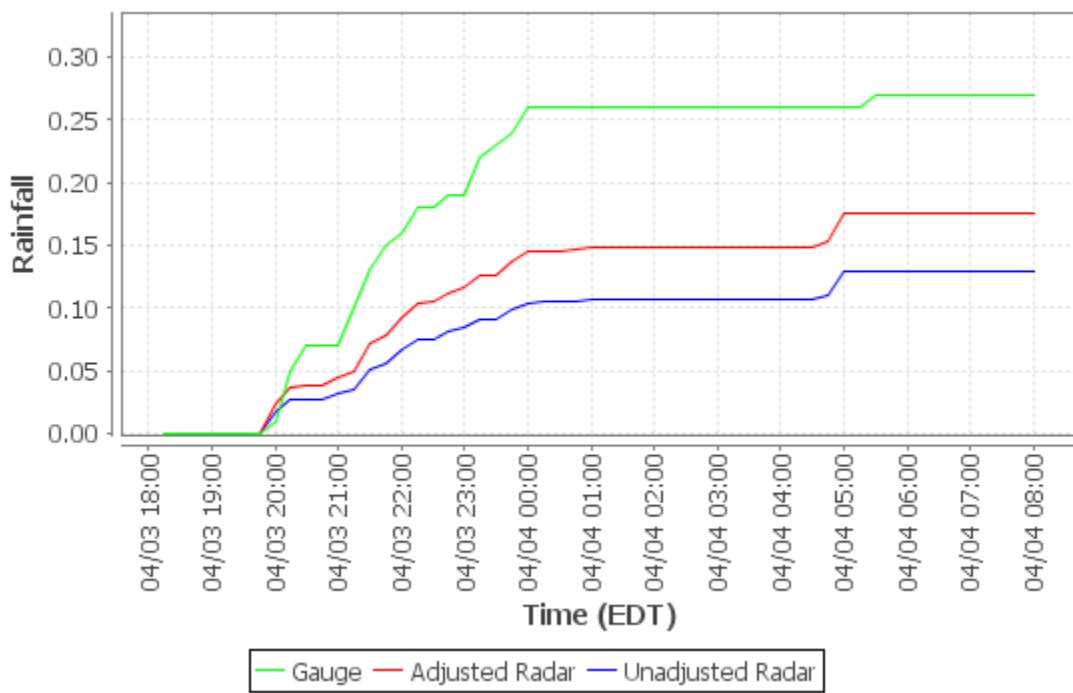
Cumulative Distribution Plot - Hampton Municipal Bldg (Loc31)



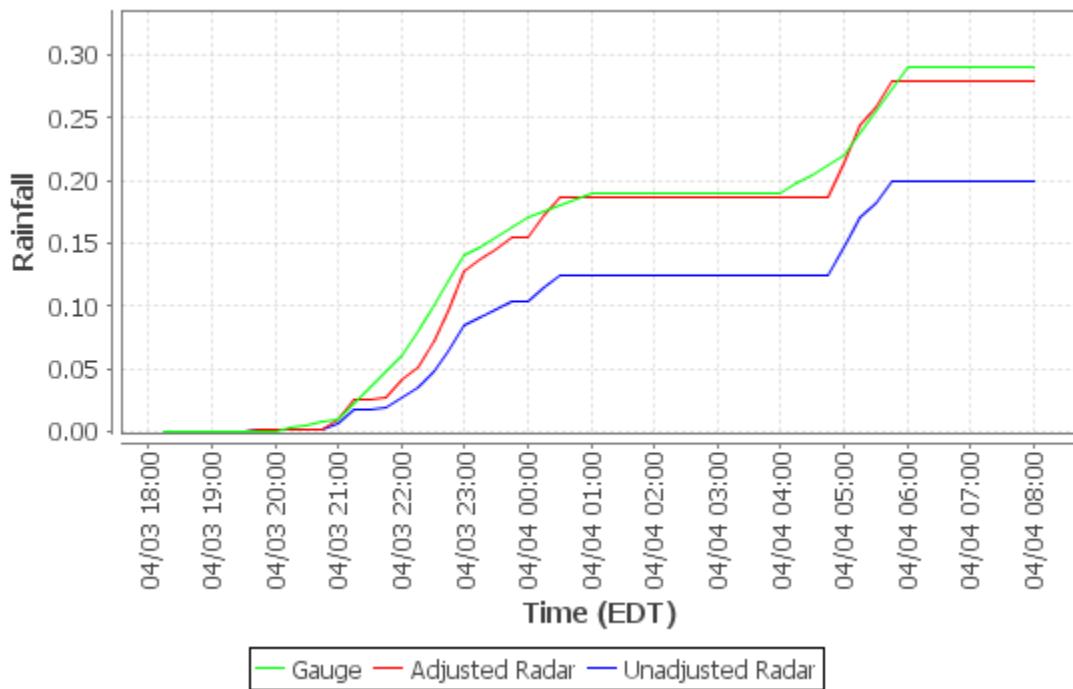
Cumulative Distribution Plot - Arnold (Loc32)



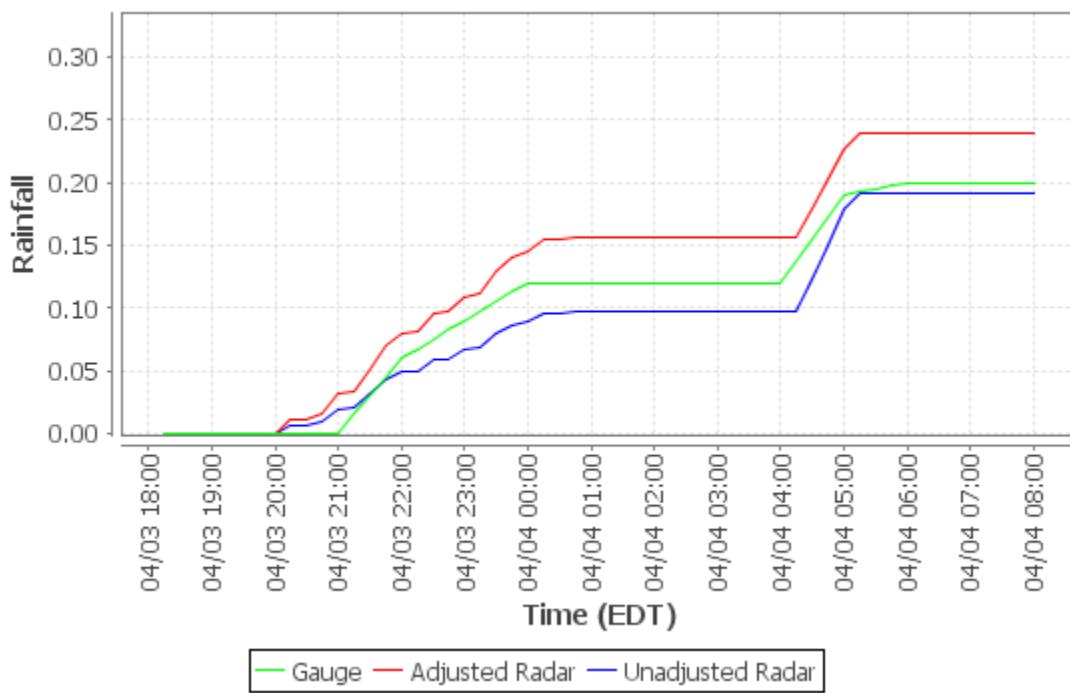
Cumulative Distribution Plot - Richland TWP (Loc33)



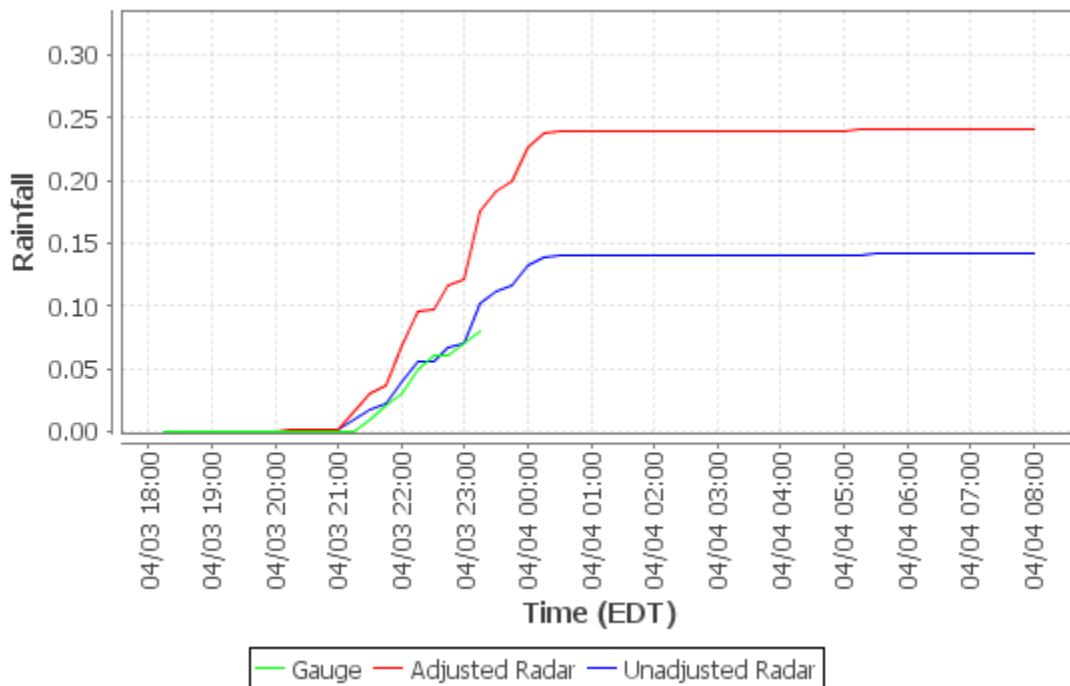
Cumulative Distribution Plot - Pittsburgh Allegheny Cty (KAGC)



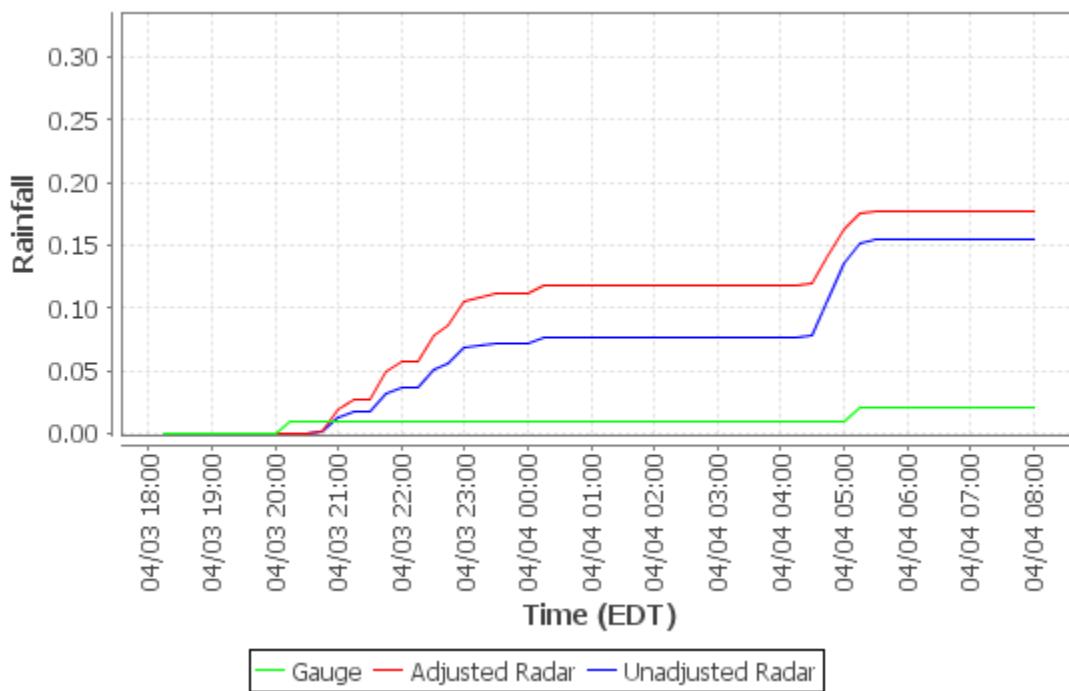
Cumulative Distribution Plot - Greater Pittsburgh Int'l (KPIT)



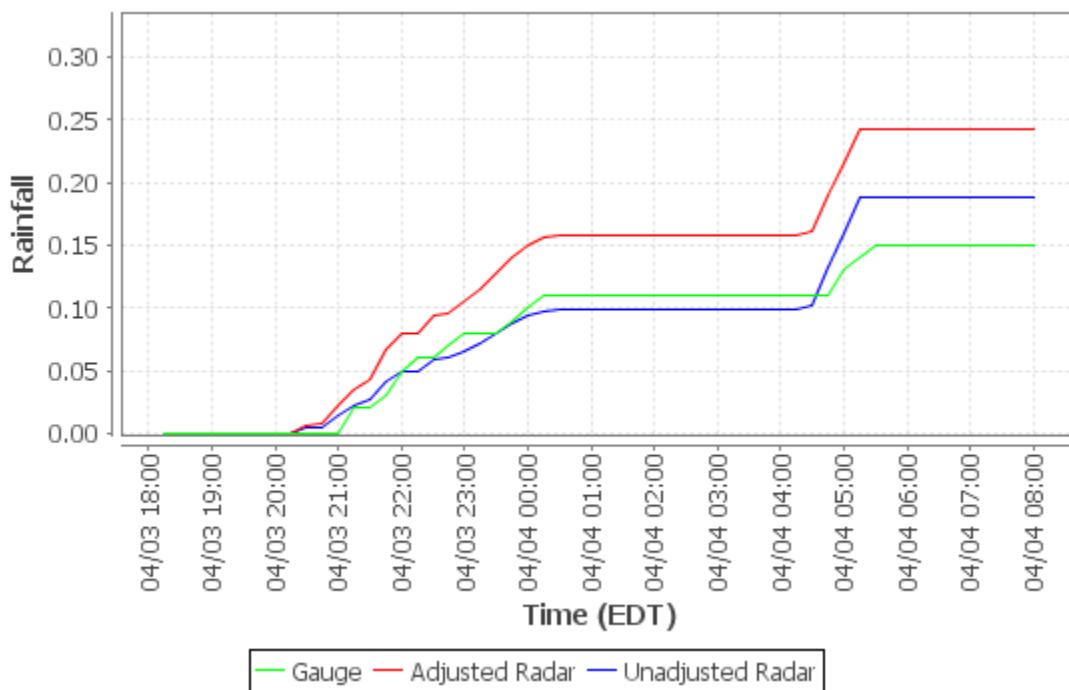
Cumulative Distribution Plot - Allegheny River at Natrona (03049500)



Cumulative Distribution Plot - Chartiers Creek at Carnegie (03085500)

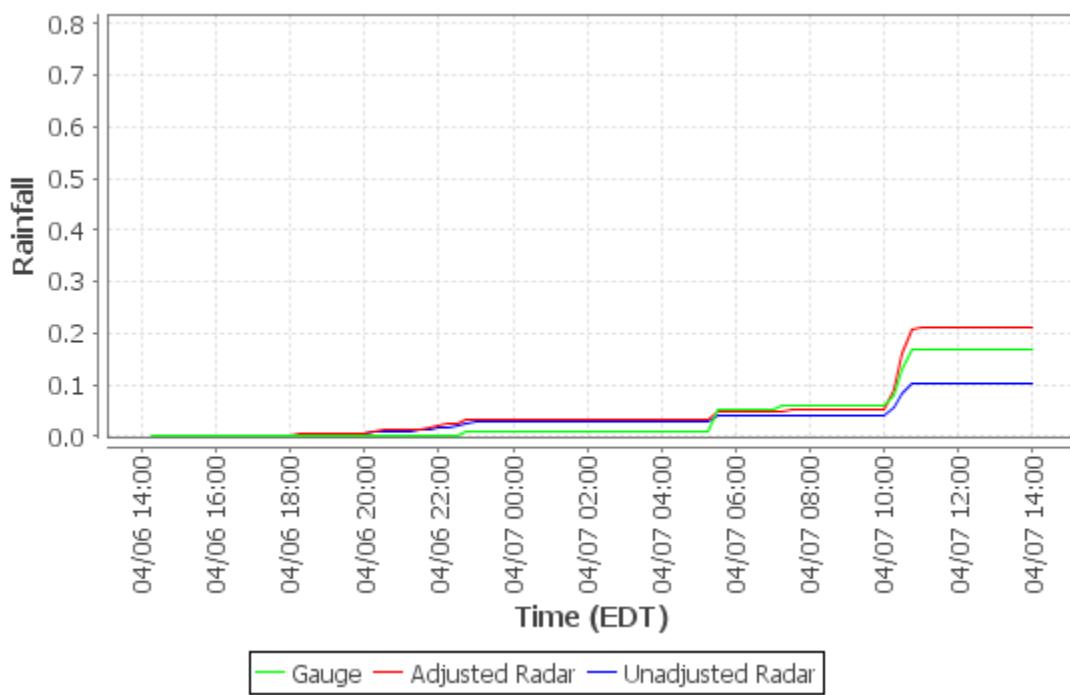


Cumulative Distribution Plot - Ohio River at Emsworth Dam Lower Pool at Emsworth (03085734)

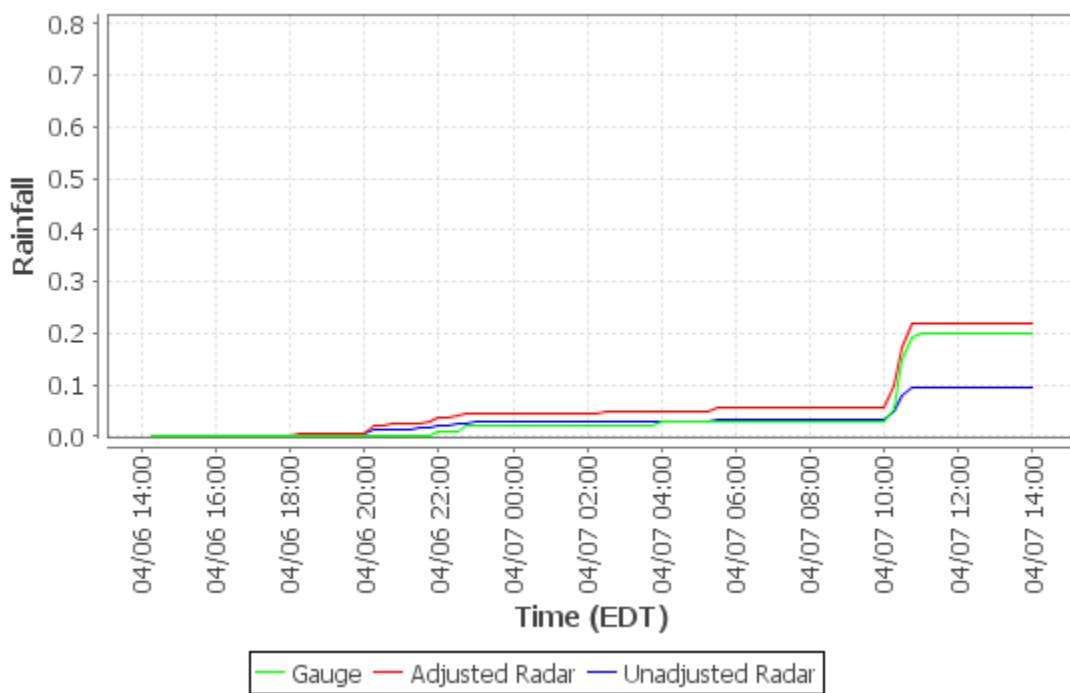


Appendix D - Event 3 (2015-04-07) CDPs

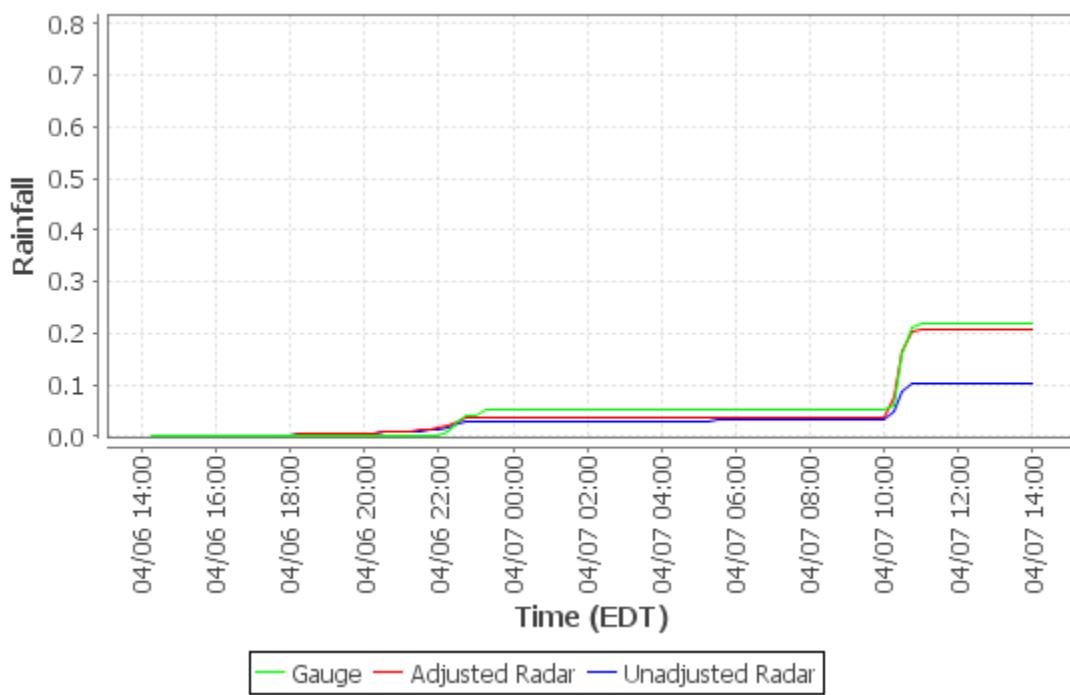
Cumulative Distribution Plot - PWSA-Montana St. (Loc01)



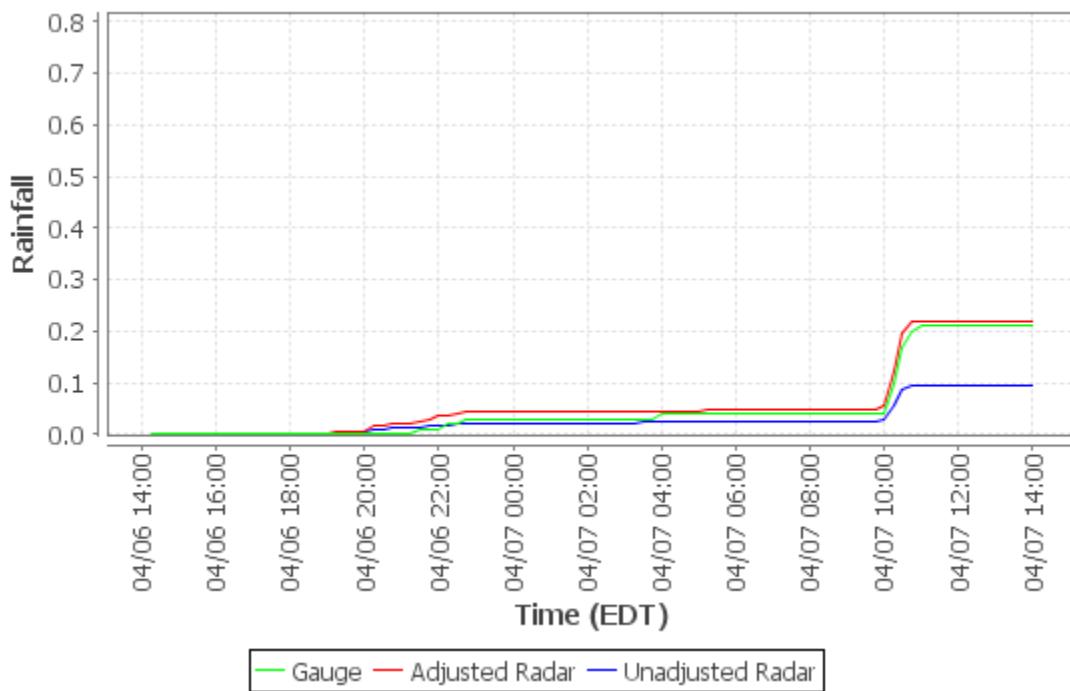
Cumulative Distribution Plot - ALCOSAN WWTP Lab (Loc02)



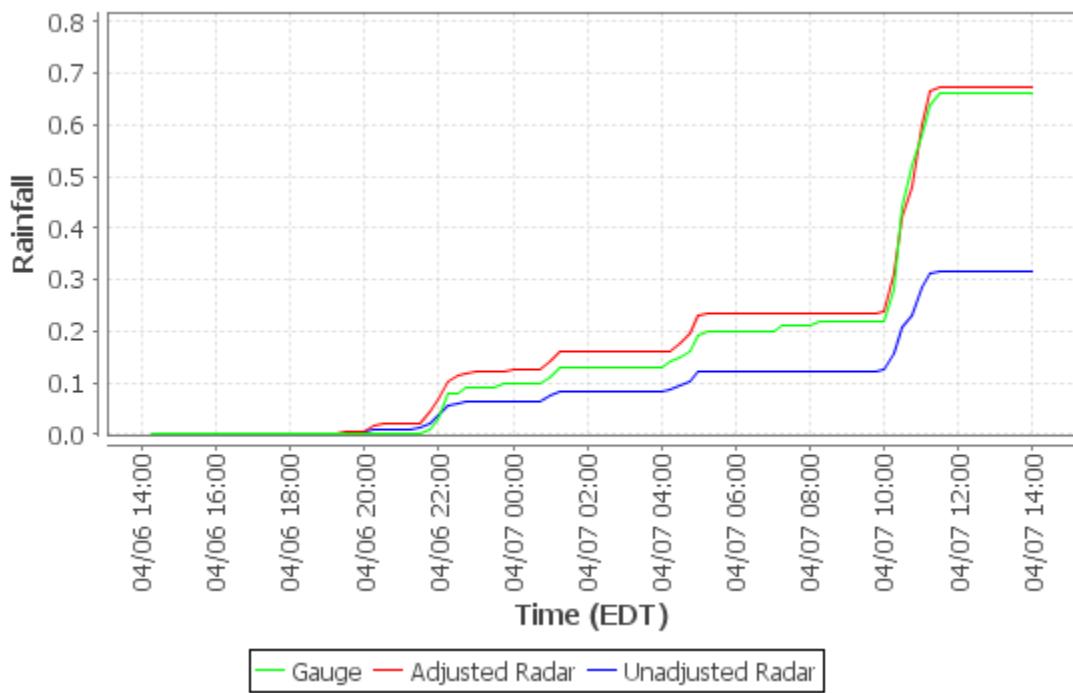
Cumulative Distribution Plot - Shaler Munic Bldg (Loc03)



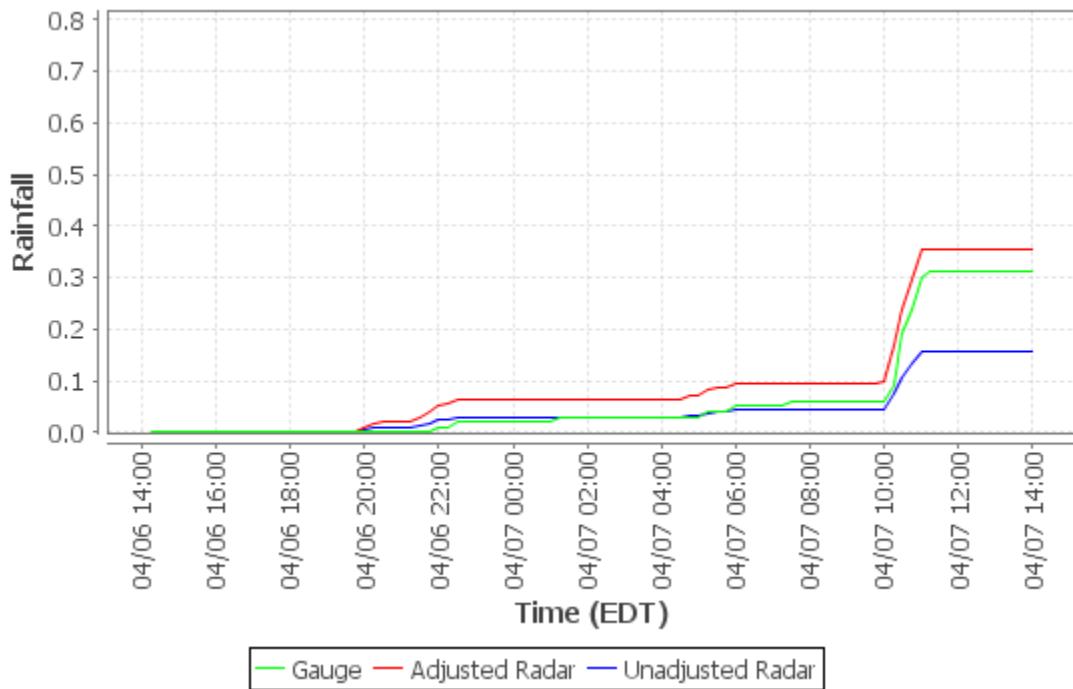
Cumulative Distribution Plot - Kennedy Twp PS (Loc04)



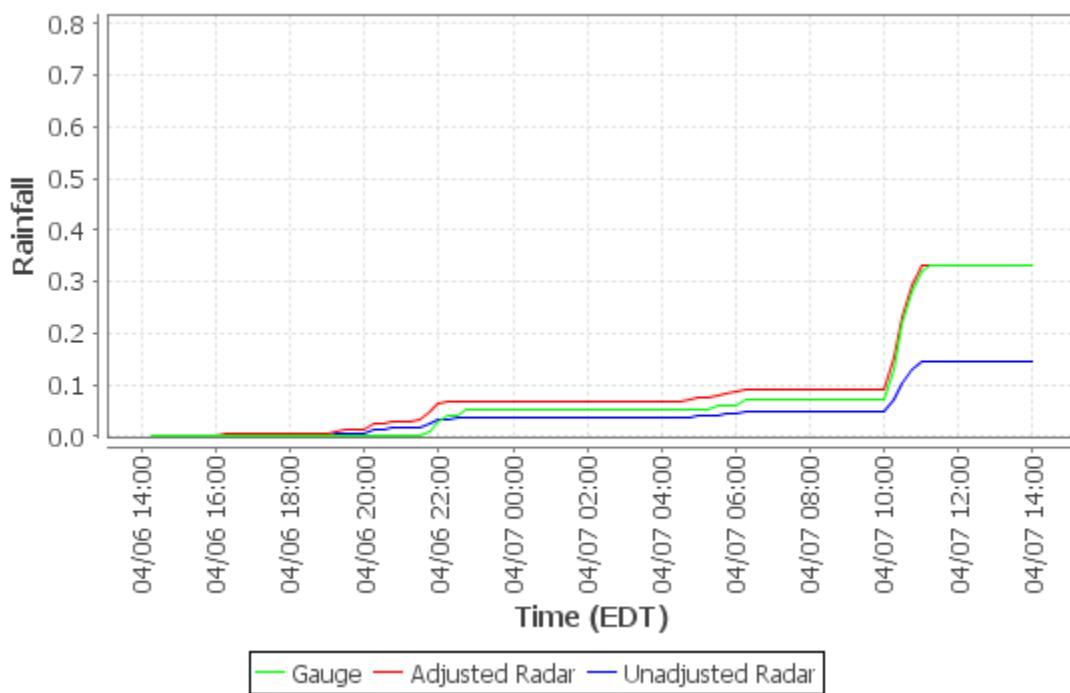
Cumulative Distribution Plot - Upper St. Clair (Loc05)



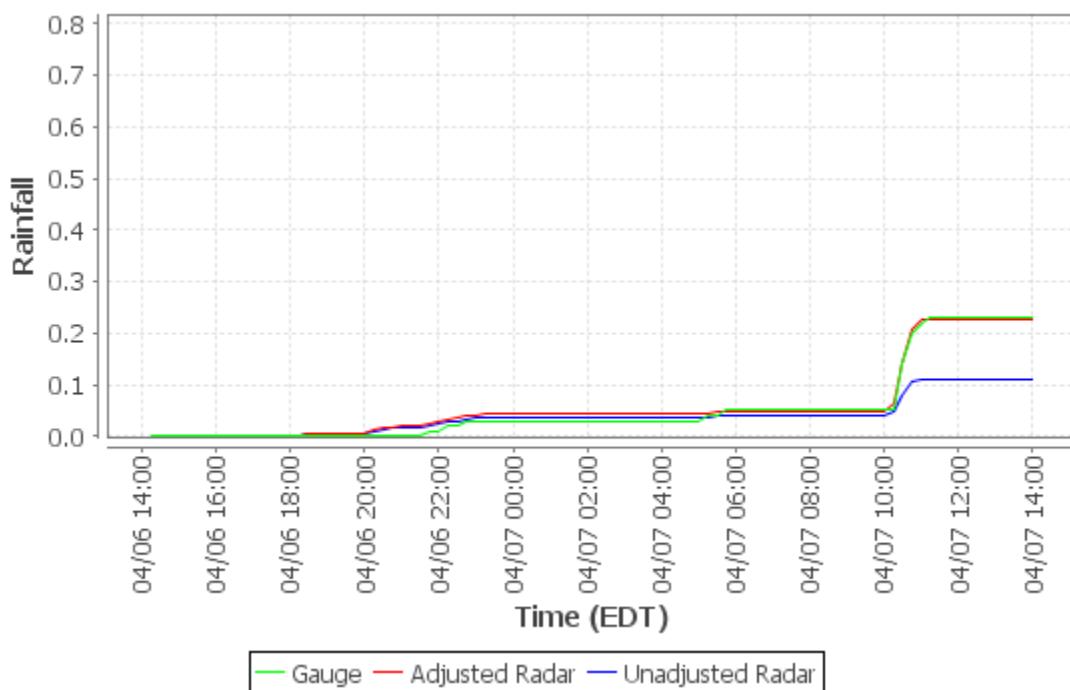
Cumulative Distribution Plot - Carnegie Transit Time (Loc06)



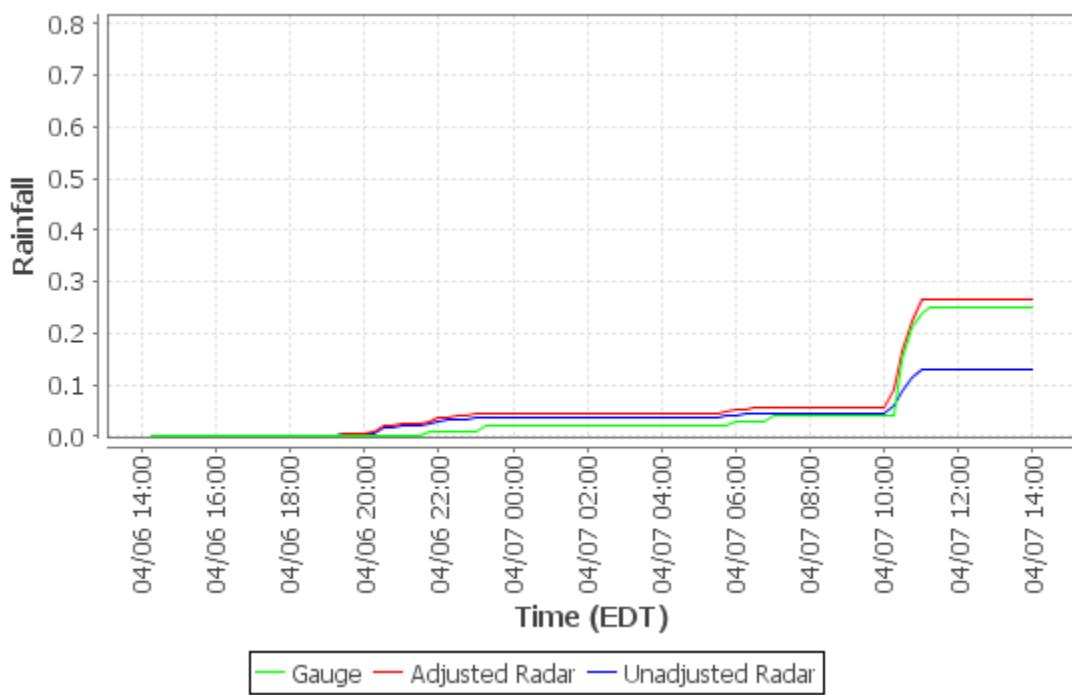
Cumulative Distribution Plot - Greentree Munic Bldg (Loc07)



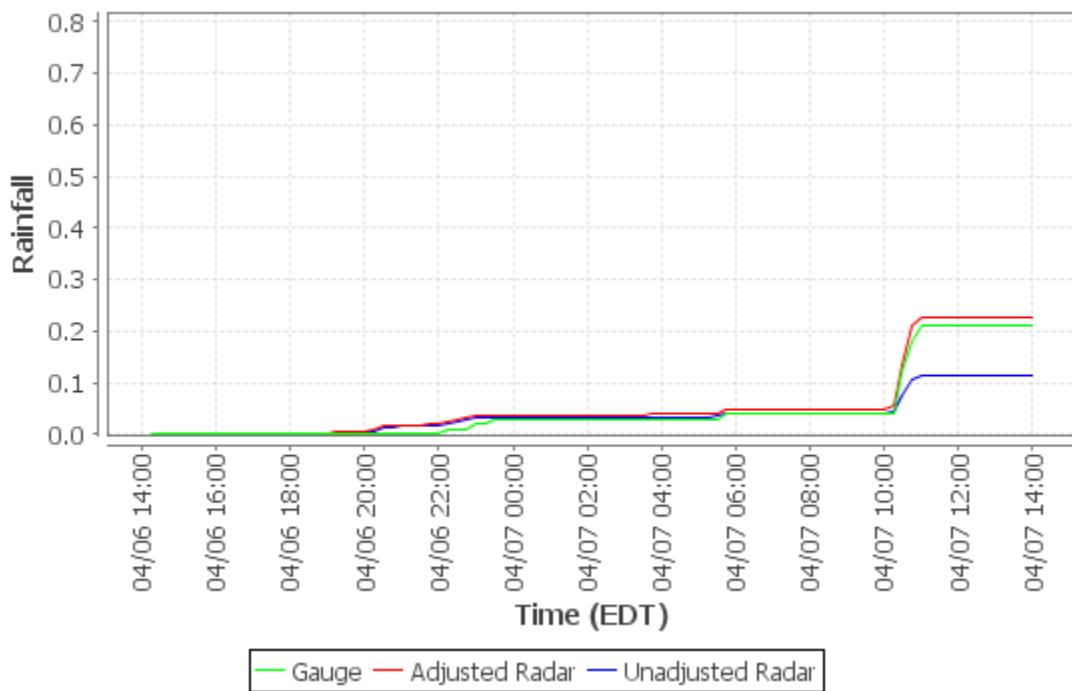
Cumulative Distribution Plot - AC Health Dept Bldg (Loc08)



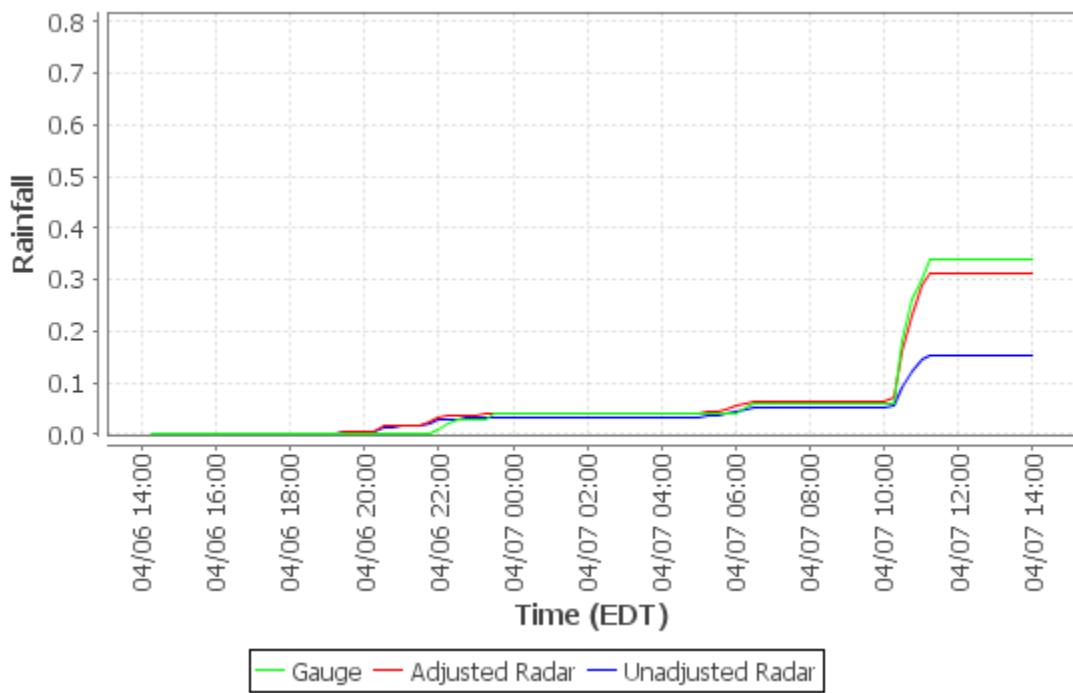
Cumulative Distribution Plot - Univ of Pittsburgh (Loc09)



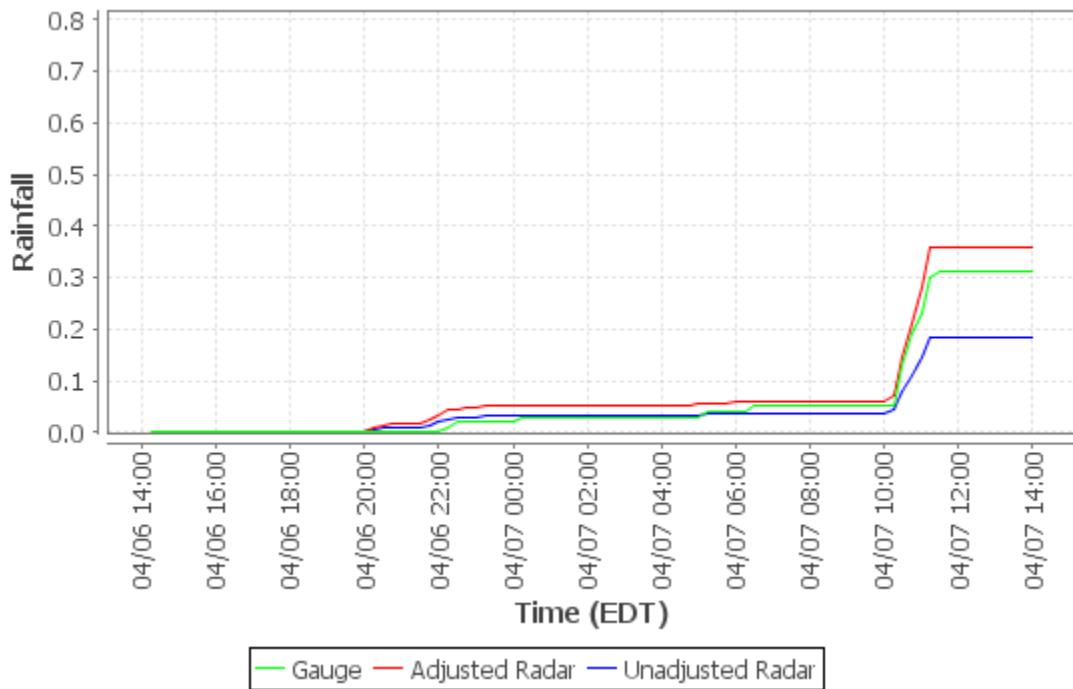
Cumulative Distribution Plot - PWSA-Highland Park (Loc10)



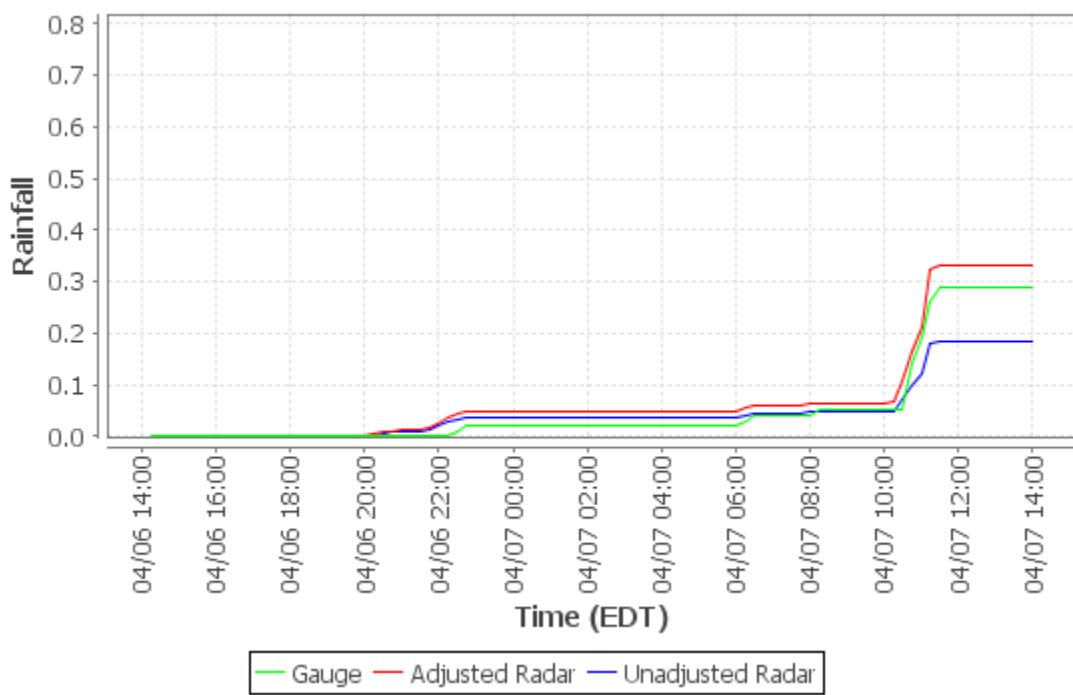
Cumulative Distribution Plot - M-46 Access Shaft (Loc11)



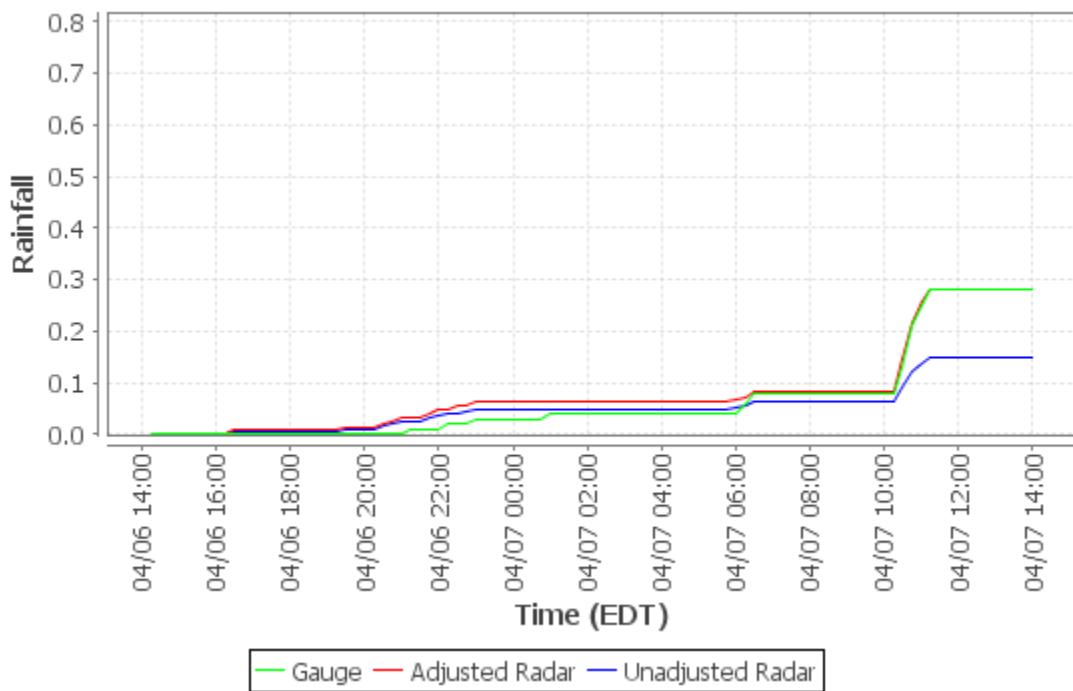
Cumulative Distribution Plot - Baldwin (Loc12)



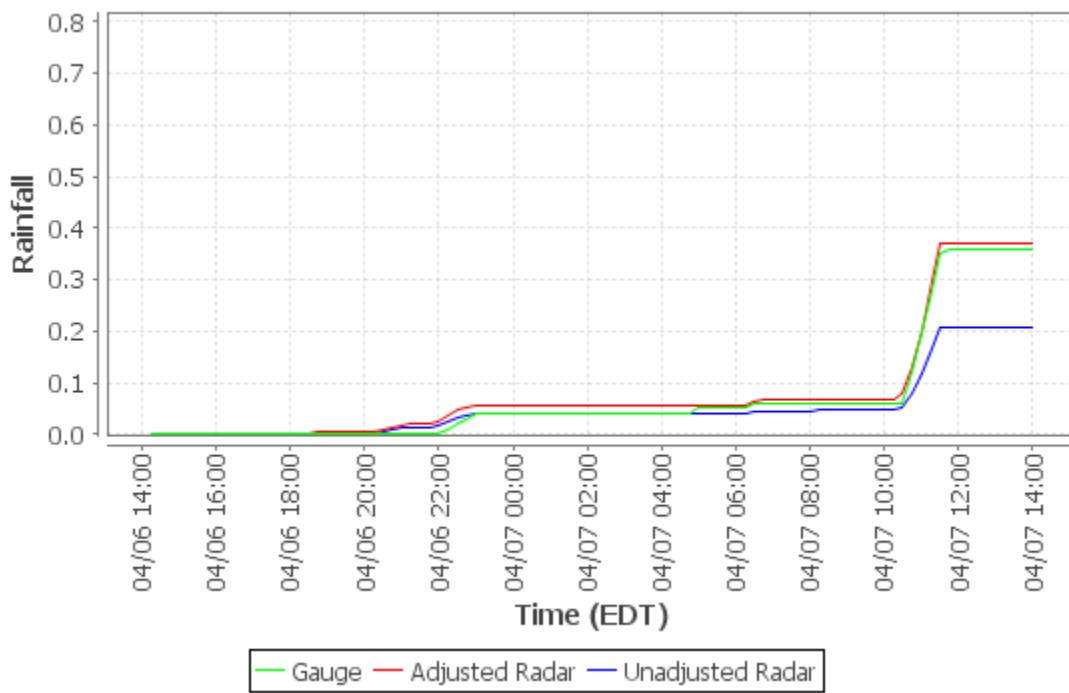
Cumulative Distribution Plot - M-59 Access Shaft (Loc13)



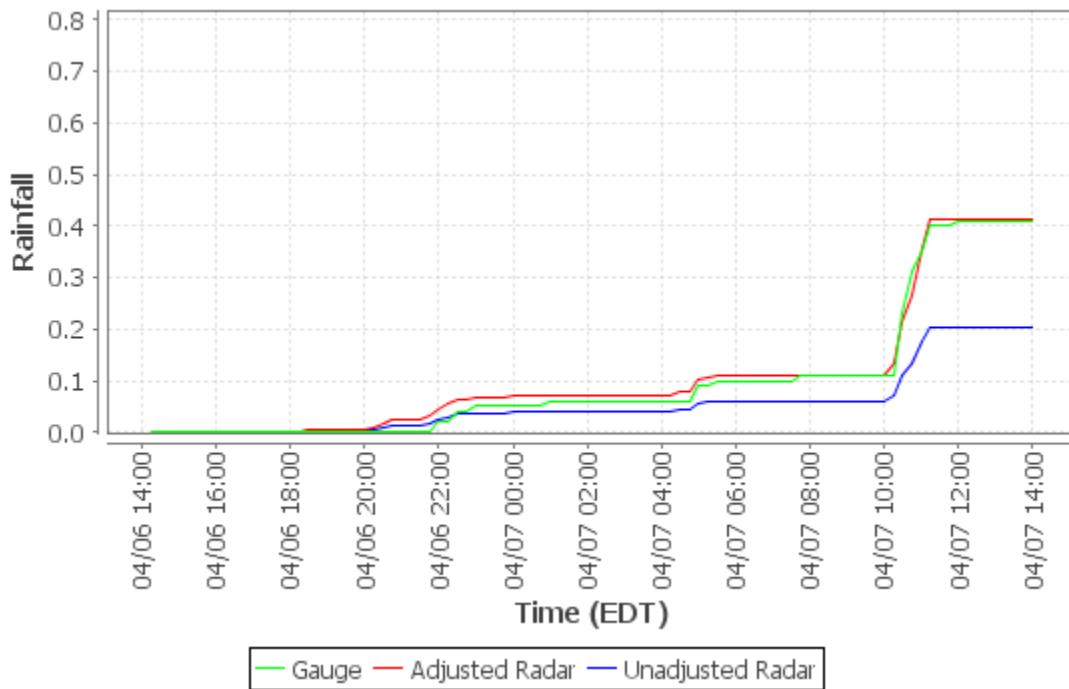
Cumulative Distribution Plot - Churchill Munic Bldg (Loc14)



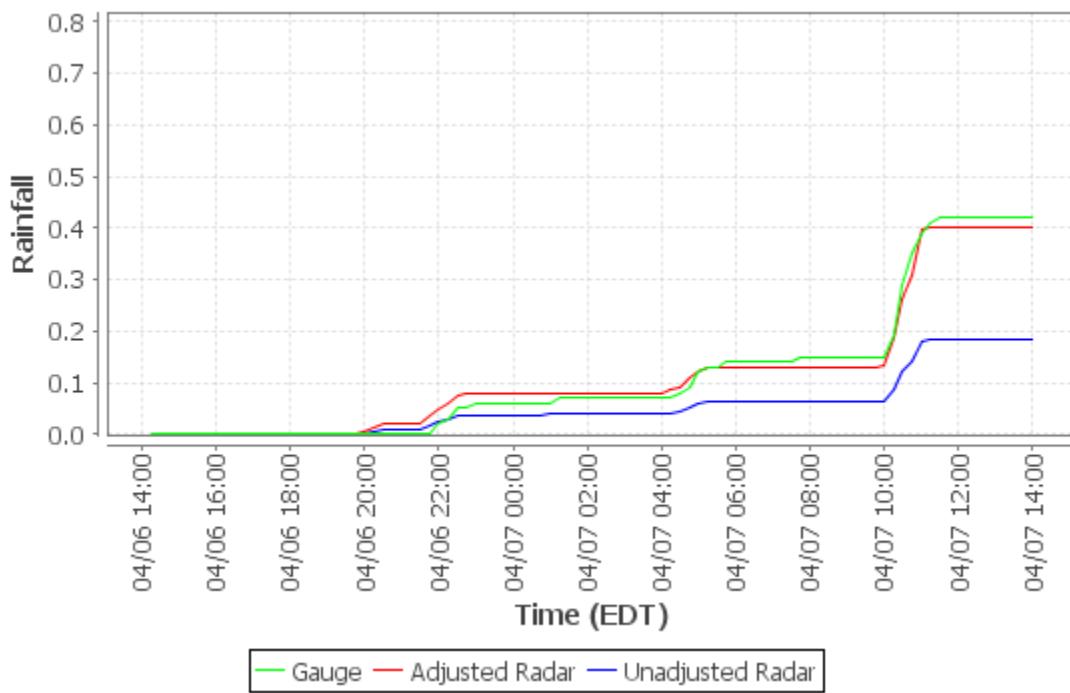
Cumulative Distribution Plot - Trafford Maint Bldg (Loc15)



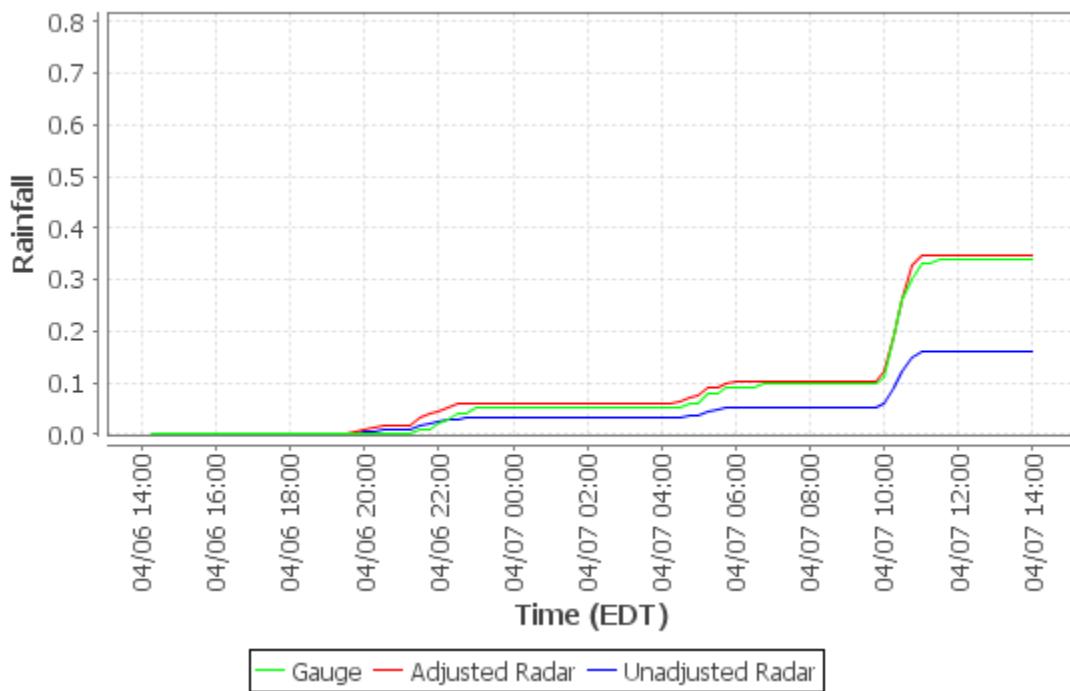
Cumulative Distribution Plot - Castle Shannon (Loc16)



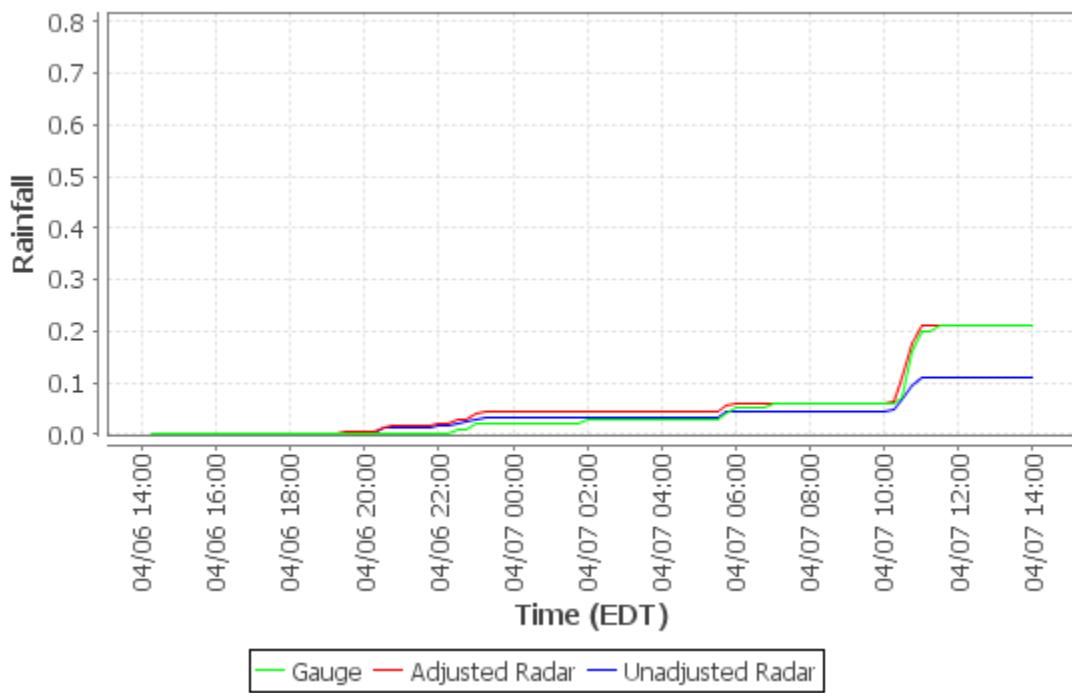
Cumulative Distribution Plot - Chartiers Pump Station (Loc17)



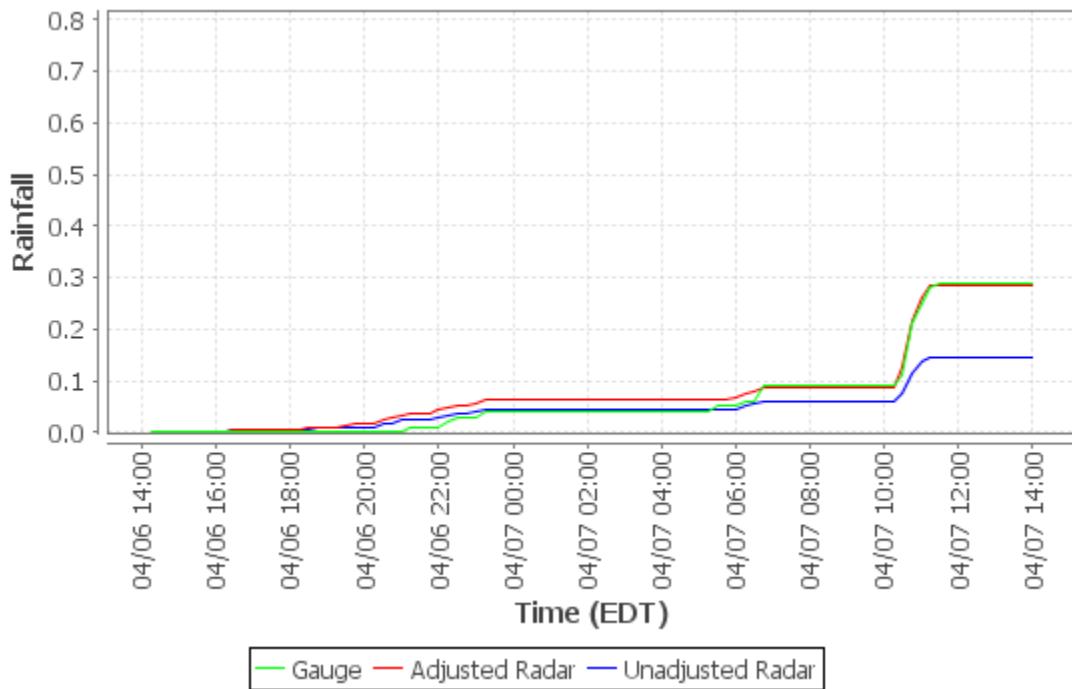
Cumulative Distribution Plot - Oakdale Pump Station (Loc18)



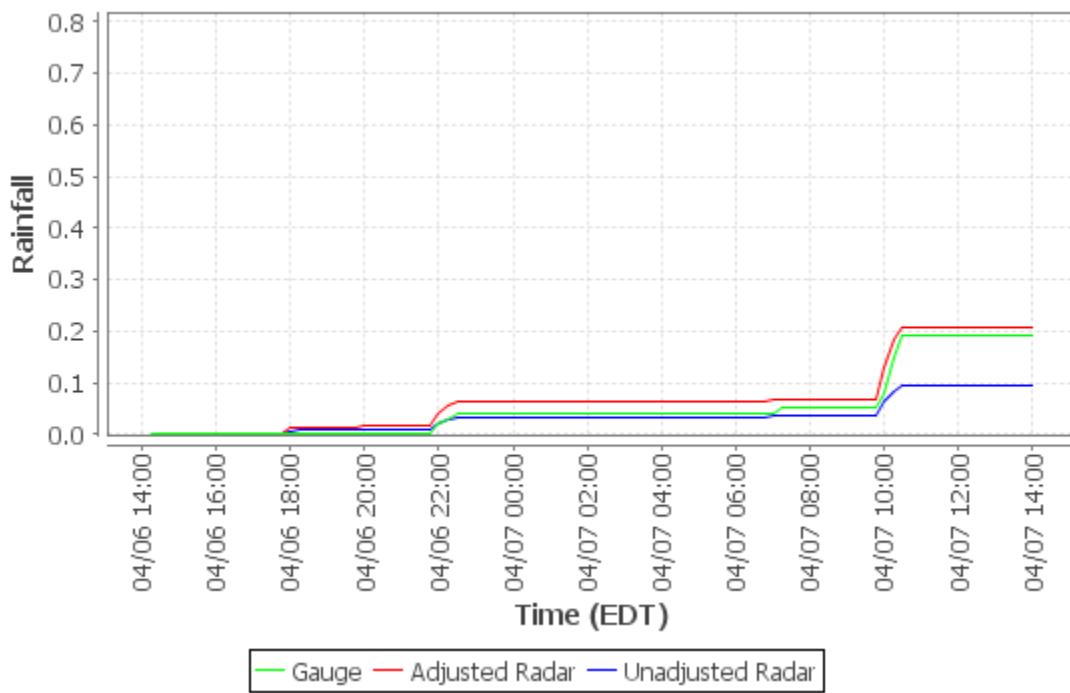
Cumulative Distribution Plot - Sandy Creek Eq Facility (Loc19)



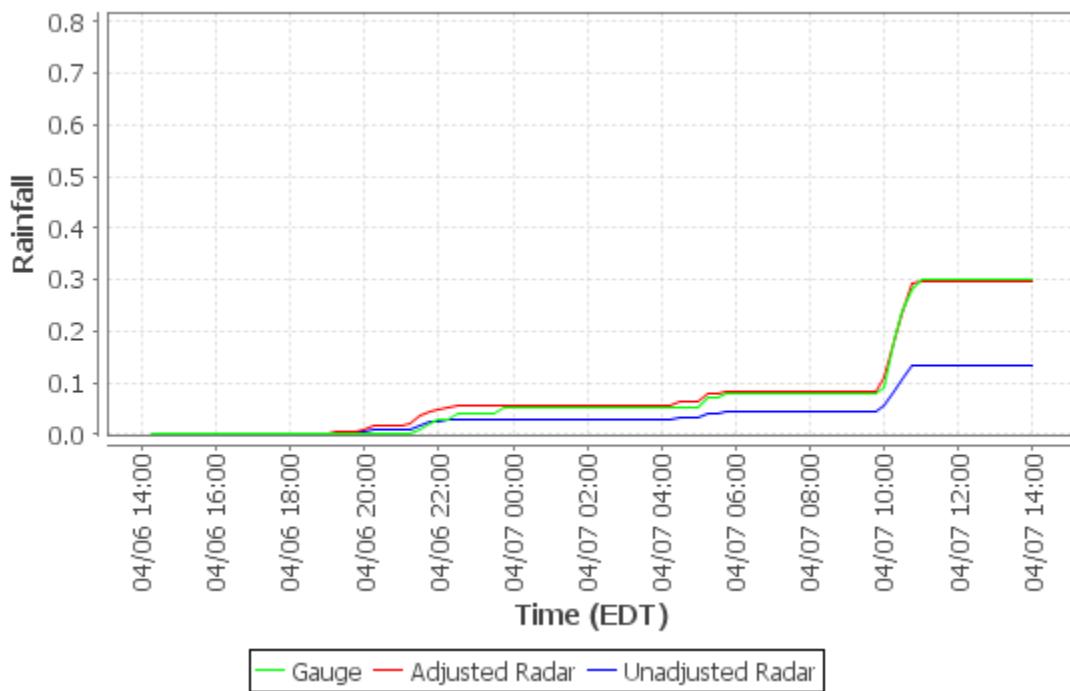
Cumulative Distribution Plot - Gascola Eq Facility (Loc20)



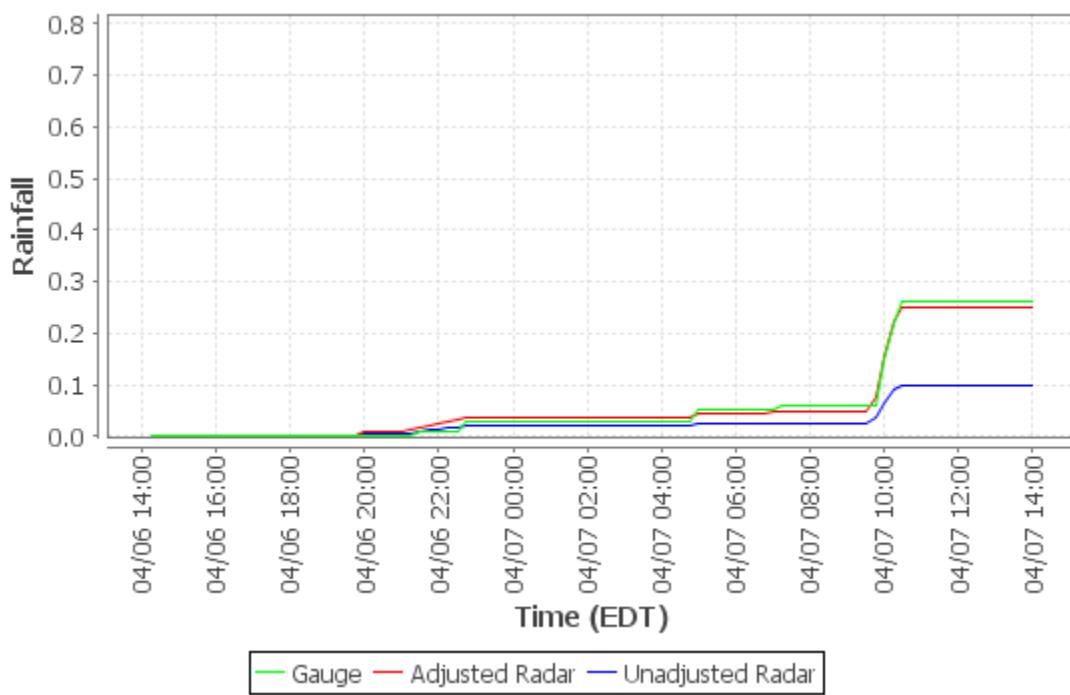
Cumulative Distribution Plot - Moon TWP (Loc21)



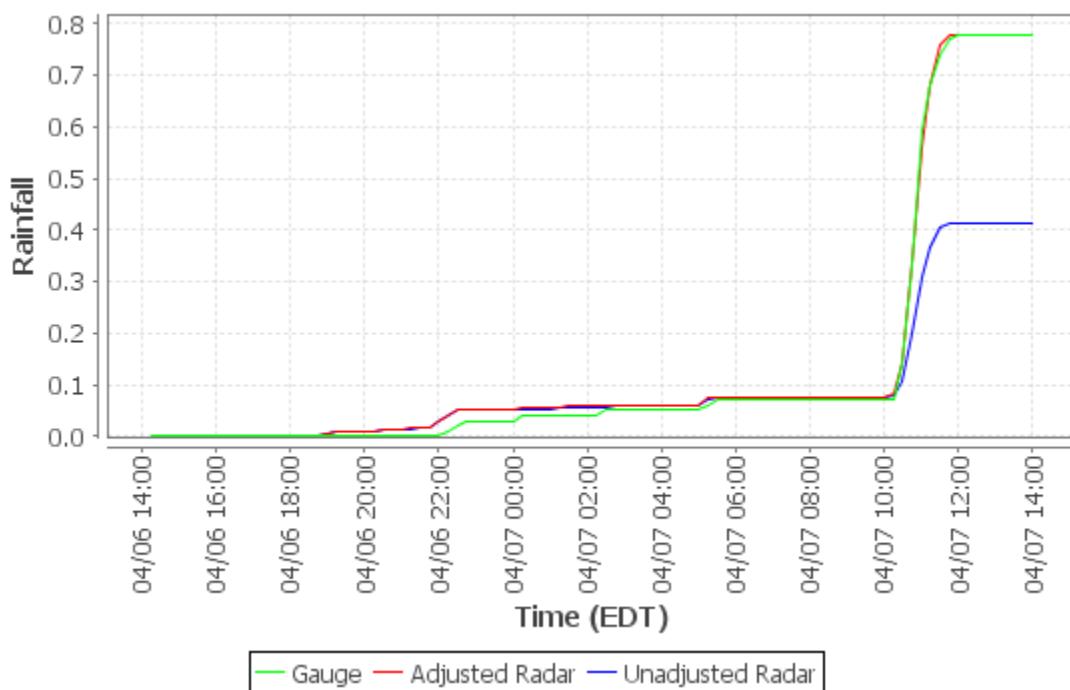
Cumulative Distribution Plot - North Fayette TWP (Loc22)



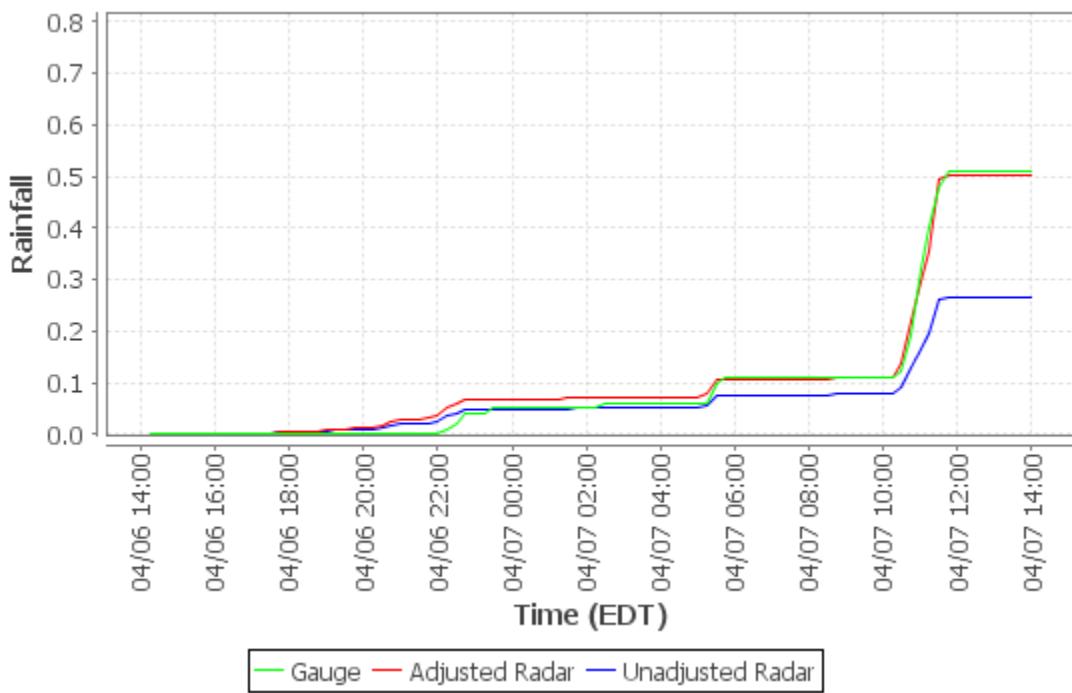
Cumulative Distribution Plot - Clinton Munic Bldg (Loc23)



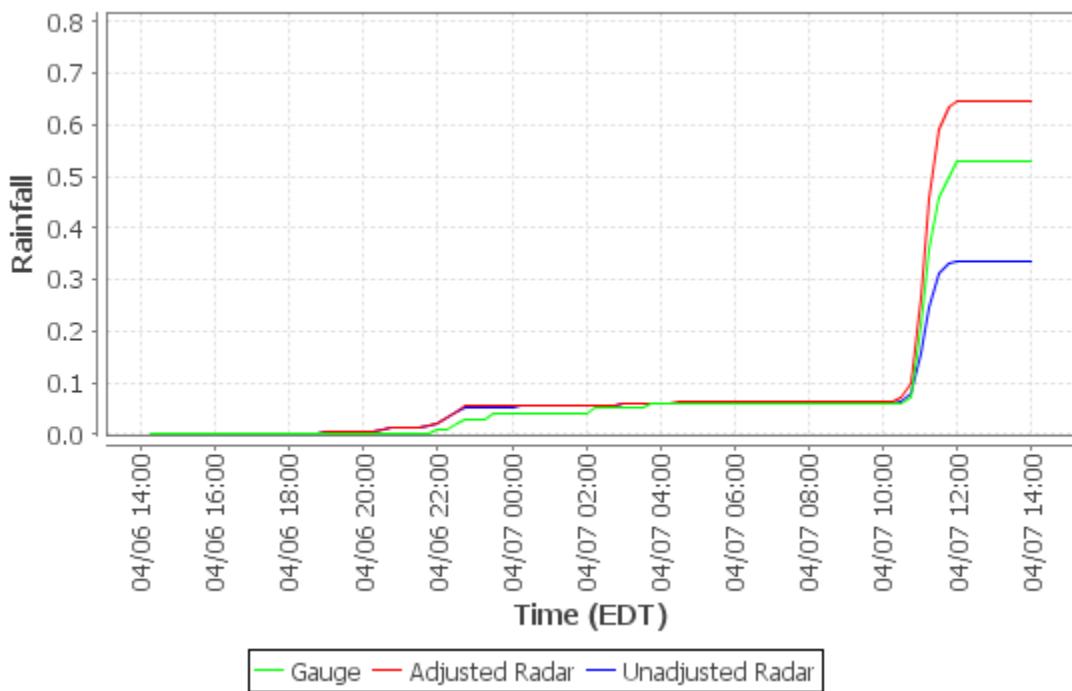
Cumulative Distribution Plot - Jefferson Hills (Loc24)



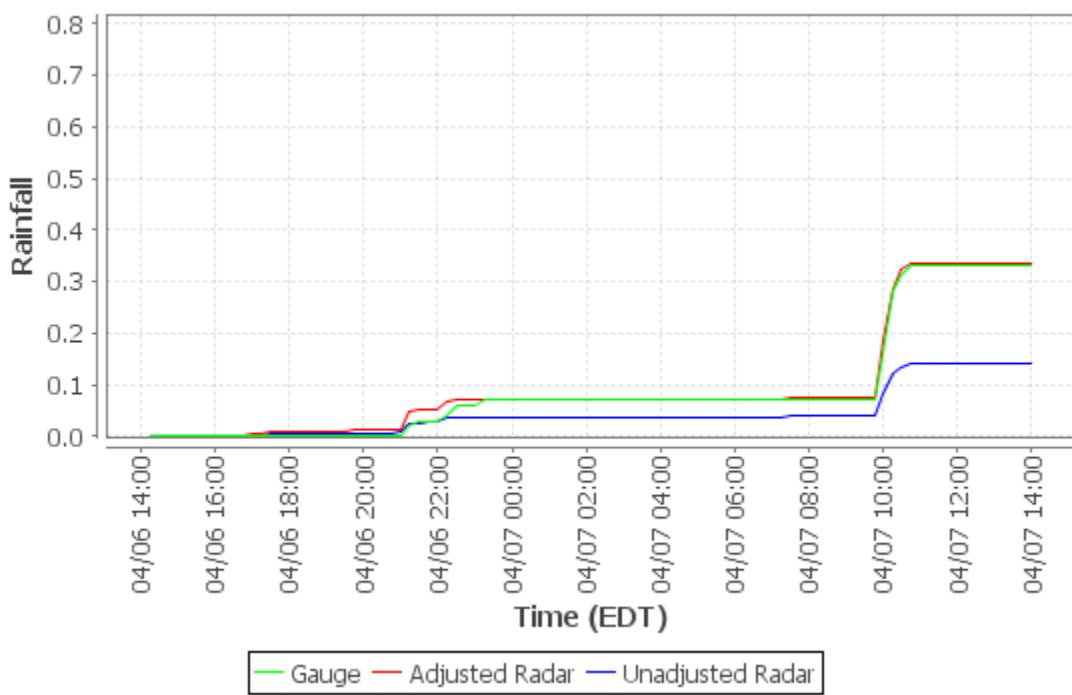
Cumulative Distribution Plot - White Oak Public Works Bldg (Loc25)



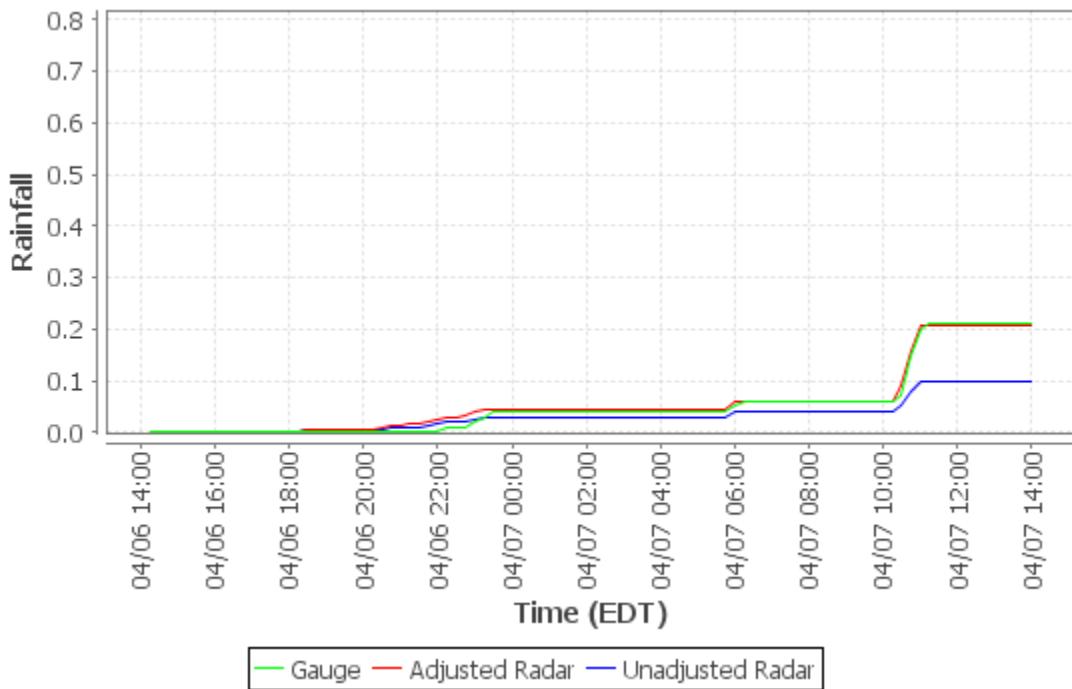
Cumulative Distribution Plot - Elizabeth TWP Municipal Bldg (Loc26)



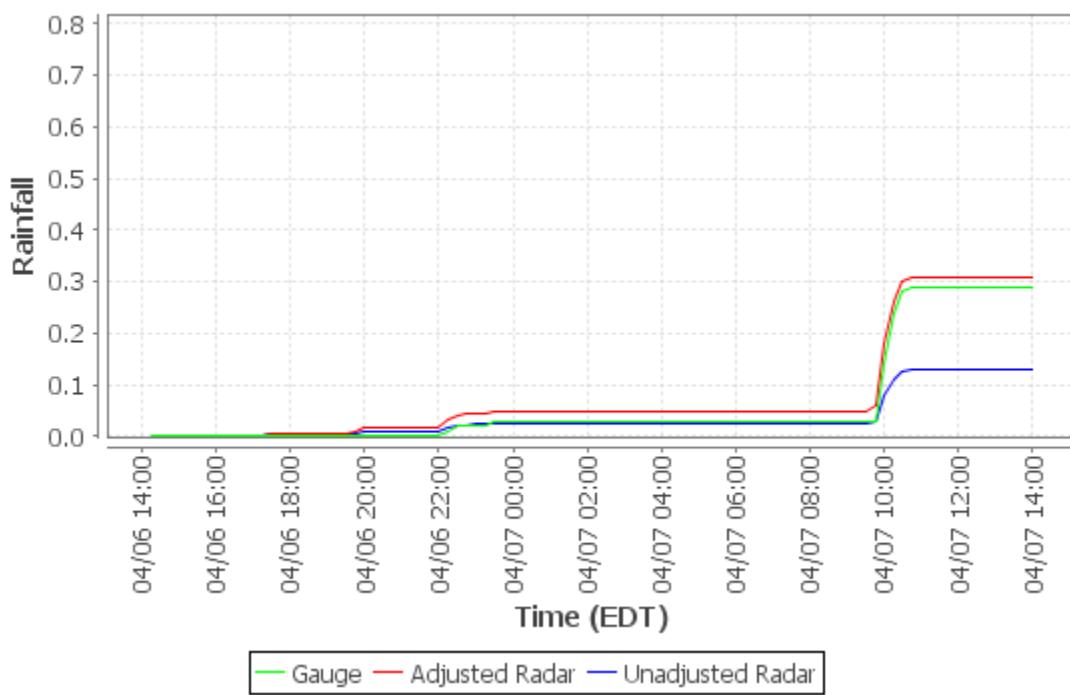
Cumulative Distribution Plot - Marshall TWP (Loc27)



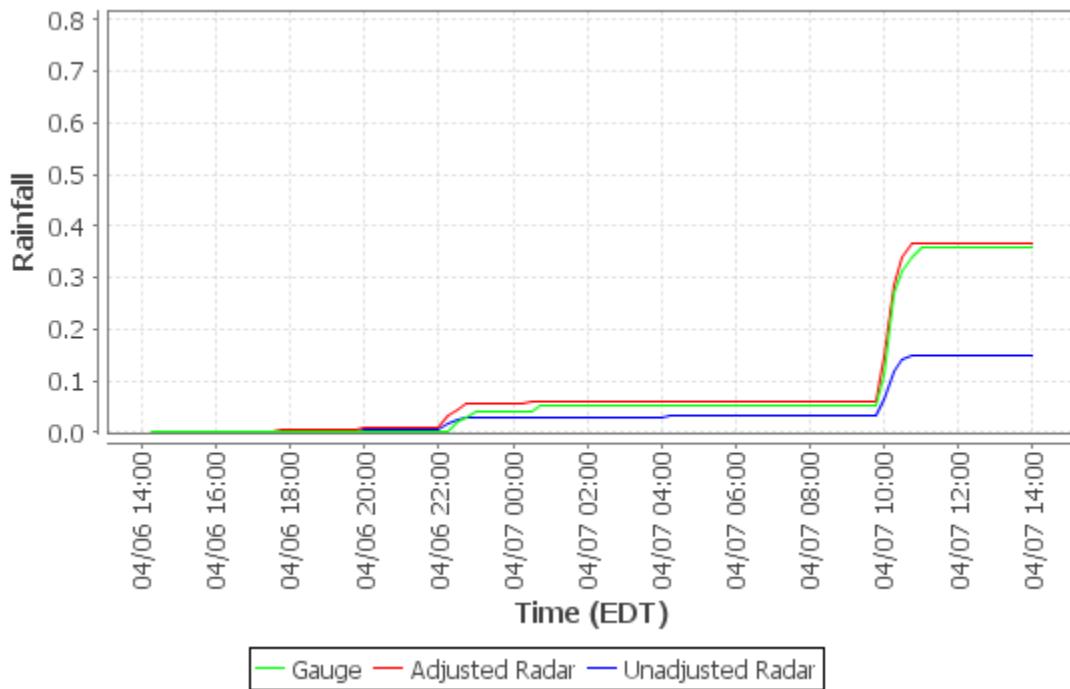
Cumulative Distribution Plot - Plum Municipal Bldg (Loc28)



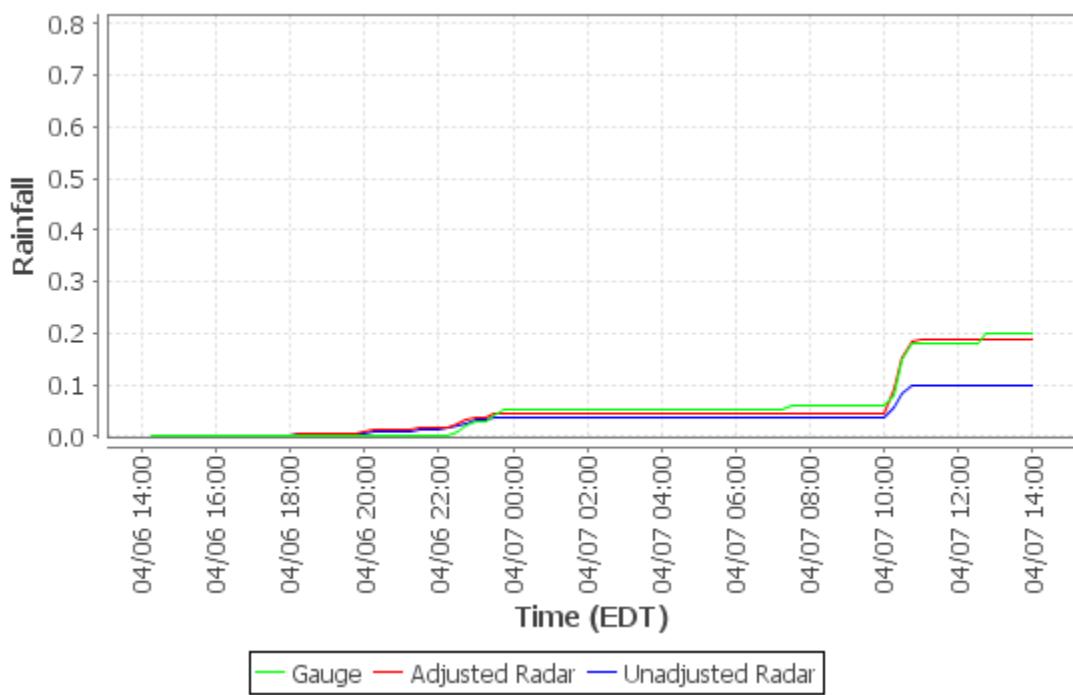
Cumulative Distribution Plot - Bell Acres Munic Bldg (Loc29)



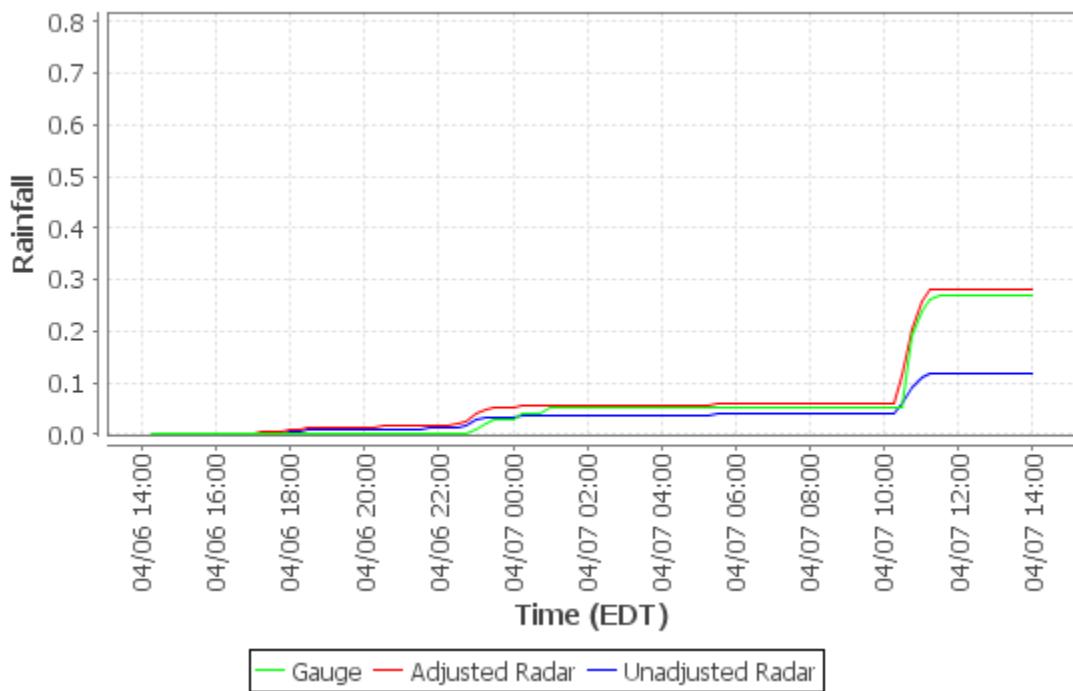
Cumulative Distribution Plot - McCandless Twn Hall (Loc30)



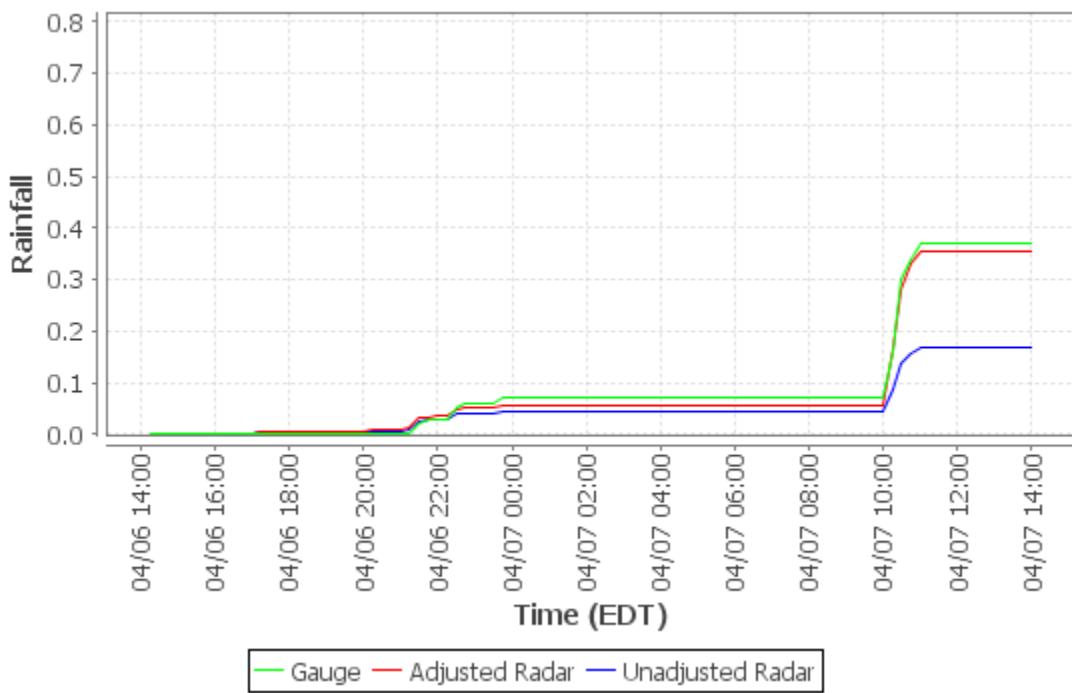
Cumulative Distribution Plot - Hampton Municipal Bldg (Loc31)



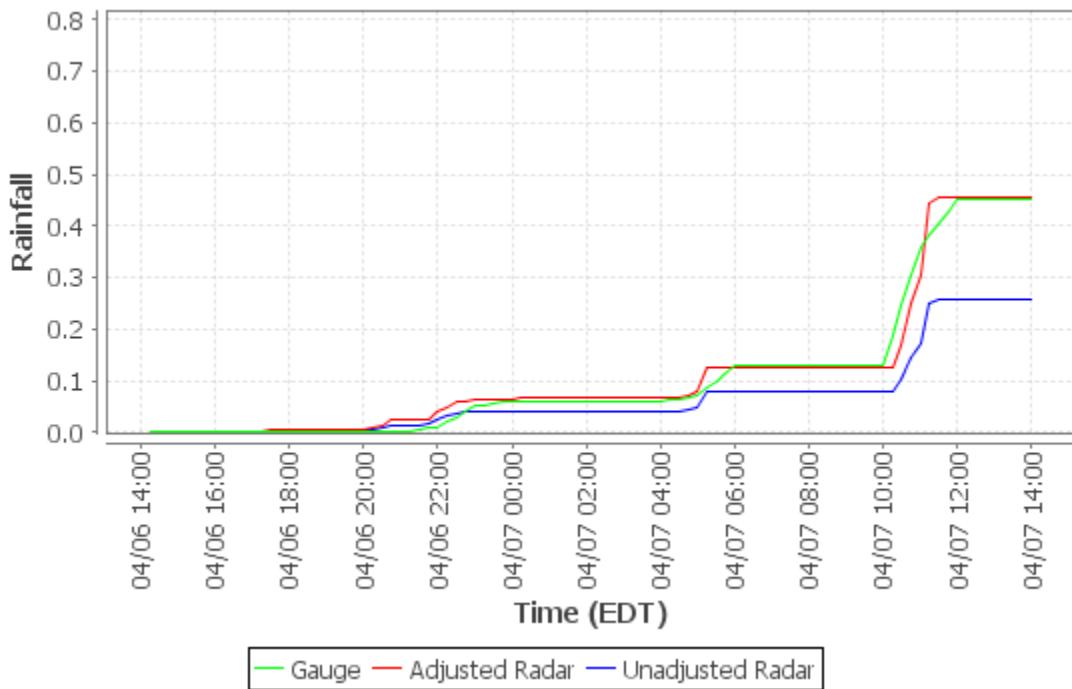
Cumulative Distribution Plot - Arnold (Loc32)



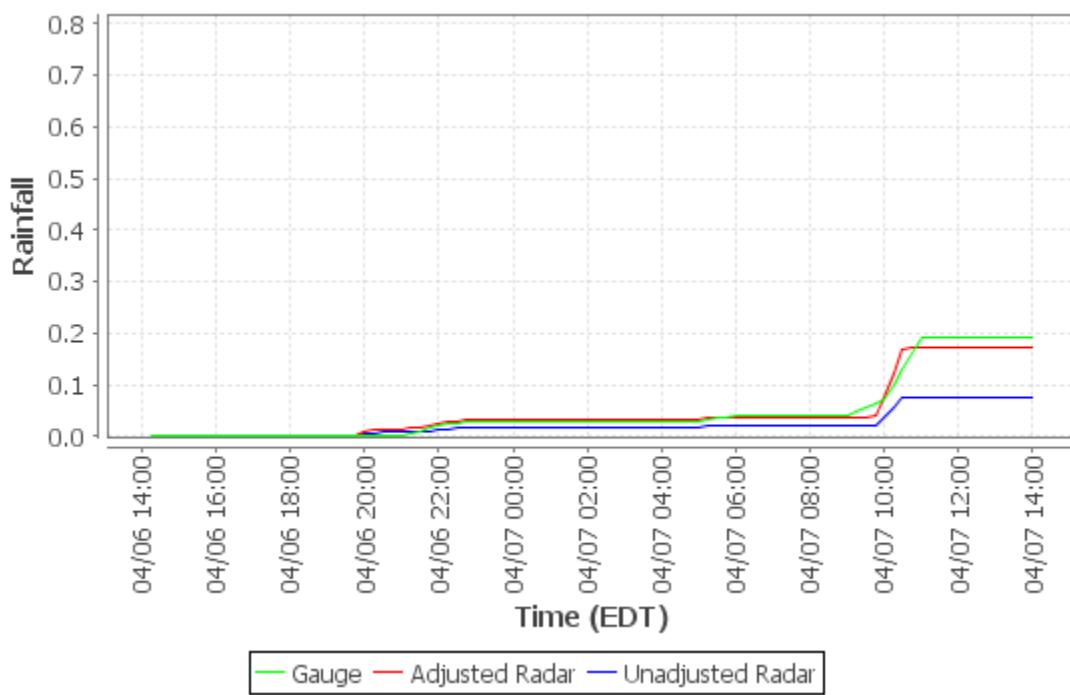
Cumulative Distribution Plot - Richland TWP (Loc33)



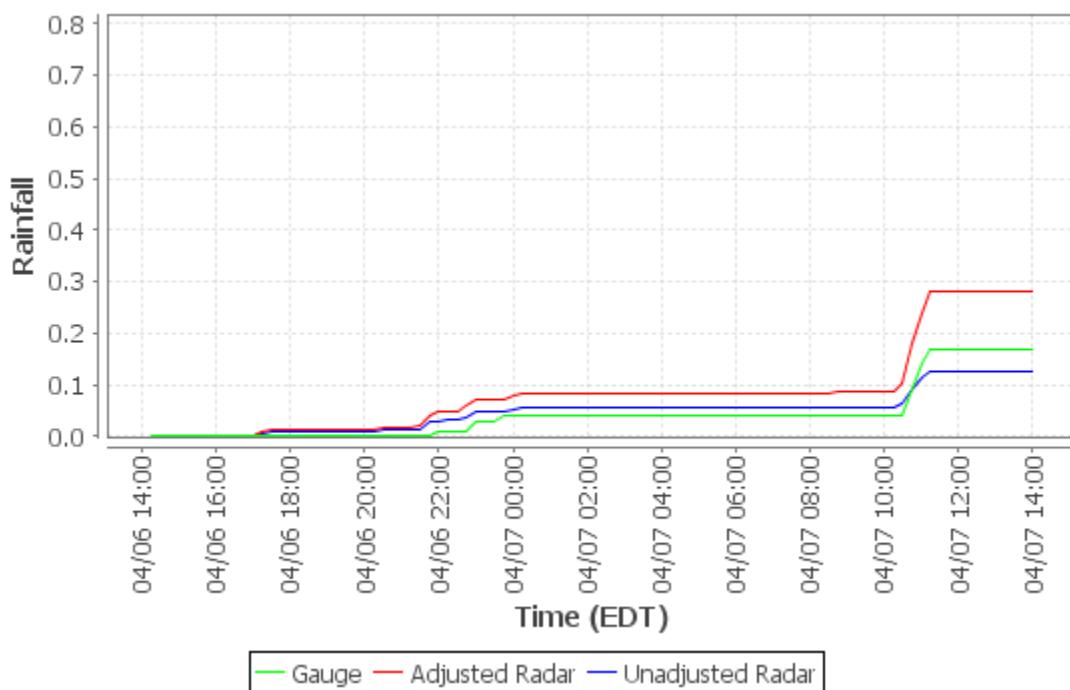
Cumulative Distribution Plot - Pittsburgh Allegheny Cty (KAGC)



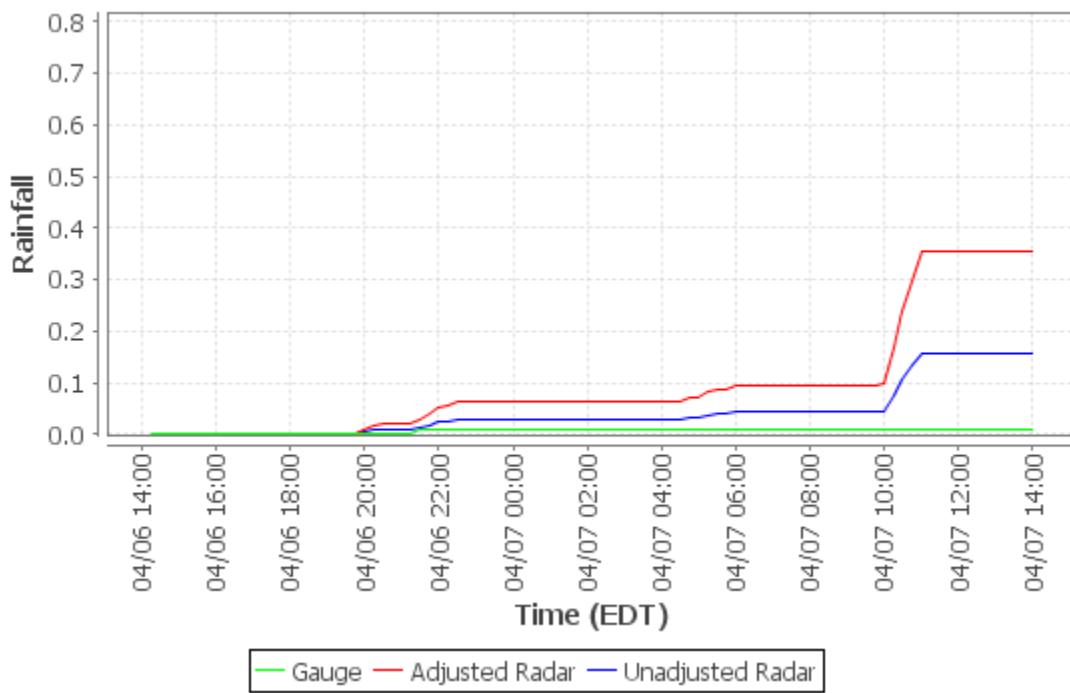
Cumulative Distribution Plot - Greater Pittsburgh Int'l (KPIT)



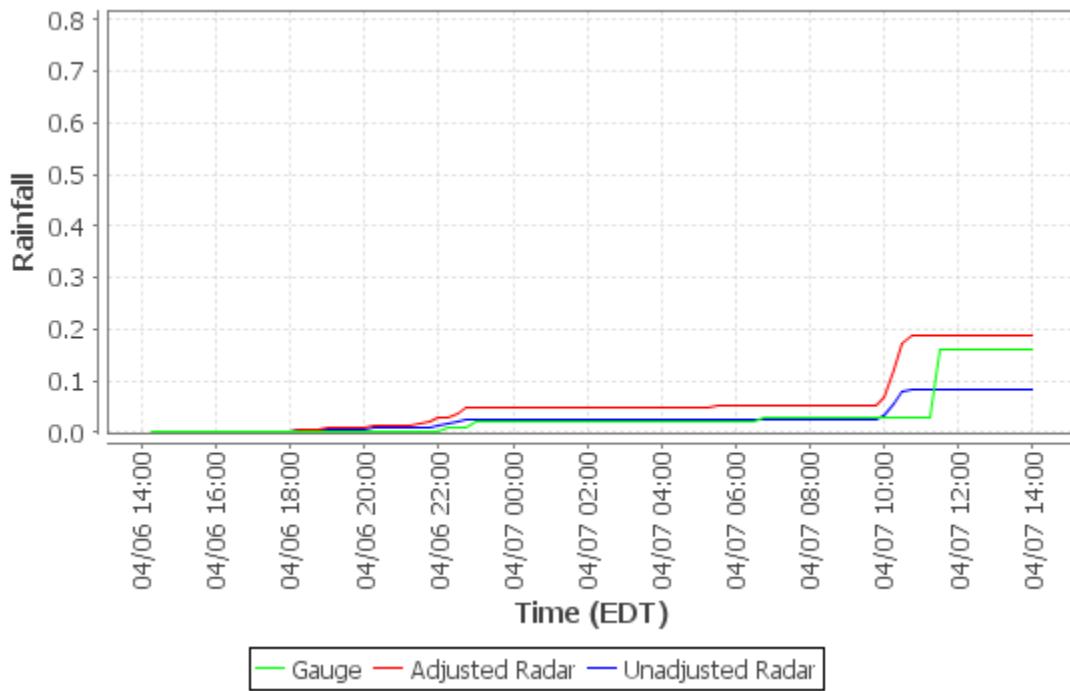
Cumulative Distribution Plot - Allegheny River at Natrona (03049500)



Cumulative Distribution Plot - Chartiers Creek at Carnegie (03085500)

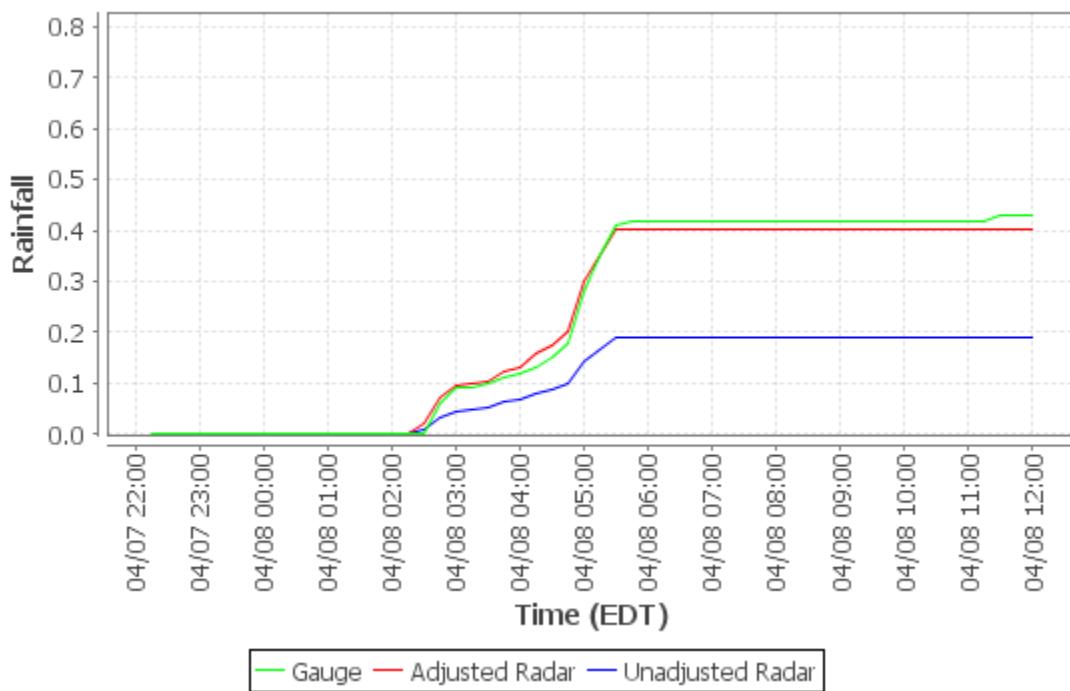


Cumulative Distribution Plot - Ohio River at Emsworth Dam Lower Pool at Emsworth (03085734)

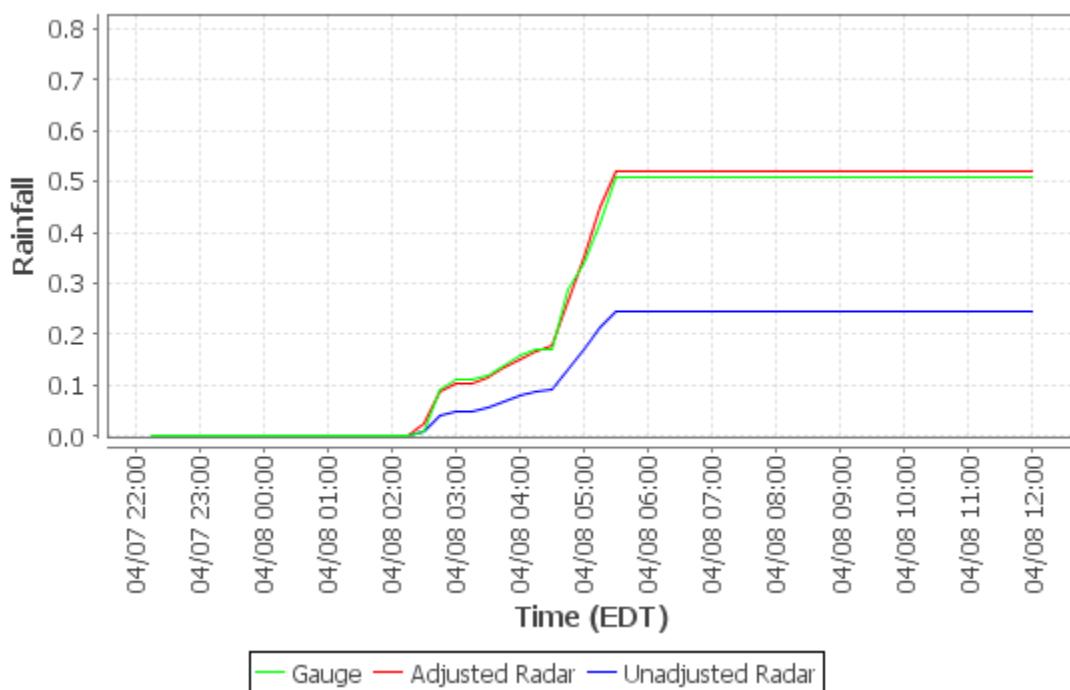


Appendix E - Event 4 (2015-04-08 AM) CDPs

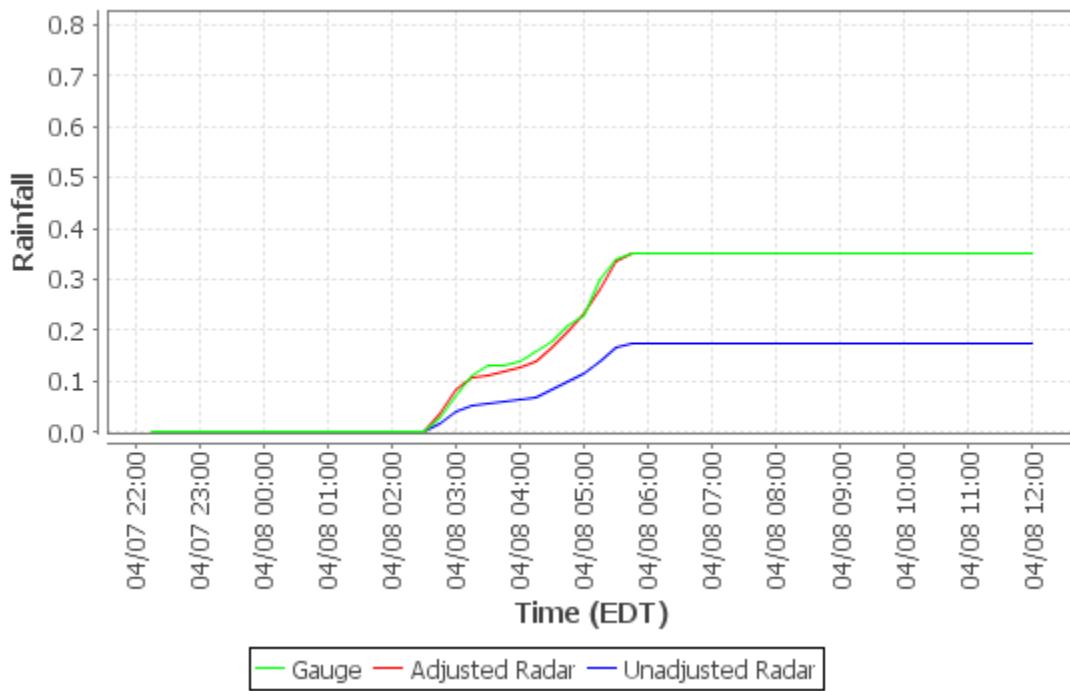
Cumulative Distribution Plot - PWSA-Montana St. (Loc01)



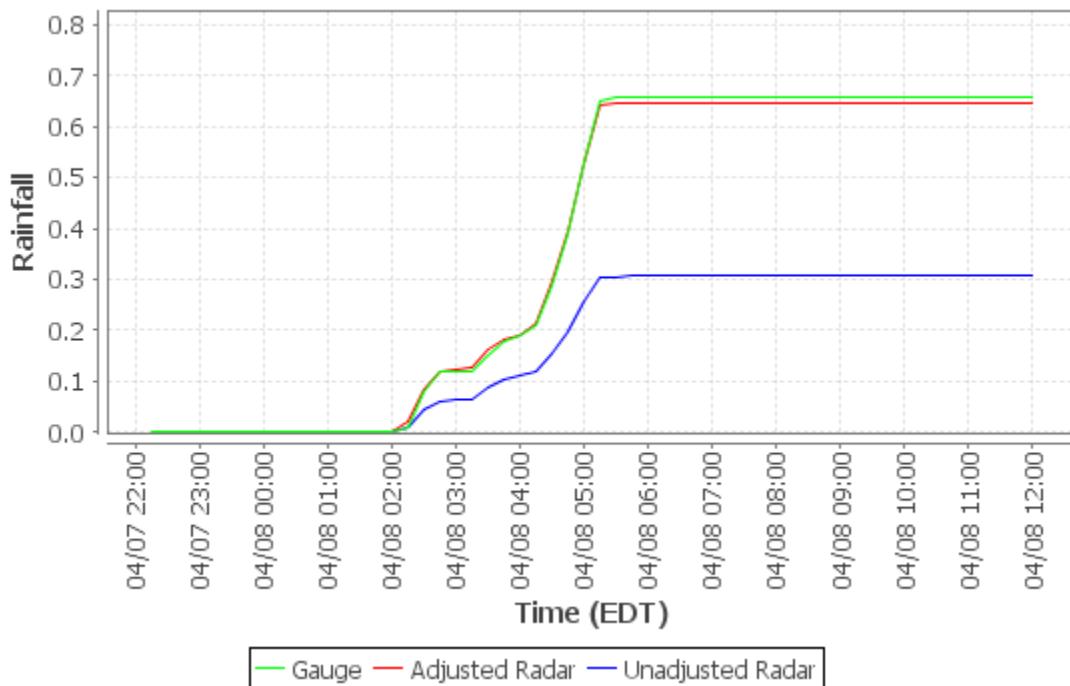
Cumulative Distribution Plot - ALCOSAN WWTP Lab (Loc02)



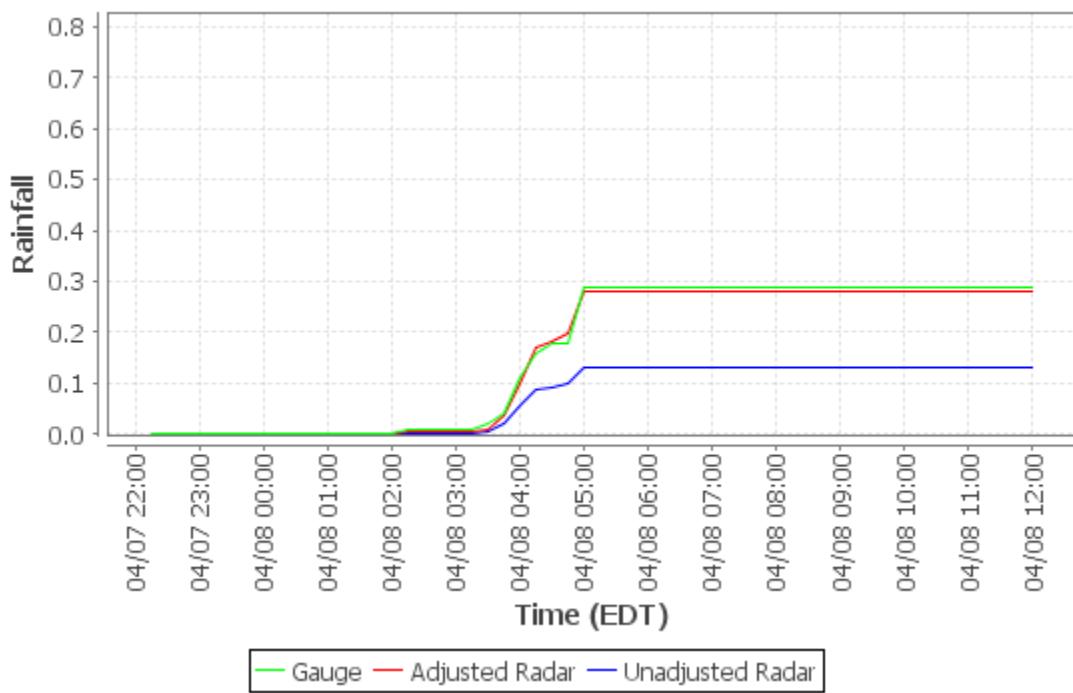
Cumulative Distribution Plot - Shaler Munic Bldg (Loc03)



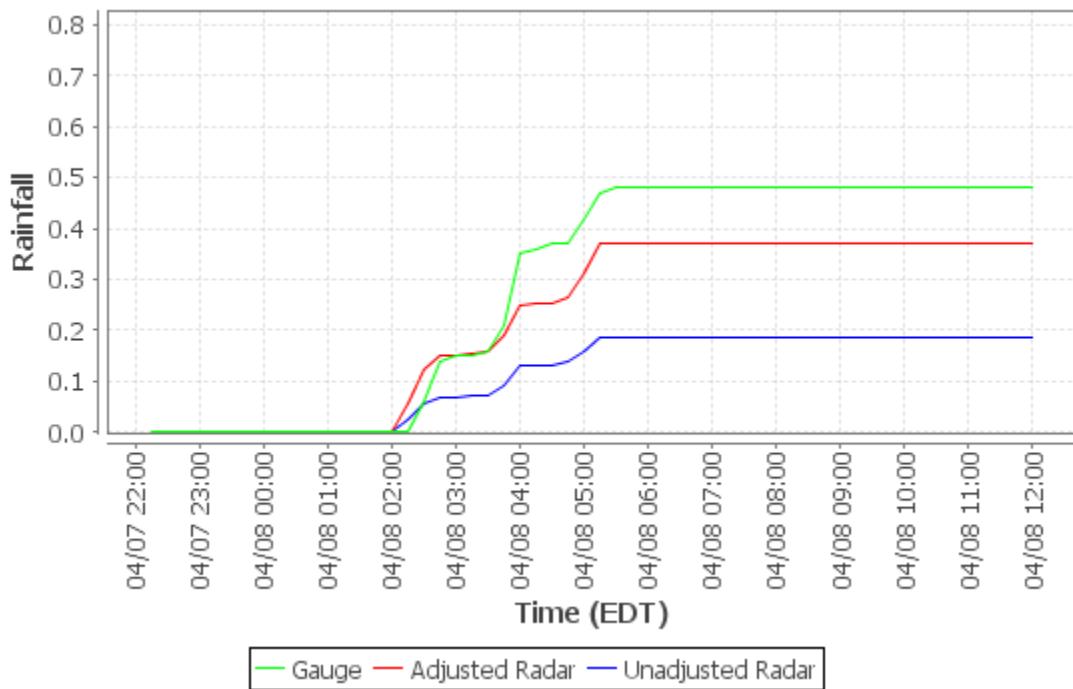
Cumulative Distribution Plot - Kennedy Twp PS (Loc04)



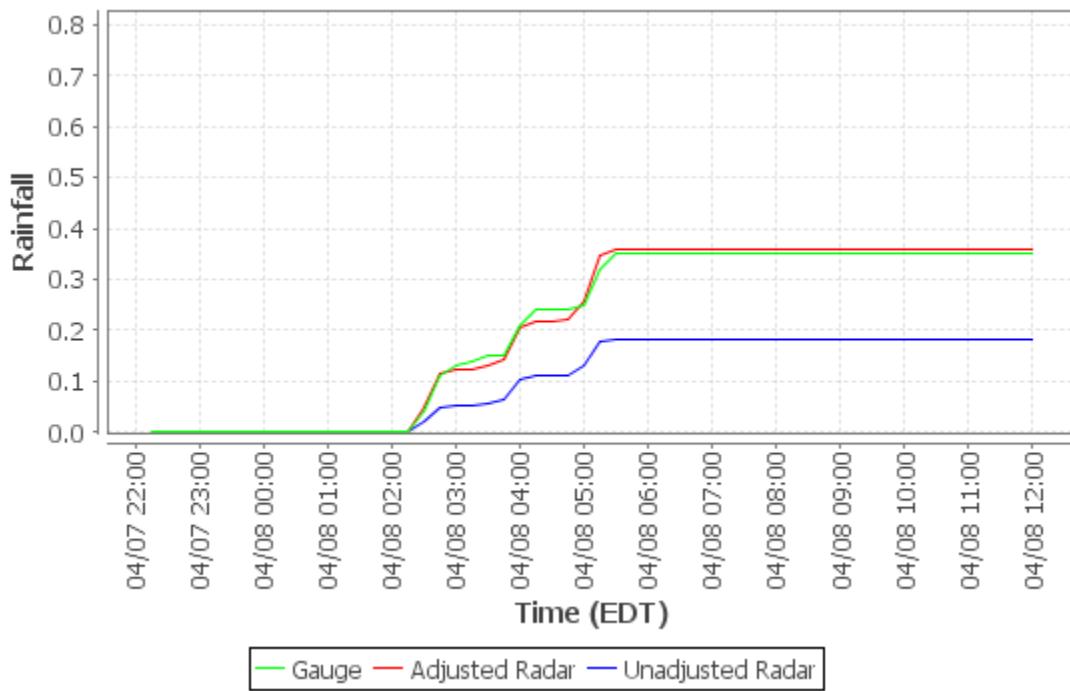
Cumulative Distribution Plot - Upper St. Clair (Loc05)



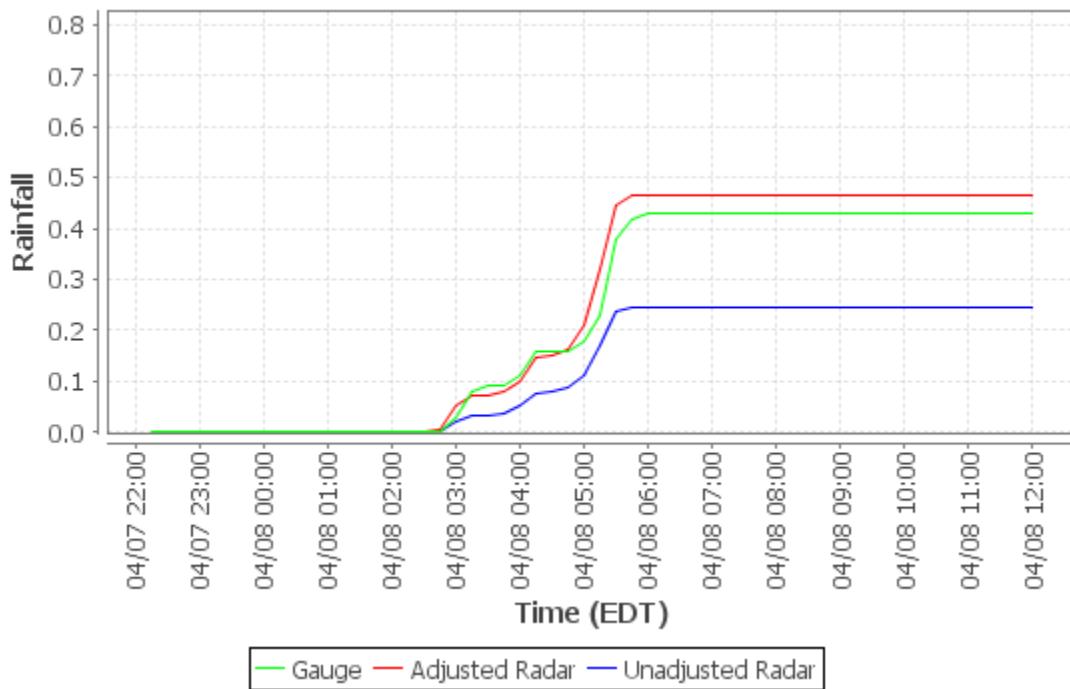
Cumulative Distribution Plot - Carnegie Transit Time (Loc06)



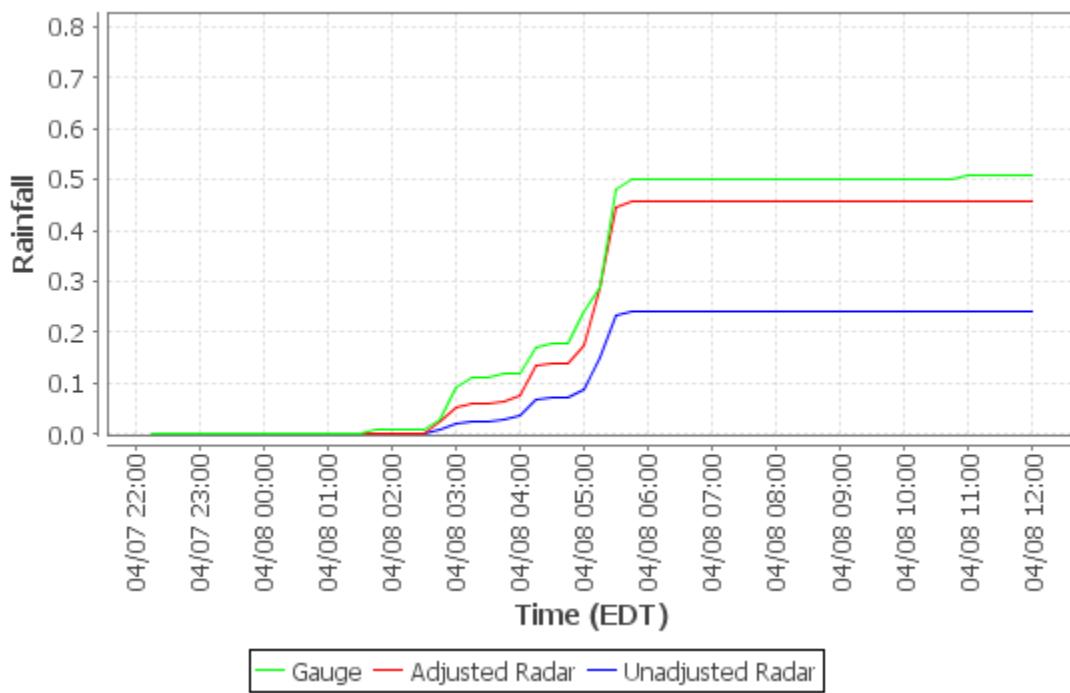
Cumulative Distribution Plot - Greentree Munic Bldg (Loc07)



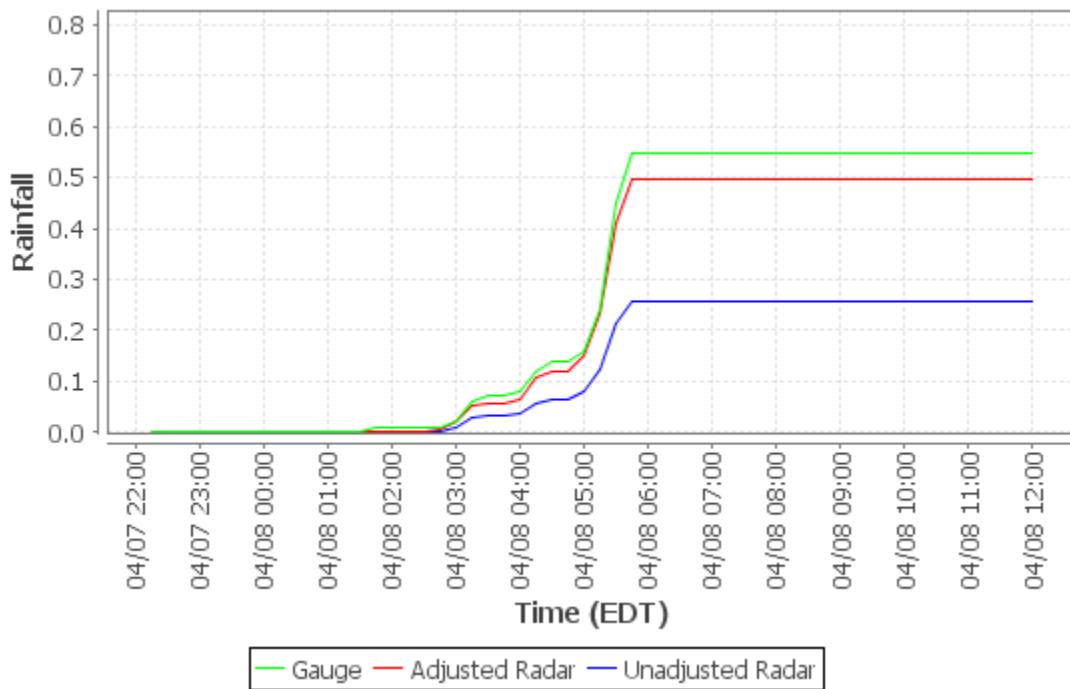
Cumulative Distribution Plot - AC Health Dept Bldg (Loc08)



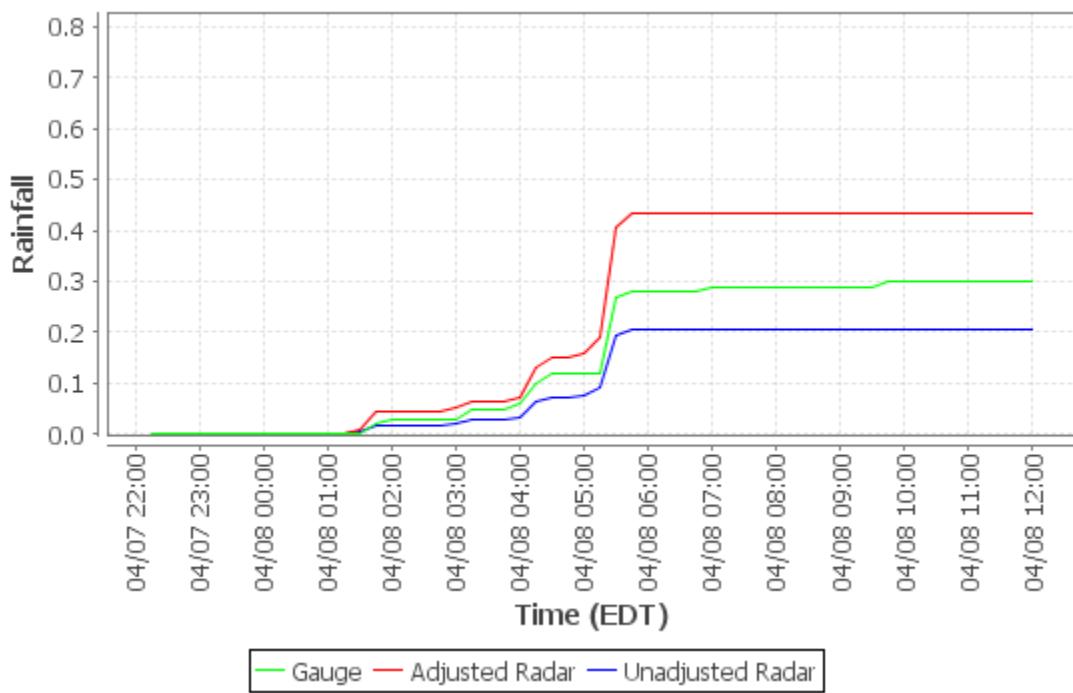
Cumulative Distribution Plot - Univ of Pittsburgh (Loc09)



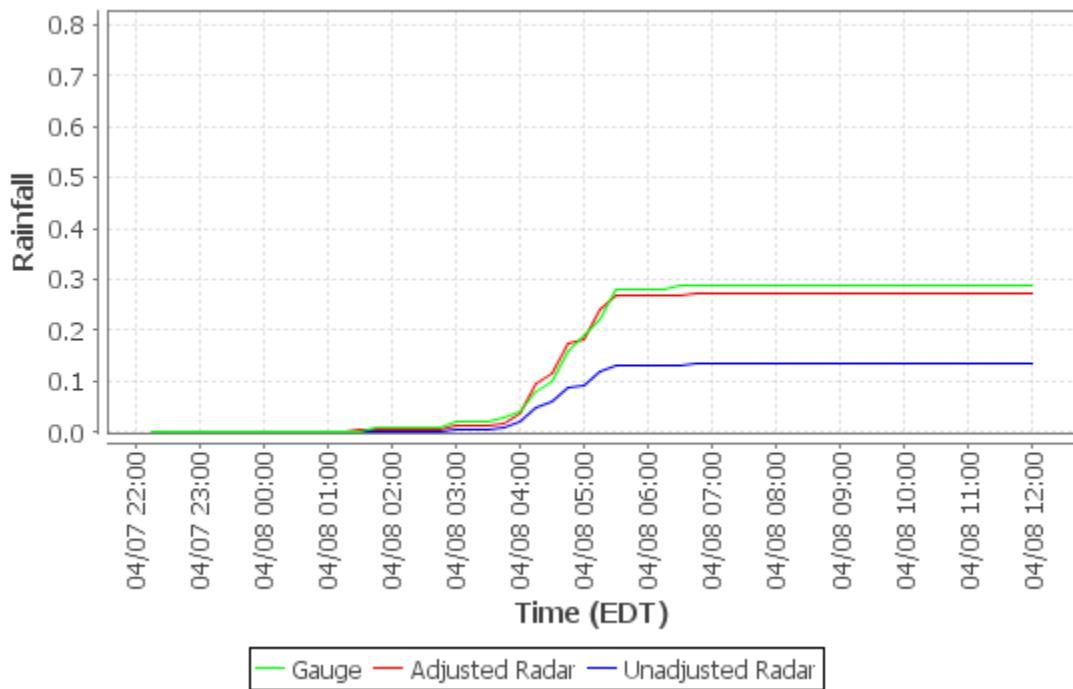
Cumulative Distribution Plot - PWSA-Highland Park (Loc10)



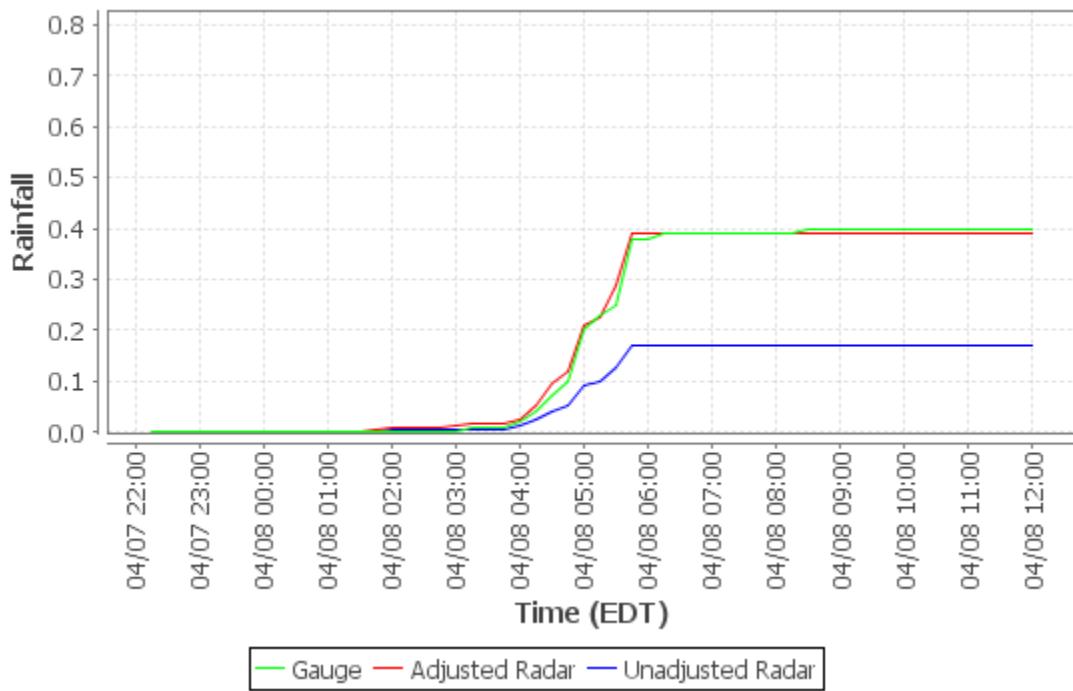
Cumulative Distribution Plot - M-46 Access Shaft (Loc11)



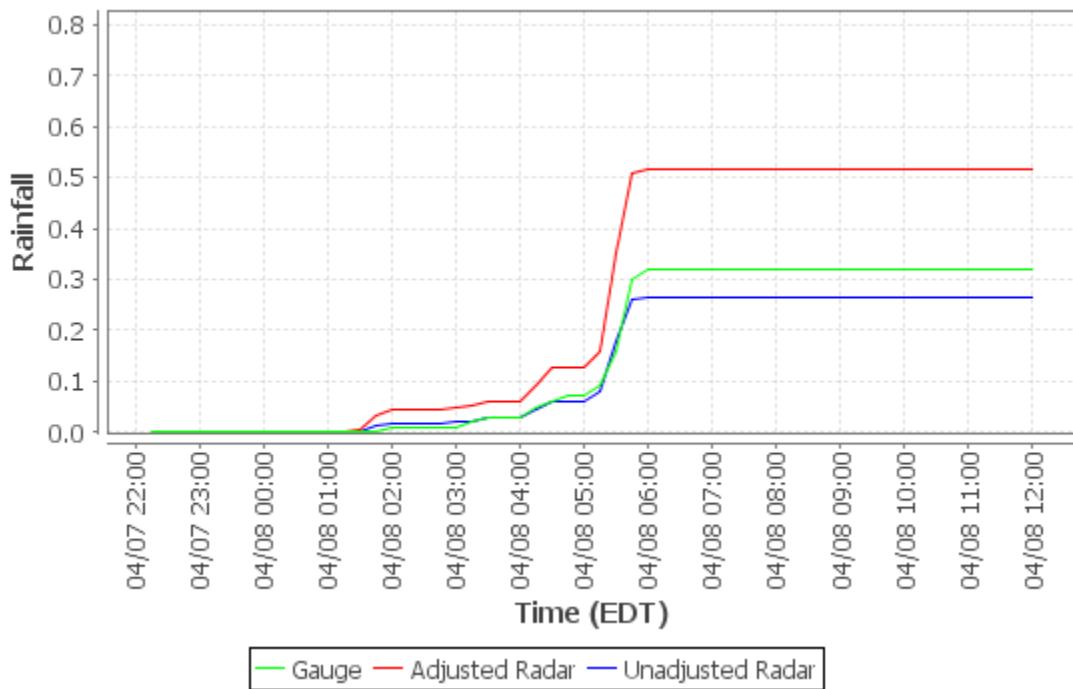
Cumulative Distribution Plot - Baldwin (Loc12)



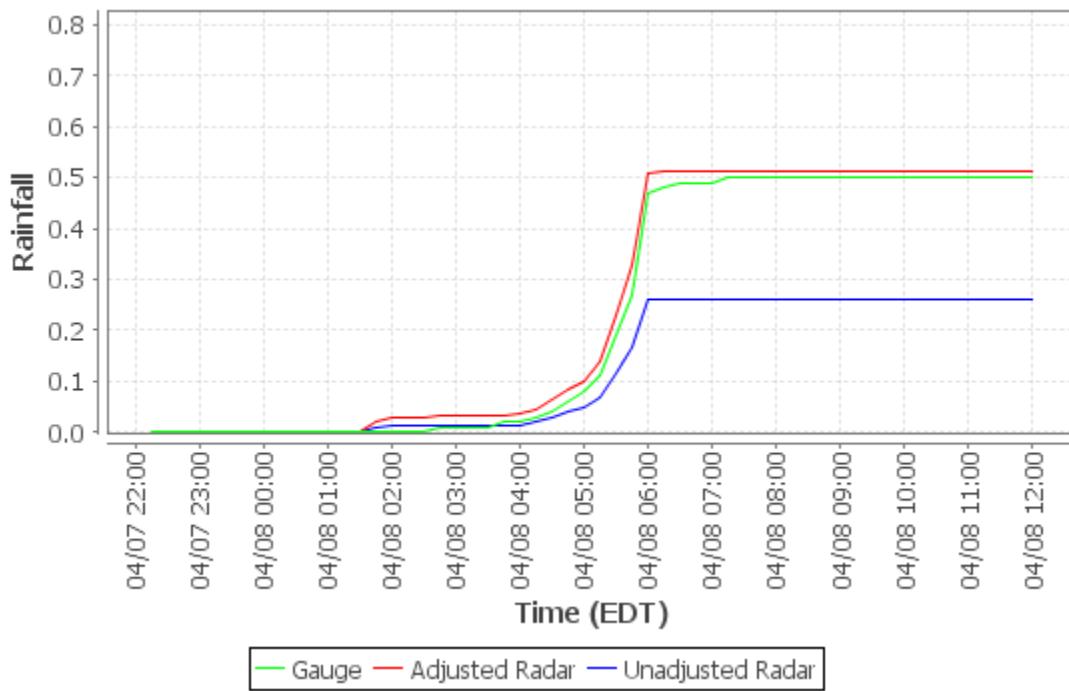
Cumulative Distribution Plot - M-59 Access Shaft (Loc13)



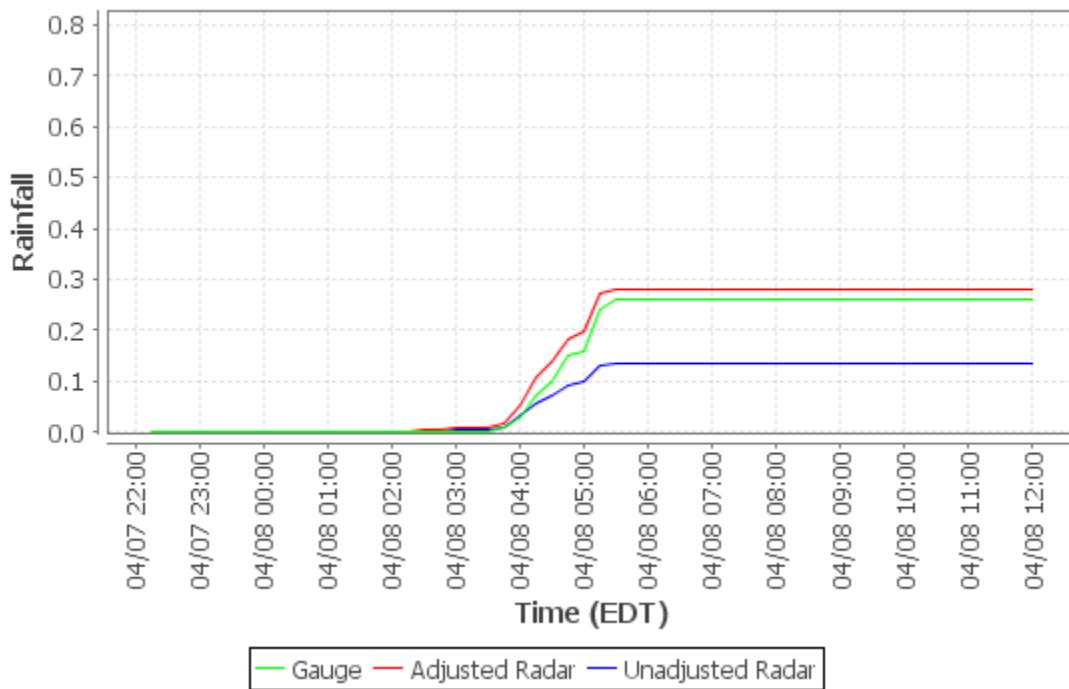
Cumulative Distribution Plot - Churchill Munic Bldg (Loc14)



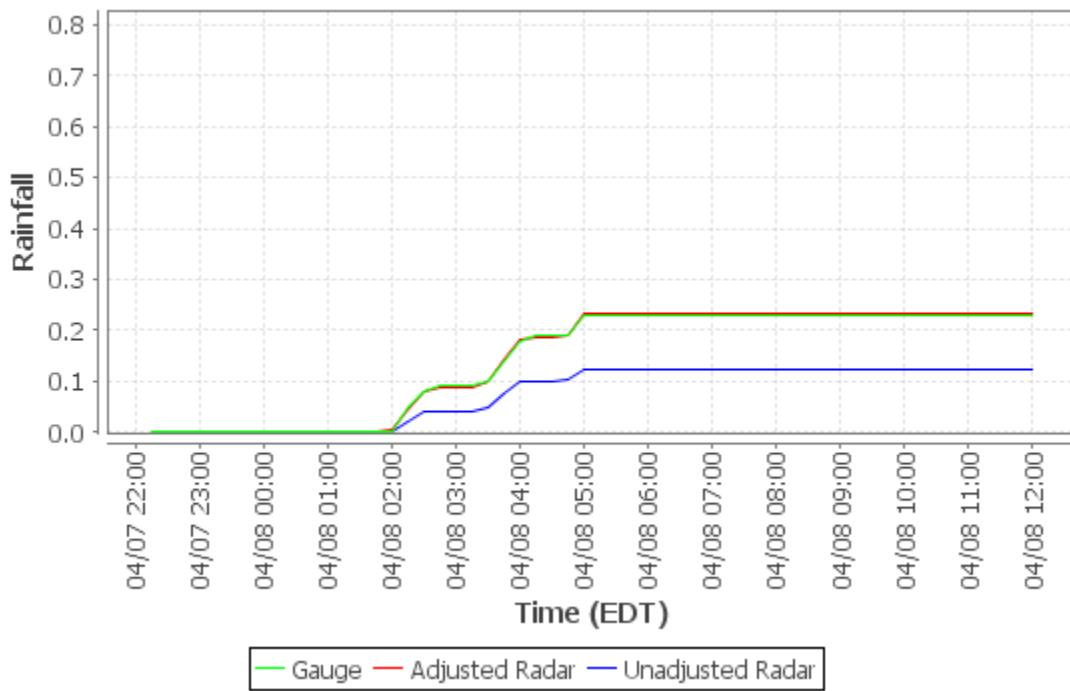
Cumulative Distribution Plot - Trafford Maint Bldg (Loc15)



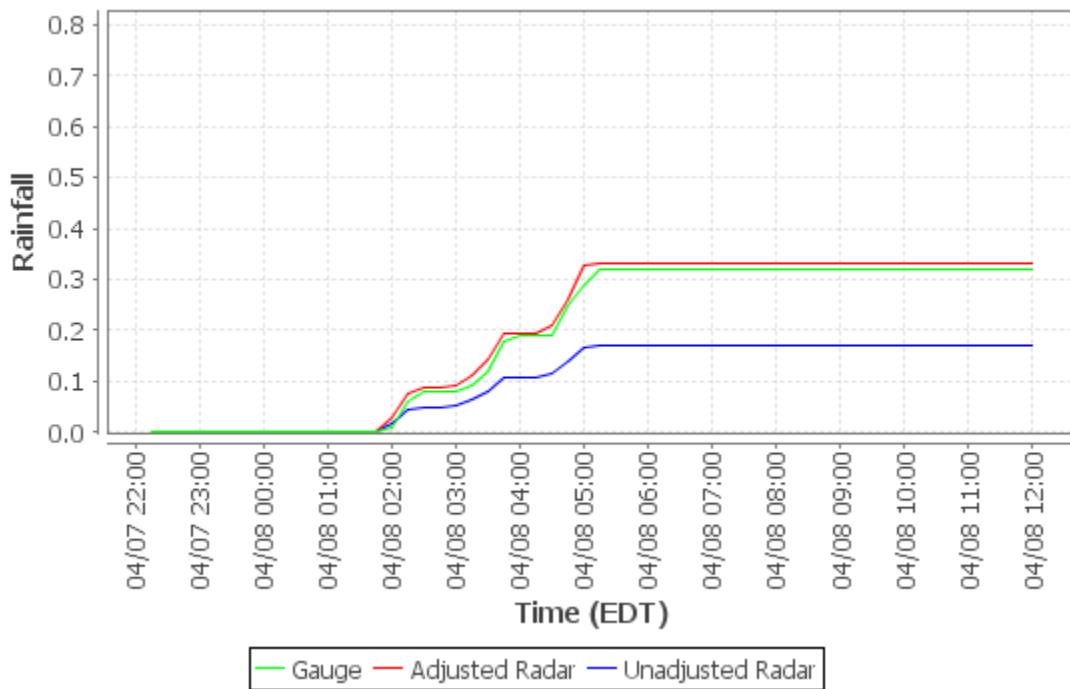
Cumulative Distribution Plot - Castle Shannon (Loc16)



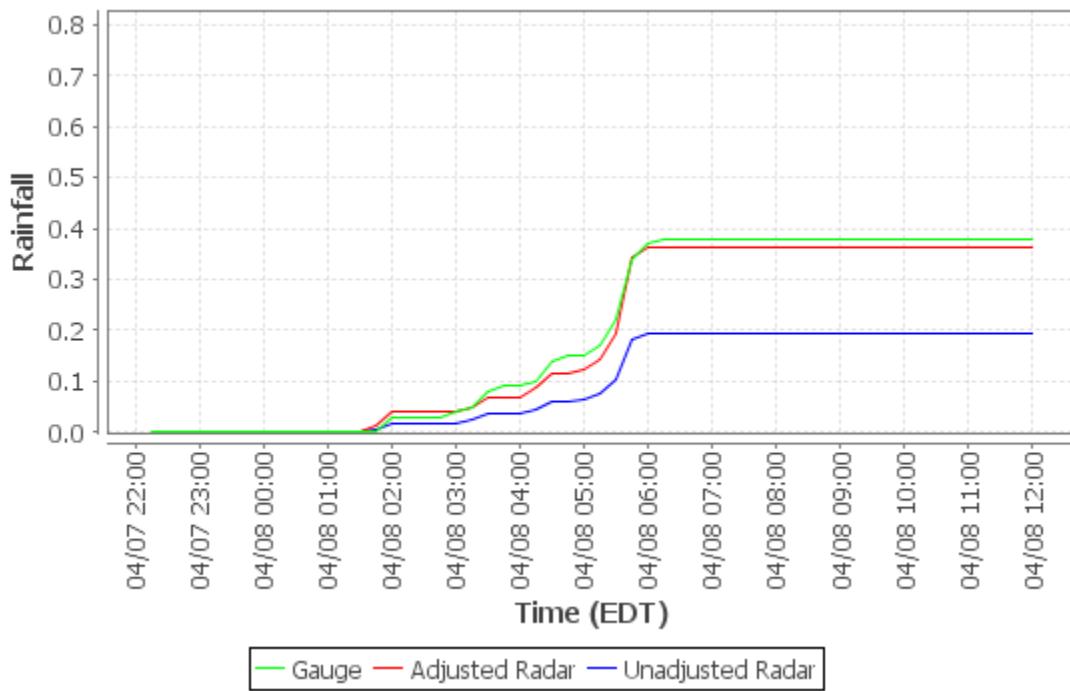
Cumulative Distribution Plot - Chartiers Pump Station (Loc17)



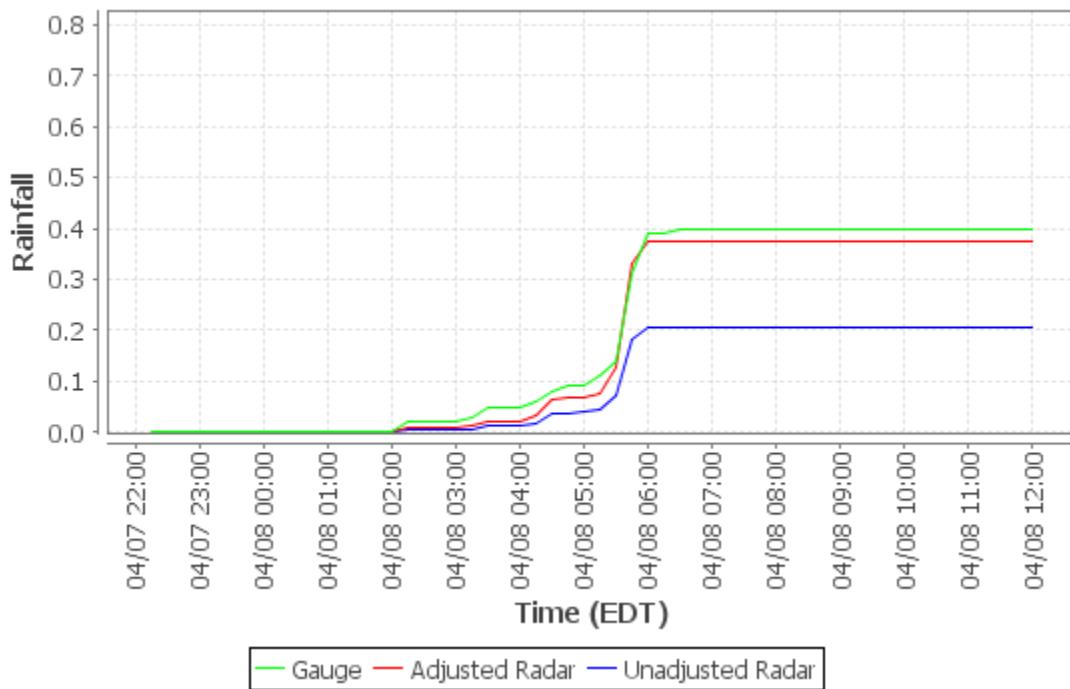
Cumulative Distribution Plot - Oakdale Pump Station (Loc18)



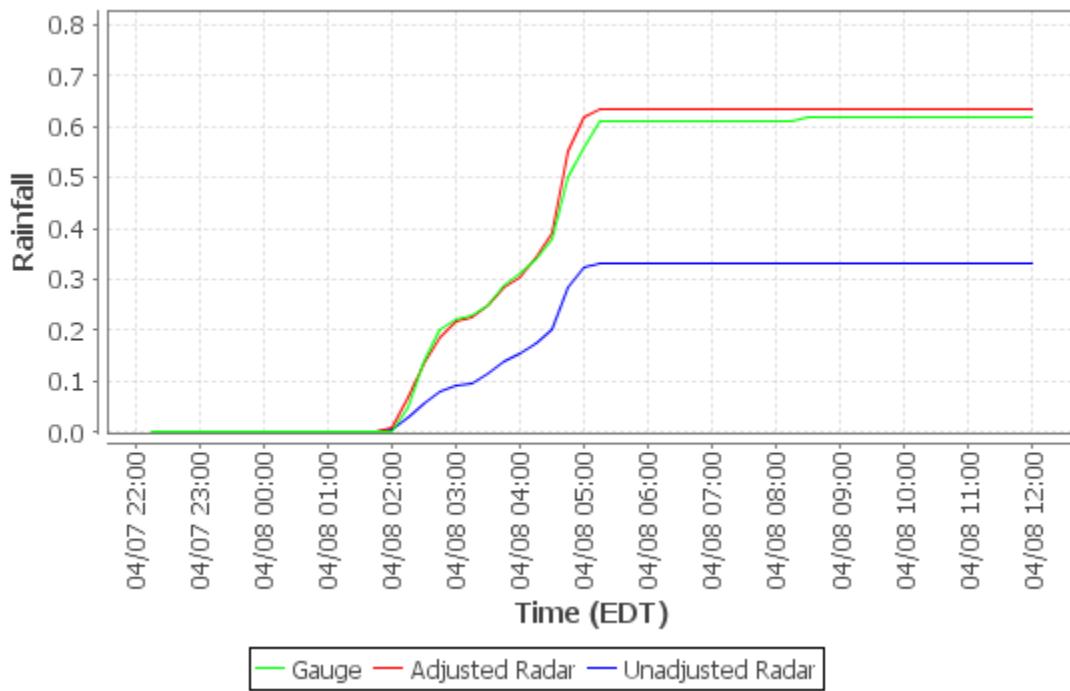
Cumulative Distribution Plot - Sandy Creek Eq Facility (Loc19)



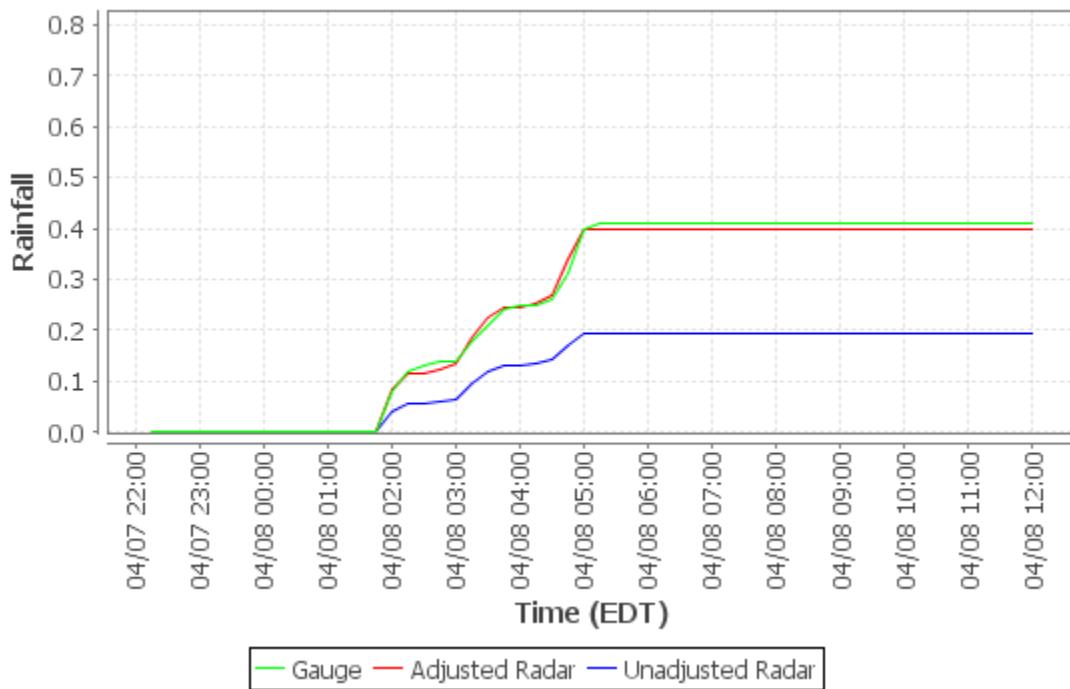
Cumulative Distribution Plot - Gascola Eq Facility (Loc20)



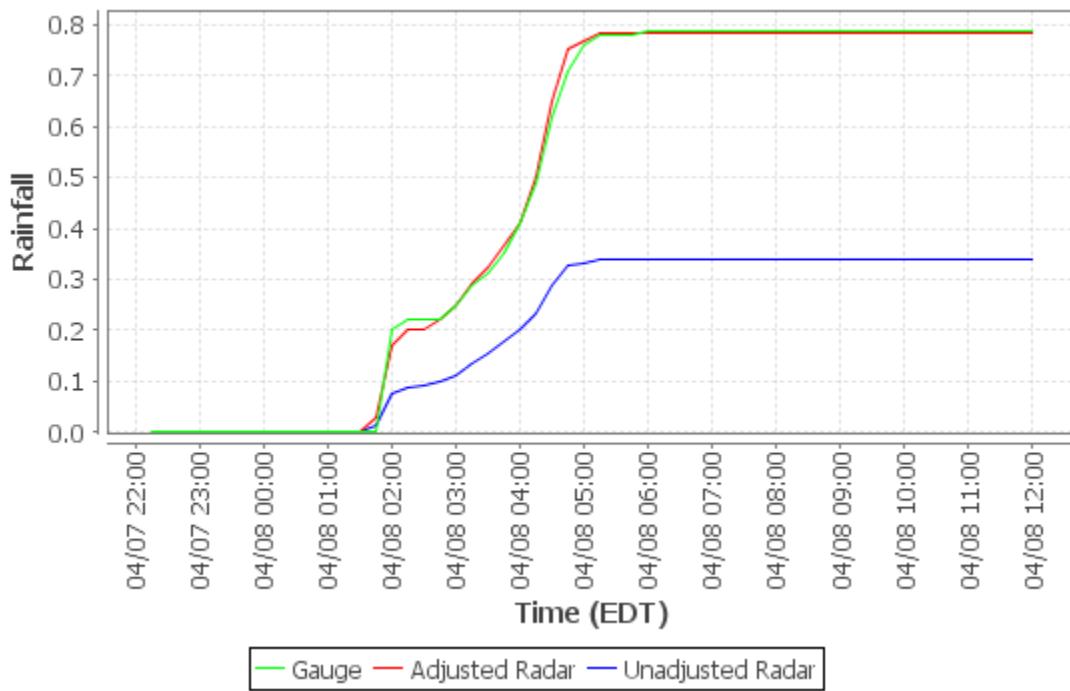
Cumulative Distribution Plot - Moon TWP (Loc21)



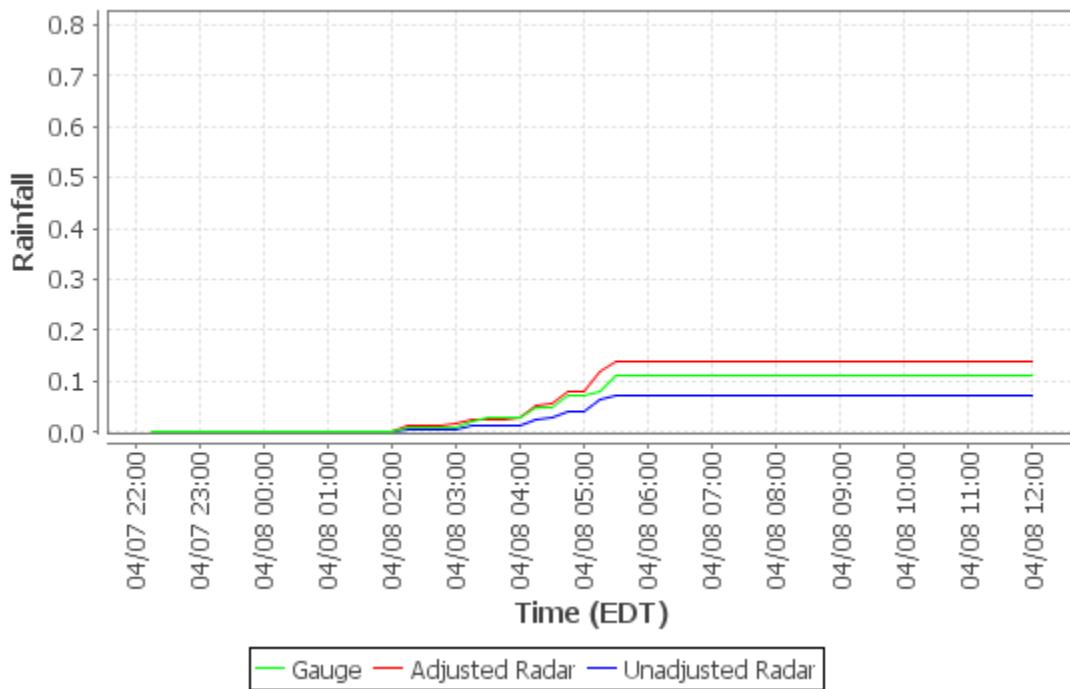
Cumulative Distribution Plot - North Fayette TWP (Loc22)



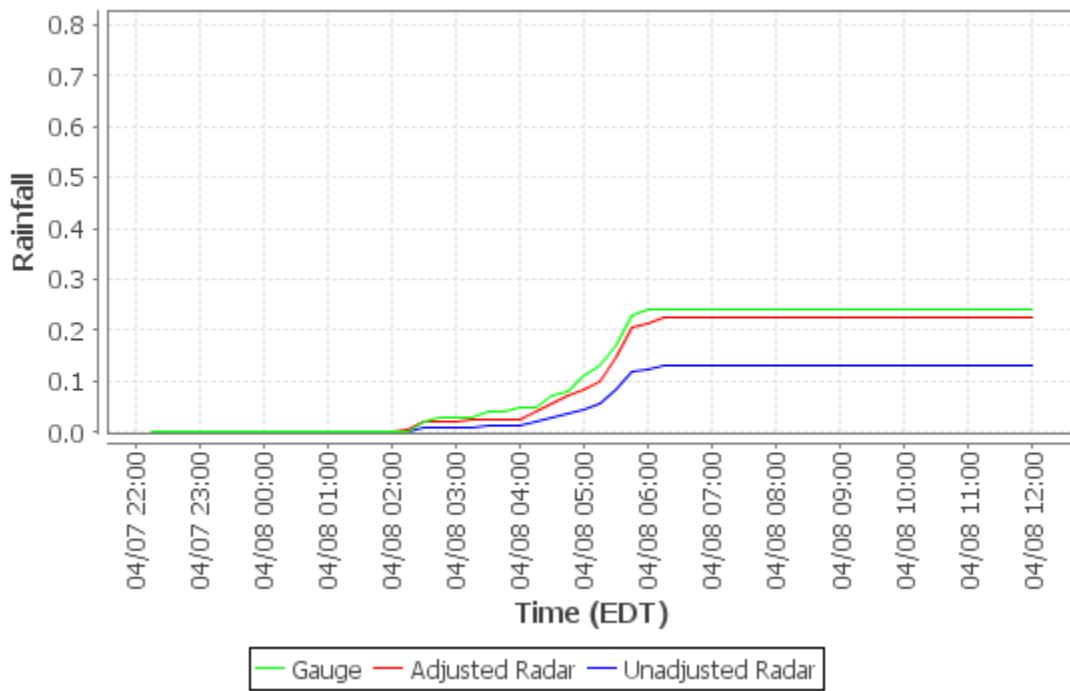
Cumulative Distribution Plot - Clinton Munic Bldg (Loc23)



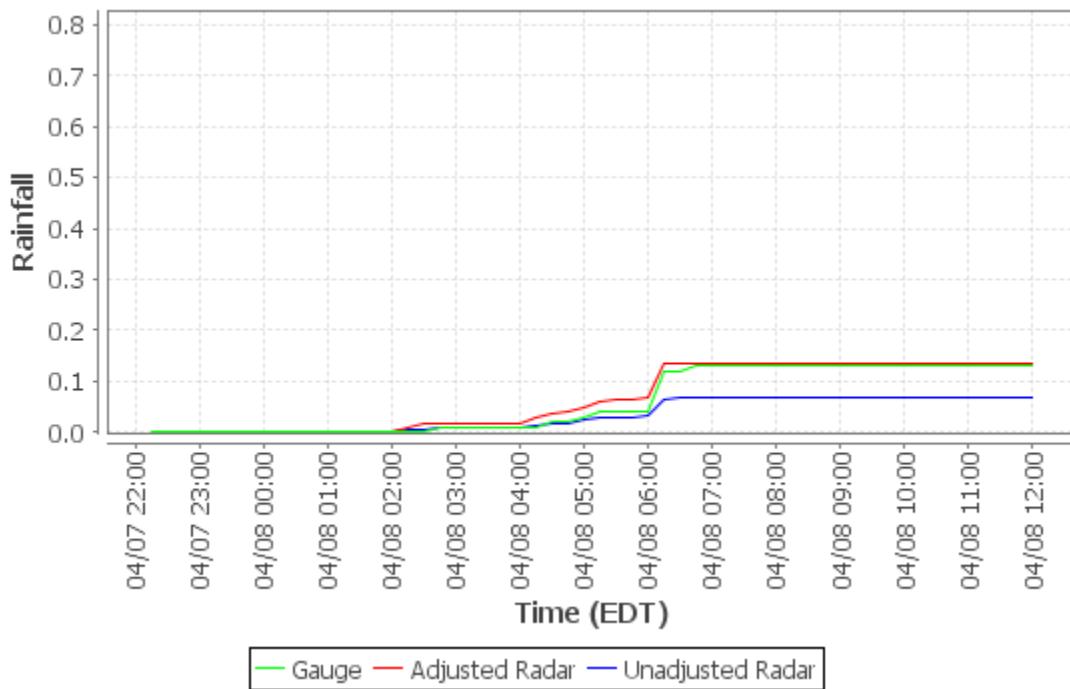
Cumulative Distribution Plot - Jefferson Hills (Loc24)



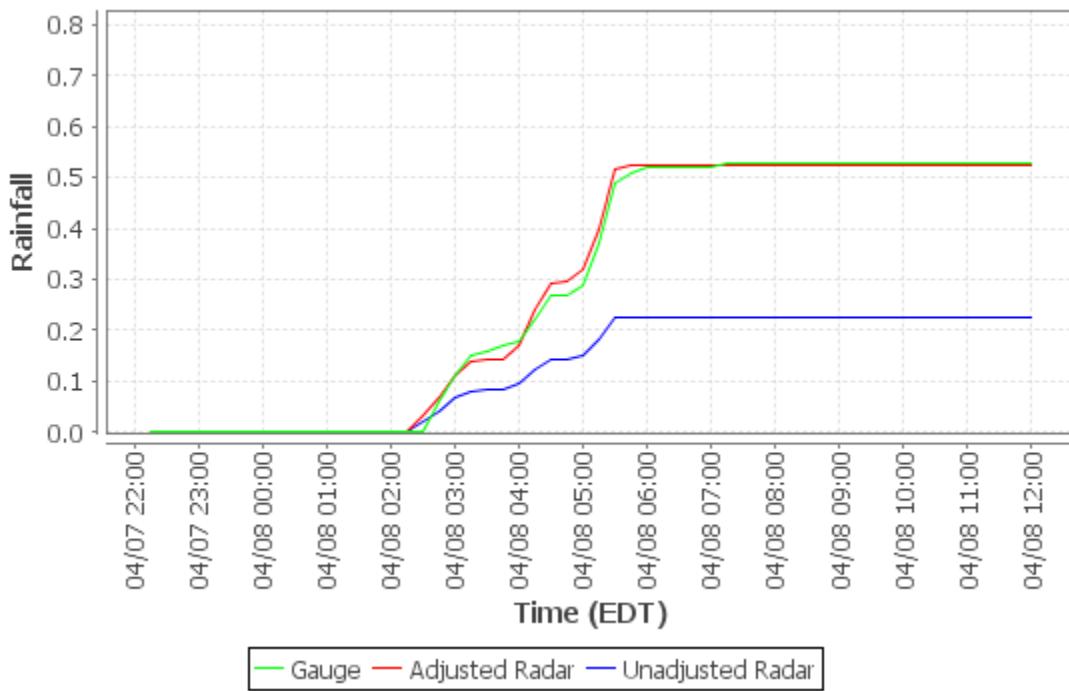
Cumulative Distribution Plot - White Oak Public Works Bldg (Loc25)



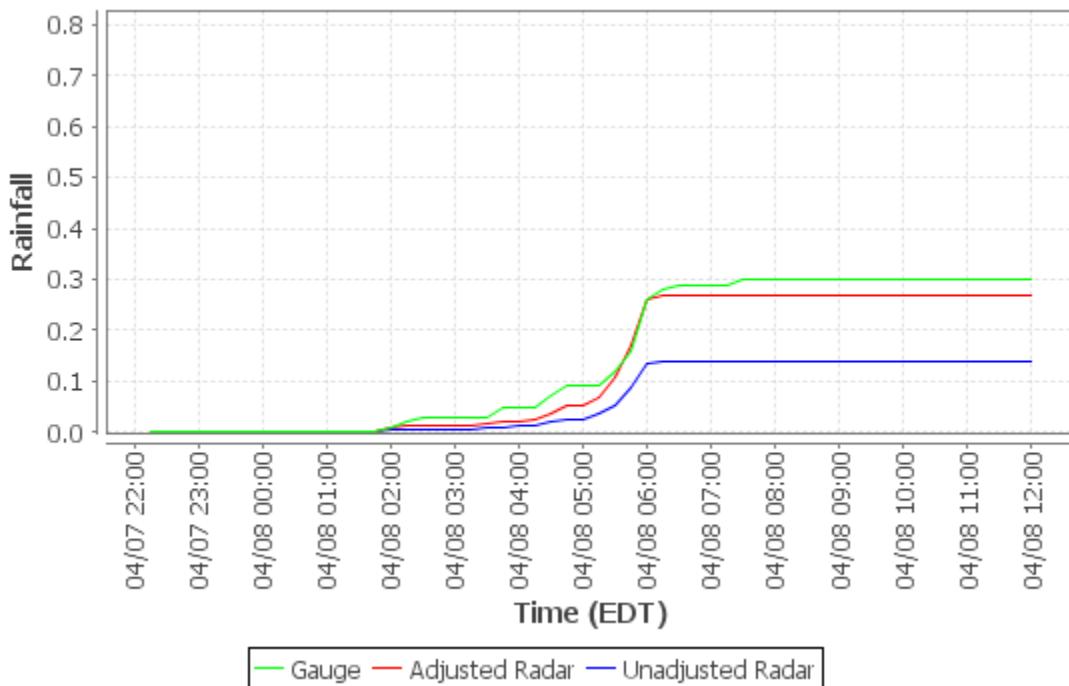
Cumulative Distribution Plot - Elizabeth TWP Municipal Bldg (Loc26)



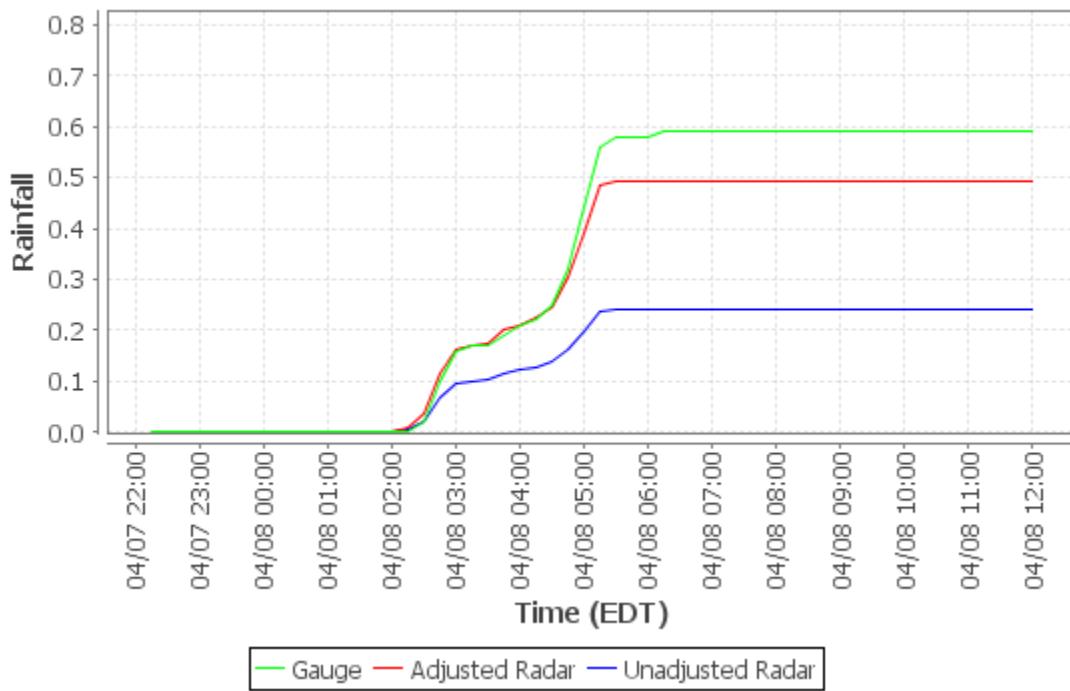
Cumulative Distribution Plot - Marshall TWP (Loc27)



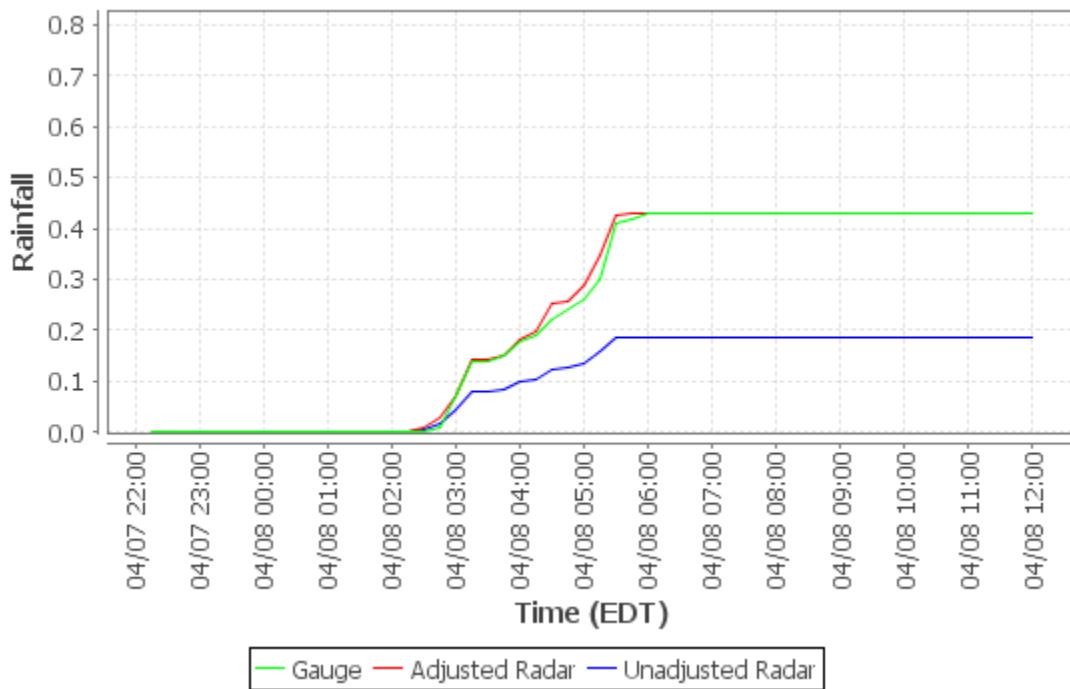
Cumulative Distribution Plot - Plum Municipal Bldg (Loc28)



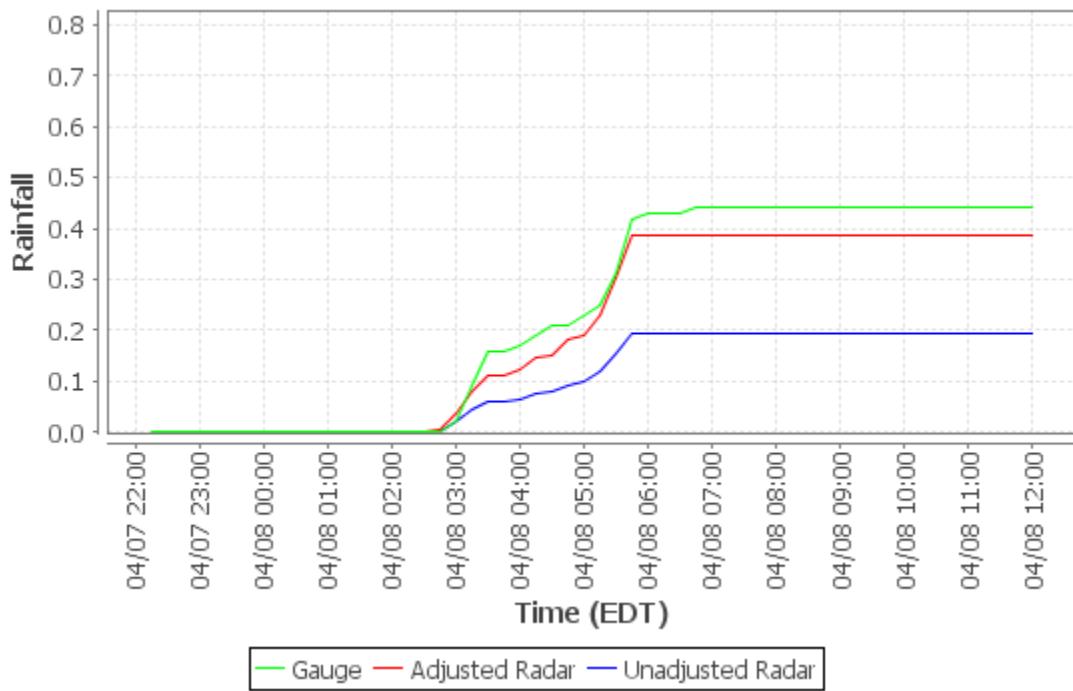
Cumulative Distribution Plot - Bell Acres Munic Bldg (Loc29)



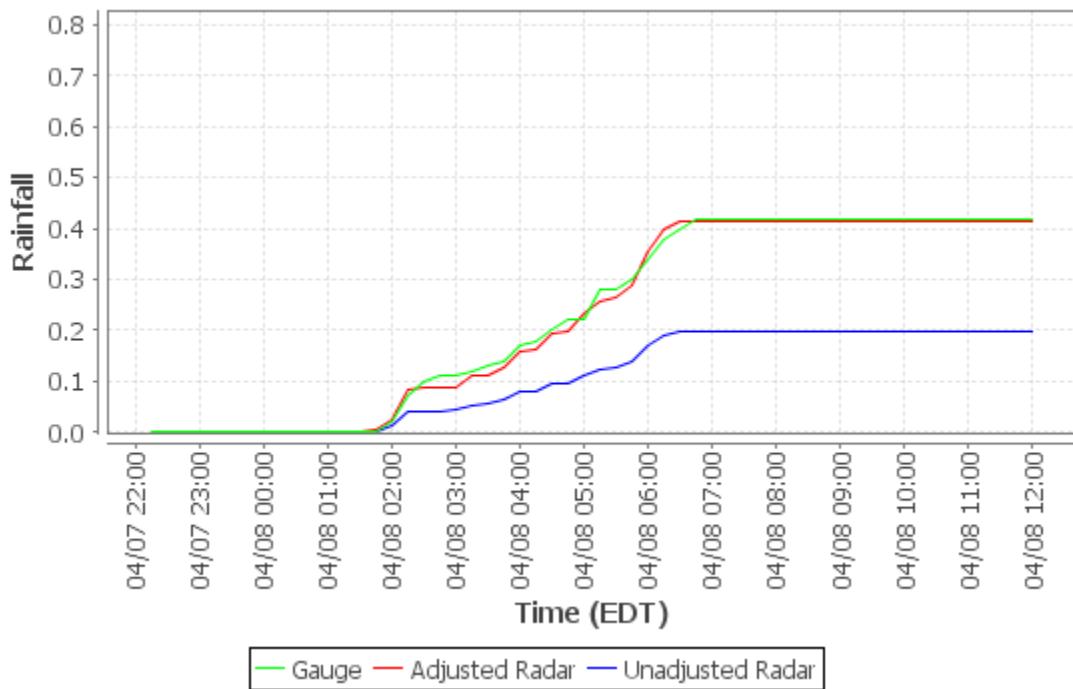
Cumulative Distribution Plot - McCandless Twn Hall (Loc30)



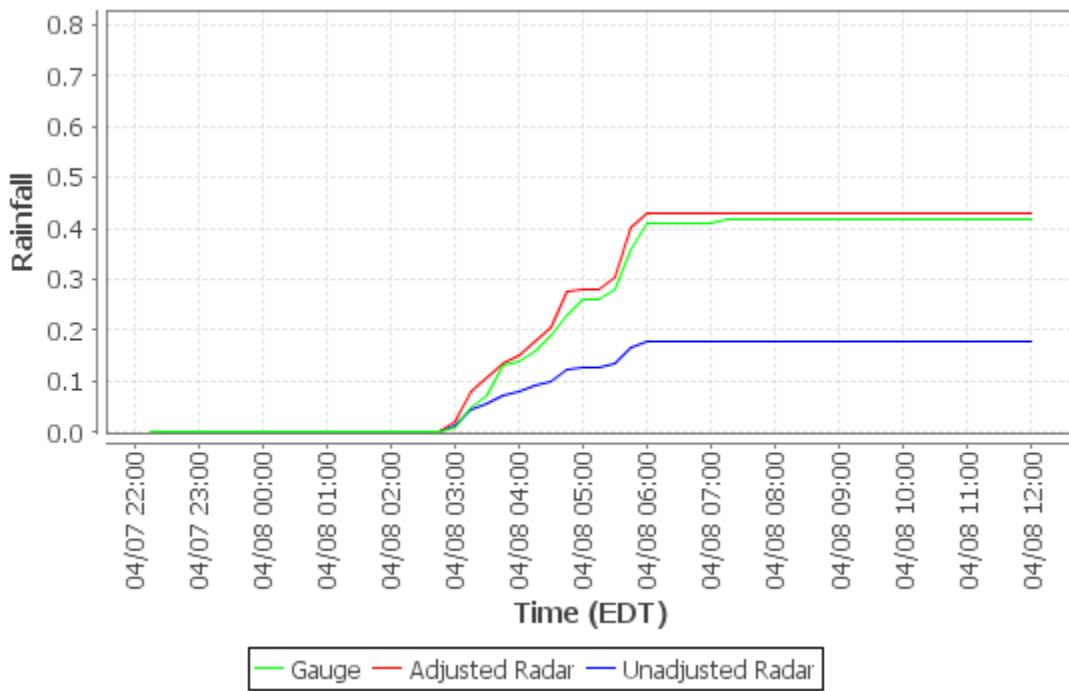
Cumulative Distribution Plot - Hampton Municipal Bldg (Loc31)



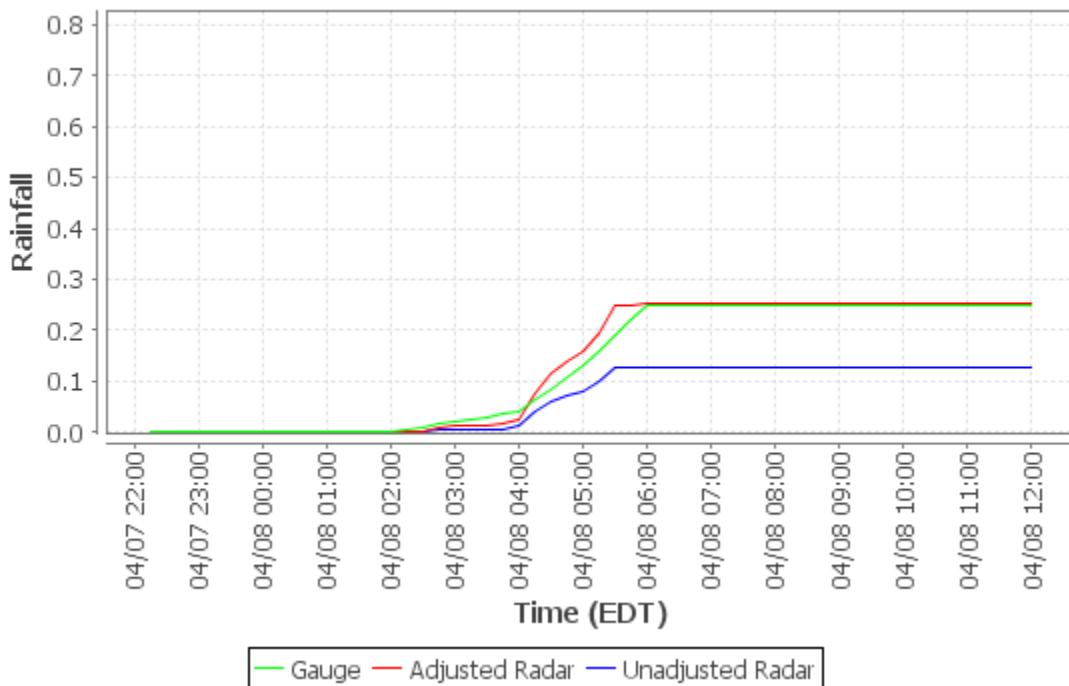
Cumulative Distribution Plot - Arnold (Loc32)



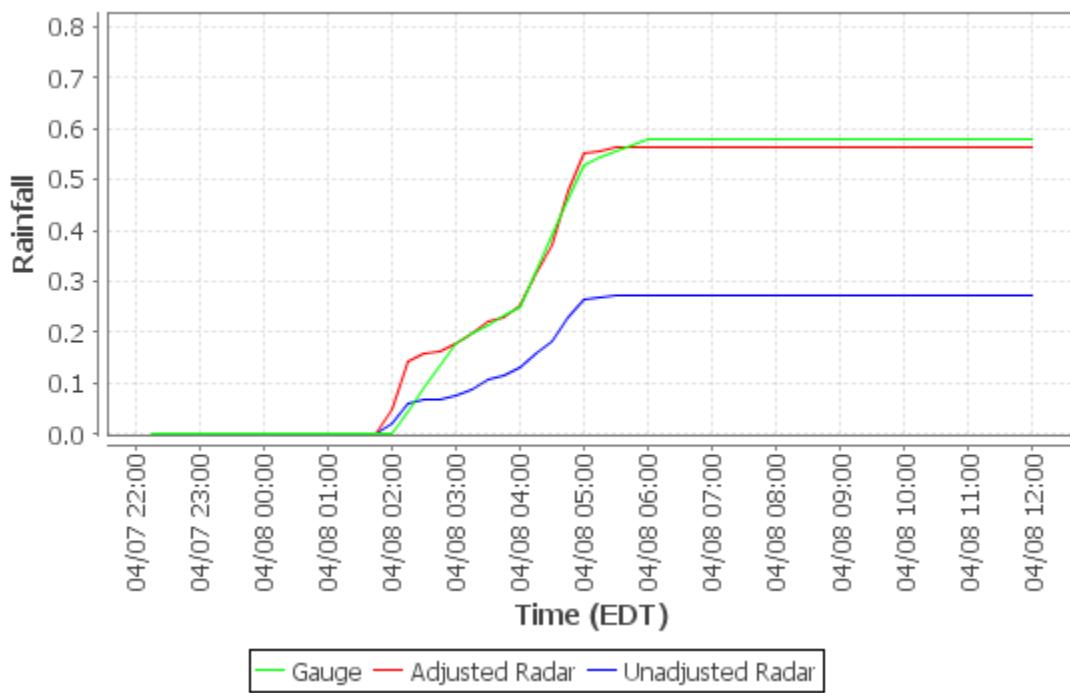
Cumulative Distribution Plot - Richland TWP (Loc33)



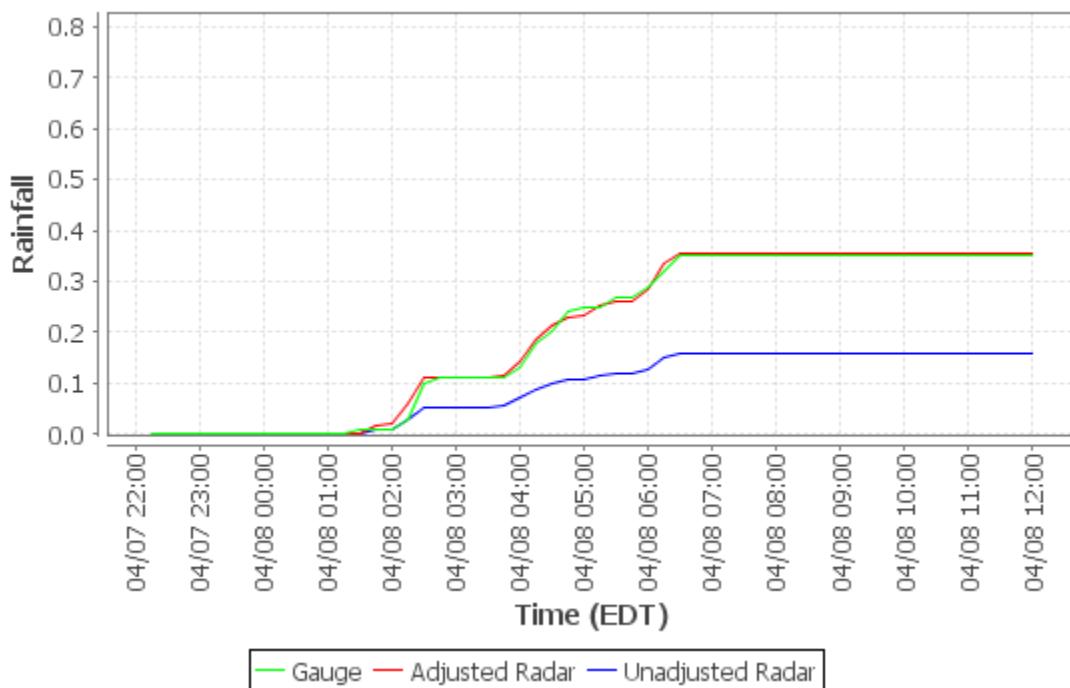
Cumulative Distribution Plot - Pittsburgh Allegheny Cty (KAGC)



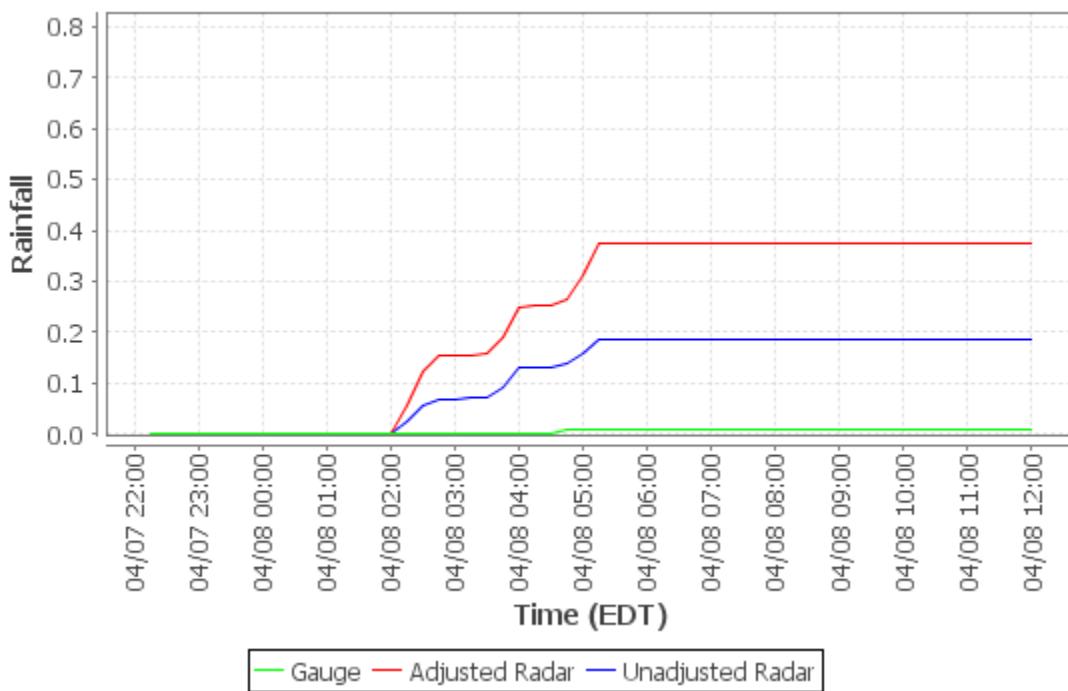
Cumulative Distribution Plot - Greater Pittsburgh Int'l (KPIT)



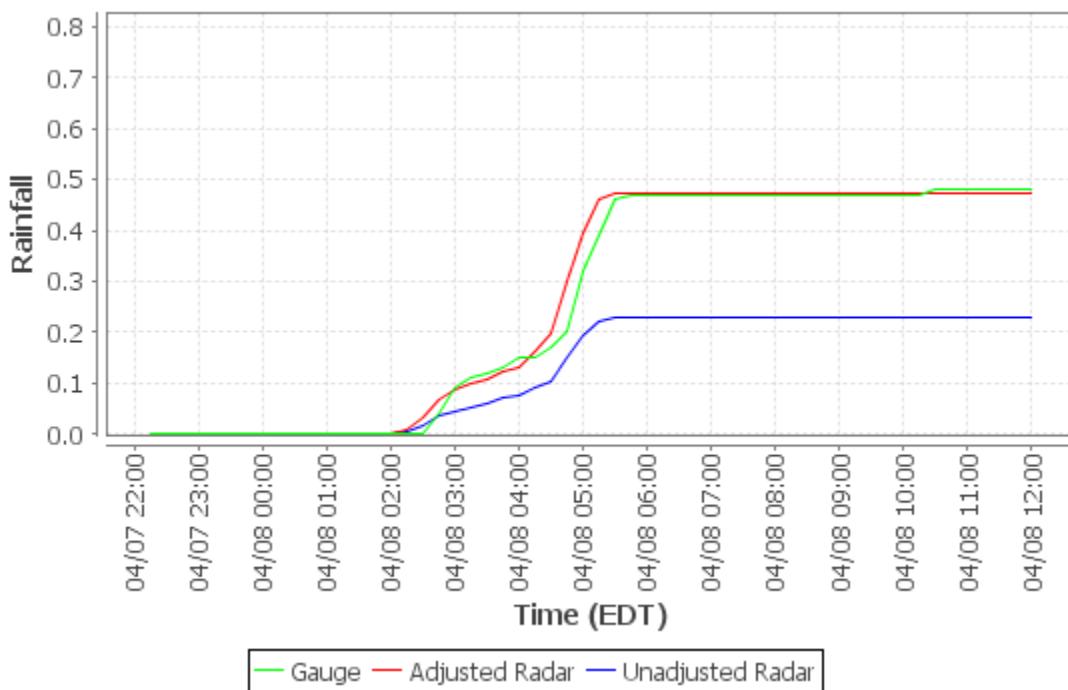
Cumulative Distribution Plot - Allegheny River at Natrona (03049500)



Cumulative Distribution Plot - Chartiers Creek at Carnegie (03085500)

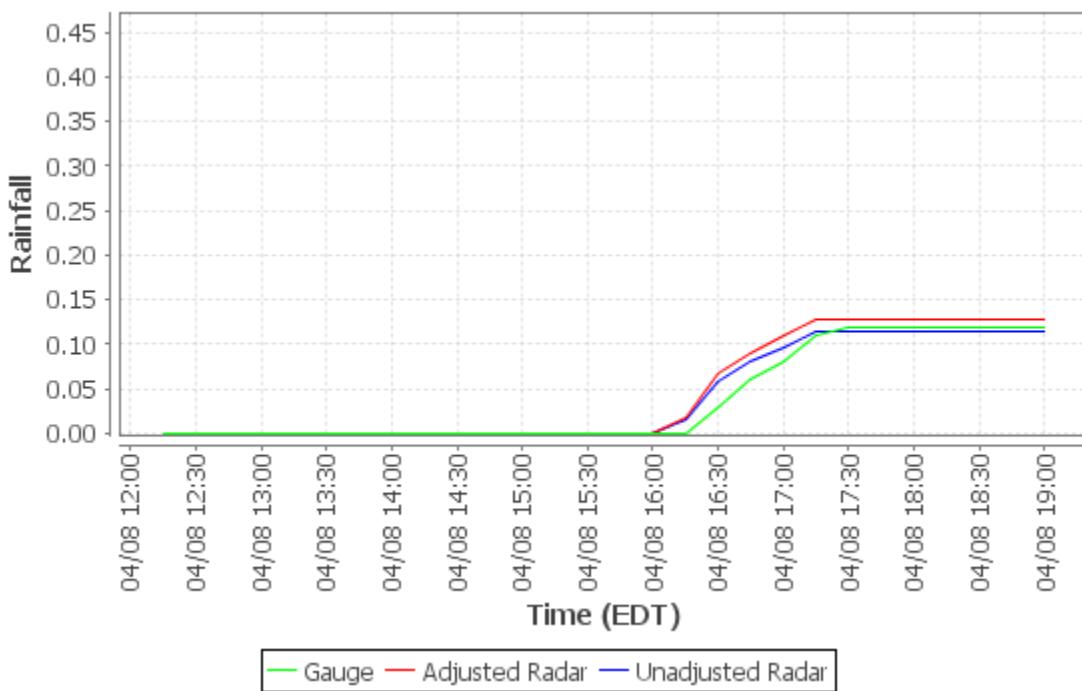


Cumulative Distribution Plot - Ohio River at Emsworth Dam Lower Pool at Emsworth (03085734)

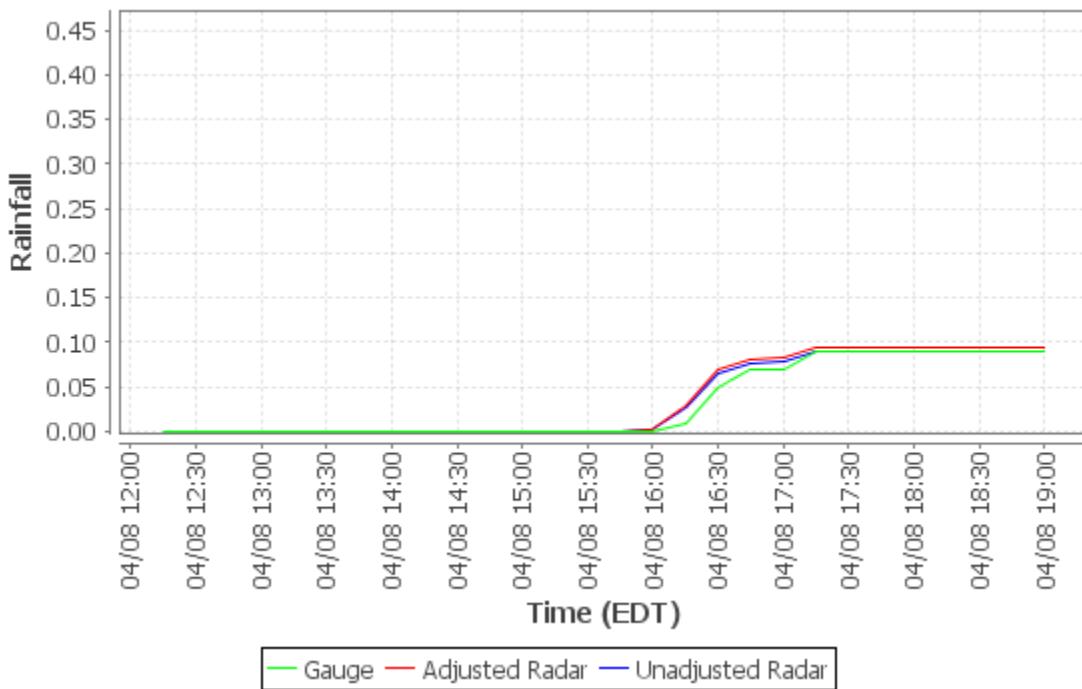


Appendix F - Event 5 (2015-04-08 PM) CDPs

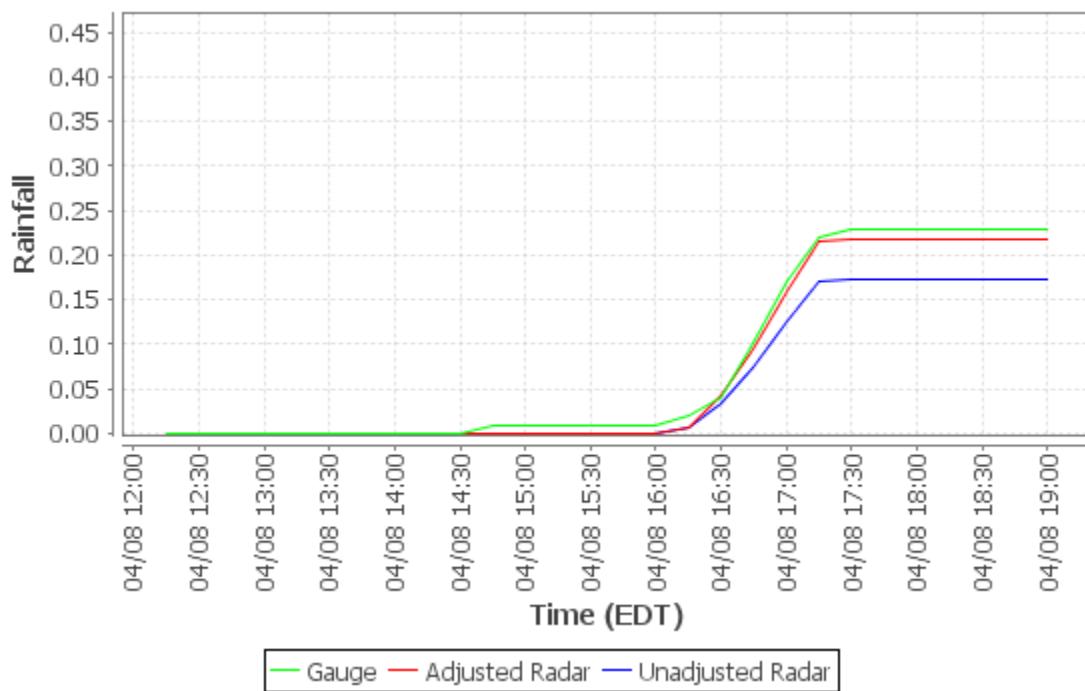
Cumulative Distribution Plot - PWSA-Montana St. (Loc01)



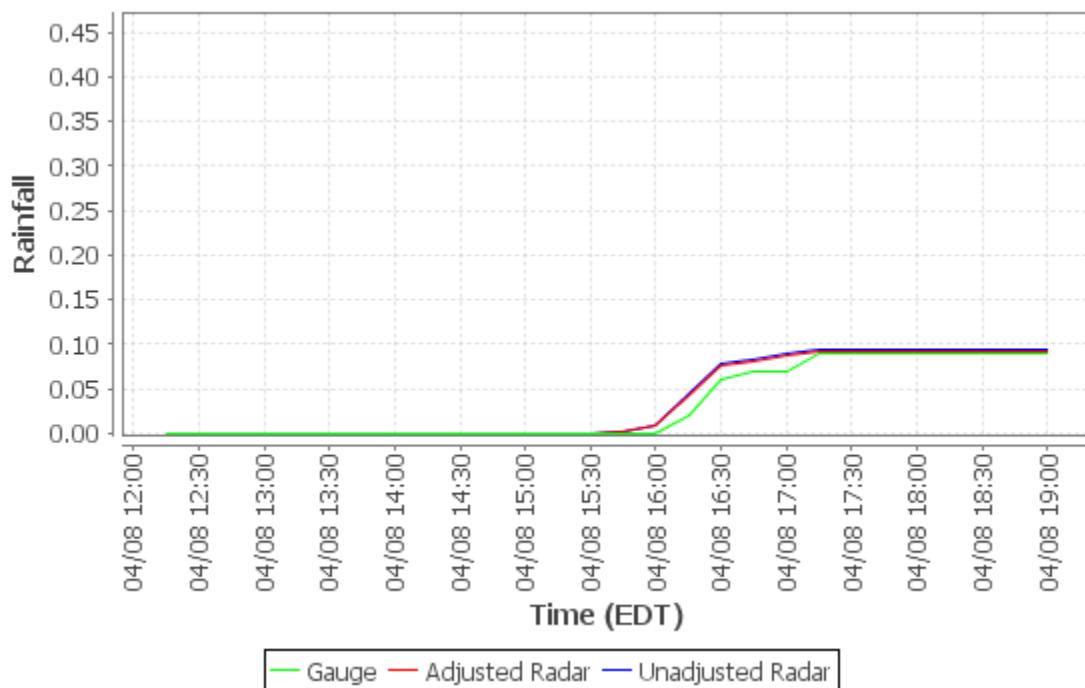
Cumulative Distribution Plot - ALCOSAN WWTP Lab (Loc02)



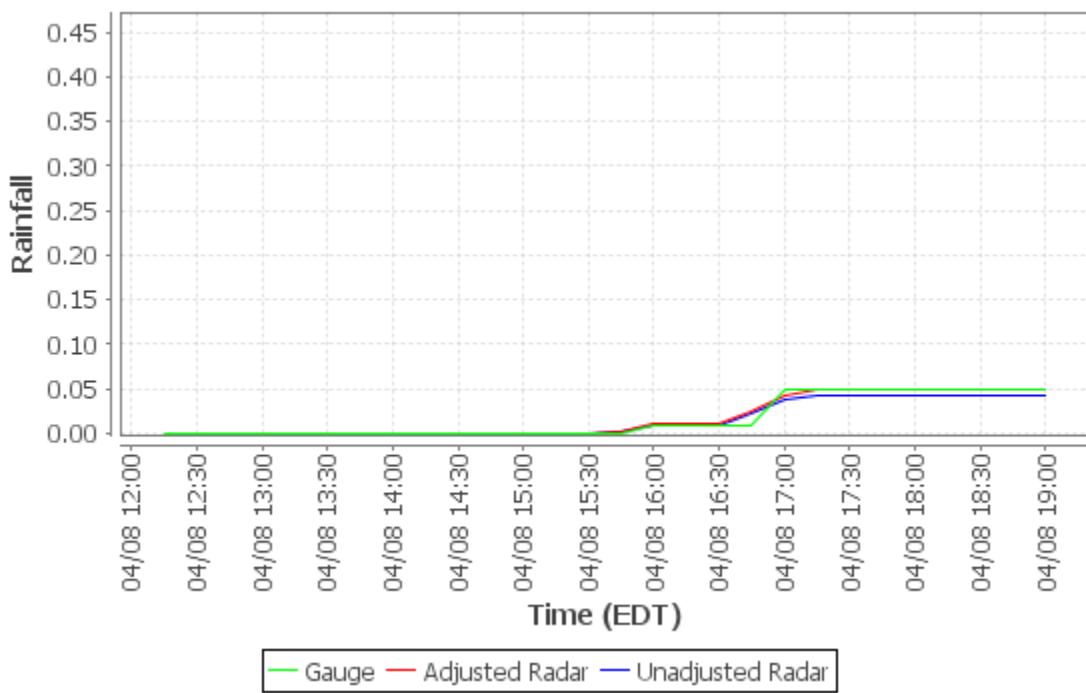
Cumulative Distribution Plot - Shaler Munic Bldg (Loc03)



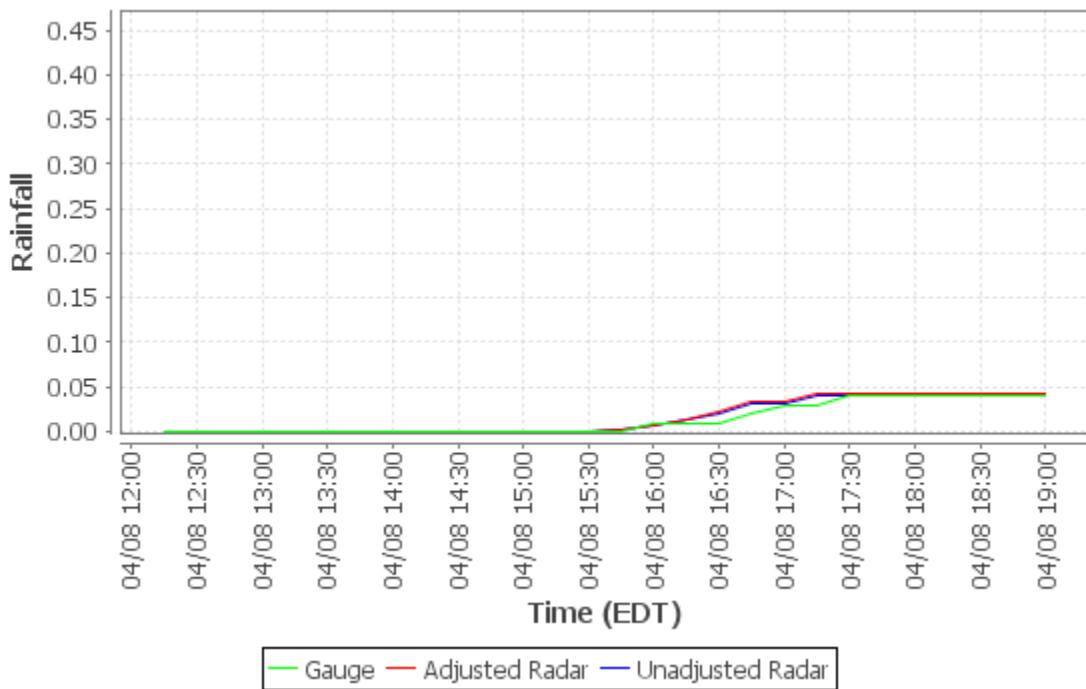
Cumulative Distribution Plot - Kennedy Twp PS (Loc04)



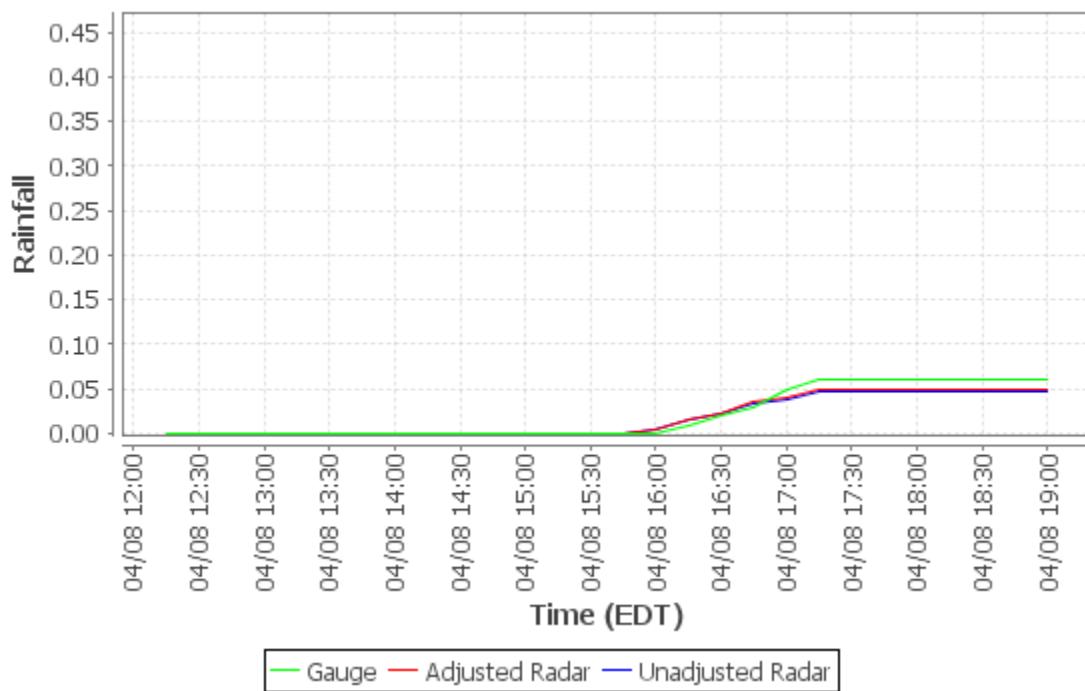
Cumulative Distribution Plot - Upper St. Clair (Loc05)



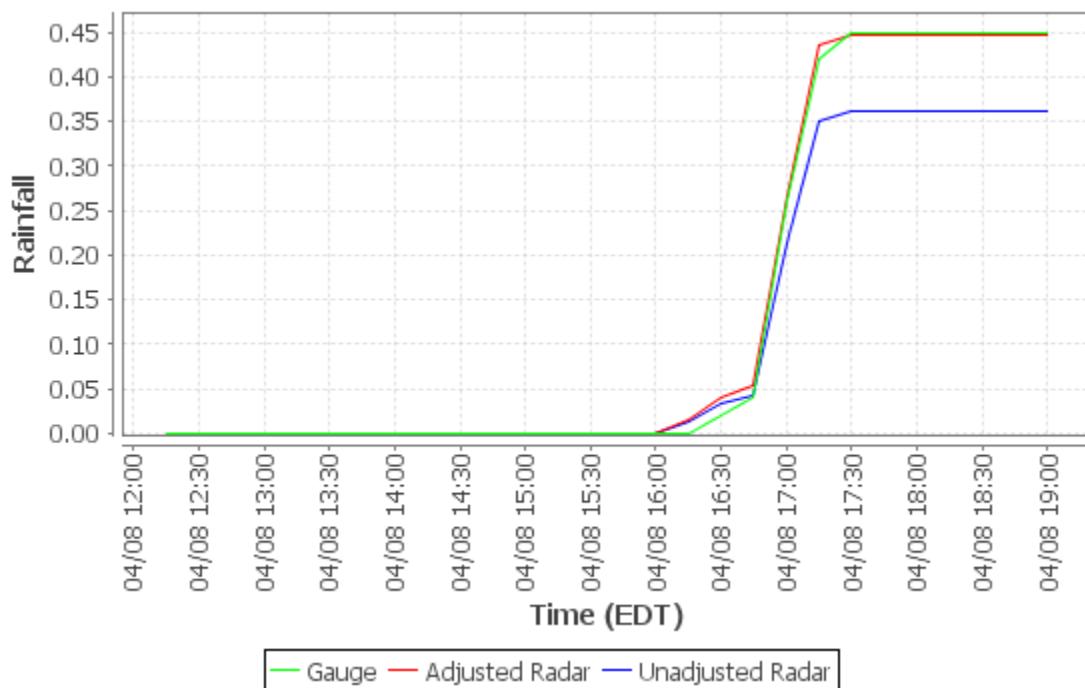
Cumulative Distribution Plot - Carnegie Transit Time (Loc06)



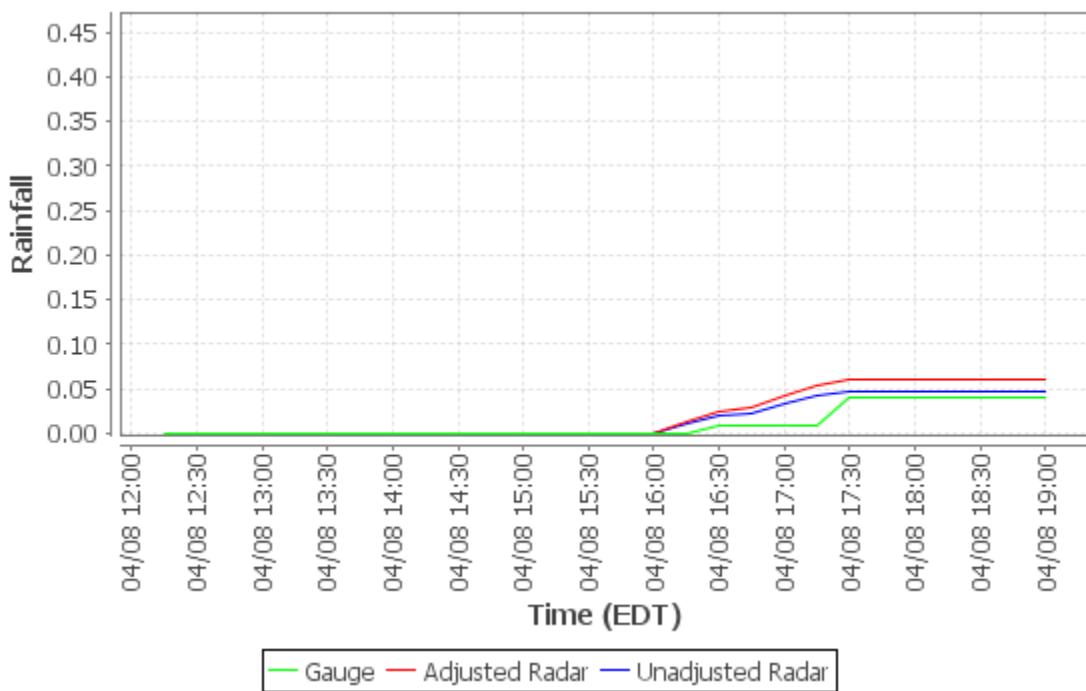
Cumulative Distribution Plot - Greentree Munic Bldg (Loc07)



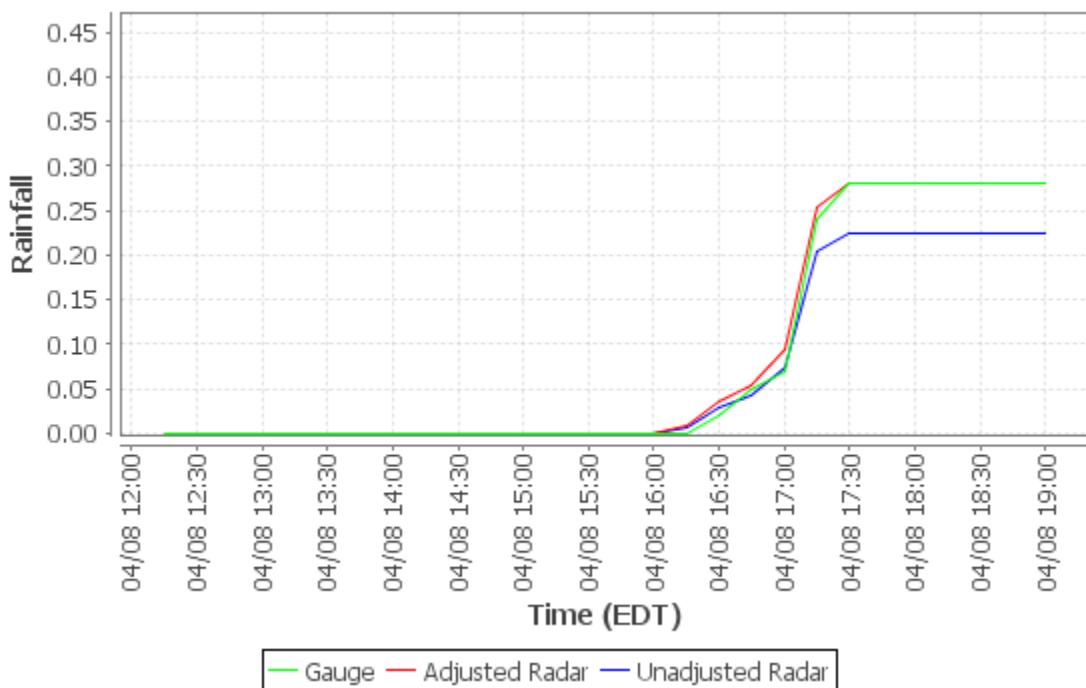
Cumulative Distribution Plot - AC Health Dept Bldg (Loc08)



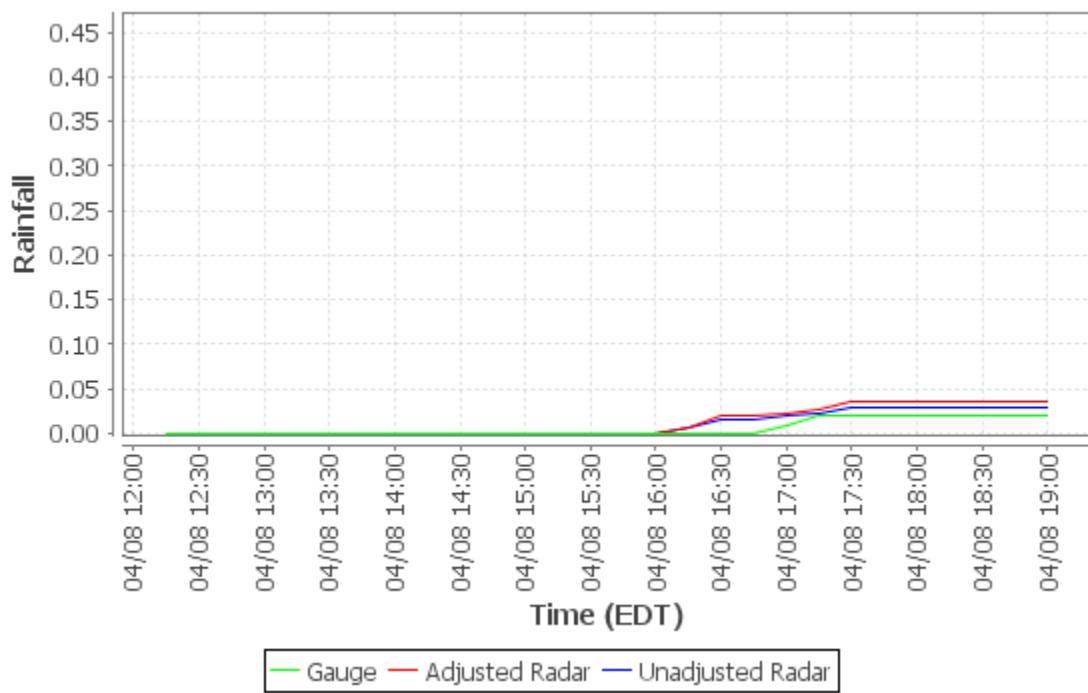
Cumulative Distribution Plot - Univ of Pittsburgh (Loc09)



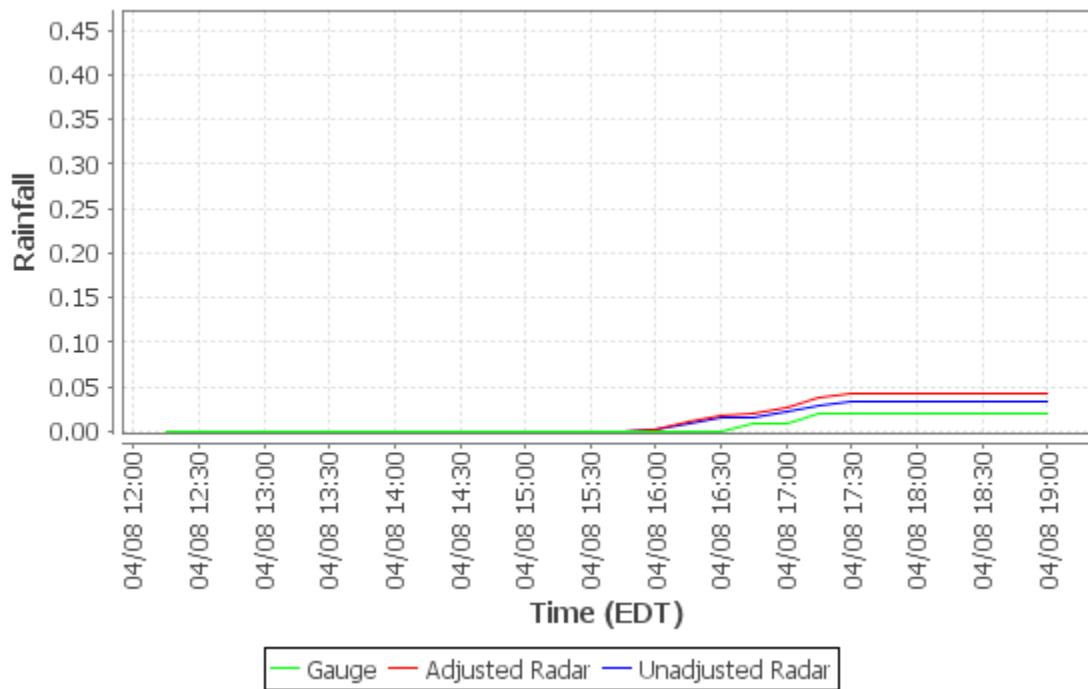
Cumulative Distribution Plot - PWSA-Highland Park (Loc10)



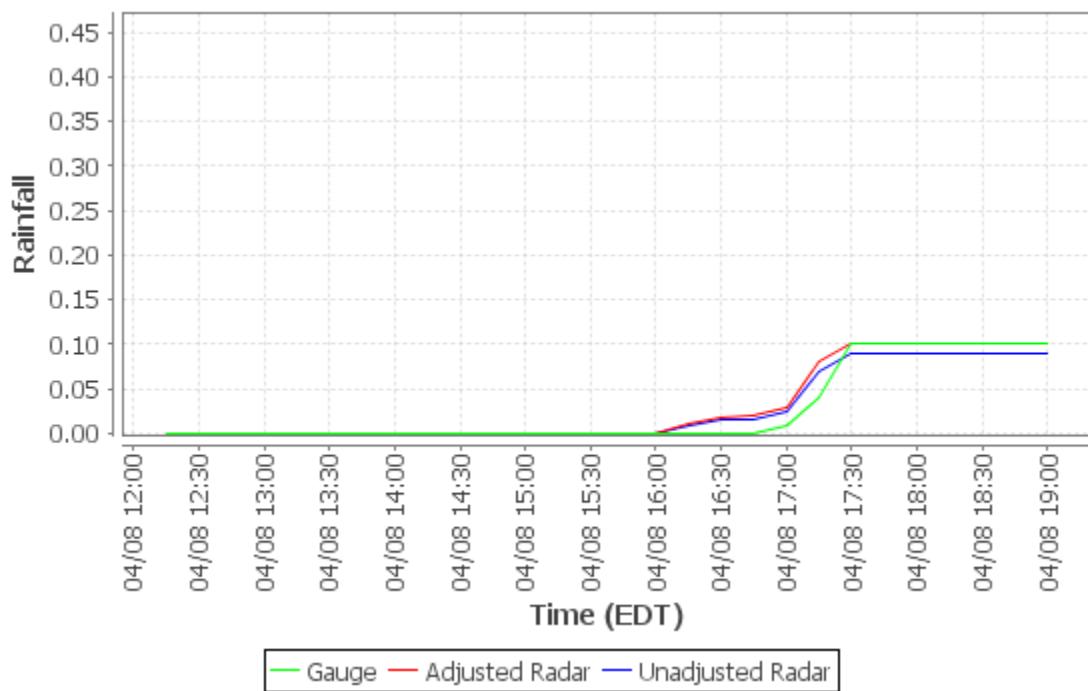
Cumulative Distribution Plot - M-46 Access Shaft (Loc11)



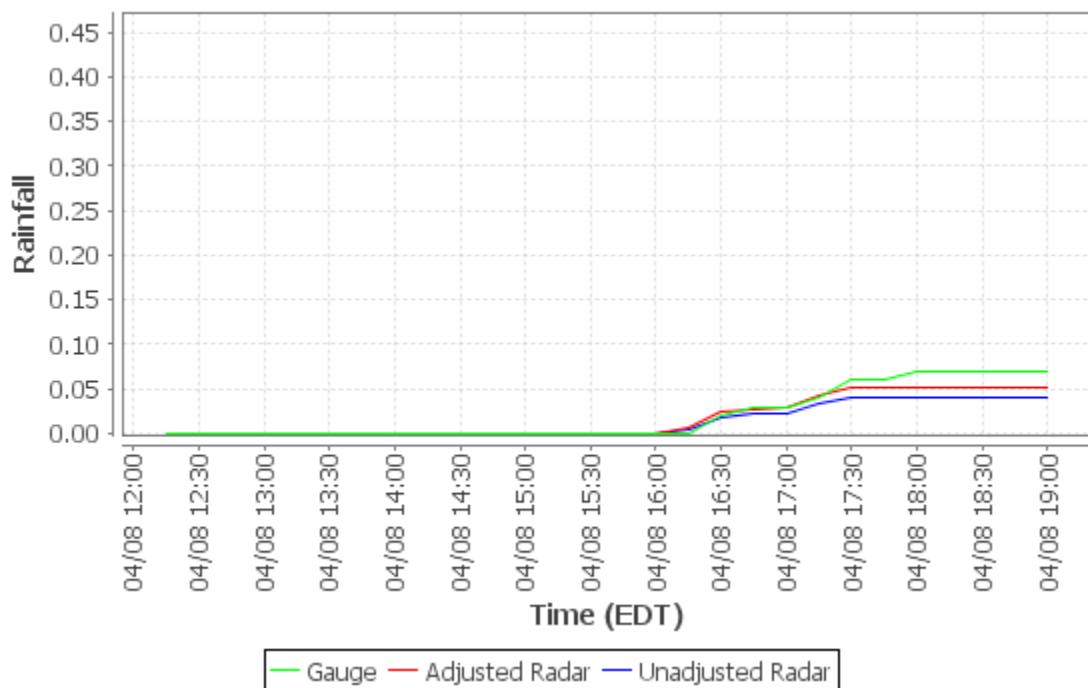
Cumulative Distribution Plot - Baldwin (Loc12)



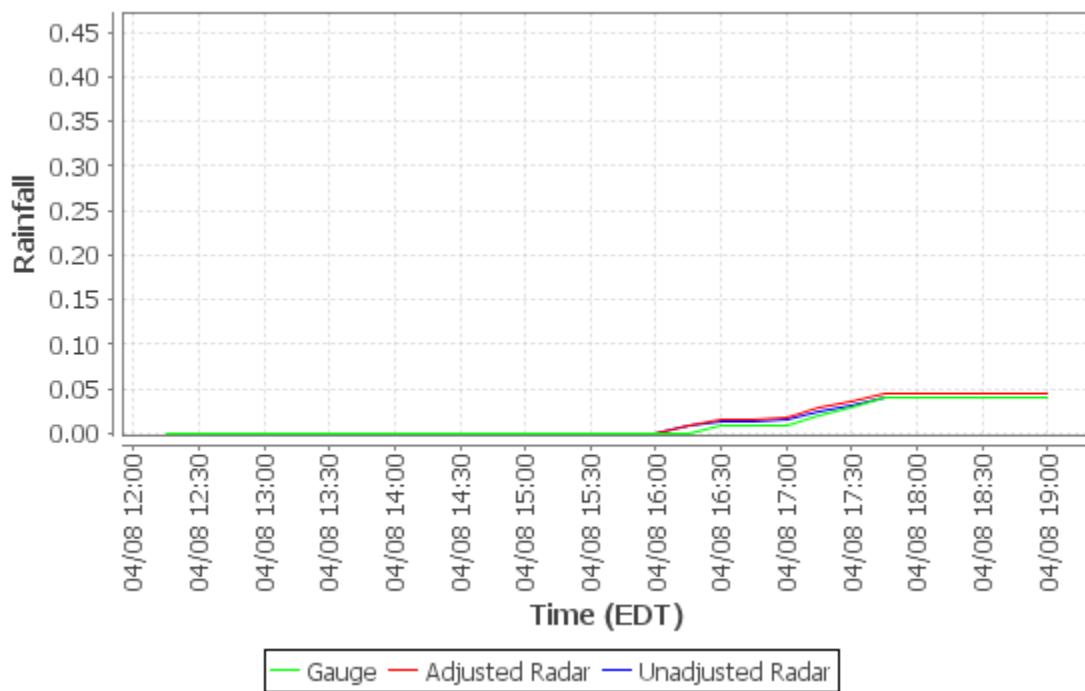
Cumulative Distribution Plot - M-59 Access Shaft (Loc13)



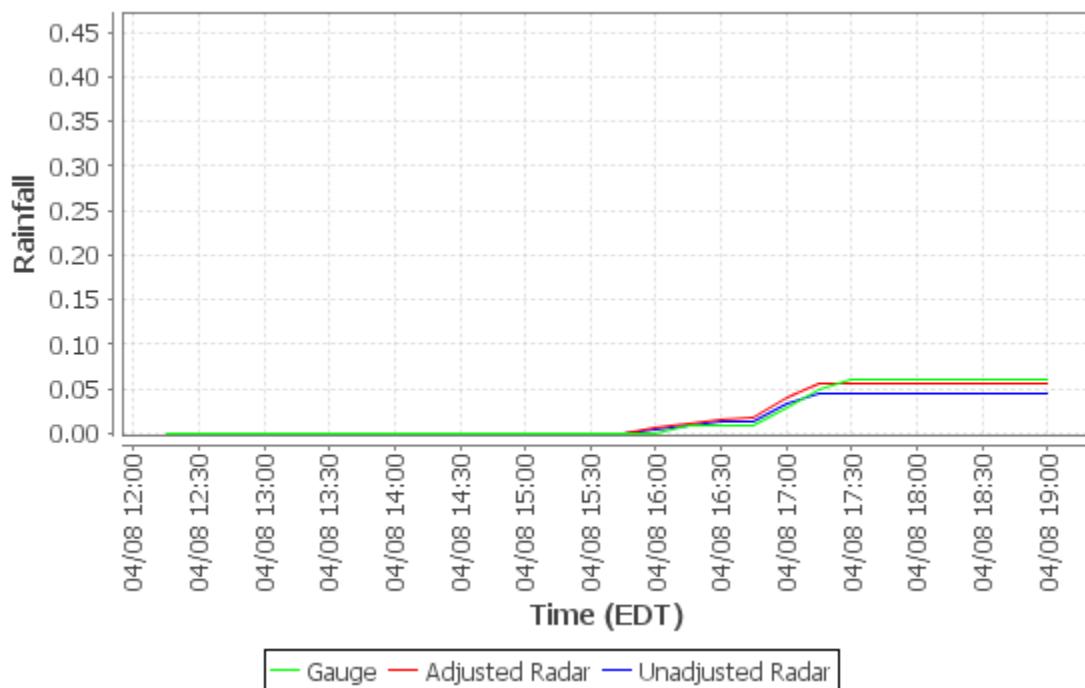
Cumulative Distribution Plot - Churchill Munic Bldg (Loc14)



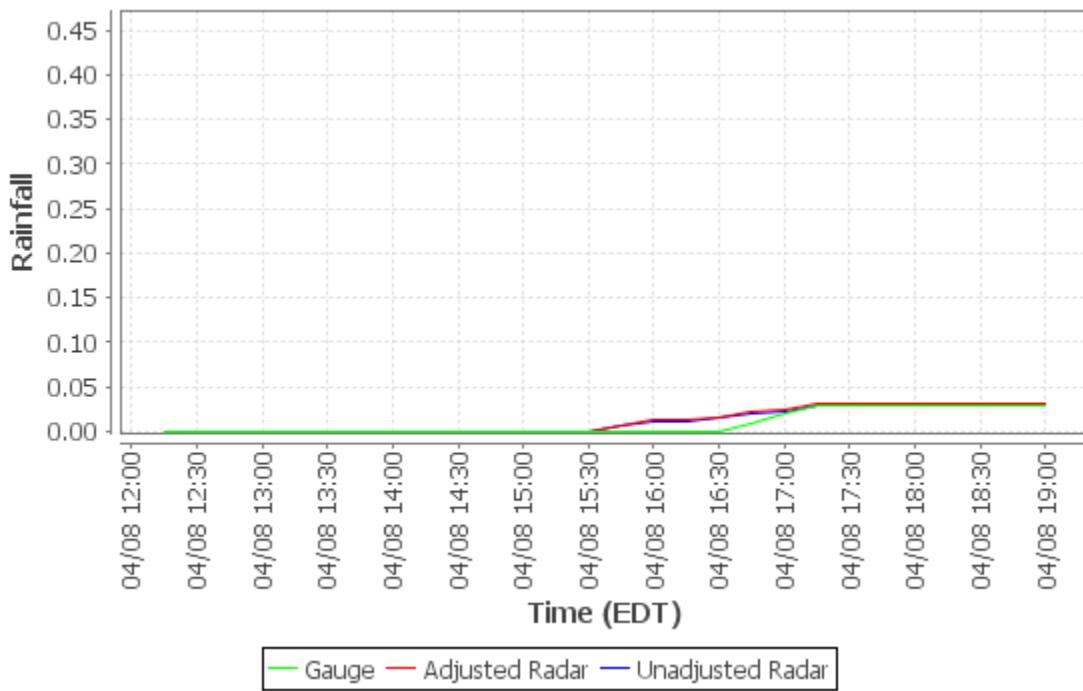
Cumulative Distribution Plot - Trafford Maint Bldg (Loc15)



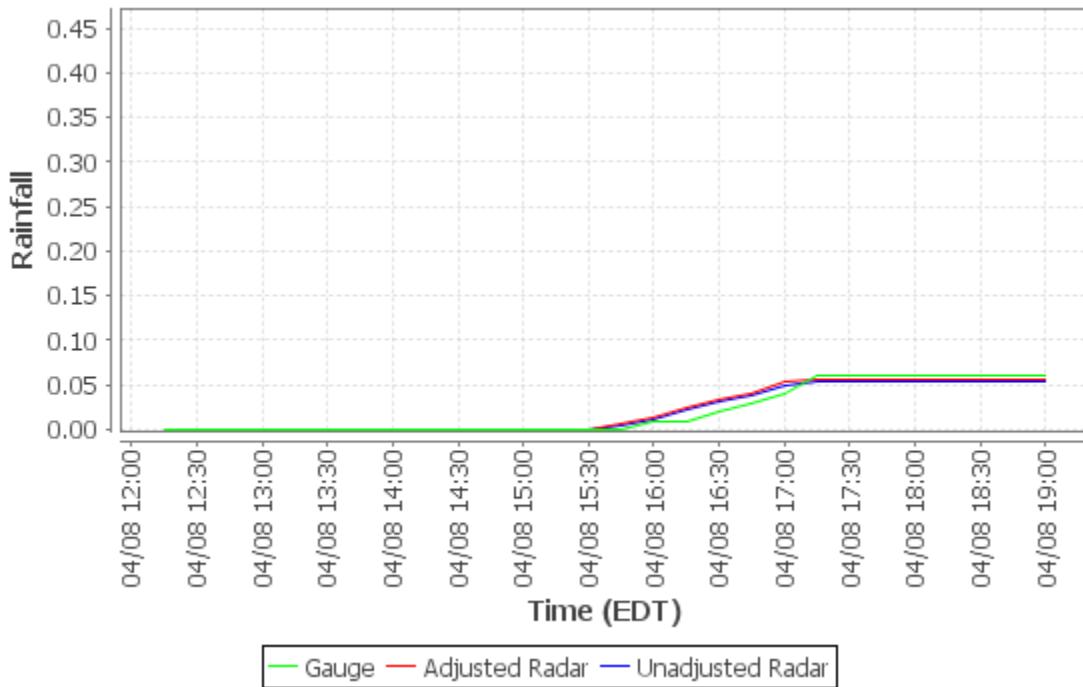
Cumulative Distribution Plot - Castle Shannon (Loc16)



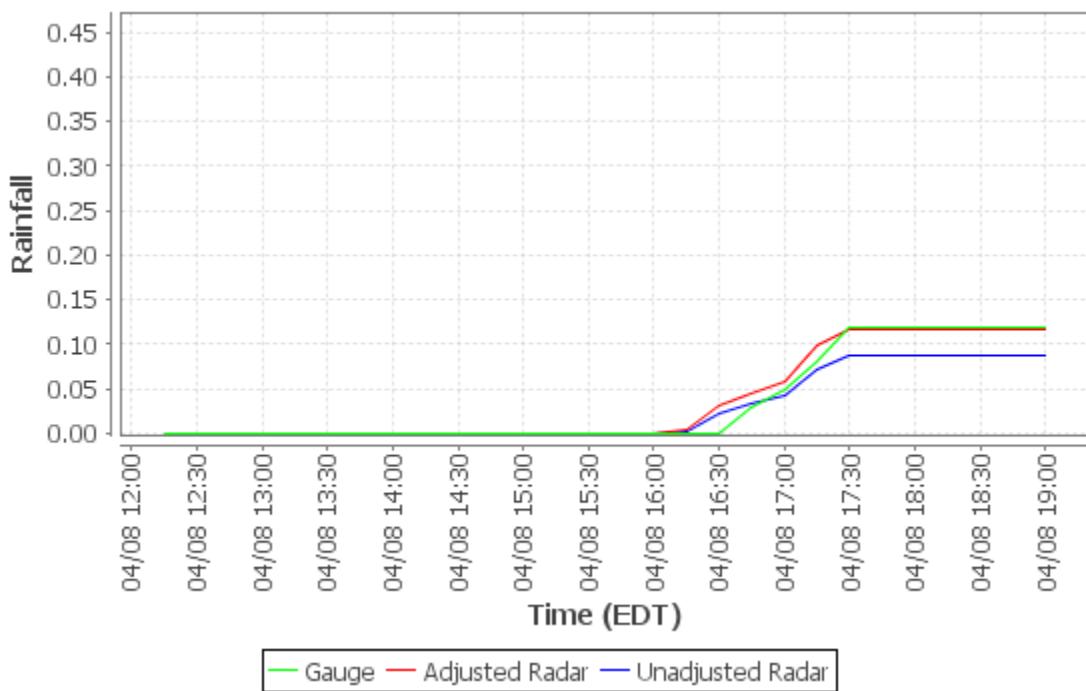
Cumulative Distribution Plot - Chartiers Pump Station (Loc17)



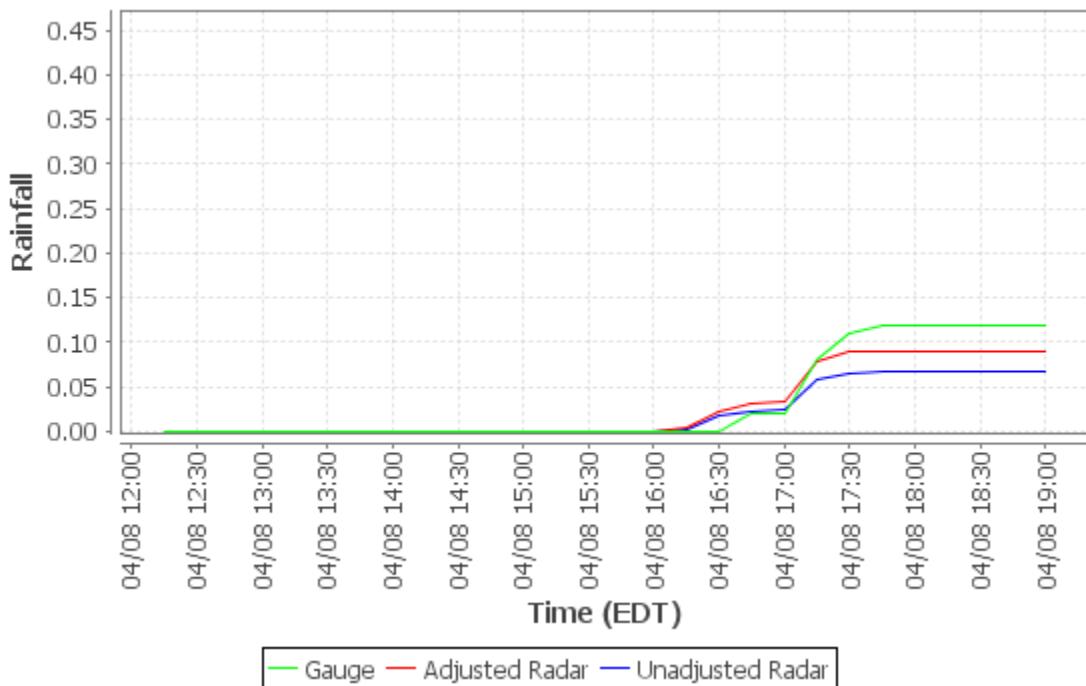
Cumulative Distribution Plot - Oakdale Pump Station (Loc18)



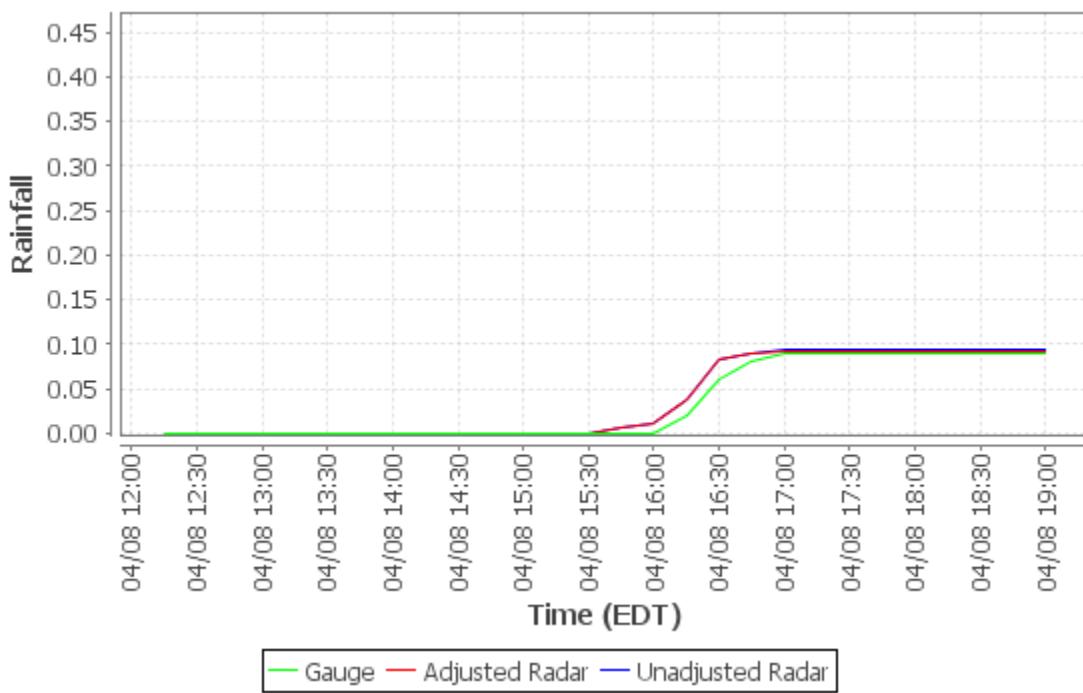
Cumulative Distribution Plot - Sandy Creek Eq Facility (Loc19)



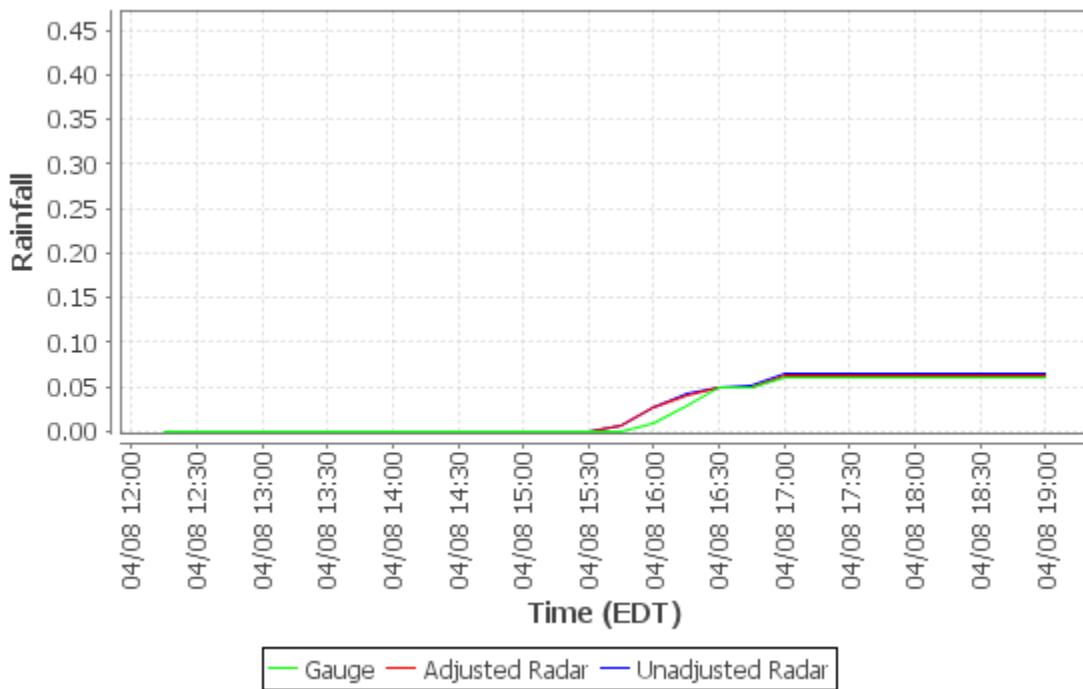
Cumulative Distribution Plot - Gascola Eq Facility (Loc20)



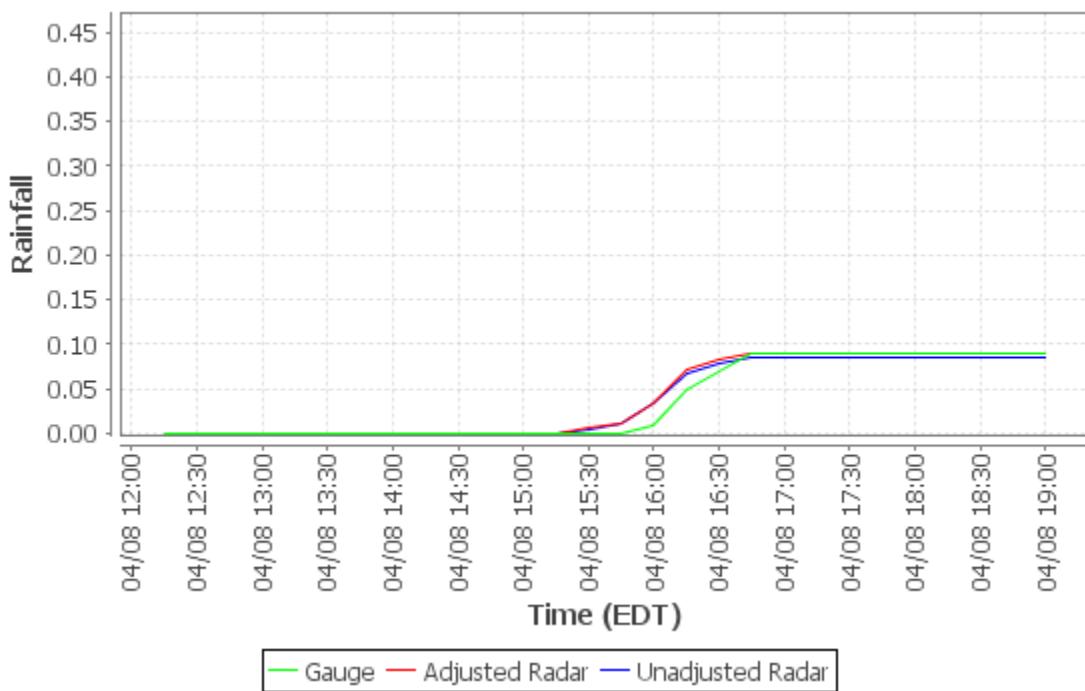
Cumulative Distribution Plot - Moon TWP (Loc21)



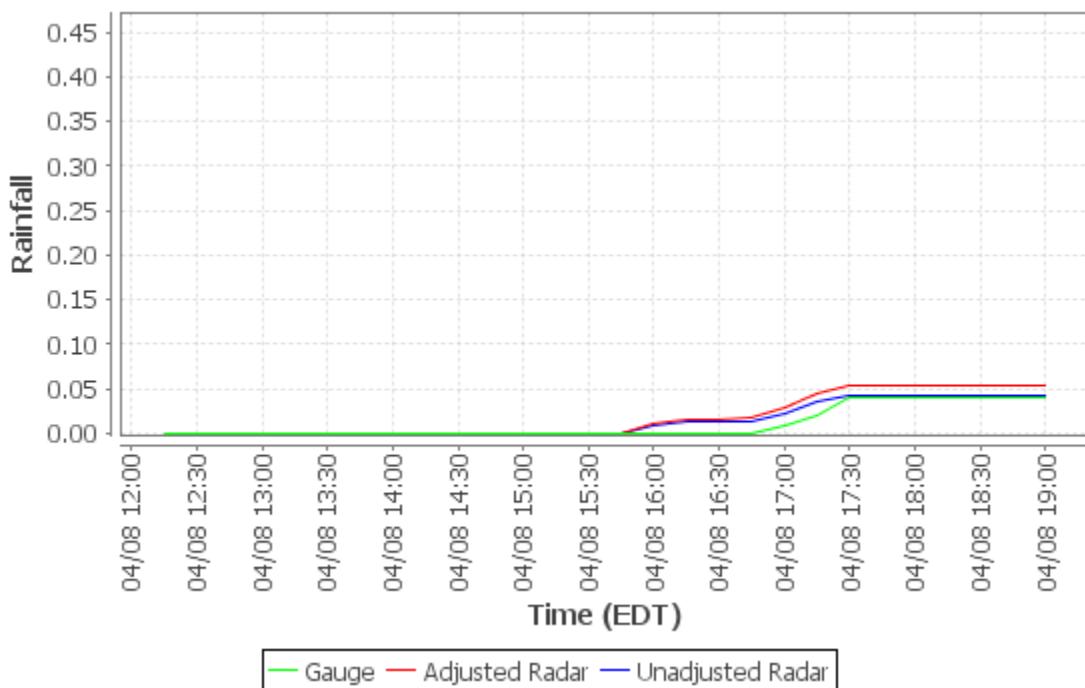
Cumulative Distribution Plot - North Fayette TWP (Loc22)



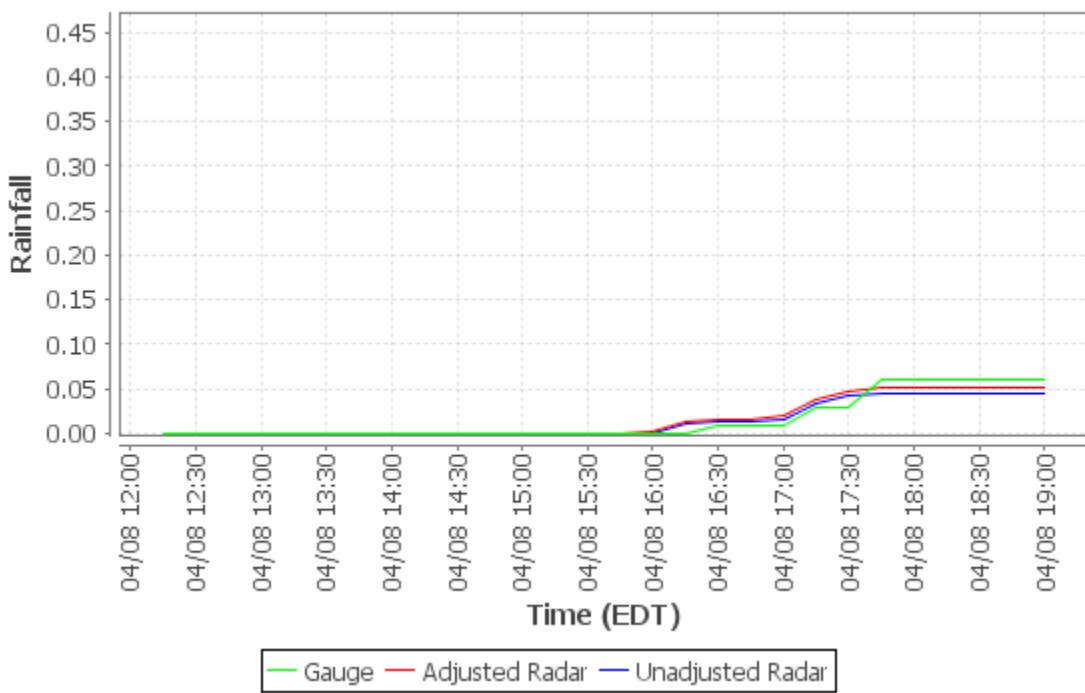
Cumulative Distribution Plot - Clinton Munic Bldg (Loc23)



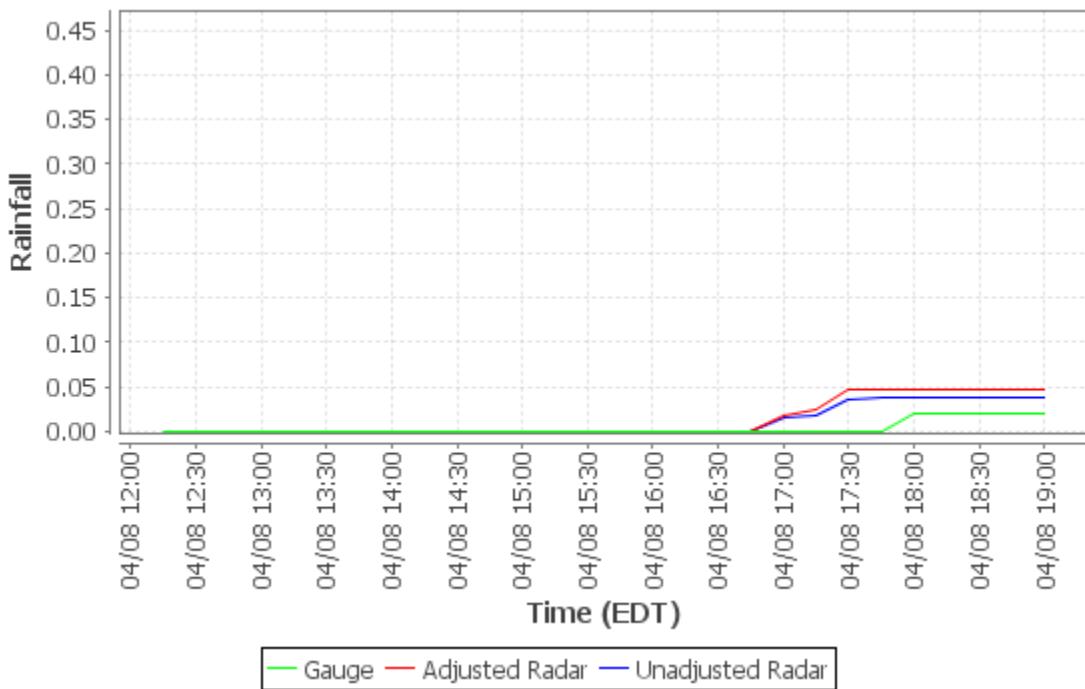
Cumulative Distribution Plot - Jefferson Hills (Loc24)



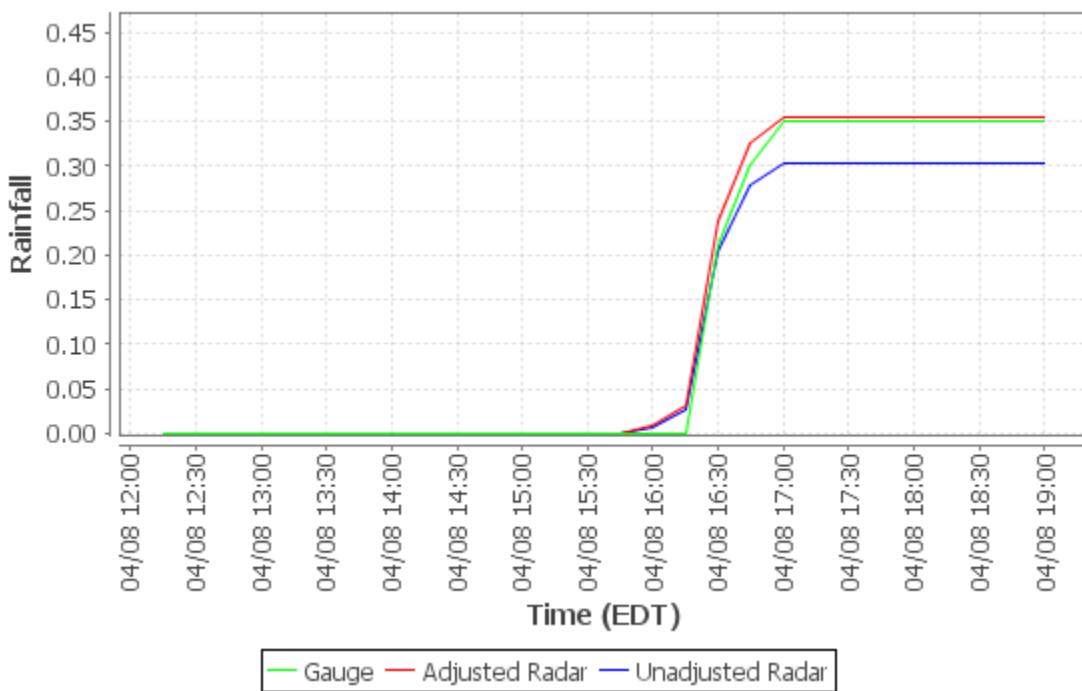
Cumulative Distribution Plot - White Oak Public Works Bldg (Loc25)



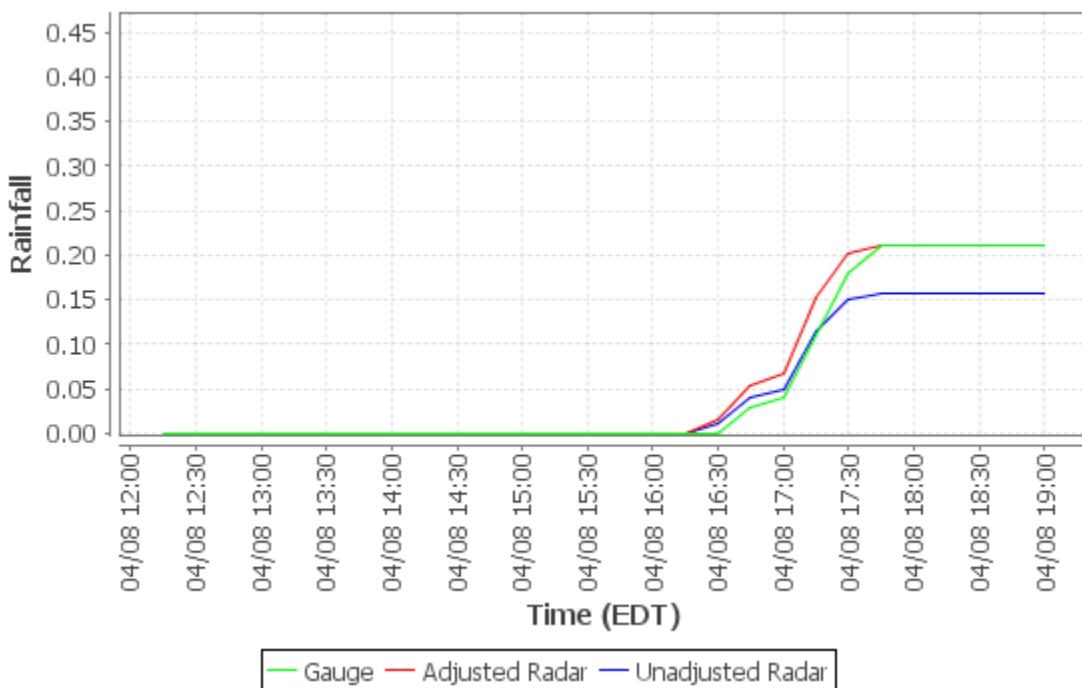
Cumulative Distribution Plot - Elizabeth TWP Municipal Bldg (Loc26)



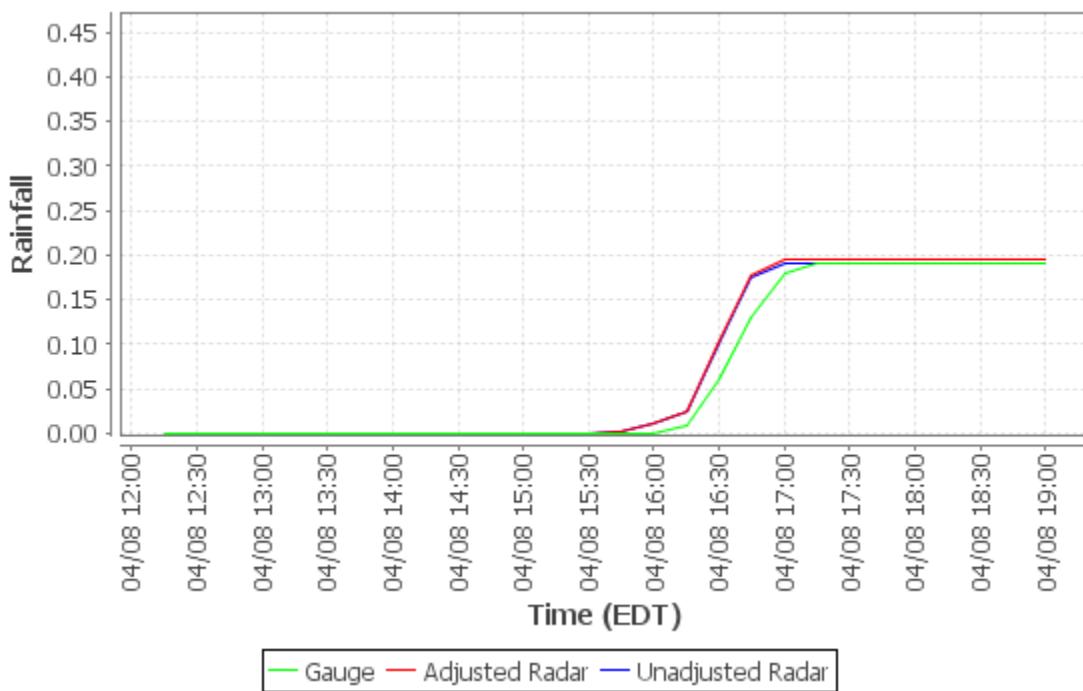
Cumulative Distribution Plot - Marshall TWP (Loc27)



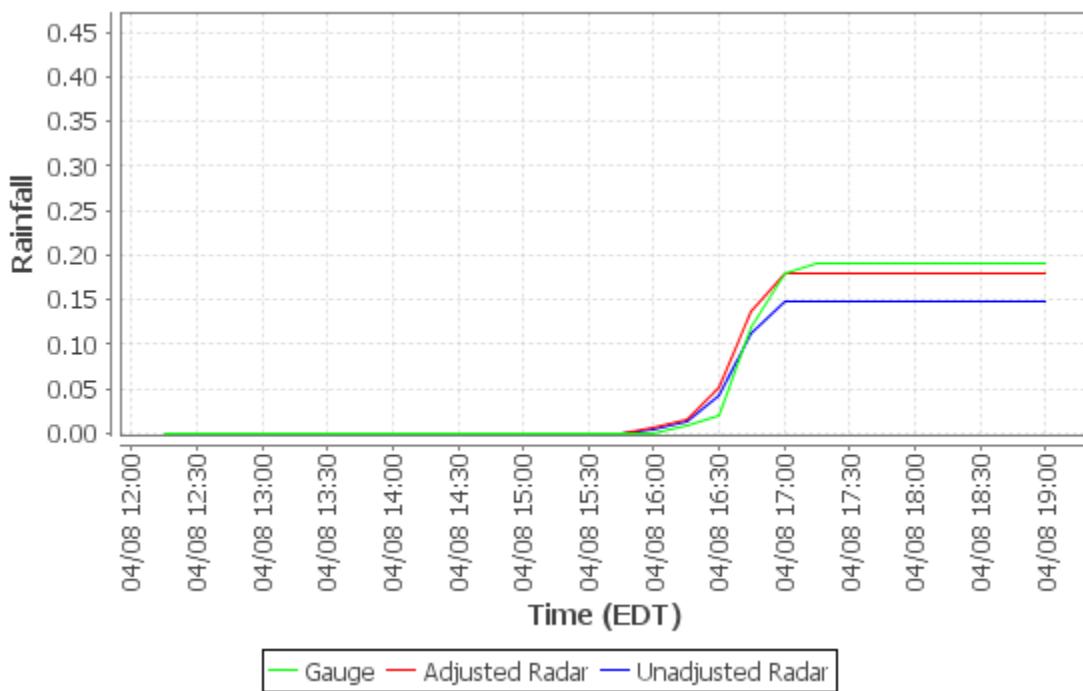
Cumulative Distribution Plot - Plum Municipal Bldg (Loc28)



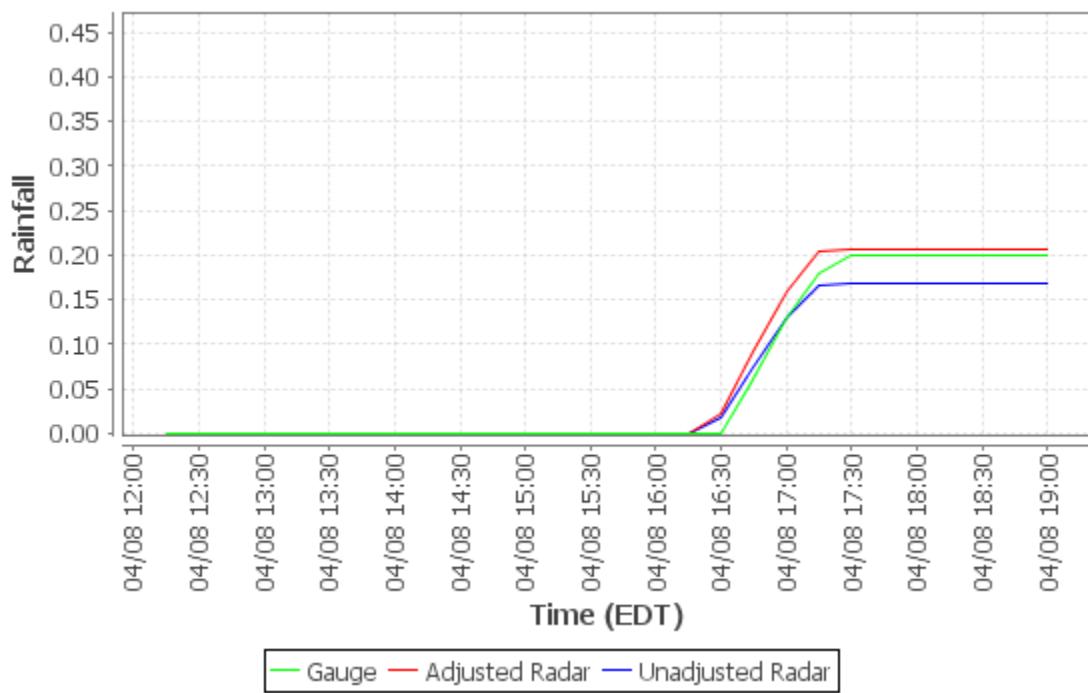
Cumulative Distribution Plot - Bell Acres Munic Bldg (Loc29)



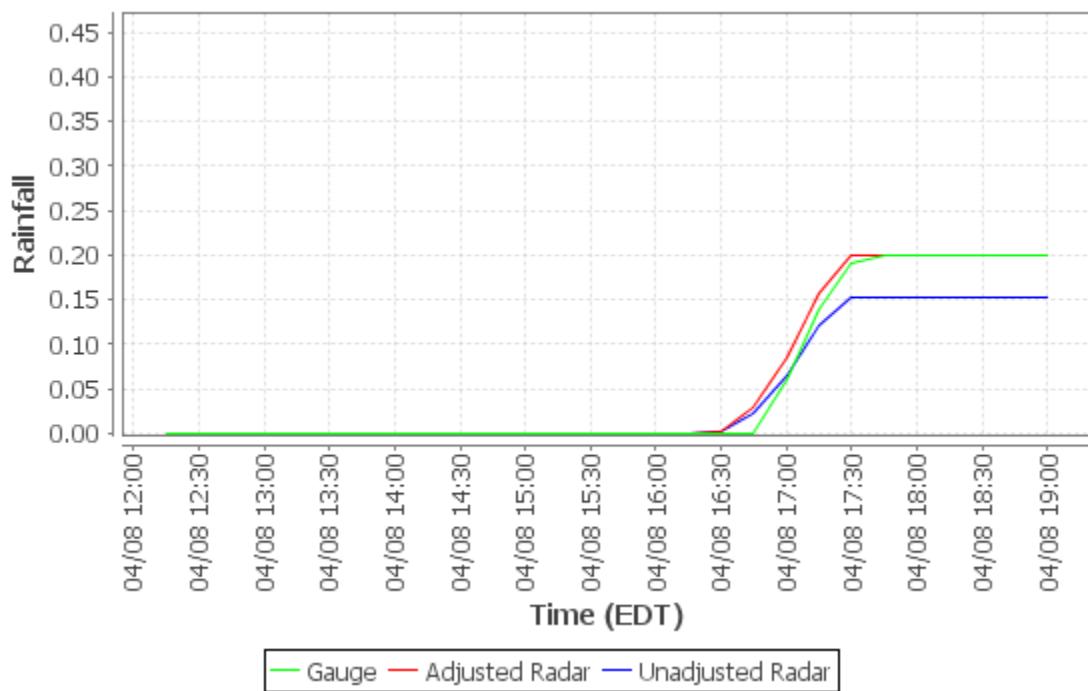
Cumulative Distribution Plot - McCandless Twn Hall (Loc30)



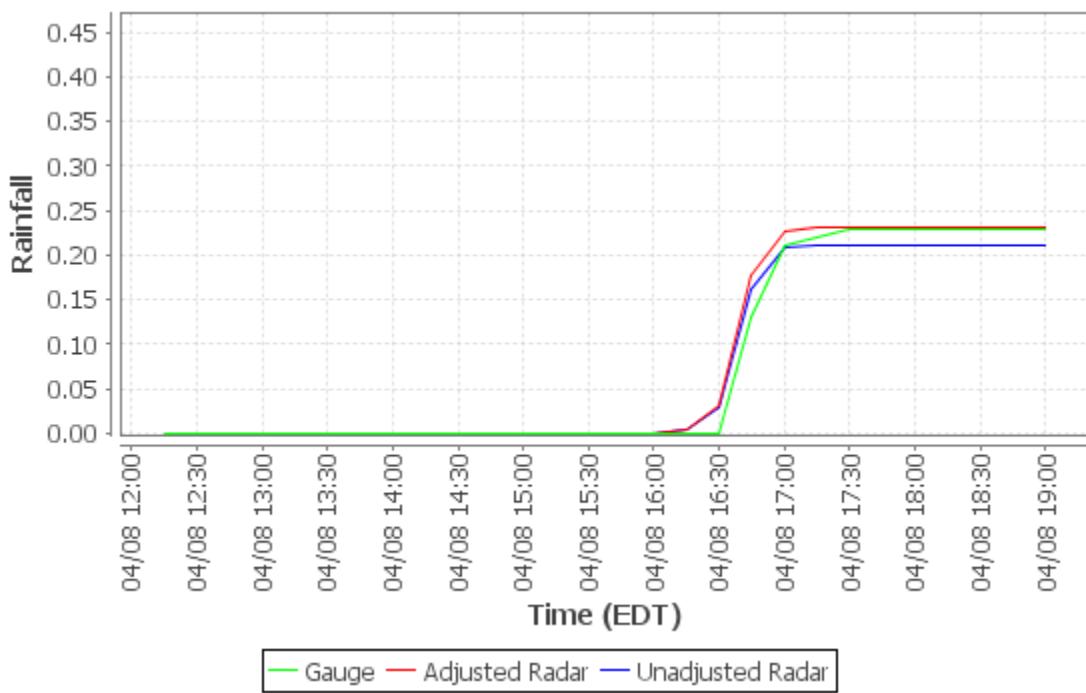
Cumulative Distribution Plot - Hampton Municipal Bldg (Loc31)



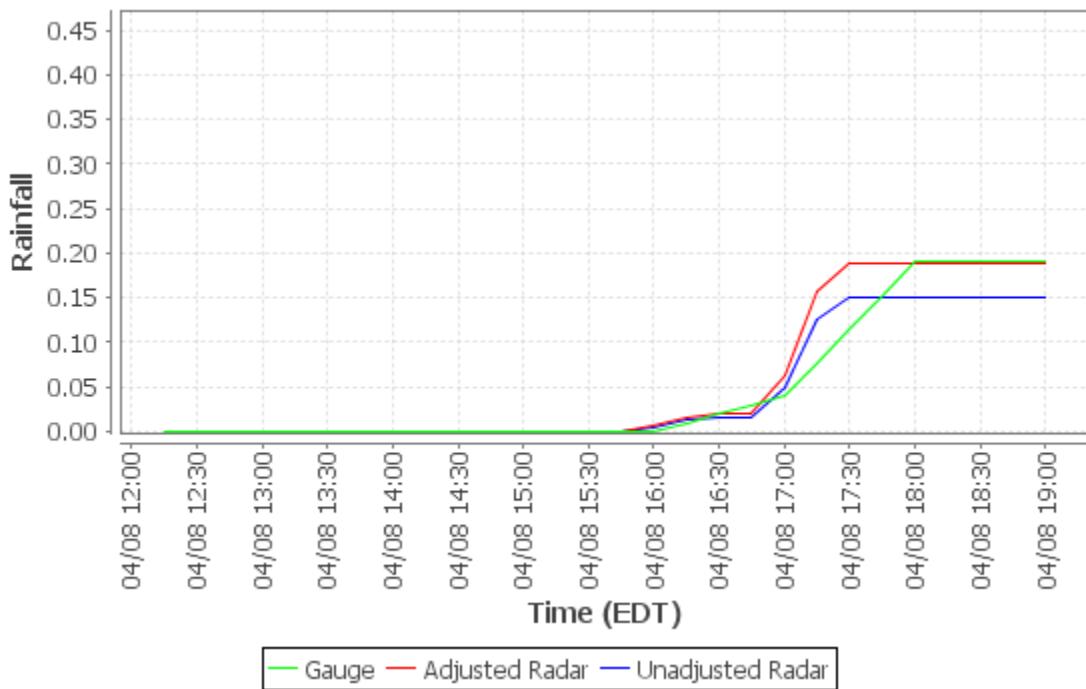
Cumulative Distribution Plot - Arnold (Loc32)



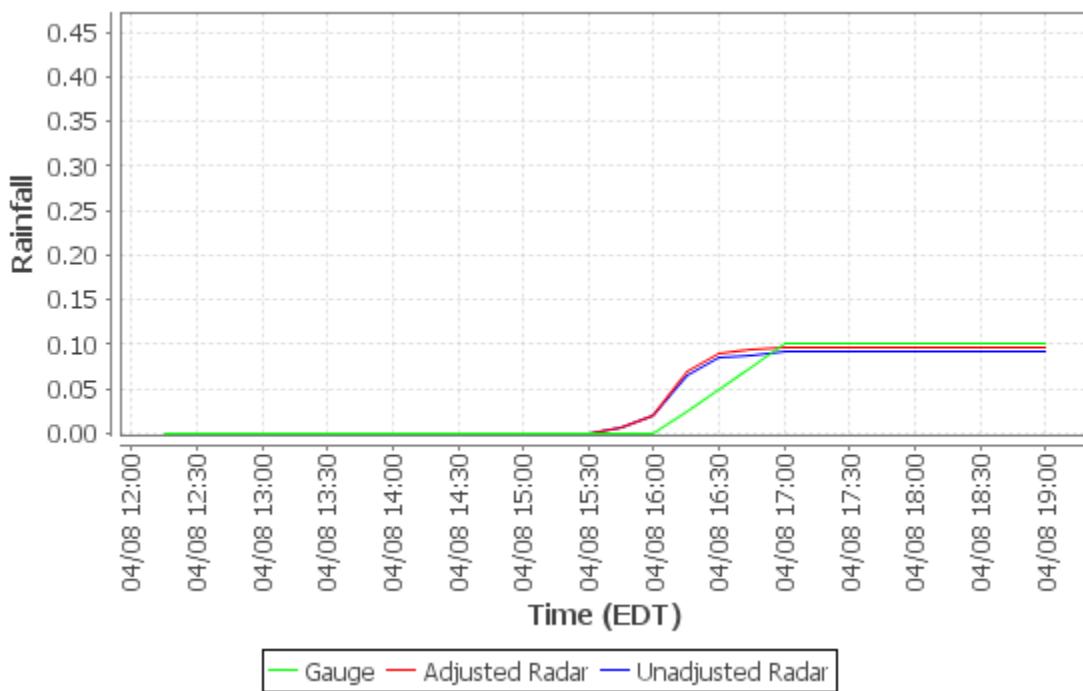
Cumulative Distribution Plot - Richland TWP (Loc33)



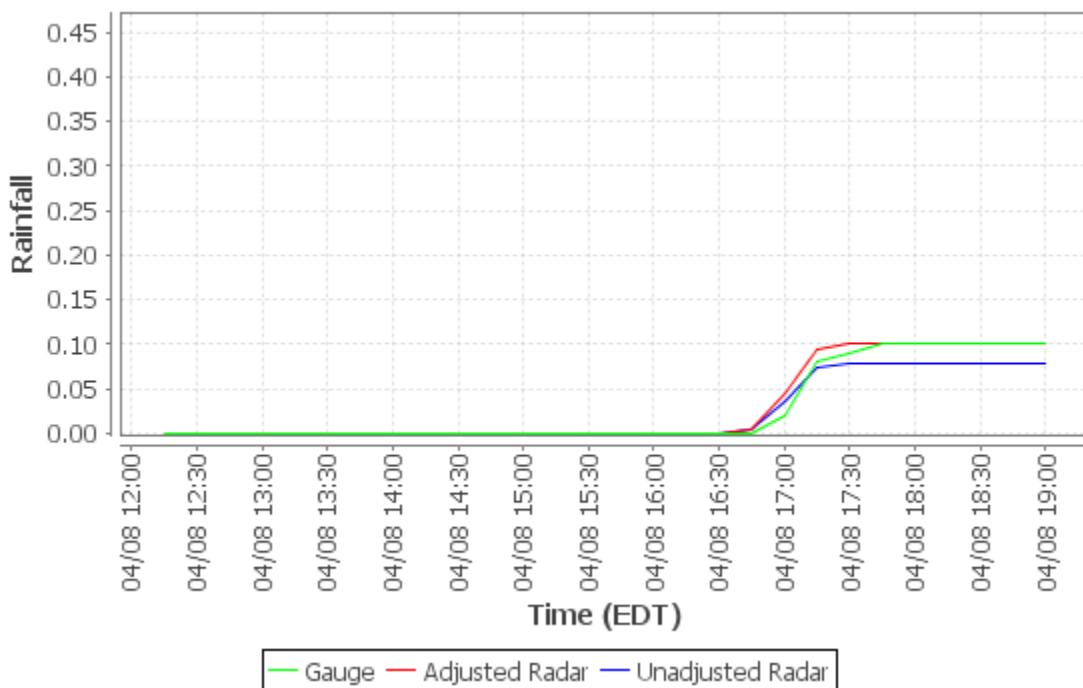
Cumulative Distribution Plot - Pittsburgh Allegheny Cty (KAGC)



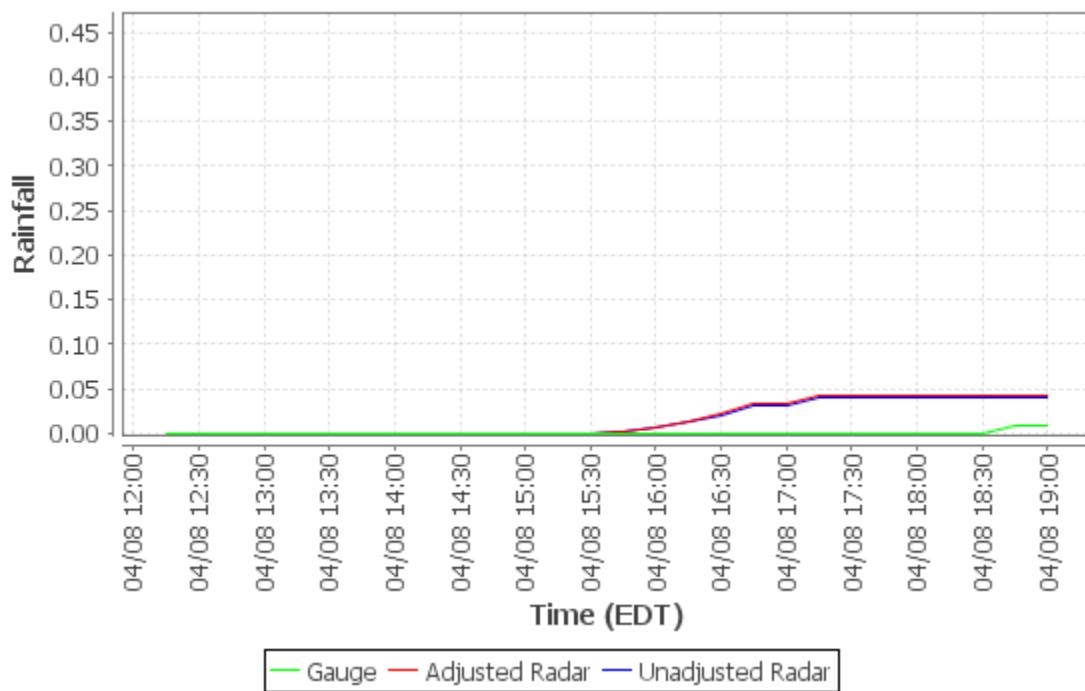
Cumulative Distribution Plot - Greater Pittsburgh Int'l (KPIT)



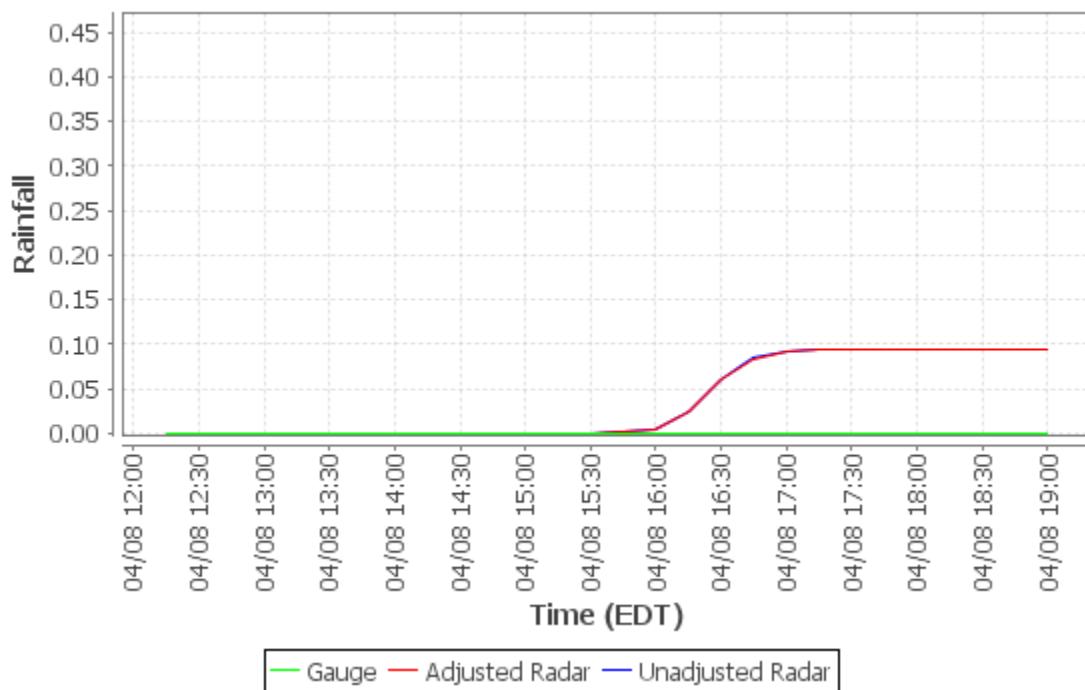
Cumulative Distribution Plot - Allegheny River at Natrona (03049500)



Cumulative Distribution Plot - Chartiers Creek at Carnegie (03085500)

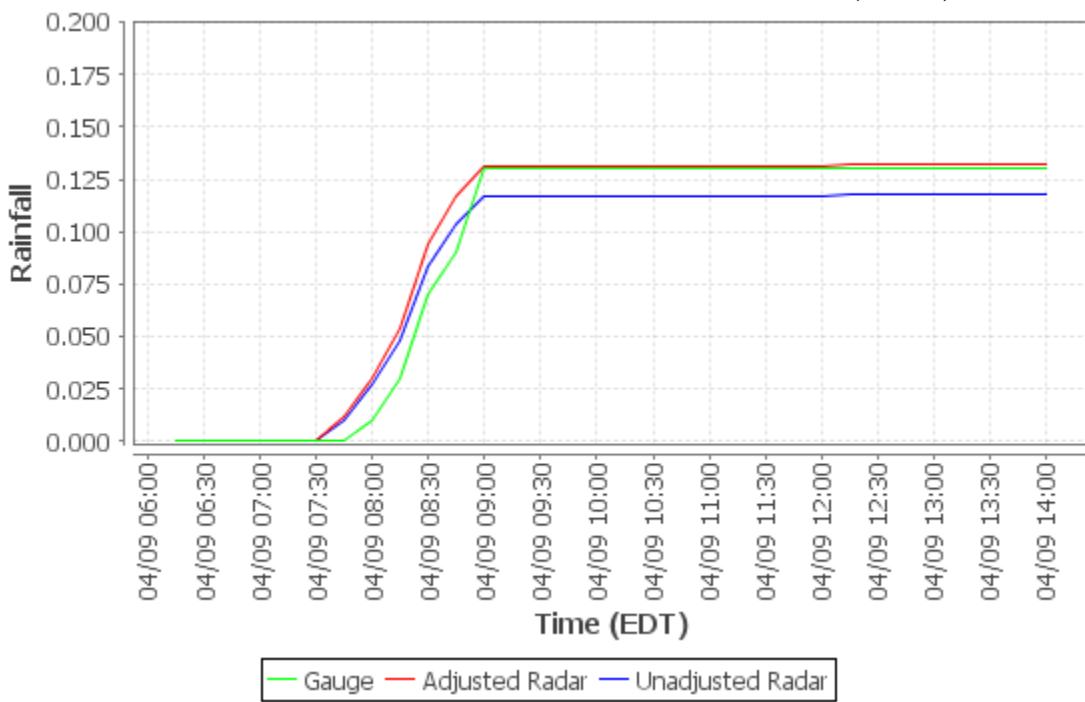


Cumulative Distribution Plot - Ohio River at Emsworth Dam Lower Pool at Emsworth (03085734)

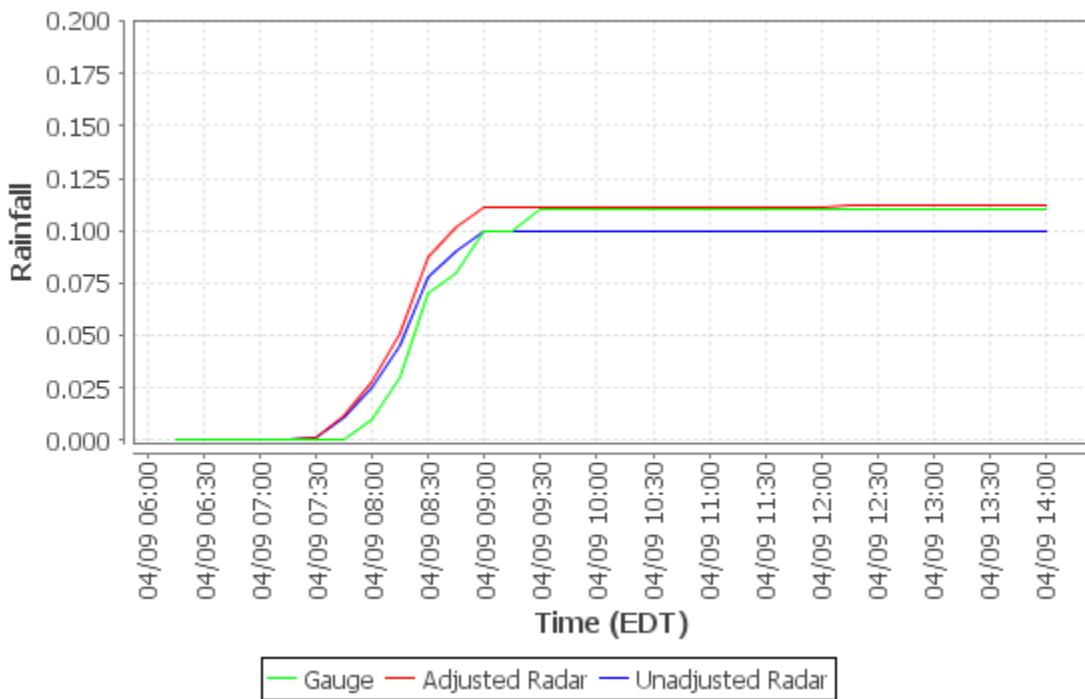


Appendix G - Event 6 (2015-04-09 AM) CDPs

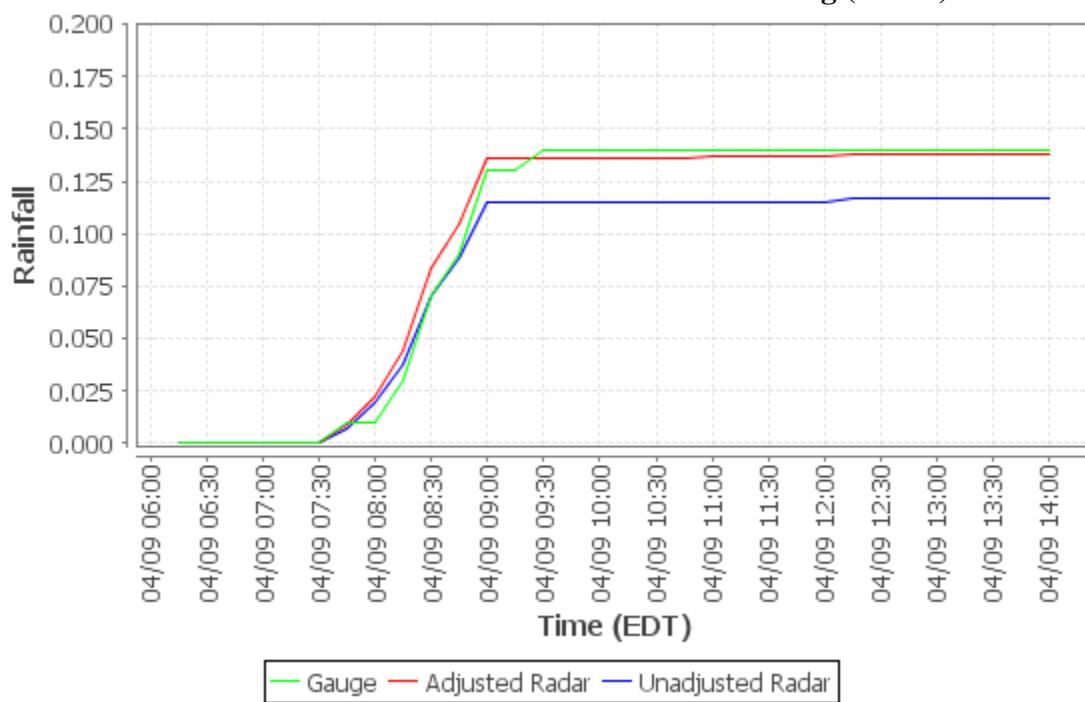
Cumulative Distribution Plot - PWSA-Montana St. (Loc01)



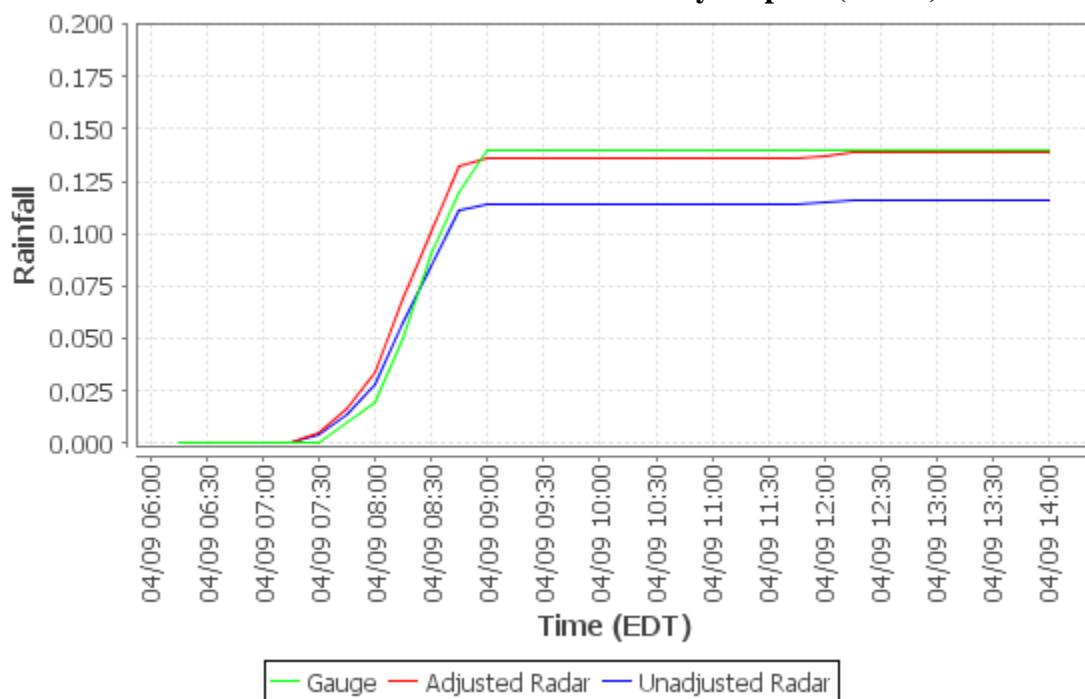
Cumulative Distribution Plot - ALCOSAN WWTP Lab (Loc02)



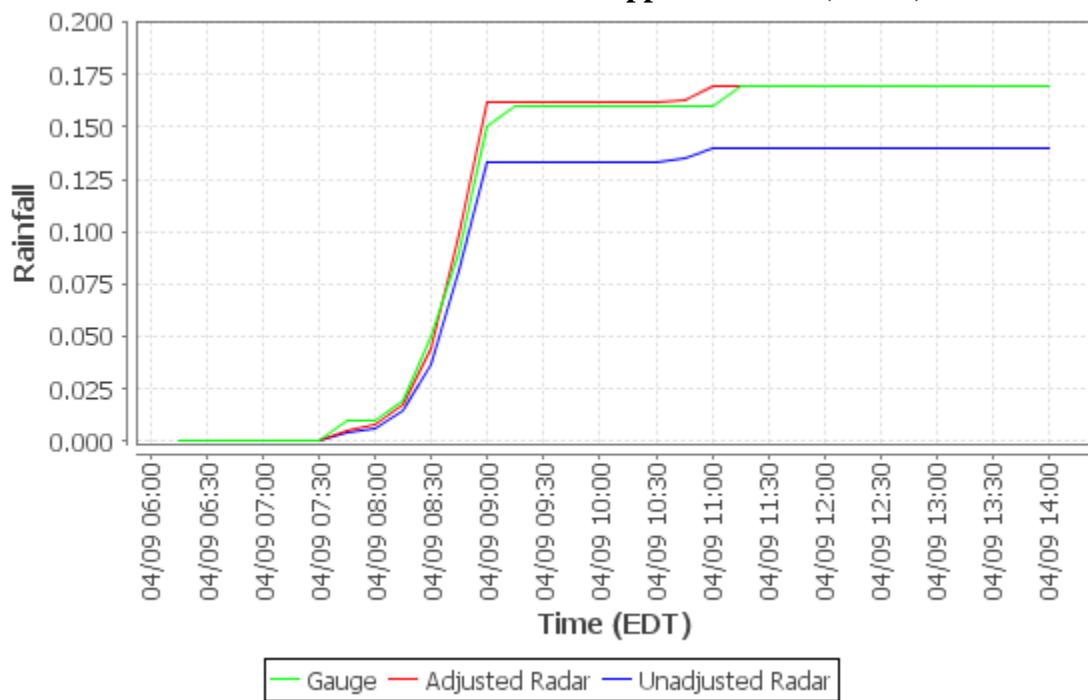
Cumulative Distribution Plot - Shaler Munic Bldg (Loc03)



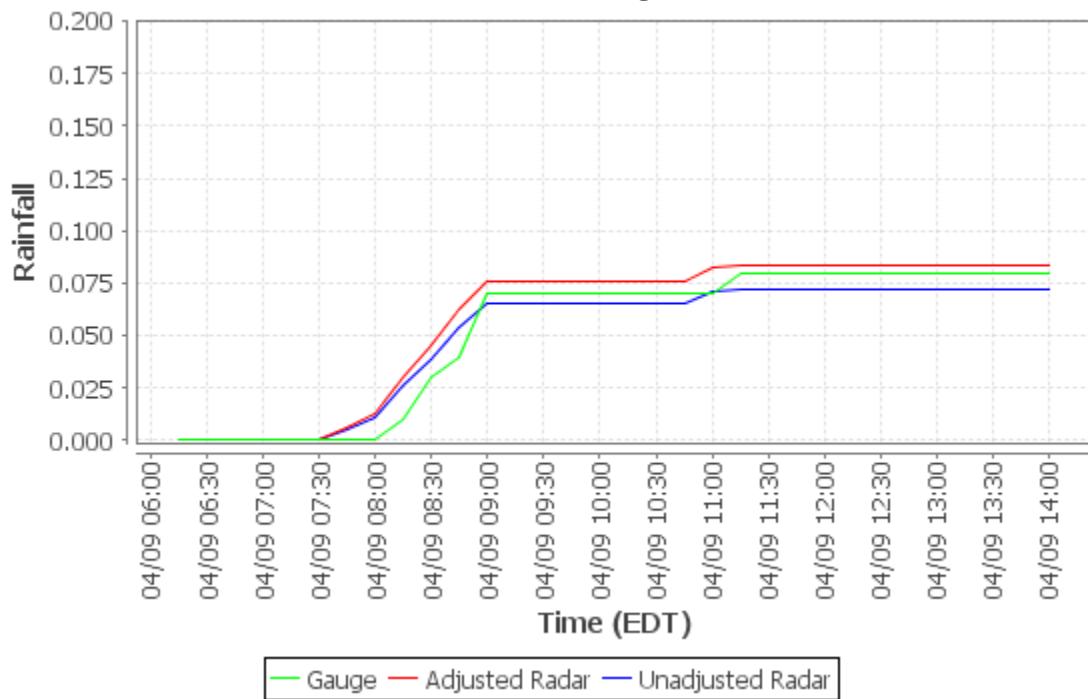
Cumulative Distribution Plot - Kennedy Twp PS (Loc04)



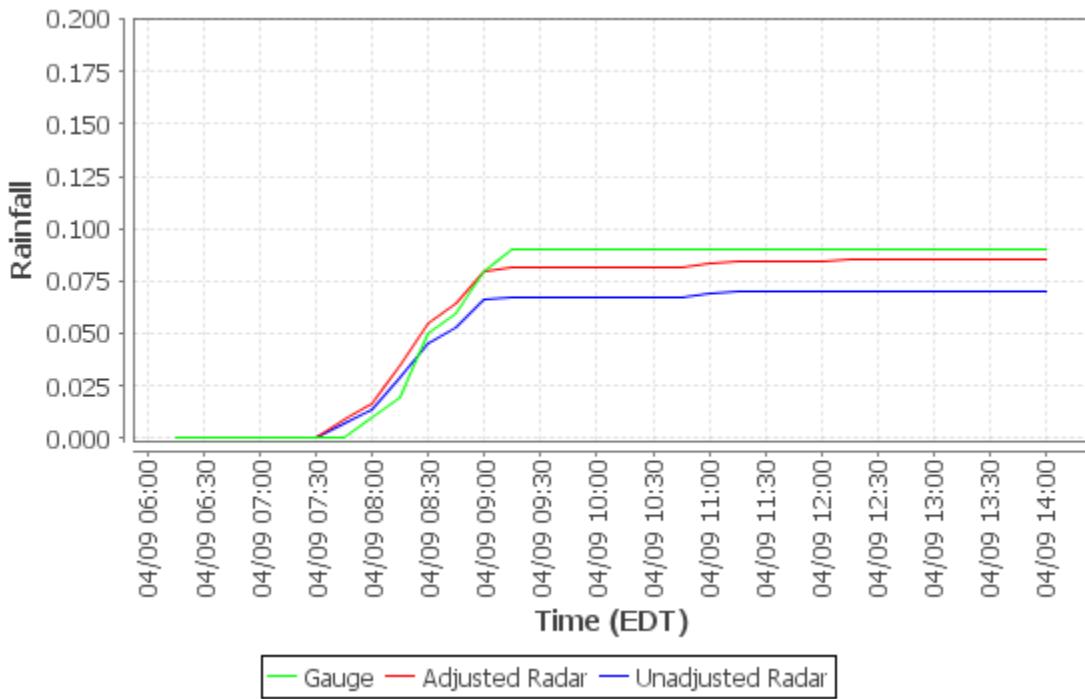
Cumulative Distribution Plot - Upper St. Clair (Loc05)



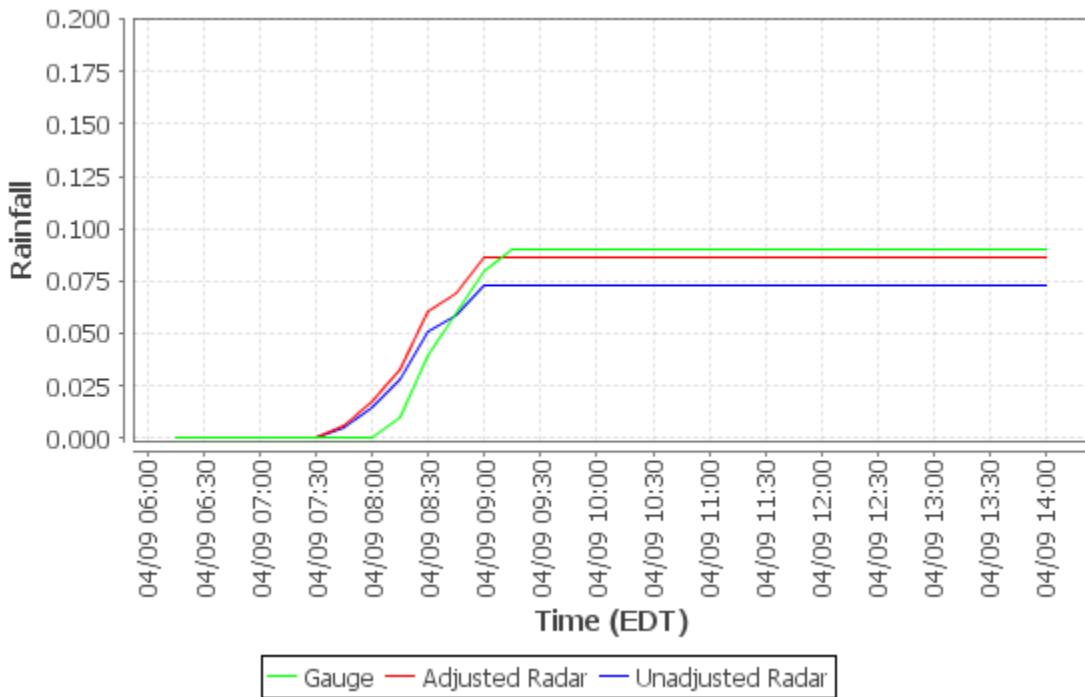
Cumulative Distribution Plot - Carnegie Transit Time (Loc06)



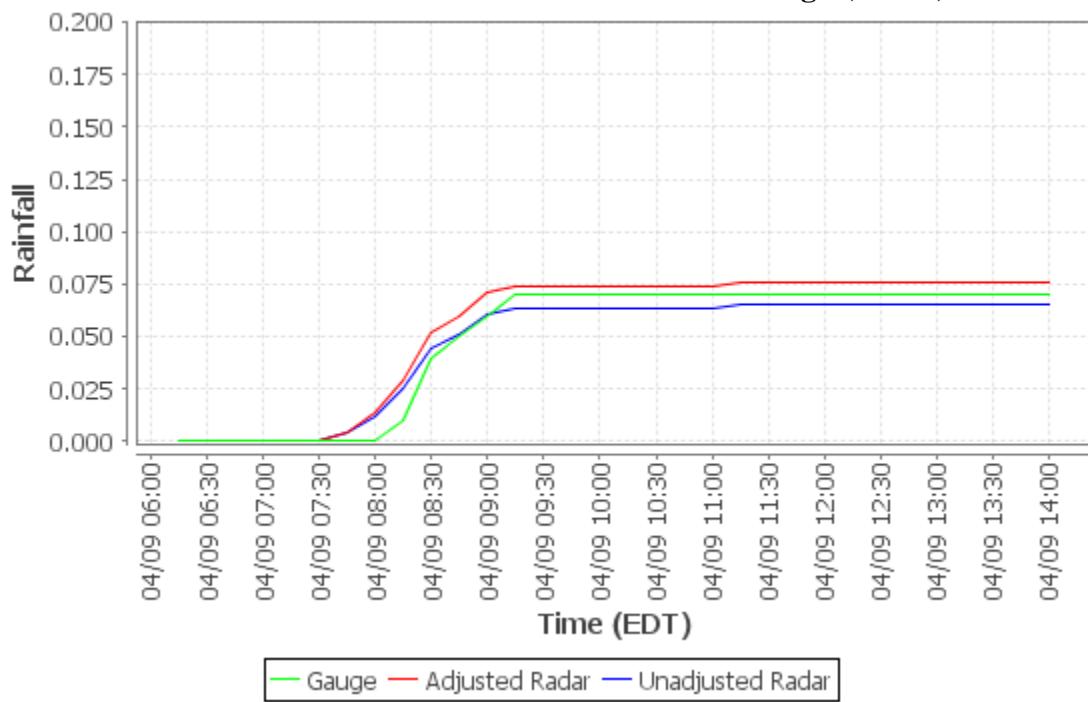
Cumulative Distribution Plot - Greentree Munic Bldg (Loc07)



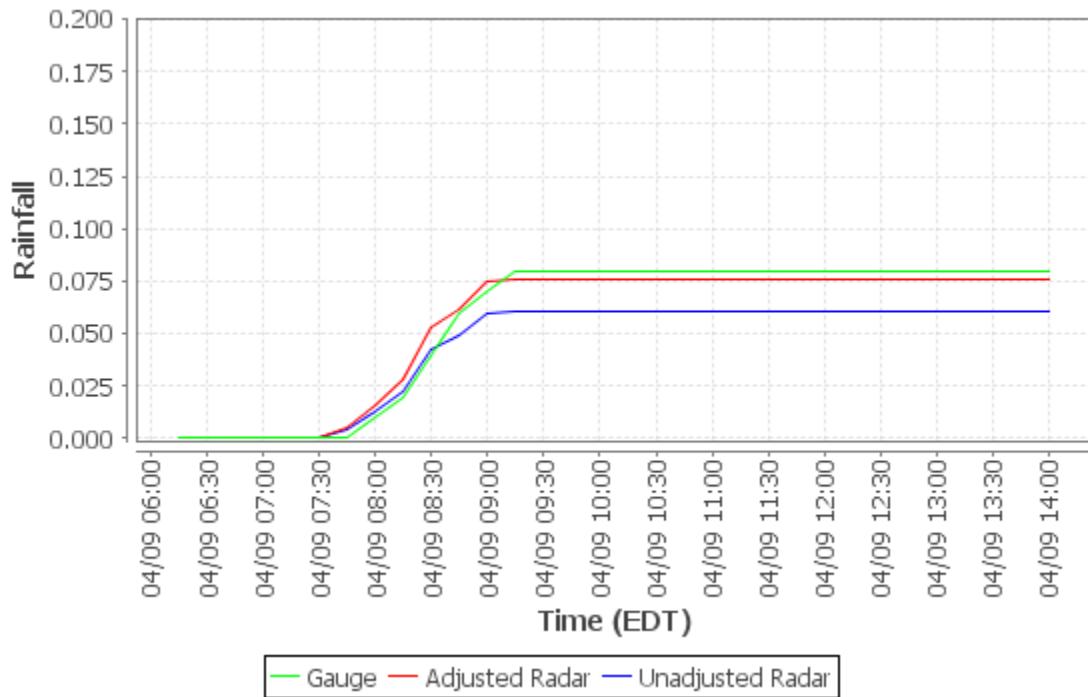
Cumulative Distribution Plot - AC Health Dept Bldg (Loc08)



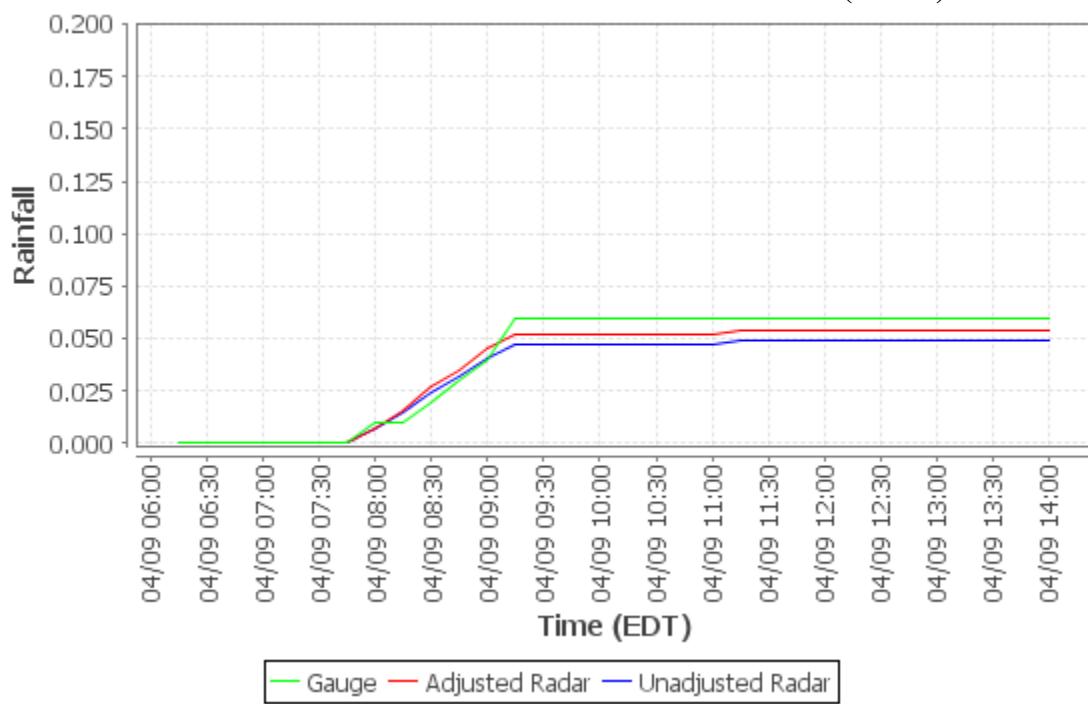
Cumulative Distribution Plot - Univ of Pittsburgh (Loc09)



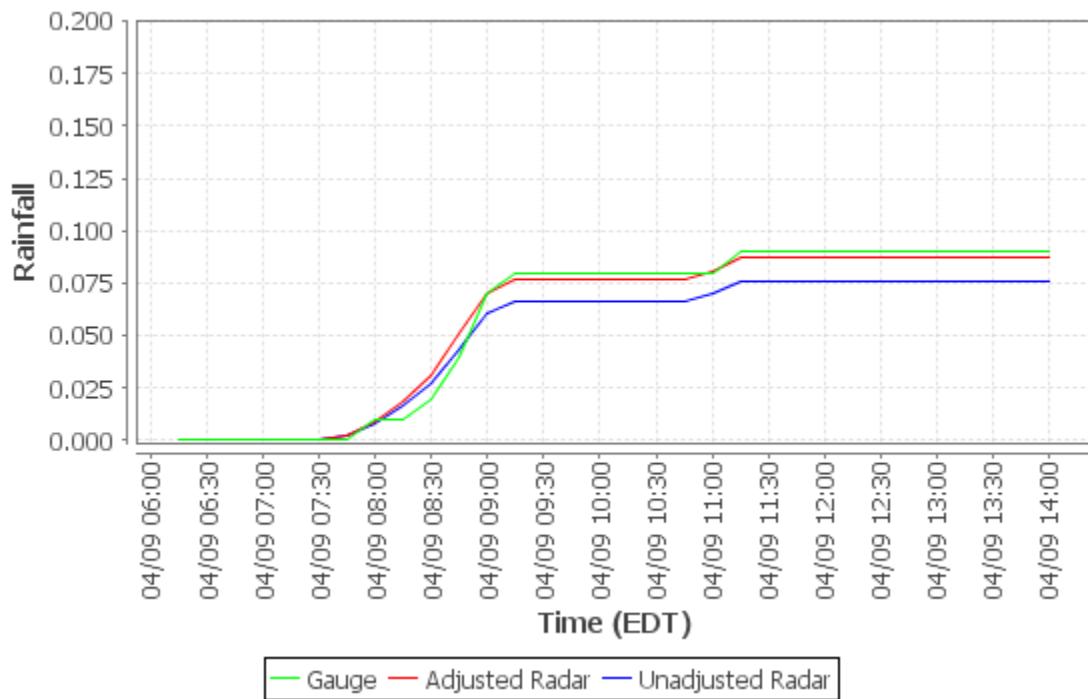
Cumulative Distribution Plot - PWSA-Highland Park (Loc10)



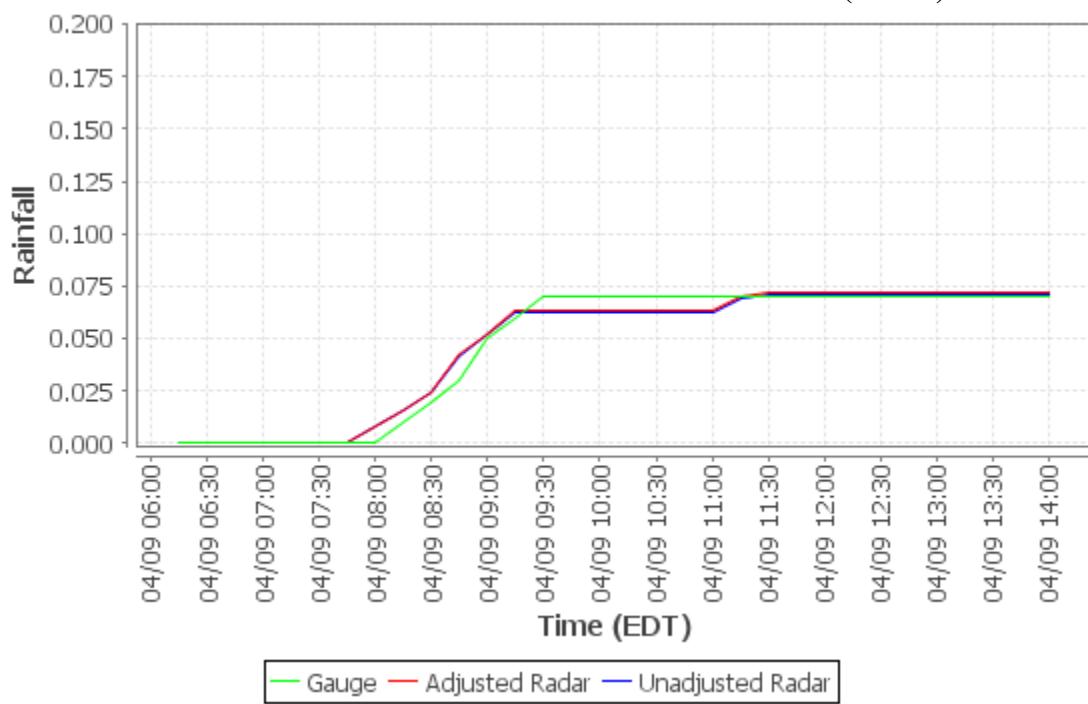
Cumulative Distribution Plot - M-46 Access Shaft (Loc11)



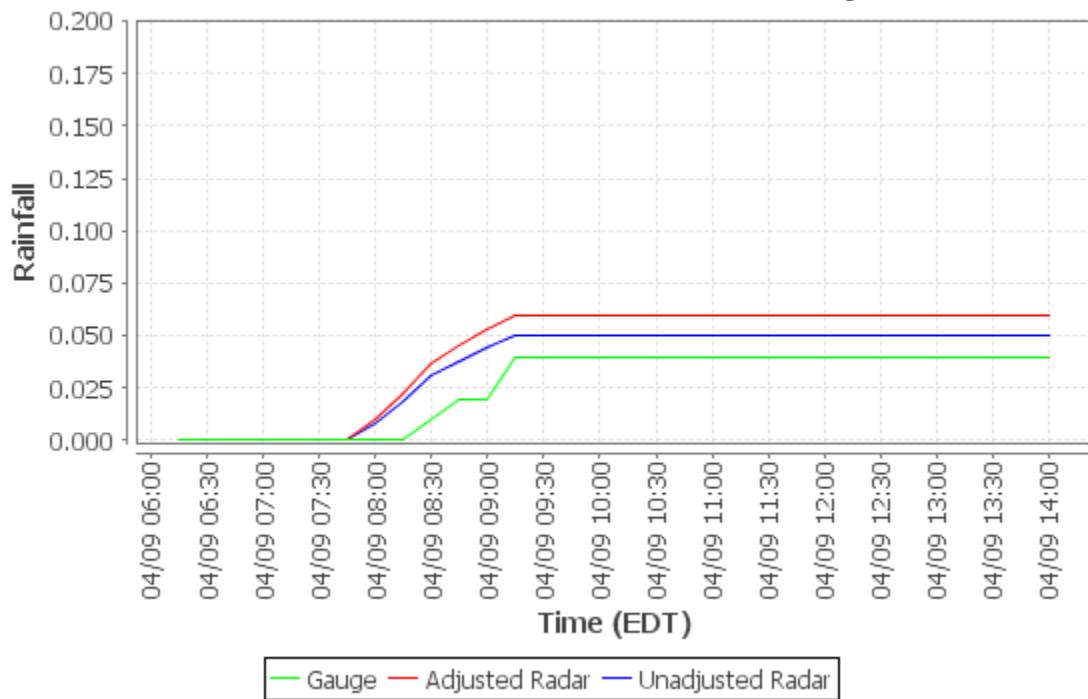
Cumulative Distribution Plot - Baldwin (Loc12)



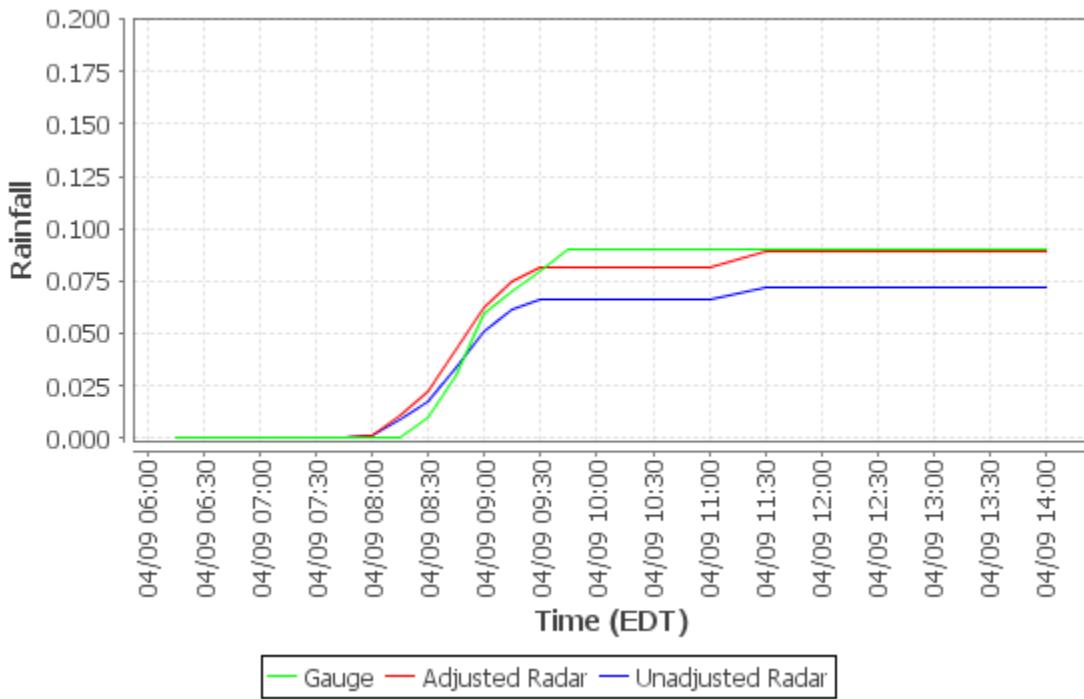
Cumulative Distribution Plot - M-59 Access Shaft (Loc13)



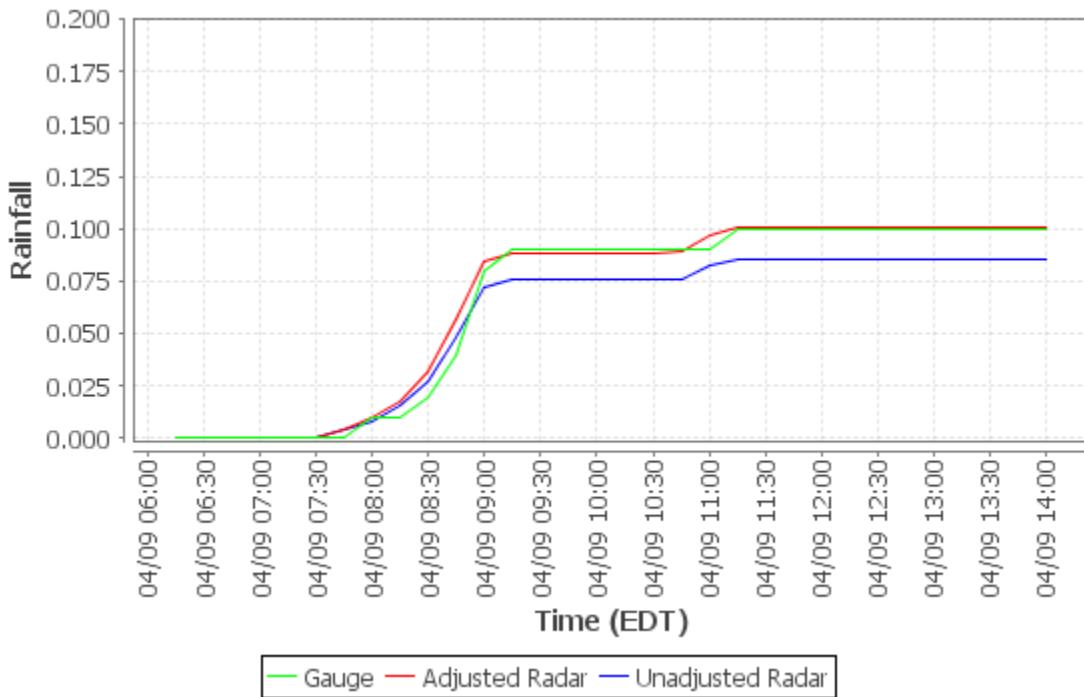
Cumulative Distribution Plot - Churchill Munic Bldg (Loc14)



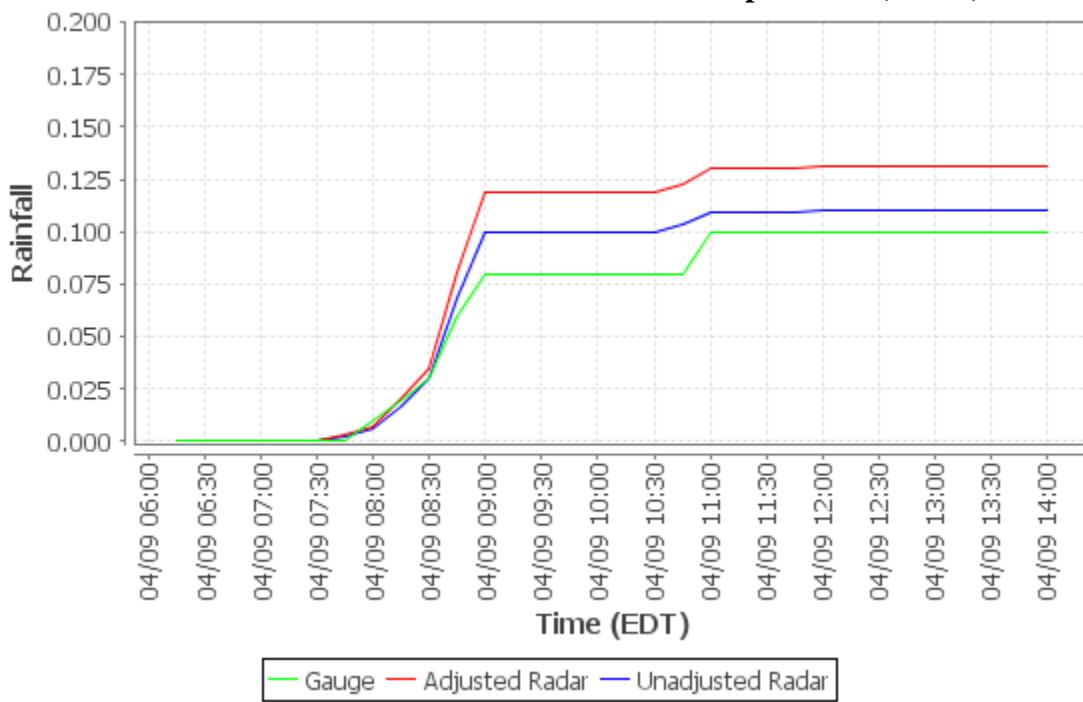
Cumulative Distribution Plot - Trafford Maint Bldg (Loc15)



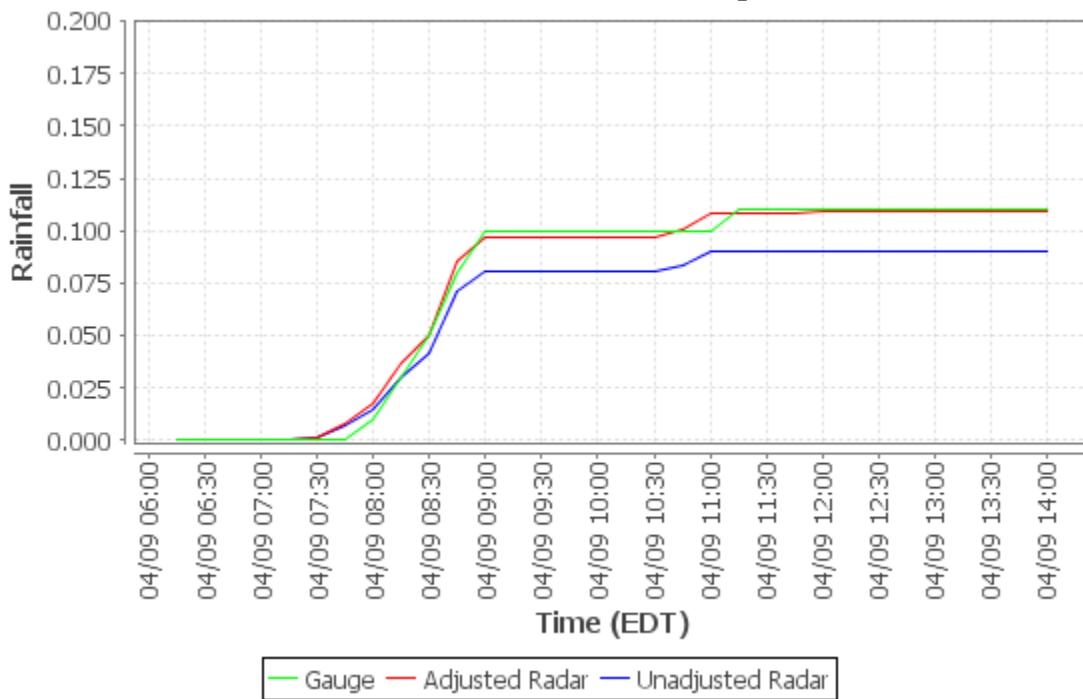
Cumulative Distribution Plot - Castle Shannon (Loc16)



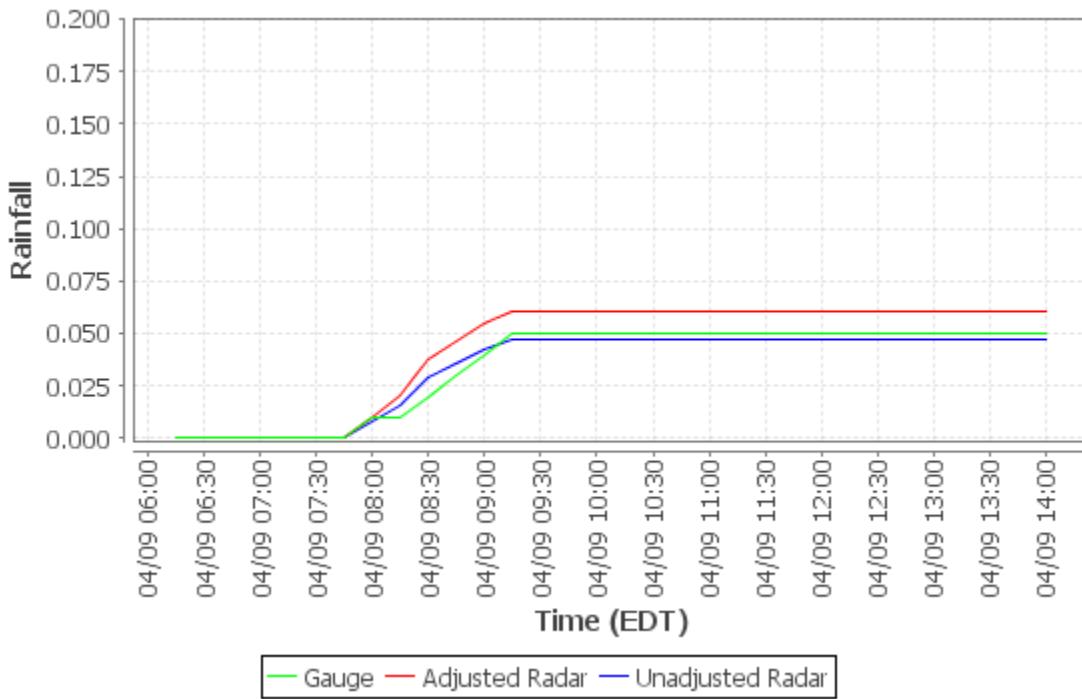
Cumulative Distribution Plot - Chartiers Pump Station (Loc17)



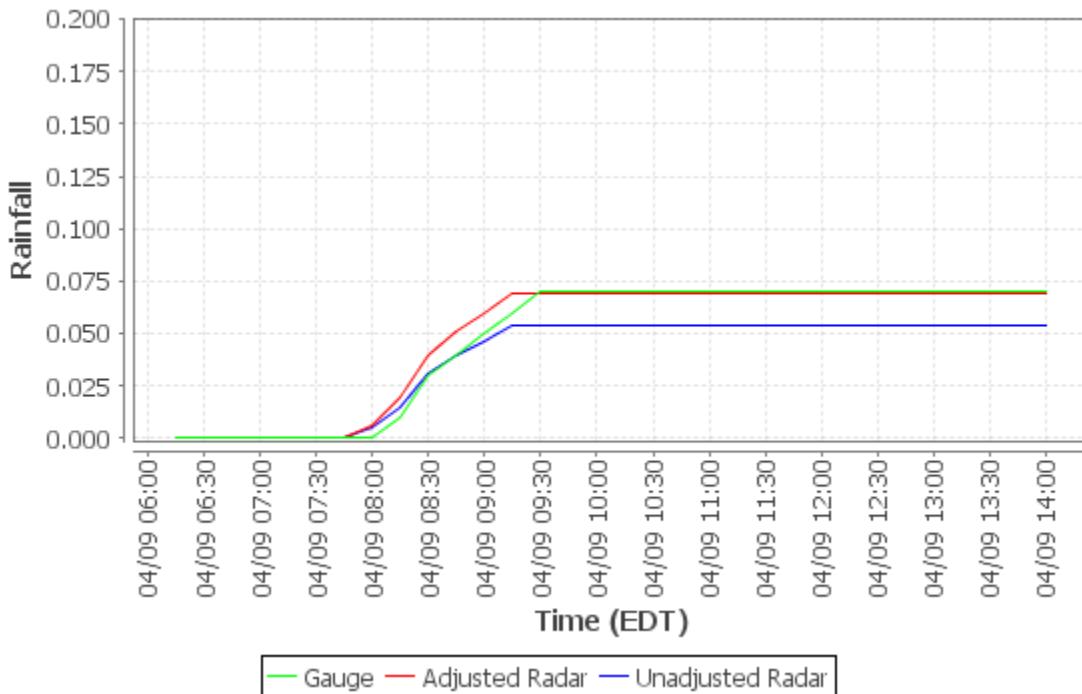
Cumulative Distribution Plot - Oakdale Pump Station (Loc18)



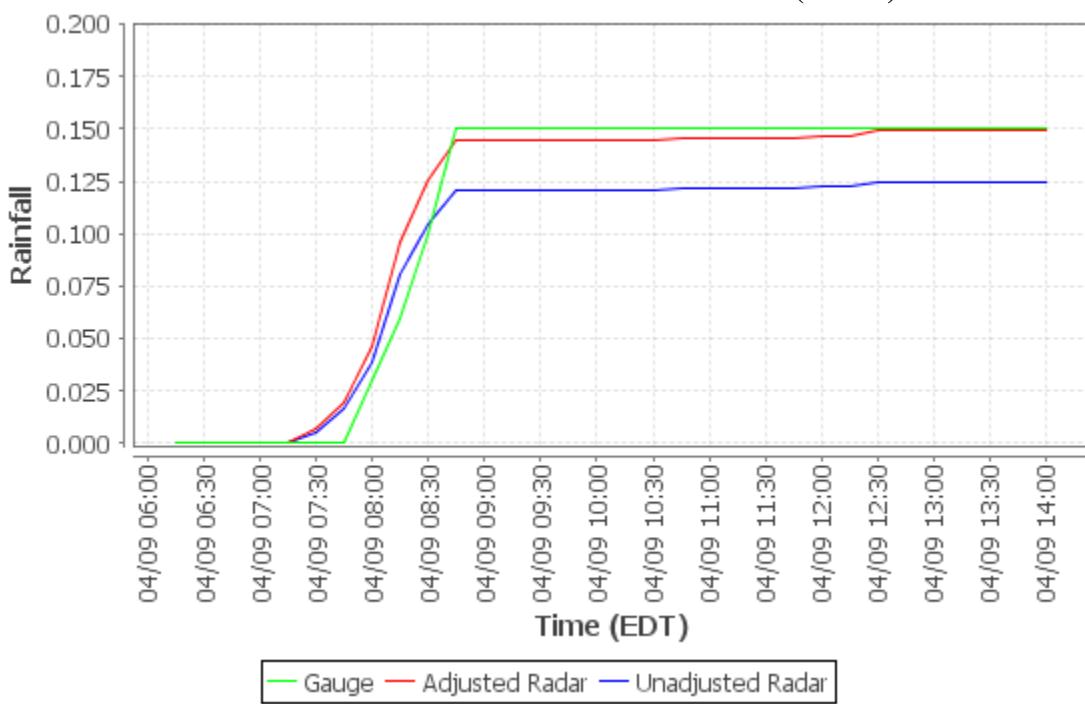
Cumulative Distribution Plot - Sandy Creek Eq Facility (Loc19)



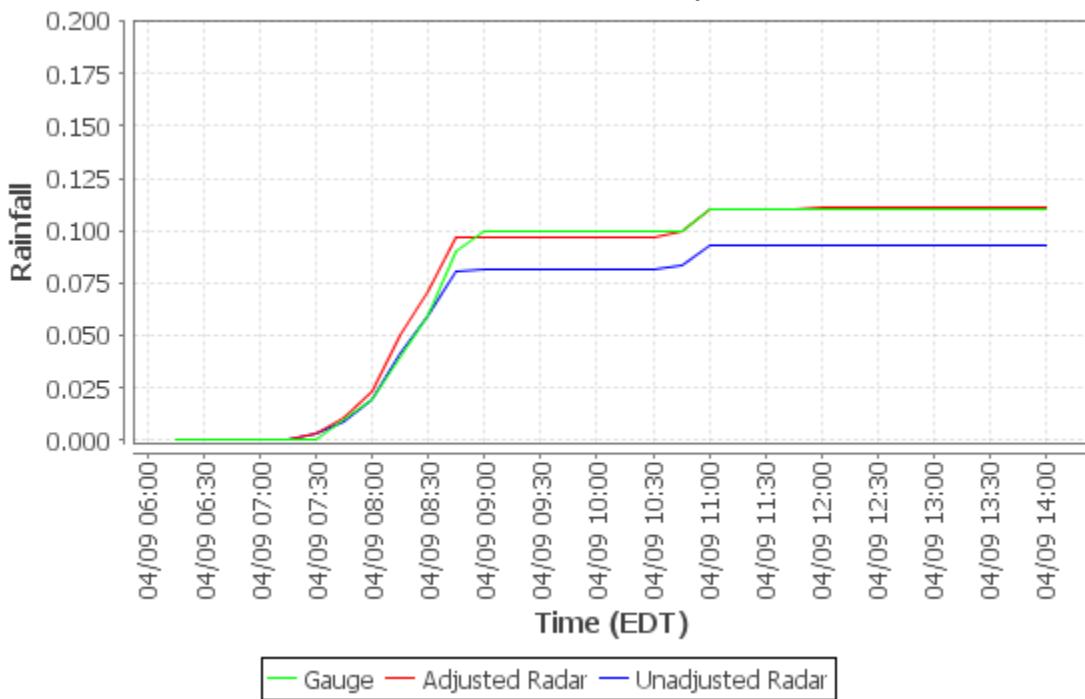
Cumulative Distribution Plot - Gascola Eq Facility (Loc20)



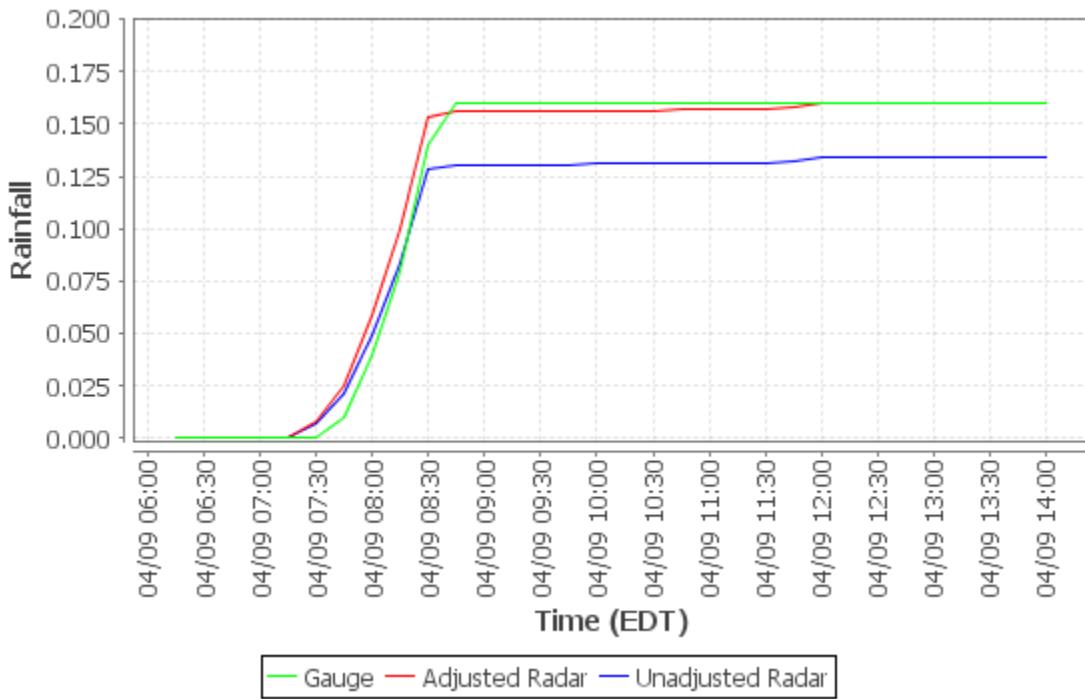
Cumulative Distribution Plot - Moon TWP (Loc21)



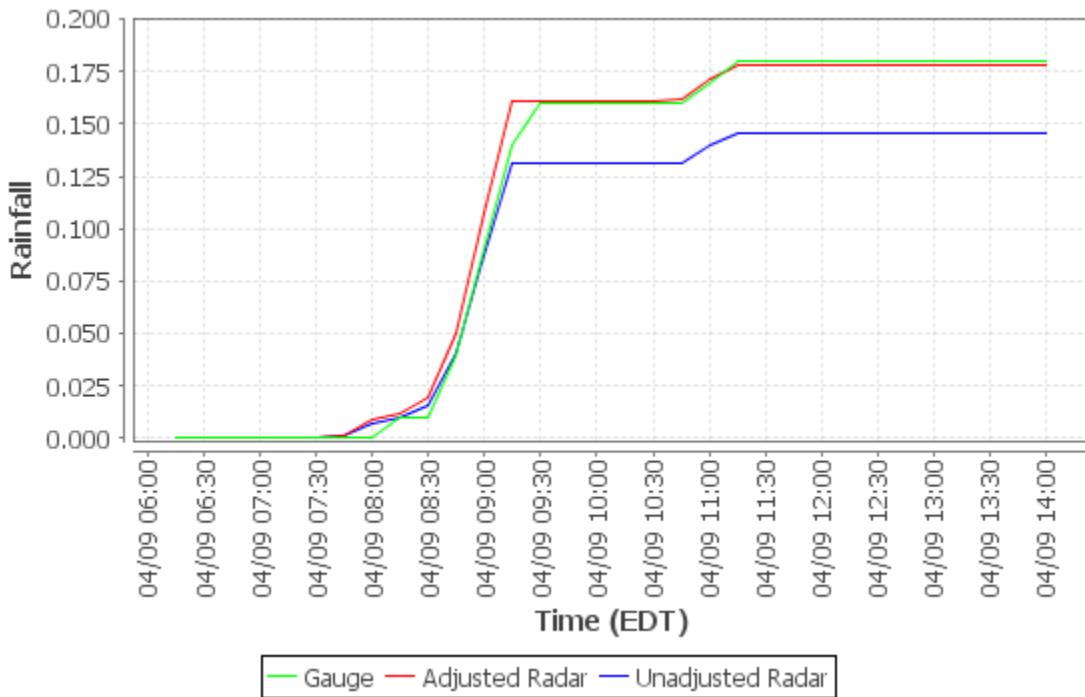
Cumulative Distribution Plot - North Fayette TWP (Loc22)



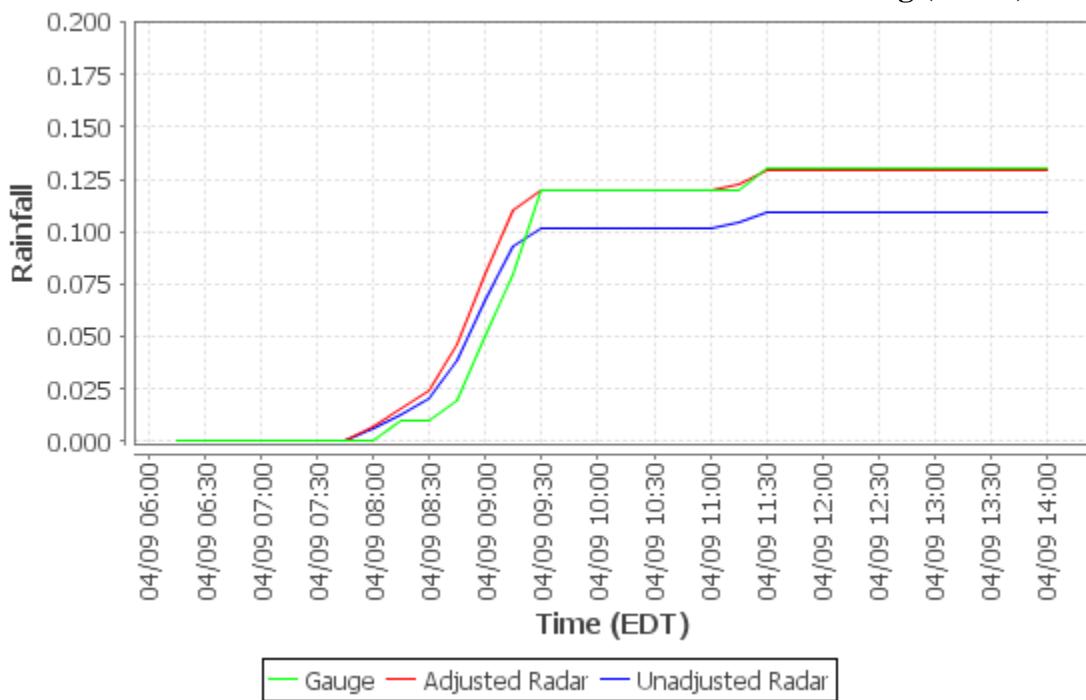
Cumulative Distribution Plot - Clinton Munic Bldg (Loc23)



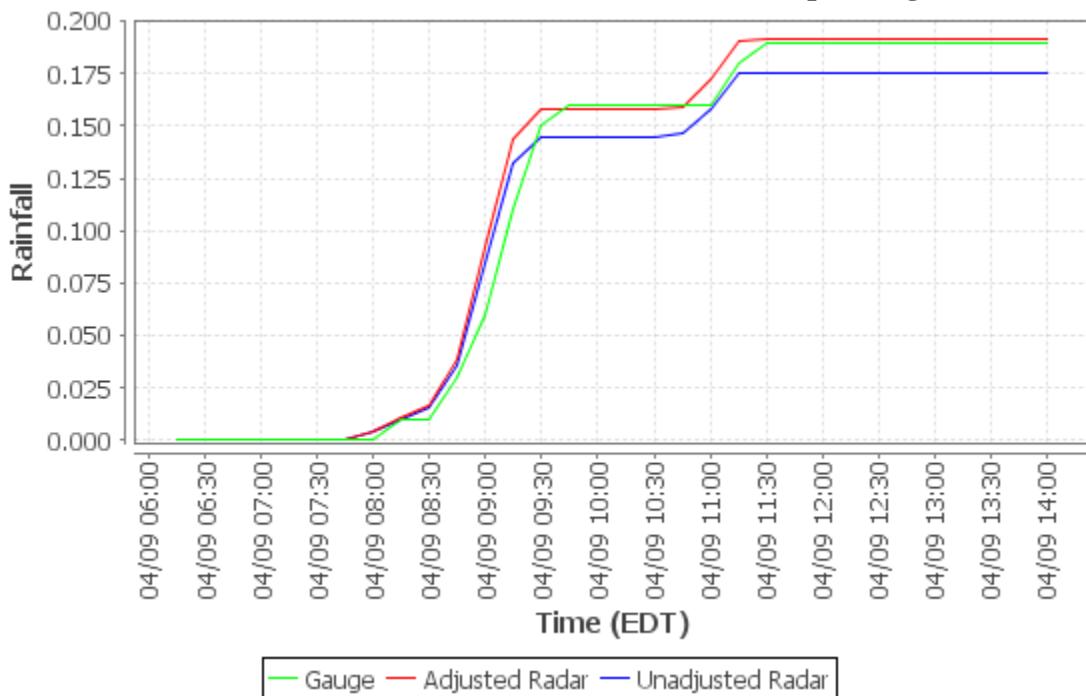
Cumulative Distribution Plot - Jefferson Hills (Loc24)



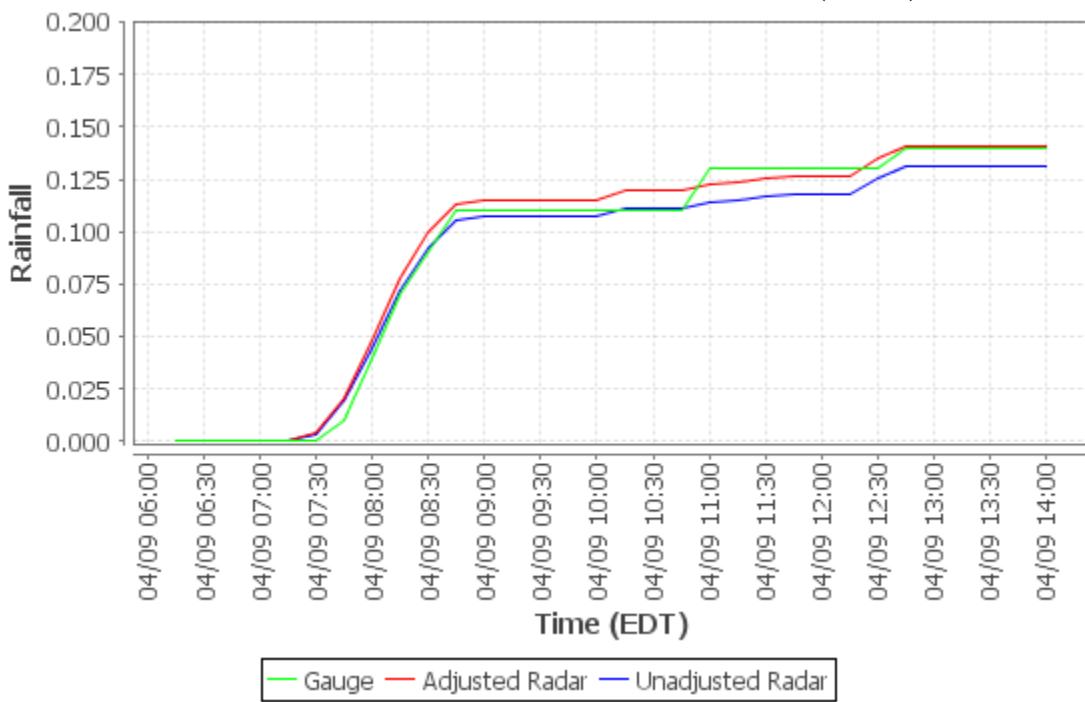
Cumulative Distribution Plot - White Oak Public Works Bldg (Loc25)



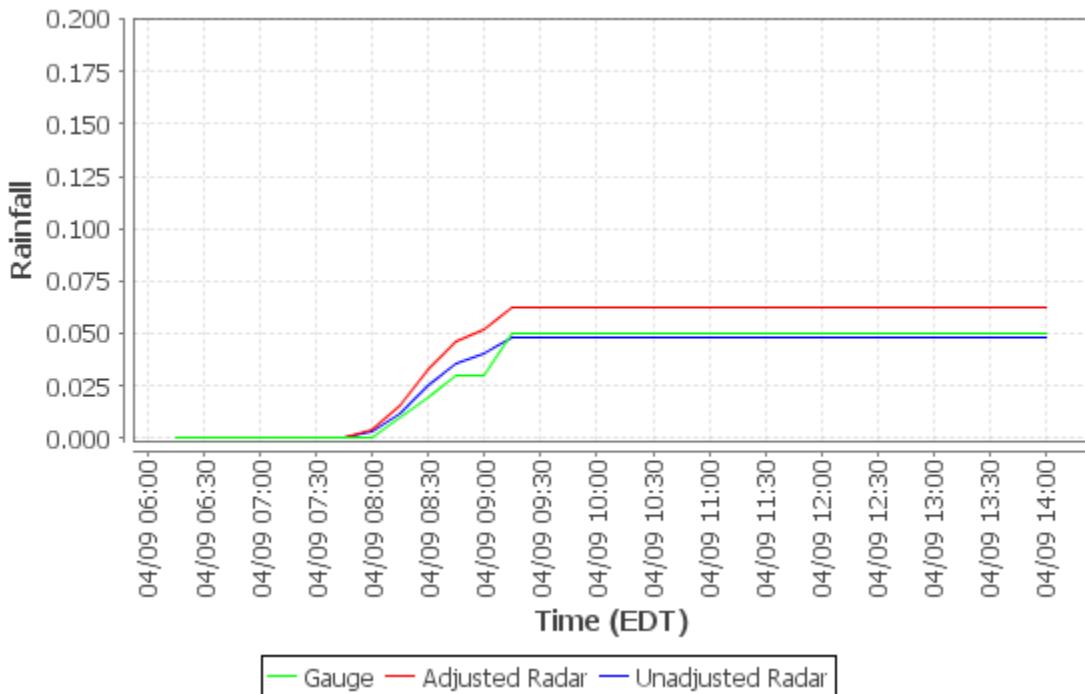
Cumulative Distribution Plot - Elizabeth TWP Municipal Bldg (Loc26)



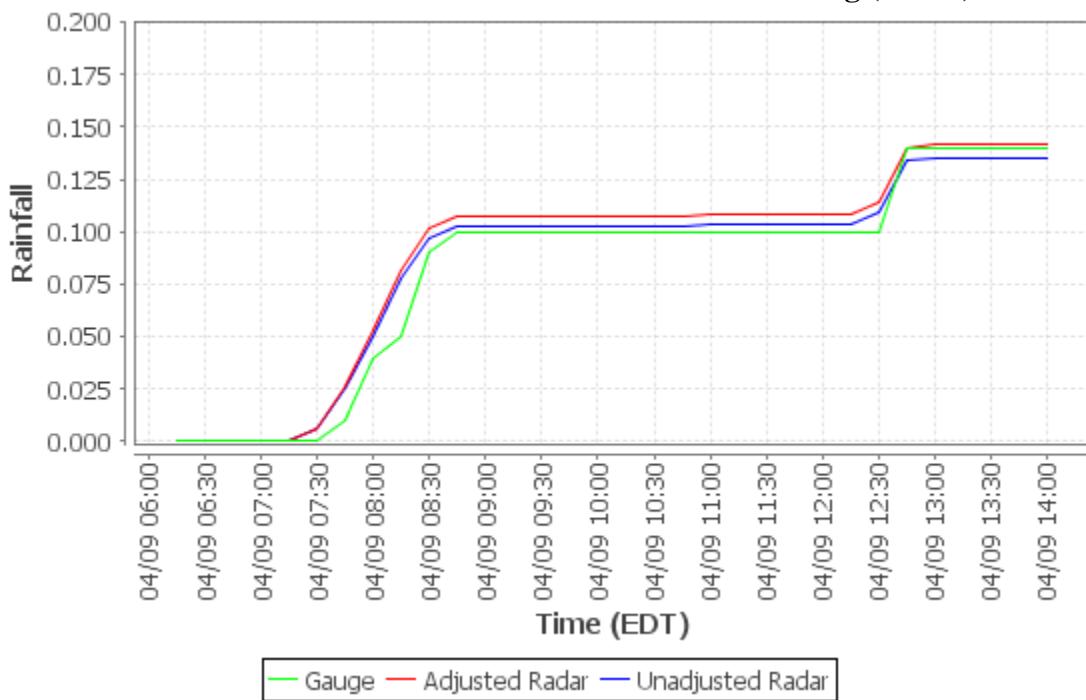
Cumulative Distribution Plot - Marshall TWP (Loc27)



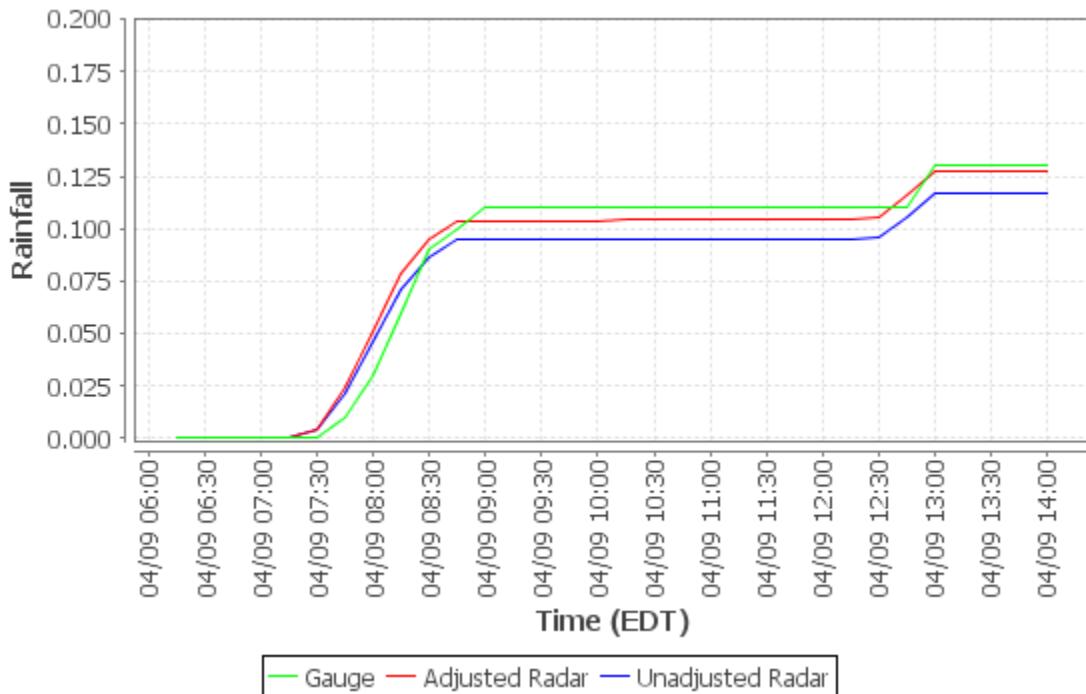
Cumulative Distribution Plot - Plum Municipal Bldg (Loc28)



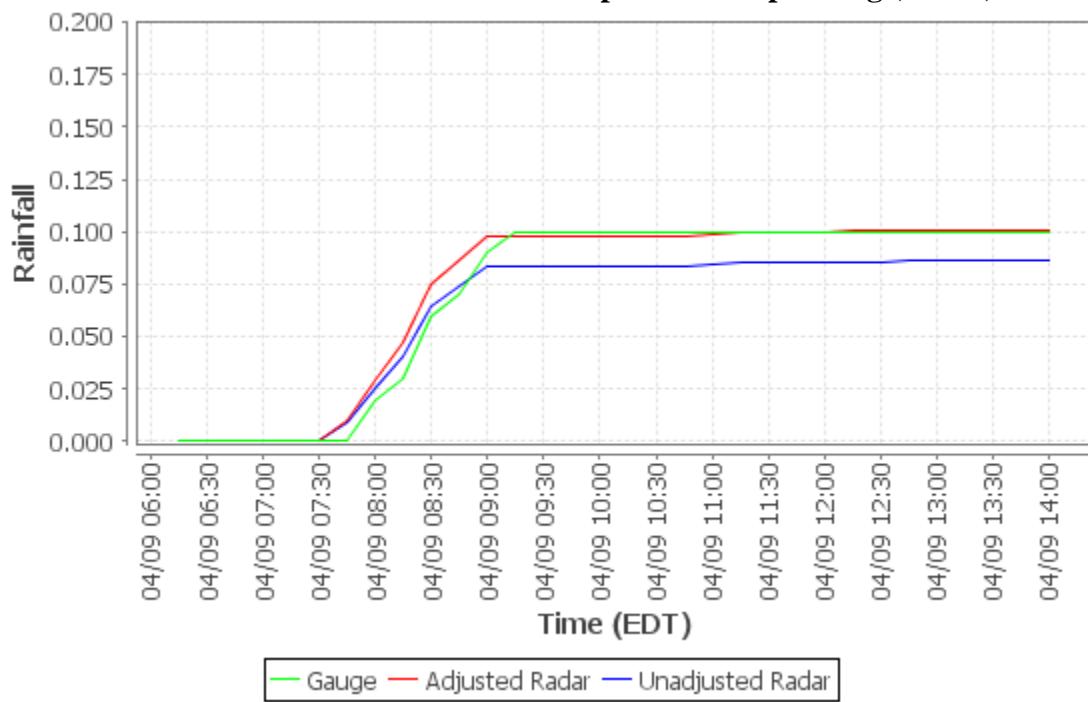
Cumulative Distribution Plot - Bell Acres Munic Bldg (Loc29)



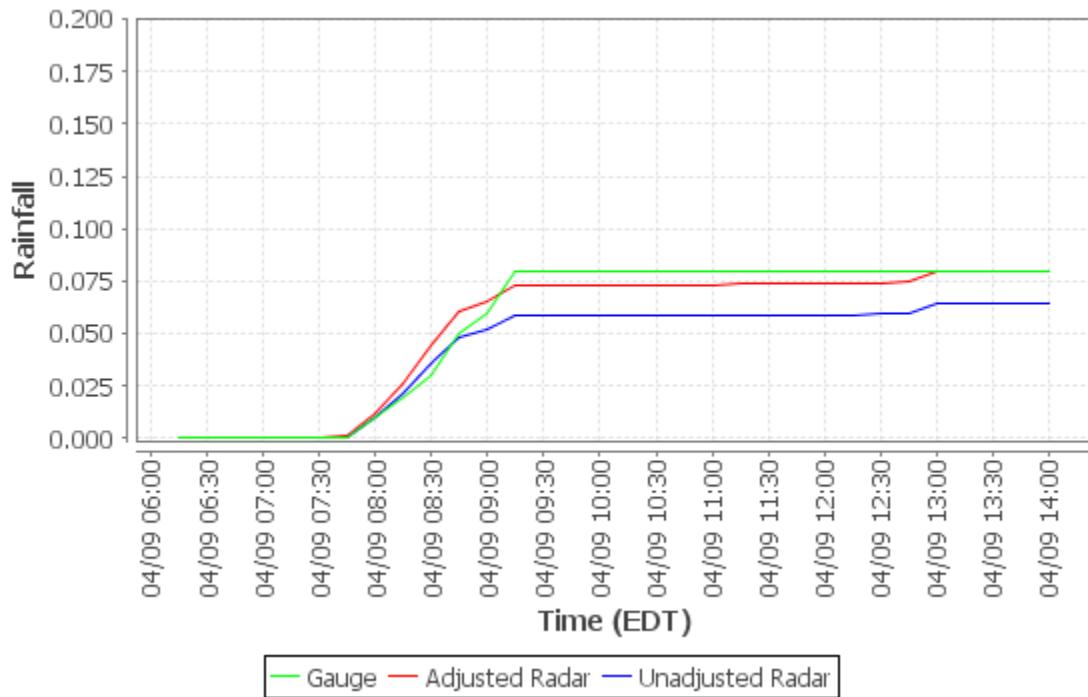
Cumulative Distribution Plot - McCandless Twn Hall (Loc30)



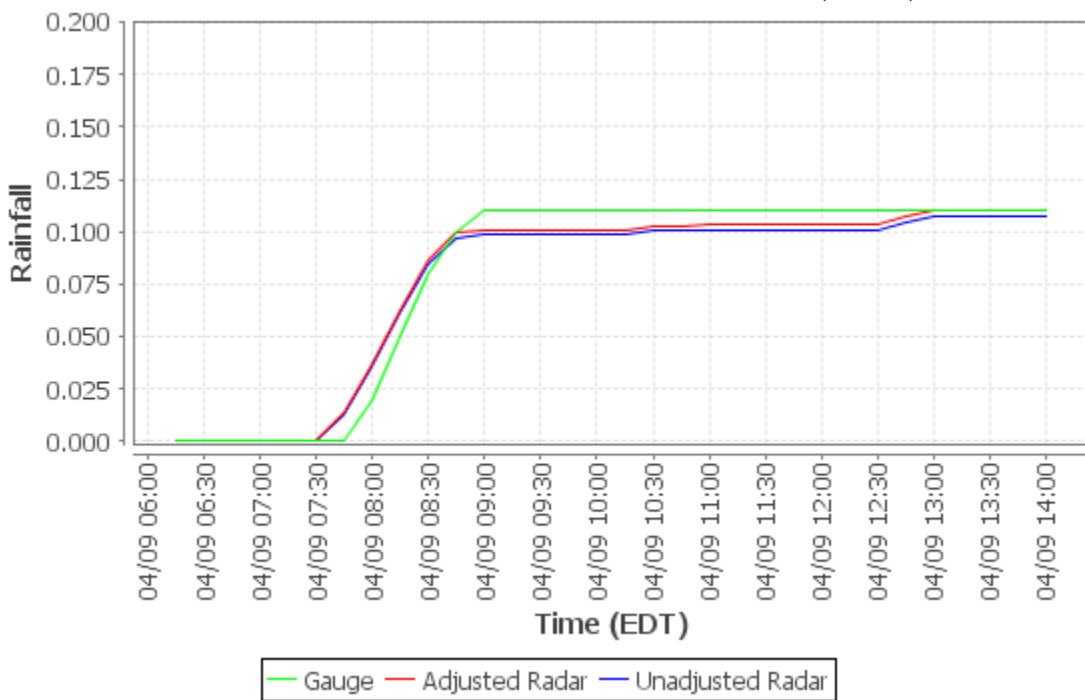
Cumulative Distribution Plot - Hampton Municipal Bldg (Loc31)



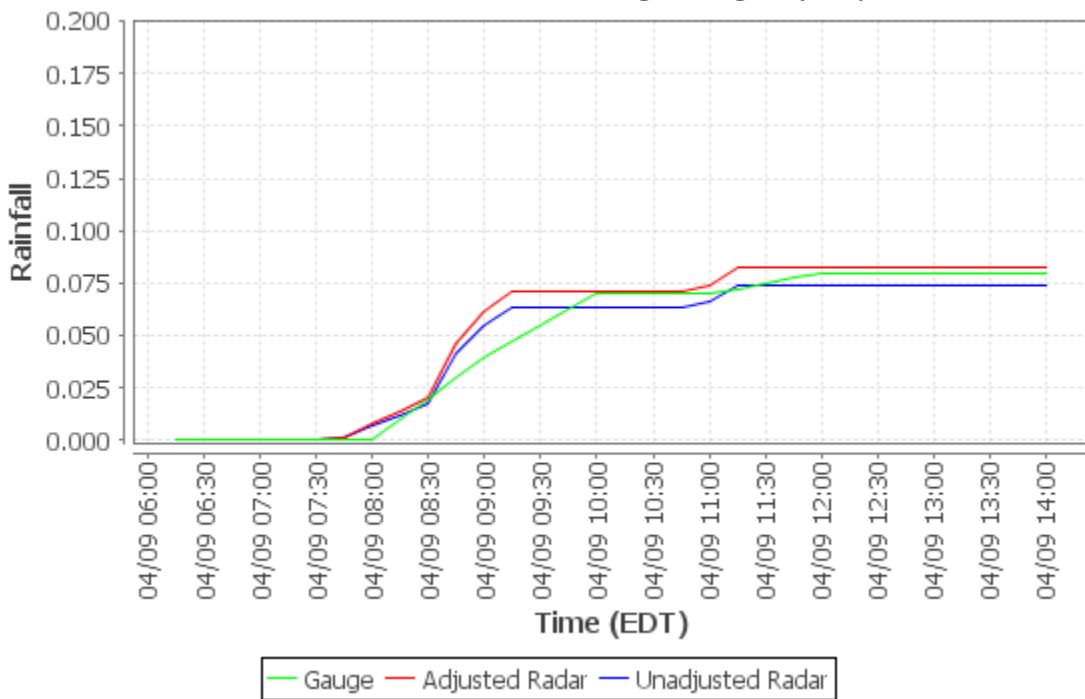
Cumulative Distribution Plot - Arnold (Loc32)



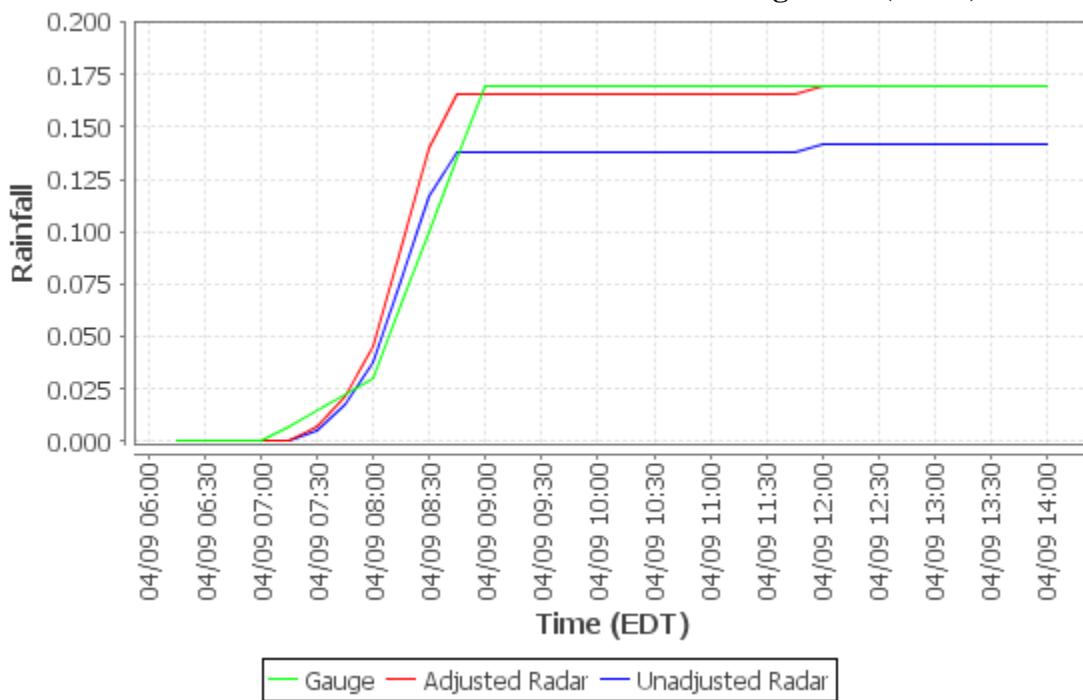
Cumulative Distribution Plot - Richland TWP (Loc33)



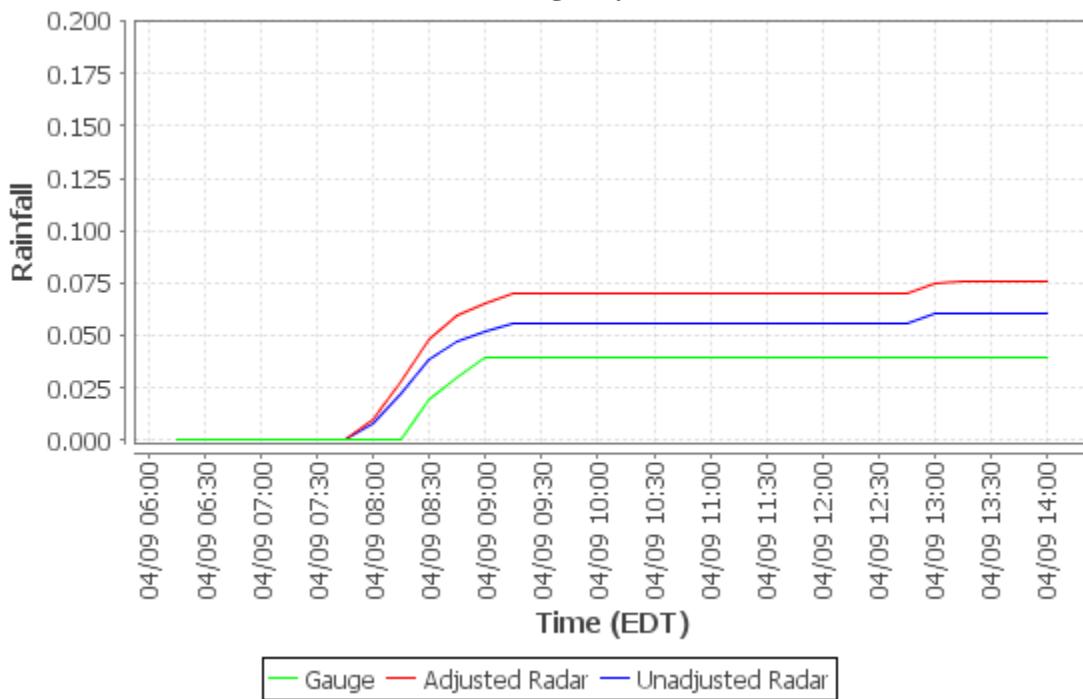
Cumulative Distribution Plot - Pittsburgh Allegheny Cty (KAGC)



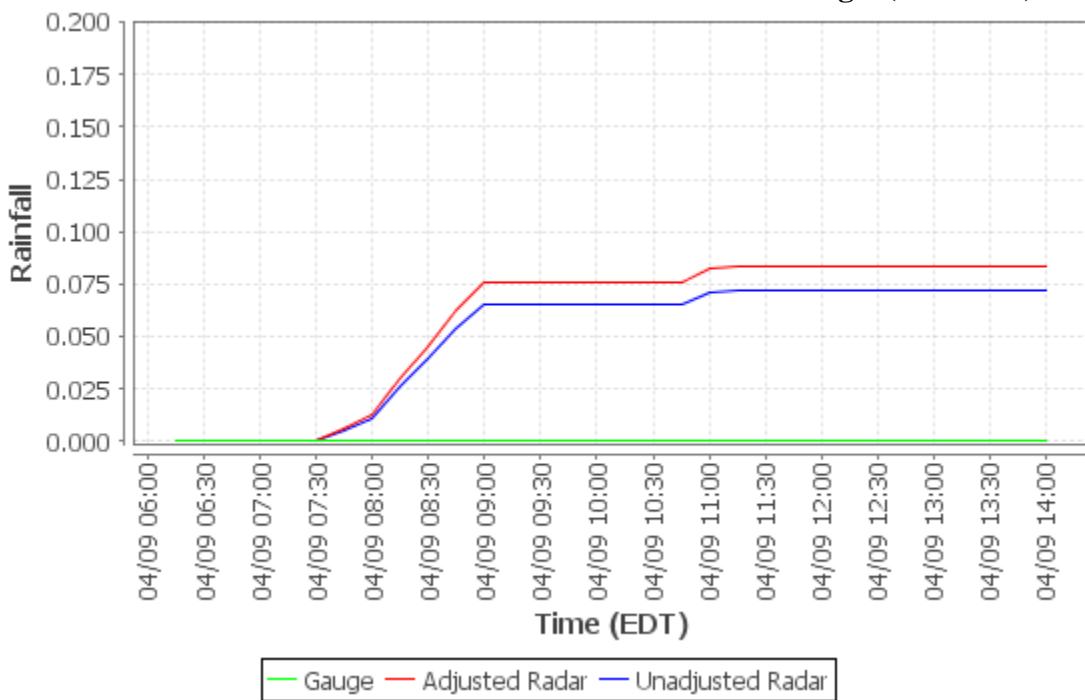
Cumulative Distribution Plot - Greater Pittsburgh Int'l (KPIT)



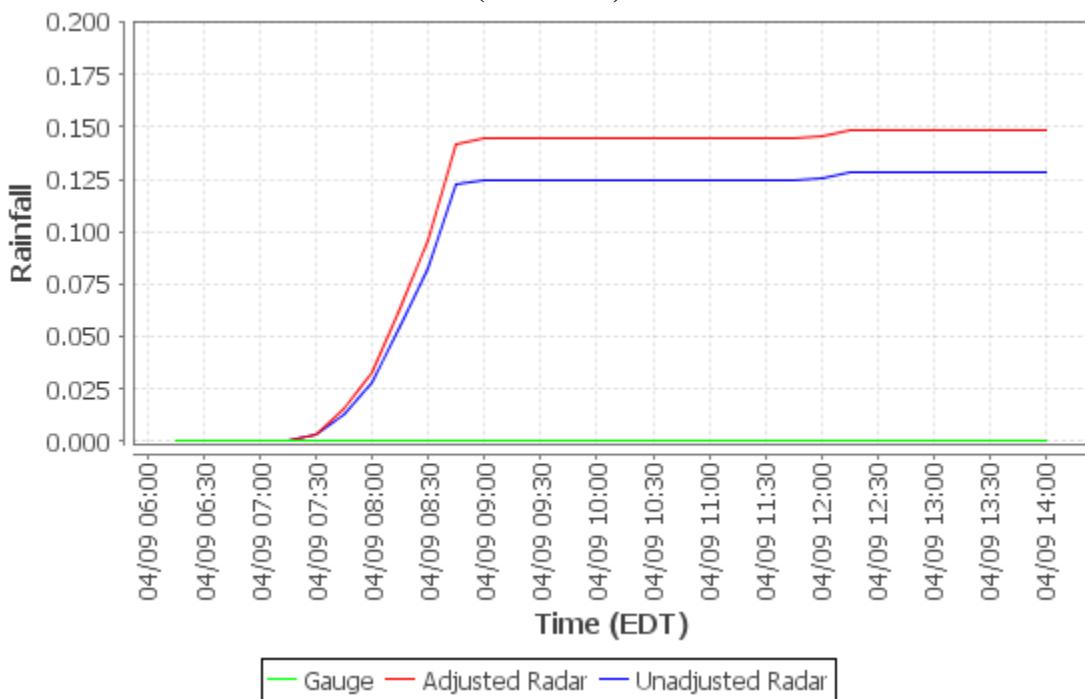
Cumulative Distribution Plot - Allegheny River at Natrona (03049500)



Cumulative Distribution Plot - Chartiers Creek at Carnegie (03085500)

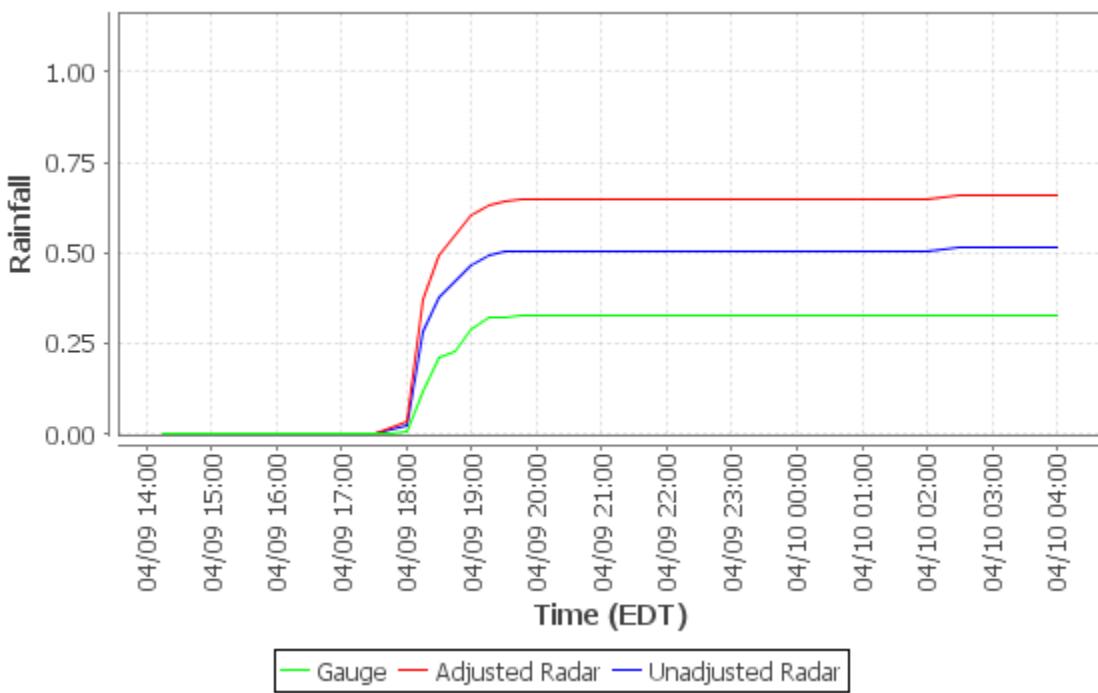


Cumulative Distribution Plot - Ohio River at Emsworth Dam Lower Pool at Emsworth (03085734)

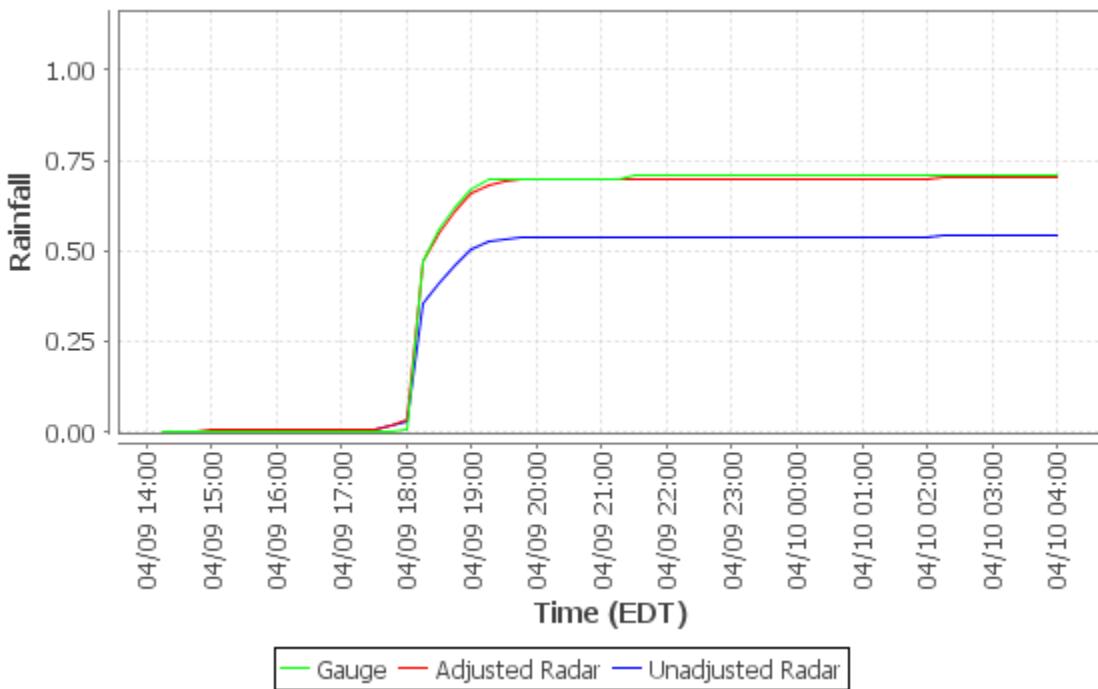


Appendix H - Event 7 (2015-04-09 PM) CDPs

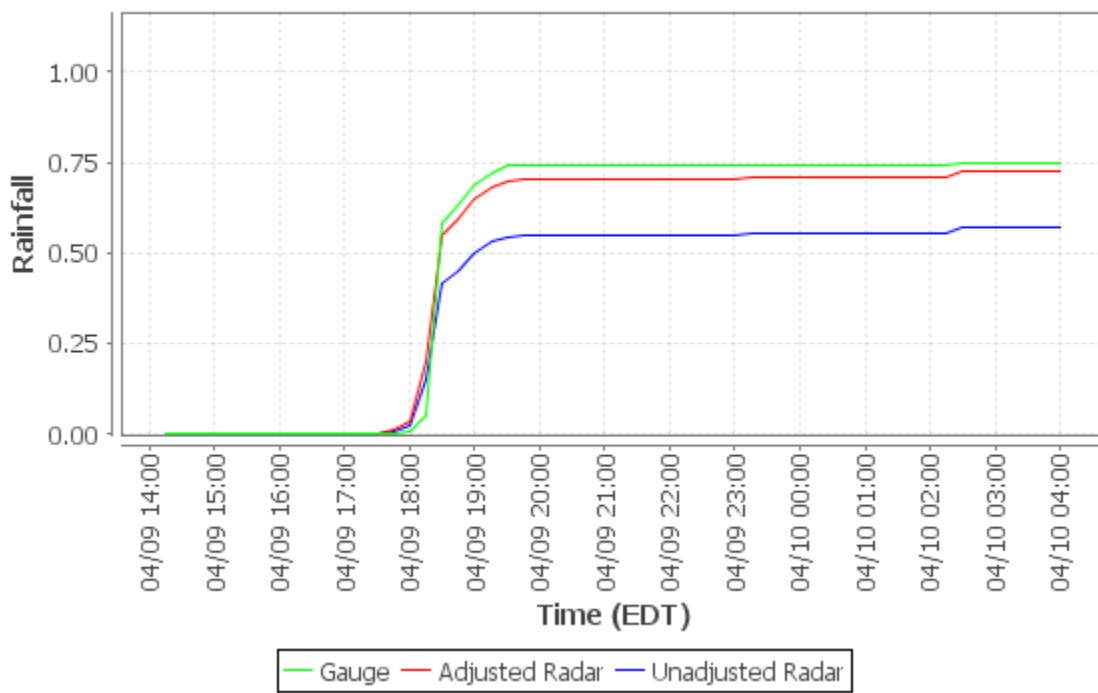
Cumulative Distribution Plot - PWSA-Montana St. (Loc01)



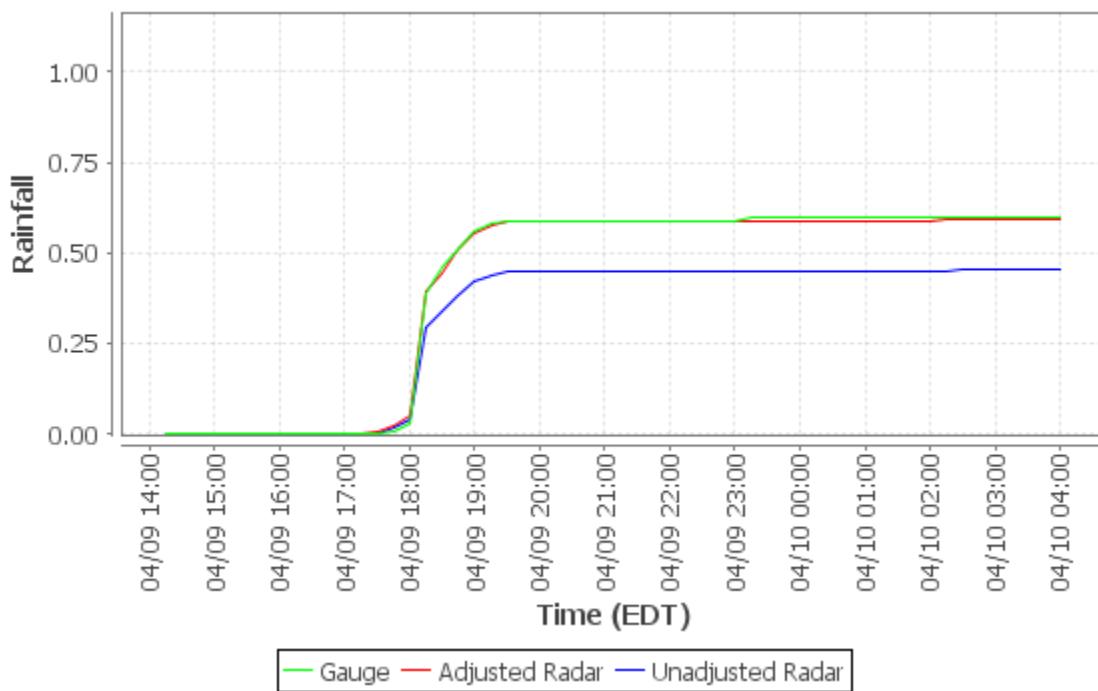
Cumulative Distribution Plot - ALCOSAN WWTP Lab (Loc02)



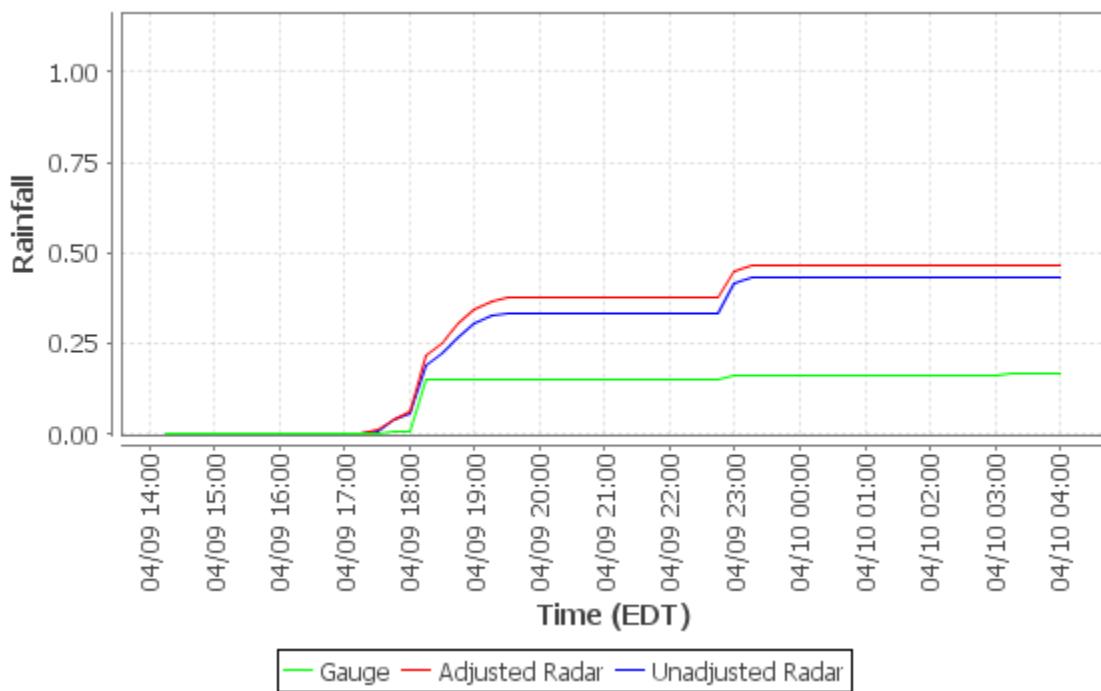
Cumulative Distribution Plot - Shaler Munic Bldg (Loc03)



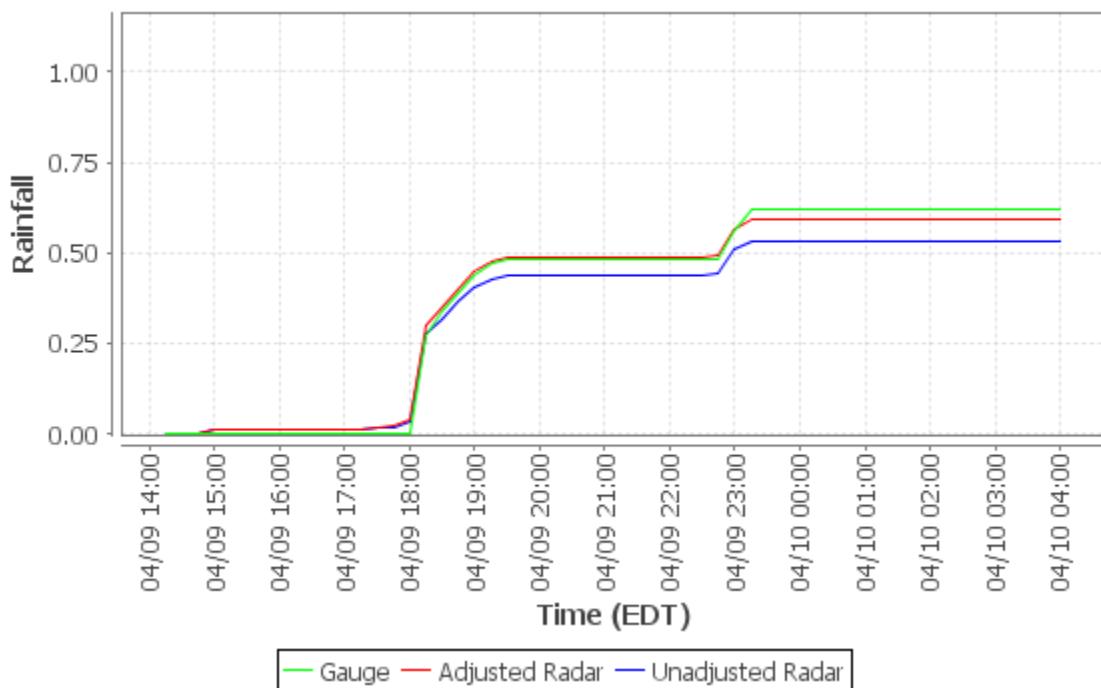
Cumulative Distribution Plot - Kennedy Twp PS (Loc04)



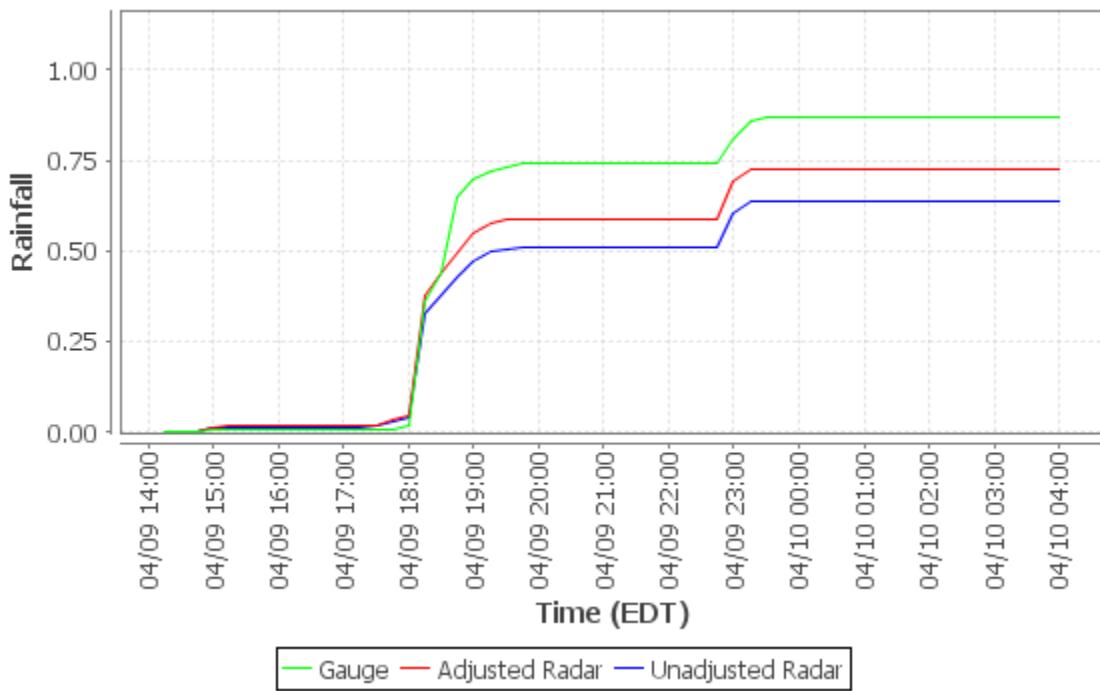
Cumulative Distribution Plot - Upper St. Clair (Loc05)



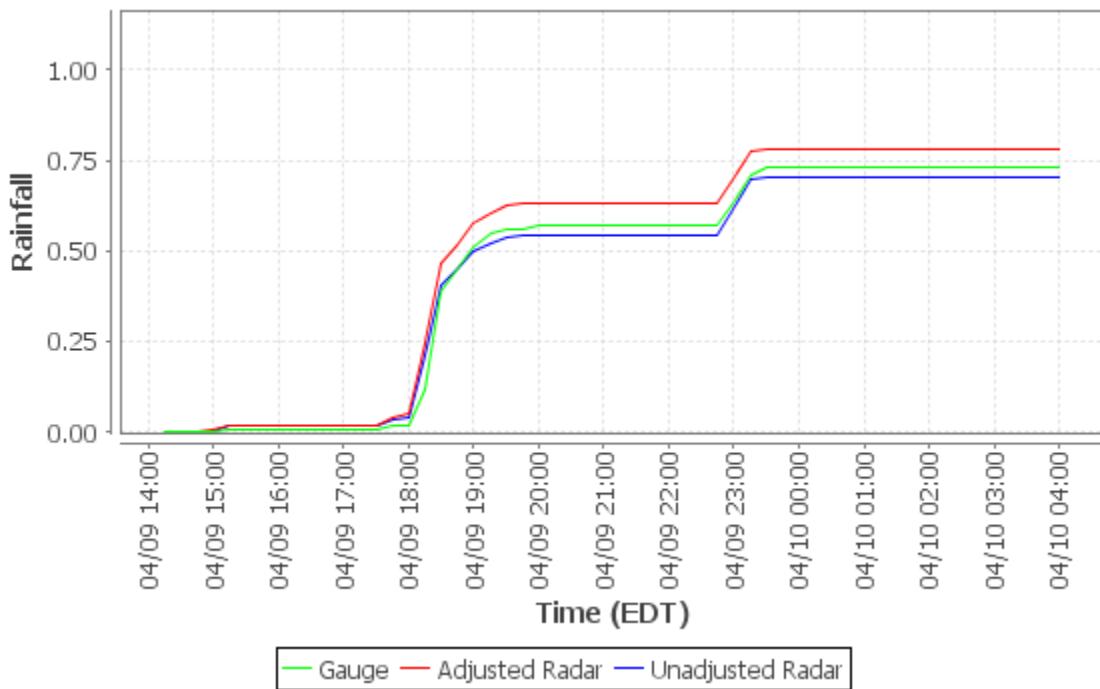
Cumulative Distribution Plot - Carnegie Transit Time (Loc06)



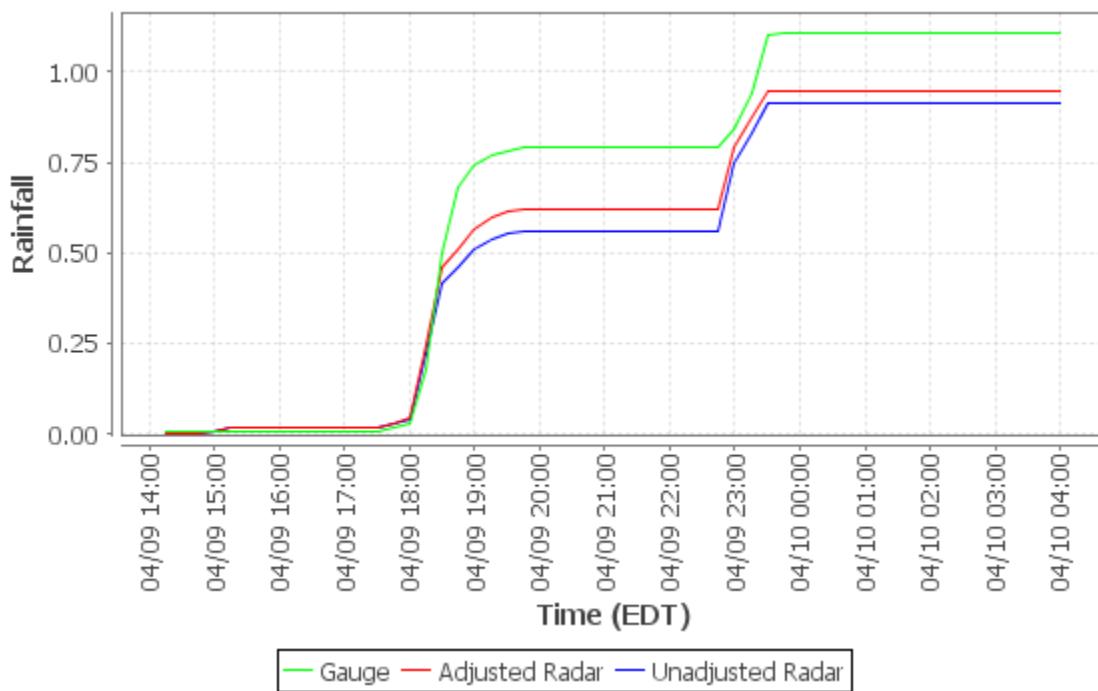
Cumulative Distribution Plot - Greentree Munic Bldg (Loc07)



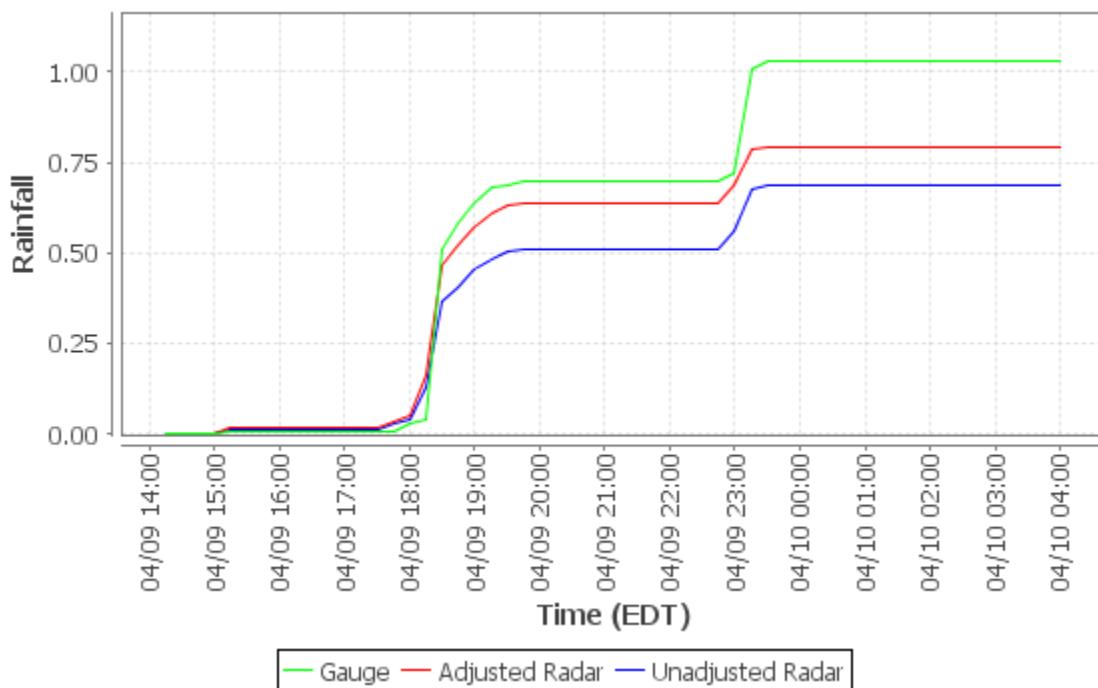
Cumulative Distribution Plot - AC Health Dept Bldg (Loc08)



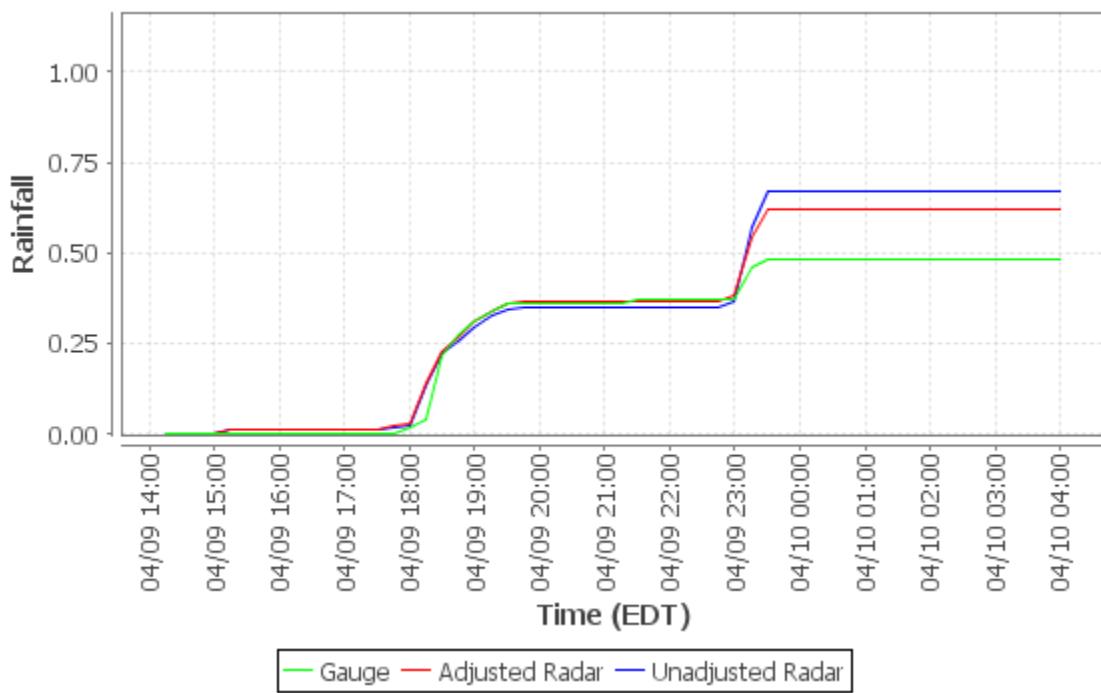
Cumulative Distribution Plot - Univ of Pittsburgh (Loc09)



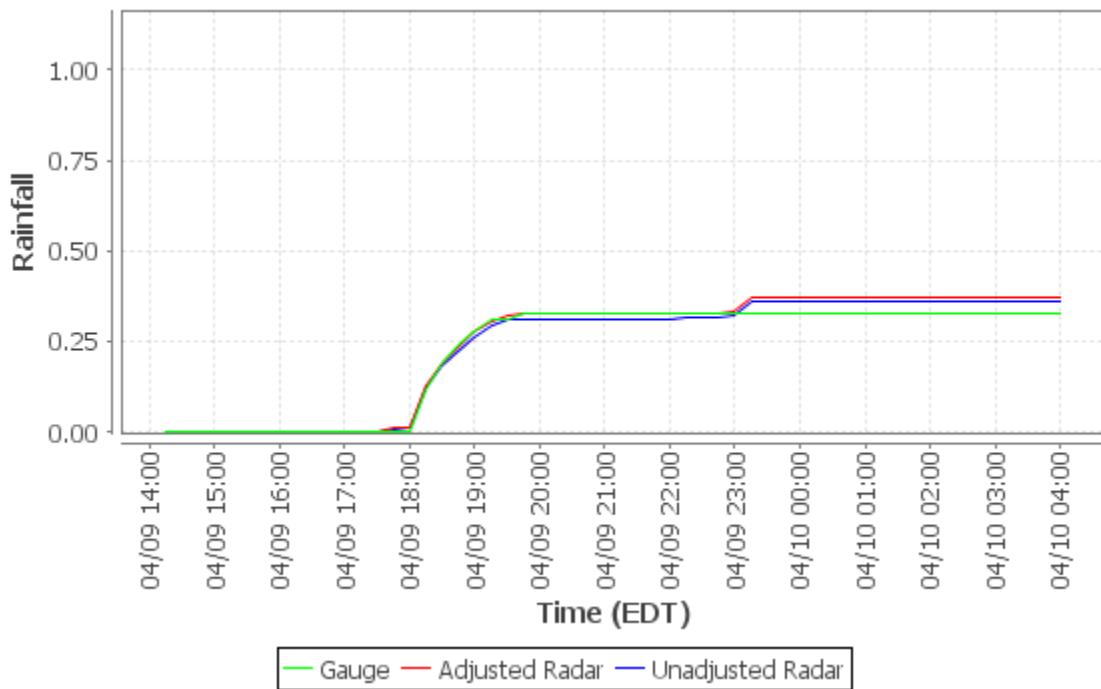
Cumulative Distribution Plot - PWSA-Highland Park (Loc10)



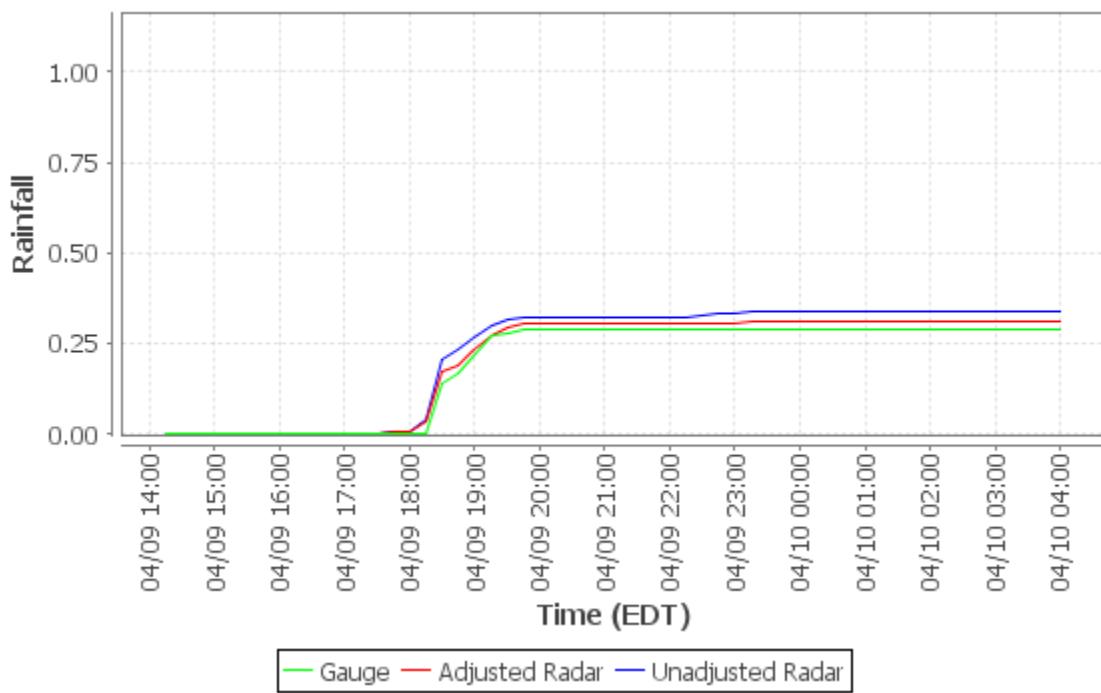
Cumulative Distribution Plot - M-46 Access Shaft (Loc11)



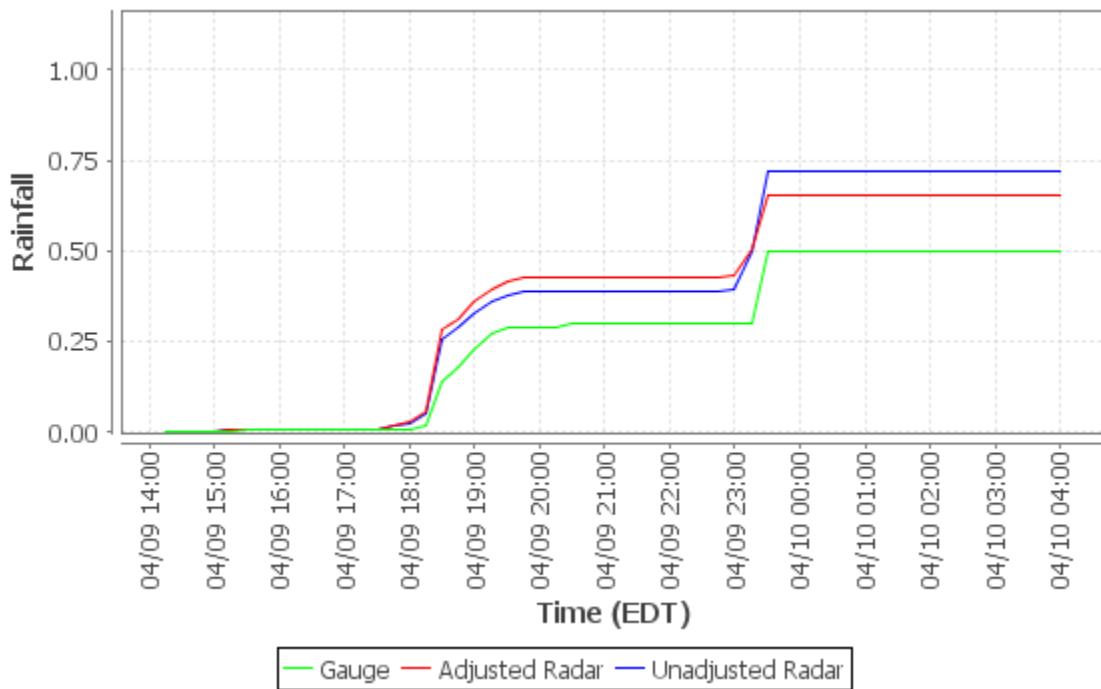
Cumulative Distribution Plot - Baldwin (Loc12)



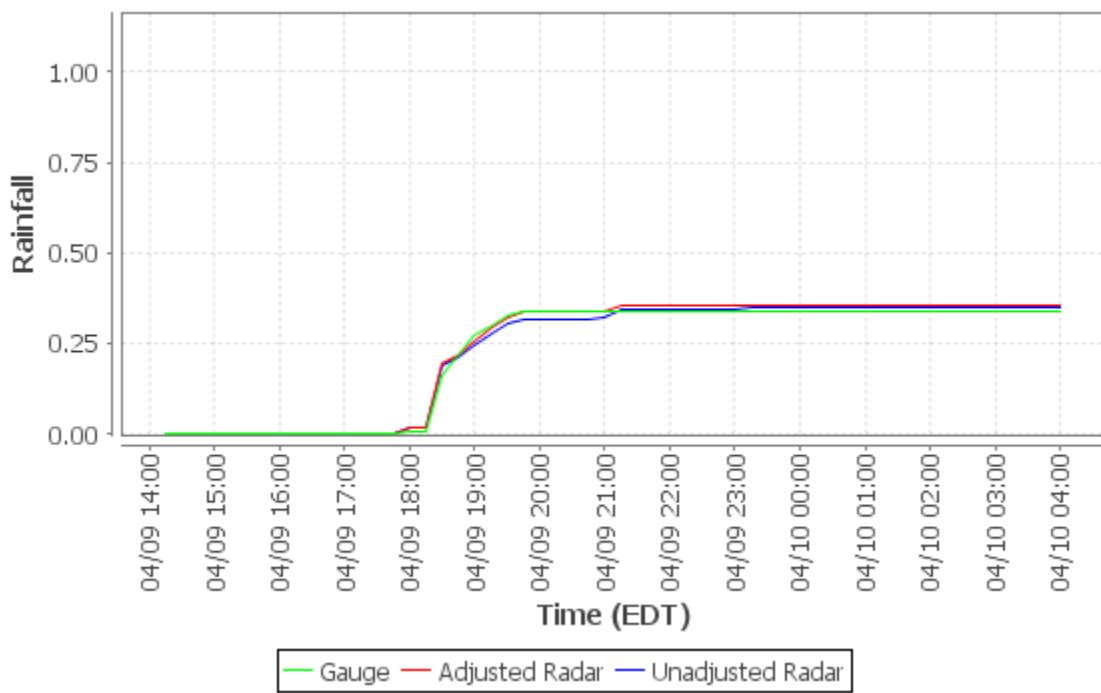
Cumulative Distribution Plot - M-59 Access Shaft (Loc13)



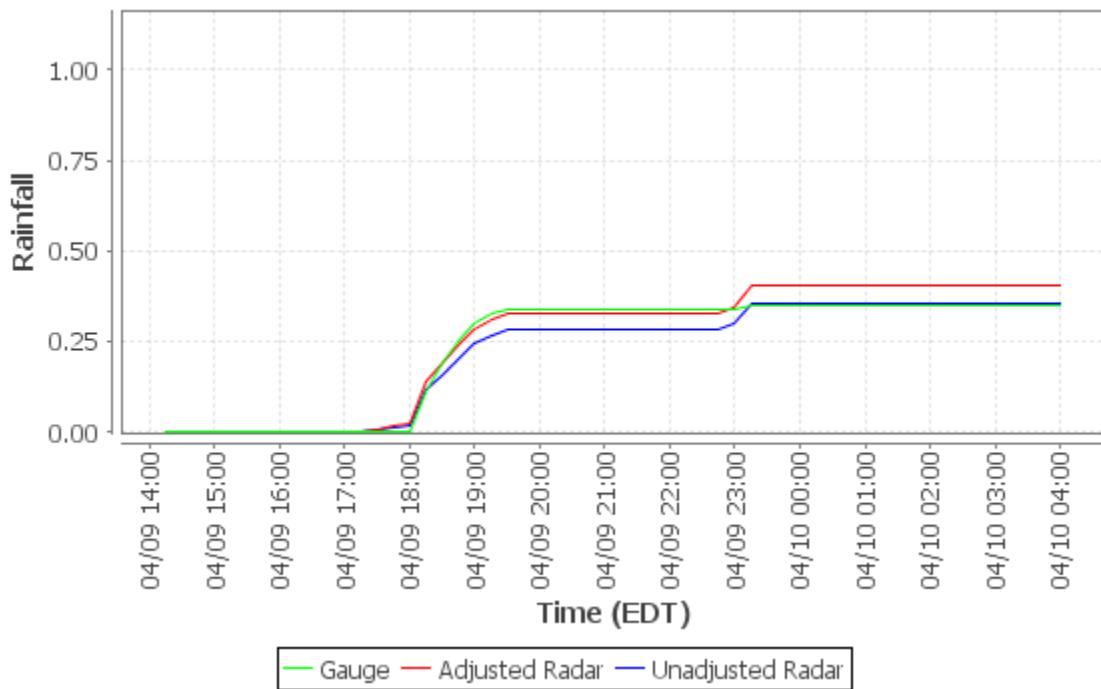
Cumulative Distribution Plot - Churchill Munic Bldg (Loc14)



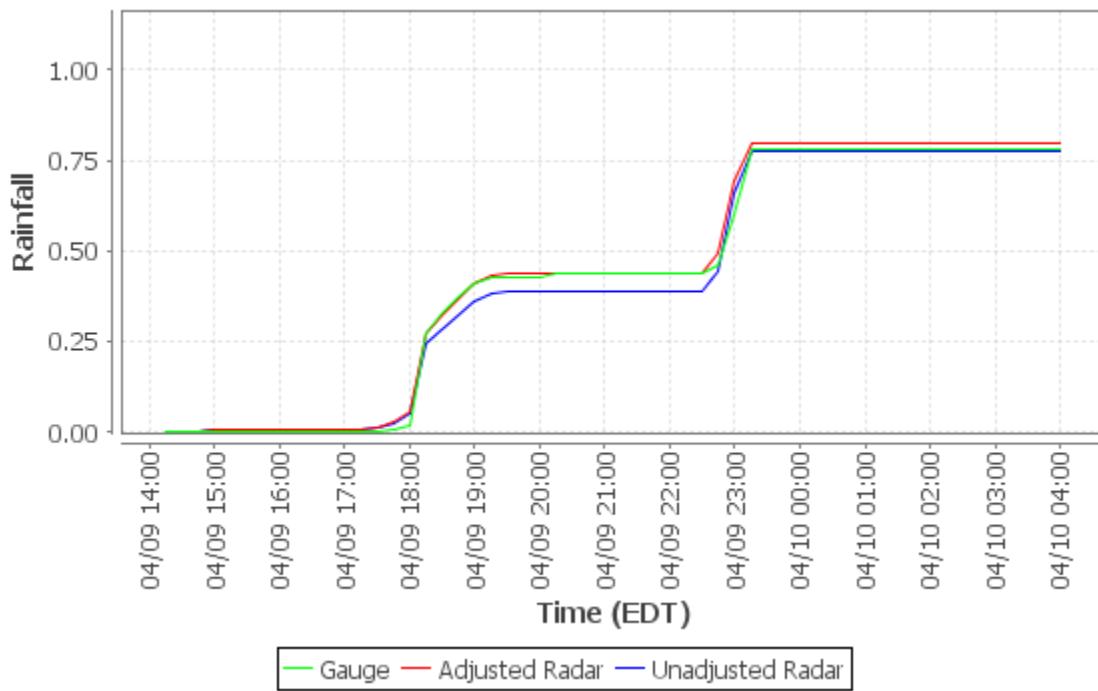
Cumulative Distribution Plot - Trafford Maint Bldg (Loc15)



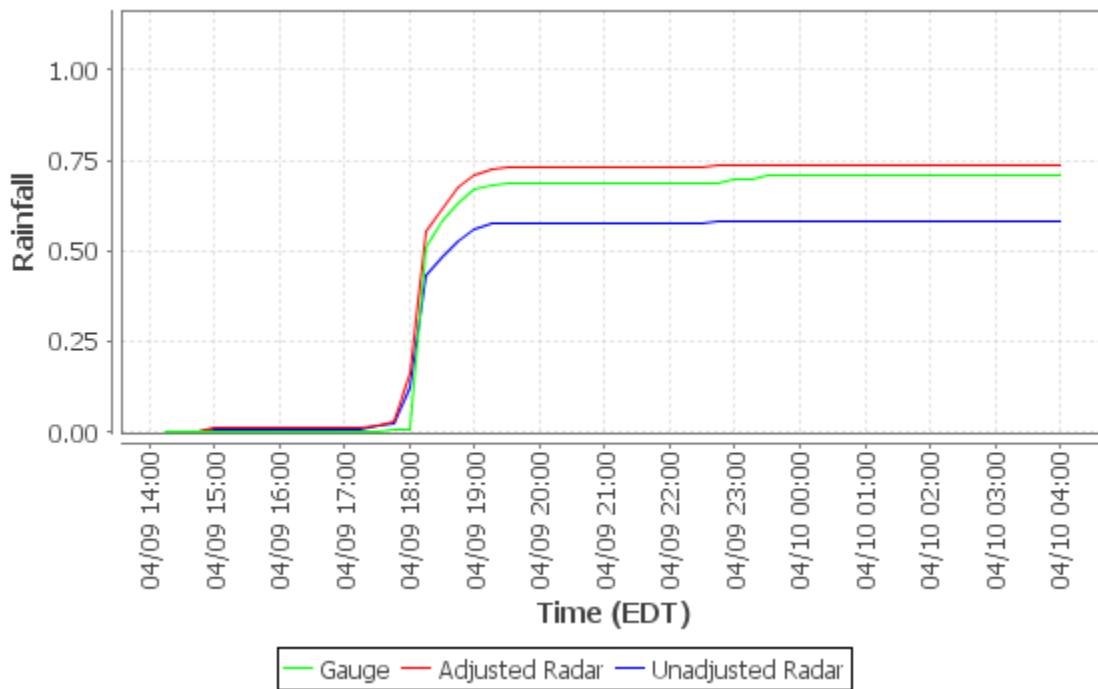
Cumulative Distribution Plot - Castle Shannon (Loc16)



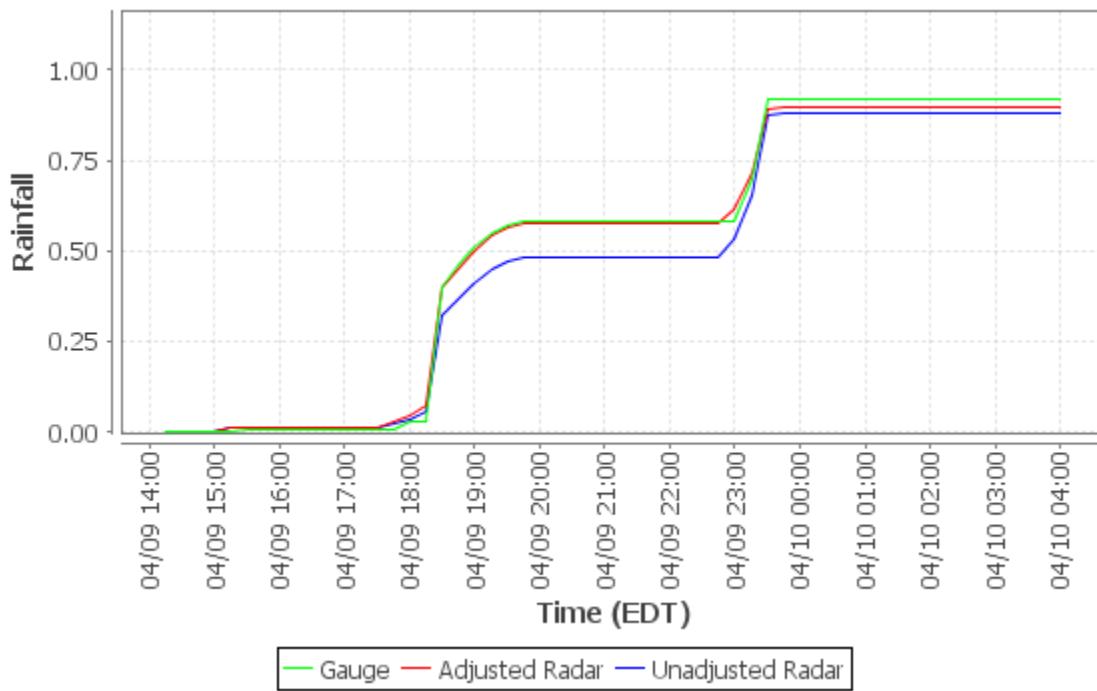
Cumulative Distribution Plot - Chartiers Pump Station (Loc17)



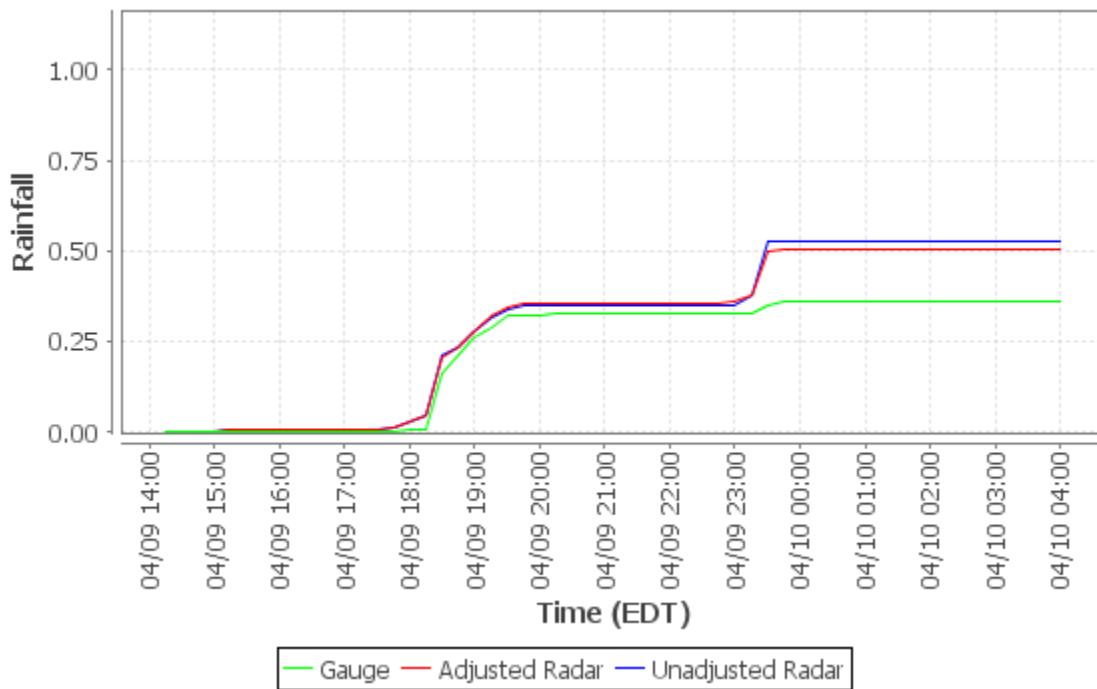
Cumulative Distribution Plot - Oakdale Pump Station (Loc18)



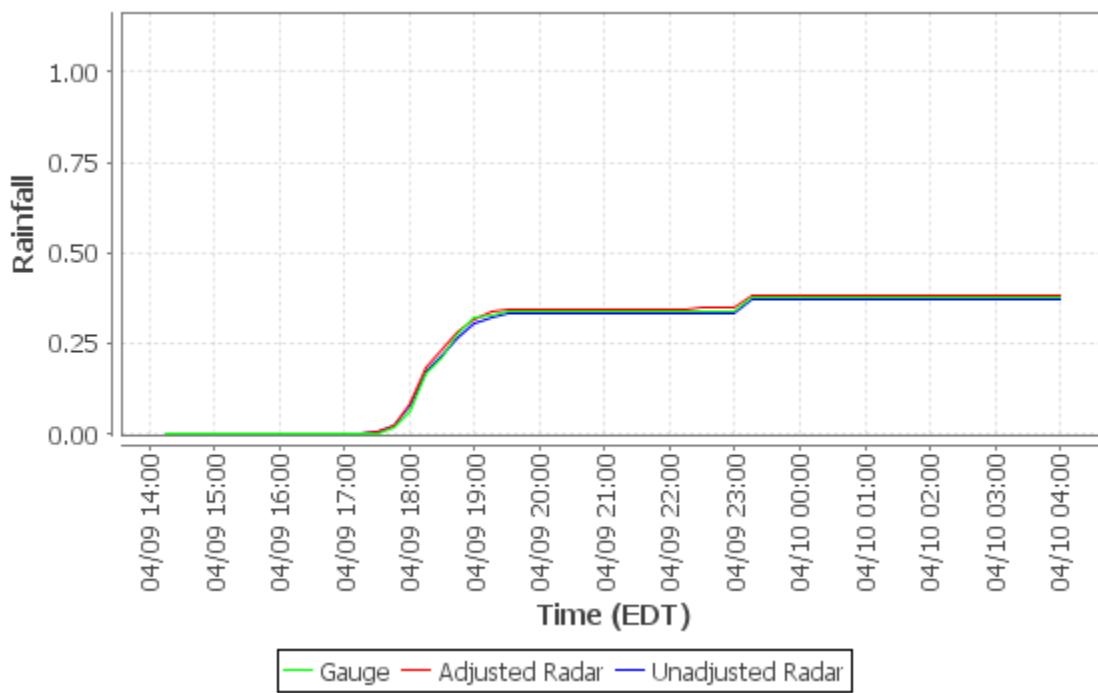
Cumulative Distribution Plot - Sandy Creek Eq Facility (Loc19)



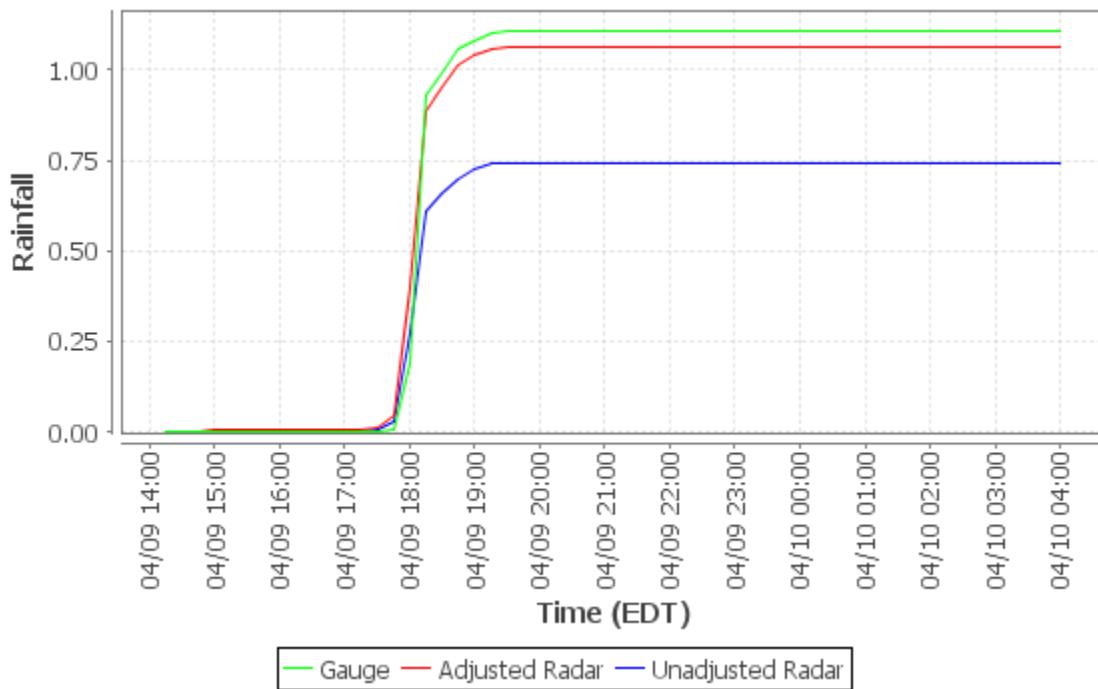
Cumulative Distribution Plot - Gascola Eq Facility (Loc20)



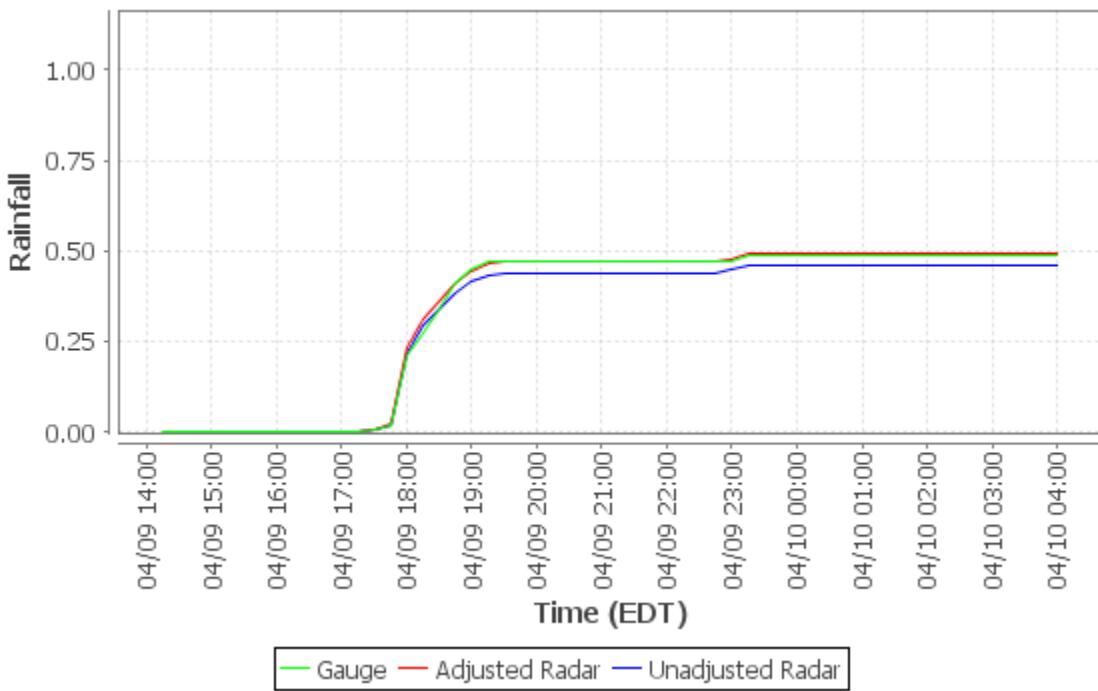
Cumulative Distribution Plot - Moon TWP (Loc21)



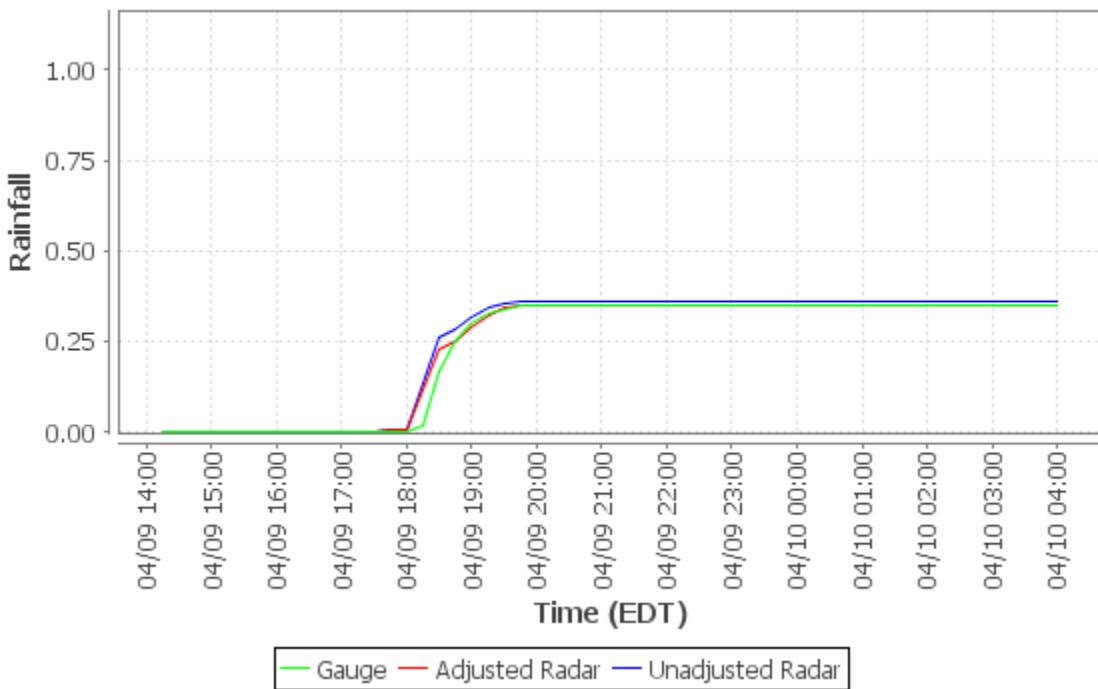
Cumulative Distribution Plot - North Fayette TWP (Loc22)



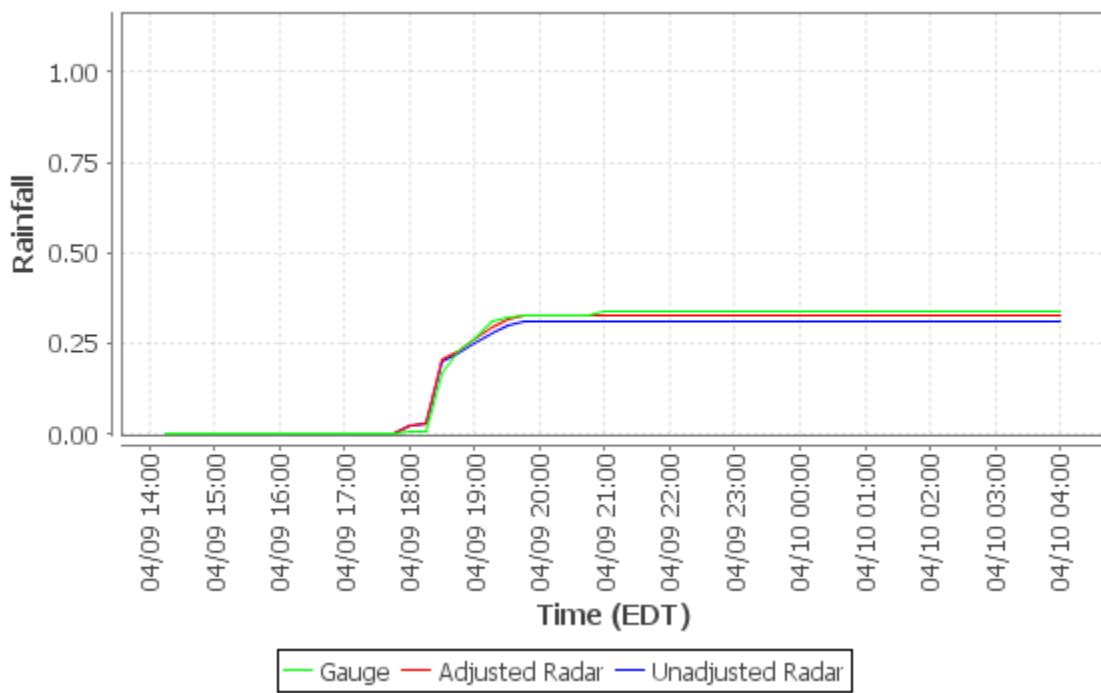
Cumulative Distribution Plot - Clinton Munic Bldg (Loc23)



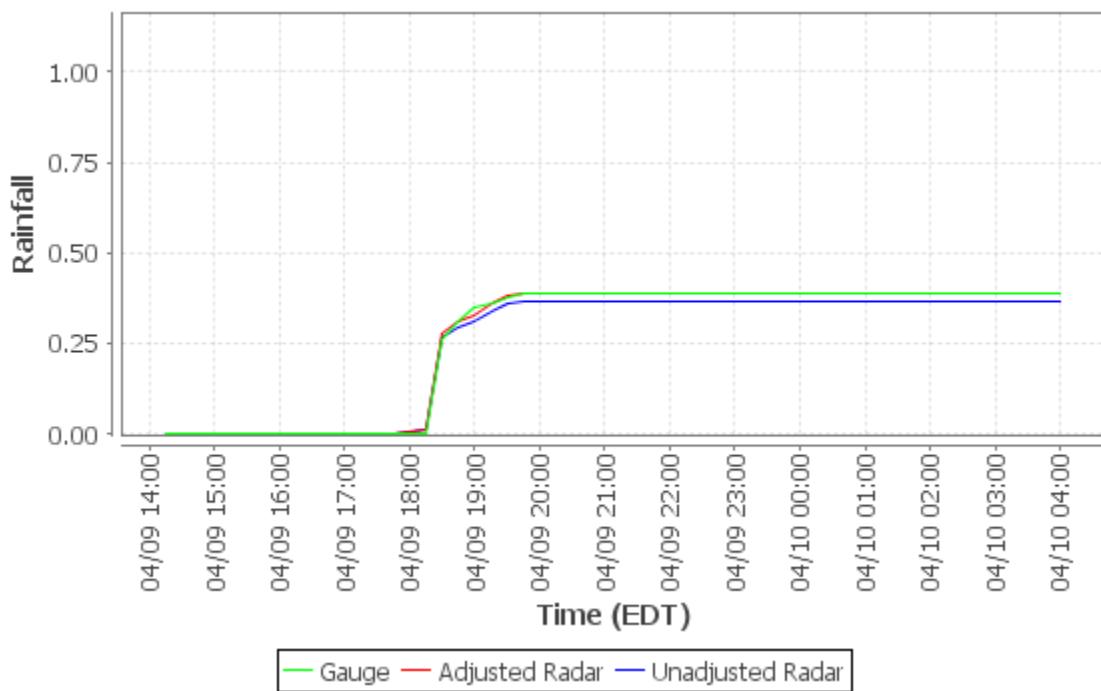
Cumulative Distribution Plot - Jefferson Hills (Loc24)



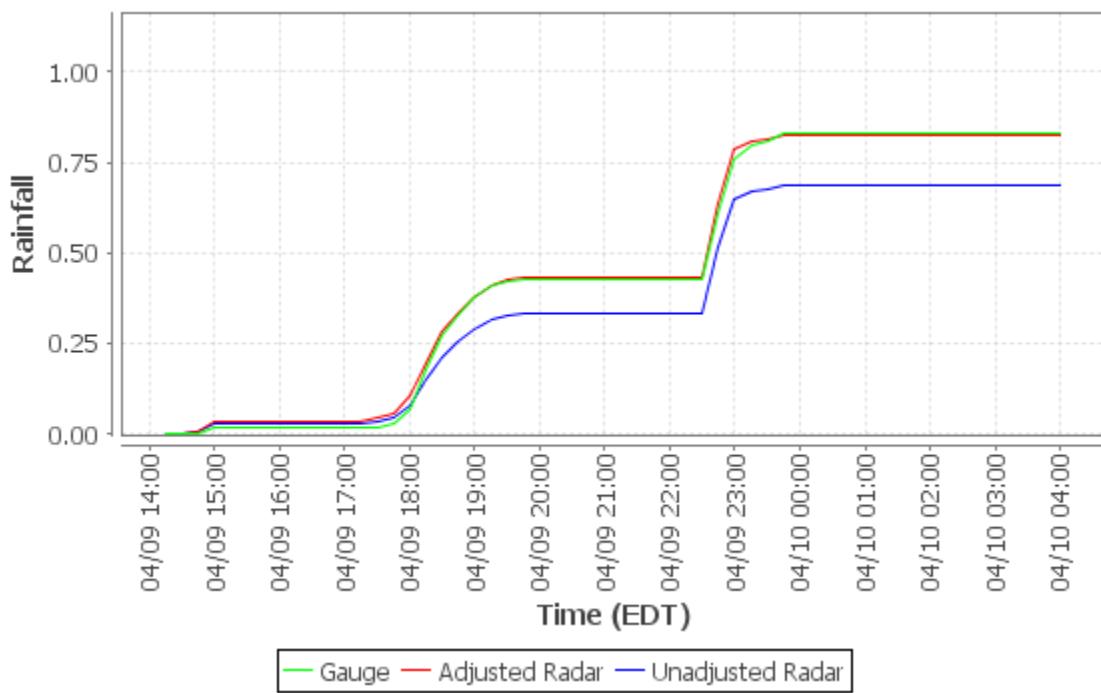
Cumulative Distribution Plot - White Oak Public Works Bldg (Loc25)



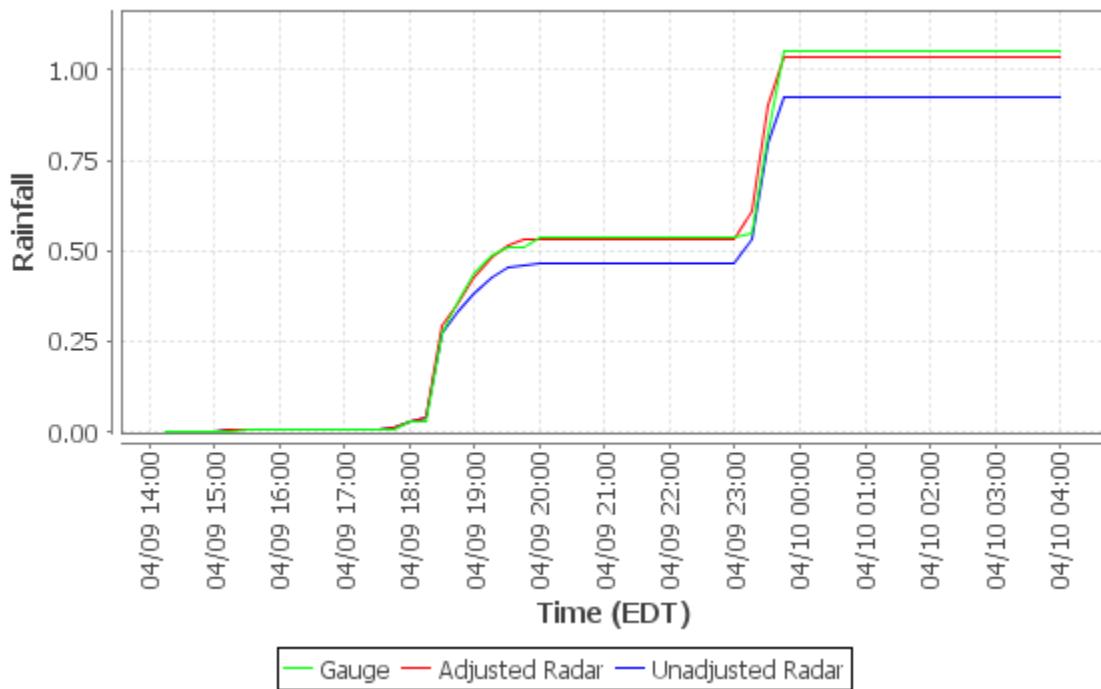
Cumulative Distribution Plot - Elizabeth TWP Municipal Bldg (Loc26)



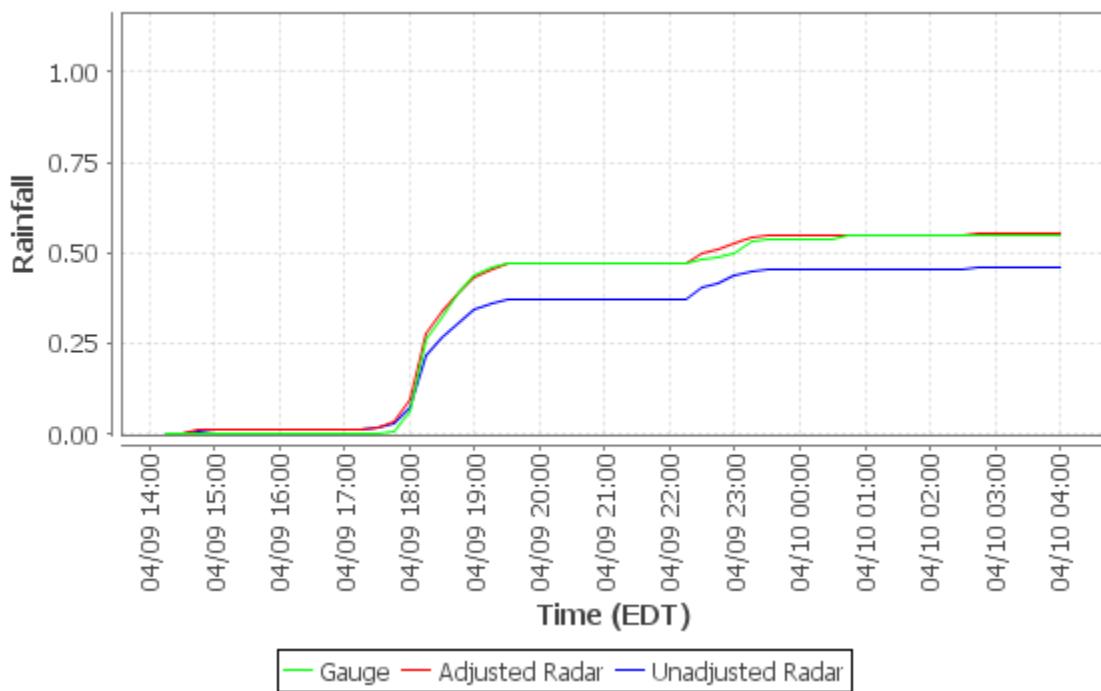
Cumulative Distribution Plot - Marshall TWP (Loc27)



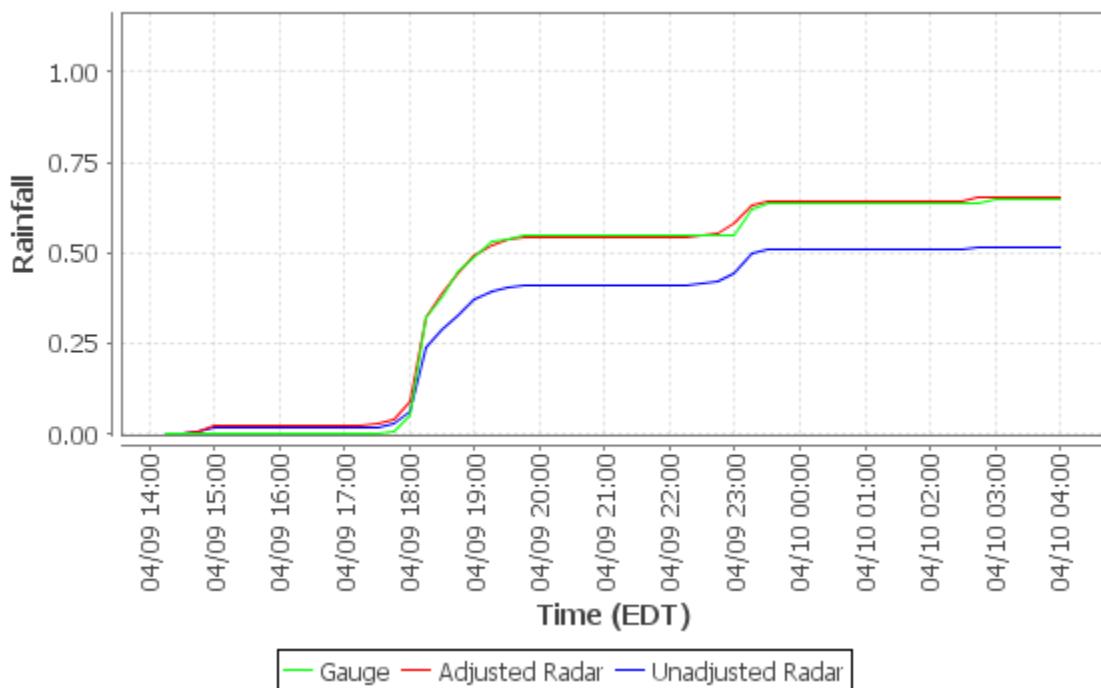
Cumulative Distribution Plot - Plum Municipal Bldg (Loc28)



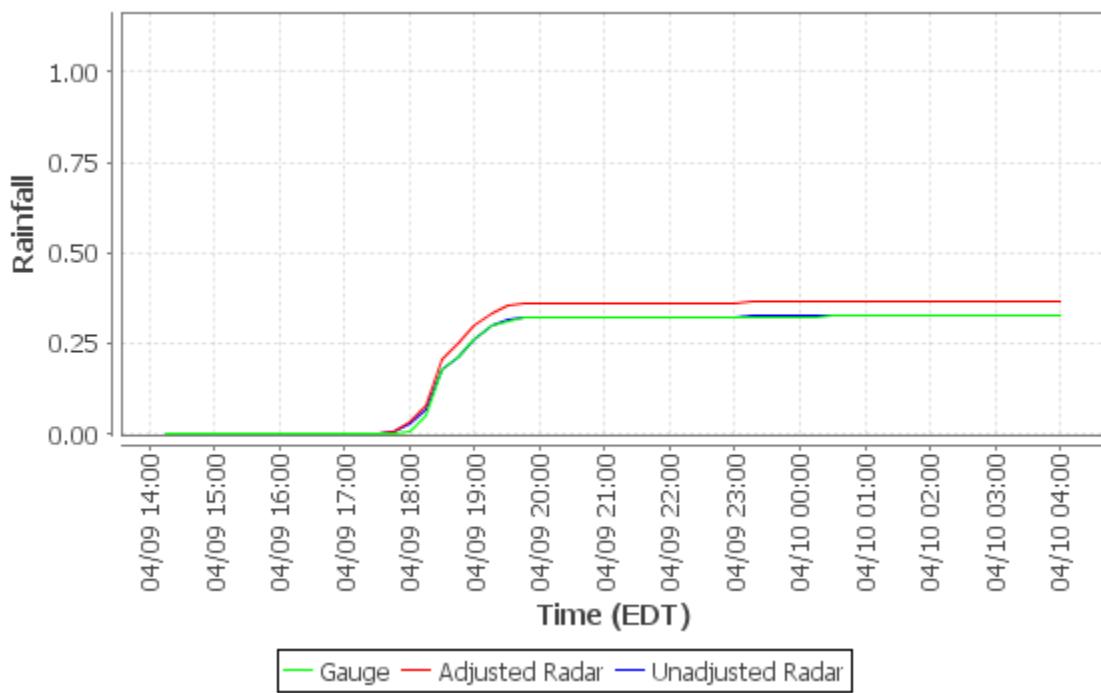
Cumulative Distribution Plot - Bell Acres Munic Bldg (Loc29)



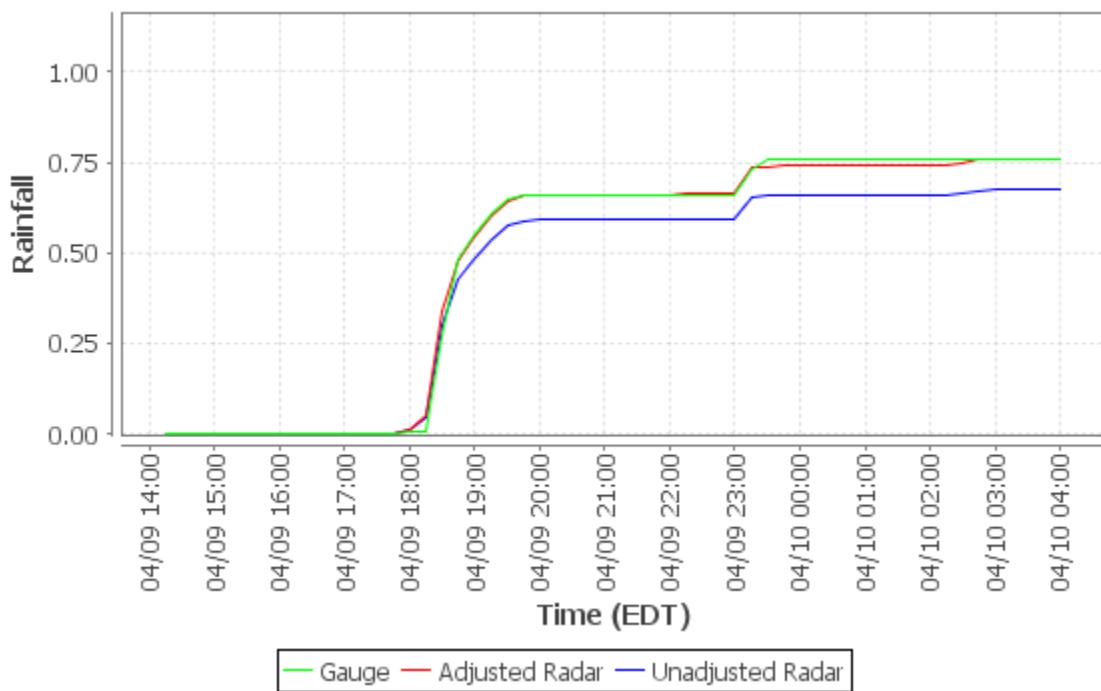
Cumulative Distribution Plot - McCandless Twn Hall (Loc30)



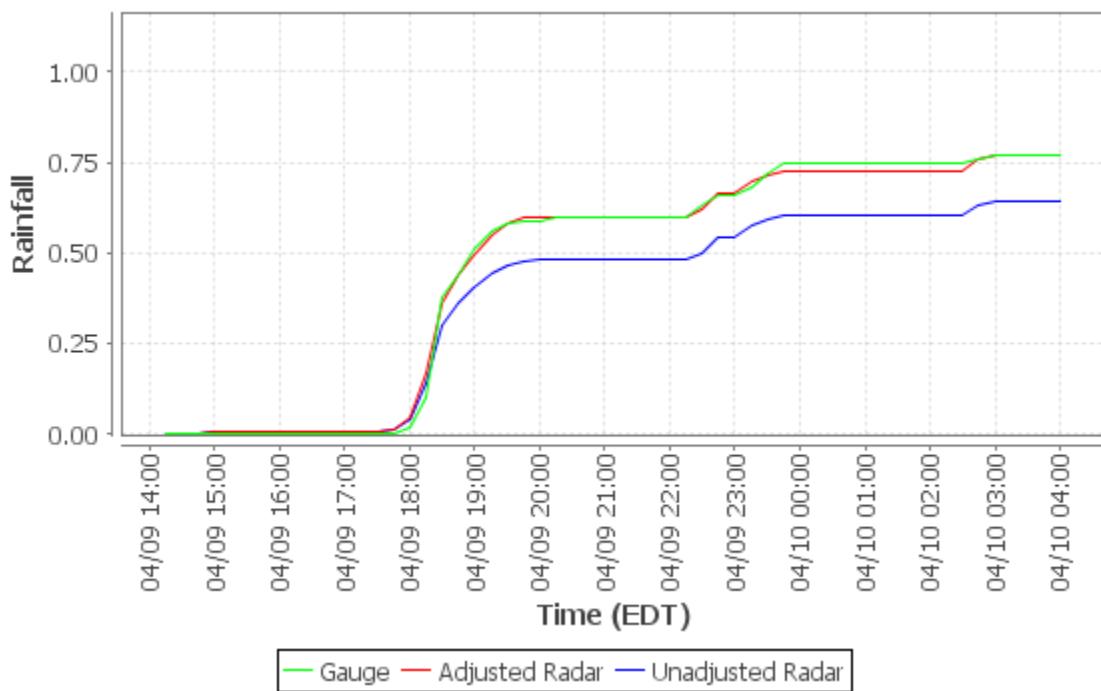
Cumulative Distribution Plot - Hampton Municipal Bldg (Loc31)



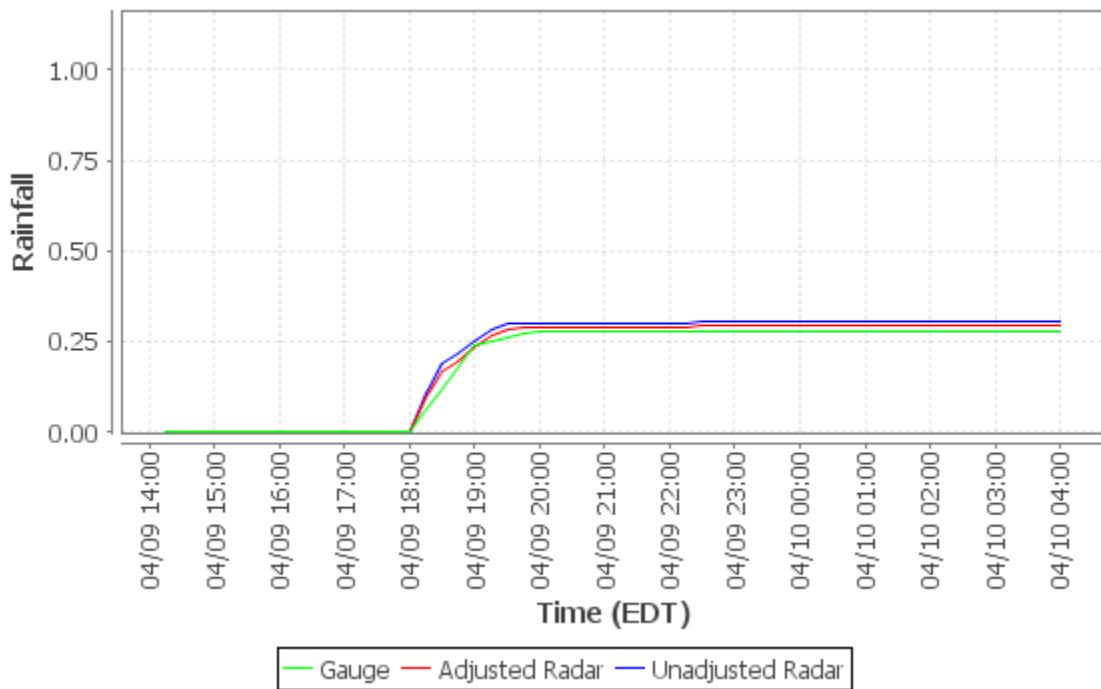
Cumulative Distribution Plot - Arnold (Loc32)



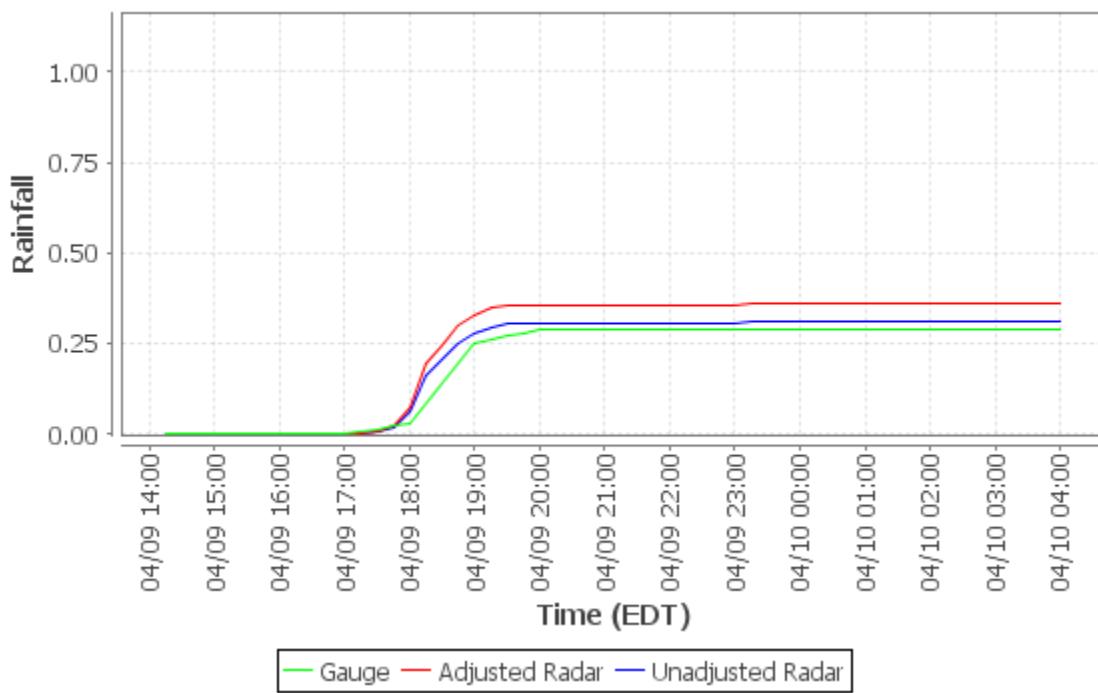
Cumulative Distribution Plot - Richland TWP (Loc33)



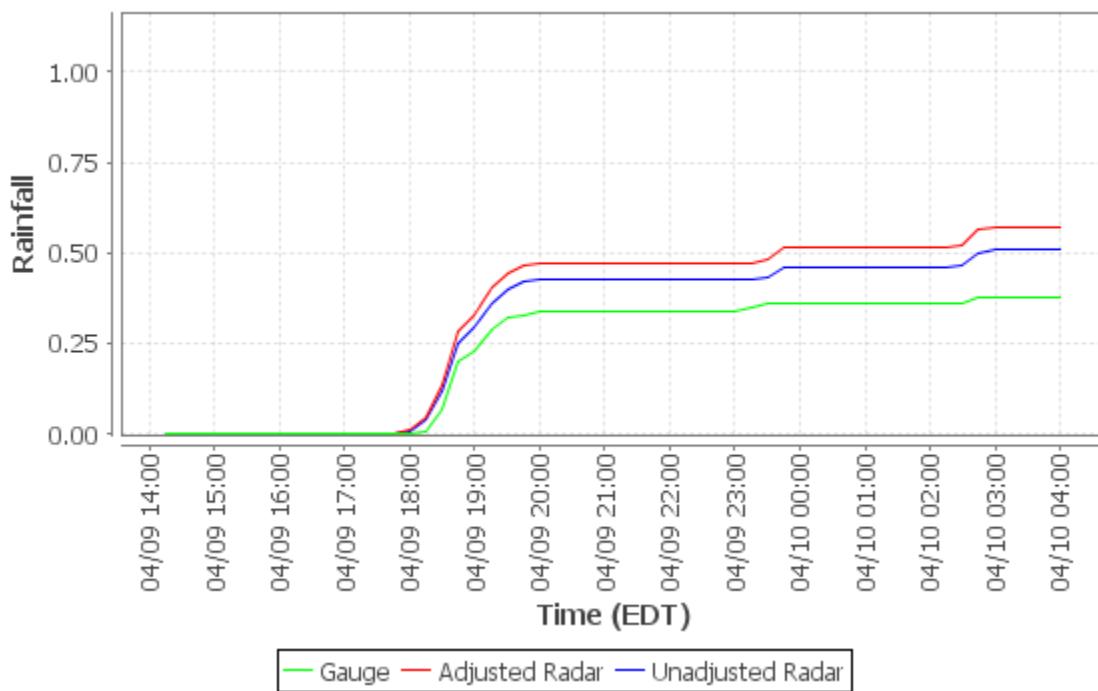
Cumulative Distribution Plot - Pittsburgh Allegheny Cty (KAGC)



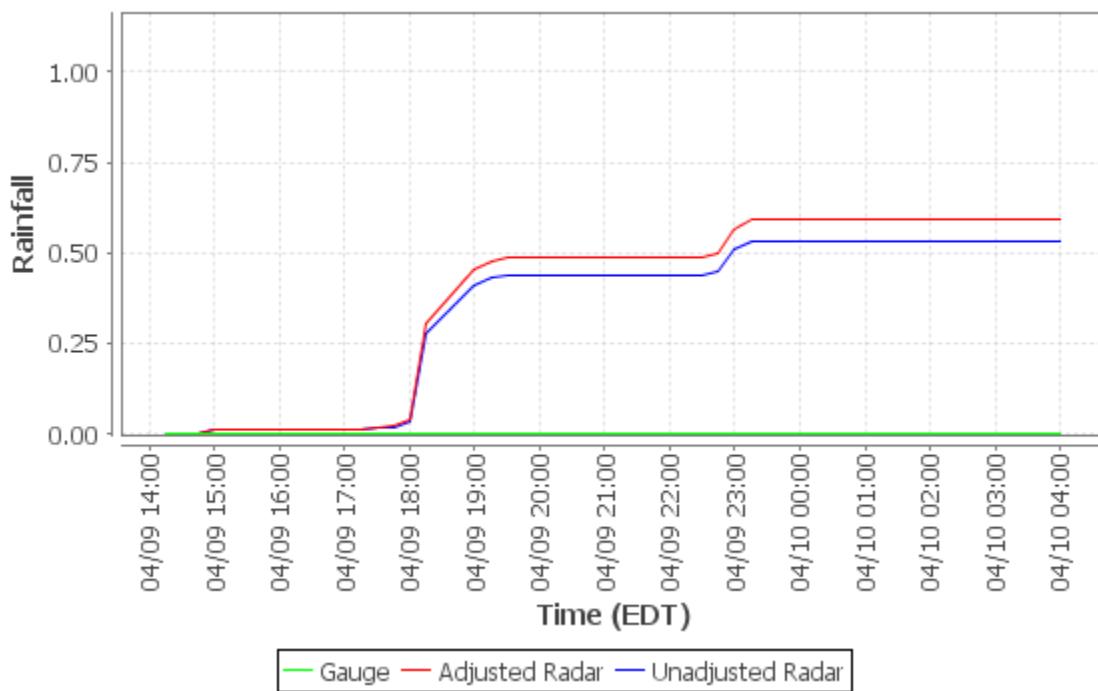
Cumulative Distribution Plot - Greater Pittsburgh Int'l (KPIT)



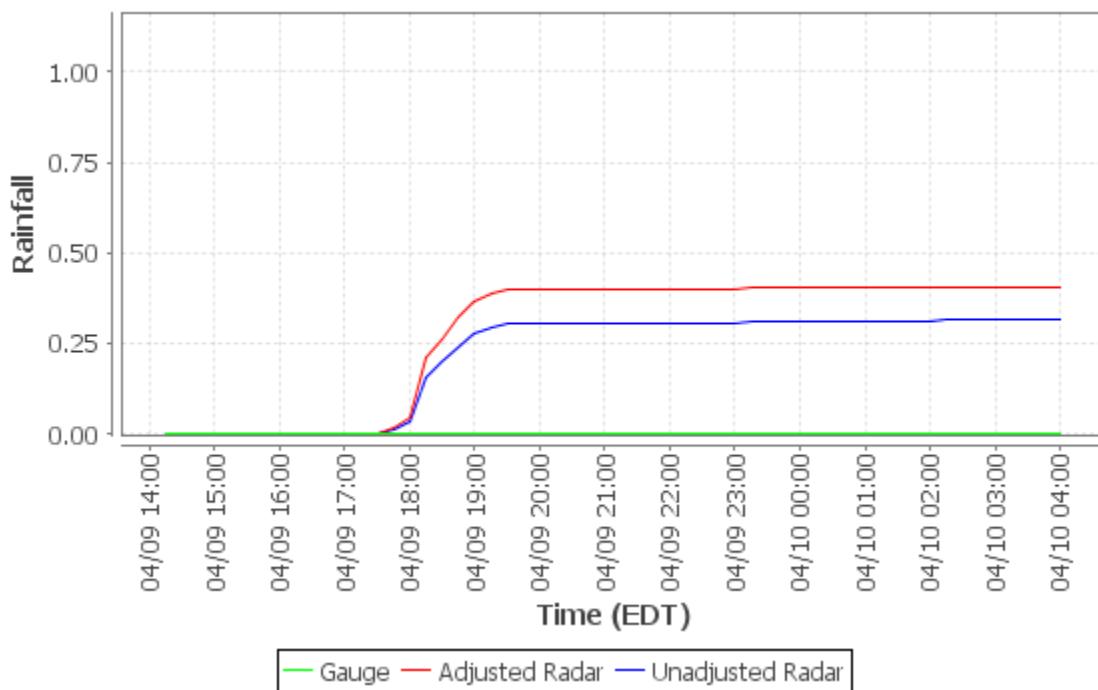
Cumulative Distribution Plot - Allegheny River at Natrona (03049500)



Cumulative Distribution Plot - Chartiers Creek at Carnegie (03085500)

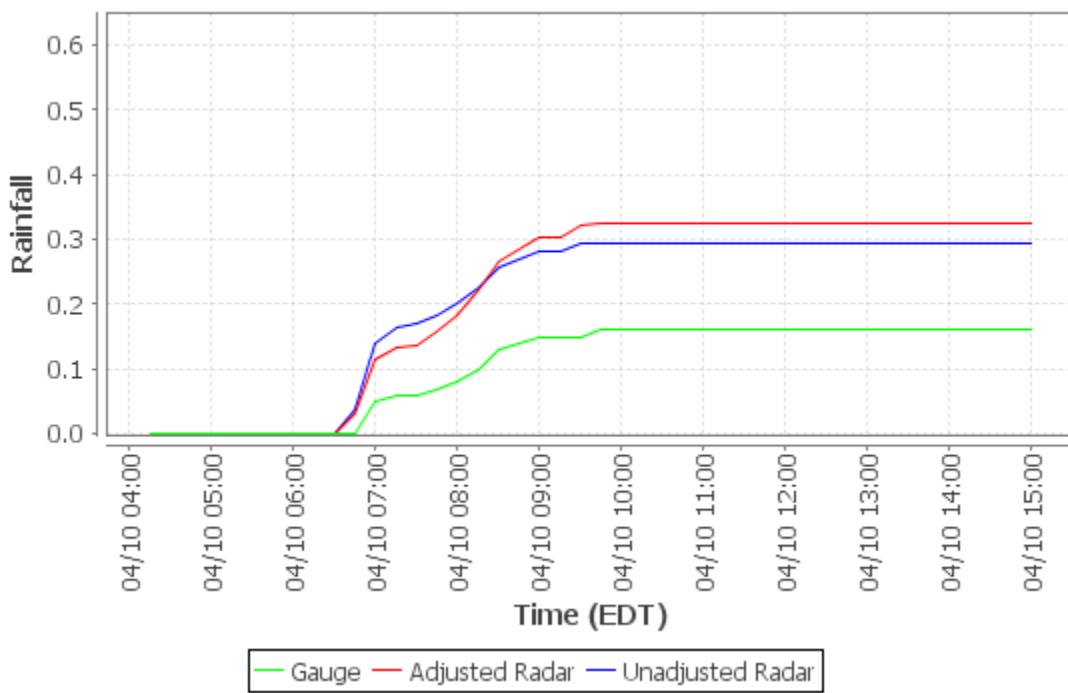


Cumulative Distribution Plot - Ohio River at Emsworth Dam Lower Pool at Emsworth (03085734)

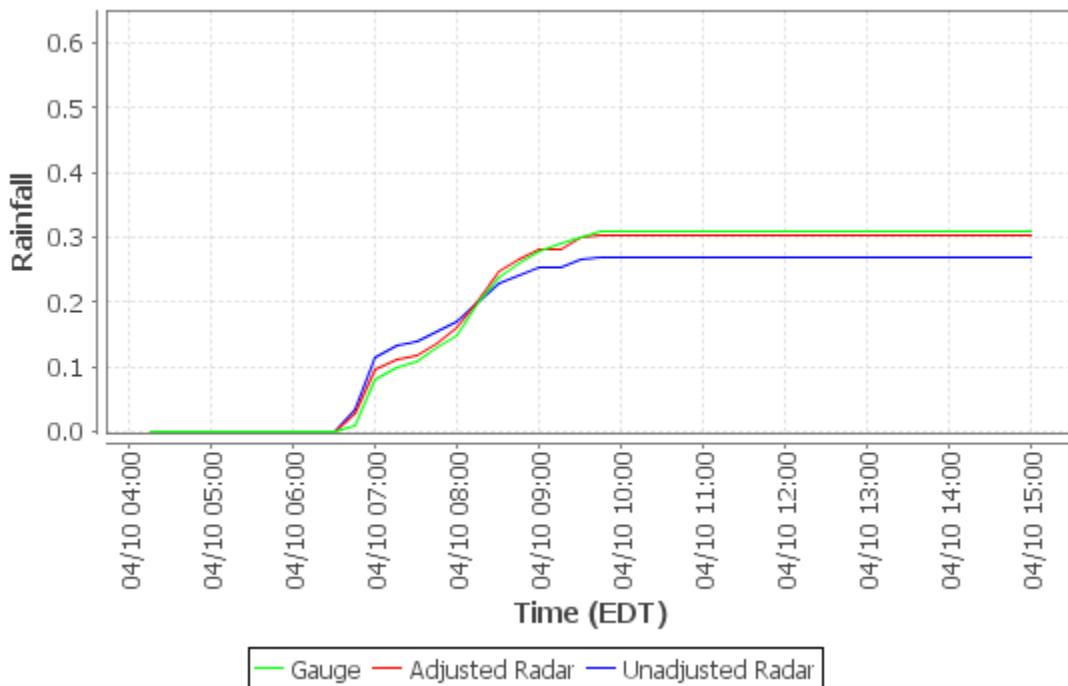


Appendix I - Event 8 (2015-04-10) CDPs

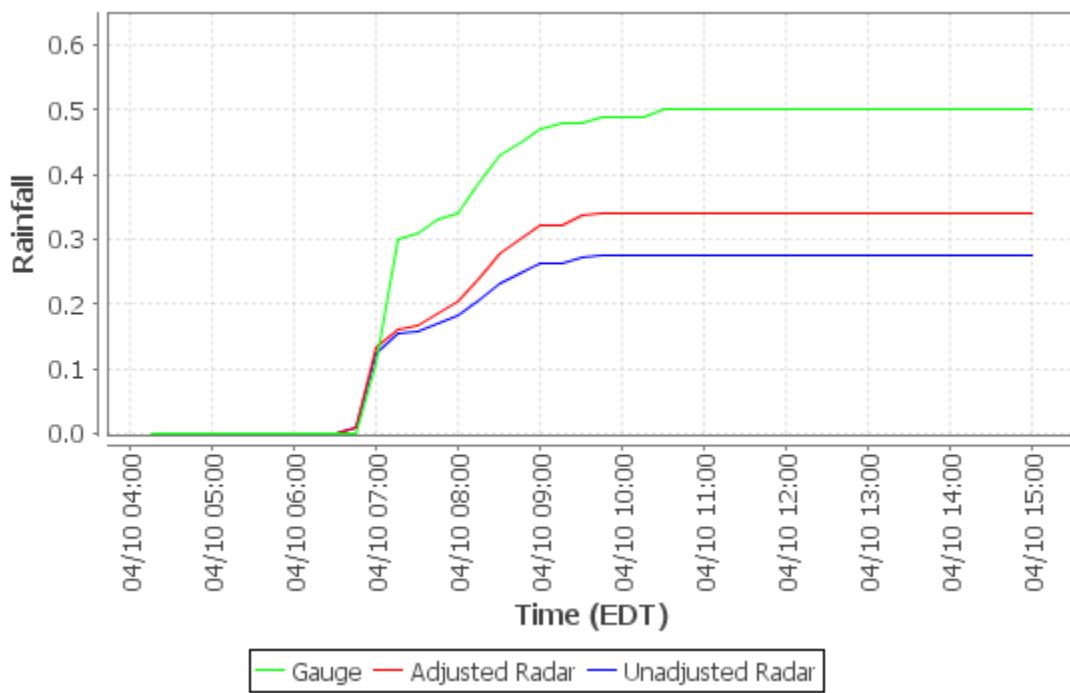
Cumulative Distribution Plot - PWSA-Montana St. (Loc01)



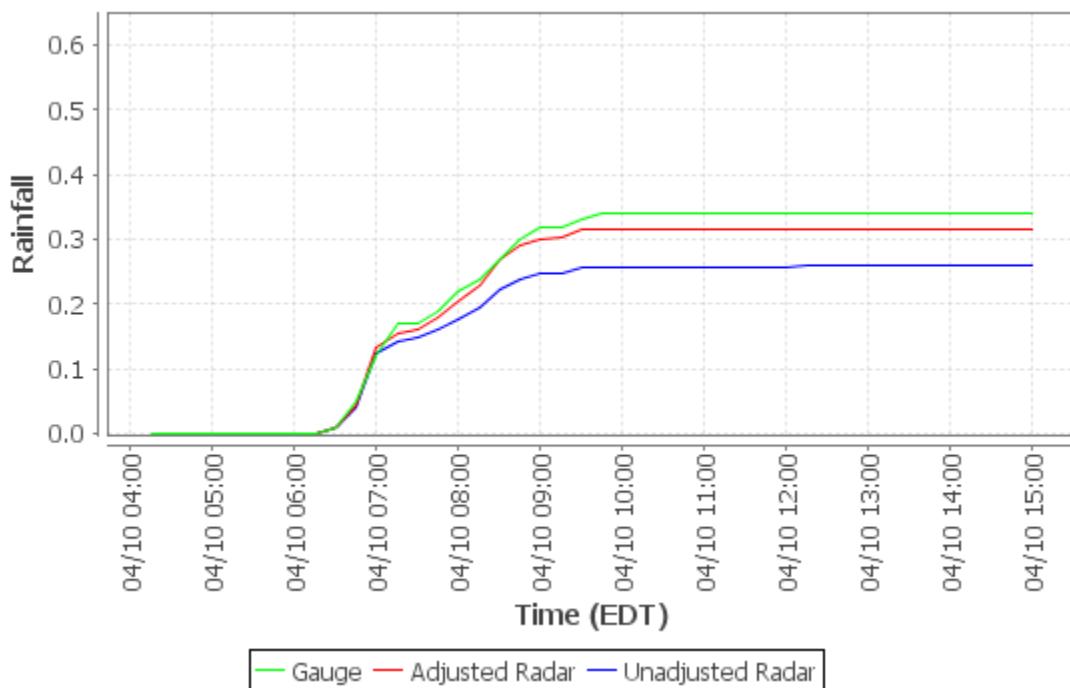
Cumulative Distribution Plot - ALCOSAN WWTP Lab (Loc02)



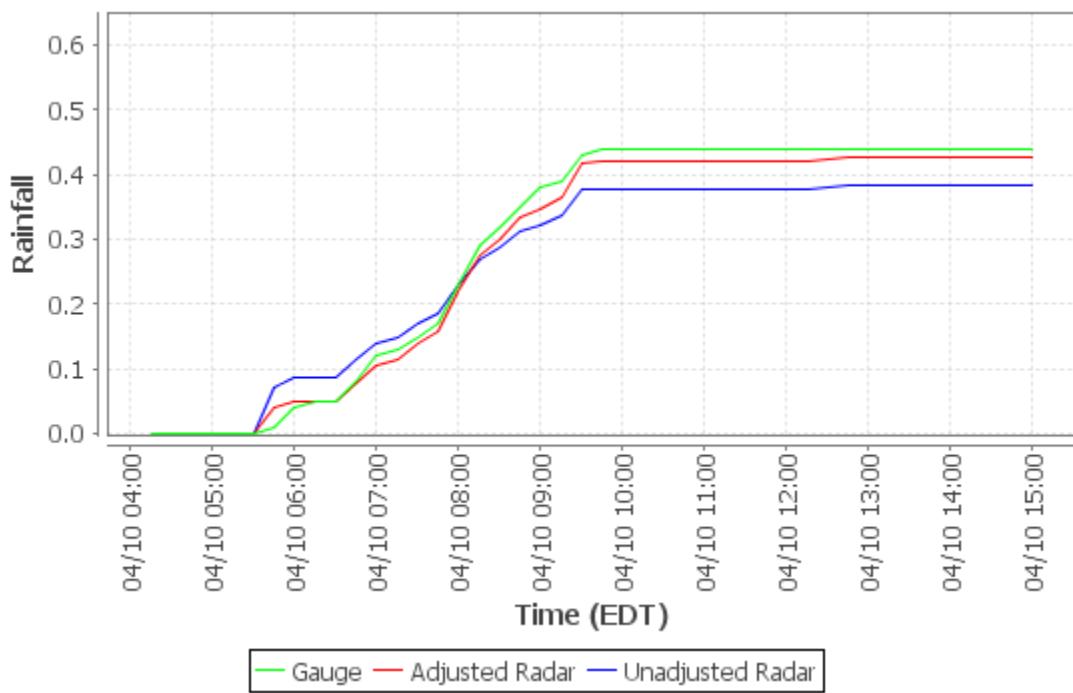
Cumulative Distribution Plot - Shaler Munic Bldg (Loc03)



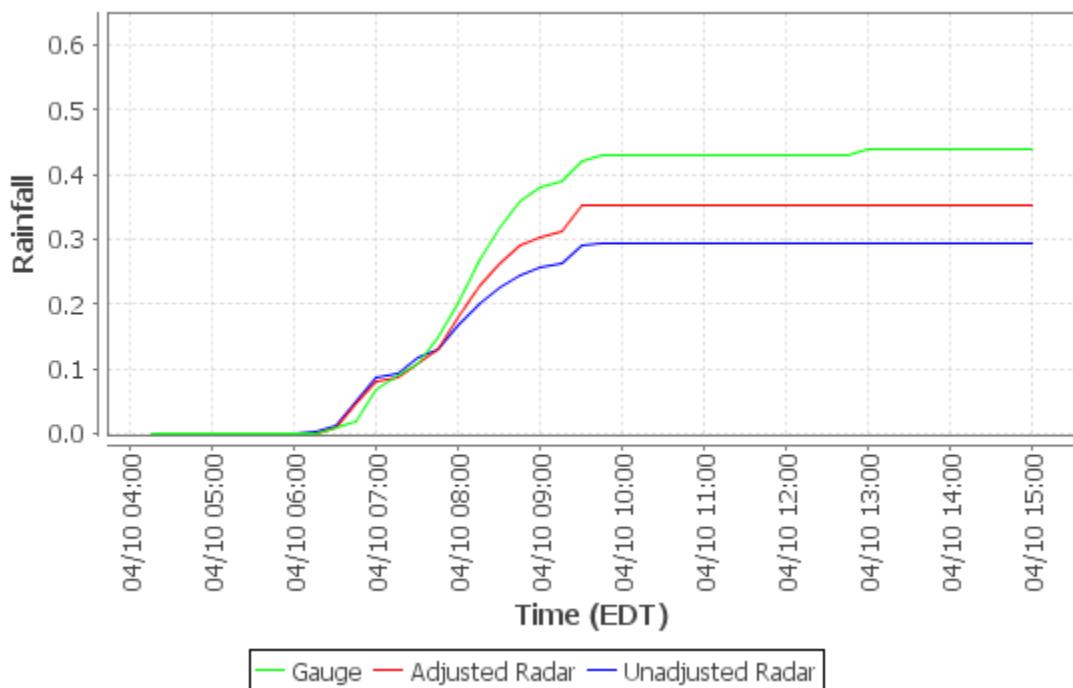
Cumulative Distribution Plot - Kennedy Twp PS (Loc04)



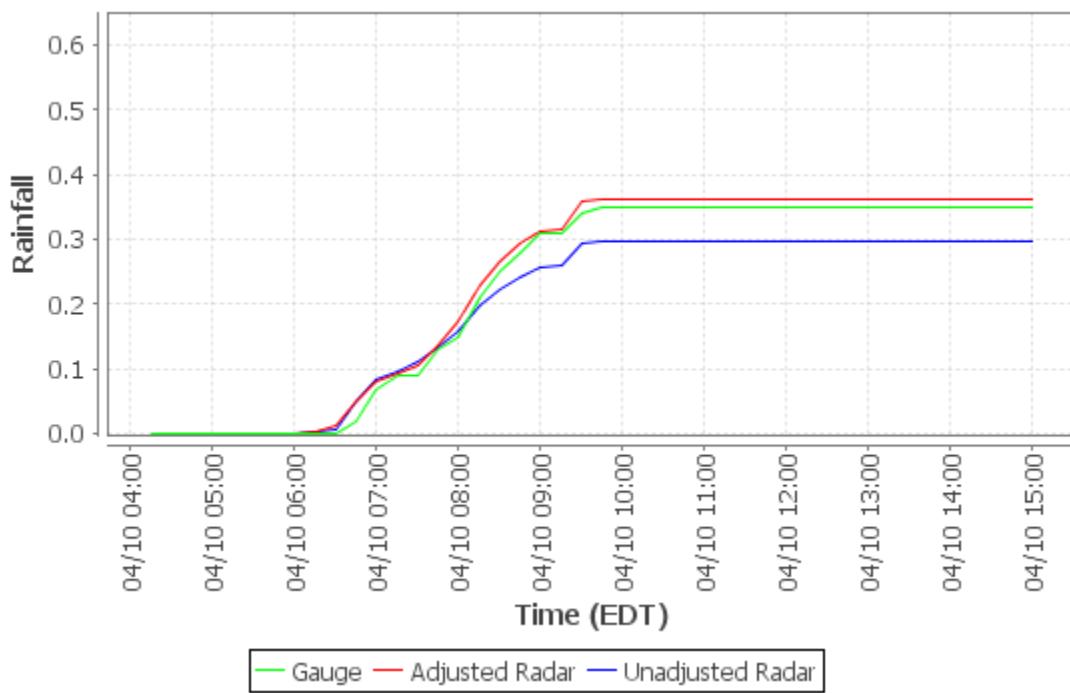
Cumulative Distribution Plot - Upper St. Clair (Loc05)



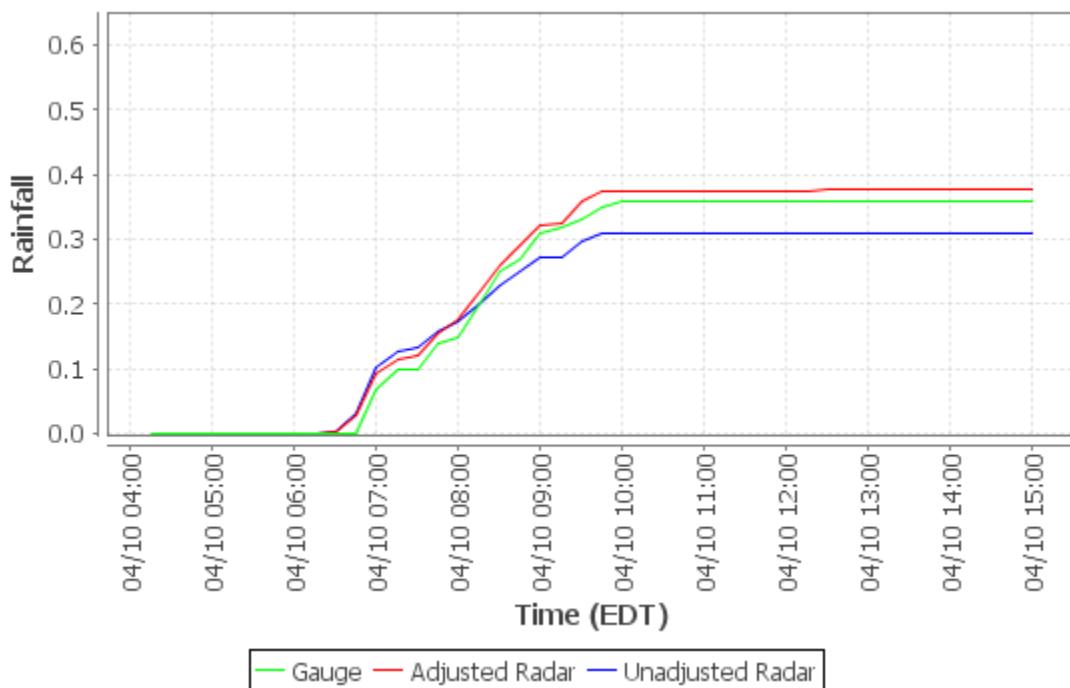
Cumulative Distribution Plot - Carnegie Transit Time (Loc06)



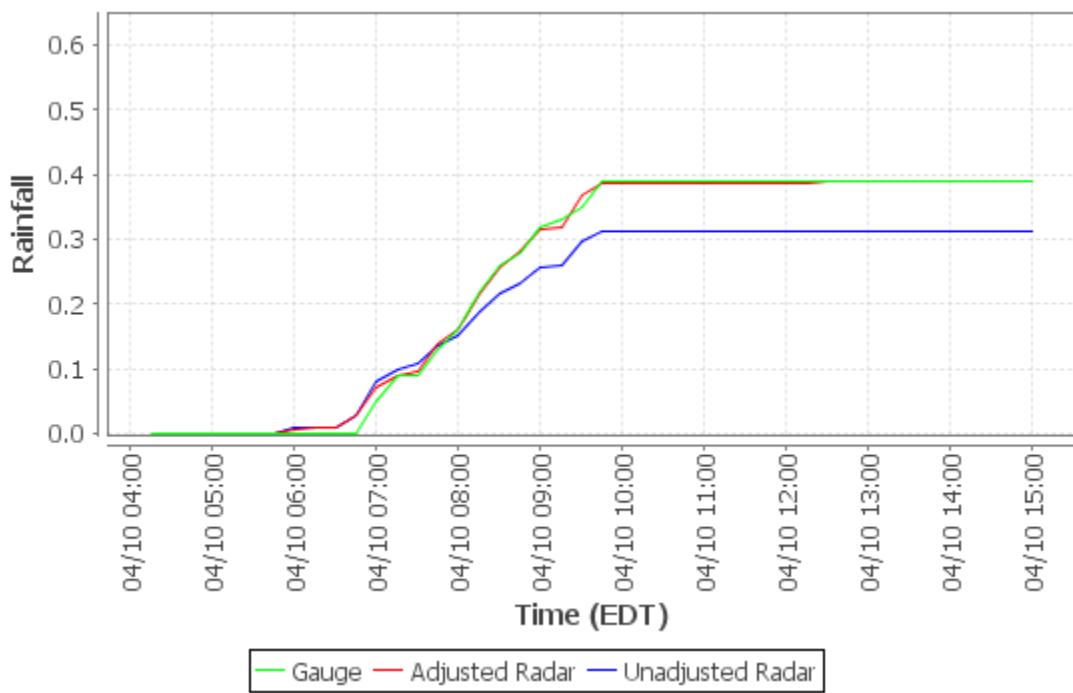
Cumulative Distribution Plot - Greentree Munic Bldg (Loc07)



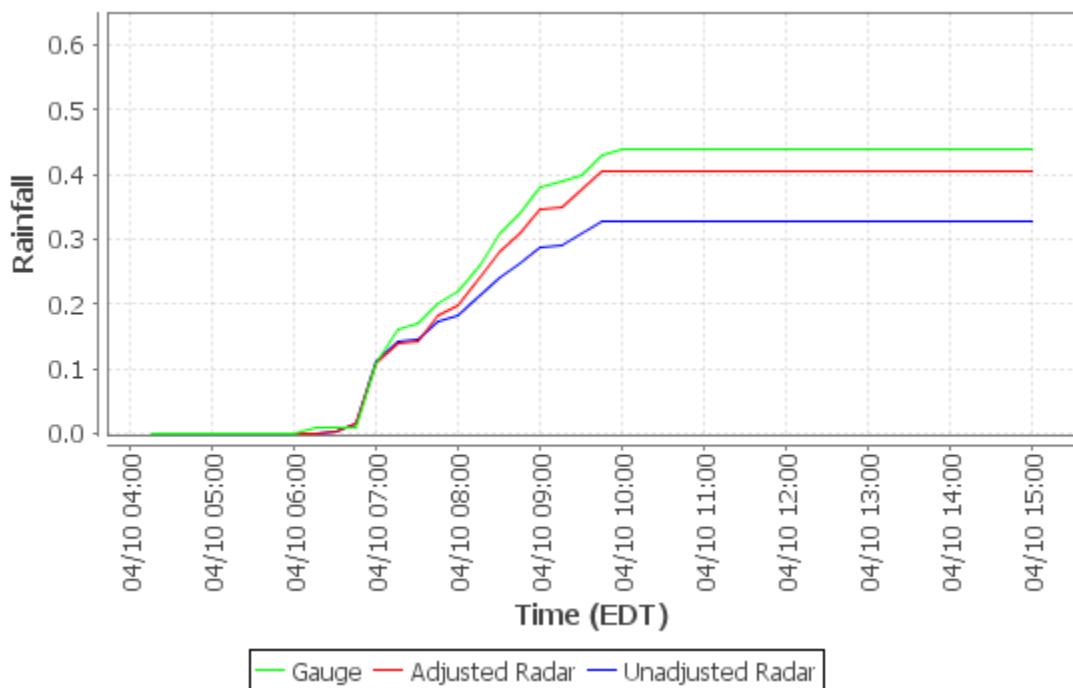
Cumulative Distribution Plot - AC Health Dept Bldg (Loc08)



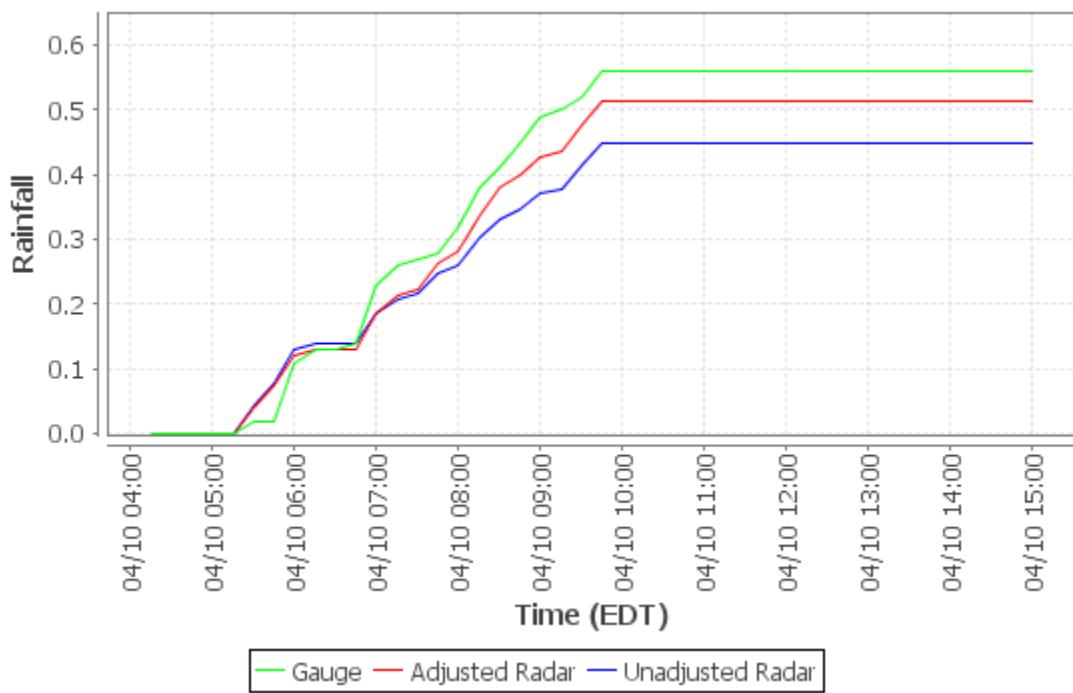
Cumulative Distribution Plot - Univ of Pittsburgh (Loc09)



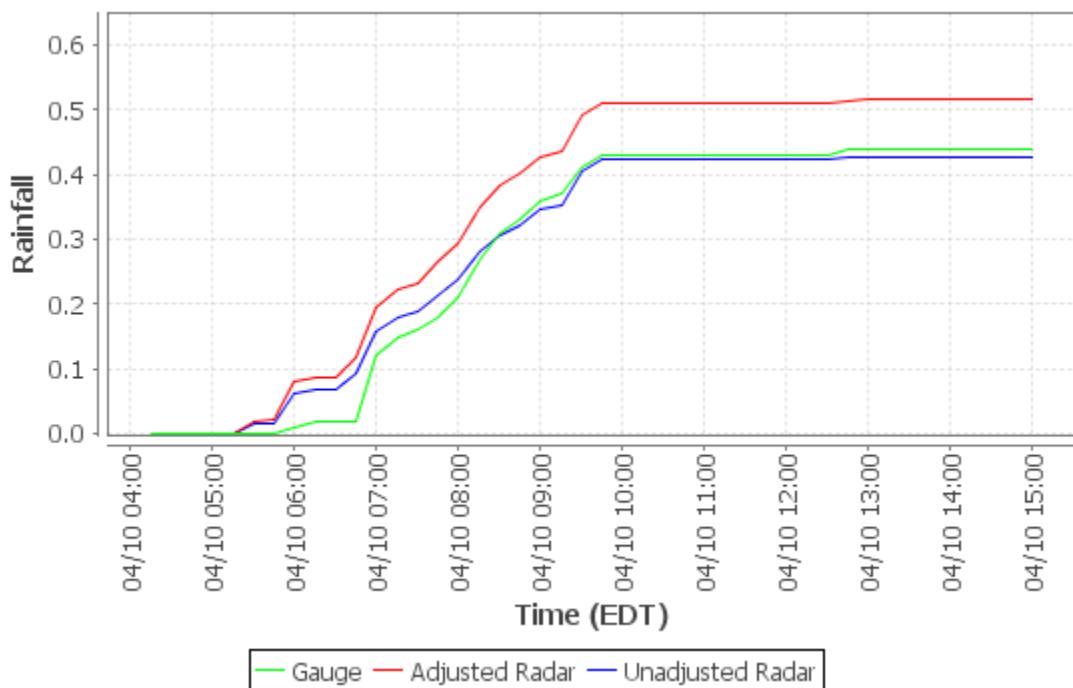
Cumulative Distribution Plot - PWSA-Highland Park (Loc10)



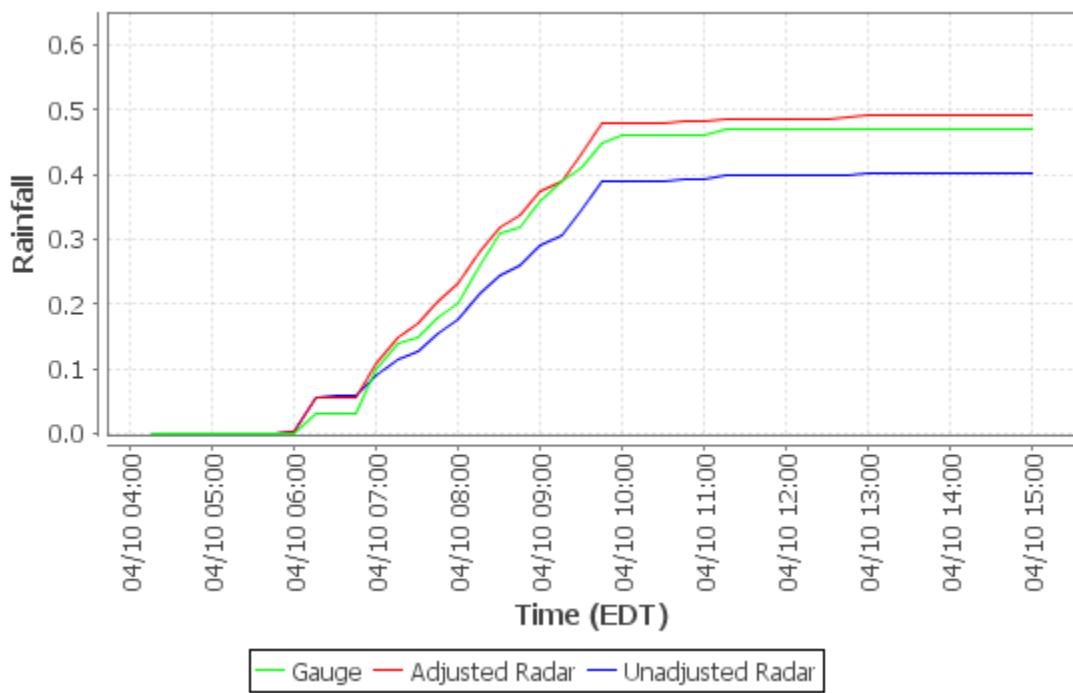
Cumulative Distribution Plot - M-46 Access Shaft (Loc11)



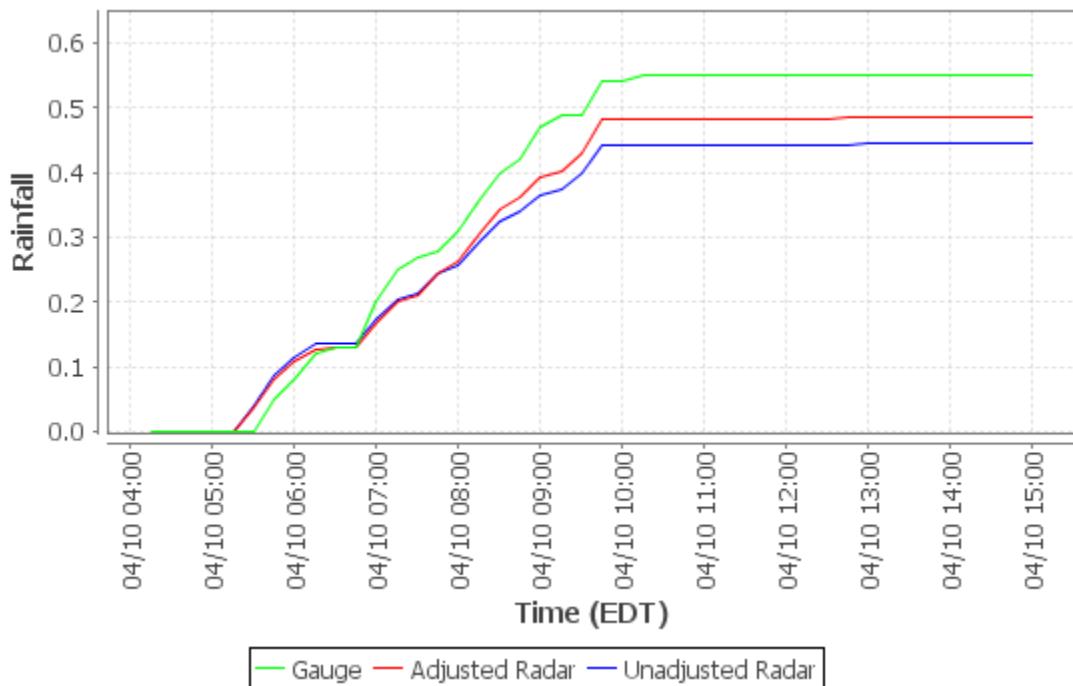
Cumulative Distribution Plot - Baldwin (Loc12)



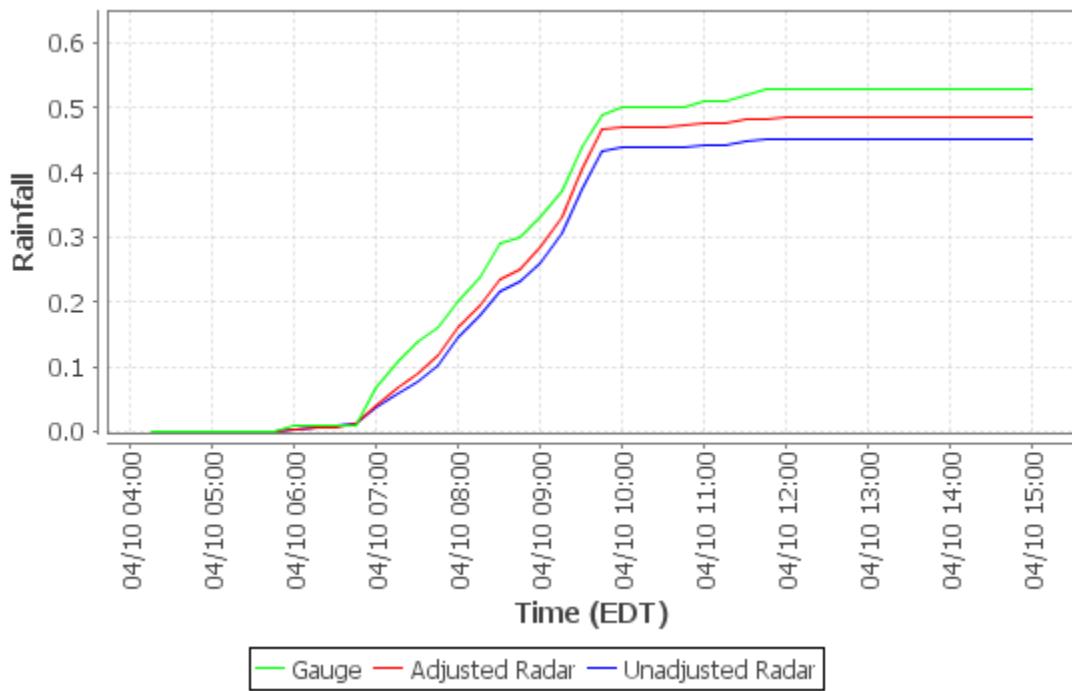
Cumulative Distribution Plot - M-59 Access Shaft (Loc13)



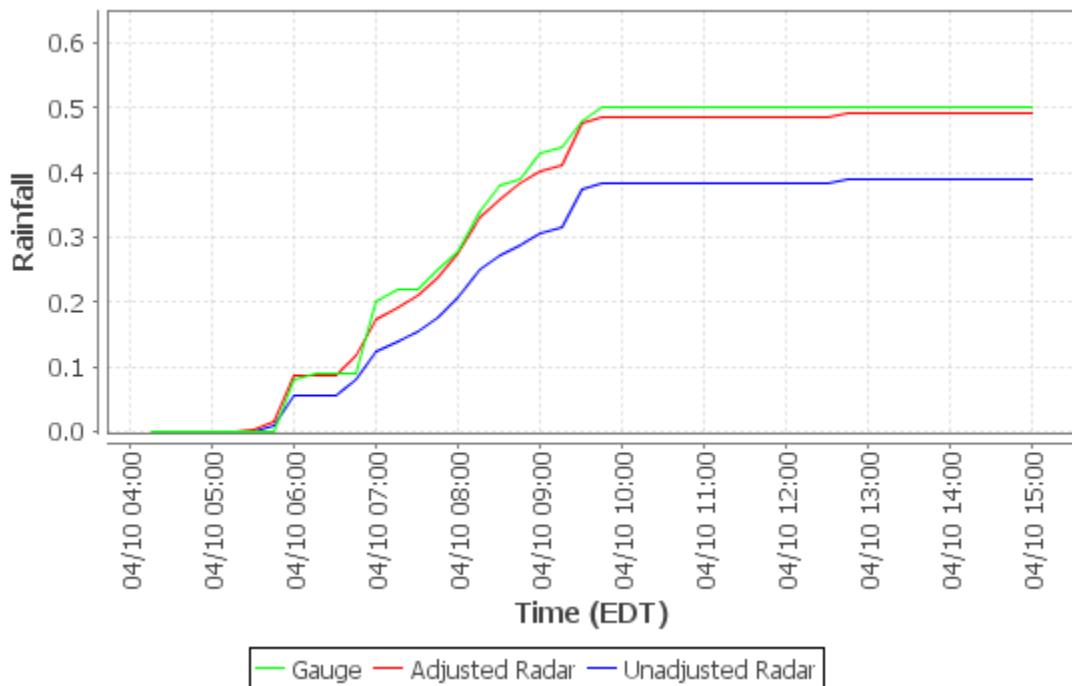
Cumulative Distribution Plot - Churchill Munic Bldg (Loc14)



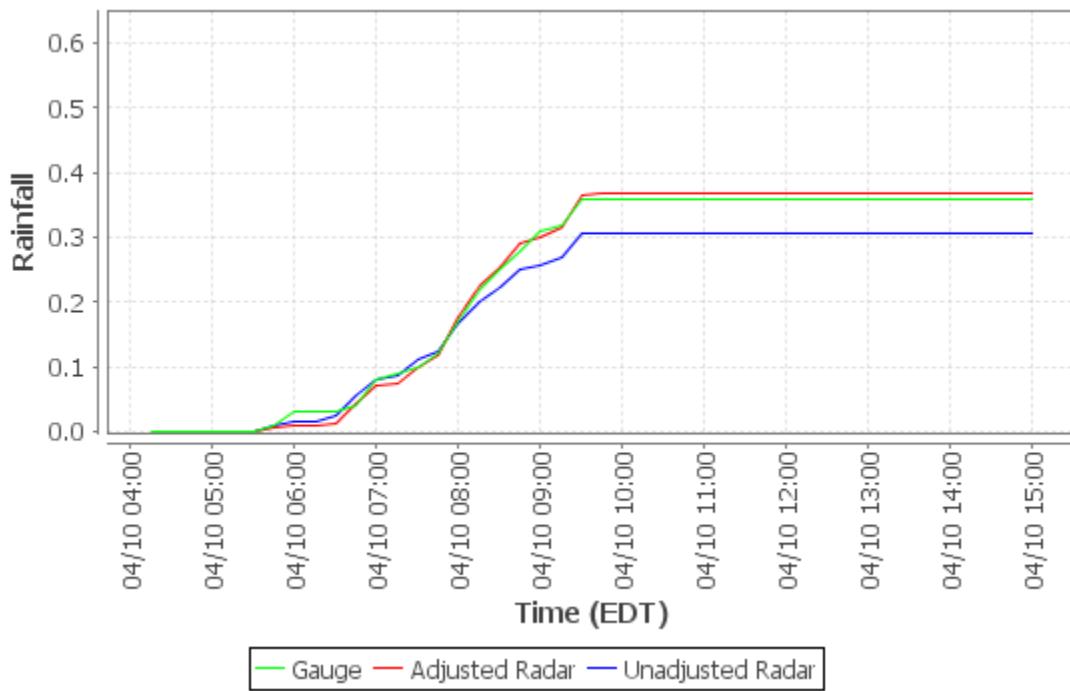
Cumulative Distribution Plot - Trafford Maint Bldg (Loc15)



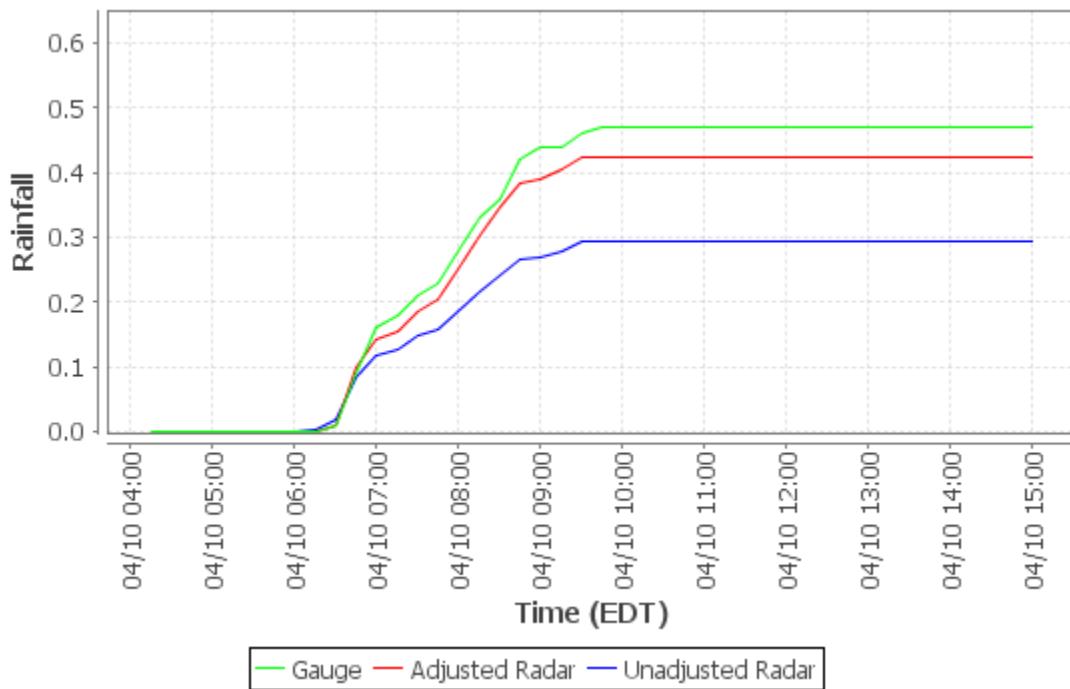
Cumulative Distribution Plot - Castle Shannon (Loc16)



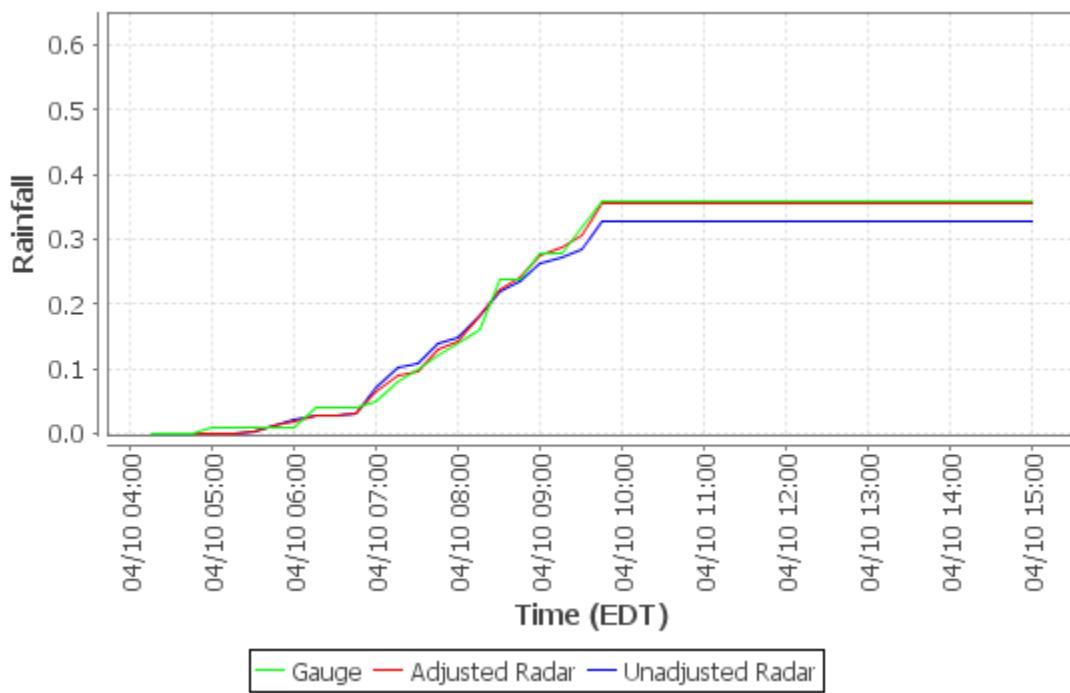
Cumulative Distribution Plot - Chartiers Pump Station (Loc17)



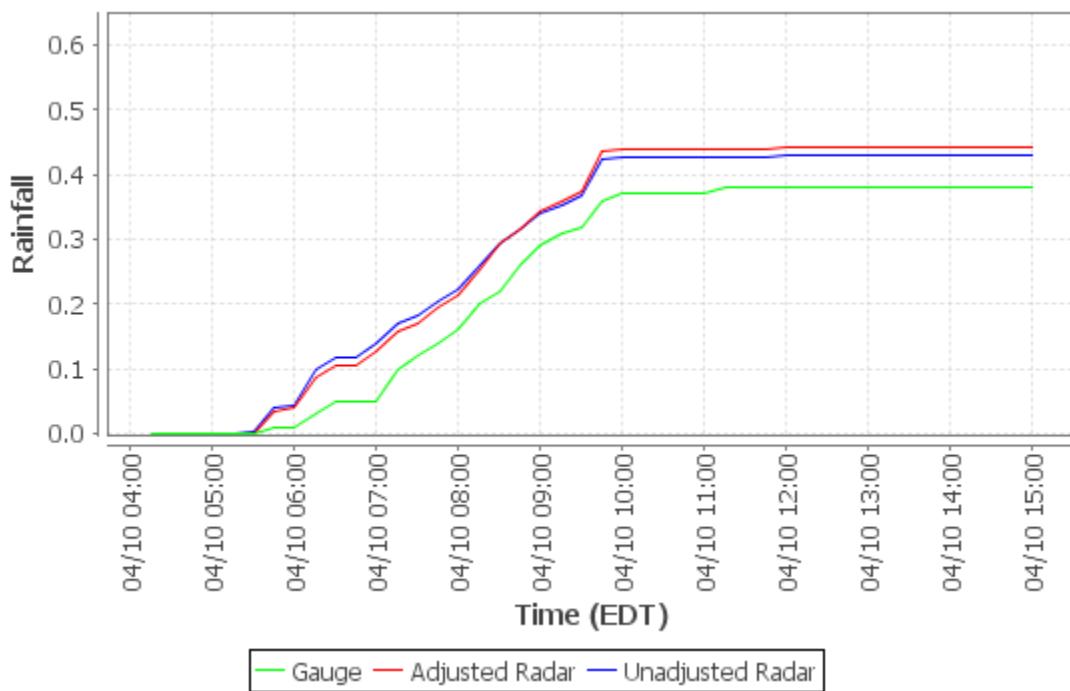
Cumulative Distribution Plot - Oakdale Pump Station (Loc18)



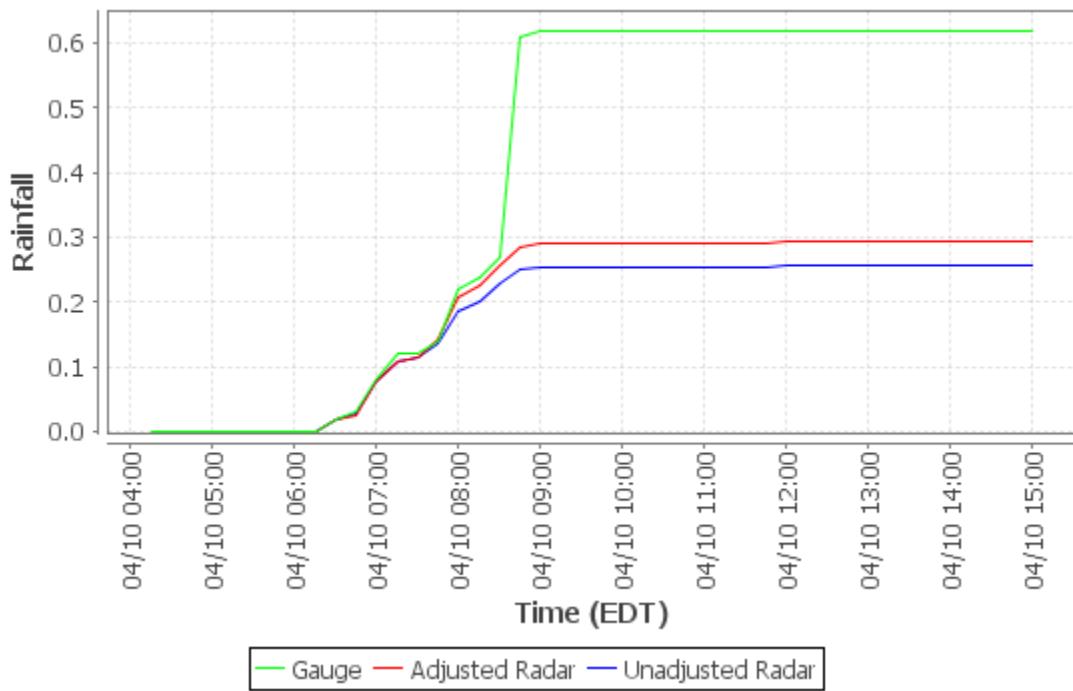
Cumulative Distribution Plot - Sandy Creek Eq Facility (Loc19)



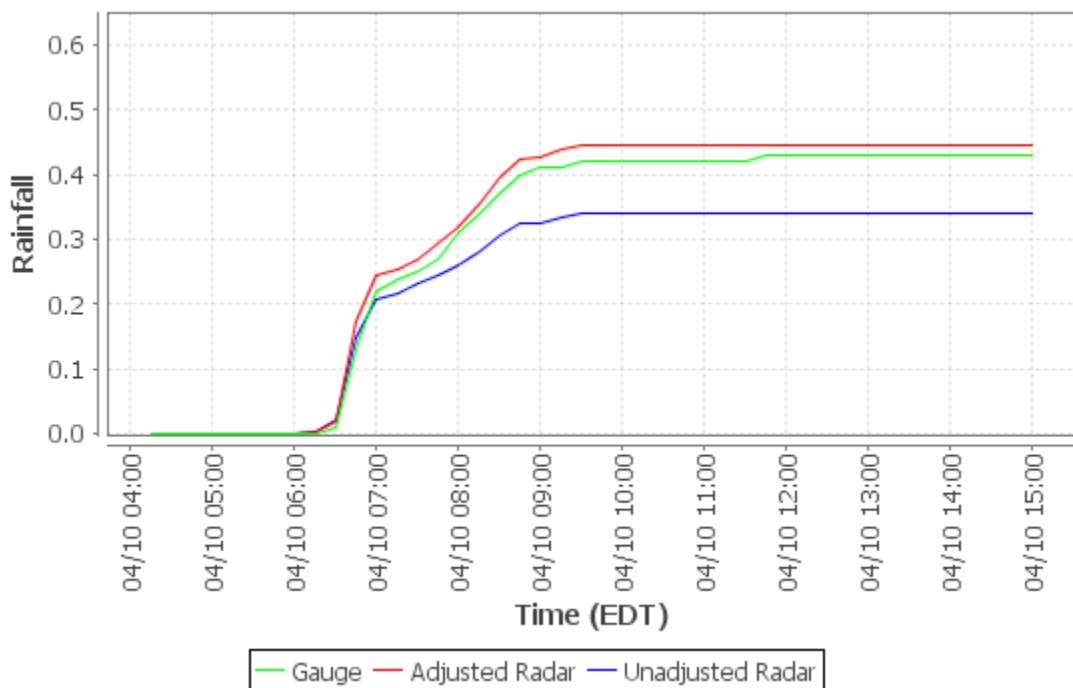
Cumulative Distribution Plot - Gascola Eq Facility (Loc20)



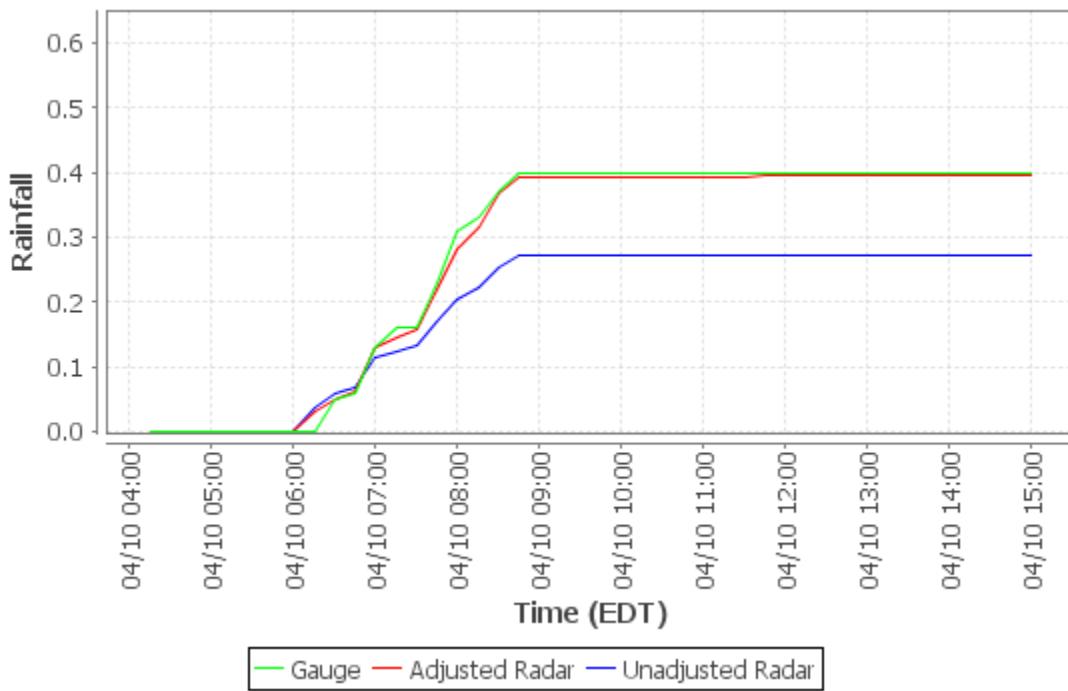
Cumulative Distribution Plot - Moon TWP (Loc21)



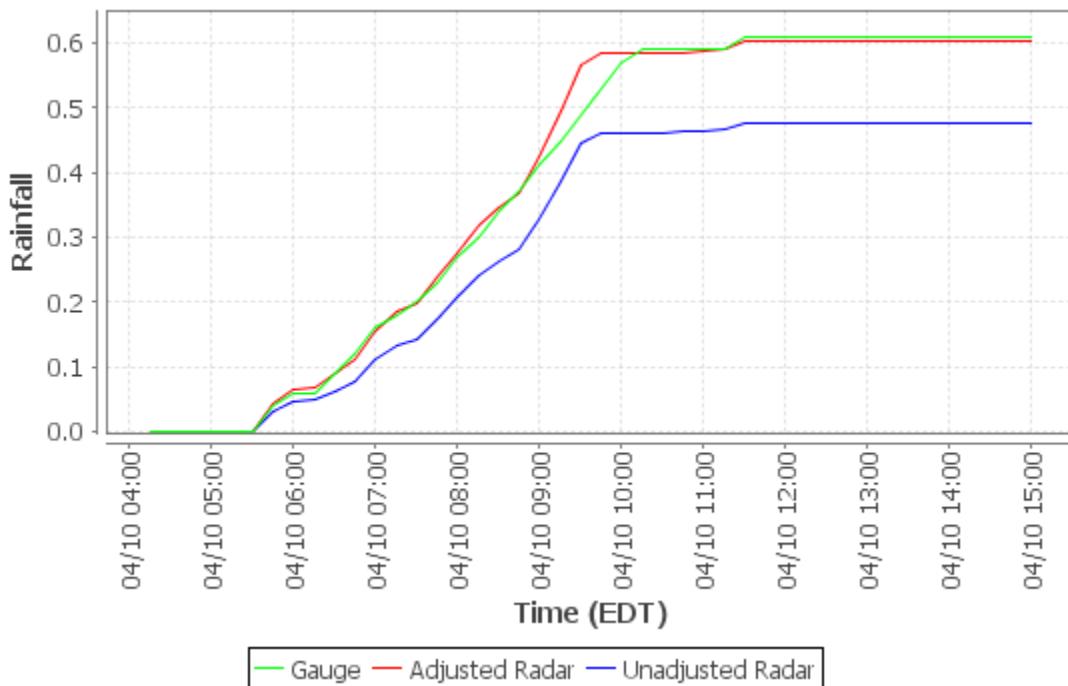
Cumulative Distribution Plot - North Fayette TWP (Loc22)



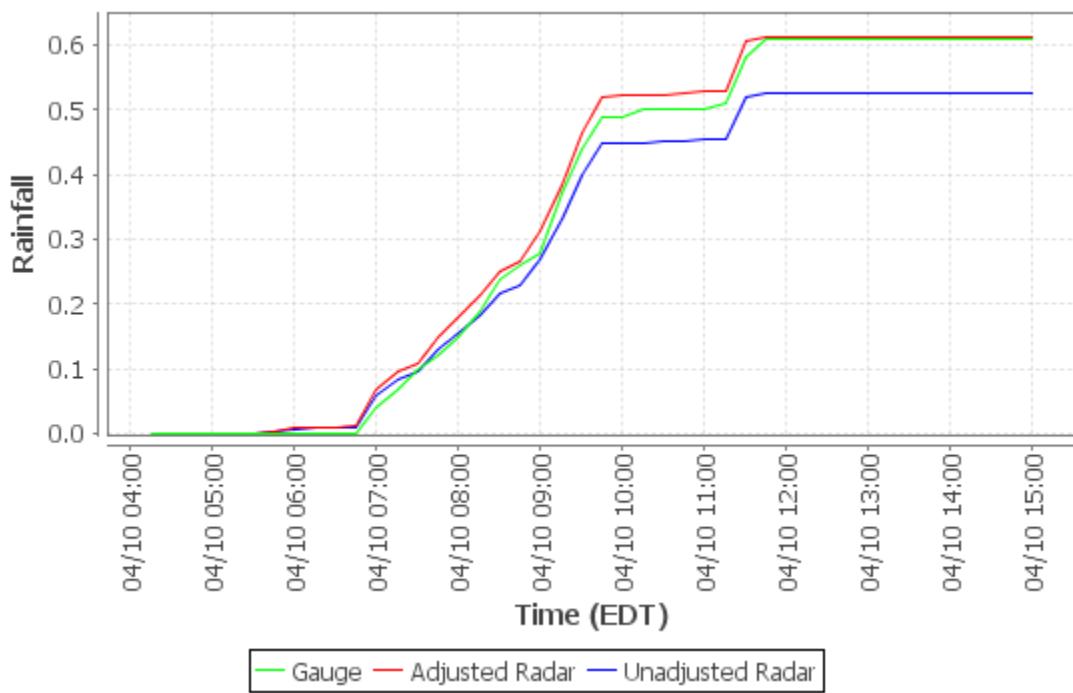
Cumulative Distribution Plot - Clinton Munic Bldg (Loc23)



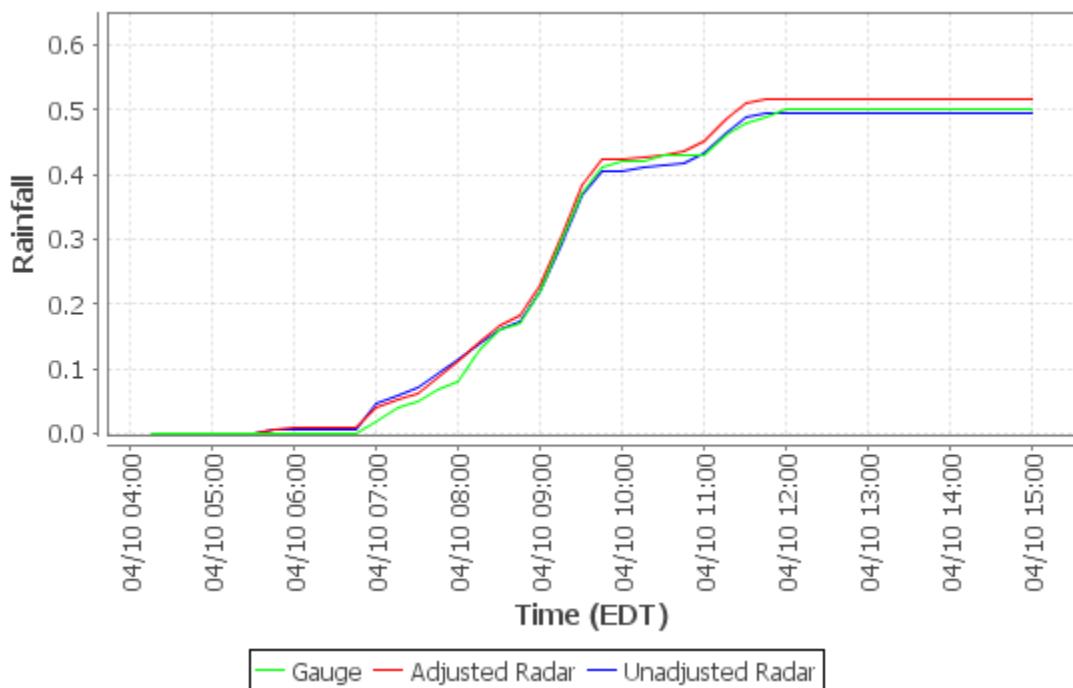
Cumulative Distribution Plot - Jefferson Hills (Loc24)



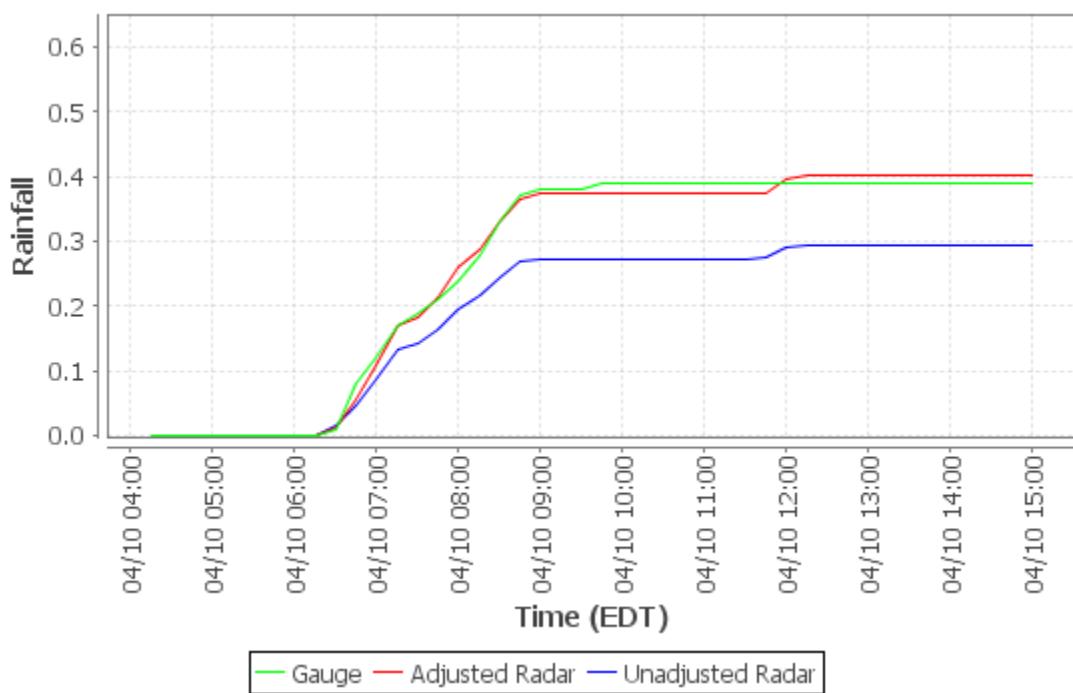
Cumulative Distribution Plot - White Oak Public Works Bldg (Loc25)



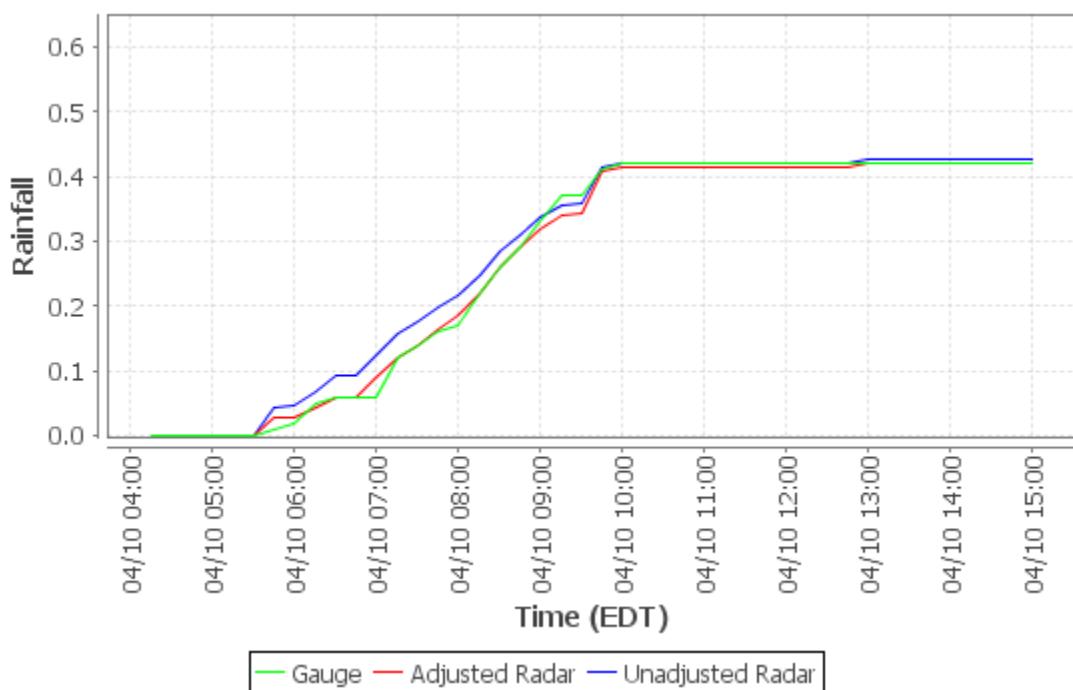
Cumulative Distribution Plot - Elizabeth TWP Municipal Bldg (Loc26)



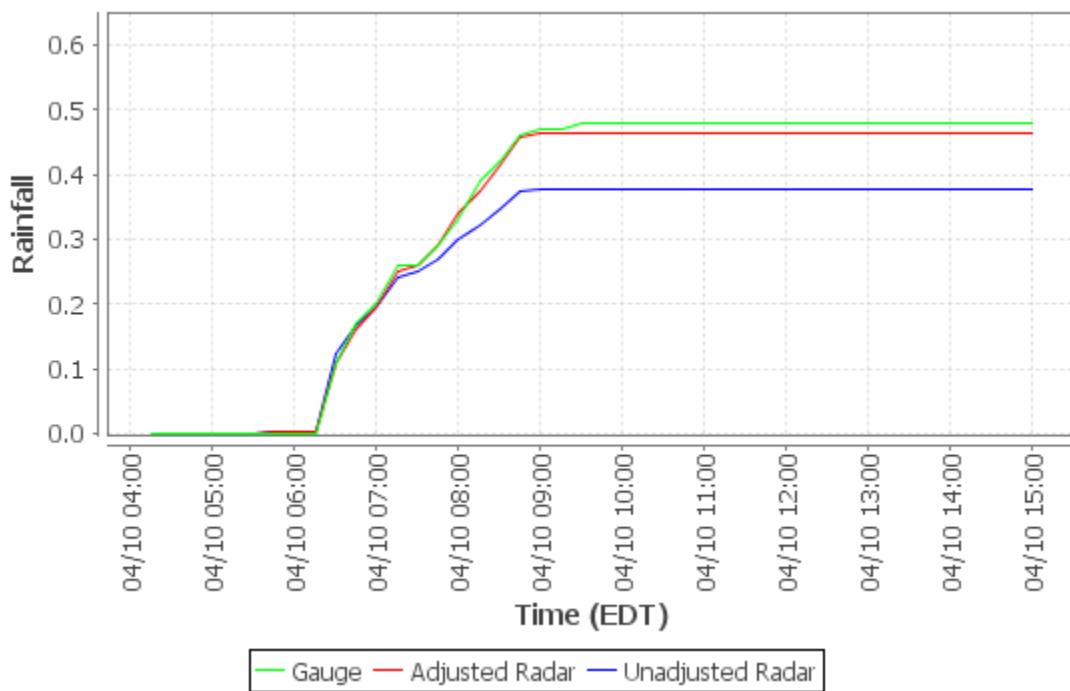
Cumulative Distribution Plot - Marshall TWP (Loc27)



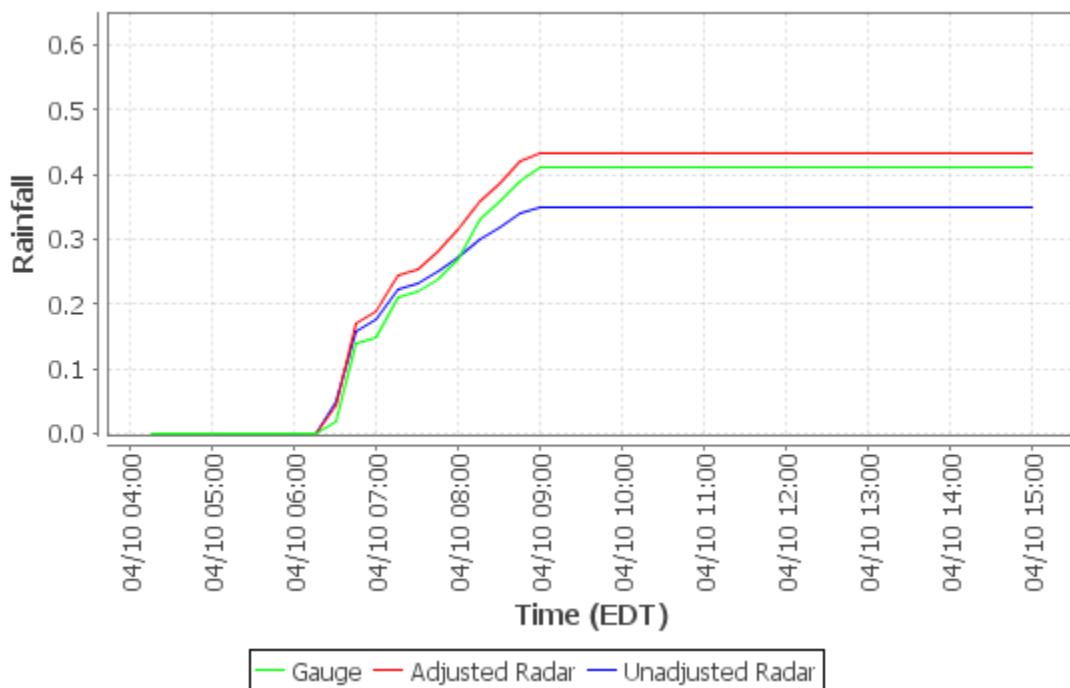
Cumulative Distribution Plot - Plum Municipal Bldg (Loc28)



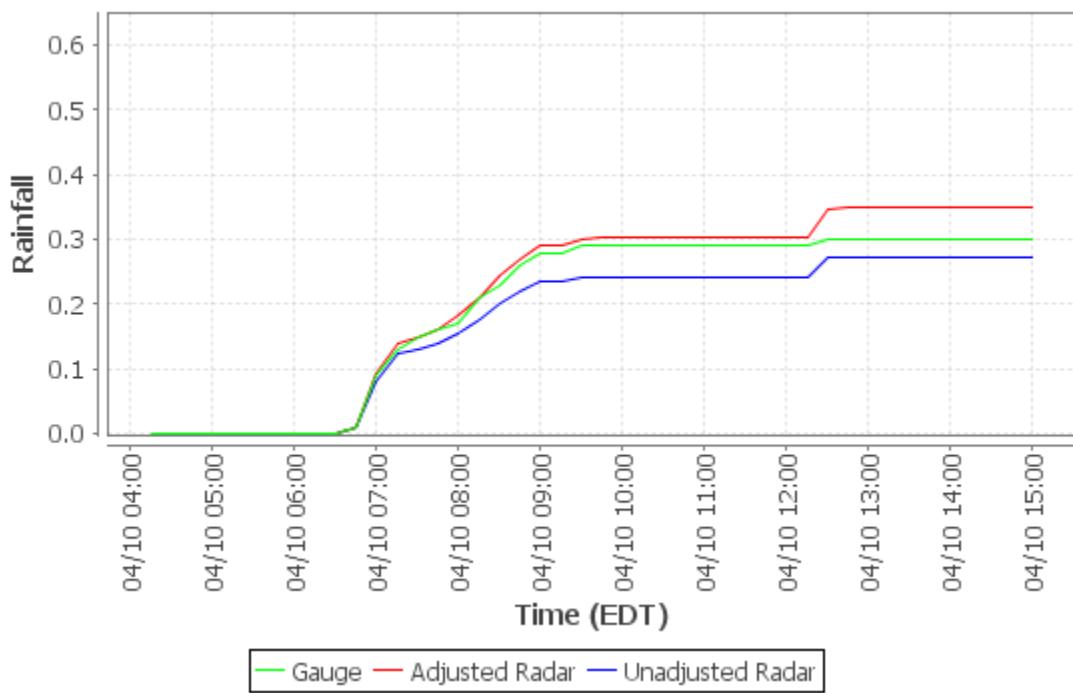
Cumulative Distribution Plot - Bell Acres Munic Bldg (Loc29)



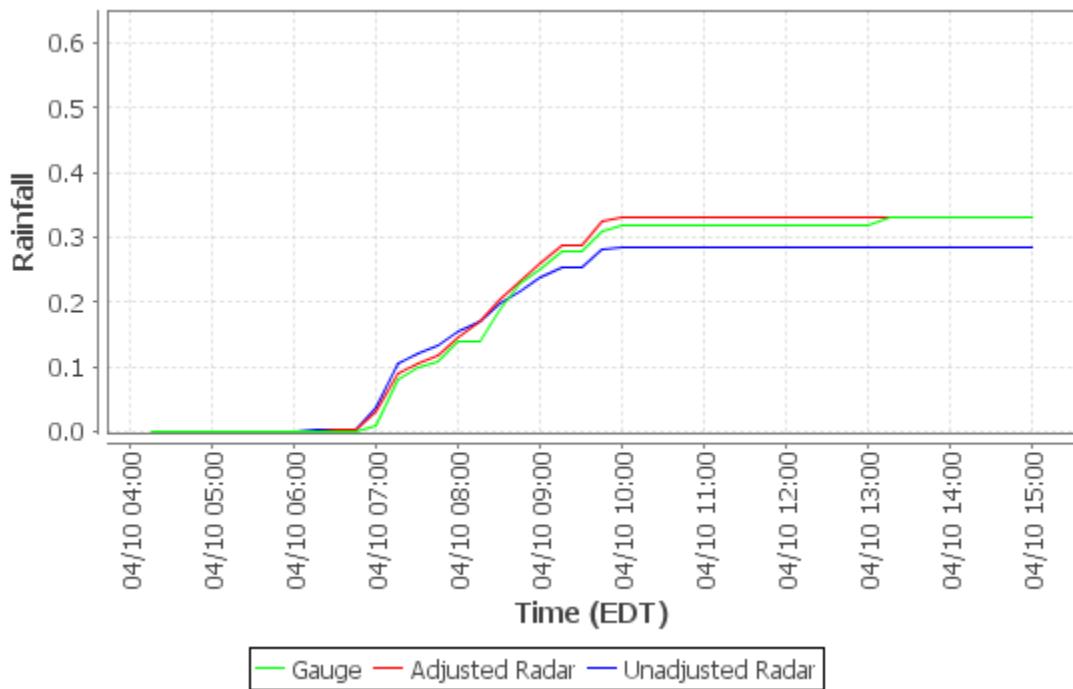
Cumulative Distribution Plot - McCandless Twn Hall (Loc30)



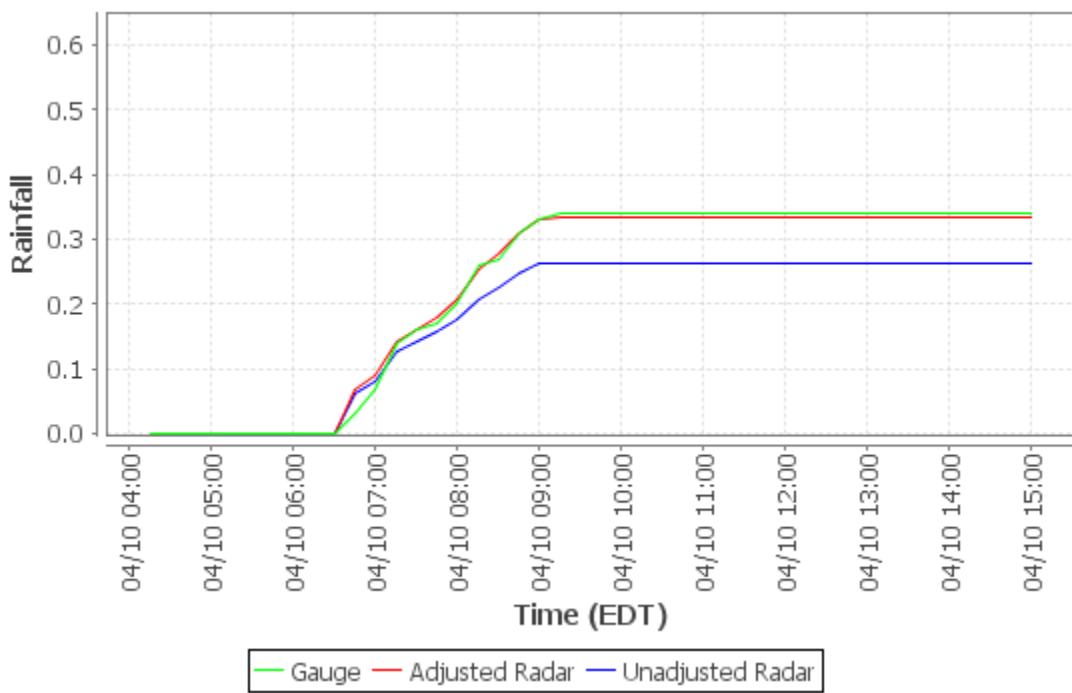
Cumulative Distribution Plot - Hampton Municipal Bldg (Loc31)



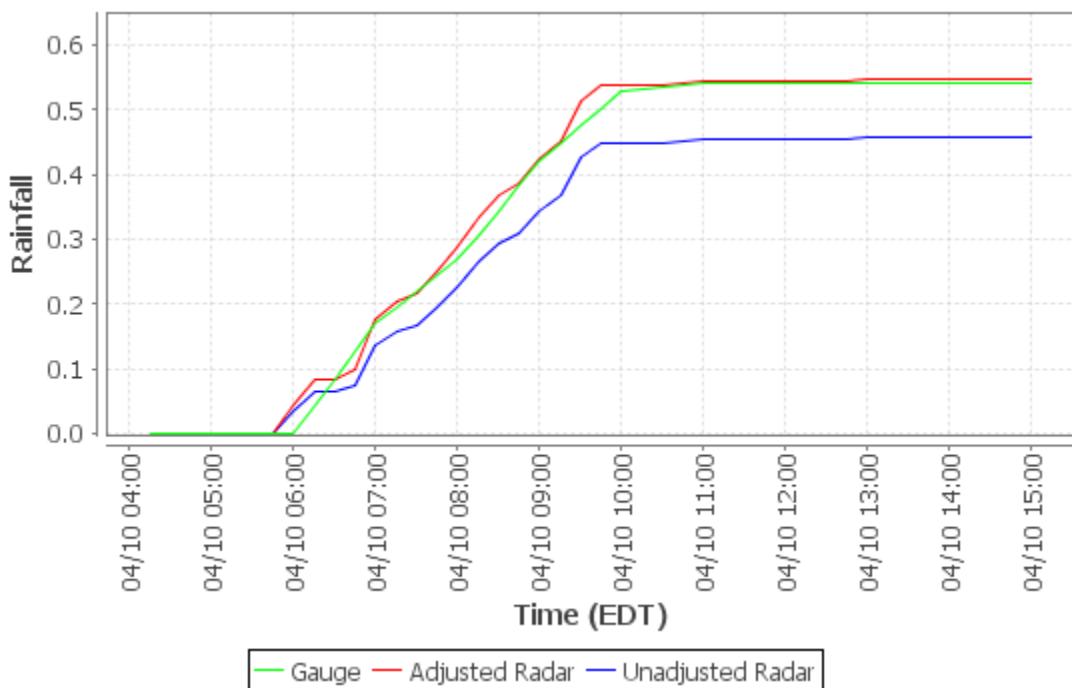
Cumulative Distribution Plot - Arnold (Loc32)



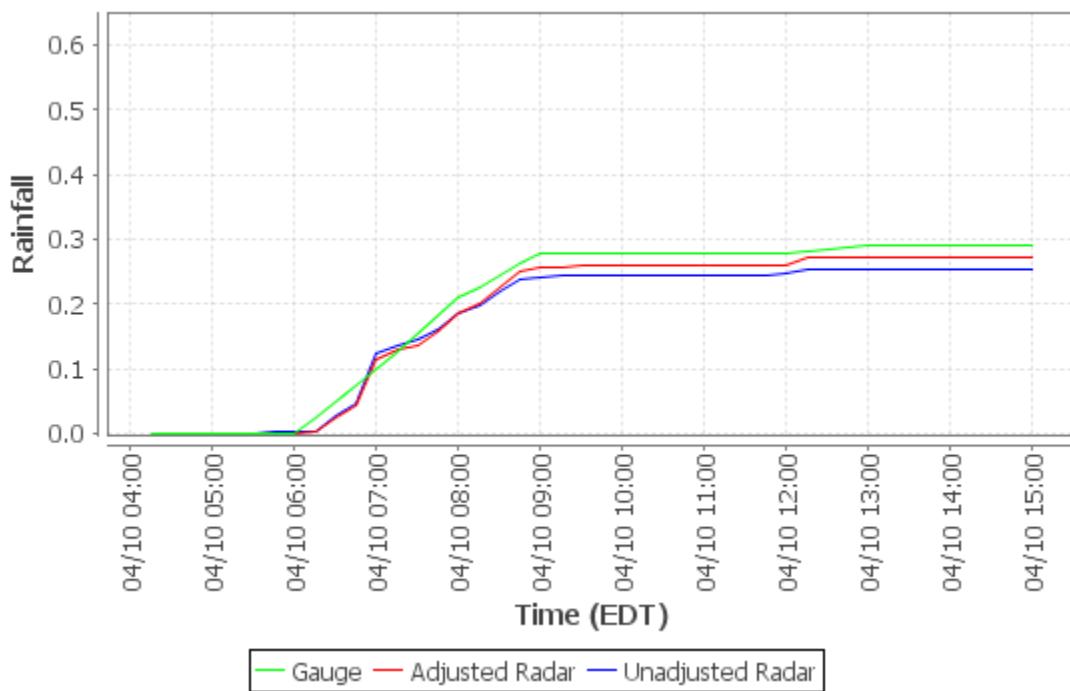
Cumulative Distribution Plot - Richland TWP (Loc33)



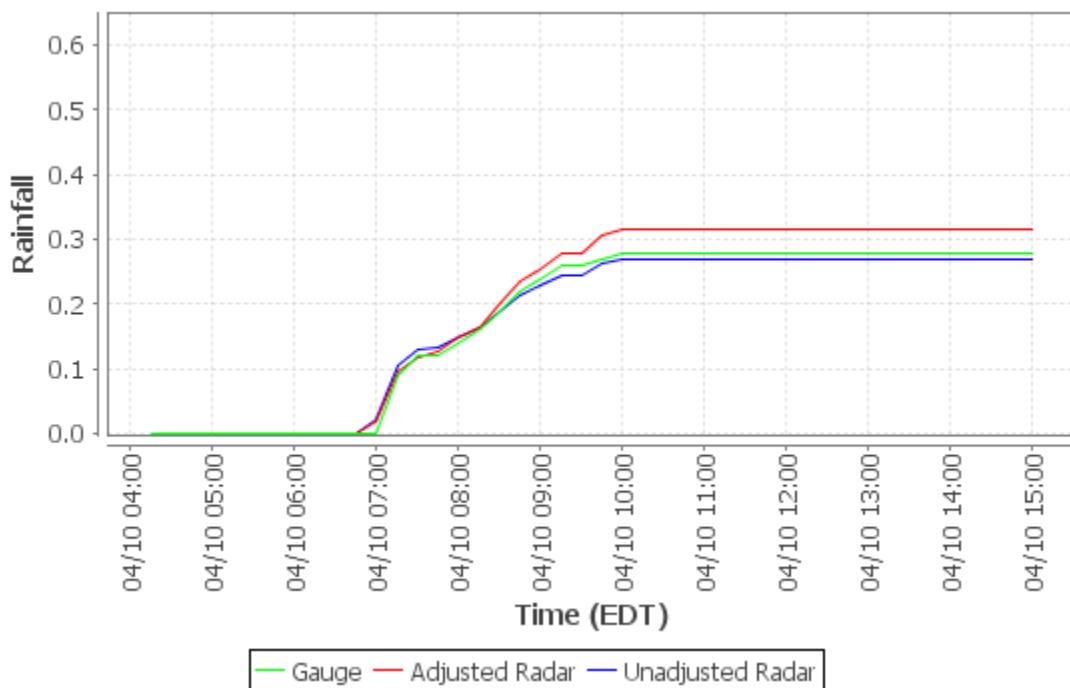
Cumulative Distribution Plot - Pittsburgh Allegheny Cty (KAGC)



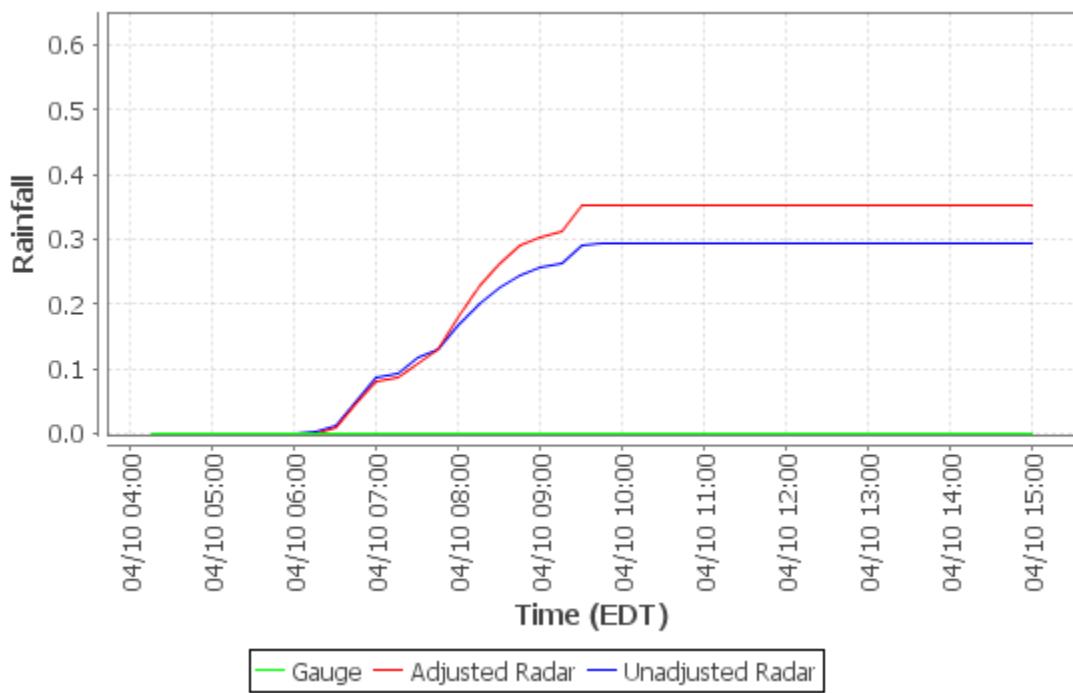
Cumulative Distribution Plot - Greater Pittsburgh Int'l (KPIT)



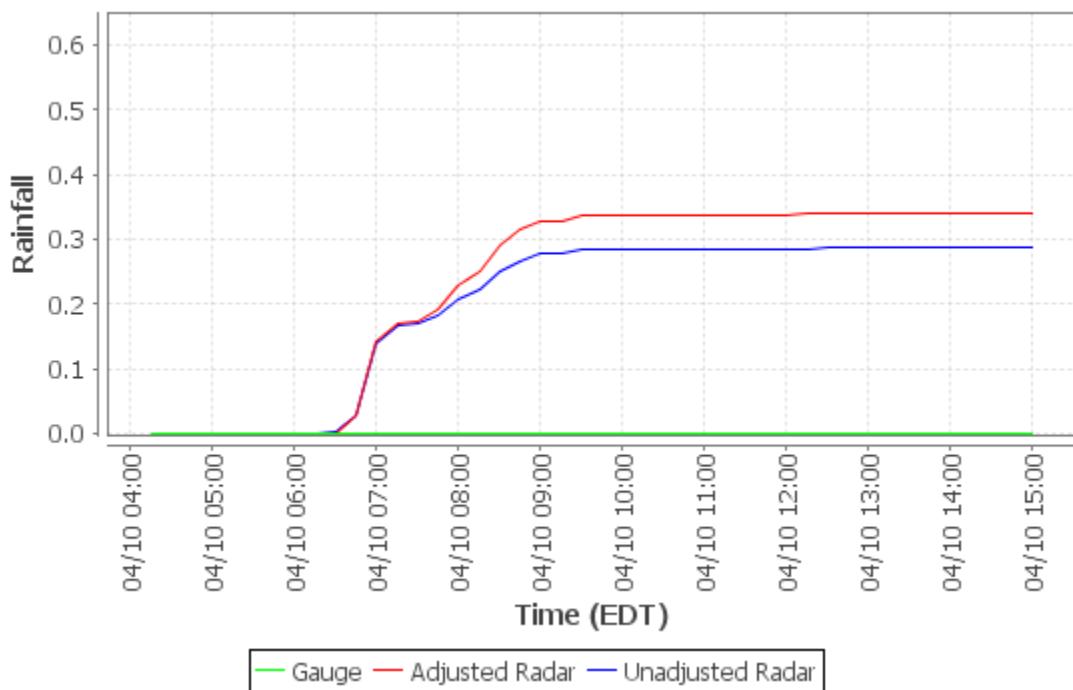
Cumulative Distribution Plot - Allegheny River at Natrona (03049500)



Cumulative Distribution Plot - Chartiers Creek at Carnegie (03085500)

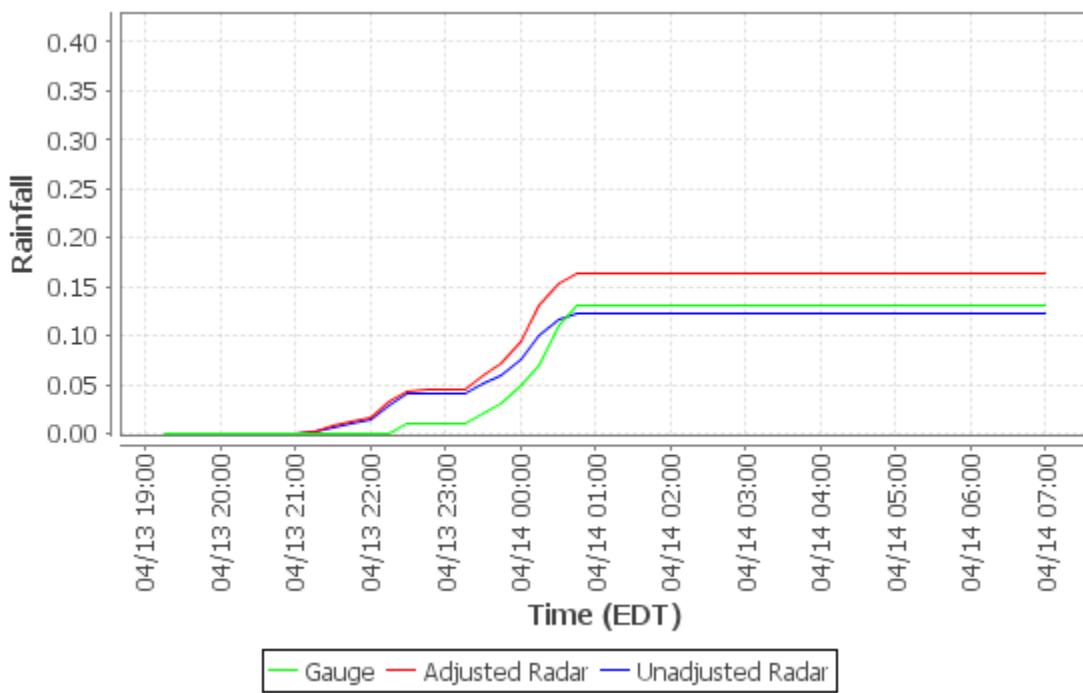


Cumulative Distribution Plot - Ohio River at Emsworth Dam Lower Pool at Emsworth (03085734)

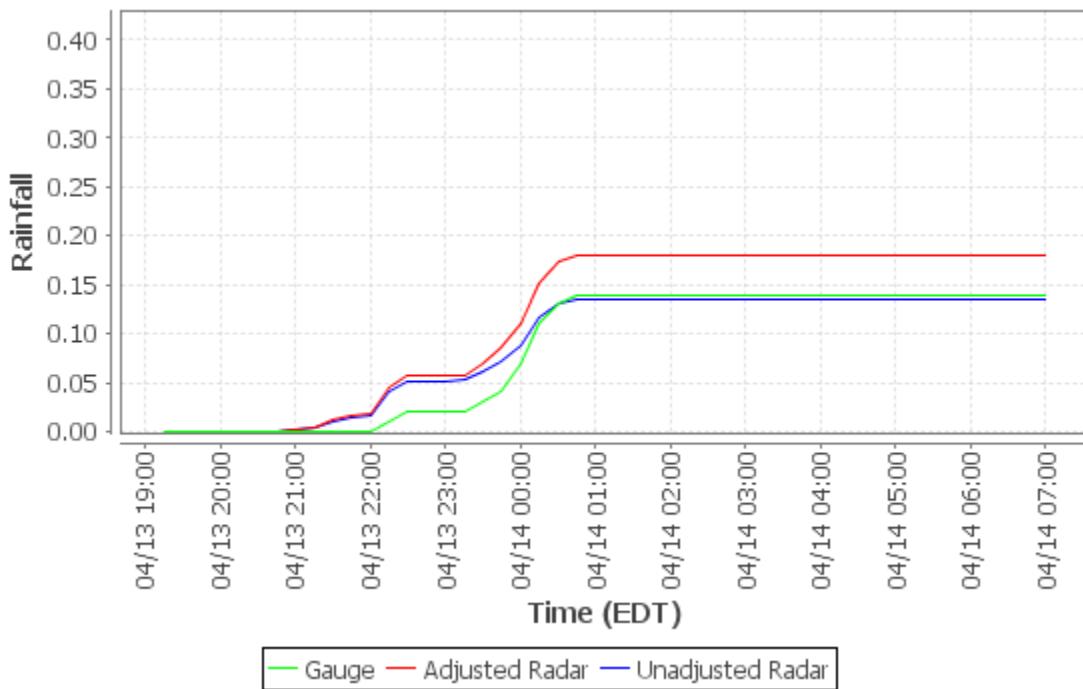


Appendix J - Event 9 (2015-04-13) CDPs

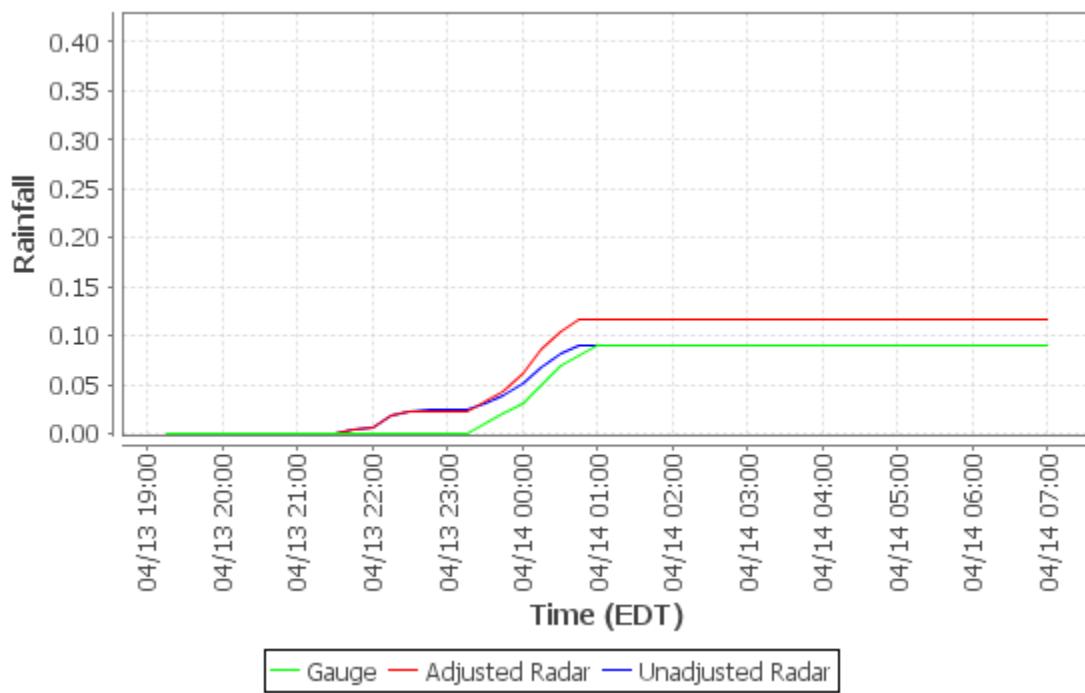
Cumulative Distribution Plot - PWSA-Montana St. (Loc01)



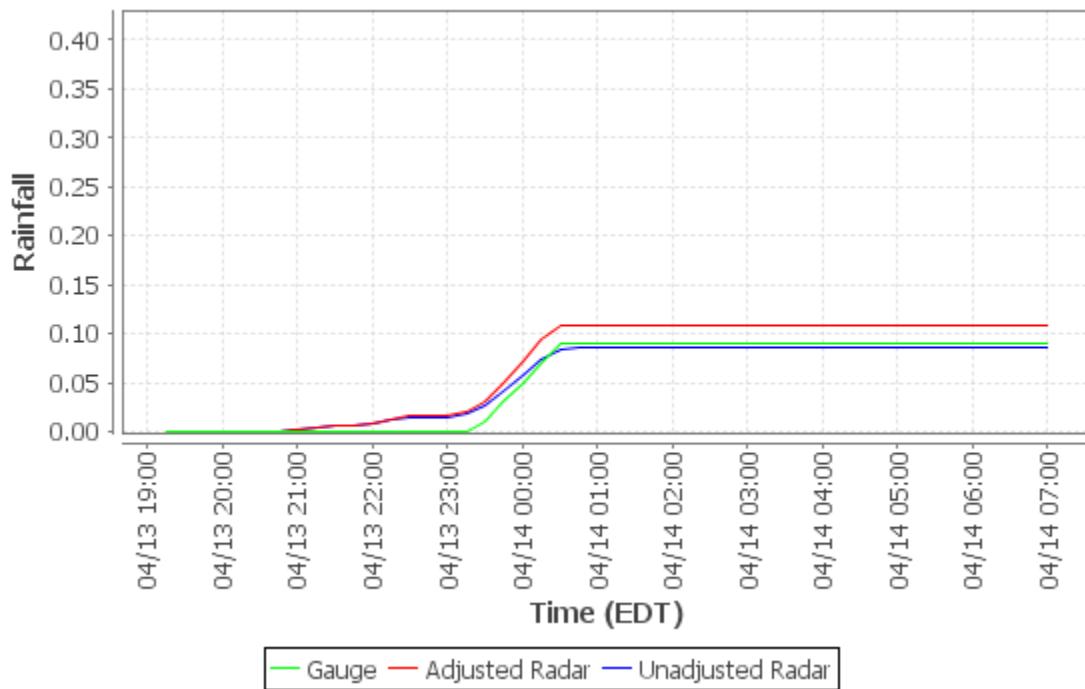
Cumulative Distribution Plot - ALCOSAN WWTP Lab (Loc02)



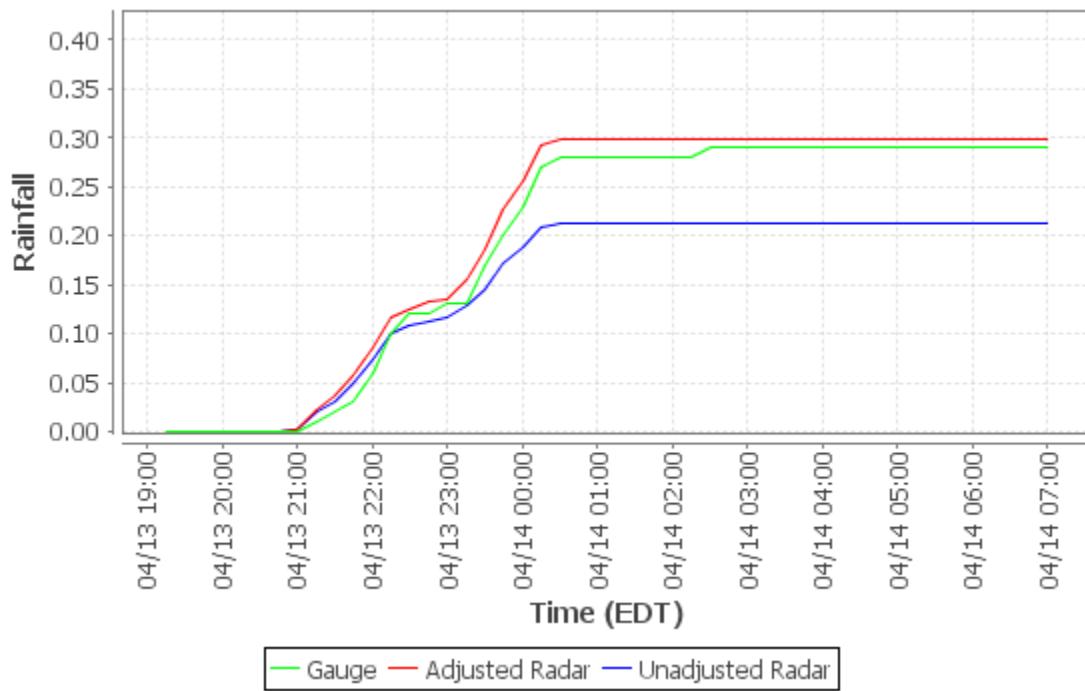
Cumulative Distribution Plot - Shaler Munic Bldg (Loc03)



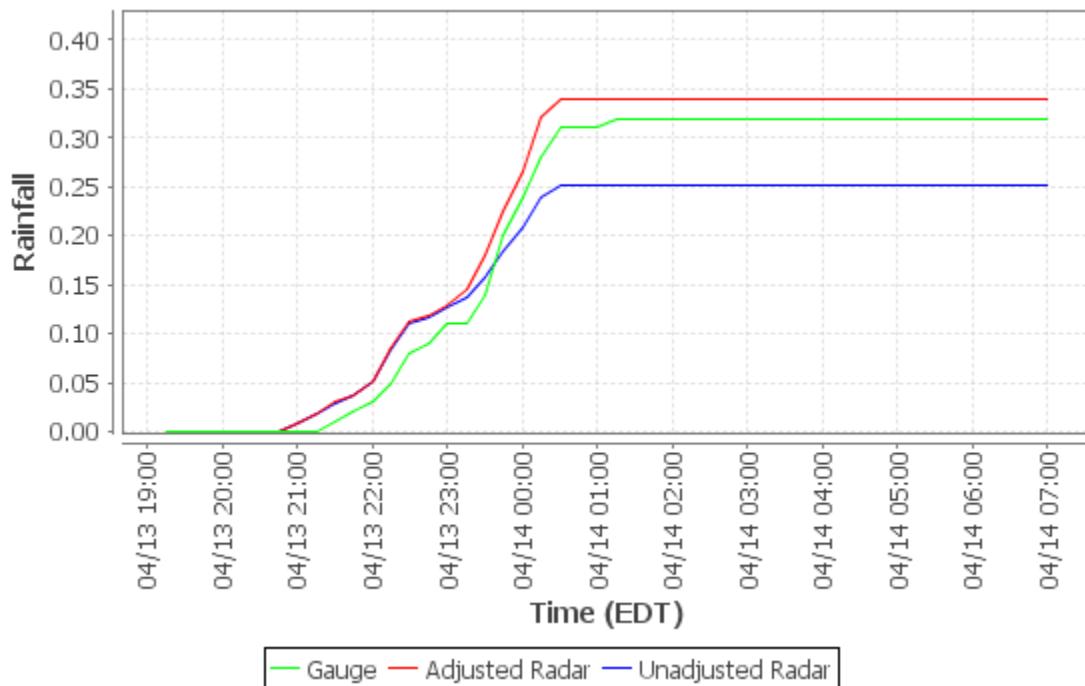
Cumulative Distribution Plot - Kennedy Twp PS (Loc04)



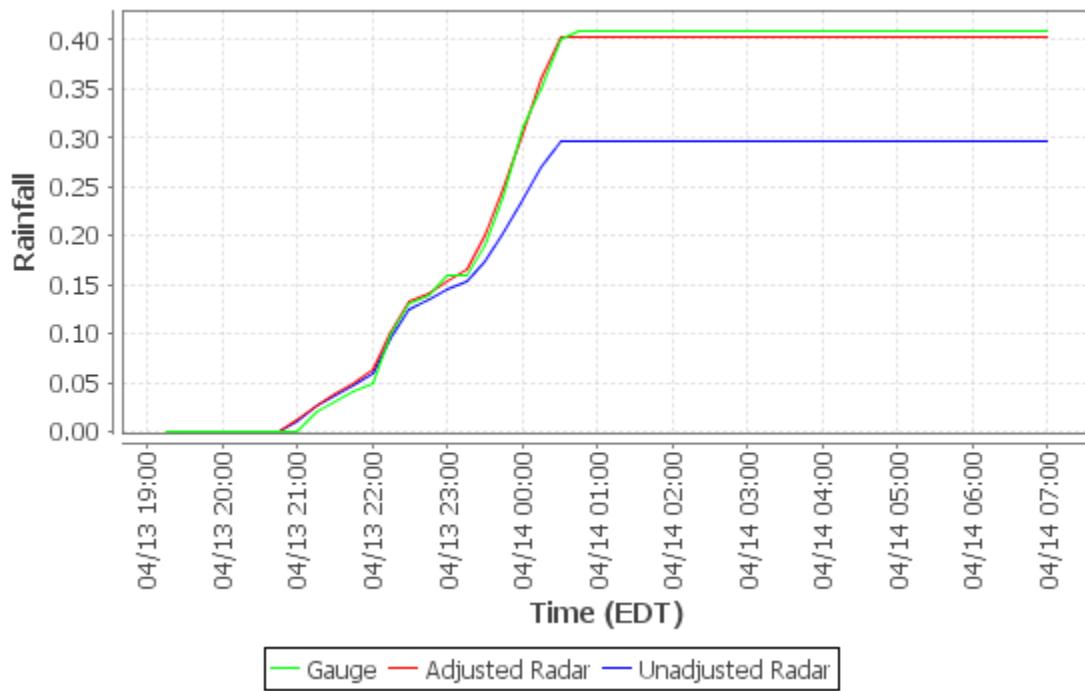
Cumulative Distribution Plot - Upper St. Clair (Loc05)



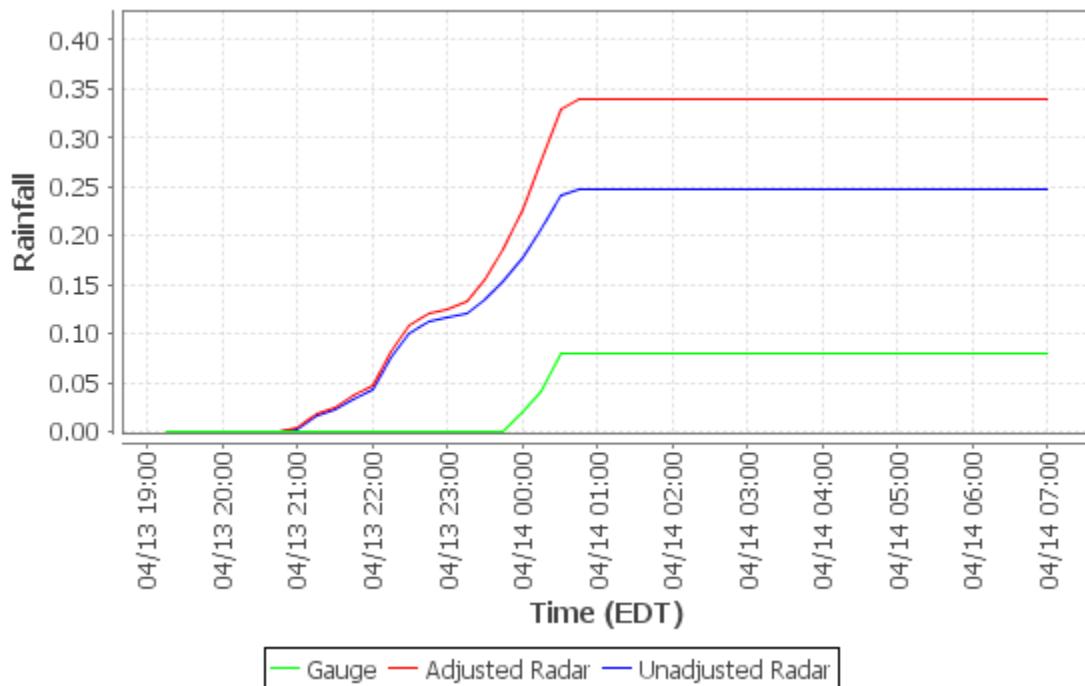
Cumulative Distribution Plot - Carnegie Transit Time (Loc06)



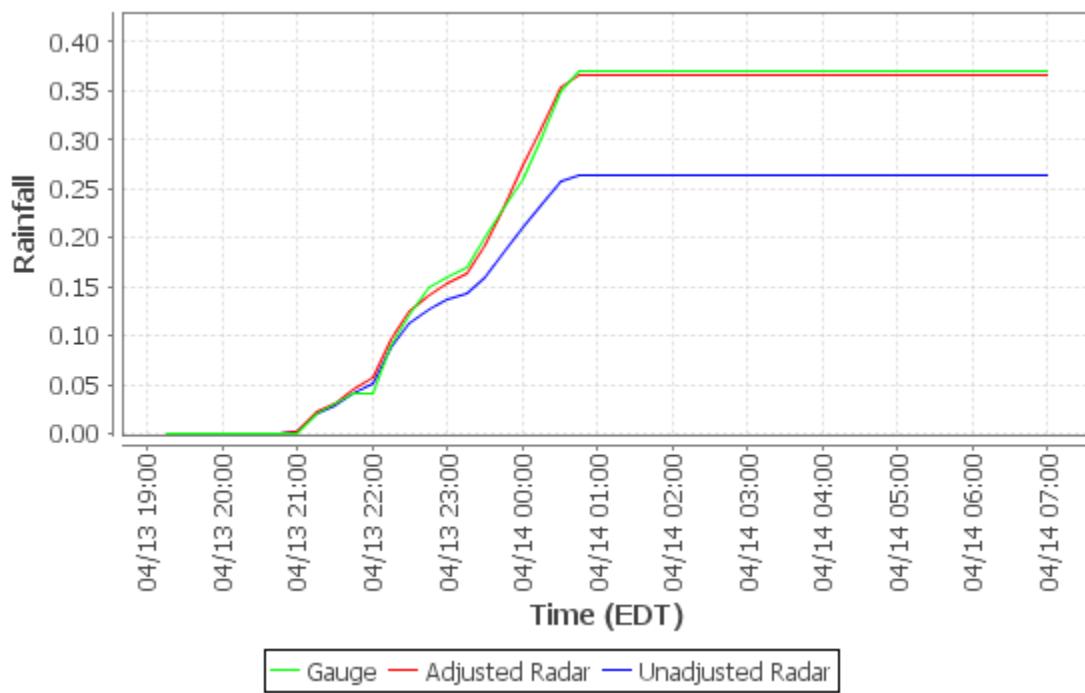
Cumulative Distribution Plot - Greentree Munic Bldg (Loc07)



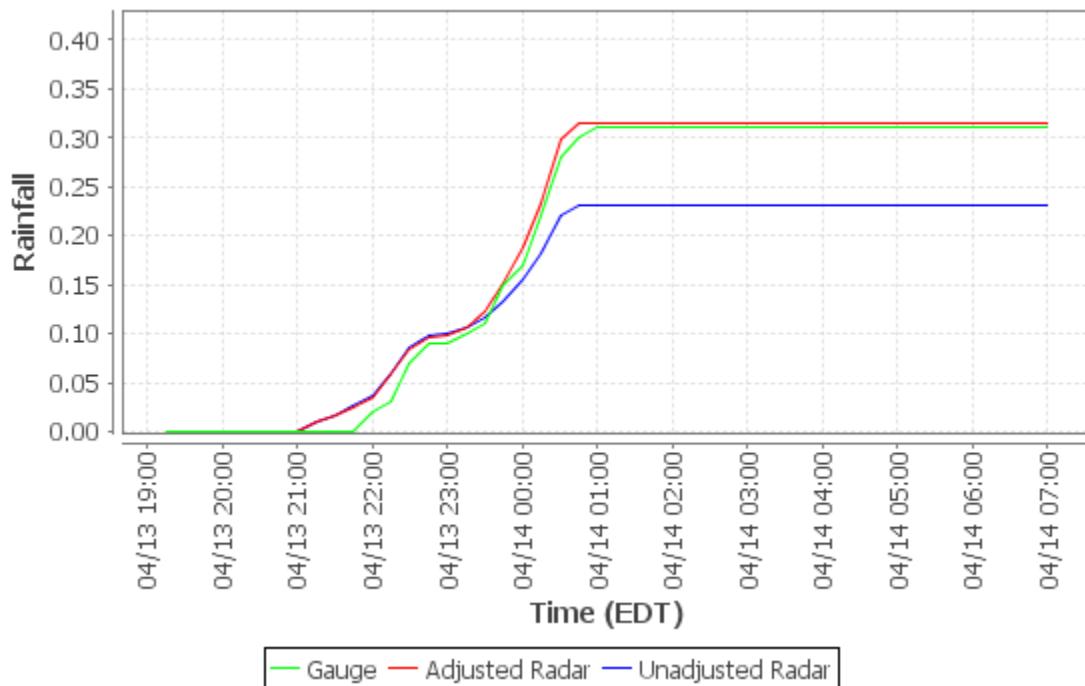
Cumulative Distribution Plot - AC Health Dept Bldg (Loc08)



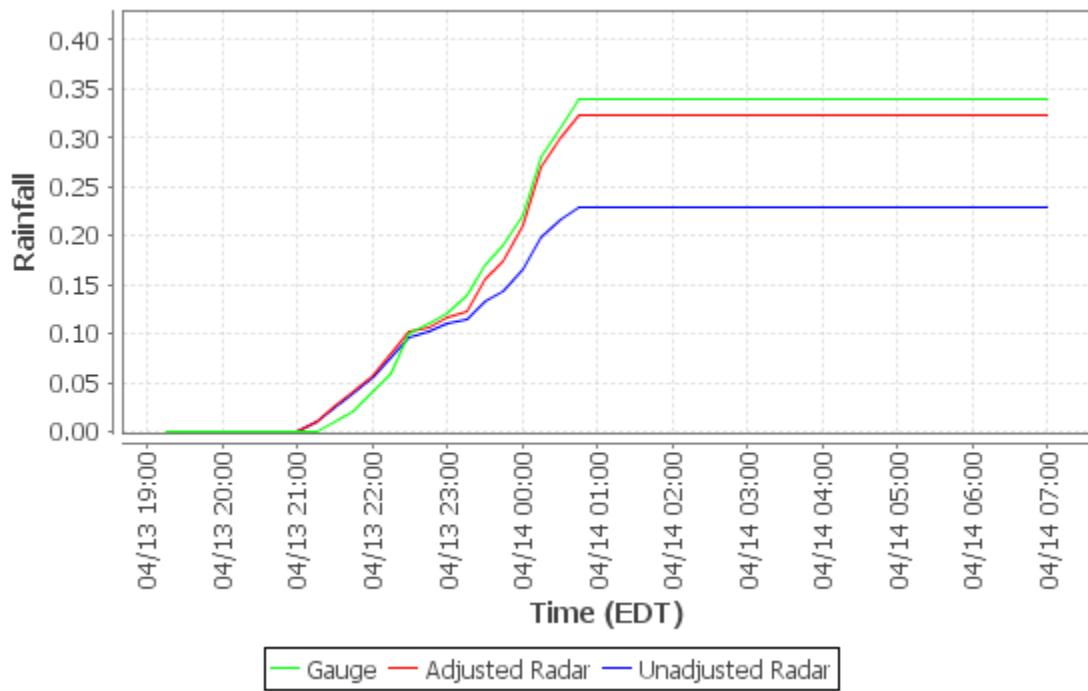
Cumulative Distribution Plot - Univ of Pittsburgh (Loc09)



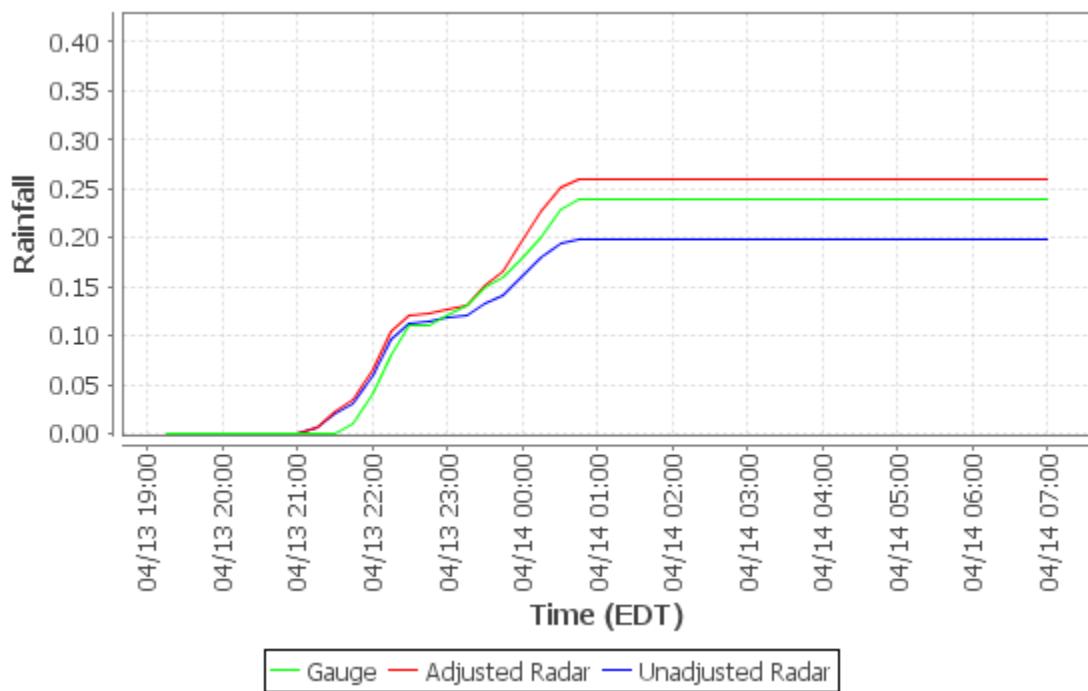
Cumulative Distribution Plot - PWSA-Highland Park (Loc10)



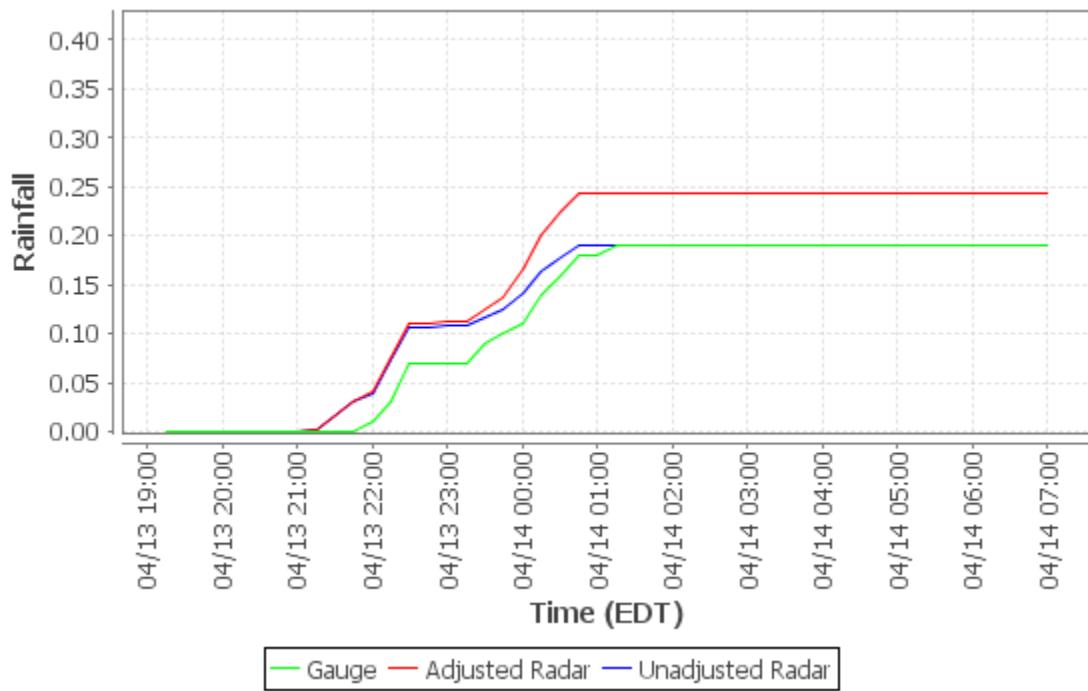
Cumulative Distribution Plot - M-46 Access Shaft (Loc11)



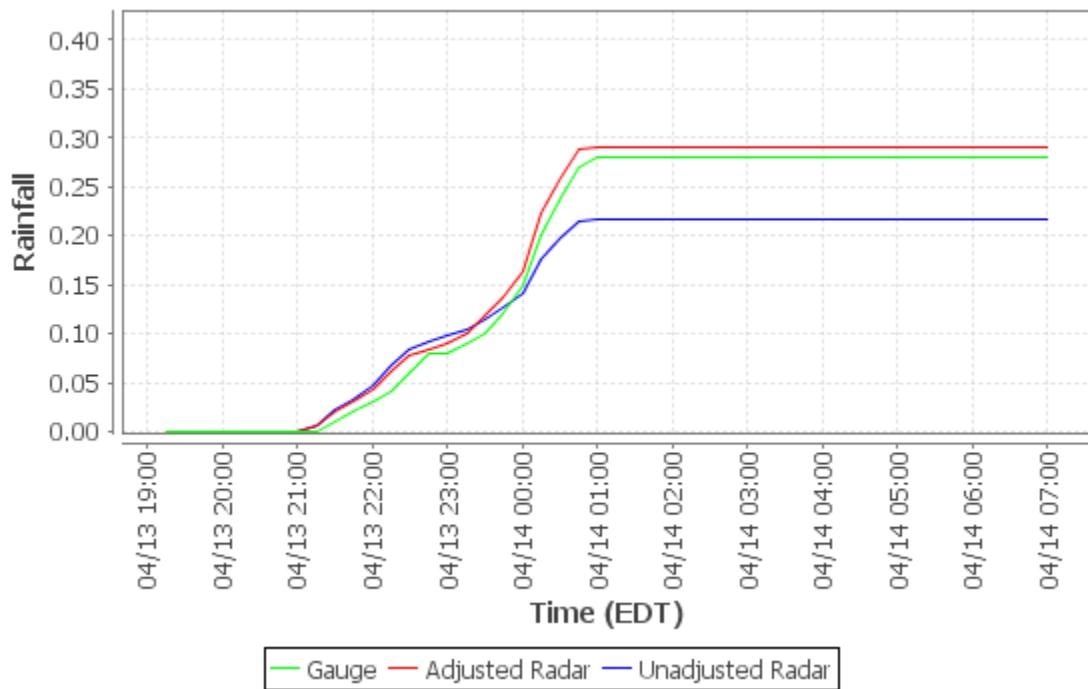
Cumulative Distribution Plot - Baldwin (Loc12)



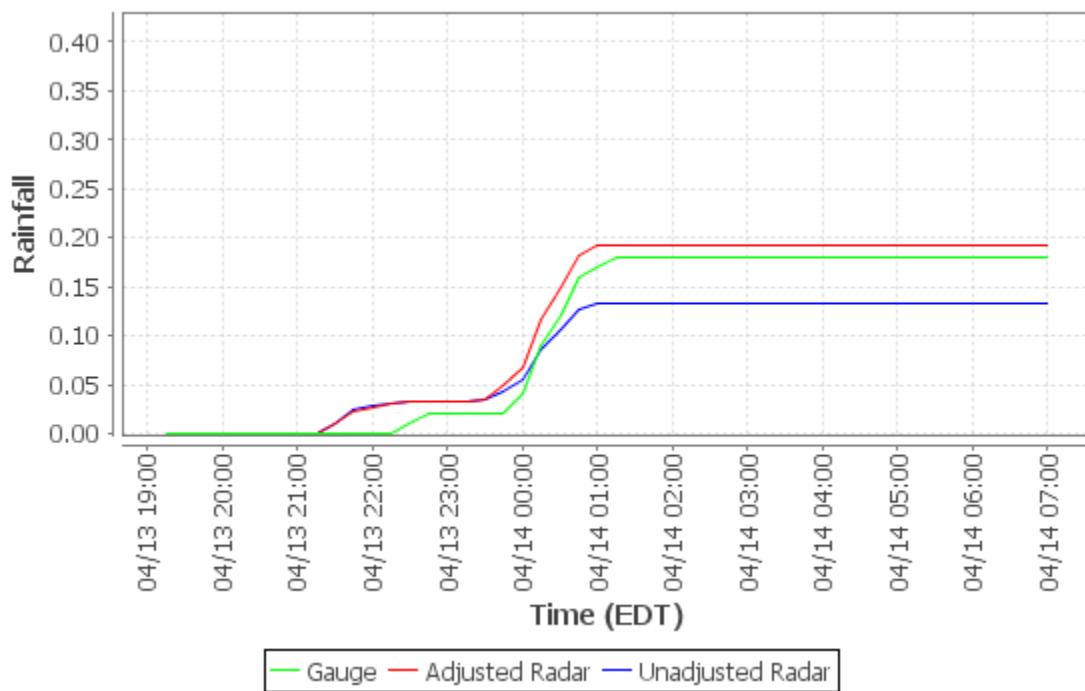
Cumulative Distribution Plot - M-59 Access Shaft (Loc13)



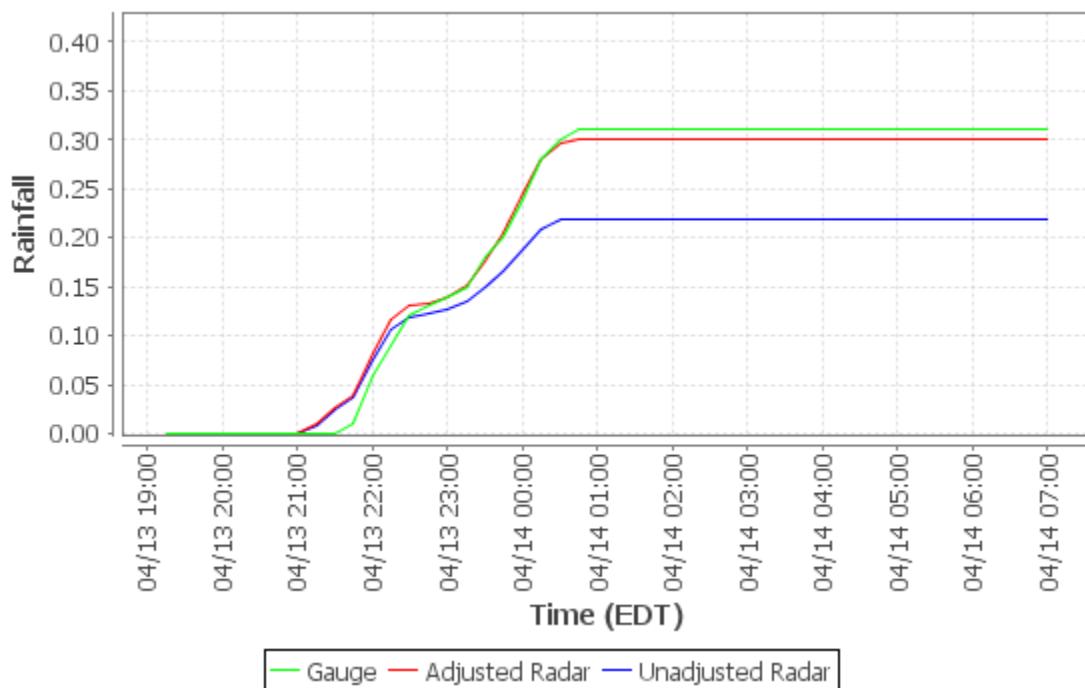
Cumulative Distribution Plot - Churchill Munic Bldg (Loc14)



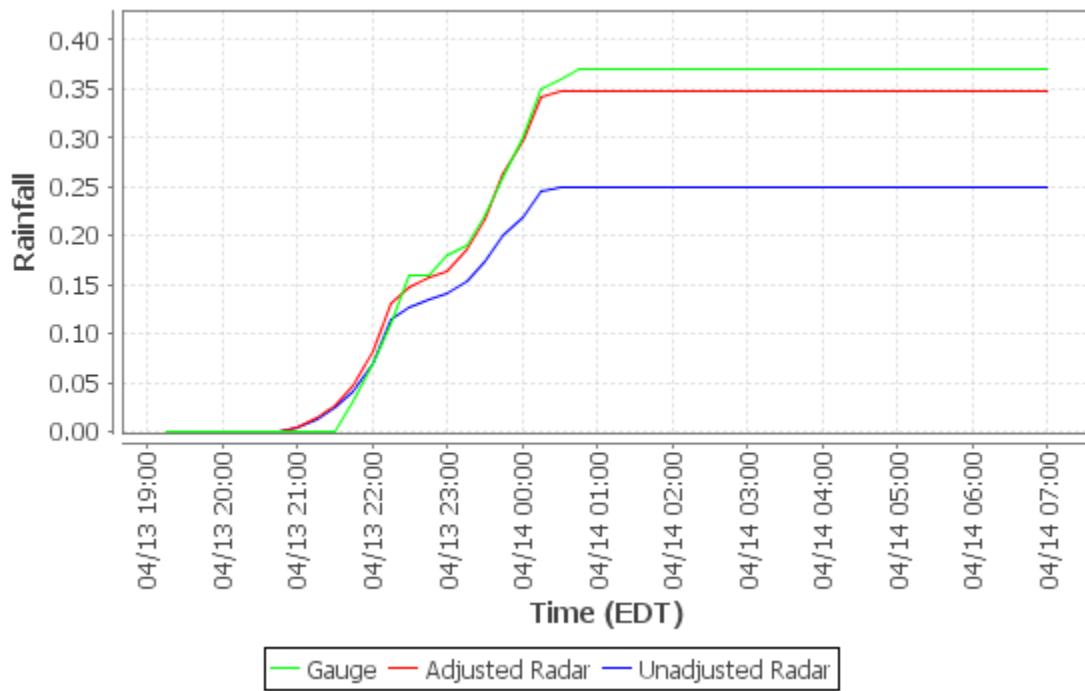
Cumulative Distribution Plot - Trafford Maint Bldg (Loc15)



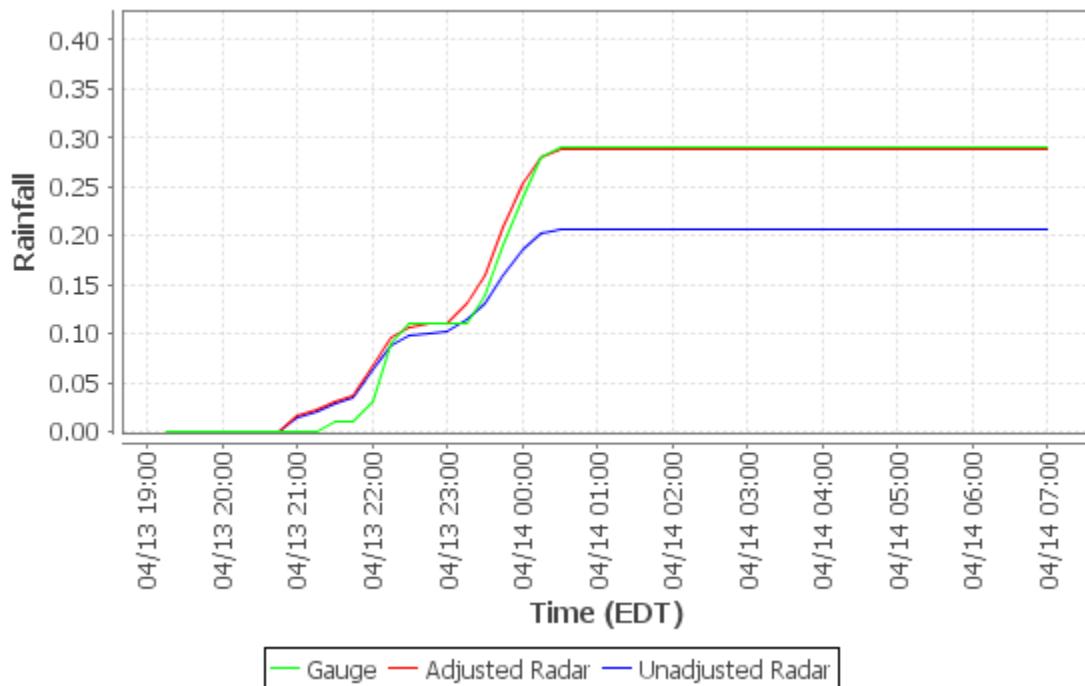
Cumulative Distribution Plot - Castle Shannon (Loc16)



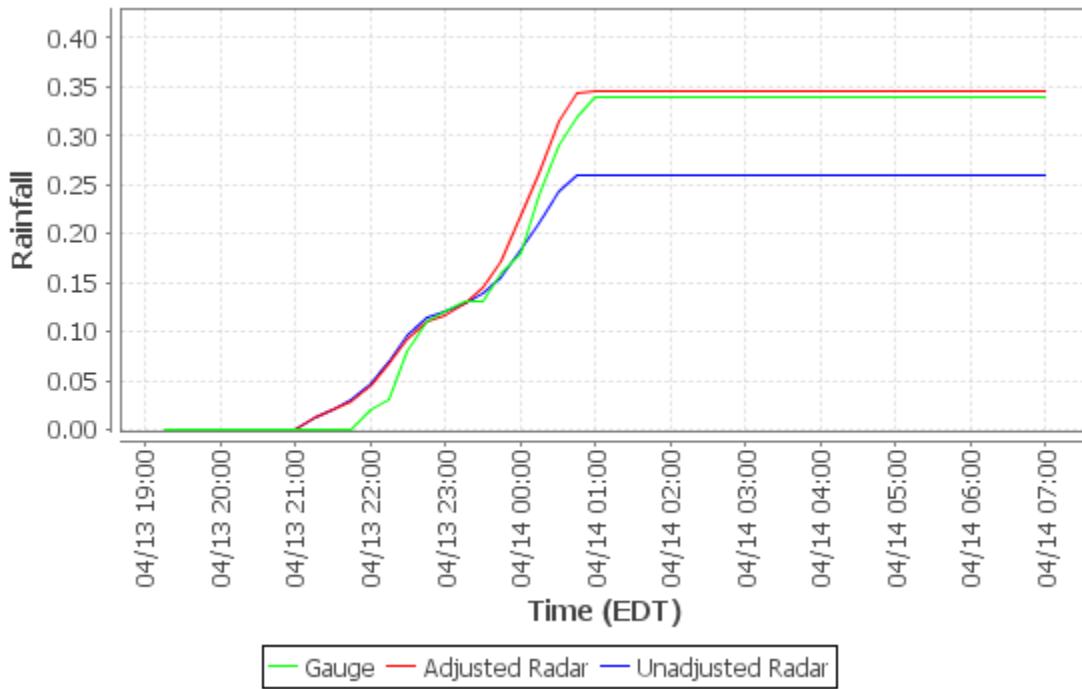
Cumulative Distribution Plot - Chartiers Pump Station (Loc17)



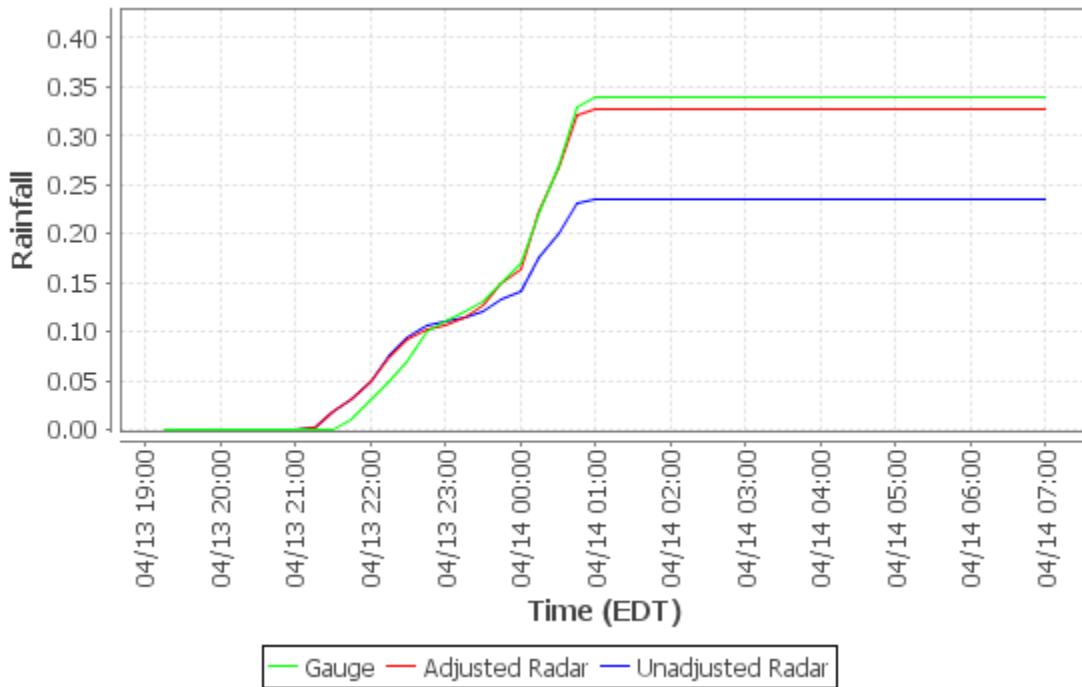
Cumulative Distribution Plot - Oakdale Pump Station (Loc18)



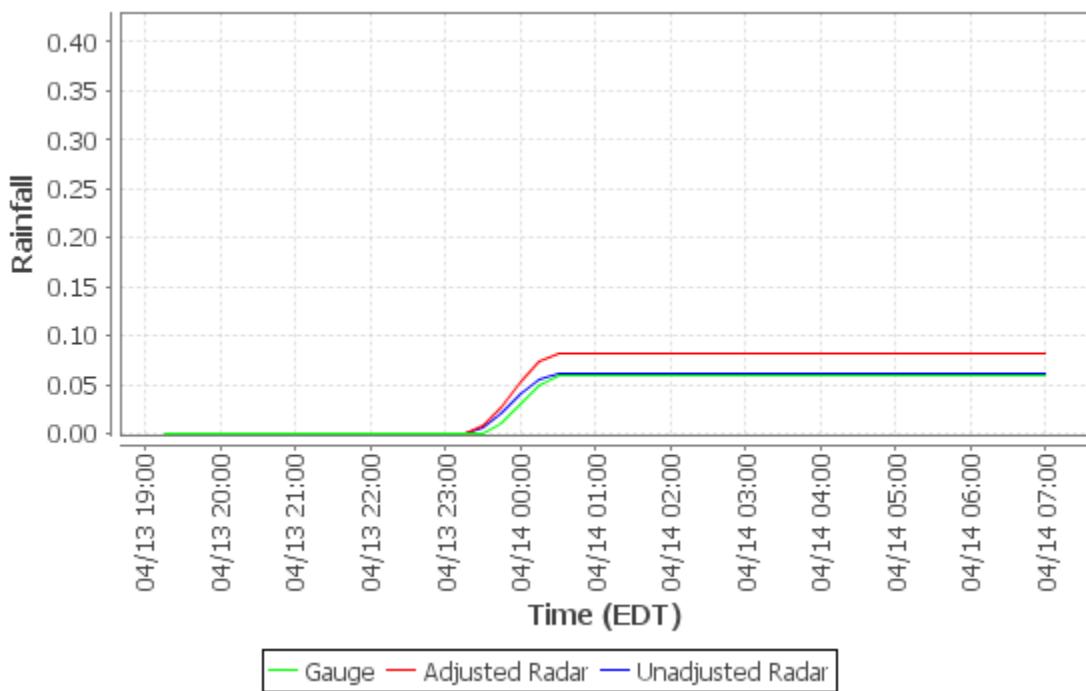
Cumulative Distribution Plot - Sandy Creek Eq Facility (Loc19)



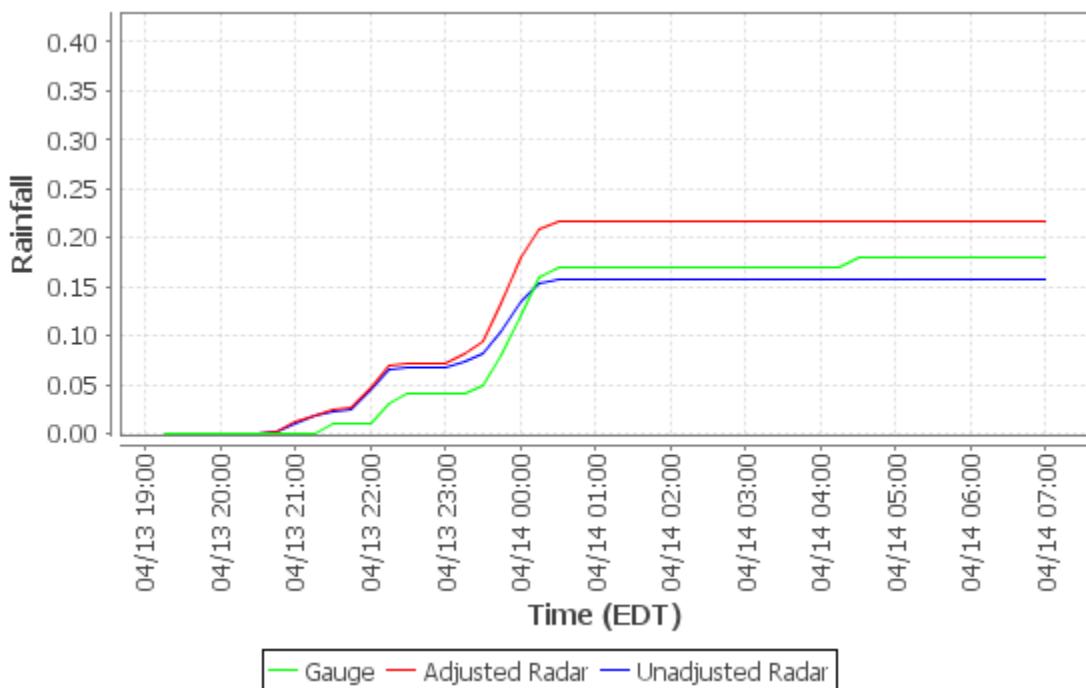
Cumulative Distribution Plot - Gascola Eq Facility (Loc20)



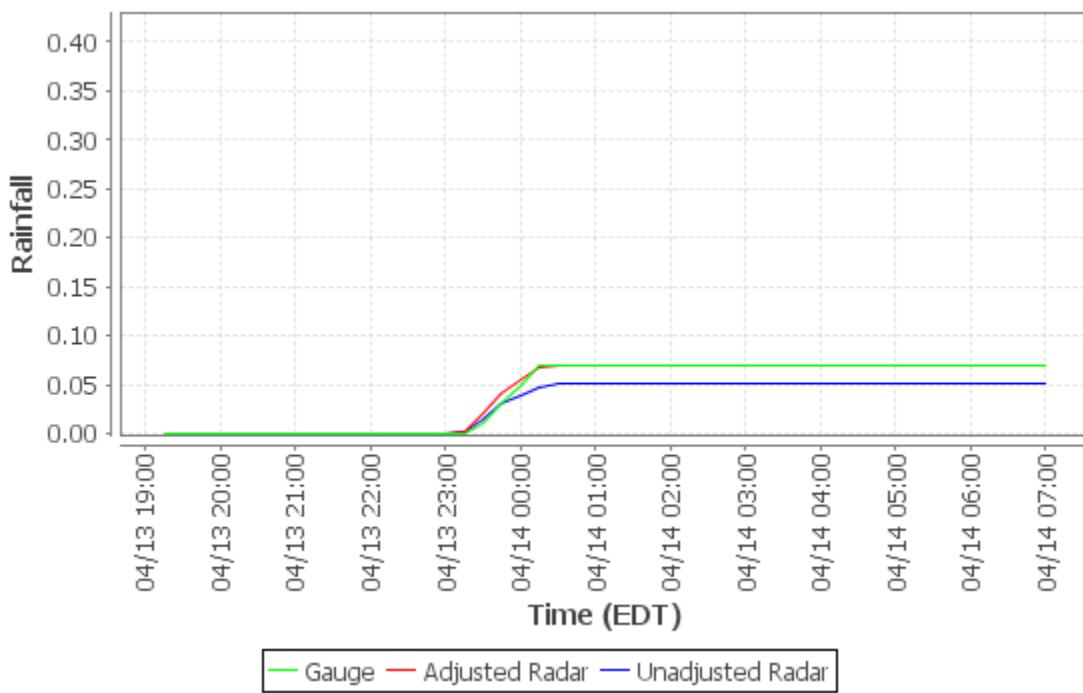
Cumulative Distribution Plot - Moon TWP (Loc21)



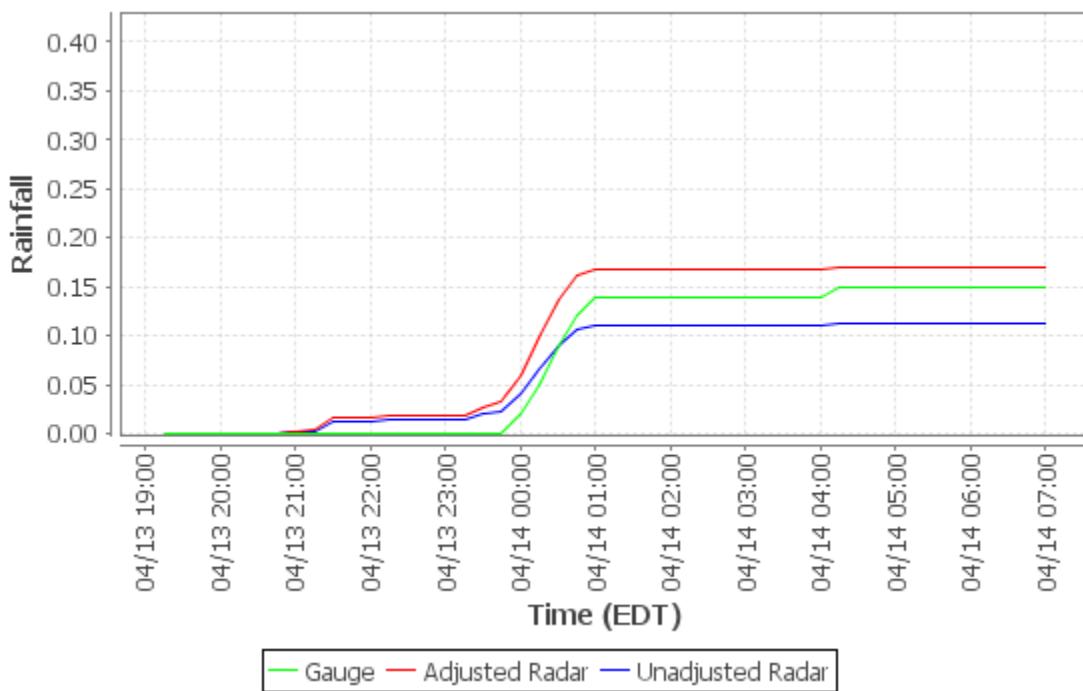
Cumulative Distribution Plot - North Fayette TWP (Loc22)



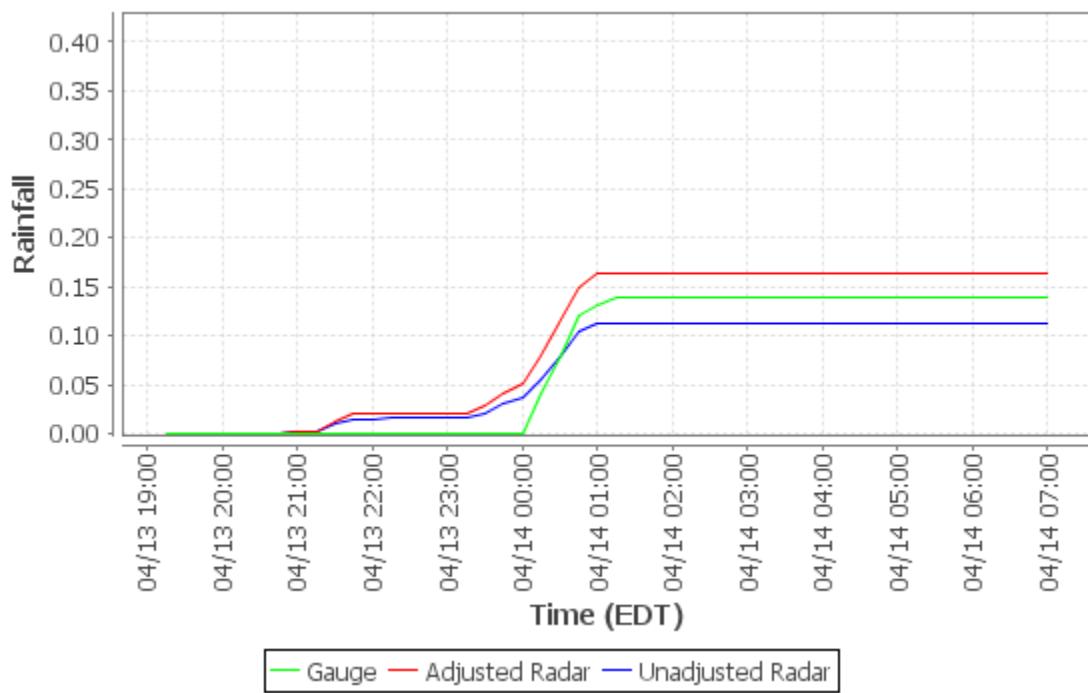
Cumulative Distribution Plot - Clinton Munic Bldg (Loc23)



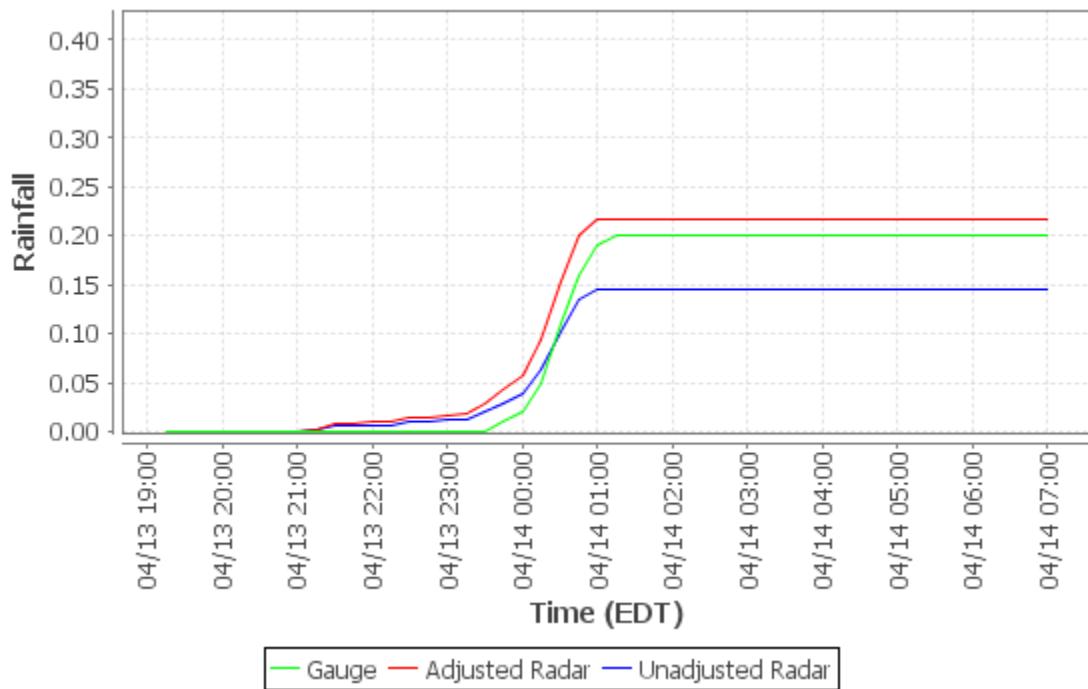
Cumulative Distribution Plot - Jefferson Hills (Loc24)



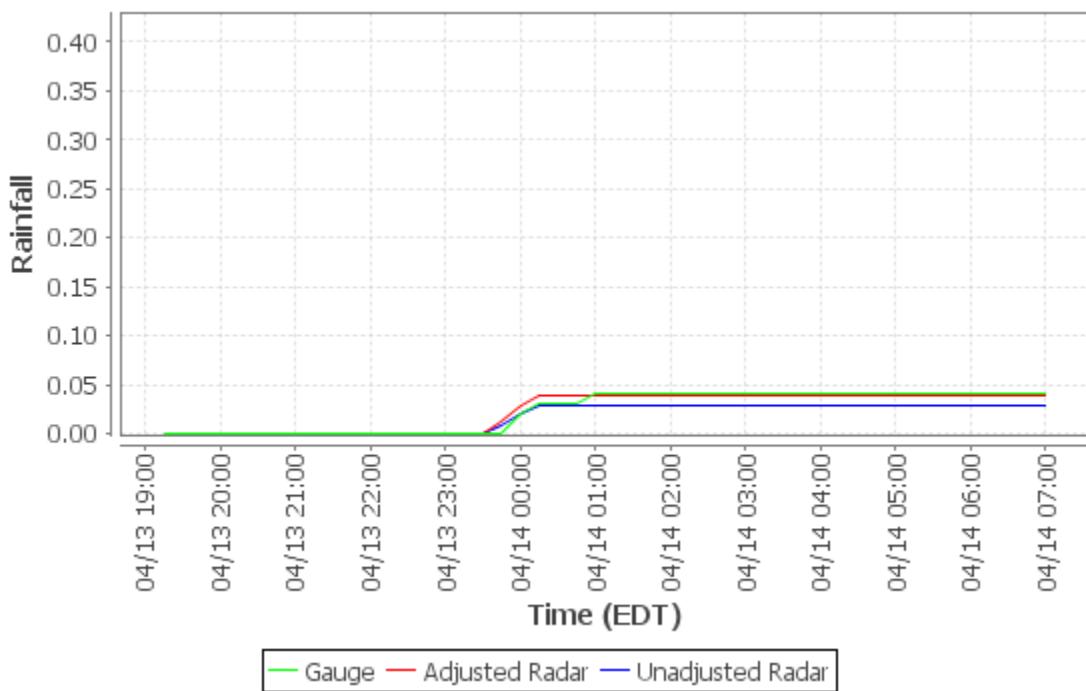
Cumulative Distribution Plot - White Oak Public Works Bldg (Loc25)



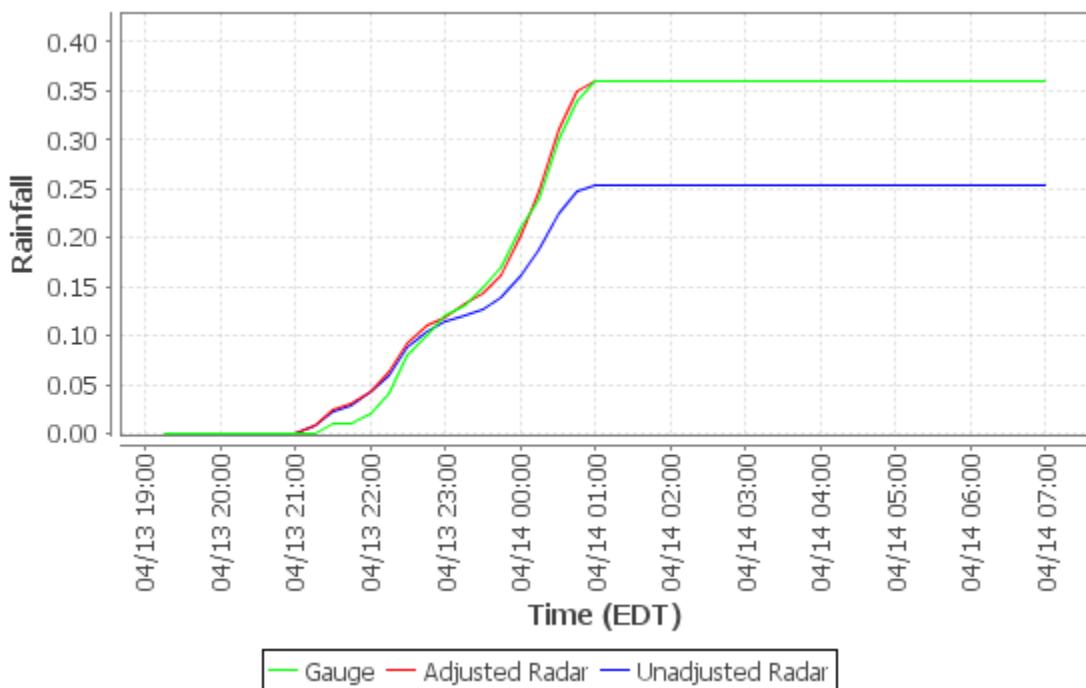
Cumulative Distribution Plot - Elizabeth TWP Municipal Bldg (Loc26)



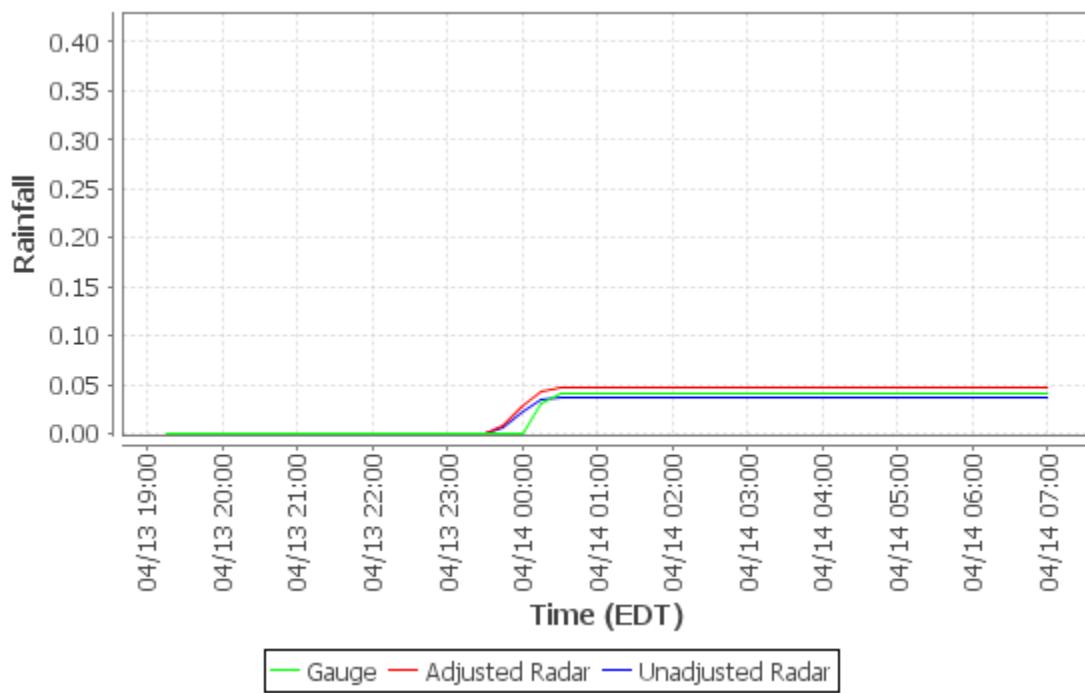
Cumulative Distribution Plot - Marshall TWP (Loc27)



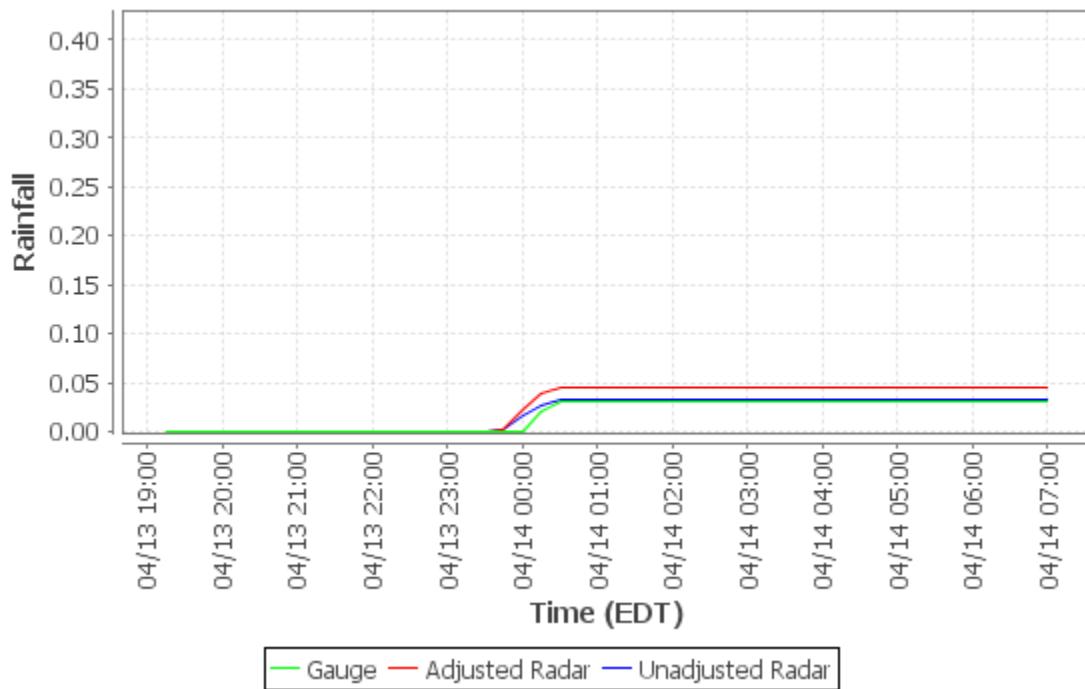
Cumulative Distribution Plot - Plum Municipal Bldg (Loc28)



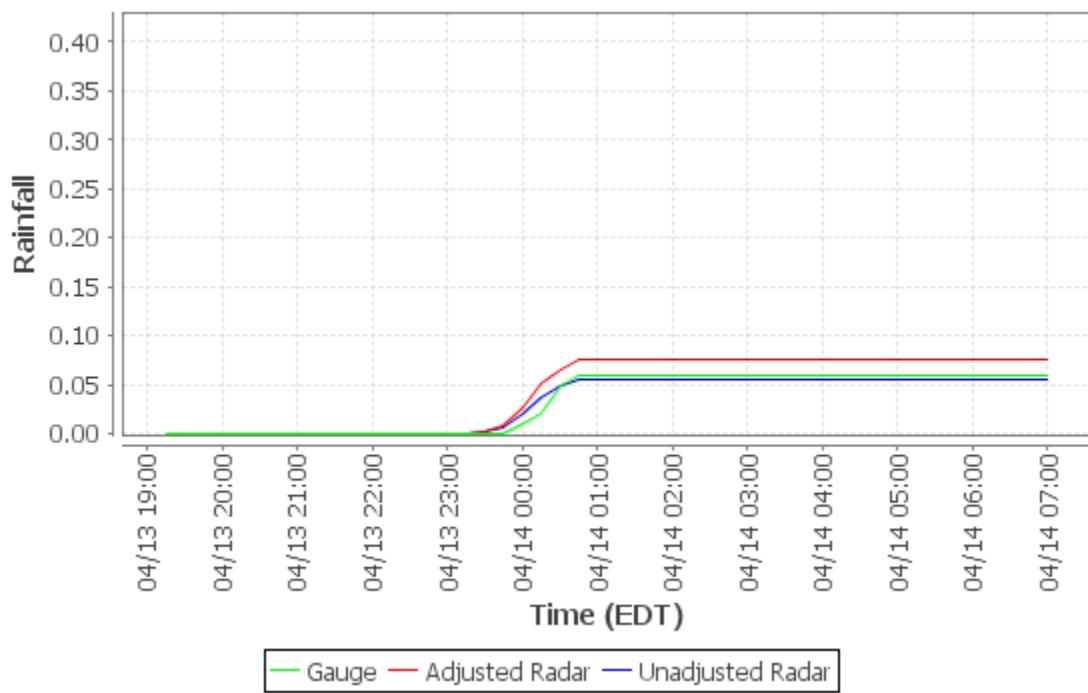
Cumulative Distribution Plot - Bell Acres Munic Bldg (Loc29)



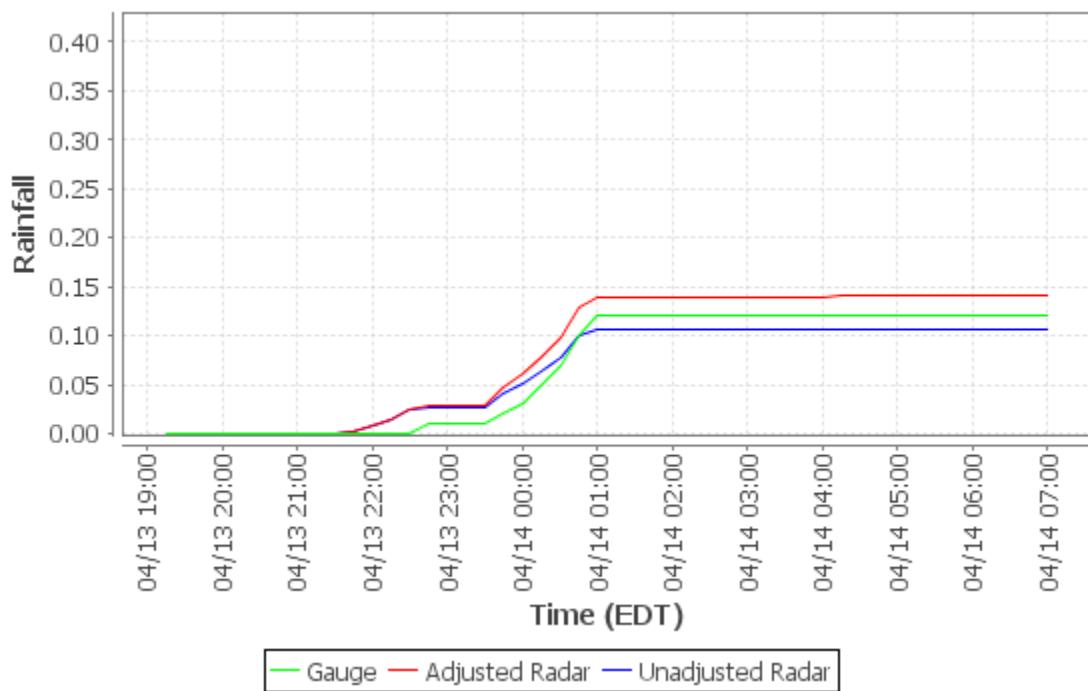
Cumulative Distribution Plot - McCandless Twn Hall (Loc30)



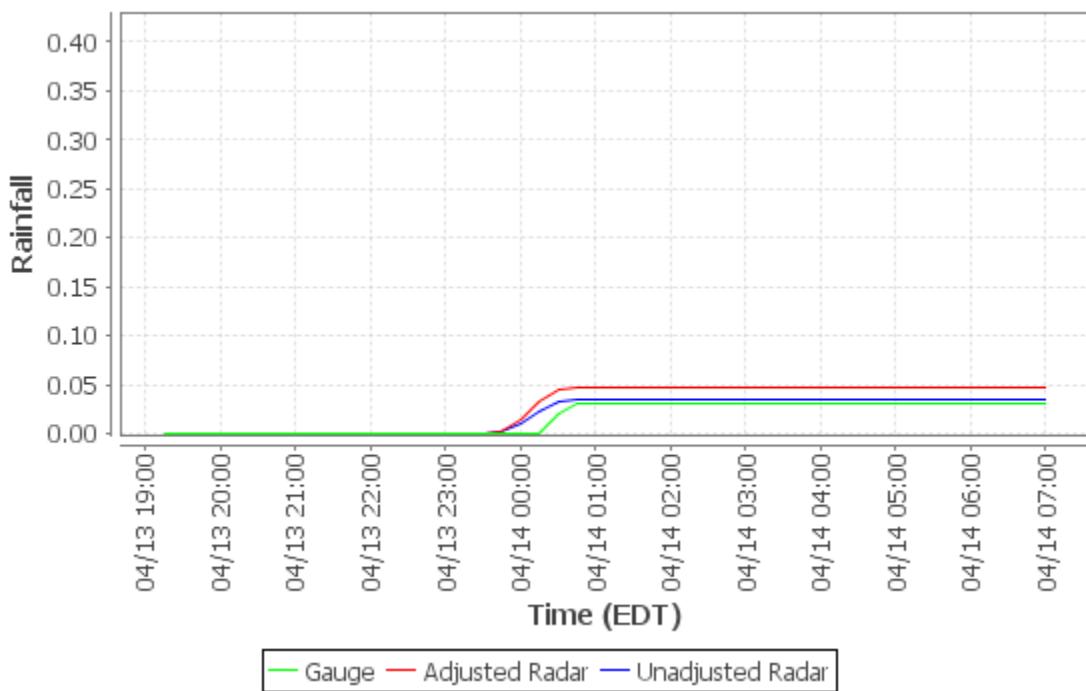
Cumulative Distribution Plot - Hampton Municipal Bldg (Loc31)



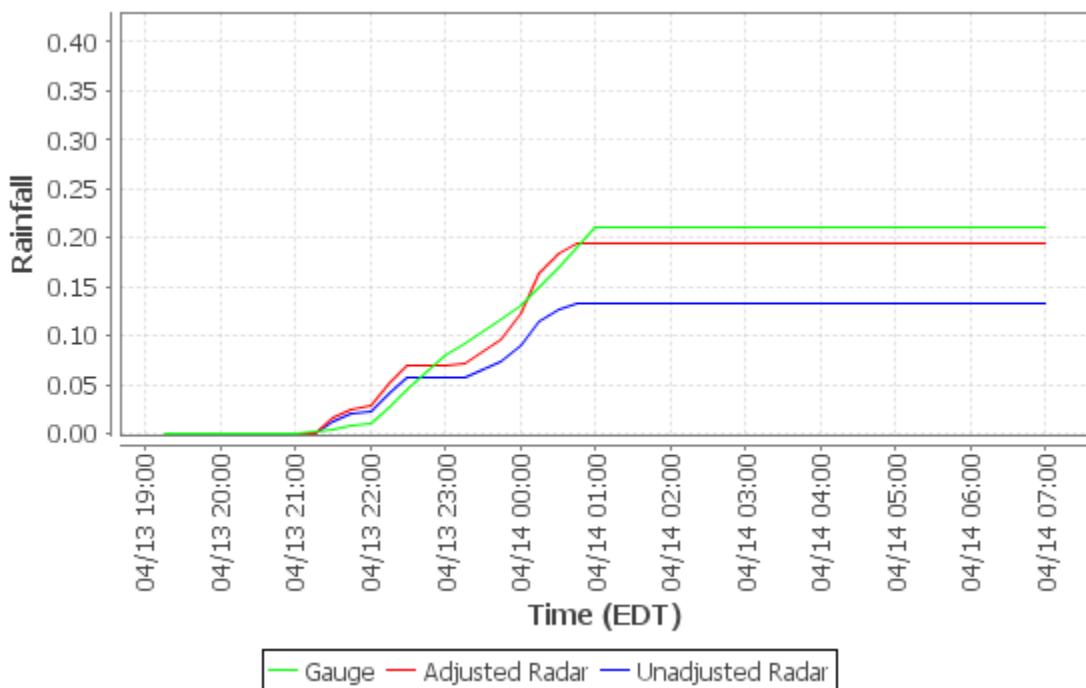
Cumulative Distribution Plot - Arnold (Loc32)



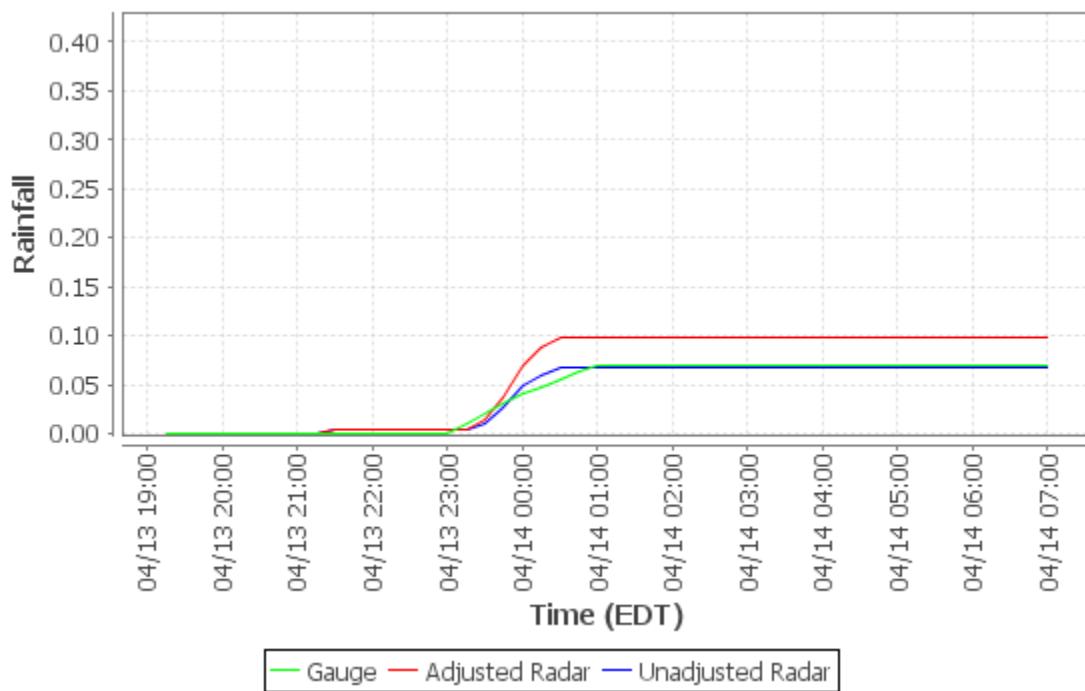
Cumulative Distribution Plot - Richland TWP (Loc33)



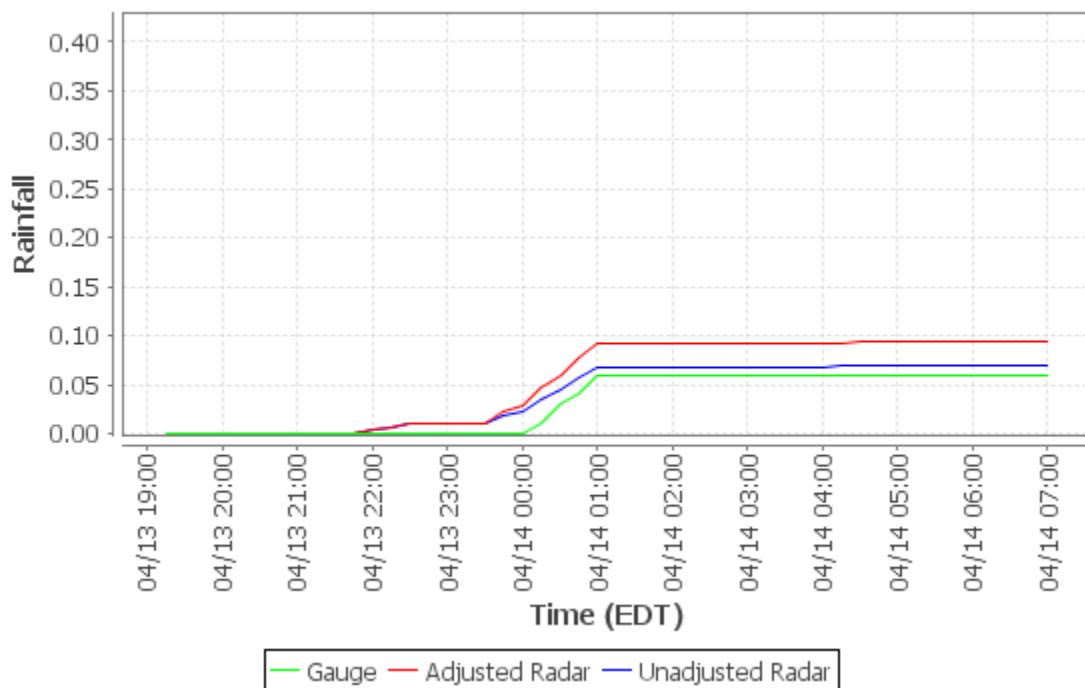
Cumulative Distribution Plot - Pittsburgh Allegheny Cty (KAGC)



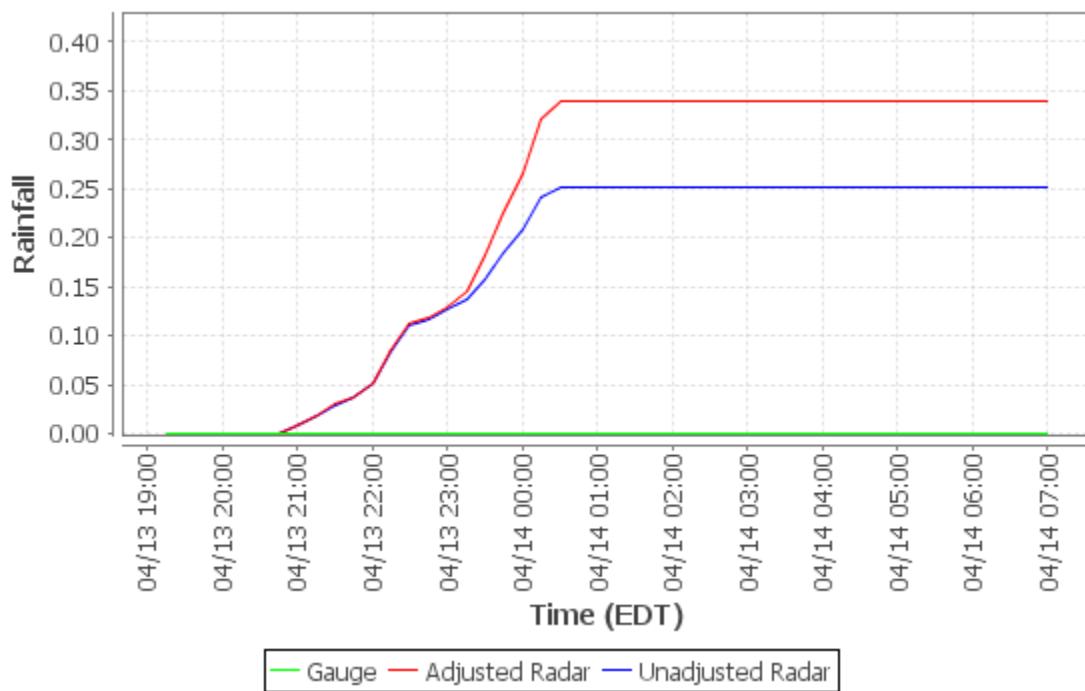
Cumulative Distribution Plot - Greater Pittsburgh Int'l (KPIT)



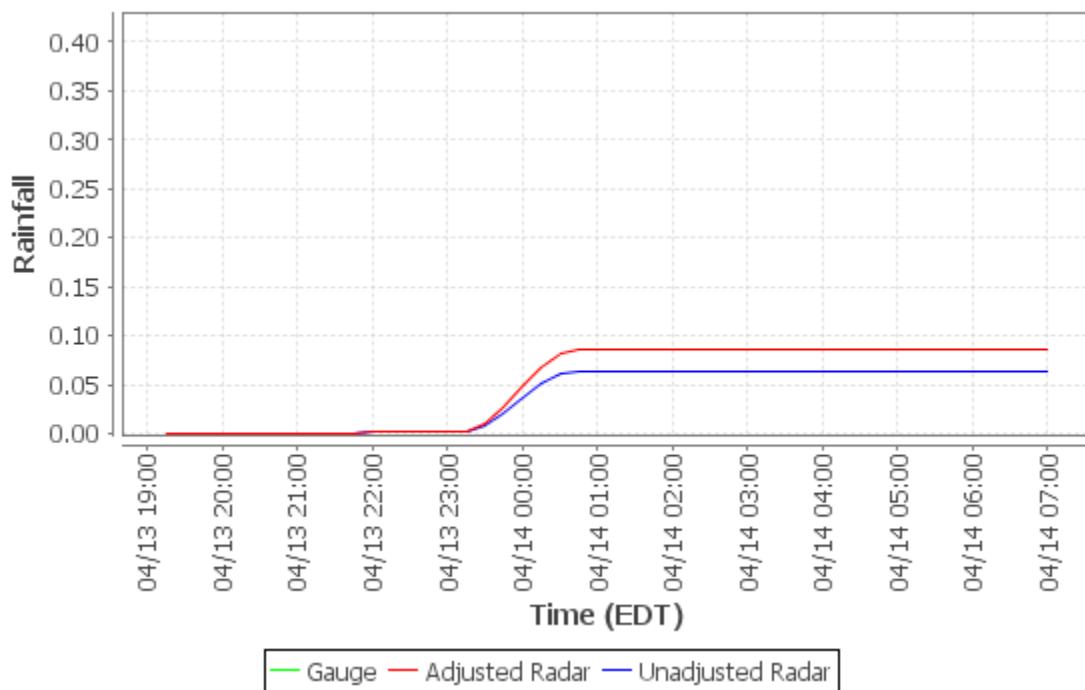
Cumulative Distribution Plot - Allegheny River at Natrona (03049500)



Cumulative Distribution Plot - Chartiers Creek at Carnegie (03085500)

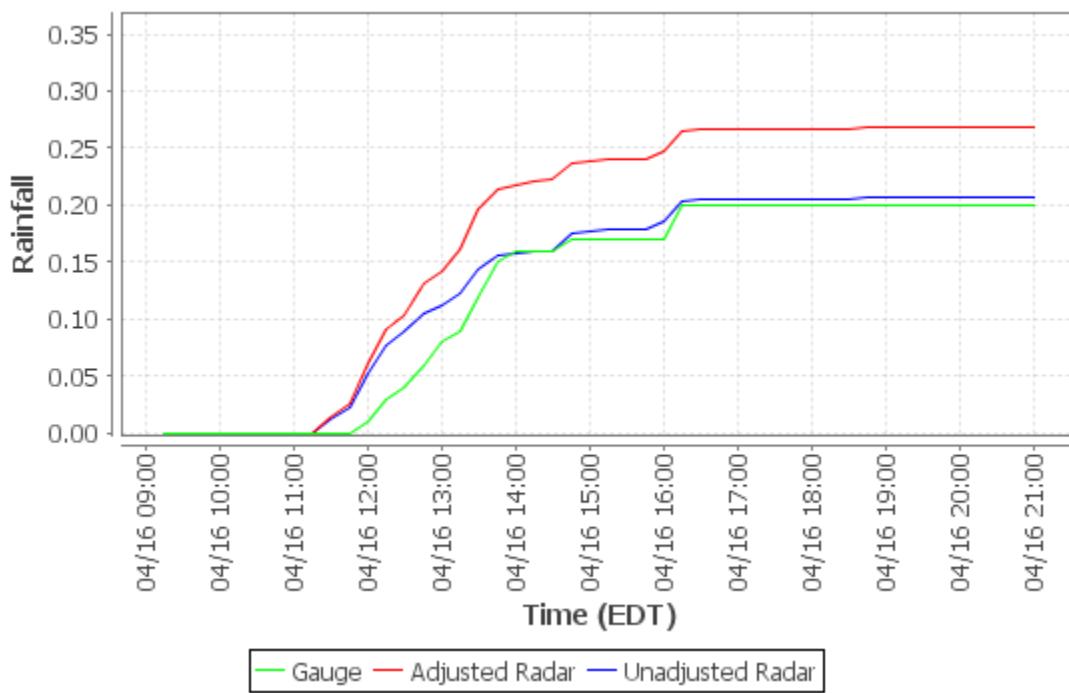


Cumulative Distribution Plot - Ohio River at Emsworth Dam Lower Pool at Emsworth (03085734)

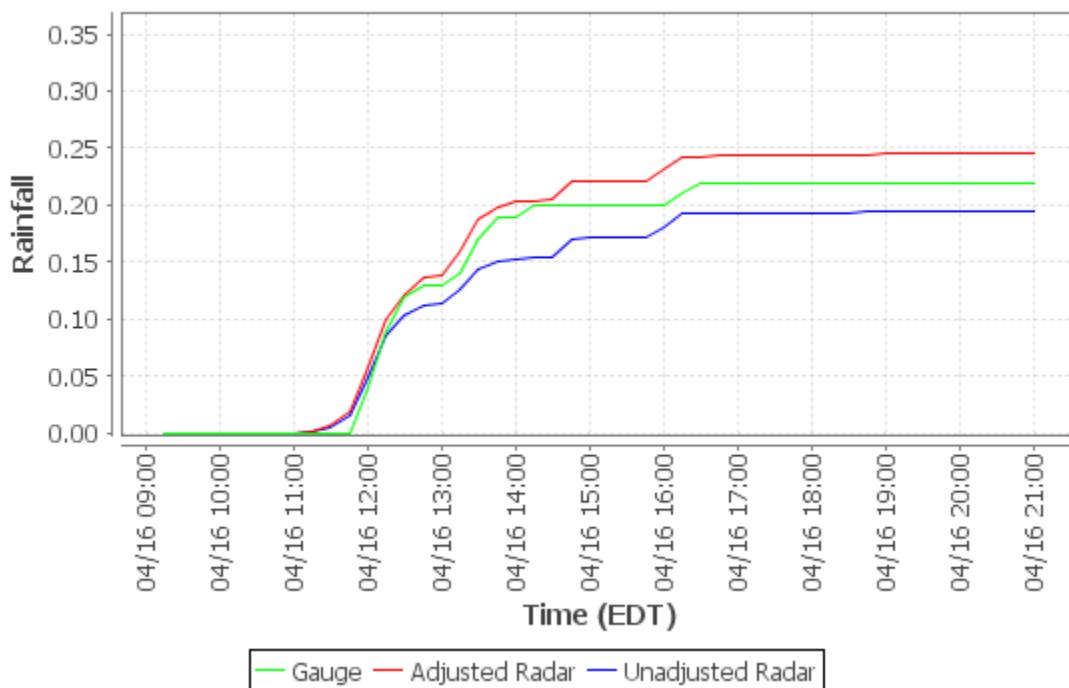


Appendix K - Event 10 (2015-04-16) CDPs

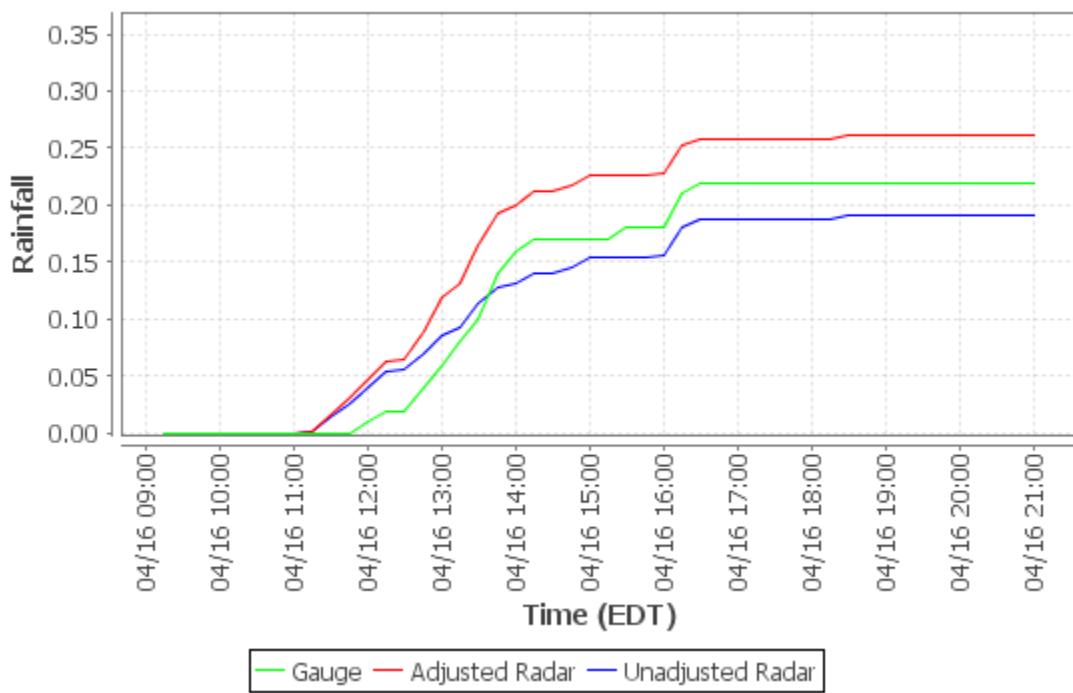
Cumulative Distribution Plot - PWSA-Montana St. (Loc01)



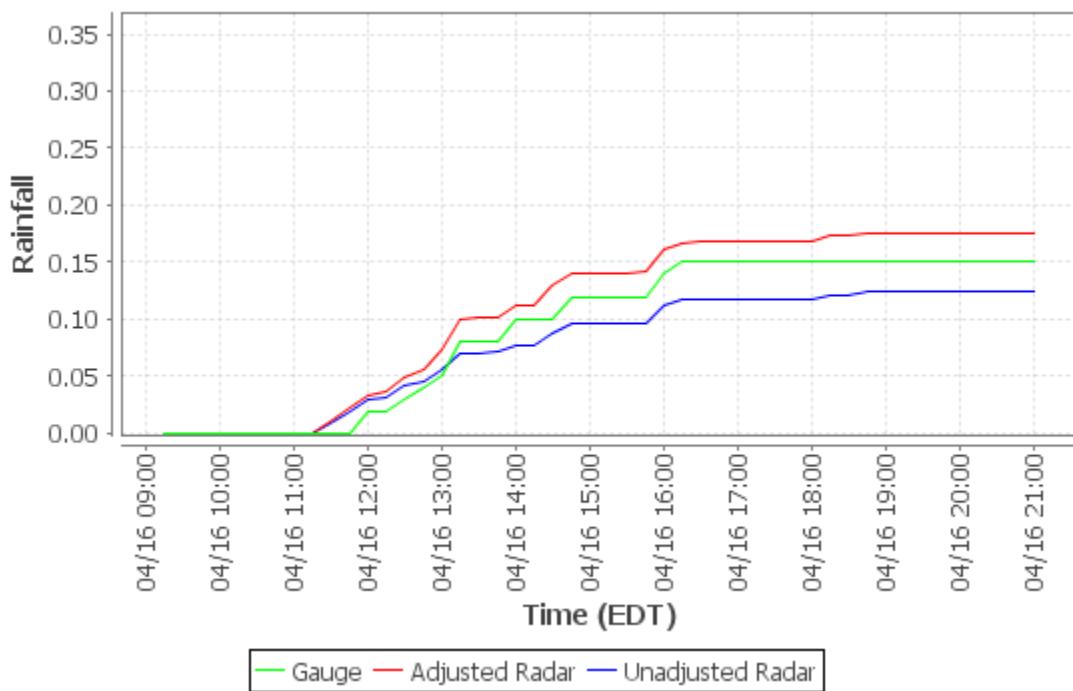
Cumulative Distribution Plot - ALCOSAN WWTP Lab (Loc02)



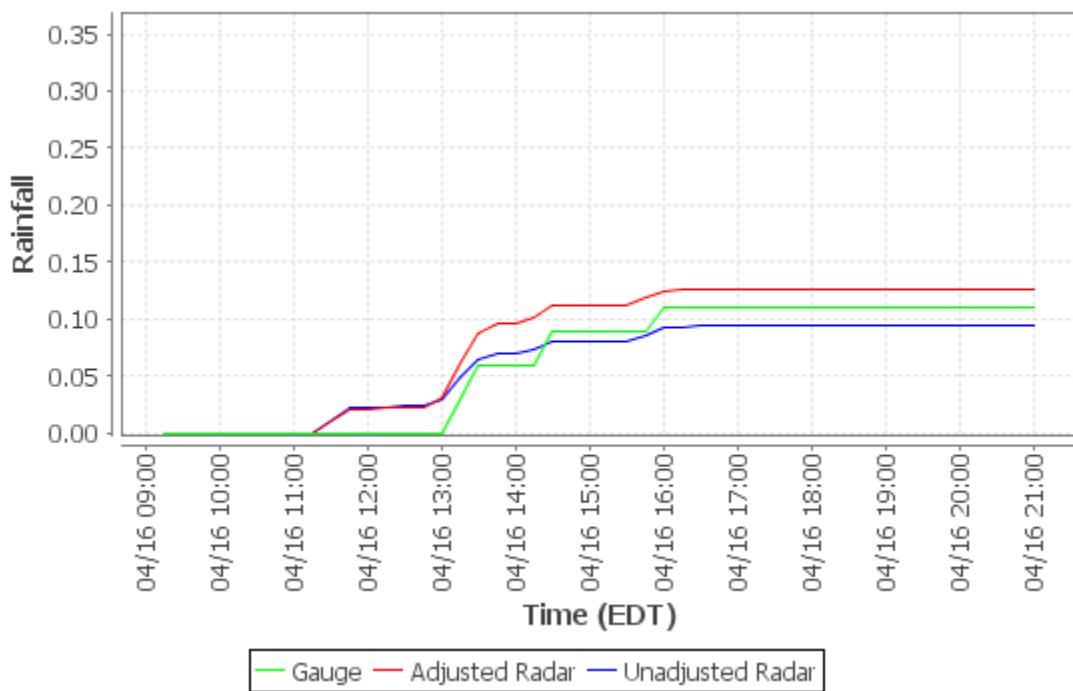
Cumulative Distribution Plot - Shaler Munic Bldg (Loc03)



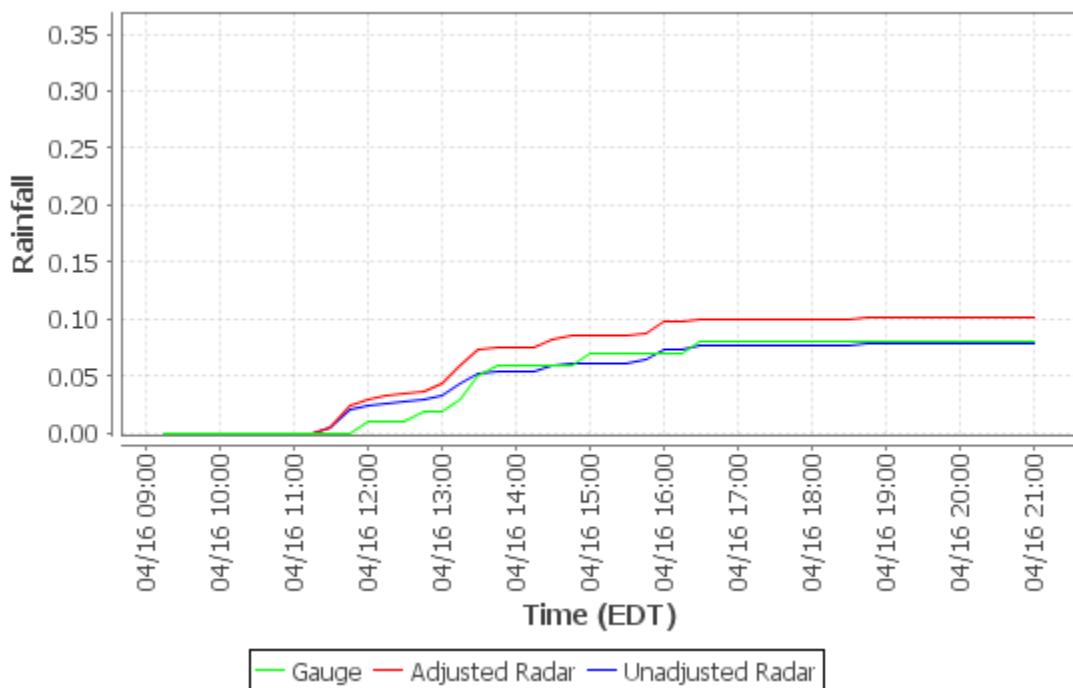
Cumulative Distribution Plot - Kennedy Twp PS (Loc04)



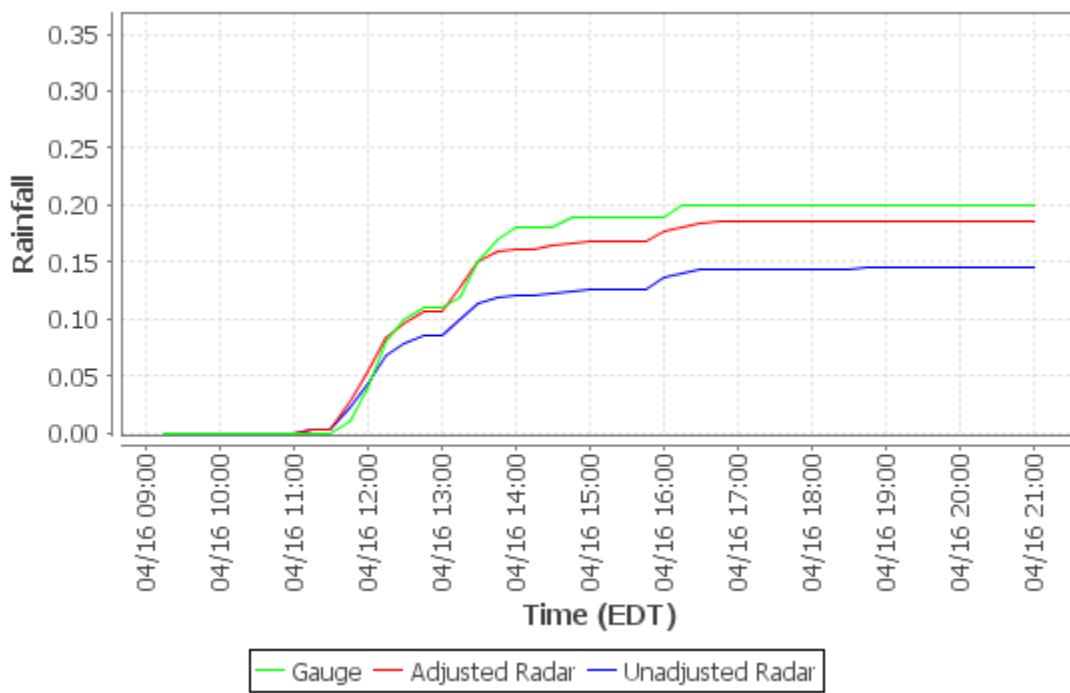
Cumulative Distribution Plot - Upper St. Clair (Loc05)



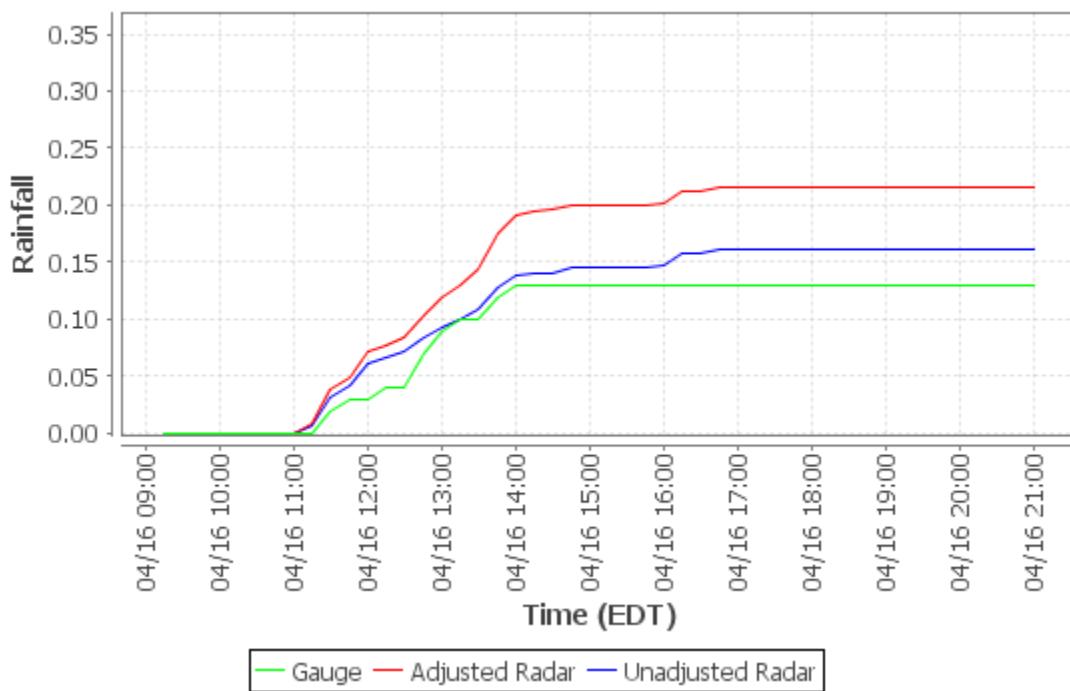
Cumulative Distribution Plot - Carnegie Transit Time (Loc06)



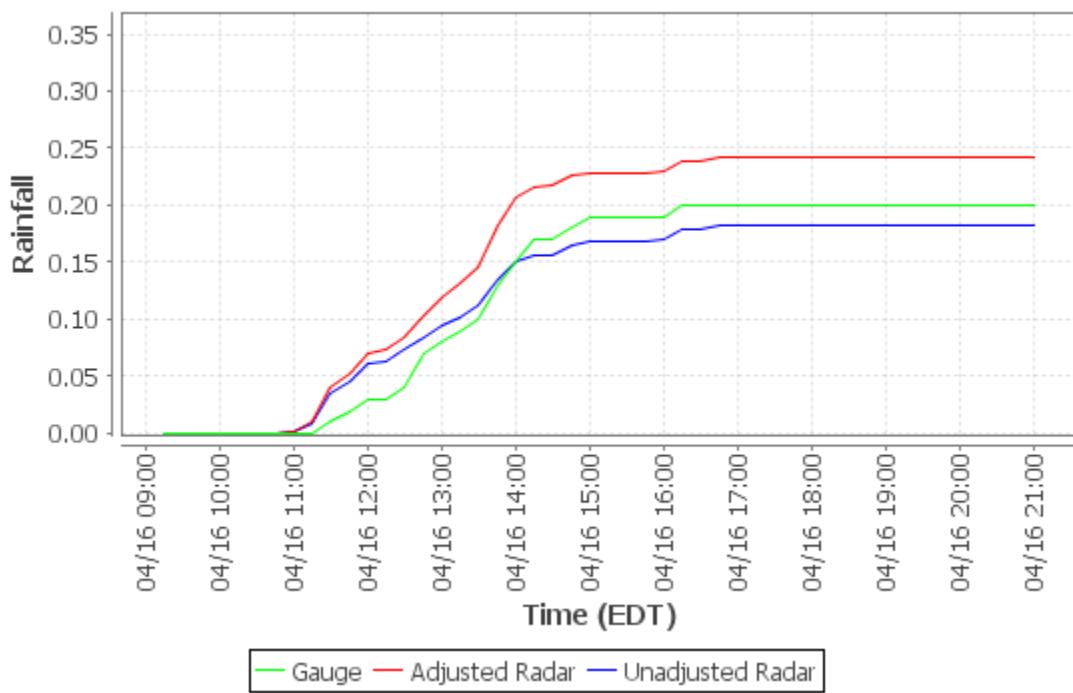
Cumulative Distribution Plot - Greentree Munic Bldg (Loc07)



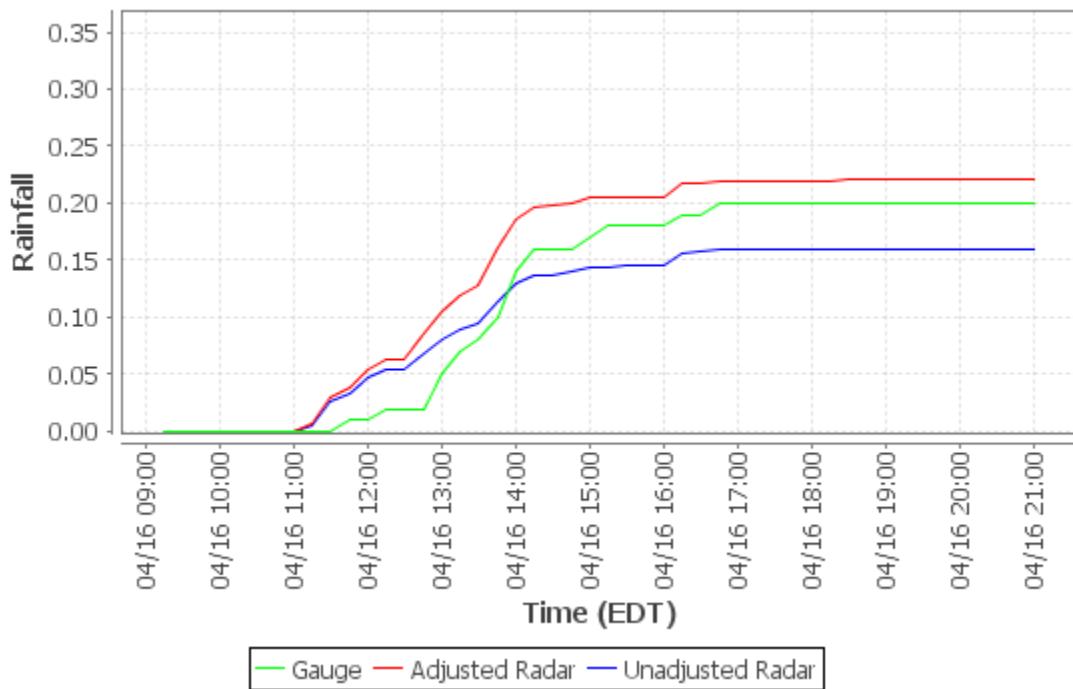
Cumulative Distribution Plot - AC Health Dept Bldg (Loc08)



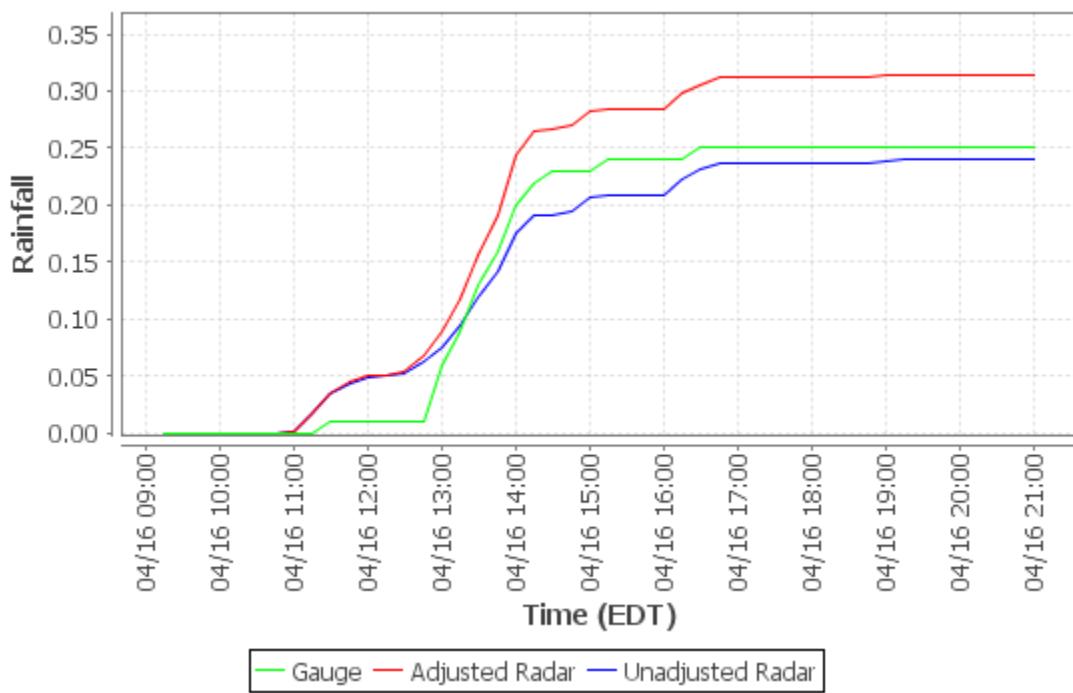
Cumulative Distribution Plot - Univ of Pittsburgh (Loc09)



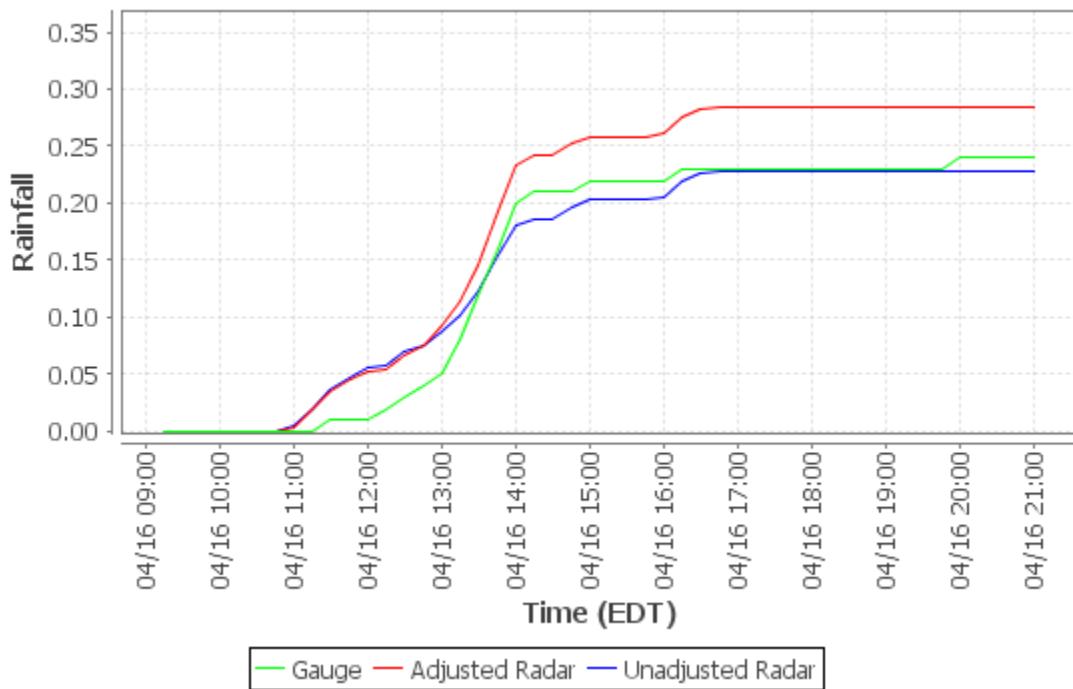
Cumulative Distribution Plot - PWSA-Highland Park (Loc10)



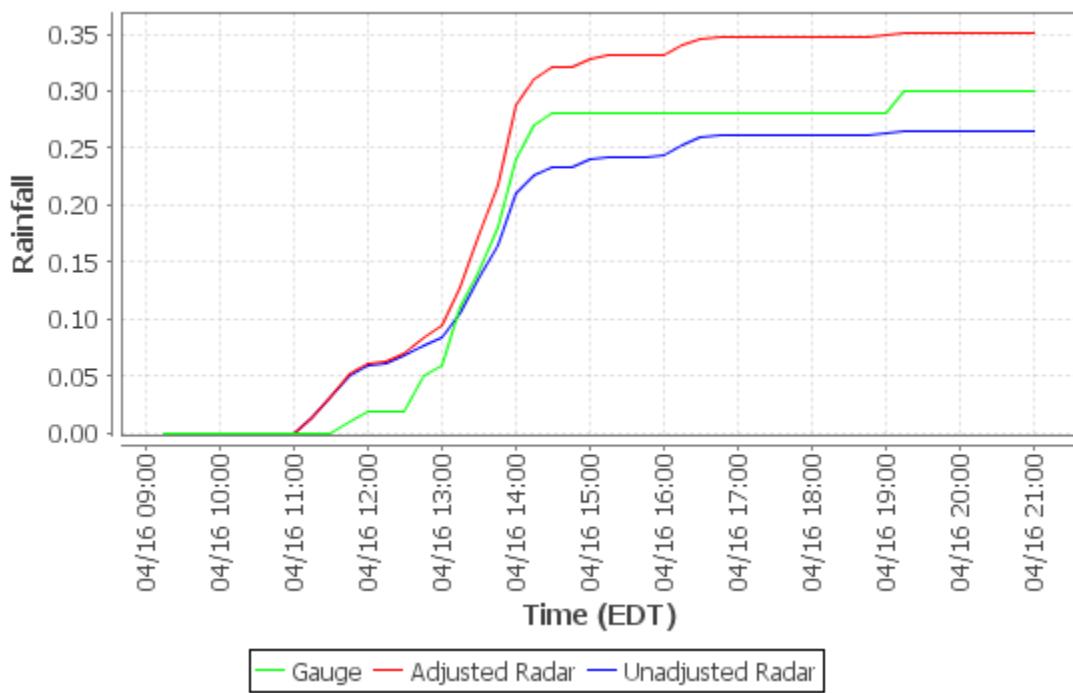
Cumulative Distribution Plot - M-46 Access Shaft (Loc11)



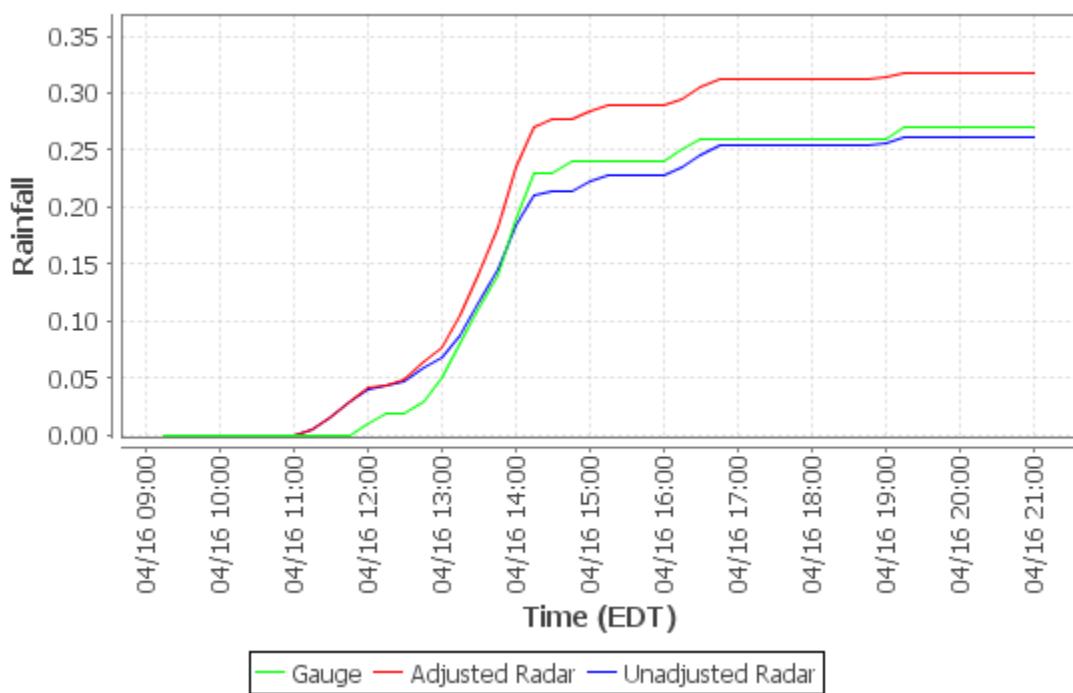
Cumulative Distribution Plot - Baldwin (Loc12)



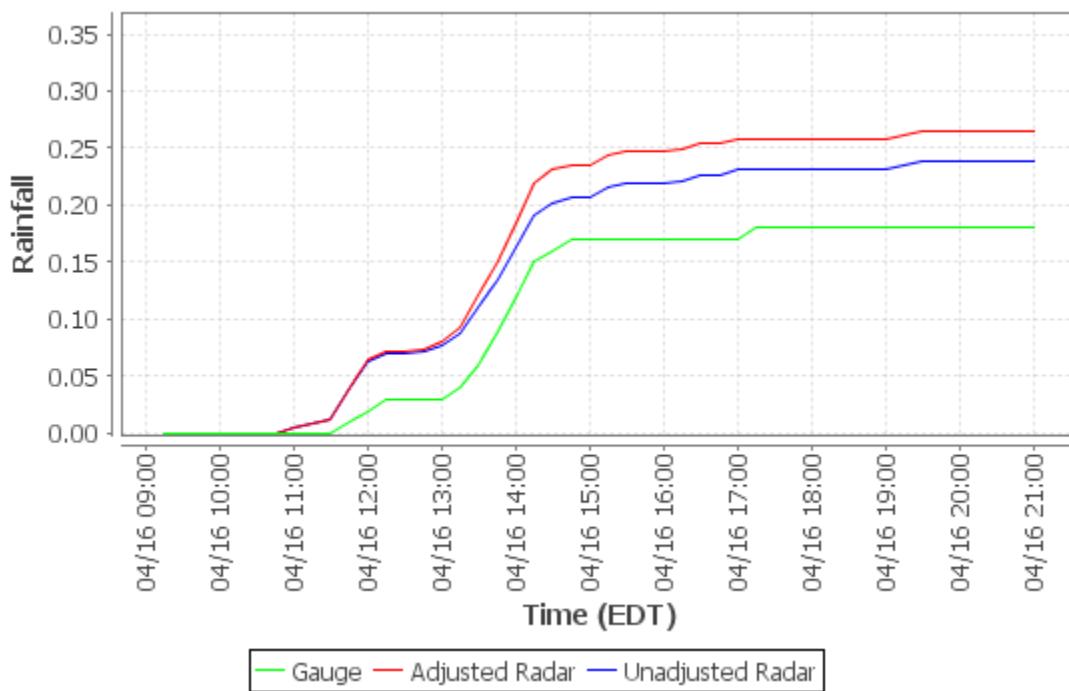
Cumulative Distribution Plot - M-59 Access Shaft (Loc13)



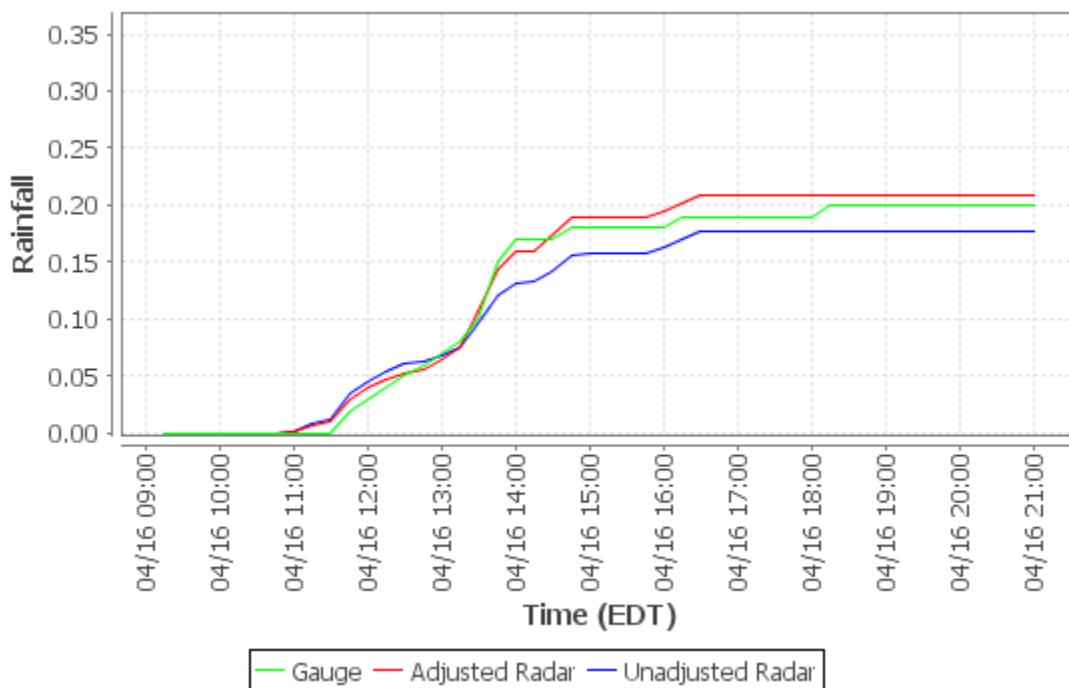
Cumulative Distribution Plot - Churchill Munic Bldg (Loc14)



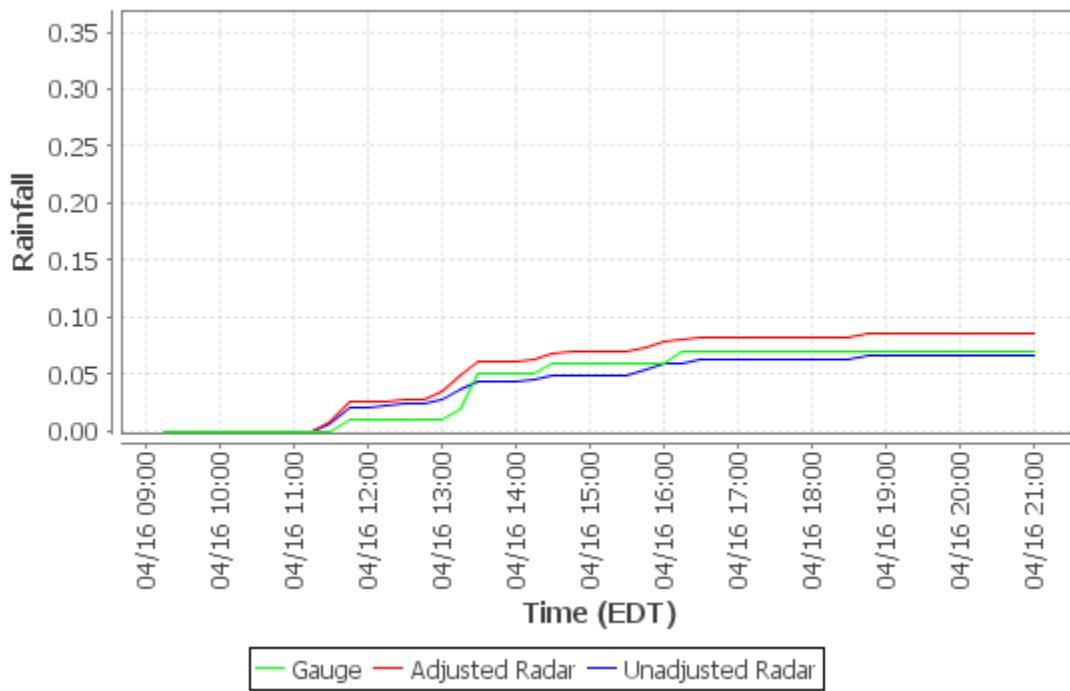
Cumulative Distribution Plot - Trafford Maint Bldg (Loc15)



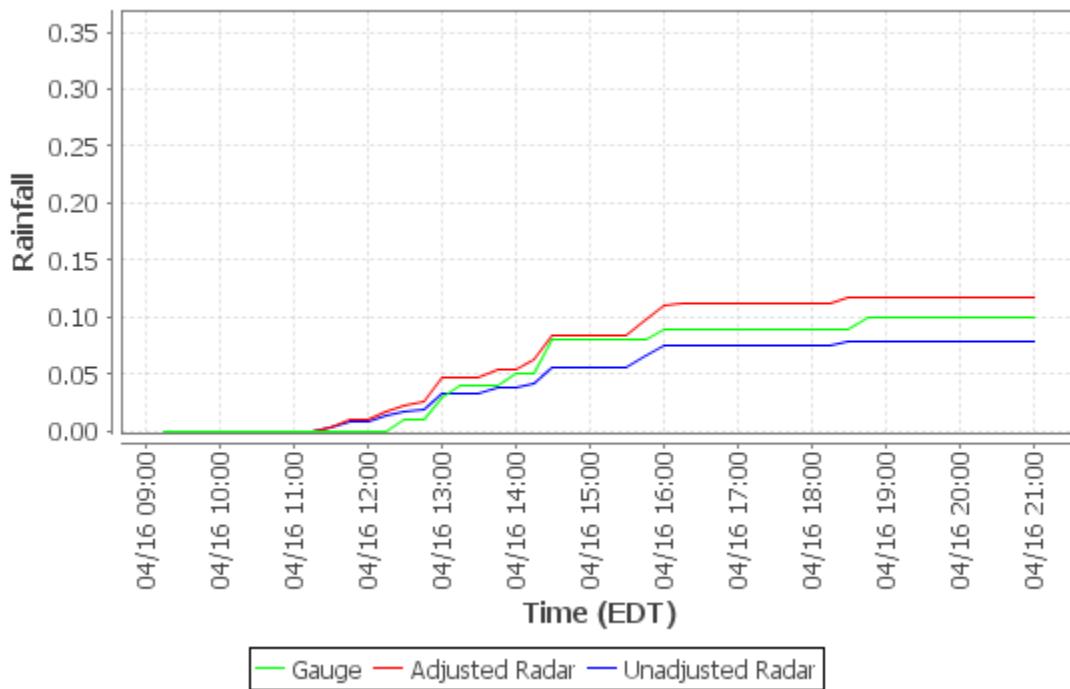
Cumulative Distribution Plot - Castle Shannon (Loc16)



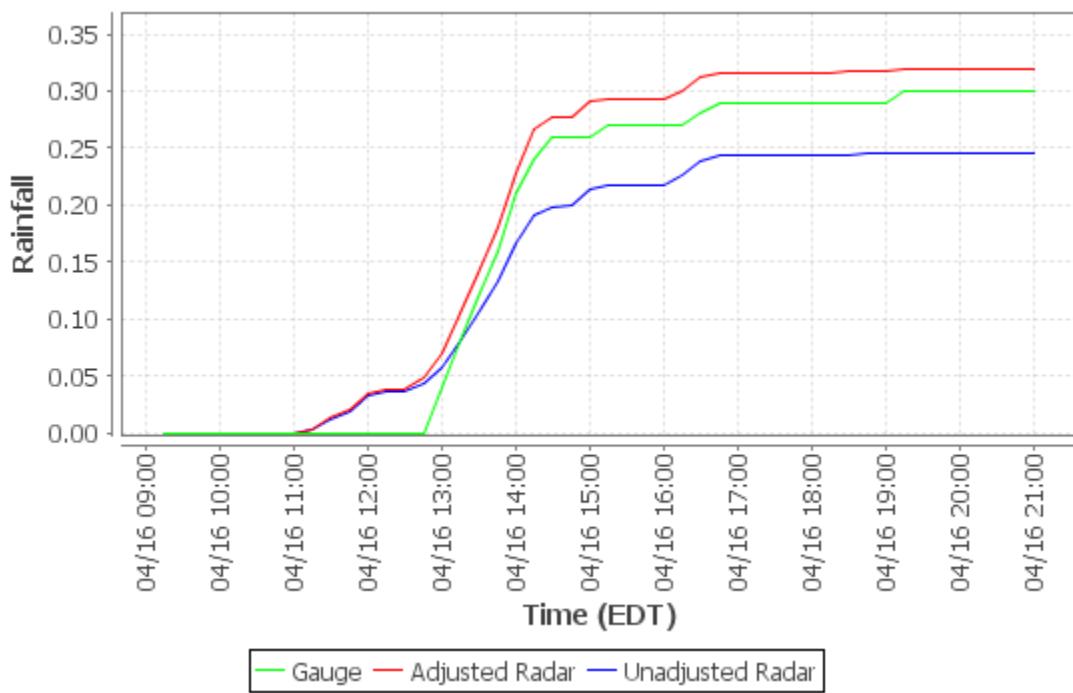
Cumulative Distribution Plot - Chartiers Pump Station (Loc17)



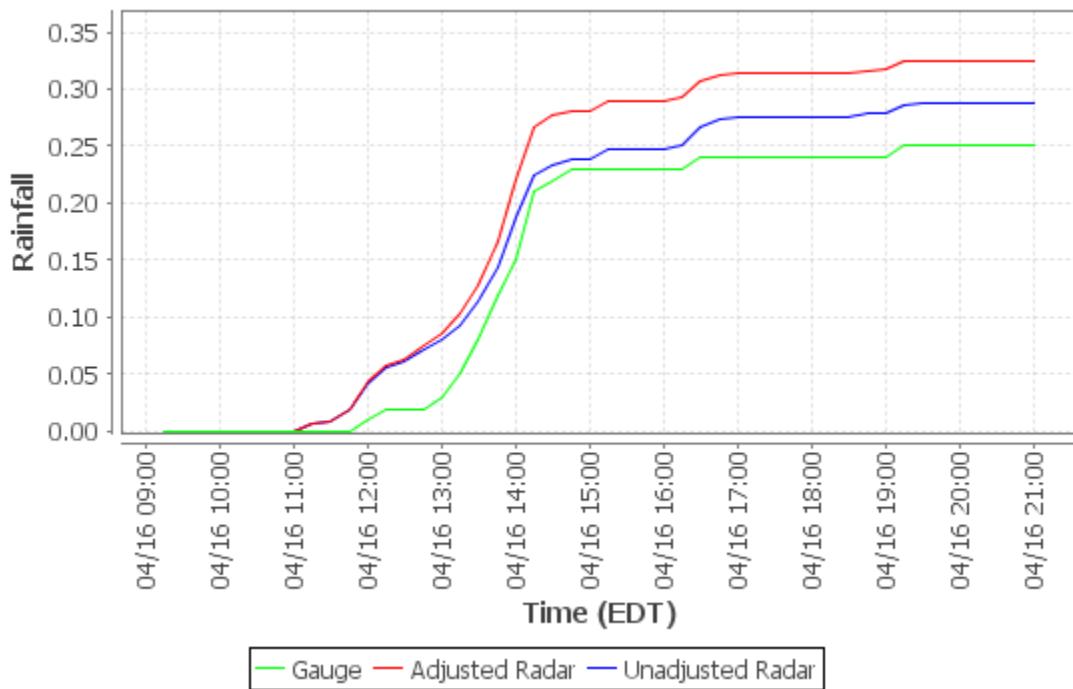
Cumulative Distribution Plot - Oakdale Pump Station (Loc18)



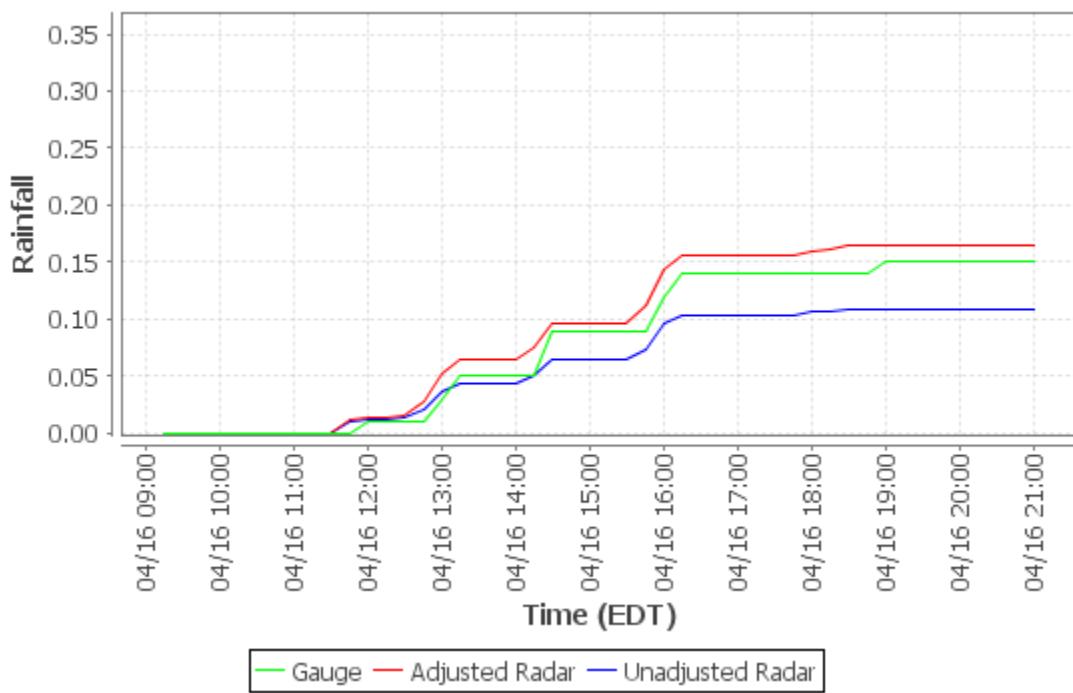
Cumulative Distribution Plot - Sandy Creek Eq Facility (Loc19)



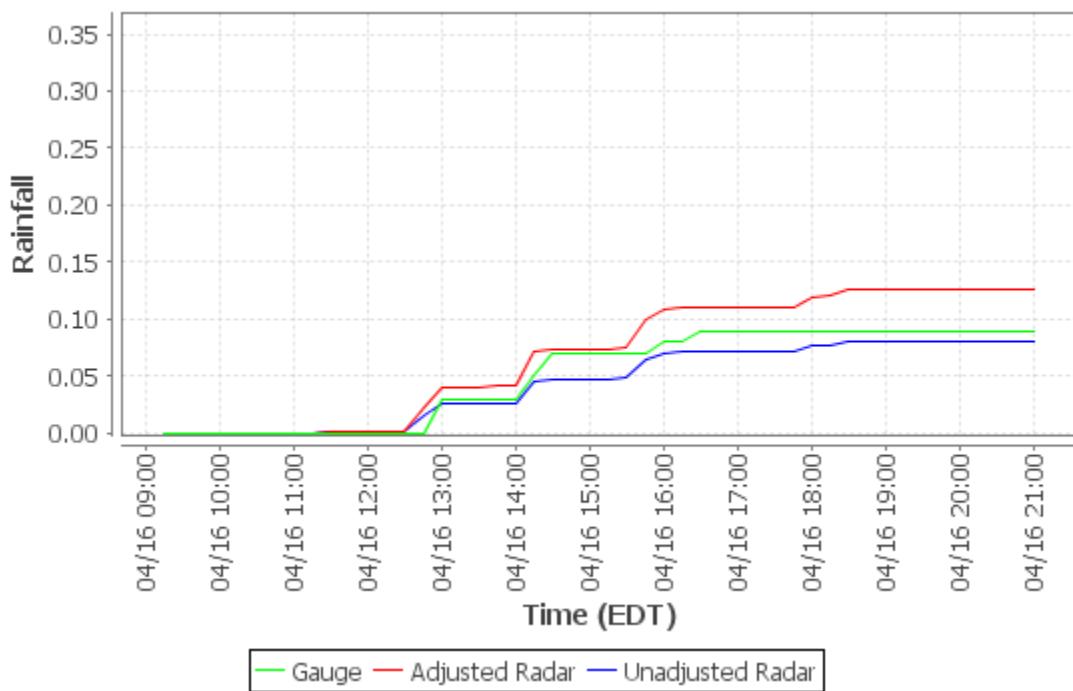
Cumulative Distribution Plot - Gascola Eq Facility (Loc20)



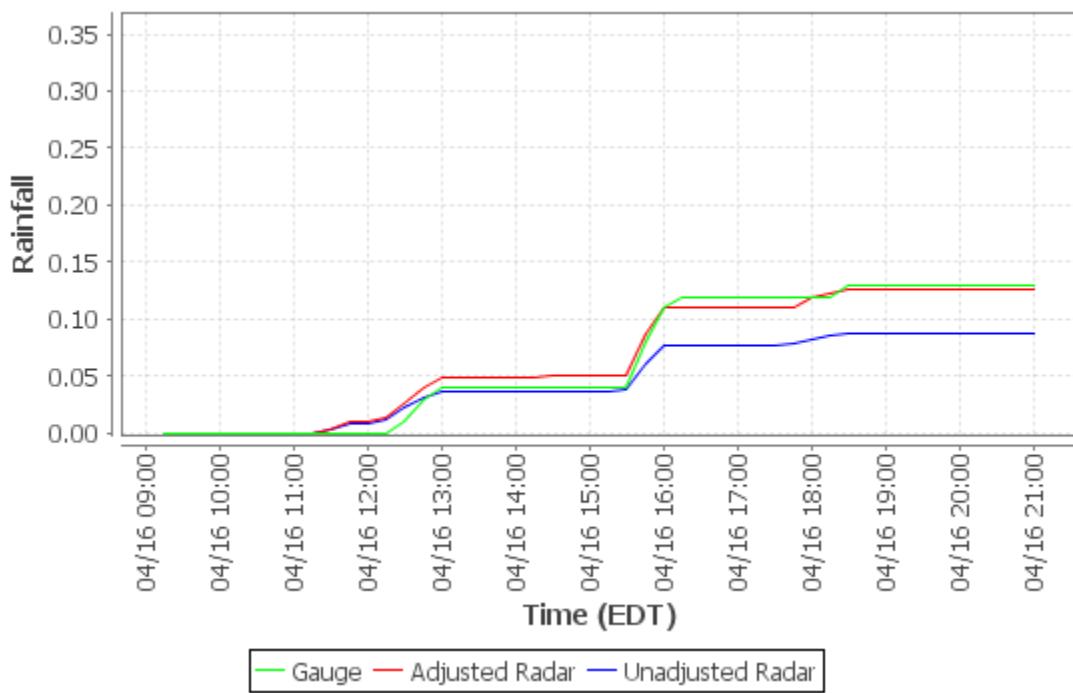
Cumulative Distribution Plot - Moon TWP (Loc21)



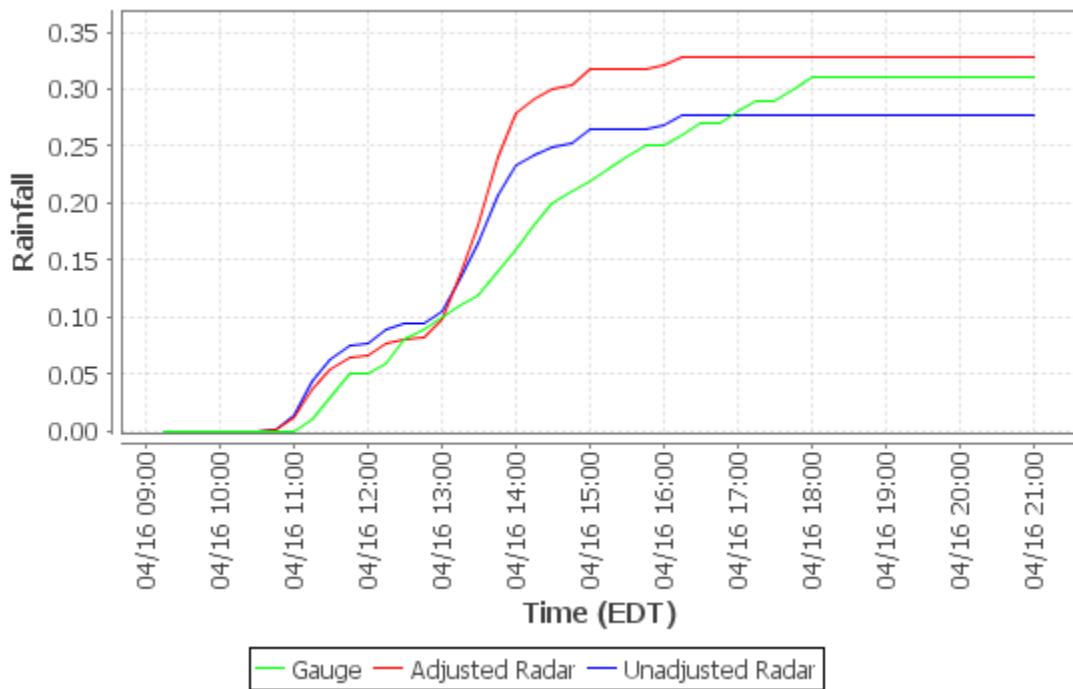
Cumulative Distribution Plot - North Fayette TWP (Loc22)



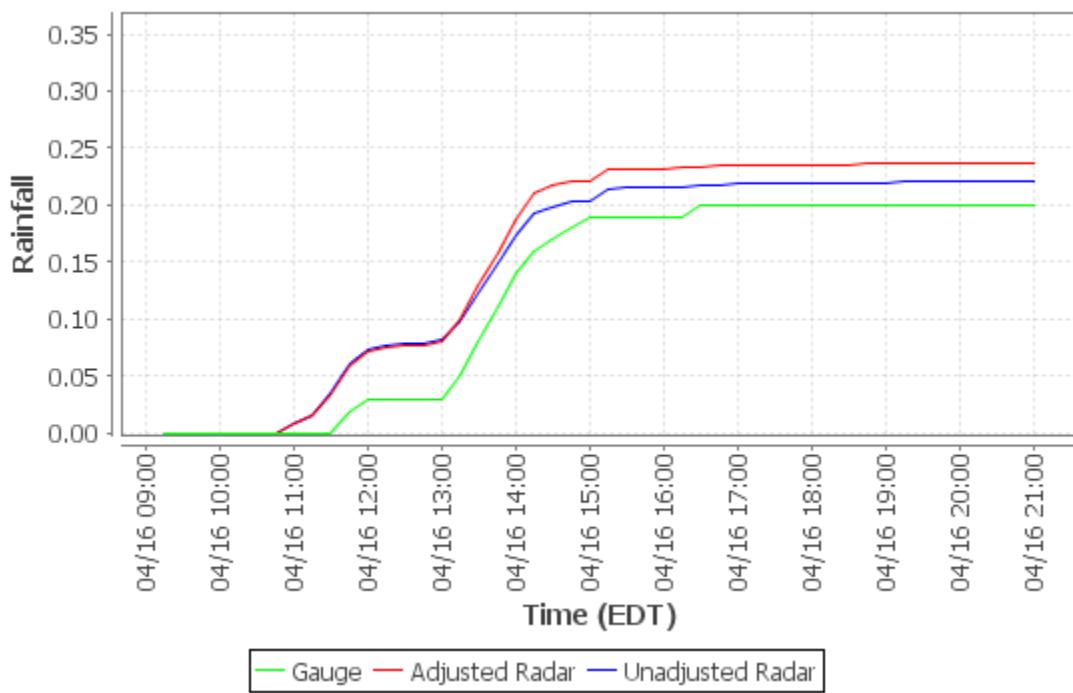
Cumulative Distribution Plot - Clinton Munic Bldg (Loc23)



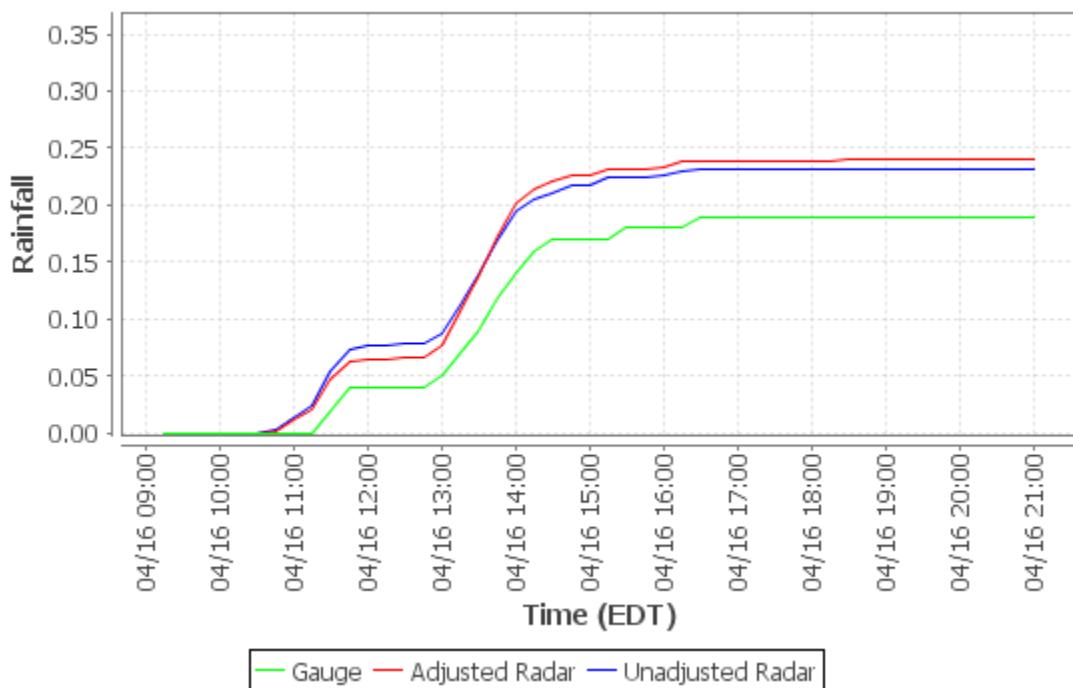
Cumulative Distribution Plot - Jefferson Hills (Loc24)



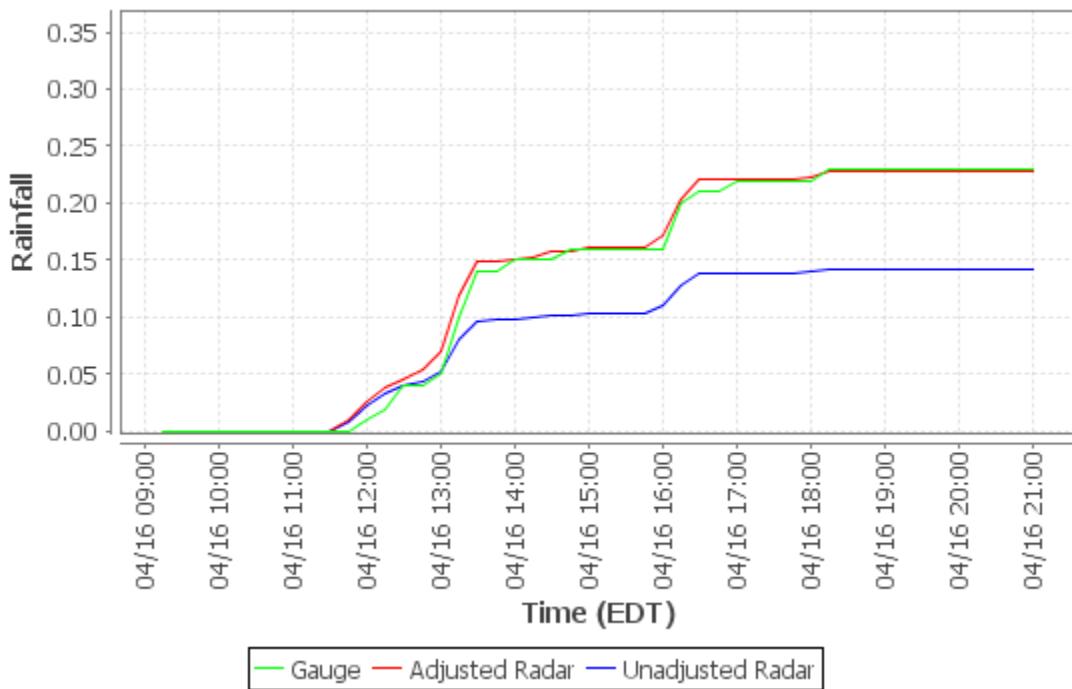
Cumulative Distribution Plot - White Oak Public Works Bldg (Loc25)



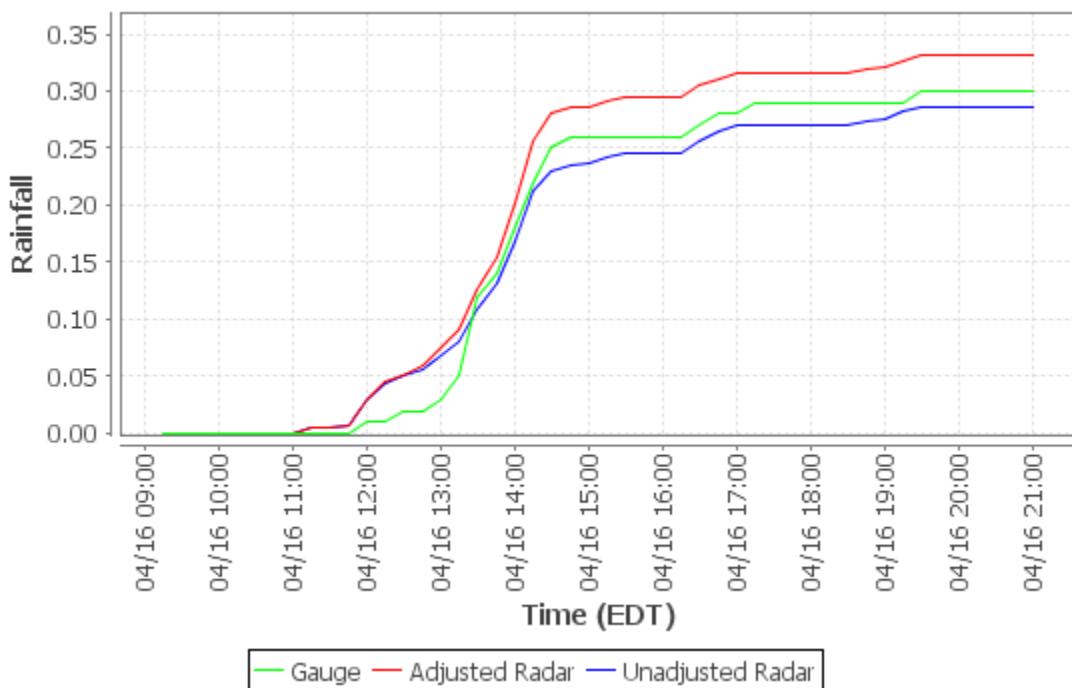
Cumulative Distribution Plot - Elizabeth TWP Municipal Bldg (Loc26)



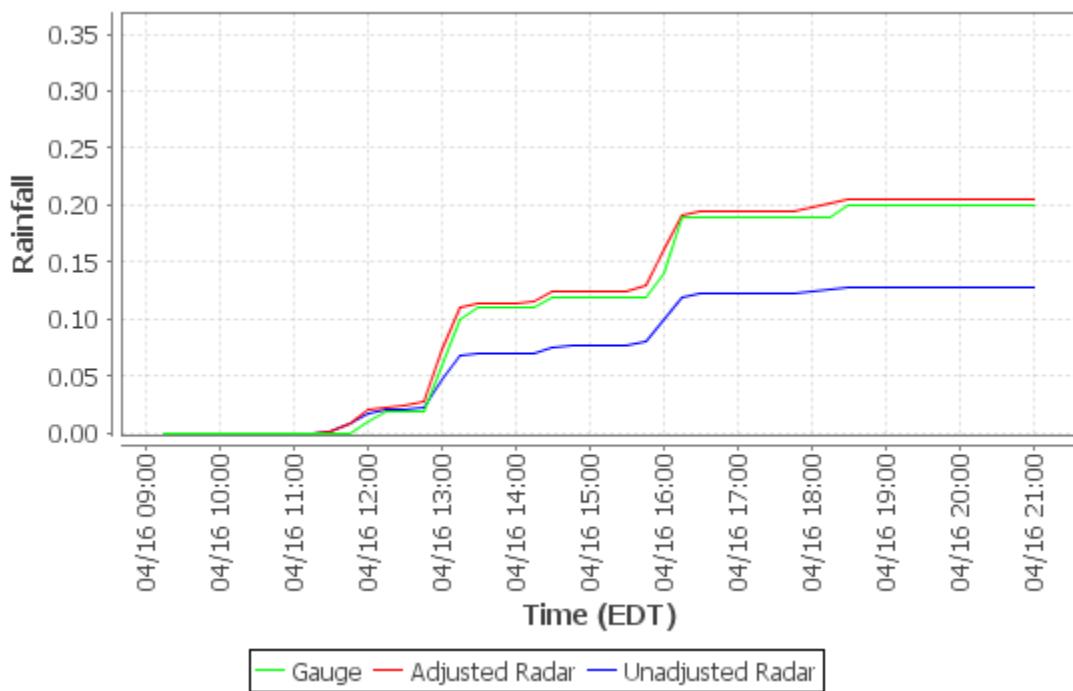
Cumulative Distribution Plot - Marshall TWP (Loc27)



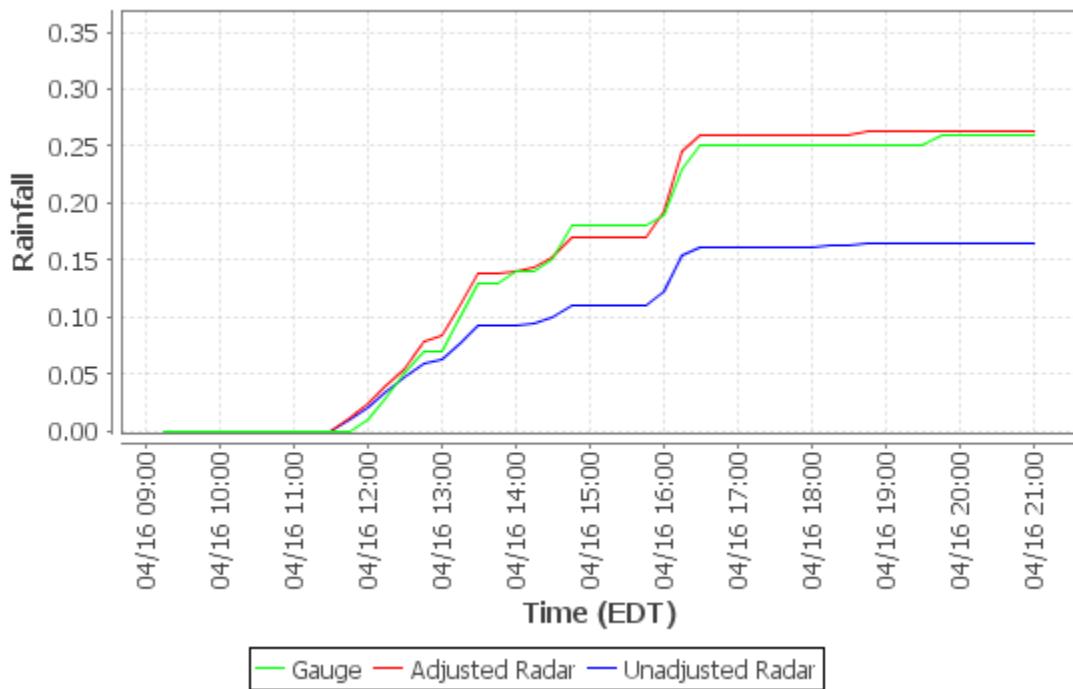
Cumulative Distribution Plot - Plum Municipal Bldg (Loc28)



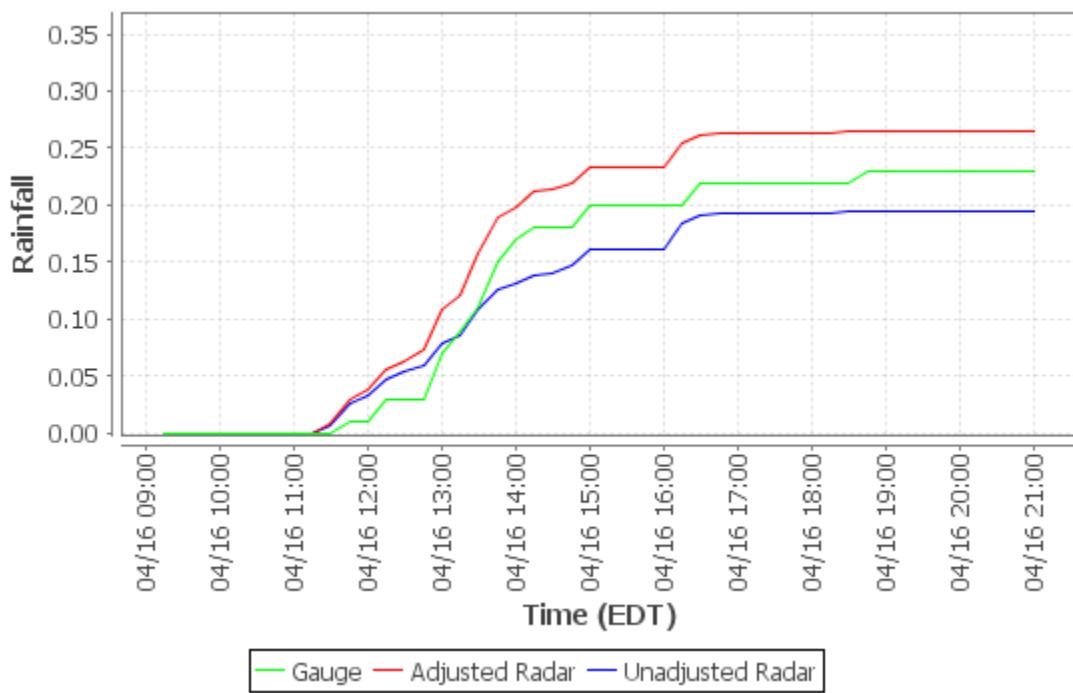
Cumulative Distribution Plot - Bell Acres Munic Bldg (Loc29)



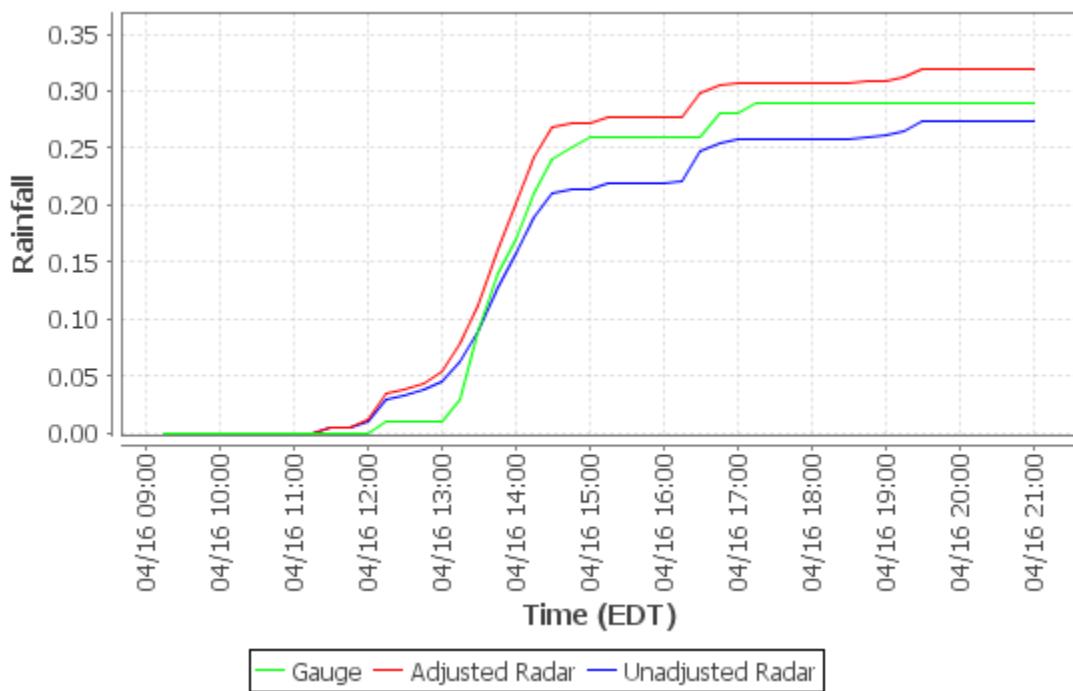
Cumulative Distribution Plot - McCandless Twn Hall (Loc30)



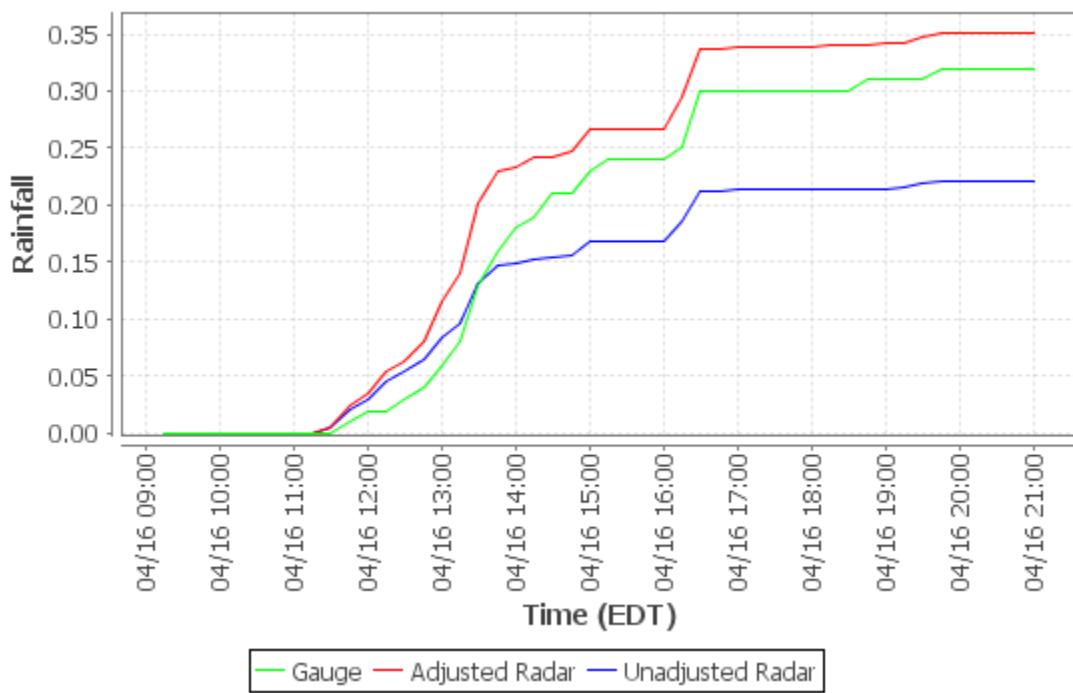
Cumulative Distribution Plot - Hampton Municipal Bldg (Loc31)



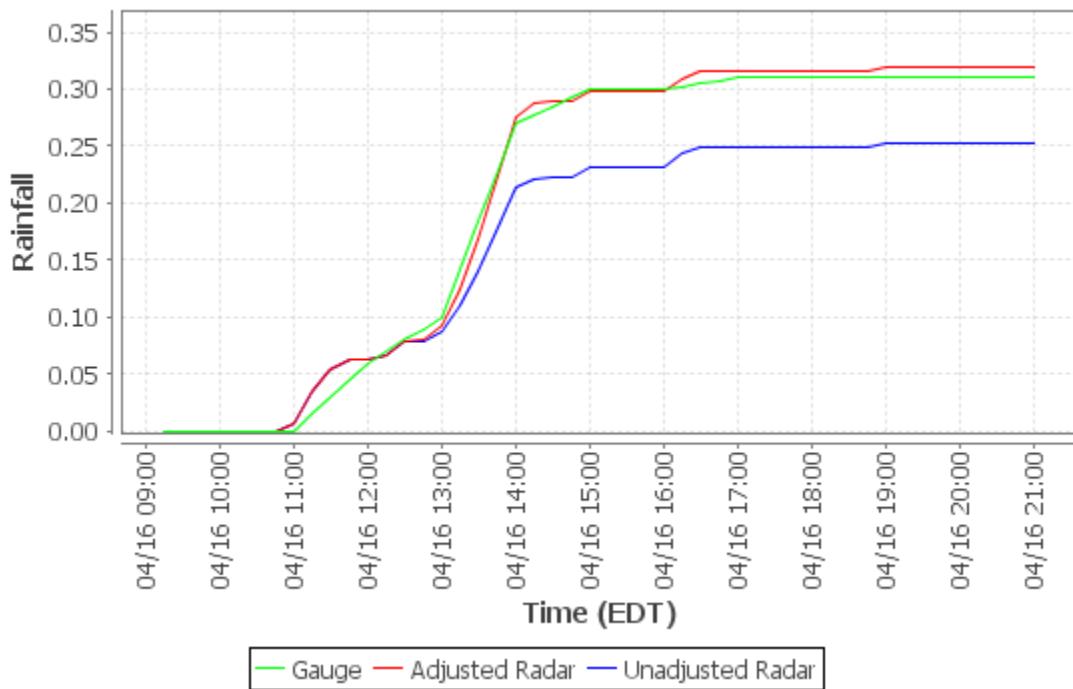
Cumulative Distribution Plot - Arnold (Loc32)



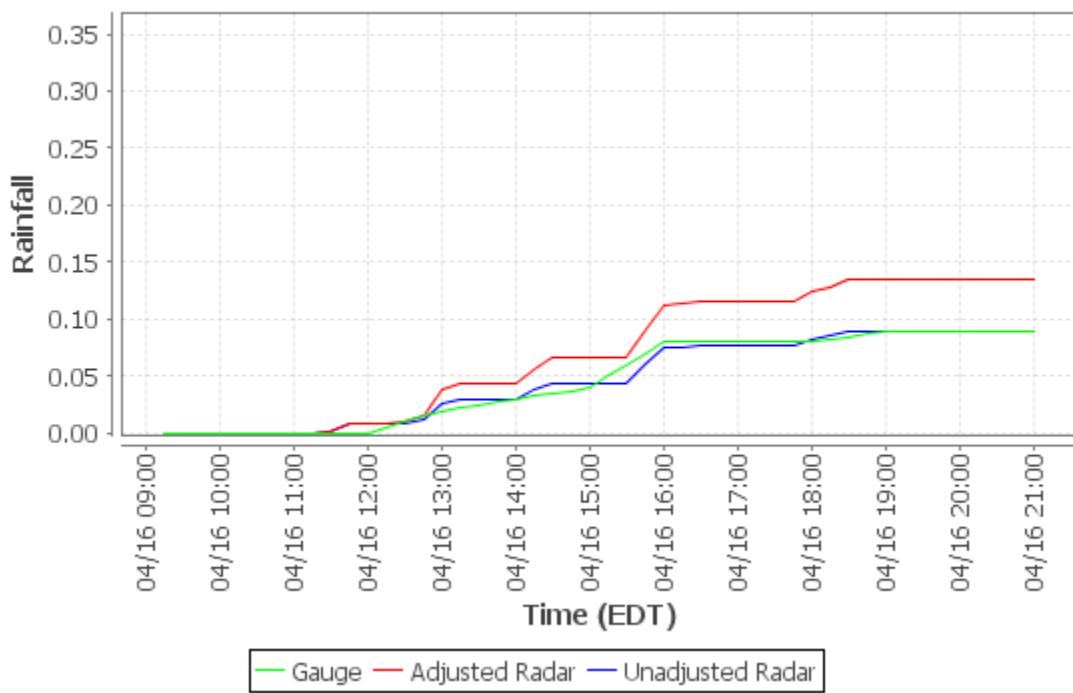
Cumulative Distribution Plot - Richland TWP (Loc33)



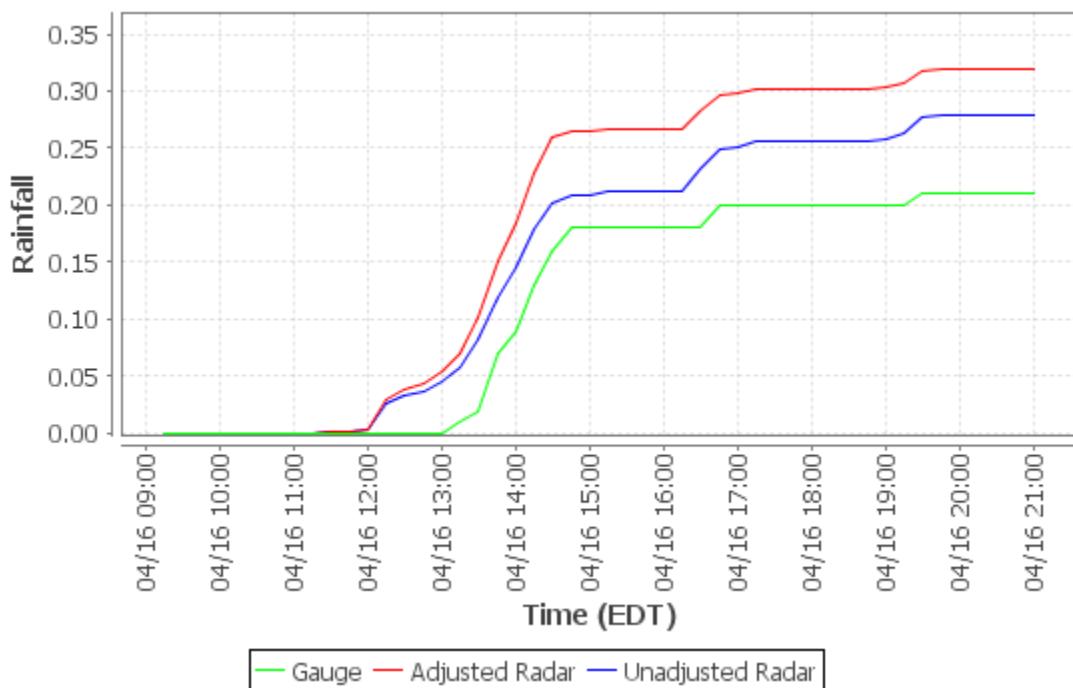
Cumulative Distribution Plot - Pittsburgh Allegheny Cty (KAGC)



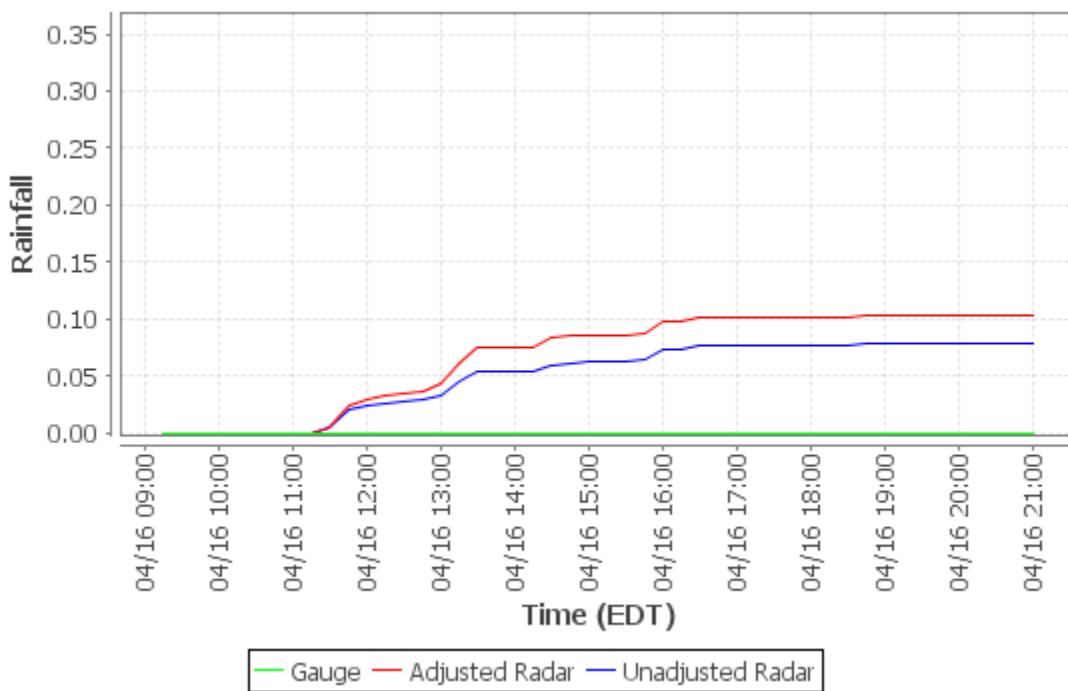
Cumulative Distribution Plot - Greater Pittsburgh Int'l (KPIT)



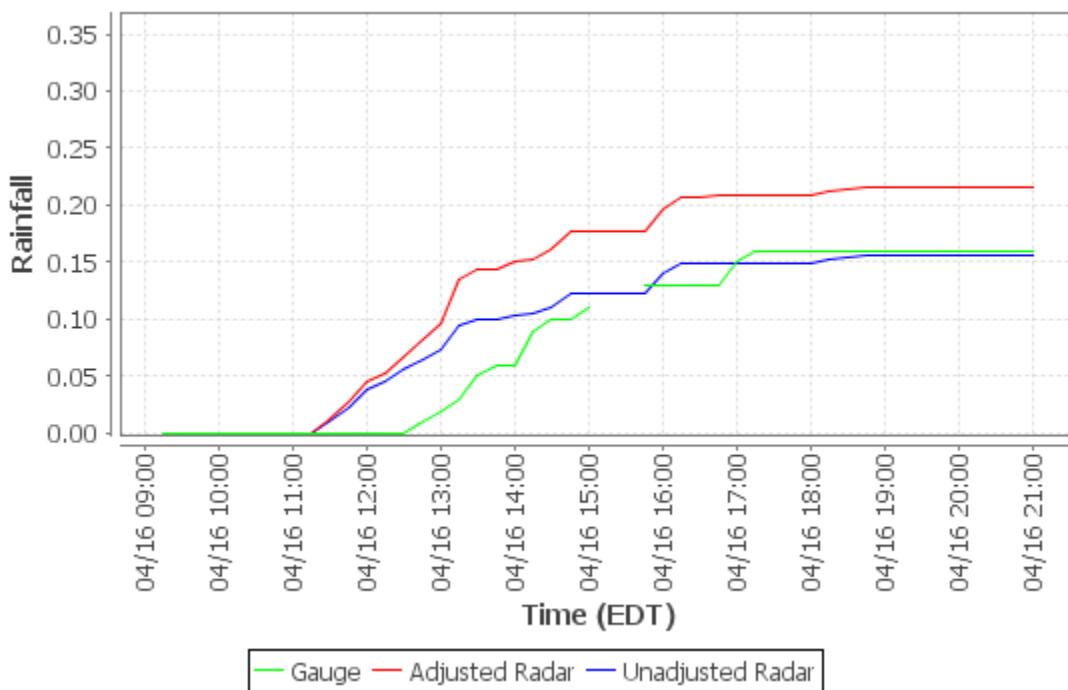
Cumulative Distribution Plot - Allegheny River at Natrona (03049500)



Cumulative Distribution Plot - Chartiers Creek at Carnegie (03085500)

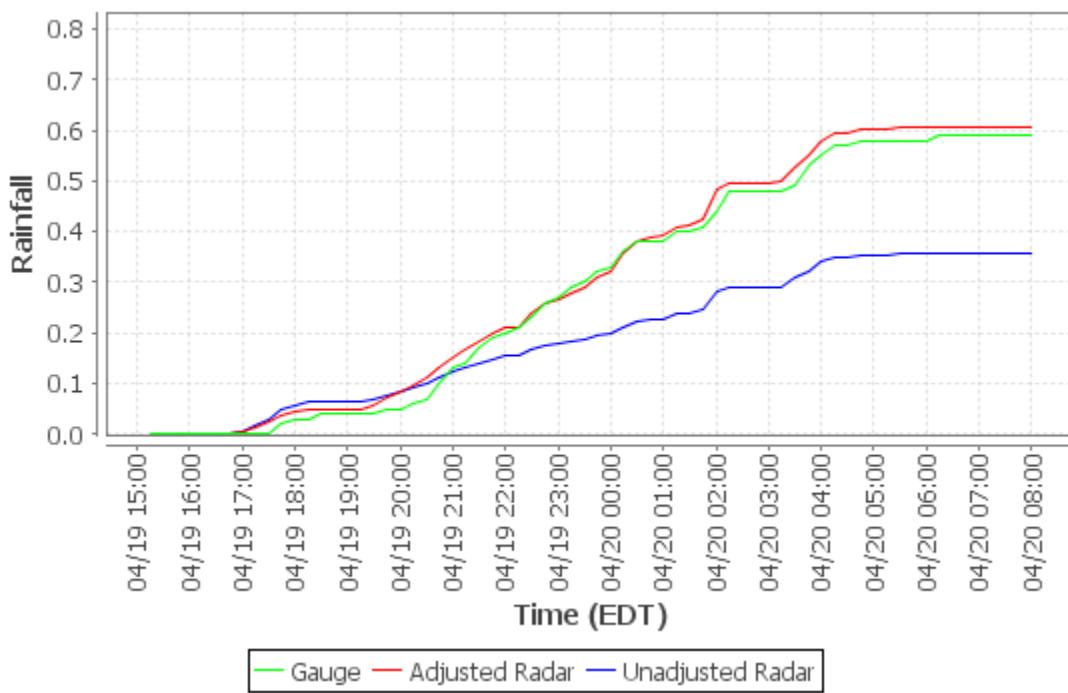


Cumulative Distribution Plot - Ohio River at Emsworth Dam Lower Pool at Emsworth (03085734)

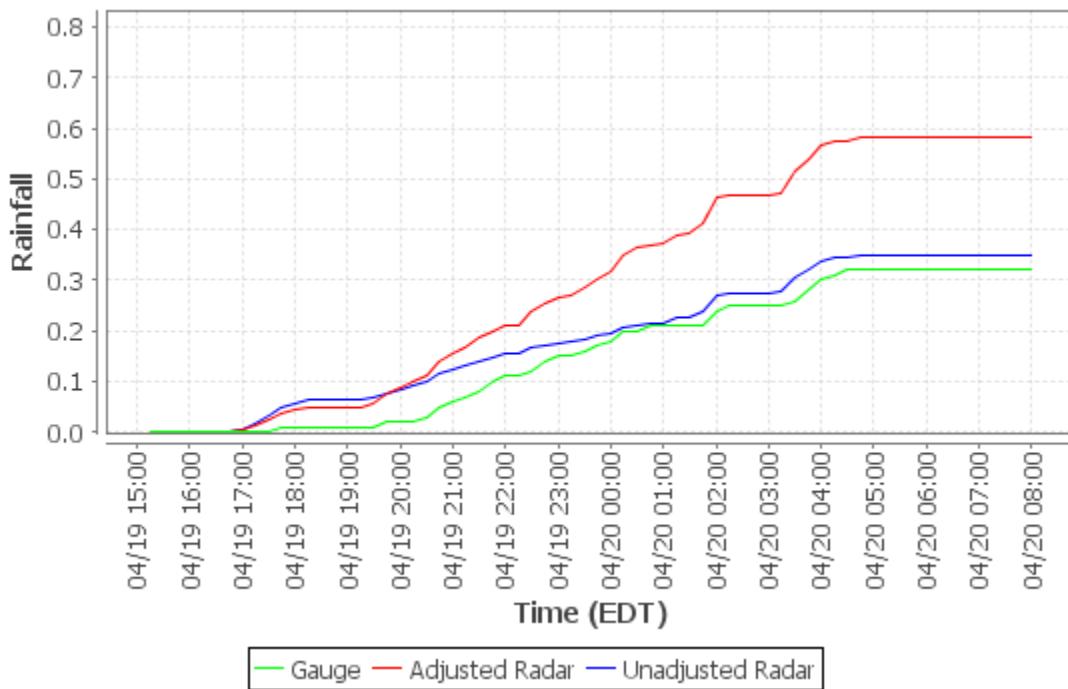


Appendix L - Event 11 (2015-04-19) CDPs

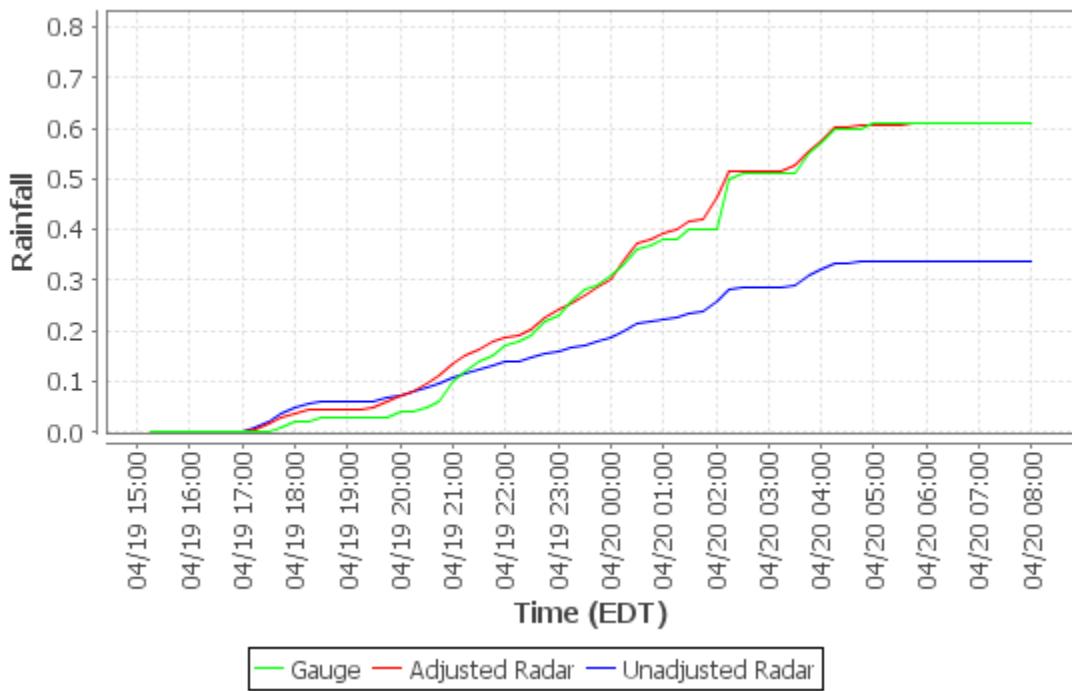
Cumulative Distribution Plot - PWSA-Montana St. (Loc01)



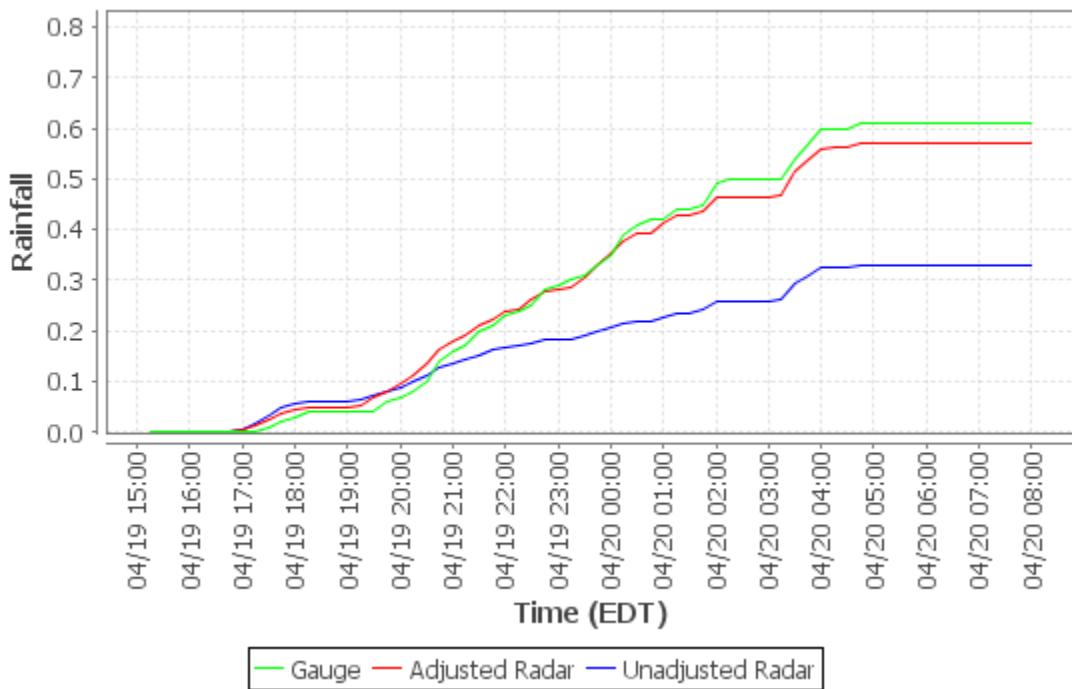
Cumulative Distribution Plot - ALCOSAN WWTP Lab (Loc02)



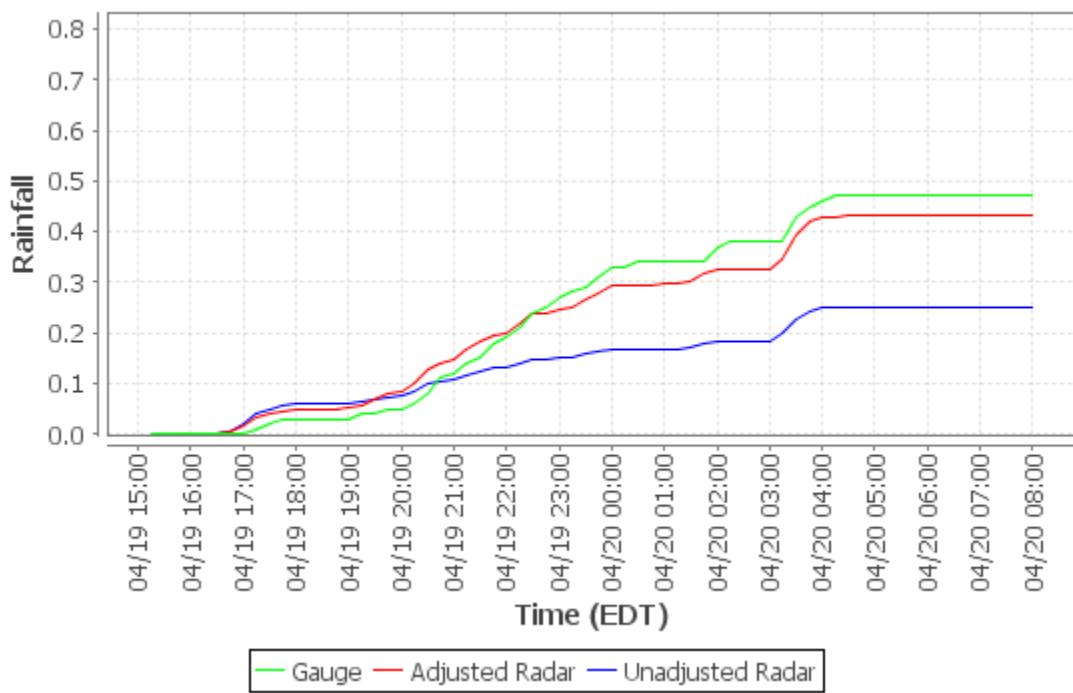
Cumulative Distribution Plot - Shaler Munic Bldg (Loc03)



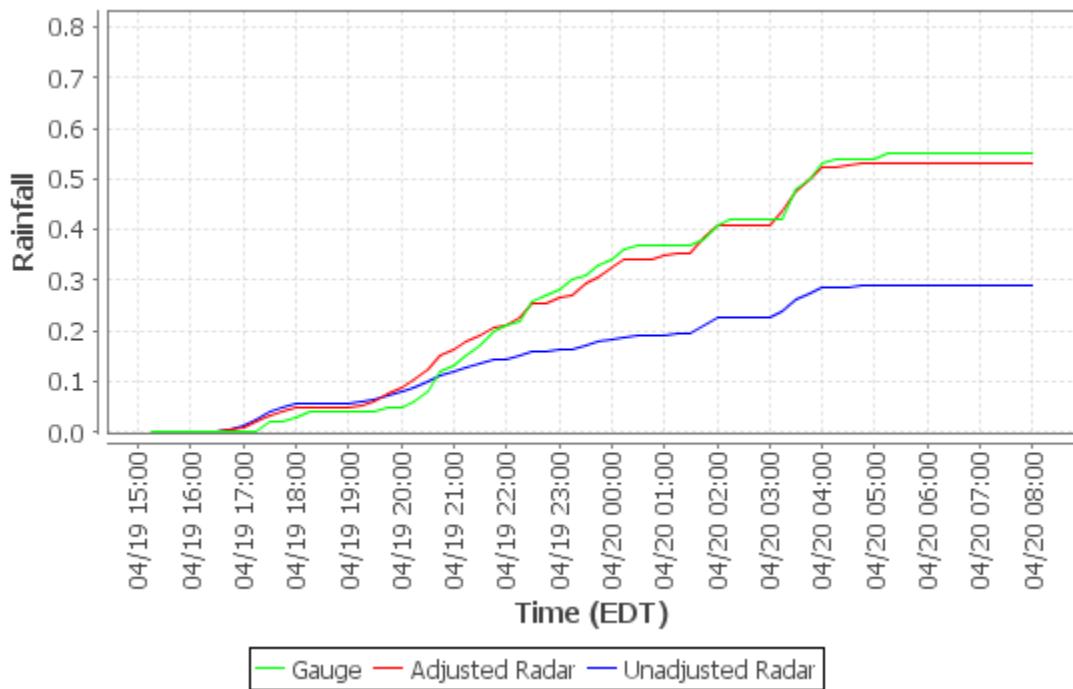
Cumulative Distribution Plot - Kennedy Twp PS (Loc04)



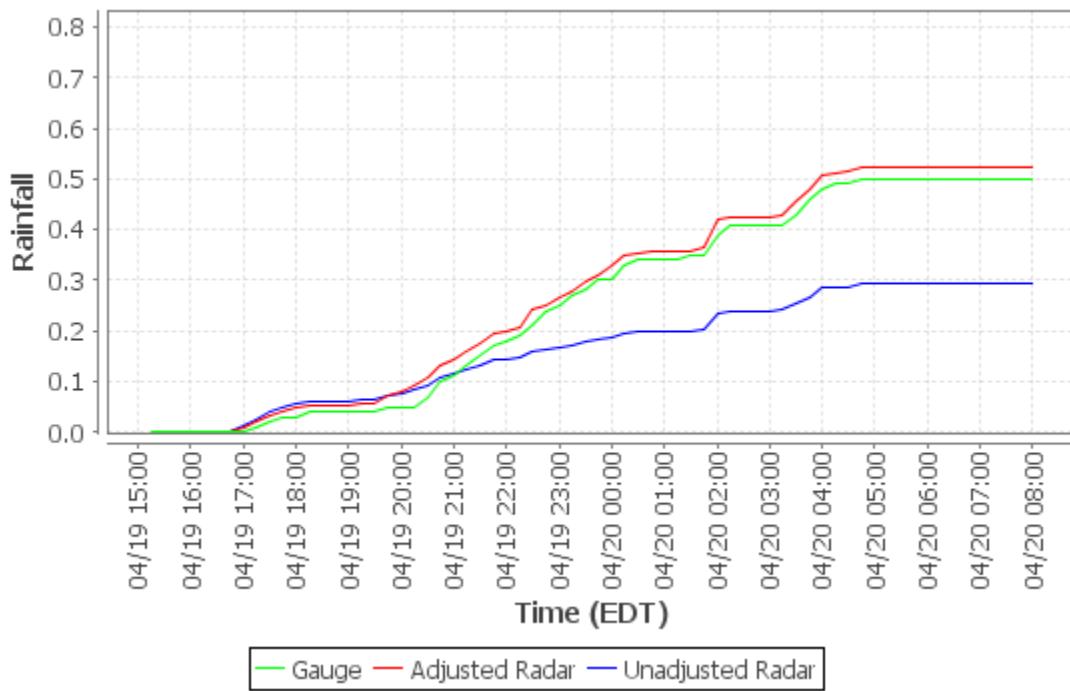
Cumulative Distribution Plot - Upper St. Clair (Loc05)



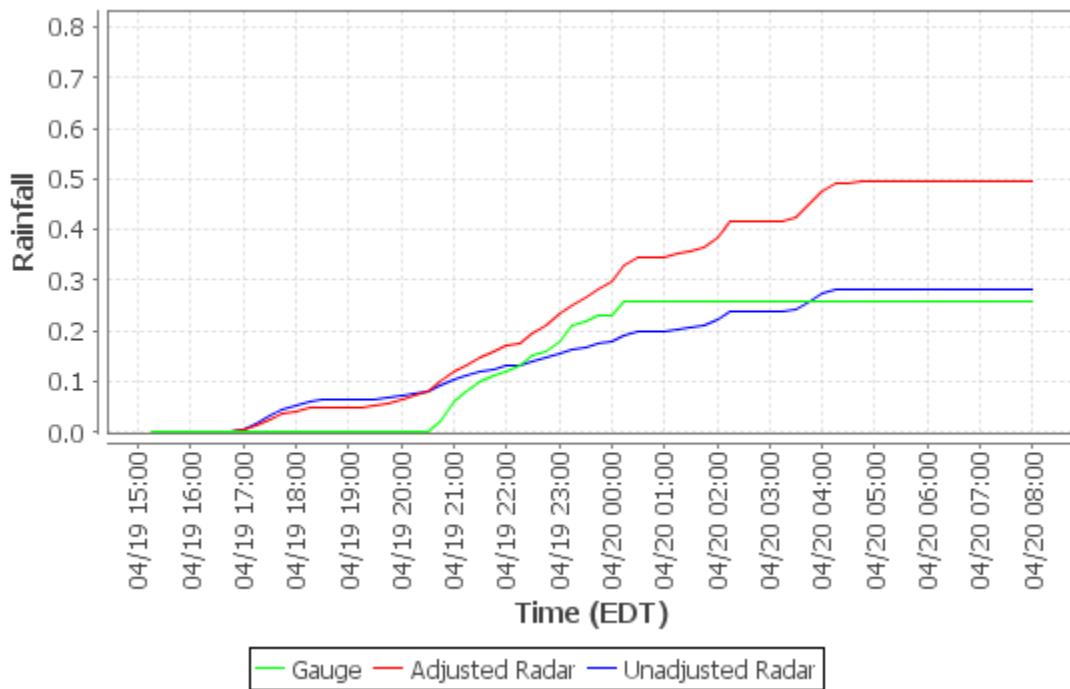
Cumulative Distribution Plot - Carnegie Transit Time (Loc06)



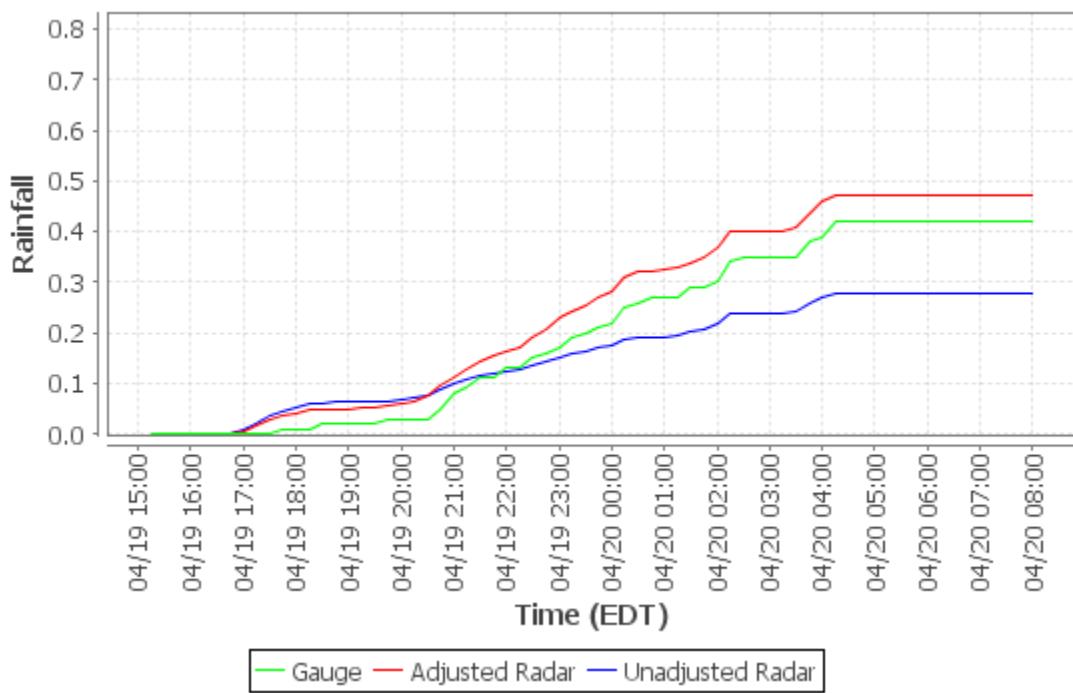
Cumulative Distribution Plot - Greentree Munic Bldg (Loc07)



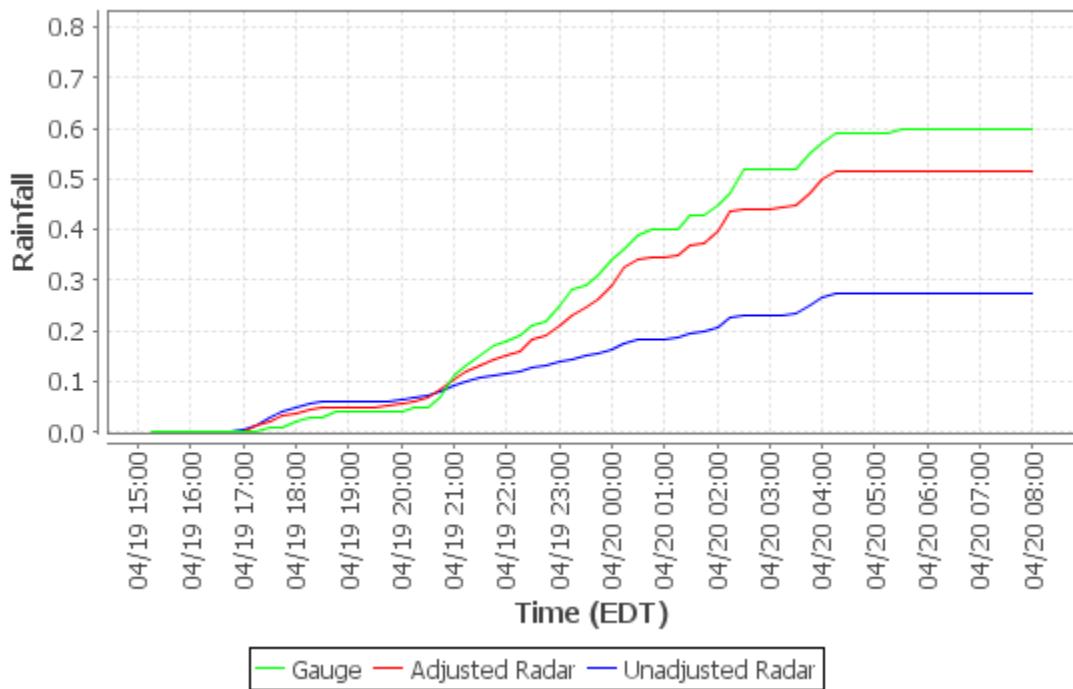
Cumulative Distribution Plot - AC Health Dept Bldg (Loc08)



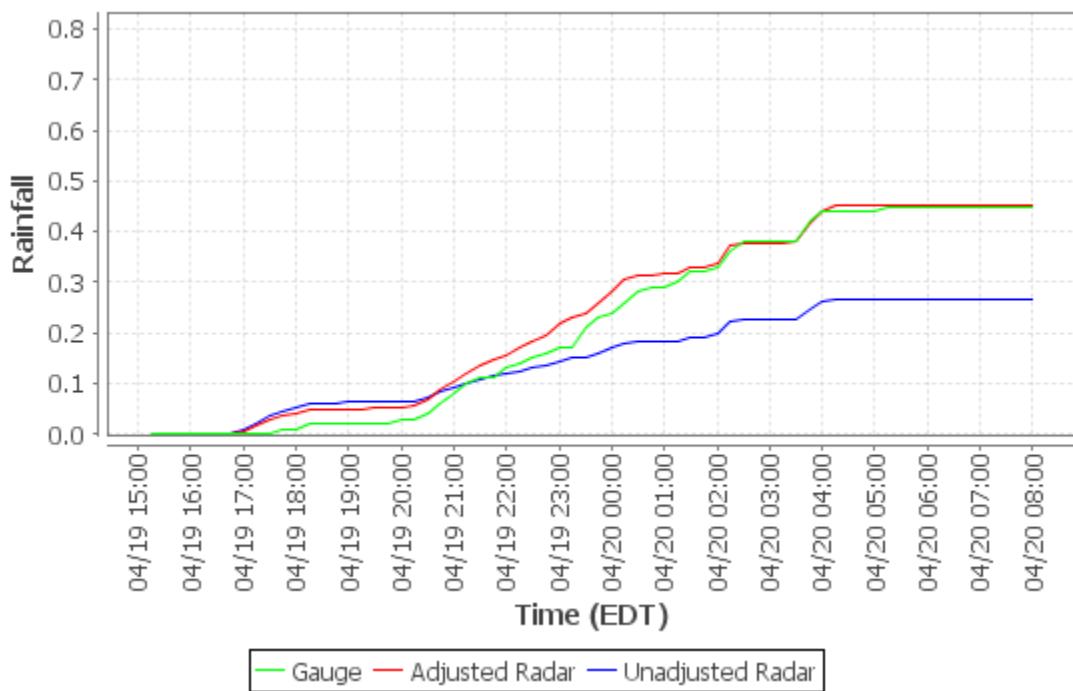
Cumulative Distribution Plot - Univ of Pittsburgh (Loc09)



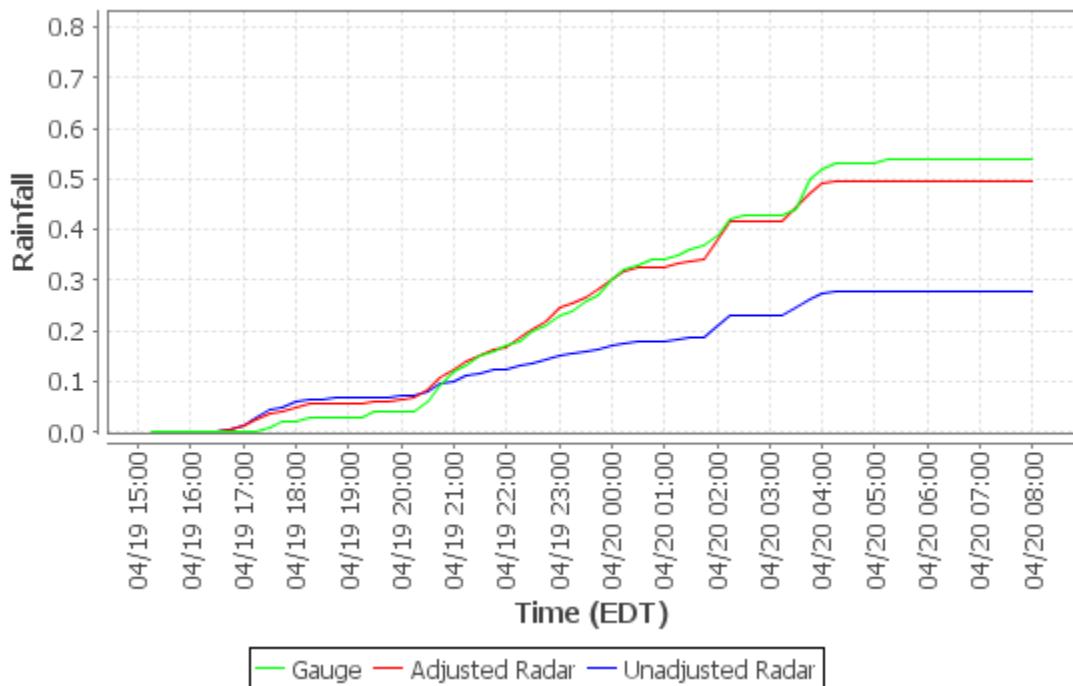
Cumulative Distribution Plot - PWSA-Highland Park (Loc10)



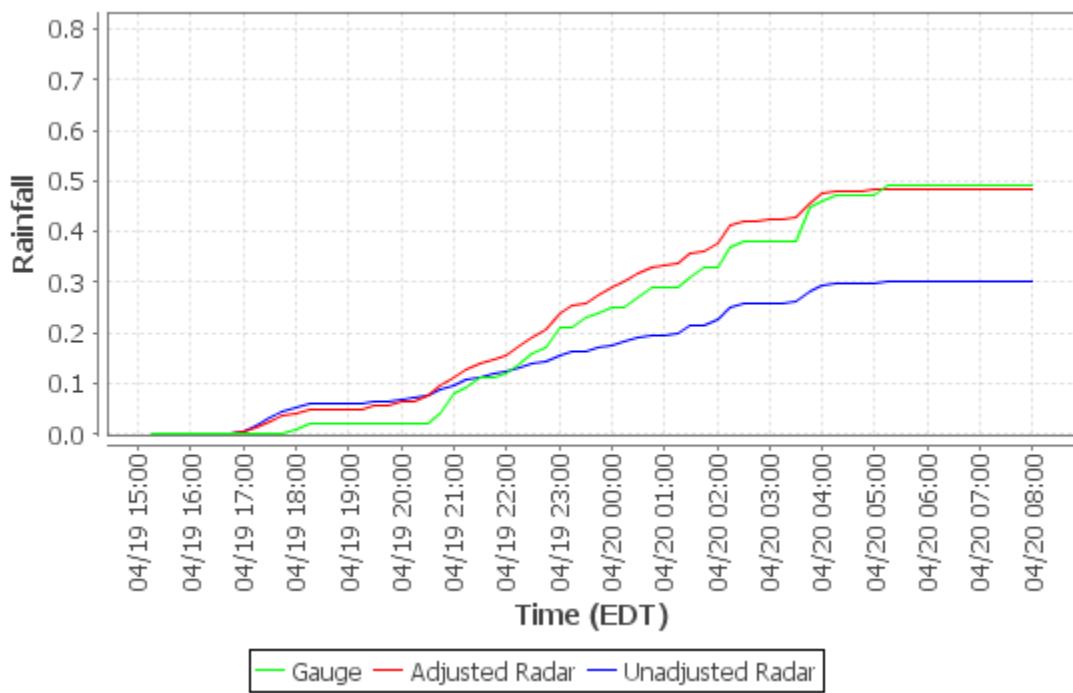
Cumulative Distribution Plot - M-46 Access Shaft (Loc11)



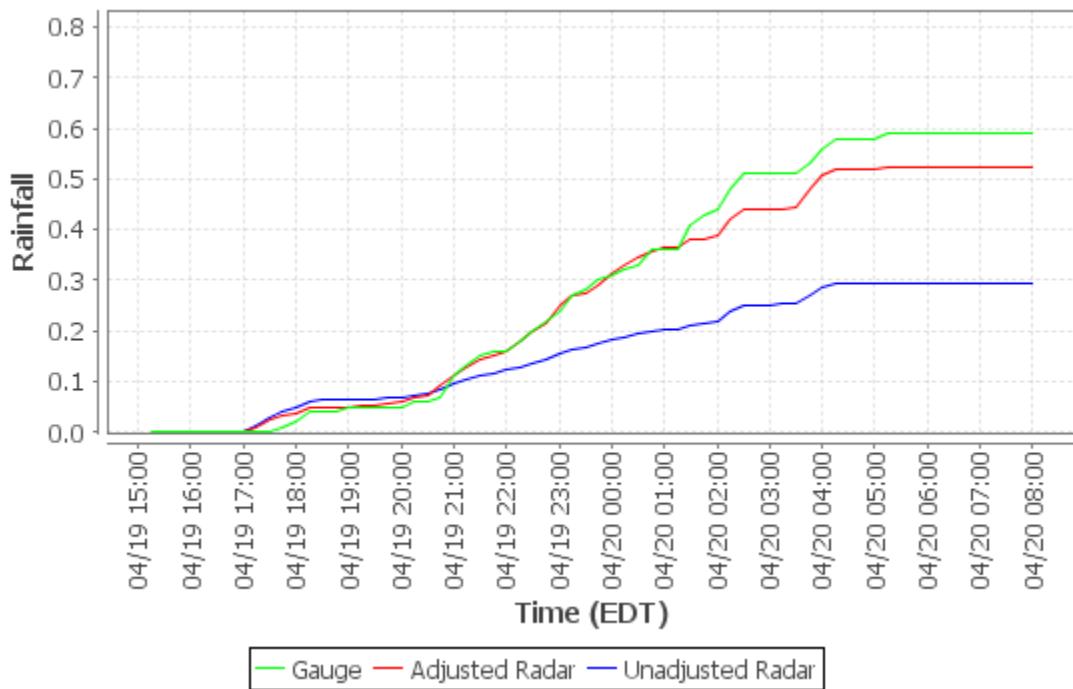
Cumulative Distribution Plot - Baldwin (Loc12)



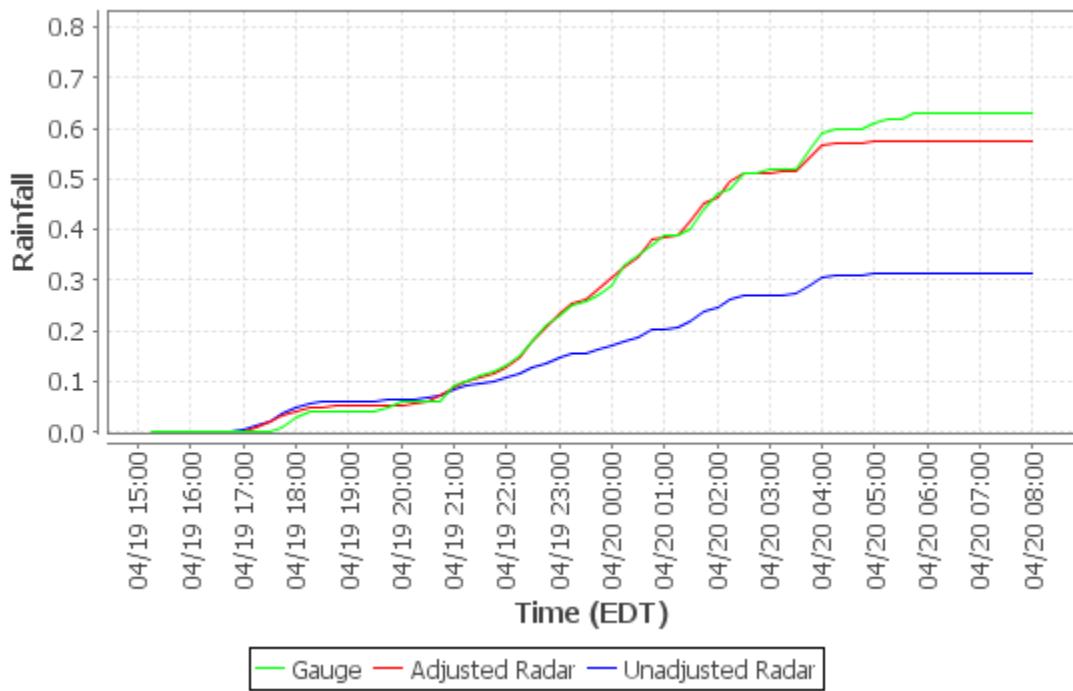
Cumulative Distribution Plot - M-59 Access Shaft (Loc13)



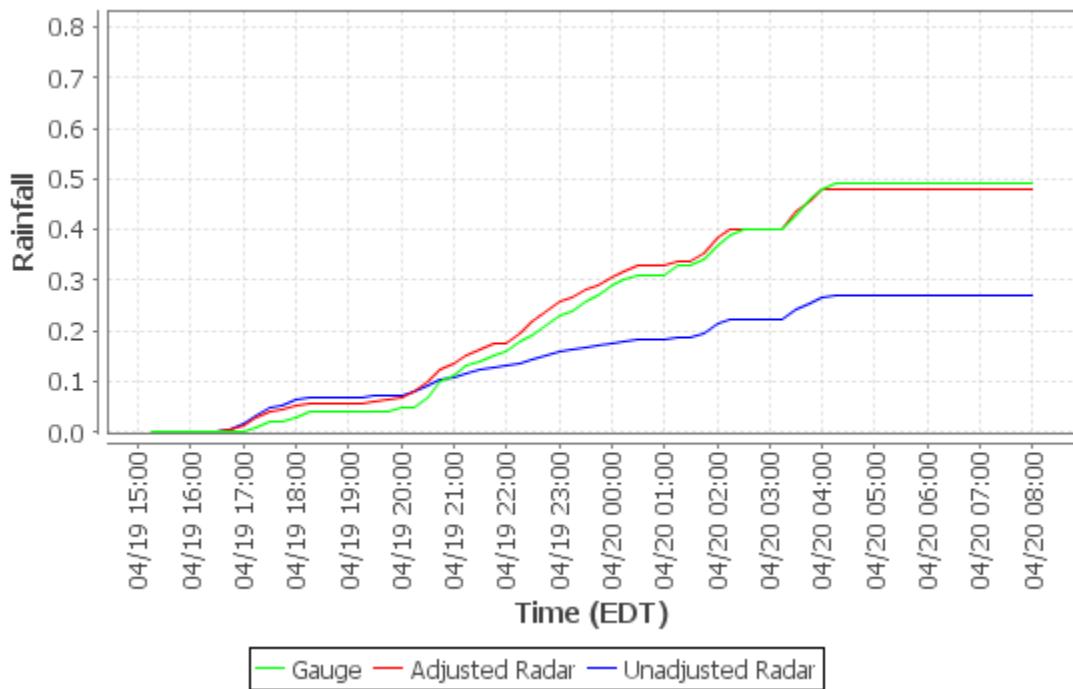
Cumulative Distribution Plot - Churchill Munic Bldg (Loc14)



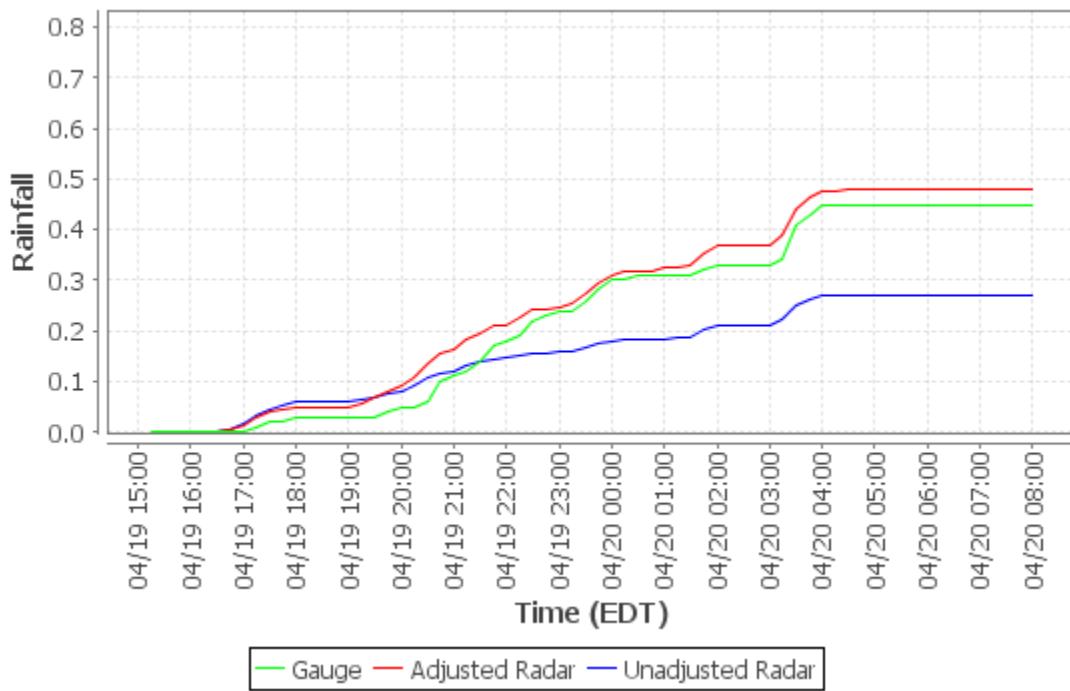
Cumulative Distribution Plot - Trafford Maint Bldg (Loc15)



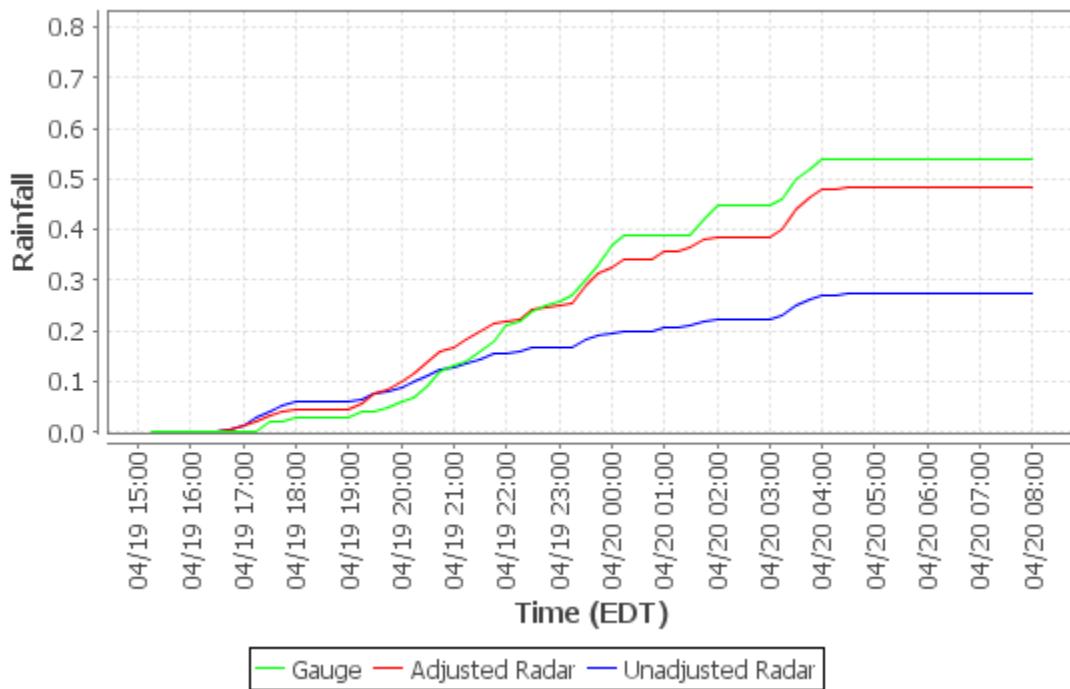
Cumulative Distribution Plot - Castle Shannon (Loc16)



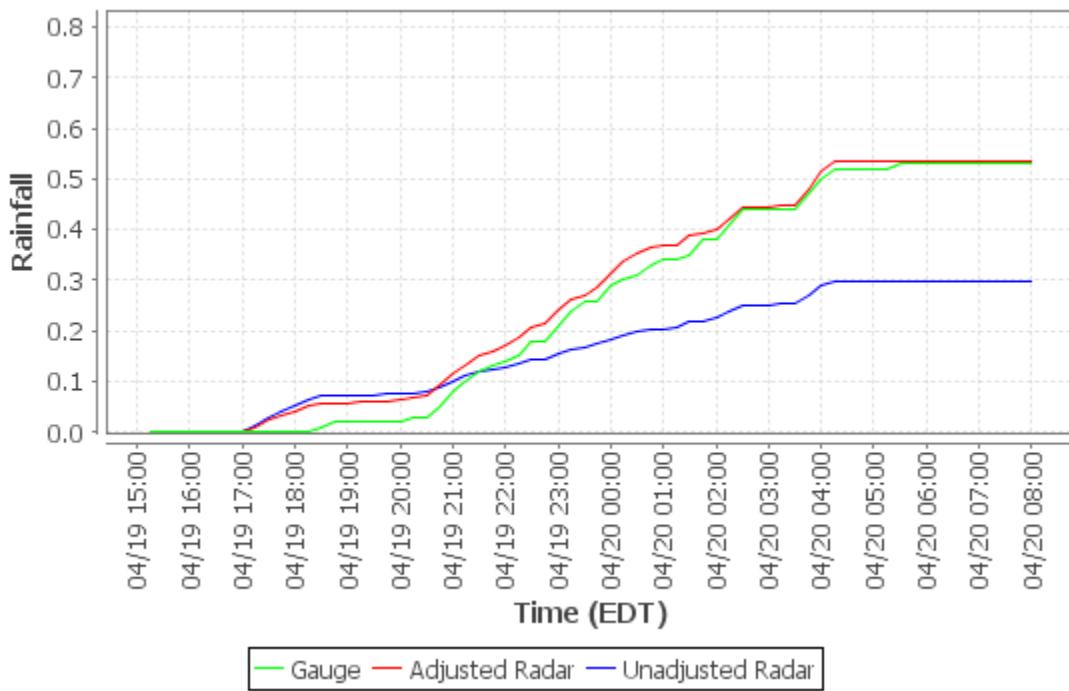
Cumulative Distribution Plot - Chartiers Pump Station (Loc17)



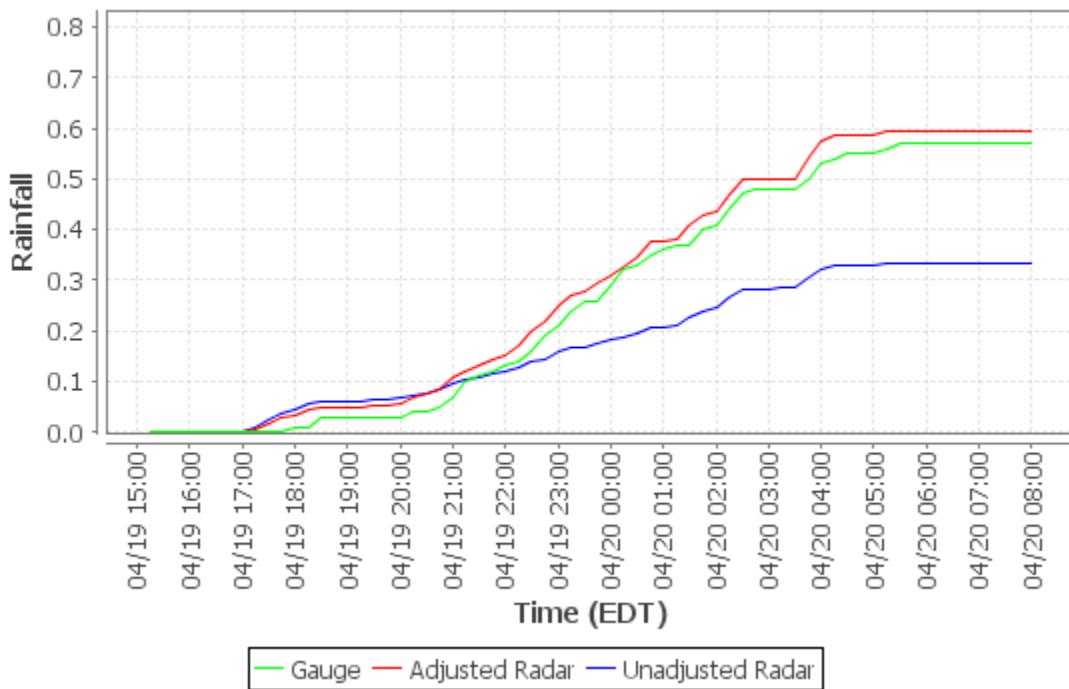
Cumulative Distribution Plot - Oakdale Pump Station (Loc18)



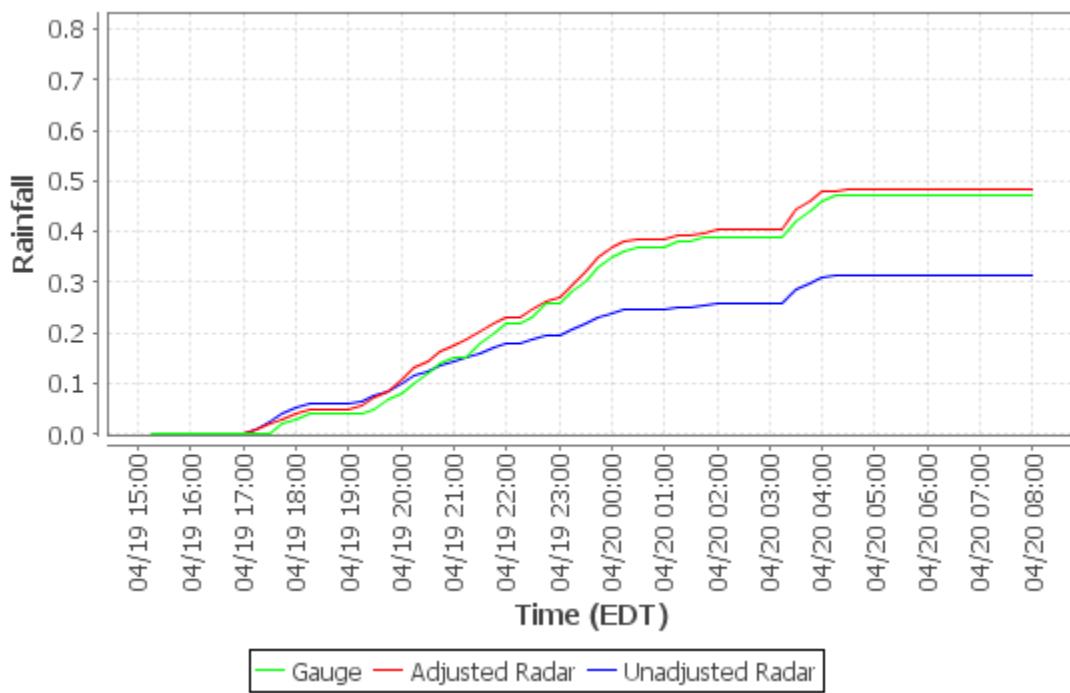
Cumulative Distribution Plot - Sandy Creek Eq Facility (Loc19)



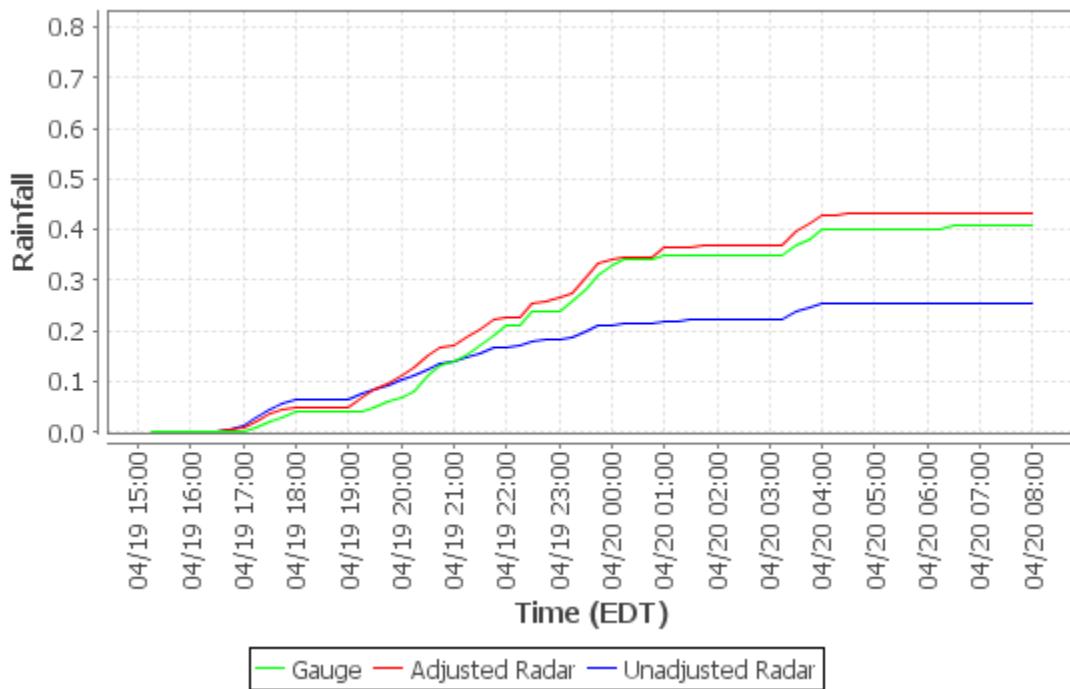
Cumulative Distribution Plot - Gascola Eq Facility (Loc20)



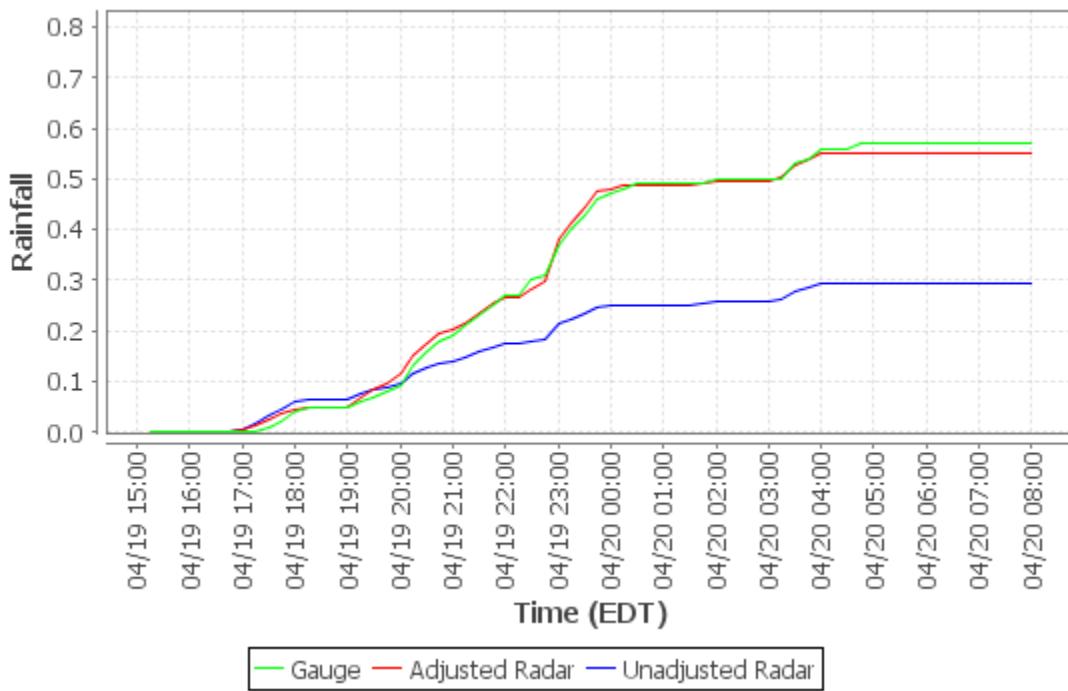
Cumulative Distribution Plot - Moon TWP (Loc21)



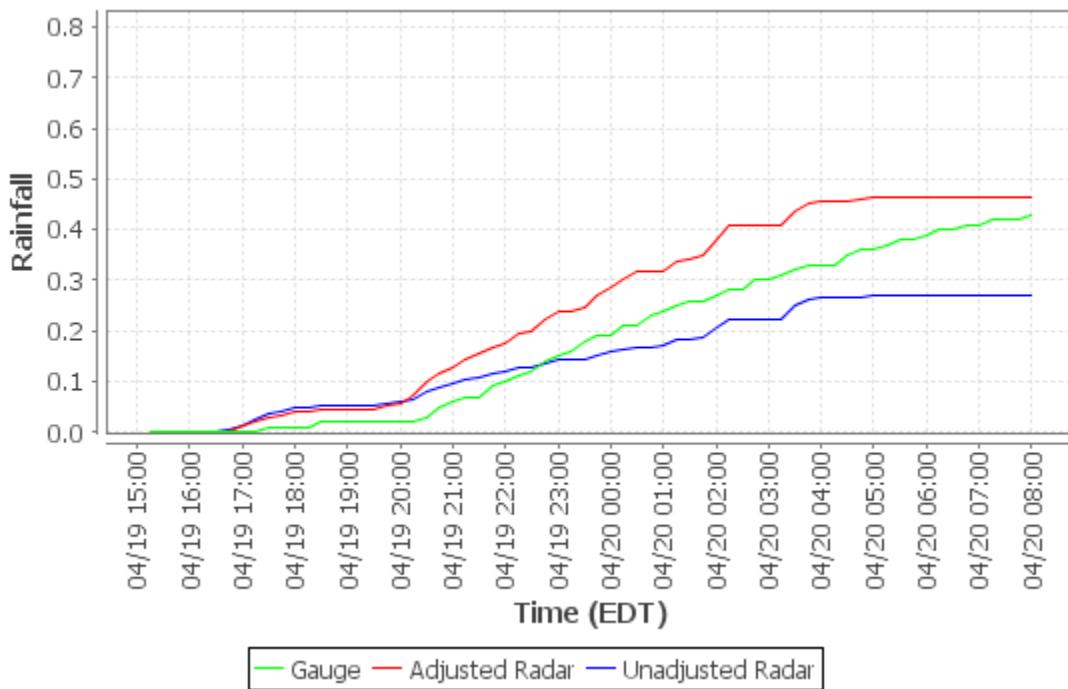
Cumulative Distribution Plot - North Fayette TWP (Loc22)



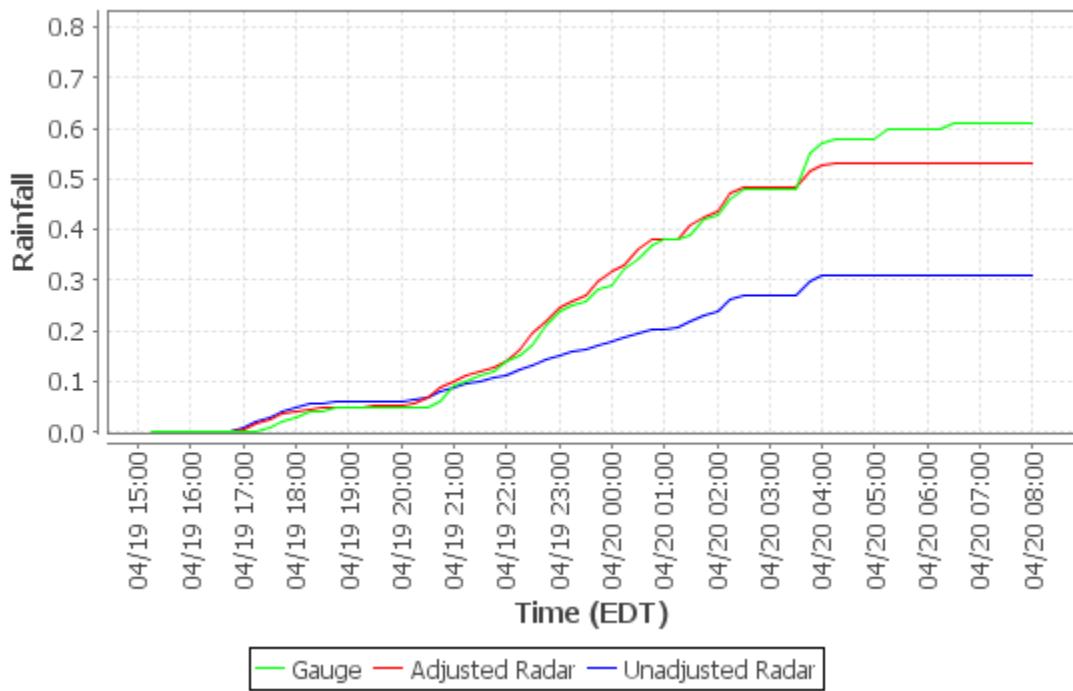
Cumulative Distribution Plot - Clinton Munic Bldg (Loc23)



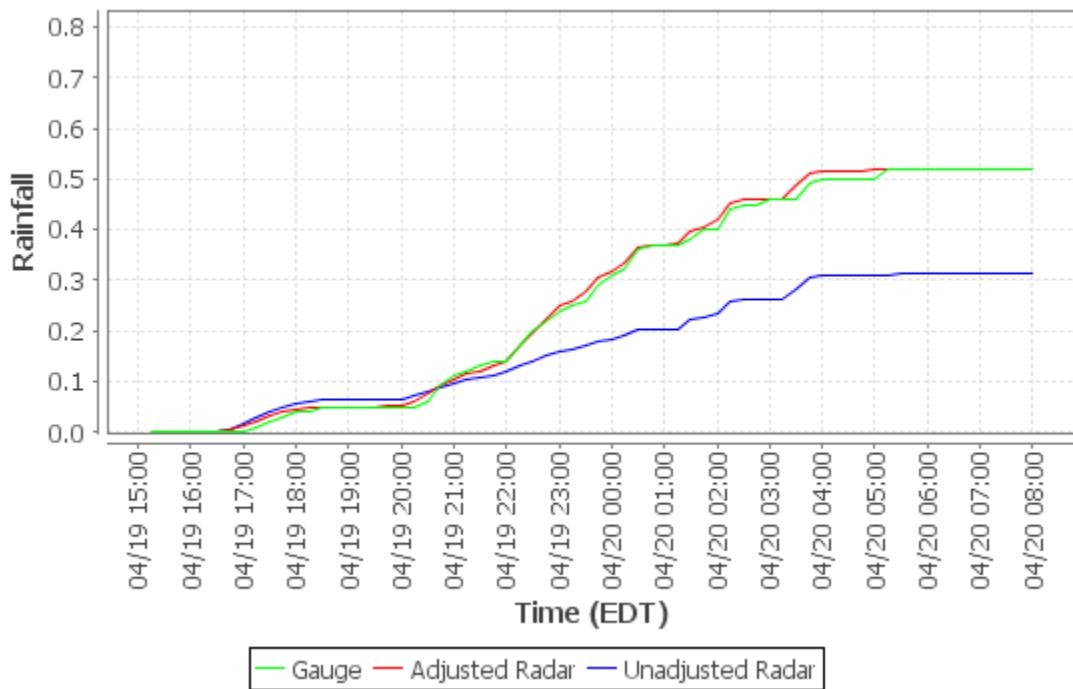
Cumulative Distribution Plot - Jefferson Hills (Loc24)



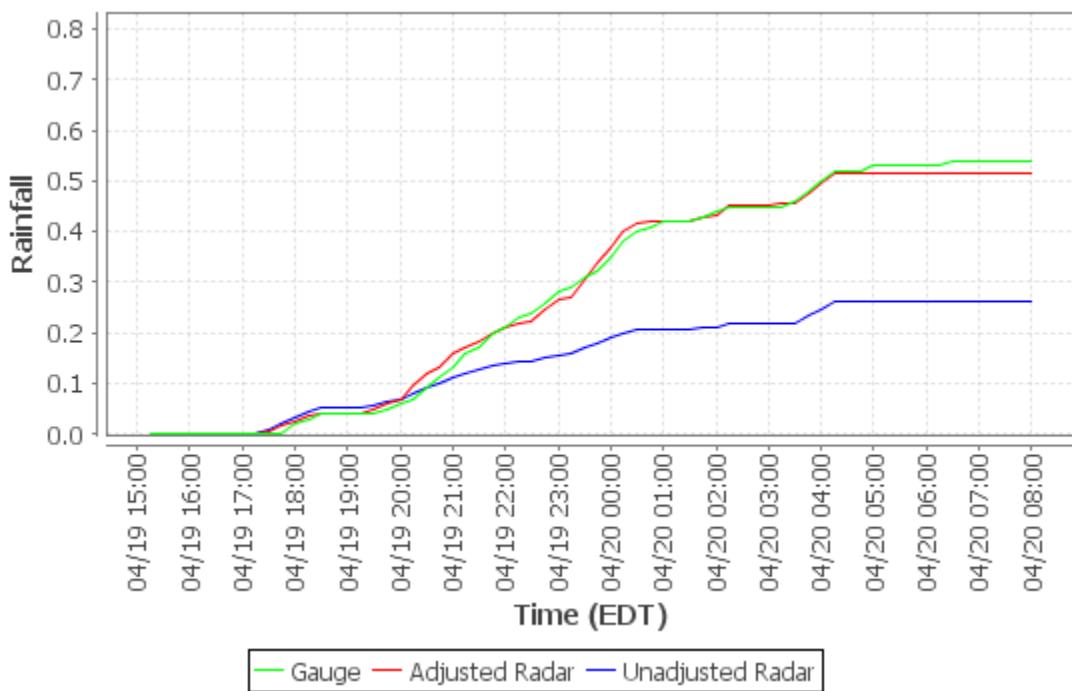
Cumulative Distribution Plot - White Oak Public Works Bldg (Loc25)



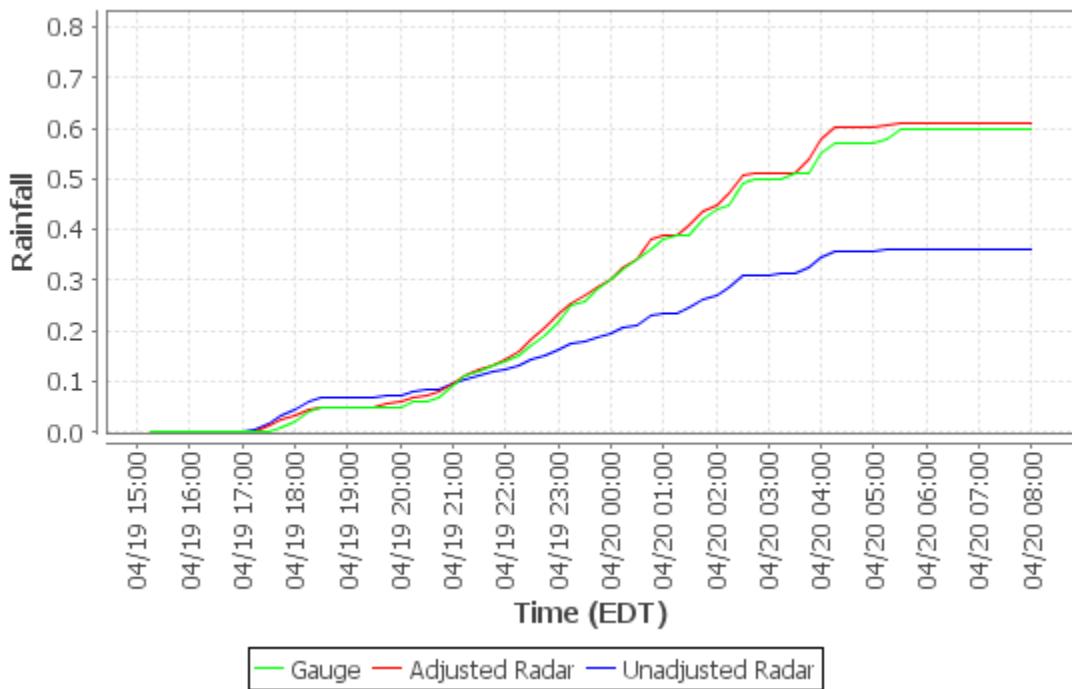
Cumulative Distribution Plot - Elizabeth TWP Municipal Bldg (Loc26)



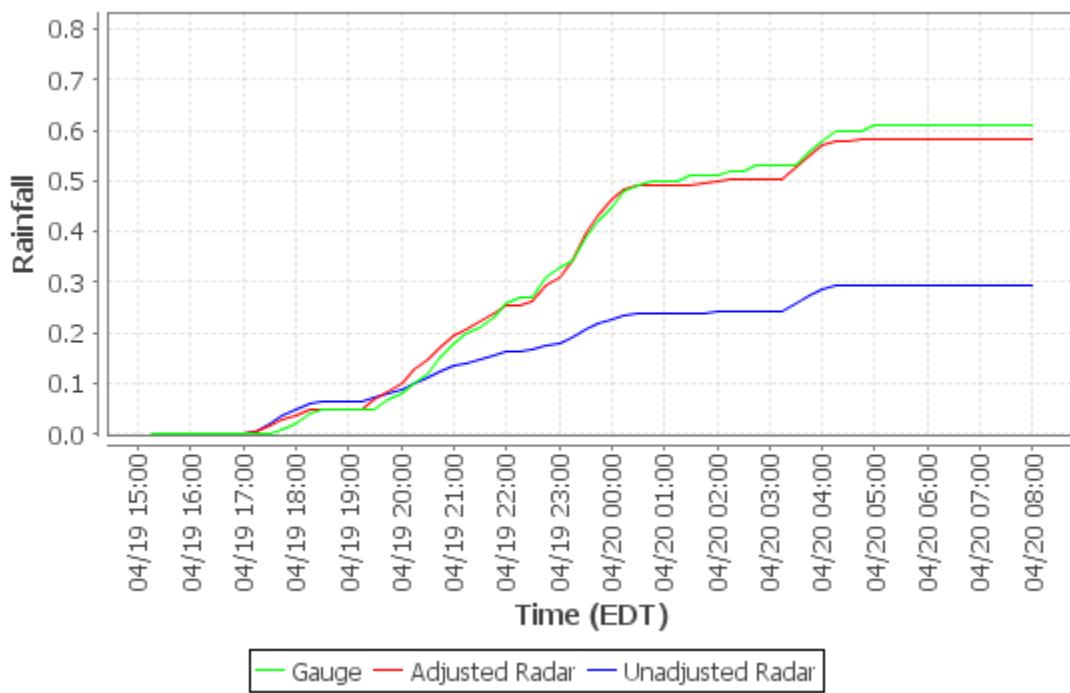
Cumulative Distribution Plot - Marshall TWP (Loc27)



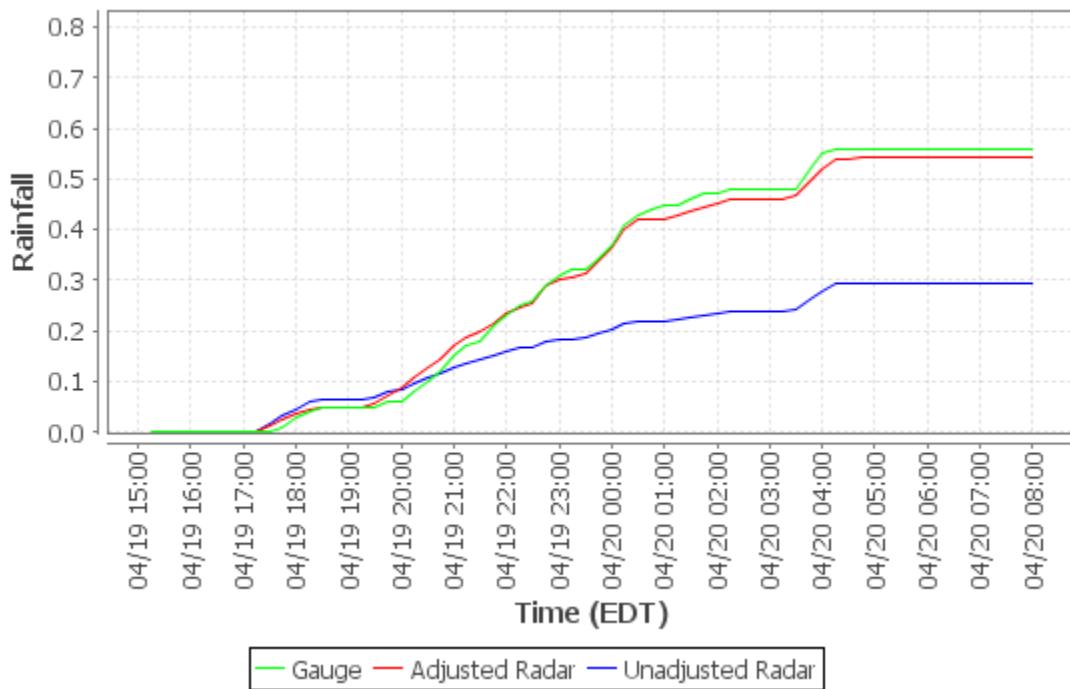
Cumulative Distribution Plot - Plum Municipal Bldg (Loc28)



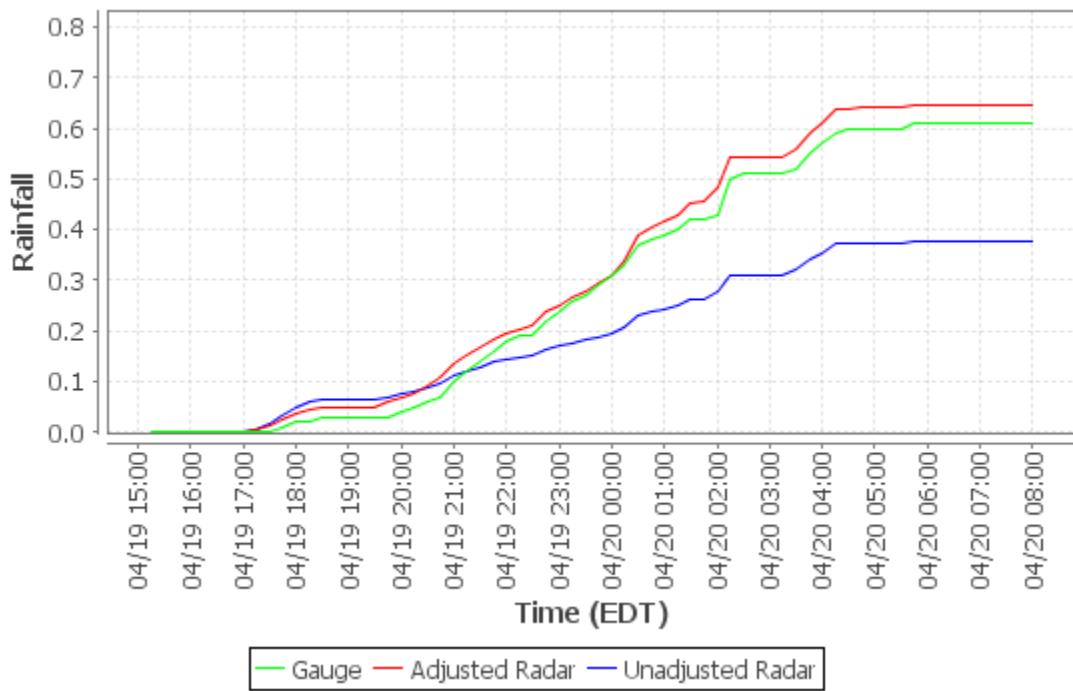
Cumulative Distribution Plot - Bell Acres Munic Bldg (Loc29)



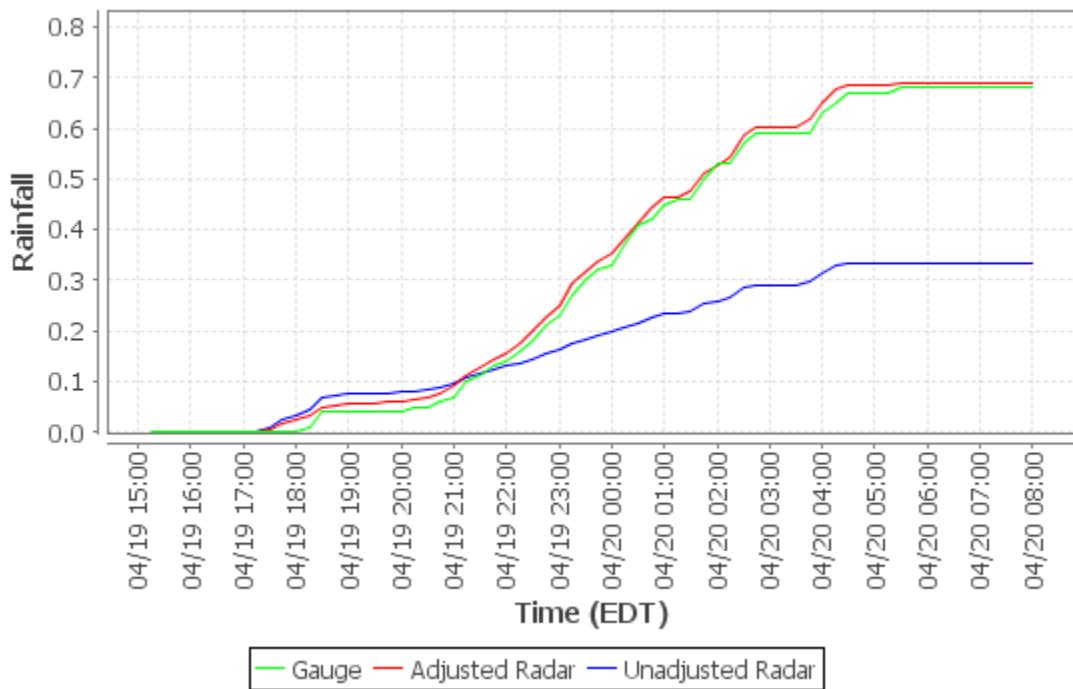
Cumulative Distribution Plot - McCandless Twn Hall (Loc30)



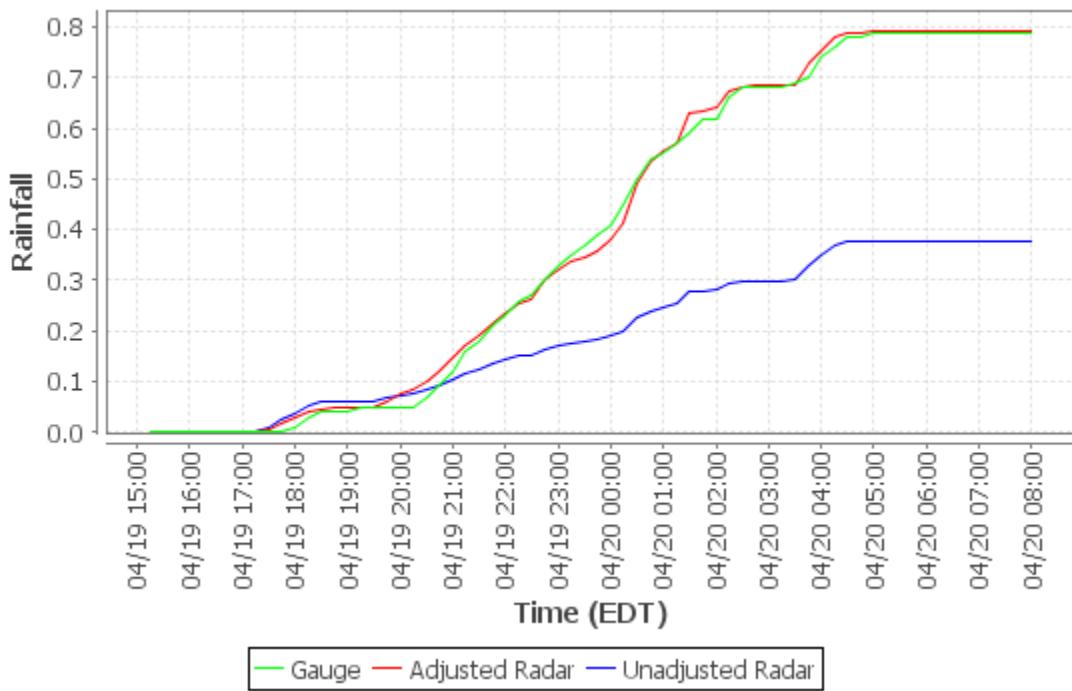
Cumulative Distribution Plot - Hampton Municipal Bldg (Loc31)



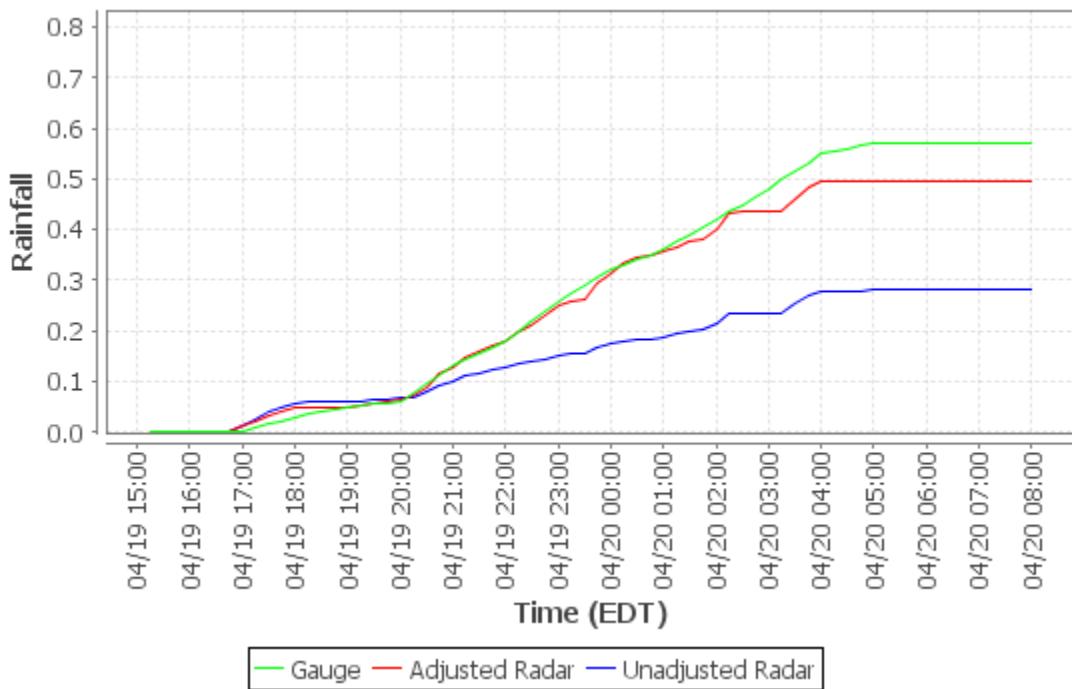
Cumulative Distribution Plot - Arnold (Loc32)



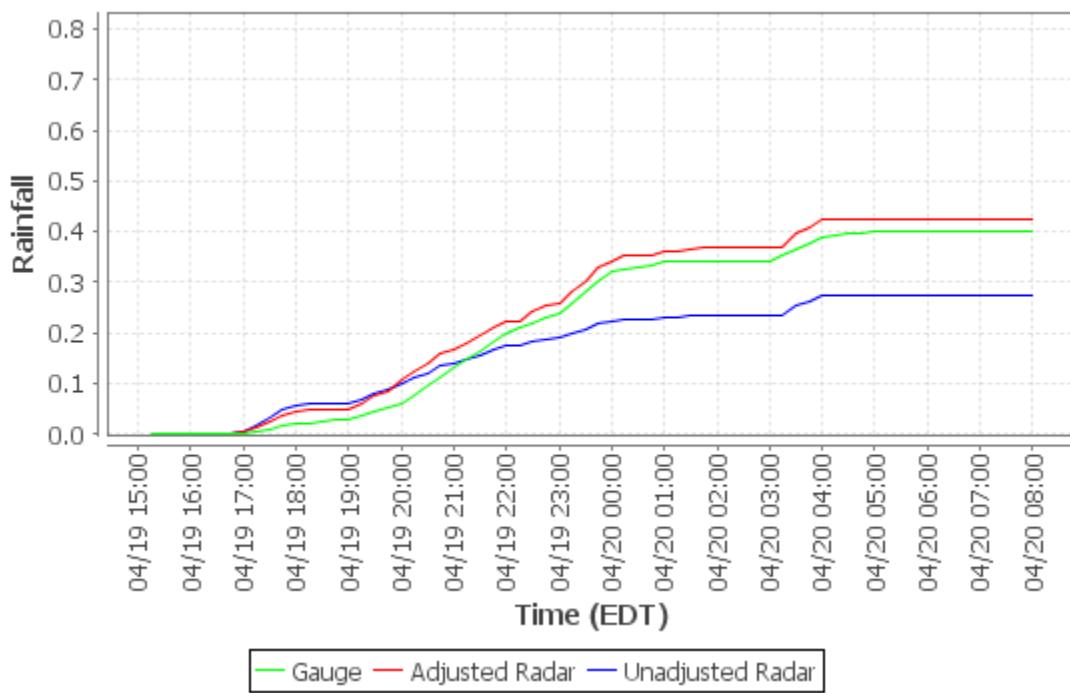
Cumulative Distribution Plot - Richland TWP (Loc33)



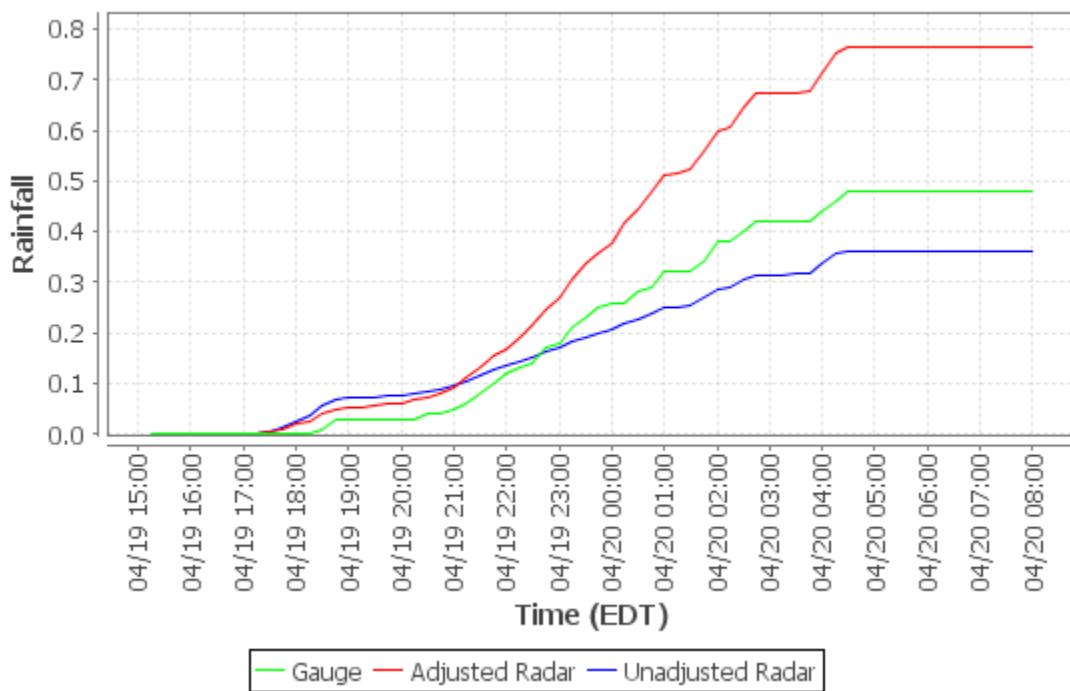
Cumulative Distribution Plot - Pittsburgh Allegheny Cty (KAGC)



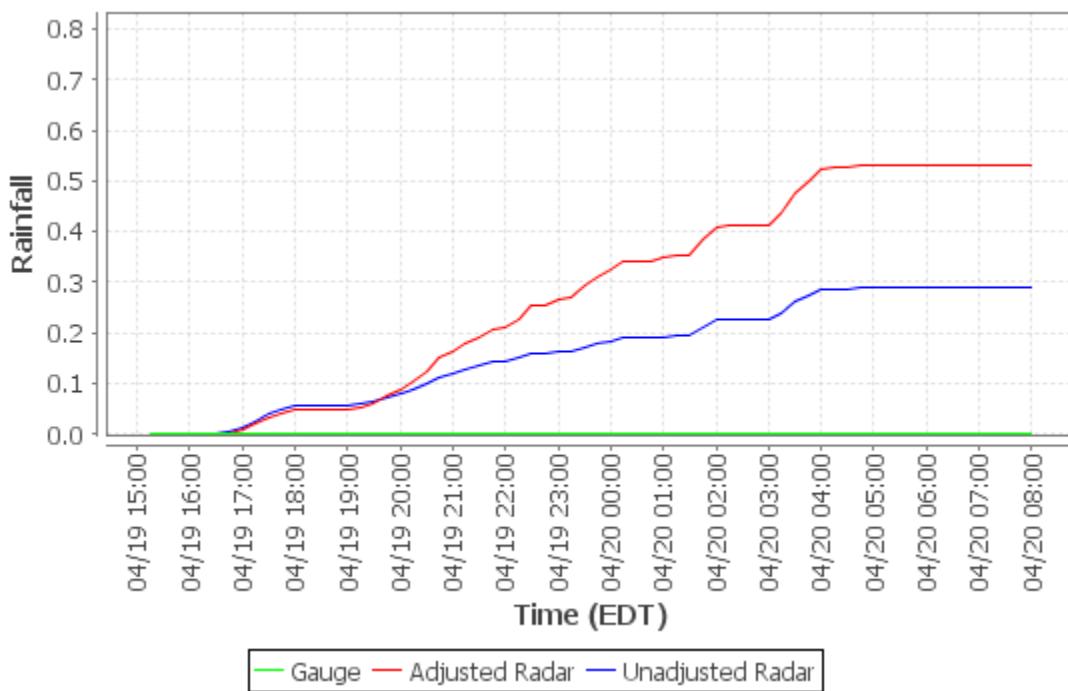
Cumulative Distribution Plot - Greater Pittsburgh Int'l (KPIT)



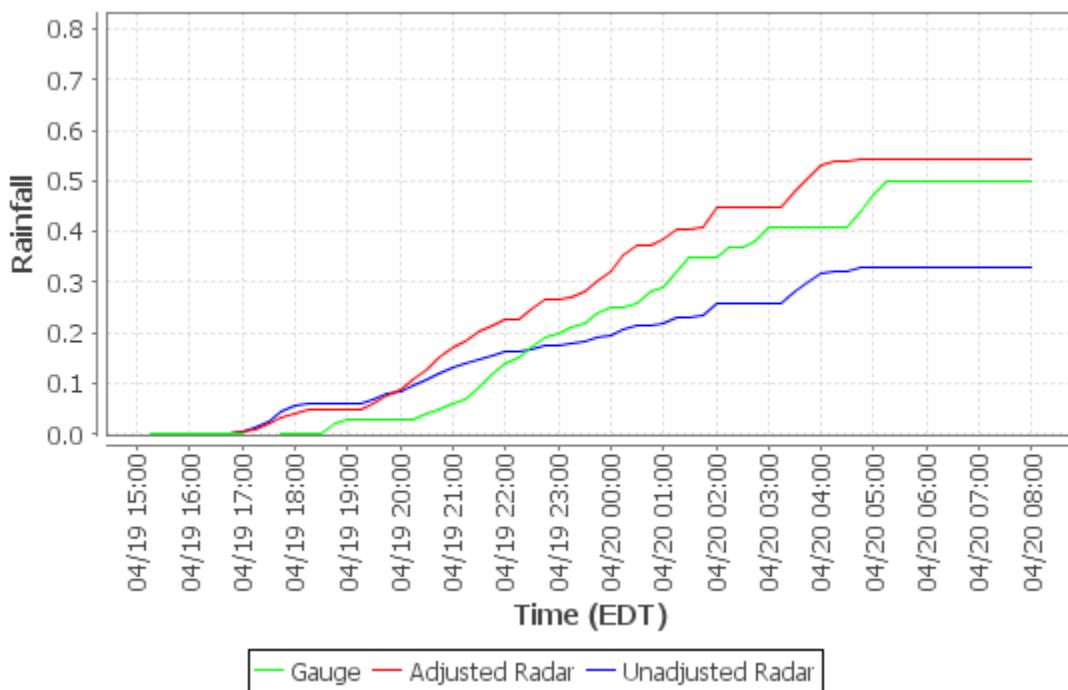
Cumulative Distribution Plot - Allegheny River at Natrona (03049500)



Cumulative Distribution Plot - Chartiers Creek at Carnegie (03085500)

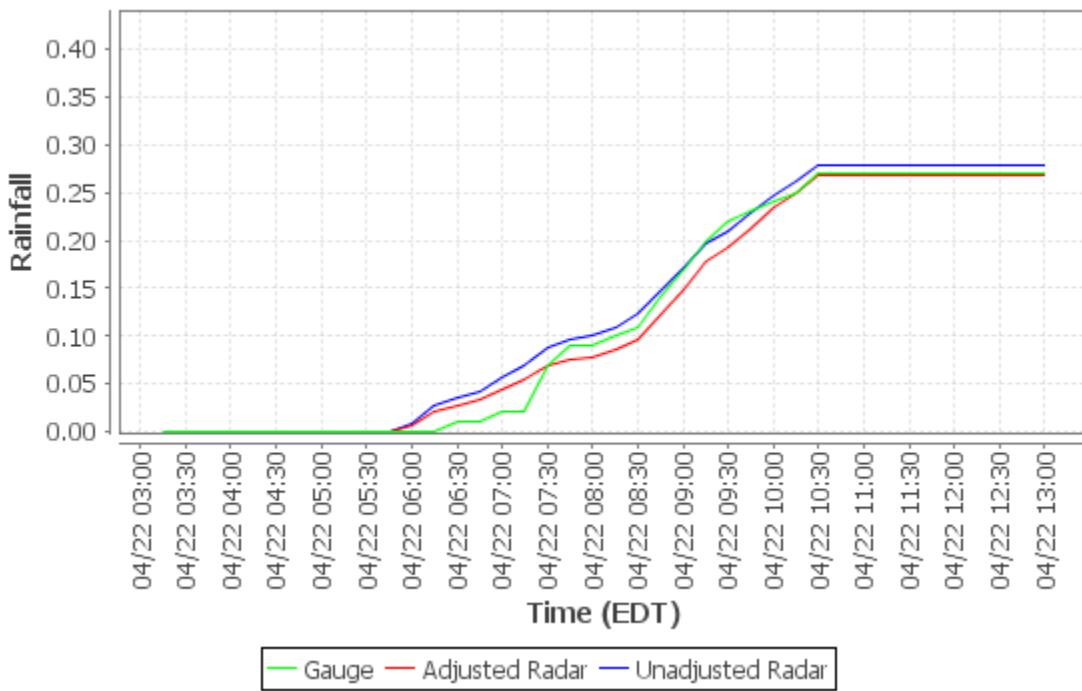


Cumulative Distribution Plot - Ohio River at Emsworth Dam Lower Pool at Emsworth (03085734)

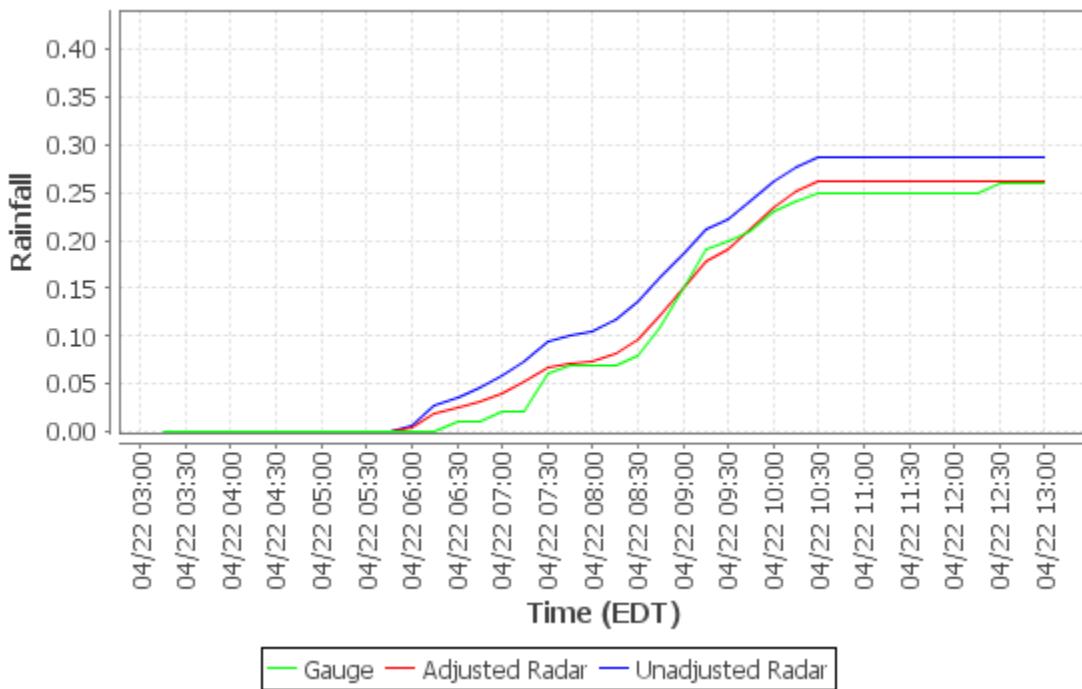


Appendix M - Event 12 (2015-04-22) CDPs

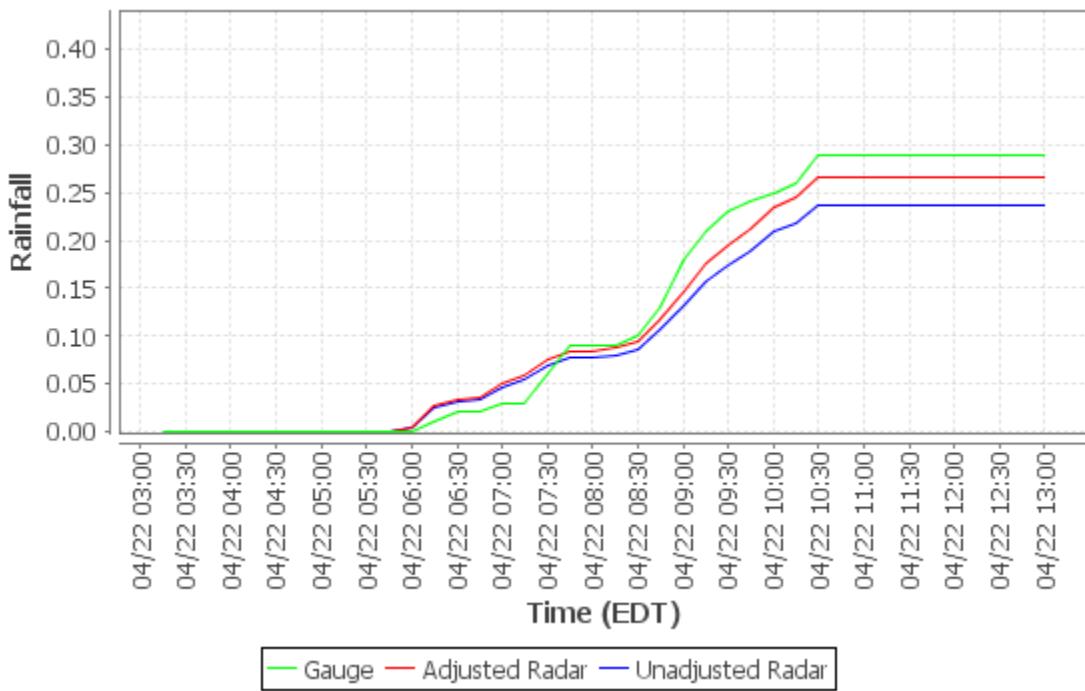
Cumulative Distribution Plot - PWSA-Montana St. (Loc01)



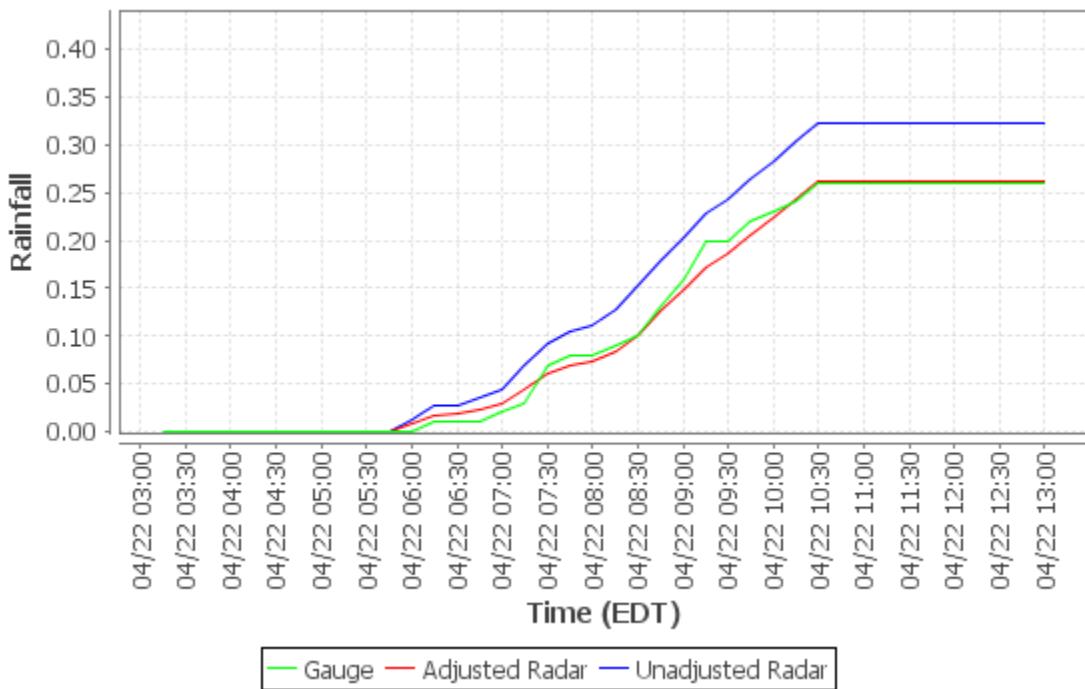
Cumulative Distribution Plot - ALCOSAN WWTP Lab (Loc02)



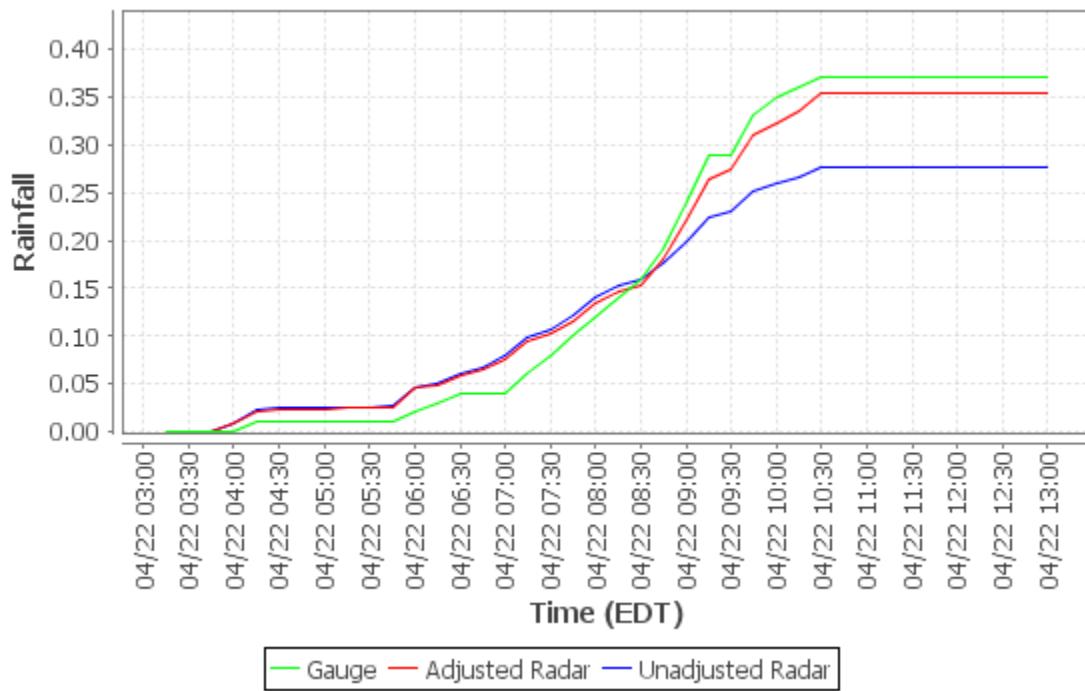
Cumulative Distribution Plot - Shaler Munic Bldg (Loc03)



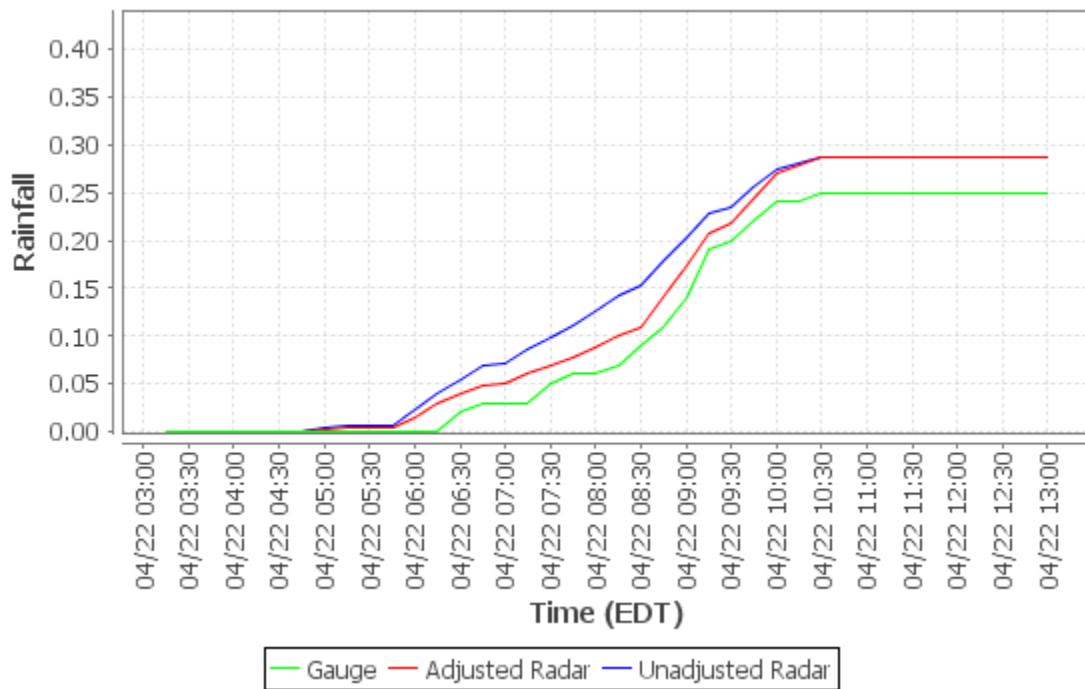
Cumulative Distribution Plot - Kennedy Twp PS (Loc04)



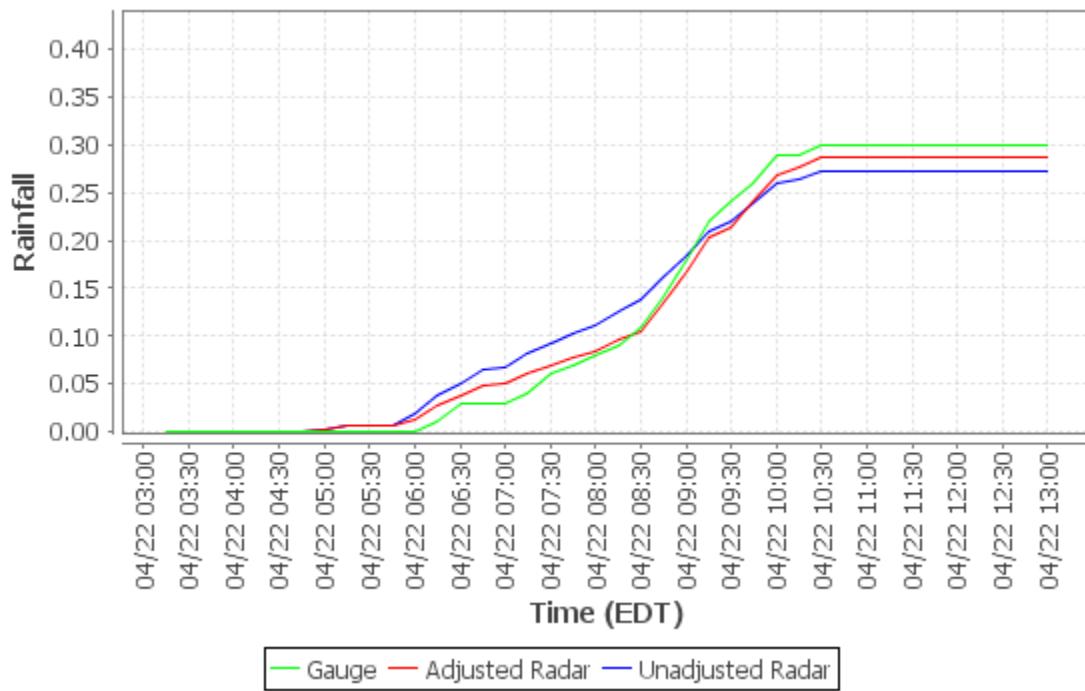
Cumulative Distribution Plot - Upper St. Clair (Loc05)



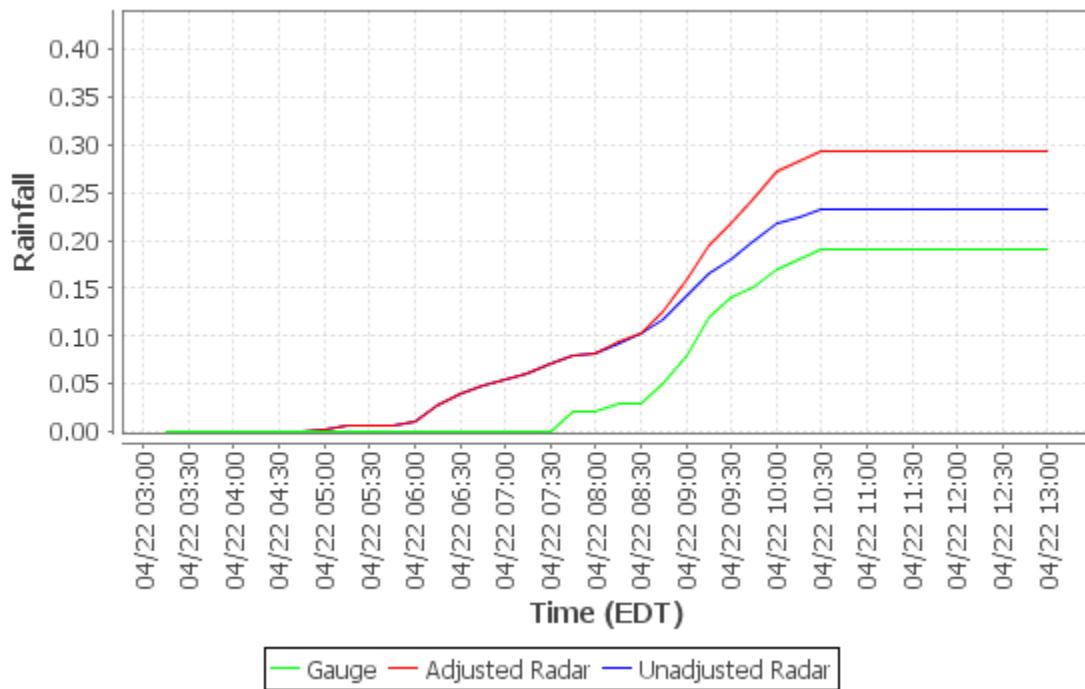
Cumulative Distribution Plot - Carnegie Transit Time (Loc06)



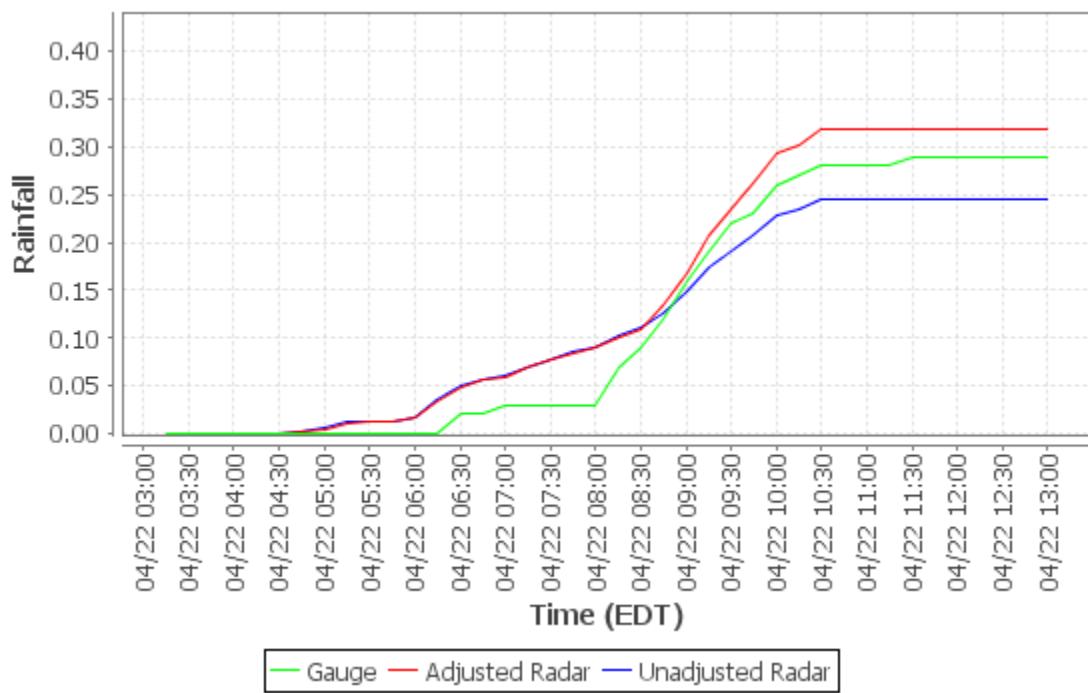
Cumulative Distribution Plot - Greentree Munic Bldg (Loc07)



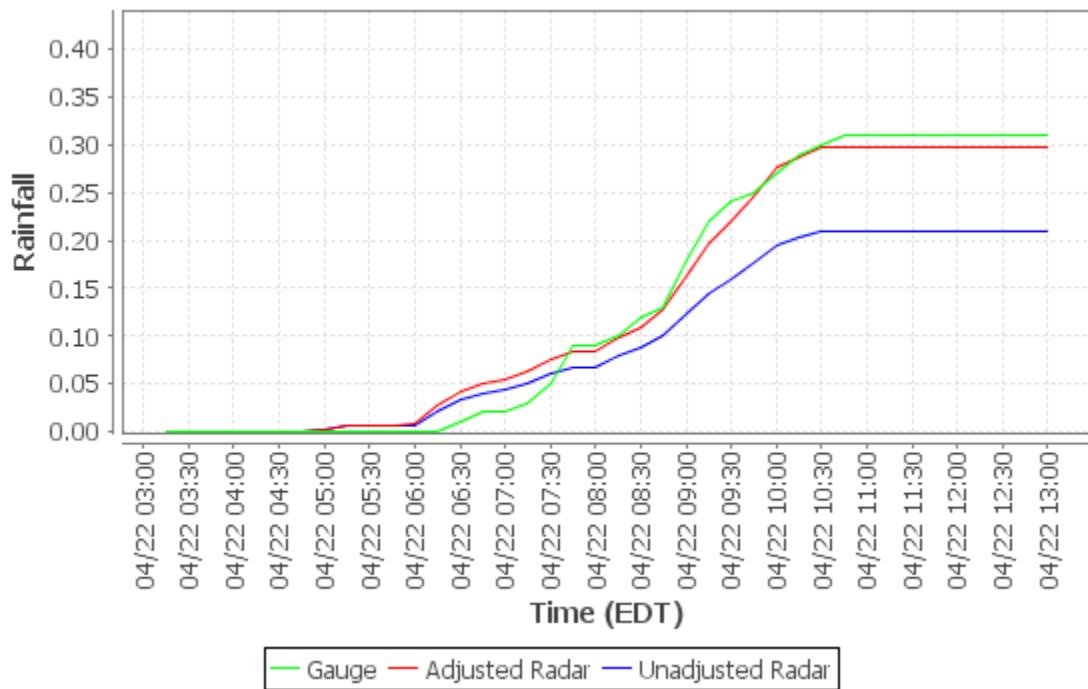
Cumulative Distribution Plot - AC Health Dept Bldg (Loc08)



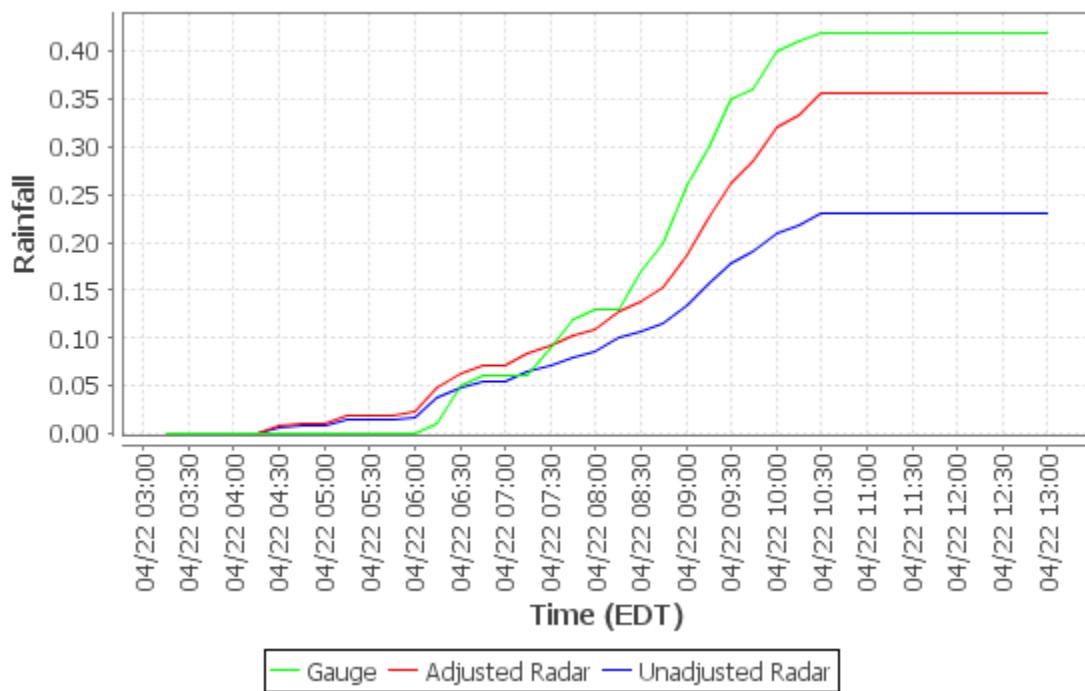
Cumulative Distribution Plot - Univ of Pittsburgh (Loc09)



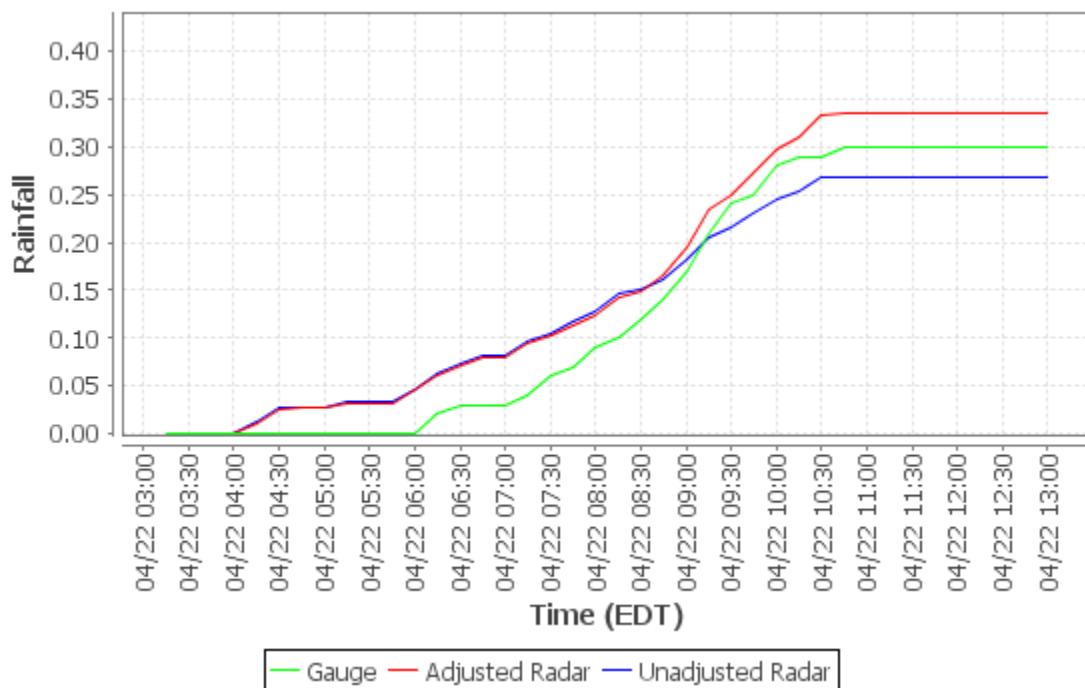
Cumulative Distribution Plot - PWSA-Highland Park (Loc10)



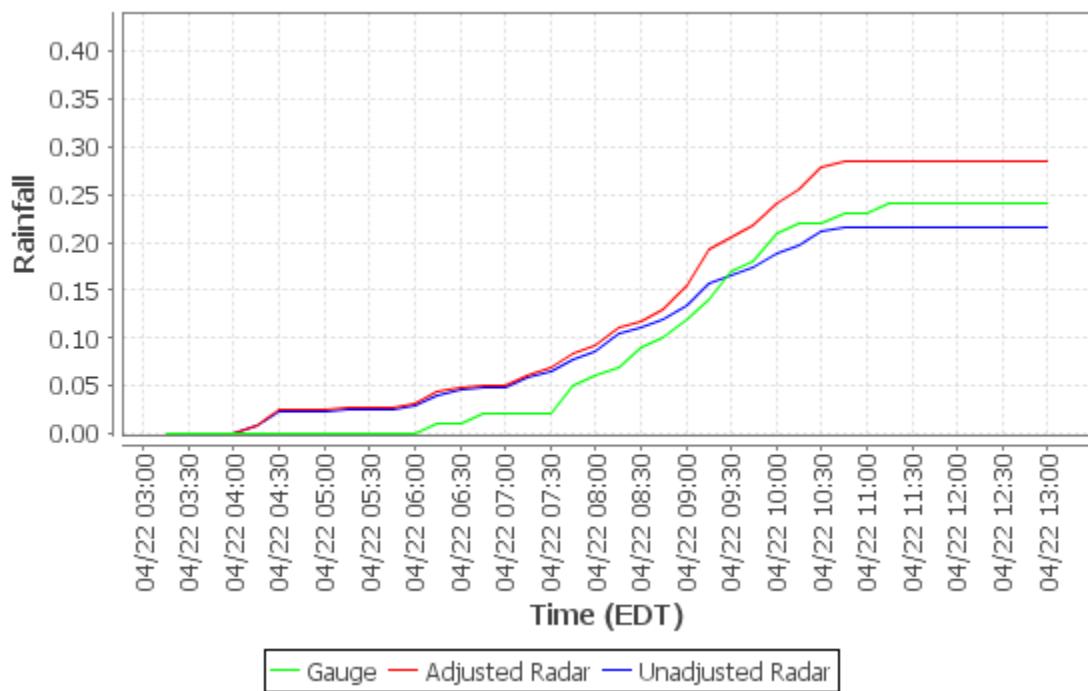
Cumulative Distribution Plot - M-46 Access Shaft (Loc11)



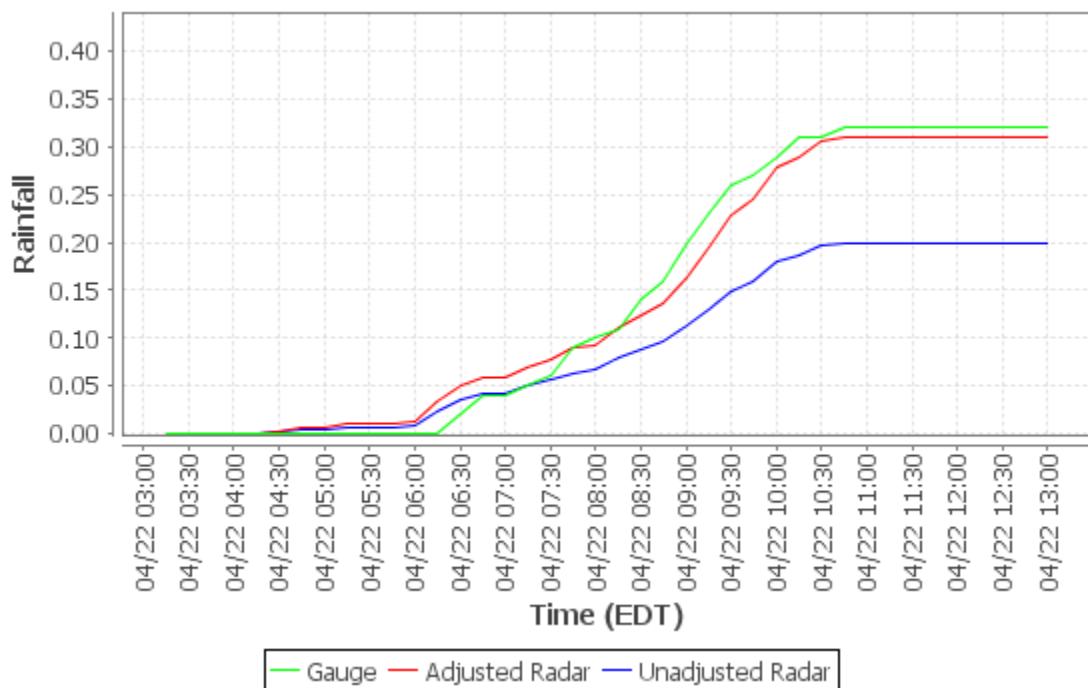
Cumulative Distribution Plot - Baldwin (Loc12)



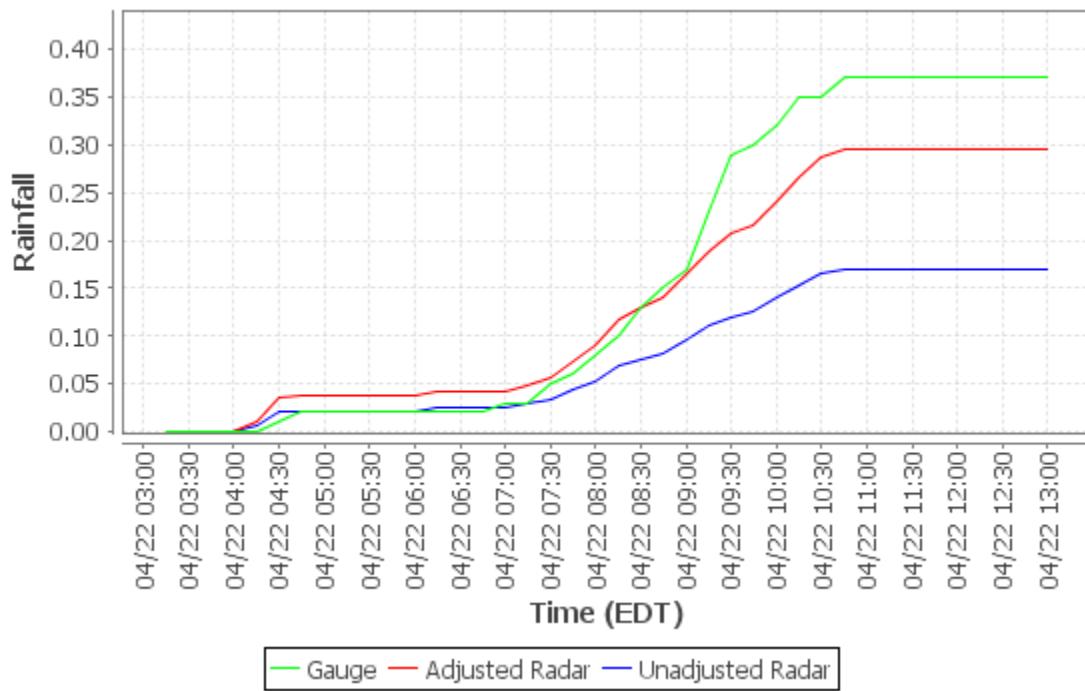
Cumulative Distribution Plot - M-59 Access Shaft (Loc13)



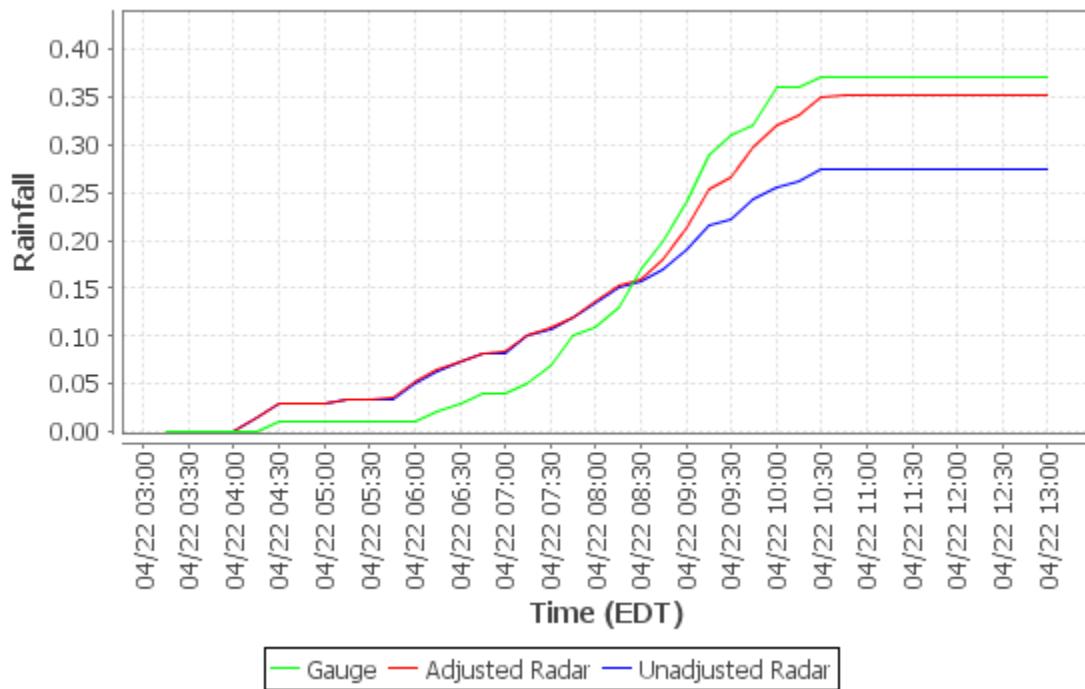
Cumulative Distribution Plot - Churchill Munic Bldg (Loc14)



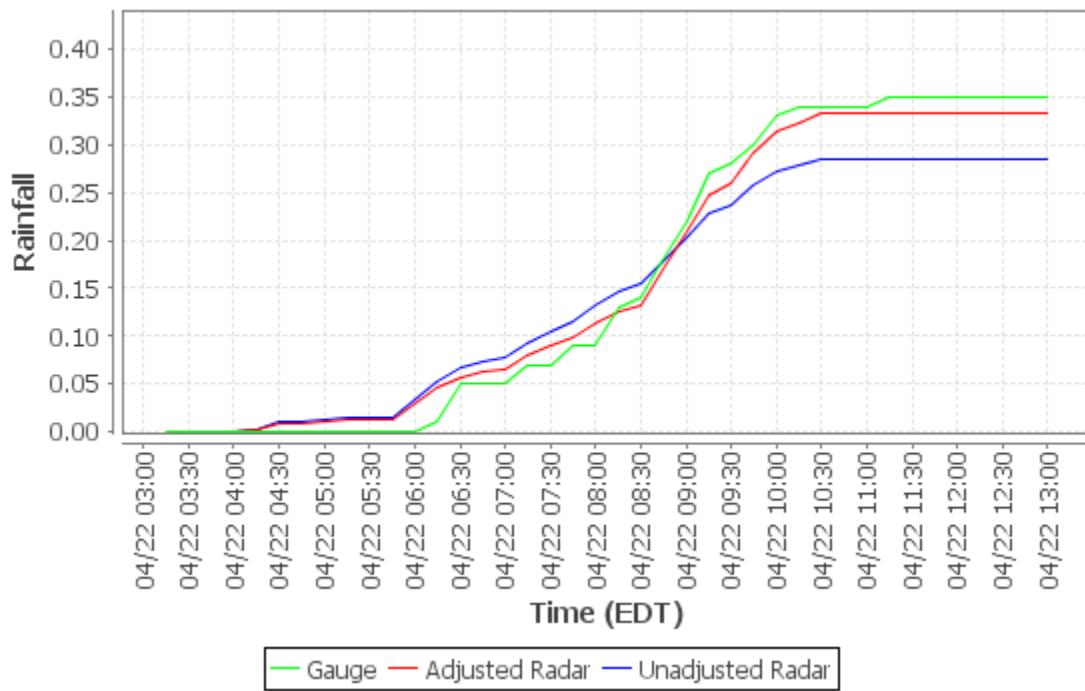
Cumulative Distribution Plot - Trafford Maint Bldg (Loc15)



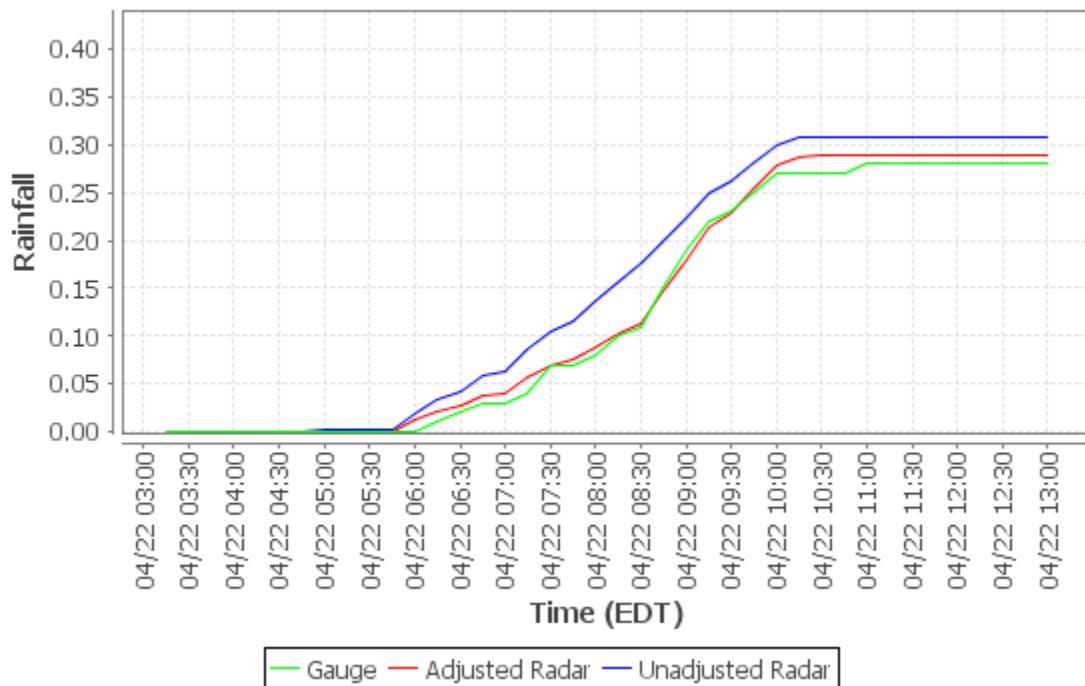
Cumulative Distribution Plot - Castle Shannon (Loc16)



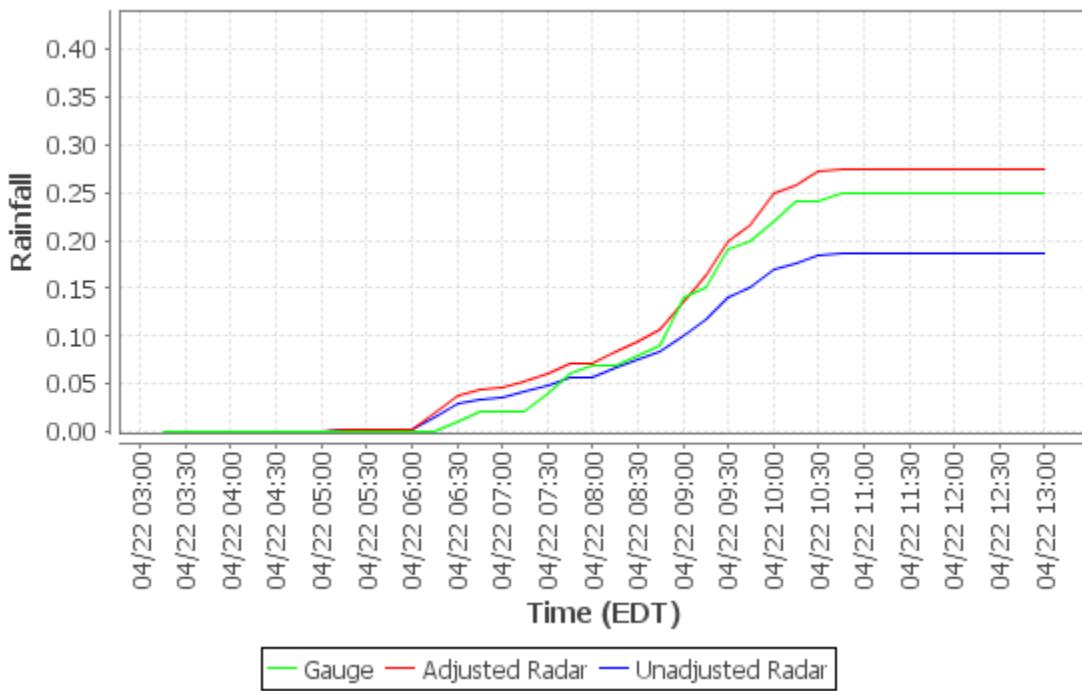
Cumulative Distribution Plot - Chartiers Pump Station (Loc17)



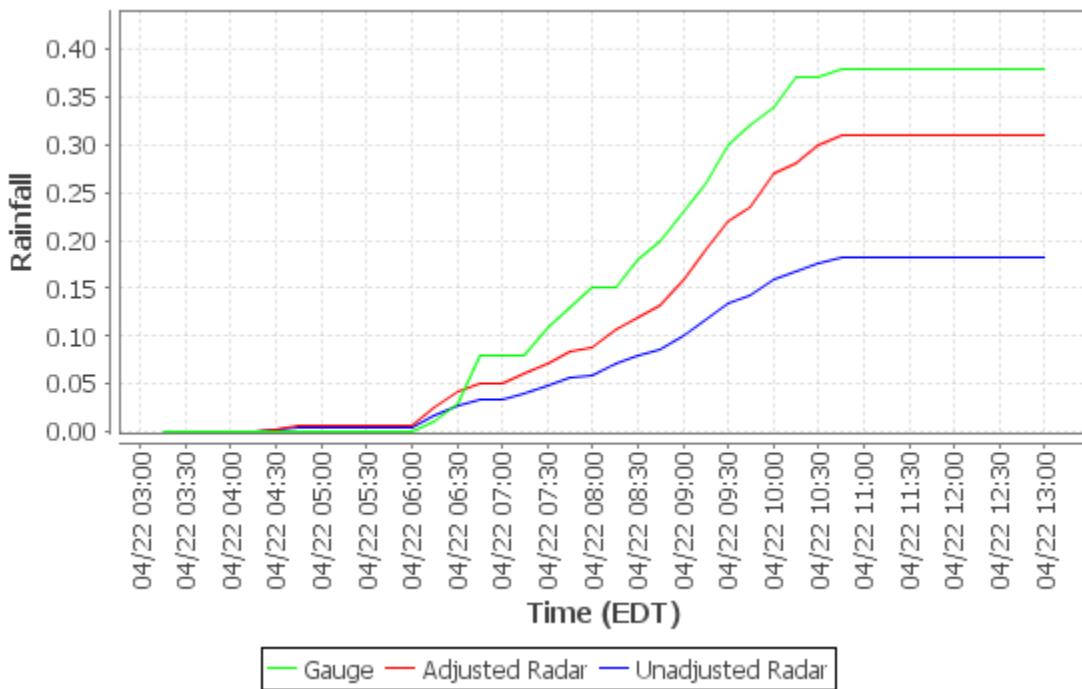
Cumulative Distribution Plot - Oakdale Pump Station (Loc18)



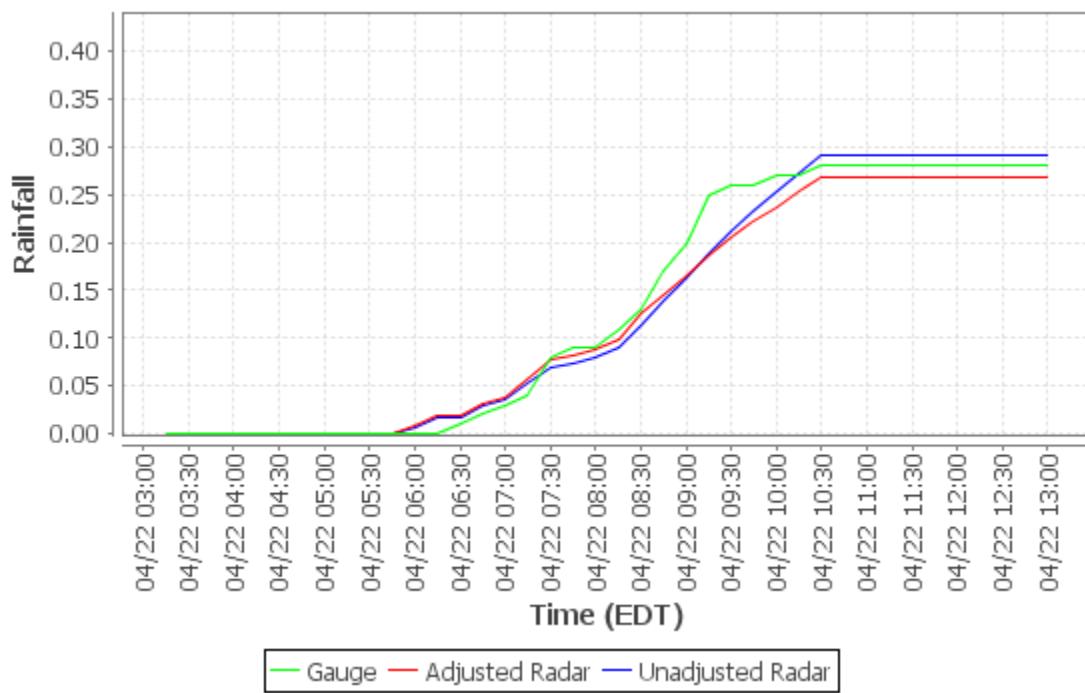
Cumulative Distribution Plot - Sandy Creek Eq Facility (Loc19)



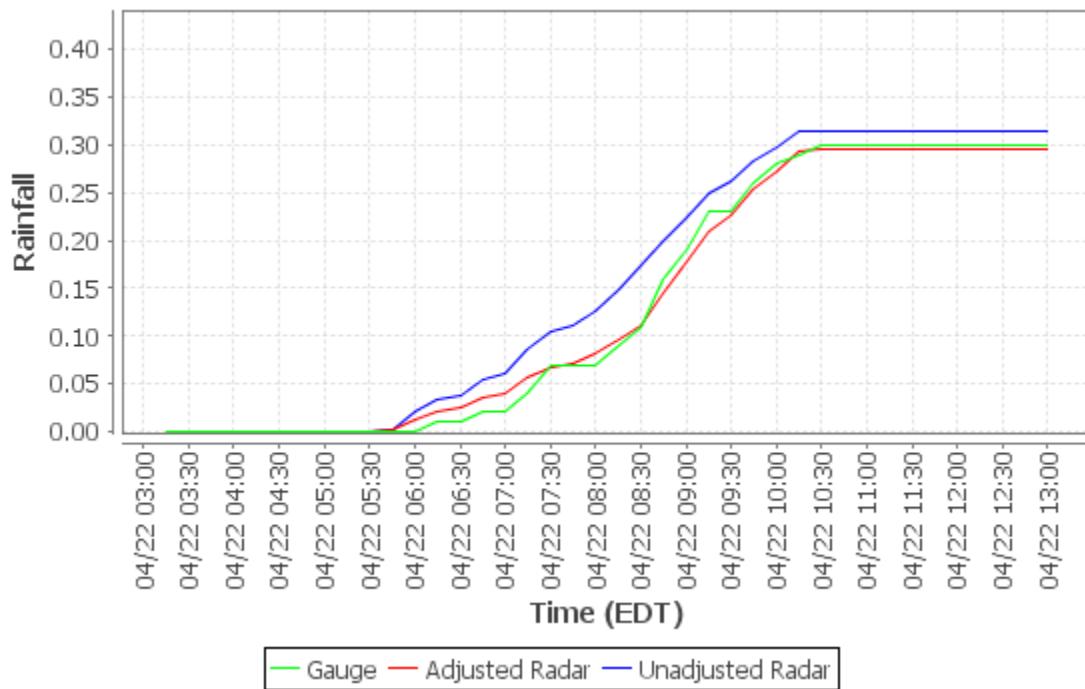
Cumulative Distribution Plot - Gascola Eq Facility (Loc20)



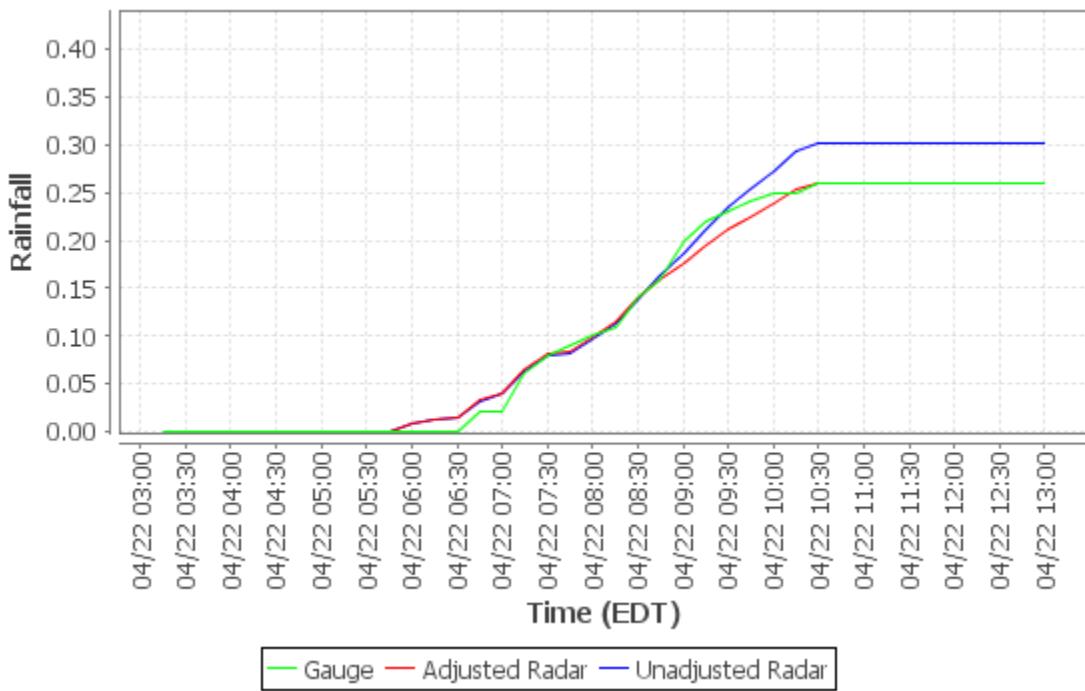
Cumulative Distribution Plot - Moon TWP (Loc21)



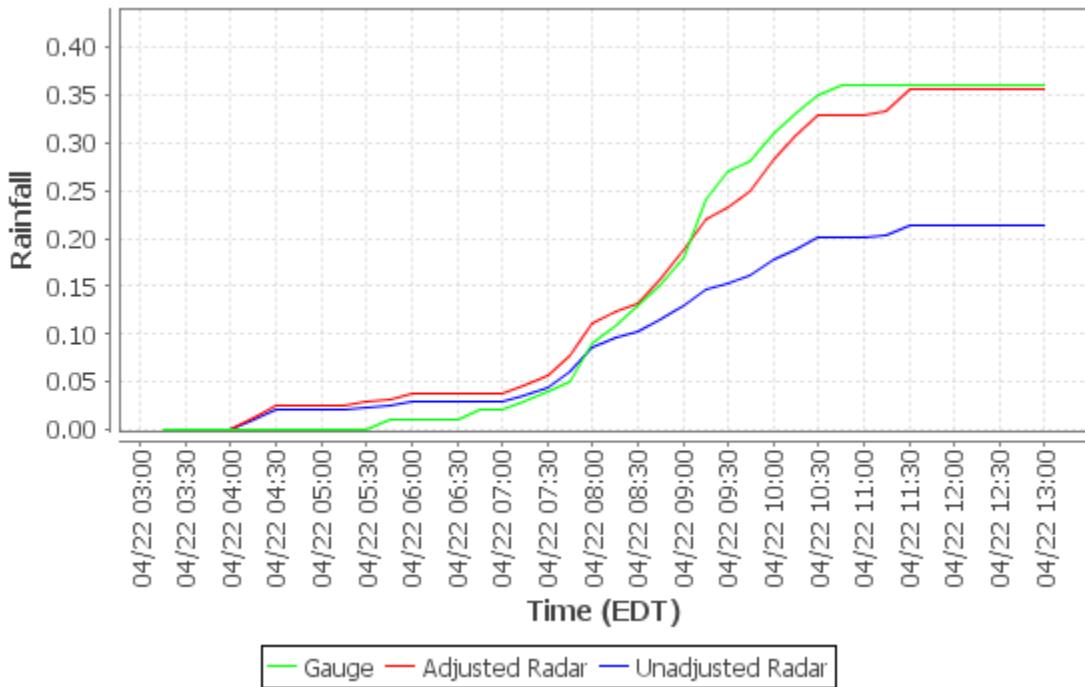
Cumulative Distribution Plot - North Fayette TWP (Loc22)



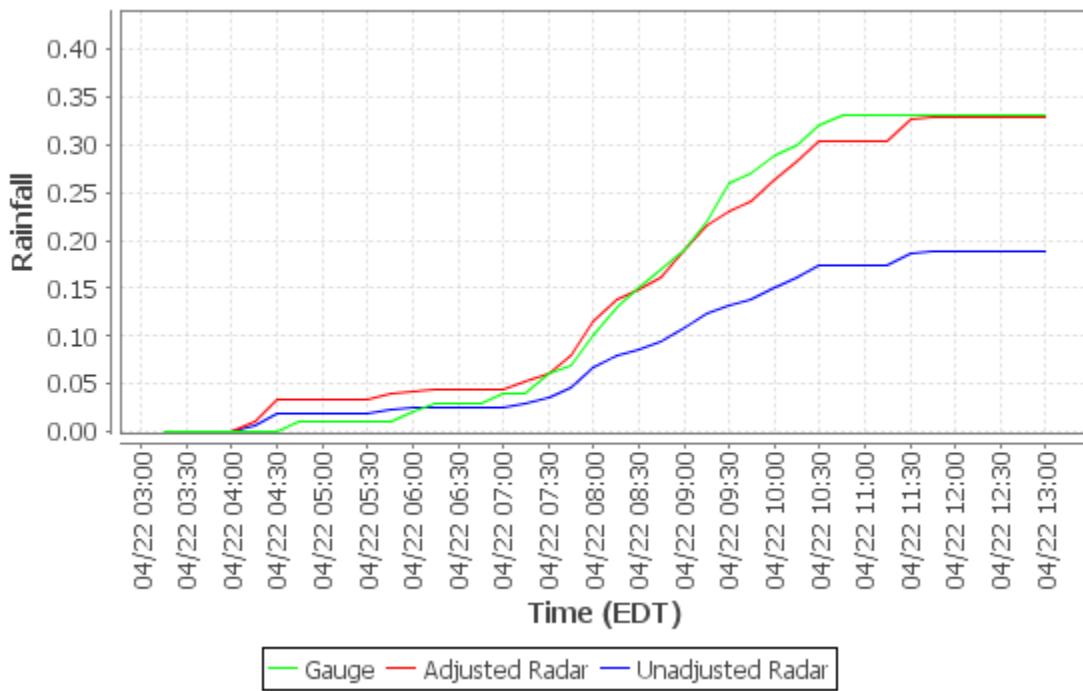
Cumulative Distribution Plot - Clinton Munic Bldg (Loc23)



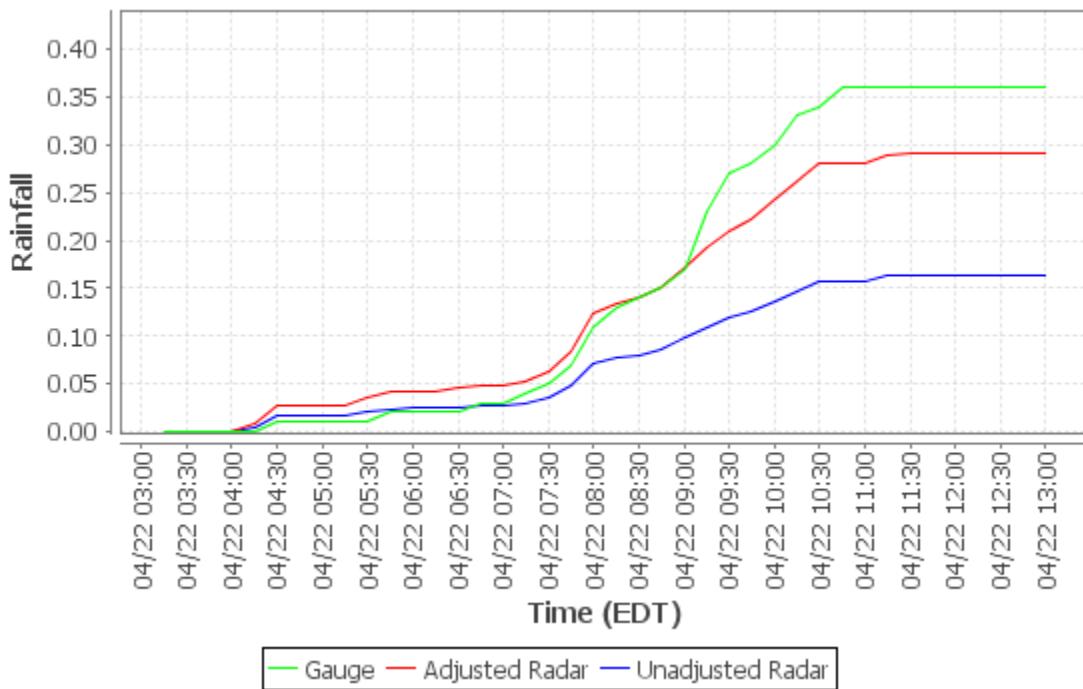
Cumulative Distribution Plot - Jefferson Hills (Loc24)



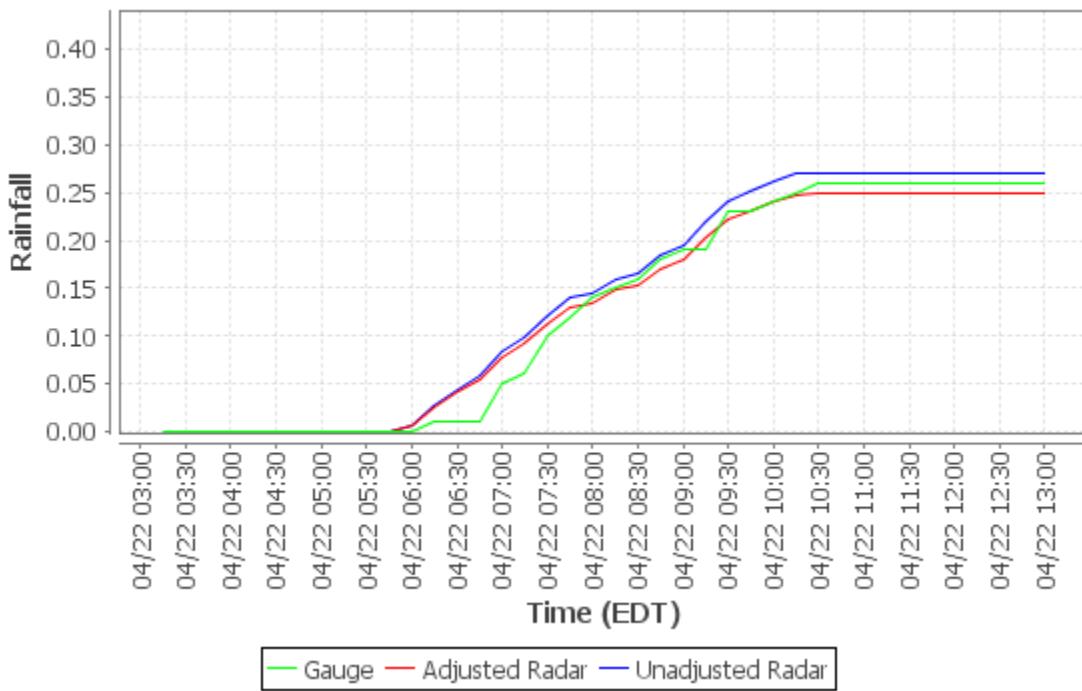
Cumulative Distribution Plot - White Oak Public Works Bldg (Loc25)



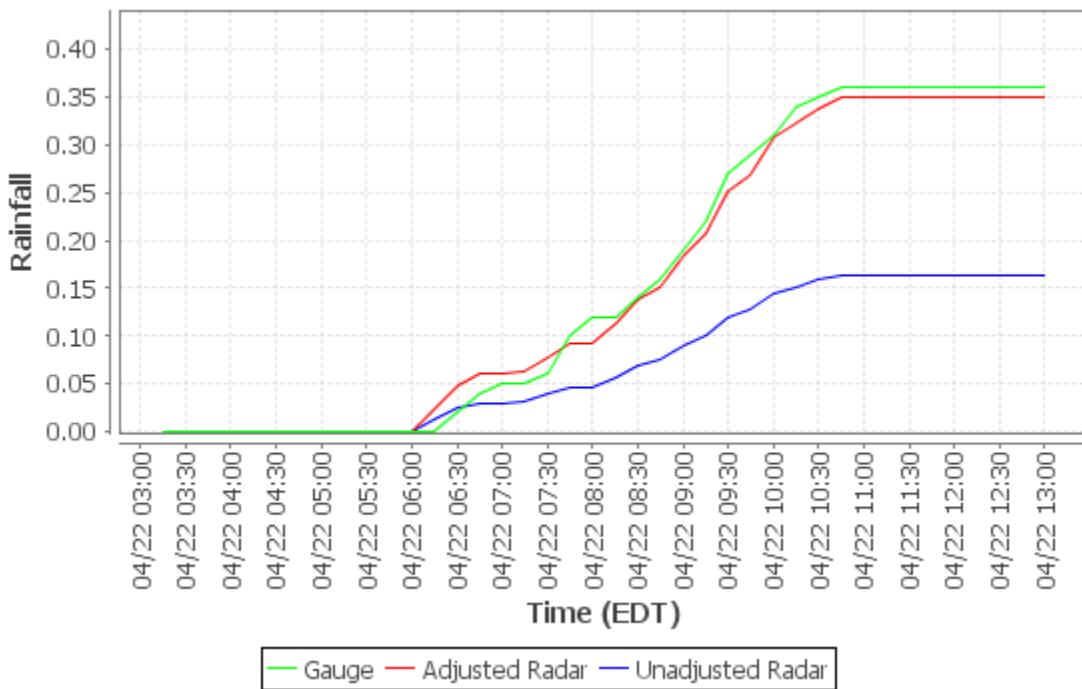
Cumulative Distribution Plot - Elizabeth TWP Municipal Bldg (Loc26)



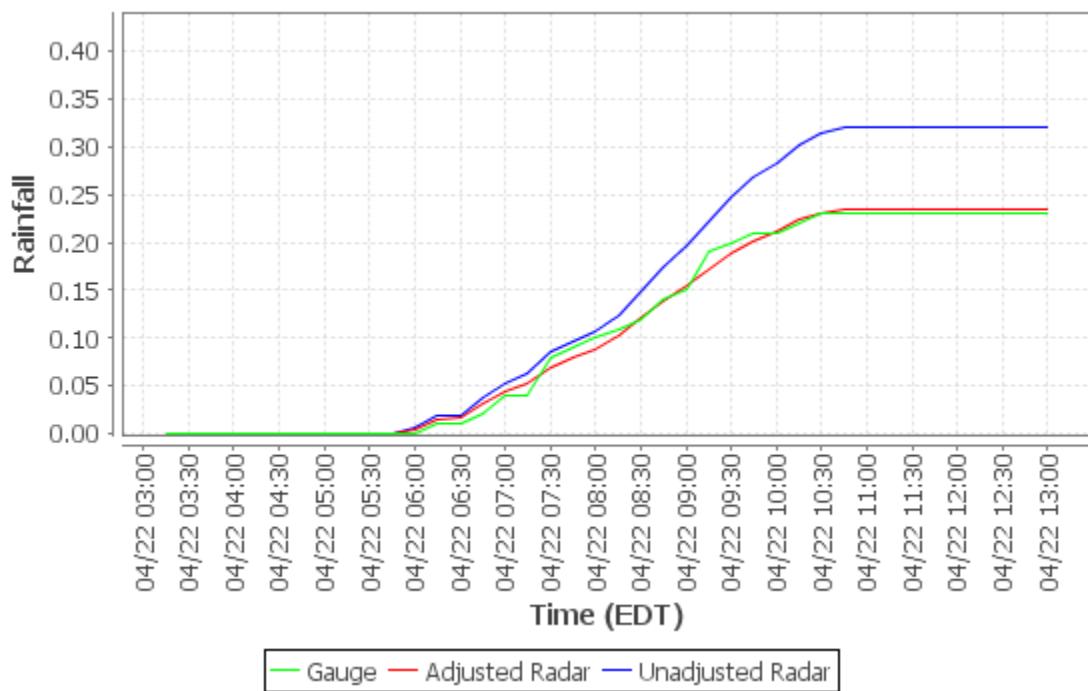
Cumulative Distribution Plot - Marshall TWP (Loc27)



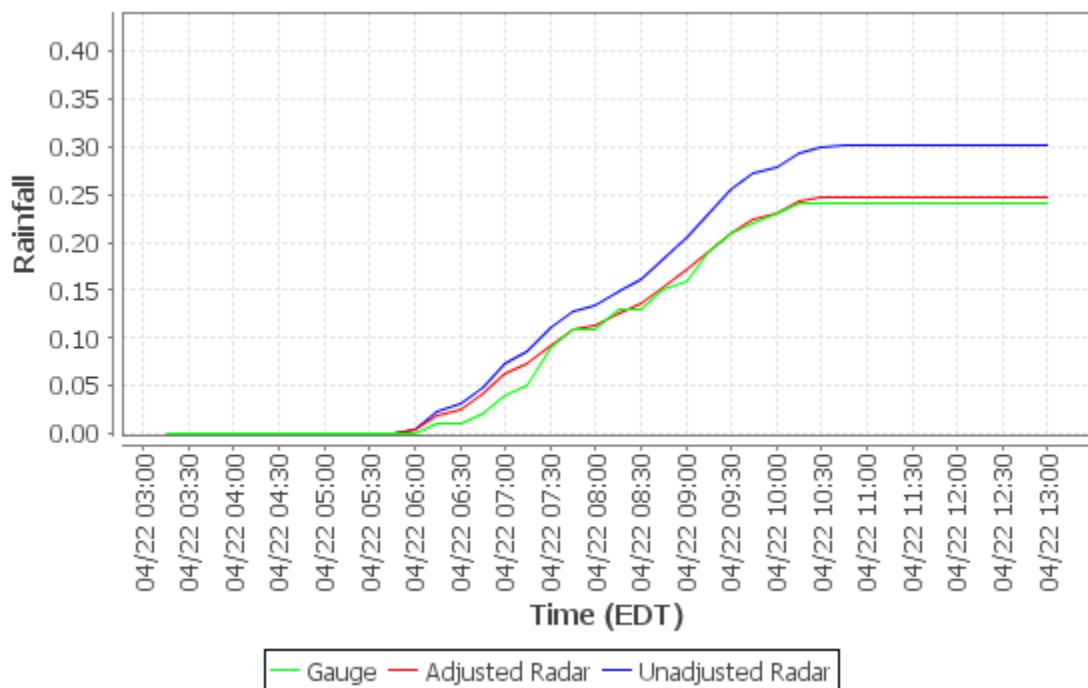
Cumulative Distribution Plot - Plum Municipal Bldg (Loc28)



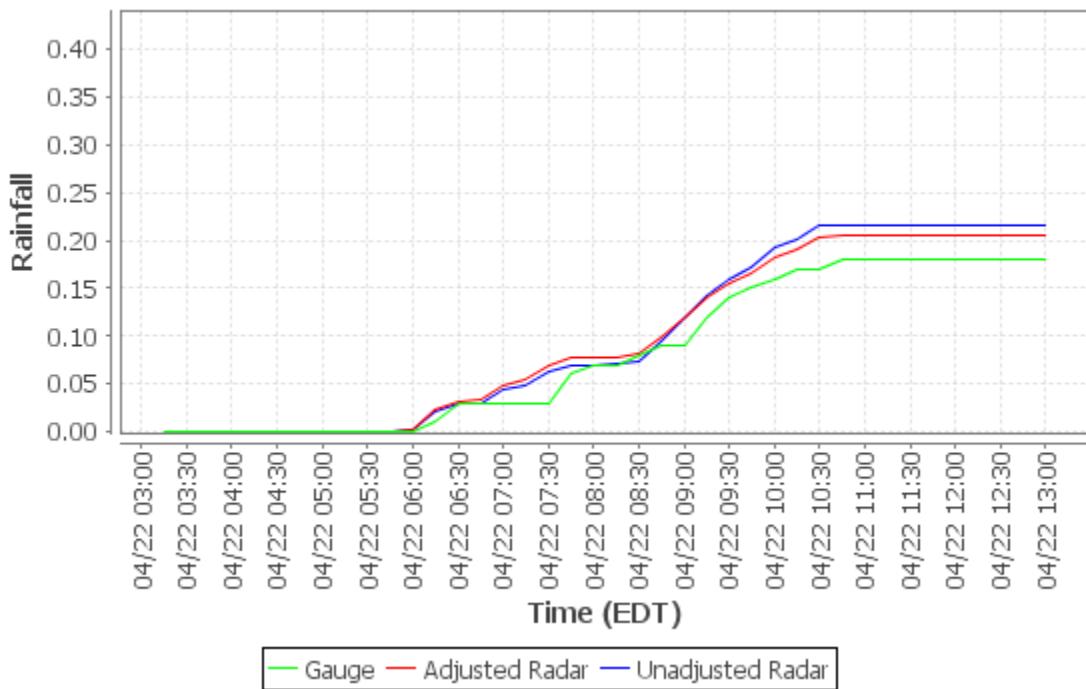
Cumulative Distribution Plot - Bell Acres Munic Bldg (Loc29)



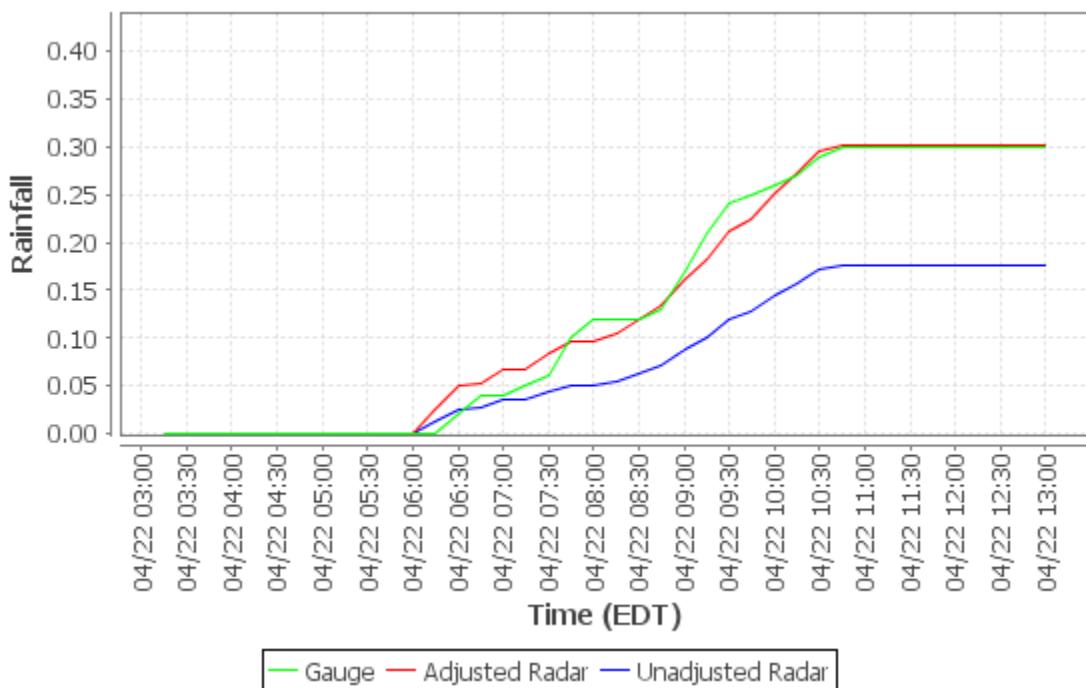
Cumulative Distribution Plot - McCandless Twn Hall (Loc30)



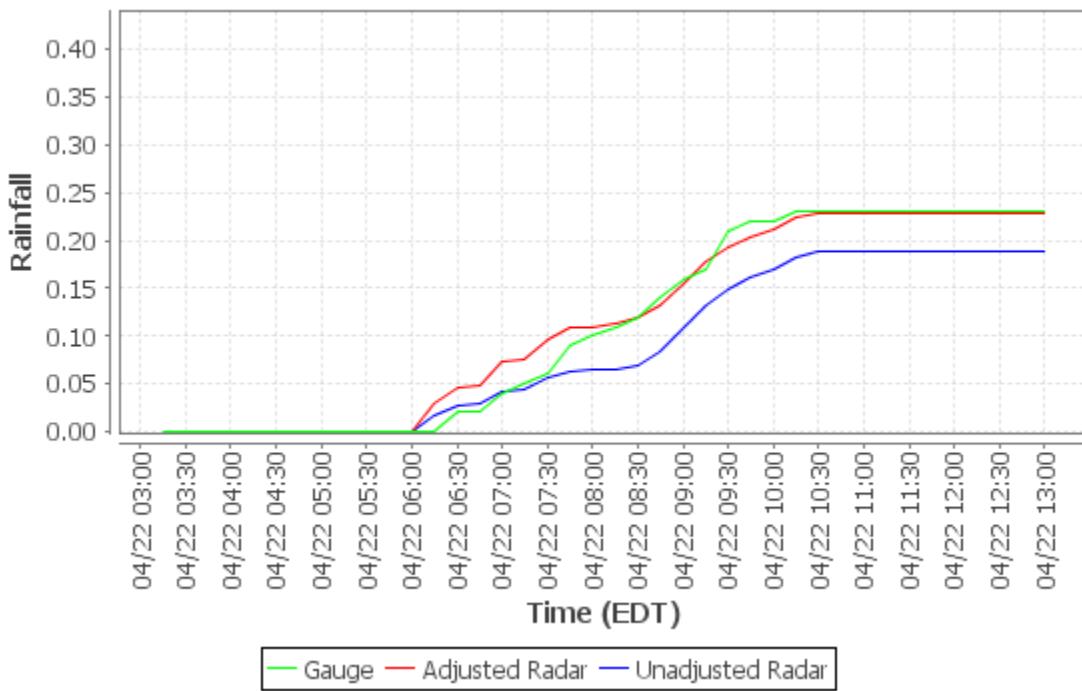
Cumulative Distribution Plot - Hampton Municipal Bldg (Loc31)



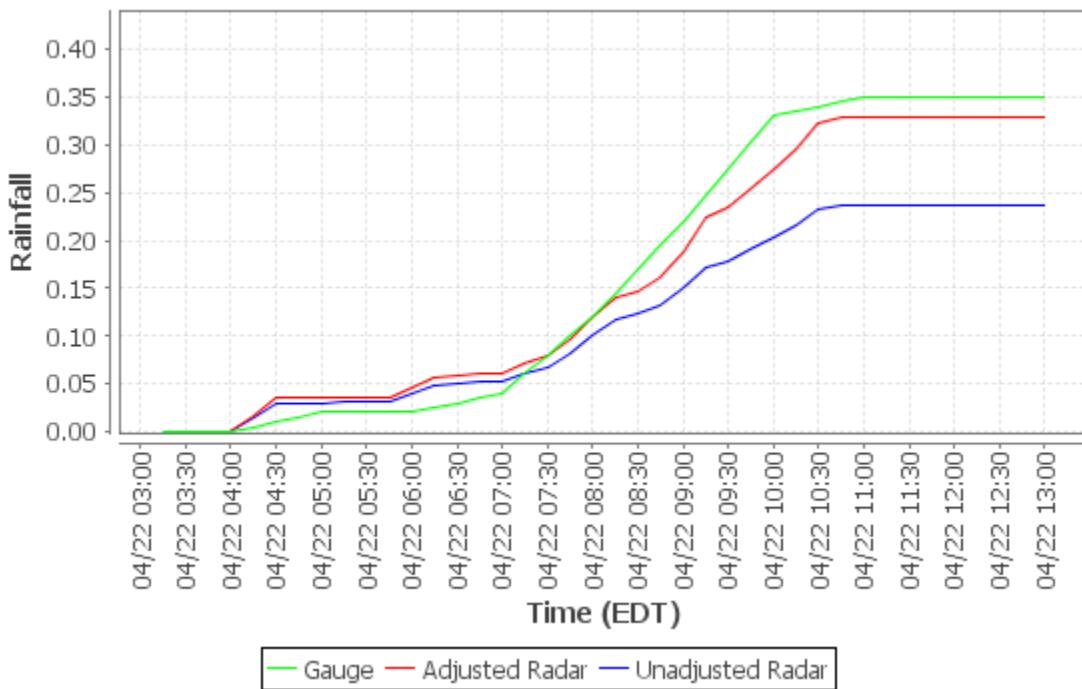
Cumulative Distribution Plot - Arnold (Loc32)



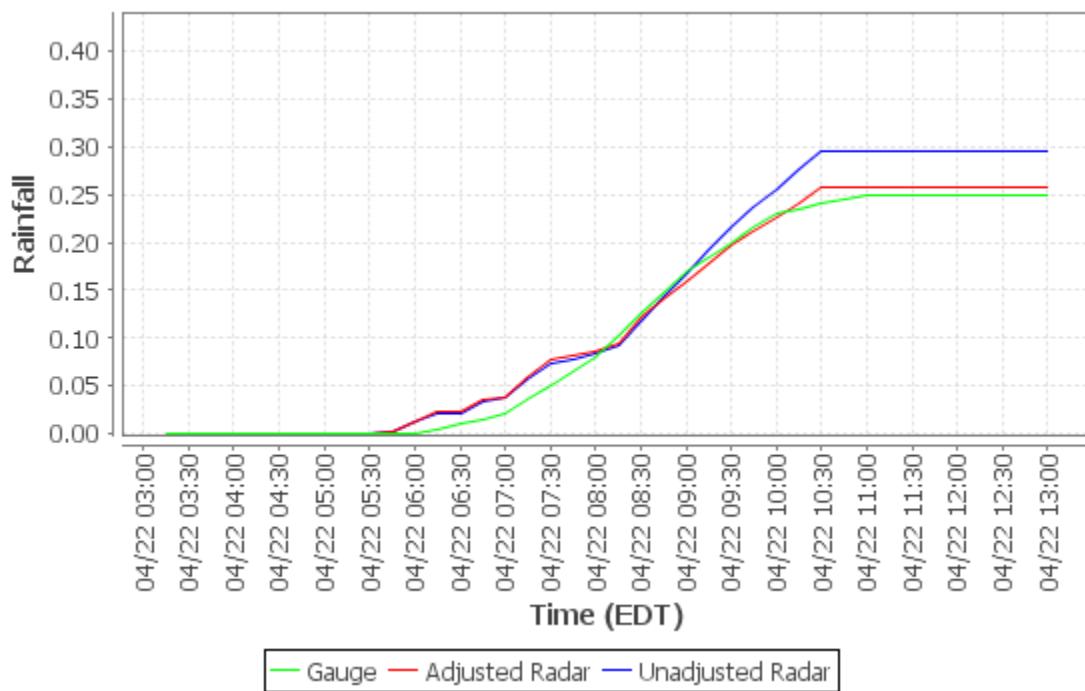
Cumulative Distribution Plot - Richland TWP (Loc33)



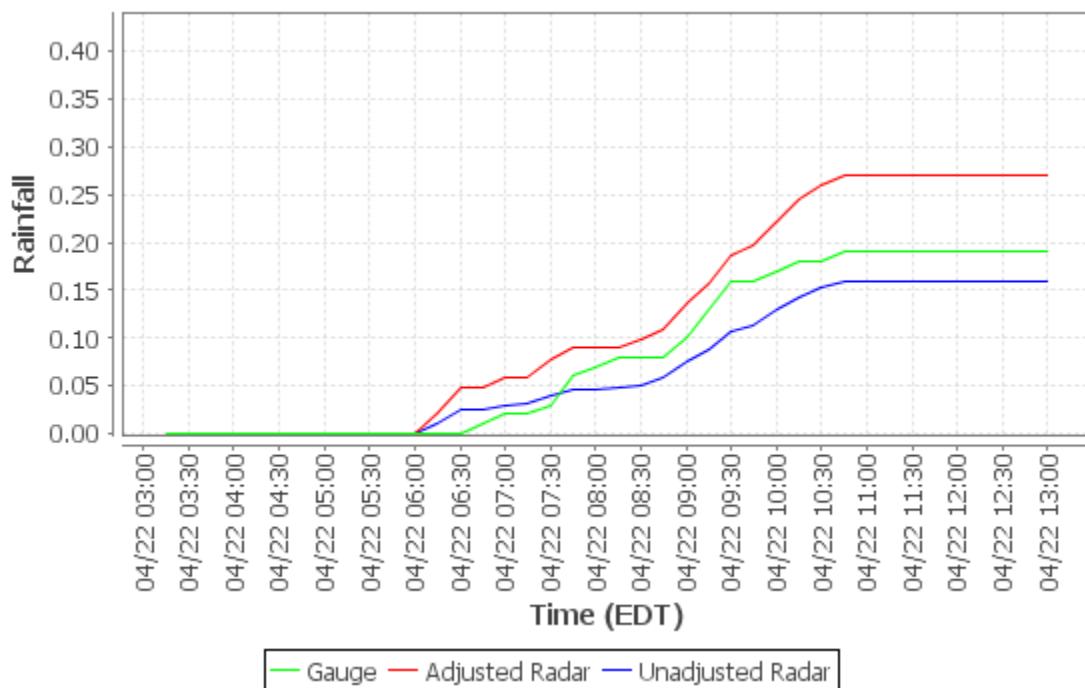
Cumulative Distribution Plot - Pittsburgh Allegheny Cty (KAGC)



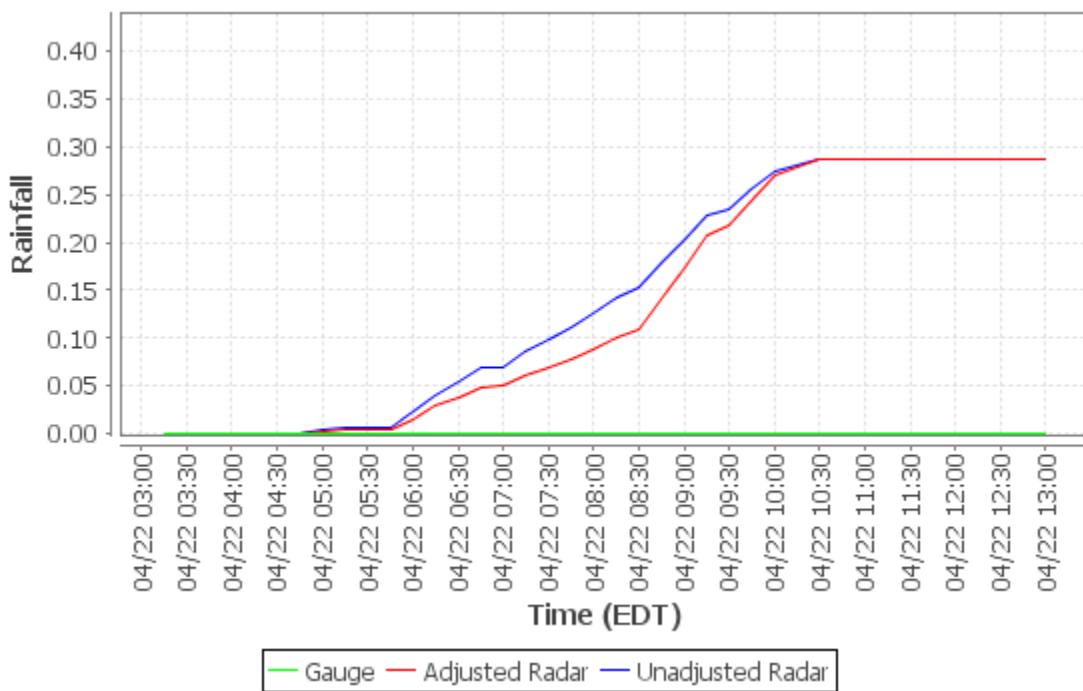
Cumulative Distribution Plot - Greater Pittsburgh Int'l (KPIT)



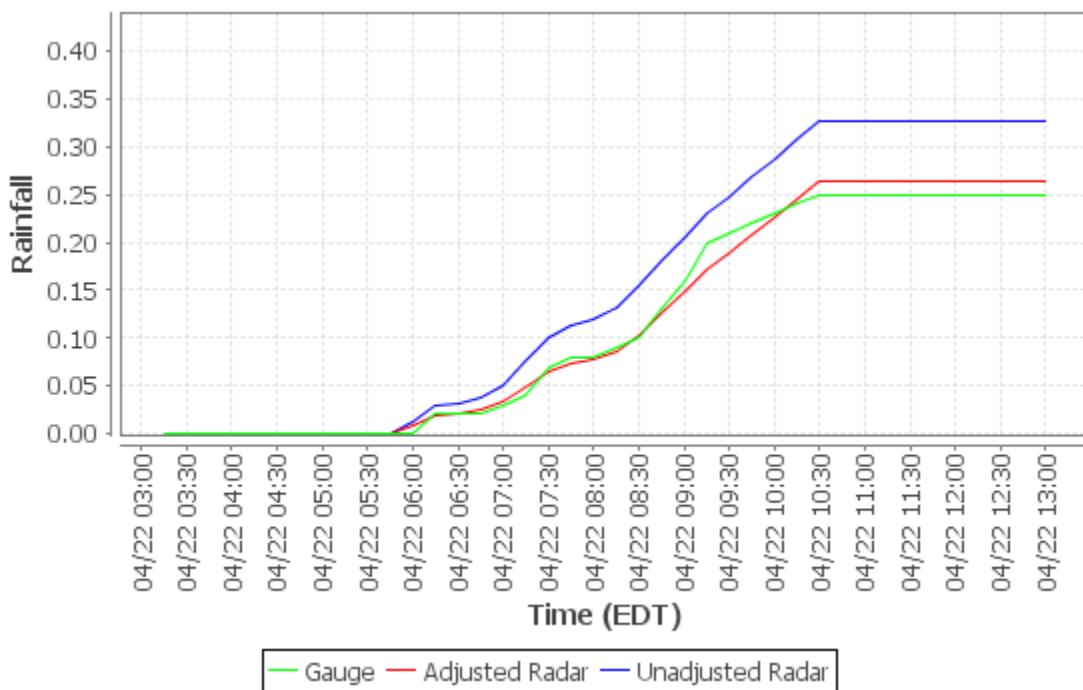
Cumulative Distribution Plot - Allegheny River at Natrona (03049500)



Cumulative Distribution Plot - Chartiers Creek at Carnegie (03085500)

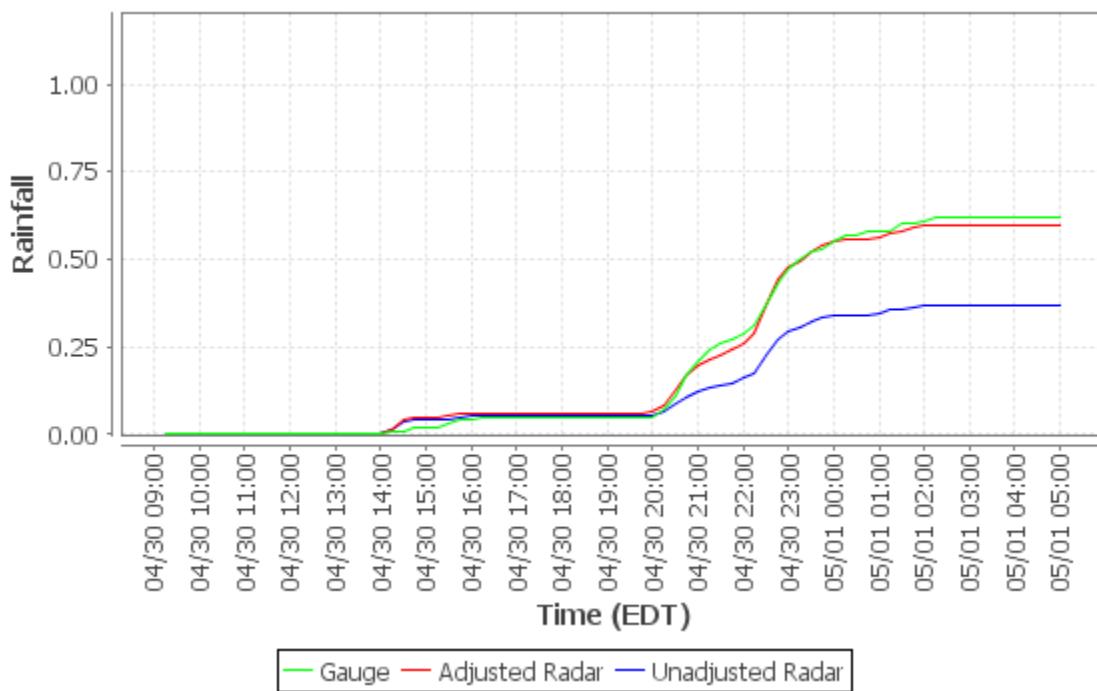


Cumulative Distribution Plot - Ohio River at Emsworth Dam Lower Pool at Emsworth (03085734)

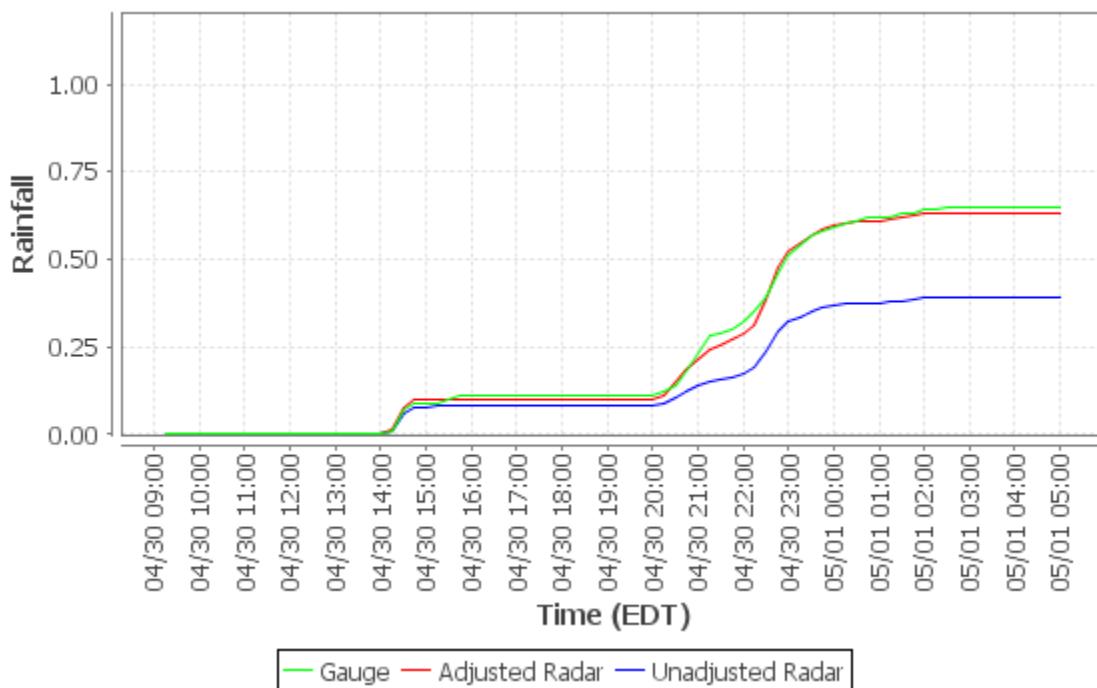


Appendix N - Event 13 (2015-04-30) CDPs

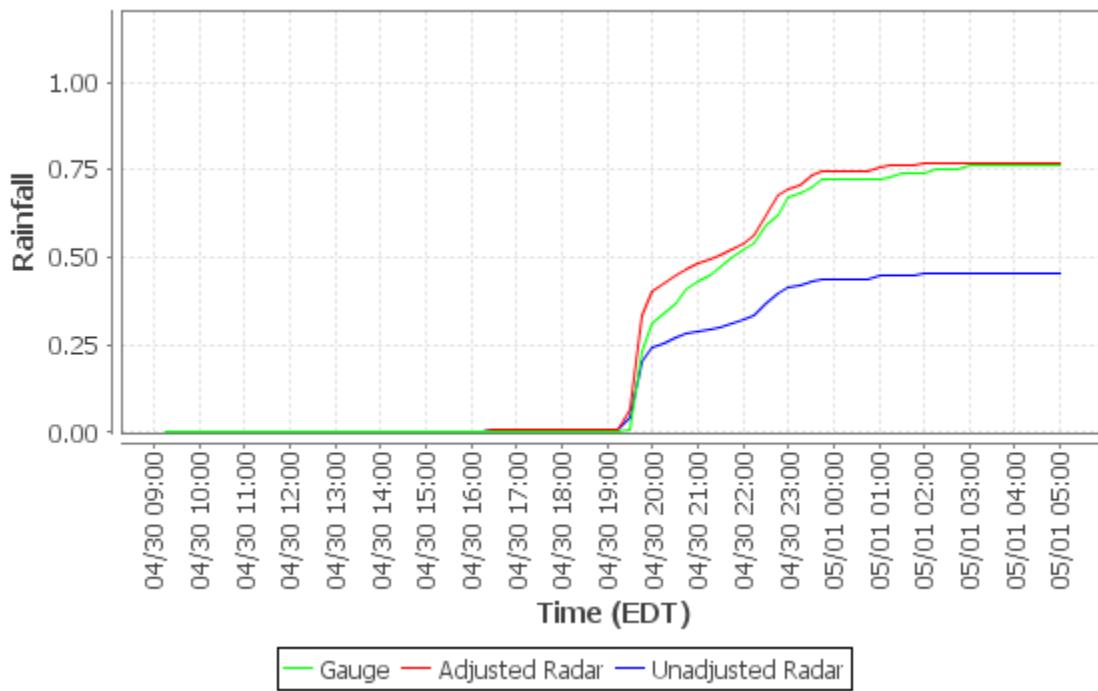
Cumulative Distribution Plot - PWSA-Montana St. (Loc01)



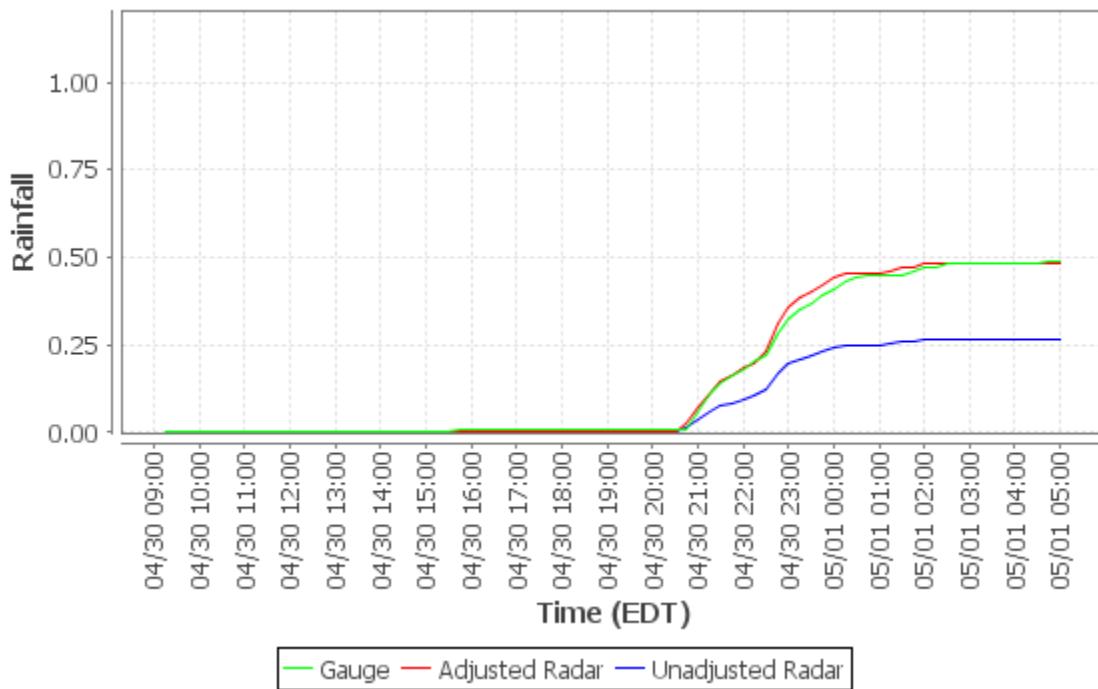
Cumulative Distribution Plot - ALCOSAN WWTP Lab (Loc02)



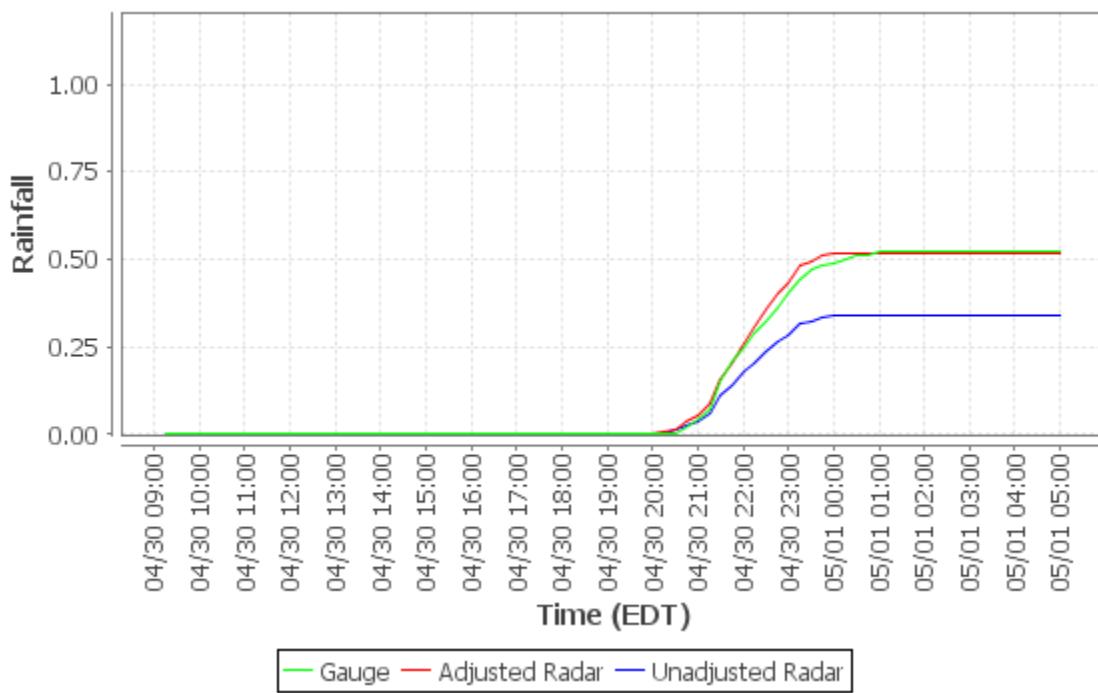
Cumulative Distribution Plot - Shaler Munic Bldg (Loc03)



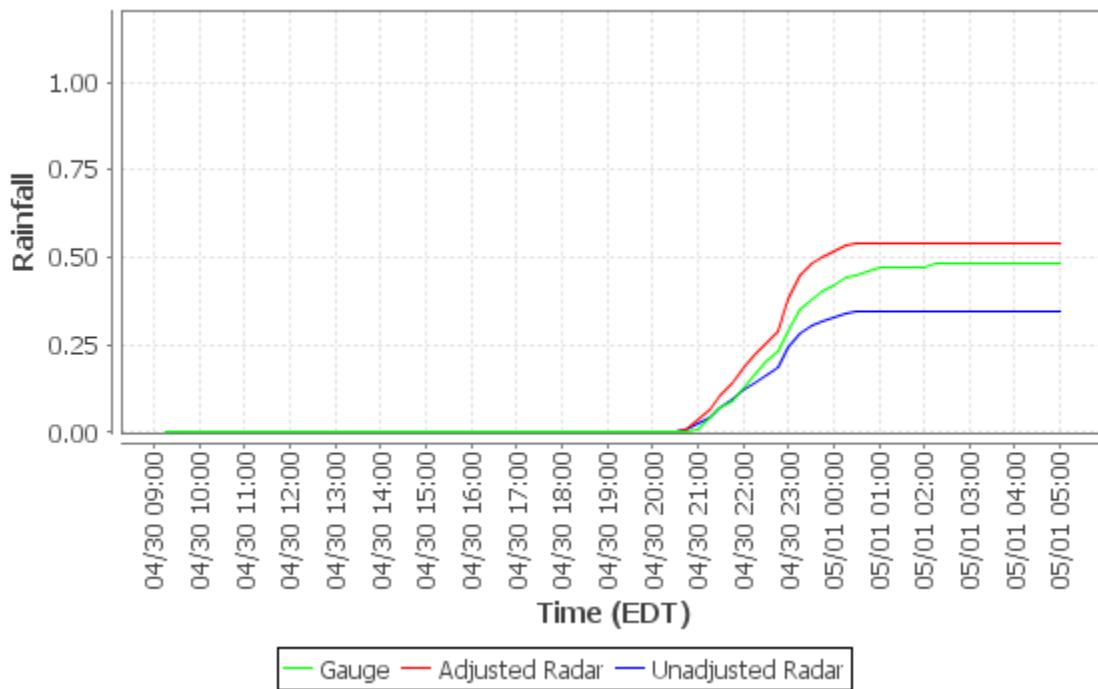
Cumulative Distribution Plot - Kennedy Twp PS (Loc04)



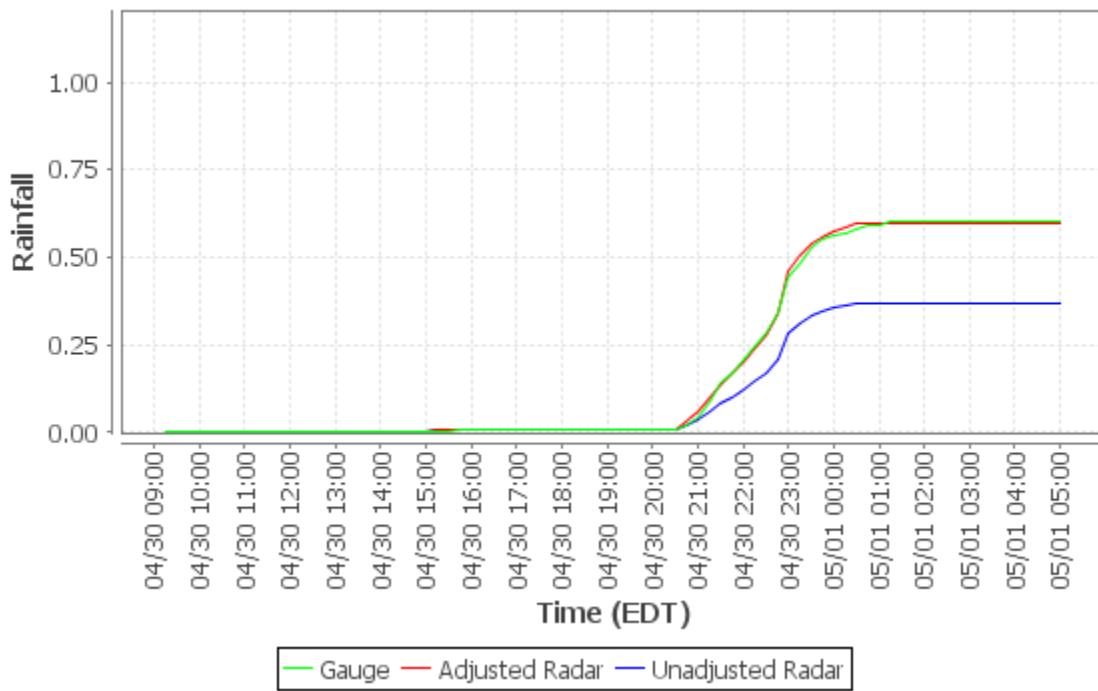
Cumulative Distribution Plot - Upper St. Clair (Loc05)



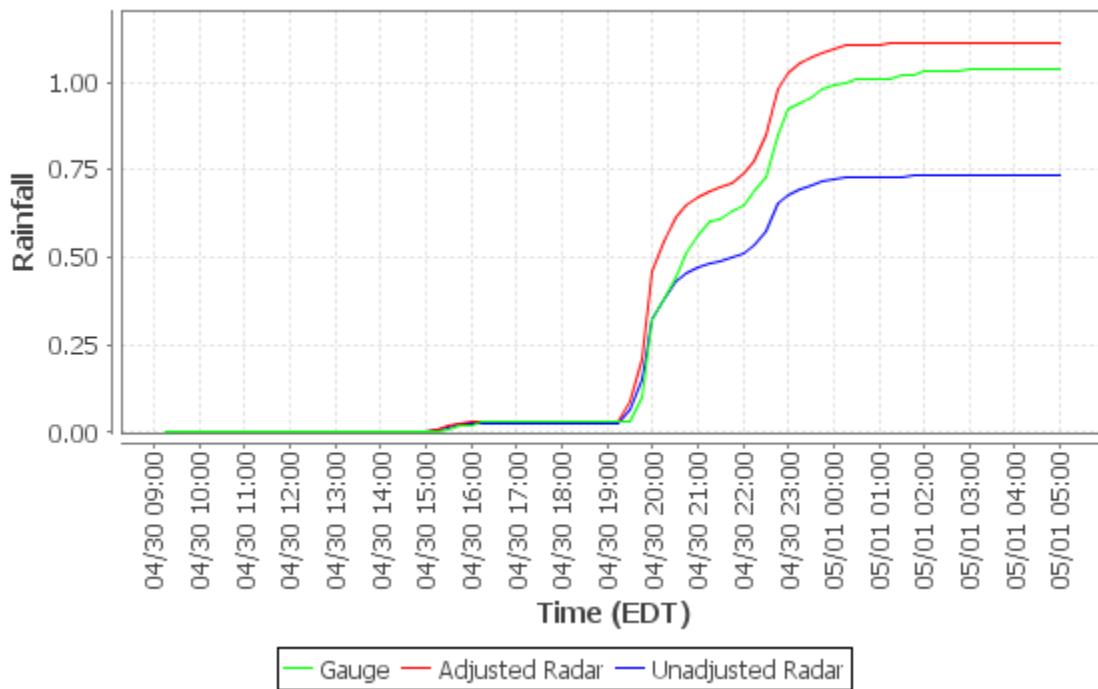
Cumulative Distribution Plot - Carnegie Transit Time (Loc06)



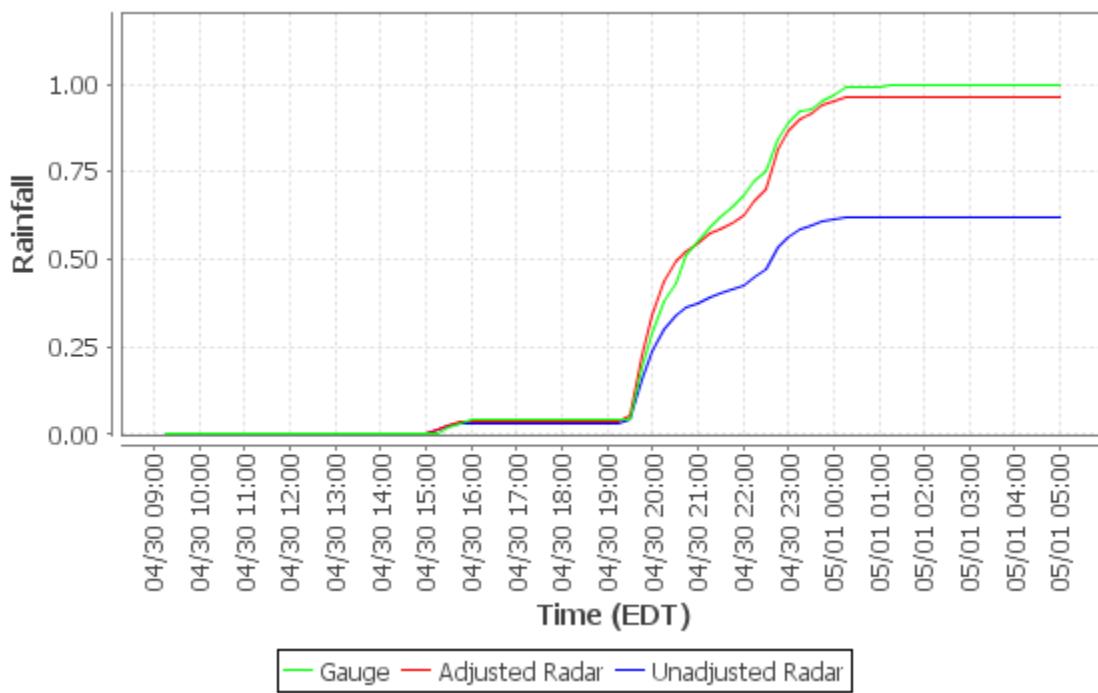
Cumulative Distribution Plot - Greentree Munic Bldg (Loc07)



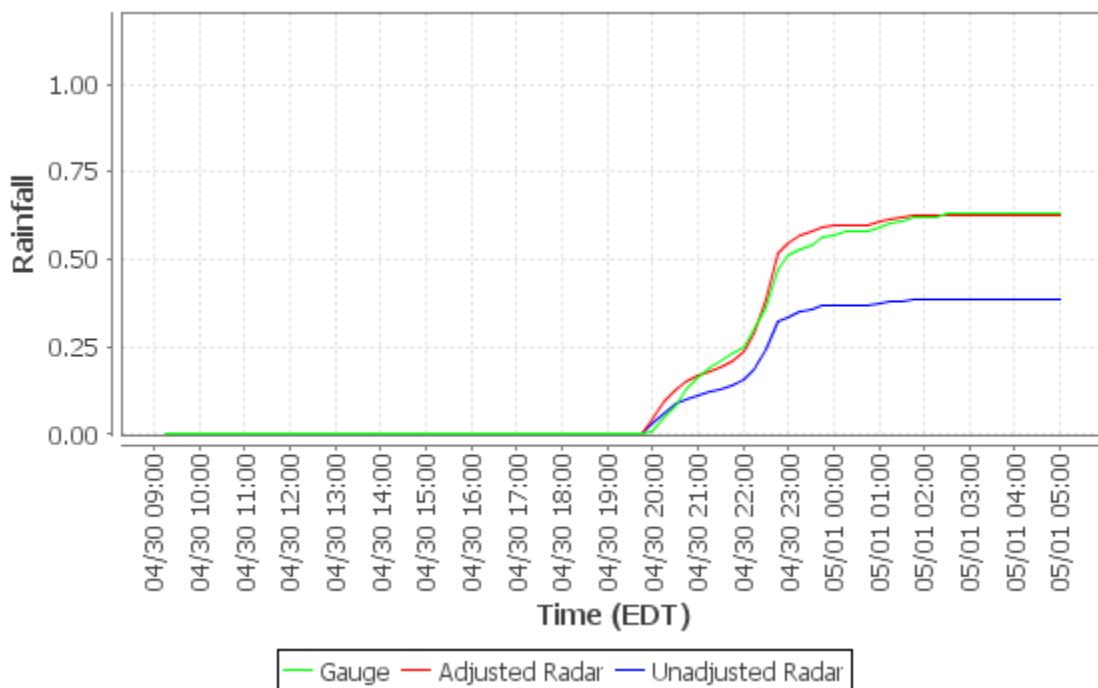
Cumulative Distribution Plot - AC Health Dept Bldg (Loc08)



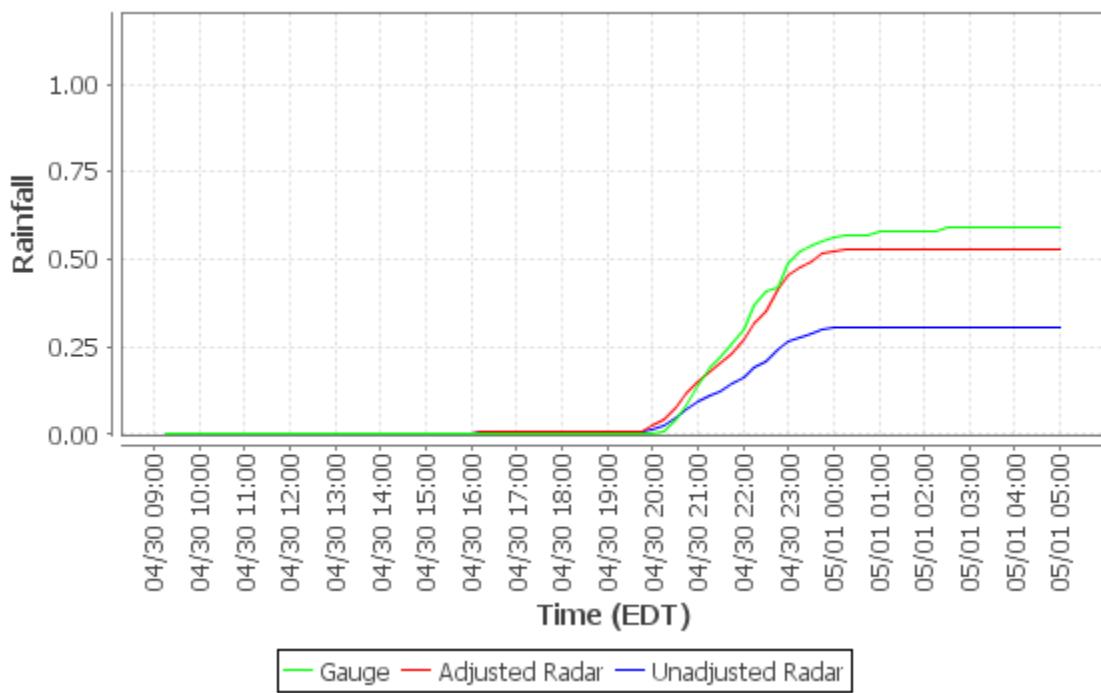
Cumulative Distribution Plot - Univ of Pittsburgh (Loc09)



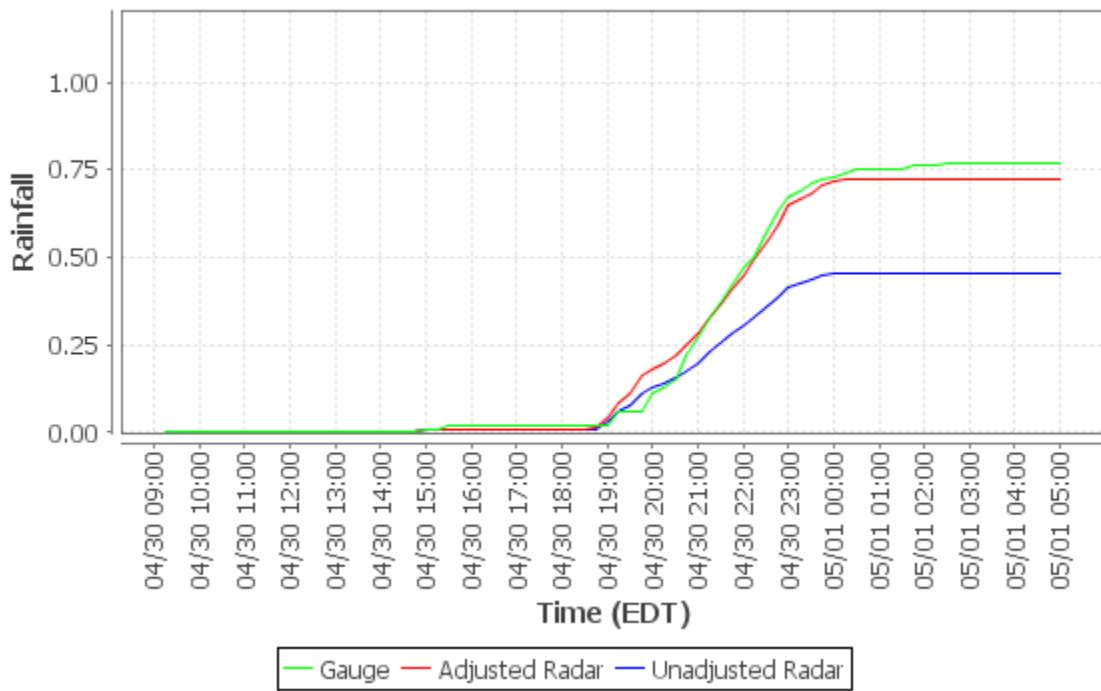
Cumulative Distribution Plot - PWSA-Highland Park (Loc10)



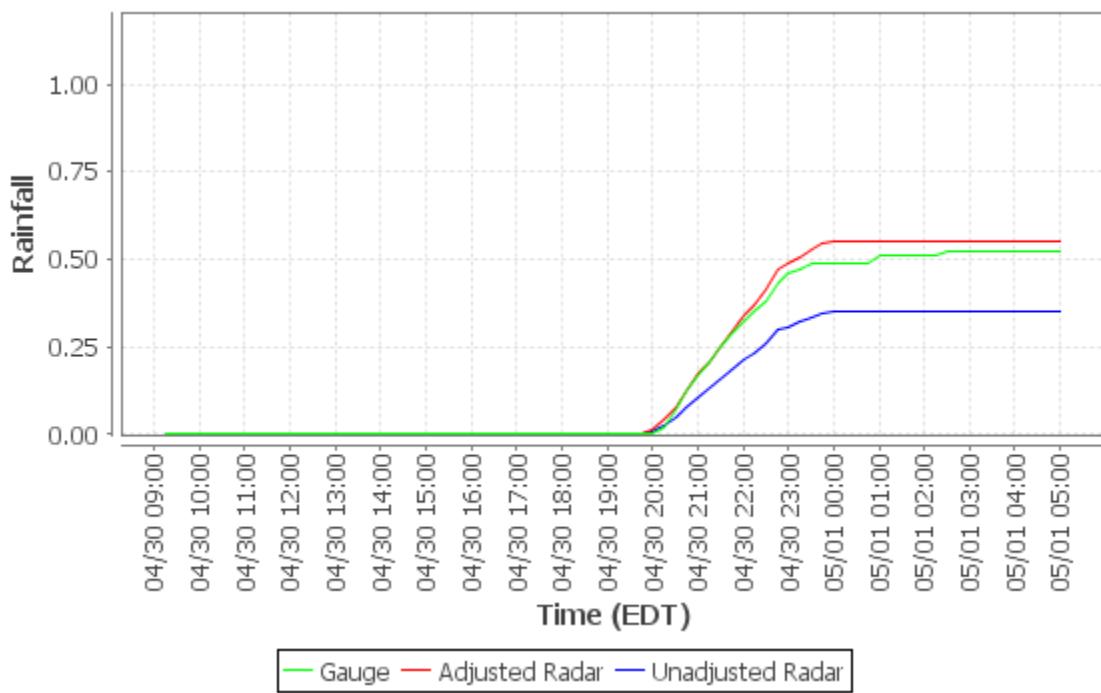
Cumulative Distribution Plot - M-46 Access Shaft (Loc11)



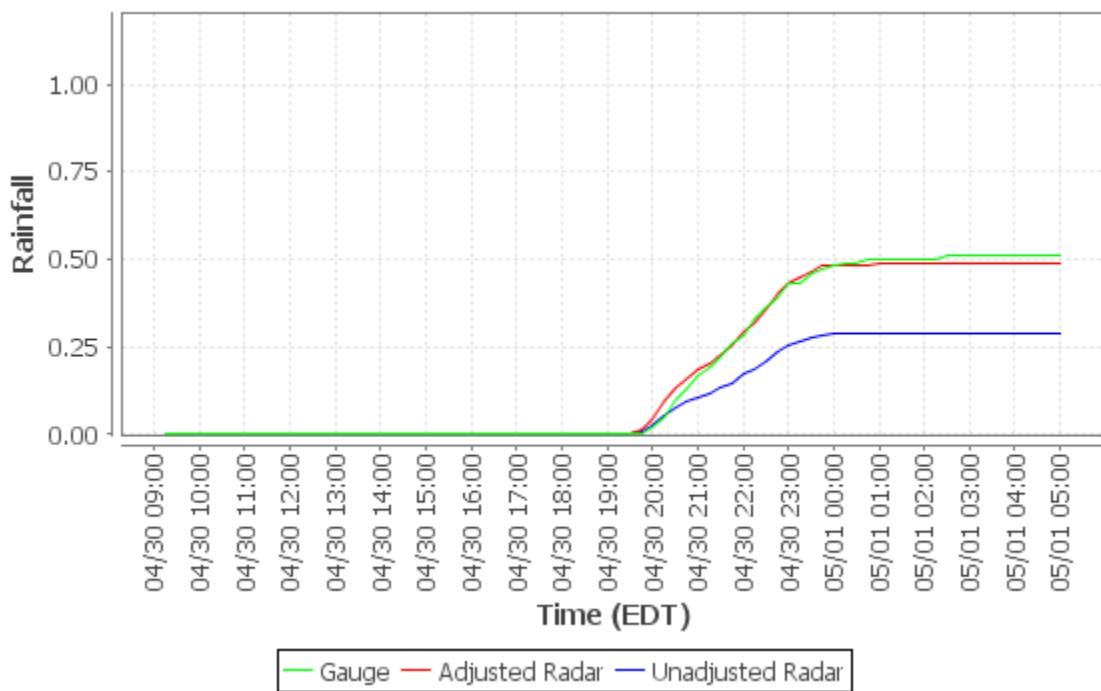
Cumulative Distribution Plot - Baldwin (Loc12)



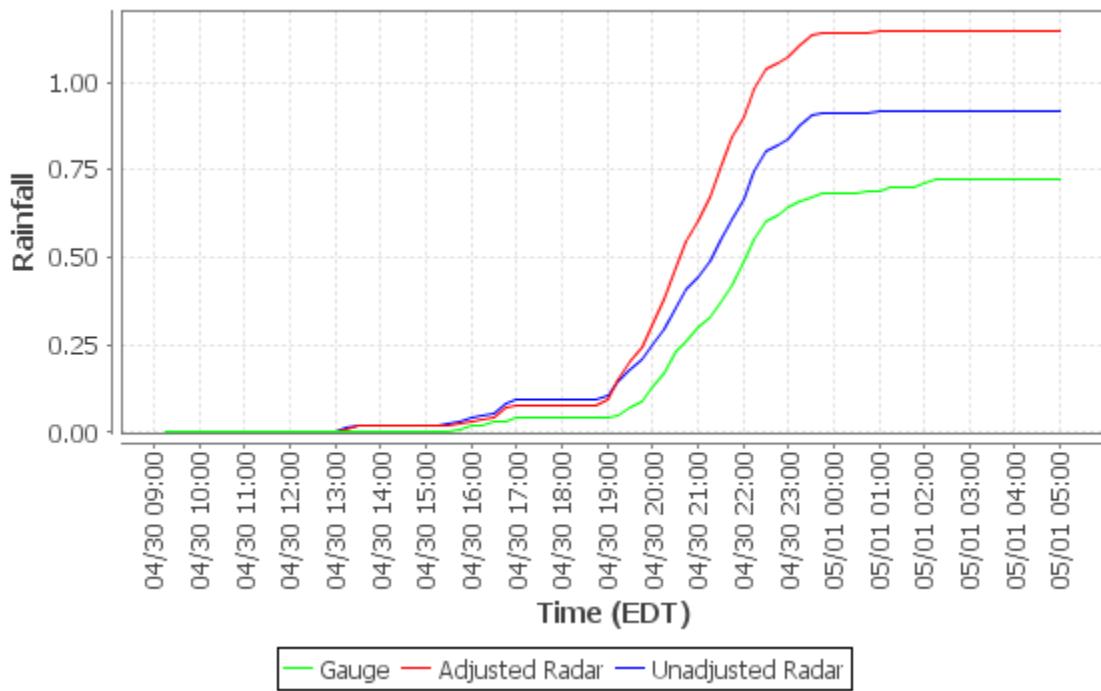
Cumulative Distribution Plot - M-59 Access Shaft (Loc13)



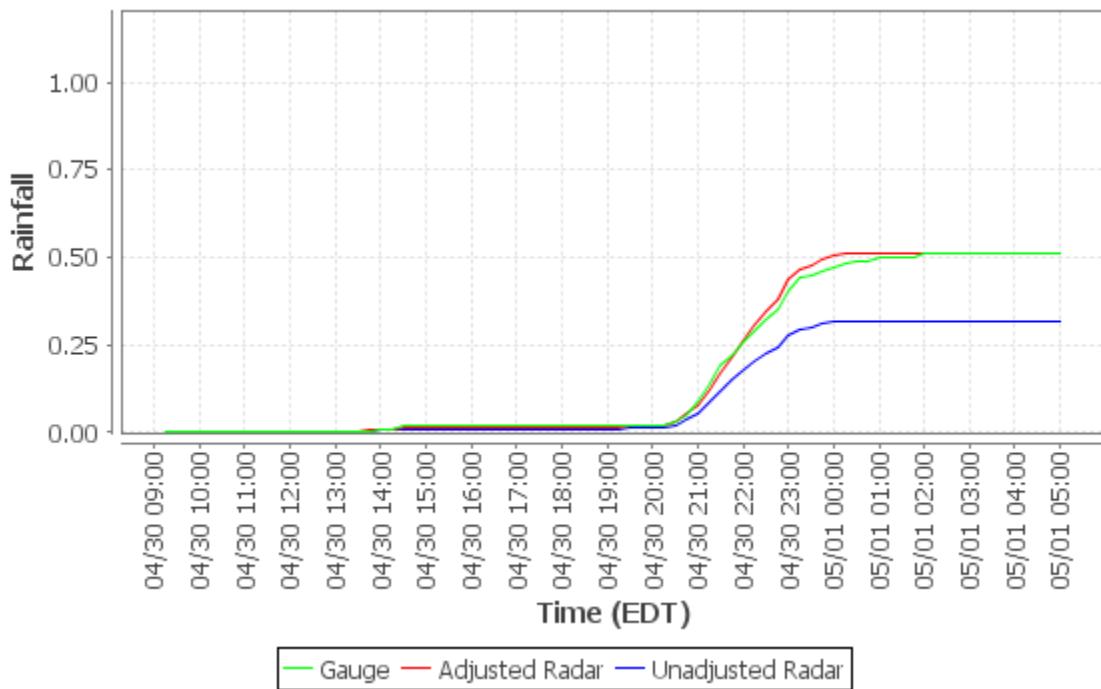
Cumulative Distribution Plot - Churchill Munic Bldg (Loc14)



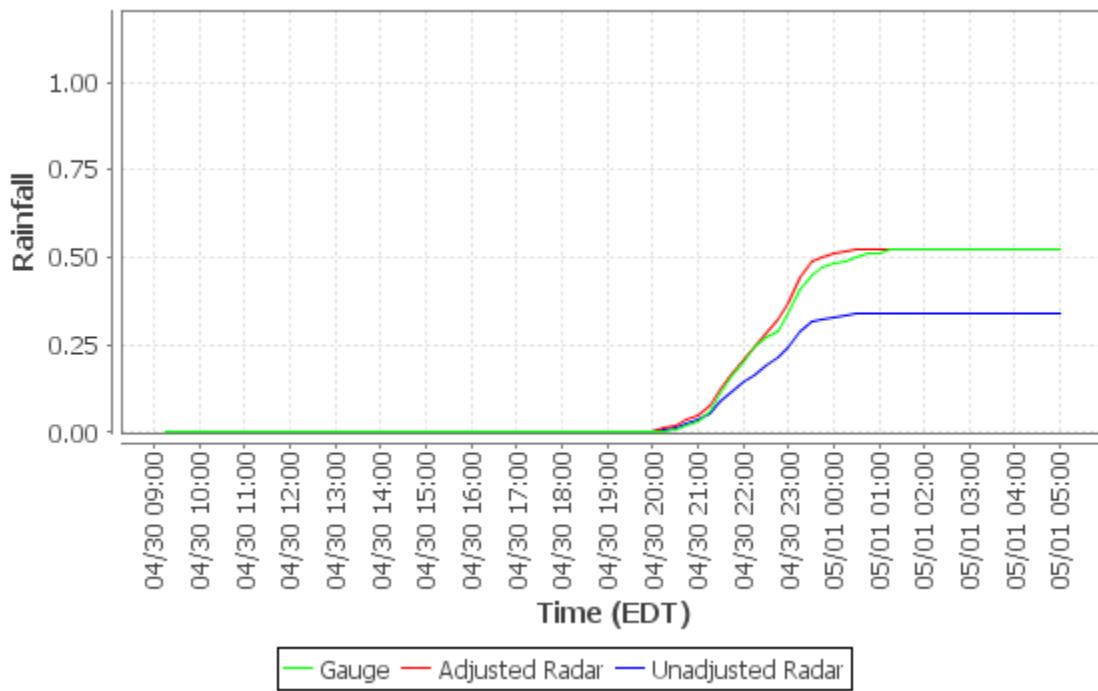
Cumulative Distribution Plot - Trafford Maint Bldg (Loc15)



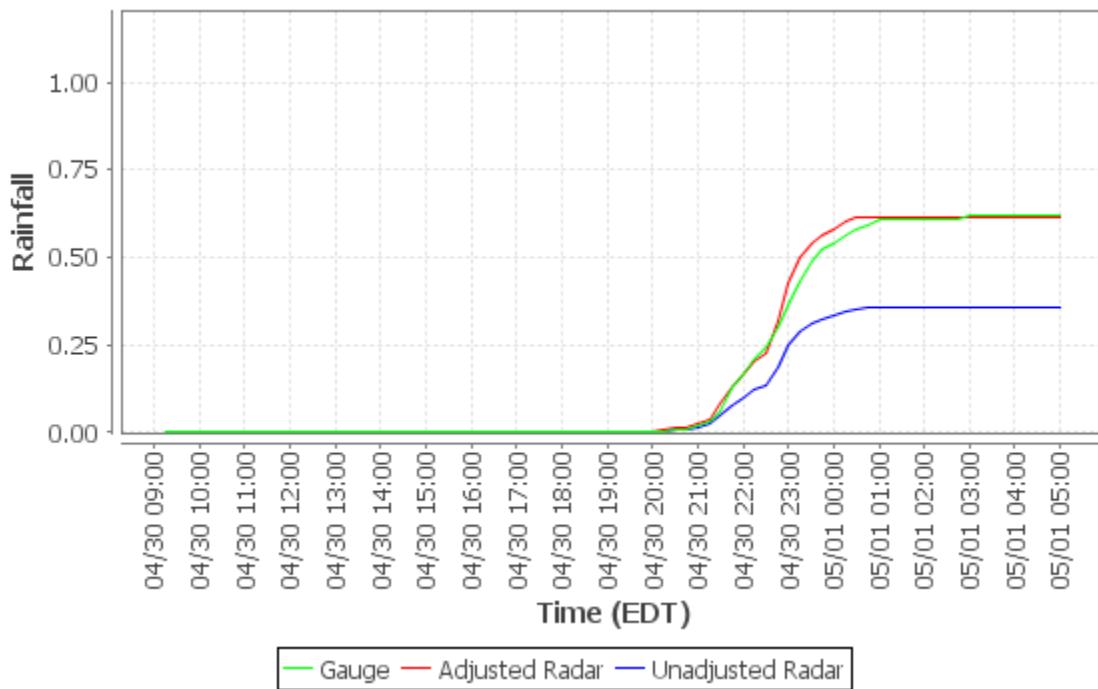
Cumulative Distribution Plot - Castle Shannon (Loc16)



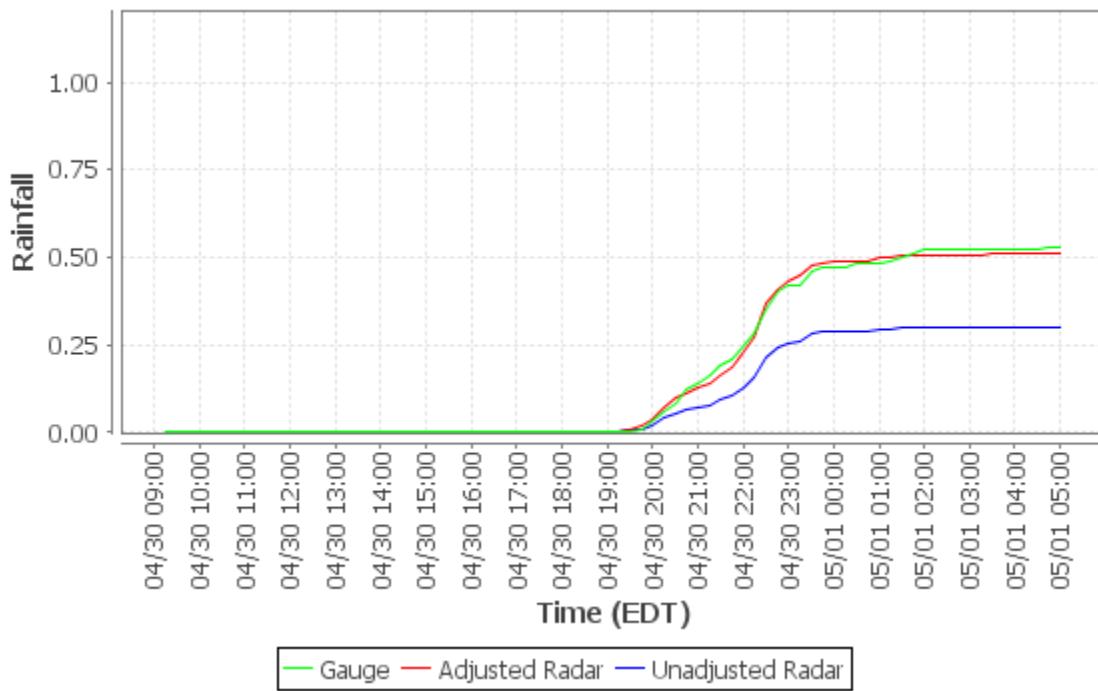
Cumulative Distribution Plot - Chartiers Pump Station (Loc17)



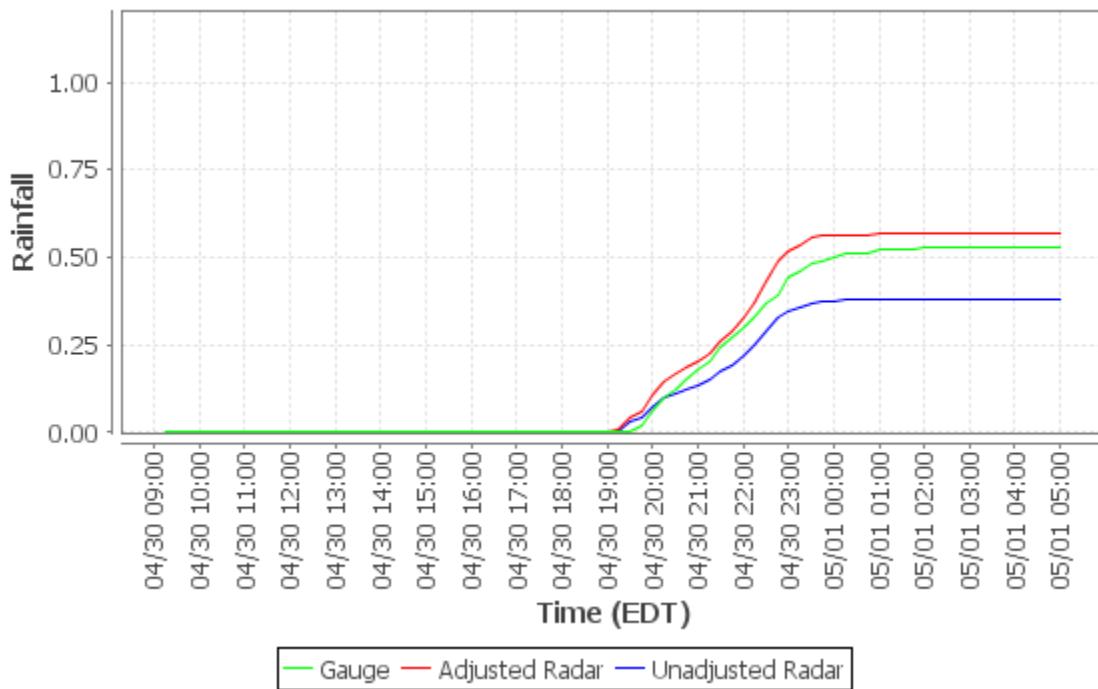
Cumulative Distribution Plot - Oakdale Pump Station (Loc18)



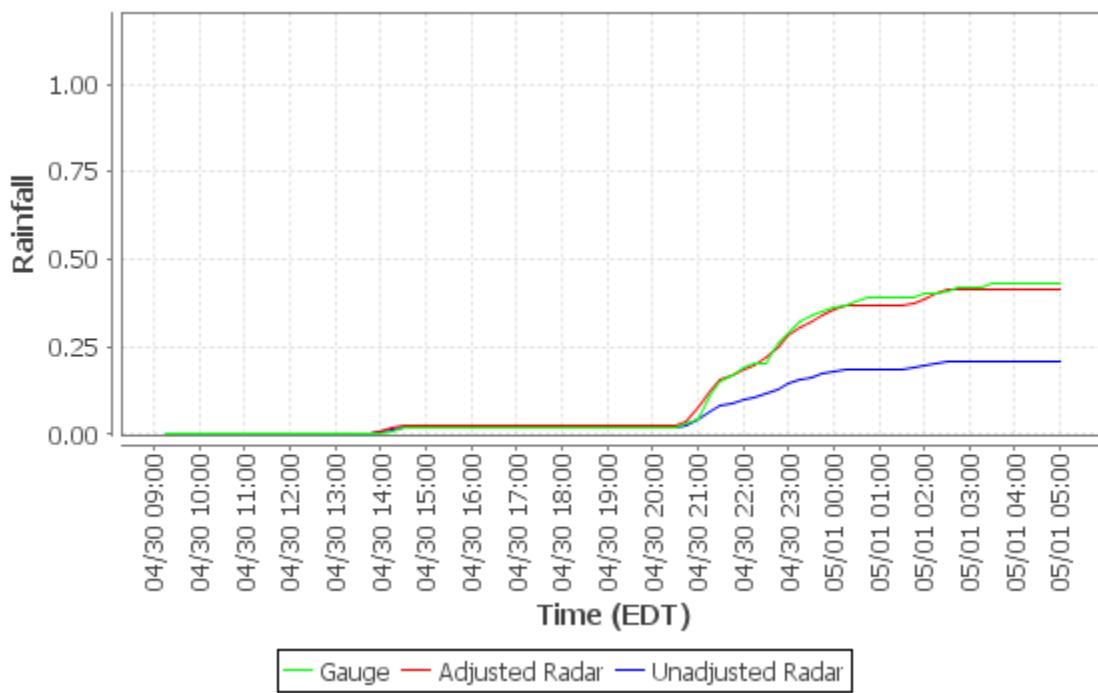
Cumulative Distribution Plot - Sandy Creek Eq Facility (Loc19)



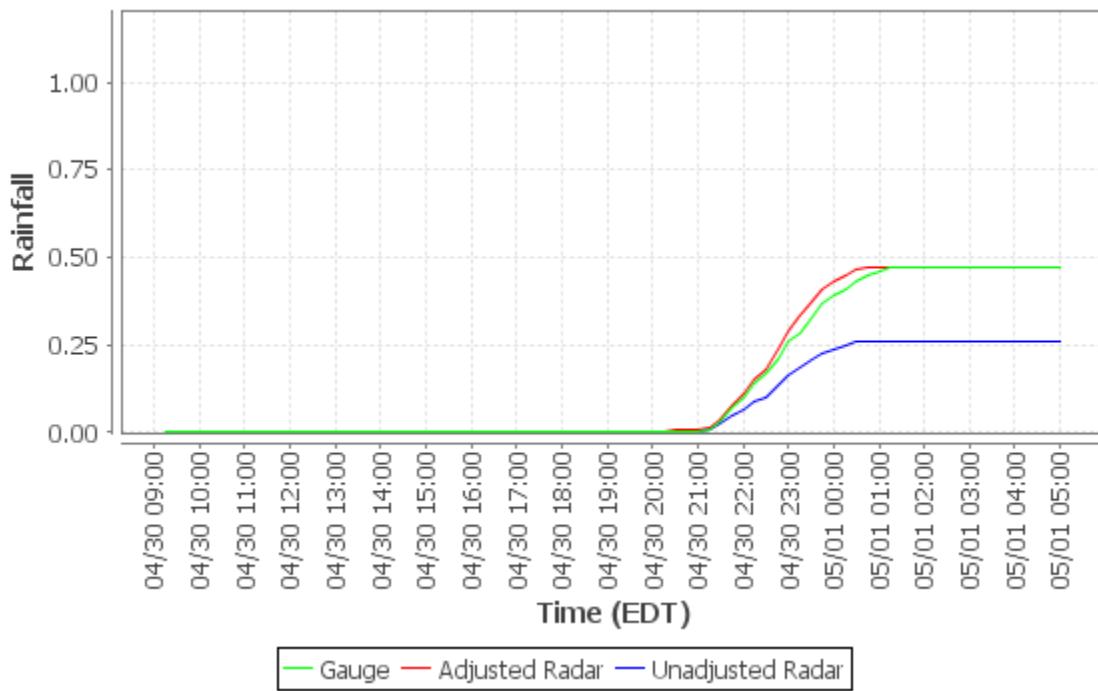
Cumulative Distribution Plot - Gascola Eq Facility (Loc20)



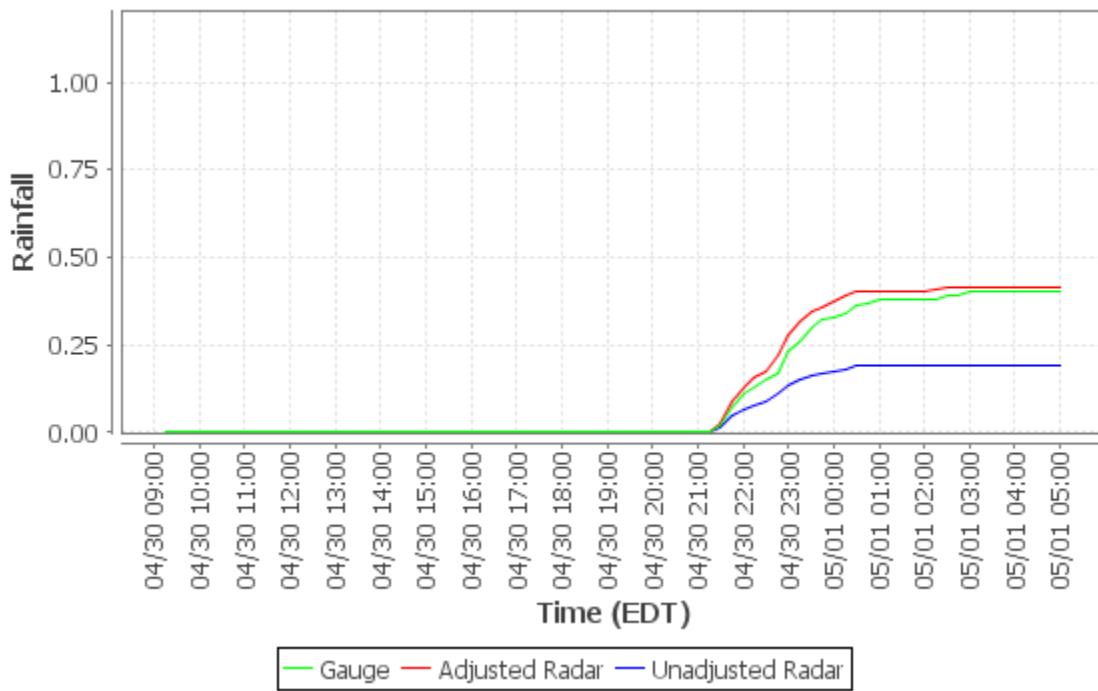
Cumulative Distribution Plot - Moon TWP (Loc21)



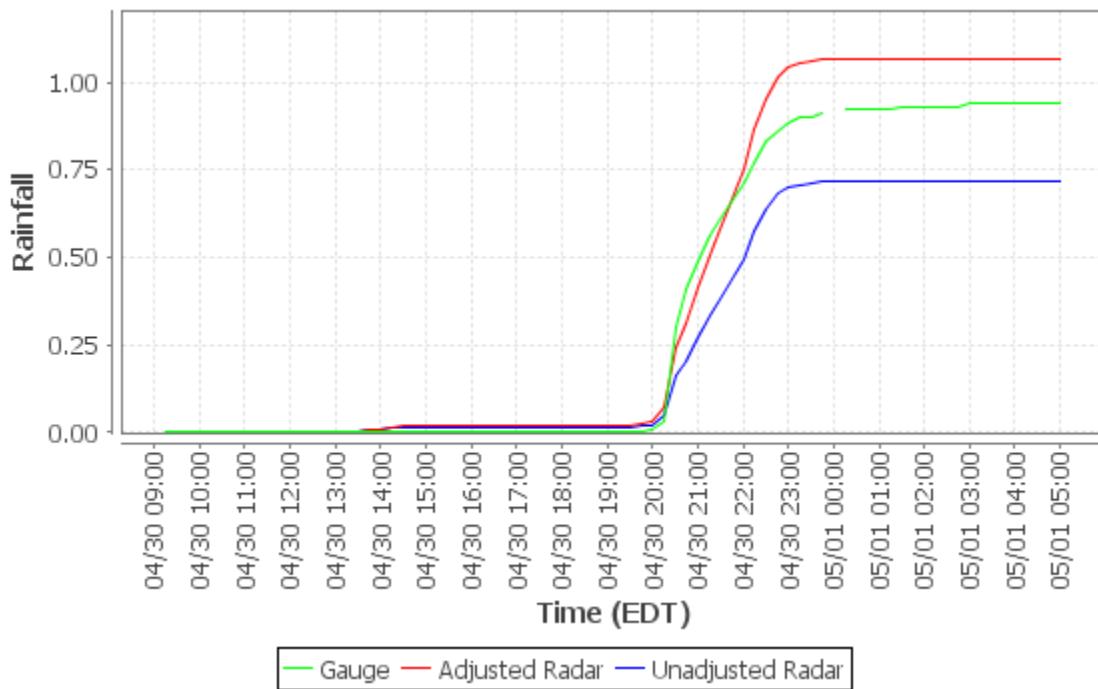
Cumulative Distribution Plot - North Fayette TWP (Loc22)



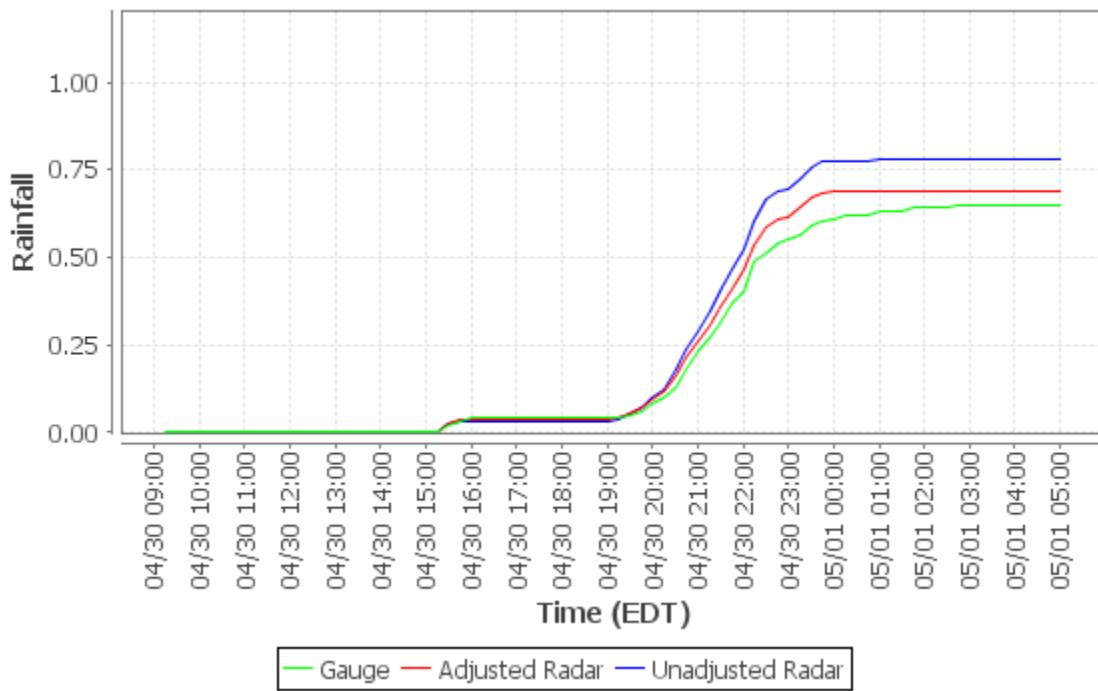
Cumulative Distribution Plot - Clinton Munic Bldg (Loc23)



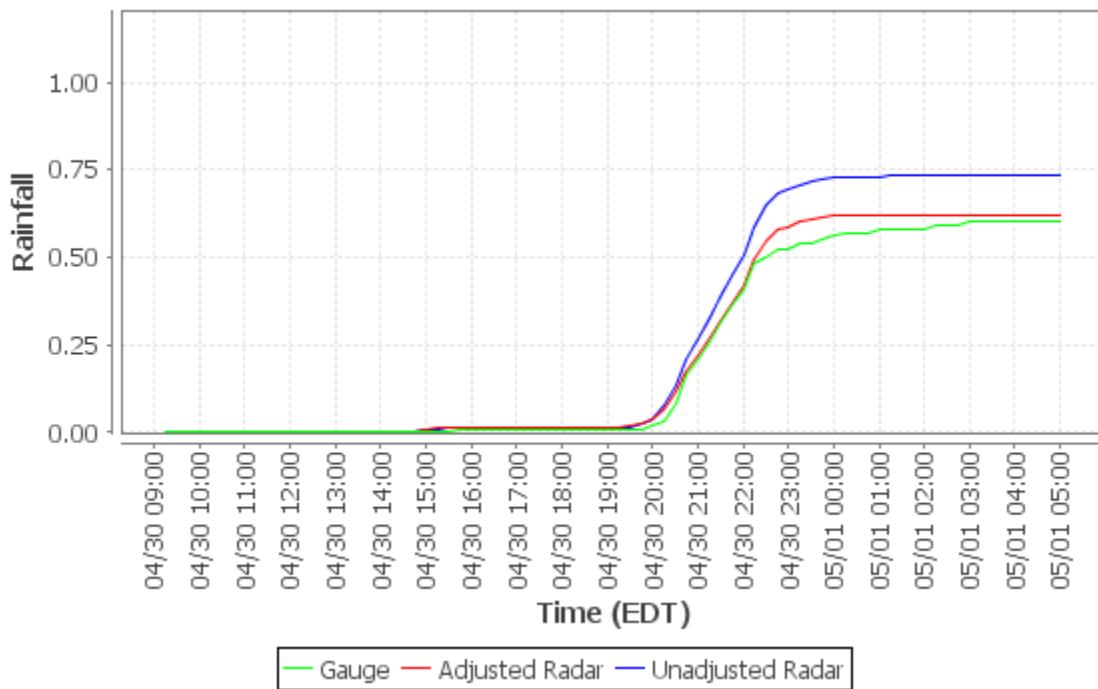
Cumulative Distribution Plot - Jefferson Hills (Loc24)



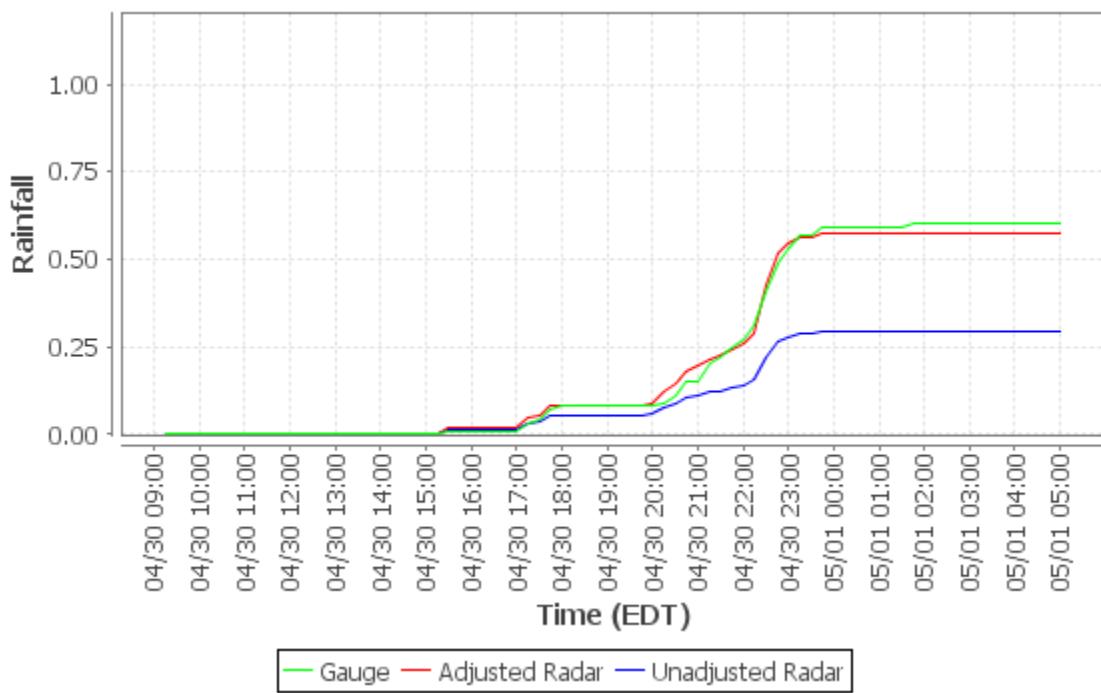
Cumulative Distribution Plot - White Oak Public Works Bldg (Loc25)



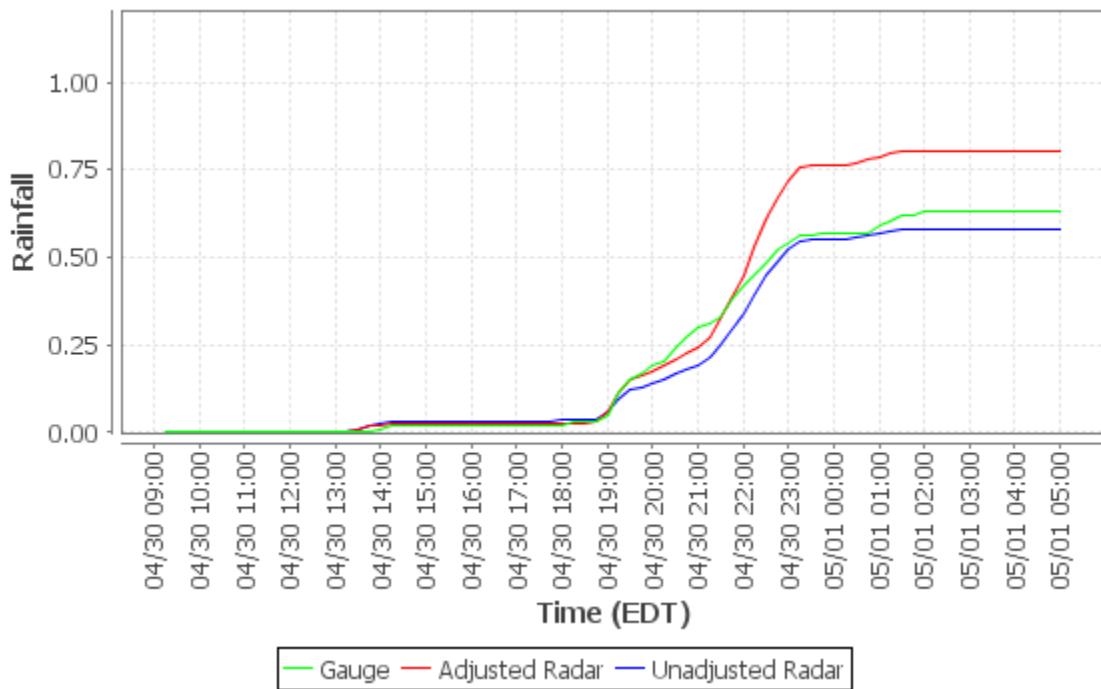
Cumulative Distribution Plot - Elizabeth TWP Municipal Bldg (Loc26)



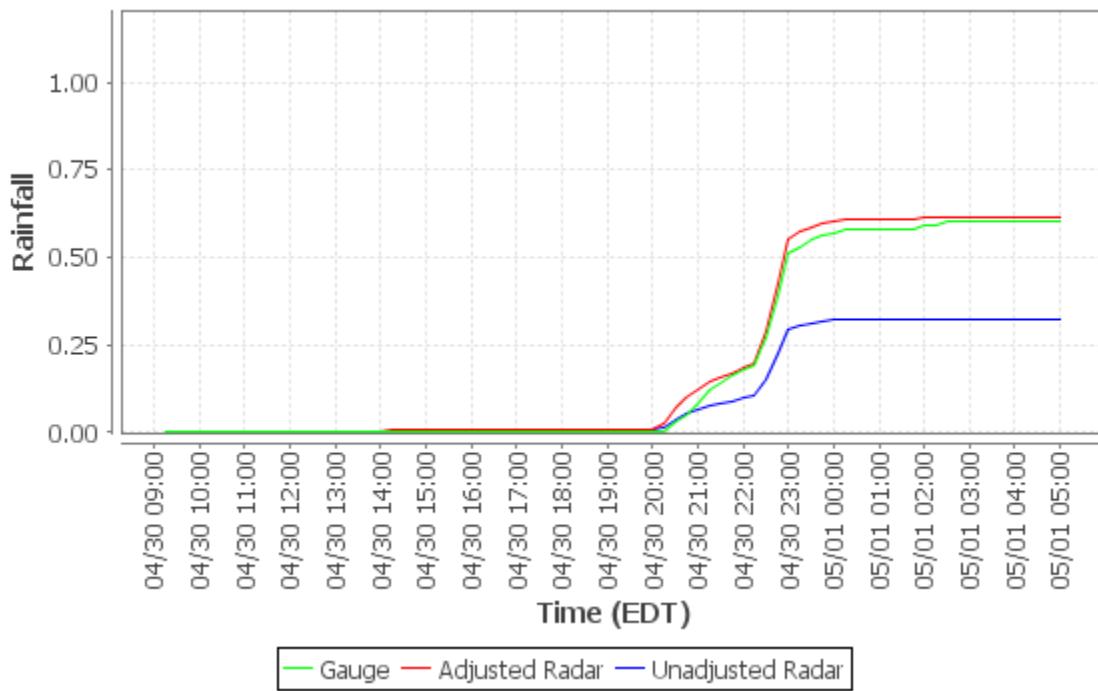
Cumulative Distribution Plot - Marshall TWP (Loc27)



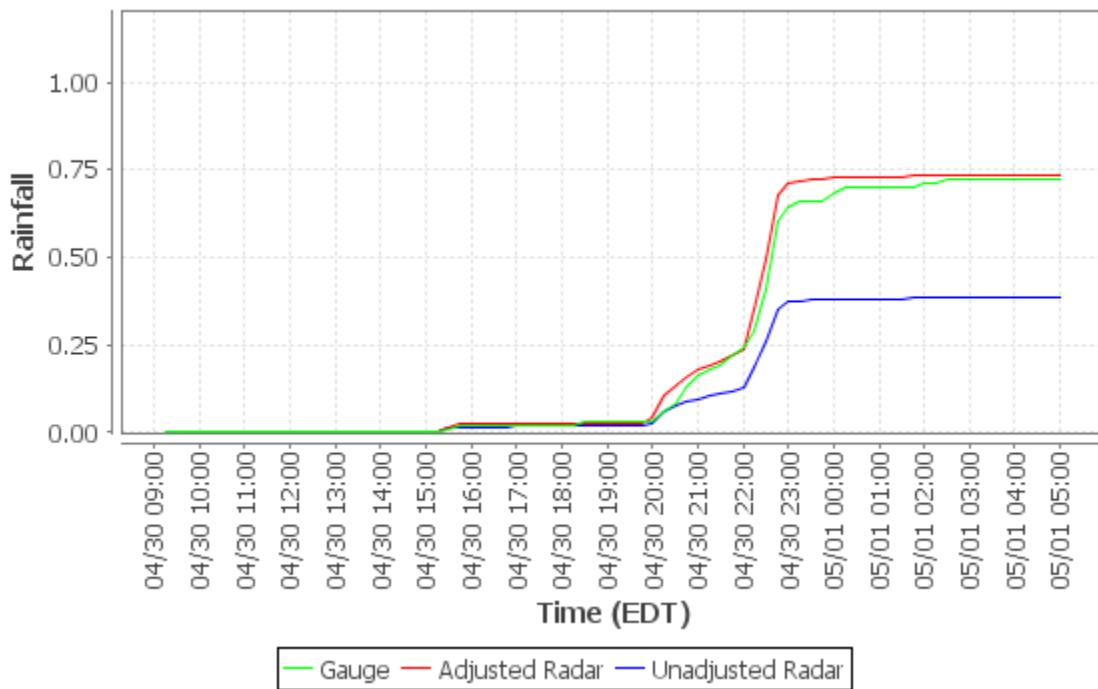
Cumulative Distribution Plot - Plum Municipal Bldg (Loc28)



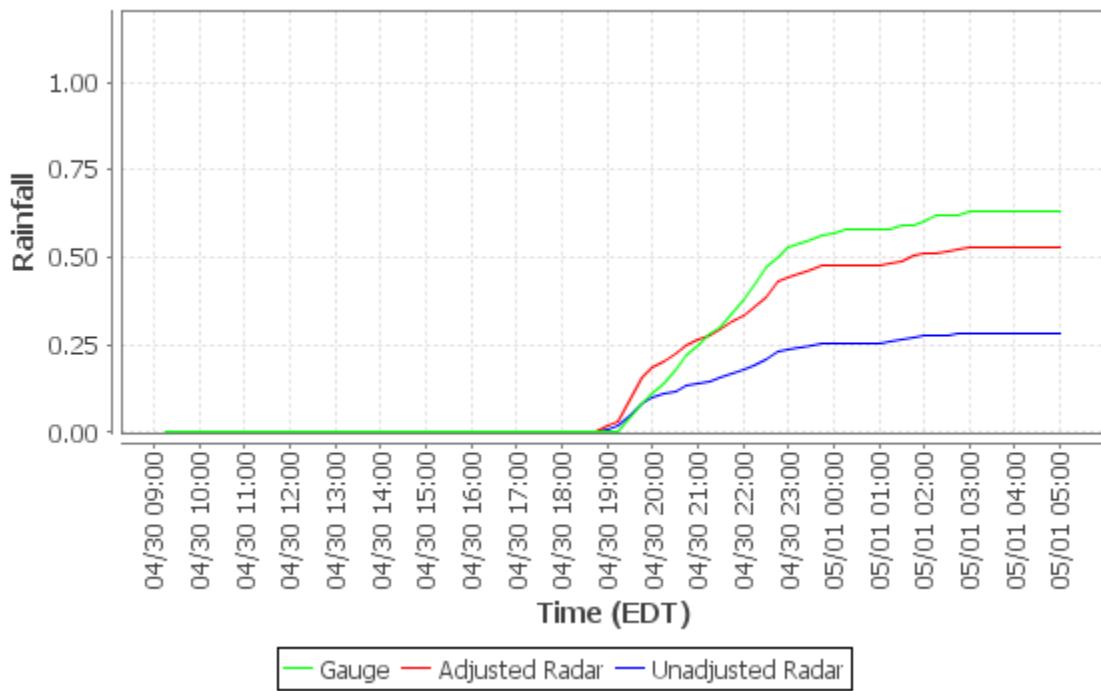
Cumulative Distribution Plot - Bell Acres Munic Bldg (Loc29)



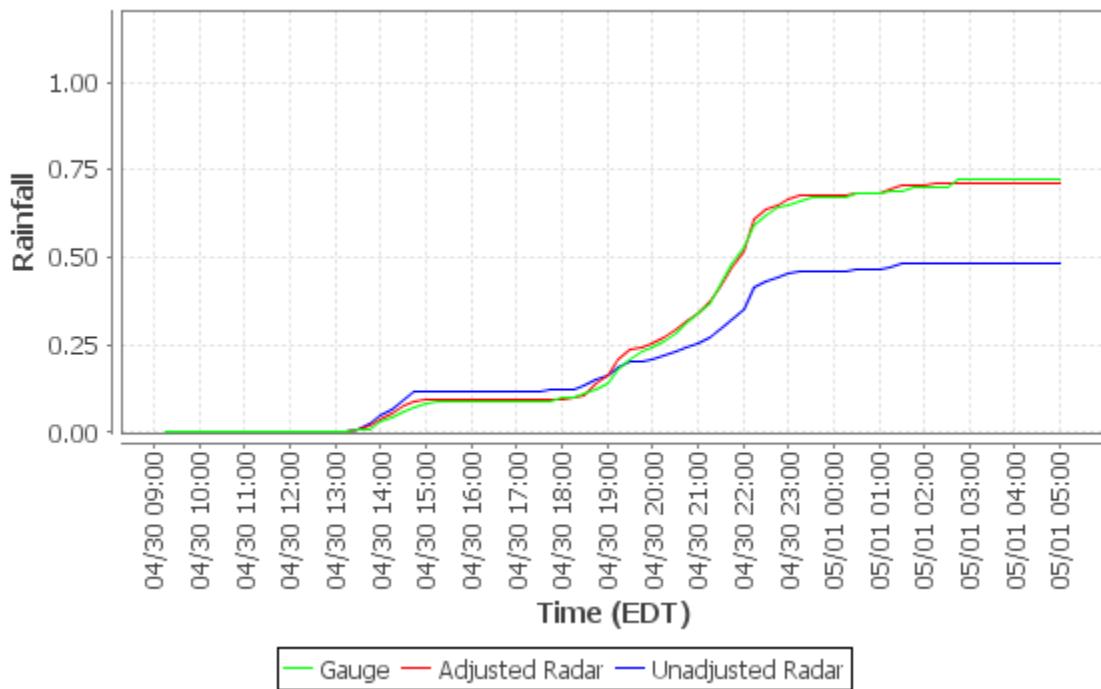
Cumulative Distribution Plot - McCandless Twn Hall (Loc30)



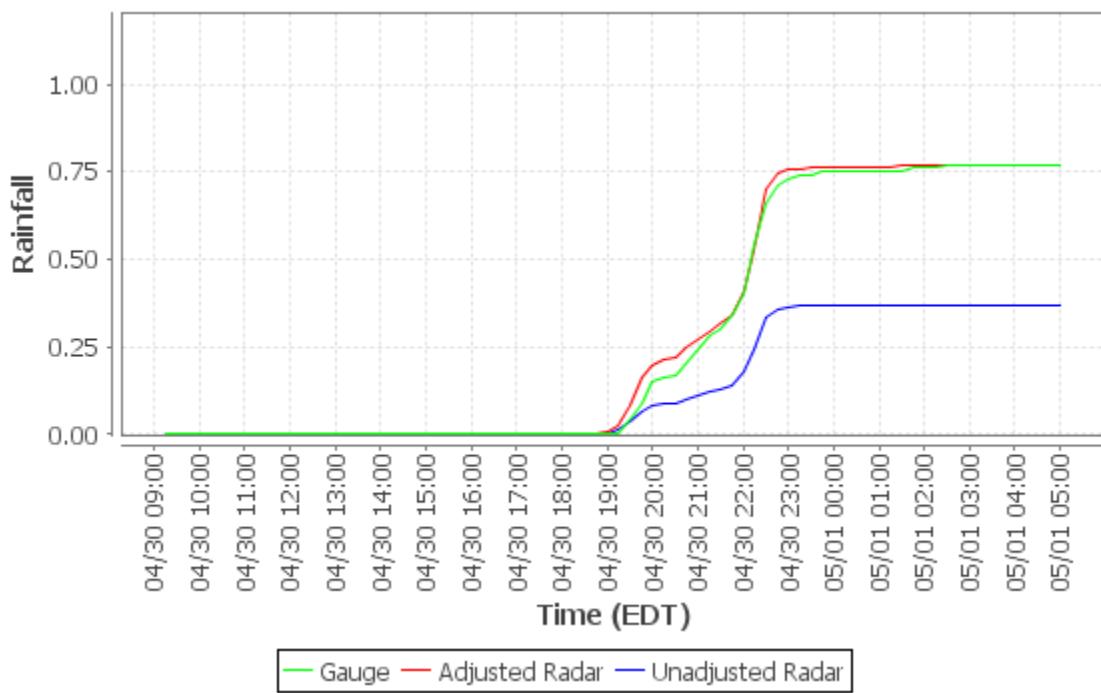
Cumulative Distribution Plot - Hampton Municipal Bldg (Loc31)



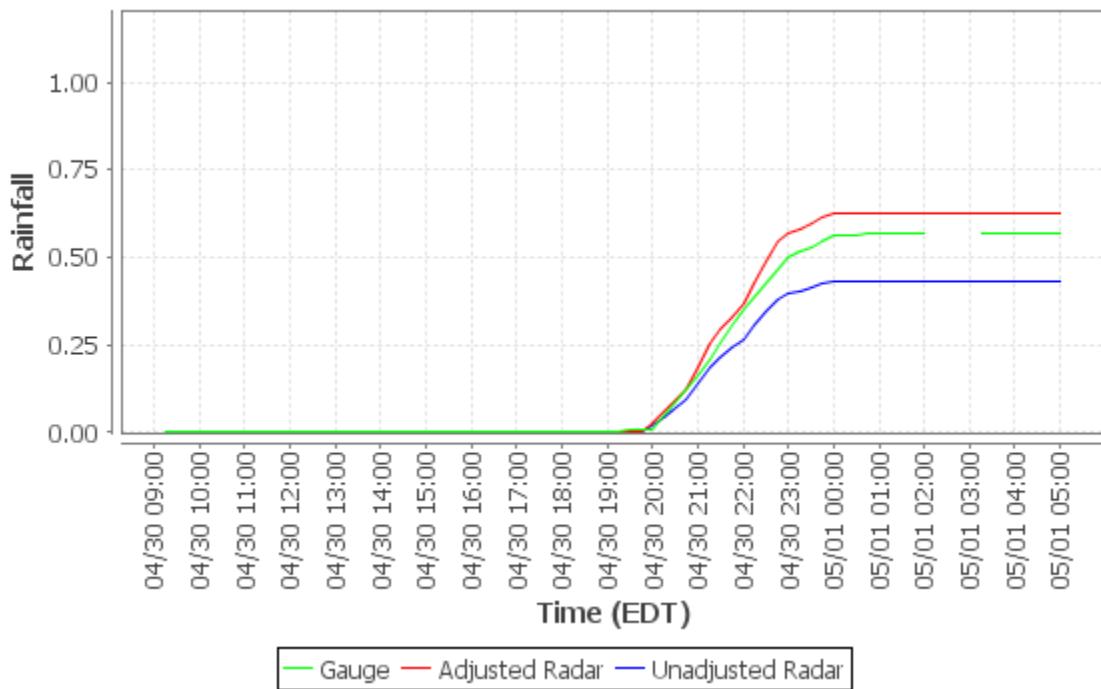
Cumulative Distribution Plot - Arnold (Loc32)



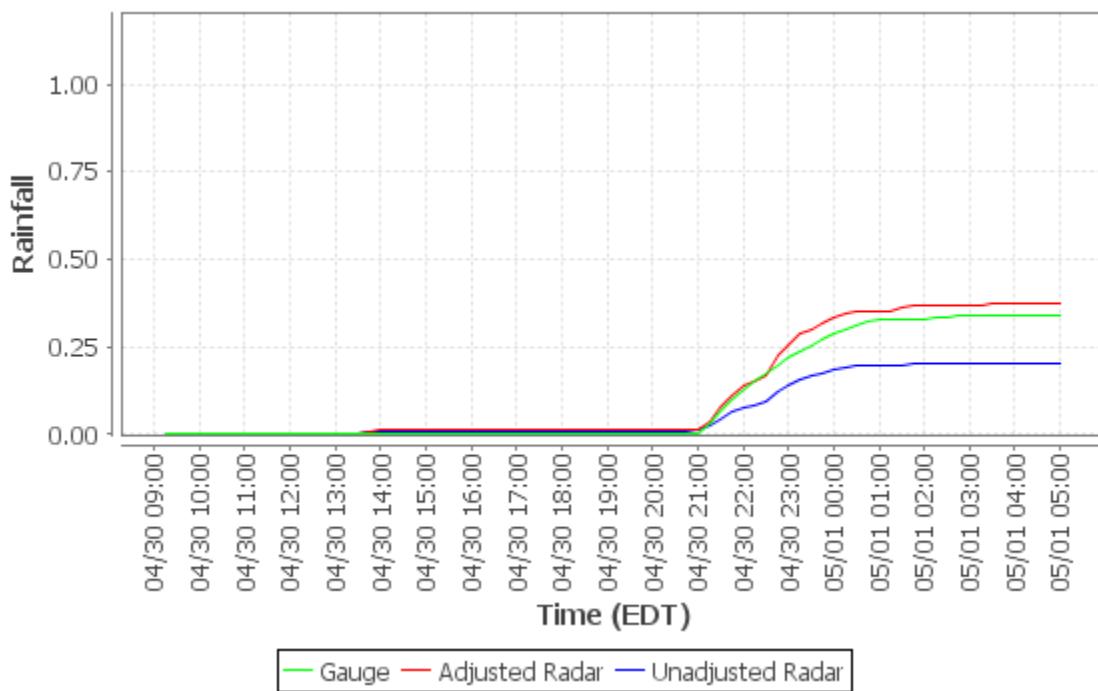
Cumulative Distribution Plot - Richland TWP (Loc33)



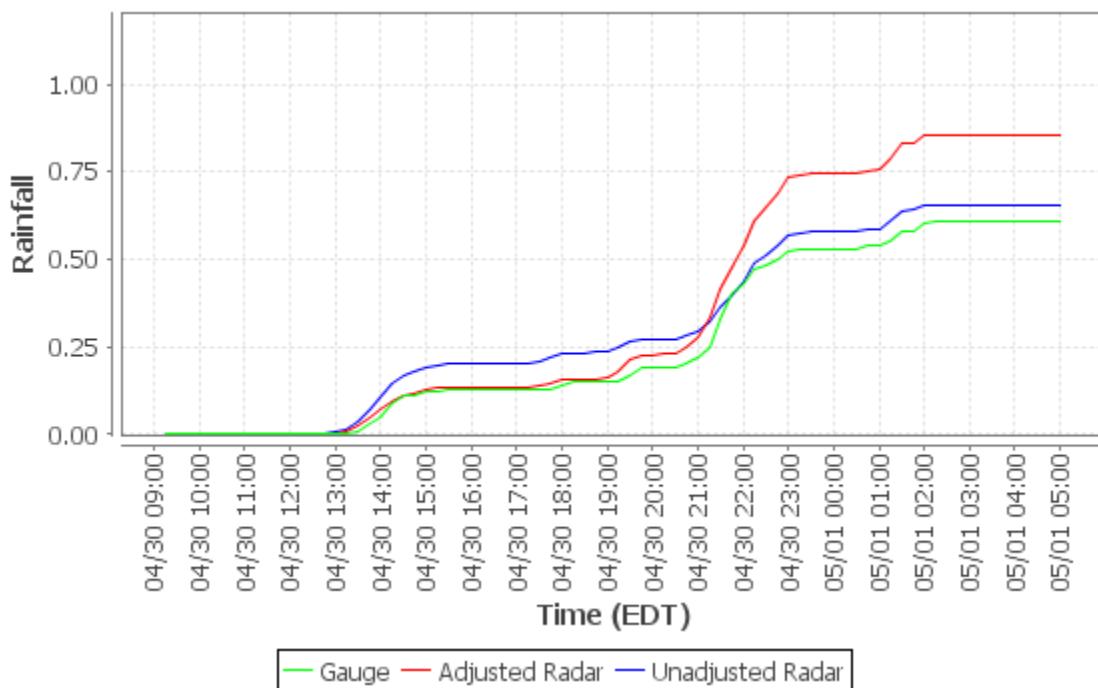
Cumulative Distribution Plot - Pittsburgh Allegheny Cty (KAGC)



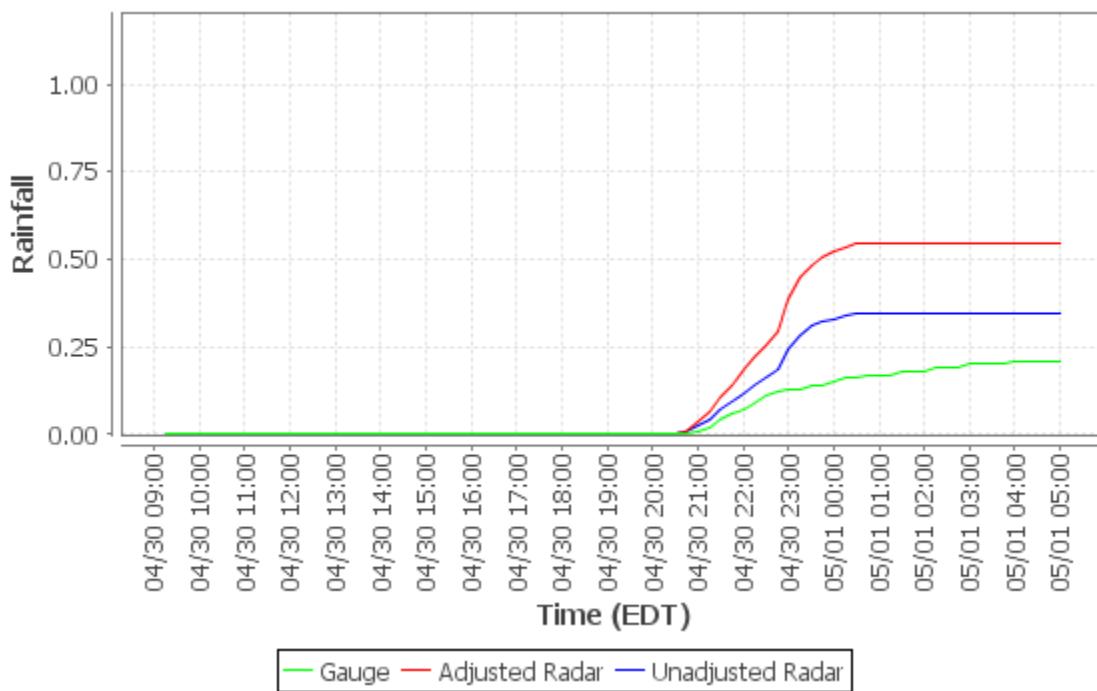
Cumulative Distribution Plot - Greater Pittsburgh Int'l (KPIT)



Cumulative Distribution Plot - Allegheny River at Natrona (03049500)



Cumulative Distribution Plot - Chartiers Creek at Carnegie (03085500)



Cumulative Distribution Plot - Ohio River at Emsworth Dam Lower Pool at Emsworth (03085734)

