Radar Rainfall Analysis
Toronto and Region Conservation Authority
Historical Rainfall Event
August 2005

Prepared for Toronto and Region Conservation Authority

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CERTIFICATION

Vieux and Associates, Inc. ensures that the Gauge Adjusted Radar Rainfall (GARR) values contained in this report are calculated based on the methodology described herein and are the result of a thorough analysis of meteorological data collected from both private and public sources. Our professionally trained hydrometeorologists employ a thorough quality-control and evaluation process, producing the most accurate and representative GARR over the defined study area. Vieux and Associates, Inc. reserves the right to amend reports at any time upon further review and/or discovery of additional data.



James Logan
Water Sector Leader

10/13/2026
Date

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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.

KBUF – Federal Communications Commission (FCC) call sign for the NEXRAD near Buffalo, NY.

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 ($mm^6\ m^{-3}$) 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 [$Z = 300R^{1.4}$]

Overview

Vieux processed radar and rain gauge data for Toronto and Region Conservation Authority (TRCA). Radar and rain gauge data are quality controlled (QC) to produce QC gauge-adjusted radar rainfall (GARR) for a historical rainfall event that occurred on August 19, 2005. To produce QC GARR, both radar and rain gauge data are reviewed manually to remove inconsistent data. QC is performed to remove anomalous radar data and inconsistent rain gauges.

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 Q0 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 KBUF located near Buffalo, NY. The succession of data used gives priority to Level II followed by Level III products. If KBUF Level II NEXRAD data are unavailable, then KBUF Level III Q0 is substituted. 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 5-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 both Level II and III is 1-km and is measured out to 230-km from the radar. Due to the locations of KBUF in relation to the target area, the polar coordinates defining resolution range in width from 1.5 to 2.7-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 is defined by a 1-km^2 grid domain shapefile produced by Vieux, Inc., resulting in 2961 1-km^2 pixels encompassing the watersheds provided by TRCA.

Rainfall data from as many as 47 gauges were used to adjust the radar: 26 City of Toronto, 18 TRCA, and three Mississauga. Figure 1 depicts the spatial distribution of the rain gauge network and the 1-km^2 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-km^2 pixels were achieved using software developed at Vieux, Inc.

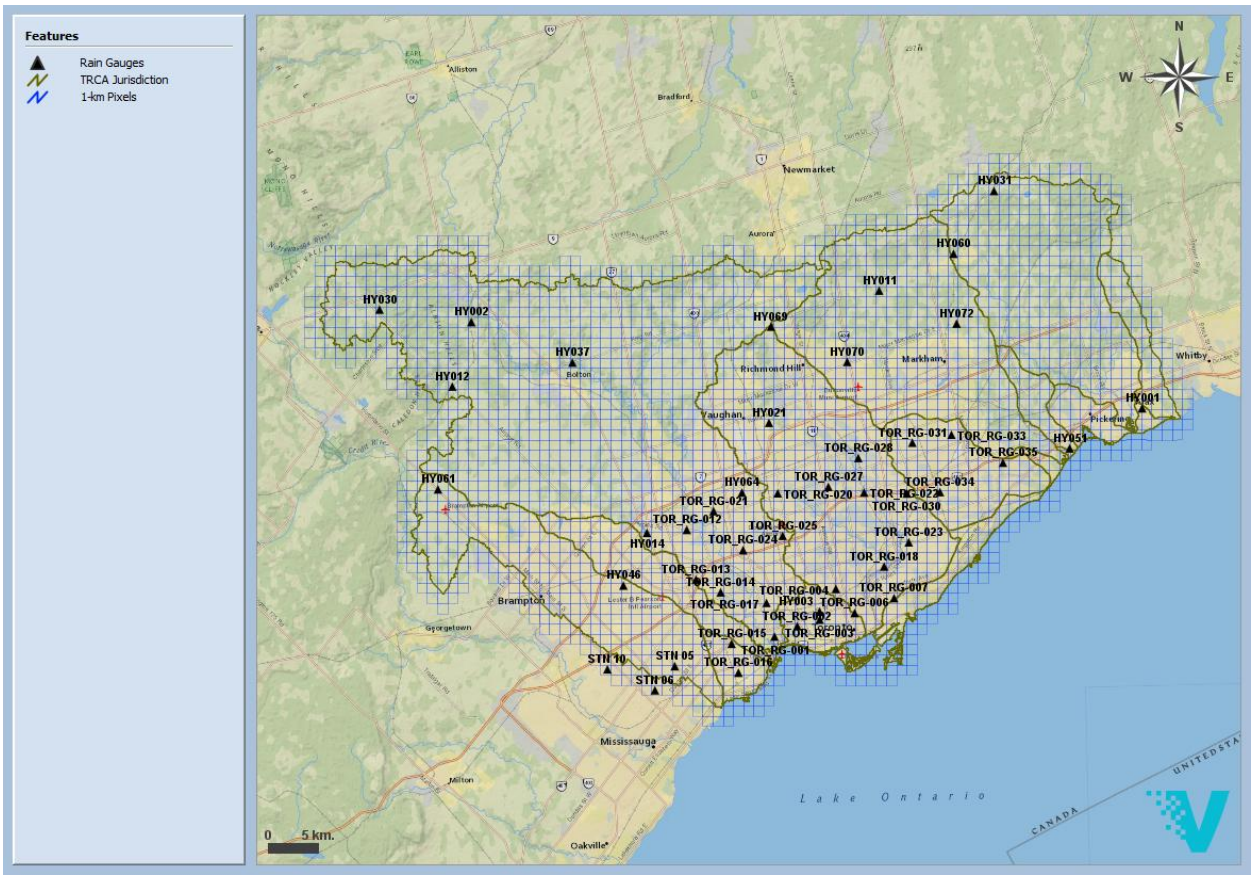


Figure 1. Spatial Distribution of the Rain Gauge Network and the 1-km^2 Pixels.

Table 1. Rain Gauge ID, Name and Source

Gauge ID	Gauge Name	Source
HY001	Ajax Works Yard	TRCA
HY002	Albion Hills	TRCA
HY003	Alex Duff Memorial Pool	TRCA
HY011	Bruces Mill CA	TRCA
HY012	Caledon Pumping Station	TRCA
HY014	Claireville Dam	TRCA
HY021	Dufferin Reservoir	TRCA
HY030	Glen Haffy	TRCA
HY031	Goodwood Pumping Station	TRCA
HY037	King and Albion-Vaughan	TRCA
HY046	Mississauga Works Yard	TRCA
HY051	Petticoat CA	TRCA
HY060	Stouffville Dam	TRCA
HY061	Sue Grange Farm	TRCA
HY064	TRCA Head Office	TRCA

Gauge ID	Gauge Name	Source
HY069	York Pumping Station	TRCA
HY070	York Region Works Yard	TRCA
HY072	Lloyd Ham Farm	TRCA
STN 05	Winding Trail	Mississauga
STN 06	Mississauga Valley Community Centre	Mississauga
STN 10	Fire Station #114	Mississauga
TOR_RG-001	Swansea	City of Toronto
TOR_RG-002	Howard	City of Toronto
TOR_RG-003	Central	City of Toronto
TOR_RG-004	Brown	City of Toronto
TOR_RG-006	Church	City of Toronto
TOR_RG-007	Greenwood	City of Toronto
TOR_RG-012	Albion	City of Toronto
TOR_RG-013	Martin Grove	City of Toronto
TOR_RG-014	Richview	City of Toronto
TOR_RG-015	Bering	City of Toronto
TOR_RG-016	Kipling	City of Toronto
TOR_RG-017	Castlefield	City of Toronto
TOR_RG-018	Thorncliffe	City of Toronto
TOR_RG-020	Finch Yard	City of Toronto
TOR_RG-021	Emery Yard	City of Toronto
TOR_RG-022	Fire Station 116	City of Toronto
TOR_RG-023	Bermondsey Yard	City of Toronto
TOR_RG-024	Wilson	City of Toronto
TOR_RG-025	Ancaster	City of Toronto
TOR_RG-027	Mitchell Field	City of Toronto
TOR_RG-028	Cummer	City of Toronto
TOR_RG-030	Pharmacy/401	City of Toronto
TOR_RG-031	Liamoreaux	City of Toronto
TOR_RG-033	Nashdene Yard	City of Toronto
TOR_RG-034	Ellesmere Yard	City of Toronto
TOR_RG-035	Morningsidede Yard	City of Toronto

The 47 rain gauges and the one NWS NEXRAD radars are used to produce gauge-adjusted radar rainfall (GARR). The methodology used in the production of GARR is described below followed by a metadata section.

Methodology

Statistical control of the data makes radar rainfall measurements more accurate. By statistical comparison between the radar and rain gauge accumulations during a GARR period, certain gauges may be identified as statistical outliers and excluded for all or part of an event. 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.

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 three 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, outlier check or gauge performance review, there must be at least three remaining RG pairs to proceed with gauge-adjustment of the radar. 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. GARR is then spatially aggregated from the final adjusted radar bins to the 1-km^2 pixels using an area-averaged technique.

After bias correction, differences between rain gauge and radar rainfall accumulations can 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.

Relatively large calibrated average differences should not necessarily be interpreted as evidence that the GARR results are unreliable, particularly when gauge accumulations are small. Because radar precipitation is spatially averaged while rain gauges provide rainfall information at a point location, differences between the two are expected and can be substantial at times even when the GARR still provides a reasonable representation of precipitation across an area.

In addition, the local bias calibration approach limits the influence of localized radar–gauge differences on the results by accounting for spatially varying differences rather than allowing individual poor matches to affect the overall calibration. Therefore, large differences at individual locations can coexist with satisfactory overall performance of the GARR product.

Any additional details regarding the methodology are considered proprietary and will not be included in this report.

Metadata

Data accompanying this document provides a continuous rainfall record of the 2961 1-km^2 pixels for the following periods:

2005/08/18 18:05 EST - 2005/08/19 22:00 EST

The data is provided Excel format. A shapefile of the 1-km^2 pixels is located in the Shapefiles subfolder. The data file documentation follows:

Excel metadata:

- Excel file with IDs across the columns and time down the rows.
- Time stamps are in EST.
- Data values represent 5-min accumulation (mm) at end of interval.
- The pixel ID uses the "ID" field from the 1-km pixel shapefile.

Shapefile metadata:

- UTM 1983, Zone 17 (meters)

Gauge-Adjusted Radar Rainfall (GARR)

GARR was processed continuously at five-minute increments and covers the period from 2005-08-18 18:00 EST to 2005-08-19 22:00 EST. The GARR statistics for the event are listed in Table 2. The event was split into multiple sub-event periods to improve gauge-adjustment of the radar, resulting in a total of seven 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. 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).

Table 2. Storm Events and GARR Statistics

Event #	Source	Event Date	Start Time (EST)	End Time (EST)	Gauges Used (47)	Avg. Depth (mm)	Bias	AD (%)	CAD (%)
E1a	KBUF LII	2005-08-19	2005-08-18 18:05	2005-08-19 05:30	28	3.726	0.655	60.1	4.0
E1b	KBUF LII	2005-08-19	2005-08-19 05:35	2005-08-19 06:30	39	4.148	0.930	28.1	6.6
E1c	KBUF LII	2005-08-19	2005-08-19 06:35	2005-08-19 07:30	30	3.796	1.372	27.6	5.3
E1d	KBUF LII	2005-08-19	2005-08-19 07:35	2005-08-19 12:45	11	1.042	1.615	38.7	3.3
E1e	KBUF LII	2005-08-19	2005-08-19 12:50	2005-08-19 15:00	25	28.652	1.272	26.8	5.0
E1f	KBUF LII	2005-08-19	2005-08-19 15:05	2005-08-19 16:00	26	16.740	1.700	38.5	7.8
E1g	KBUF LII	2005-08-19	2005-08-19 16:05	2005-08-19 22:00	30	7.512	1.427	27.7	4.1

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 Appendix C. CDPs are useful for visualizing rain gauge performance. Figure 2 shows the rainfall accumulation at the Nashdene Yard (TOR_RG-033) gauge during the 2005-08-19 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.

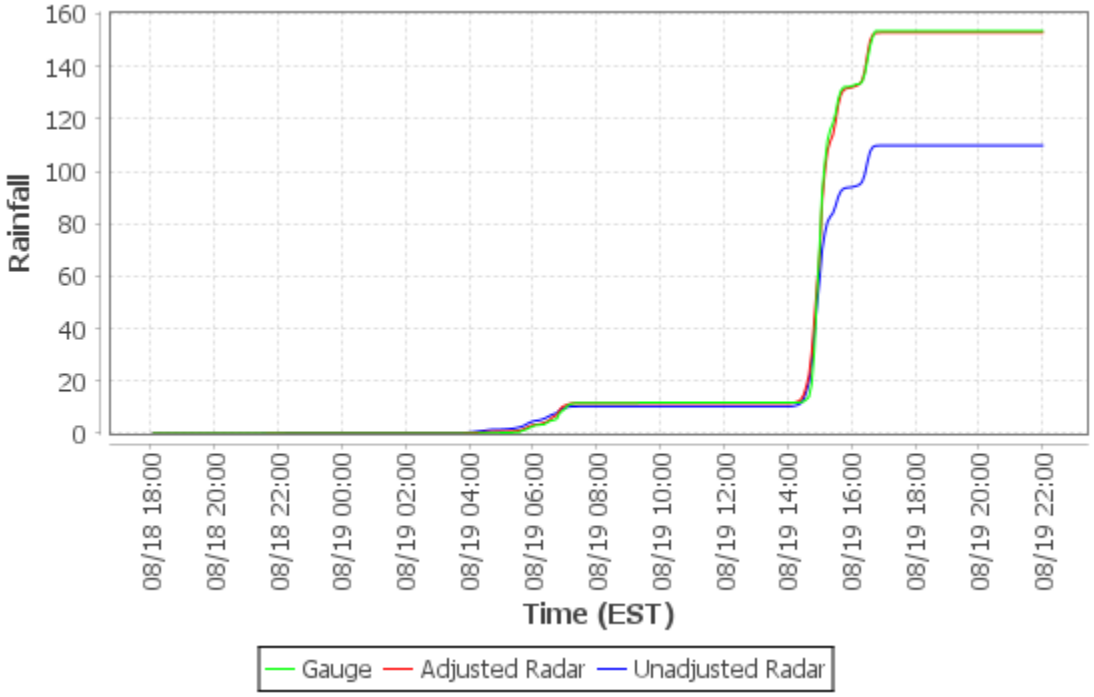


Figure 2. CDP Showing Rain Gauge Versus Unadjusted Radar Versus GARR

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 based on gauge performance 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. A list of reasons for not using a gauge based on statistical criteria is shown in Table 4. The gauges listed in Appendix B did not meet statistical criteria for gauge-adjustment of the radar and were not used to adjust the radar.

Table 3. Reasons for Gauge Exclusion Based on Performance

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

Table 4. Reasons for Gauge Exclusion Based on Statistical Criteria

Reason	Explanation
Minimum Storm Total Threshold (MSTT)	The radar or gauge cumulative sum during the event or sub-event period was less than MSTT
Outlier Based on Mean Field Bias (OMFB)	The RG pair bias (G/R) was greater than three standard deviations from the mean bias (e.g. G>>R)
Outlier Based on Average Difference (OAD)	The RG pair average difference ((G-R)/G)) was greater than three standard deviations from the mean average difference (e.g. G<<R)

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: 2005-08-19

The analysis period was from 2005-08-18 18:00 EST to 2005-08-19 22:00 EST. The event was then split into seven sub-event periods at 2005-08-19 05:30 EST, 2005-08-19 06:30 EST, 2005-08-19 07:30 EST, 2005-08-19 12:45 EST, 2005-08-19 15:00 EST and 2005-08-19 16:00 EST 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.

The gauges listed in Appendix B were not used to adjust the radar since they did not meet statistical criteria for gauge-adjustment.

A convective Z-R relationship was used to convert radar reflectivity to rainfall rates. Table 5 shows the mean bias and average depth of the event along with the AD and CAD, respectively. Tables 6 - 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. Those gauges not used to adjust the radar are shown at the bottom of the table and are highlighted in red. The specific reason for gauge exclusion is displayed in the Flag column. Figures 3 - 9 show the scatter plots of the gauge-adjusted RG pairs. Those gauges not used to adjust the radar are shown in red. Figure 10 depicts the GARR storm total over the 1-km^2 pixels. The GARR amounts for the 2961 1-km^2 pixels range from 12.1 - 178.2 millimeters with a mean of 65.6 millimeters.

Table 5. GARR Statistics for Event 1

Event #	Radar	Event Date	Start Time (EST)	End Time (EST)	Gauges Used (47)	Avg. Depth (mm)	Bias	AD (%)	CAD (%)
E1a	KBUF LII	2005-08-19	2005-08-18 18:05	2005-08-19 05:30	28	3.726	0.655	60.1	4.0
E1b	KBUF LII	2005-08-19	2005-08-19 05:35	2005-08-19 06:30	39	4.148	0.930	28.1	6.6
E1c	KBUF LII	2005-08-19	2005-08-19 06:35	2005-08-19 07:30	30	3.796	1.372	27.6	5.3
E1d	KBUF LII	2005-08-19	2005-08-19 07:35	2005-08-19 12:45	11	1.042	1.615	38.7	3.3
E1e	KBUF LII	2005-08-19	2005-08-19 12:50	2005-08-19 15:00	25	28.652	1.272	26.8	5.0
E1f	KBUF LII	2005-08-19	2005-08-19 15:05	2005-08-19 16:00	26	16.740	1.700	38.5	7.8
E1g	KBUF LII	2005-08-19	2005-08-19 16:05	2005-08-19 22:00	30	7.512	1.427	27.7	4.1

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

Gauge ID	Name	G_i (mm)	R_i (mm)	R_i* (mm)	Diff* (mm)	Diff* (%)	Flag
HY003	Alex Duff Memorial Pool	1.60	3.40	1.92	-0.32	-20.0	
HY014	Claireville Dam	4.60	7.19	5.00	-0.40	-8.7	
STN 06	Mississauga Valley Community Centre	3.20	5.30	3.40	-0.20	-6.2	
TOR_RG-003	Central	1.75	3.29	1.85	-0.10	-5.7	

Gauge ID	Name	G_i (mm)	R_i (mm)	R_i* (mm)	Diff* (mm)	Diff* (%)	Flag
TOR_RG-022	Fire Station 116	2.20	3.72	2.32	-0.12	-5.5	
TOR_RG-031	Liamoreaux	1.40	3.02	1.47	-0.07	-5.0	
HY069	York Pumping Station	1.80	4.27	1.84	-0.04	-2.2	
STN 05	Winding Trail	3.60	5.81	3.68	-0.08	-2.2	
TOR_RG-016	Kipling	2.50	4.08	2.55	-0.05	-2.0	
HY002	Albion Hills	8.00	13.76	8.06	-0.06	-0.8	
TOR_RG-014	Richview	4.20	6.41	4.23	-0.03	-0.7	
HY012	Caledon Pumping Station	7.60	12.62	7.63	-0.03	-0.4	
HY064	TRCA Head Office	4.80	6.33	4.81	-0.01	-0.2	
HY037	King and Albion-Vaughan	4.60	8.33	4.60	0.00	0.0	
HY021	Dufferin Reservoir	3.40	4.65	3.39	0.01	0.3	
HY030	Glen Haffy	9.60	15.36	9.57	0.03	0.3	
HY061	Sue Grange Farm	8.80	9.86	8.74	0.06	0.7	
TOR_RG-020	Finch Yard	4.60	6.07	4.55	0.05	1.1	
TOR_RG-027	Mitchell Field	3.40	4.90	3.36	0.04	1.2	
TOR_RG-002	Howard	2.25	3.82	2.20	0.05	2.2	
TOR_RG-015	Bering	3.40	5.26	3.31	0.09	2.6	
HY046	Mississauga Works Yard	5.20	6.96	5.04	0.16	3.1	
TOR_RG-004	Brown	2.00	3.32	1.90	0.10	5.0	
TOR_RG-012	Albion	5.30	6.87	4.99	0.31	5.8	
TOR_RG-001	Swansea	2.75	4.28	2.57	0.18	6.5	
TOR_RG-006	Church	1.50	2.47	1.40	0.10	6.7	
STN 10	Fire Station #114	5.20	6.58	4.79	0.41	7.9	
TOR_RG-025	Ancaster	4.20	5.23	3.87	0.33	7.9	
HY001	Ajax Works Yard	0.00	---	---	---	---	MSTT

Gauge ID	Name	G_i (mm)	R_i (mm)	R_i* (mm)	Diff* (mm)	Diff* (%)	Flag
HY011	Bruces Mill CA	0.70	---	---	---	---	MSTT
HY031	Goodwood Pumping Station	0.40	---	---	---	---	MSTT
HY051	Petticoat CA	0.20	---	---	---	---	MSTT
HY060	Stouffville Dam	0.40	---	---	---	---	MSTT
HY070	York Region Works Yard	0.80	---	---	---	---	MSTT
HY072	Lloyd Ham Farm	0.60	---	---	---	---	MSTT
TOR_RG-007	Greenwood	1.25	---	---	---	---	MSTT
TOR_RG-013	Martin Grove	5.75	---	---	---	---	O
TOR_RG-017	Castlefield	3.50	---	---	---	---	T
TOR_RG-018	Thorncliffe	1.00	---	---	---	---	MSTT
TOR_RG-021	Emery Yard	0.00	---	---	---	---	Z
TOR_RG-023	Bermondsey Yard	0.80	---	---	---	---	MSTT
TOR_RG-024	Wilson	0.00	---	---	---	---	Z
TOR_RG-028	Cummer	1.40	---	---	---	---	C
TOR_RG-030	Pharmacy/401	0.80	---	---	---	---	MSTT
TOR_RG-033	Nashdene Yard	0.60	---	---	---	---	MSTT
TOR_RG-034	Ellesmere Yard	0.60	---	---	---	---	MSTT
TOR_RG-035	Morningsidede Yard	0.40	---	---	---	---	MSTT

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

Gauge ID	Name	G_i (mm)	R_i (mm)	R_i* (mm)	Diff* (mm)	Diff* (%)	Flag
TOR_RG-034	Ellesmere Yard	1.80	3.09	2.34	-0.54	-30.0	
TOR_RG-002	Howard	2.00	3.57	2.55	-0.55	-27.5	
TOR_RG-023	Bermondsey Yard	1.60	2.48	1.80	-0.20	-12.5	
TOR_RG-007	Greenwood	1.50	2.25	1.68	-0.18	-12.0	
STN 06	Mississauga Valley Community Centre	4.60	5.78	5.04	-0.44	-9.6	
HY021	Dufferin Reservoir	5.00	5.79	5.44	-0.44	-8.8	
TOR_RG-022	Fire Station 116	3.40	4.43	3.68	-0.28	-8.2	
STN 05	Winding Trail	4.80	5.89	5.18	-0.38	-7.9	
TOR_RG-012	Albion	6.10	5.54	6.49	-0.39	-6.4	
HY003	Alex Duff Memorial Pool	2.40	3.50	2.54	-0.14	-5.8	
TOR_RG-027	Mitchell Field	4.80	5.45	5.08	-0.28	-5.8	
TOR_RG-003	Central	2.25	3.26	2.35	-0.10	-4.4	
HY046	Mississauga Works Yard	10.60	9.62	10.86	-0.26	-2.5	
HY012	Caledon Pumping Station	3.60	4.49	3.68	-0.08	-2.2	
TOR_RG-001	Swansea	2.75	3.74	2.81	-0.06	-2.2	
HY072	Lloyd Ham Farm	3.60	6.13	3.67	-0.07	-1.9	
HY002	Albion Hills	3.40	4.08	3.43	-0.03	-0.9	
HY060	Stouffville Dam	3.20	5.48	3.23	-0.03	-0.9	
HY031	Goodwood Pumping Station	2.40	4.18	2.41	-0.01	-0.4	
HY011	Bruces Mill CA	4.40	6.27	4.40	0.00	0.0	
HY037	King and Albion-Vaughan	5.20	4.83	5.18	0.02	0.4	
HY070	York Region Works Yard	4.60	5.32	4.58	0.02	0.4	
HY061	Sue Grange Farm	3.20	2.22	3.17	0.03	0.9	
HY030	Glen Haffy	3.40	2.99	3.35	0.05	1.5	
HY069	York Pumping Station	4.80	4.82	4.73	0.07	1.5	
TOR_RG-033	Nashdene Yard	4.00	4.39	3.92	0.08	2.0	

Gauge ID	Name	G_i (mm)	R_i (mm)	R_i* (mm)	Diff* (mm)	Diff* (%)	Flag
TOR_RG-020	Finch Yard	7.00	5.96	6.80	0.20	2.9	
HY014	Claireville Dam	5.40	4.47	5.22	0.18	3.3	
TOR_RG-013	Martin Grove	9.00	7.23	8.62	0.38	4.2	
HY064	TRCA Head Office	7.60	6.07	7.24	0.36	4.7	
TOR_RG-004	Brown	2.75	3.45	2.62	0.13	4.7	
TOR_RG-014	Richview	7.60	6.13	7.06	0.54	7.1	
TOR_RG-018	Thorncliffe	2.00	2.47	1.85	0.15	7.5	
TOR_RG-030	Pharmacy/401	3.20	3.70	2.90	0.30	9.4	
TOR_RG-016	Kipling	3.25	3.25	2.93	0.32	9.8	
STN 10	Fire Station #114	9.00	7.82	8.09	0.91	10.1	
TOR_RG-025	Ancaster	6.40	4.97	5.65	0.75	11.7	
TOR_RG-031	Liamoreaux	5.20	5.07	4.56	0.64	12.3	
TOR_RG-006	Church	2.25	2.59	1.94	0.31	13.8	
HY001	Ajax Works Yard	0.40	---	---	---	---	MSTT
HY051	Petticoat CA	0.60	---	---	---	---	MSTT
TOR_RG-015	Bering	3.00	---	---	---	---	U
TOR_RG-017	Castlefield	6.00	---	---	---	---	T
TOR_RG-021	Emery Yard	1.60	---	---	---	---	U
TOR_RG-024	Wilson	0.00	---	---	---	---	Z
TOR_RG-028	Cummer	5.80	---	---	---	---	C
TOR_RG-035	Morningsidede Yard	1.20	---	---	---	---	MSTT

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

Gauge ID	Name	G_i (mm)	R_i (mm)	R_i* (mm)	Diff* (mm)	Diff* (%)	Flag
TOR_RG-023	Bermondsey Yard	6.60	6.61	7.92	-1.32	-20.0	
STN 05	Winding Trail	6.00	5.44	6.93	-0.93	-15.5	
TOR_RG-018	Thorncliffe	5.25	5.35	6.01	-0.76	-14.5	
TOR_RG-013	Martin Grove	8.00	7.32	9.02	-1.02	-12.7	
HY051	Petticoat CA	4.80	5.82	5.32	-0.52	-10.8	
TOR_RG-003	Central	4.25	3.62	4.65	-0.40	-9.4	
TOR_RG-004	Brown	5.50	4.69	5.69	-0.19	-3.5	
HY060	Stouffville Dam	4.20	3.55	4.32	-0.12	-2.9	
HY069	York Pumping Station	1.60	1.64	1.64	-0.04	-2.5	
HY014	Claireville Dam	9.00	6.98	9.20	-0.20	-2.2	
HY072	Lloyd Ham Farm	4.60	3.98	4.70	-0.10	-2.2	
TOR_RG-012	Albion	13.20	9.33	13.44	-0.24	-1.8	
TOR_RG-035	Morningsidede Yard	6.40	4.39	6.50	-0.10	-1.6	
HY070	York Region Works Yard	2.60	2.06	2.62	-0.02	-0.8	
HY001	Ajax Works Yard	4.80	6.02	4.81	-0.01	-0.2	
TOR_RG-006	Church	4.25	3.55	4.23	0.02	0.5	
TOR_RG-031	Liamoreaux	4.40	2.41	4.38	0.02	0.5	
TOR_RG-034	Ellesmere Yard	6.80	4.19	6.74	0.06	0.9	
STN 10	Fire Station #114	8.20	6.14	8.12	0.08	1.0	
HY031	Goodwood Pumping Station	3.00	2.11	2.94	0.06	2.0	
HY011	Bruces Mill CA	3.50	2.48	3.39	0.11	3.1	
TOR_RG-027	Mitchell Field	7.40	3.09	7.11	0.29	3.9	
TOR_RG-020	Finch Yard	9.00	3.45	8.60	0.40	4.4	
HY064	TRCA Head Office	5.60	2.23	5.32	0.28	5.0	
TOR_RG-033	Nashdene Yard	7.00	3.75	6.62	0.38	5.4	

Gauge ID	Name	G_i (mm)	R_i (mm)	R_i* (mm)	Diff* (mm)	Diff* (%)	Flag
TOR_RG-002	Howard	5.00	3.45	4.70	0.30	6.0	
TOR_RG-001	Swansea	5.50	3.57	5.15	0.35	6.4	
TOR_RG-022	Fire Station 116	8.60	4.02	8.04	0.56	6.5	
TOR_RG-016	Kipling	7.25	4.45	6.75	0.50	6.9	
STN 06	Mississauga Valley Community Centre	9.00	6.45	8.36	0.64	7.1	
HY002	Albion Hills	0.20	---	---	---	---	MSTT
HY003	Alex Duff Memorial Pool	3.80	---	---	---	---	U
HY012	Caledon Pumping Station	0.40	---	---	---	---	MSTT
HY021	Dufferin Reservoir	0.60	---	---	---	---	MSTT
HY030	Glen Haffy	0.00	---	---	---	---	MSTT
HY037	King and Albion-Vaughan	0.80	---	---	---	---	MSTT
HY046	Mississauga Works Yard	7.20	---	---	---	---	S
HY061	Sue Grange Farm	0.20	---	---	---	---	MSTT
TOR_RG-007	Greenwood	0.00	---	---	---	---	Z
TOR_RG-014	Richview	5.00	---	---	---	---	U
TOR_RG-015	Bering	3.90	---	---	---	---	U
TOR_RG-017	Castlefield	7.50	---	---	---	---	T
TOR_RG-021	Emery Yard	0.20	---	---	---	---	S
TOR_RG-024	Wilson	0.00	---	---	---	---	Z
TOR_RG-025	Ancaster	12.40	---	---	---	---	S
TOR_RG-028	Cummer	4.20	---	---	---	---	C
TOR_RG-030	Pharmacy/401	6.00	---	---	---	---	U

Table 9. Summary of Individual RG Pairs for Event 1d

Gauge ID	Name	G_i (mm)	R_i (mm)	R_i* (mm)	Diff* (mm)	Diff* (%)	Flag
TOR_RG-015	Bering	7.40	5.07	8.19	-0.79	-10.7	
TOR_RG-016	Kipling	13.75	8.97	14.10	-0.35	-2.5	
HY046	Mississauga Works Yard	1.80	1.32	1.84	-0.04	-2.2	
STN 10	Fire Station #114	2.80	2.00	2.85	-0.05	-1.8	
TOR_RG-002	Howard	5.75	3.27	5.83	-0.08	-1.4	
TOR_RG-004	Brown	2.50	1.34	2.51	-0.01	-0.4	
TOR_RG-001	Swansea	7.00	4.09	7.00	0.00	0.0	
TOR_RG-034	Ellesmere Yard	2.20	1.38	2.20	0.00	0.0	
STN 05	Winding Trail	12.00	7.60	11.79	0.21	1.8	
HY003	Alex Duff Memorial Pool	4.60	2.35	4.33	0.27	5.9	
TOR_RG-014	Richview	2.80	1.38	2.51	0.29	10.4	
HY001	Ajax Works Yard	0.40	---	---	---	---	MSTT
HY002	Albion Hills	0.00	---	---	---	---	MSTT
HY011	Bruces Mill CA	0.00	---	---	---	---	MSTT
HY012	Caledon Pumping Station	0.00	---	---	---	---	MSTT
HY014	Claireville Dam	0.20	---	---	---	---	MSTT
HY021	Dufferin Reservoir	0.20	---	---	---	---	MSTT
HY030	Glen Haffy	0.00	---	---	---	---	MSTT
HY031	Goodwood Pumping Station	0.20	---	---	---	---	MSTT
HY037	King and Albion-Vaughan	0.00	---	---	---	---	MSTT
HY051	Petticoat CA	0.40	---	---	---	---	MSTT
HY060	Stouffville Dam	0.00	---	---	---	---	MSTT
HY061	Sue Grange Farm	0.00	---	---	---	---	MSTT
HY064	TRCA Head Office	0.00	---	---	---	---	MSTT
HY069	York Pumping Station	0.00	---	---	---	---	MSTT
HY070	York Region Works Yard	0.00	---	---	---	---	MSTT
HY072	Lloyd Ham Farm	0.00	---	---	---	---	MSTT
STN 06	Mississauga Valley Community Centre	5.60	---	---	---	---	U

Gauge ID	Name	G_i (mm)	R_i (mm)	R_i* (mm)	Diff* (mm)	Diff* (%)	Flag
TOR_RG-003	Central	4.00	---	---	---	---	U
TOR_RG-006	Church	3.00	---	---	---	---	U
TOR_RG-007	Greenwood	0.00	---	---	---	---	Z
TOR_RG-012	Albion	0.00	---	---	---	---	MSTT
TOR_RG-013	Martin Grove	1.50	---	---	---	---	MSTT
TOR_RG-017	Castlefield	1.50	---	---	---	---	T
TOR_RG-018	Thorncliffe	1.75	---	---	---	---	MSTT
TOR_RG-020	Finch Yard	0.00	---	---	---	---	MSTT
TOR_RG-021	Emery Yard	0.00	---	---	---	---	MSTT
TOR_RG-022	Fire Station 116	0.00	---	---	---	---	MSTT
TOR_RG-023	Bermondsey Yard	0.40	---	---	---	---	U
TOR_RG-024	Wilson	0.00	---	---	---	---	MSTT
TOR_RG-025	Ancaster	0.40	---	---	---	---	MSTT
TOR_RG-027	Mitchell Field	0.00	---	---	---	---	MSTT
TOR_RG-028	Cummer	0.40	---	---	---	---	C
TOR_RG-030	Pharmacy/401	1.80	---	---	---	---	MSTT
TOR_RG-031	Liamoreaux	0.00	---	---	---	---	MSTT
TOR_RG-033	Nashdene Yard	0.20	---	---	---	---	MSTT
TOR_RG-035	Morningsidede Yard	0.20	---	---	---	---	MSTT

Table 10. Summary of Individual RG Pairs for Event 1e

Gauge ID	Name	G_i (mm)	R_i (mm)	R_i* (mm)	Diff* (mm)	Diff* (%)	Flag
TOR_RG-034	Ellesmere Yard	31.00	34.22	36.91	-5.91	-19.1	
TOR_RG-025	Ancaster	30.40	32.56	35.43	-5.03	-16.5	
TOR_RG-018	Thorncliffe	5.00	6.44	5.63	-0.63	-12.6	
HY072	Lloyd Ham Farm	12.20	9.14	13.66	-1.46	-12.0	
HY014	Claireville Dam	51.60	55.79	53.98	-2.38	-4.6	
HY070	York Region Works Yard	23.00	17.52	23.73	-0.73	-3.2	
HY046	Mississauga Works Yard	21.00	23.54	21.54	-0.54	-2.6	
TOR_RG-020	Finch Yard	77.60	66.13	79.52	-1.92	-2.5	
HY002	Albion Hills	22.20	12.84	22.59	-0.39	-1.8	
HY030	Glen Haffy	33.60	21.36	33.81	-0.21	-0.6	
HY069	York Pumping Station	11.40	8.14	11.42	-0.02	-0.2	
TOR_RG-031	Liamoreaux	69.00	59.56	69.05	-0.05	-0.1	
HY061	Sue Grange Farm	61.20	29.30	61.10	0.10	0.2	
HY037	King and Albion-Vaughan	21.80	9.85	21.73	0.07	0.3	
TOR_RG-012	Albion	57.90	54.45	57.48	0.42	0.7	
HY011	Bruces Mill CA	13.70	7.71	13.56	0.14	1.0	
HY012	Caledon Pumping Station	36.20	18.90	35.73	0.47	1.3	
TOR_RG-022	Fire Station 116	55.20	45.56	54.43	0.77	1.4	
TOR_RG-014	Richview	13.10	10.93	12.63	0.47	3.6	
TOR_RG-033	Nashdene Yard	59.00	48.38	56.17	2.83	4.8	
TOR_RG-027	Mitchell Field	78.60	61.01	74.60	4.00	5.1	
HY021	Dufferin Reservoir	87.40	55.17	82.02	5.38	6.2	
HY064	TRCA Head Office	94.20	71.67	87.55	6.65	7.1	
HY060	Stouffville Dam	4.20	1.69	3.87	0.33	7.9	
TOR_RG-030	Pharmacy/401	49.00	39.69	44.77	4.23	8.6	
HY001	Ajax Works Yard	0.20	---	---	---	---	MSTT

Gauge ID	Name	G_i (mm)	R_i (mm)	R_i* (mm)	Diff* (mm)	Diff* (%)	Flag
HY003	Alex Duff Memorial Pool	0.00	---	---	---	---	MSTT
HY031	Goodwood Pumping Station	1.00	---	---	---	---	MSTT
HY051	Petticoat CA	0.80	---	---	---	---	MSTT
STN 05	Winding Trail	1.20	---	---	---	---	MSTT
STN 06	Mississauga Valley Community Centre	0.60	---	---	---	---	MSTT
STN 10	Fire Station #114	1.00	---	---	---	---	MSTT
TOR_RG-001	Swansea	0.25	---	---	---	---	MSTT
TOR_RG-002	Howard	0.00	---	---	---	---	MSTT
TOR_RG-003	Central	0.00	---	---	---	---	MSTT
TOR_RG-004	Brown	0.00	---	---	---	---	MSTT
TOR_RG-006	Church	0.00	---	---	---	---	MSTT
TOR_RG-007	Greenwood	0.00	---	---	---	---	MSTT
TOR_RG-013	Martin Grove	32.00	---	---	---	---	O
TOR_RG-015	Bering	0.20	---	---	---	---	MSTT
TOR_RG-016	Kipling	0.00	---	---	---	---	MSTT
TOR_RG-017	Castlefield	12.25	---	---	---	---	T
TOR_RG-021	Emery Yard	10.00	---	---	---	---	S
TOR_RG-023	Bermondsey Yard	2.80	---	---	---	---	U
TOR_RG-024	Wilson	0.00	---	---	---	---	Z
TOR_RG-028	Cummer	12.00	---	---	---	---	C
TOR_RG-035	Morningsidede Yard	4.40	---	---	---	---	U

Table 11. Summary of Individual RG Pairs for Event 1f

Gauge ID	Name	G_i (mm)	R_i (mm)	R_i* (mm)	Diff* (mm)	Diff* (%)	Flag
TOR_RG-023	Bermondsey Yard	3.00	3.39	4.51	-1.51	-50.3	
TOR_RG-012	Albion	4.40	6.48	5.43	-1.03	-23.4	
TOR_RG-020	Finch Yard	7.80	9.88	9.18	-1.38	-17.7	
TOR_RG-027	Mitchell Field	12.40	10.74	13.60	-1.20	-9.7	
HY011	Bruces Mill CA	5.50	3.56	6.01	-0.51	-9.3	
HY031	Goodwood Pumping Station	4.20	2.95	4.57	-0.37	-8.8	
HY012	Caledon Pumping Station	26.20	15.50	27.91	-1.71	-6.5	
TOR_RG-033	Nashdene Yard	61.60	35.18	64.20	-2.60	-4.2	
HY051	Petticoat CA	63.60	37.75	65.66	-2.06	-3.2	
HY037	King and Albion-Vaughan	17.60	10.52	17.70	-0.10	-0.6	
HY061	Sue Grange Farm	16.60	9.93	16.60	0.00	0.0	
HY030	Glen Haffy	14.00	5.60	13.93	0.07	0.5	
HY001	Ajax Works Yard	74.60	40.86	74.18	0.42	0.6	
HY069	York Pumping Station	6.20	3.98	6.16	0.04	0.6	
HY064	TRCA Head Office	10.40	12.01	10.31	0.09	0.9	
TOR_RG-031	Liamoreaux	50.80	27.75	49.77	1.03	2.0	
HY072	Lloyd Ham Farm	20.20	7.16	19.32	0.88	4.4	
HY060	Stouffville Dam	8.40	3.40	8.01	0.39	4.6	
HY046	Mississauga Works Yard	11.20	7.88	10.65	0.55	4.9	
TOR_RG-035	Morningsidede Yard	52.40	25.92	49.84	2.56	4.9	
HY002	Albion Hills	22.20	9.02	20.93	1.27	5.7	
HY021	Dufferin Reservoir	12.20	10.10	11.47	0.73	6.0	
TOR_RG-030	Pharmacy/401	24.20	13.46	22.51	1.69	7.0	
TOR_RG-034	Ellesmere Yard	37.40	19.65	34.46	2.94	7.9	
TOR_RG-013	Martin Grove	3.25	2.75	2.96	0.29	8.9	
TOR_RG-022	Fire Station 116	22.60	13.37	20.46	2.14	9.5	

Gauge ID	Name	G_i (mm)	R_i (mm)	R_i* (mm)	Diff* (mm)	Diff* (%)	Flag
HY003	Alex Duff Memorial Pool	0.00	---	---	---	---	MSTT
HY014	Claireville Dam	5.40	---	---	---	---	U
HY070	York Region Works Yard	17.20	---	---	---	---	O
STN 05	Winding Trail	0.00	---	---	---	---	MSTT
STN 06	Mississauga Valley Community Centre	0.00	---	---	---	---	MSTT
STN 10	Fire Station #114	0.20	---	---	---	---	MSTT
TOR_RG-001	Swansea	0.00	---	---	---	---	MSTT
TOR_RG-002	Howard	0.00	---	---	---	---	MSTT
TOR_RG-003	Central	0.00	---	---	---	---	MSTT
TOR_RG-004	Brown	0.25	---	---	---	---	MSTT
TOR_RG-006	Church	0.00	---	---	---	---	MSTT
TOR_RG-007	Greenwood	0.00	---	---	---	---	MSTT
TOR_RG-014	Richview	1.30	---	---	---	---	MSTT
TOR_RG-015	Bering	0.10	---	---	---	---	MSTT
TOR_RG-016	Kipling	0.00	---	---	---	---	MSTT
TOR_RG-017	Castlefield	0.25	---	---	---	---	T
TOR_RG-018	Thorncliffe	0.25	---	---	---	---	MSTT
TOR_RG-021	Emery Yard	0.20	---	---	---	---	S
TOR_RG-024	Wilson	0.00	---	---	---	---	Z
TOR_RG-025	Ancaster	1.60	---	---	---	---	OAD
TOR_RG-028	Cummer	24.60	---	---	---	---	C

Table 12. Summary of Individual RG Pairs for Event 1g

Gauge ID	Name	G_i (mm)	R_i (mm)	R_i* (mm)	Diff* (mm)	Diff* (%)	Flag
TOR_RG-027	Mitchell Field	12.60	11.23	14.50	-1.90	-15.1	
HY011	Bruces Mill CA	7.80	7.64	8.59	-0.79	-10.1	
TOR_RG-020	Finch Yard	14.80	11.67	16.13	-1.33	-9.0	
TOR_RG-012	Albion	7.10	4.84	7.53	-0.43	-6.1	
STN 06	Mississauga Valley Community Centre	3.80	3.67	3.99	-0.19	-5.0	
TOR_RG-034	Ellesmere Yard	17.20	12.99	18.03	-0.83	-4.8	
TOR_RG-006	Church	24.00	15.60	24.98	-0.98	-4.1	
HY072	Lloyd Ham Farm	5.40	4.56	5.60	-0.20	-3.7	
HY051	Petticoat CA	13.00	12.73	13.41	-0.41	-3.2	
TOR_RG-002	Howard	19.75	13.50	20.38	-0.63	-3.2	
TOR_RG-031	Liamoreaux	17.60	13.43	18.00	-0.40	-2.3	
TOR_RG-022	Fire Station 116	13.80	10.31	14.04	-0.24	-1.7	
STN 05	Winding Trail	5.40	4.81	5.46	-0.06	-1.1	
TOR_RG-035	Morningsidede Yard	15.00	12.34	15.16	-0.16	-1.1	
TOR_RG-003	Central	22.75	14.78	22.83	-0.08	-0.4	
TOR_RG-001	Swansea	17.00	11.57	17.05	-0.05	-0.3	
HY001	Ajax Works Yard	17.40	15.87	17.31	0.09	0.5	
TOR_RG-033	Nashdene Yard	21.00	15.89	20.88	0.12	0.6	
TOR_RG-016	Kipling	11.50	8.37	11.39	0.11	1.0	
HY031	Goodwood Pumping Station	6.00	3.53	5.93	0.07	1.2	
TOR_RG-030	Pharmacy/401	18.80	13.03	18.51	0.29	1.5	
HY046	Mississauga Works Yard	10.00	5.89	9.82	0.18	1.8	

Gauge ID	Name	G_i (mm)	R_i (mm)	R_i* (mm)	Diff* (mm)	Diff* (%)	Flag
TOR_RG-004	Brown	32.75	19.67	31.61	1.14	3.5	
HY060	Stouffville Dam	9.20	5.94	8.87	0.33	3.6	
TOR_RG-023	Bermondsey Yard	20.60	12.05	19.74	0.86	4.2	
HY070	York Region Works Yard	12.40	6.75	11.84	0.56	4.5	
HY014	Claireville Dam	4.60	2.68	4.39	0.21	4.6	
HY021	Dufferin Reservoir	6.60	3.69	6.25	0.35	5.3	
TOR_RG-018	Thorncliffe	31.25	16.45	28.11	3.14	10.0	
TOR_RG-025	Ancaster	17.00	10.08	15.25	1.75	10.3	
HY002	Albion Hills	0.00	---	---	---	---	MSTT
HY003	Alex Duff Memorial Pool	18.60	---	---	---	---	U
HY012	Caledon Pumping Station	0.00	---	---	---	---	MSTT
HY030	Glen Haffy	0.00	---	---	---	---	MSTT
HY037	King and Albion-Vaughan	0.20	---	---	---	---	MSTT
HY061	Sue Grange Farm	0.00	---	---	---	---	MSTT
HY064	TRCA Head Office	0.00	---	---	---	---	Z
HY069	York Pumping Station	3.60	---	---	---	---	OMFB
STN 10	Fire Station #114	1.20	---	---	---	---	MSTT
TOR_RG-007	Greenwood	15.75	---	---	---	---	U
TOR_RG-013	Martin Grove	26.50	---	---	---	---	O
TOR_RG-014	Richview	14.90	---	---	---	---	U
TOR_RG-015	Bering	8.00	---	---	---	---	U
TOR_RG-017	Castlefield	17.25	---	---	---	---	T
TOR_RG-021	Emery Yard	0.00	---	---	---	---	Z
TOR_RG-024	Wilson	4.60	---	---	---	---	U
TOR_RG-028	Cummer	43.60	---	---	---	---	C

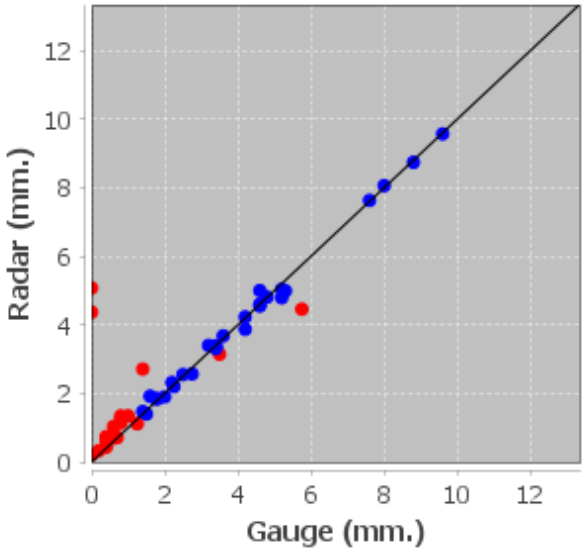


Figure 3. Scatter Plot of RG Pairs for Event 1a

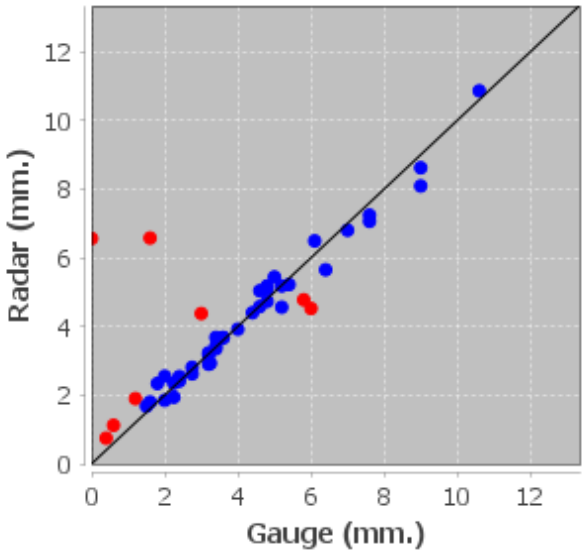


Figure 4. Scatter Plot of RG Pairs for Event 1b

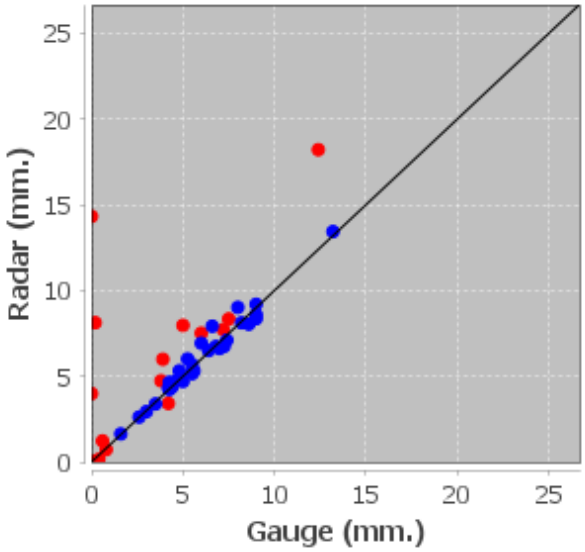


Figure 5. Scatter Plot of RG Pairs for Event 1c

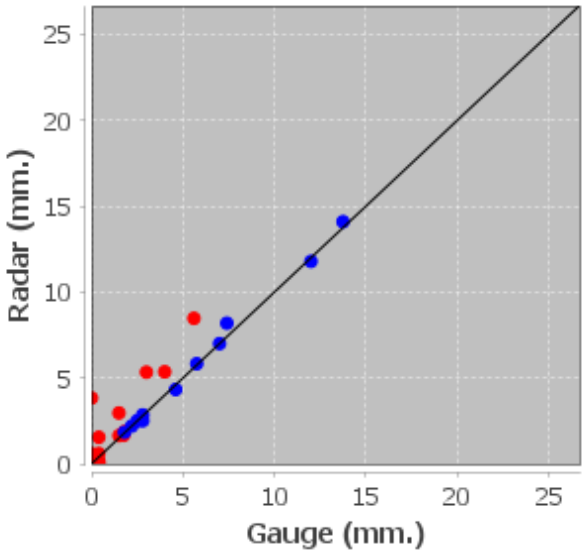


Figure 6. Scatter Plot of RG Pairs for Event 1d

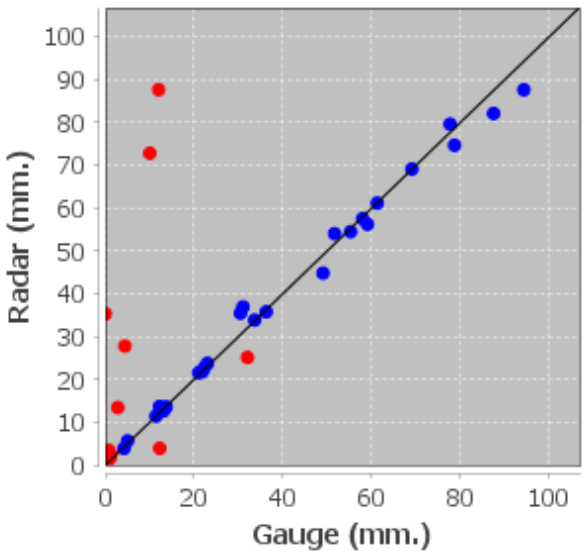


Figure 7. Scatter Plot of RG Pairs for Event 1e

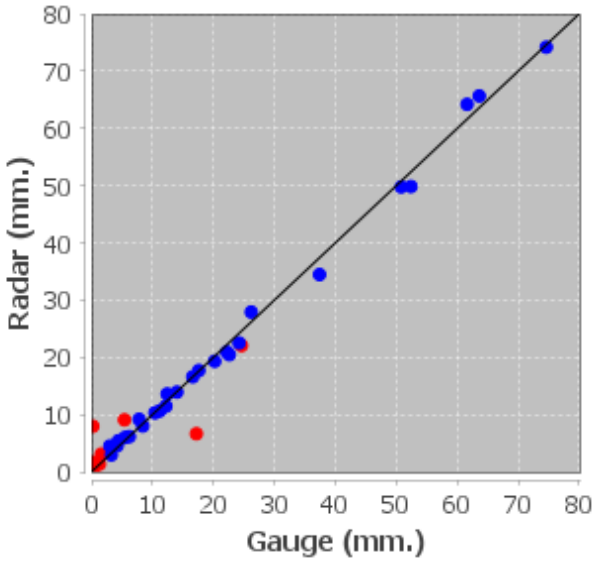


Figure 8. Scatter Plot of RG Pairs for Event 1f

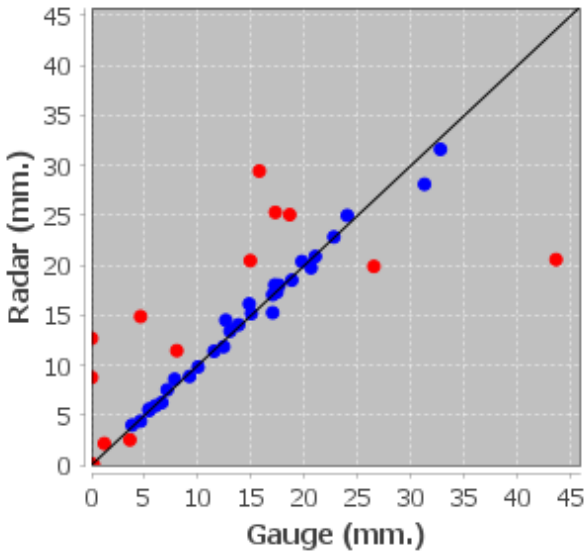


Figure 9. Scatter Plot of RG Pairs for Event 1g

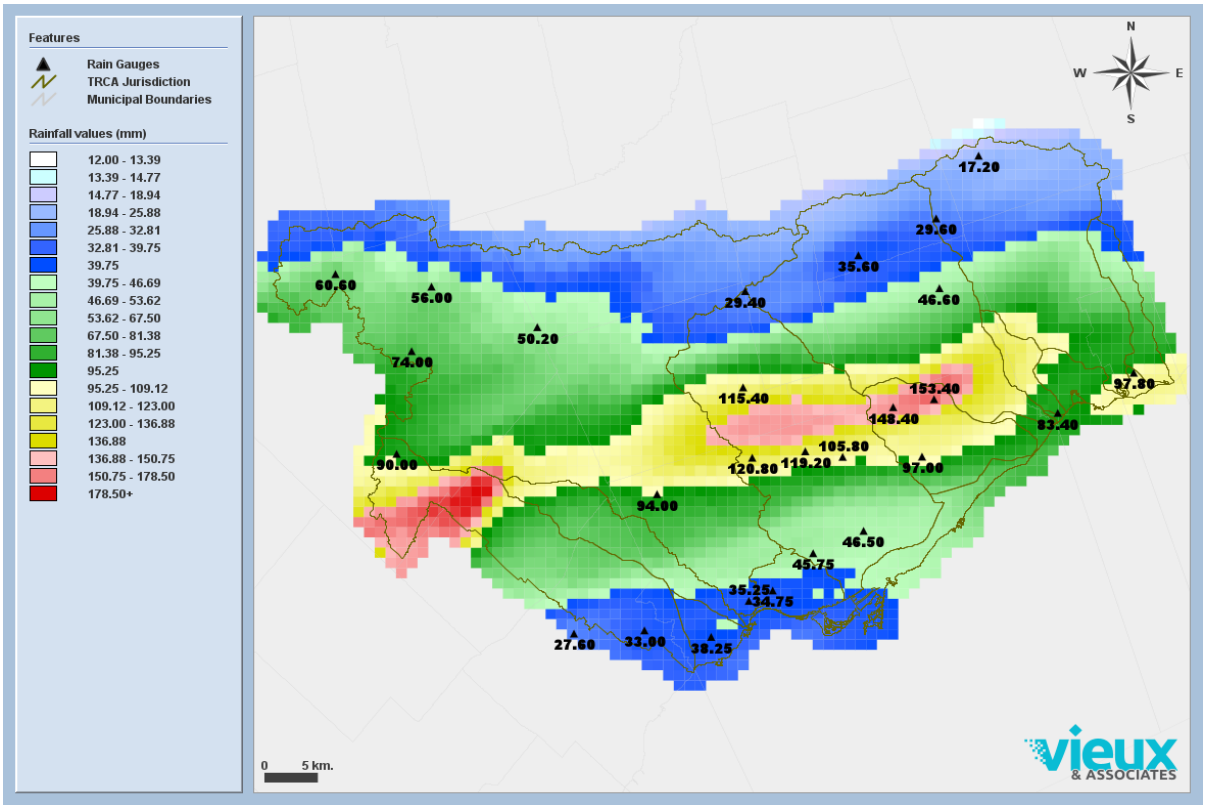


Figure 10. GARR Storm Total for Event 1

Appendices

Appendix A - Gauge Performance Exclusion Table
Appendix B - Gauge Statistical Criteria Exclusion Table
Appendix C - Event 1 (2005-08-19) CDPs

Appendix A - Gauge Performance Exclusion 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

Event #	E1a	E1b	E1c	E1d	E1e
Event Date	**2005-08-19**	**2005-08-19**	**2005-08-19**	**2005-08-19**	**2005-08-19**
Start Time (EST)	2005-08-18 18:05	2005-08-19 05:35	2005-08-19 06:35	2005-08-19 07:35	2005-08-19 12:50
End Time (EST)	2005-08-19 05:30	2005-08-19 06:30	2005-08-19 07:30	2005-08-19 12:45	2005-08-19 15:00
HY001					
HY002					
HY003			U		
HY011					
HY012					
HY014					
HY021					
HY030					
HY031					
HY037					
HY046			S		
HY051					
HY060					
HY061					
HY064					
HY069					
HY070					
HY072					
TOR_RG-001					
TOR_RG-002					
TOR_RG-003				U	
TOR_RG-004					
TOR_RG-006				U	
TOR_RG-007			Z	Z	
TOR_RG-012					
TOR_RG-013	O				O
TOR_RG-014			U		
TOR_RG-015		U	U		

Event #	E1a	E1b	E1c	E1d	E1e
Event Date	**2005-08-19**	**2005-08-19**	**2005-08-19**	**2005-08-19**	**2005-08-19**
Start Time (EST)	2005-08-18 18:05	2005-08-19 05:35	2005-08-19 06:35	2005-08-19 07:35	2005-08-19 12:50
End Time (EST)	2005-08-19 05:30	2005-08-19 06:30	2005-08-19 07:30	2005-08-19 12:45	2005-08-19 15:00
TOR_RG-016					
TOR_RG-017	T	T	T	T	T
TOR_RG-018					
TOR_RG-020					
TOR_RG-021	Z	U	S		S
TOR_RG-022					
TOR_RG-023				U	U
TOR_RG-024	Z	Z	Z		Z
TOR_RG-025			S		
TOR_RG-027					
TOR_RG-028	C	C	C	C	C
TOR_RG-030			U		
TOR_RG-031					
TOR_RG-033					
TOR_RG-034					
TOR_RG-035					U
STN 05					
STN 06				U	
STN 10					

Event #	E1f	E1g
Event Date	**2005-08-19**	**2005-08-19**
Start Time (EST)	2005-08-19 15:05	2005-08-19 16:05
End Time (EST)	2005-08-19 16:00	2005-08-19 22:00
HY001		
HY002		
HY003		U
HY011		
HY012		
HY014	U	
HY021		
HY030		
HY031		
HY037		
HY046		
HY051		
HY060		
HY061		
HY064		Z
HY069		
HY070	O	
HY072		
TOR_RG-001		
TOR_RG-002		
TOR_RG-003		
TOR_RG-004		
TOR_RG-006		
TOR_RG-007		U
TOR_RG-012		
TOR_RG-013		O
TOR_RG-014		U
TOR_RG-015		U

Event #	E1f	E1g
Event Date	**2005-08-19**	**2005-08-19**
Start Time (EST)	2005-08-19 15:05	2005-08-19 16:05
End Time (EST)	2005-08-19 16:00	2005-08-19 22:00
TOR_RG-016		
TOR_RG-017	T	T
TOR_RG-018		
TOR_RG-020		
TOR_RG-021	S	Z
TOR_RG-022		
TOR_RG-023		
TOR_RG-024	Z	U
TOR_RG-025		
TOR_RG-027		
TOR_RG-028	C	C
TOR_RG-030		
TOR_RG-031		
TOR_RG-033		
TOR_RG-034		
TOR_RG-035		
STN 05		
STN 06		
STN 10		

Appendix B - Gauge Statistical Criteria Exclusion Table

Reason	Explanation
Minimum Storm Total Threshold (MSTT)	The radar or gauge cumulative sum during the event or sub-event period was less than MSTT
Outlier Based on Mean Field Bias (OMFB)	The RG pair bias (G/R) was greater than three standard deviations from the mean bias (e.g. G>>R)
Outlier Based on Average Difference (OAD)	The RG pair average difference ((G-R)/G)) was greater than three standard deviations from the mean average difference (e.g. G<<R)

Event #	E1a	E1b	E1c	E1d	E1e
Event Date	**2005-08-19**	**2005-08-19**	**2005-08-19**	**2005-08-19**	**2005-08-19**
Start Time (EST)	2005-08-18 18:05	2005-08-19 05:35	2005-08-19 06:35	2005-08-19 07:35	2005-08-19 12:50
End Time (EST)	2005-08-19 05:30	2005-08-19 06:30	2005-08-19 07:30	2005-08-19 12:45	2005-08-19 15:00
Source	KBUF LII	KBUF LII	KBUF LII	KBUF LII	KBUF LII
HY001	MSTT	MSTT		MSTT	MSTT
HY002			MSTT	MSTT	
HY003					MSTT
HY011	MSTT			MSTT	
HY012			MSTT	MSTT	
HY014				MSTT	
HY021			MSTT	MSTT	
HY030			MSTT	MSTT	
HY031	MSTT			MSTT	MSTT
HY037			MSTT	MSTT	
HY046					
HY051	MSTT	MSTT		MSTT	MSTT
HY060	MSTT			MSTT	
HY061			MSTT	MSTT	
HY064				MSTT	
HY069				MSTT	
HY070	MSTT			MSTT	
HY072	MSTT			MSTT	
TOR_RG-001					MSTT
TOR_RG-002					MSTT
TOR_RG-003					MSTT
TOR_RG-004					MSTT
TOR_RG-006					MSTT
TOR_RG-007	MSTT				MSTT
TOR_RG-012				MSTT	
TOR_RG-013				MSTT	
TOR_RG-014					

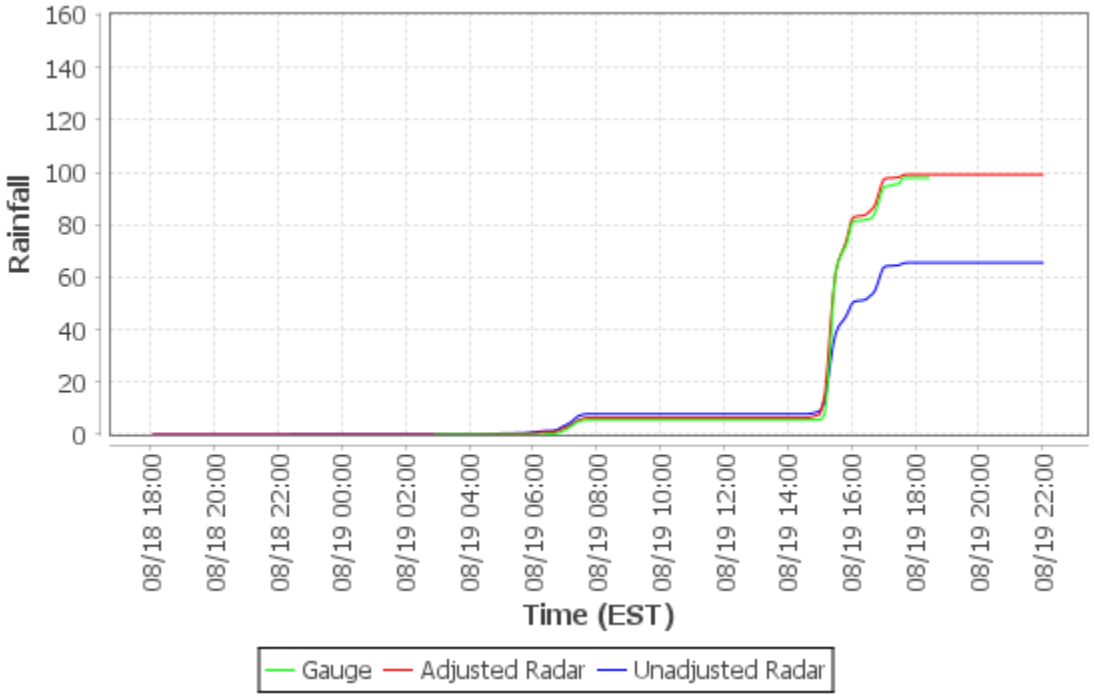
Event #	E1a	E1b	E1c	E1d	E1e
Event Date	**2005-08-19**	**2005-08-19**	**2005-08-19**	**2005-08-19**	**2005-08-19**
Start Time (EST)	2005-08-18 18:05	2005-08-19 05:35	2005-08-19 06:35	2005-08-19 07:35	2005-08-19 12:50
End Time (EST)	2005-08-19 05:30	2005-08-19 06:30	2005-08-19 07:30	2005-08-19 12:45	2005-08-19 15:00
Source	KBUF LII	KBUF LII	KBUF LII	KBUF LII	KBUF LII
TOR_RG-015					MSTT
TOR_RG-016					MSTT
TOR_RG-017					
TOR_RG-018	MSTT			MSTT	
TOR_RG-020				MSTT	
TOR_RG-021				MSTT	
TOR_RG-022				MSTT	
TOR_RG-023	MSTT				
TOR_RG-024				MSTT	
TOR_RG-025				MSTT	
TOR_RG-027				MSTT	
TOR_RG-028					
TOR_RG-030	MSTT			MSTT	
TOR_RG-031				MSTT	
TOR_RG-033	MSTT			MSTT	
TOR_RG-034	MSTT				
TOR_RG-035	MSTT	MSTT		MSTT	
STN 05					MSTT
STN 06					MSTT
STN 10					MSTT

Event #	E1f	E1g
Event Date	**2005-08-19**	**2005-08-19**
Start Time (EST)	2005-08-19 15:05	2005-08-19 16:05
End Time (EST)	2005-08-19 16:00	2005-08-19 22:00
Source	KBUF LII	KBUF LII
HY001		
HY002		MSTT
HY003	MSTT	
HY011		
HY012		MSTT
HY014		
HY021		
HY030		MSTT
HY031		
HY037		MSTT
HY046		
HY051		
HY060		
HY061		MSTT
HY064		
HY069		OMFB
HY070		
HY072		
TOR_RG-001	MSTT	
TOR_RG-002	MSTT	
TOR_RG-003	MSTT	
TOR_RG-004	MSTT	
TOR_RG-006	MSTT	
TOR_RG-007	MSTT	
TOR_RG-012		
TOR_RG-013		
TOR_RG-014	MSTT	

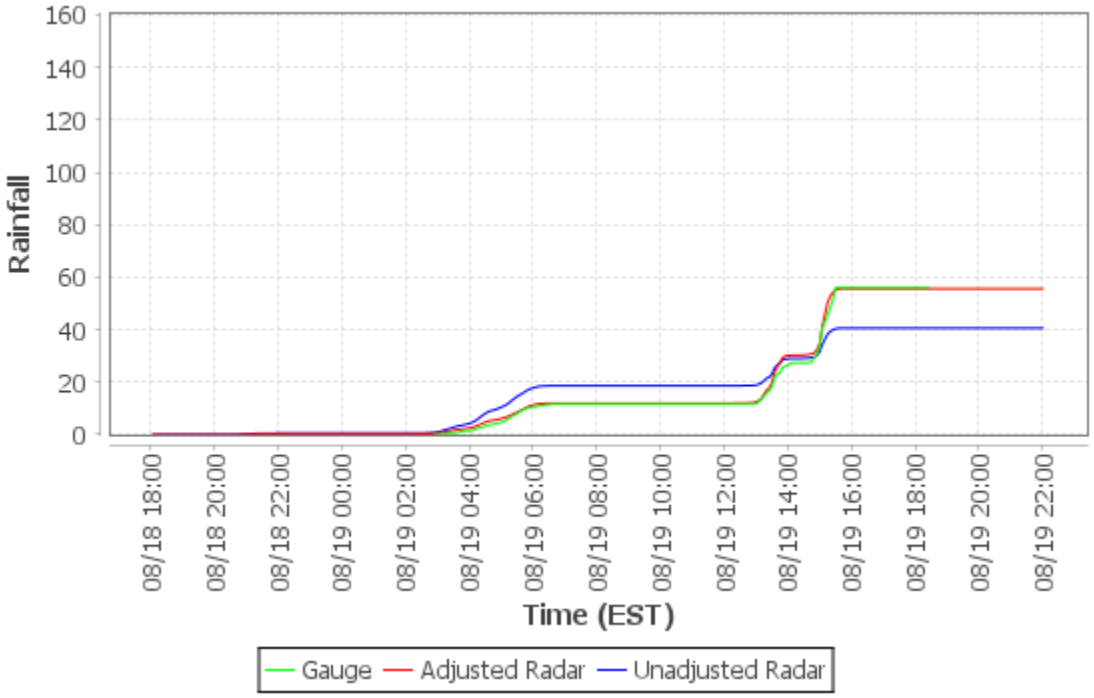
Event #	E1f	E1g
Event Date	**2005-08-19**	**2005-08-19**
Start Time (EST)	2005-08-19 15:05	2005-08-19 16:05
End Time (EST)	2005-08-19 16:00	2005-08-19 22:00
Source	KBUF LII	KBUF LII
TOR_RG-015	MSTT	
TOR_RG-016	MSTT	
TOR_RG-017		
TOR_RG-018	MSTT	
TOR_RG-020		
TOR_RG-021		
TOR_RG-022		
TOR_RG-023		
TOR_RG-024		
TOR_RG-025	OAD	
TOR_RG-027		
TOR_RG-028		
TOR_RG-030		
TOR_RG-031		
TOR_RG-033		
TOR_RG-034		
TOR_RG-035		
STN 05	MSTT	
STN 06	MSTT	
STN 10	MSTT	MSTT

Appendix C - Event 1 (2005-08-19) CDPs

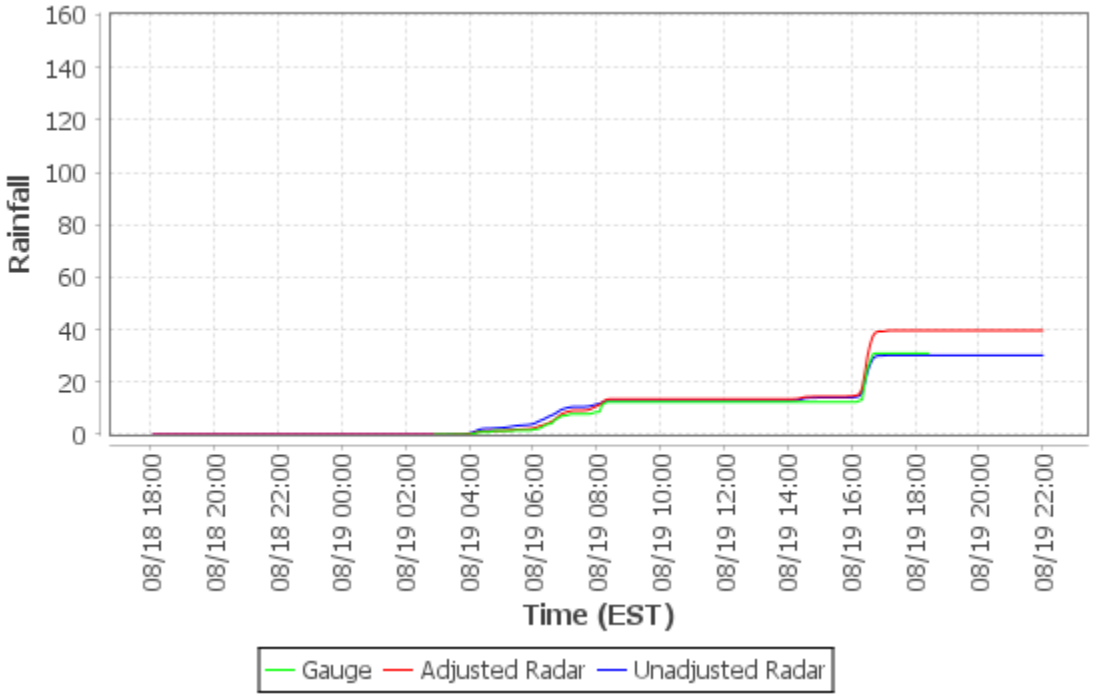
Cumulative Distribution Plot - Ajax Works Yard (HY001)



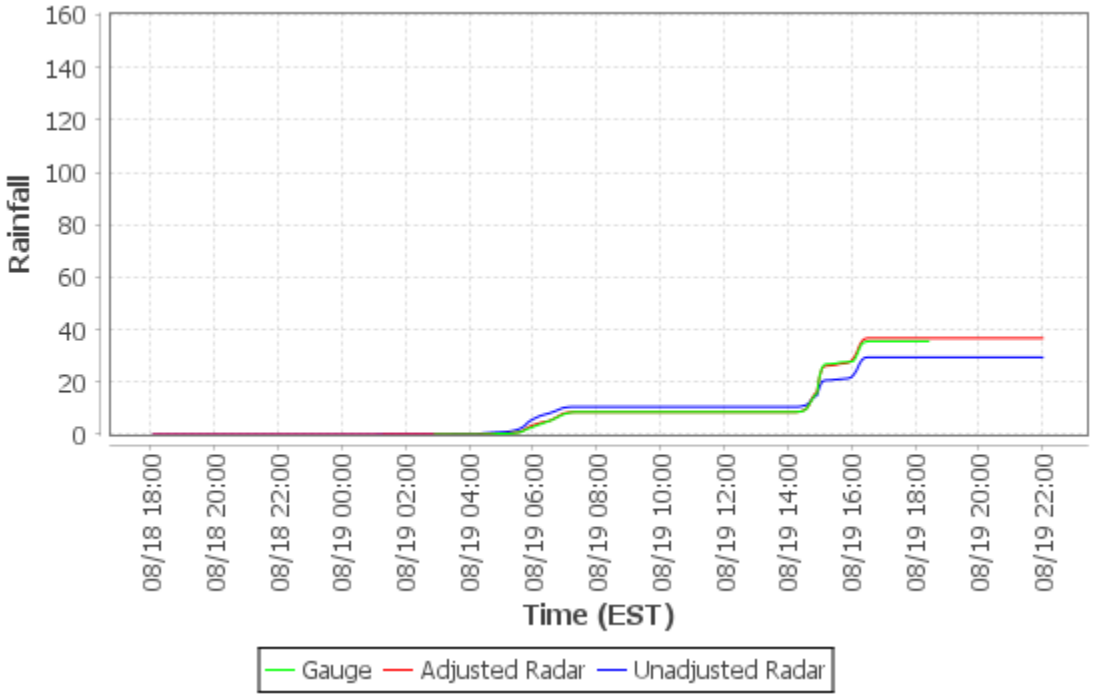
Cumulative Distribution Plot - Albion Hills (HY002)



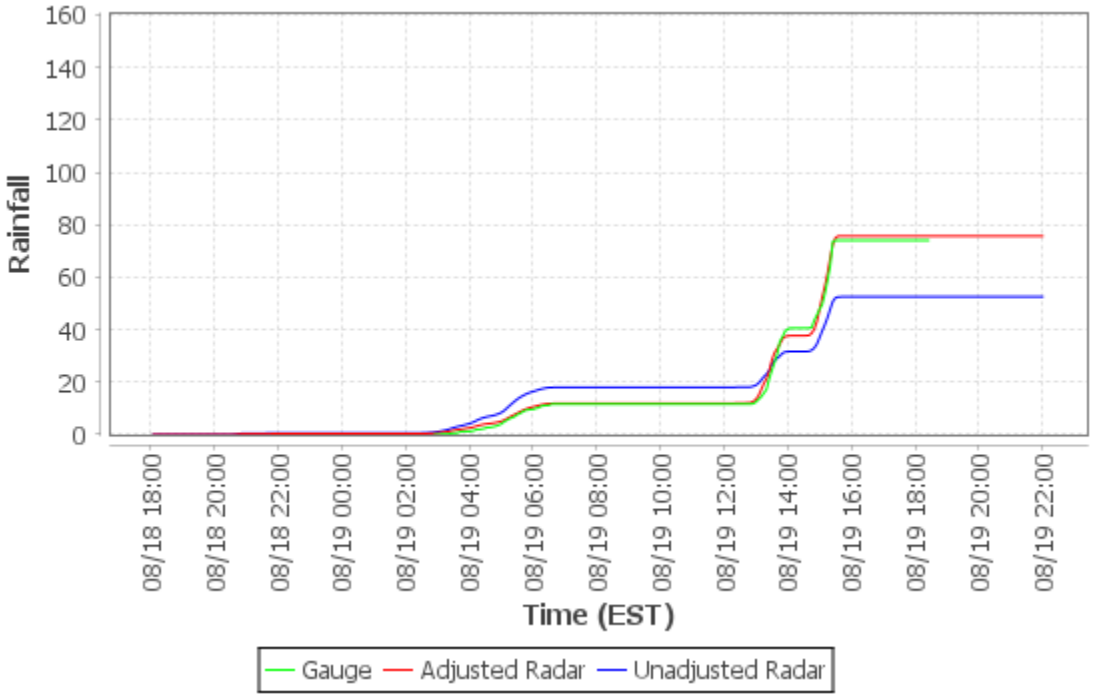
Cumulative Distribution Plot - Alex Duff Memorial Pool (HY003)



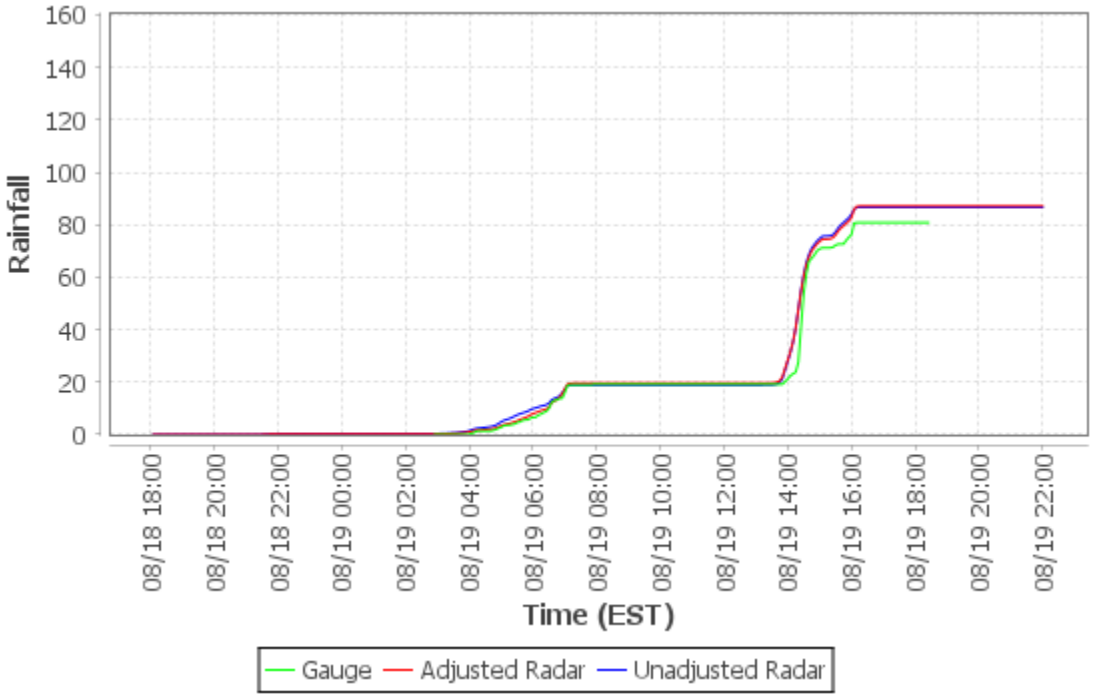
Cumulative Distribution Plot - Bruces Mill CA (HY011)



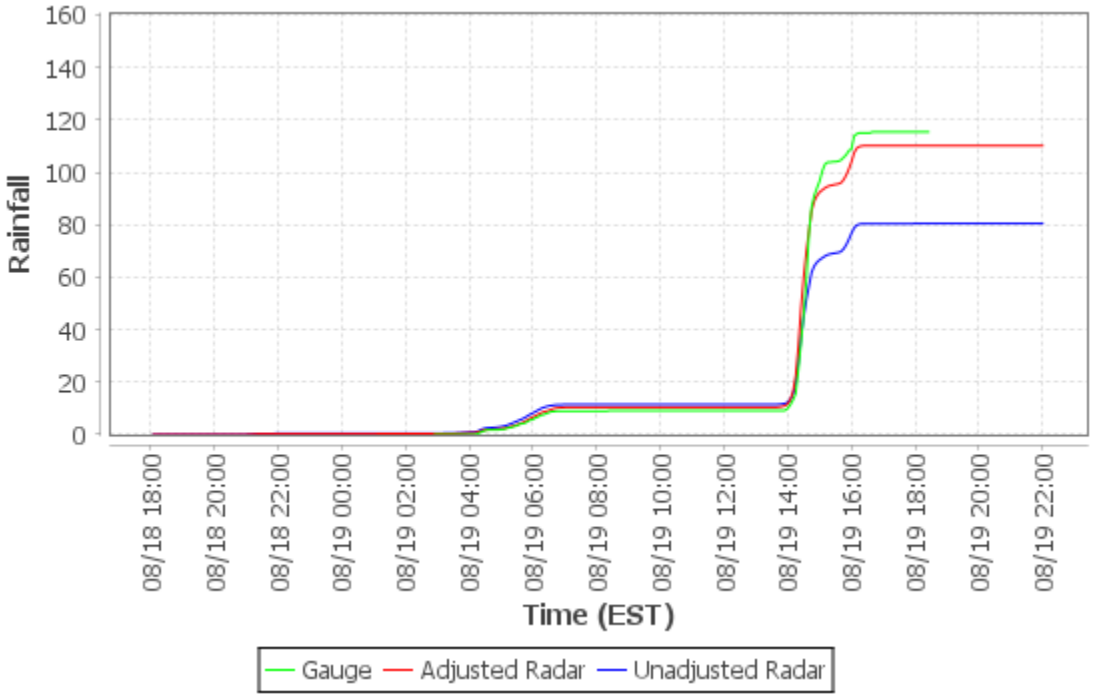
Cumulative Distribution Plot - Caledon Pumping Station (HY012)



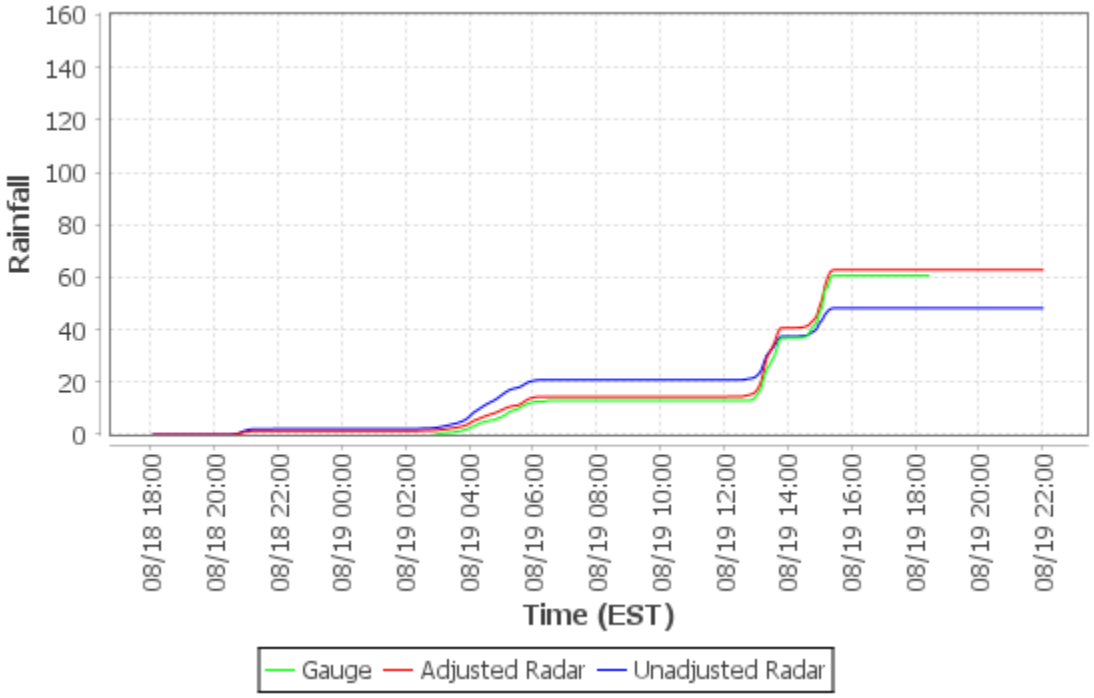
Cumulative Distribution Plot - Claireville Dam (HY014)



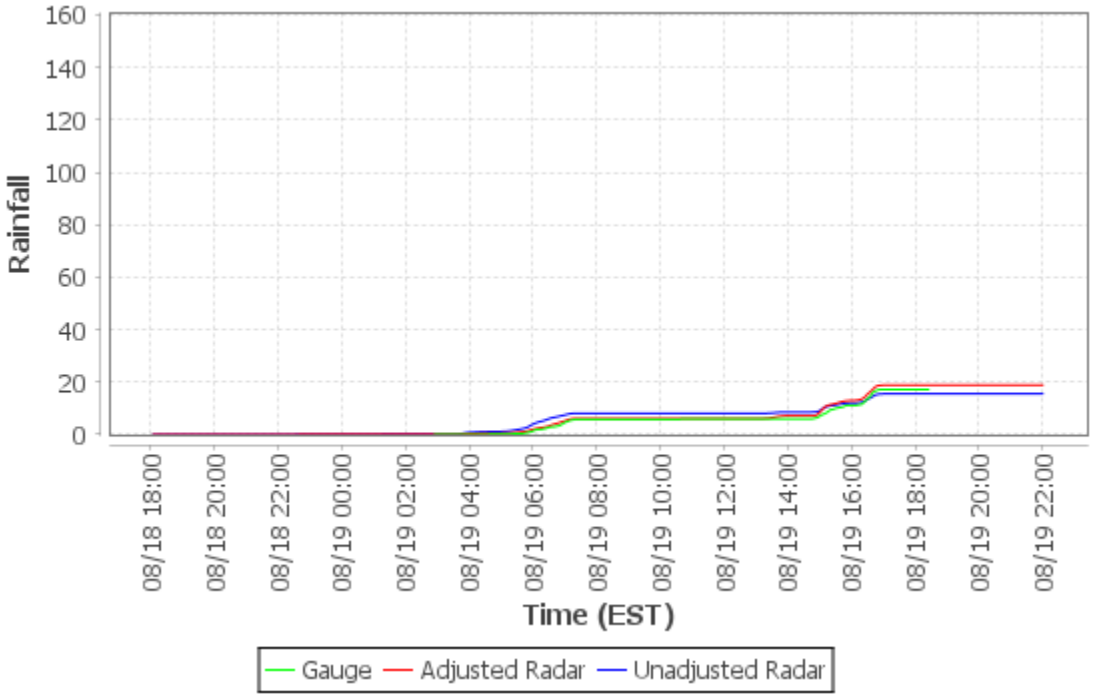
Cumulative Distribution Plot - Dufferin Reservoir (HY021)



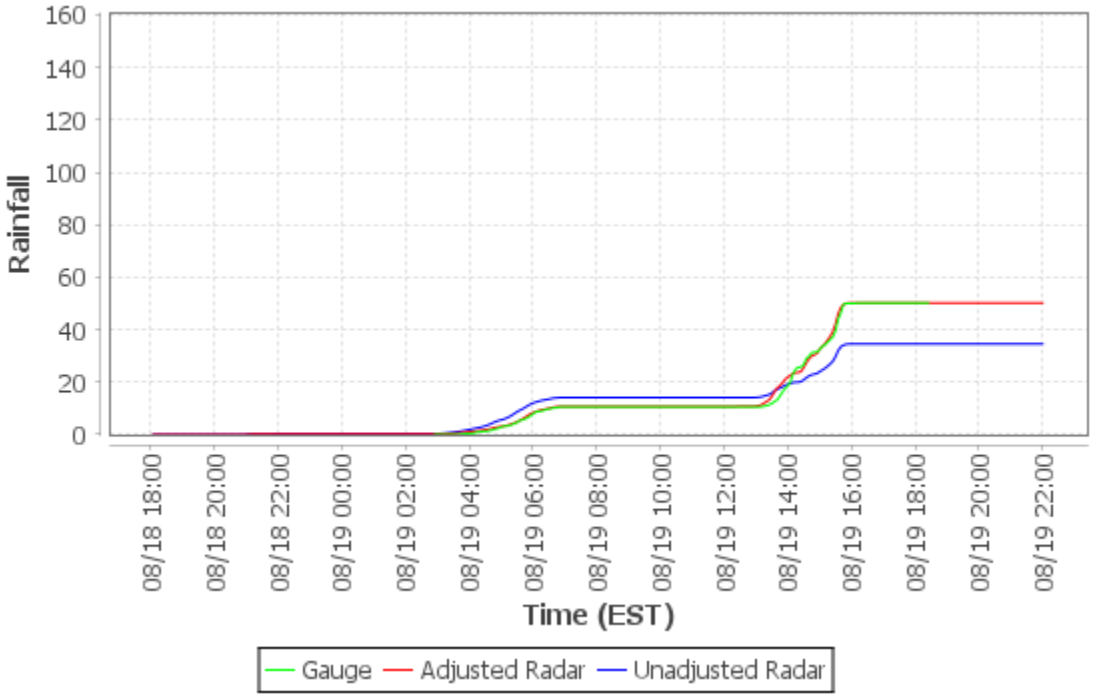
Cumulative Distribution Plot - Glen Haffy (HY030)



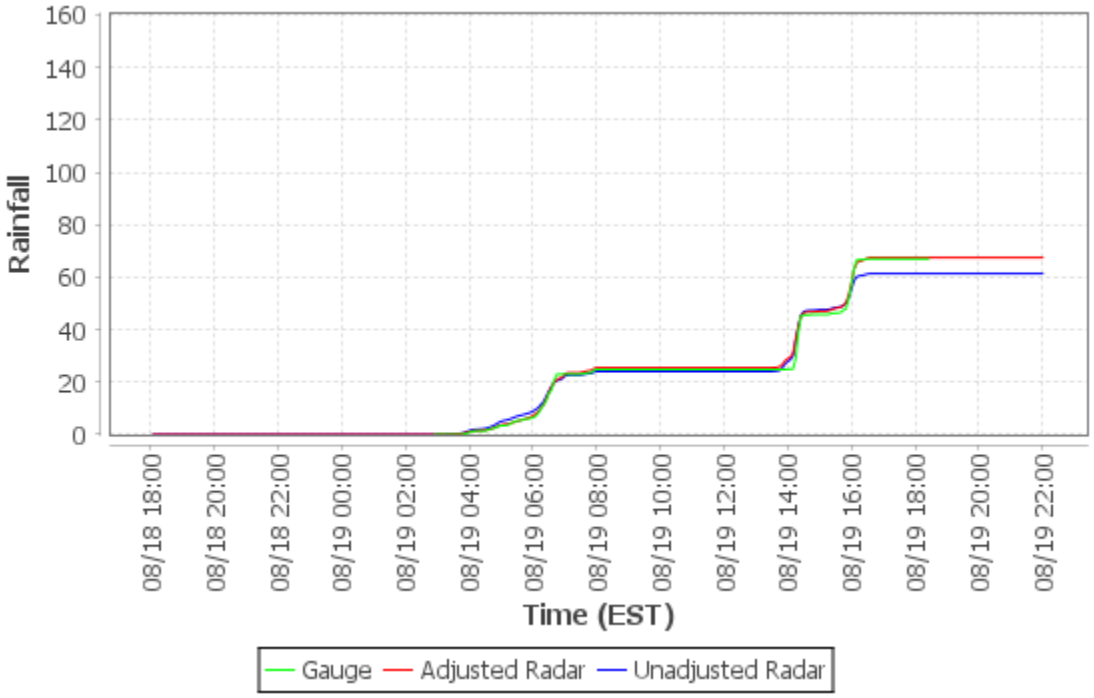
Cumulative Distribution Plot - Goodwood Pumping Station (HY031)



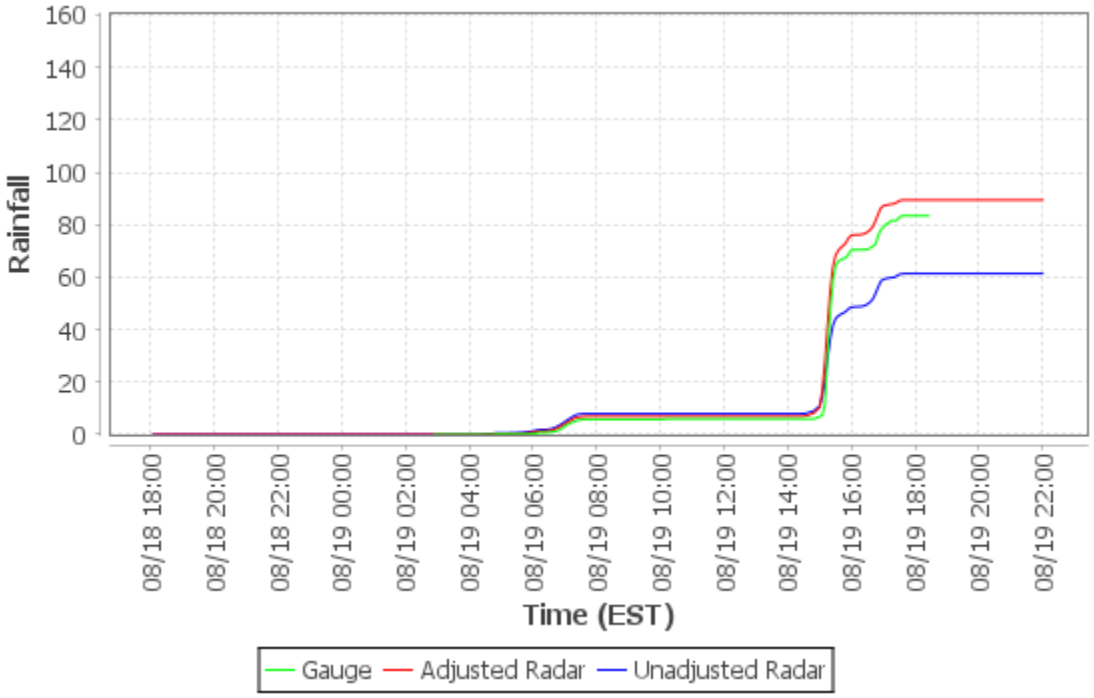
Cumulative Distribution Plot - King and Albion-Vaughan (HY037)



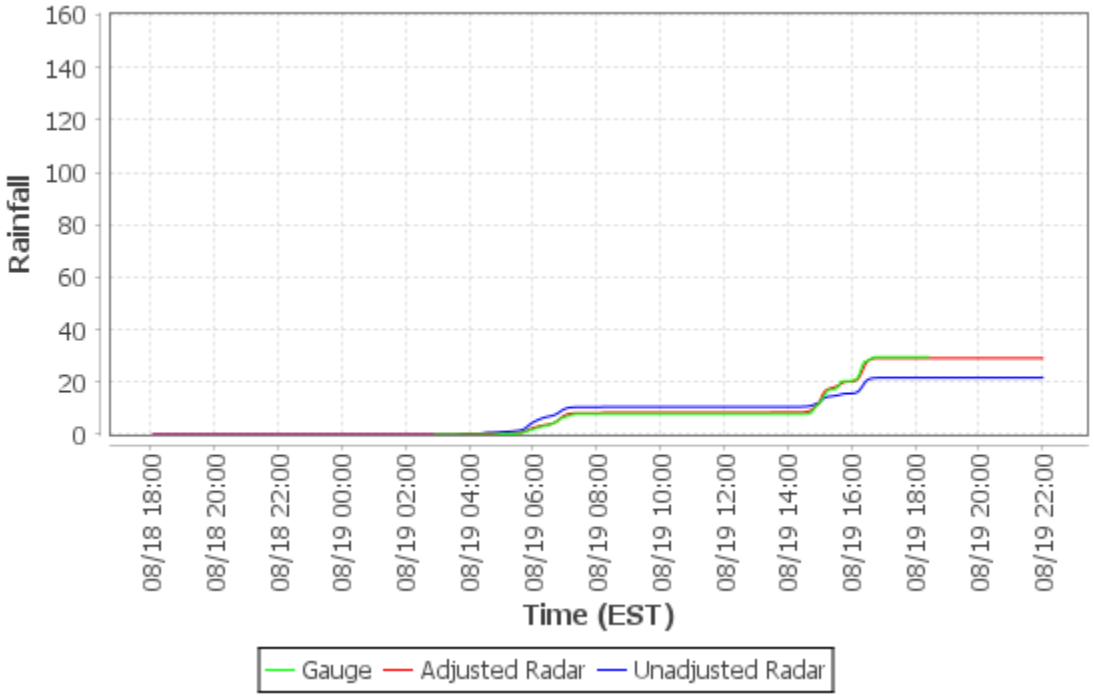
Cumulative Distribution Plot - Mississauga Works Yard (HY046)



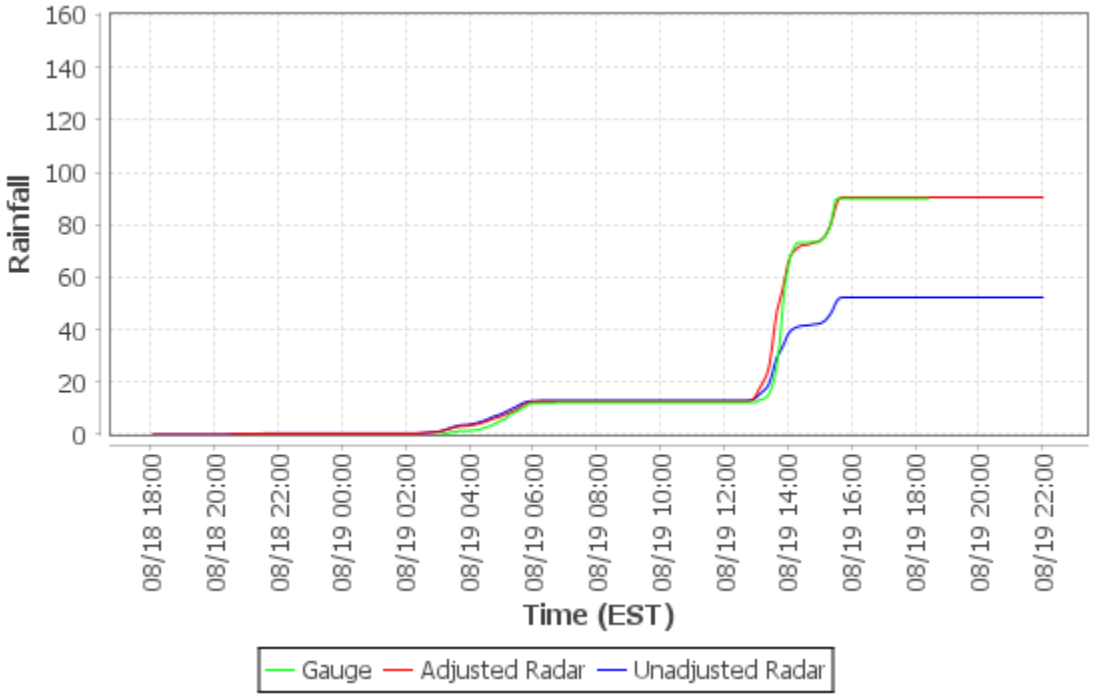
Cumulative Distribution Plot - Petticoat CA (HY051)



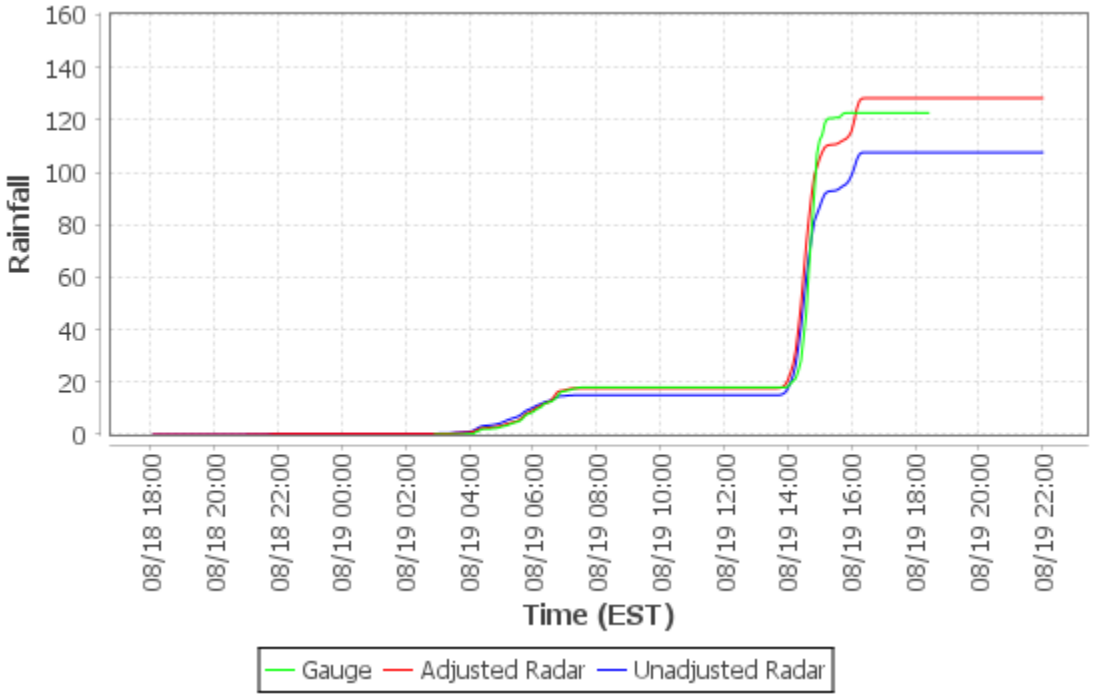
Cumulative Distribution Plot - Stouffville Dam (HY060)



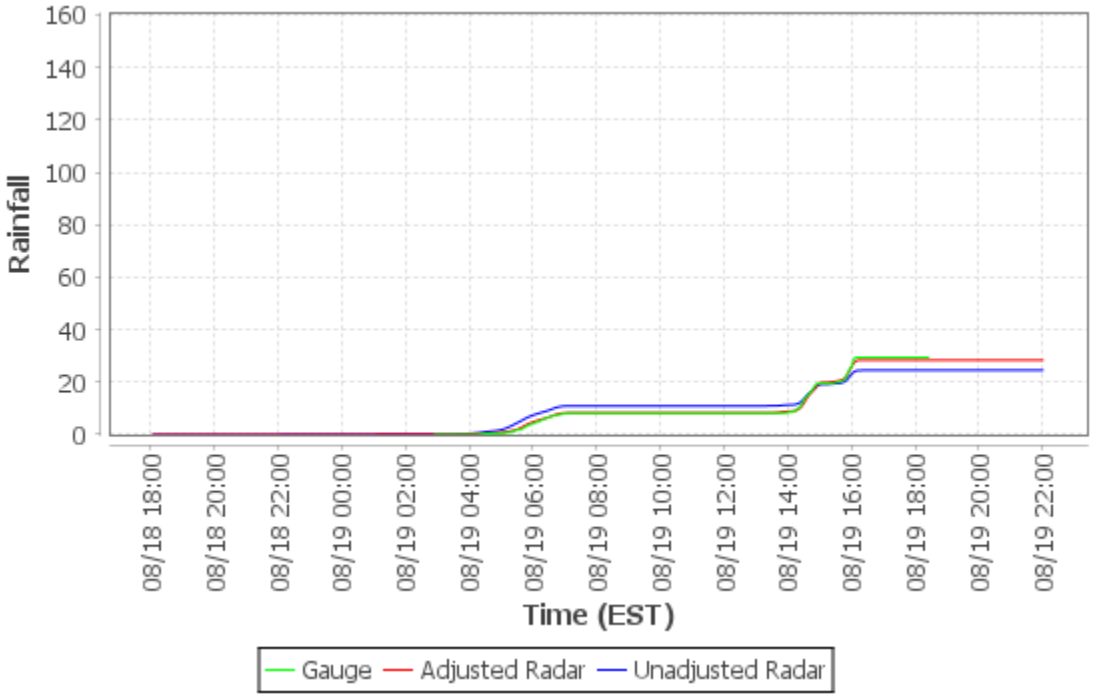
Cumulative Distribution Plot - Sue Grange Farm (HY061)



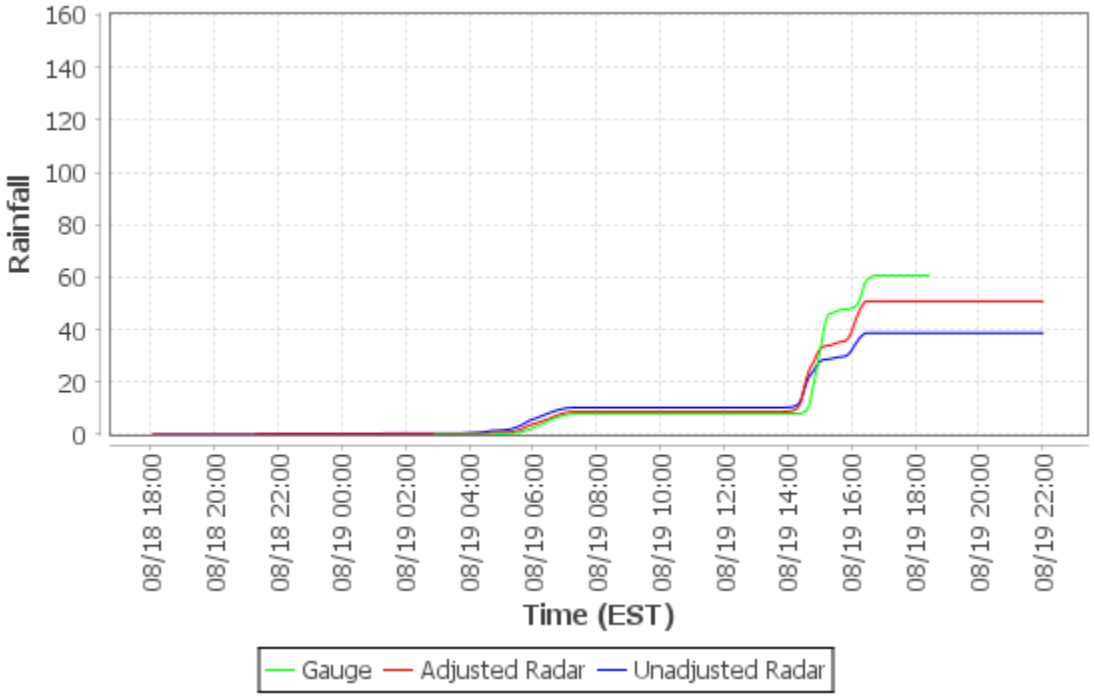
Cumulative Distribution Plot - TRCA Head Office (HY064)



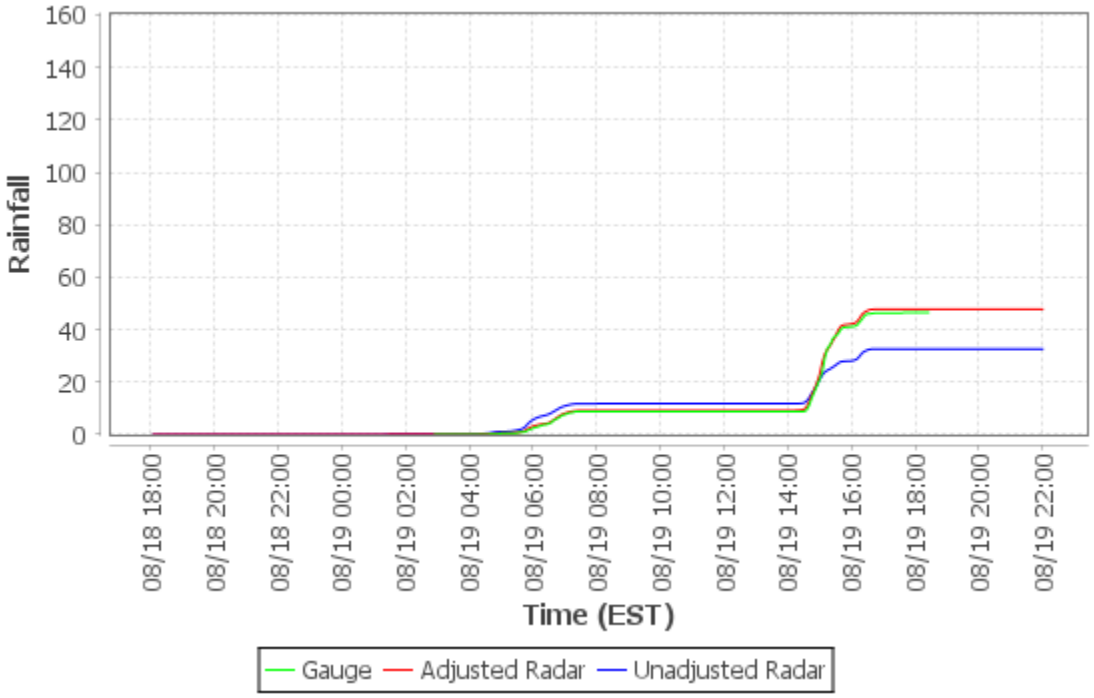
Cumulative Distribution Plot - York Pumping Station (HY069)



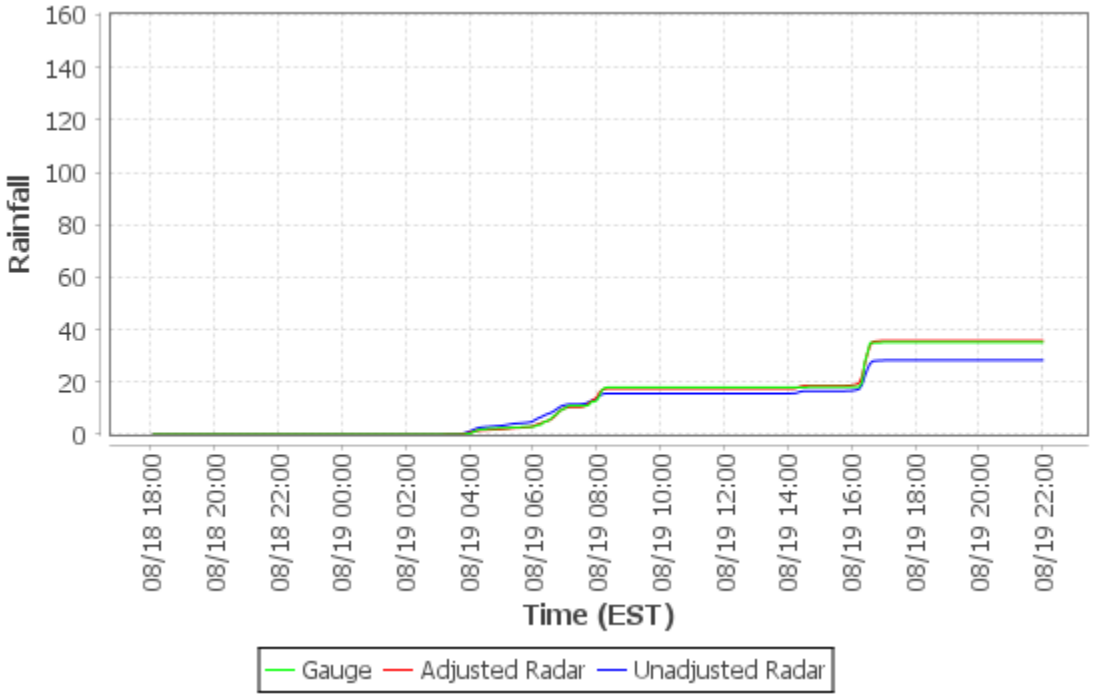
Cumulative Distribution Plot - York Region Works Yard (HY070)



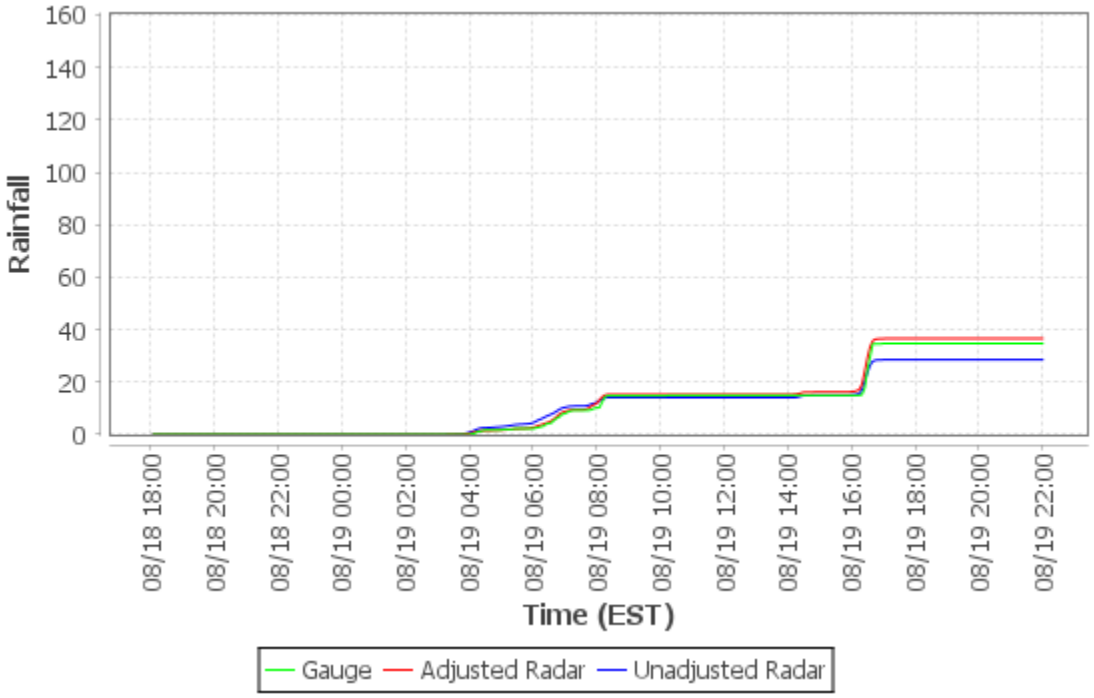
Cumulative Distribution Plot - Lloyd Ham Farm (HY072)



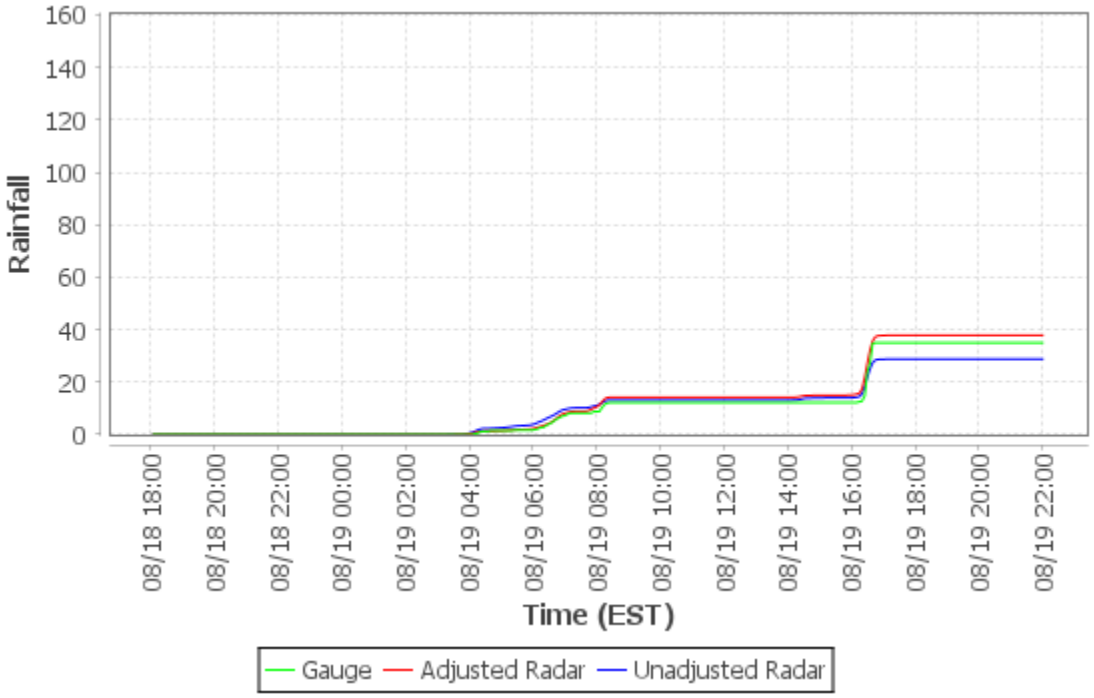
Cumulative Distribution Plot - Swansea (TOR_RG-001)



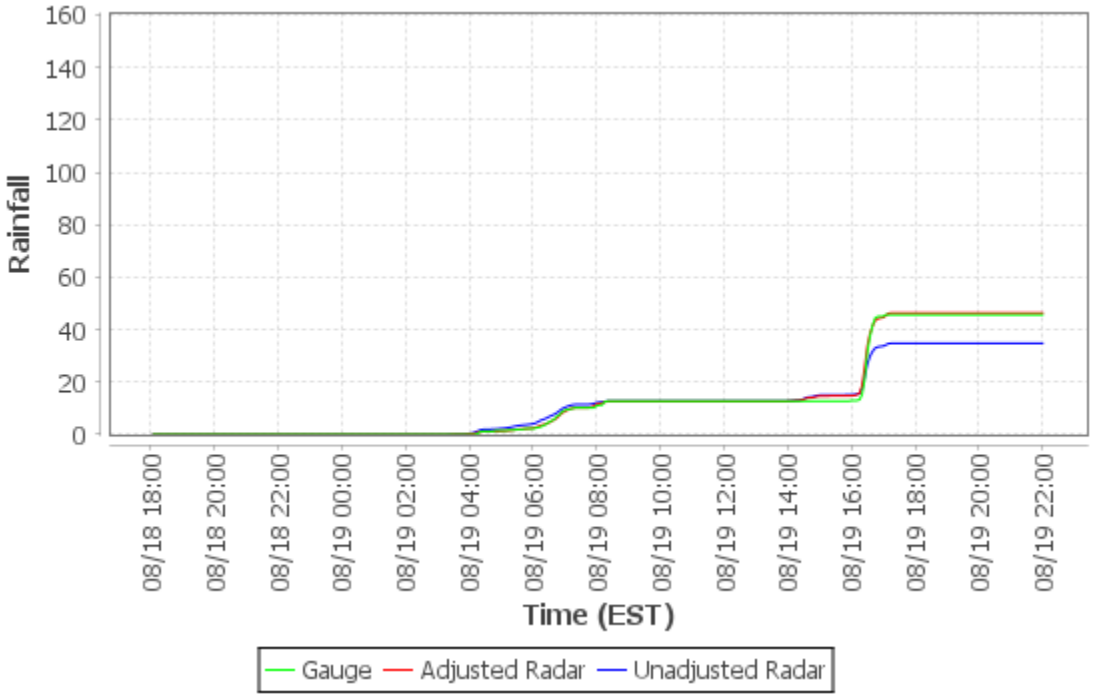
Cumulative Distribution Plot - Howard (TOR_RG-002)



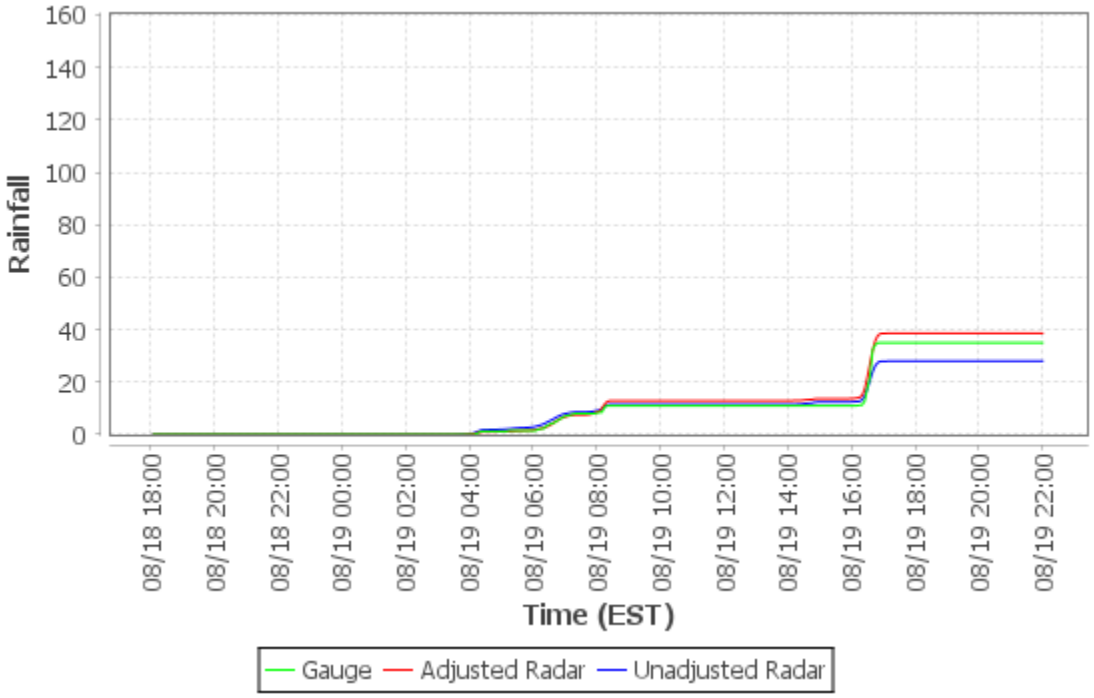
Cumulative Distribution Plot - Central (TOR_RG-003)



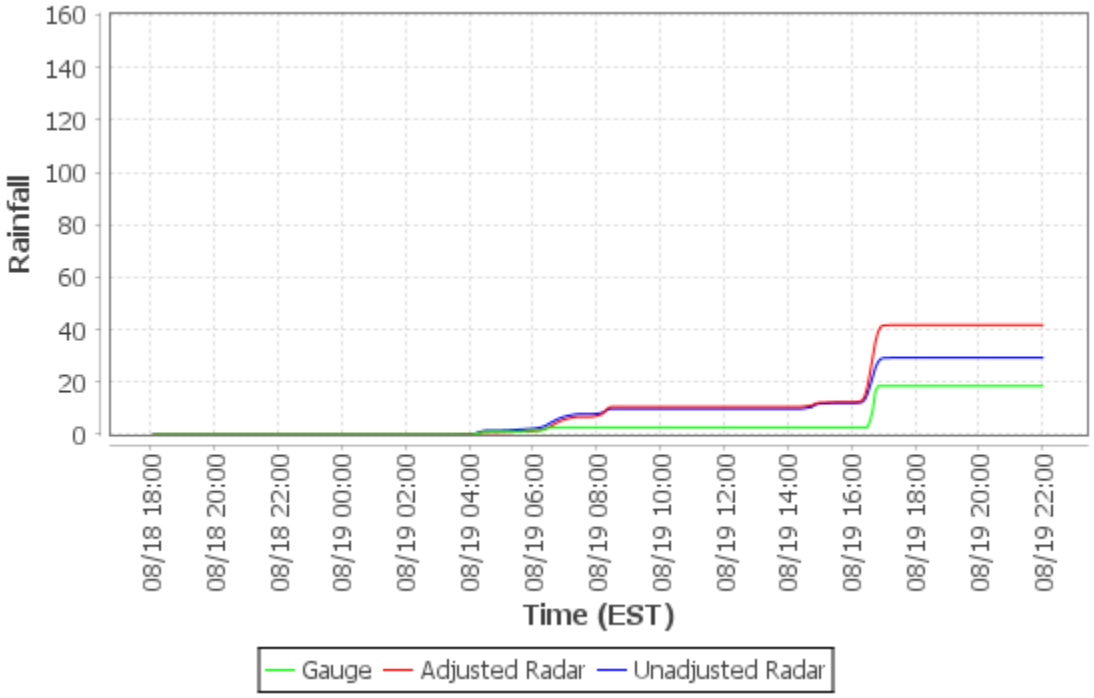
Cumulative Distribution Plot - Brown (TOR_RG-004)



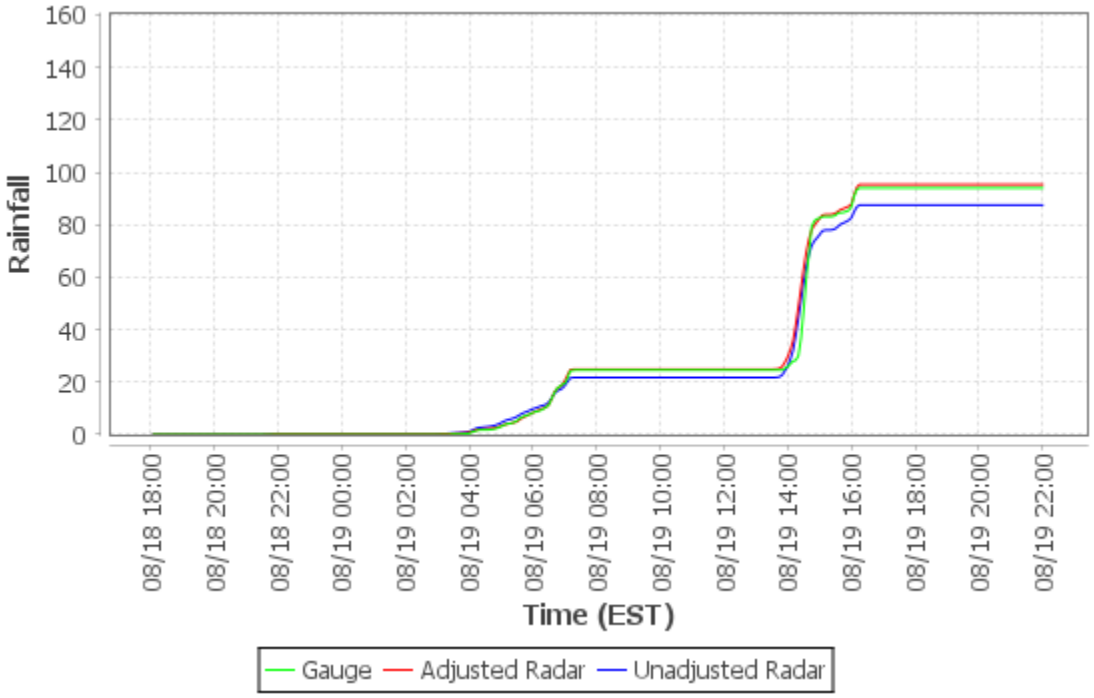
Cumulative Distribution Plot - Church (TOR_RG-006)



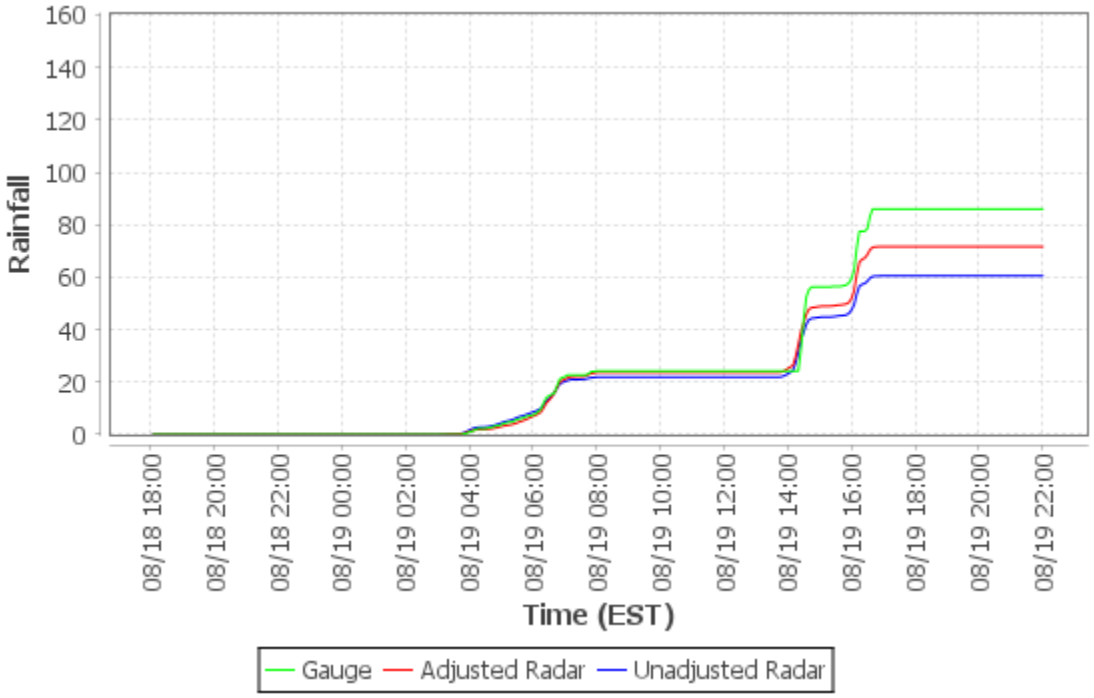
Cumulative Distribution Plot - Greenwood (TOR_RG-007)



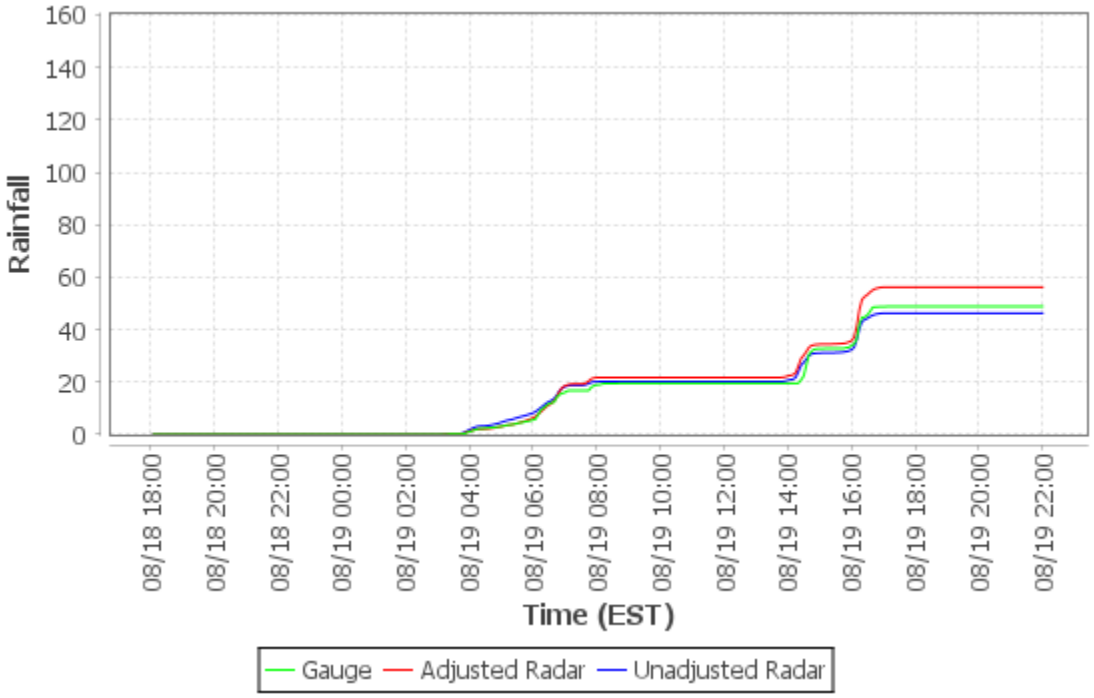
Cumulative Distribution Plot - Albion (TOR_RG-012)



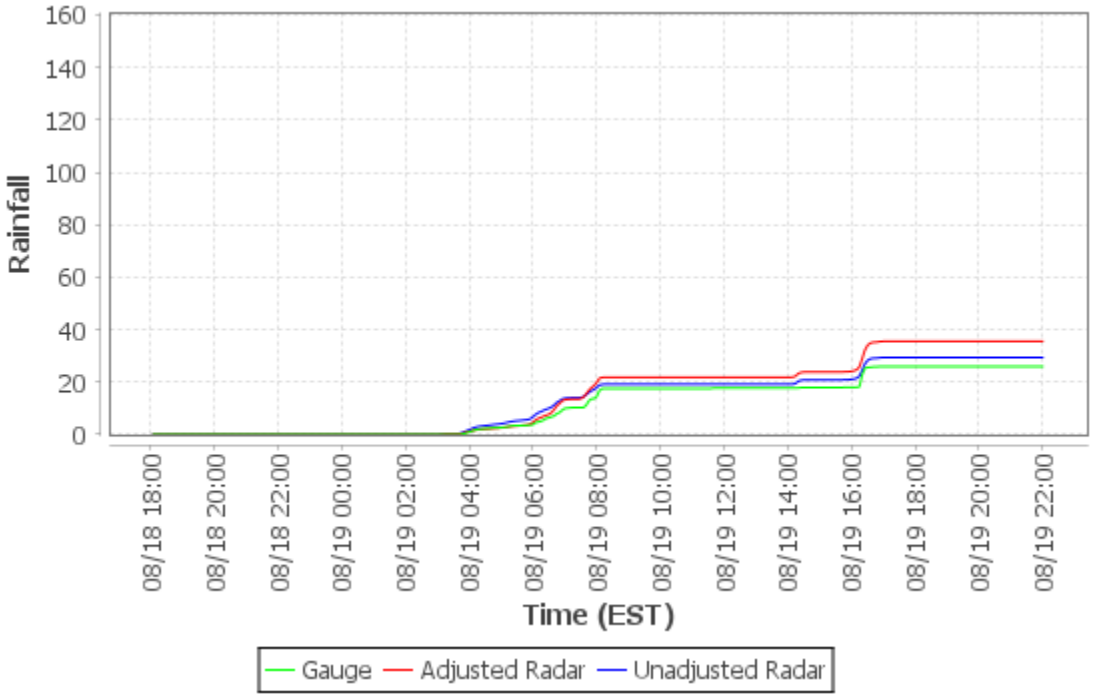
Cumulative Distribution Plot - Martin Grove (TOR_RG-013)



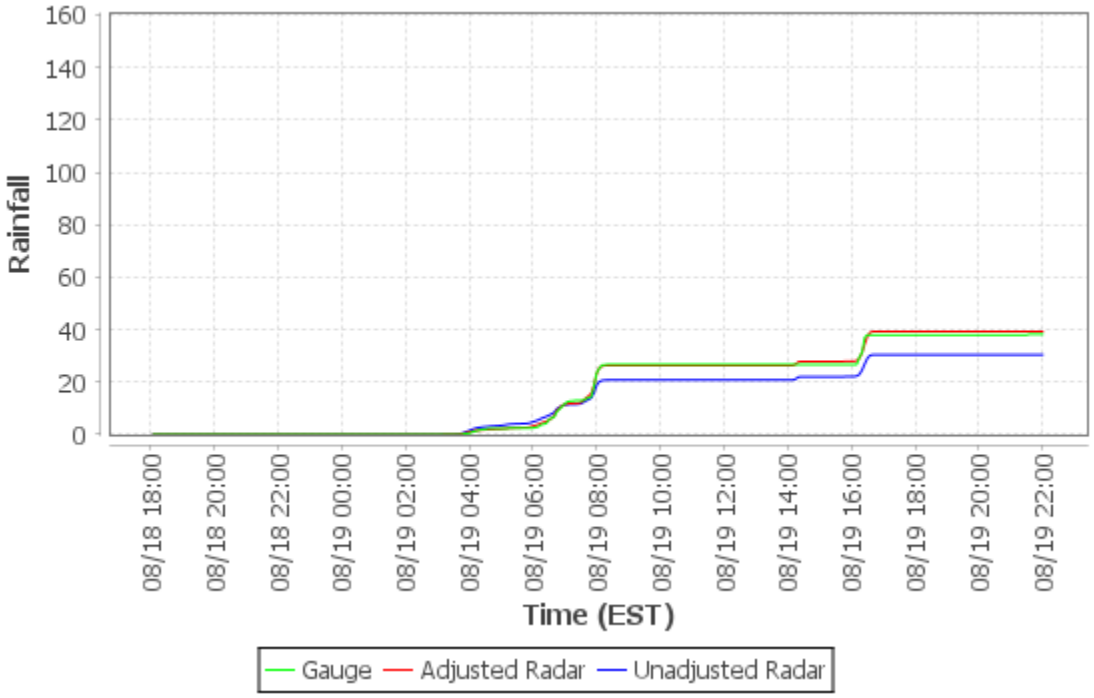
Cumulative Distribution Plot - Richview (TOR_RG-014)



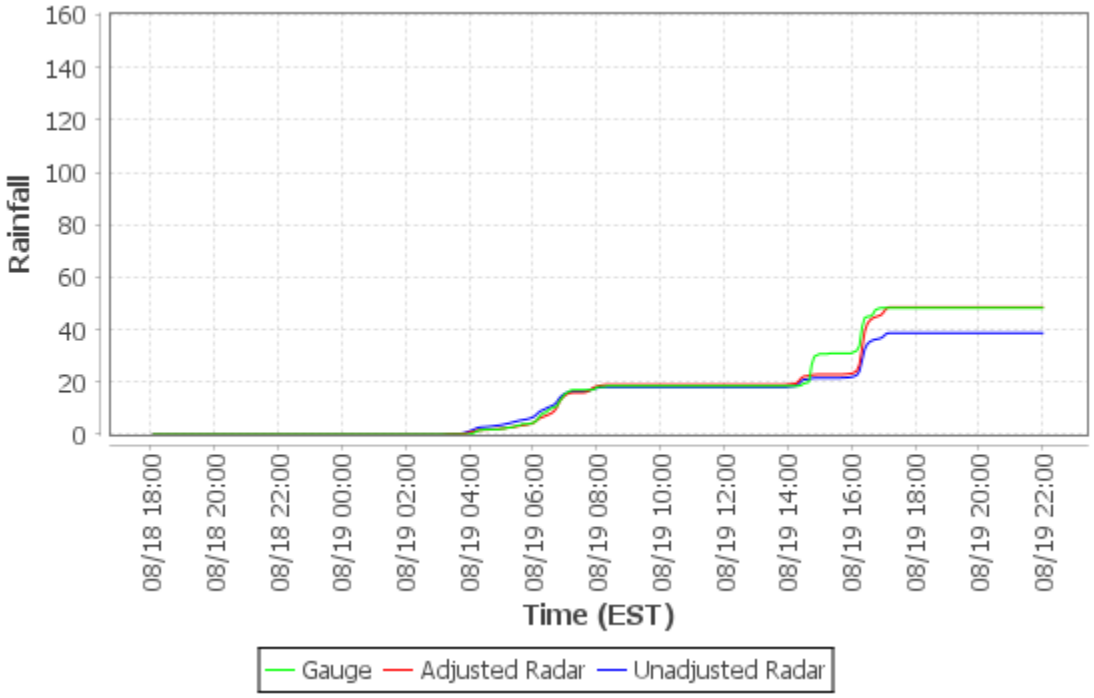
Cumulative Distribution Plot - Bering (TOR_RG-015)



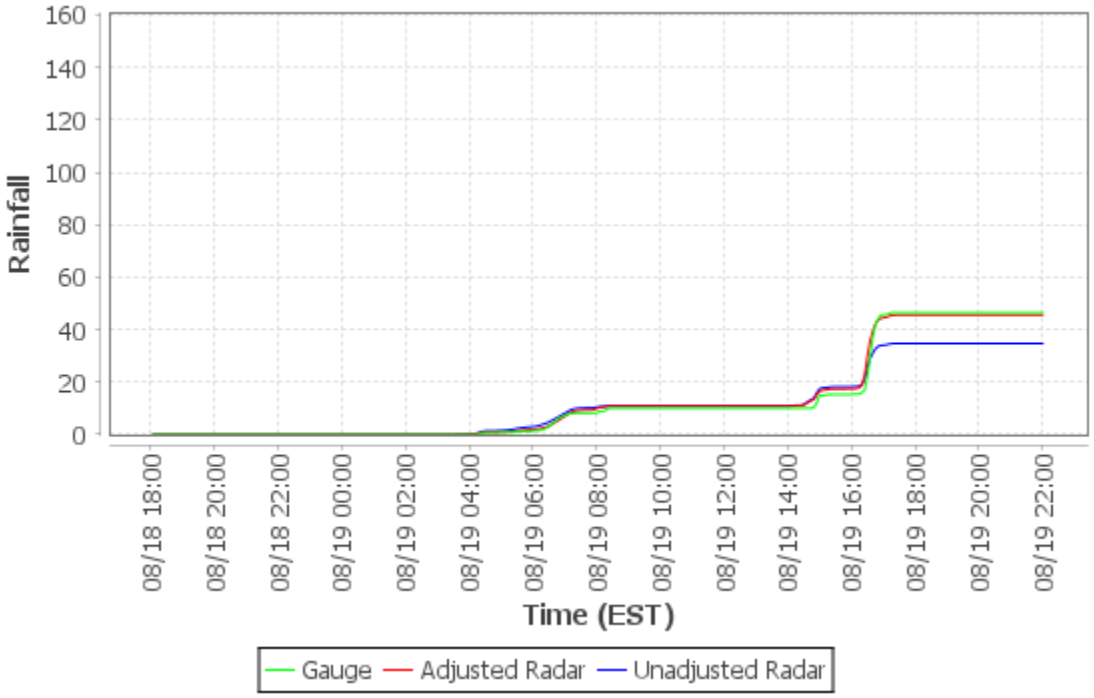
Cumulative Distribution Plot - Kipling (TOR_RG-016)



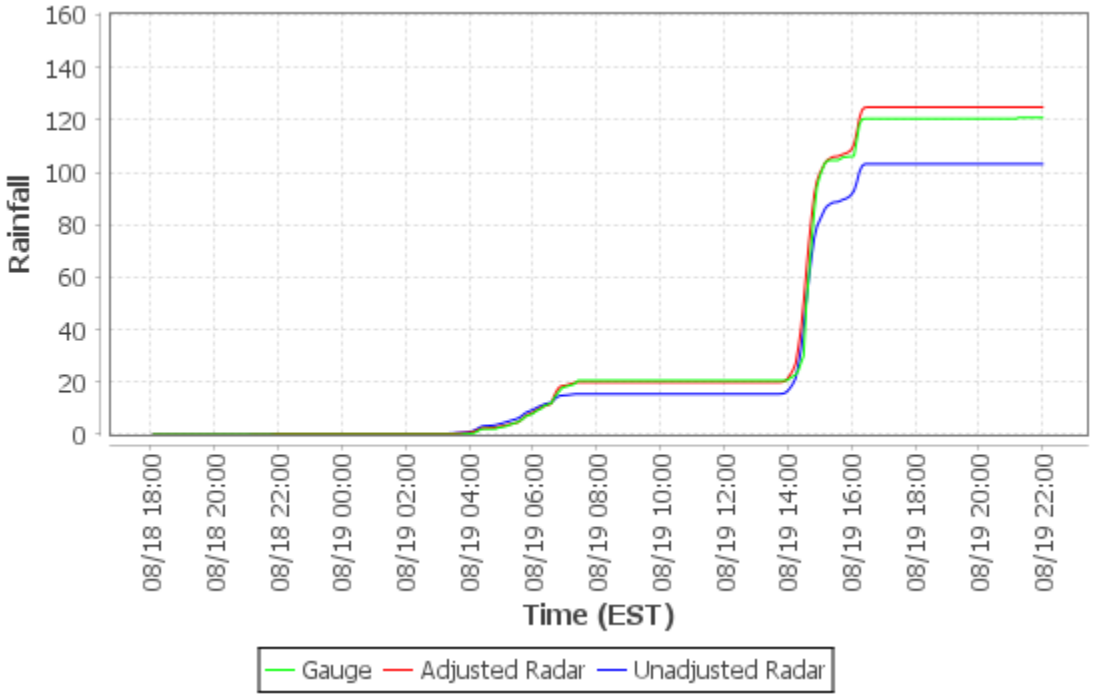
Cumulative Distribution Plot - Castlefield (TOR_RG-017)



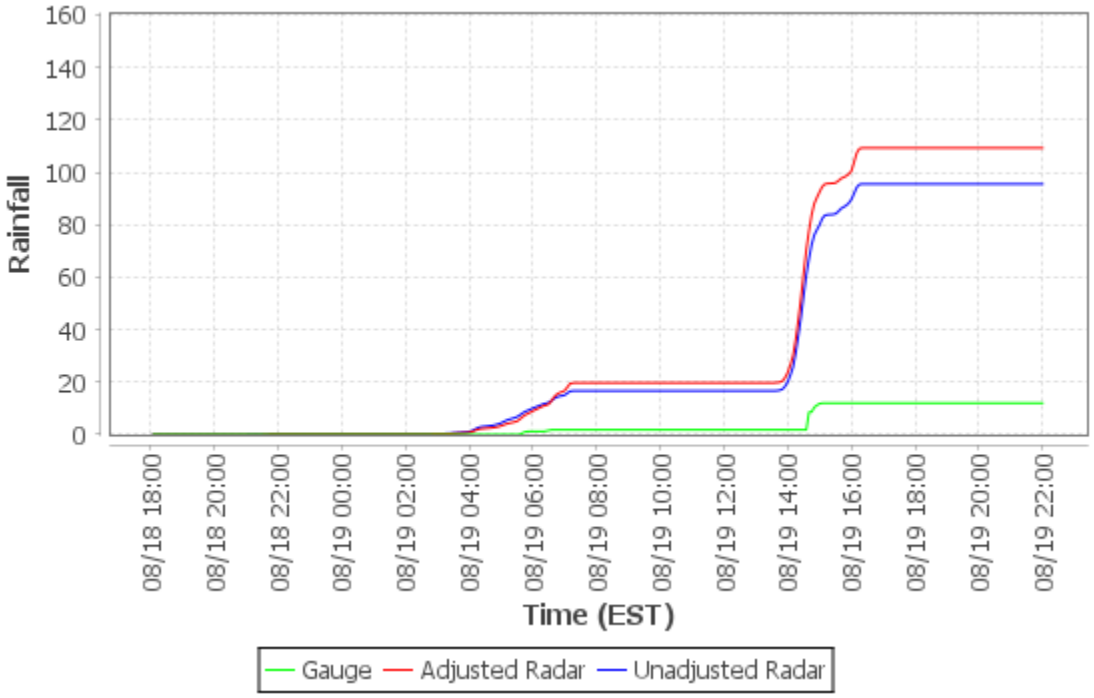
Cumulative Distribution Plot - Thorncliffe (TOR_RG-018)



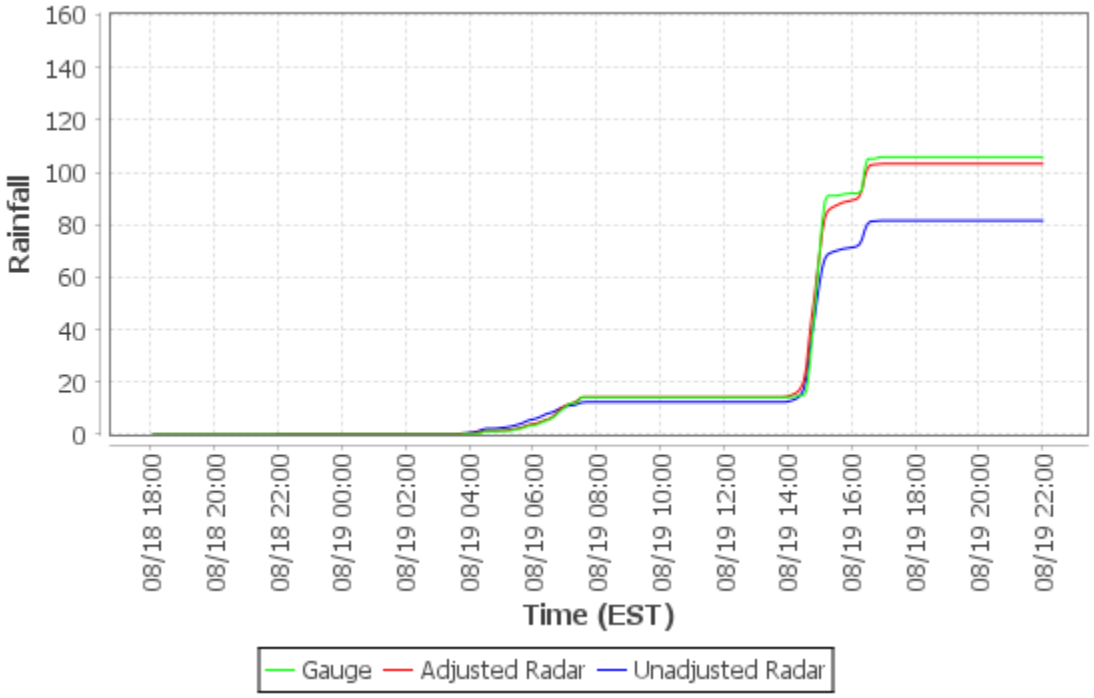
Cumulative Distribution Plot - Finch Yard (TOR_RG-020)



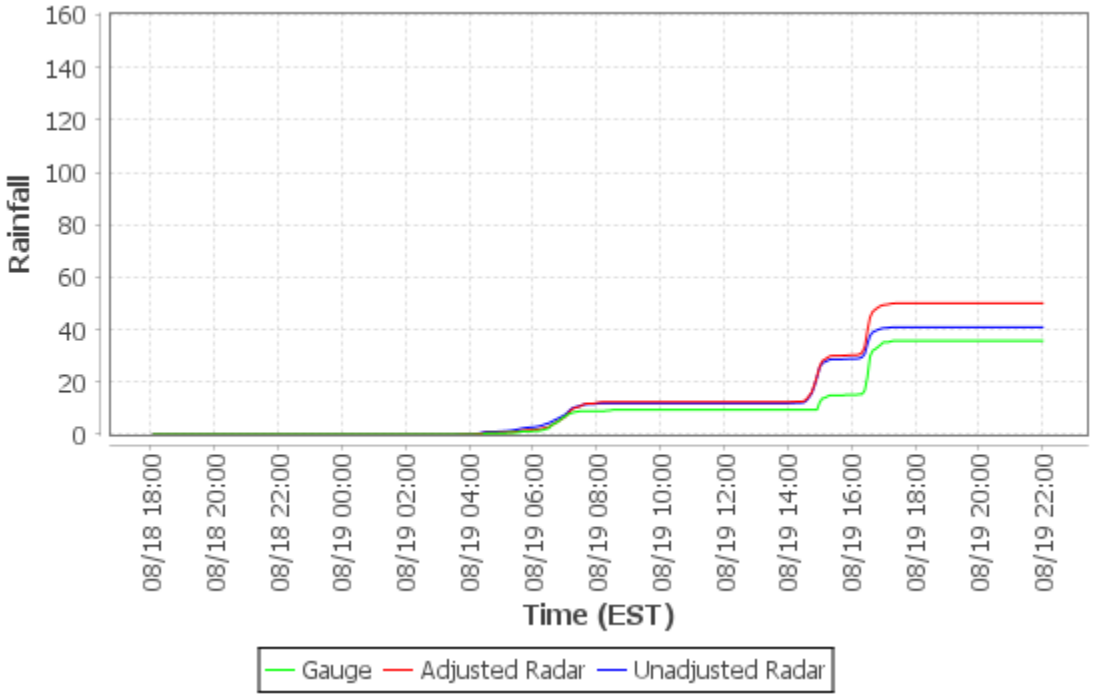
Cumulative Distribution Plot - Emery Yard (TOR_RG-021)



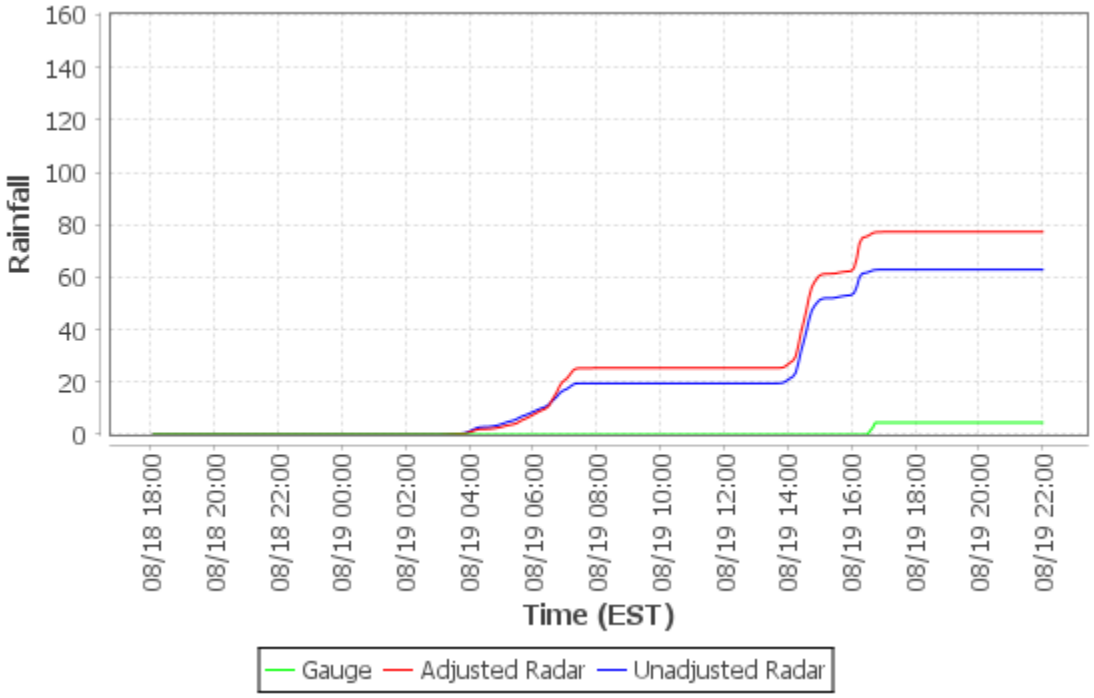
Cumulative Distribution Plot - Fire Station 116 (TOR_RG-022)



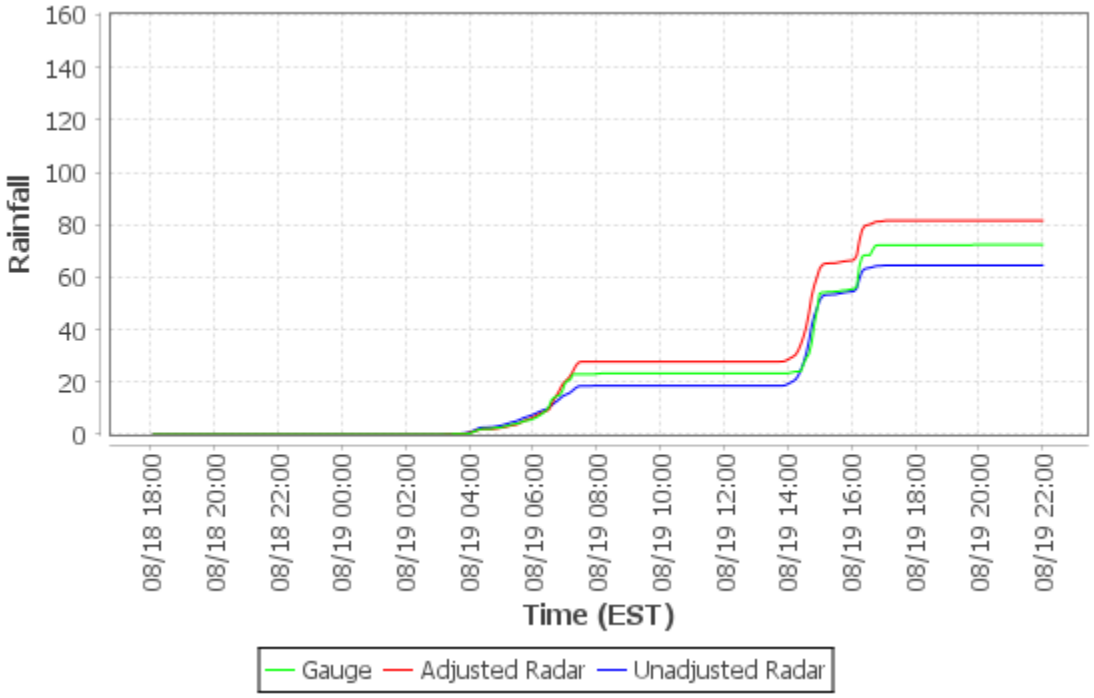
Cumulative Distribution Plot - Bermondsey Yard (TOR_RG-023)



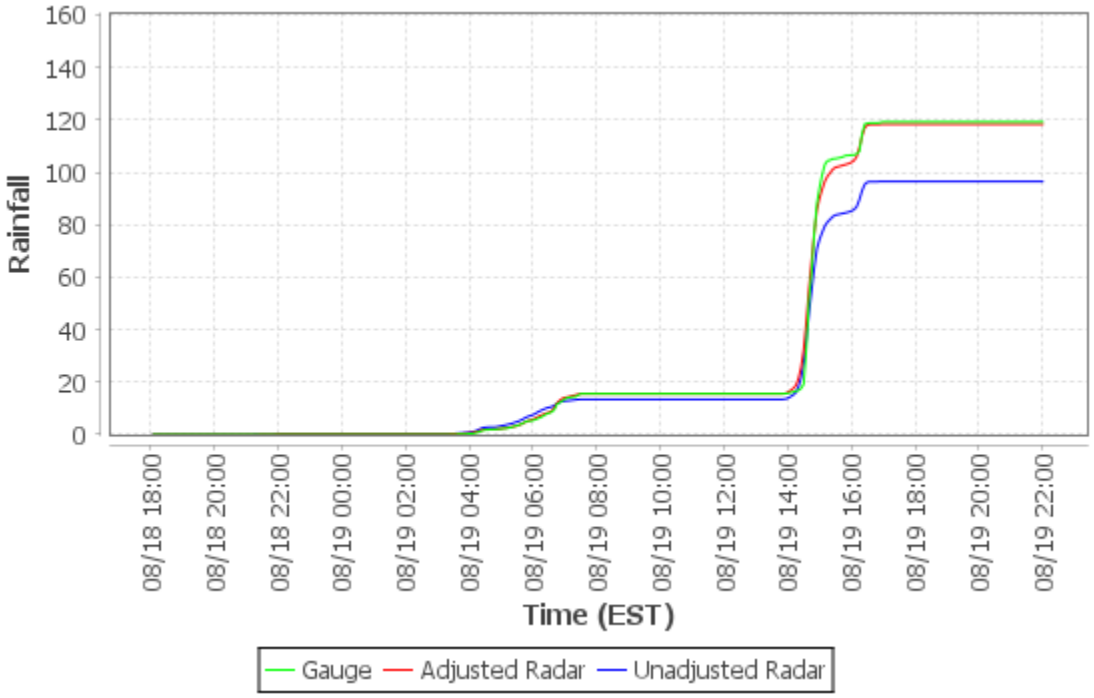
Cumulative Distribution Plot - Wilson (TOR_RG-024)



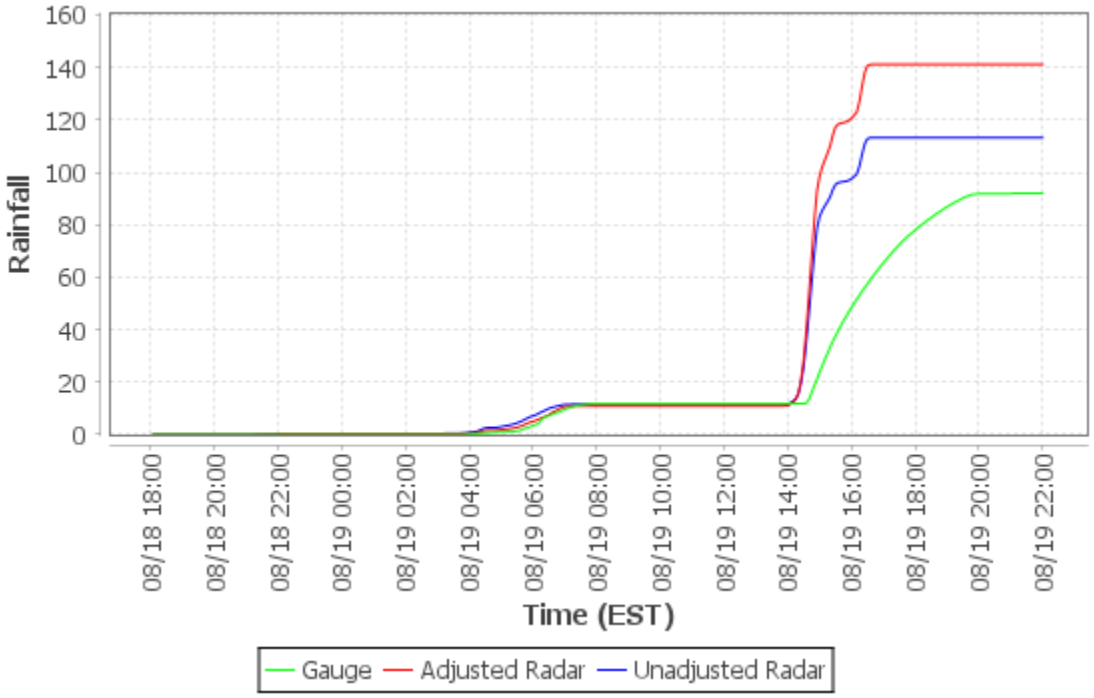
Cumulative Distribution Plot - Ancaster (TOR_RG-025)



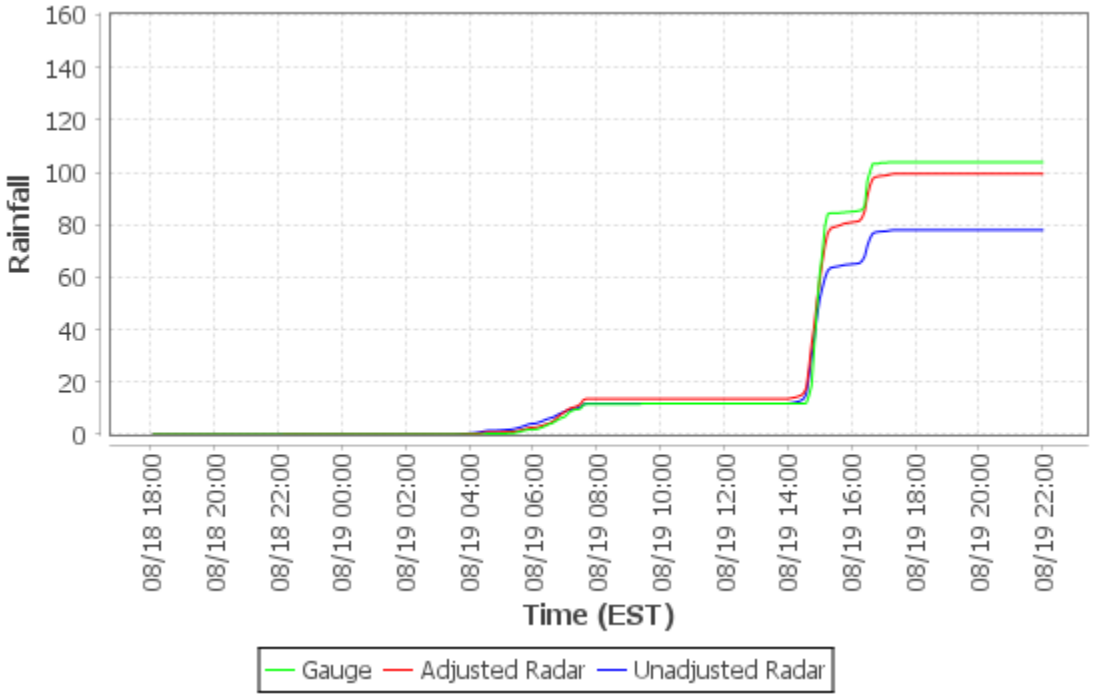
Cumulative Distribution Plot - Mitchell Field (TOR_RG-027)



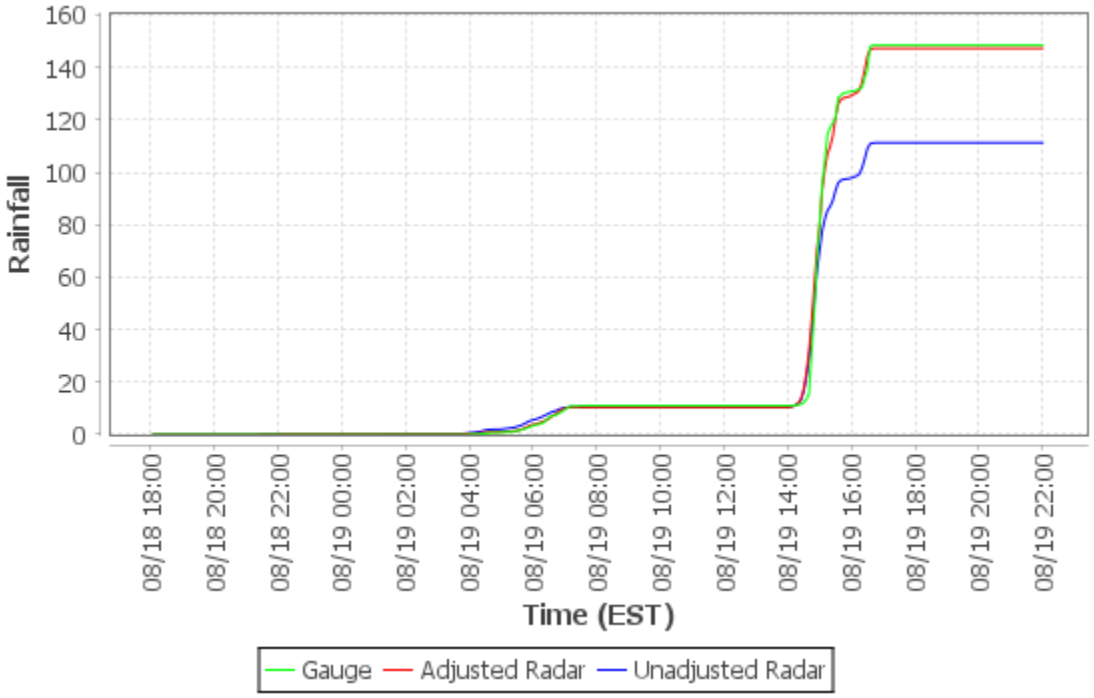
Cumulative Distribution Plot - Cummer (TOR_RG-028)



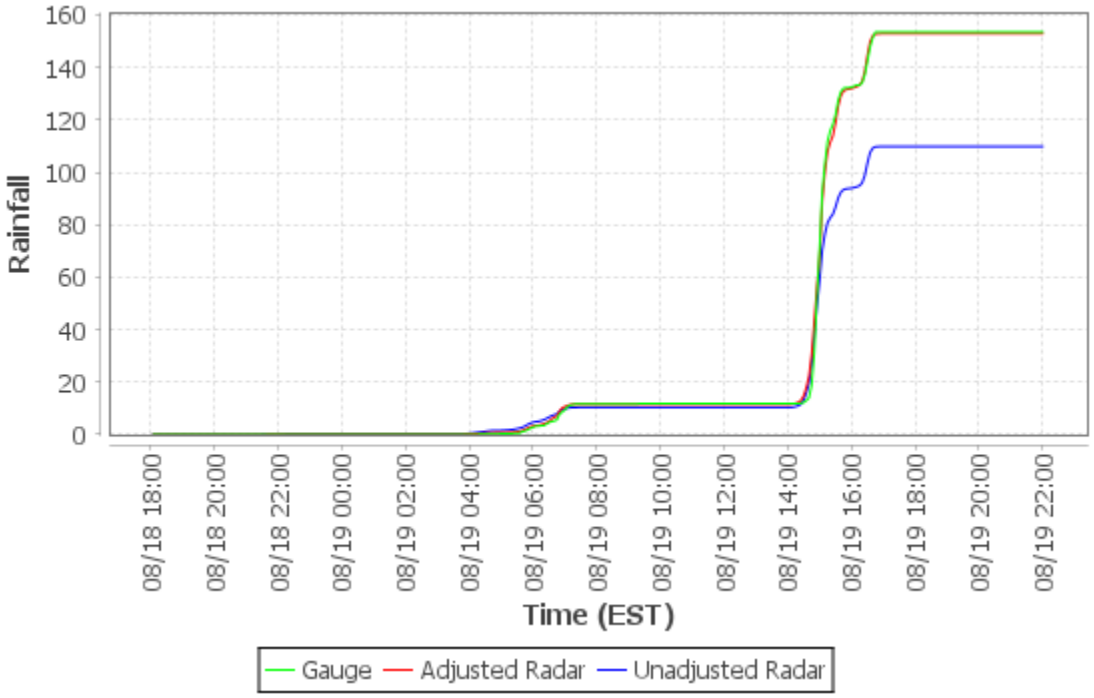
Cumulative Distribution Plot - Pharmacy/401 (TOR_RG-030)



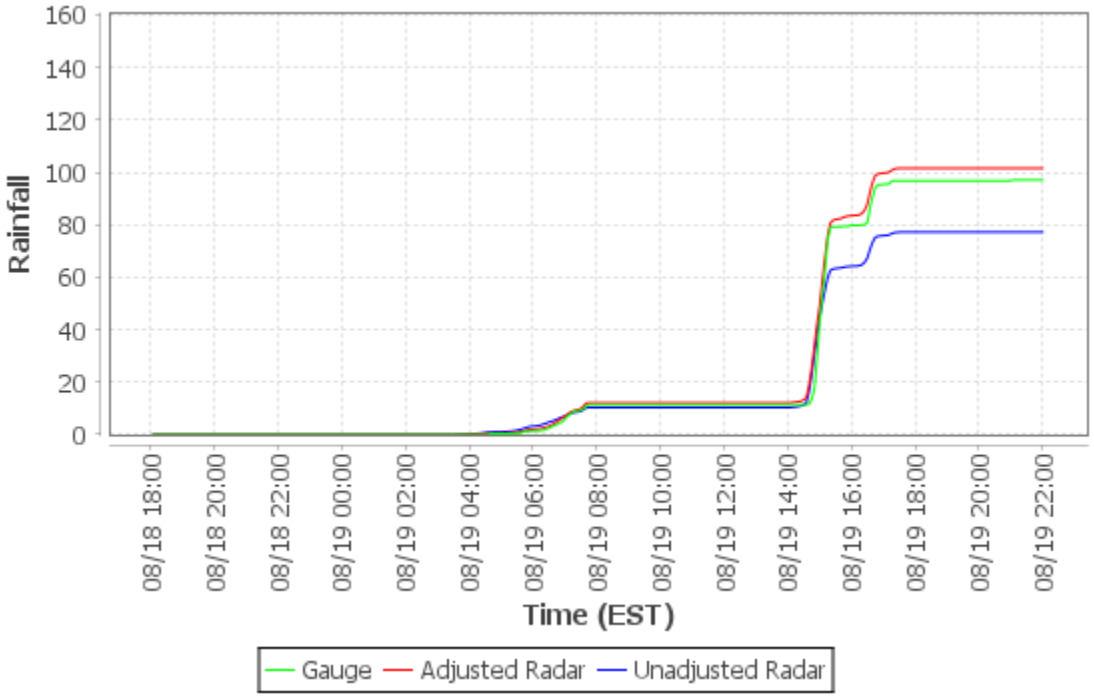
Cumulative Distribution Plot - Liamoreaux (TOR_RG-031)



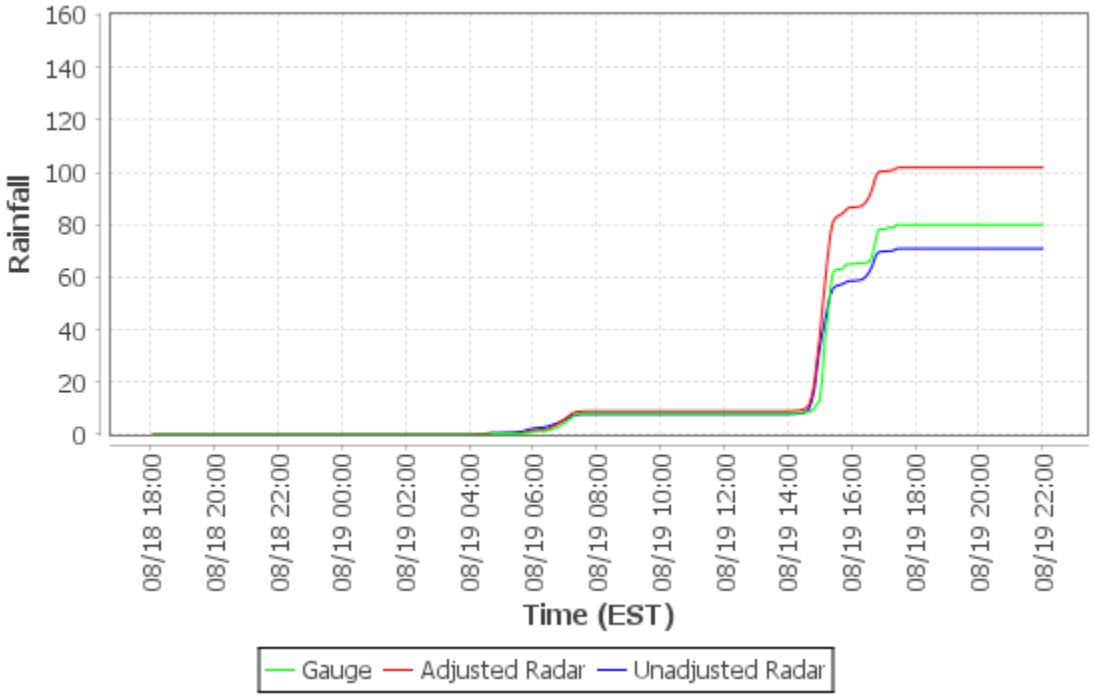
Cumulative Distribution Plot - Nashdene Yard (TOR_RG-033)



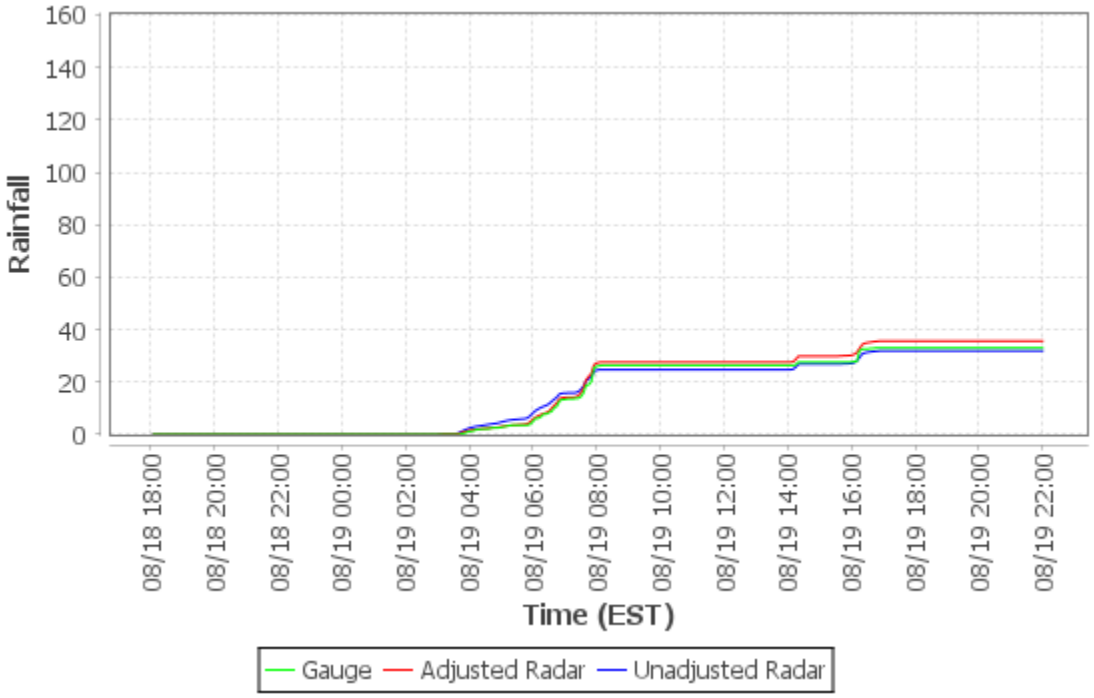
Cumulative Distribution Plot - Ellesmere Yard (TOR_RG-034)



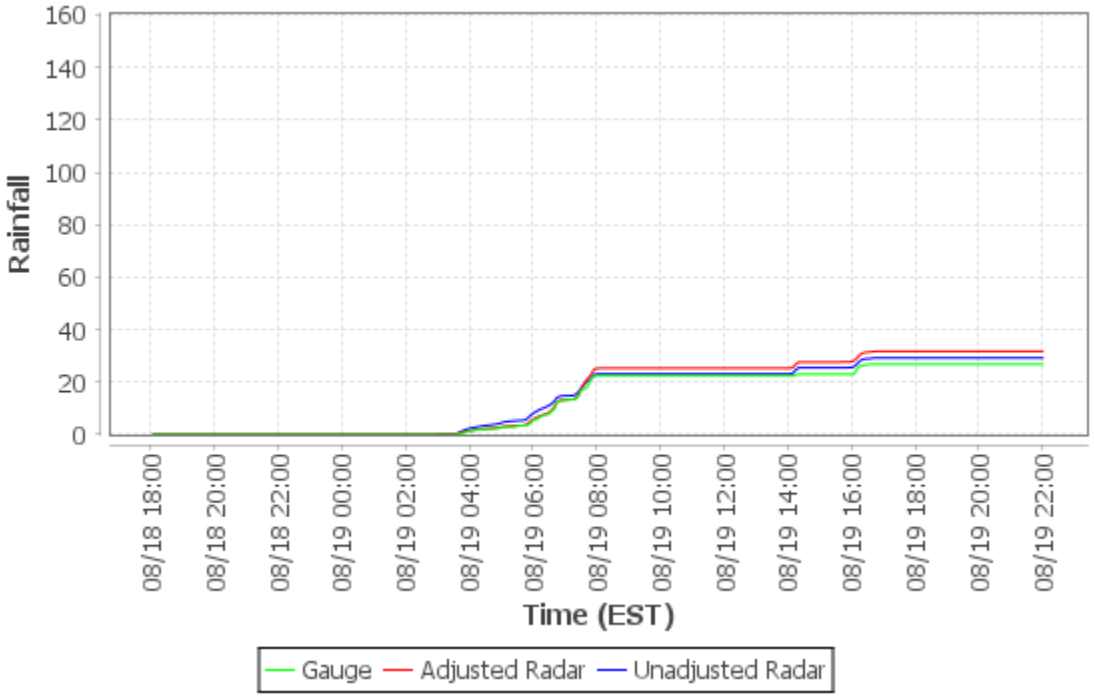
Cumulative Distribution Plot - Morningsidede Yard (TOR_RG-035)



Cumulative Distribution Plot - Winding Trail (STN 05)



Cumulative Distribution Plot - Mississauga Valley Community Centre (STN 06)



Cumulative Distribution Plot - Fire Station #114 (STN 10)

