



**Appendix 2-1: UPDATED: Revised Typical Year for
Development of the Long Term Control Plan**



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Date:
March 27, 2012

ARCADIS Project No.:
01777122.0000

Subject:
UPDATE: Revised Typical Year for Development of the Long Term Control Plan

During the model calibration and system characterization completed in 2001, Malcolm Pirnie/ARCADIS (Pirnie/ARCADIS) developed a typical year precipitation dataset that used Buffalo-Niagara International Airport National Weather Service (NWS) data from May 1948 through December 1999. The typical year selection efforts were summarized in Appendix A of the 2001 BSA Model Calibration Report. Precipitation data for 1986 with some adjustments was selected as the basis for the typical year rainfall hyetograph, and was subsequently applied to characterize the system in the 2001 Model Calibration Report and to support alternatives evaluation as part of the Phase I LTCP in 2004. In recent correspondence, USEPA has requested that BSA reevaluate the originally selected typical year precipitation data by including more recent precipitation data from 2000 to 2010. In response to this request, Pirnie/ARCADIS developed an updated typical year of rainfall data for use with the 2011 LTCP development using an expanded rainfall data set as compared to that used in the original LTCP. This analysis incorporated more recently collected rainfall data from the Buffalo-Niagara International Airport NWS station. This memorandum documents the re-evaluation of the complete rainfall record and presents a revised typical year for use in this LTCP development. Please note that all figures and tables referenced are included in the back of this memo.

The evaluation described below that was used to develop the updated typical year of rainfall occurred over two phases. In the initial phase (as documented in the memo "Revised Typical Year for Development of the Long Term Control Plan" dated September 12, 2011), two candidate years (a modified 2006 hyetograph and a modified 1993 hyetograph) were identified. Following this phase of the analysis, EPA requested that the historical record be re-evaluated using a cumulative frequency analysis approach. Using the cumulative frequency analysis approach that gave equal weighting to peak hourly rainfall and total event rainfall, and then modifying that approach to include monthly rainfall (as was presented to EPA

on December 14, 2011), the modified 1993 hyetograph developed during the initial analysis phase was found to best represent typical year conditions.

1 Evaluation of Historical Rainfall Record

1.1 Defining of Rainfall Events

Pirnie/ARCADIS obtained hourly rainfall data for this station through the National Climate Data Center website for the period May 1948 through September 2010. As a first step in the analysis, rainfall events for the period analyzed were defined assuming a 6-hour inter-event duration. For each defined event, the start time, total rainfall depth, and event duration were summarized. The output file from this analysis is included in **Appendix A**.

1.2 Monthly and Annual Rainfall Depth and Event Calculations

For each month of the analyzed period, the total rainfall depth was calculated. From these values, the average rainfall depth for each month was determined. The average monthly rainfall depths were then summed in order to calculate the average annual rainfall. The monthly rainfall volumes for the analyzed period are shown in **Table 1**. The table also includes average annual and monthly volumes for the period 1948-2010, average annual and monthly volumes for the period 2005-2009 (the last five years for which full records are available), and normal annual and monthly normals for the period 1981-2010 (National Climatic Data Center, July 2011).

Using the defined rainfall events, the number of rainfall events occurring during each month of the analyzed period was calculated. From these values, the average number of events for each month was determined. The average monthly rainfall events were then summed in order to calculate the average annual number of rainfall events. The monthly rainfall events for the analyzed period are shown in **Table 2**. The table also includes average annual and monthly rainfall events for the period 1948-2010, and average annual and monthly rainfall events for the period 2005-2009. **Table 3** is structured the same as **Table 2**, except that it includes only those events with a total rainfall depth of at least 0.05”.

1.3 Calculation of Event Return Periods

For the next portion of the analysis, return periods were calculated for each of the defined rainfall events. For each of the rainfall events, peak rainfall depths were calculated for each of the following partial storm durations: 1 hour, 2 hours, 3 hours, 6 hours, 12 hours, and 24 hours. For each of these partial storm durations, the resulting peak rainfall depths were then ranked, and the return period calculated for each rainfall event using the following equation:

$$RP = (n + 1 - 2*0.4)/(m - 0.4)$$

Where:

- RP = Return Period (yrs)
- n = Length of Period Analyzed (yrs)
- m = Event Ranking

1.4 Comparison of 2011 Analysis Data with 2000 Pirnie/ARCADIS Analysis Data

The rainfall results described previously were compared to the analysis completed by Pirnie/ARCADIS during the 2000 study. The 2000 study analyzed the 1969 to 1999 portion of the Buffalo-Niagara International Airport data obtained from NWS. As noted earlier, Pirnie/ARCADIS performed this analysis using the full May 1948 to September 2010 dataset. Pirnie/ARCADIS compared the 2000 and 2011 data sets to verify the reliability of each analysis. The 2000 and 2011 analyses yielded the following results:

- The number of years analyzed:
 - 2000 Study: 31
 - 2011 Study: 62
- The number of rainfall events analyzed:
 - 2000 Study: 4,857
 - 2011 Study: 9,556
- The average yearly rainfall:
 - 2000 Study: 38.9 inches
 - 2011 Study: 37.6 inches
- The month with the highest average rainfall:
 - 2000 Study: August and September with an average of 3.78 inches each year
 - 2011 Study: November with an average of 3.77 inches each year
- The month with the lowest average rainfall:
 - 2000 Study: February with an average of 2.26 inches each year
 - 2011 Study: February with an average of 2.33 inches each year

Table 4 compares the monthly average rainfall, events per month, rainfall per event, average event duration, and average event intensity for the two studies. **Table 5** provides a summary of key monthly metrics for the full 1948-2010 dataset. **Table 6** summarizes key annual metrics for each year contained in the full 1948-2010 dataset.

2 Selection of Typical Year (Initial Analysis Phase)

The selection of the typical year occurred over a series of steps:

- The initial focus was to try to find a year to use within the last 40 years (i.e., 1971-2010). If no good candidates were identified during this period, then earlier years would be considered.
- As a first screening, years were identified for further consideration if they met the two following conditions:
 - The annual rainfall volume for the year was within 10% of the annual normal rainfall (1981-2010) of 40.48".
 - The number of rainfall events of at least 0.05" during the year was within 10 of the average annual number of rainfall events of at least 0.05" for the 1948-2010 period of analysis (100).
 - Based on these criteria, the following years were kept for further consideration as the typical year: 1973, 1975, 1979, 1980, 1982, 1983, 1984, 1986, 1987, 1988, 1989, 1991, 1993, 1994, 2004, 2006, and 2009
- For the next screening step, the following comparisons were done for each remaining candidate years. These comparisons were done with the goal of identifying those years which would require the least amount of modifications to get close to typical year conditions with respect to monthly rainfall volumes and monthly rainfall events:
 - The number of months was determined where the rainfall volume for the month was within 30% of the normal (1981-2010) rainfall volume for that month.
 - The number of months was determined where the number of rainfall events of at least 0.05" was within two of the average (1948-2010) number of rainfall events of at least 0.05" for that month.
 - The two numbers were then summed, and the remaining years ranked based upon this sum. The top ten years were kept for further consideration: 1973, 1982, 1983, 1984, 1986, 1987, 1991, 1993, 1994, and 2006. **Figure 1** compares the monthly rainfall volumes for each of these years to the normal (1981-2010) rainfall volume for that month. **Figure 2** compares the monthly rainfall events of at least 0.05" for each of these years to the average (1948-2010) number of rainfall events of at least 0.05" for that month.
- For the final screening step, the return period distributions for each of the partial storm durations previously analyzed were summarized for the following return period break points: ≥ 2 years, ≥ 1 year, ≥ 9 months, ≥ 6 months, ≥ 4 months, ≥ 3 months, ≥ 2 months, and ≥ 1 month. This was done in order to try to identify the candidate years that would require the fewest number of modifications in order to meet as many of the following return period criteria as possible:
 - Contain no "extreme" events (i.e., events with a return period of greater than 2 years).
 - For each partial storm duration considered, have one event in the 0.75-1.5 year return period range.
 - Come reasonably close to matching the "ideal" distribution of number of storm events for each of the return period break points listed above for each partial storm duration.

Based on this review, 2006 is recommended for use as the updated typical year. The return period distribution for the unmodified 2006 rainfall hyetograph is shown in **Table 7**. 1993 is recommended as a second choice for the typical year. The return period distribution for the unmodified 1993 rainfall hyetograph is shown in **Table 8**.

2.1 Modifications to Typical Year Hyetographs

2.1.1 Modifications to 2006 Hyetograph

In order to get the 2006 hyetograph closer to “typical year” conditions with respect to annual statistics, monthly statistics, and event return period distributions, the following modifications were made to the hyetograph:

- Removed the 7/29/06 event (0.83”).
- Removed the 9/13/06 event (1.67”).
- Removed the 10/11/06 event (2.58”).
- Added a 1.14” event on 5/4/06 that corresponds to a historical event that occurred on 5/4/90.
- Added a 0.89” event on 11/26/06 that corresponds to a historical event that occurred on 11/26/99.

The impacts of these modifications on the 2006 hyetograph are shown in the following:

- **Table 9** shows a comparison of the unmodified and modified 2006 monthly and annual rainfall volumes as compared to normal volumes (1981-2010).
- **Figure 3** shows the comparison of monthly volumes in graphical form.
- **Table 10** shows a comparison of the unmodified and modified 2006 monthly and annual rainfall events of at least 0.05” as compared to average values (1948-2010).
- **Figure 4** shows the comparison of monthly events in graphical form.
- **Table 11** shows the updated return period distribution for the modified 2006 rainfall hyetograph.

2.1.2 Modifications to 1993 Hyetograph

In order to get the 1993 hyetograph closer to “typical year” conditions with respect to annual statistics, monthly statistics, and event return period distributions, the following modifications were made to the hyetograph:

- Removed the 1/3/93 event (1.6”).
- Added a 1.24” event on 5/6/93 that corresponds to a historical event that occurred on 5/6/85.
- Removed the 6/9/93 event (0.8”).
- Added a 0.52” event on 7/7/93 that corresponds to a historical event that occurred on 7/7/61.
- Added a 0.77” event on 7/28/93 that corresponds to a historical event that occurred on 7/28/73.

- Added a 0.60" event on 8/19/93 that corresponds to a historical event that occurred on 8/19/73.
- Removed the 8/20/93 event (1.46").
- Removed the 9/25/93 event (1.26").

The impacts of these modifications on the 1993 hyetograph are shown in the following:

- **Table 12** shows a comparison of the unmodified and modified 1993 monthly and annual rainfall volumes as compared to normal volumes (1981-2010).
- **Figure 5** shows the comparison of monthly volumes in graphical form.
- **Table 13** shows a comparison of the unmodified and modified 1993 monthly and annual rainfall events of at least 0.05" as compared to average values (1948-2010).
- **Figure 6** shows the comparison of monthly events in graphical form.
- **Table 14** shows the updated return period distribution for the modified 1993 rainfall hyetograph.

2.2 Comparison of Modified 2006 and 1993 Typical Year Hyetographs to 1986 Typical Year Hyetograph

The following tables and figures compare the modified 2006 and modified 1993 typical year hyetographs with the 1986 typical year hyetograph (the hyetograph used during the 2004 LTCP development):

- **Table 15** shows a comparison of the modified 2006, modified 1993, and 1986 typical year hyetograph monthly and annual rainfall volumes as compared to normal volumes (1981-2010).
- **Figure 7** shows the comparison of monthly volumes in graphical form.
- **Table 16** shows a comparison of the modified 2006, modified 1993, and 1986 typical year hyetograph monthly and annual rainfall events of at least 0.05" as compared to average values (1948-2010).
- **Figure 8** shows the comparison of monthly events in graphical form.
- **Table 17** shows the return period distribution for the 1986 typical year hyetograph.

As shown, the modified 2006 typical year compares more favorably to long term average volumes and event return periods as well as to the most current monthly normals (1981 – 2010, as presented in NOAA's recently published update of Climatology No. 81). One of the primary reasons for recommending a different typical year is that the modified 1986 typical year used in the 2004 LTCP development has a significant number of extreme events compared to the long term average rainfall: three events with greater than 1 year RP and one event that is nearly a 10y RP (in May of 1986). Inclusion of events of this magnitude in evaluating CSO control could lead to overly conservative control sizes and costs. The recommended typical year, a modified 2006, provides a more reasonable representation of typical year rainfall conditions for CSO planning.

3 Updated Analysis Using Cumulative Frequency Approach

3.1 EPA Proposed Approach

In late November 2011, EPA proposed the following cumulative frequency analysis approach for selecting the typical year hyetograph:

- Do an initial screening of the 1981-2010 rainfall years to identify those years where the rainfall meets the following criteria:
 - Annual volume within -5% to +10% of annual normal rainfall for 1981-2010
 - Annual number of rainfall events of at least 0.05" within -10% to +10% of average number of events of 1981-2010
- For the years that make it through the initial screening, sum up the absolute deviations between calculated cumulative frequency distributions for the 1981-2010 period and each candidate year for the following parameters:
 - Event Peak Hourly Rainfall
 - Total Event Rainfall
- Rank the candidate years based on the peak hourly rainfall absolute deviations
- Rank the candidate years based on the total event rainfall absolute deviations
- Identify the year with the highest peak hourly rainfall deviation ranking that is also within the Top 6 for total event rainfall deviation ranking

3.2 Proposed Modifications to Approach

Based on a review of the approach proposed by EPA, Pirnie/ARCADIS proposed the following modified version of the approach:

- Use the initial screening criteria proposed by EPA.
- For the years that make it through the initial screening, sum up the absolute deviations between calculated cumulative frequency distributions for the 1981-2010 period and each candidate year for the following parameters:
 - Event Peak Hourly Rainfall
 - Total Event Rainfall
- For the years that make it through the initial screening, sum up the absolute deviations between the monthly rainfall and the normal monthly rainfall for the 1981-2010 period
- Rank the candidate years based on the peak hourly rainfall absolute deviations
- Rank the candidate years based on the total event rainfall absolute deviations
- Rank the candidate years based on the monthly rainfall absolute deviations
- Aggregate the rankings for the three categories
- The highest ranked year would be the lowest sum of the rankings

The modifications to EPA's original approach were proposed for the following reasons:

- The modified approach accounts for seasonal/monthly distributions, which are critical for assessing a demonstration approach (water quality based approach). EPA's originally proposed approach did not take this into consideration.
- The modified approach gives equal weighting to peak hourly and total event rainfalls, while EPA's original approach gives a considerably higher weighting to peak hourly rainfall. Pirnie\ARCADIS believes that the equal weighting approach is justified since many of the technologies being considered in BSA's CSO mitigation alternatives are storage-based technologies. The sizing of these facilities is more dependent on total event rainfall than on peak hourly rainfall.

3.3 Results of Analysis Using Modified Cumulative Frequency Approach

- The initial screening looked at the period 1981-2010 and included the modified 1993 and modified 2006 hyetographs developed during the initial typical year analysis.
- The following candidate years were identified from the initial screening: 1982, 1983, 1986, 1987, 1988, 1989, 1991, 1993 (Unmodified), 1993 (Modified), 2006 (Unmodified), 2006 (Modified), and 2009
- **Table 18** shows the results of the absolute deviation analysis for the peak hourly rainfall, total event rainfall, and monthly rainfall for each of the candidate years.
- Based on the results presented in Table 18, the modified 1993 hyetograph is the highest ranked year.

Table 1. Monthly rainfall volumes (inches) for the Buffalo International Airport, 1948-2010.

Year	January	February	March	April	May	June	July	August	September	October	November	December	Total
1948	N/A	N/A	N/A	N/A	3.12	3.07	2.58	1.10	5.74	4.74	4.01	2.03	N/A
1949	2.73	2.70	2.56	2.42	2.09	1.17	3.15	5.27	3.09	1.67	6.35	3.67	36.87
1950	5.02	4.25	3.23	2.00	2.13	2.08	0.01	4.11	1.96	2.36	4.83	1.84	33.82
1951	2.63	2.96	4.57	4.03	2.01	4.48	3.50	1.36	2.52	1.87	4.47	3.35	37.75
1952	3.75	2.02	2.51	2.56	3.91	1.13	1.28	3.12	2.72	0.68	2.89	2.57	29.14
1953	2.79	1.44	3.80	2.23	6.40	0.98	3.60	3.21	3.09	0.32	4.94	3.08	35.88
1954	2.94	3.72	5.24	3.95	1.35	2.57	2.06	2.47	2.20	9.13	3.32	5.83	44.78
1955	2.58	2.44	4.61	3.35	1.65	0.11	2.13	4.81	2.97	8.12	4.20	2.82	39.79
1956	2.12	3.33	5.25	3.69	4.61	0.99	3.54	5.89	3.95	0.86	2.88	4.82	41.93
1957	4.92	1.65	2.23	4.86	4.03	2.92	2.97	1.11	3.84	1.12	5.30	3.74	38.69
1958	3.81	4.75	1.39	3.95	1.79	2.91	1.49	3.16	4.58	1.41	3.47	1.68	34.39
1959	6.47	3.43	3.89	3.21	2.10	1.94	1.98	4.78	2.51	4.94	3.58	3.98	42.81
1960	3.90	5.80	2.35	2.33	4.06	2.48	1.89	3.75	1.20	1.88	2.94	2.58	35.16
1961	1.41	2.63	2.54	5.95	3.01	3.66	3.02	4.03	2.53	2.41	3.29	2.62	37.10
1962	2.77	2.66	1.22	2.25	2.37	2.80	1.89	3.00	3.14	1.90	1.78	2.77	28.55
1963	1.51	1.03	2.19	2.77	2.22	0.61	6.43	8.04	1.20	0.30	5.07	1.83	33.20
1964	2.12	1.09	3.72	3.36	2.88	1.58	2.57	5.02	0.77	1.89	2.09	2.58	29.67
1965	3.27	2.99	1.97	1.99	1.21	1.50	3.69	4.04	2.42	5.10	4.69	2.59	35.46
1966	3.75	2.07	2.82	2.06	1.36	1.97	4.92	3.60	2.65	0.93	4.50	2.25	32.88
1967	1.18	1.39	1.20	2.60	3.69	2.50	1.57	4.04	6.36	4.78	3.13	2.15	34.59
1968	2.19	0.81	2.62	1.81	3.32	4.45	1.15	5.37	5.63	3.03	4.47	3.41	38.26
1969	3.86	0.97	1.62	4.16	3.75	3.51	3.83	2.48	2.04	2.77	4.09	3.09	36.17
1970	2.06	1.74	1.72	2.54	2.87	2.55	4.02	2.01	4.55	4.20	3.20	3.25	34.71
1971	1.46	3.03	2.07	1.48	1.56	4.25	4.50	4.43	1.88	1.57	3.07	3.61	32.91
1972	2.17	3.44	3.99	2.99	3.63	6.07	0.99	4.19	3.06	2.96	4.28	3.86	41.63
1973	2.03	1.98	3.27	3.56	2.99	1.68	3.68	2.98	1.44	4.16	4.18	4.89	36.84
1974	2.44	2.18	3.20	3.15	3.36	3.86	1.80	3.64	2.42	1.75	5.38	3.12	36.30
1975	2.12	2.93	2.92	1.86	3.13	3.83	2.34	8.49	2.44	1.13	2.76	4.59	38.54
1976	3.19	3.43	5.58	4.02	4.68	3.36	5.65	1.65	5.39	3.61	2.16	3.83	46.55
1977	3.37	1.60	2.42	3.60	1.18	3.00	3.64	10.67	8.98	2.62	4.43	8.04	53.55
1978	6.29	1.36	1.72	1.84	3.95	2.42	1.48	3.51	4.38	3.74	1.55	3.47	35.71
1979	5.40	2.09	2.48	3.16	1.63	2.18	3.51	6.26	5.61	3.88	4.03	3.54	43.77
1980	1.96	1.08	4.06	2.43	1.60	5.82	3.55	3.58	4.53	4.69	2.36	2.65	38.31
1981	1.11	3.50	1.70	3.09	2.56	3.68	5.05	3.13	4.24	3.31	2.22	2.86	36.45
1982	6.83	1.34	2.64	2.33	3.66	3.14	1.50	4.62	3.37	2.05	6.32	3.32	41.12
1983	1.44	1.30	3.20	2.55	3.28	2.99	2.01	3.51	2.11	4.62	5.19	7.30	39.50
1984	1.54	3.59	1.77	2.53	4.67	6.86	1.37	4.16	3.73	0.87	2.62	3.71	37.42
1985	4.27	3.34	4.39	1.36	3.46	3.21	1.81	4.63	1.20	3.73	9.75	4.85	46.00
1986	2.31	2.60	1.95	3.33	4.42	4.15	2.82	2.73	3.88	4.34	3.11	4.02	39.66
1987	2.90	0.80	3.71	3.40	1.35	8.36	3.09	3.38	5.31	2.63	4.42	2.80	42.15
1988	1.55	4.10	2.99	2.96	2.74	1.56	6.35	2.69	2.07	6.08	3.37	2.15	38.61
1989	1.77	2.54	3.15	1.88	7.14	7.91	0.93	1.84	3.85	2.98	4.83	2.34	41.16
1990	2.69	5.90	1.50	5.22	6.08	3.55	3.14	3.25	3.65	4.59	2.61	8.71	50.89
1991	2.07	2.06	5.97	5.83	3.10	0.86	3.34	2.84	3.19	3.11	4.02	3.81	40.20
1992	2.01	2.45	2.90	4.71	3.48	2.21	8.93	3.79	5.56	2.80	4.92	3.80	47.56
1993	4.35	1.92	2.97	2.60	1.79	4.99	1.78	3.86	5.53	3.68	3.59	3.60	40.66
1994	2.90	1.40	2.61	4.01	3.55	4.27	2.08	4.09	3.19	1.86	4.09	2.67	36.72
1995	4.89	2.61	1.34	1.41	2.40	1.33	3.53	2.07	1.32	6.07	4.12	0.06	31.15
1996	0.86	0.24	0.28	3.04	3.59	3.93	3.49	1.34	6.84	3.74	2.35	1.95	31.65
1997	1.59	1.93	2.73	1.07	3.25	1.88	0.86	4.56	4.83	2.18	3.21	1.19	29.28
1998	4.30	1.72	2.00	2.41	3.47	2.36	4.28	1.64	2.33	1.99	1.29	1.16	28.95
1999	2.55	0.83	1.16	2.10	2.75	1.93	1.00	4.37	3.95	2.95	3.32	1.76	28.67
2000	1.69	1.21	1.52	4.07	4.37	6.50	2.90	3.21	3.91	1.11	2.49	1.82	34.80
2001	0.91	1.69	1.75	1.20	4.28	1.34	0.73	2.13	3.45	4.34	3.34	2.64	27.80
2002	1.50	2.28	2.79	4.21	5.23	1.45	3.24	1.77	2.54	3.21	3.14	1.99	33.35
2003	0.62	1.79	2.50	0.78	5.43	1.80	3.64	2.52	3.91	3.43	3.85	2.39	32.66
2004	1.34	0.82	2.38	3.70	5.71	2.02	6.04	1.86	4.07	2.98	2.87	4.06	37.85
2005	2.44	1.74	1.01	4.03	0.60	3.26	1.82	5.92	4.89	2.64	5.33	1.78	35.46
2006	3.67	2.45	2.14	1.98	1.90	3.38	4.60	3.28	6.94	7.62	2.09	3.00	43.05
2007	4.38	1.17	2.53	2.90	0.87	1.82	3.31	1.13	3.55	2.73	5.36	4.21	33.96
2008	1.95	4.26	4.16	2.05	2.54	4.91	2.80	5.33	3.94	4.15	3.29	6.33	45.71
2009	1.81	2.57	3.25	3.15	1.89	2.92	4.37	5.32	5.65	4.77	2.94	5.08	43.72
2010	2.83	1.59	1.71	2.07	2.84	8.13	3.17	1.84	2.85	N/A	N/A	N/A	N/A
Ave. (1948-2010)	2.79	2.33	2.74	2.94	3.11	3.10	2.99	3.68	3.61	3.18	3.77	3.31	37.56
Ave. (2005-2009)	2.85	2.44	2.62	2.82	1.56	3.26	3.38	4.20	4.99	4.38	3.80	4.08	40.38
Normal (1981-2010)	3.18	2.49	2.87	3.01	3.46	3.66	3.23	3.26	3.90	3.52	4.01	3.89	40.48

Table 2. Monthly rainfall events for the Buffalo International Airport, 1948-2010.

Year	January	February	March	April	May	June	July	August	September	October	November	December	Total
1948	N/A	N/A	N/A	N/A	14	10	6	6	7	11	17	14	N/A
1949	14	11	13	13	10	6	9	7	9	8	20	16	136
1950	23	13	15	18	8	8	0	11	9	12	16	20	153
1951	22	11	14	18	9	12	12	6	8	7	15	19	153
1952	19	14	16	13	6	7	10	9	11	6	13	19	143
1953	16	13	18	16	15	7	10	9	7	8	7	17	143
1954	15	13	10	13	10	12	10	14	12	18	15	19	161
1955	26	17	19	12	12	4	6	12	4	9	18	23	162
1956	16	20	16	14	16	7	12	12	14	4	13	18	162
1957	17	11	14	16	8	9	9	8	12	3	15	16	138
1958	18	12	14	10	9	10	13	9	15	12	18	21	161
1959	21	13	11	13	11	8	9	11	7	11	17	10	142
1960	20	20	11	17	18	10	8	8	6	12	10	20	160
1961	15	9	18	16	11	9	15	18	8	10	13	19	161
1962	21	16	12	14	11	10	11	12	12	14	8	16	157
1963	21	18	18	12	14	5	5	13	7	3	17	23	156
1964	16	17	18	17	8	9	9	12	7	10	12	19	154
1965	19	17	18	13	10	11	8	16	12	14	18	17	173
1966	17	19	16	21	16	7	10	12	14	11	15	15	173
1967	23	20	14	13	13	8	8	12	7	11	14	20	163
1968	14	20	11	9	14	14	5	14	11	15	15	20	162
1969	16	12	18	11	11	13	10	2	5	13	24	24	159
1970	20	12	15	12	15	11	12	6	16	11	15	18	163
1971	26	16	16	15	11	13	9	12	7	9	15	18	167
1972	18	14	18	11	10	12	10	17	9	14	14	20	167
1973	13	14	13	13	23	15	11	8	7	12	14	21	164
1974	17	18	14	13	13	12	10	11	9	13	16	18	164
1975	14	17	16	7	10	16	10	13	11	8	20	21	163
1976	13	15	16	12	14	11	15	6	11	13	12	24	162
1977	23	26	13	12	9	9	14	16	12	11	17	20	182
1978	25	20	13	9	12	7	4	11	11	14	7	21	154
1979	23	15	8	15	9	9	11	15	7	16	17	12	157
1980	18	23	17	15	14	13	13	9	12	16	13	18	181
1981	20	17	20	16	10	13	9	10	17	14	9	15	170
1982	19	10	18	10	10	10	7	10	13	10	15	14	146
1983	22	11	15	17	12	7	8	10	9	13	13	21	158
1984	18	15	13	15	14	9	7	12	9	9	10	16	147
1985	17	14	16	10	11	11	15	10	11	13	11	22	161
1986	19	22	16	15	9	16	15	9	14	14	13	10	172
1987	19	9	7	12	4	13	9	9	19	13	13	15	142
1988	12	23	15	16	11	7	12	8	9	19	16	17	165
1989	12	21	14	11	15	15	7	10	7	9	21	22	164
1990	14	15	13	14	13	13	8	9	12	16	11	16	154
1991	17	18	15	15	11	4	8	7	8	13	18	16	150
1992	15	19	18	14	15	10	14	10	8	14	22	19	178
1993	18	13	14	13	11	15	8	15	13	8	12	16	156
1994	19	13	16	13	10	12	13	11	11	10	10	8	146
1995	14	12	13	15	11	11	16	6	11	14	16	4	143
1996	4	6	7	15	10	21	9	3	13	10	8	12	118
1997	12	9	10	6	15	9	4	7	15	8	13	12	120
1998	10	10	12	8	11	10	11	6	6	5	7	7	103
1999	16	13	5	15	8	10	12	11	8	10	7	13	128
2000	15	9	9	12	11	18	11	13	11	9	14	12	144
2001	13	11	16	10	9	12	8	12	11	13	10	11	136
2002	11	7	14	16	13	13	10	8	8	10	17	13	140
2003	10	9	12	8	13	12	16	13	14	12	13	11	143
2004	15	5	17	15	21	13	13	13	3	14	9	13	151
2005	18	10	8	9	8	10	8	12	9	9	16	14	131
2006	14	20	12	12	9	15	11	9	16	13	10	11	152
2007	22	17	12	13	7	6	11	9	10	9	15	16	147
2008	19	16	11	9	13	19	14	16	15	10	13	20	175
2009	16	8	8	10	12	10	14	11	7	13	8	22	139
2010	14	12	7	8	11	16	7	11	10	N/A	N/A	N/A	N/A
Ave. (1948-2010)	17.1	14.5	13.8	13.0	11.6	10.9	10.0	10.4	10.2	11.2	13.9	16.7	153
Ave. (2005-2009)	17.8	14.2	10.2	10.6	9.8	12.0	11.6	11.4	11.4	10.8	12.4	16.6	149

Table 3. Monthly rainfall events (0.05" cutoff) for the Buffalo International Airport, 1948-2010.

Year	January	February	March	April	May	June	July	August	September	October	November	December	Total
1948	N/A	N/A	N/A	N/A	12	8	3	4	5	9	14	7	N/A
1949	9	7	8	11	7	5	8	6	6	7	14	11	99
1950	14	8	9	9	5	5	0	8	8	6	9	10	91
1951	10	8	12	15	6	9	10	4	4	4	8	10	100
1952	11	7	7	7	6	4	5	9	9	2	11	9	87
1953	12	7	11	12	12	5	7	6	5	3	7	7	94
1954	9	6	9	12	4	9	7	10	8	12	11	12	109
1955	14	11	12	10	7	1	3	10	4	8	13	11	104
1956	8	10	14	8	10	4	7	11	10	3	10	13	108
1957	10	5	9	13	6	7	9	6	11	2	12	11	101
1958	13	10	8	9	6	8	10	8	11	7	12	8	110
1959	15	11	9	10	6	5	9	9	2	7	13	7	103
1960	14	9	8	10	10	7	5	6	4	7	8	11	99
1961	7	6	9	10	9	8	10	17	7	5	7	9	104
1962	11	8	7	13	4	8	7	9	6	9	6	11	99
1963	7	7	11	7	8	5	5	10	4	3	7	10	84
1964	9	5	9	12	6	4	4	10	5	6	7	12	89
1965	8	8	10	8	9	5	8	11	8	9	9	9	102
1966	5	7	13	7	6	7	6	9	8	6	9	6	89
1967	7	6	6	8	10	7	5	10	5	6	10	12	92
1968	9	5	7	7	10	8	3	12	10	9	10	11	101
1969	12	5	4	8	10	11	8	2	3	10	13	9	95
1970	10	7	4	5	12	7	11	6	13	11	8	14	108
1971	7	9	8	9	4	9	8	9	5	6	10	12	96
1972	14	9	11	8	9	8	4	10	9	10	10	13	115
1973	7	6	8	8	14	9	8	6	5	10	7	12	100
1974	10	8	7	12	11	7	5	7	8	10	12	12	109
1975	8	11	9	4	9	6	7	10	10	2	12	9	97
1976	12	10	11	7	10	9	13	3	9	7	8	15	114
1977	17	8	9	7	7	7	10	14	12	7	13	14	125
1978	17	5	5	6	9	7	3	9	9	10	4	11	95
1979	13	10	8	8	7	7	4	11	7	13	12	8	108
1980	8	7	12	10	5	8	10	7	8	7	12	8	102
1981	7	9	12	11	6	11	8	8	8	12	5	13	110
1982	13	7	11	8	8	9	4	8	10	8	11	8	105
1983	10	4	9	10	12	5	5	8	7	8	9	17	104
1984	9	9	10	8	9	7	7	11	7	4	8	11	100
1985	12	10	11	6	8	8	10	9	8	10	9	13	114
1986	7	9	8	9	4	11	11	8	8	12	12	6	105
1987	12	5	4	9	3	12	6	6	12	9	10	10	98
1988	7	12	10	8	8	5	10	7	5	11	9	10	102
1989	8	8	7	9	15	12	4	5	6	8	15	9	106
1990	9	9	8	9	9	9	6	6	8	11	8	12	104
1991	13	9	9	11	7	4	5	5	7	11	13	10	104
1992	10	11	10	10	10	6	14	10	7	10	16	9	123
1993	10	5	12	7	5	14	7	11	11	6	9	11	108
1994	11	8	9	10	8	6	6	8	5	6	9	7	93
1995	9	10	8	9	9	8	12	6	8	8	10	0	97
1996	3	1	2	10	8	13	8	3	12	9	7	10	86
1997	8	6	8	3	12	6	4	6	14	7	9	7	90
1998	8	3	6	7	10	9	9	5	6	5	6	5	79
1999	10	6	3	10	7	6	7	8	7	7	5	10	86
2000	9	6	6	7	9	14	10	9	8	6	10	7	101
2001	3	4	10	7	9	7	5	9	8	9	8	7	86
2002	5	6	9	9	12	6	8	8	5	8	8	7	91
2003	6	4	11	4	12	5	11	8	11	9	10	7	98
2004	6	3	12	10	15	6	9	10	2	7	7	10	97
2005	11	7	5	9	3	7	5	8	8	6	10	9	88
2006	9	10	7	8	6	10	7	8	10	9	8	8	100
2007	10	6	8	9	4	6	7	5	8	9	10	8	90
2008	10	12	9	7	11	14	11	11	10	8	7	17	127
2009	7	4	5	10	9	10	8	11	3	9	7	15	98
2010	8	5	6	6	8	15	5	8	8	N/A	N/A	N/A	N/A
Ave. (1948-2010)	9.6	7.3	8.5	8.7	8.3	7.7	7.2	8.1	7.5	7.7	9.6	10.0	100
Ave. (2005-2009)	9.4	7.8	6.8	8.6	6.6	9.4	7.6	8.6	7.8	8.2	8.4	11.4	101

Table 4
Monthly Rainfall Comparisons - 2000 and 2011 studies

Months	Average Monthly Rainfall (inches)		Number Precipitation Events Per Month		Average Precipitation Per Event (inches)		Average Event Duration (hours)		Average Event Intensity (inch/hr)	
	1969-1999	1948-2010	1969-1999	1948-2010	1969-1999	1948-2010	1969-1999	1948-2010	1969-1999	1948-2010
January	2.87	2.79	17	17	0.17	0.16	9.6	8.6	0.02	0.02
February	2.26	2.33	15	15	0.15	0.16	8.0	8.1	0.02	0.02
March	2.72	2.74	14	14	0.19	0.20	7.9	8.0	0.02	0.02
April	2.90	2.94	13	13	0.22	0.23	7.4	7.5	0.03	0.03
May	3.35	3.11	12	12	0.28	0.27	6.9	6.8	0.04	0.04
June	3.55	3.10	12	11	0.31	0.28	5.1	5.0	0.06	0.06
July	3.11	2.99	10	10	0.30	0.30	4.4	4.5	0.07	0.07
August	3.78	3.68	10	11	0.38	0.36	5.2	4.9	0.07	0.07
September	3.78	3.61	11	10	0.36	0.35	6.7	6.4	0.05	0.06
October	3.31	3.18	12	11	0.27	0.29	6.8	7.3	0.04	0.04
November	3.77	3.77	14	14	0.27	0.27	9.0	8.7	0.03	0.03
December	3.53	3.31	17	17	0.21	0.20	8.6	8.2	0.02	0.02

Table 5
Rainfall Analysis - Monthly Totals 1948-2010

Month		Number	Total	Minimum	Maximum	Average
January	Duration	1063	9110	1	67	8.570
	Intensity	1063	43.36	0.01	0.51	0.041
	Volume	1063	174.66	0.01	2.88	0.164
February	Duration	900	7307	1	71	8.119
	Intensity	900	34.95	0.01	0.4	0.039
	Volume	900	144.38	0.01	2.51	0.160
March	Duration	856	6817	1	59	7.964
	Intensity	856	47.71	0.01	0.38	0.056
	Volume	856	167.77	0.01	2.21	0.196
April	Duration	805	6068	1	73	7.538
	Intensity	805	58.66	0.01	0.82	0.073
	Volume	805	181.39	0.01	3.99	0.225
May	Duration	732	4968	1	66	6.787
	Intensity	732	75.86	0.01	1.71	0.104
	Volume	732	197.55	0.01	3.63	0.270
June	Duration	684	3432	1	39	5.018
	Intensity	684	99.03	0.01	2.45	0.145
	Volume	684	193.1	0.01	5.01	0.282
July	Duration	629	2818	1	30	4.480
	Intensity	629	102.82	0.01	1.67	0.163
	Volume	629	188.81	0.01	3.38	0.300
August	Duration	657	3210	1	33	4.886
	Intensity	657	126.87	0.01	1.75	0.193
	Volume	657	234.01	0.01	3.88	0.356
September	Duration	643	4109	1	49	6.390
	Intensity	643	91.76	0.01	1.38	0.143
	Volume	643	226.86	0.01	4.94	0.353
October	Duration	693	5049	1	47	7.286
	Intensity	693	62.79	0.01	0.69	0.091
	Volume	693	198.06	0.01	3.13	0.286
November	Duration	860	7508	1	91	8.730
	Intensity	860	63.84	0.01	0.56	0.074
	Volume	860	235.1	0.01	5.23	0.273
December	Duration	1034	8433	1	58	8.156
	Intensity	1034	52.16	0.01	0.48	0.050
	Volume	1034	203.62	0.01	2.88	0.197

Table 6
Rainfall Analysis - Yearly Totals 1948-2010

Year	Parameter	Number	Total	Minimum	Maximum	Average
1948	Duration	85	627	1	40	7.376
	Intensity	85	11.69	0.01	1.02	0.138
	Volume	85	26.72	0.01	2.12	0.314
	Months	8	26.39	1.1	5.74	3.299
1949	Duration	136	959	1	41	7.051
	Intensity	136	14.74	0.01	1.19	0.108
	Volume	136	36.54	0.01	2.72	0.269
	Months	12	36.87	1.17	6.35	3.073
1950	Duration	153	1062	1	50	6.941
	Intensity	153	10.55	0.01	0.86	0.069
	Volume	153	33.84	0.01	2.27	0.221
	Months	12	33.82	0.01	5.02	2.818
1951	Duration	153	1175	1	43	7.680
	Intensity	153	14.38	0.01	0.79	0.094
	Volume	153	37.75	0.01	1.66	0.247
	Months	12	37.75	1.36	4.57	3.146
1952	Duration	143	938	1	38	6.559
	Intensity	143	9.83	0.01	0.51	0.069
	Volume	143	29.14	0.01	1.7	0.204
	Months	12	29.14	0.68	3.91	2.428
1953	Duration	143	967	1	46	6.762
	Intensity	143	13.81	0.01	1.67	0.097
	Volume	143	35.88	0.01	2.44	0.251
	Months	12	35.88	0.32	6.4	2.990
1954	Duration	161	1279	1	55	7.944
	Intensity	161	14.9	0.01	0.69	0.093
	Volume	161	44.78	0.01	2.45	0.278
	Months	12	44.78	1.35	9.13	3.732
1955	Duration	162	1146	1	46	7.074
	Intensity	162	13.43	0.01	0.69	0.083
	Volume	162	39.79	0.01	3.13	0.246
	Months	12	39.79	0.11	8.12	3.316
1956	Duration	162	1125	1	29	6.944
	Intensity	162	16.28	0.01	0.98	0.100
	Volume	162	41.93	0.01	2.09	0.259
	Months	12	41.93	0.86	5.89	3.494
1957	Duration	138	1019	1	42	7.384
	Intensity	138	13.28	0.01	0.56	0.096
	Volume	138	38.69	0.01	2.76	0.280
	Months	12	38.69	1.11	5.3	3.224
1958	Duration	161	1194	1	68	7.416
	Intensity	161	12.04	0.01	0.77	0.075
	Volume	161	34.39	0.01	1.77	0.214
	Months	12	34.39	1.39	4.75	2.866
1959	Duration	142	1198	1	55	8.437
	Intensity	142	14.5	0.01	1.12	0.102

Table 6
Rainfall Analysis - Yearly Totals 1948-2010

Year	Parameter	Number	Total	Minimum	Maximum	Average
	Volume	142	42.81	0.01	2.84	0.301
	Months	12	42.81	1.94	6.47	3.568
1960	Duration	160	1172	1	59	7.325
	Intensity	160	12.39	0.01	0.62	0.077
	Volume	160	35.16	0.01	1.71	0.220
	Months	12	35.16	1.2	5.8	2.930
1961	Duration	161	1143	1	36	7.099
	Intensity	161	14.51	0.01	1.01	0.090
	Volume	161	37.1	0.01	1.77	0.230
	Months	12	37.1	1.41	5.95	3.092
1962	Duration	157	1060	1	49	6.752
	Intensity	157	10.66	0.01	0.83	0.068
	Volume	157	28.55	0.01	2.5	0.182
	Months	12	28.55	1.22	3.14	2.379
1963	Duration	156	1031	1	53	6.609
	Intensity	156	12.5	0.01	1.75	0.080
	Volume	156	33.2	0.01	3.88	0.213
	Months	12	33.2	0.3	8.04	2.767
1964	Duration	154	992	1	30	6.442
	Intensity	154	11.66	0.01	0.56	0.076
	Volume	154	29.67	0.01	1.89	0.193
	Months	12	29.67	0.77	5.02	2.473
1965	Duration	173	1152	1	42	6.659
	Intensity	173	12.56	0.01	0.5	0.073
	Volume	173	35.48	0.01	2.3	0.205
	Months	12	35.46	1.21	5.1	2.955
1966	Duration	173	1143	1	46	6.607
	Intensity	173	12.09	0.01	0.64	0.070
	Volume	173	32.86	0.01	1.66	0.190
	Months	12	32.88	0.93	4.92	2.740
1967	Duration	163	1117	1	42	6.853
	Intensity	163	11.76	0.01	0.94	0.072
	Volume	163	34.64	0.01	4.4	0.213
	Months	12	34.59	1.18	6.36	2.883
1968	Duration	162	1163	1	44	7.179
	Intensity	162	14.03	0.01	1.3	0.087
	Volume	162	38.25	0.01	3.11	0.236
	Months	12	38.26	0.81	5.63	3.188
1970	Duration	163	1256	1	36	7.706
	Intensity	163	12.94	0.01	0.6	0.079
	Volume	163	34.71	0.01	1.89	0.213
	Months	12	34.71	1.72	4.55	2.893
1971	Duration	167	1162	1	44	6.958
	Intensity	167	13.67	0.01	1.3	0.082
	Volume	167	32.91	0.01	2.33	0.197
	Months	12	32.91	1.46	4.5	2.743

Table 6
Rainfall Analysis - Yearly Totals 1948-2010

Year	Parameter	Number	Total	Minimum	Maximum	Average
1972	Duration	167	1481	1	46	8.868
	Intensity	167	12.76	0.01	0.88	0.076
	Volume	167	41.63	0.01	3.73	0.249
	Months	12	41.63	0.99	6.07	3.469
1973	Duration	164	1142	1	57	6.963
	Intensity	164	14.42	0.01	0.76	0.088
	Volume	164	36.84	0.01	1.75	0.225
	Months	12	36.84	1.44	4.89	3.070
1974	Duration	164	1305	1	43	7.957
	Intensity	164	12.36	0.01	0.5	0.075
	Volume	164	36.32	0.01	1.29	0.221
	Months	12	36.3	1.75	5.38	3.025
1975	Duration	163	1180	1	59	7.239
	Intensity	163	16.22	0.01	1.23	0.100
	Volume	163	38.52	0.01	3.56	0.236
	Months	12	38.54	1.13	8.49	3.212
1976	Duration	162	1322	1	36	8.160
	Intensity	162	17.69	0.01	1.3	0.109
	Volume	162	46.55	0.01	2.87	0.287
	Months	12	46.55	1.65	5.65	3.879
1977	Duration	182	1544	1	49	8.484
	Intensity	182	19.53	0.01	1.06	0.107
	Volume	182	53.55	0.01	2.43	0.294
	Months	12	53.55	1.18	10.67	4.463
1978	Duration	154	1220	1	60	7.922
	Intensity	154	12.55	0.01	0.71	0.081
	Volume	154	36.37	0.01	1.69	0.236
	Months	12	35.71	1.36	6.29	2.976
1979	Duration	157	1333	1	45	8.490
	Intensity	157	14.61	0.01	1.38	0.093
	Volume	157	43.11	0.01	4.94	0.275
	Months	12	43.77	1.63	6.26	3.648
1980	Duration	181	1080	1	35	5.967
	Intensity	181	15.31	0.01	1.15	0.085
	Volume	181	38.31	0.01	2.69	0.212
	Months	12	38.31	1.08	5.82	3.193
1981	Duration	170	1193	1	57	7.018
	Intensity	170	13.79	0.01	0.66	0.081
	Volume	170	36.59	0.01	1.97	0.215
	Months	12	36.45	1.11	5.05	3.038
1982	Duration	146	1171	1	53	8.021
	Intensity	146	13.83	0.01	0.67	0.095
	Volume	146	40.98	0.01	2.88	0.281
	Months	12	41.12	1.34	6.83	3.427
1983	Duration	158	1234	1	51	7.810
	Intensity	158	12.43	0.01	0.54	0.079

Table 6
Rainfall Analysis - Yearly Totals 1948-2010

Year	Parameter	Number	Total	Minimum	Maximum	Average
	Volume	158	39.5	0.01	1.63	0.250
	Months	12	39.5	1.3	7.3	3.292
1984	Duration	147	1086	1	53	7.388
	Intensity	147	13.93	0.01	0.85	0.095
	Volume	147	38.07	0.01	2.51	0.259
	Months	12	37.42	0.87	6.86	3.118
1985	Duration	161	1526	1	91	9.478
	Intensity	161	14.04	0.01	0.98	0.087
	Volume	161	45.35	0.01	5.23	0.282
	Months	12	46	1.2	9.75	3.833
1986	Duration	172	1058	1	45	6.151
	Intensity	172	16.48	0.01	1.71	0.096
	Volume	172	39.66	0.01	3.63	0.231
	Months	12	39.66	1.95	4.42	3.305
1987	Duration	142	1057	1	41	7.444
	Intensity	142	15.26	0.01	2.45	0.107
	Volume	142	42.15	0.01	5.01	0.297
	Months	12	42.15	0.8	8.36	3.513
1988	Duration	165	990	1	38	6.000
	Intensity	165	15.49	0.01	1.33	0.094
	Volume	165	38.61	0.01	1.67	0.234
	Months	12	38.61	1.55	6.35	3.218
1989	Duration	164	1210	1	41	7.378
	Intensity	164	13.92	0.01	0.91	0.085
	Volume	164	41.16	0.01	3.01	0.251
	Months	12	41.16	0.93	7.91	3.430
1990	Duration	154	1222	1	49	7.935
	Intensity	154	15.3	0.01	0.69	0.099
	Volume	154	50.89	0.01	2.88	0.330
	Months	12	50.89	1.5	8.71	4.241
1991	Duration	150	1084	1	73	7.227
	Intensity	150	15.12	0.01	0.93	0.101
	Volume	150	40.2	0.01	3.99	0.268
	Months	12	40.2	0.86	5.97	3.350
1992	Duration	178	1277	1	43	7.174
	Intensity	178	16.67	0.01	0.73	0.094
	Volume	178	47.56	0.01	2.3	0.267
	Months	12	47.56	2.01	8.93	3.963
1993	Duration	156	1108	1	42	7.103
	Intensity	156	13.76	0.01	0.67	0.088
	Volume	156	40.66	0.01	1.76	0.261
	Months	12	40.66	1.78	5.53	3.388
1994	Duration	146	1106	1	37	7.575
	Intensity	146	13.12	0.01	0.56	0.090
	Volume	146	36.91	0.01	2.81	0.253
	Months	12	36.72	1.4	4.27	3.060

Table 6
Rainfall Analysis - Yearly Totals 1948-2010

Year	Parameter	Number	Total	Minimum	Maximum	Average
1995	Duration	143	942	1	67	6.587
	Intensity	143	11.31	0.01	0.7	0.079
	Volume	143	30.96	0.01	2.22	0.217
	Months	12	31.15	0.06	6.07	2.596
1996	Duration	118	810	1	41	6.864
	Intensity	118	12.16	0.01	1.1	0.103
	Volume	118	31.65	0.01	2.06	0.268
	Months	12	31.65	0.24	6.84	2.638
1997	Duration	120	625	1	26	5.208
	Intensity	120	11.81	0.02	0.79	0.098
	Volume	120	29.28	0.02	1.86	0.244
	Months	12	29.28	0.86	4.83	2.440
1998	Duration	103	530	1	39	5.146
	Intensity	103	12.7	0.02	0.97	0.123
	Volume	103	28.95	0.02	2.33	0.281
	Months	12	28.95	1.16	4.3	2.413
2009	Duration	139	1025	1	39	7.374
	Intensity	139	16.21	0.01	1	0.117
	Volume	139	43.73	0.01	3.79	0.315
	Months	12	43.72	1.81	5.65	3.643
2000	Duration	144	1037	1	41	7.201
	Intensity	144	13.85	0.01	0.66	0.096
	Volume	144	34.8	0.01	1.49	0.242
	Months	12	34.8	1.11	6.5	2.900
2001	Duration	136	948	1	62	6.971
	Intensity	136	10.42	0.01	0.72	0.077
	Volume	136	27.8	0.01	1.82	0.204
	Months	12	27.8	0.73	4.34	2.317
2002	Duration	140	1026	1	66	7.329
	Intensity	140	11.8	0.01	0.53	0.084
	Volume	140	33.35	0.01	2.28	0.238
	Months	12	33.35	1.45	5.23	2.779
2003	Duration	143	1119	1	47	7.825
	Intensity	143	13.11	0.01	0.58	0.092
	Volume	143	32.66	0.01	1.1	0.228
	Months	12	32.66	0.62	5.43	2.722
2004	Duration	151	1049	1	34	6.947
	Intensity	151	13.66	0.01	1.15	0.090
	Volume	151	37.85	0.01	3.99	0.251
	Months	12	37.85	0.82	6.04	3.154
2005	Duration	131	900	1	48	6.870
	Intensity	131	12.47	0.01	0.94	0.095
	Volume	131	35.46	0.01	3	0.271
	Months	12	35.46	0.6	5.92	2.955
2006	Duration	152	1048	1	47	6.895
	Intensity	152	15.54	0.01	0.75	0.102

Table 6
Rainfall Analysis - Yearly Totals 1948-2010

Year	Parameter	Number	Total	Minimum	Maximum	Average
	Volume	152	43.2	0.01	2.58	0.284
	Months	12	43.05	1.9	7.62	3.588
2007	Duration	147	1008	1	54	6.857
	Intensity	147	12.58	0.01	0.79	0.086
	Volume	147	33.81	0.01	2.45	0.230
	Months	12	33.96	0.87	5.36	2.830
2008	Duration	175	1210	1	43	6.914
	Intensity	175	18.35	0.01	1.14	0.105
	Volume	175	45.71	0.01	1.69	0.261
	Months	12	45.71	1.95	6.33	3.809
2009	Duration	139	1025	1	39	7.374
	Intensity	139	16.21	0.01	1	0.117
	Volume	139	43.73	0.01	3.79	0.315
	Months	12	43.72	1.81	5.65	3.643
2010	Duration	96	649	1	27	6.760
	Intensity	96	12.44	0.01	0.78	0.130
	Volume	96	27.02	0.01	2.19	0.281
	Months	9	27.03	1.59	8.13	3.003

Table 7. Event return period distributions for the unmodified 2006 rainfall hyetograph.

Duration (hrs)	Max. RP (yrs)	Events with RP \geq 2 years	Events with RP \geq 1 years	Events with RP \geq 9 months	Events with RP \geq 6 months	Events with RP \geq 4 months	Events with RP \geq 3 months	Events with RP \geq 2 months	Events with RP \geq 1 month
1	0.90	0	0	3	3	3	4	8	16
2	0.87	0	0	1	4	4	5	8	13
3	0.98	0	0	2	3	5	5	8	10
6	1.44	0	1	2	3	5	7	8	14
12	1.37	0	1	2	3	4	6	10	17
24	0.84	0	0	1	5	5	7	8	16

Table 8. Event return period distributions for the unmodified 1993 rainfall hyetograph.

Duration (hrs)	Max. RP (yrs)	Events with RP \geq 2 years	Events with RP \geq 1 years	Events with RP \geq 9 months	Events with RP \geq 6 months	Events with RP \geq 4 months	Events with RP \geq 3 months	Events with RP \geq 2 months	Events with RP \geq 1 month
1	0.65	0	0	0	2	4	4	6	12
2	2.35	1	1	1	3	5	5	6	11
3	1.76	0	1	3	3	4	5	6	11
6	1.09	0	2	3	3	3	5	9	10
12	1.19	0	1	1	3	5	5	7	13
24	0.80	0	0	1	1	4	6	7	15

Table 9. Comparison of 2006 unmodified and modified monthly and annual rainfall volumes to normal (1981-2010) rainfall volumes.

Year	January	February	March	April	May	June	July	August	September	October	November	December	Total
2006 (Unmodified)	3.67	2.45	2.14	1.98	1.90	3.38	4.60	3.28	6.94	7.62	2.09	3.00	43.05
2006 (Modified)	3.67	2.45	2.14	1.98	3.04	3.38	3.77	3.28	5.27	5.04	2.98	3.00	40.00
Normal (1981-2010)	3.18	2.49	2.87	3.01	3.46	3.66	3.23	3.26	3.9	3.52	4.01	3.89	40.48
% Difference: 2006 (Unmodified) vs. Normal (1981-2010)	15.4	-1.6	-25.4	-34.2	-45.1	-7.7	42.4	0.6	77.9	116.5	-47.9	-22.9	6.3
% Difference: 2006 (Modified) vs. Normal (1981-2010)	15.4	-1.6	-25.4	-34.2	-12.1	-7.7	16.7	0.6	35.1	43.2	-25.7	-22.9	-1.2

Table 10. Comparison of 2006 unmodified and modified monthly and annual events of at least 0.05" to average (1948-2010) events

Year	January	February	March	April	May	June	July	August	September	October	November	December	Total
2006 (Unmodified)	9	10	7	8	6	10	7	8	10	9	8	8	100
2006 (Modified)	9	10	7	8	7	10	6	8	9	8	9	8	99
Average (1948-2010)	9.6	7.3	8.5	8.7	8.3	7.7	7.2	8.1	7.5	7.7	9.6	10.0	100
Difference: 2006 (Unmodified) vs. Average (1948-2010)	-1	3	-2	-1	-2	2	0	0	2	1	-2	-2	0
Difference: 2006 (Modified) vs. Average (1948-2010)	-1	3	-2	-1	-1	2	-1	0	1	0	-1	-2	-1

Table 11. Event return period distributions for the modified 2006 rainfall hyetograph.

Duration (hrs)	Max. RP (yrs)	Events with RP \geq 2 years	Events with RP \geq 1 years	Events with RP \geq 9 months	Events with RP \geq 6 months	Events with RP \geq 4 months	Events with RP \geq 3 months	Events with RP \geq 2 months	Events with RP \geq 1 month
1	0.86	0	0	2	2	2	2	6	14
2	0.87	0	0	1	2	2	3	6	11
3	0.90	0	0	1	2	3	3	6	8
6	0.81	0	0	1	2	3	6	6	11
12	1.37	0	1	1	2	3	5	9	15
24	0.84	0	0	1	3	3	5	7	15

Table 12. Comparison of 1993 unmodified and modified monthly and annual rainfall volumes to normal (1981-2010) rainfall volumes.

Year	January	February	March	April	May	June	July	August	September	October	November	December	Total
1993 (Unmodified)	4.35	1.92	2.97	2.60	1.79	4.99	1.78	3.86	5.53	3.68	3.59	3.60	40.66
1993 (Modified)	2.75	1.92	2.97	2.60	3.03	4.19	3.07	3.00	4.27	3.68	3.59	3.60	38.67
Normal (1981-2010)	3.18	2.49	2.87	3.01	3.46	3.66	3.23	3.26	3.9	3.52	4.01	3.89	40.48
% Difference: 1993 (Unmodified) vs. Normal (1981-2010)	36.8	-22.9	3.5	-13.6	-48.3	36.3	-44.9	18.4	41.8	4.5	-10.5	-7.5	0.4
% Difference: 1993 (Modified) vs. Normal (1981-2010)	-13.5	-22.9	3.5	-13.6	-12.4	14.5	-5.0	-8.0	9.5	4.5	-10.5	-7.5	-4.5

Table 13. Comparison of 1993 unmodified and modified monthly and annual events of at least 0.05" to average (1948-2010) events.

Year	January	February	March	April	May	June	July	August	September	October	November	December	Total
1993 (Unmodified)	10	5	12	7	5	14	7	11	11	6	9	11	108
1993 (Modified)	9	5	12	7	6	13	9	11	10	6	9	11	108
Average (1948-2010)	9.6	7.3	8.5	8.7	8.3	7.7	7.2	8.1	7.5	7.7	9.6	10.0	100
Difference: 1993 (Unmodified) vs. Average (1948-2010)	0	-2	3	-2	-3	6	0	3	3	-2	-1	1	8
Difference: 1993 (Modified) vs. Average (1948-2010)	-1	-2	3	-2	-2	5	2	3	2	-2	-1	1	8

Table 14. Event return period distributions for the modified 1993 rainfall hyetograph.

Duration (hrs)	Max. RP (yrs)	Events with RP \geq 2 years	Events with RP \geq 1 years	Events with RP \geq 9 months	Events with RP \geq 6 months	Events with RP \geq 4 months	Events with RP \geq 3 months	Events with RP \geq 2 months	Events with RP \geq 1 month
1	0.94	0	0	1	1	3	4	6	13
2	0.68	0	0	0	2	4	4	5	11
3	0.82	0	0	2	2	3	4	5	11
6	1.02	0	1	2	2	2	4	7	9
12	1.19	0	1	1	2	3	3	5	11
24	0.80	0	0	1	1	3	4	5	13

Table 15. Comparison of 2006 modified, 1993 modified, and 1986 typical year hyetograph monthly and annual rainfall volumes to normal (1981-2010) rainfall volume:

Year	January	February	March	April	May	June	July	August	September	October	November	December	Total
2006 (Modified)	3.67	2.45	2.14	1.98	3.04	3.38	3.77	3.28	5.27	5.04	2.98	3.00	40.00
1993 (Modified)	2.75	1.92	2.97	2.60	3.03	4.19	3.07	3.00	4.27	3.68	3.59	3.60	38.67
1986 Typical Year	1.51	2.02	1.85	3.11	4.38	4.15	2.72	4.23	4.63	4.34	2.90	3.34	39.18
Normal (1981-2010)	3.18	2.49	2.87	3.01	3.46	3.66	3.23	3.26	3.9	3.52	4.01	3.89	40.48
% Difference: 2006 (Modified) vs. Normal (1981-2010)	15.4	-1.6	-25.4	-34.2	-12.1	-7.7	16.7	0.6	35.1	43.2	-25.7	-22.9	-1.2
% Difference: 1993 (Modified) vs. Normal (1981-2010)	-13.5	-22.9	3.5	-13.6	-12.4	14.5	-5.0	-8.0	9.5	4.5	-10.5	-7.5	-4.5
% Difference: 1986 Typical Year vs. Normal (1981-2010)	-52.5	-18.9	-35.5	3.3	26.6	13.4	-15.8	29.8	18.7	23.3	-27.7	-14.1	-3.2

Table 16. Comparison of 2006 modified, 1993 modified, and 1986 typical year hyetograph monthly and annual events of at least 0.05" to average (1948-2010) events.

Year	January	February	March	April	May	June	July	August	September	October	November	December	Total
2006 (Modified)	9	10	7	8	7	10	6	8	9	8	9	8	99
1993 (Modified)	9	5	12	7	6	13	9	11	10	6	9	11	108
1986 Typical Year	5	8	8	7	4	11	10	9	9	12	11	5	99
Average (1948-2010)	9.6	7.3	8.5	8.7	8.3	7.7	7.2	8.1	7.5	7.7	9.6	10.0	100
Difference: 2006 (Modified) vs. Average (1948-2010)	-1	3	-2	-1	-1	2	-1	0	1	0	-1	-2	-1
Difference: 1993 (Modified) vs. Average (1948-2010)	-1	-2	3	-2	-2	5	2	3	2	-2	-1	1	8
Difference: 1986 Typical Year vs. Average (1948-2010)	-5	1	-1	-2	-4	3	3	1	1	4	1	-5	-1

Table 17. Event return period distributions for the 1986 typical year rainfall hyetograph.

Duration (hrs)	Max. RP (yrs)	Events with RP \geq 2 years	Events with RP \geq 1 years	Events with RP \geq 9 months	Events with RP \geq 6 months	Events with RP \geq 4 months	Events with RP \geq 3 months	Events with RP \geq 2 months	Events with RP \geq 1 month
1	24.08	1	2	3	6	6	7	9	15
2	17.39	1	3	3	3	5	7	8	13
3	9.49	1	3	3	3	4	6	8	13
6	9.49	1	3	3	3	5	7	9	14
12	7.28	1	2	2	3	4	5	8	13
24	8.24	1	1	1	2	4	4	5	15

Table 18. Ranking of Candidate Typical Year Records Using Modified EPA Approach

Year	Sum of Total Rainfall Absolute Deviations (in.)	Sum of Peak Hourly Rainfall Absolute Deviations (in.)	Sum of Monthly Rainfall Absolute Deviations (in.)	Ranking for Total Rainfall Absolute Deviation	Ranking for Peak Hourly Rainfall Absolute Deviation	Ranking for Monthly Rainfall Absolute Deviation	Sum of Rankings
Mod. 1993	2.35	1.04	4.13	1	2	1	4
1993	2.54	1.08	9.8	2	3	4	9
Mod. 2006	4.41	1.28	8.36	8	4	3	15
1982	3.66	0.96	14.4	6	1	9	16
1991	3.43	1.65	12.36	5	7	5	17
1986	4.02	2.35	6.48	7	10	2	19
1989	2.93	1.37	17.48	3	5	12	20
1983	4.66	1.54	13.52	9	6	7	22
1988	3.39	1.93	16.69	4	8	11	23
2006	6.49	2	15.47	10	9	10	29
1987	7.68	2.86	14.07	11	11	8	30
2009	7.96	3.09	12.74	12	12	6	30

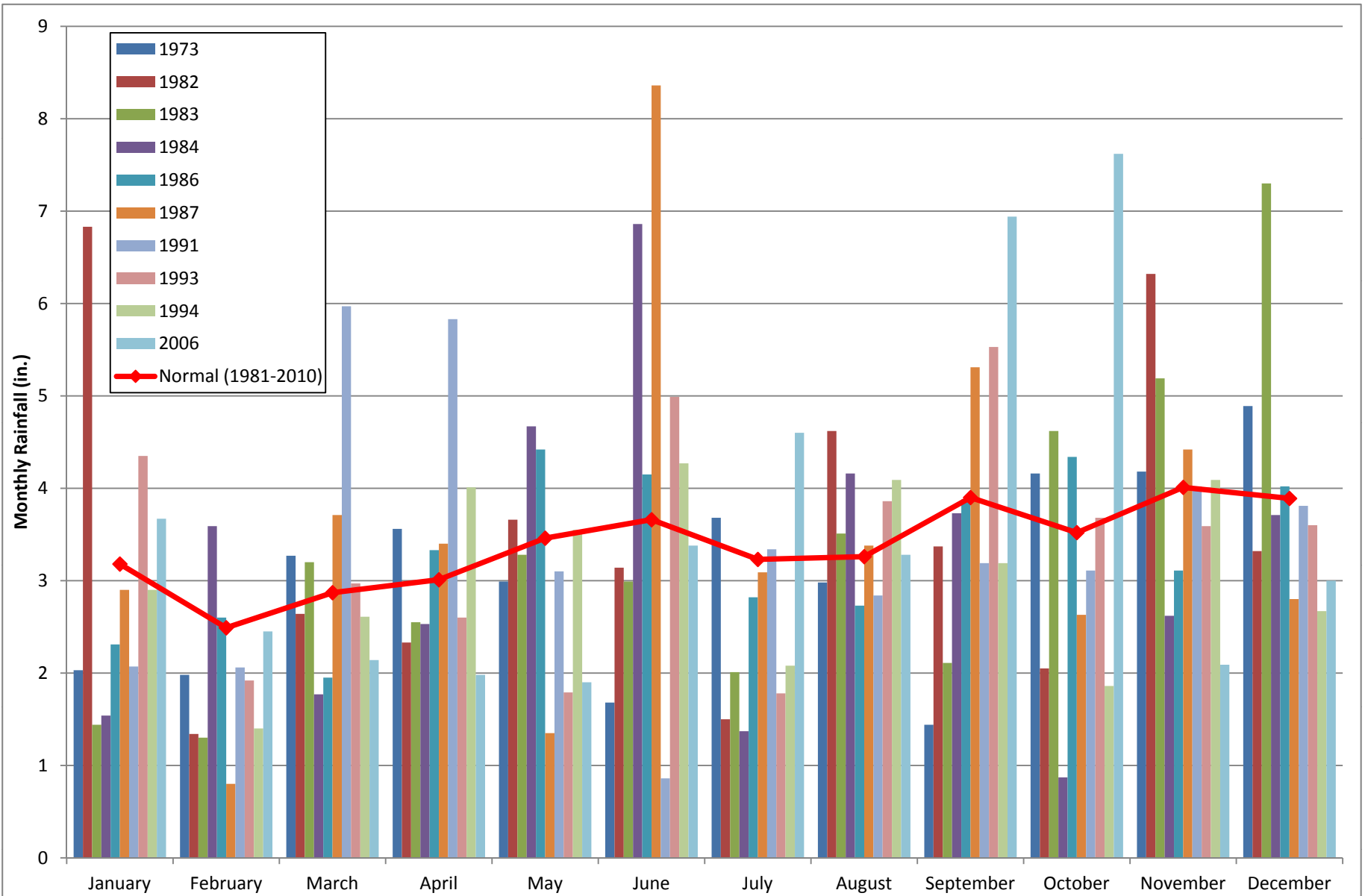


Figure 1. Monthly Rainfall Depths for Selected Years as Compared to Normal Monthly Rainfall (1981-2010)

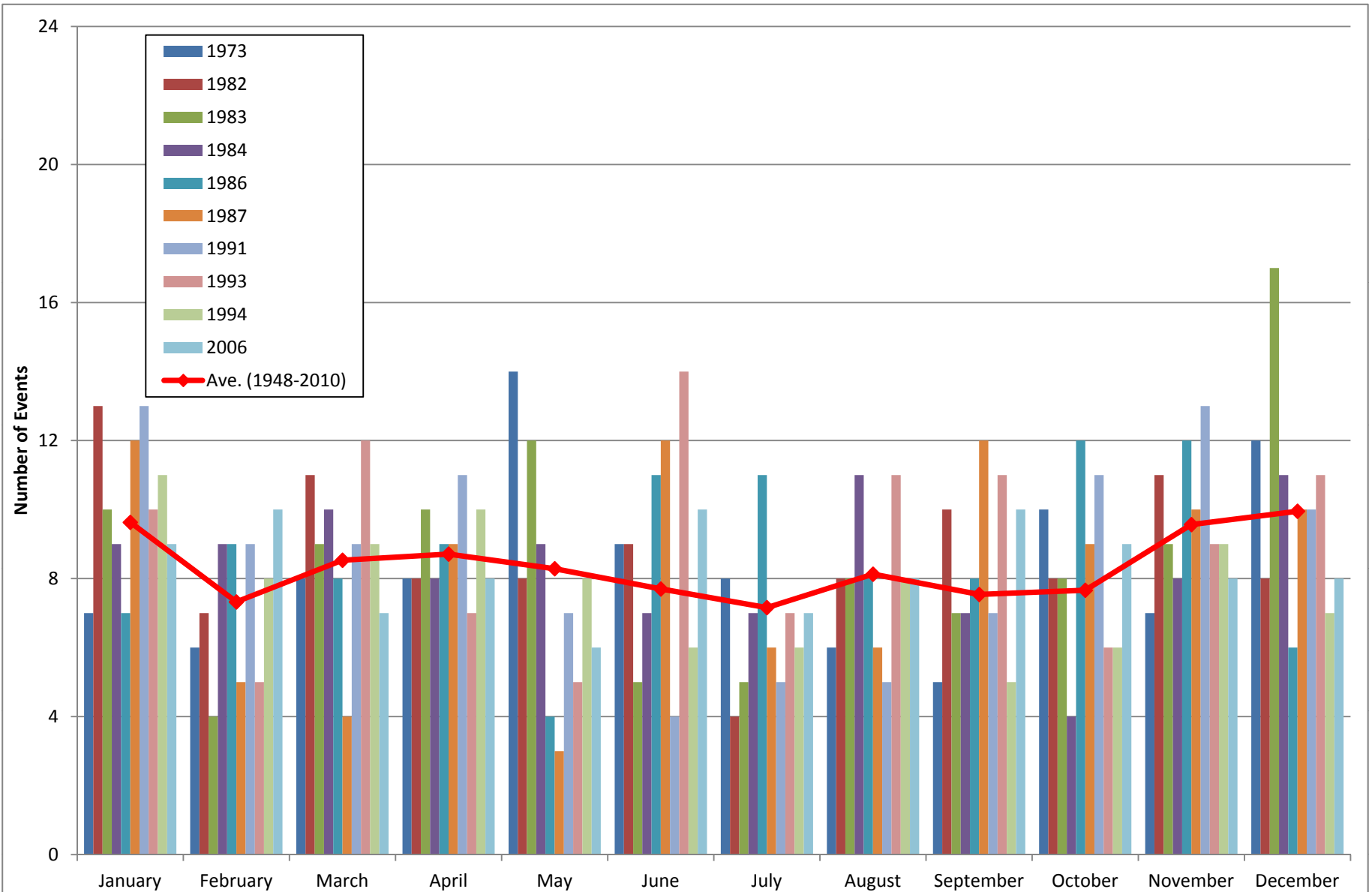


Figure 2. Monthly Rainfall Events of at Least 0.05" for Selected Years as Compared to Average Monthly Events (1948-2010)

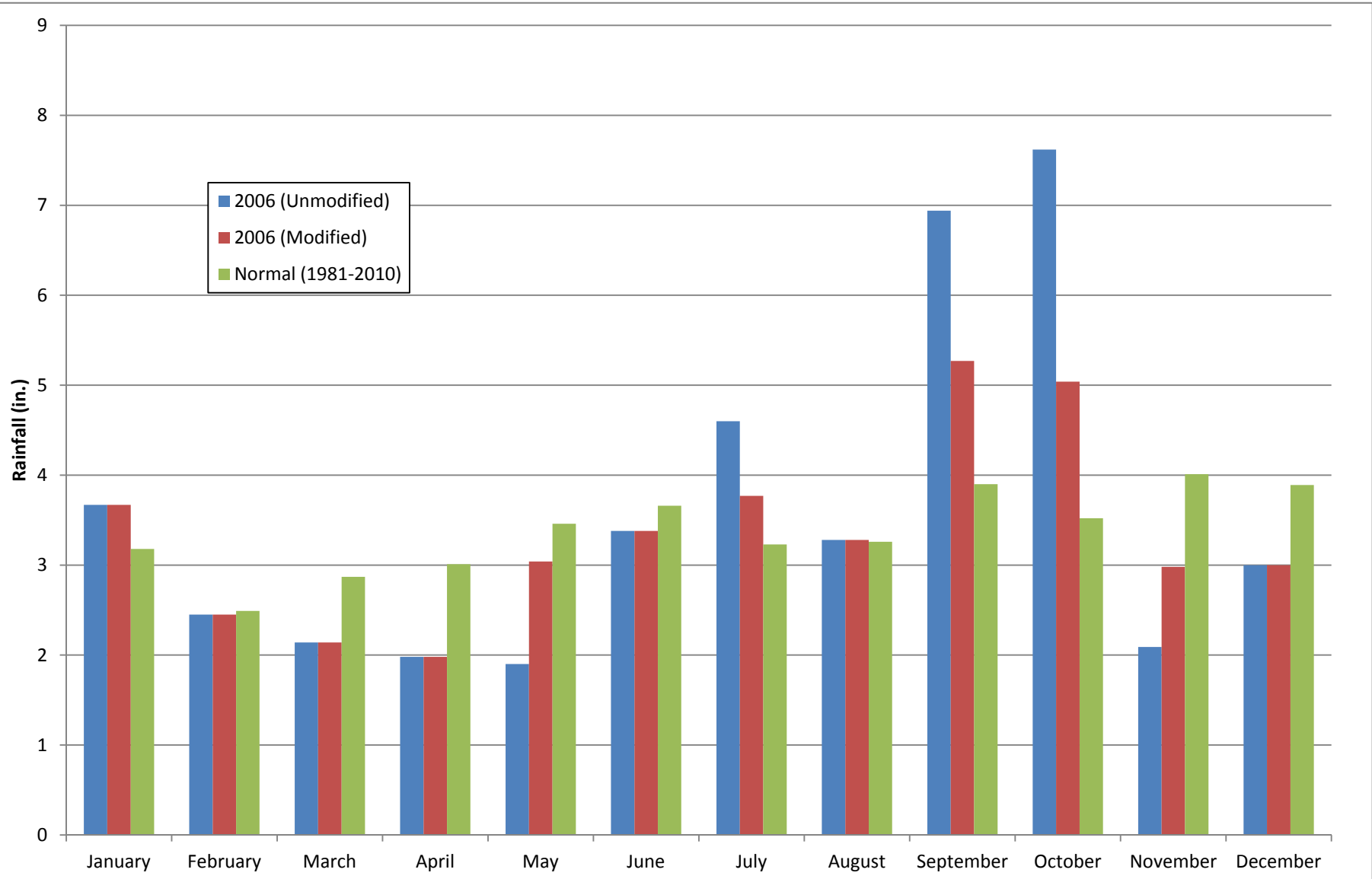


Figure 3. Comparison of Unmodified and Modified 2006 Monthly Rainfall Volumes as Compared to Normals (1981-2010)

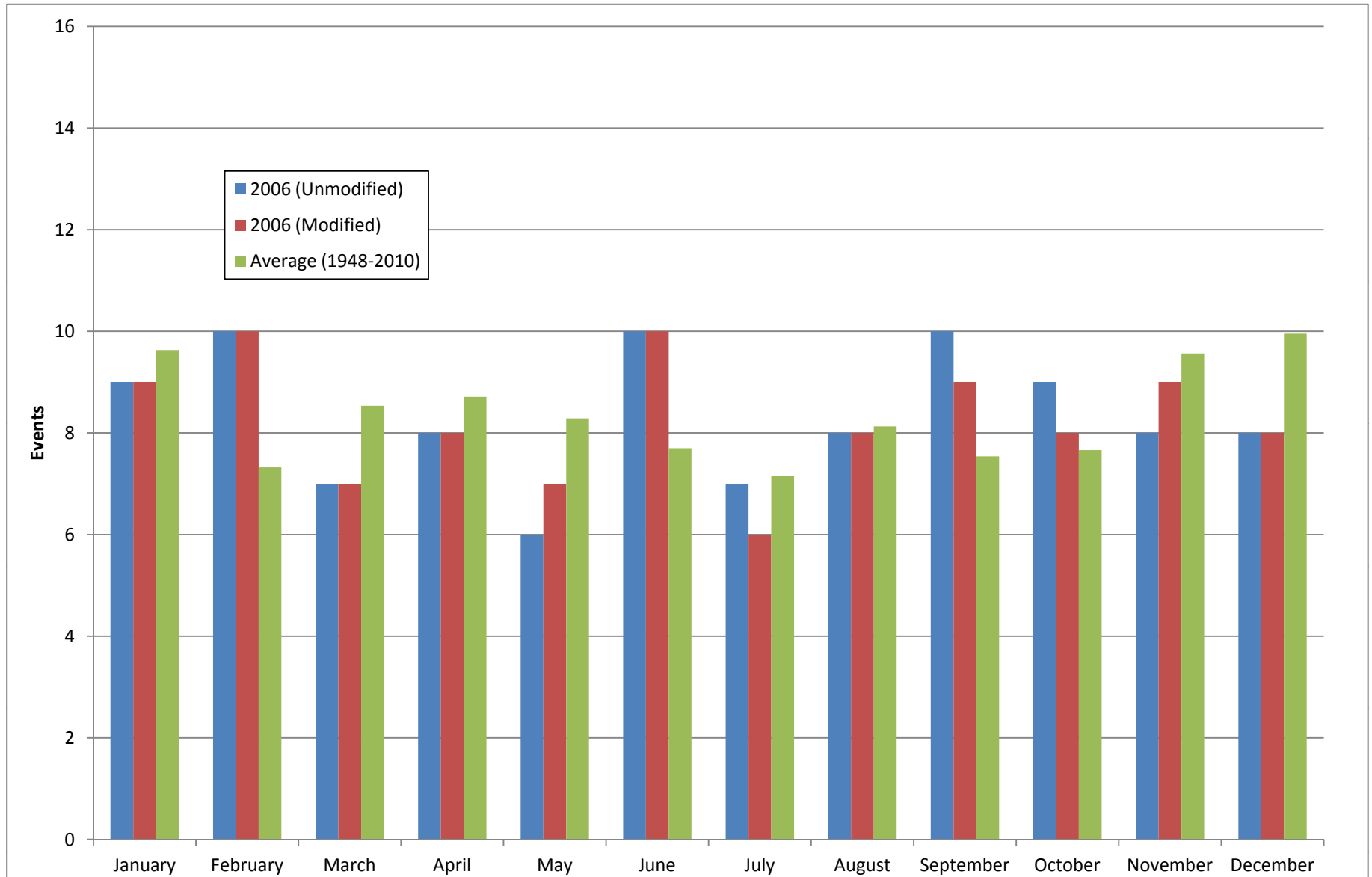


Figure 4. Comparison of Unmodified and Modified 2006 Monthly Rainfall Events of at Least 0.05" to Average (1948-2010) Monthly Rainfall Events

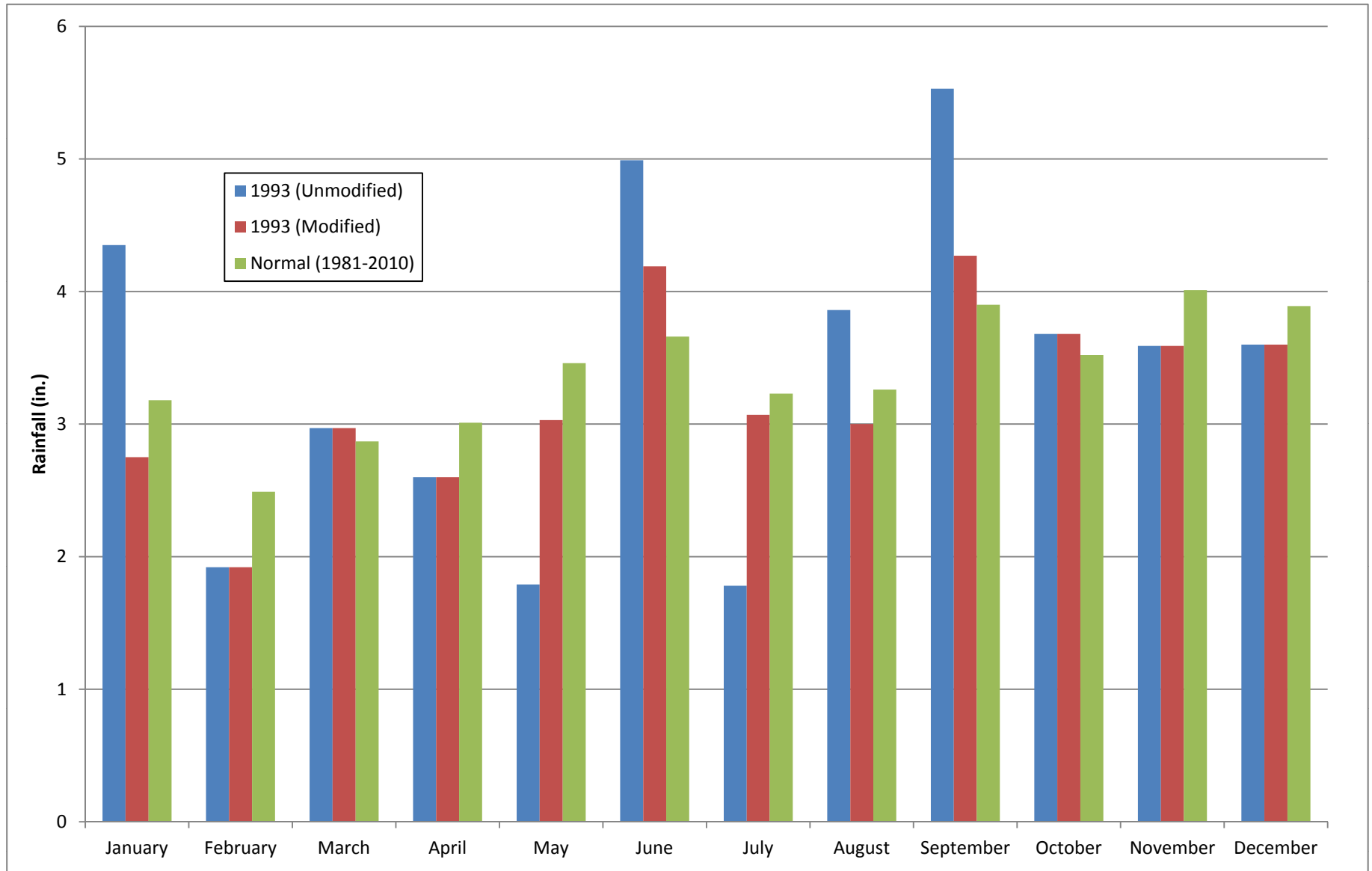


Figure 5. Comparison of Unmodified and Modified 1993 Monthly Rainfall Volumes as Compared to Normals (1981-2010)

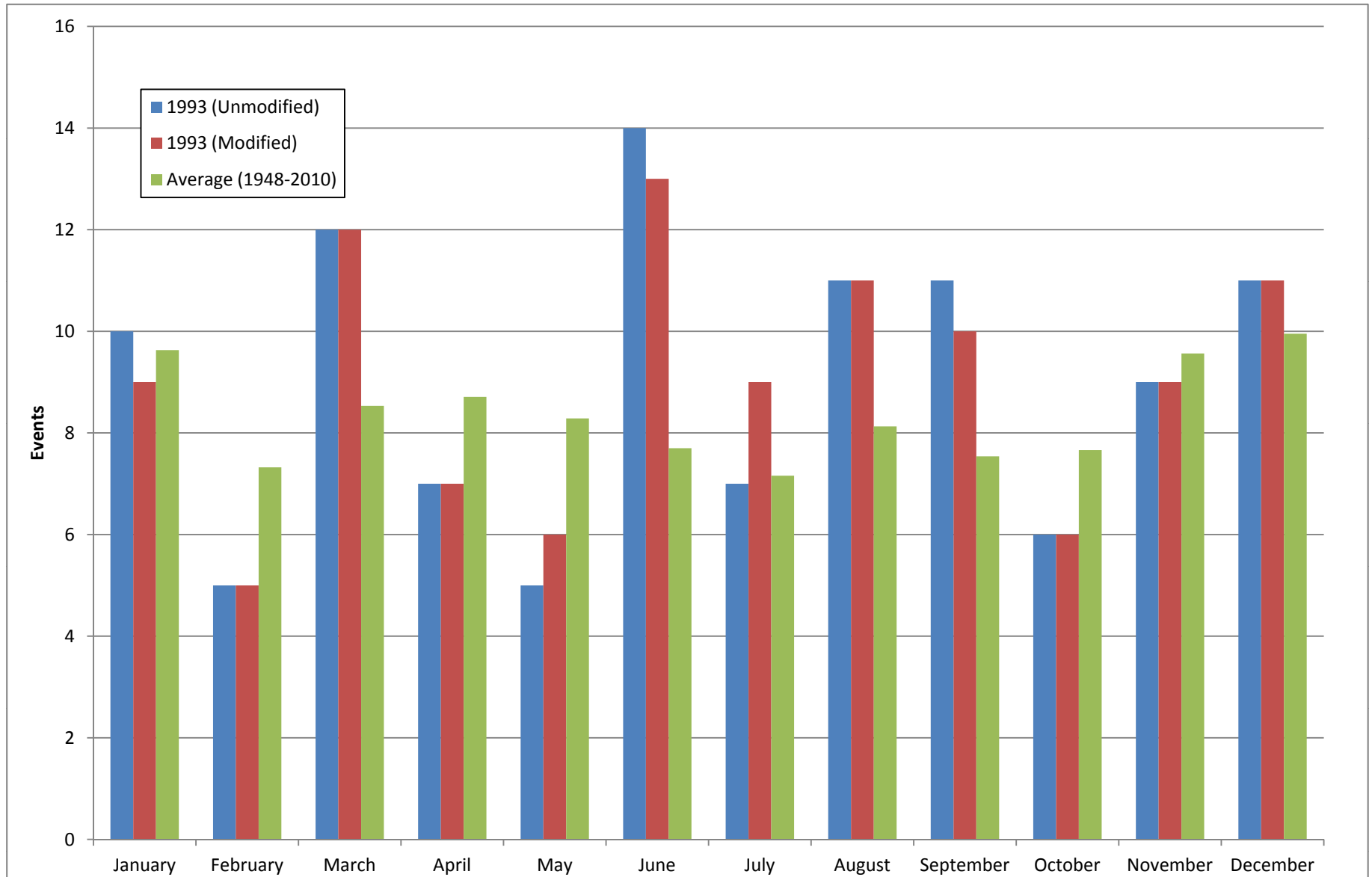


Figure 6. Comparison of Unmodified and Modified 1993 Monthly Rainfall Events of at Least 0.05" to Average (1948-2010) Monthly Rainfall Events

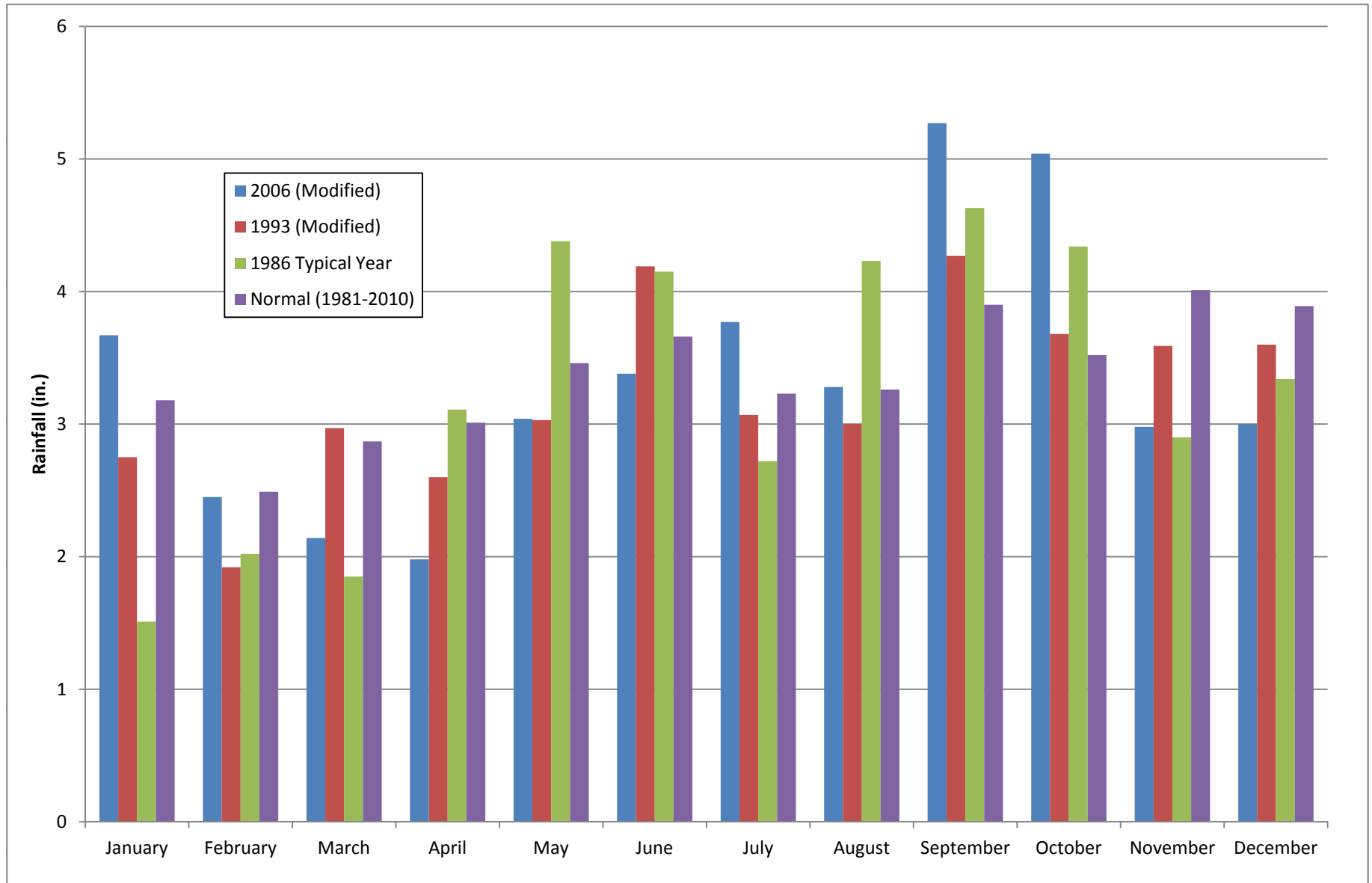


Figure 7. Comparison of Modified 2006, Modified 1993, and 1986 Typical Year Hyetograph Monthly Rainfall Volumes as Compared to Normals (1981-2010)

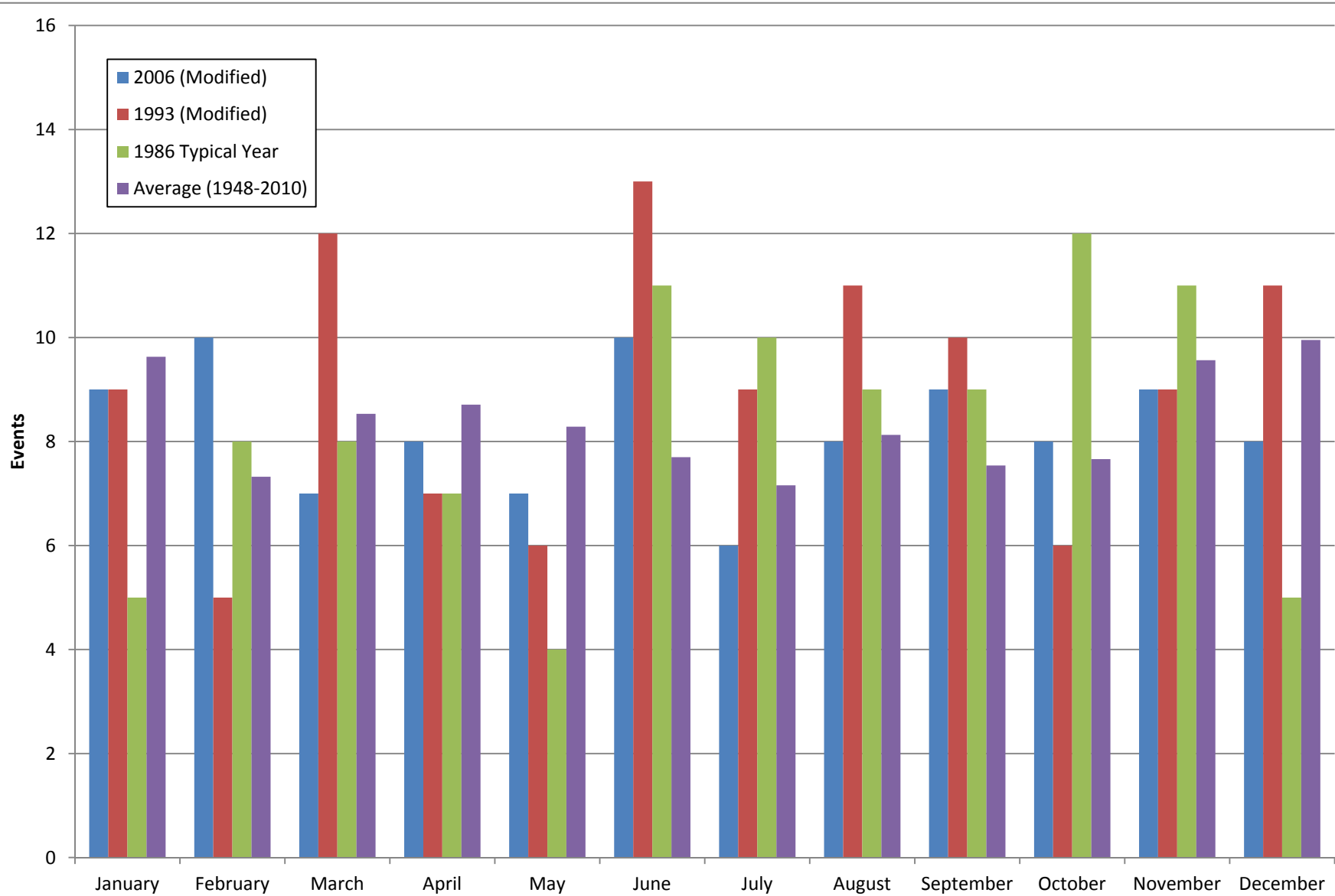


Figure 8. Comparison of Modified 2006, Modified 1993, and 1986 Typical Year Hyetograph Monthly Rainfall Events of at Least 0.05" to Average (1948-2010) Monthly Rainfall Events