Hydraulic Analysis of the USGS Stream Gages within the Rouge River Watershed

Alliance of Rouge Communities

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Prepared For: Alliance of Rouge Communities

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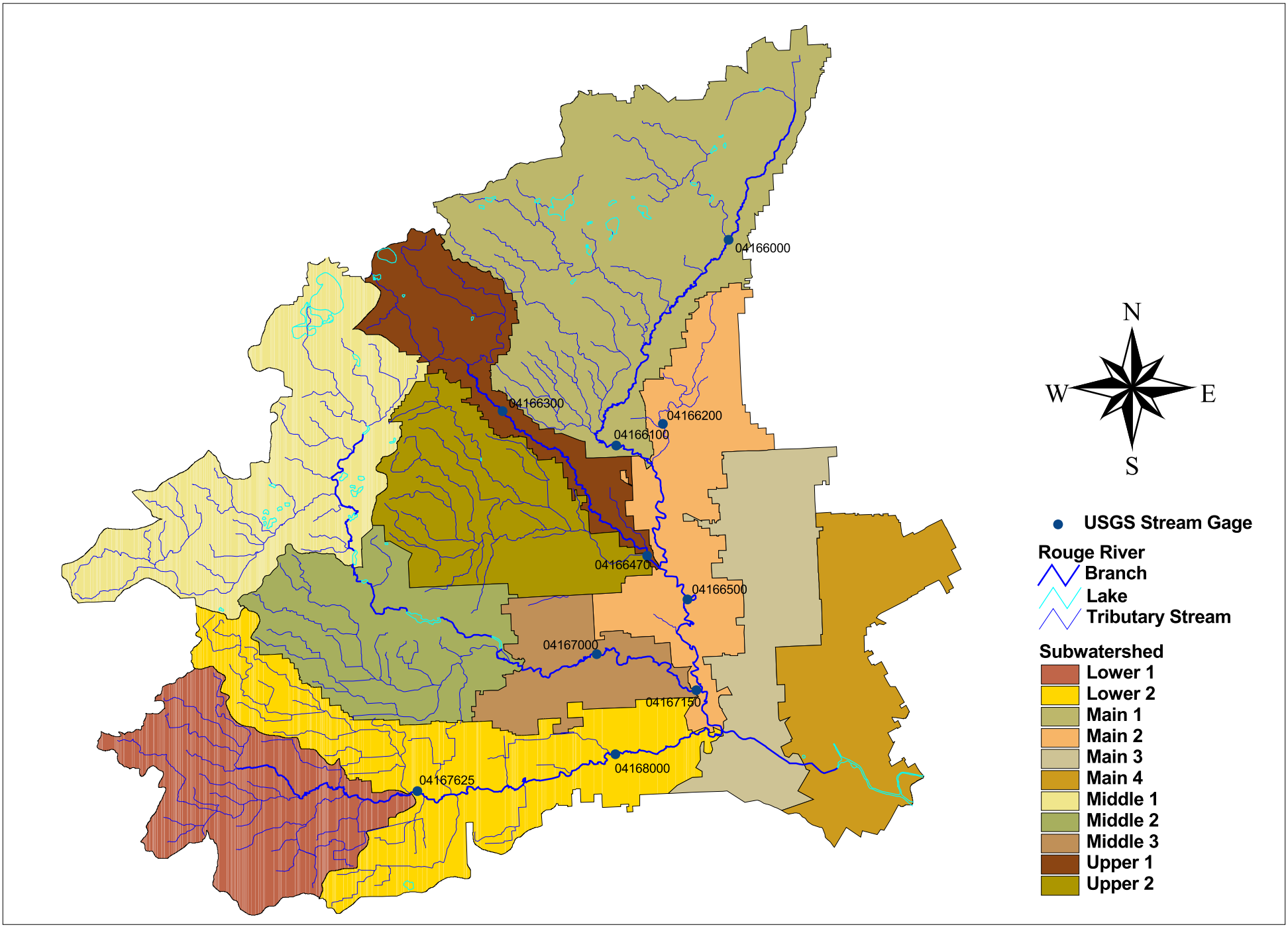
Introduction

The purpose of this study is to conduct a hydraulic analysis of the USGS stream gages within the Rouge River Watershed. This work was done in order to develop an updated Watershed Management Plan that contains a range of Best Management Practice (BMP) measures that may be applied in the watershed to reduce the flashiness of the river.

The annual peak, annual mean, daily mean, and 15-minute flow rate data for ten (10) USGS stream gages were analyzed to identify statistics and trends through the history of record especially for smaller, more frequent flood events. The current overbank, 1-month, and 15-day flood flow rates were determined at each of the USGS stream gage locations. Storm water BMP control measures that reduce flashiness (such as detention basin retrofits, new detention basins, and infiltration basins) will be developed, evaluated, and recommended from this analysis. Eleven (11) USGS stream gages with more than 5 years of record were initially considered for the analysis. There are seven (7) long-term and four (4) short-term USGS gages in the Rouge River Watershed with years of record that vary from 1931 through 2007. All gages were included except the short-term gage on the Lower Branch of the Rouge River at Dearborn at Military Road (04168400) which is within the Dearborn CSO Control Program's Contract 8 worksite. The worksite could not be accessed and the overbank level determined due to the construction activities altering the topography in the area.

Figure 1 shows the locations of the 10 USGS stream gages used in the hydrologic analysis.

Figure 1. Rouge Subwatersheds and USGS Stream Gage Locations



Data and Methods

Flow rate data were obtained from the USGS's website, http://mi.water.usgs.gov/. USGS flow rate data were not recorded digitally until the beginning of Water Year 1990. Only annual peak, annual mean, and daily mean flow rate data are digitally available from the USGS before this water year because they have been transferred from historical records. The USGS began recording 15-minute flow rate data at the beginning of Water Year 1990.

Missing 15-Minute Flow Rate Data

Data gaps existed throughout all of the 15-minute flow rate data. The missing data were treated differently depending on the extent of missing data. If only one 15-minute interval was missing, the missing 15-minute interval was given the same flow rate as its previous. Extents larger than this were left out of any calculations. A C++ program was written that recorded every gap in a gage's data. The following Table 1 shows the percentage of 15-minute data missing for each gage in the last ten water years.

Table 1. Percentage of Missing 15-Minute Flow Rate Data at each USGS Gage

USGS Gage Location	ID	Water Years Downloaded	Years of Record	Percent Missing	Actual Amount of Data (Years)
Main Rouge at Birmingham	04166000	1997 through 2006	10	4.29%	9.57
Main Rouge at Southfield	04166100	1997 through 2006	10	12.85%	8.71
Evans Ditch at Southfield	04166200	1997 through 2006	10	11.59%	8.84
Upper Rouge at Farmington	04166300	1997 through 2006	10	13.51%	8.65
Upper Rouge at Detroit	04166470	1999 through 2005	7	10.65%	6.25
Main Rouge at Detroit	04166500	1997 through 2006	10	10.49%	8.95
Middle Rouge near Garden City	04167000	1997 through 2006	10	10.77%	8.92
Middle Rouge at Dearborn Heights	04167150	1999 through 2005	7	8.08%	6.43
Lower Rouge at Wayne	04167625	2002 through 2006	5	0.39%	4.98
Lower Rouge at Inkster	04168000	1997 through 2006	10	11.75%	8.82

If annual peak or daily mean data were missing, the entire water year was excluded from any analyses. Daily mean flow rate data did not have any gaps because the USGS fills in any missing data with correlations based off of surrounding gage readings.

Correlating Daily Mean Flow Rate to Peak 15-Minute Flow Rate for Small Flood Events

A method of correlating daily mean to 15-minute peak flow rate for smaller flood events was developed for the 10 USGS stream gages in the analysis. This correlation provides a way of estimating the peak flood flow rate of historical daily mean data, thereby allowing trends in peak flow rate to be observed for the entire period of record.

Flood events were separated out for a recent year of 15-minute and daily mean flow rate data. The period chosen was from February 12, 2006 through February 11, 2007 or a gage's last full year of data if it had been decommissioned before this period. The peak 15-minute and the daily mean flow rate for each flood event in the period was tabulated, and a linear correlation between peak 15-minute flow rate and the daily mean flow rate was developed for each gage following the formula.

$$y = mx + b \qquad \text{Equation 1}$$

Where y is the peak flow rate in cfs, x is the daily mean flow rate in cfs, and m and b are statistically determined coefficients. Table 2 shows the coefficients m and b as well as the square of the correlation coefficient, R, for each USGS stream gage. The number of data points (small flood events) used in the correlation varied from 36 to 47 for the one year period.

Table 2. Daily Mean to Peak Flow Rate Correlation Coefficients for Each USGS Stream Gage

USGS Stream Gage Location	I.D. Number	m	b	R^2
Main Rouge at Birmingham	04166000	1.6089	-5.4796	0.9828
Main Rouge at Southfield	04166100	1.3086	19.177	0.9702
Evans Ditch at Southfield	04166200	3.4119	19.689	0.8529
Upper Rouge at Farmington	04166300	1.5828	-0.9561	0.9697
Upper Rouge at Detroit	04166470	1.181	29.721	0.9397
Main Rouge at Detroit	04166500	1.217	30.786	0.9762
Middle Rouge near Garden City	04167000	1.0654	62.005	0.9189
Middle Rouge at Dearborn Heights	04167150	1.1276	20.703	0.9755
Lower Rouge at Wayne	04167625	1.2484	22.94	0.9427
Lower Rouge at Inkster	04168000	1.1056	52.064	0.9506

All of the correlations between daily mean and peak 15-minute flow rate for the numerous small storm events were good to excellent. Plots of the correlations are located in Appendix A, Daily Mean Flow Rate to Peak 15-Minute Flow Rate Correlation Plots.

Return Periods of Flow Rates

Flood events above a cut-off flow rate of twice the average daily mean flow rate of the entire period of record of daily mean flow rates (or less if more events were needed) were separated out of 10 years of 15-minute flow rate data (Water Years 1997 through 2006). Events with multiple peaks were counted as a single event unless the flow rate dropped below the cut-off flow rate between peaks. A partial-duration series analysis was performed for each gage using these sets

of peak flow rates. Table 3 gives the peak flood flow rates for the 1-month and 15-day return periods for each of the USGS stream gages as determined by the partial-duration series analysis.

Table 3. 1-Month and 15-Day Return Period Peak Flood Flow Rates

USGS Stream Gage Location	I.D. Number	1-Month	15-Day	Cut-off
		Flow Rate (cfs)	Flow Rate (cfs)	Flow Rate (cfs)
Main Rouge at Birmingham	04166000	110	52	43
Main Rouge at Southfield	04166100	357	190	140
Evans Ditch at Southfield	04166200	190	86	18
Upper Rouge at Farmington	04166300	81	46	29
Upper Rouge at Detroit	04166470	274	153	106
Main Rouge at Detroit	04166500	650	363	257
Middle Rouge near Garden City	04167000	315	173	102
Middle Rouge at Dearborn Heights	04167150	339	175	150
Lower Rouge at Wayne	04167625	266	130	110
Lower Rouge at Inkster	04168000	352	171	125

Plots of the partial-duration series analysis as well as an annual peak analysis for each gage are located in Appendix B, Flood Statistics Plots.

Overbank Flood Flow Rate

Both the left and right low flow channel overbank (or bankfull) flood stages were surveyed on February 12, 2008 at each USGS stream gage location. USGS stage-discharge rating tables were obtained and used to determine an overbank flood flow rate from the lower of the two overbank flood stages at each site and are shown in Table 3. From the partial-duration series analysis, the

return period of the overbank flood flow rate was determined and is also shown in Table 4. The return period of the overbank flood varied from 1.7 to 21.1 months.

Table 4. Overbank Flood Flow Rate and Return Period

USGS Stream Gage	I.D. Number	Measured River Stage on 2/12/2008 (feet)	Overbank Flood Stage (feet)		Overbank Flood Flow Rate (cfs)	Return Period (months)
			Left	Right		
Main Rouge at Birmingham	04166000	2.0	5.1	4.8	495	8.6
Main Rouge at Southfield	04166100	5.2	10.3	9.6	664	2.2
Evans Ditch at Southfield	04166200	6.0	10.8	10.1	357	2.8
Upper Rouge at Farmington	04166300	3.2	5.8	6.0	478	21.1
Upper Rouge at Detroit	04166470	1.7	5.5	6.1	314	1.3
Main Rouge at Detroit	04166500	6.5	12.9	12.8	1309	3.5
Middle Rouge near Garden City	04167000	3.1	6.8	8.6	525	2.2
Middle Rouge at Dearborn Heights	04167150	3.0	7.8	6.9	550	2.4
Lower Rouge at Wayne	04167625	4.1	7.6	7.9	321	1.2
Lower Rouge at Inkster	04168000	3.9	9.6	11.0	1047	7.2

Histograms of Flood Events

Equation 1 was applied to the entire period of record of daily mean data. Histograms were created by grouping the number of flood events per water year that exceeded the current overbank, 1-month, and 15-day flood peak flow rates. The histograms are located in Appendix C, Flood Frequency Histograms. These histograms show an increasing trend over time in the 1-month and 15-day flood flow rates. Clear trends for the overbank flood event were not evident.

Calculating Volumes of Flood Events

Flood volumes were calculated for every flood event that exceeded the annual mean flow rate within the last ten water years (1997 through 2006) of available 15-minute flow rate data. The flood volume above the annual mean flow rate was summed for each event. The volumes are ranked from largest to smallest and given a color according to what the peak flow rate during the flood exceeded. These plots are presented in Appendix D, Flood Volume Plots.

Annual Peak and Annual Mean Flow Rates

Annual peak and annual mean flow rate data from each USGS gage were plotted and can be found in Appendix E, Annual Peak Flow Rate Plots and Appendix F, Annual Mean Flow Rate Plots. Tables of these data are found in Appendix G, USGS Annual Peak and Mean Flow Rate Data.

Flashiness Reduction Targets

The 15-day and 1-month flood events can be used to develop frequency reduction targets for the design of storm water BMP control measures. The flood volume plots provide a method of determining the amount of storm water needed to be managed to accomplish these targets. For example, to reduce the frequency of the current 15-day return period to a 1-month return period, one would have to store and release the volume of storm water per flood event that half of the 15-day flood events fall below. Table 5 summarizes this for each USGS stream gage.

Table 5. Storage Volume Required to Halve the Current 15-Day Flood Flow Rate Frequency.

USGS Stream Gage Location	To Halve 15-Day Flood Frequency	To Halve 1-Month Flood Frequency	Release Rate (cfs/acre)
	Inches Over Watershed	Inches Over Watershed	
Main Rouge at Birmingham	0.067	0.187	0.0013
Main Rouge at Southfield	0.099	0.336	0.0014
Evans Ditch at Southfield	0.167	0.319	0.0016
Upper Rouge at Farmington	0.147	0.318	0.0016
Upper Rouge at Detroit	0.034	0.249	0.0013
Main Rouge at Detroit	0.121	0.209	0.0014
Middle Rouge near Garden City	0.087	0.216	0.0015
Middle Rouge at Dearborn Heights	0.112	0.227	0.0014
Lower Rouge at Wayne	0.159	0.362	0.0022
Lower Rouge at Inkster	0.098	0.284	0.0018

2000 Land Use and DCIA for USGS Stream Gages

Each USGS stream gage's tributary drainage area was delineated to the subarea level using ArcView. Appendix H, USGS Stream Gage Drainage Areas shows the subareas assigned to each USGS stream gage. Area-weighted land use percentages were determined from the Year 2000 SEMCOG data. The DCIA values for each land use category were obtained from previous WMM modeling calibration work and were used to calculate an area-weighted DCIA for each gage. Land use breakdowns and area-weighted DCIAs for each USGS stream gage are presented in Table 6.

Table 6. Land Use Breakdown and Area-Weighted DCIA for USGS Stream Gages

USGS Stream Gage Location	I.D. Number	Drainage Area (acres)	2000 Land Use Breakdown (% of total area)									WMM DCIA (%)
			Forest/ Rural Open	Urban Open	Agricultural/ Pasture	Medium Density Residential	High Density Residential	Commercial	Industrial	Highways	Water/ Wetlands	
Main Rouge at Birmingham	04166000	19,404	5.9	4.5	0.4	64.5	4.0	7.4	2.2	2.4	8.6	11.8
Main Rouge at Southfield	04166100	54,964	5.9	5.5	0.2	64.9	5.4	9.8	1.0	1.8	5.5	10.1
Evans Ditch at Southfield	04166200	5,757	4.4	5.2	0.0	55.1	5.0	21.5	0.5	2.6	0.5	29.5
Upper Rouge at Farmington	04166300	11,044	14.1	7.7	1.0	50.5	6.9	8.6	2.4	1.6	7.2	34.6
Upper Rouge at Detroit	04166470	40,758	8.5	7.3	0.4	53.9	5.2	13.8	4.2	2.6	4.2	26.4
Main Rouge at Detroit	04166500	113,007	6.5	6.5	0.2	61.0	5.2	12.5	2.7	2.3	4.4	18.9
Middle Rouge near Garden City	04167000	67,673	16.2	5.1	7.2	35.2	4.5	8.8	10.4	2.3	10.1	17.2
Middle Rouge at Dearborn Heights	04167150	72,308	15.3	5.6	6.7	37.2	4.3	9.1	9.8	2.3	9.7	17.3
Lower Rouge at Wayne	04167625	35,737	20.4	4.8	27.0	23.6	1.4	2.5	7.7	1.5	11.0	8.5
Lower Rouge at Inkster	04168000	55,399	15.6	5.7	18.9	29.5	1.7	5.2	9.7	1.5	12.1	13.4

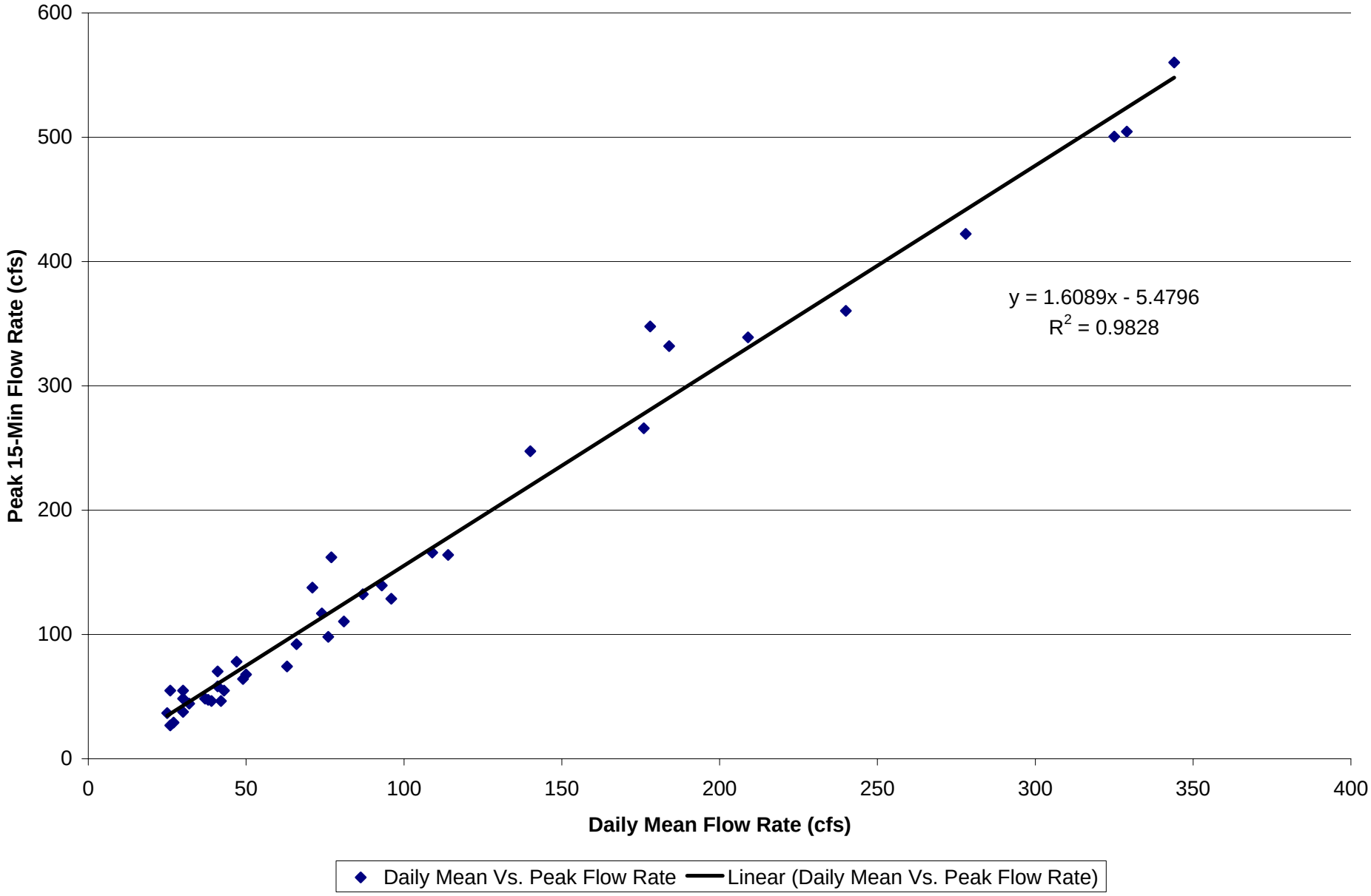
Discussion

The main factor in a USGS gage site's overbank flood frequency was its channel morphology. The return period of the overbank flood varied considerably among the USGS gages from 1.2 to 21.1-months. In some instances, the low flow channel has had time to deepen and widen to adapt to urbanization of the tributary watershed. Also, overbank flood frequency and its relevance to bank stability were not considered in this analysis.

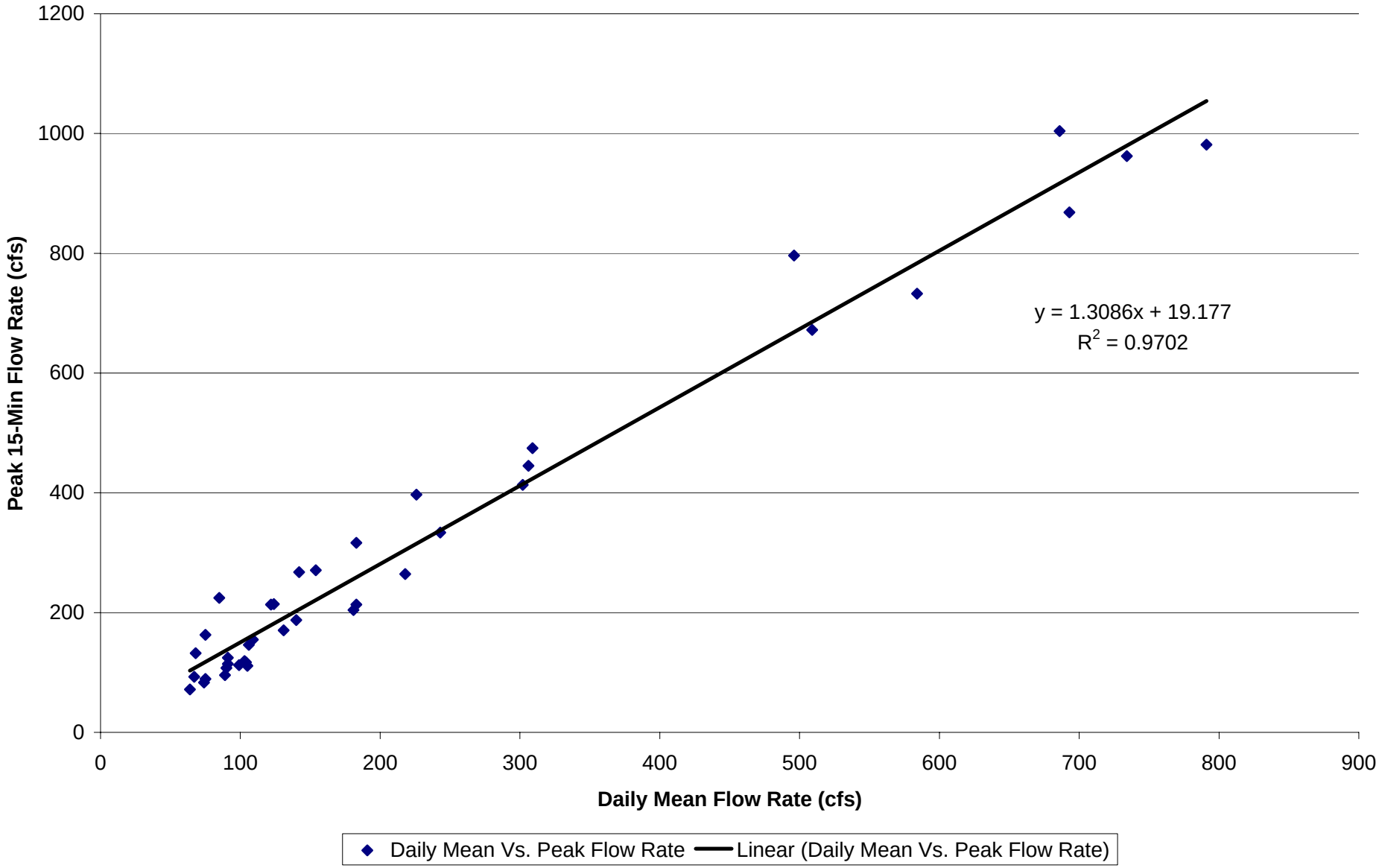
Histograms of the overbank flood frequency do not show a clear increasing trend over time. However, clear increasing trends in the frequency of smaller flood flow rates (such as the current 1-month and 15-day events) are evident for all of the seven long-term gages. The current 15-day flood flow rate is being exceeded about twice as often in recent years as in the 1950's and 1960's.

Appendix A. Daily Mean Flow to Peak 15-Minute Flow Rate Correlation Plots

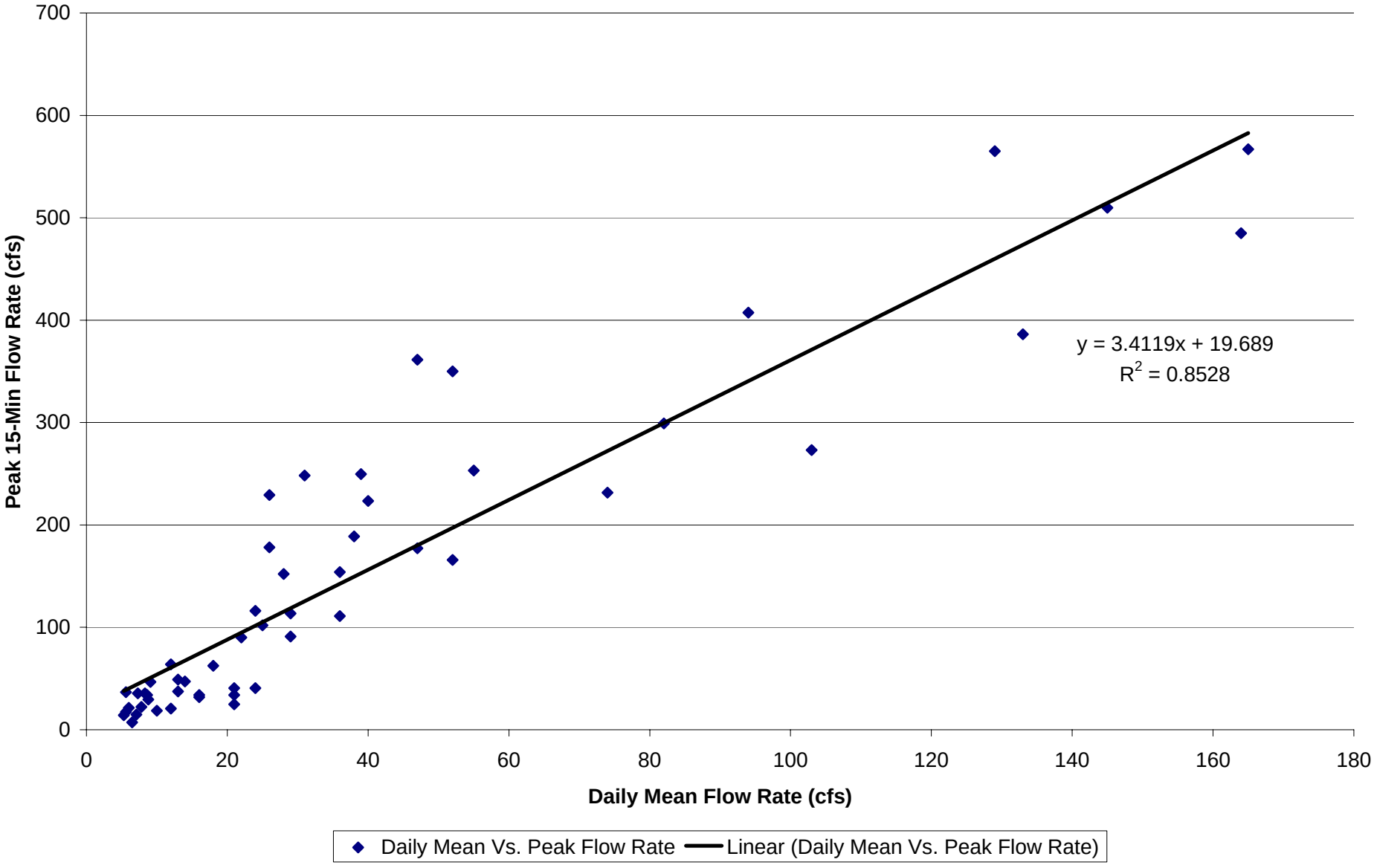
Main Branch of the Rouge River at Birmingham
Peak Flow Rate Versus Daily Mean Flow Rate for Flood Events from 2/12/2006 to 2/12/2007



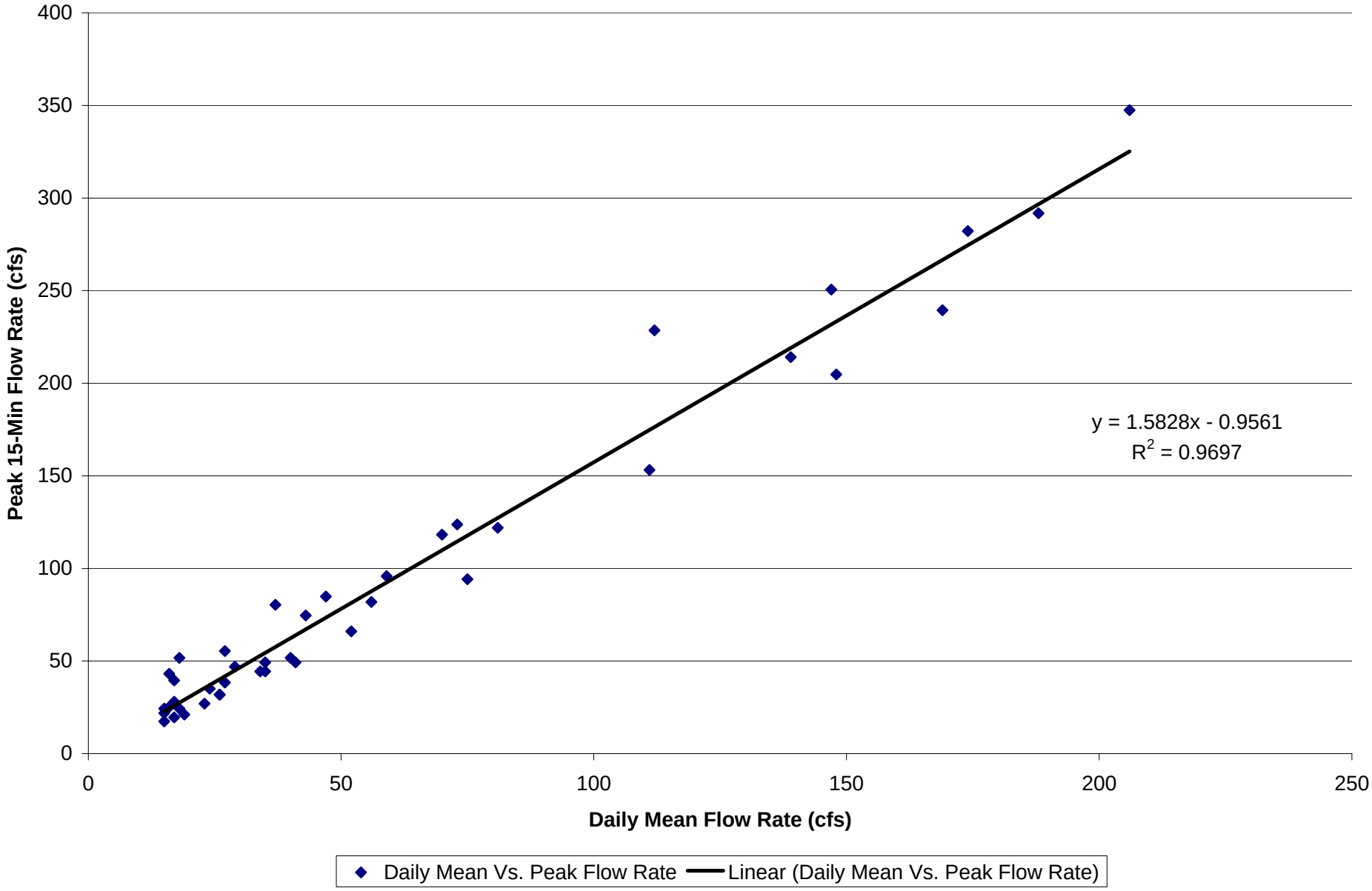
Main Branch of the Rouge River at Southfield
Peak Flow Rate Versus Daily Mean Flow Rate for Flood Events from 2/12/2006 to 2/12/2007



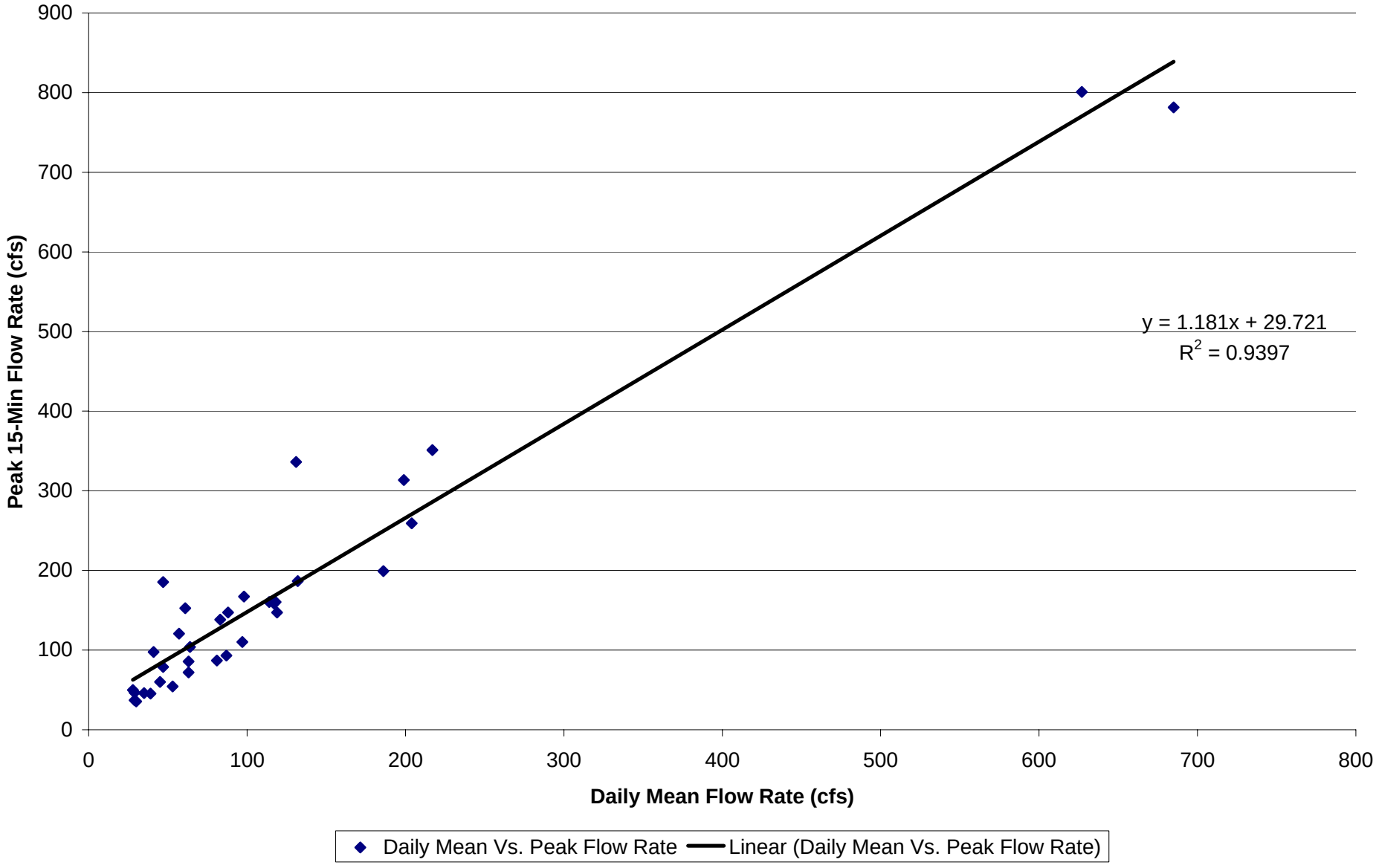
Evans Ditch at Southfield
Peak Flow Rate Versus Daily Mean Flow Rate for Flood Events from 2/12/2006 to 2/12/2007



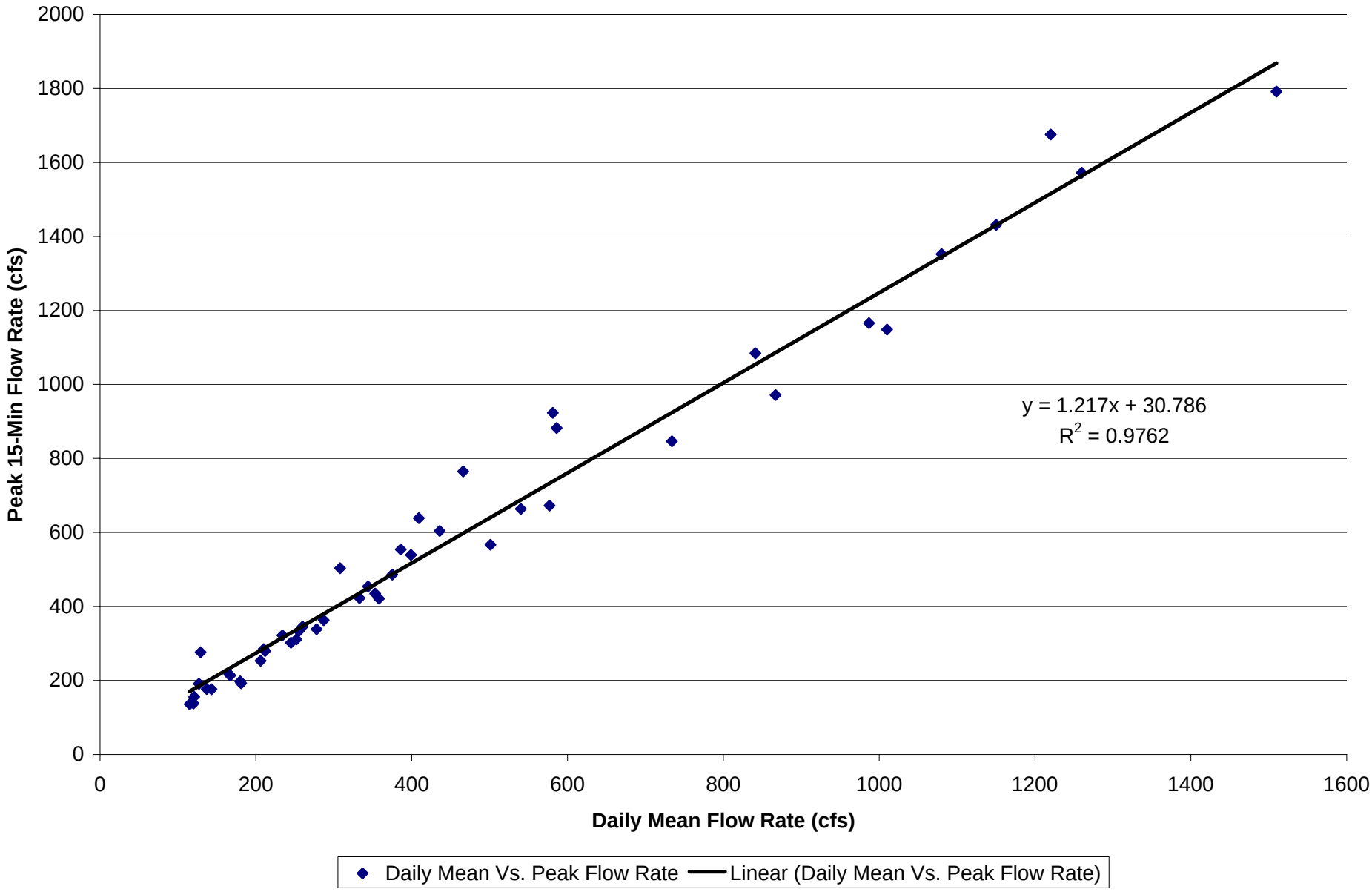
Upper Branch of the Rouge River at Farmington
Peak Flow Rate Versus Daily Mean Flow Rate for Flood Events from 2/12/2006 to 2/12/2007



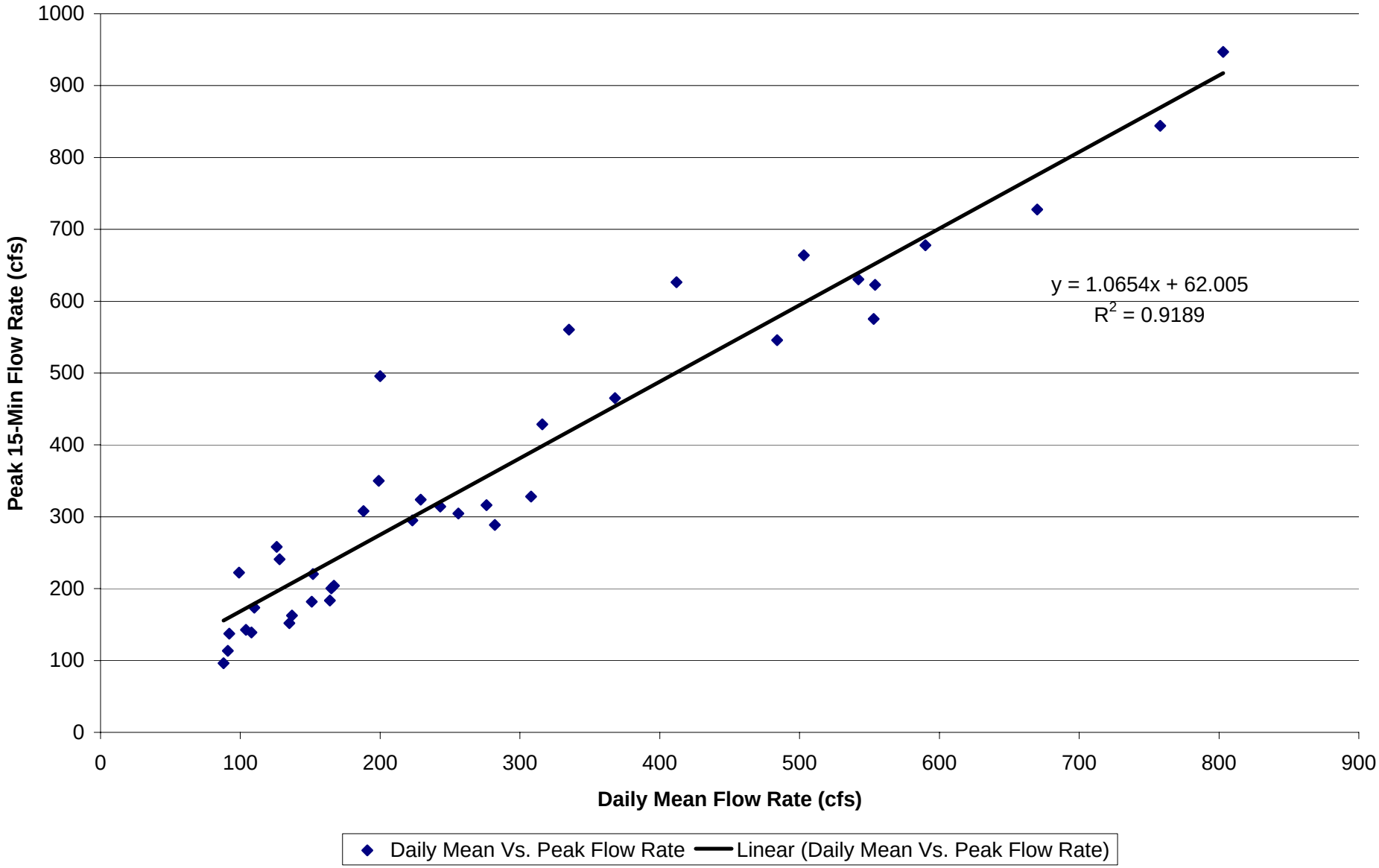
Upper Branch of the Rouge River at Detroit
Peak Flow Rate Versus Daily Mean Flow Rate for Flood Events from 12/31/2004 to 12/31/2005



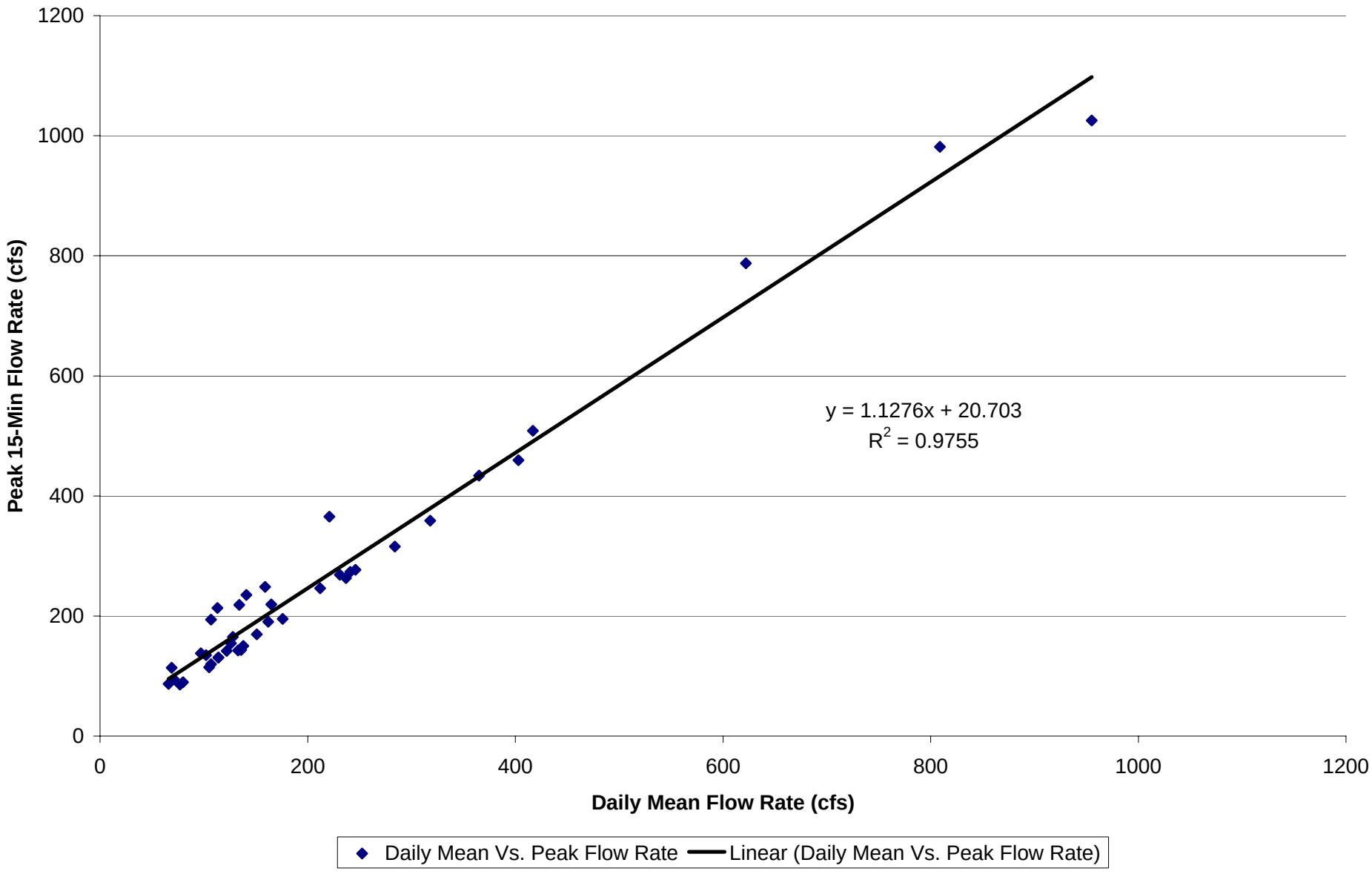
Main Branch of the Rouge River at Detroit
Peak Flow Rate Versus Daily Mean Flow Rate for Flood Events from 2/12/2006 to 2/12/2007



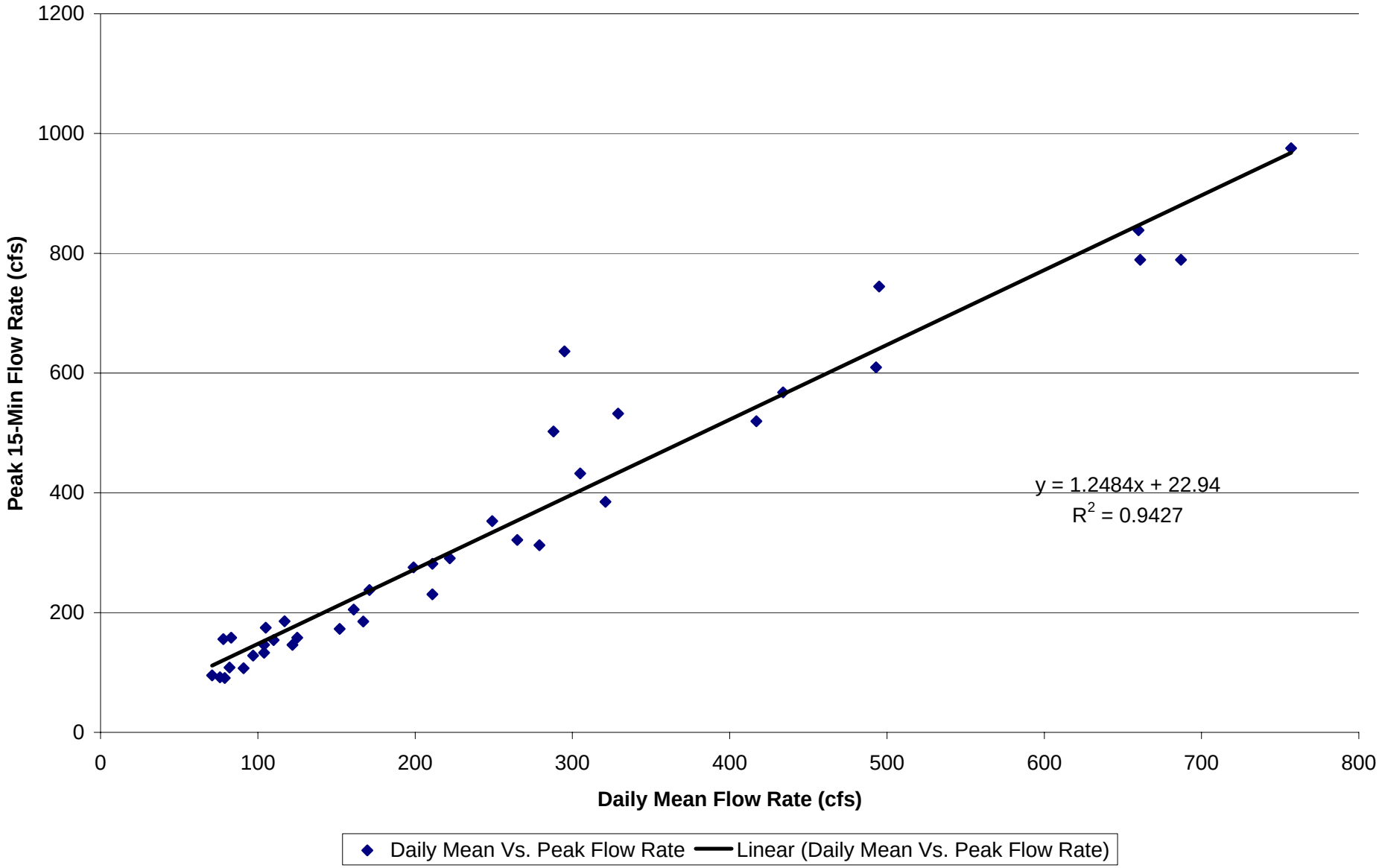
Main Branch of the Rouge River at Detroit
Peak Flow Rate Versus Daily Mean Flow Rate for Flood Events from 2/12/2006 to 2/12/2007



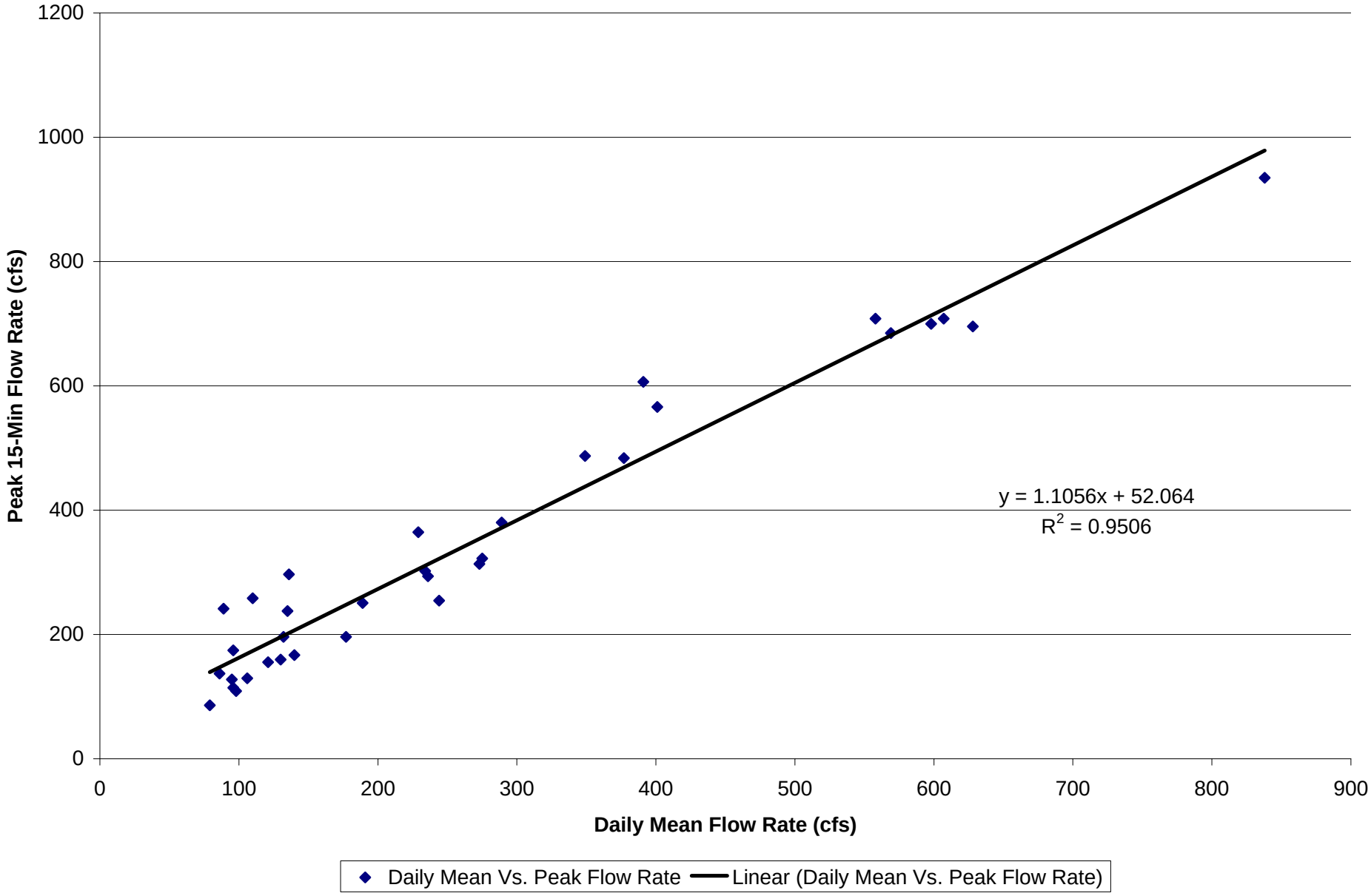
Middle Branch of the Rouge River at Dearborn Heights
Peak Flow Rate Versus Daily Mean Flow Rate for Flood Events from 12/31/2004 to 12/31/2005



Lower Branch of the Rouge River at Wayne
Peak Flow Rate Versus Daily Mean Flow Rate for Flood Events from 12/31/2005 to 12/31/2006

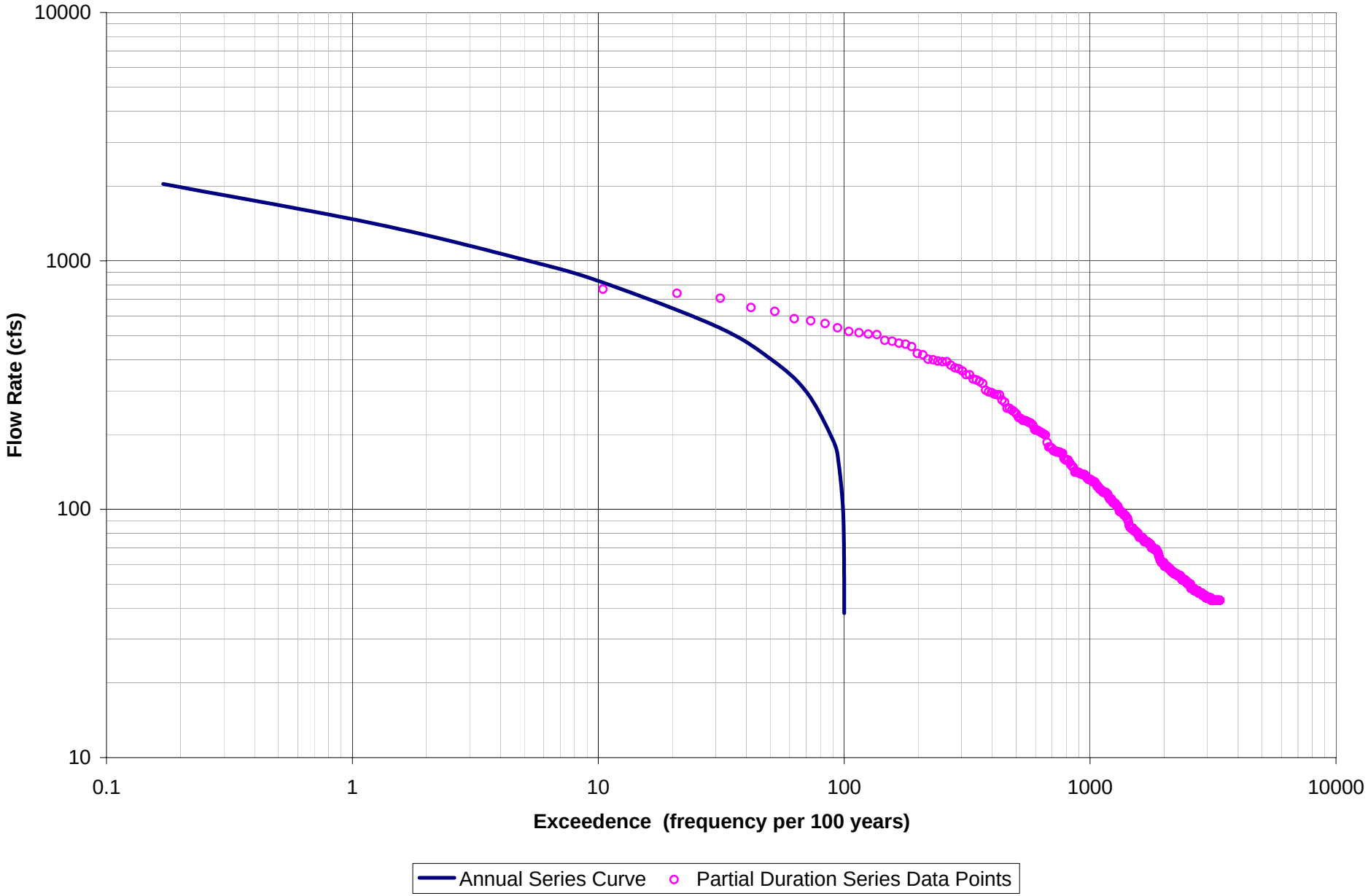


Lower Branch of the Rouge River at Inkster
Peak Flow Rate Versus Daily Mean Flow Rate for Flood Events from 2/12/2006 to 2/12/2007

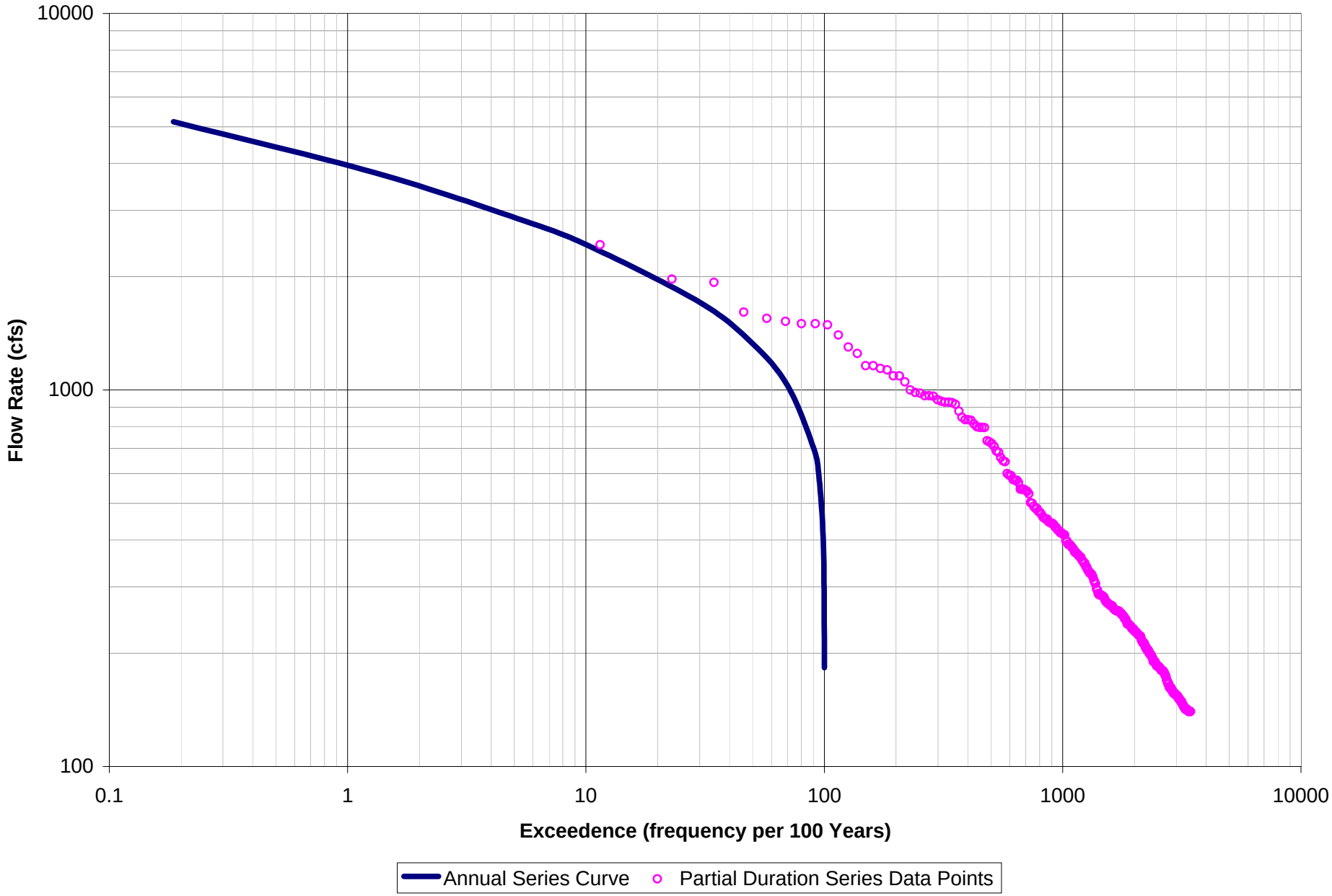


Appendix B. Flood Statistics Plots

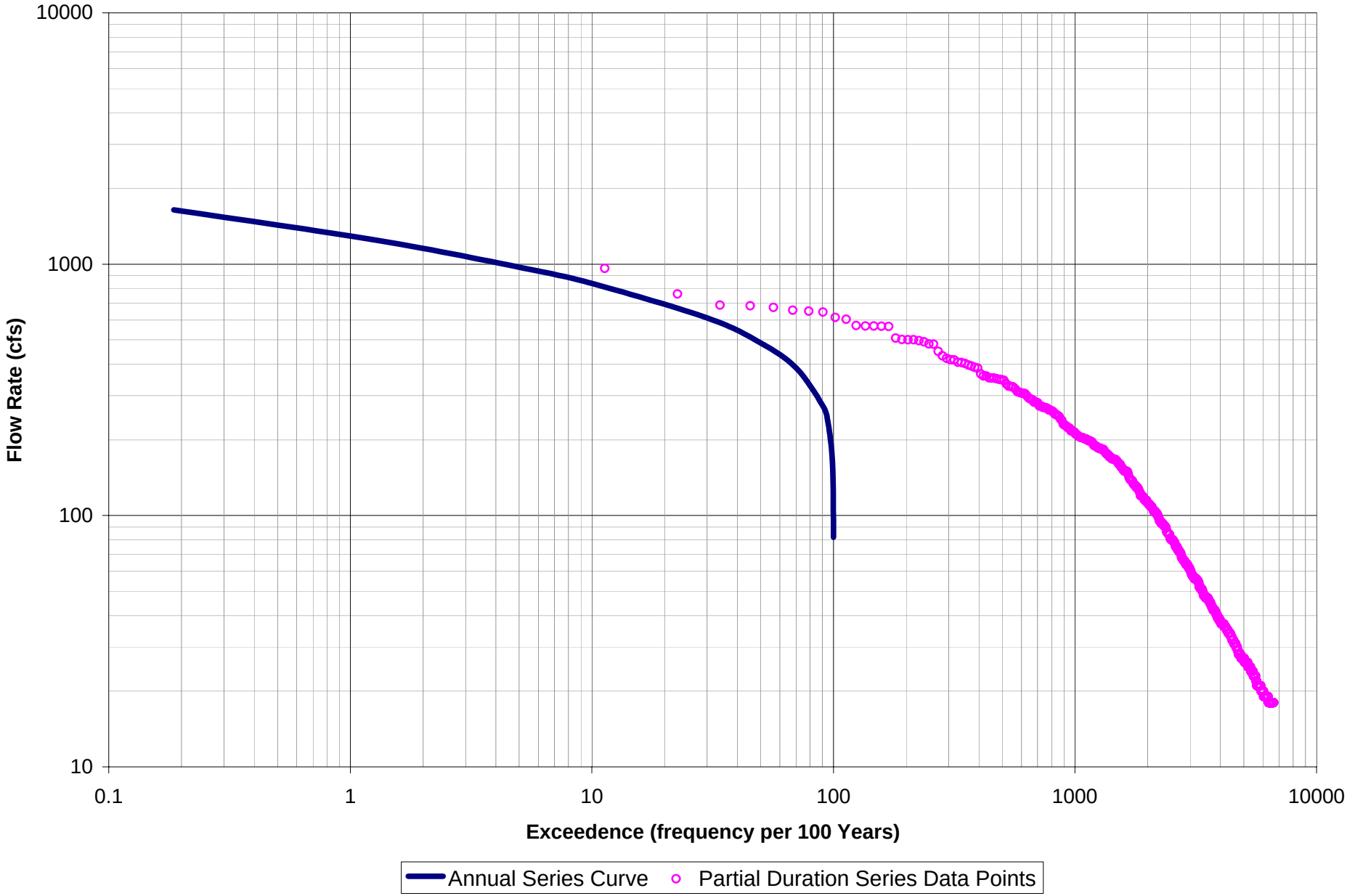
Main Branch of the Rouge River at Birmingham
Partial Duration Series Plot for Water Years 1997 through 2006 and
Annual Series Curve for Water Years 1951 through 2006

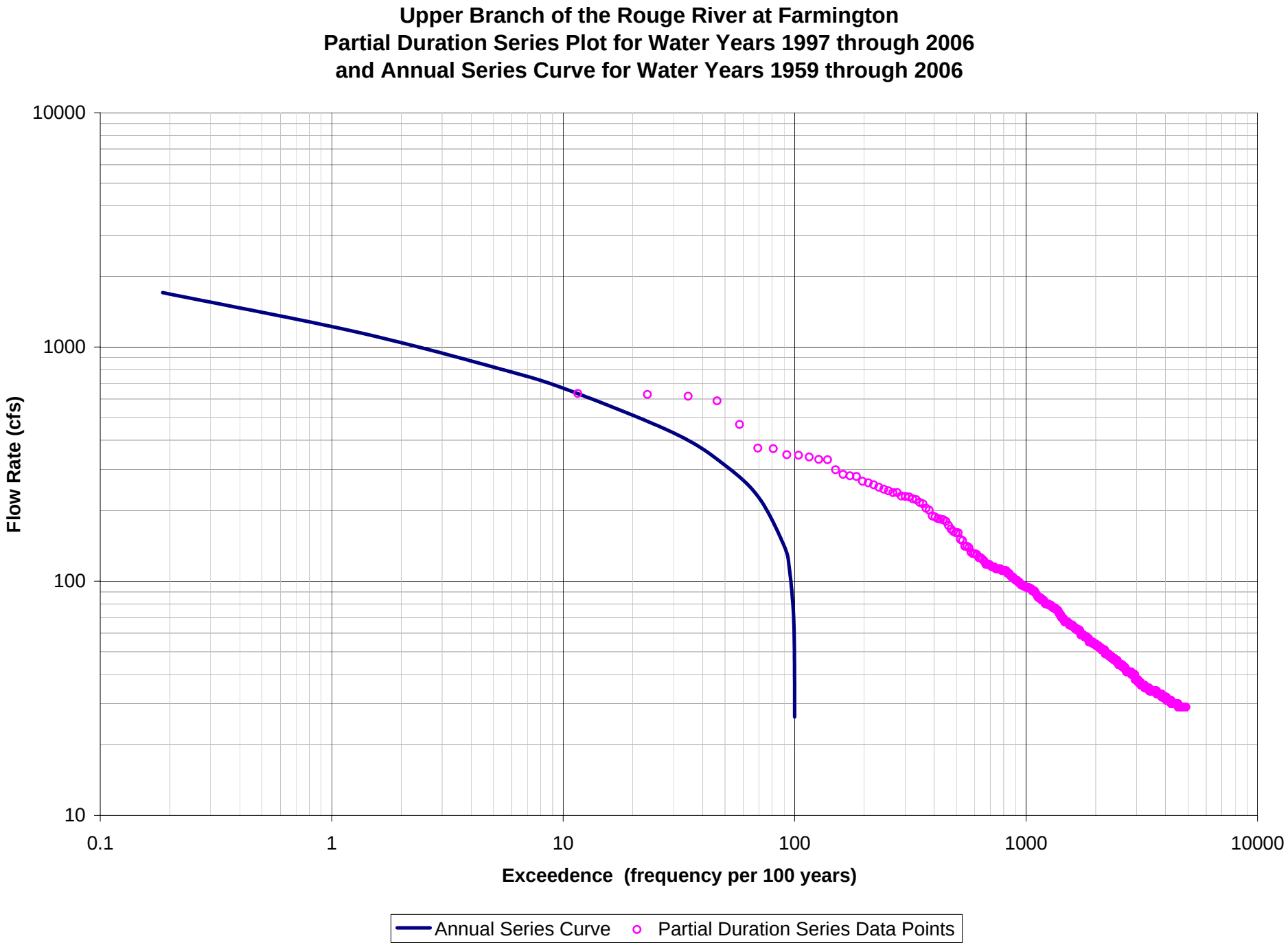


Main Branch of the Rouge River at Southfield
Partial Duration Series Plot for Water Years 1997 through 2006 and
Annual Series Curve for Water Years 1959 through 2006

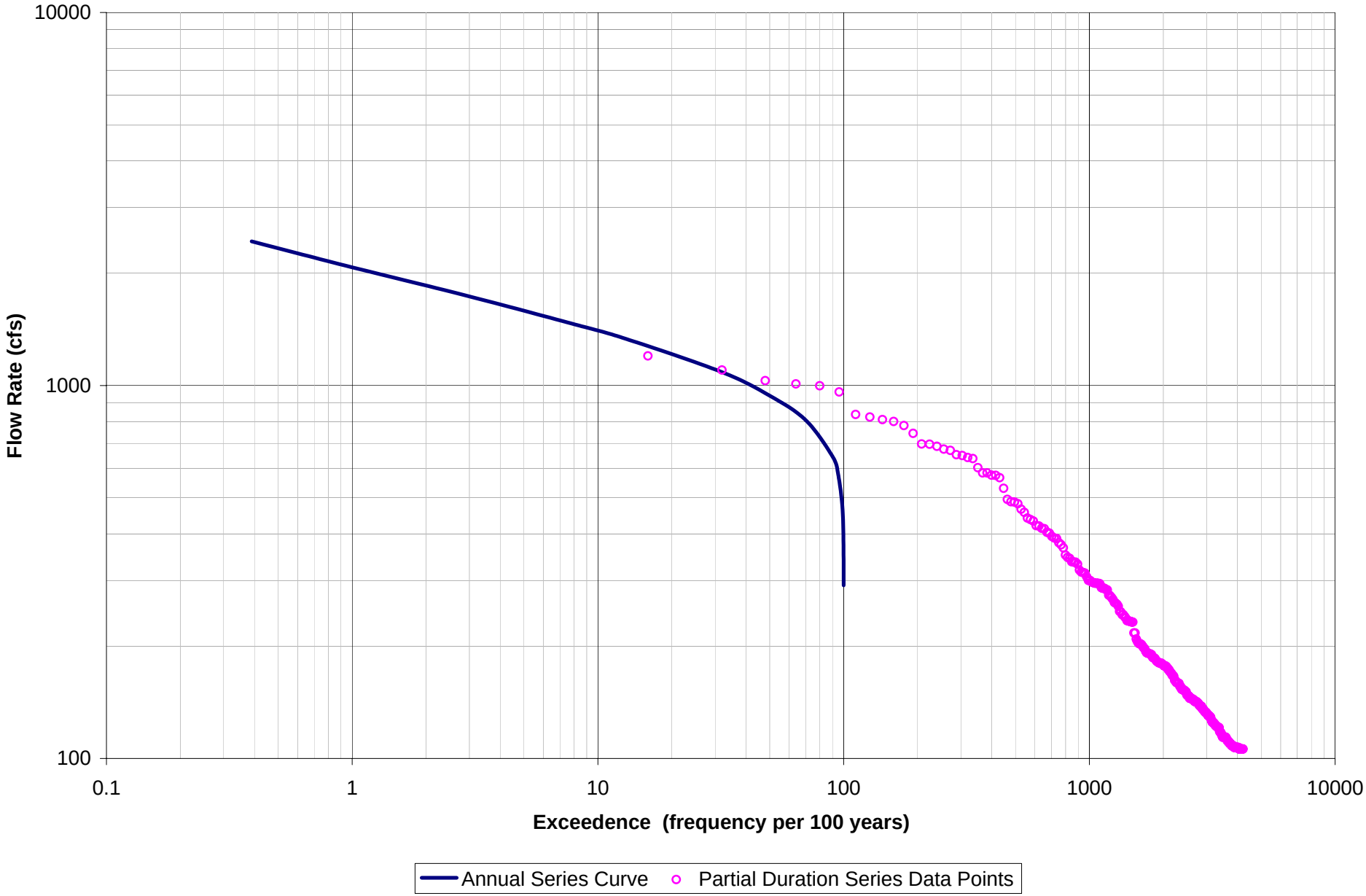


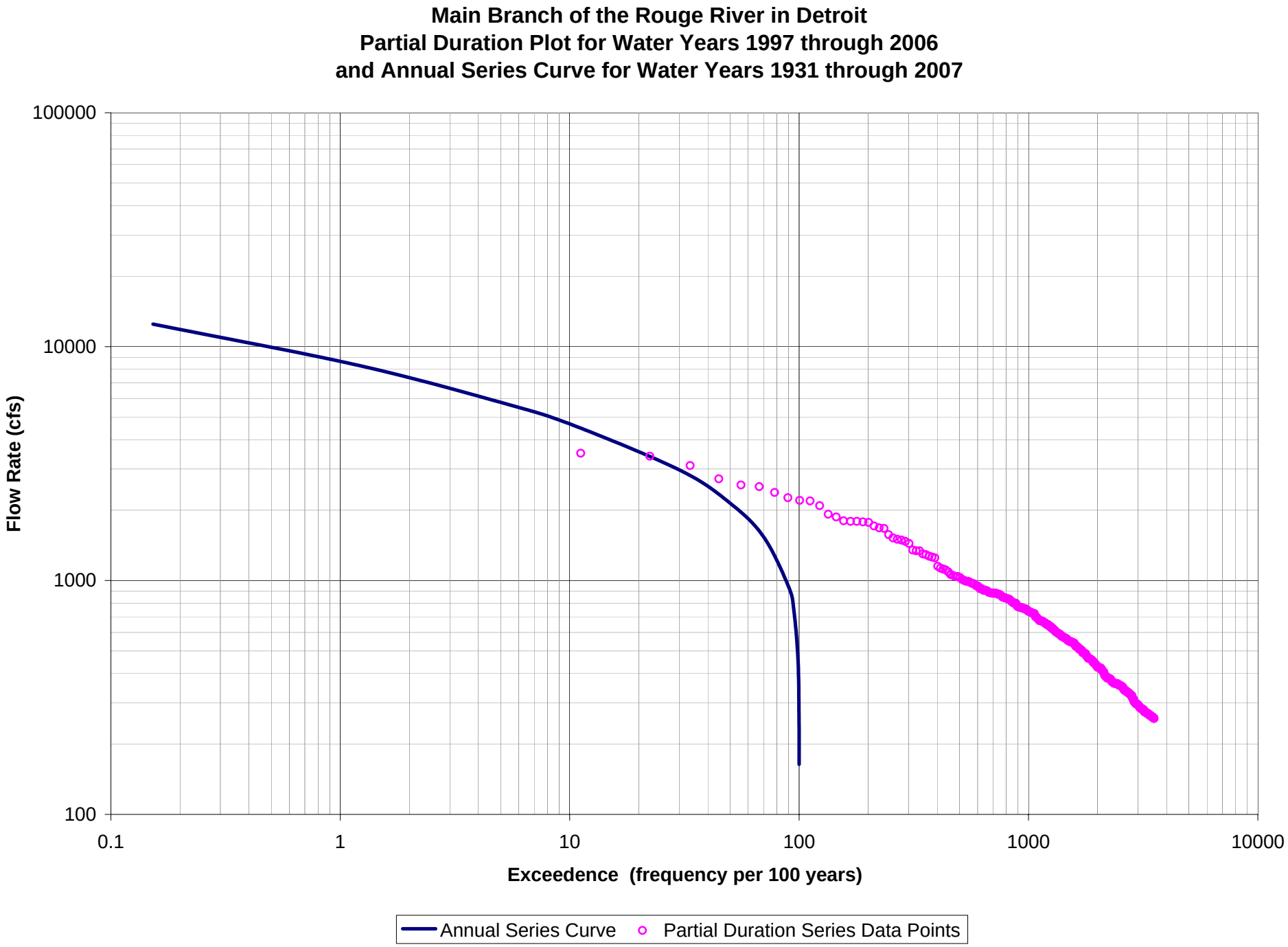
Evans Ditch at Southfield
Partial Duration Series Plot for Water Years 1997 through 2006
and Annual Series Curve for Water Year 1959 through 2007



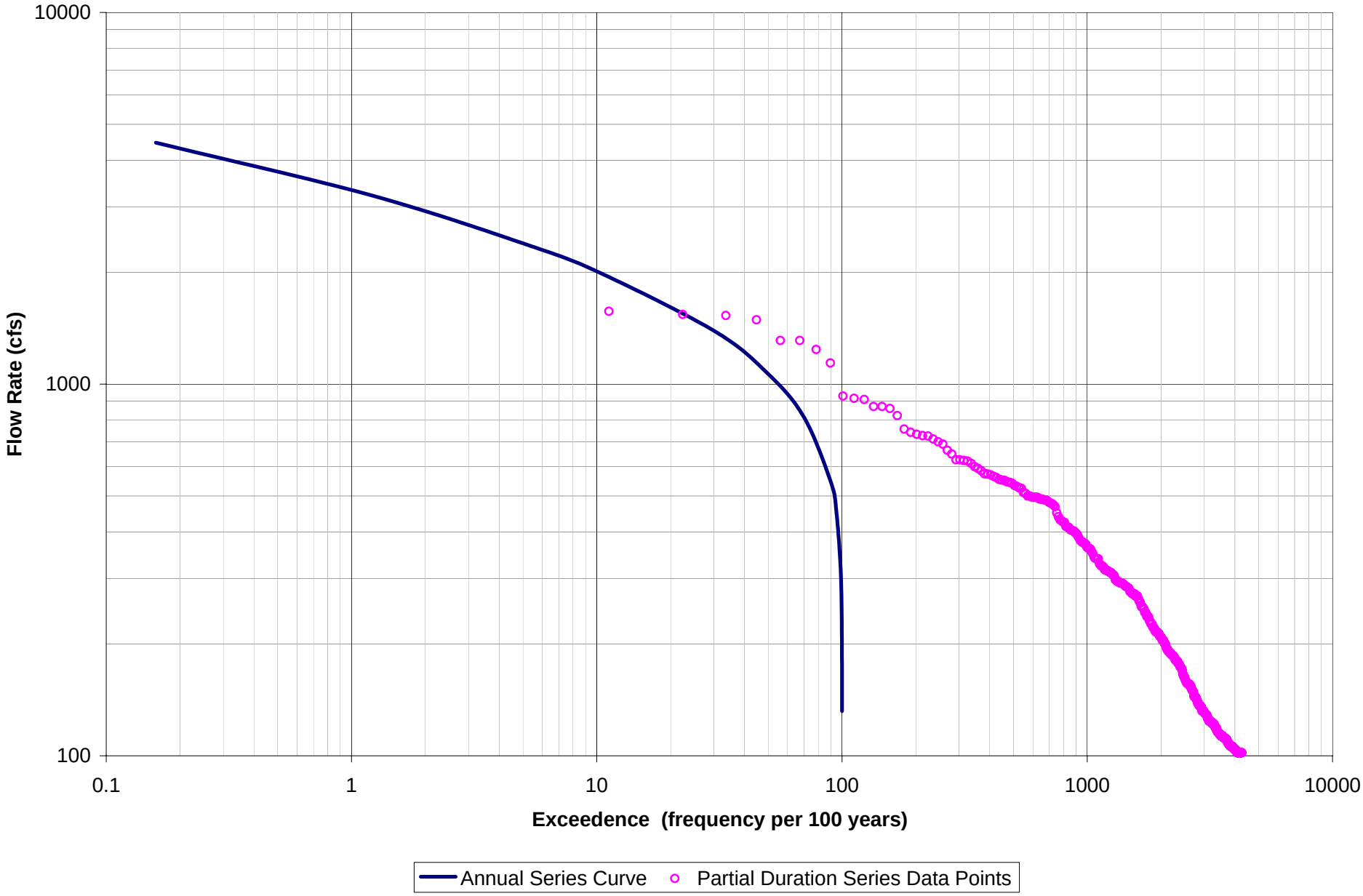

Upper Branch of the Rouge River at Farmington
Partial Duration Series Plot for Water Years 1997 through 2006
and Annual Series Curve for Water Years 1959 through 2006
10000
1000
100
10
Flow Rate (cfs)
0.1
1
10
100
1000
10000
Exceedence (frequency per 100 years)
Annual Series Curve
Partial Duration Series Data Points

Upper Branch of the Rouge River in Detroit
Partial Duration Series Plot for Water Years 1999 through 2005 and
Annual Series Curve for Water Years 1998 through 2006

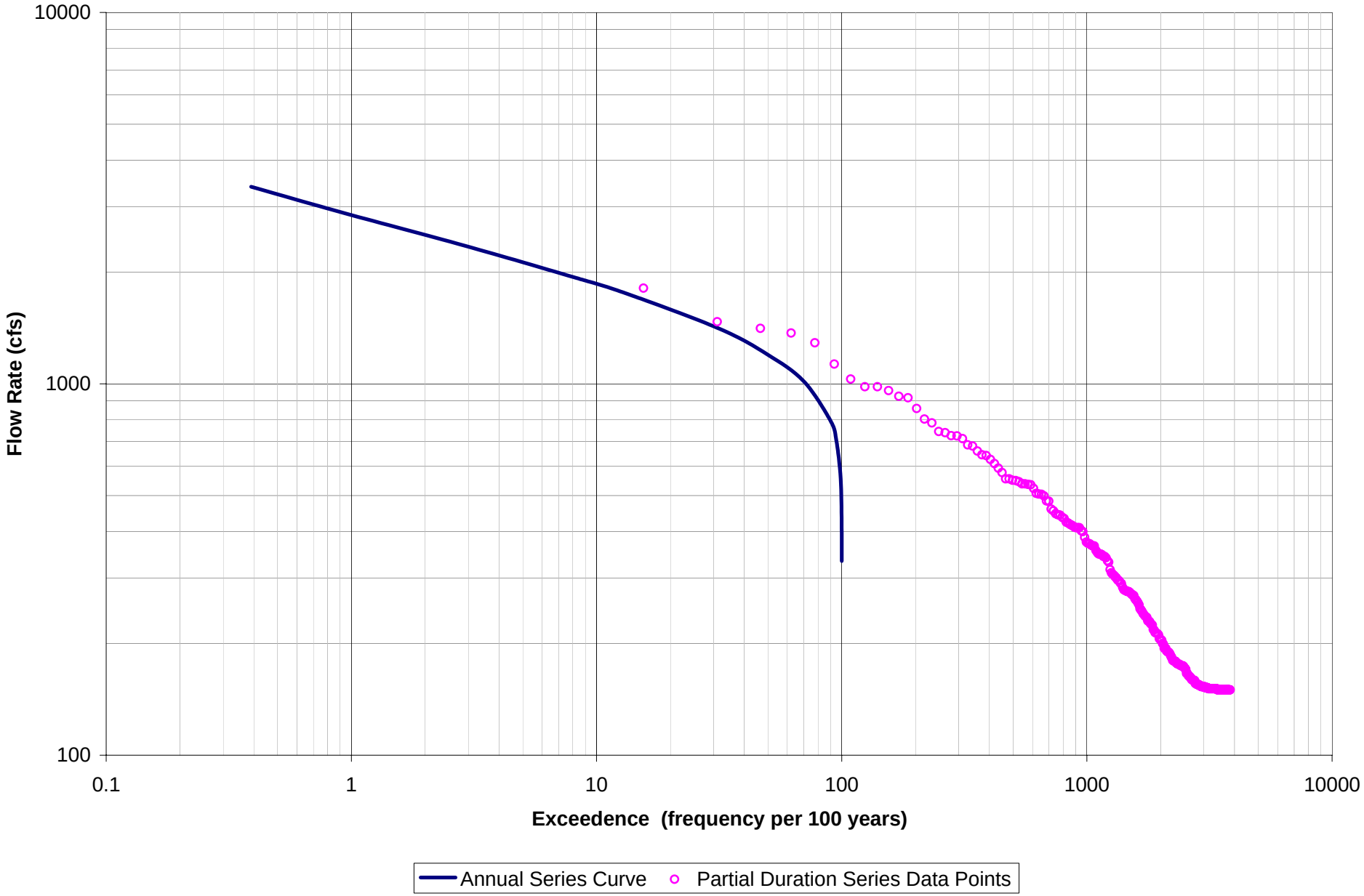


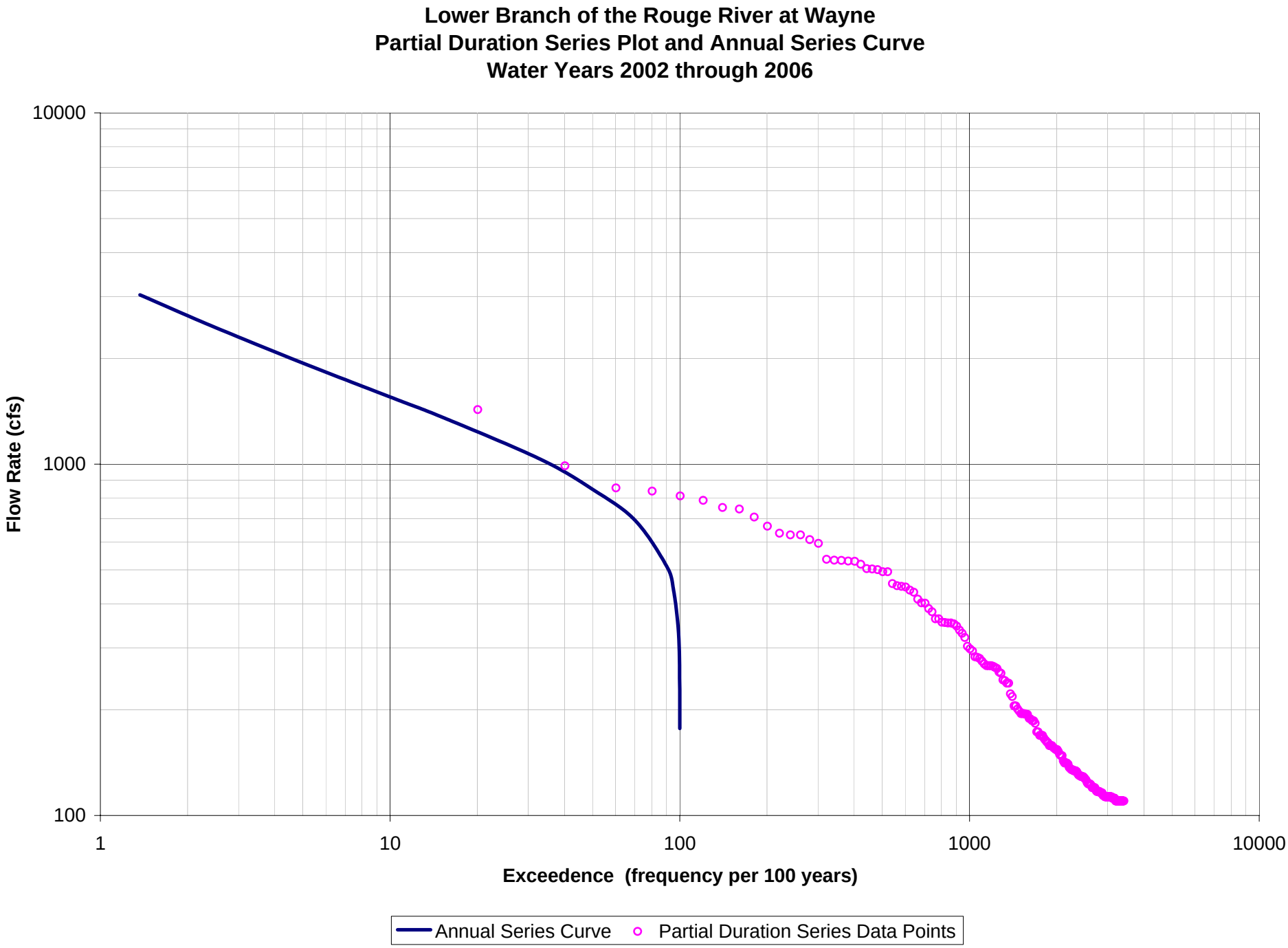

Main Branch of the Rouge River in Detroit
Partial Duration Plot for Water Years 1997 through 2006
and Annual Series Curve for Water Years 1931 through 2007
100000
10000
1000
100
Flow Rate (cfs)
0.1
1
10
100
1000
10000
Exceedence (frequency per 100 years)
Annual Series Curve
Partial Duration Series Data Points

Middle Branch of the Rouge River near Garden City
Partial Duration Series Plot for Water Years 1997 through 2006 and
Annual Series Curve for Water Years 1931 through 2007

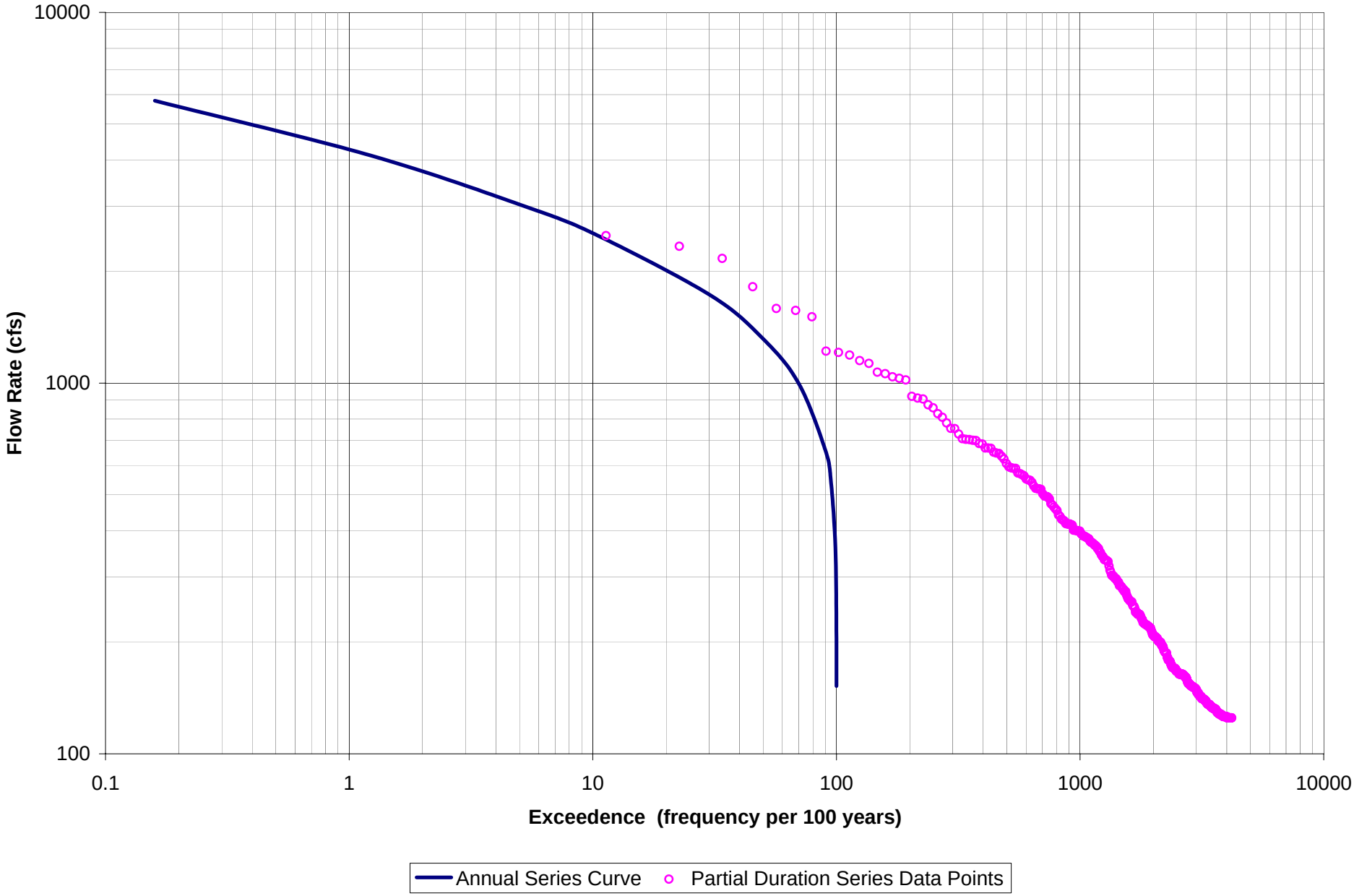


Middle Branch of the Rouge River at Dearborn Heights
Partial Duration Series Plot for Water Years 1999 through 2005 and
Annual Series Curve for Water Years 1998 through 2006




Lower Branch of the Rouge River at Wayne
Partial Duration Series Plot and Annual Series Curve
Water Years 2002 through 2006
10000
1000
100
Flow Rate (cfs)
1
10
100
1000
10000
Exceedence (frequency per 100 years)
Annual Series Curve
Partial Duration Series Data Points

Lower Branch of the Rouge River at Inkster
Partial Duration Series Plot for Water Years 1997 through 2006 and
Annual Series Curve for Water Years 1931 through 2007

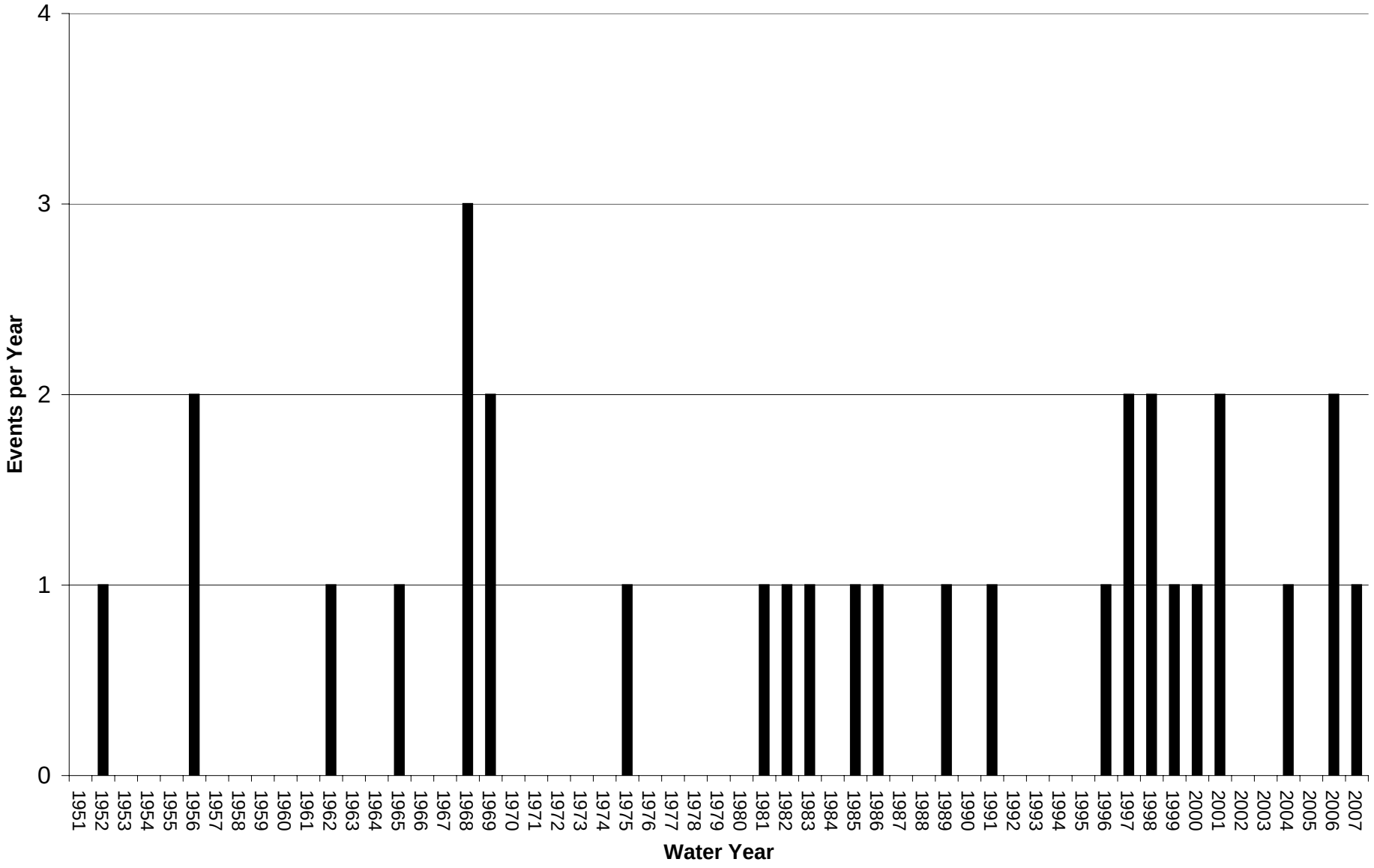


Appendix C. Flood Frequency Histograms

Main Branch of the Rouge River at Birmingham

Histogram of Flood Events Greater than Overbank Flood Event

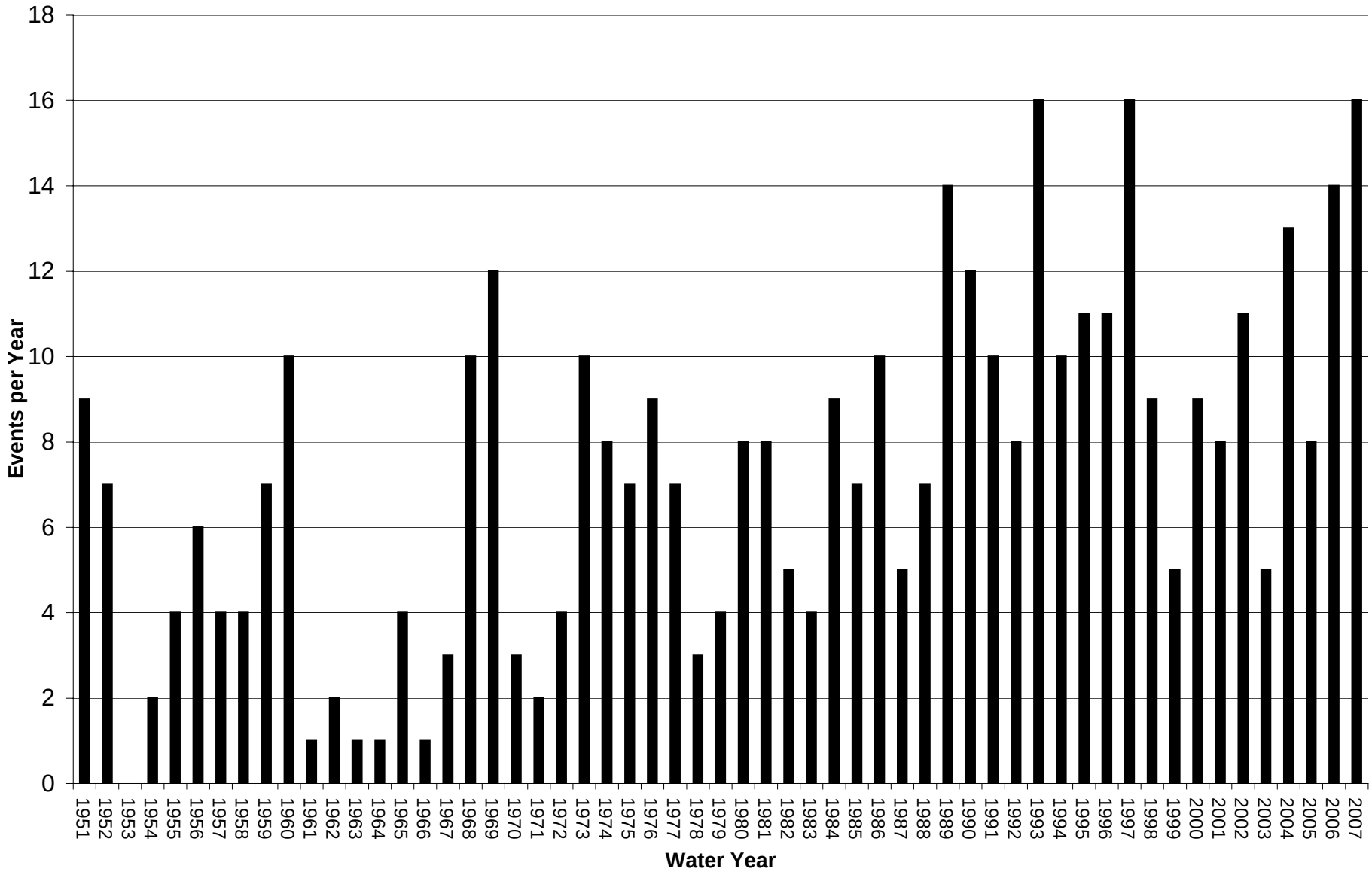
Overbank Flood Flow Rate = 495 cfs



Main Branch of the Rouge River at Birmingham

Histogram of Flood Events Greater than 1-Month Flood Event

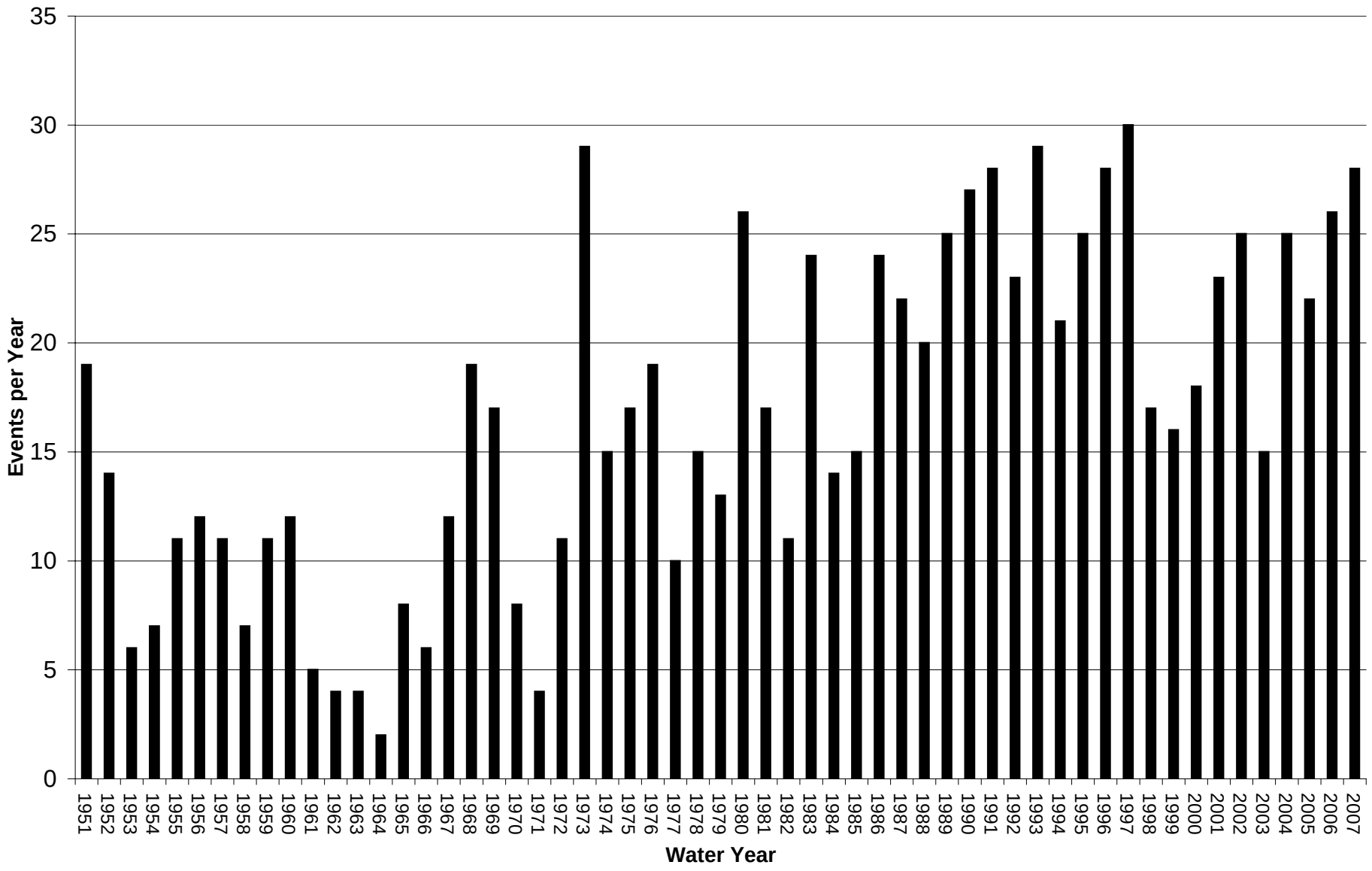
1-Month Flood Flow Rate from Partial Duration Series of Water Years 1997 through 2006 = 110 cfs



Main Branch of the Rouge River at Birmingham

Histogram of Flood Events Greater than 15-Day Flood Event

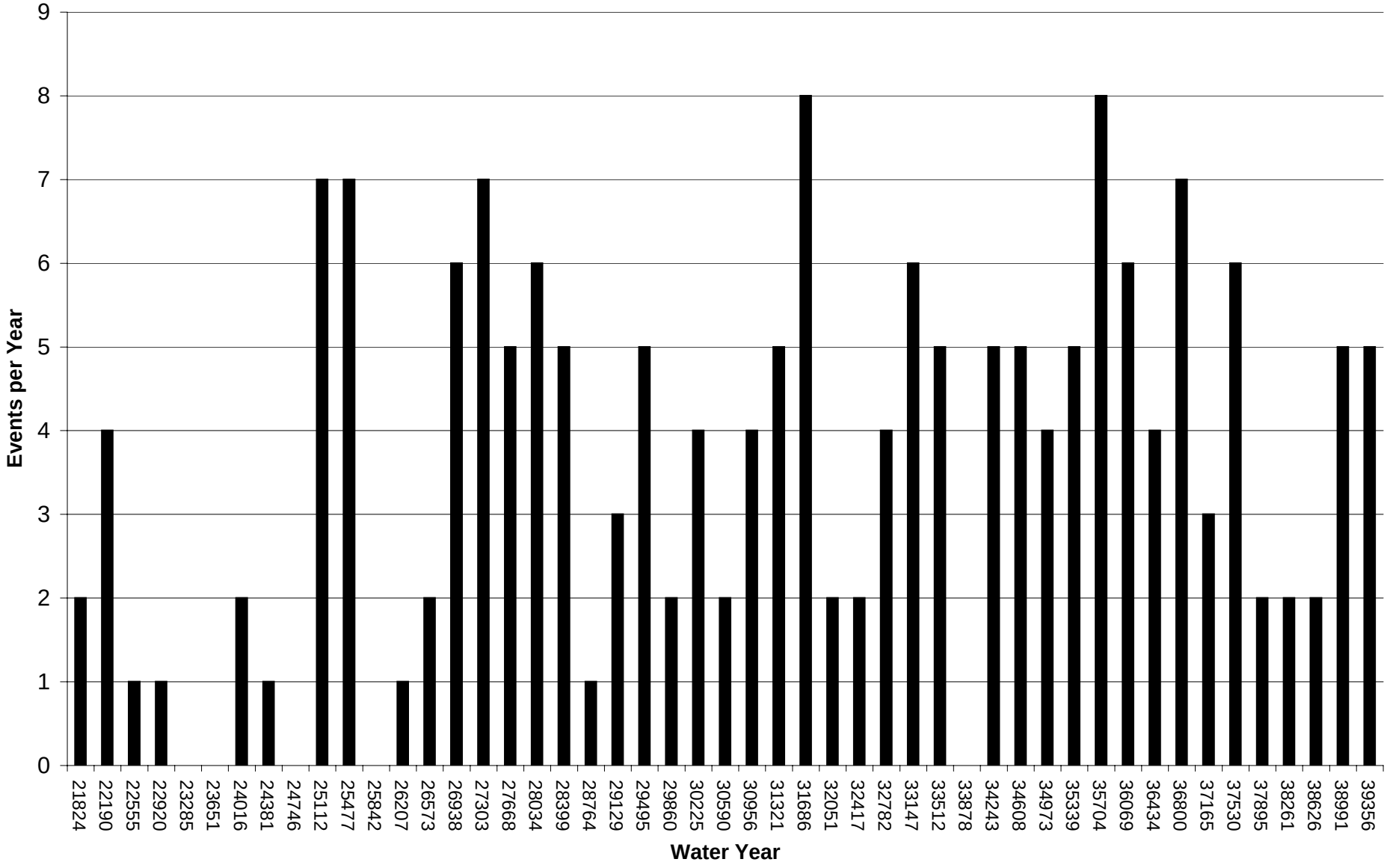
15-Day Flood Flow Rate from Partial Duration Series of Water Years 1997 through 2006 = 52 cfs



Main Branch of the Rouge River at Southfield

Histogram of Flood Events Greater than Overbank Flood Event

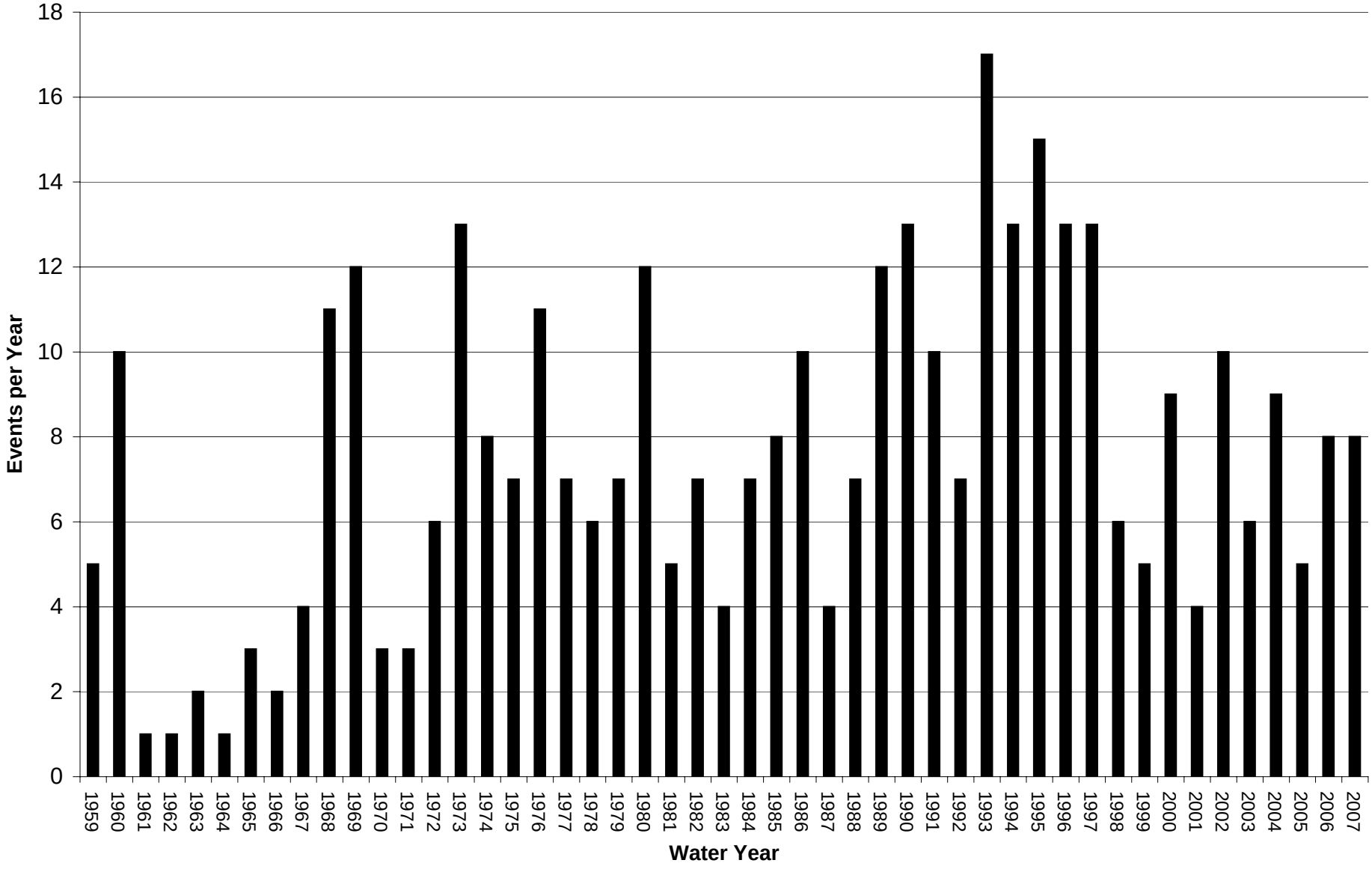
Overbank Flood Flow Rate = 664 cfs



Main Branch of the Rouge River at Southfield

Histogram of Flood Events Greater than 1-Month Flooding Event

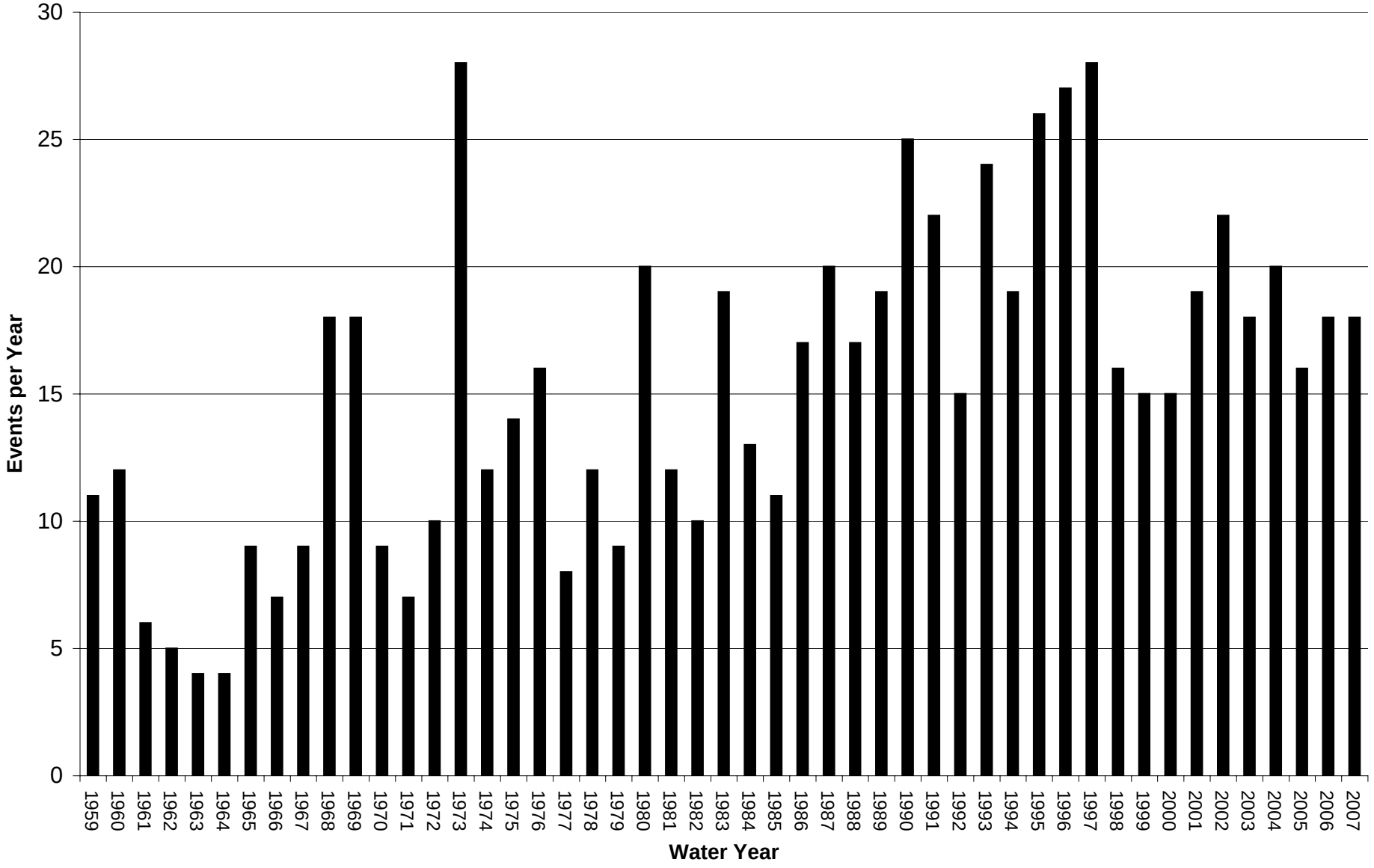
1-Month Flood Flow Rate from Partial Duration Series of Water Years 1997 through 2006 = 357 cfs



Main Branch of the Rouge River at Southfield

Histogram of Flood Events Greater than 15-Day Flooding Event

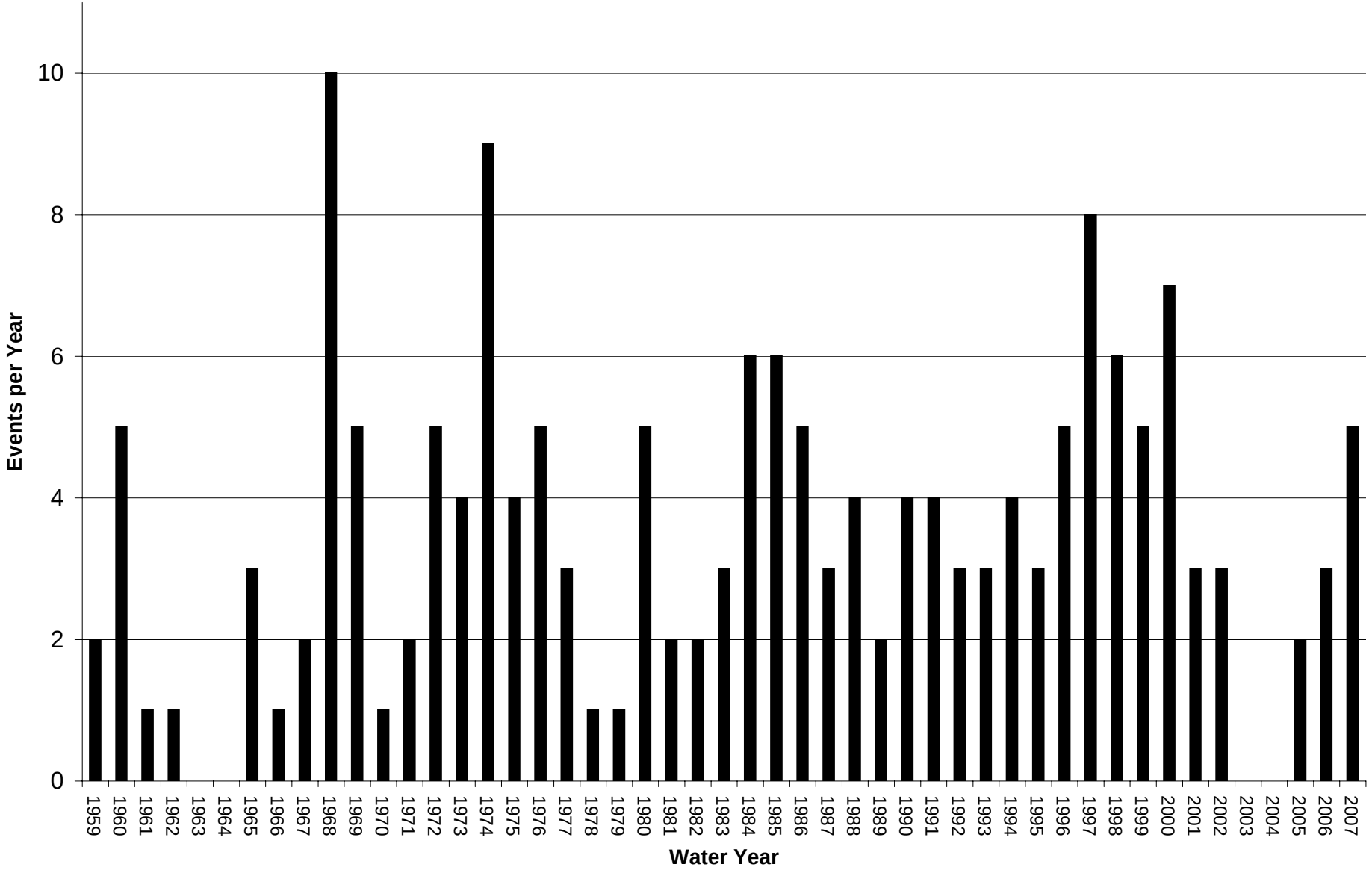
15-Day Flood Flow Rate from Partial Duration Series of Water Years 1997 through 2006 = 190 cfs



Evans Ditch at Southfield

Histogram of Flood Events Greater than Overbank Flood Event

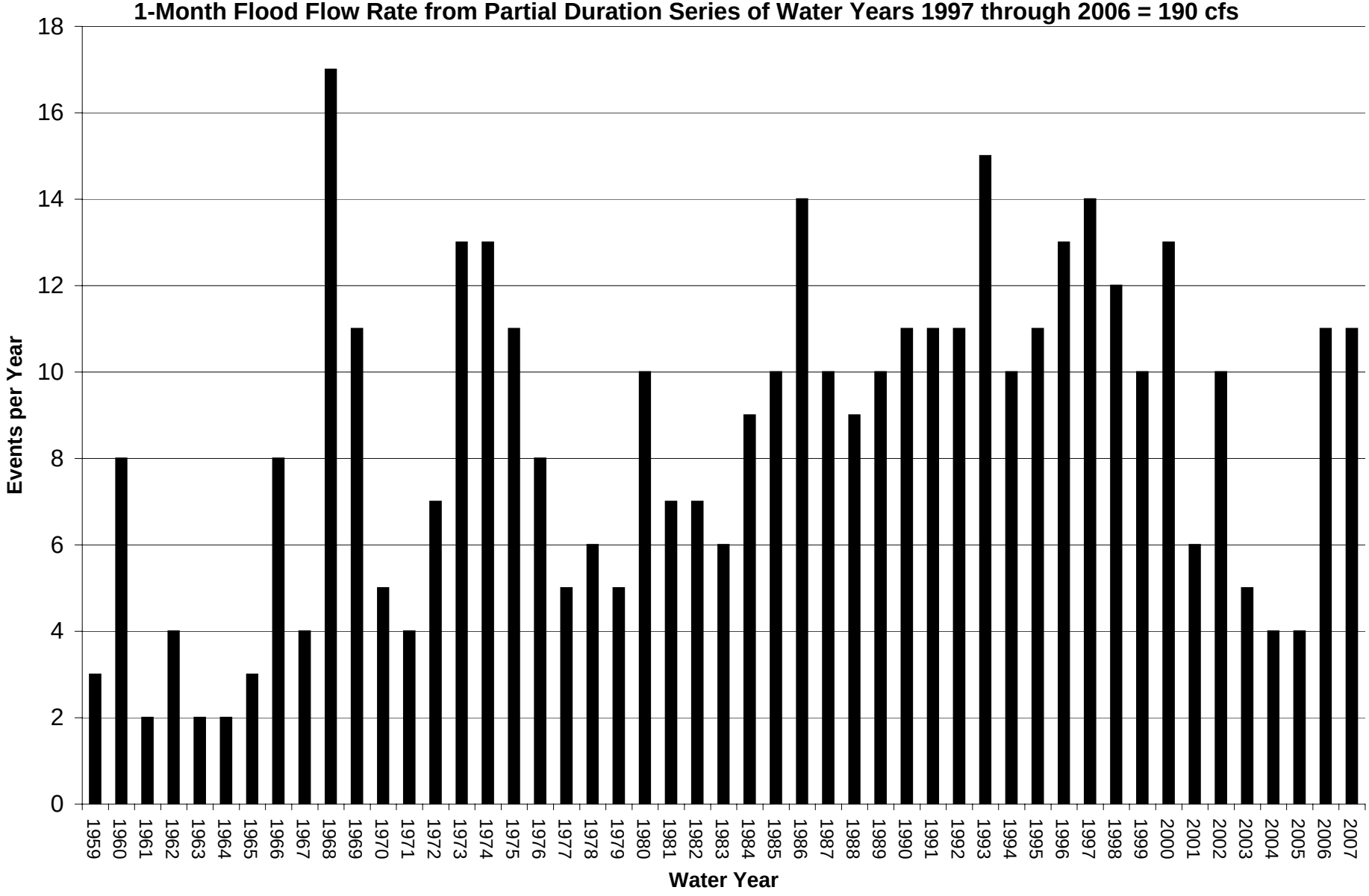
Overbank Flood Flow Rate = 357 cfs



Evans Ditch at Southfield

Histogram of Flooding Events Greater than 1-Month Flood Event

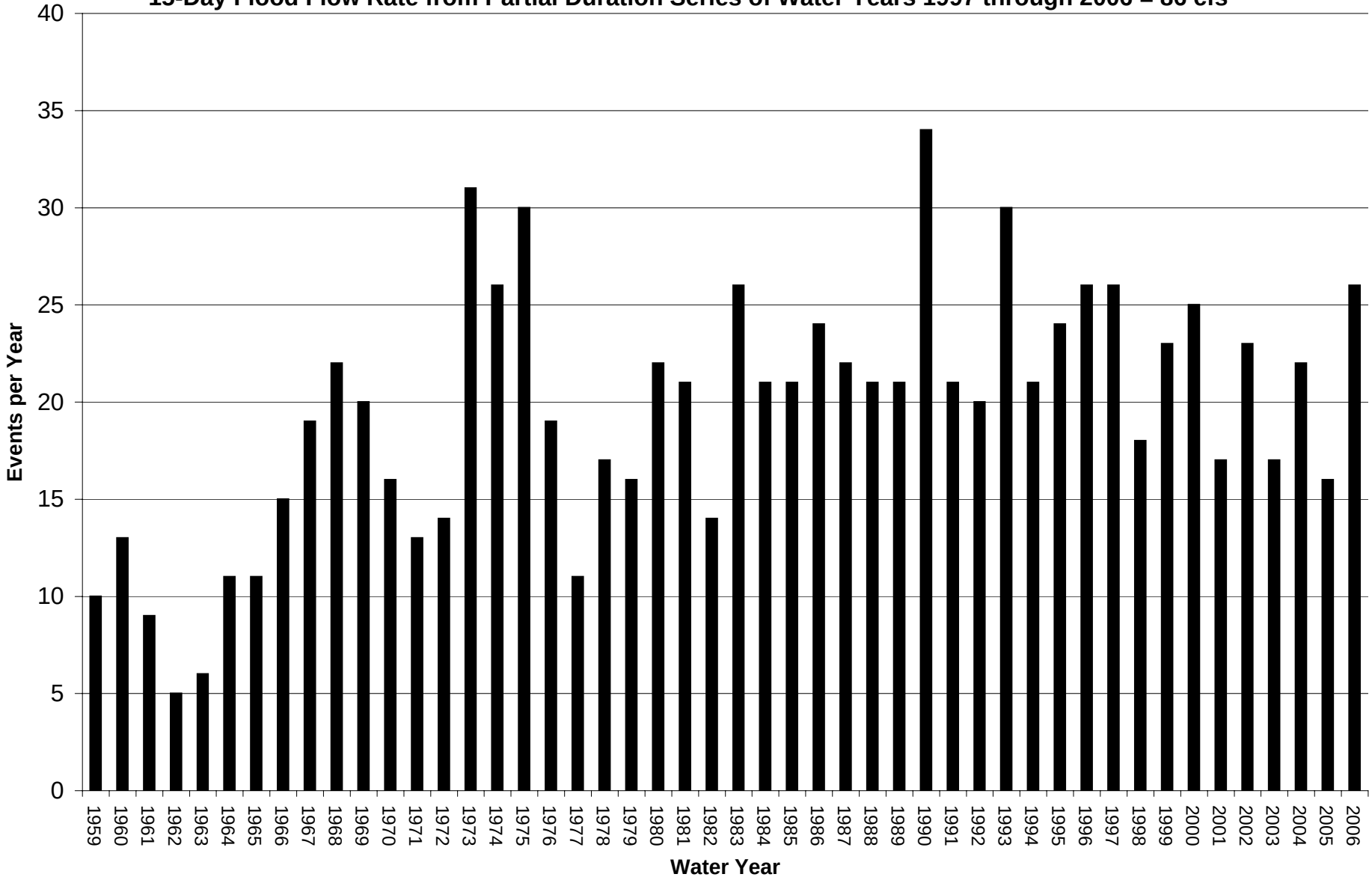
1-Month Flood Flow Rate from Partial Duration Series of Water Years 1997 through 2006 = 190 cfs



Evans Ditch at Southfield

Histogram of Flooding Events Greater than 15-Day Flood Event

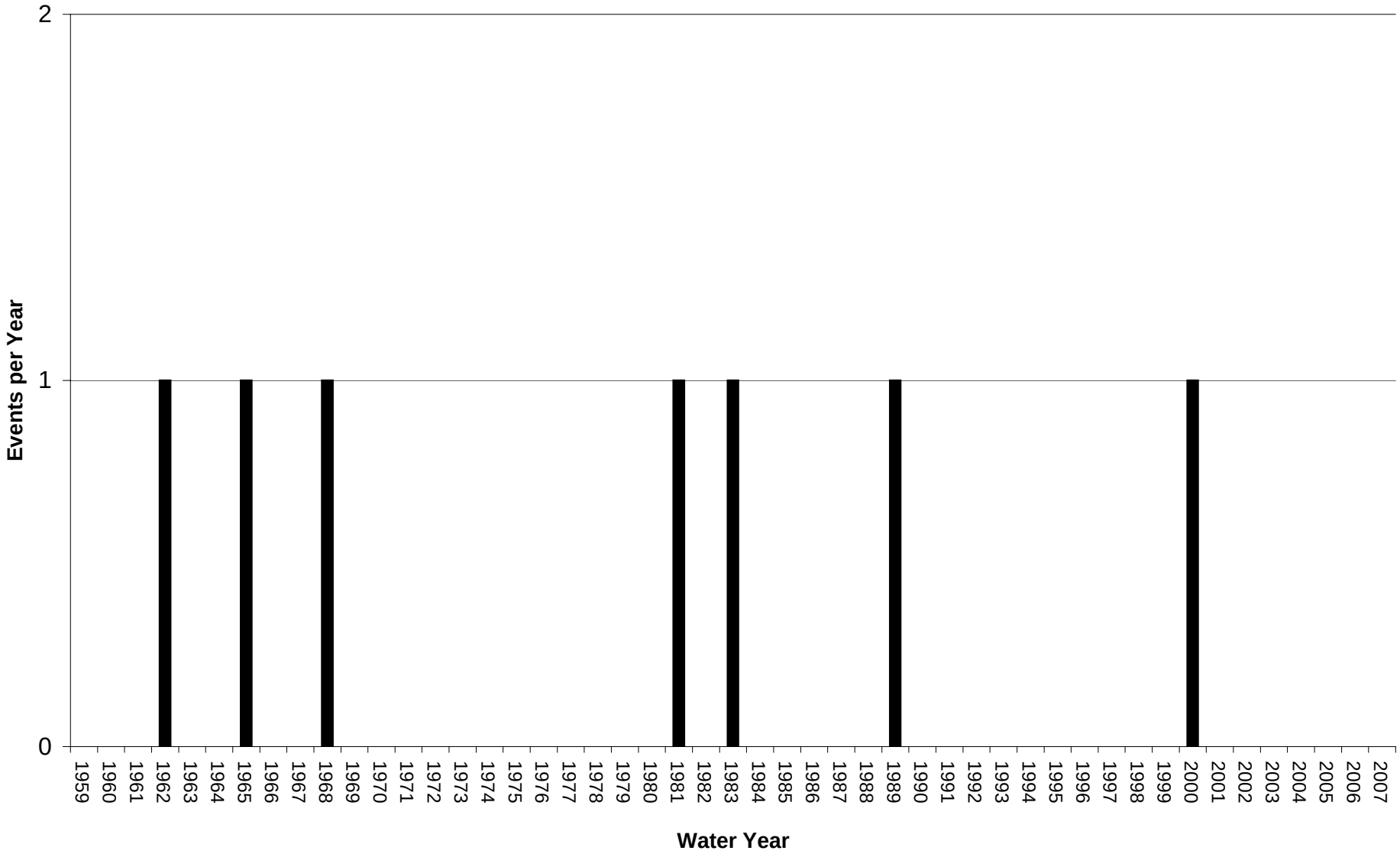
15-Day Flood Flow Rate from Partial Duration Series of Water Years 1997 through 2006 = 86 cfs



Upper Branch of the Rouge River at Farmington

Histogram of Flood Events Greater than Overbank Flood Event

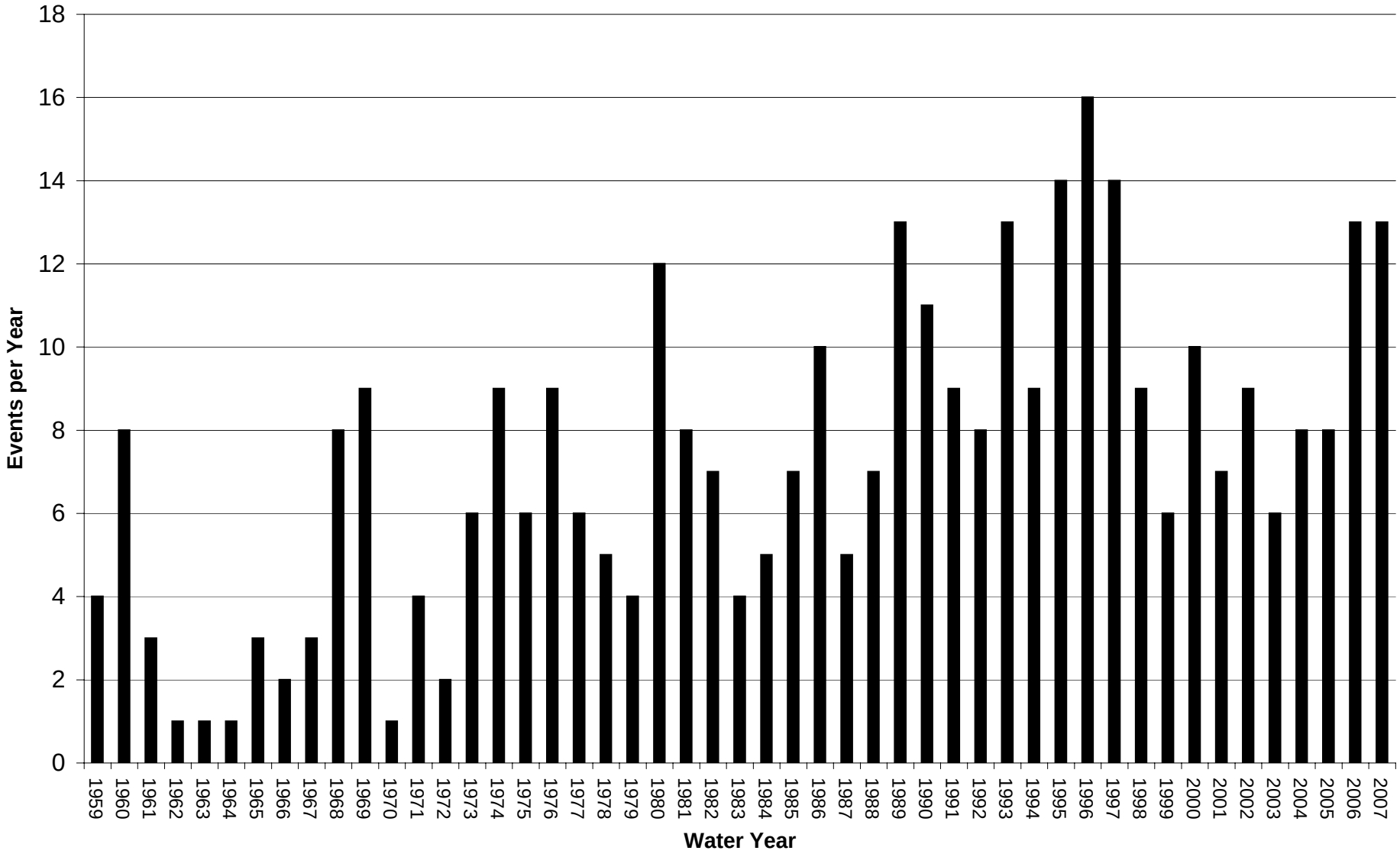
Overbank Flood Flow Rate = 478 cfs



Upper Branch of the Rouge River at Farmington

Histogram of Flood Events Greater than 1-Month Flood Event

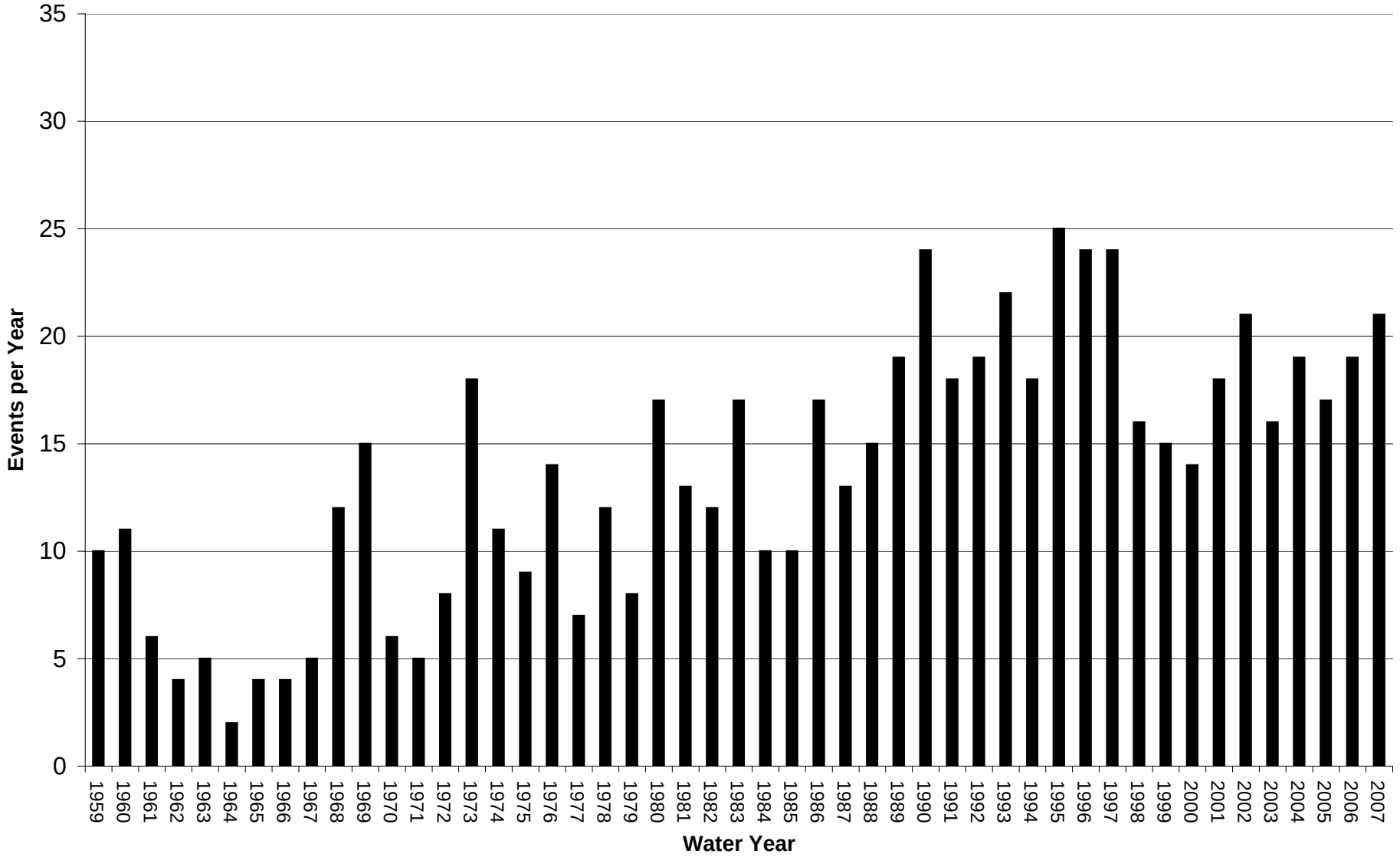
1-Month Flood Flow Rate from Partial Duration Series of Water Years 1997 through 2006 = 81 cfs



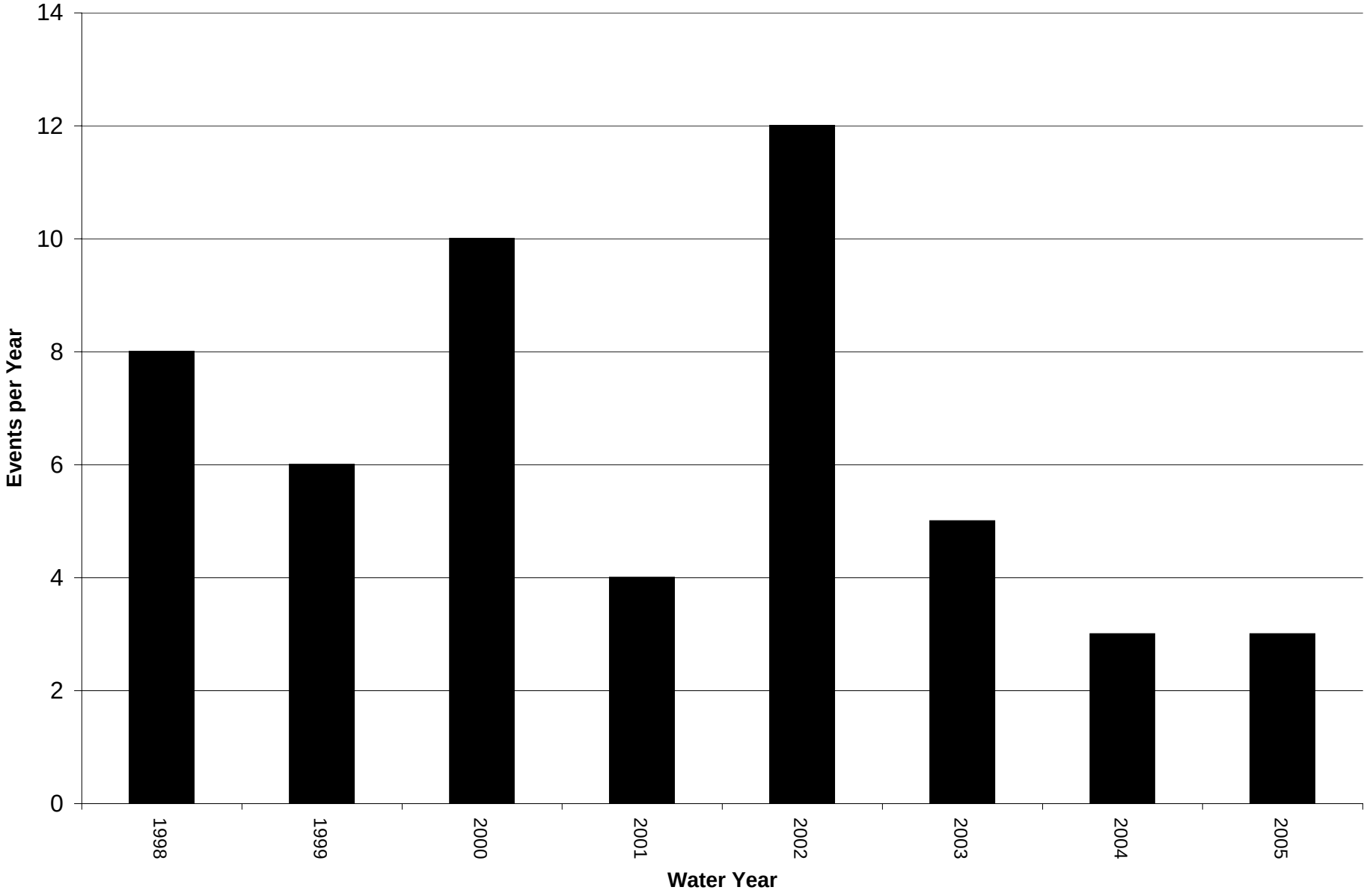
Upper Branch of the Rouge River at Farmington

Histogram of Flood Events Greater than 15-Day Flooding Event

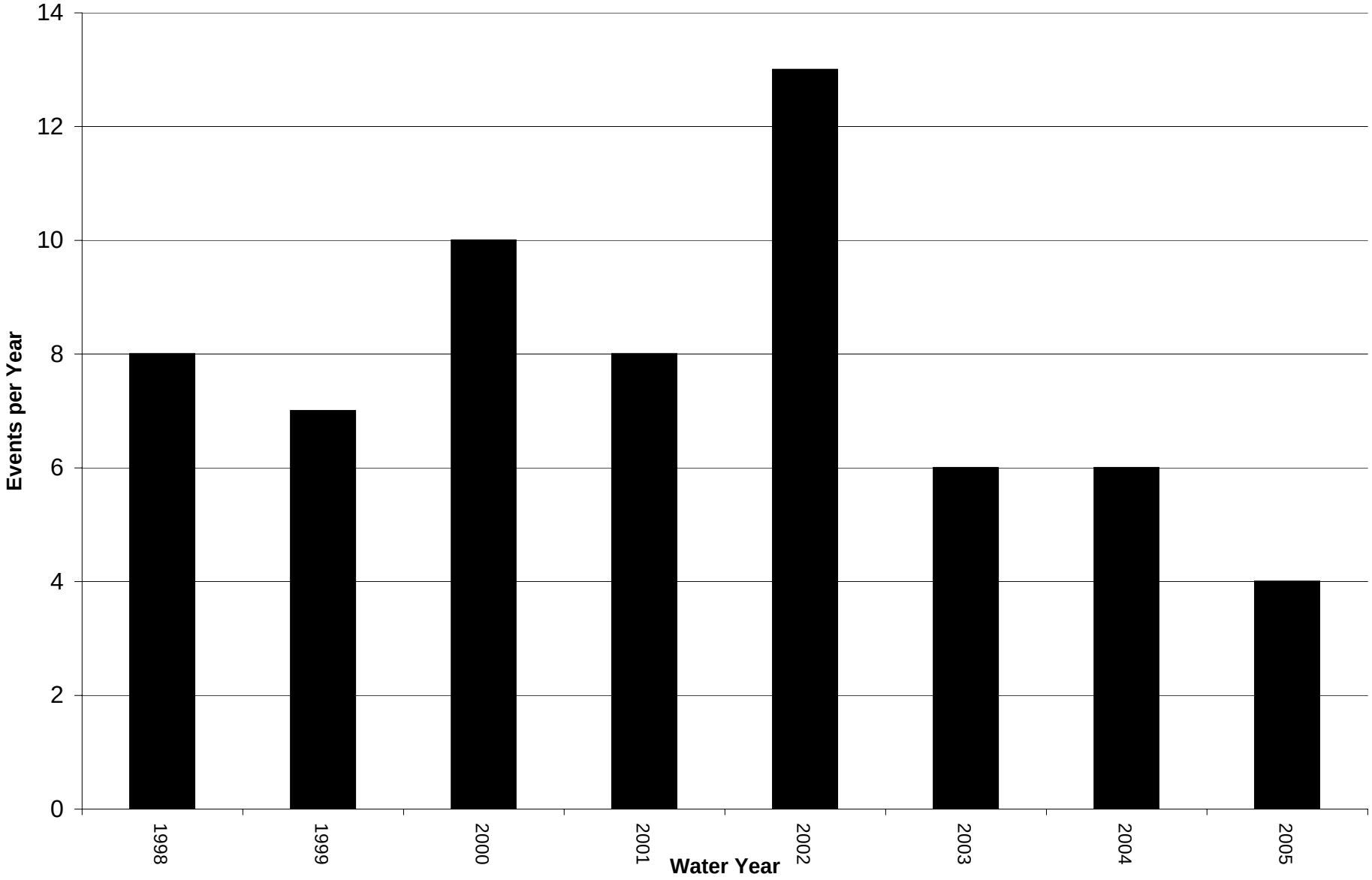
15-Day Flood Flow Rate from Partial Duration Series of Water Years 1997 through 2006 = 46 cfs



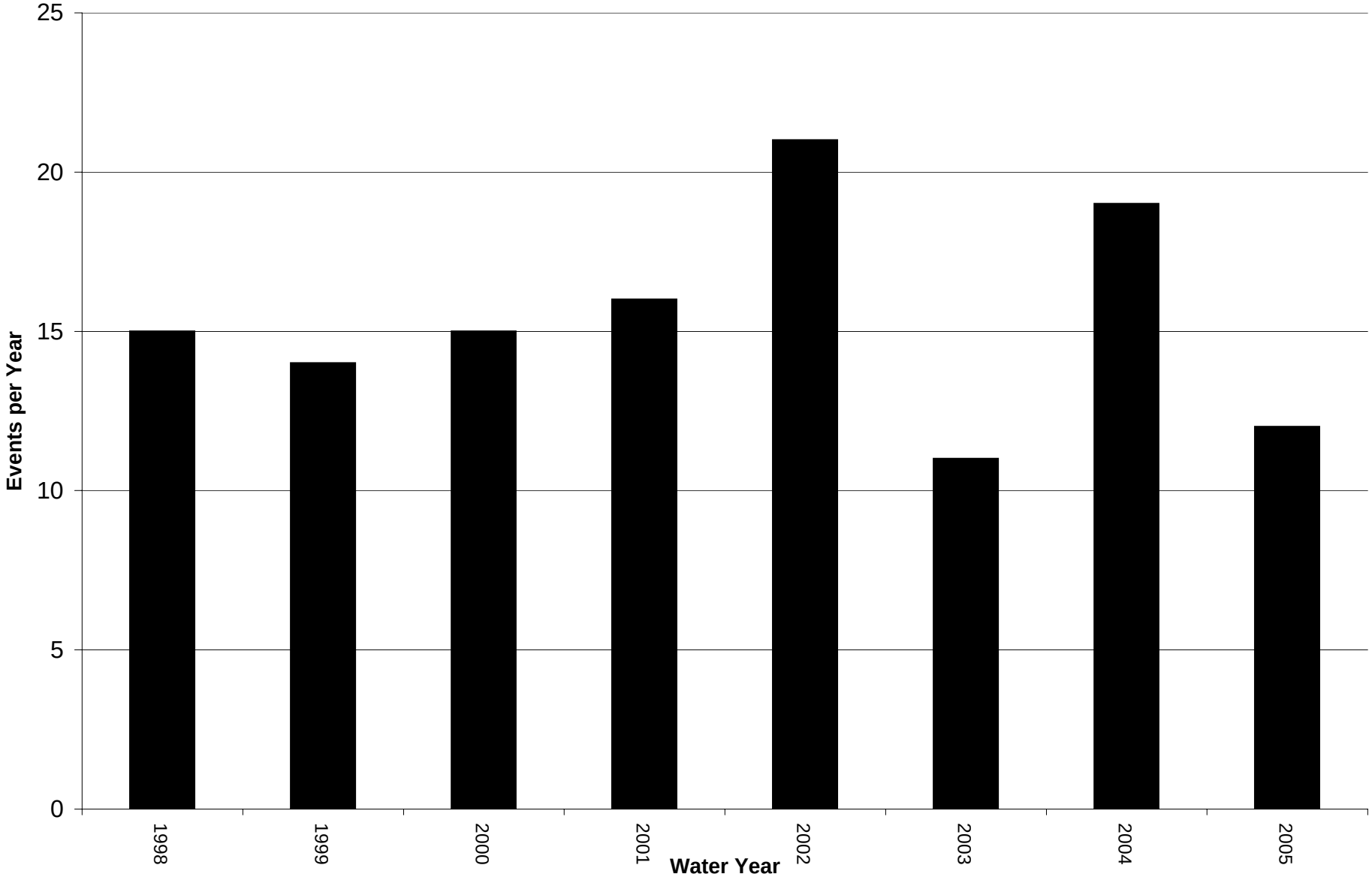
Upper Branch of the Rouge River at Detroit
Histogram of Flood Events Greater than Overbank Flood Event
Overbank Flood Flow Rate = 314 cfs



Upper Branch of the Rouge River at Detroit
Histogram of Flood Events Greater than 1-Month Flood Event
1-Month Flood Flow Rate from Partial Duration Series of Water Years 1999 to 2005 = 274 cfs



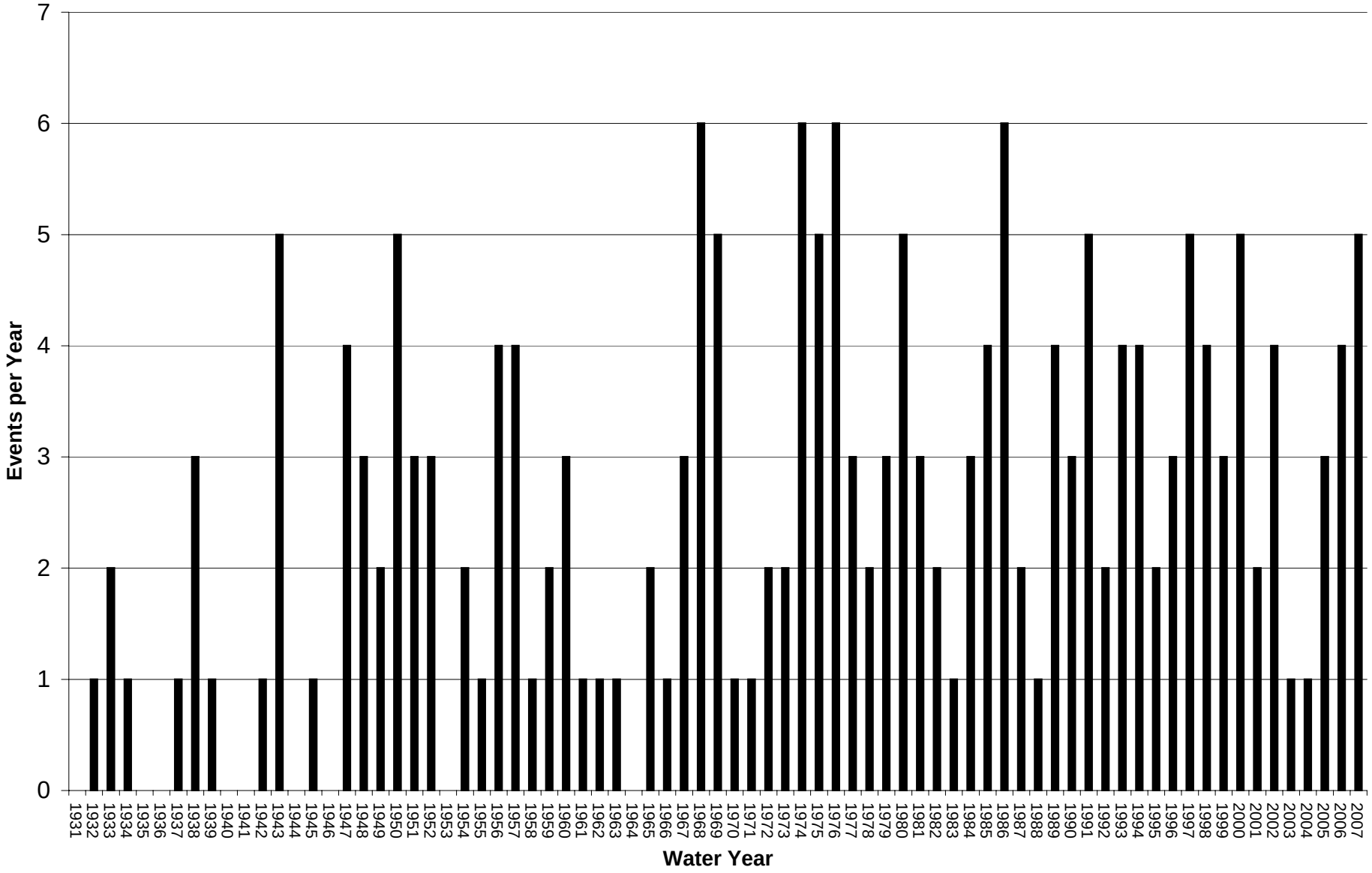
Upper Branch of the Rouge River at Detroit
Histogram of Flood Events Greater than 15-Day Flood Event
15-Day Flood Flow Rate from Partial Duration Series of Water Years 1999 through 2005 = 153 cfs



Main Branch of the Rouge River at Detroit

Histogram of Flood Events Greater than Overbank Flood Event

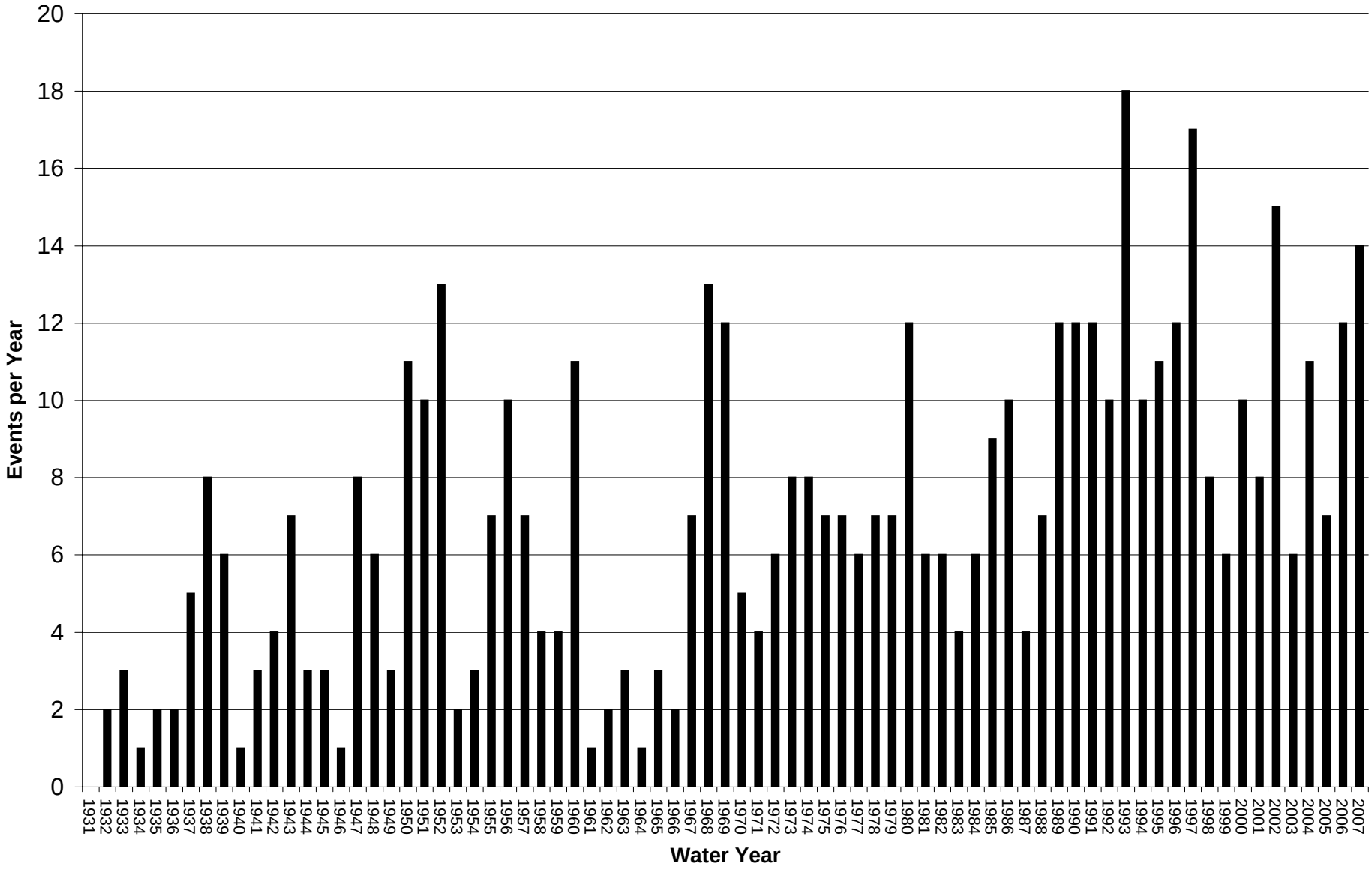
Overbank Flood Flow Rate = 1309 cfs



Main Branch of the Rouge River at Detroit

Histogram of Flood Events Greater than 1-Month Flood Event

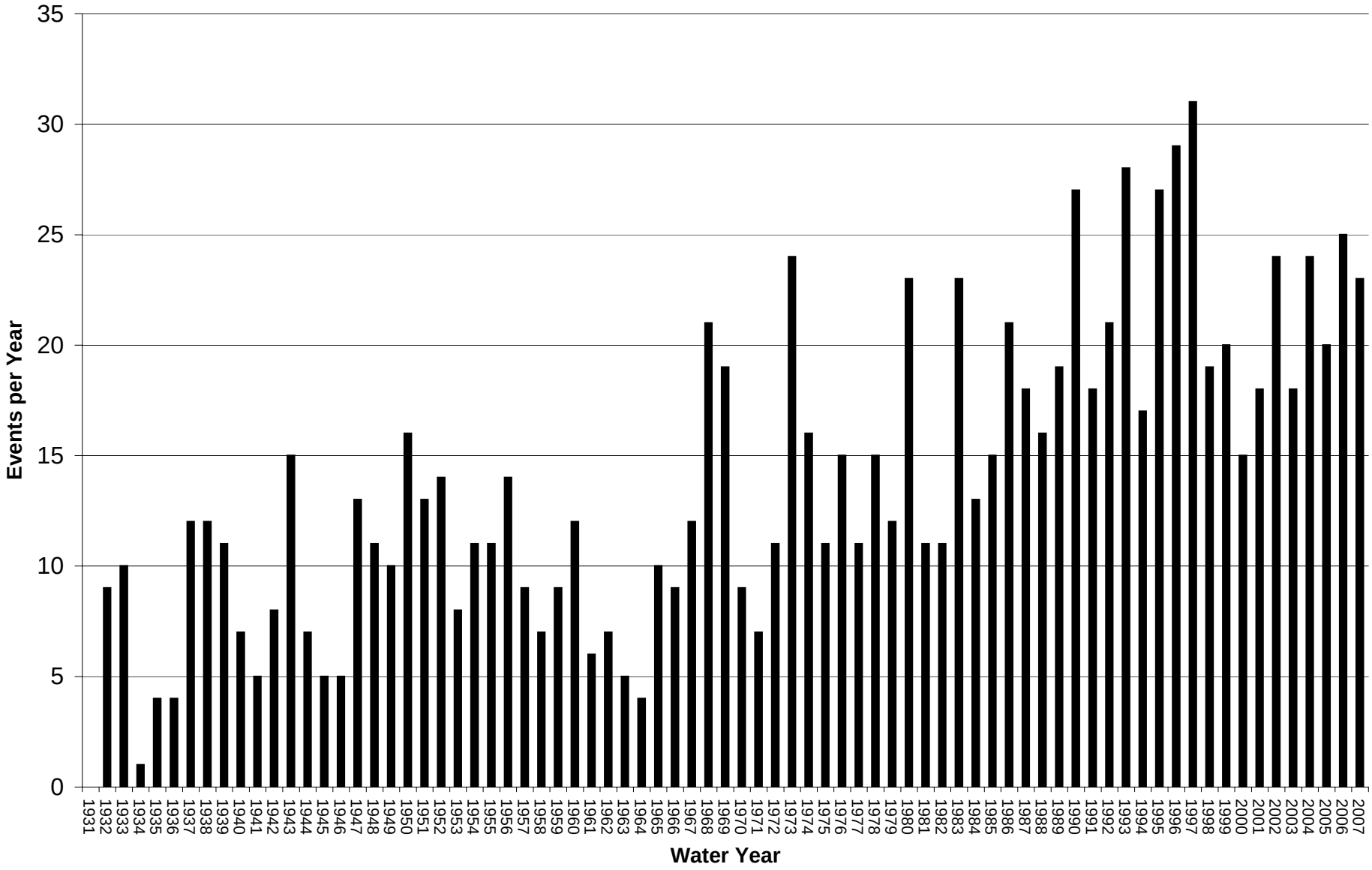
1-Month Flood Flow Rate from Partial Duration Series of Water Years 1997 through 2006 = 650 cfs



Main Branch of the Rouge River at Detroit

Histogram of Flood Events Greater than 15-Day Flood Event

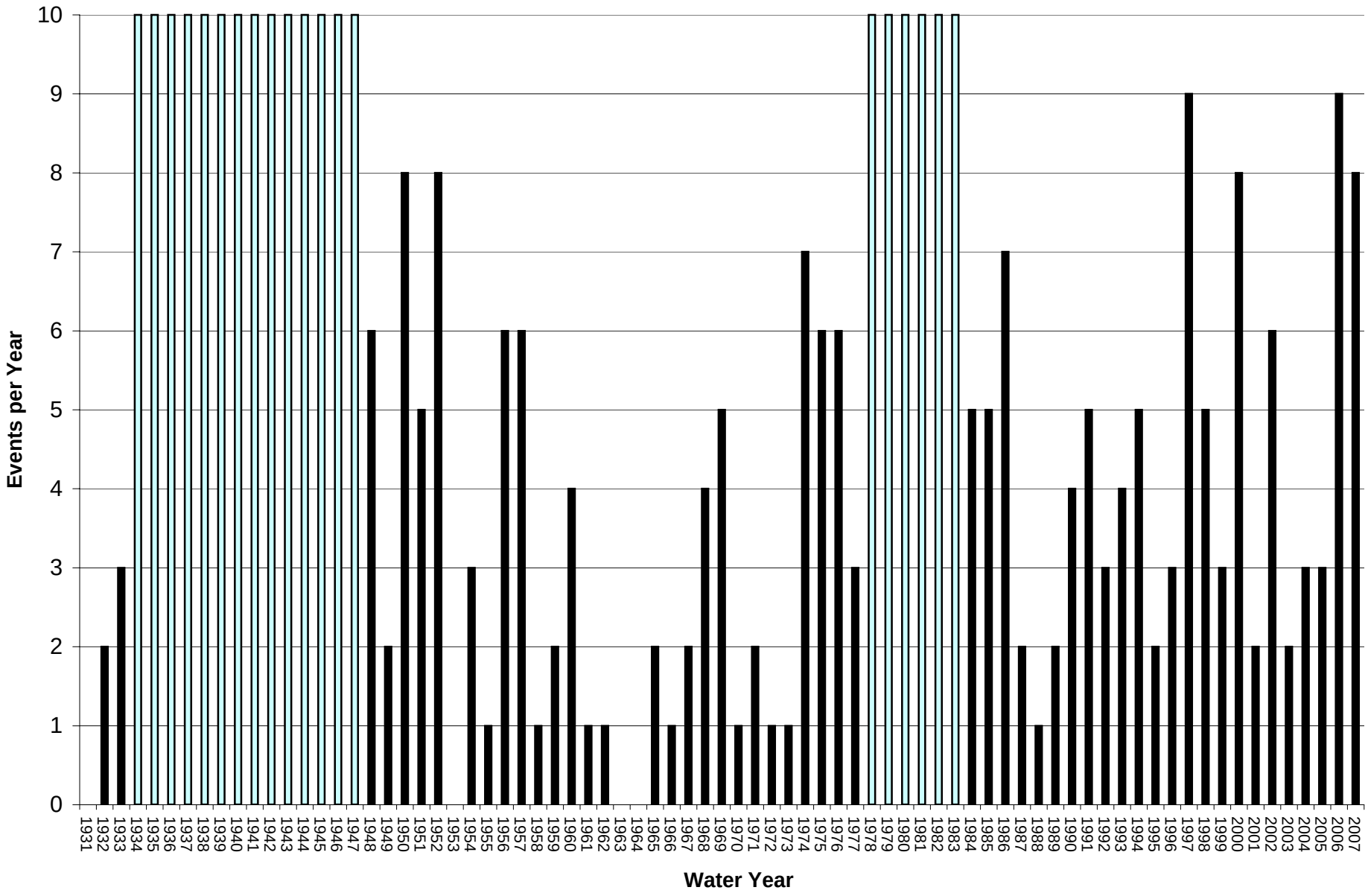
15-Day Flood Flow Rate from Partial Duration Series of Water Years 1997 through 2006 = 363 cfs



Middle Branch of the Rouge River near Garden City

Histogram of Flood Events Greater than Overbank Flood Event

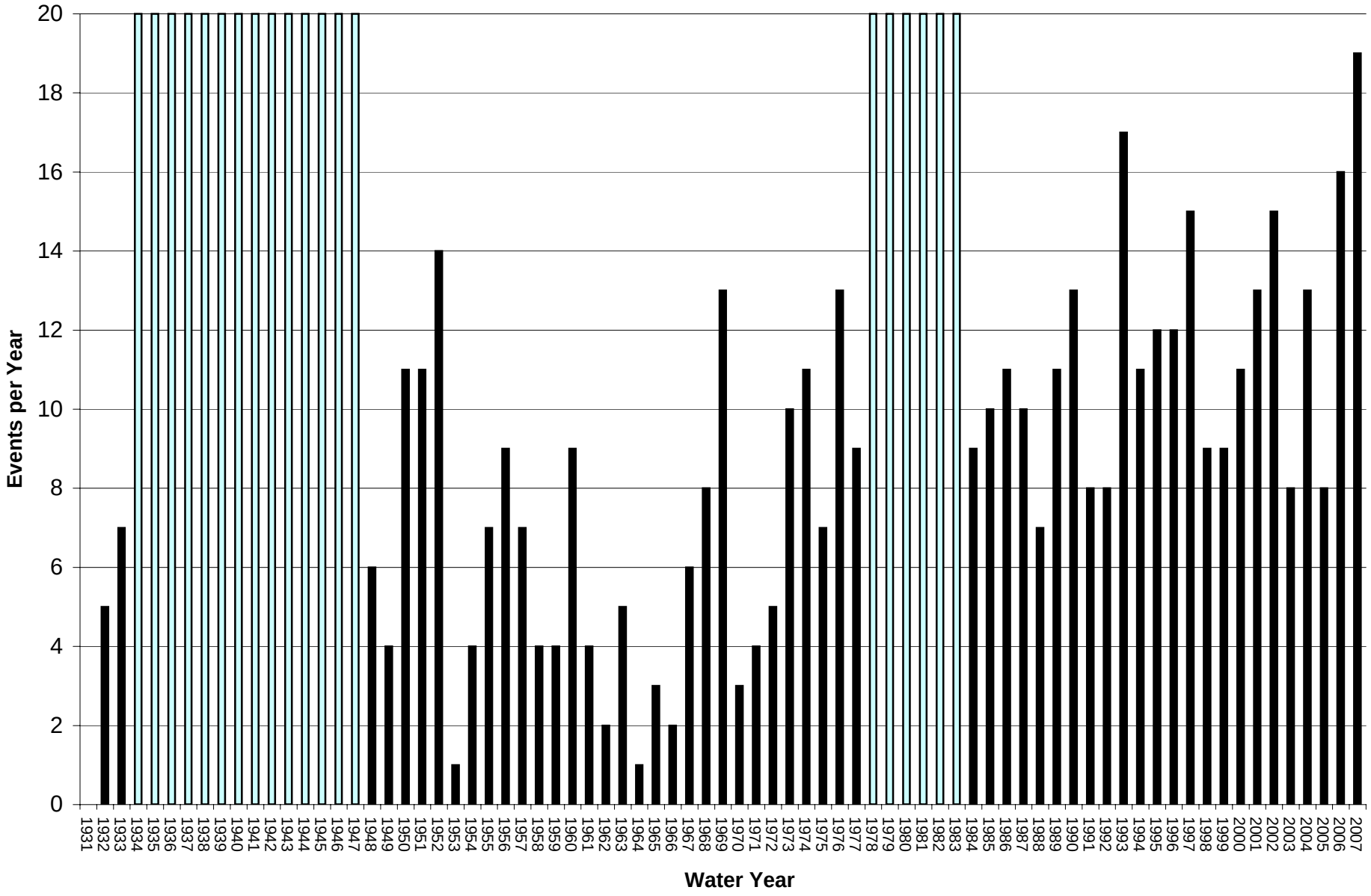
Overbank Flood Flow Rate = 525 cfs



Middle Branch of the Rouge River near Garden City

Histogram of Flood Events Greater than 1-Month Flood Event

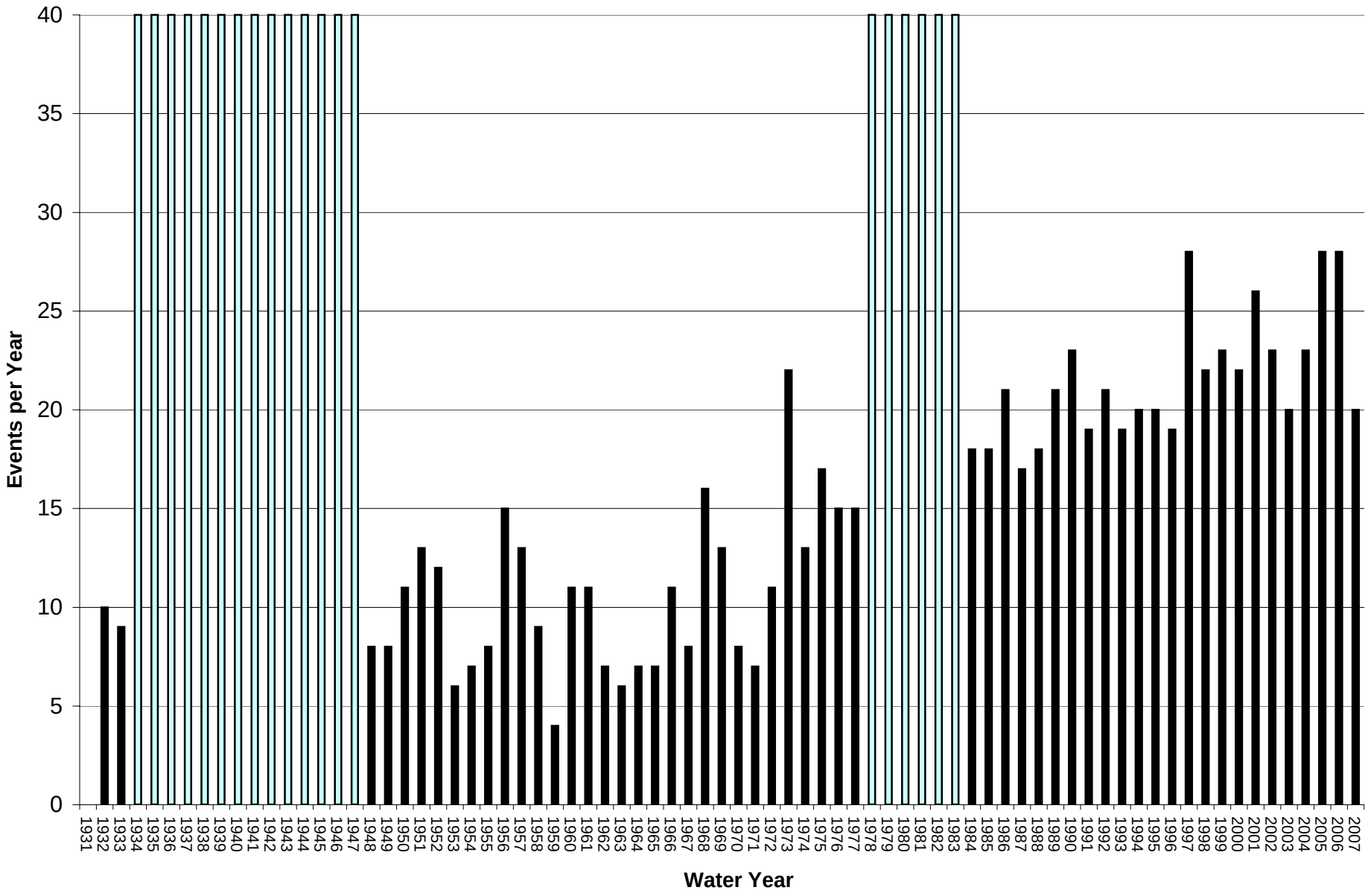
1-Month Flood Flow Rate from Partial Duration Series of Water Years 1997 through 2006 = 315 cfs



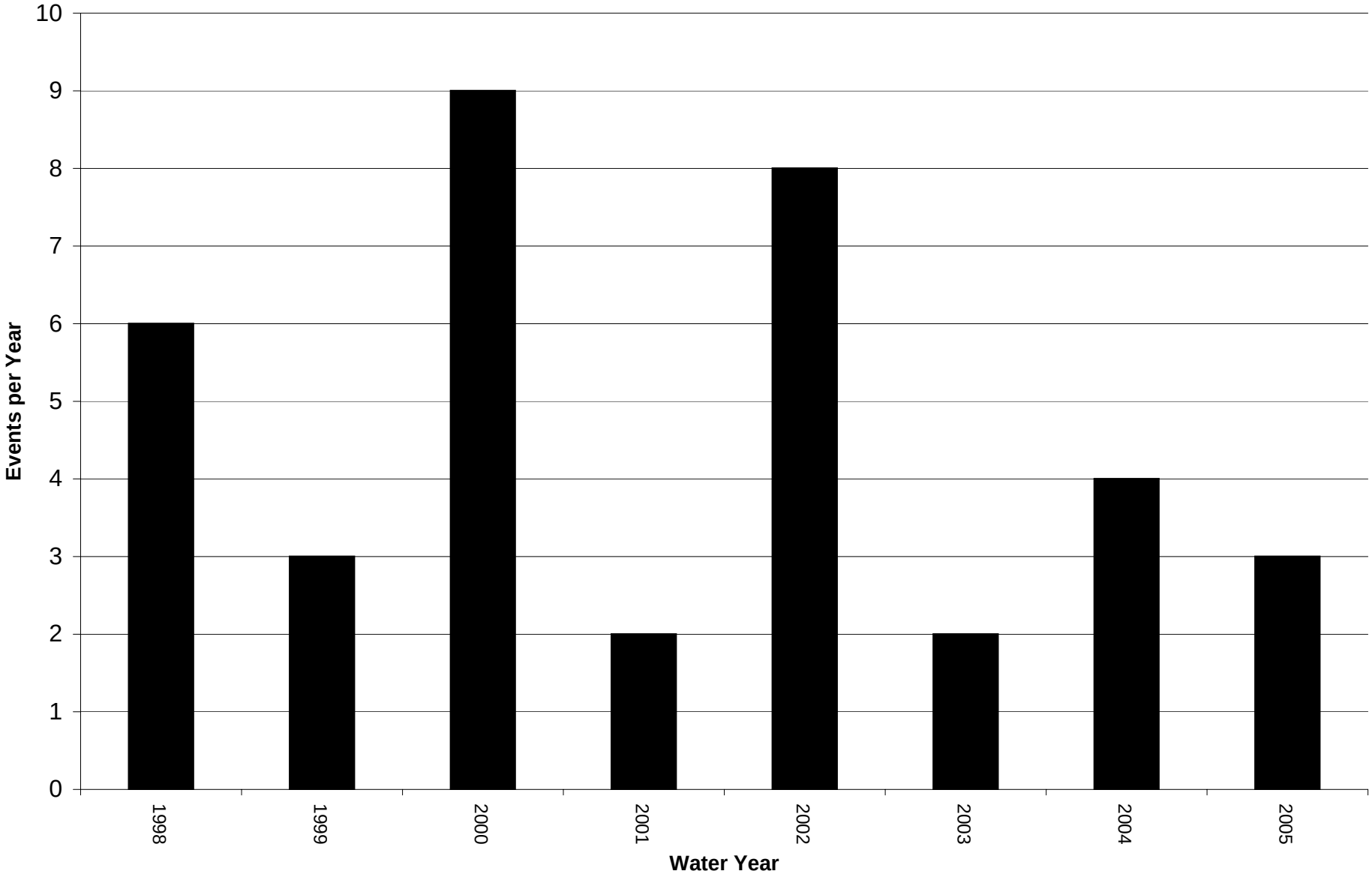
Middle Branch of the Rouge River near Garden City

Histogram of Flood Events Greater than 15-Day Flood Event

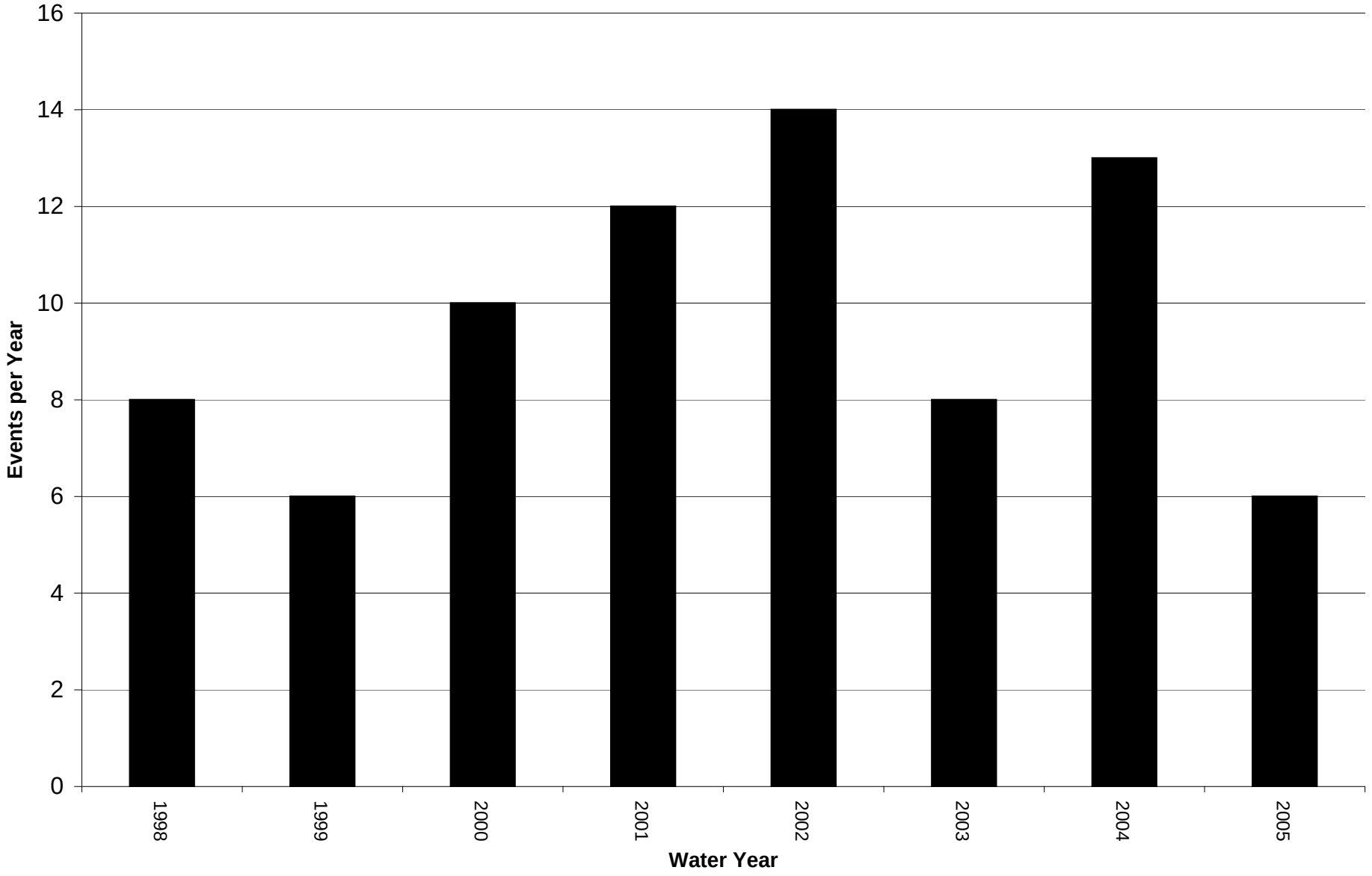
15-Day Flood Flow Rate from Partial Duration Series of Water Years 1997 through 2006 = 173 cfs



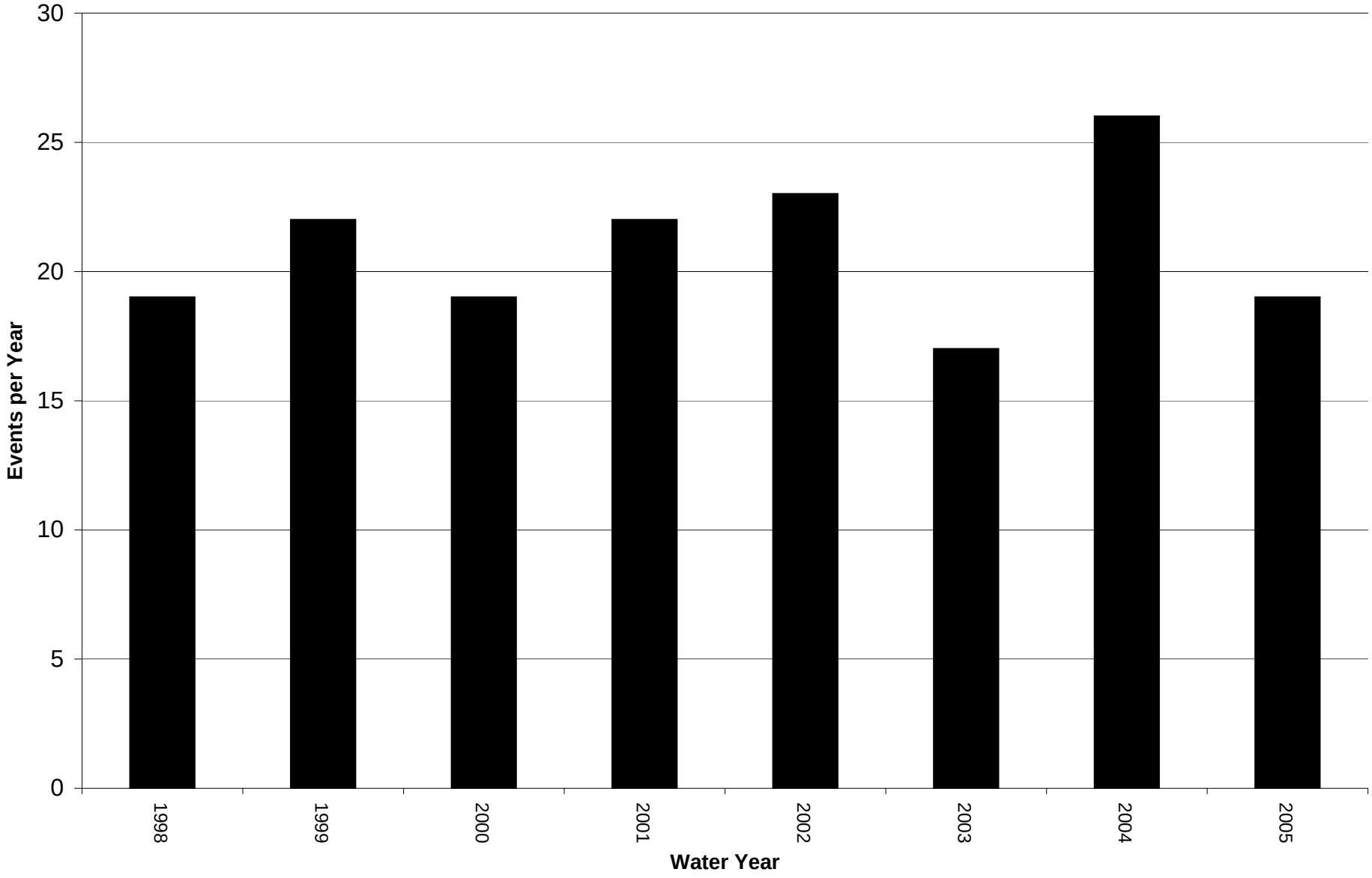
Middle Branch of the Rouge River at Dearborn Heights
Histogram of Flood Events Greater than Overbank Flood Event
Overbank Flood Flow Rate = 550 cfs



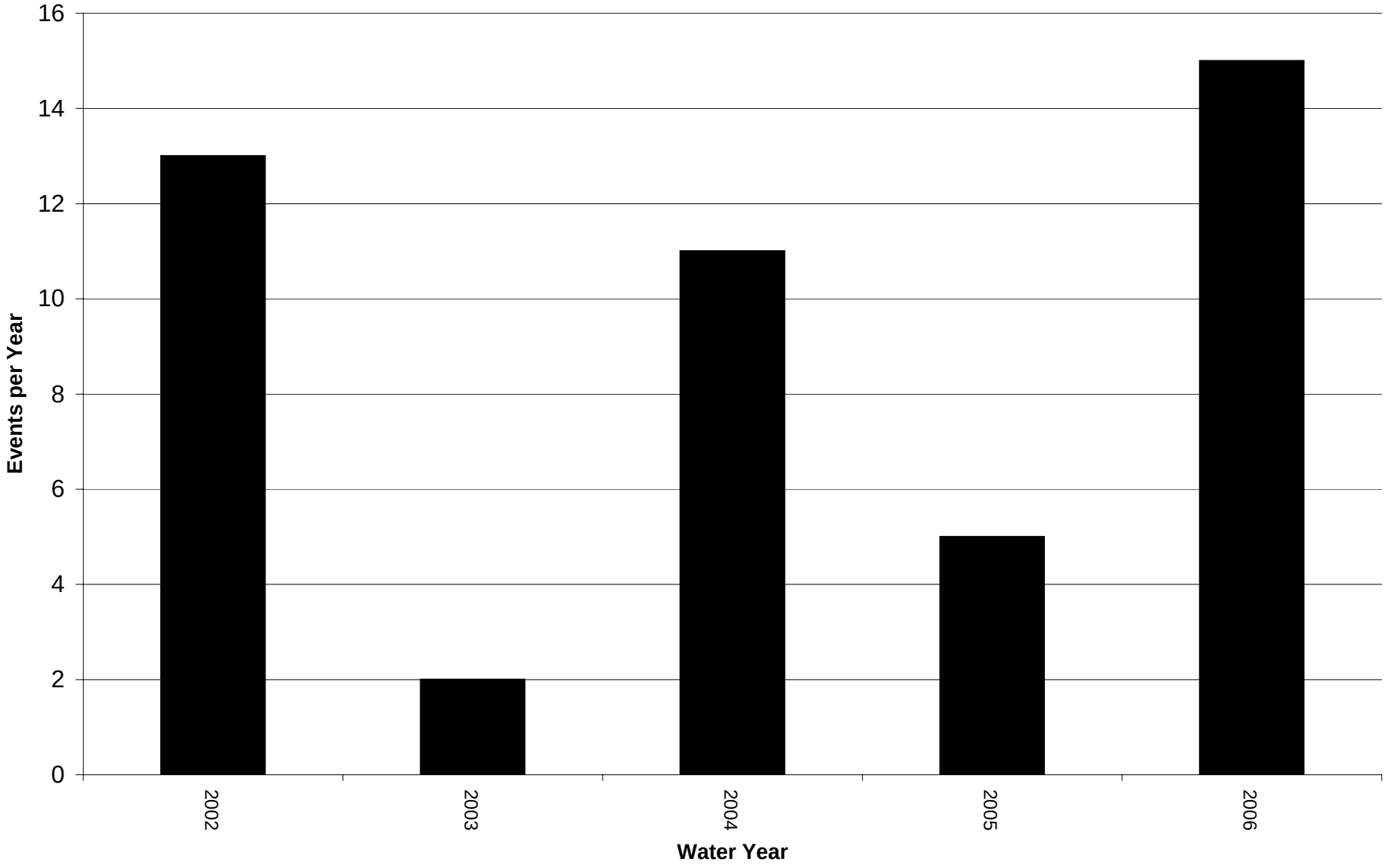
Middle Branch of the Rouge River at Dearborn Heights
Histogram of Flood Events Greater than 1-Month Flood Event
1-Month Flood Flow Rate from Partial Duration Series of Water Years 1999 through 2005 = 339 cfs



Middle Branch of the Rouge River at Dearborn Heights
Histogram of Flood Events Greater than 15-Day Flood Event
15-Day Flood Flow Rate from Partial Duration Series of Water Years 1999 through 2005 = 175 cfs



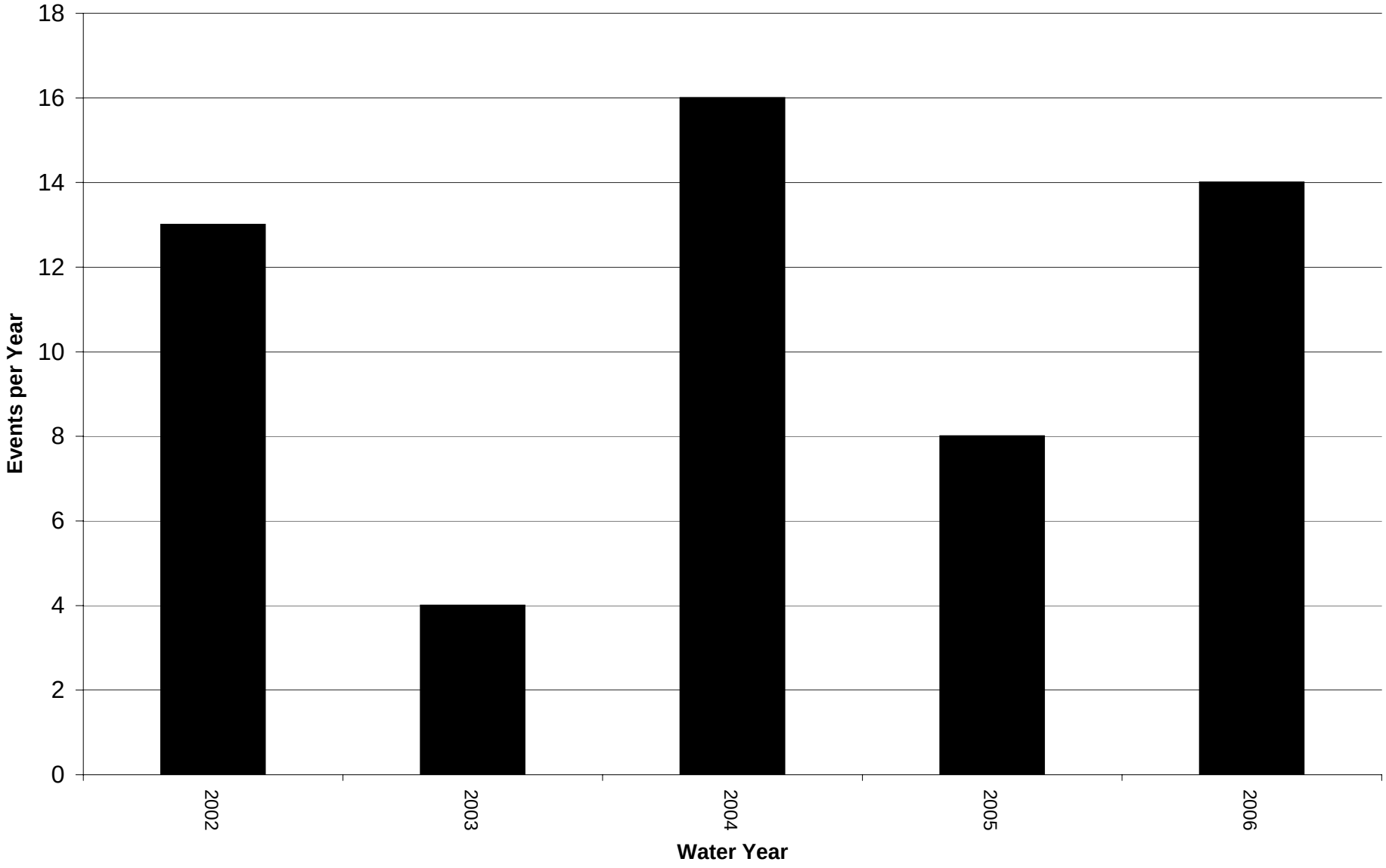
Lower Branch of the Rouge River at Wayne
Histogram of Flood Events Greater than Overbank Flood Event
Overbank Flood Flow Rate = 321 cfs



Lower Branch of the Rouge River at Wayne

Histogram of Flood Events Greater than 1-Month Flood Event

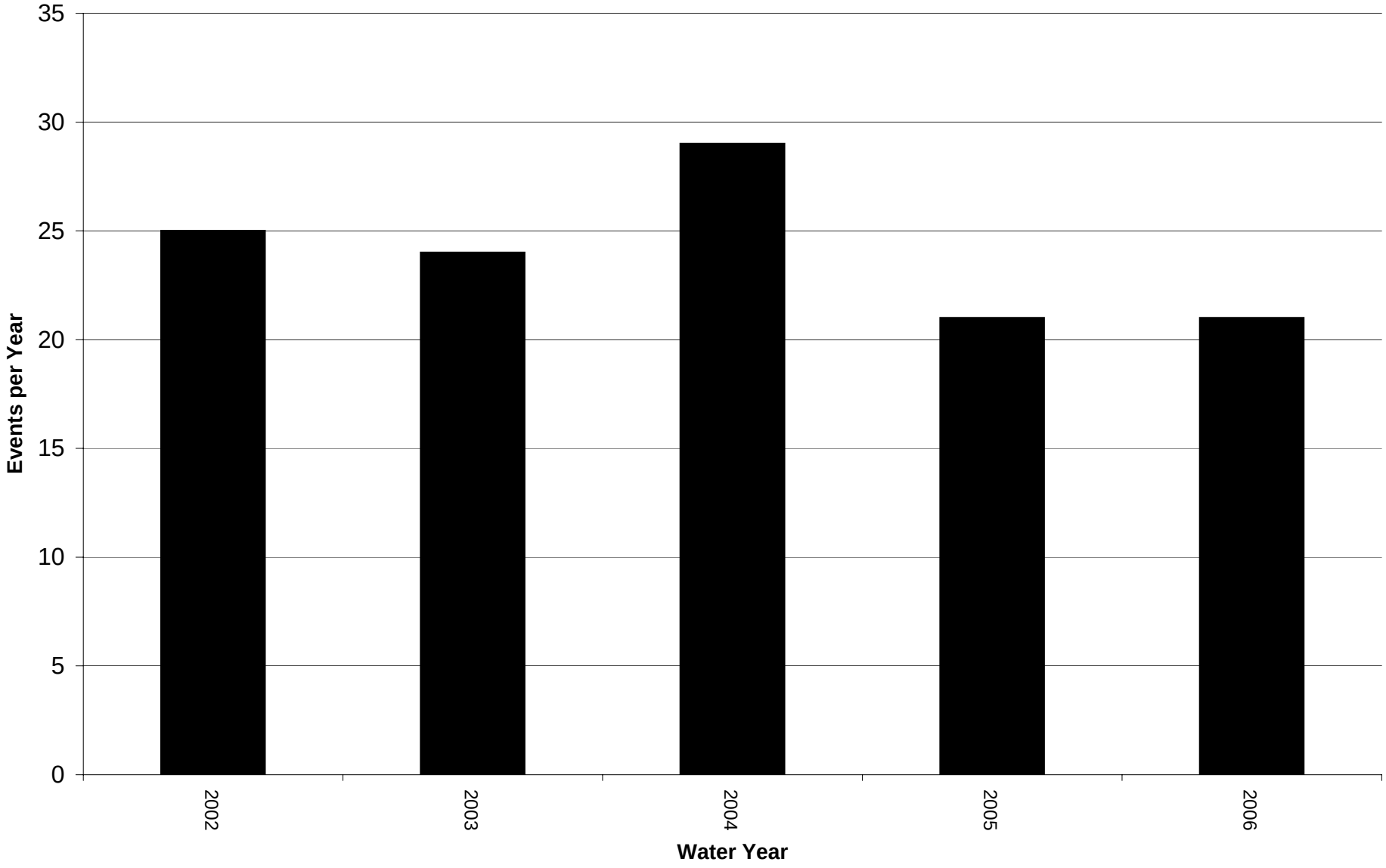
1-Month Flood Flow Rate from Partial Duration Series of Water Years 2002 through 2006 = 266 cfs



Lower Branch of the Rouge River at Wayne

Histogram of Flood Events Greater than 15-Day Flood Event

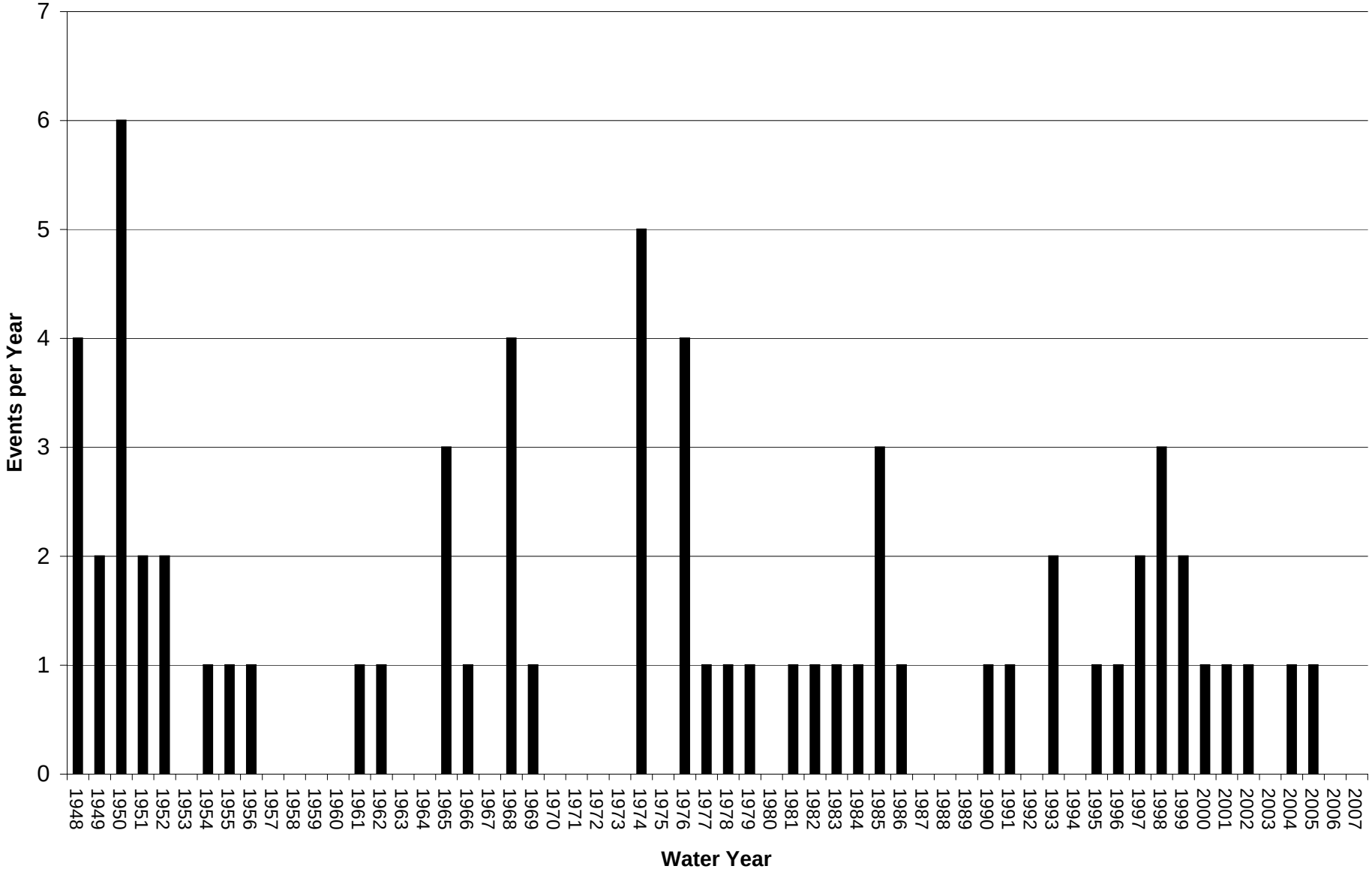
15-Day Flood Flow Rate from Partial Duration Series of Water Years 2002 through 2006 = 130 cfs



Lower Branch of the Rouge River at Inkster

Histogram of Flood Events Greater than Overbank Flood Event

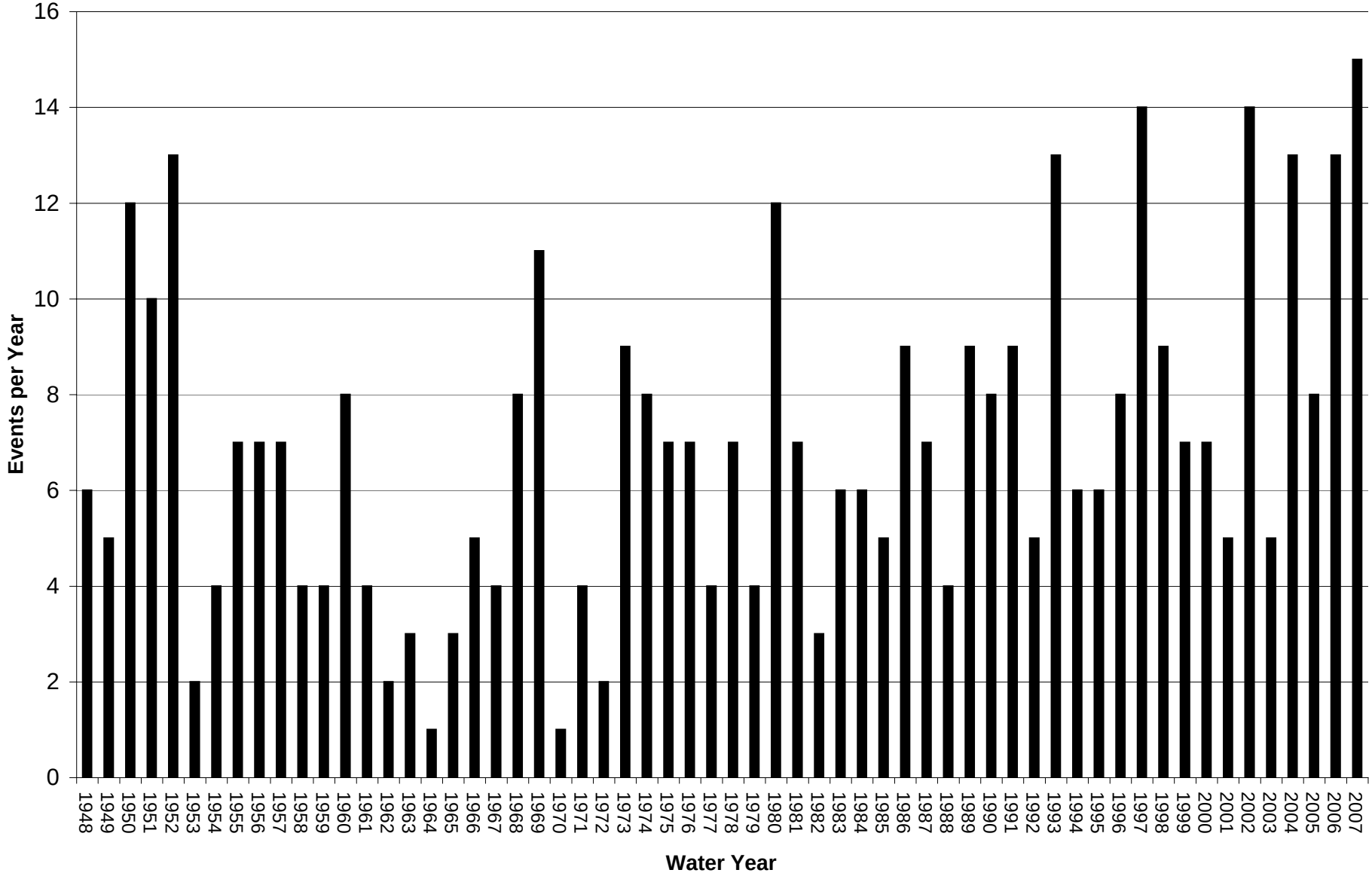
Overbank Flood Flow Rate = 1047 cfs



Lower Branch of the Rouge River at Inkster

Histogram of Flood Events Greater than 1-Month Flood Event

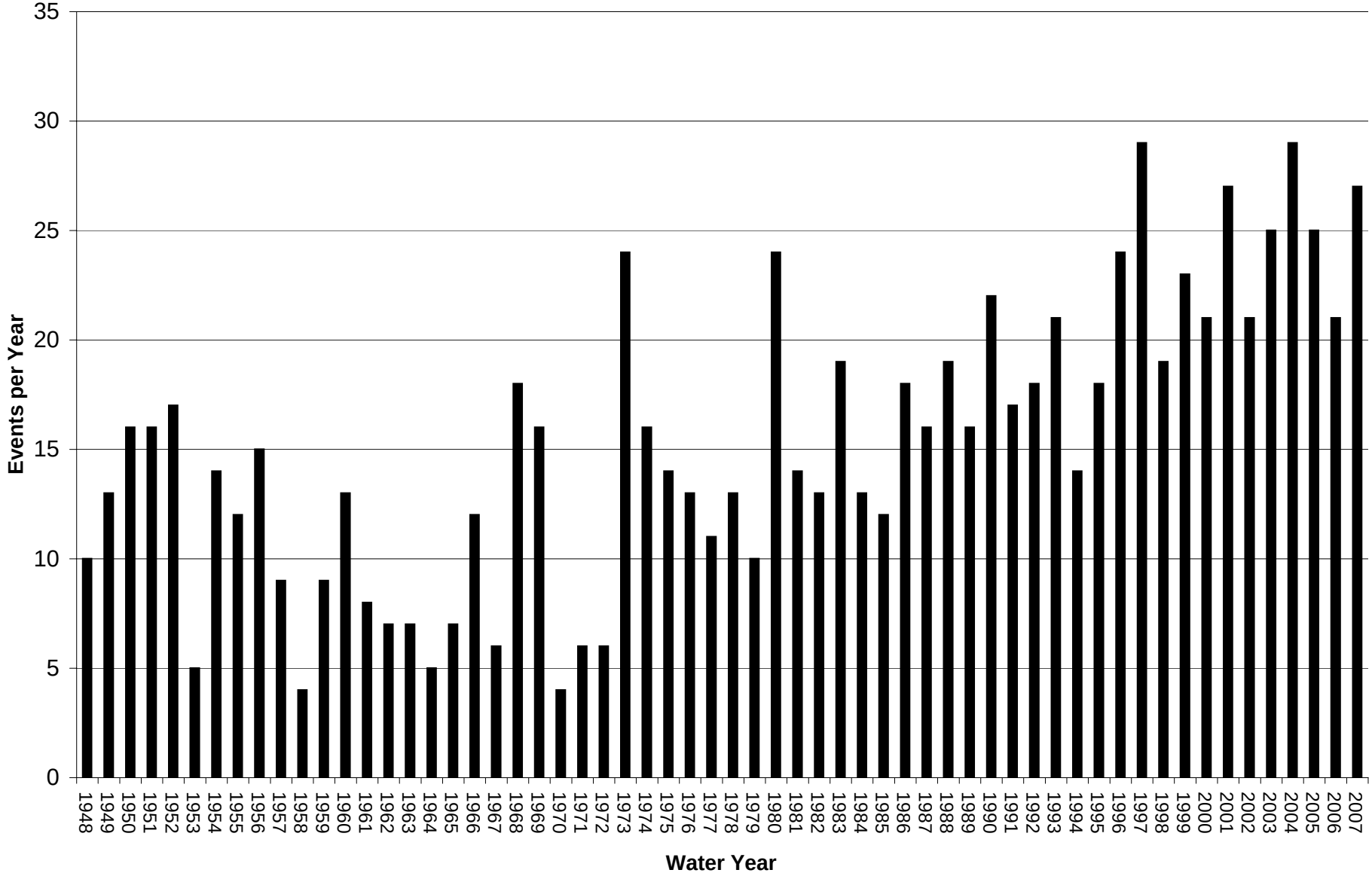
1-Month Flood Flow Rate from Partial Duration Series of Water Years 1997 to 2006 = 352 cfs



Lower Branch of the Rouge River at Inkster

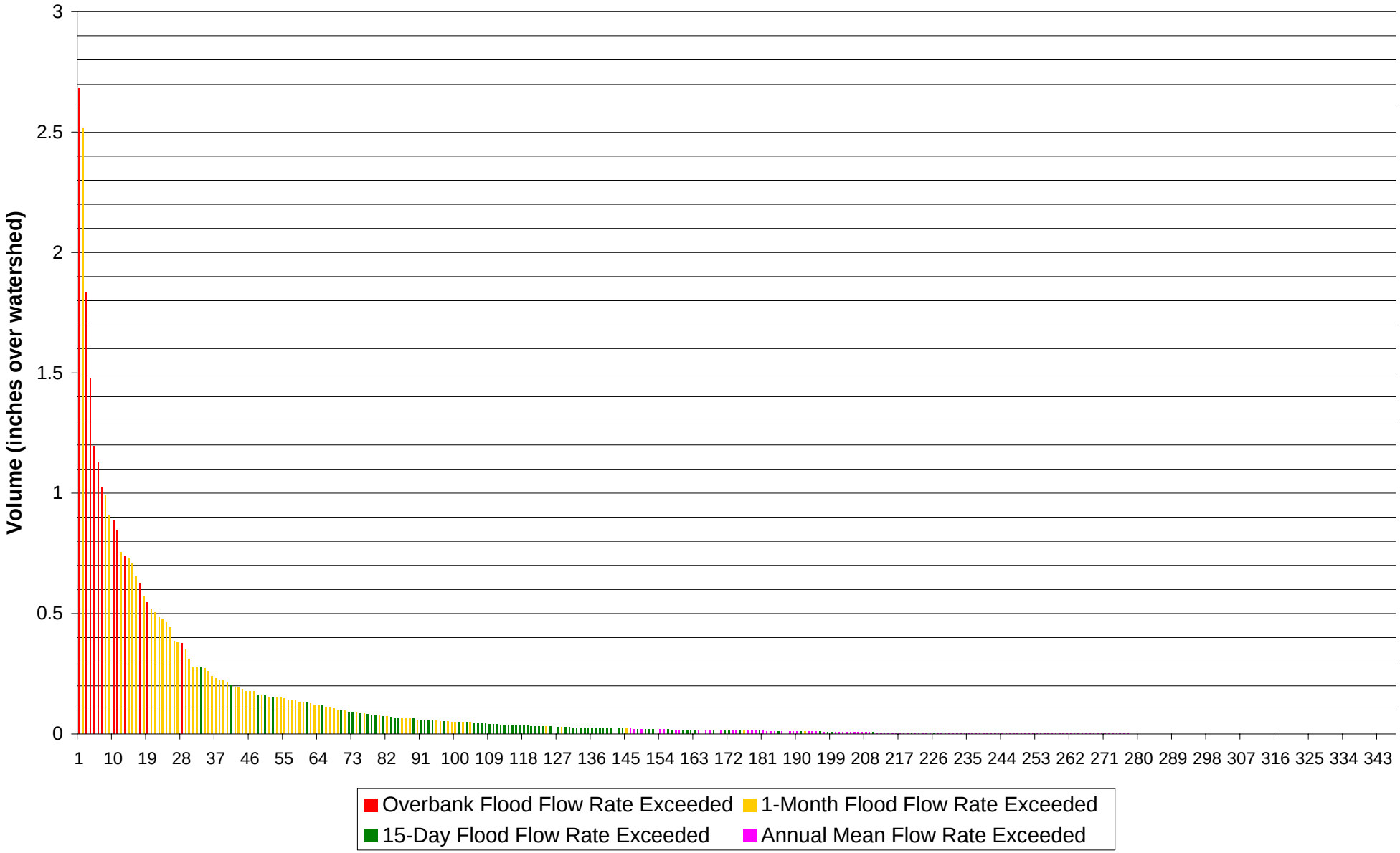
Histogram of Flood Events Greater than 15-Day Flood Event

15-Day Flood Flow Rate from Partial Duration Series of Water Years 1997 through 2006 = 171 cfs

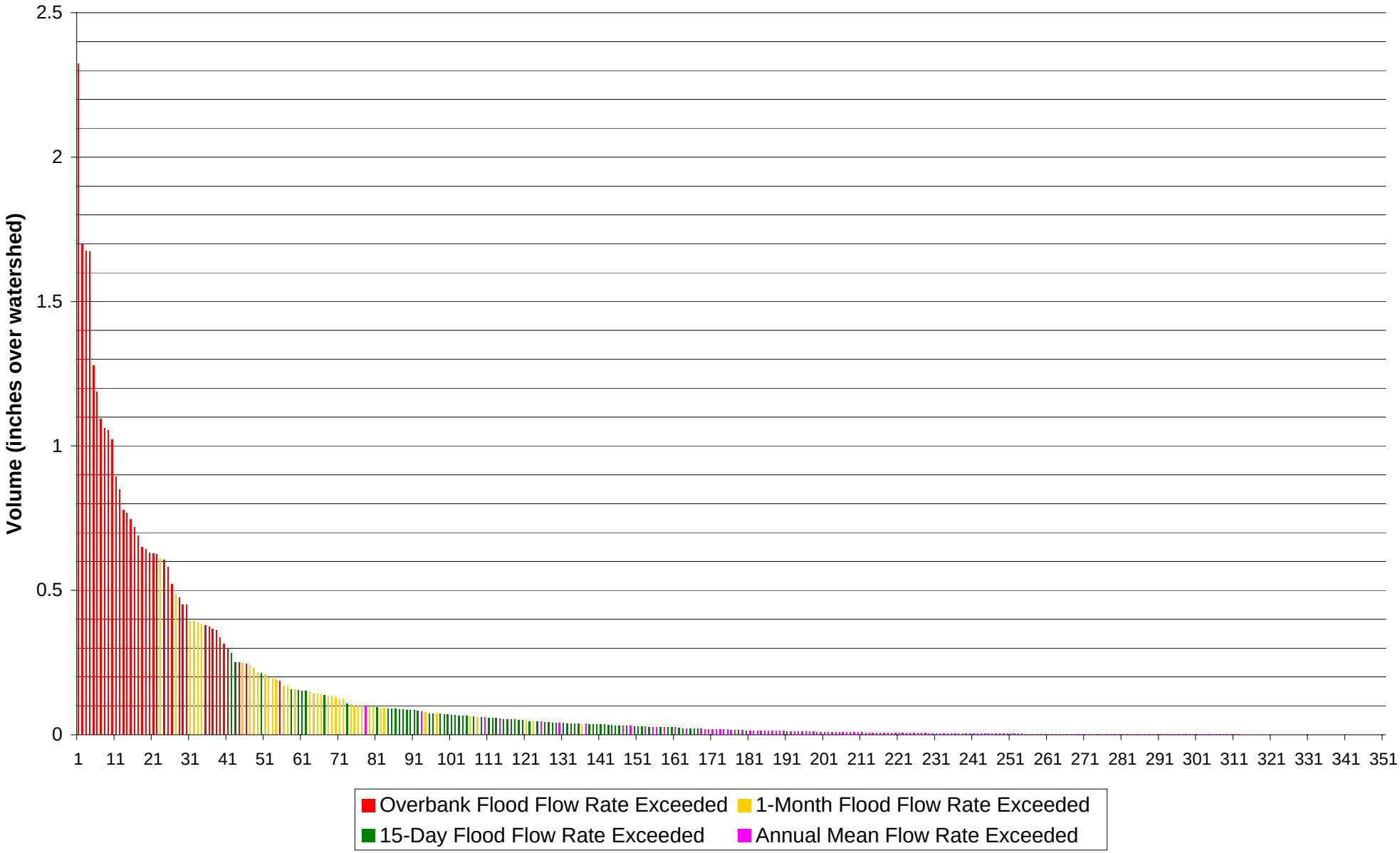


Appendix D. Flood Volume Plots

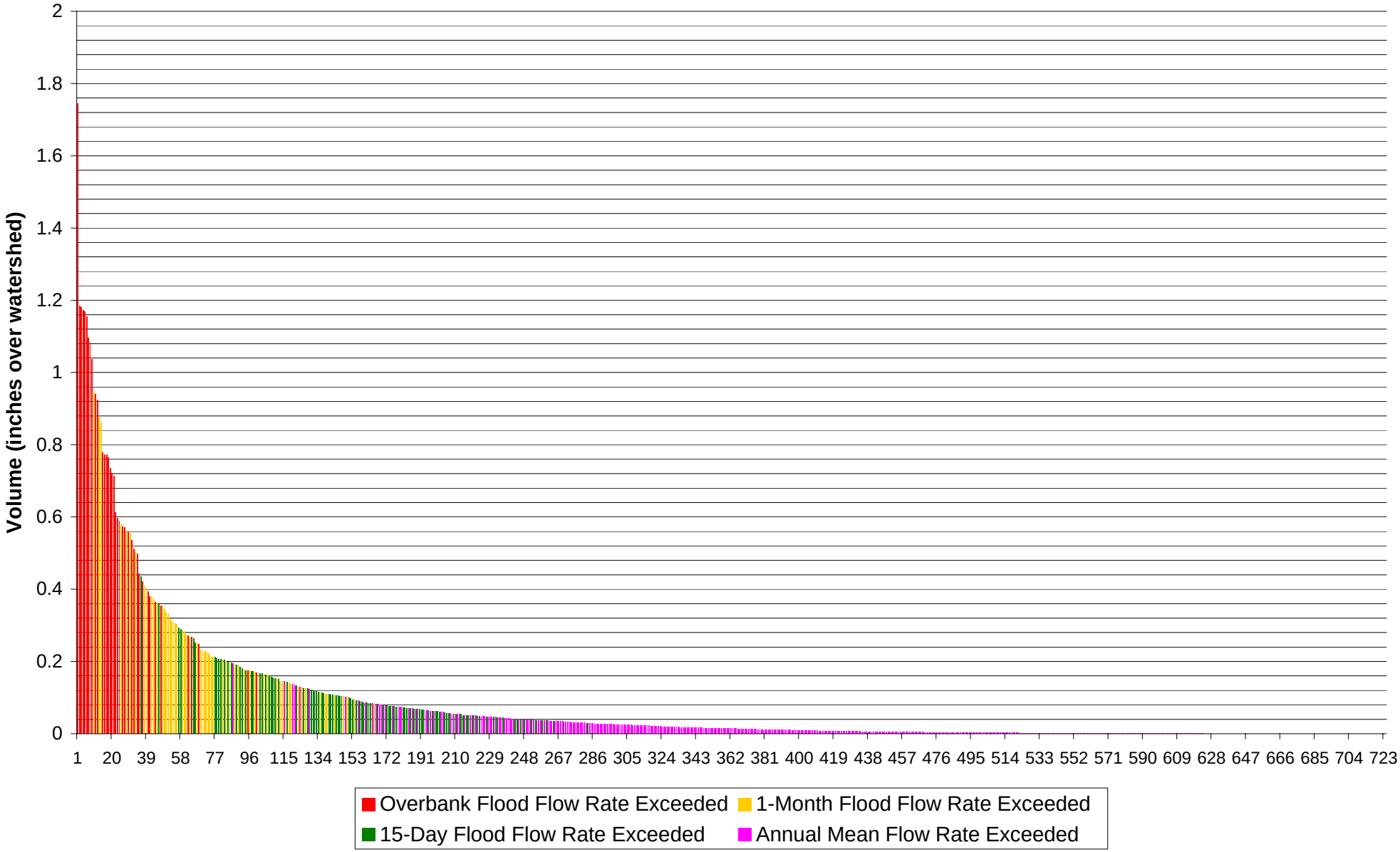
Main Branch of the Rouge River at Birmingham
Total Flood Volume of All Flood Events Exceeding Annual Mean Flood Flow Rate
Water Years 1997 through 2006, Calculated from 15-Minute Flow Rate Data



Main Branch of the Rouge River at Southfield
Total Flood Volume of All Flood Events Exceeding Annual Mean Flood Flow Rate
Water Years 1997 through 2006, Calculated from 15-Minute Flow Rate Data

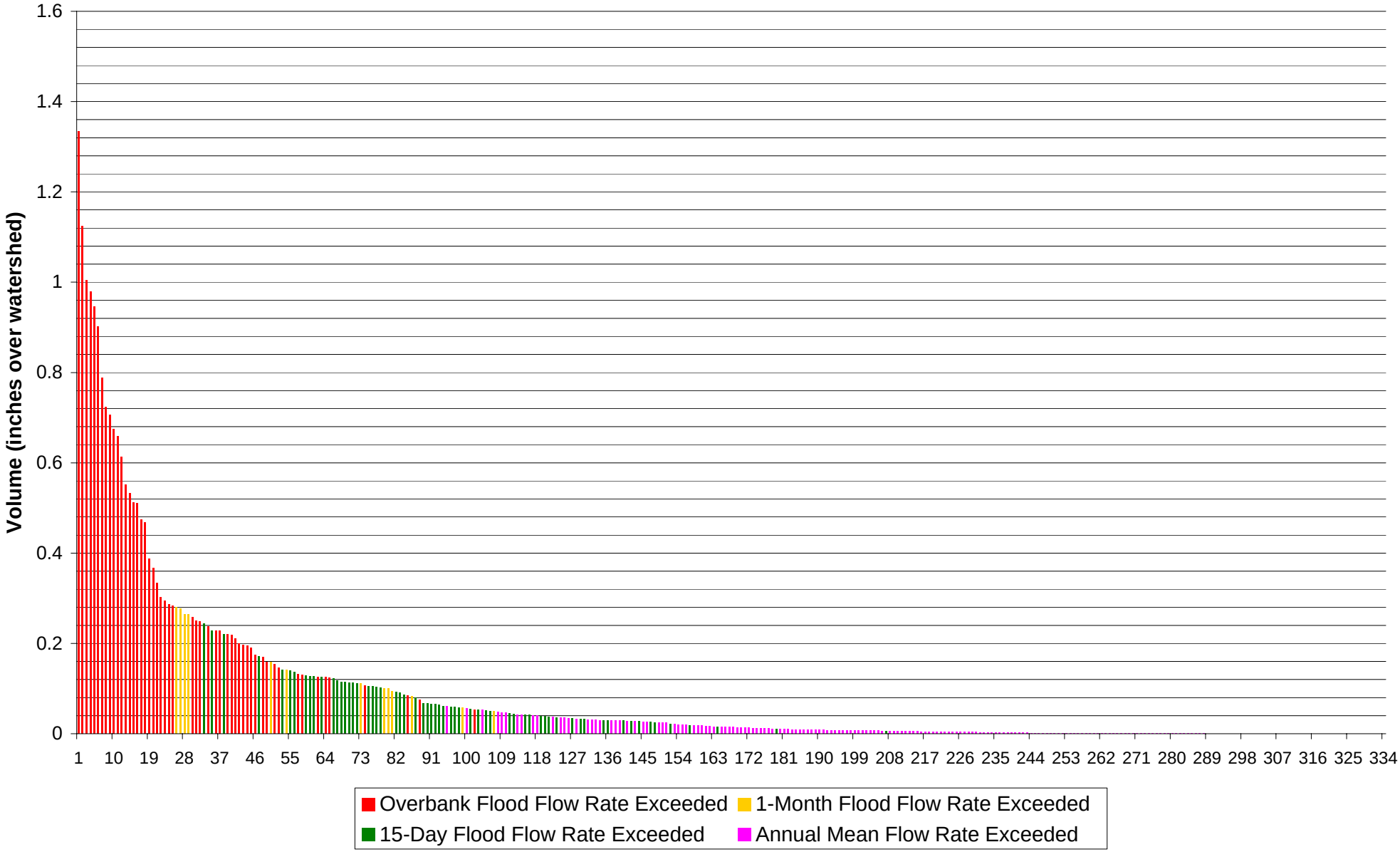


Evans Ditch at Southfield
Total Flood Volume of All Flood Events Exceeding Annual Mean Flood Flow Rate
Water Years 1997 through 2006, Calculated from 15-Minute Flow Rate Data

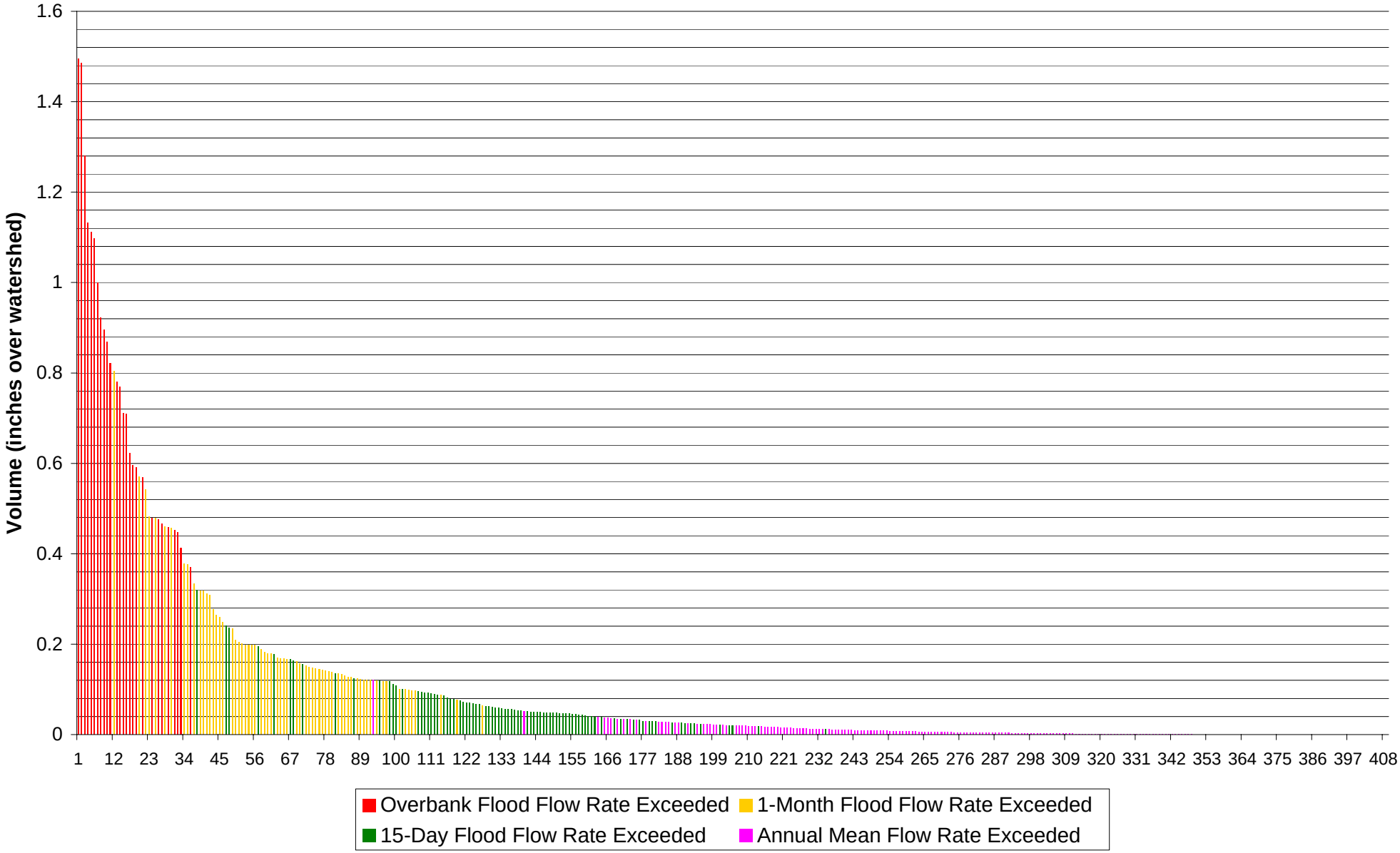


Upper Branch of the Rouge River at Farmington
Total Flood Volume of All Flood Events Exceeding Annual Mean Flood Flow Rate
Water Years 1997 through 2006, Calculated from 15-Minute Flow Rate Data

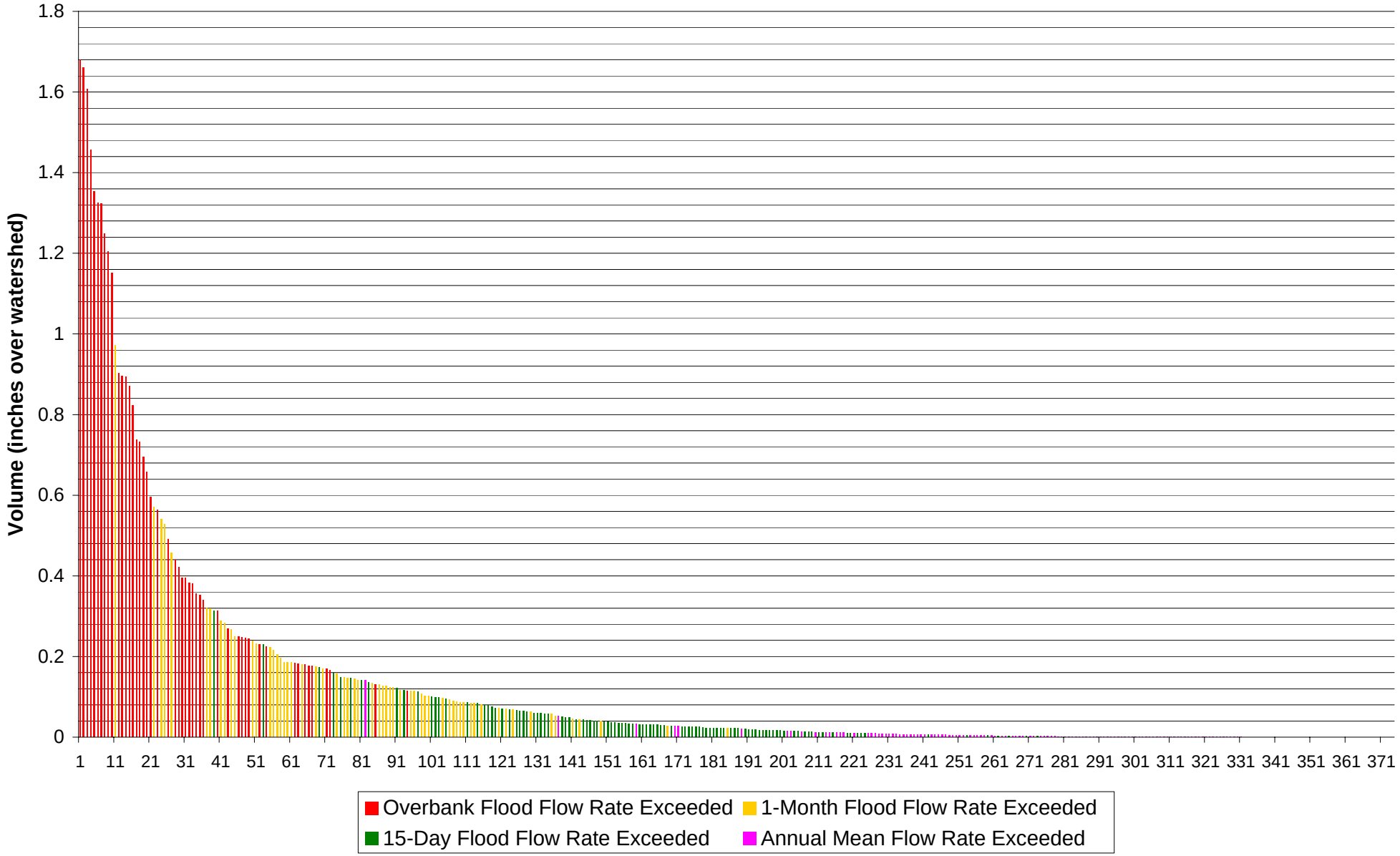
Upper Branch of the Rouge River at Detroit
Total Flood Volume of All Flood Events Exceeding Annual Mean Flood Flow Rate
Water Years 1999 through 2005, Calculated from 15-Minute Flow Rate Data



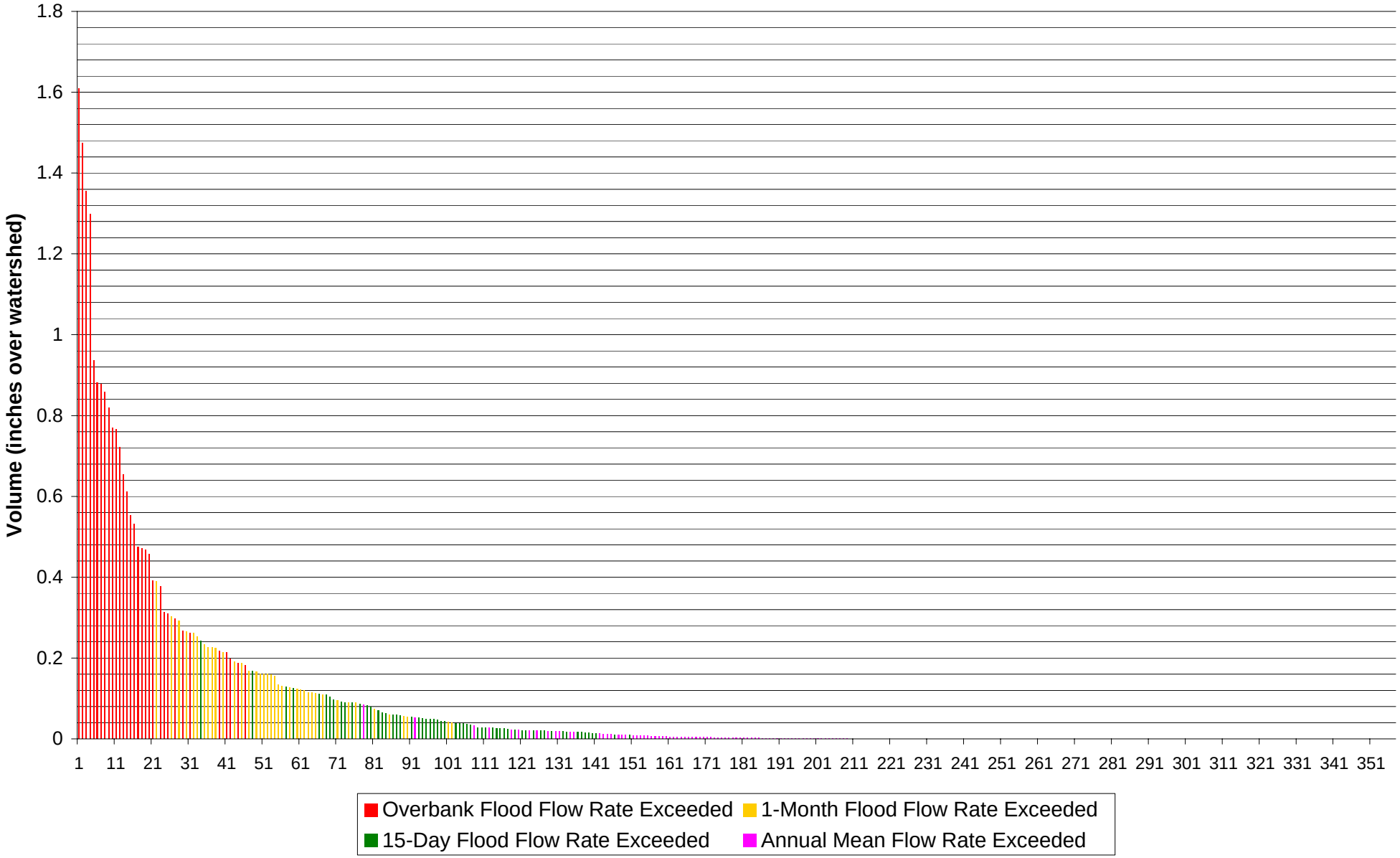
Main Branch of the Rouge River at Detroit
Total Flood Volume of All Flood Events Exceeding Annual Mean Flood Flow Rate
Water Years 1997 through 2006, Calculated from 15-Minute Flow Rate Data



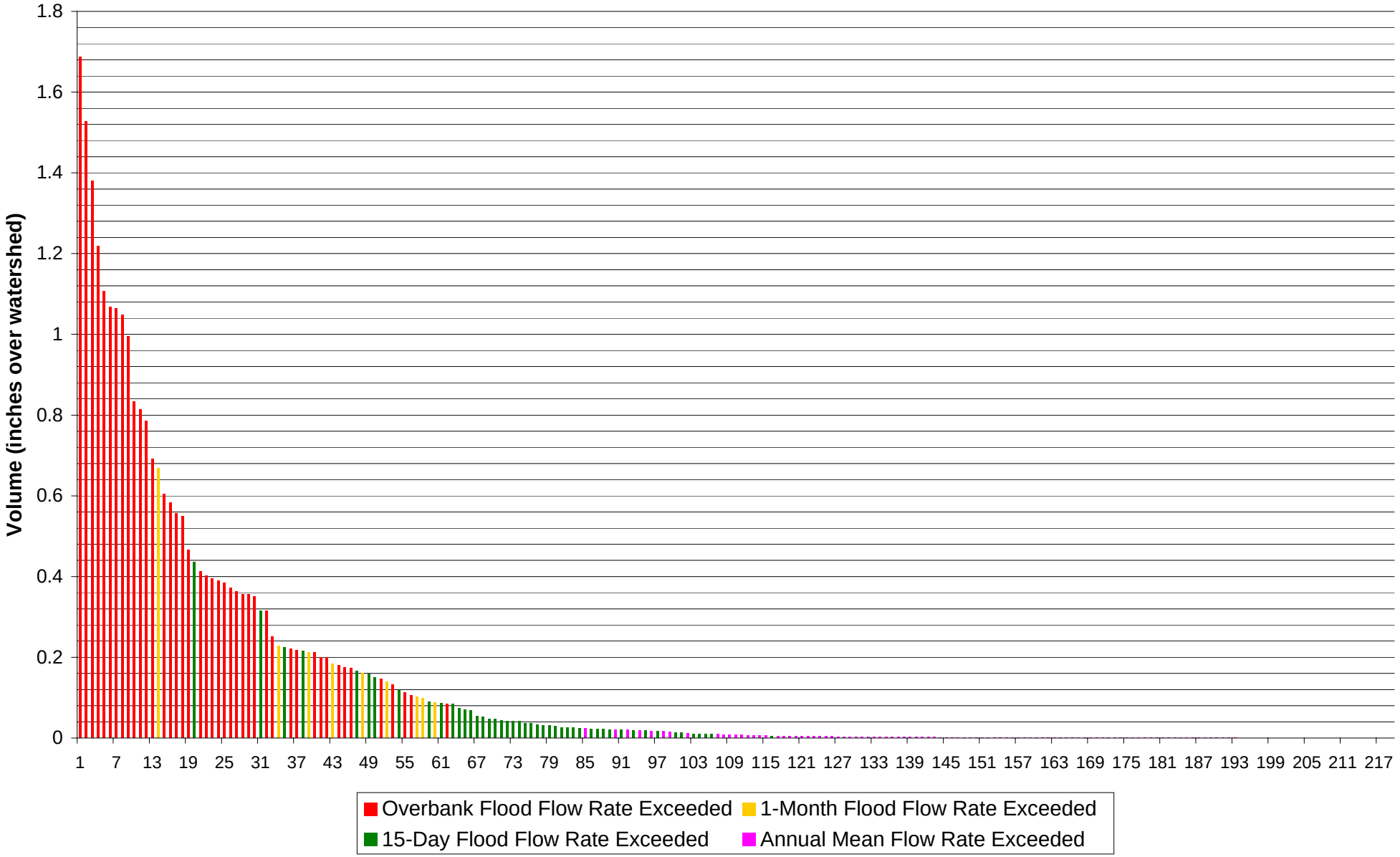
Middle Branch of the Rouge River near Garden City
Total Flood Volume of All Flood Events Exceeding Annual Mean Flood Flow Rate
Water Years 1997 through 2006, Calculated from 15-Minute Flow Rate Data



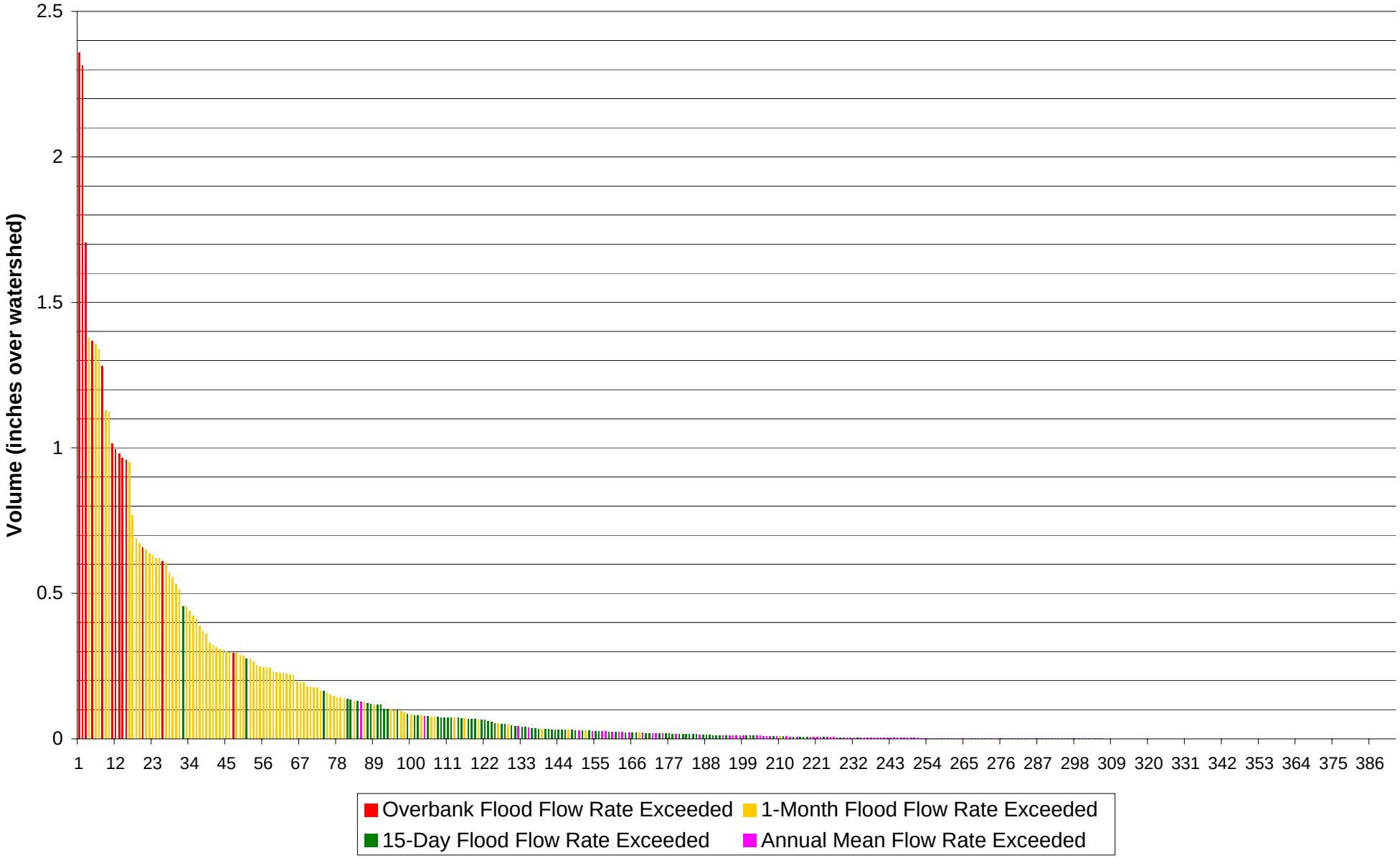
Middle Branch of the Rouge River at Dearborn Heights
Total Flood Volume of All Flood Events Exceeding Annual Mean Flood Flow Rate
Water Years 1999 through 2005, Calculated from 15-Minute Flow Rate Data



Lower Branch of the Rouge River at Wayne
Total Flood Volume of All Flood Events Exceeding Annual Mean Flood Flow Rate
Water Years 2002 through 2006, Calculated from 15-Minute Flow Rate Data

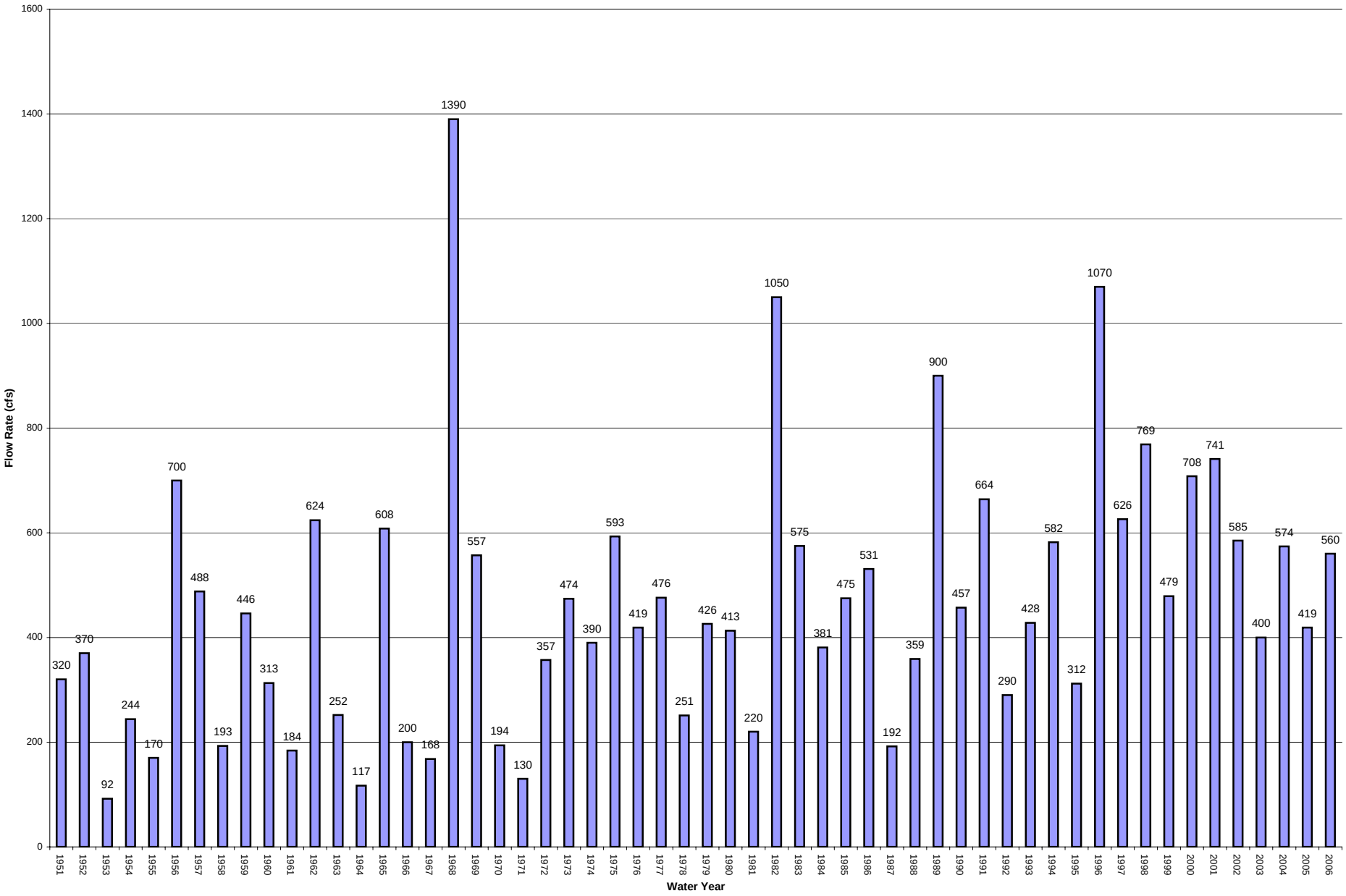


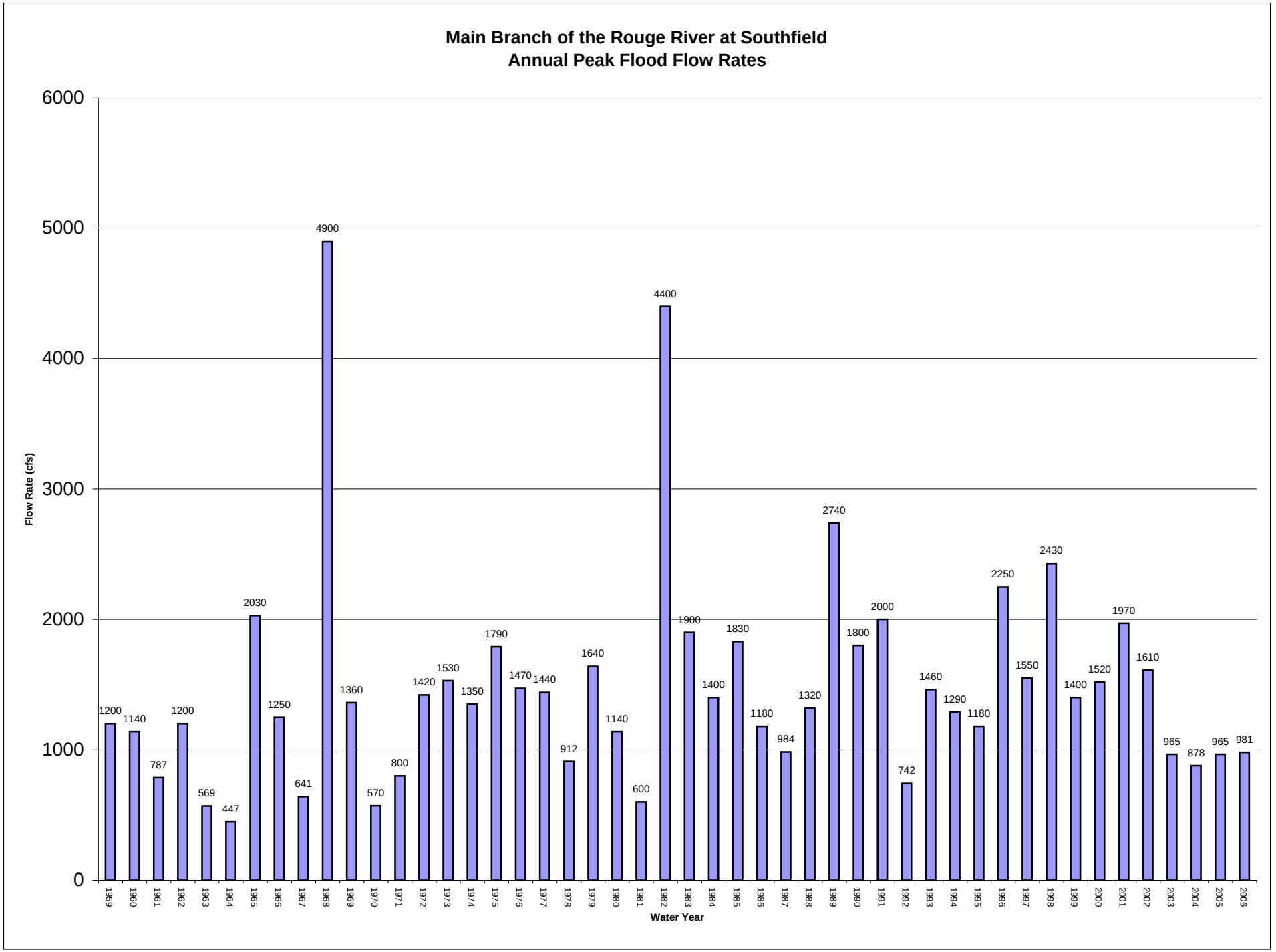
Lower Branch of the Rouge River at Inkster
Total Flood Volume of All Flood Events Exceeding Annual Mean Flood Flow Rate
Water Years 1997 through 2006, Calculated from 15-Minute Flow Rate Data



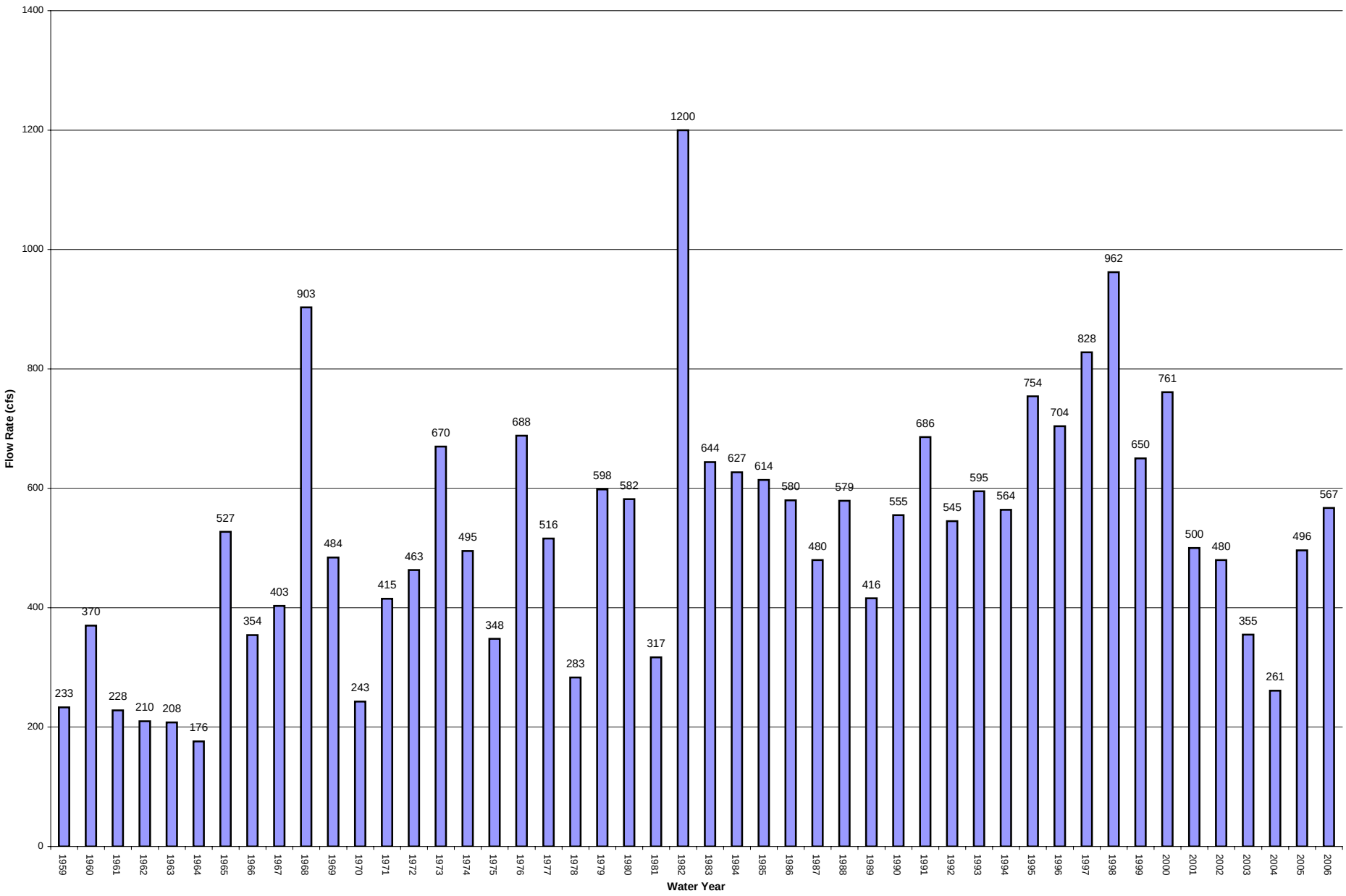
Appendix E. Annual Peak Flow Rate Plots

Main Branch of the Rouge River at Birmingham
Annual Peak Flood Flow Rates

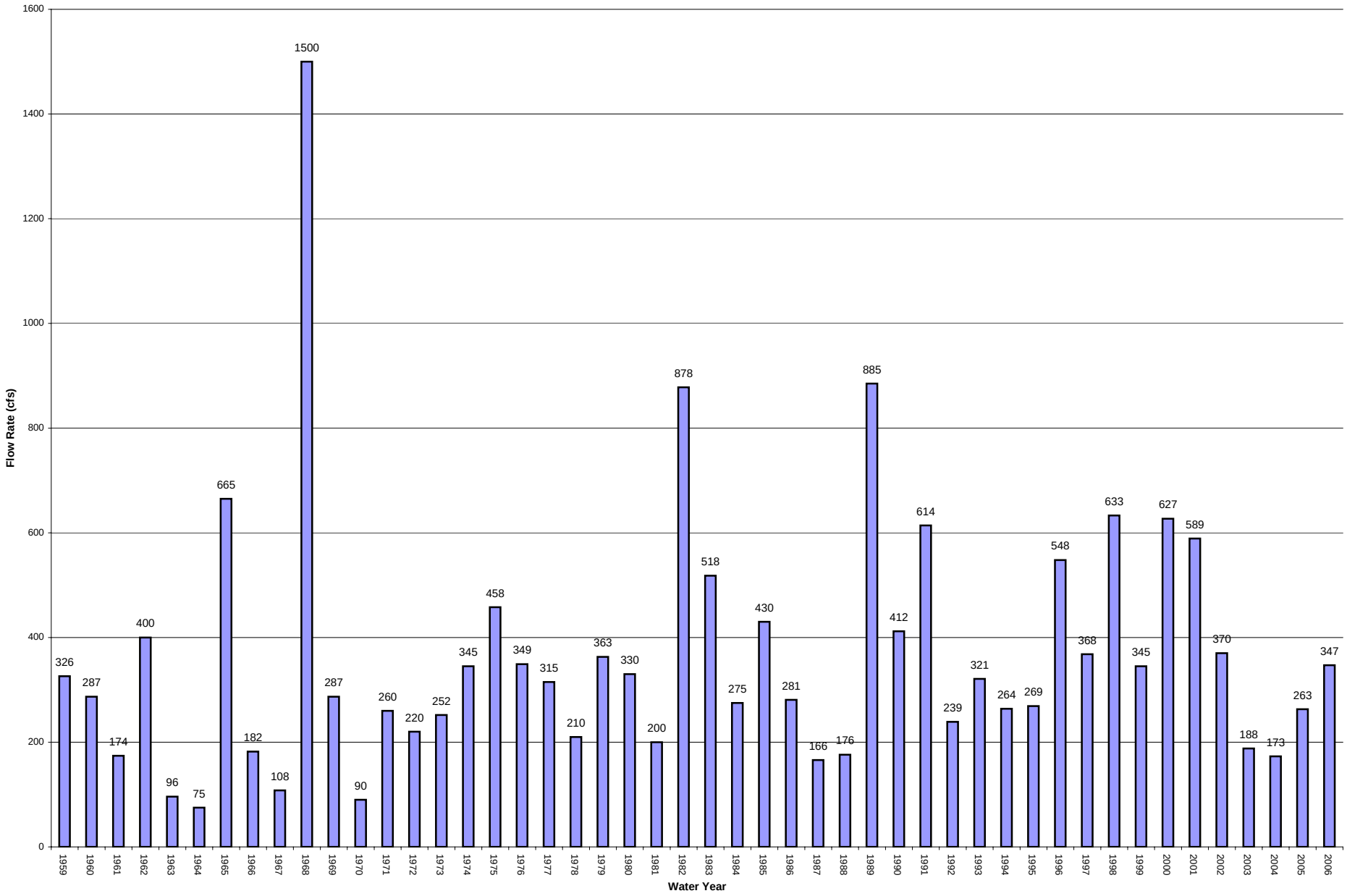


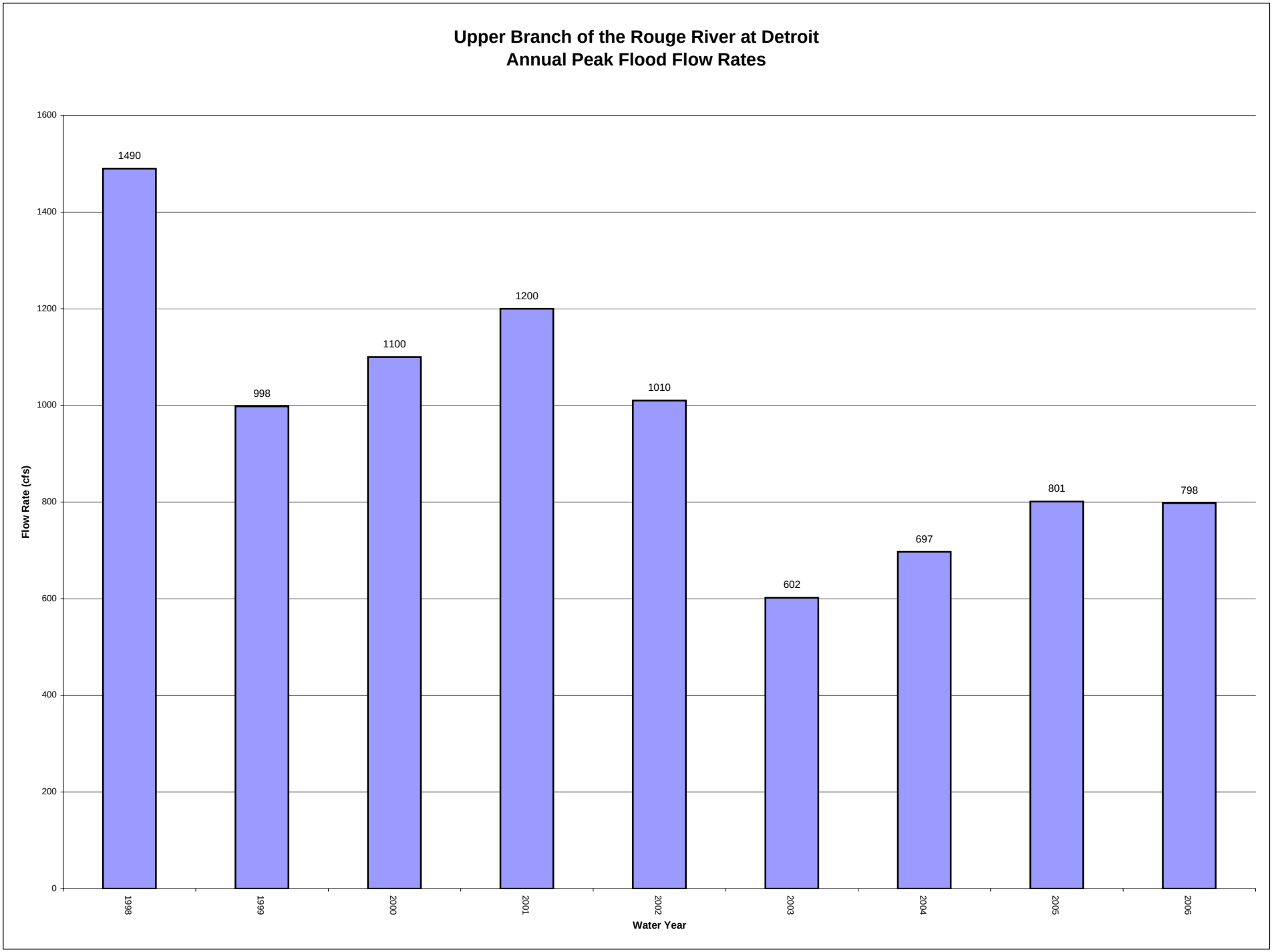

Main Branch of the Rouge River at Southfield
Annual Peak Flood Flow Rates
Flow Rate (cfs)
Water Year
0
1000
2000
3000
4000
5000
6000
1959 1200
1960 1140
1961 787
1962 1200
1963 569
1964 447
1965 2030
1966 1250
1967 641
1968 4900
1969 1360
1970 570
1971 800
1972 1420
1973 1530
1974 1350
1975 1790
1976 1470
1977 1440
1978 912
1979 1640
1980 1140
1981 600
1982 4400
1983 1900
1984 1400
1985 1830
1986 1180
1987 984
1988 1320
1989 2740
1990 1800
1991 2000
1992 742
1993 1460
1994 1290
1995 1180
1996 2250
1997 1550
1998 2430
1999 1400
2000 1520
2001 1970
2002 1610
2003 965
2004 878
2005 965
2006 981

Evans Ditch at Southfield
Annual Peak Flood Flow Rates

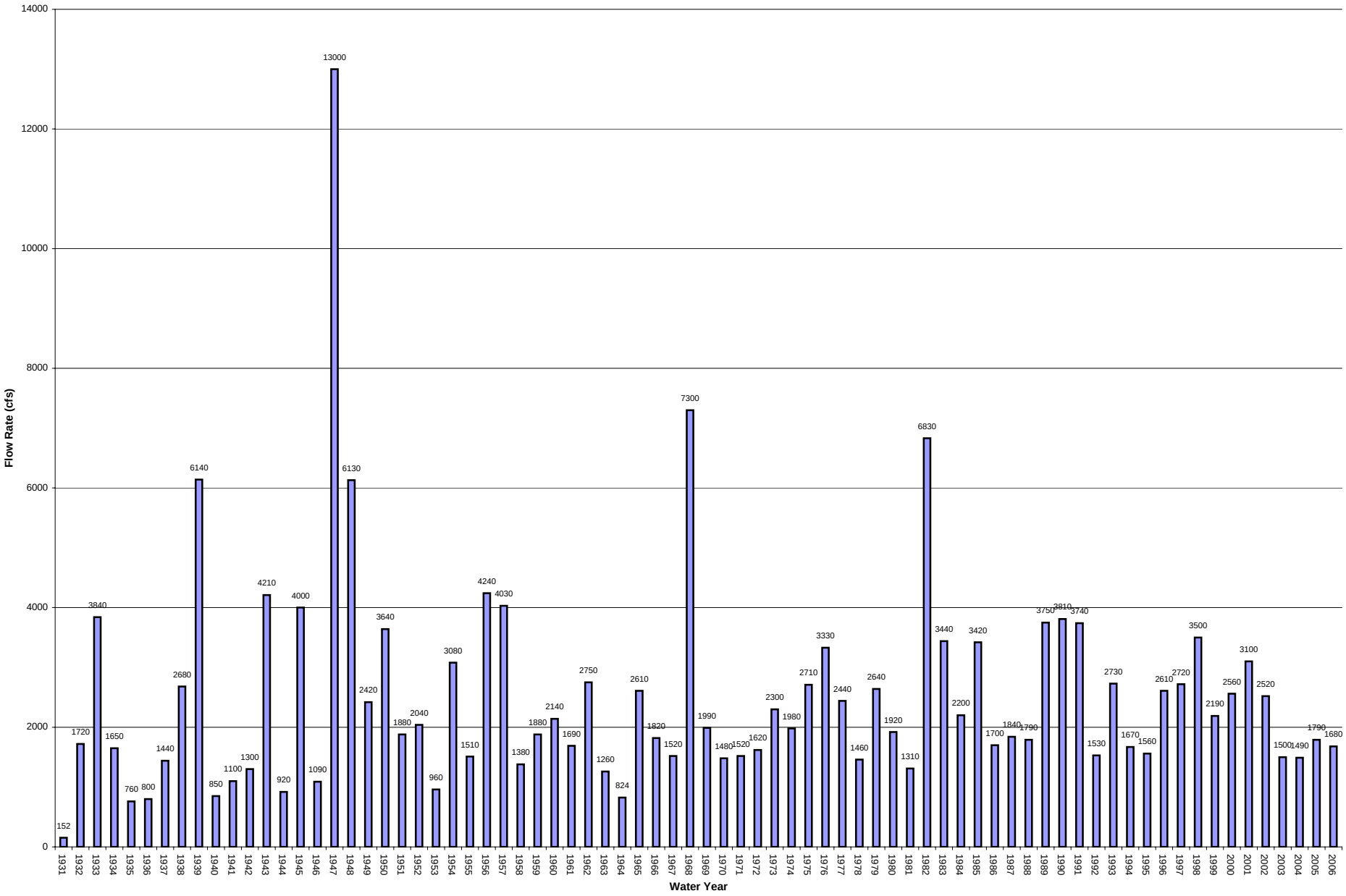


Upper Branch of the Rouge River at Farmington
Annual Peak Flood Flow Rates

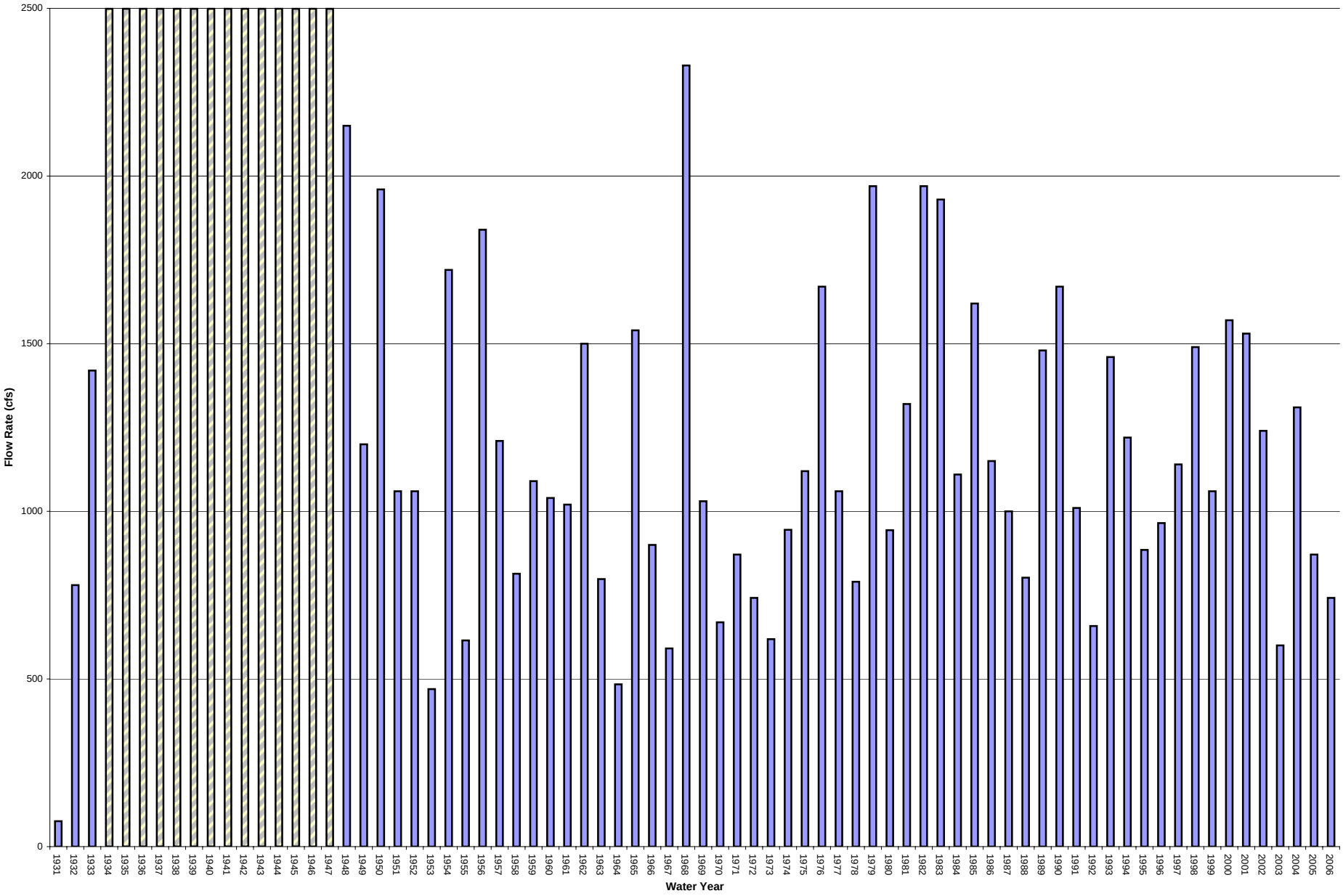


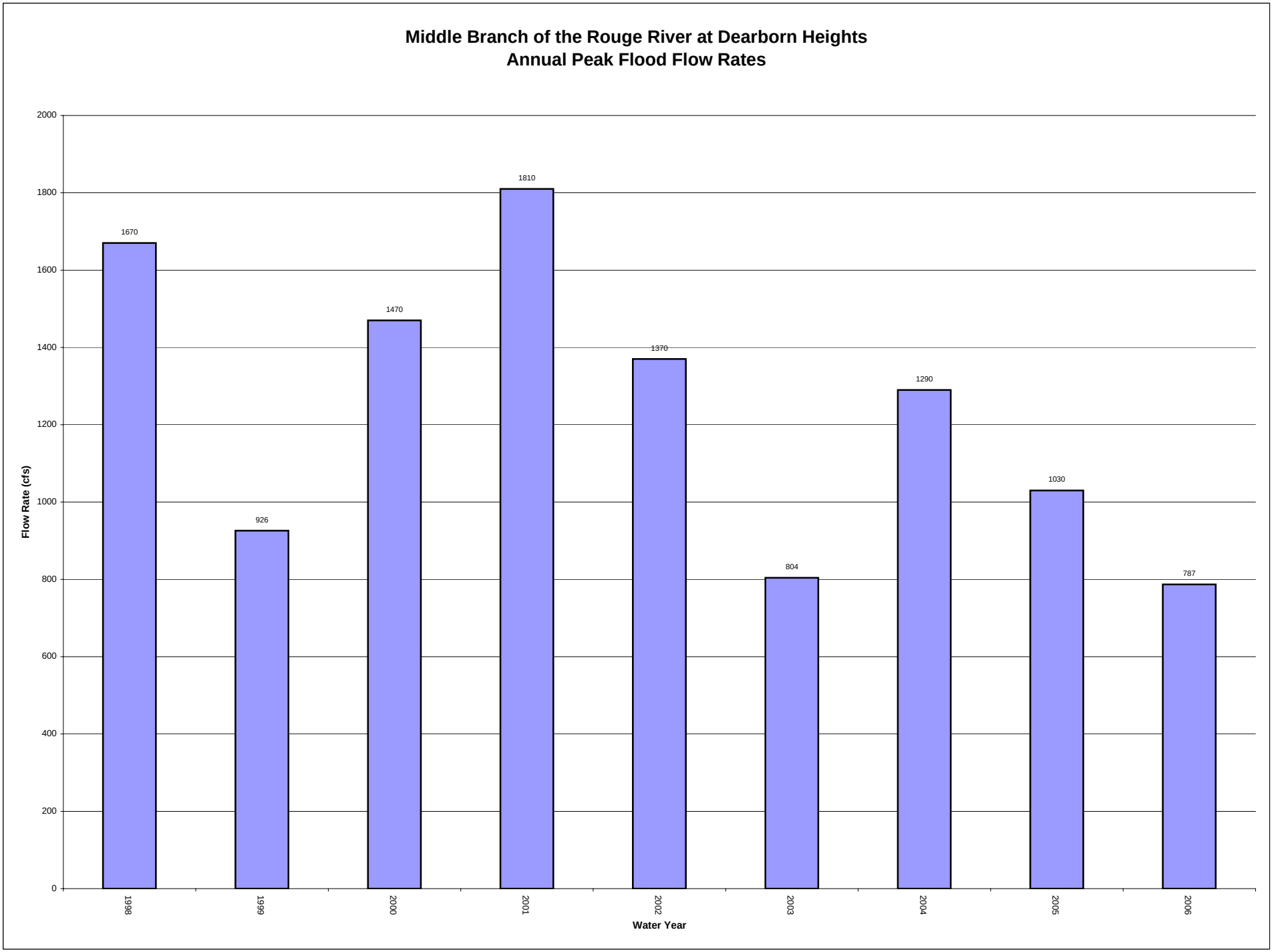

Upper Branch of the Rouge River at Detroit
Annual Peak Flood Flow Rates
Flow Rate (cfs)
0
200
400
600
800
1000
1200
1400
1600
1490
998
1100
1200
1010
602
697
801
798
1998
1999
2000
2001
2002
2003
2004
2005
2006
Water Year

Main Branch of the Rouge River at Detroit
Annual Peak Flood Flow Rates

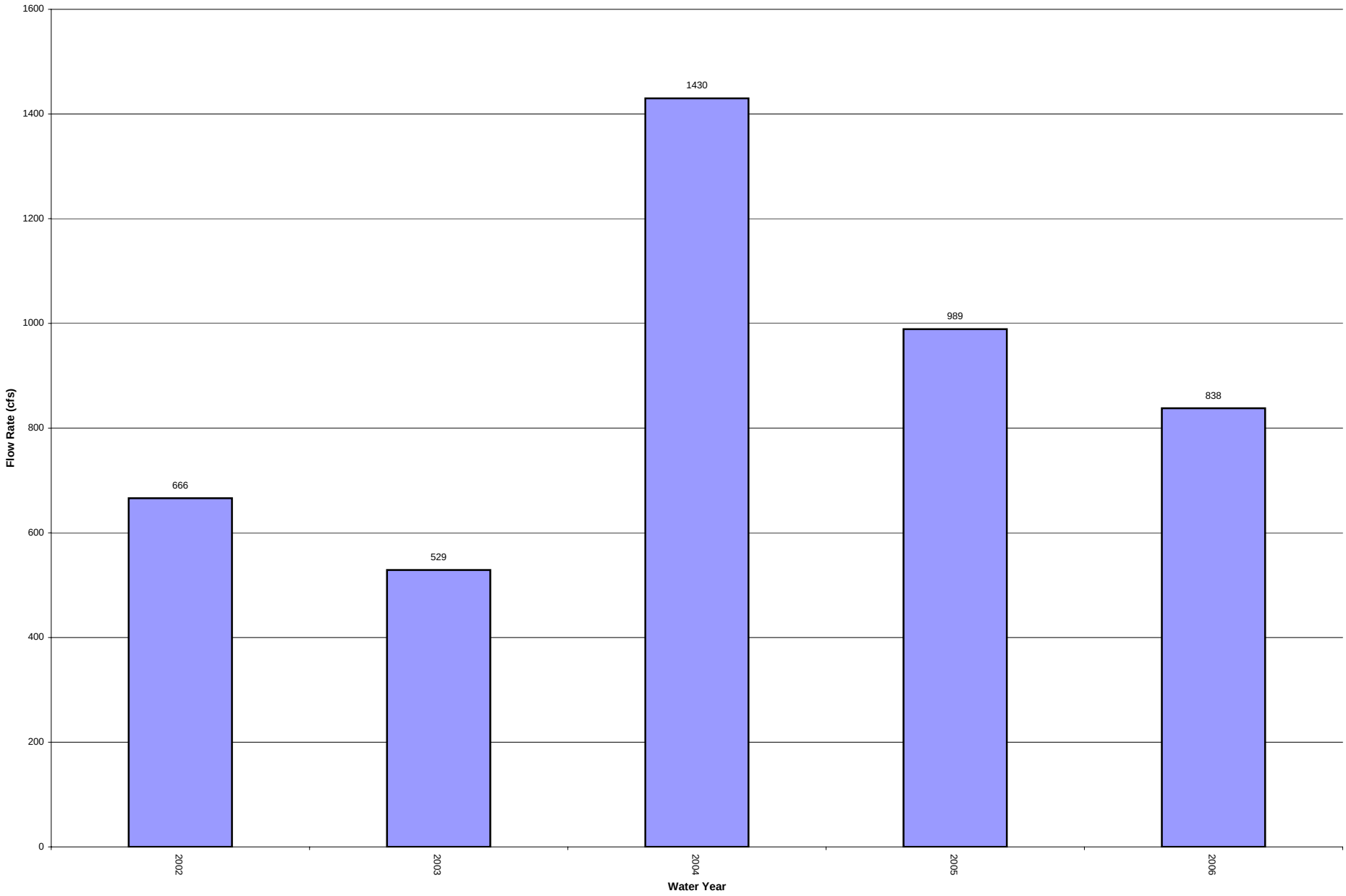


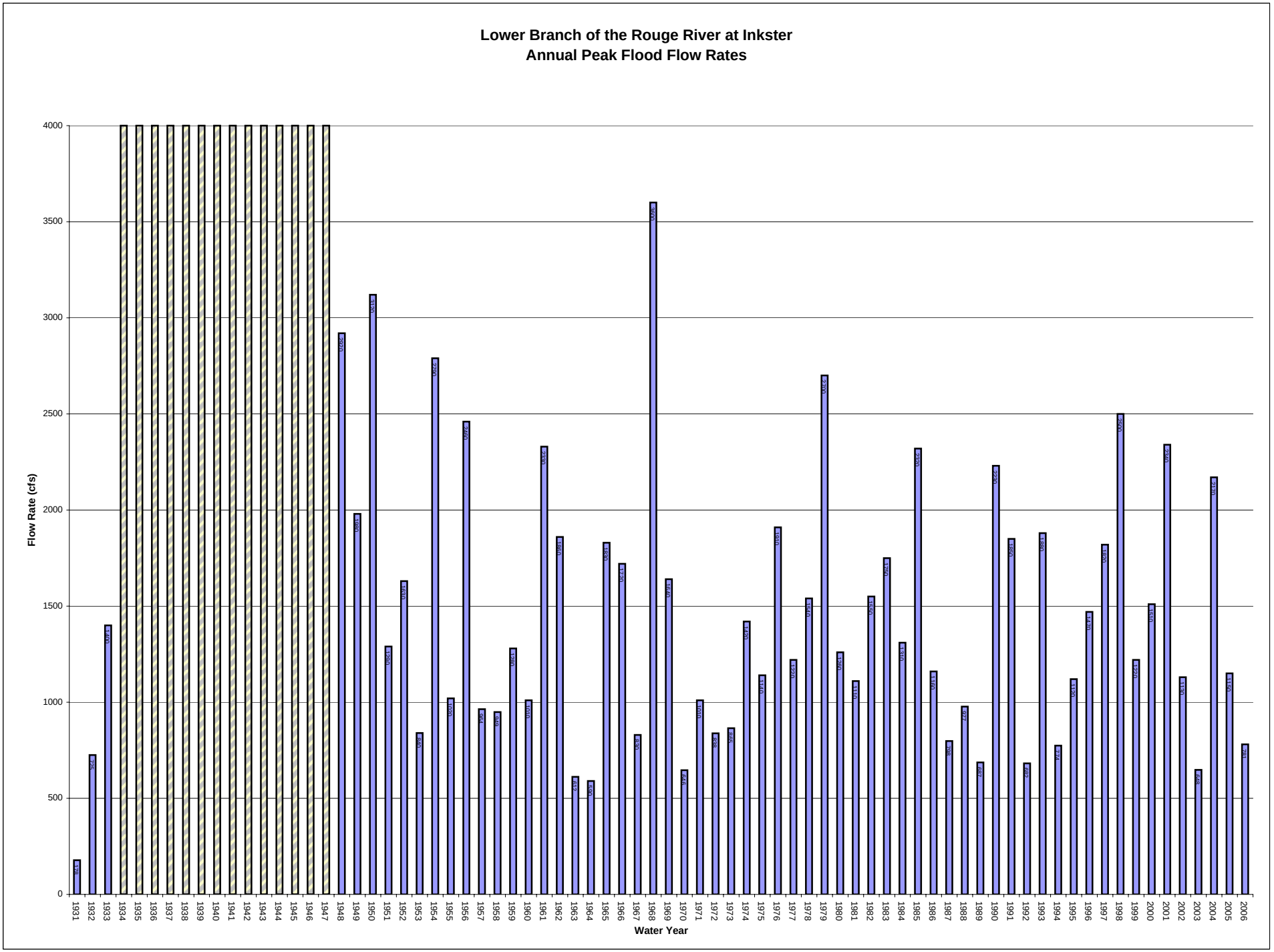
Middle Branch of the Rouge River near Garden City
Annual Peak Flood Rates




Middle Branch of the Rouge River at Dearborn Heights
Annual Peak Flood Flow Rates
Flow Rate (cfs)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
1670
926
1470
1810
1370
804
1290
1030
787
1998
1999
2000
2001
2002
2003
2004
2005
2006
Water Year

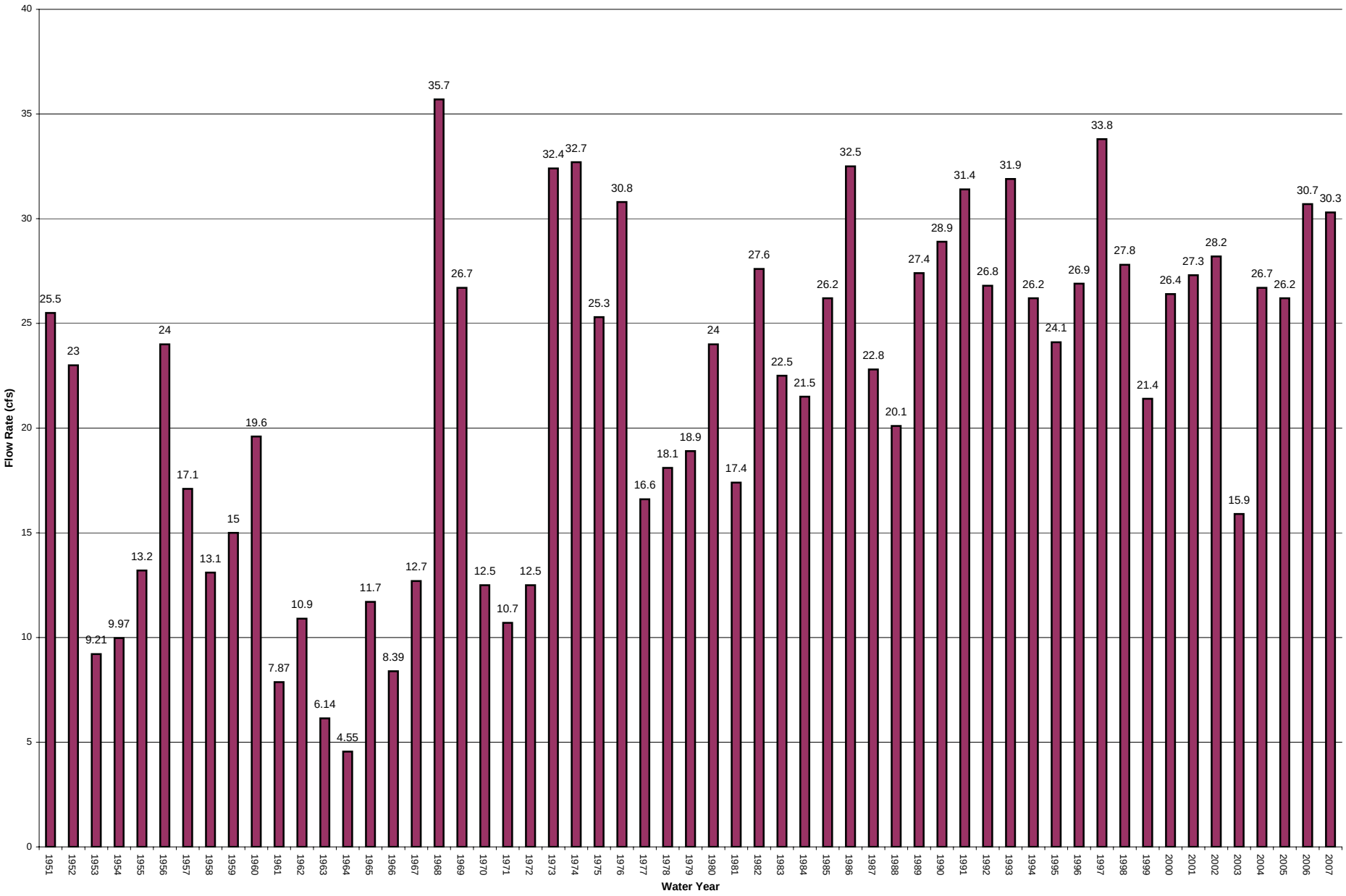
Lower Branch of the Rouge River at Wayne
Annual Peak Flood Flow Rates

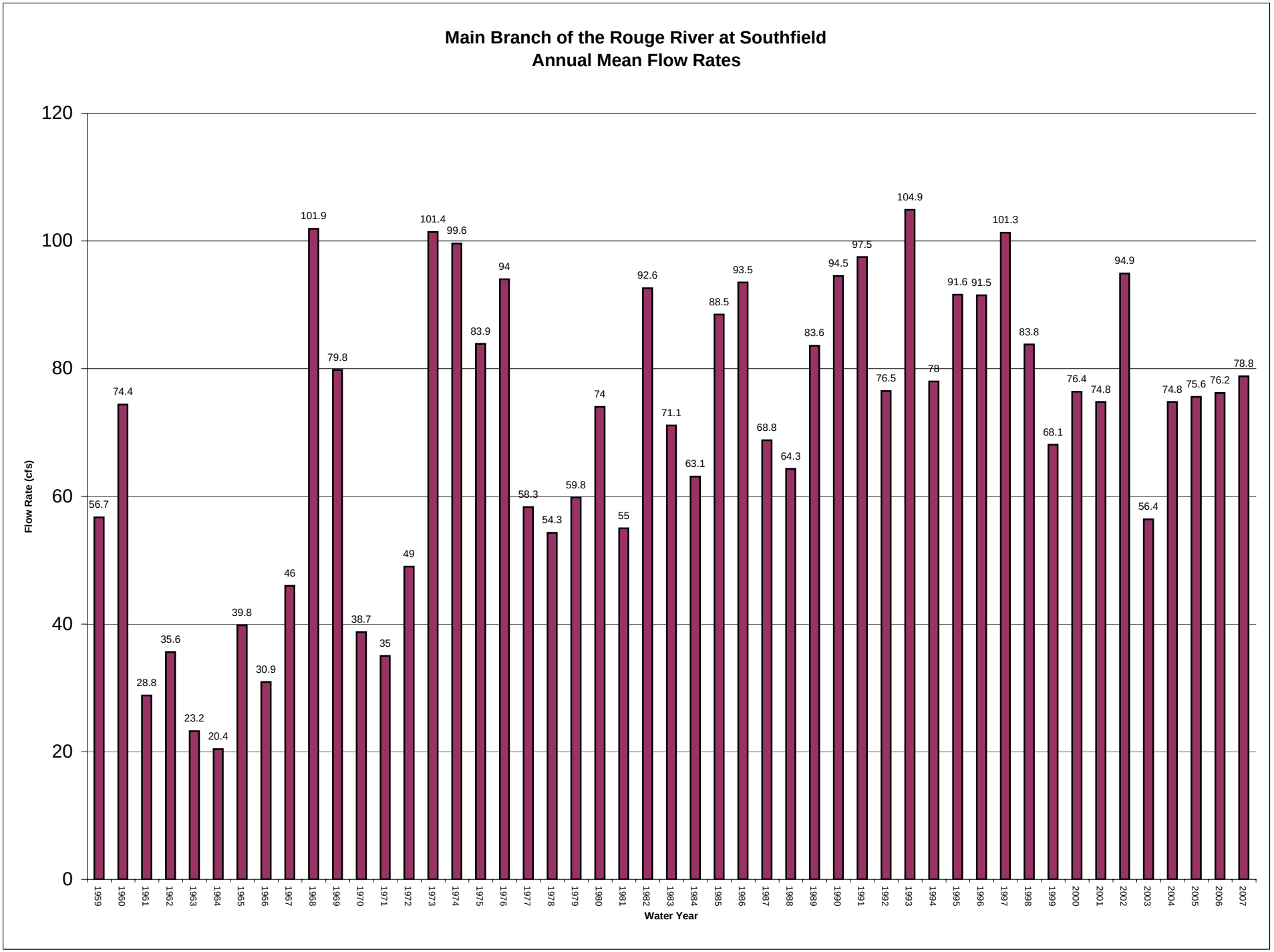



Lower Branch of the Rouge River at Inkster
Annual Peak Flood Flow Rates
Flow Rate (cfs)
Water Year
0
500
1000
1500
2000
2500
3000
3500
4000
1931 1932 1933 1934 1935 1936 1937 1938 1939 1940 1941 1942 1943 1944 1945 1946 1947 1948 1949 1950 1951 1952 1953 1954 1955 1956 1957 1958 1959 1960 1961 1962 1963 1964 1965 1966 1967 1968 1969 1970 1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006

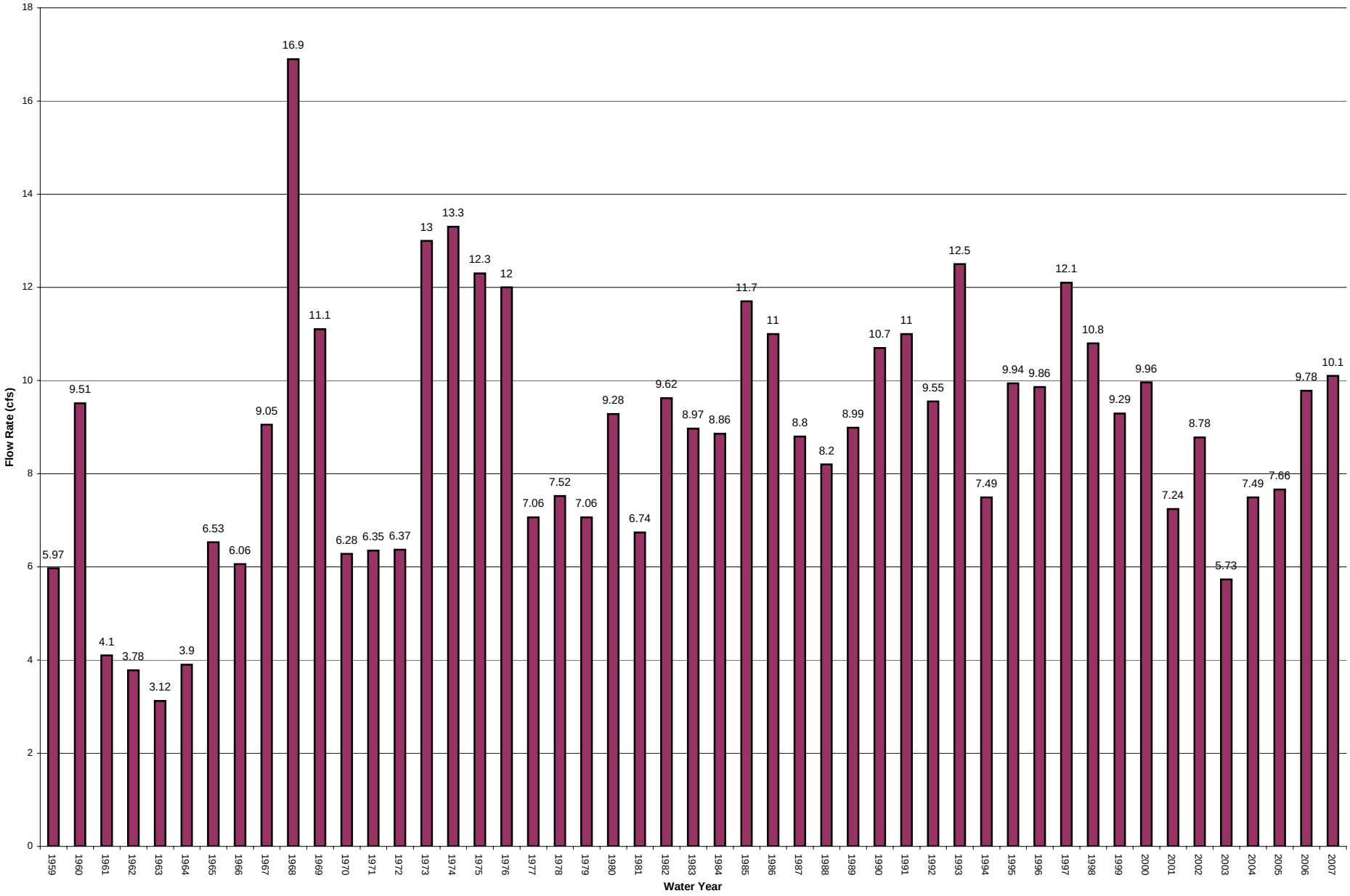
Appendix F. Annual Mean Flow Rate Plots

Main Branch of the Rouge River at Birmingham
Annual Mean Flow Rates

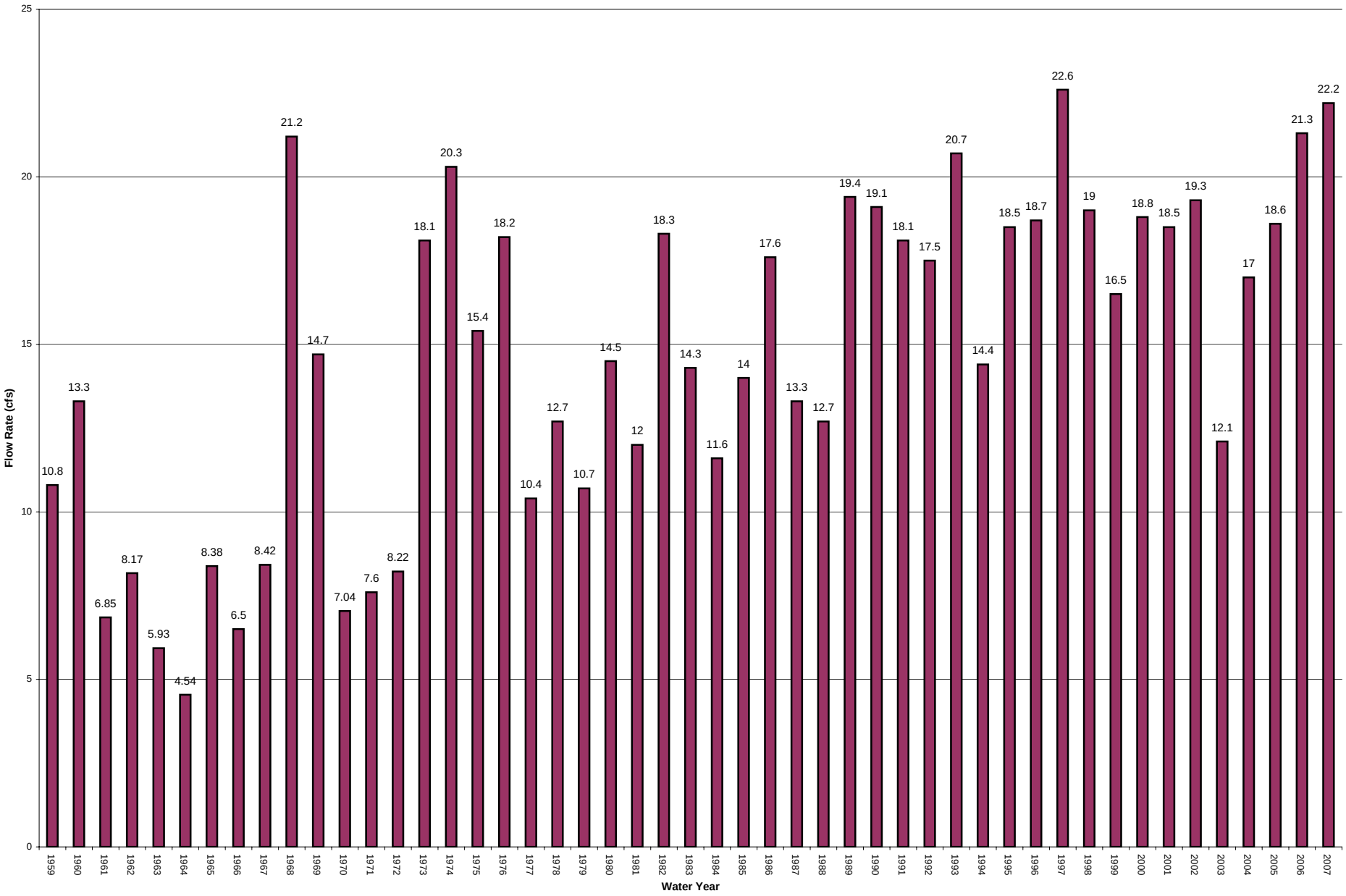



Main Branch of the Rouge River at Southfield
Annual Mean Flow Rates
Flow Rate (cfs)
Water Year
0
20
40
60
80
100
120
1959 56.7
1960 74.4
1961 28.8
1962 35.6
1963 23.2
1964 20.4
1965 39.8
1966 30.9
1967 46
1968 101.9
1969 79.8
1970 38.7
1971 35
1972 49
1973 101.4
1974 99.6
1975 83.9
1976 94
1977 58.3
1978 54.3
1979 59.8
1980 74
1981 55
1982 92.6
1983 71.1
1984 63.1
1985 88.5
1986 93.5
1987 68.8
1988 64.3
1989 83.6
1990 94.5
1991 97.5
1992 76.5
1993 104.9
1994 78
1995 91.6
1996 91.5
1997 101.3
1998 83.8
1999 68.1
2000 76.4
2001 74.8
2002 94.9
2003 56.4
2004 74.8
2005 75.6
2006 76.2
2007 78.8

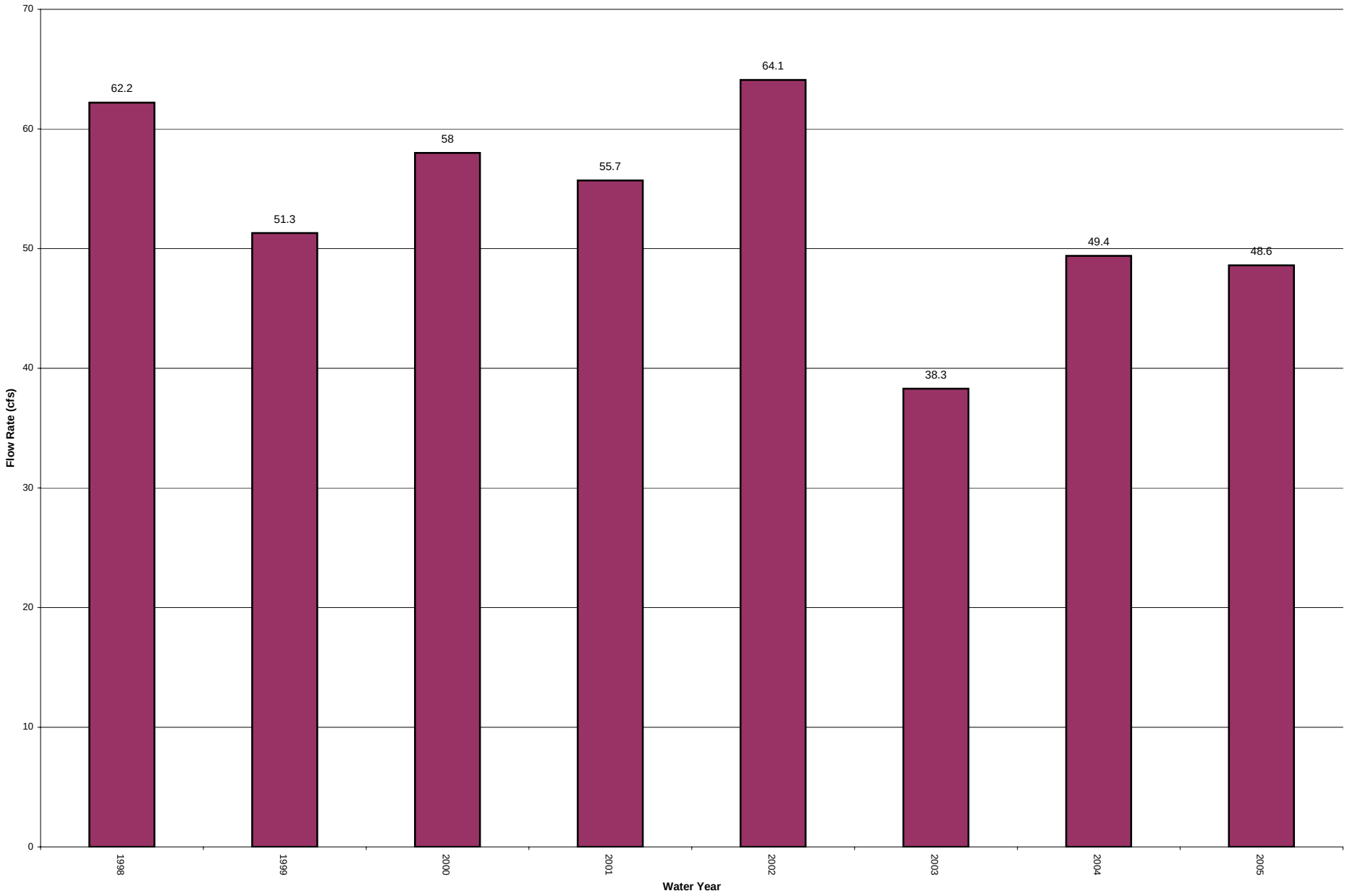
Evans Ditch at Southfield
Annual Mean Flow Rates



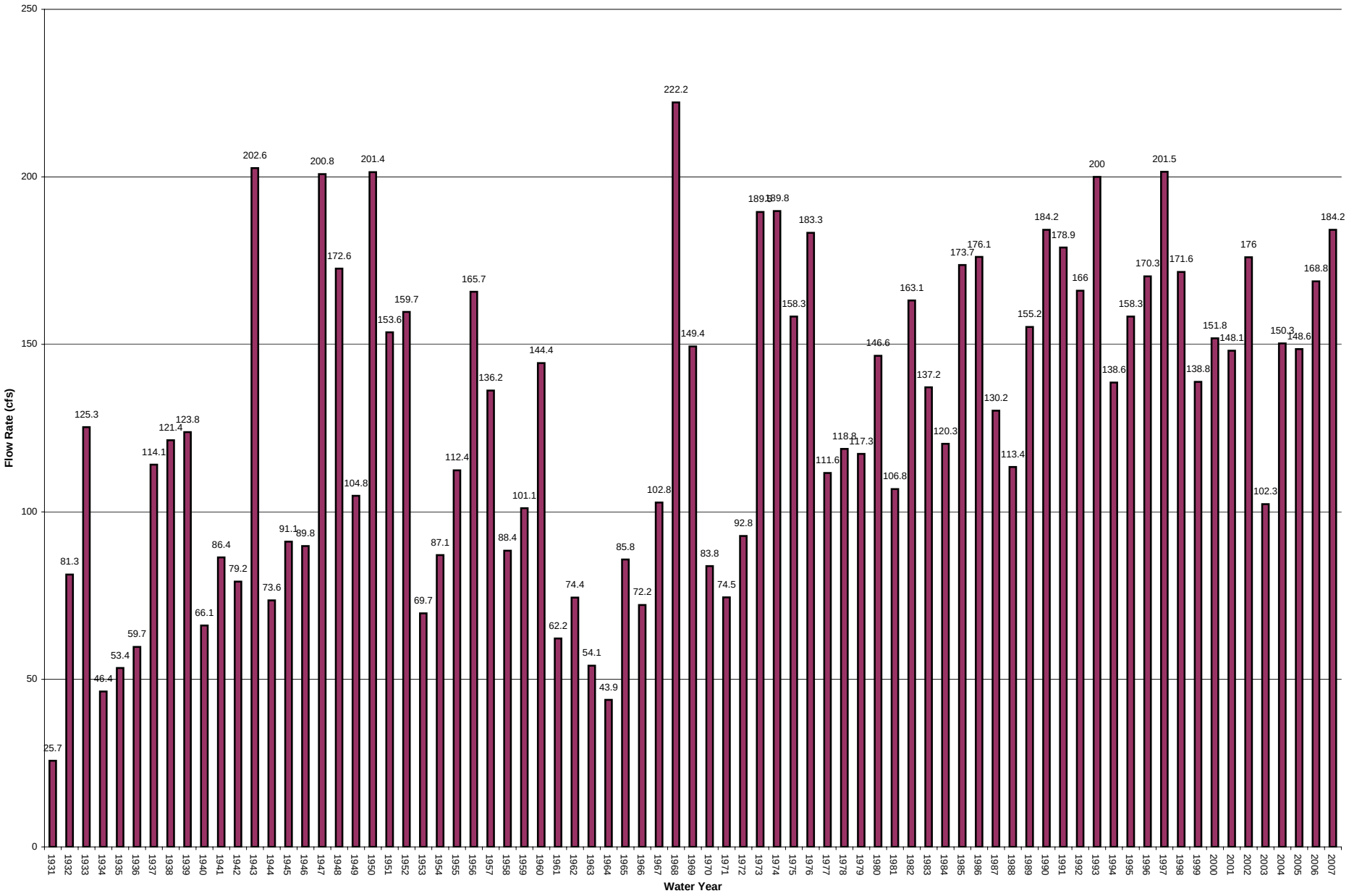
Upper Branch of the Rouge River at Farmington
Annual Mean Flow Rates

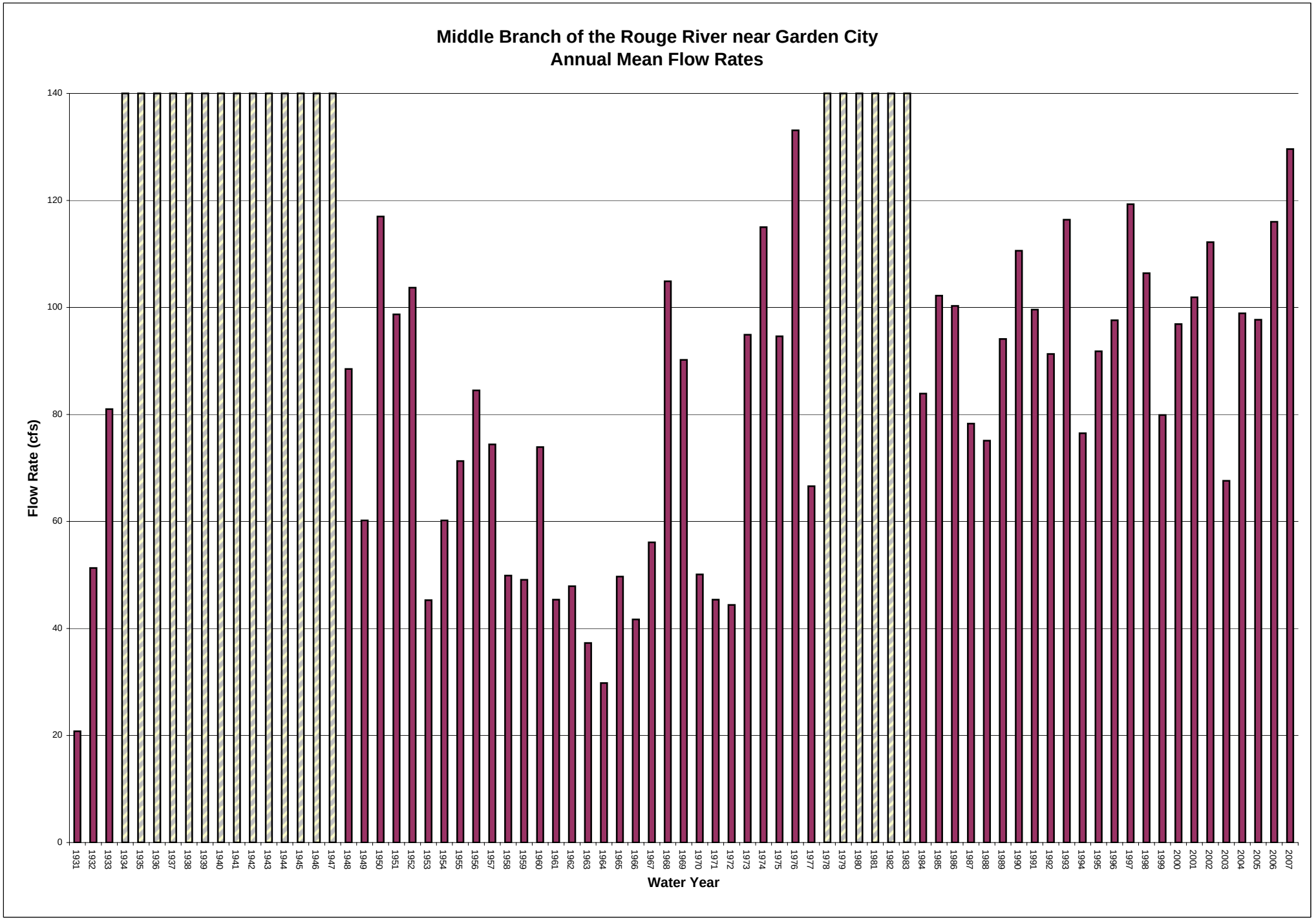


Upper Branch of the Rouge River at Detroit
Annual Mean Flow Rates

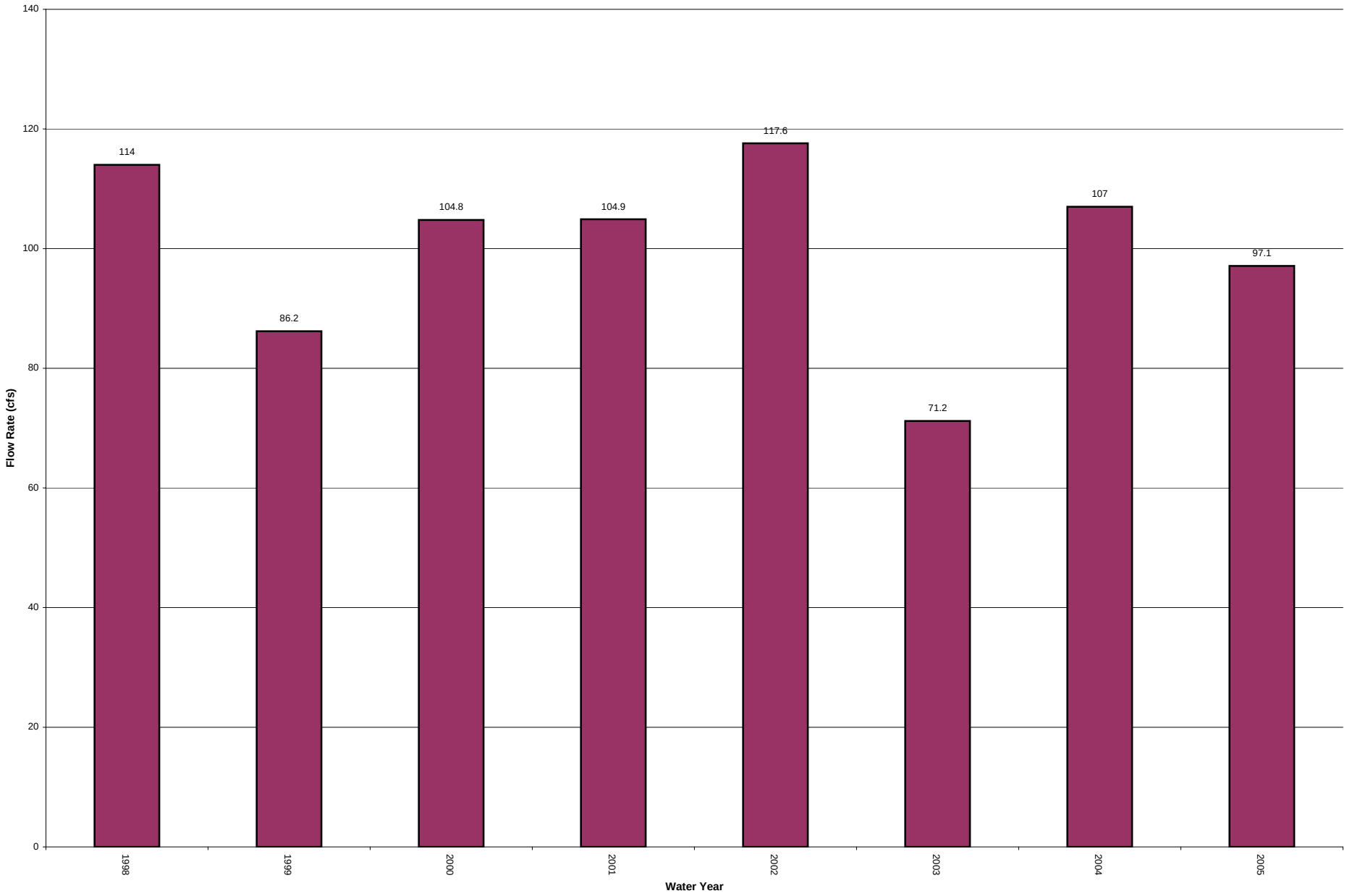


Main Branch of the Rouge River at Detroit
Annual Mean Flow Rates

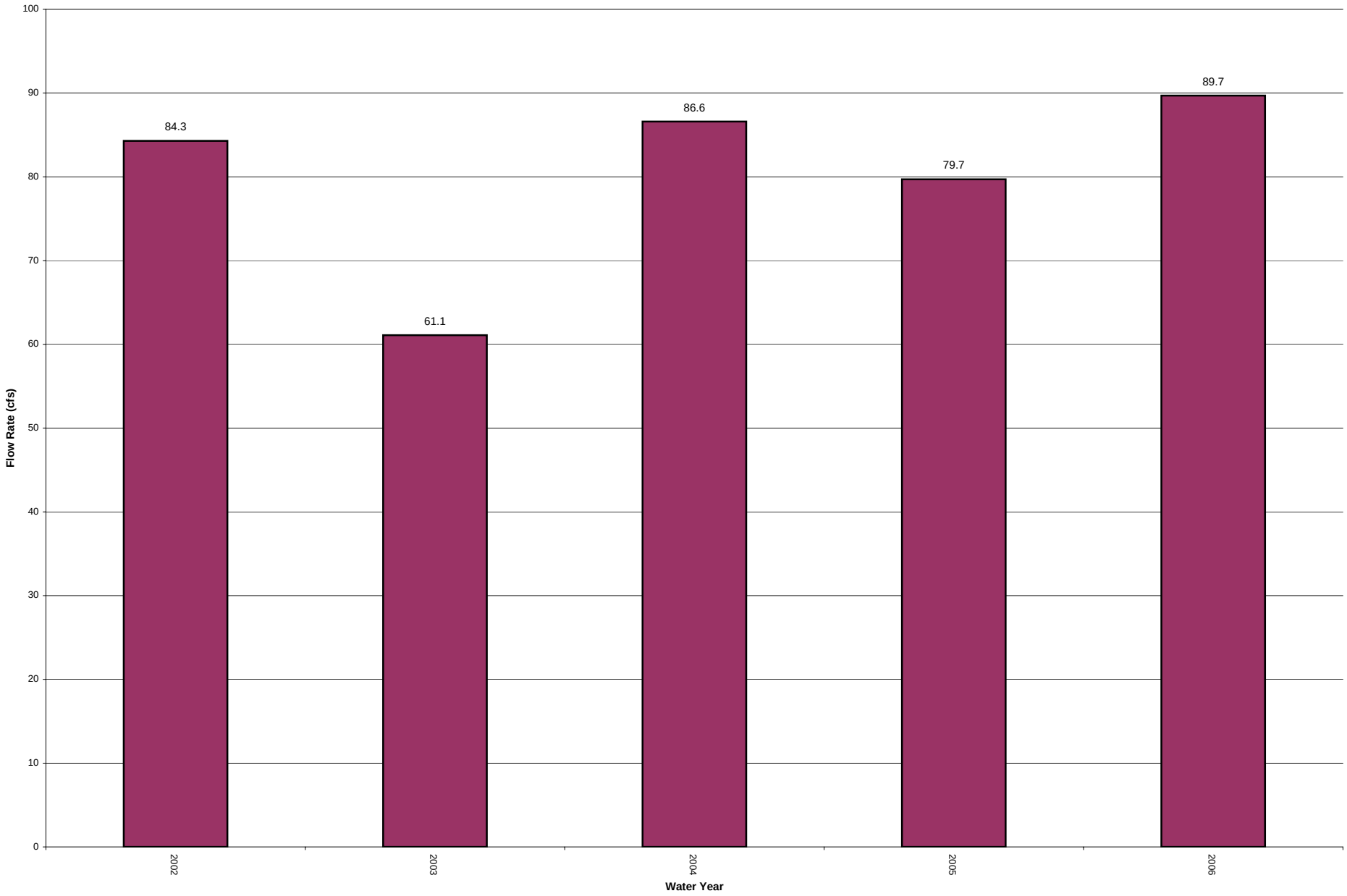


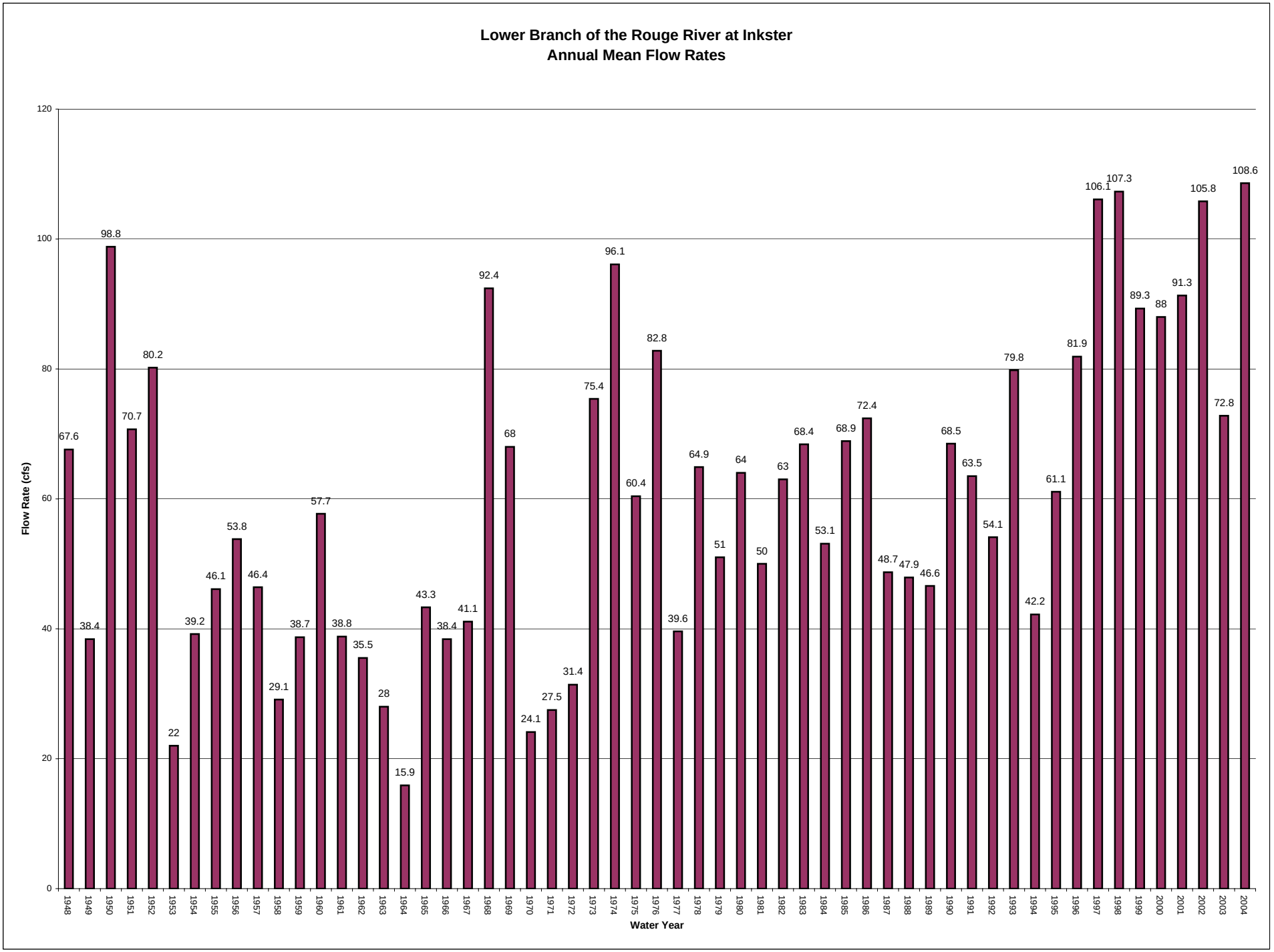

Middle Branch of the Rouge River near Garden City
Annual Mean Flow Rates
Flow Rate (cfs)
0
20
40
60
80
100
120
140
1931
1932
1933
1934
1935
1936
1937
1938
1939
1940
1941
1942
1943
1944
1945
1946
1947
1948
1949
1950
1951
1952
1953
1954
1955
1956
1957
1958
1959
1960
1961
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
Water Year

Middle Branch of the Rouge River at Dearborn Heights
Annual Mean Flow Rates



Lower Branch of the Rouge River at Wayne
Annual Mean Flow Rates




Lower Branch of the Rouge River at Inkster
Annual Mean Flow Rates
Flow Rate (cfs)
Water Year
0
20
40
60
80
100
120
1948 67.6
1949 38.4
1950 98.8
1951 70.7
1952 80.2
1953 22
1954 39.2
1955 46.1
1956 53.8
1957 46.4
1958 29.1
1959 38.7
1960 57.7
1961 38.8
1962 35.5
1963 28
1964 15.9
1965 43.3
1966 38.4
1967 41.1
1968 92.4
1969 68
1970 24.1
1971 27.5
1972 31.4
1973 75.4
1974 96.1
1975 60.4
1976 82.8
1977 39.6
1978 64.9
1979 51
1980 64
1981 50
1982 63
1983 68.4
1984 53.1
1985 68.9
1986 72.4
1987 48.7
1988 47.9
1989 46.6
1990 68.5
1991 63.5
1992 54.1
1993 79.8
1994 42.2
1995 61.1
1996 81.9
1997 106.1
1998 107.3
1999 89.3
2000 88
2001 91.3
2002 105.8
2003 72.8
2004 108.6

Appendix G. USGS Annual Peak and Mean Flow Rate Data

Table G1. USGS Stream Gage Annual Mean and Peak Flow Rate Data

Main Branch of the Rouge River at Birmingham		
Water Year	Annual Mean (cfs)	Annual Peak (cfs)
1951	25.5	320
1952	23	370
1953	9.21	92
1954	9.97	244
1955	13.2	170
1956	24	700
1957	17.1	488
1958	13.1	193
1959	15	446
1960	19.6	313
1961	7.87	184
1962	10.9	624
1963	6.14	252
1964	4.55	117
1965	11.7	608
1966	8.39	200
1967	12.7	168
1968	35.7	1390
1969	26.7	557
1970	12.5	194
1971	10.7	130
1972	12.5	357
1973	32.4	474
1974	32.7	390
1975	25.3	593
1976	30.8	419
1977	16.6	476
1978	18.1	251
1979	18.9	426
1980	24	413
1981	17.4	220
1982	27.6	1050
1983	22.5	575
1984	21.5	381
1985	26.2	475
1986	32.5	531
1987	22.8	192
1988	20.1	359
1989	27.4	900
1990	28.9	457
1991	31.4	664
1992	26.8	290
1993	31.9	428
1994	26.2	582
1995	24.1	312
1996	26.9	1070
1997	33.8	626

Table G1. USGS Stream Gage Annual Mean and Peak Flow Rate Data

1998	27.8	769
1999	21.4	479
2000	26.4	708
2001	27.3	741
2002	28.2	585
2003	15.9	400
2004	26.7	574
2005	26.2	419
2006	30.7	560
2007	30.3	--

Table G2. USGS Stream Gage Annual Mean and Peak Flow Rate Data

Main Branch of the Rouge River at Southfield		
Water Year	Annual Mean (cfs)	Annual Maximum (cfs)
1959	56.7	1200
1960	74.4	1140
1961	28.8	787
1962	35.6	1200
1963	23.2	569
1964	20.4	447
1965	39.8	2030
1966	30.9	1250
1967	46	641
1968	101.9	4900
1969	79.8	1360
1970	38.7	570
1971	35	800
1972	49	1420
1973	101.4	1530
1974	99.6	1350
1975	83.9	1790
1976	94	1470
1977	58.3	1440
1978	54.3	912
1979	59.8	1640
1980	74	1140
1981	55	600
1982	92.6	4400
1983	71.1	1900
1984	63.1	1400
1985	88.5	1830
1986	93.5	1180
1987	68.8	984
1988	64.3	1320
1989	83.6	2740
1990	94.5	1800
1991	97.5	2000
1992	76.5	742
1993	104.9	1460
1994	78	1290
1995	91.6	1180
1996	91.5	2250
1997	101.3	1550
1998	83.8	2430
1999	68.1	1400
2000	76.4	1520
2001	74.8	1970
2002	94.9	1610
2003	56.4	965
2004	74.8	878
2005	75.6	965

Table G2. USGS Stream Gage Annual Mean and Peak Flow Rate Data

2006	76.2	981
2007	78.8	--

Table G3. USGS Stream Gage Annual Mean and Peak Flow Rate Data

Evans Ditch at Southfield		
Water Year	Annual Mean (cfs)	Annual Maximum (cfs)
1959	5.97	233
1960	9.51	370
1961	4.1	228
1962	3.78	210
1963	3.12	208
1964	3.9	176
1965	6.53	527
1966	6.06	354
1967	9.05	403
1968	16.9	903
1969	11.1	484
1970	6.28	243
1971	6.35	415
1972	6.37	463
1973	13	670
1974	13.3	495
1975	12.3	348
1976	12	688
1977	7.06	516
1978	7.52	283
1979	7.06	598
1980	9.28	582
1981	6.74	317
1982	9.62	1200
1983	8.97	644
1984	8.86	627
1985	11.7	614
1986	11	580
1987	8.8	480
1988	8.2	579
1989	8.99	416
1990	10.7	555
1991	11	686
1992	9.55	545
1993	12.5	595
1994	7.49	564
1995	9.94	754
1996	9.86	704
1997	12.1	828
1998	10.8	962
1999	9.29	650
2000	9.96	761
2001	7.24	500
2002	8.78	480
2003	5.73	355
2004	7.49	261
2005	7.66	496

Table G3. USGS Stream Gage Annual Mean and Peak Flow Rate Data

2006	9.78	567
2007	10.1	--

Table G4. USGS Stream Gage Annual Mean and Peak Flow Rate Data

Upper Branch of the Rouge River at Farmington		
Water Year	Annual Mean (cfs)	Annual Maximum (cfs)
1959	10.8	326
1960	13.3	287
1961	6.85	174
1962	8.17	400
1963	5.93	96
1964	4.54	75
1965	8.38	665
1966	6.5	182
1967	8.42	108
1968	21.2	1500
1969	14.7	287
1970	7.04	90
1971	7.6	260
1972	8.22	220
1973	18.1	252
1974	20.3	345
1975	15.4	458
1976	18.2	349
1977	10.4	315
1978	12.7	210
1979	10.7	363
1980	14.5	330
1981	12	200
1982	18.3	878
1983	14.3	518
1984	11.6	275
1985	14	430
1986	17.6	281
1987	13.3	166
1988	12.7	176
1989	19.4	885
1990	19.1	412
1991	18.1	614
1992	17.5	239
1993	20.7	321
1994	14.4	264
1995	18.5	269
1996	18.7	548
1997	22.6	368
1998	19	633
1999	16.5	345
2000	18.8	627
2001	18.5	589
2002	19.3	370
2003	12.1	188
2004	17	173
2005	18.6	263

Table G4. USGS Stream Gage Annual Mean and Peak Flow Rate Data

2006	21.3	347
2007	22.2	--

Table G5. USGS Stream Gage Annual Mean and Peak Flow Rate Data

Upper Branch of the Rouge River at Detroit		
Water Year	Annual Mean (cfs)	Annual Maximum (cfs)
1998	62.2	1490
1999	51.3	998
2000	58	1100
2001	55.7	1200
2002	64.1	1010
2003	38.3	602
2004	49.4	697
2005	48.6	801
2006	--	798

Table G6. USGS Stream Gage Annual Mean and Peak Flow Rate Data

Main Branch of the Rouge River at Detroit		
Water Year	Annual Mean (cfs)	Annual Maximum (cfs)
1931	25.7	152
1932	81.3	1720
1933	125.3	3840
1934	46.4	1650
1935	53.4	760
1936	59.7	800
1937	114.1	1440
1938	121.4	2680
1939	123.8	6140
1940	66.1	850
1941	86.4	1100
1942	79.2	1300
1943	202.6	4210
1944	73.6	920
1945	91.1	4000
1946	89.8	1090
1947	200.8	13000
1948	172.6	6130
1949	104.8	2420
1950	201.4	3640
1951	153.6	1880
1952	159.7	2040
1953	69.7	960
1954	87.1	3080
1955	112.4	1510
1956	165.7	4240
1957	136.2	4030
1958	88.4	1380
1959	101.1	1880
1960	144.4	2140
1961	62.2	1690
1962	74.4	2750
1963	54.1	1260
1964	43.9	824
1965	85.8	2610
1966	72.2	1820
1967	102.8	1520
1968	222.2	7300
1969	149.4	1990
1970	83.8	1480
1971	74.5	1520
1972	92.8	1620
1973	189.5	2300
1974	189.8	1980
1975	158.3	2710
1976	183.3	3330
1977	111.6	2440

Table G6. USGS Stream Gage Annual Mean and Peak Flow Rate Data

1978	118.8	1460
1979	117.3	2640
1980	146.6	1920
1981	106.8	1310
1982	163.1	6830
1983	137.2	3440
1984	120.3	2200
1985	173.7	3420
1986	176.1	1700
1987	130.2	1840
1988	113.4	1790
1989	155.2	3750
1990	184.2	3810
1991	178.9	3740
1992	166	1530
1993	200	2730
1994	138.6	1670
1995	158.3	1560
1996	170.3	2610
1997	201.5	2720
1998	171.6	3500
1999	138.8	2190
2000	151.8	2560
2001	148.1	3100
2002	176	2520
2003	102.3	1500
2004	150.3	1490
2005	148.6	1790
2006	168.8	1680
2007	184.2	--

Table G7. USGS Stream Gage Annual Mean and Peak Flow Rate Data

Middle Branch of the Rouge River Near Garden City		
Water Year	Annual Mean (cfs)	Annual Maximum (cfs)
1931	20.8	76
1932	51.3	780
1933	81	1420
1934	--	--
1935	--	--
1936	--	--
1937	--	--
1938	--	--
1939	--	--
1940	--	--
1941	--	--
1942	--	--
1943	--	--
1944	--	--
1945	--	--
1946	--	--
1947	--	--
1948	88.5	2150
1949	60.2	1200
1950	117	1960
1951	98.7	1060
1952	103.7	1060
1953	45.3	470
1954	60.2	1720
1955	71.3	615
1956	84.5	1840
1957	74.4	1210
1958	49.9	814
1959	49.1	1090
1960	73.9	1040
1961	45.4	1020
1962	47.9	1500
1963	37.3	798
1964	29.8	484
1965	49.7	1540
1966	41.7	900
1967	56.1	591
1968	104.9	2330
1969	90.2	1030
1970	50.1	669
1971	45.4	871
1972	44.4	742
1973	94.9	619
1974	115	945
1975	94.6	1120
1976	133.1	1670
1977	66.6	1060

Table G7. USGS Stream Gage Annual Mean and Peak Flow Rate Data

1978	--	790
1979	--	1970
1980	--	944
1981	--	1320
1982	--	1970
1983	--	1930
1984	83.9	1110
1985	102.2	1620
1986	100.3	1150
1987	78.3	1000
1988	75.1	802
1989	94.1	1480
1990	110.6	1670
1991	99.6	1010
1992	91.3	658
1993	116.4	1460
1994	76.5	1220
1995	91.8	885
1996	97.6	965
1997	119.3	1140
1998	106.4	1490
1999	79.9	1060
2000	96.9	1570
2001	101.9	1530
2002	112.2	1240
2003	67.6	600
2004	98.9	1310
2005	97.7	871
2006	116	742
2007	129.6	--

Table G8. USGS Stream Gage Annual Mean and Peak Flow Rate Data

Middle Branch of the Rouge River at Dearborn Heights		
Water Year	Annual Mean (cfs)	Annual Maximum (cfs)
1998	114	1670
1999	86.2	926
2000	104.8	1470
2001	104.9	1810
2002	117.6	1370
2003	71.2	804
2004	107	1290
2005	97.1	1030
2006	--	787

Table G9. USGS Stream Gage Annual Mean and Peak Flow Rate Data

Lower Branch of the Rouge River at Wayne		
Water Year	Annual Mean (cfs)	Annual Maximum (cfs)
2002	84.3	666
2003	61.1	529
2004	86.6	1430
2005	79.7	989
2006	89.7	838

Table G10. USGS Stream Gage Annual Mean and Peak Flow Rate Data

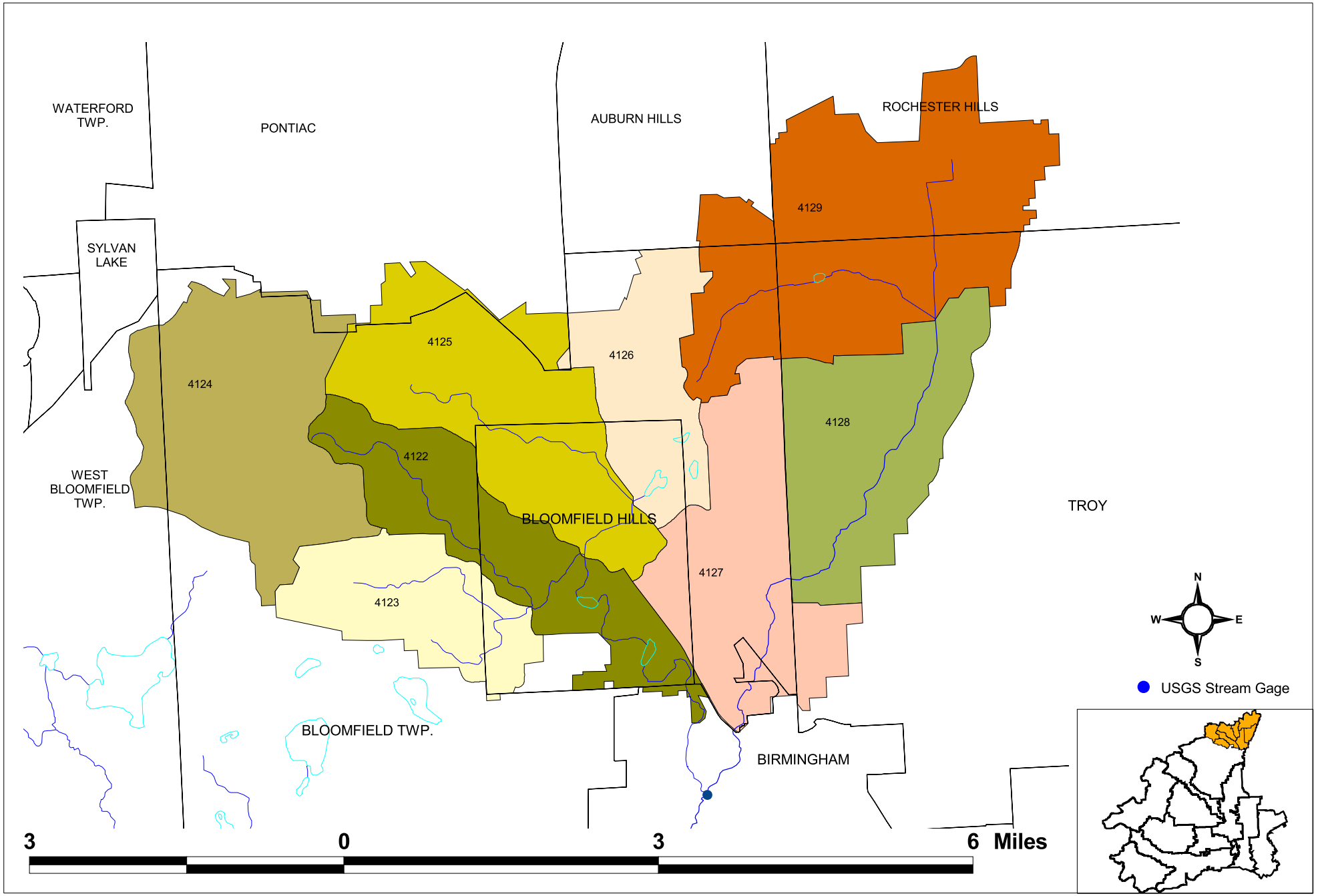
Lower Branch of the Rouge River at Inkster		
Water Year	Annual Mean (cfs)	Annual Maximum (cfs)
1931	--	178
1932	--	725
1933	--	1400
1948	67.6	2920
1949	38.4	1980
1950	98.8	3120
1951	70.7	1290
1952	80.2	1630
1953	22	840
1954	39.2	2790
1955	46.1	1020
1956	53.8	2460
1957	46.4	964
1958	29.1	949
1959	38.7	1280
1960	57.7	1010
1961	38.8	2330
1962	35.5	1860
1963	28	612
1964	15.9	590
1965	43.3	1830
1966	38.4	1720
1967	41.1	830
1968	92.4	3600
1969	68	1640
1970	24.1	646
1971	27.5	1010
1972	31.4	838
1973	75.4	865
1974	96.1	1420
1975	60.4	1140
1976	82.8	1910
1977	39.6	1220
1978	64.9	1540
1979	51	2700
1980	64	1260
1981	50	1110
1982	63	1550
1983	68.4	1750
1984	53.1	1310
1985	68.9	2320
1986	72.4	1160
1987	48.7	798
1988	47.9	977
1989	46.6	687
1990	68.5	2230
1991	63.5	1850

Table G10. USGS Stream Gage Annual Mean and Peak Flow Rate Data

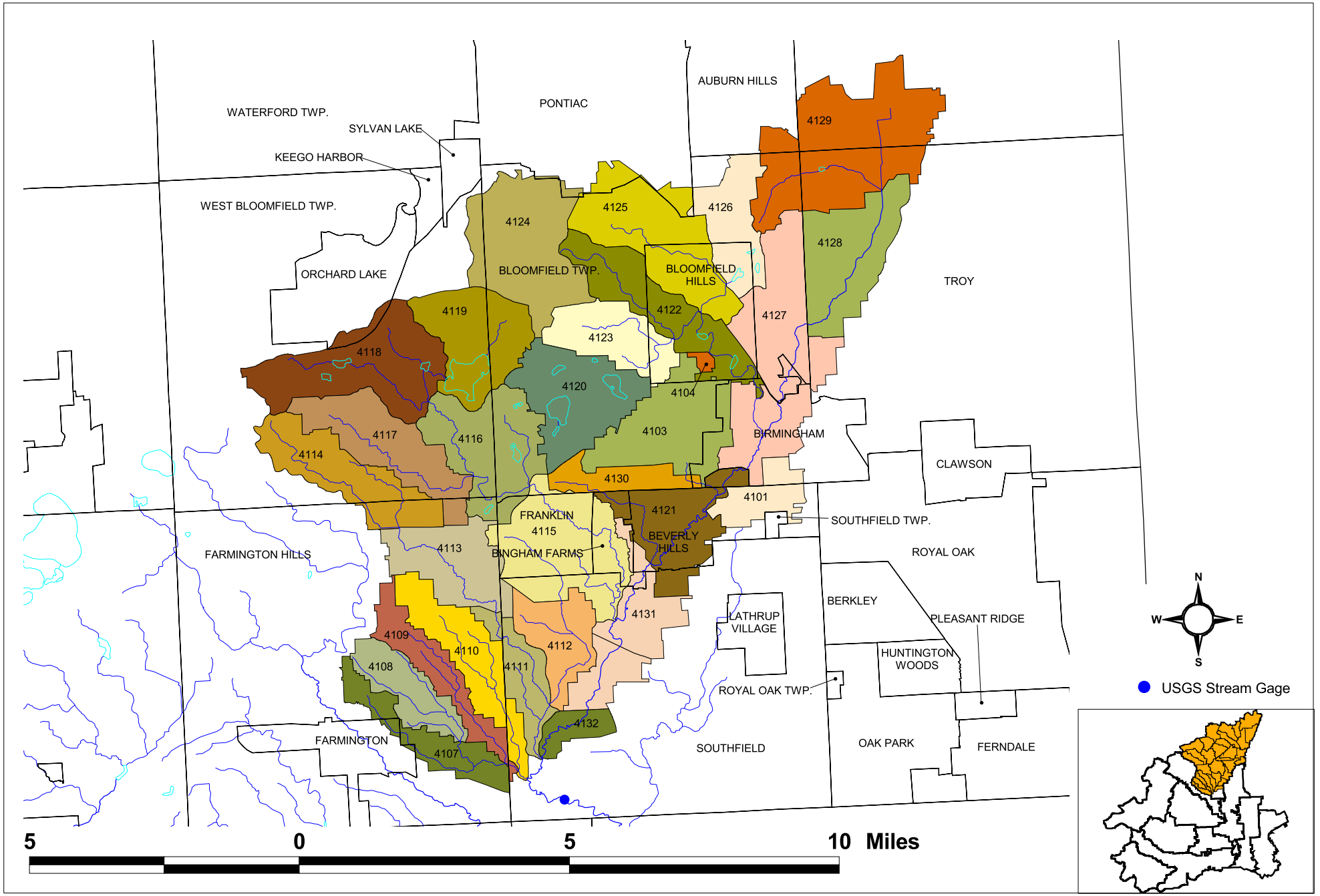
1992	54.1	682
1993	79.8	1880
1994	42.2	774
1995	61.1	1120
1996	81.9	1470
1997	106.1	1820
1998	107.3	2500
1999	89.3	1220
2000	88	1510
2001	91.3	2340
2002	105.8	1130
2003	72.8	648
2004	108.6	2170
2005	97.3	1150
2006	101	781
2007	113	--

Appendix H. USGS Stream Gage Drainage Areas

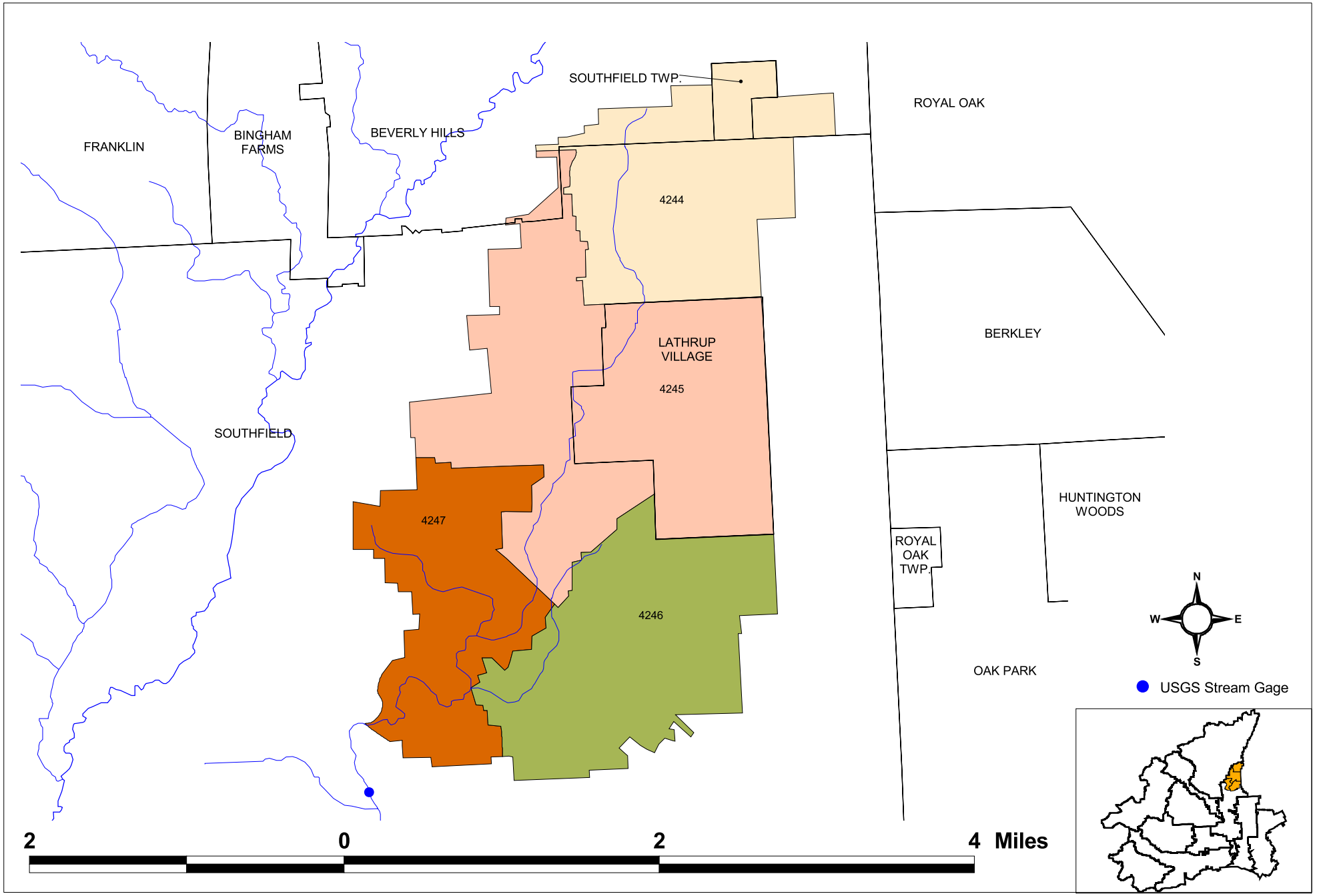
Main Branch of the Rouge River at Birmingham



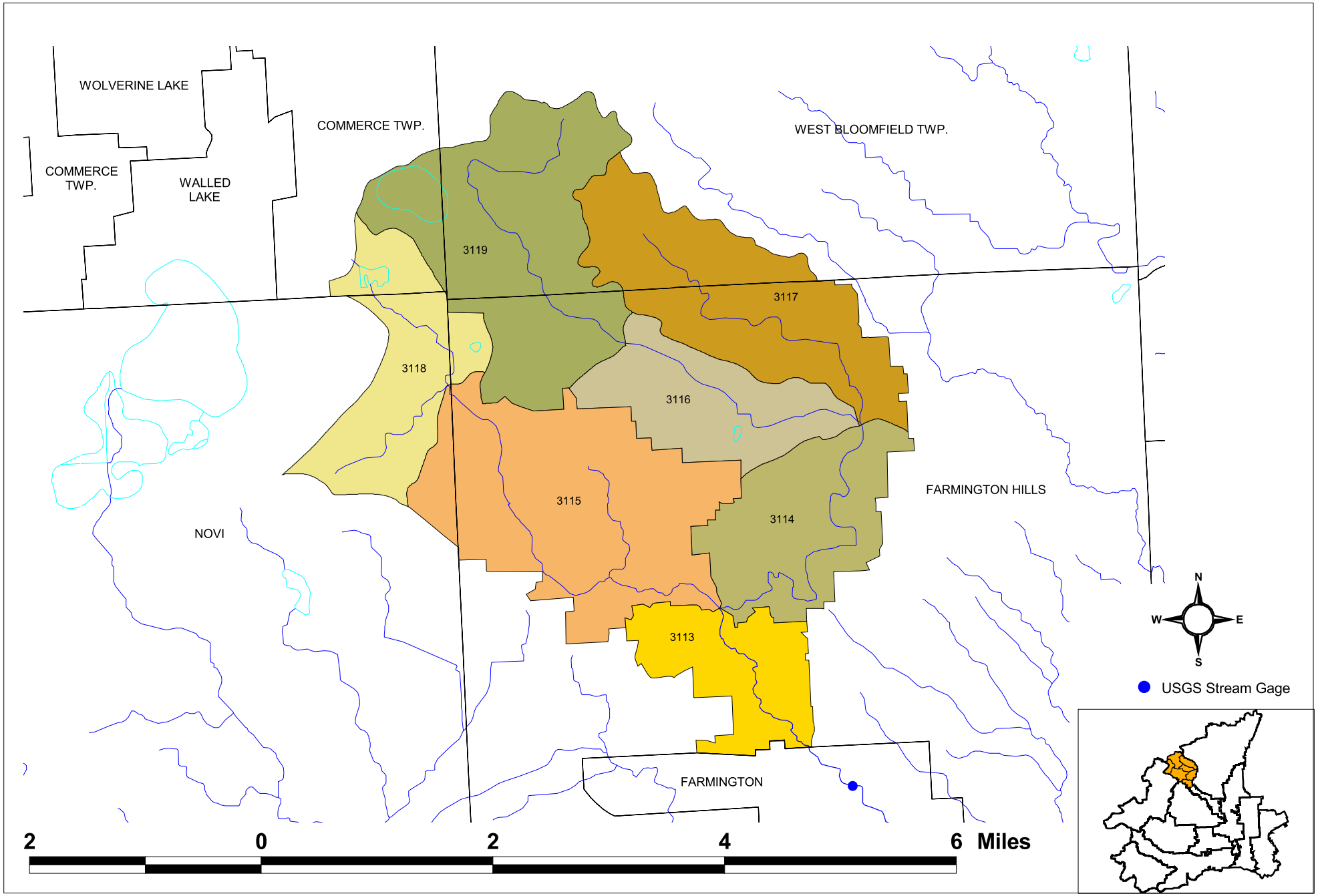
Main Branch of the Rouge River at Southfield



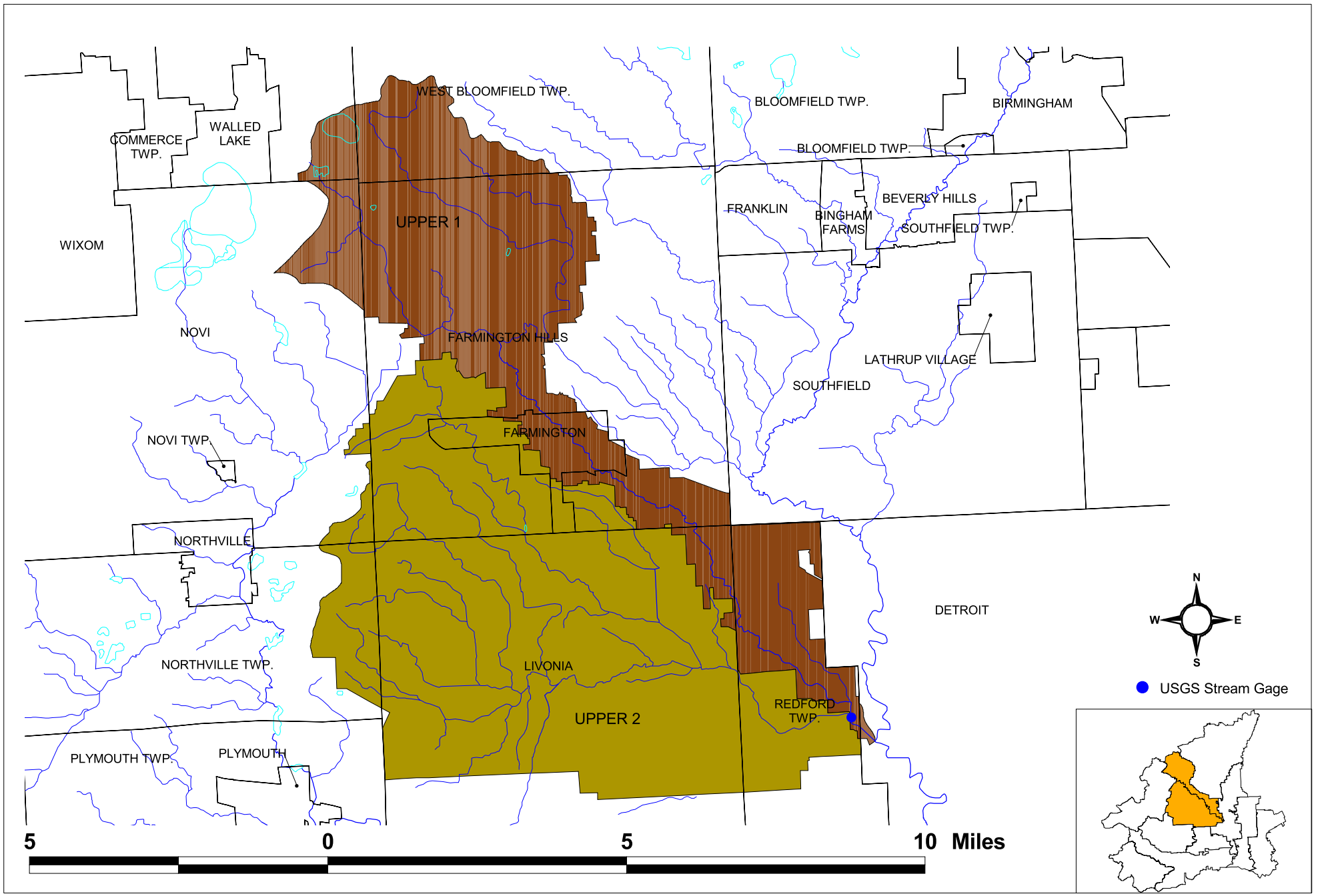
Evans Ditch at Southfield



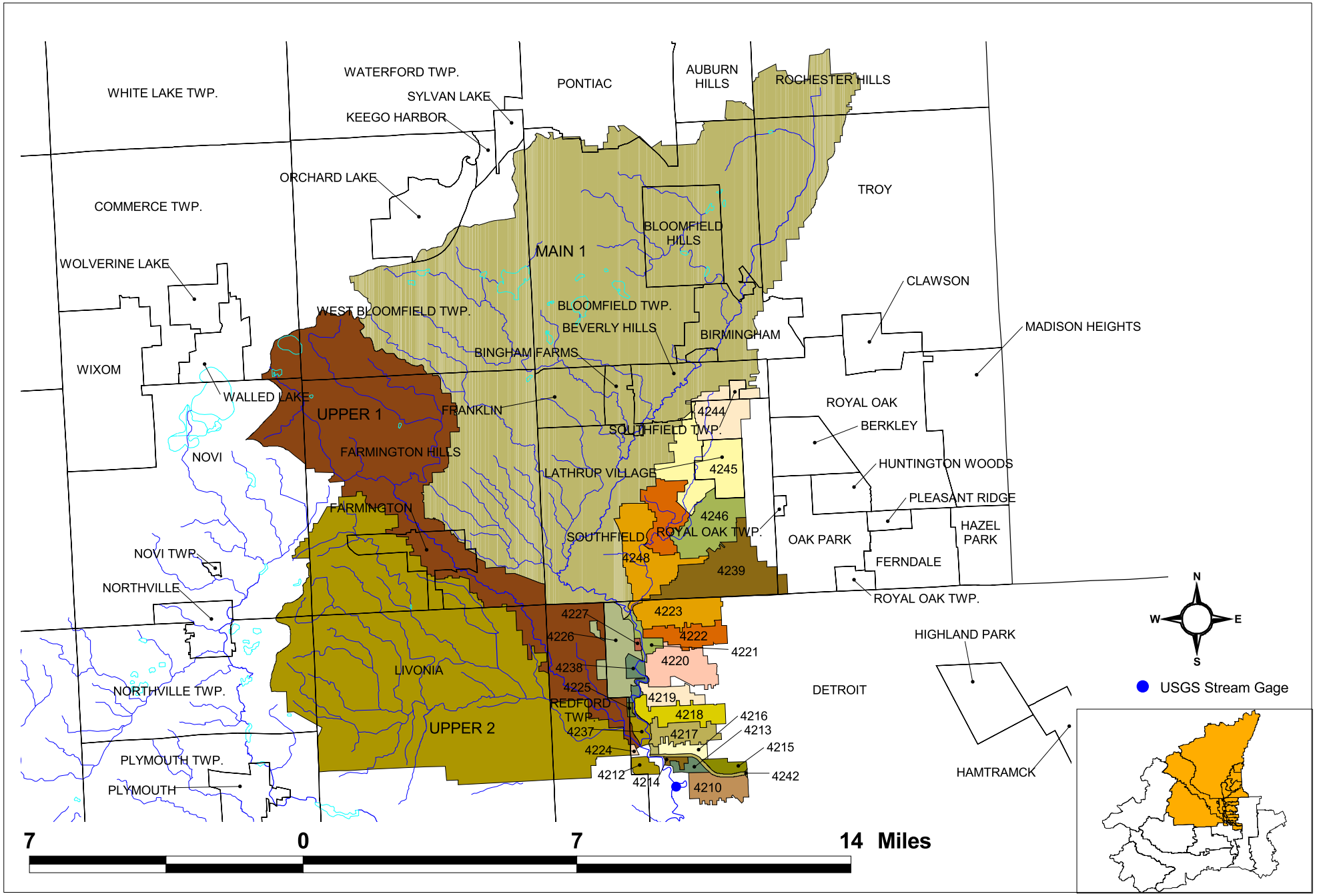
Upper Branch of the Rouge River at Farmington



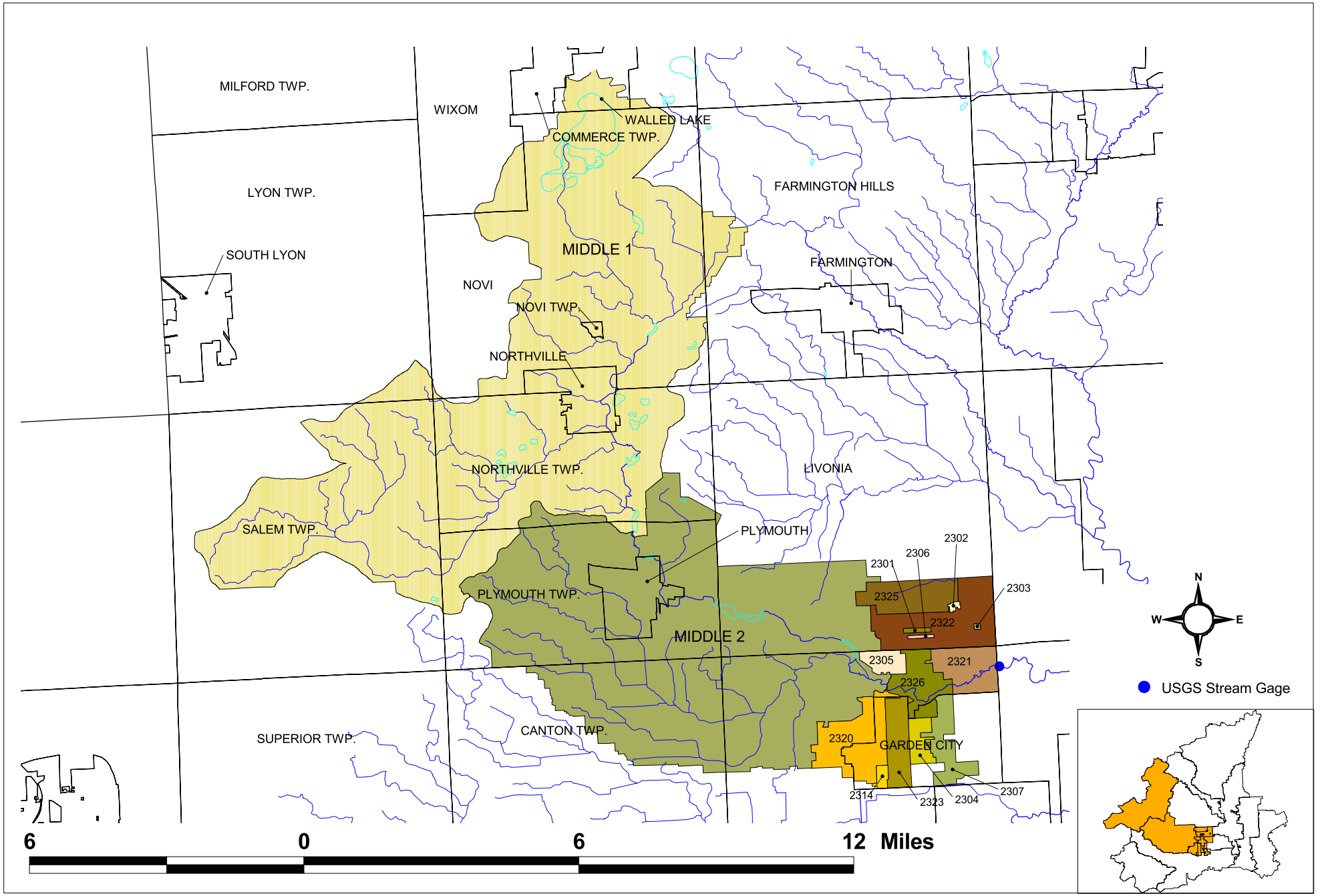
Upper Branch of the Rouge River at Detroit



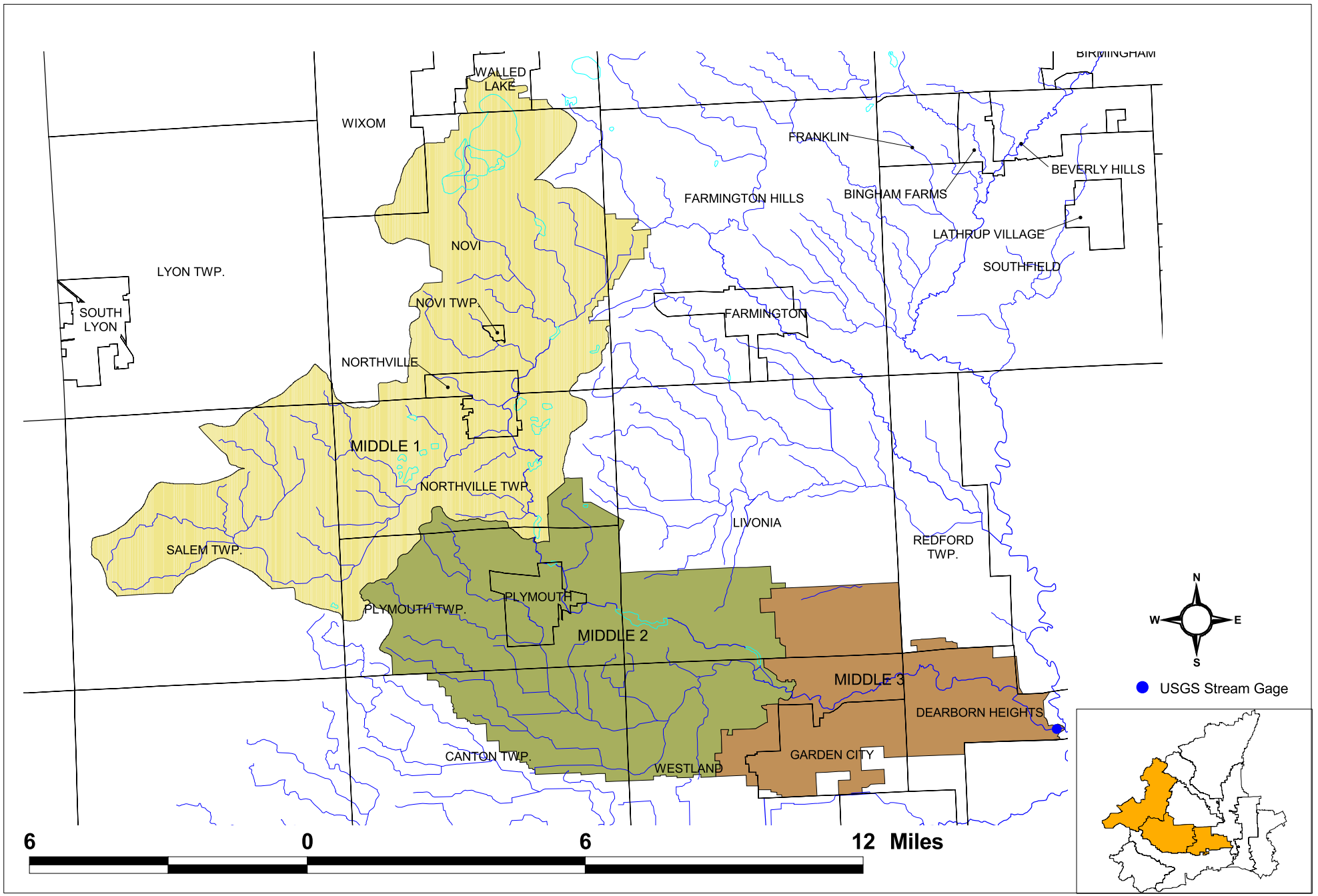
Main Branch of the Rouge River at Detroit



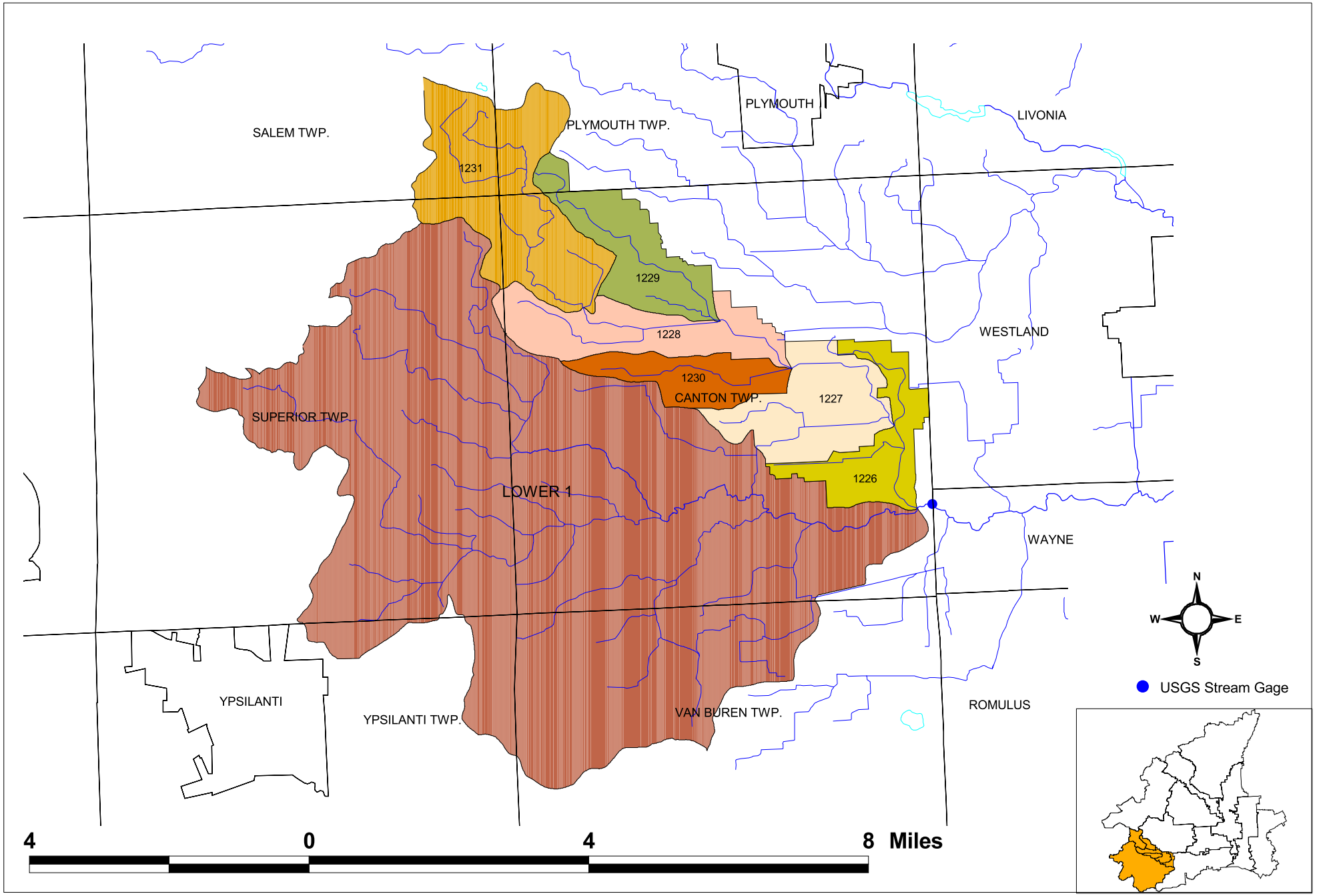
Middle Branch of the Rouge River near Garden City



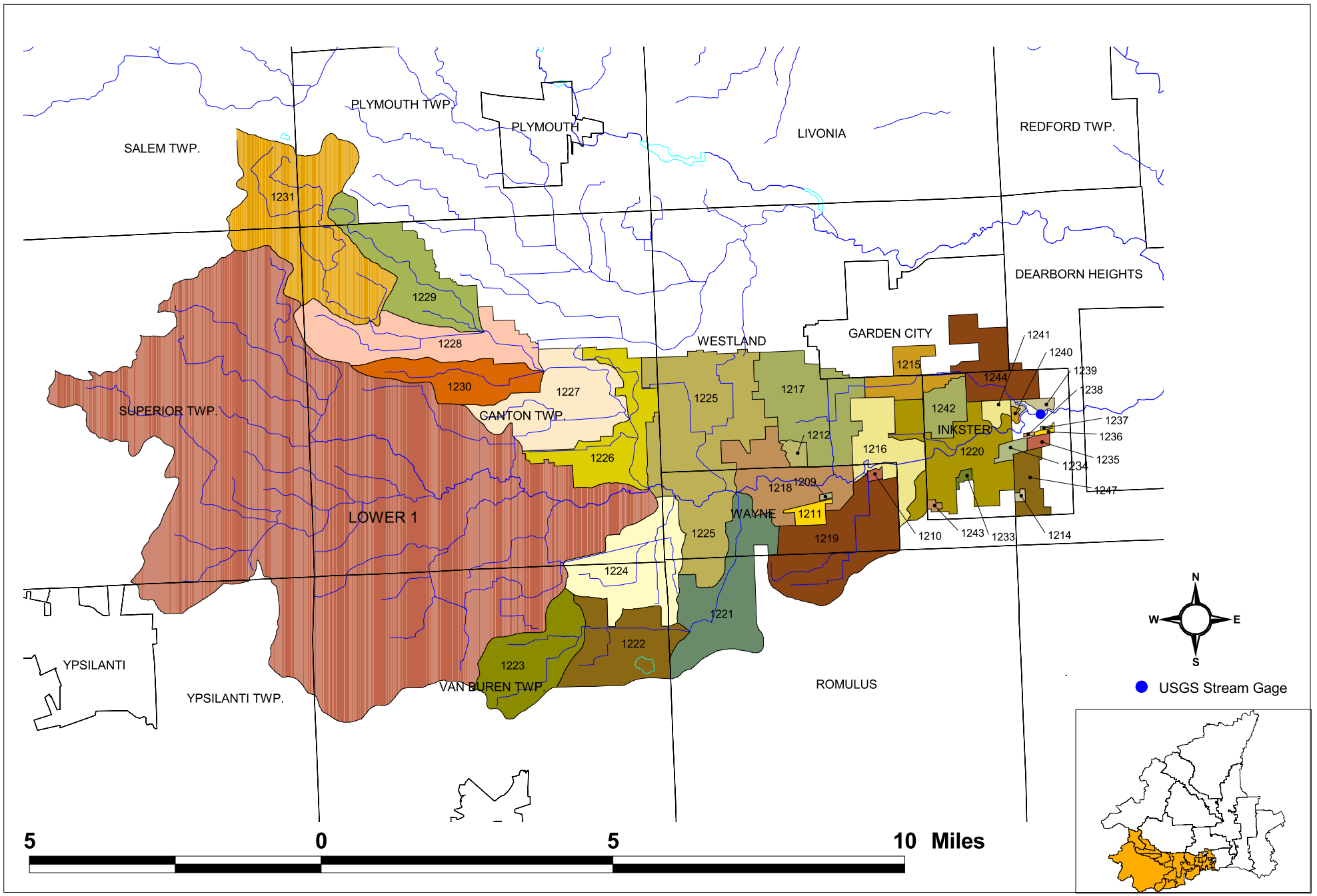
Middle Branch of the Rouge River at Dearborn Heights



Lower Branch of the Rouge River at Wayne



Lower Branch of the Rouge River at Inkster



Appendix I. Photographs of Right and Left Bank at Each Stream Gage Site

Main Branch of the Rouge River at Birmingham (04166000)

Right Bank

Left Bank

Main Branch of the Rouge River at Southfield (04166100)

Right Bank

Left Bank

Evans Ditch at Southfield (04166200)

Right Bank

Left Bank

Upper Branch of the Rouge River at Farmington (04166300)

Right Bank

Left Bank

Upper Branch of the Rouge River at Detroit (04166470)

Right Bank

Left Bank

Main Branch of the Rouge River at Detroit (04166500)

Right Bank

Left Bank

Note: Banks at gage very high and steep. Photos are of banks roughly 50 feet downstream of gage.

Middle Branch of the Rouge River near Garden City (04166500)

Right Bank

Left Bank

Middle Branch of the Rouge River at Dearborn Heights (04166500)

Right Bank

Left Bank

Lower Branch of the Rouge River at Wayne (04166500)

Right Bank

Left Bank

Lower Branch of the Rouge River at Ikster (04166500)

Right Bank

Left Bank