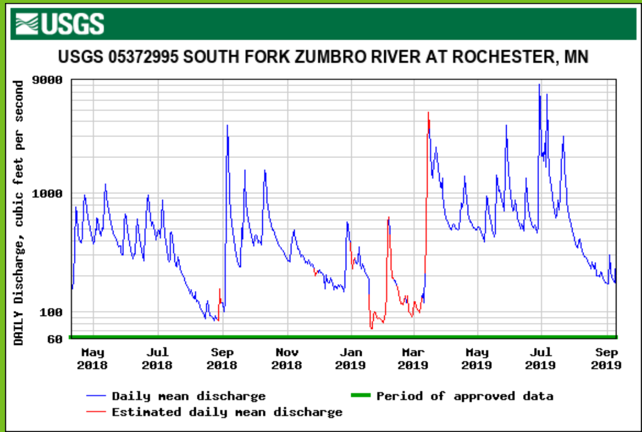
DEPARTMENT OF NATURAL RESOURCES

Division of Ecological & Water Resources

The Evaluation of Hydrologic Change (EHC) for the St. Louis River Watershed

Clean Water Hydrologist

Jason Carlson



CLIMATE

Wetness Indices		Hydrologic Persistence		DNR Hydrologic Assessment Tool	Climate Assessment Tool (USACE): Historical Climatic trends and future conditions
Palmer Hydrologic Drought Index (PHDI)	Standardized Precipitation Index (SPI)	Correlogram	Hurst Coefficient		
PHDI data allows a regional analysis and provides historical context to climatic conditions.	SPI data provides a watershed level analysis of precipitation levels and historic trends.	Correlation plots are useful in evaluating whether annual runoff values are independent, or show dependence on values from previous years.	Quantifiable measure of hydrologic persistence that allows a normalized record to be compared to others in the region or state in order to assess general trends.	Allows for analysis of overall precipitation trends on an annual, monthly or cumulative scale, as well as break point identification.	This tool allows an identified break point to be incorporated, and using trends in discharge and climate, attempts to predict future peak flows at a HUC 4 scale.

Historical Agricultural Land Use Comparison

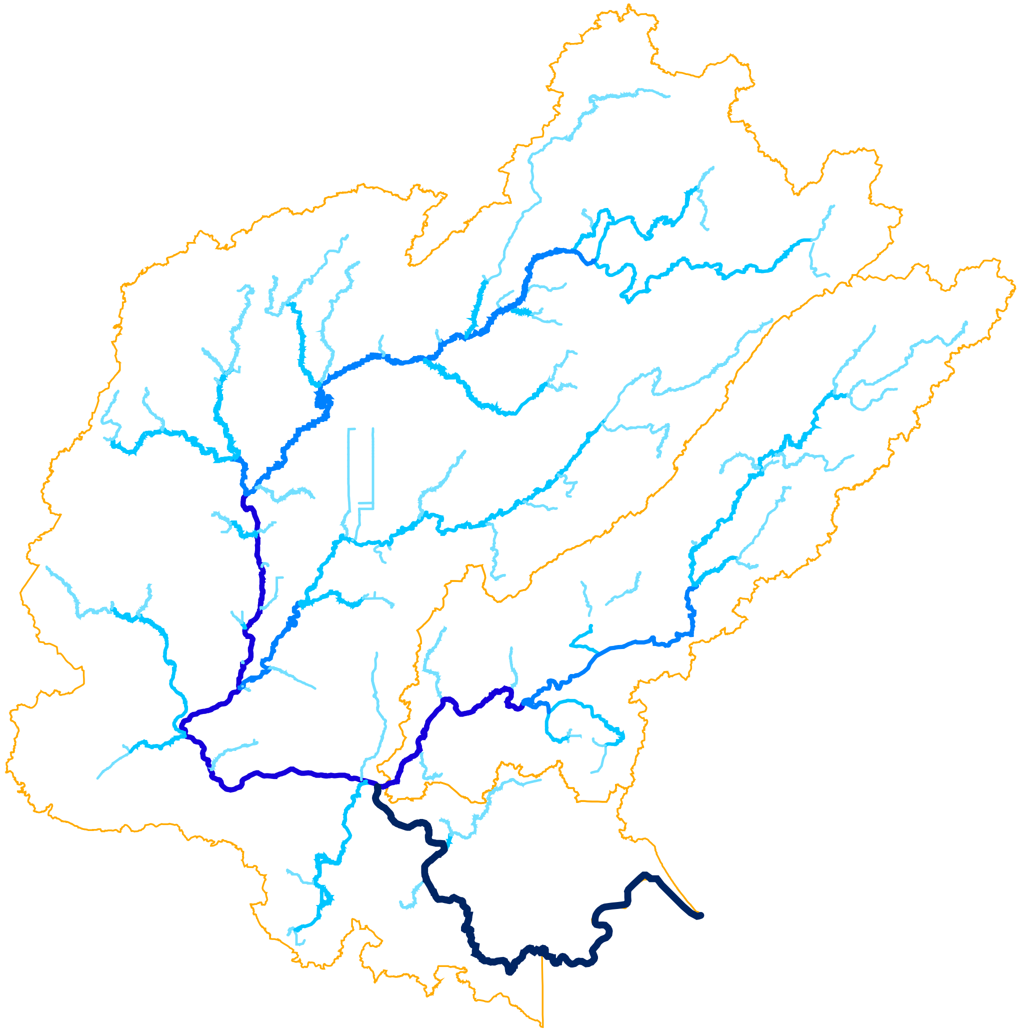
Analysis of historic crop harvest changes through time for the upstream catchment of a specific stream gage.

Evaluation of Hydrologic Change

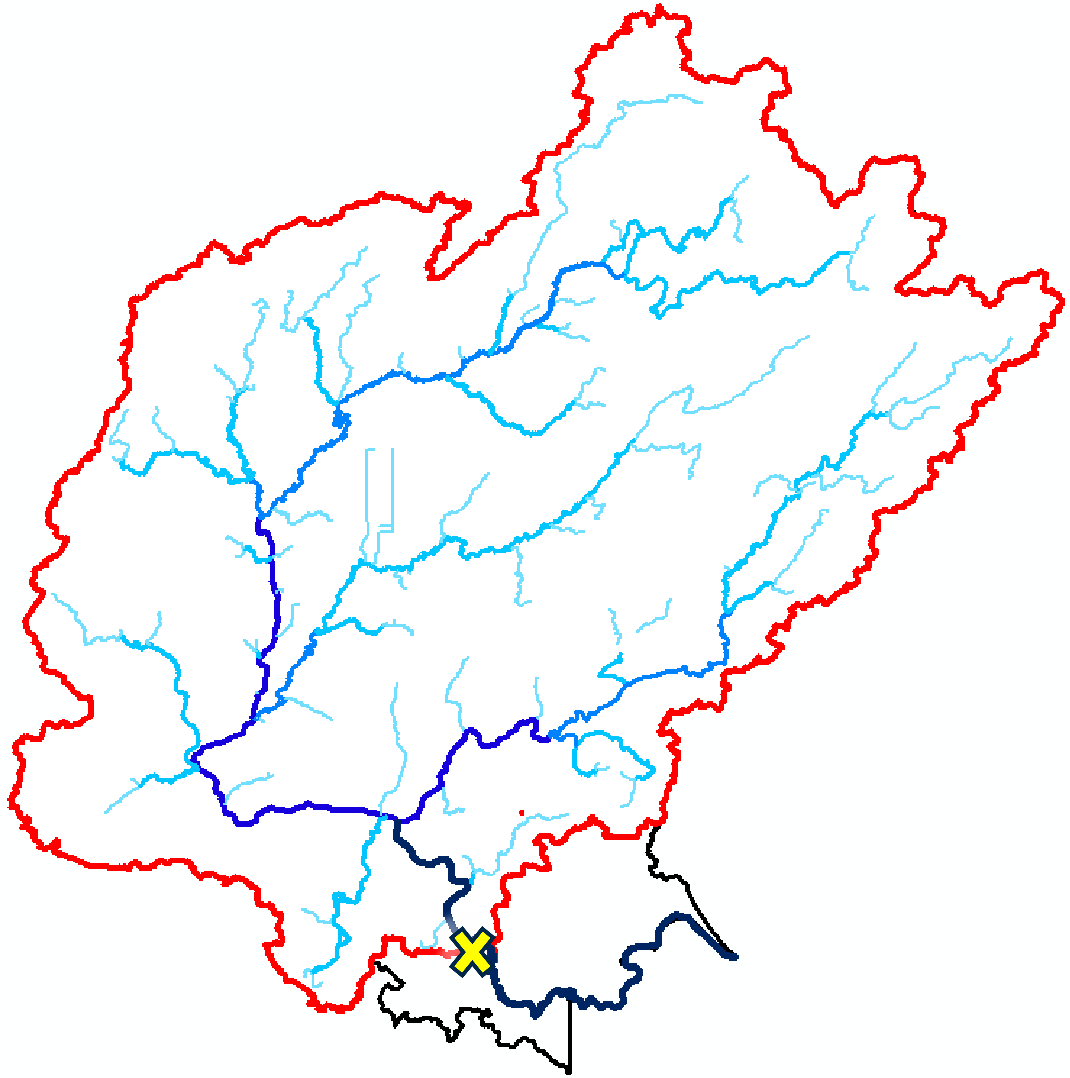
STREAMS

Double Mass Curve	Non-Stationary Detection Tool (USACE) & Parametric Trend Test:	DNR Hydrologic Assessment Tool	Flow Duration Curve Assessment	Indicators of Hydrologic Alteration (IHA)	
				Ecologically Relevant Hydrologic Indicators (ERHI's)	Range of Variability (RVA) Scorecard
Analyze the consistency of precipitation/runoff relationship at a given station. Allows for definition of a specific time in which conditions changed.	Defining break points in a record using statistical analysis of record mean, variance and distribution. Provides support for break point determined by DMC.	Break point detection, trend analysis, random forest regression modeling, variable effect analysis	Quantification and assessment of the changes in time exceedance for periods of discharge determined by break point identification methods.	Condensed assessment of non-redundant parameters likely to be the most indicative of hydrologic alteration.	Assessment of all IHA parameters to determine whether values exceed normal levels of variability for periods pre and post break point.

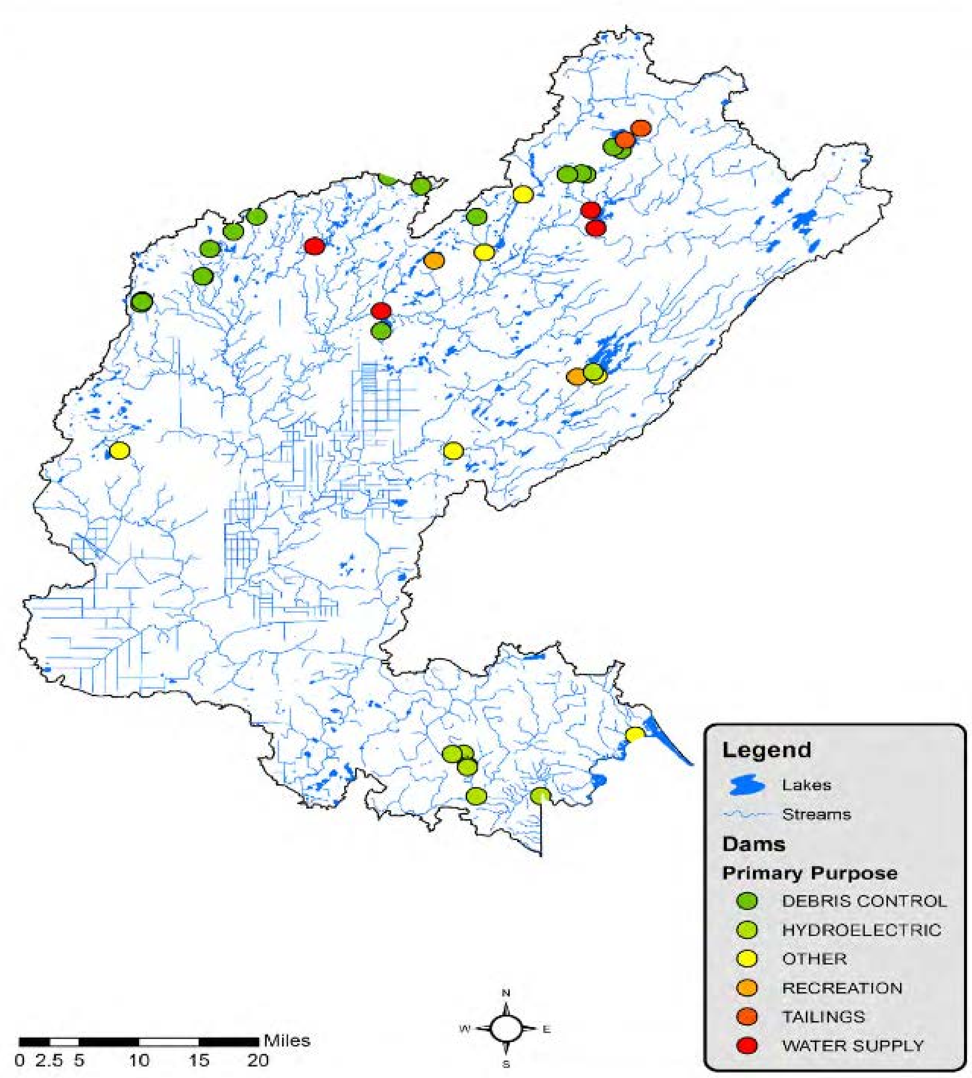
St. Louis and Cloquet River Watersheds



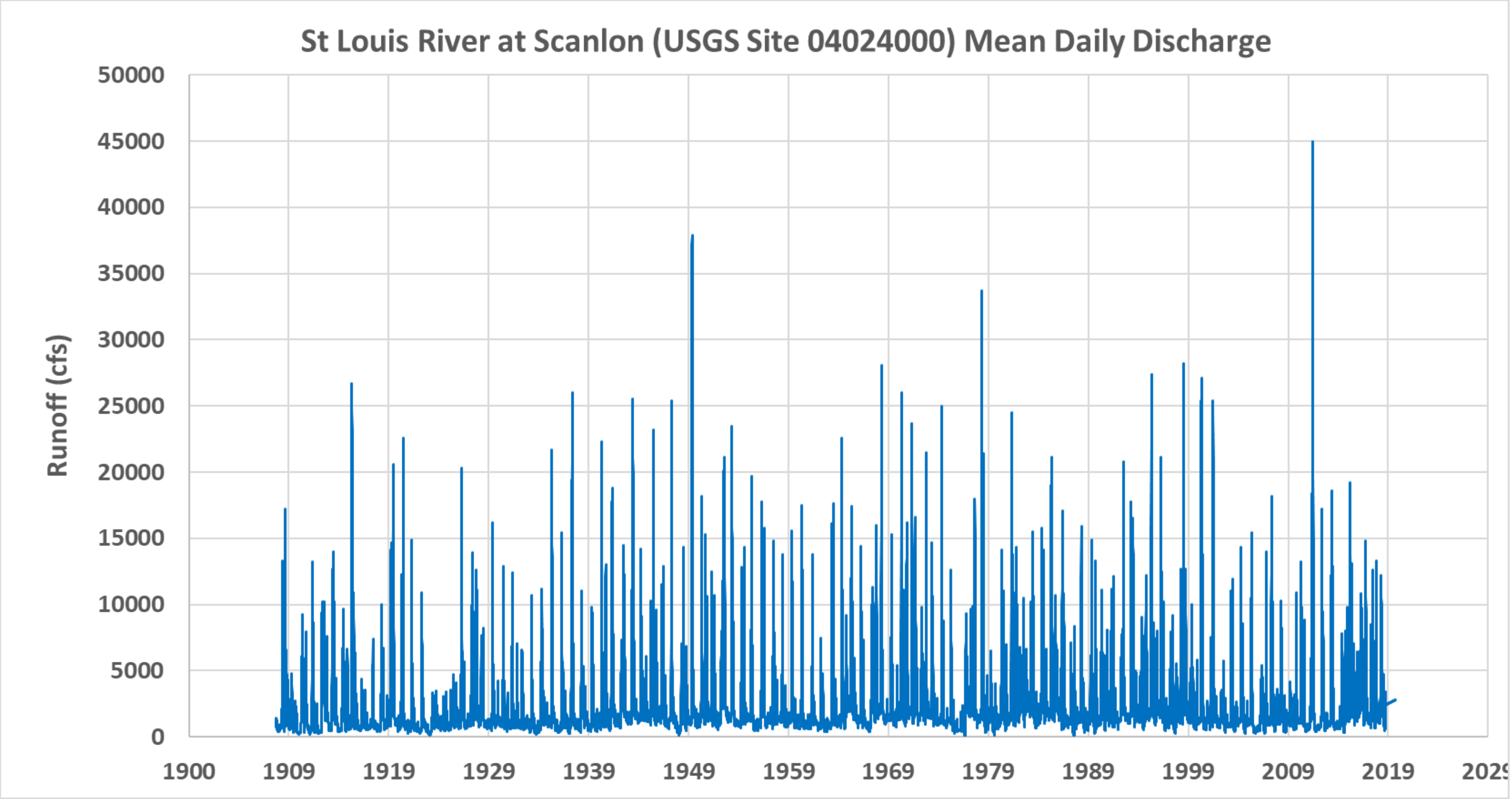
St. Louis River at Scanlon (USGS Gage 04024000) Contributing Watershed



St. Louis River Dams

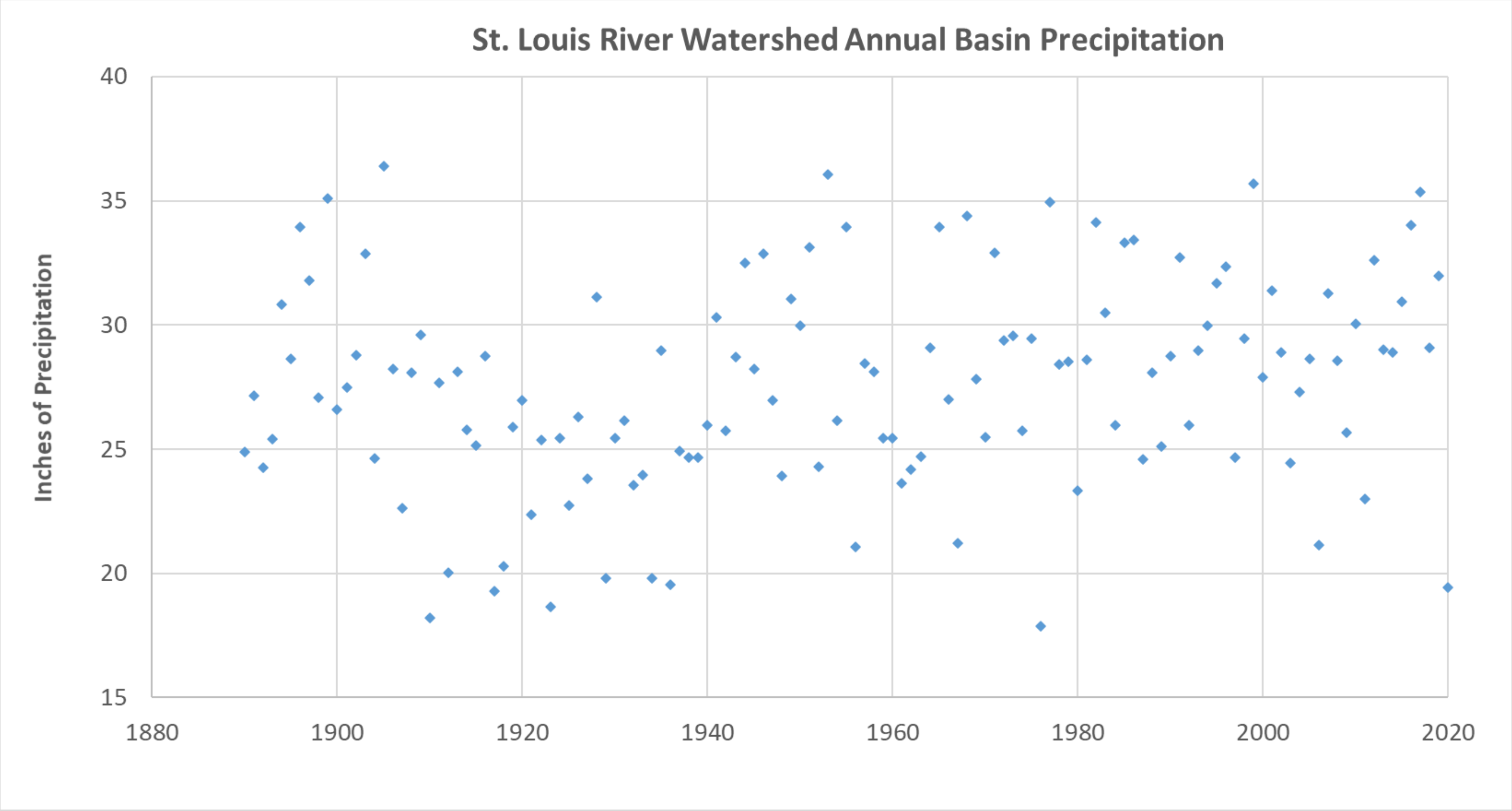


EHC Data

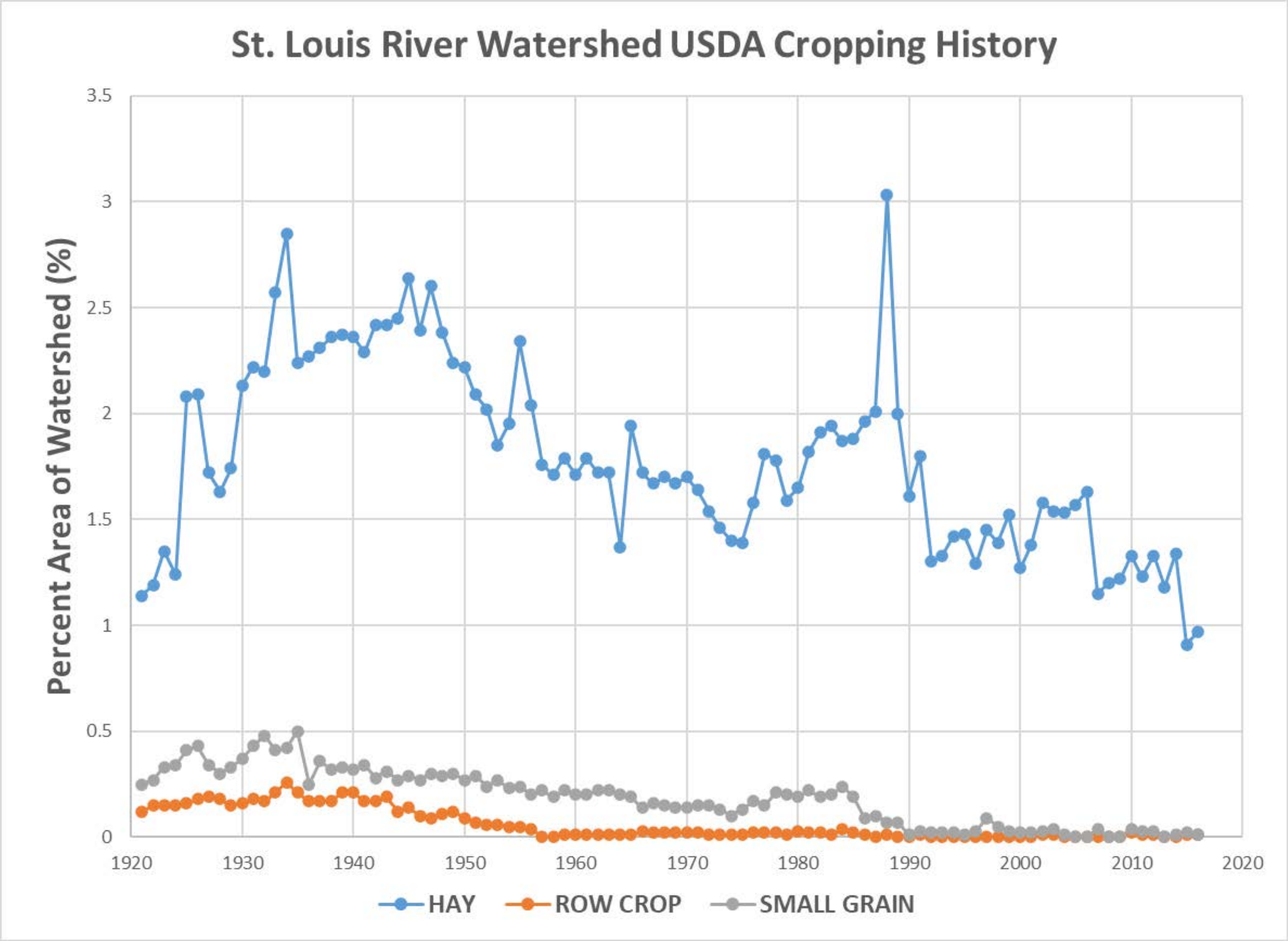


St Louis River at Scanlon (USGS Site 04024000) Mean Daily Discharge
Runoff (cfs)
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
1900
1909
1919
1929
1939
1949
1959
1969
1979
1989
1999
2009
2019

EHC Data


St. Louis River Watershed Annual Basin Precipitation
Inches of Precipitation
40
35
30
25
20
15
1880
1900
1920
1940
1960
1980
2000
2020

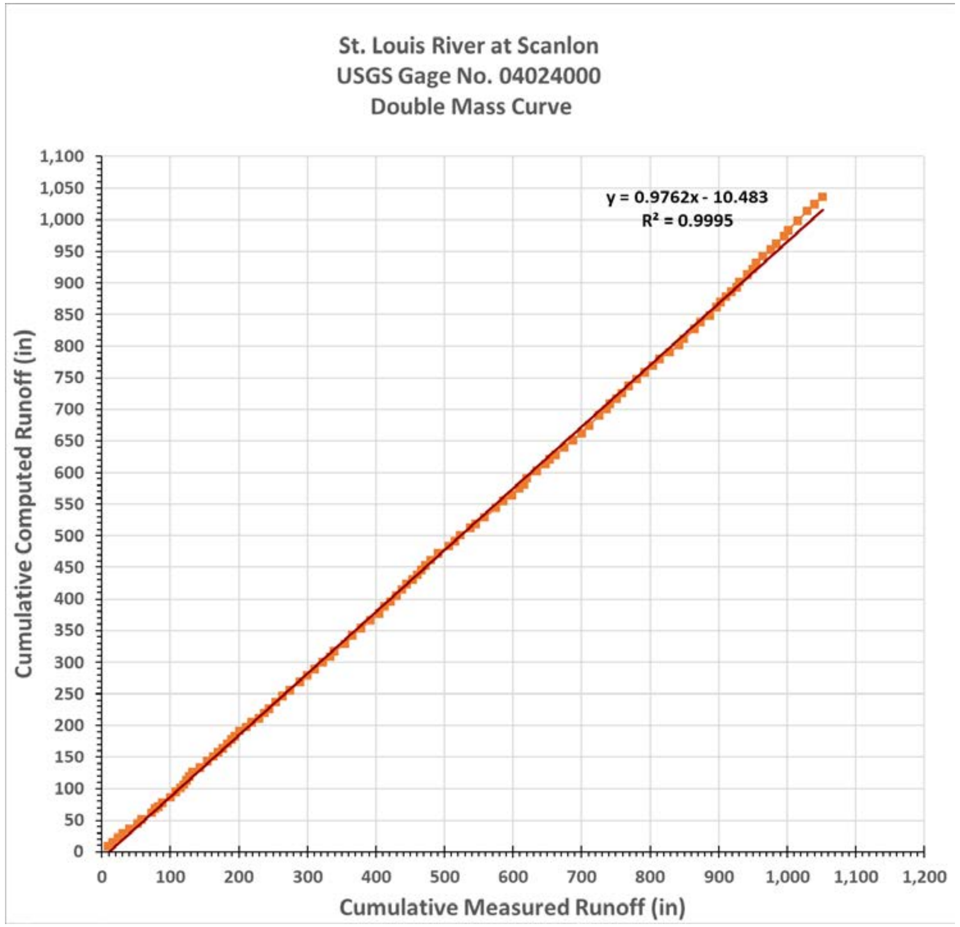
EHC Data

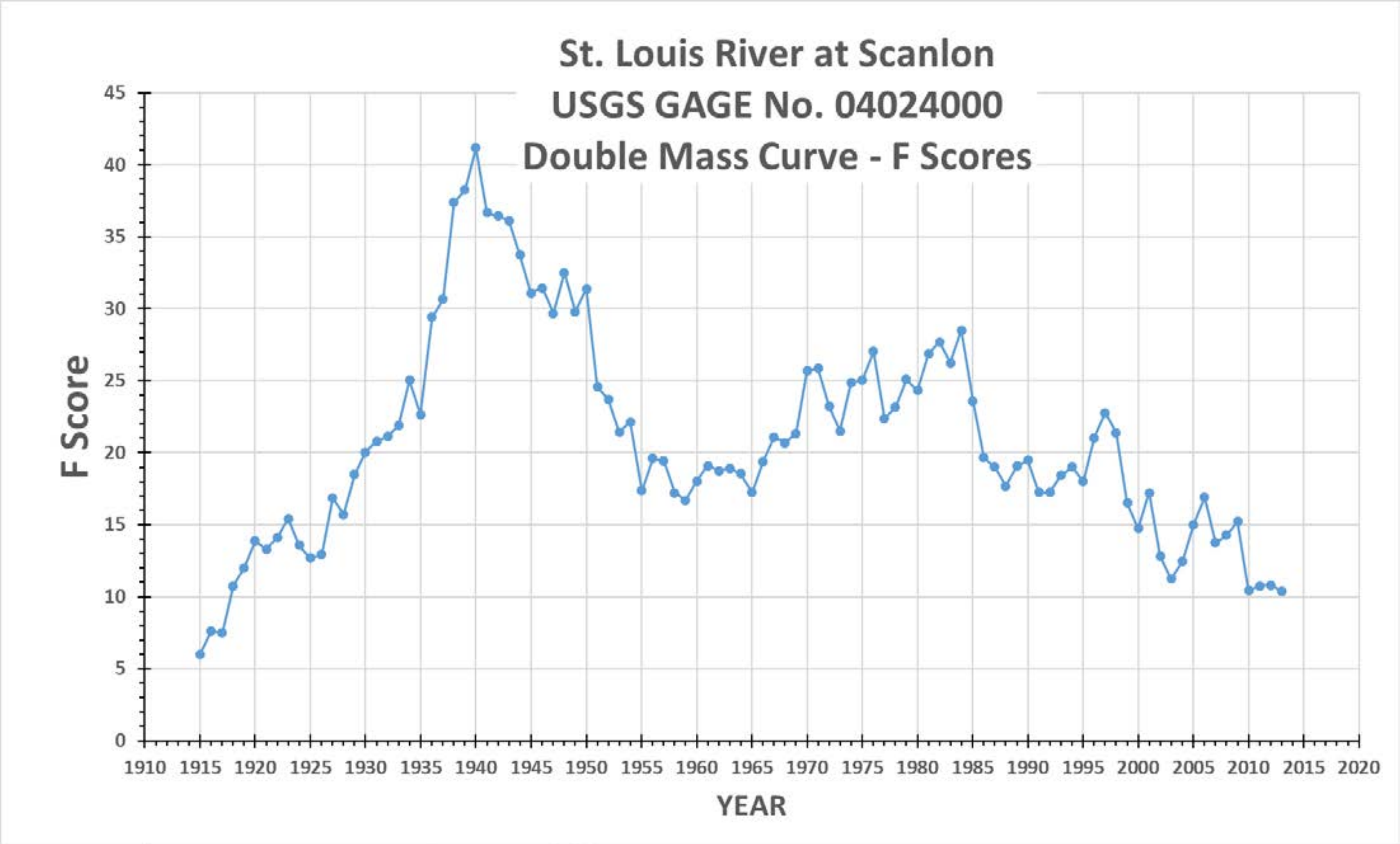

St. Louis River Watershed USDA Cropping History
Percent Area of Watershed (%)
3.5
3
2.5
2
1.5
1
0.5
0
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
HAY
ROW CROP
SMALL GRAIN

Break Point Determination

Data Category	Breakpoint Test	Break Point Year
Precipitation	Hurst Precipitation	1940
	DNR Hydrologic Assess. Tool (ED)	1941
Runoff	Hurst Runoff	1940
	DNR Hydrologic Assess. Tool (ED)	1941
Precipitation/Runoff Relationship	Double Mass Curve	1940
Annual Peak Discharge	Cramer-Von-Mises (CPM)	1935
	Kolmogorov-Smirnov (CPM	1935
	LePage (CPM)	1935
	Energy Divisive Method	1936, 1941
	Lombard Wilcoxon	1934
	Pettitt	1940
	Mann-Whitney (CPM)	1935
	Bayesian	none
	Lombard Mood	none
	Mood (CPM)	none
	Smooth Lombard Wilcoxon	none
	Smooth Lombard Mood	none

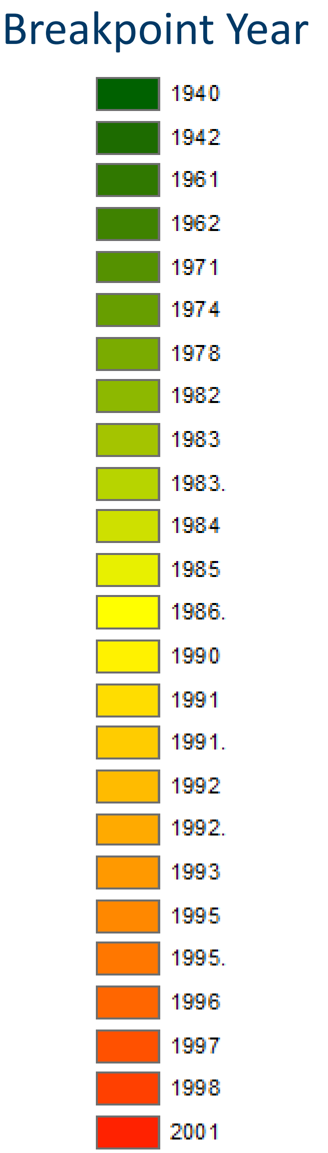
Double Mass Curve Analysis

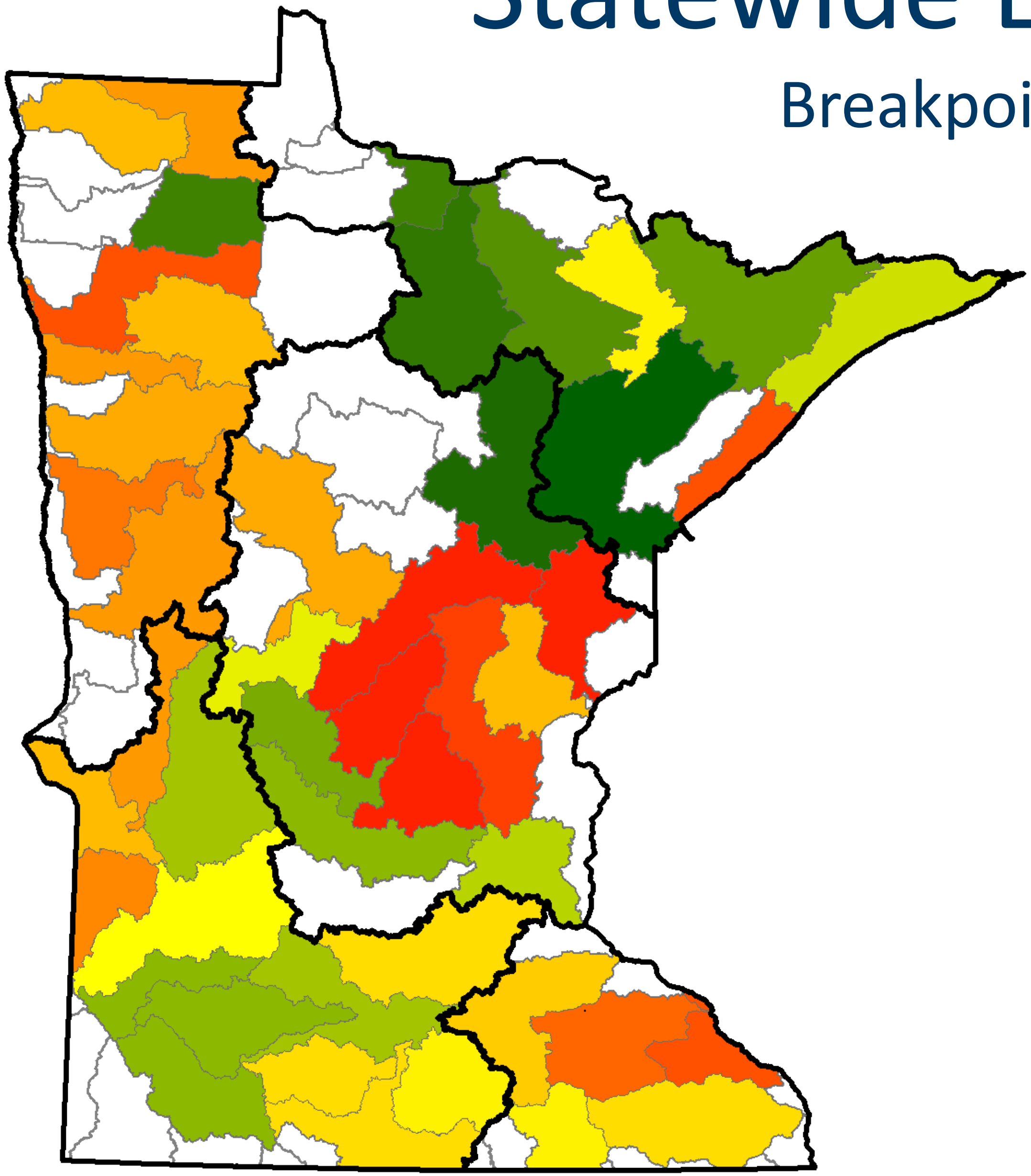




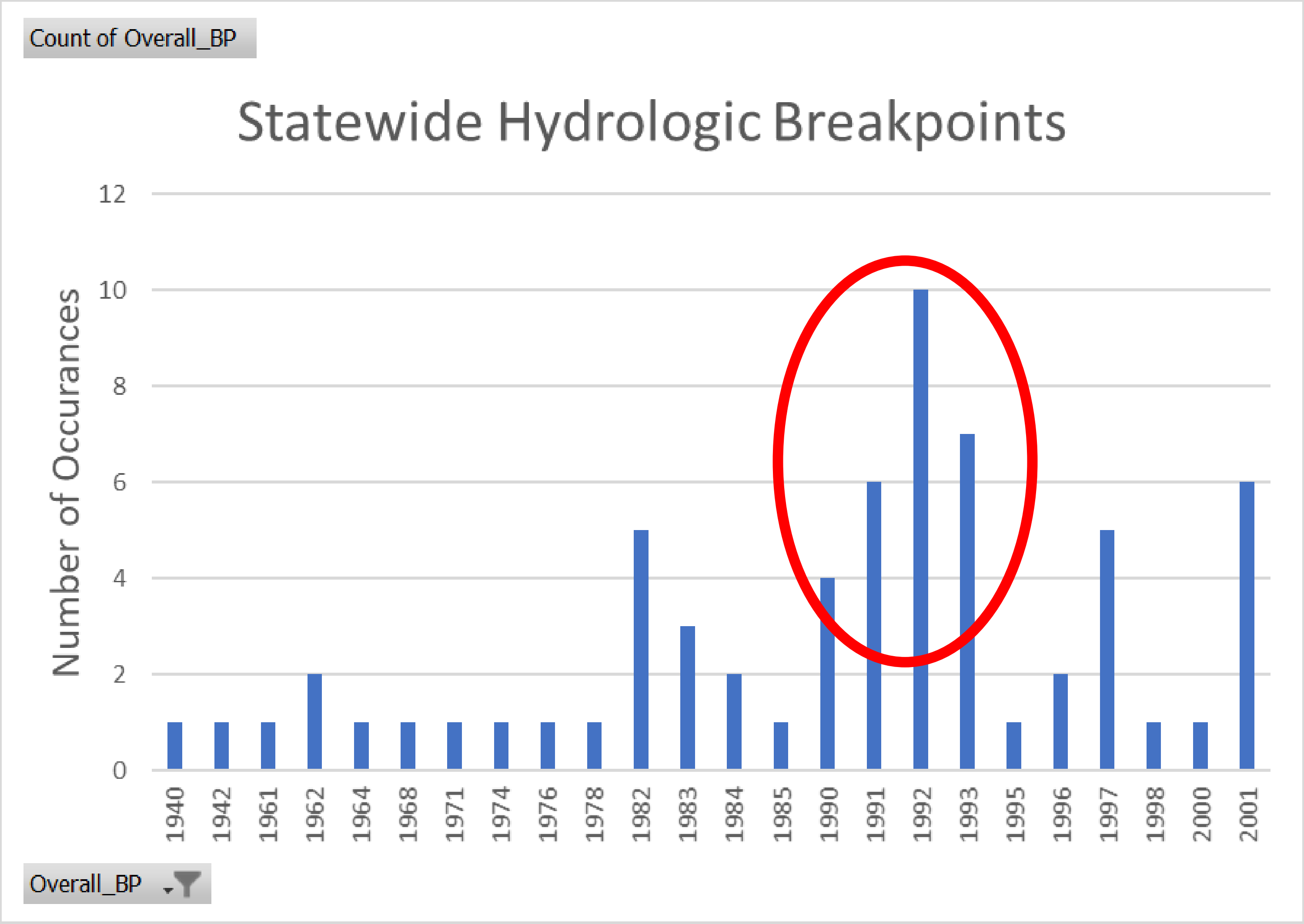
Statewide EHC Results

Breakpoint Year

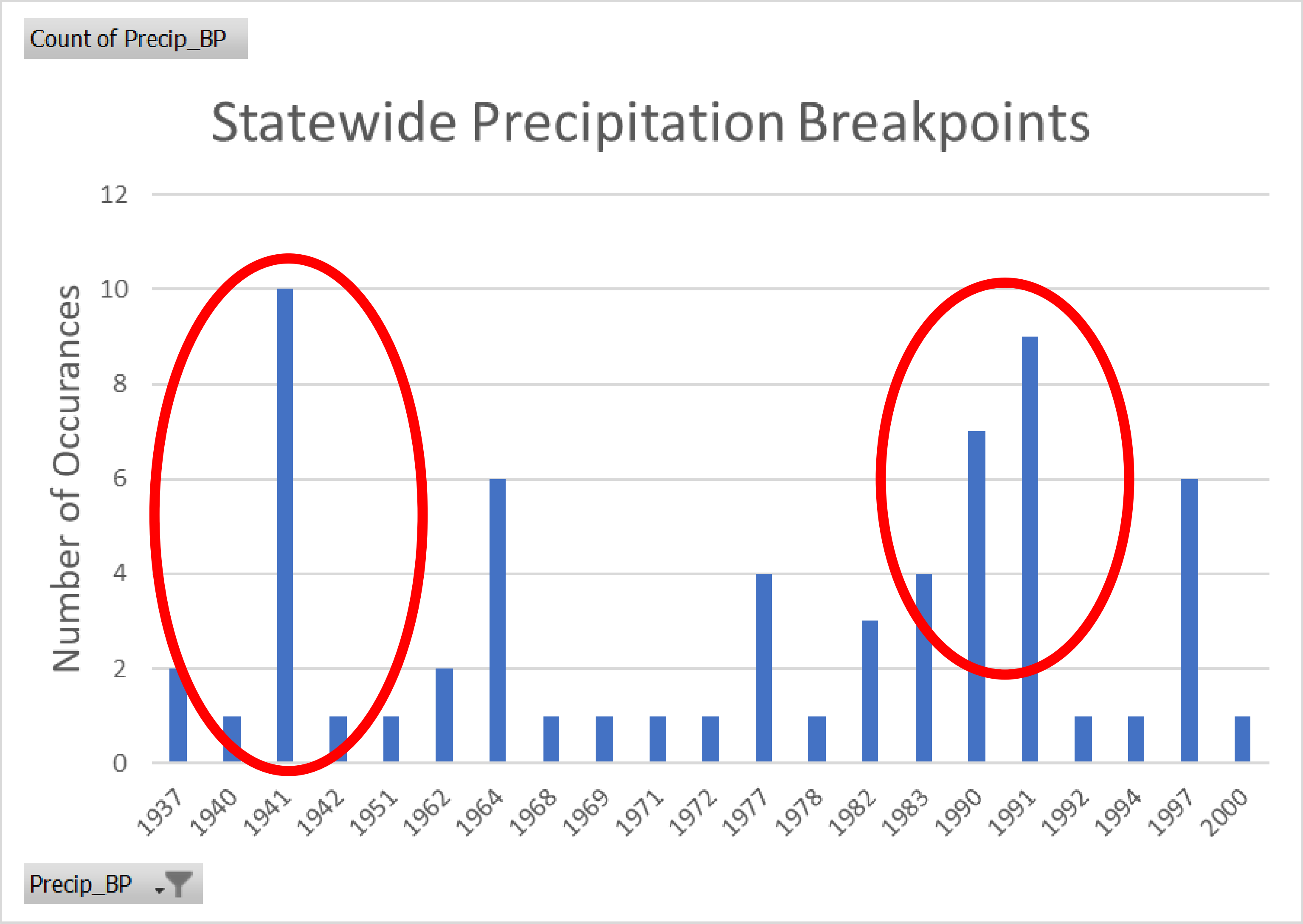




Hydrologic Change in Minnesota



Hydrologic Change in Minnesota



Discharge and Precipitation Averages – 1940 BP

	Discharge (in.)	Precip (in.)	D/P (%)
Pre 1940	7.64	24.31	0.31
Post 1940	10.18	28.60	0.36
Change	2.55	4.29	0.042

Using EHC to Compare Time Periods

20 metrics assessed before and after the chosen breakpoint (1940)

1. Frequency:

Range of Variability Analysis (RVA) – % change of occurrences between 25th and 75th percentiles

2. Magnitude:

% Change = (Post Median Value - Pre Median Value)/Pre Median Value

Comparing Time Periods

20 metrics assessed before and after the chosen breakpoint (1940)

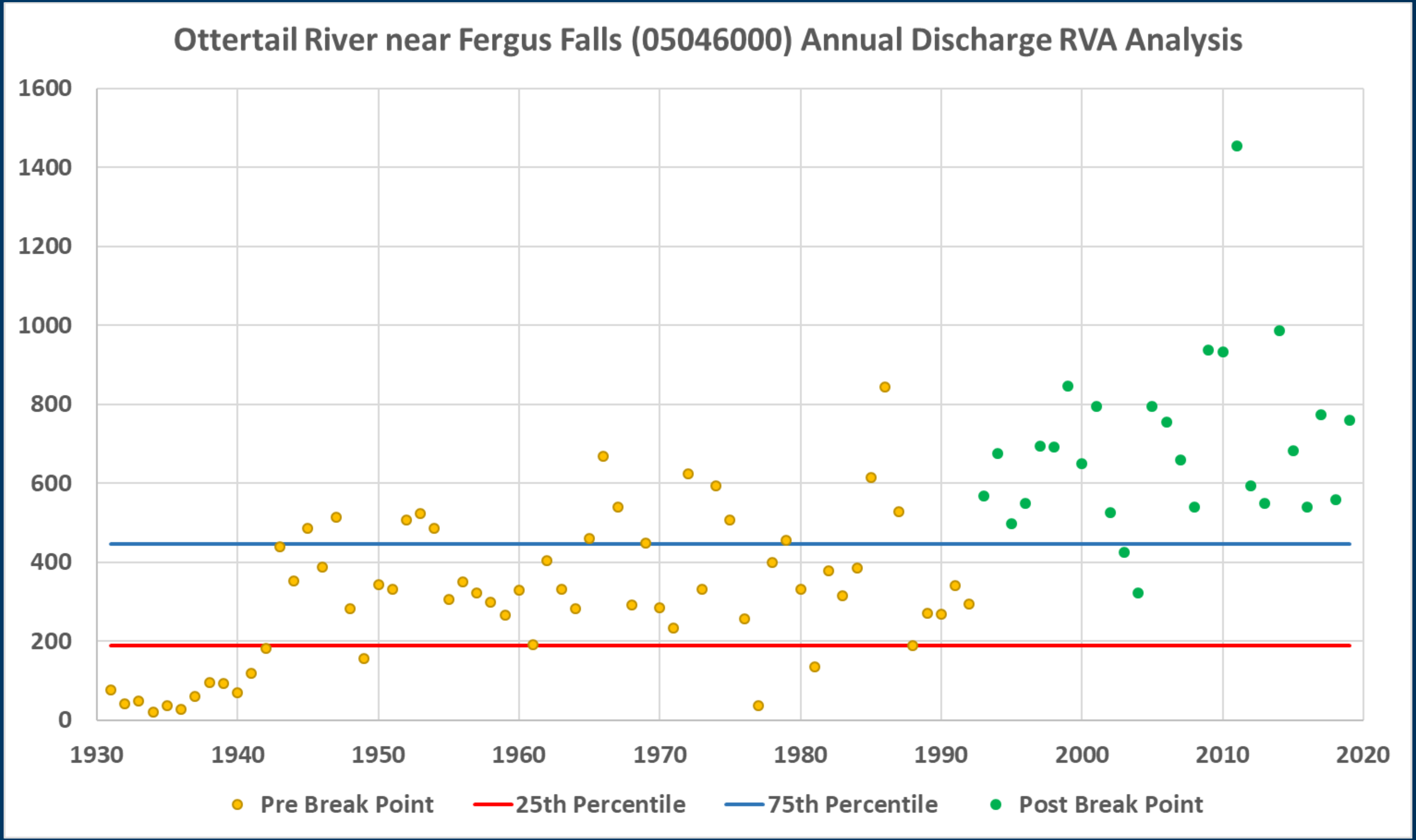
1. Frequency:

Range of Variability Analysis (RVA) – % change of occurrences between 25^{th} and 75^{th} percentiles of each data set

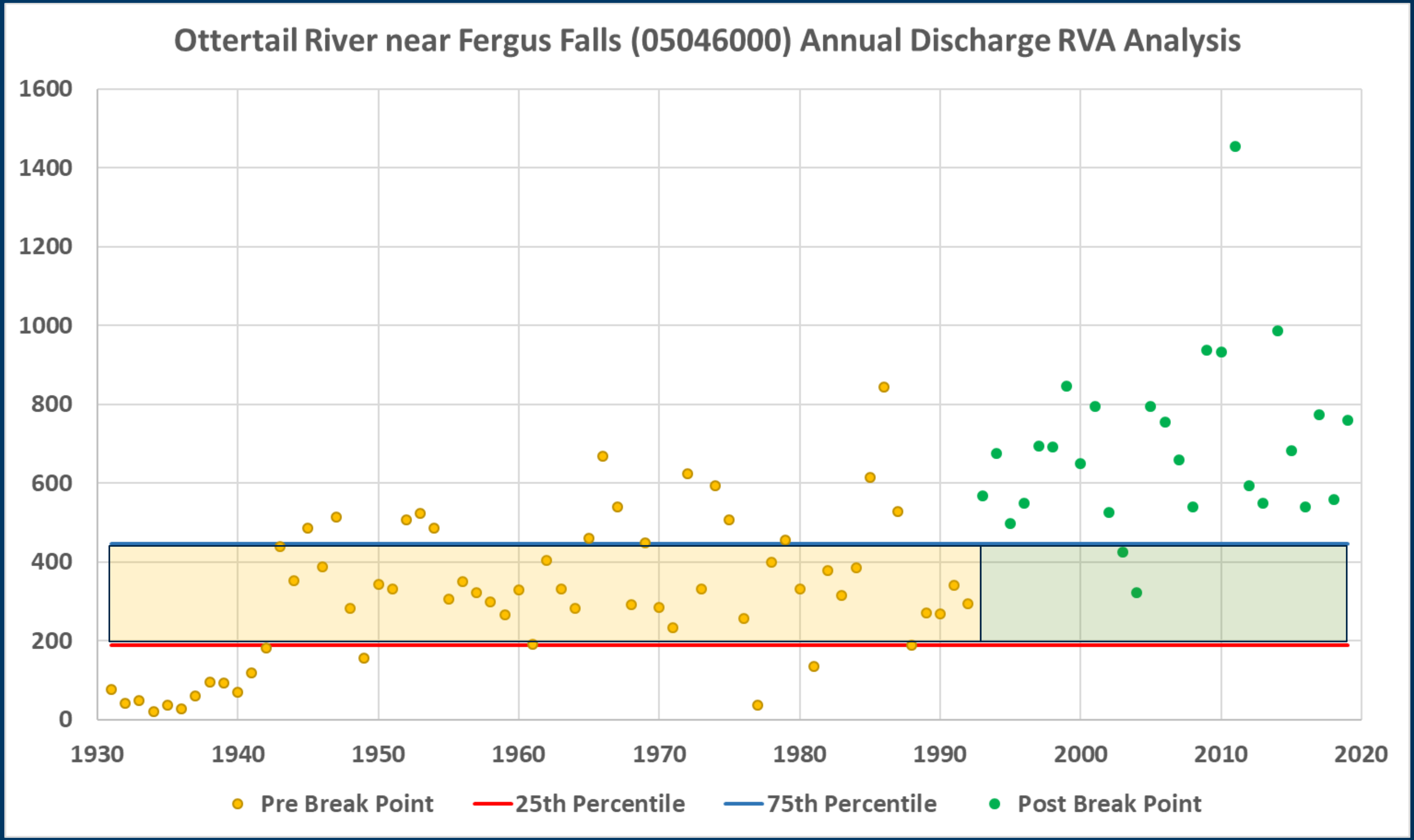
2. Magnitude:

% Change = (Post Median Value - Pre Median Value)/Pre Median Value

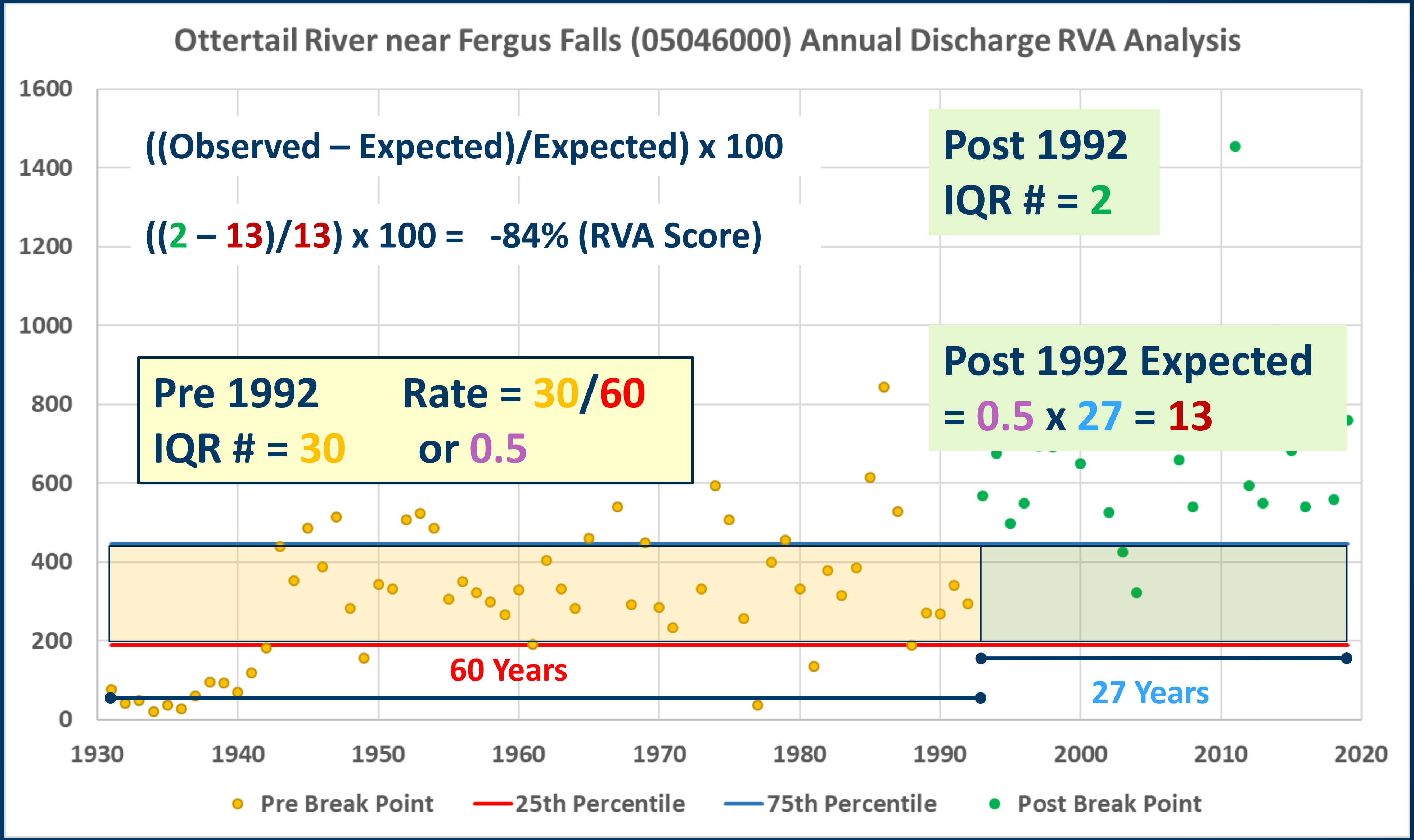
Range of Variability (RVA) Example



Range of Variability (RVA) Example



Range of Variability (RVA) – Frequency Change



EHC Summary Table 1940 Break Point

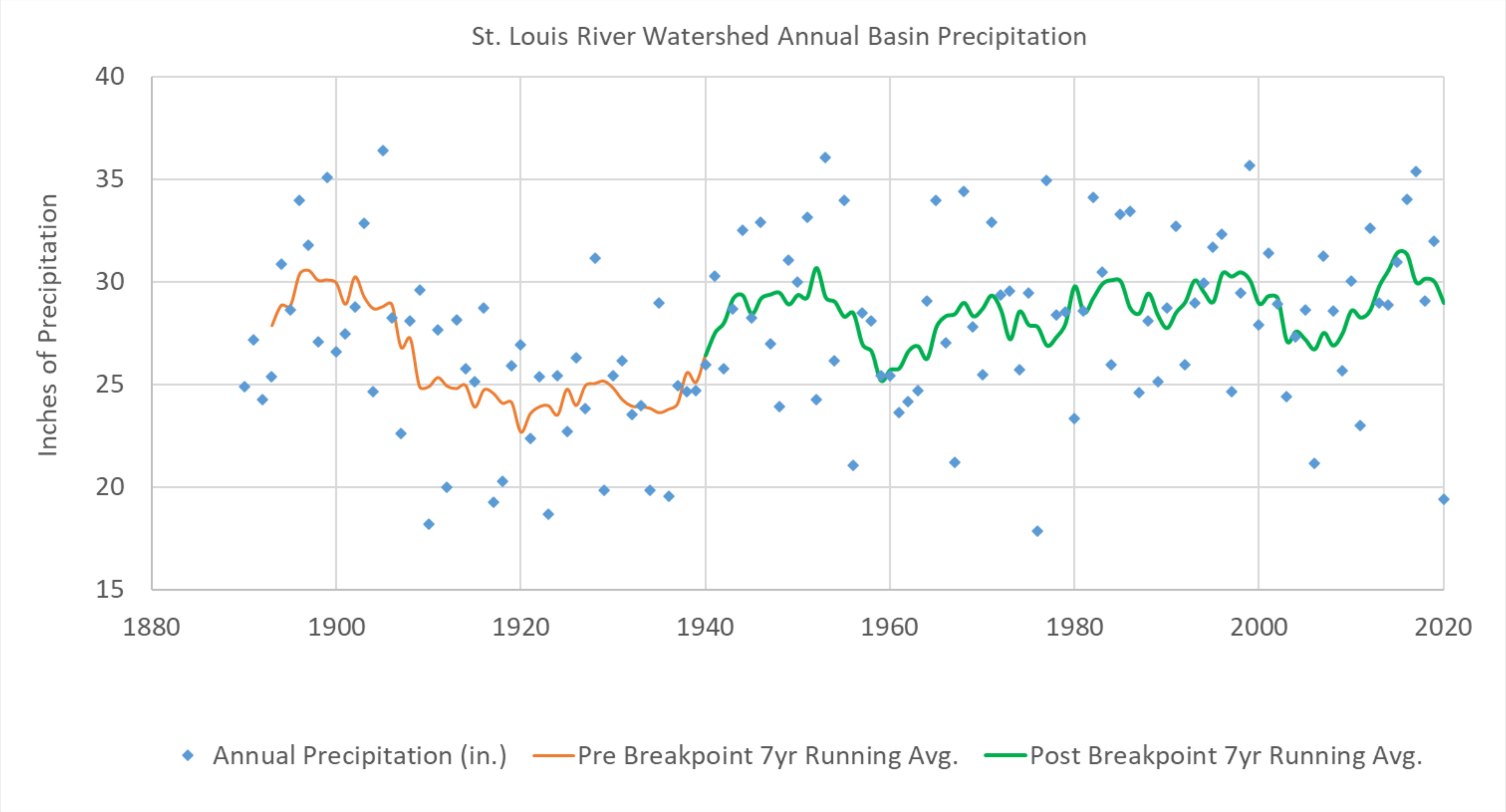
EHC Parameter Grouping	Parameter	RVA Change (%)	RVA Impact	Magnitude Change (%)	Magnitude Impact
Annual Values	Annual Precipitation	-36	Major	10	Moderate
	Annual Discharge	-34	Major	33	Major
	Annual Peak Discharge	-21	Major	46	Major
	Annual Runoff Ratio	-33	Major	13	Moderate
Low Flows	7-Day Minimum	-13	Moderate	32	Major
	August Median Base Flow	-38	Major	25	Major
	90% Flow Duration	-65	Extreme	43	Major
Moderate Flows	May Median Flow	5	Neutral	17	Moderate
	50% Flow Duration			44	Major
	1.5 Year Return Interval Flows			45	Major
High Flows	10% Flow Duration	46	Major	32	Major
	5 Year Return Interval Flows			28	Major
	10 Year Return Interval Flows			24	Major
	3-Day Maximum	-15	Moderate	40	Major
Flow Timing	Julian Day Max Flow	-15	Moderate	-6	Neutral
	Julian Day Min Flow	75	Extreme	24	Major
Rate of Change/Flashiness	High Pulse Count	13	Moderate	0	Neutral
	Low Pulse Count	-45	Major	-75	Extreme
	Number of Reversals	-78	Extreme	-16	Moderate
	Rise Rate	-3	Neutral	-3	Neutral

Positive = (blue)

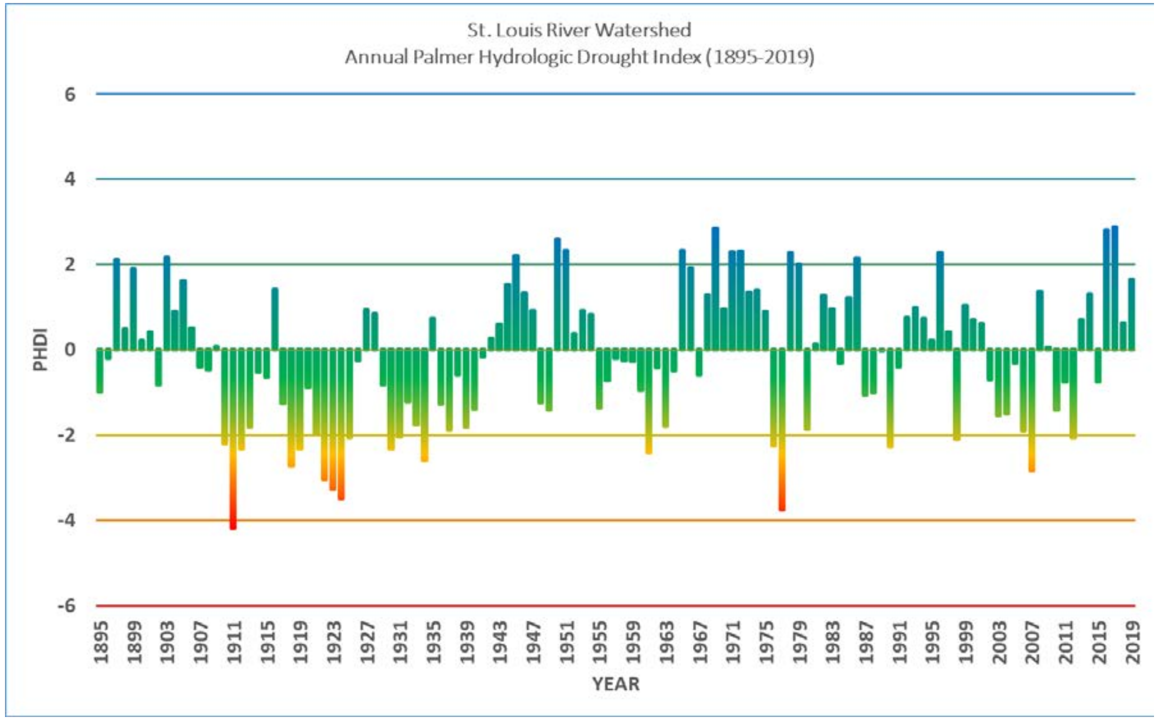
Negative = (red)

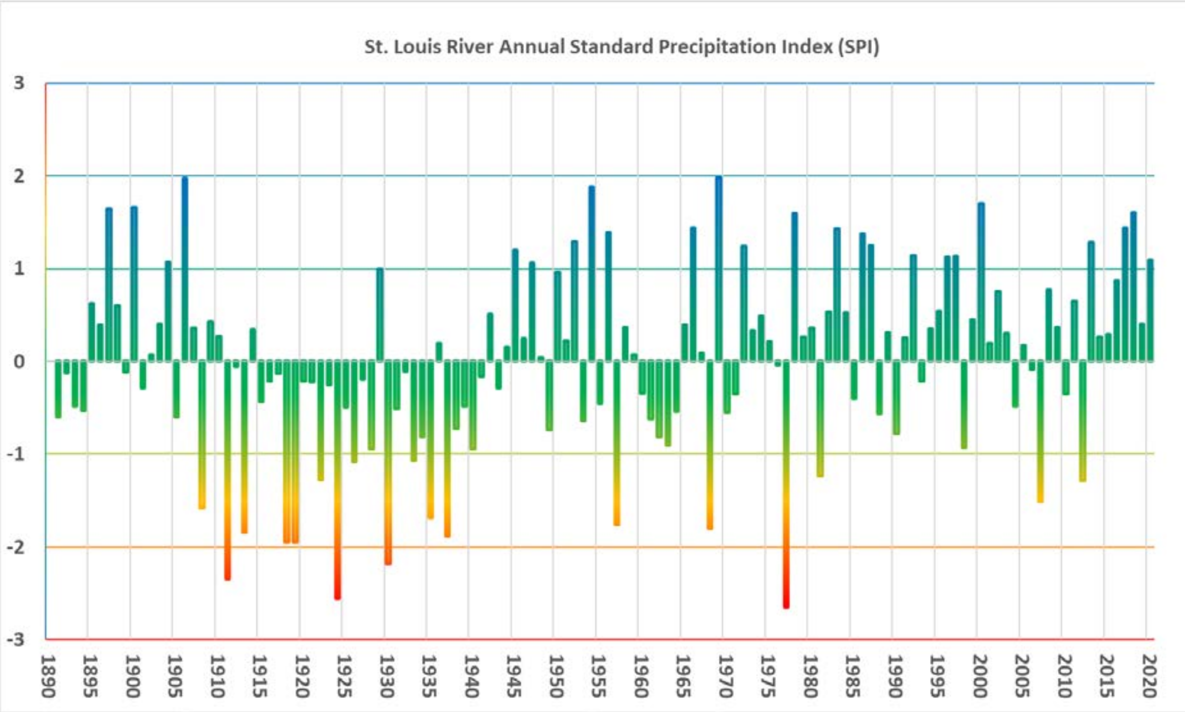
Impact Categories (+/-) Neutral <10%, Moderate 11-20%, Major 21-50%, Extreme >50%

Precipitation



Wetness Indices

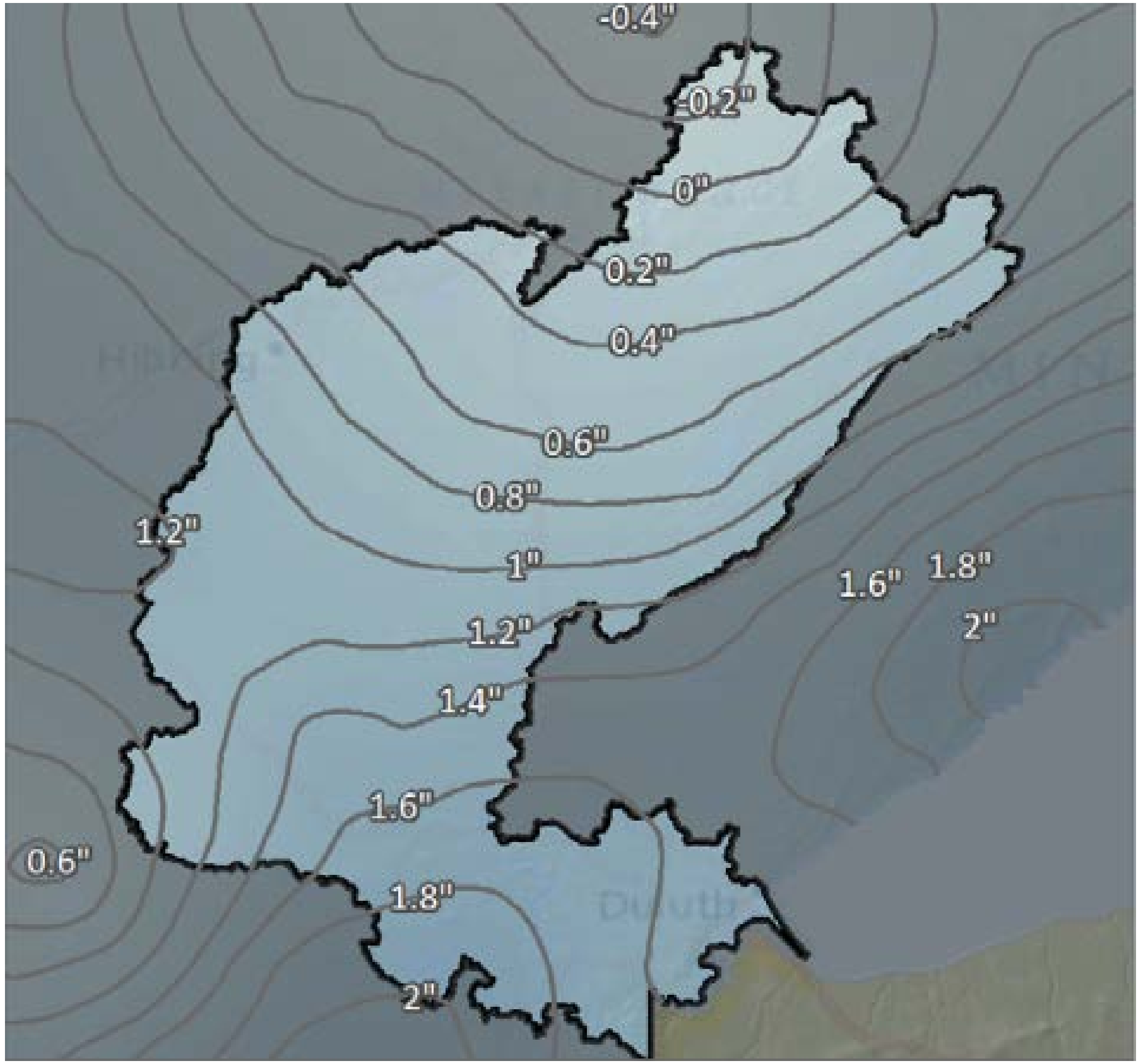




PHDI VALUES	PERCENT CHANGE
Extremely Wet	NA
Very Wet	42
Moderate to Norma	178
Severe Drought	-68
Extreme Drought	-54

SPI VALUES	PERCENT CHANGE
Extremely wet	-10
Very wet	65
Moderately wet	14
Moderately dry	-30
Severely dry	-40
Extremely dry	-10

Precipitation Departure from Historic Average



Watershed Average Departure

Time period	Value
Annual	0.9"
Winter (Dec. - Feb.)	0.1"
Spring (March - May)	0.1"
Summer (June - Aug.)	0.2"
Fall (Sept. Nov.)	0.5"

Large Rain Events

Time Period	1-2"	2-3"	3-4"	+4"
1901-1930	122	13	2	1
1931-1960	136	22	7	0
1961-1990	133	26	5	2
1991-2020	181	25	4	1

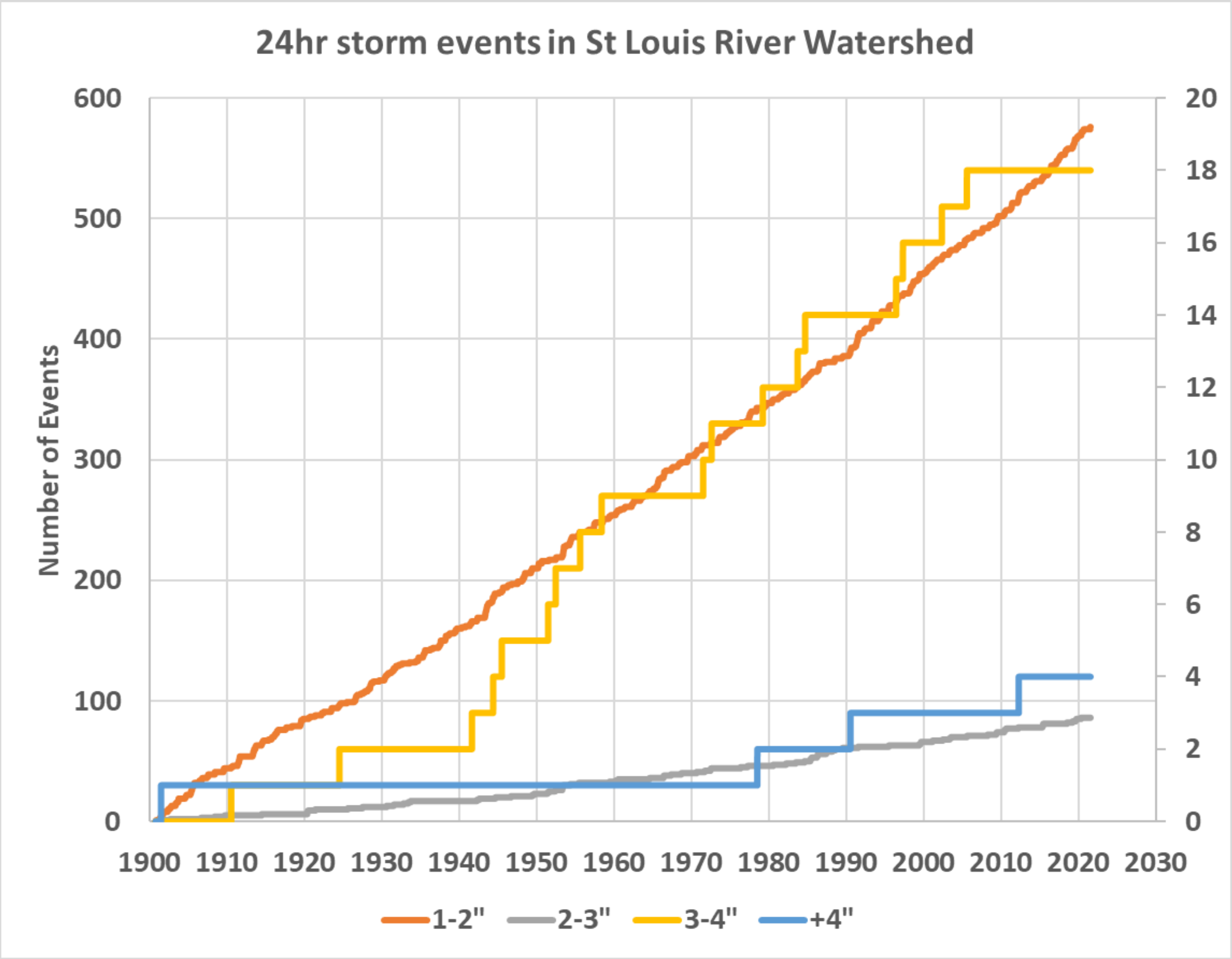
Composite Record from Pokegama Dam (NWS PKGM5) 1901-1911 and Cloquet Gage (NWS CLQM5) 1911-2020

Large Rain Events

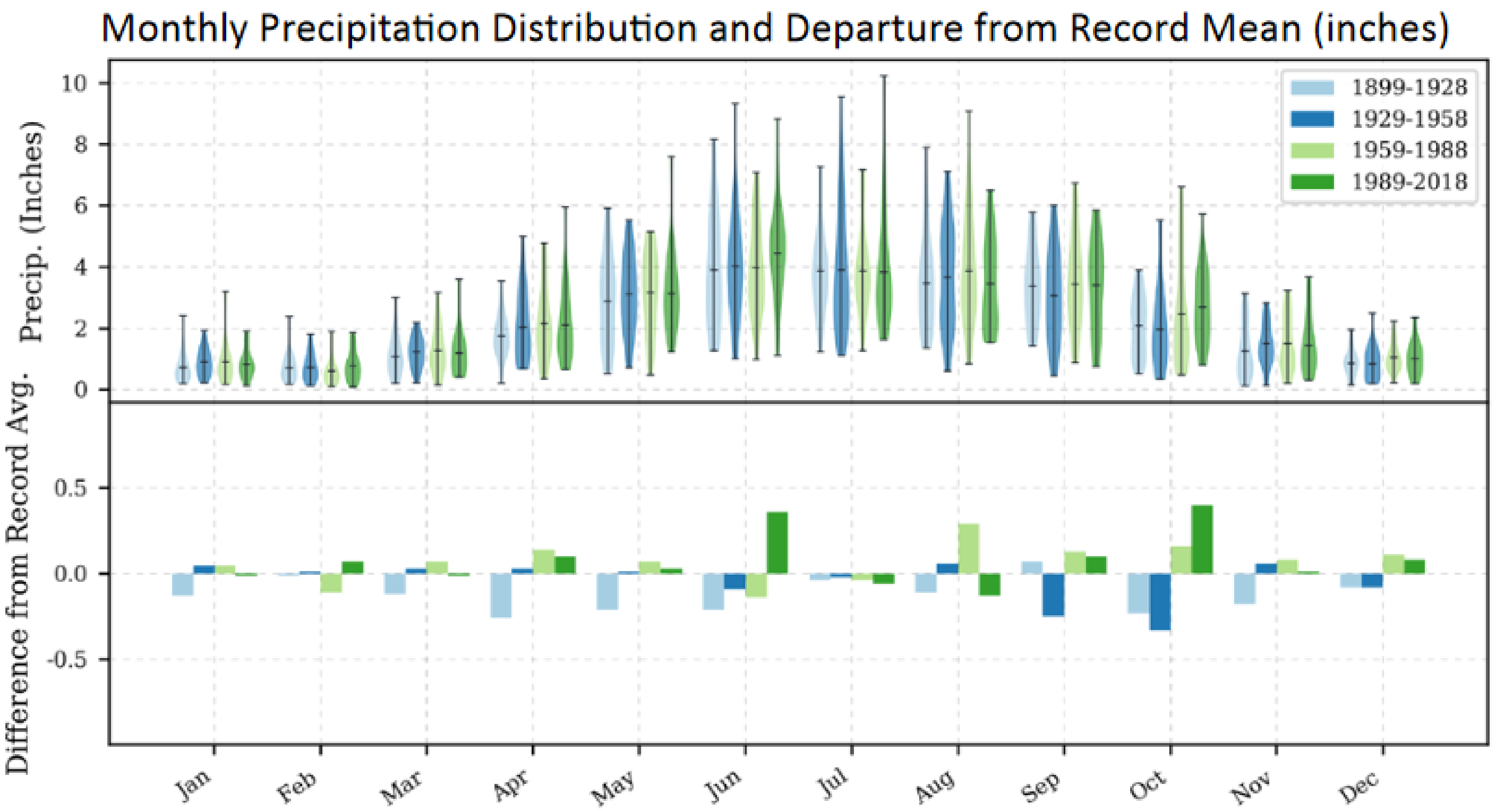
48 Additional 1-2” events in the latest 30-year period = 1.6 additional events per year

Time Period	1-2"	2-3"	3-4"	+4"
1901-1930	122	13	2	1
1931-1960	136	22	7	0
1961-1990	133	26	5	2
1991-2020	181	25	4	1

Large Rain Events



Rainfall Timing Changes



EHC Summary Table
1990 Breakpoint

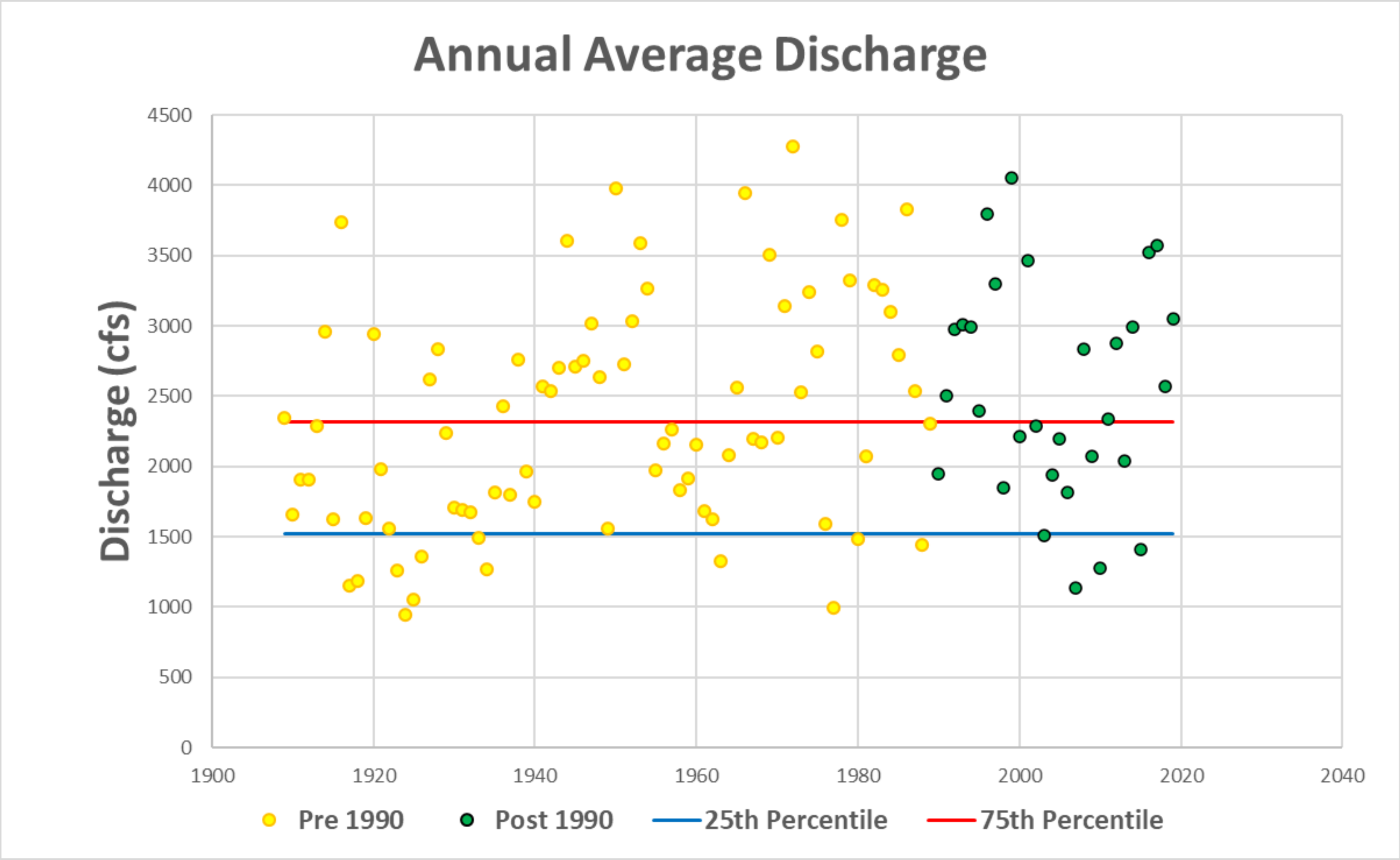
EHC Parameter Grouping	Parameter	RVA	Obs Freq Change	Percent Change	Magnitude Change
Annual Values	Annual Precipitation	-10	Neutral	7	Neutral
	Annual Discharge	-10	Neutral	8	Neutral
	Annual Peak Discharge	-1	Neutral	-2	Neutral
	Annual Runoff Ratio	59	Extreme	-1	Neutral
Low Flows	7-Day Minimum	-7	Neutral	-21	Major
	August Median Base Flow	-67	Extreme	-29	Major
	90% Flow Duration	-6	Extreme	3	Neutral
Moderate Flows	May Median Flow	20	Moderate	1	Neutral
	50% Flow Duration			9	Neutral
	1.5 Year Return Interval Flows			-6	Neutral
High Flows	10% Flow Duration	16	Moderate	11	Moderate
	5 Year Return Interval Flows			5	Neutral
	10 Year Return Interval Flows			9	Neutral
	3-Day Maximum	-7	Neutral	-1	Neutral
Flow Timing	Julian Day Max Flow	-20	Moderate	7	Neutral
	Julian Day Min Flow	87	Extreme	11	Moderate
Rate of Change/Flashiness	High Pulse Count	13	Moderate	0	Neutral
	Low Pulse Count	13	Moderate	-50	Major
	Number of Reversals	-33	Major	-18	Moderate
	Rise Rate	0	Neutral	-29	Major

Positive =

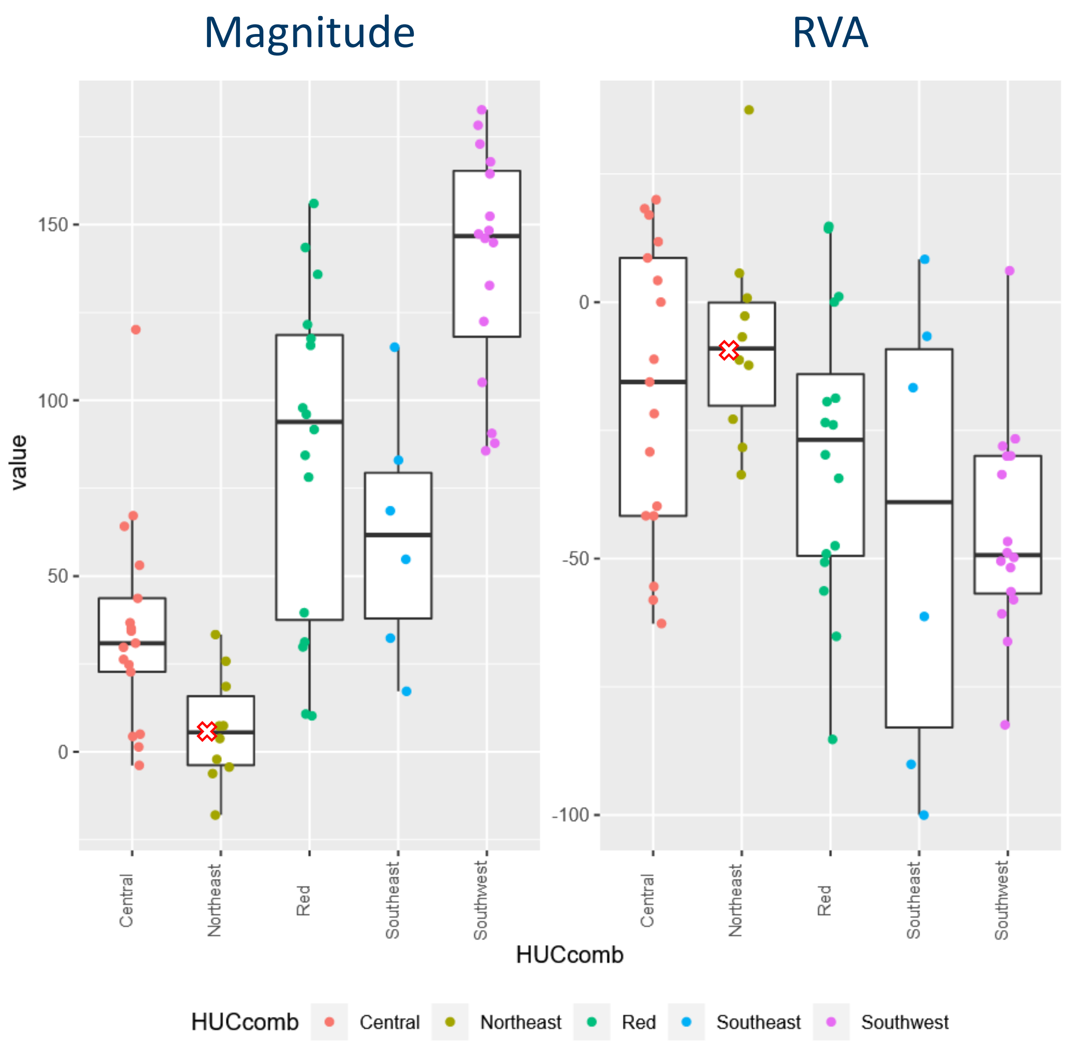
Negative =

Impact Categories (+/-) Neutral <10%, Moderate 11-20%, Major 21-50%, Extreme >50%

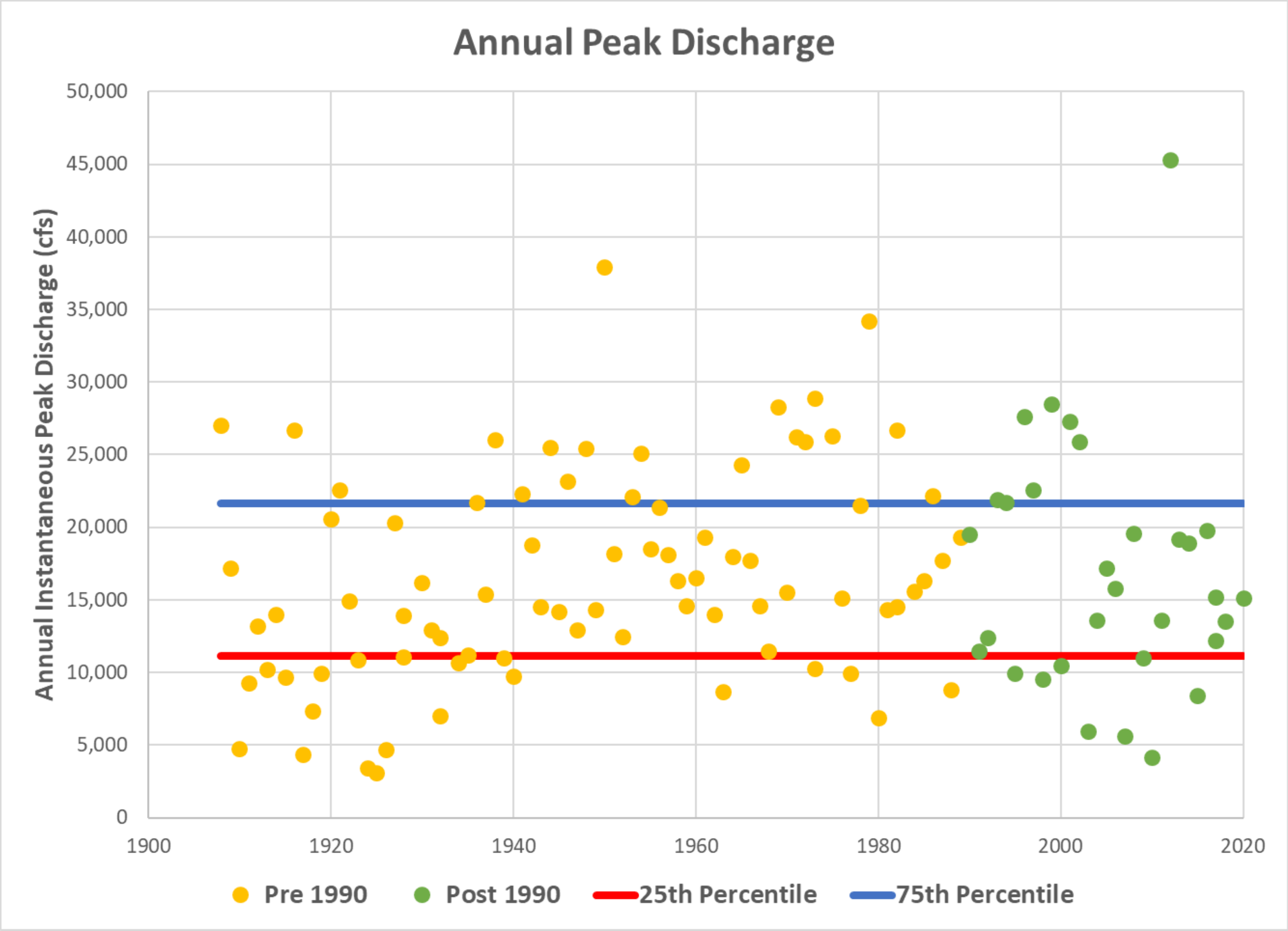
Annual Discharge



Annual Discharge

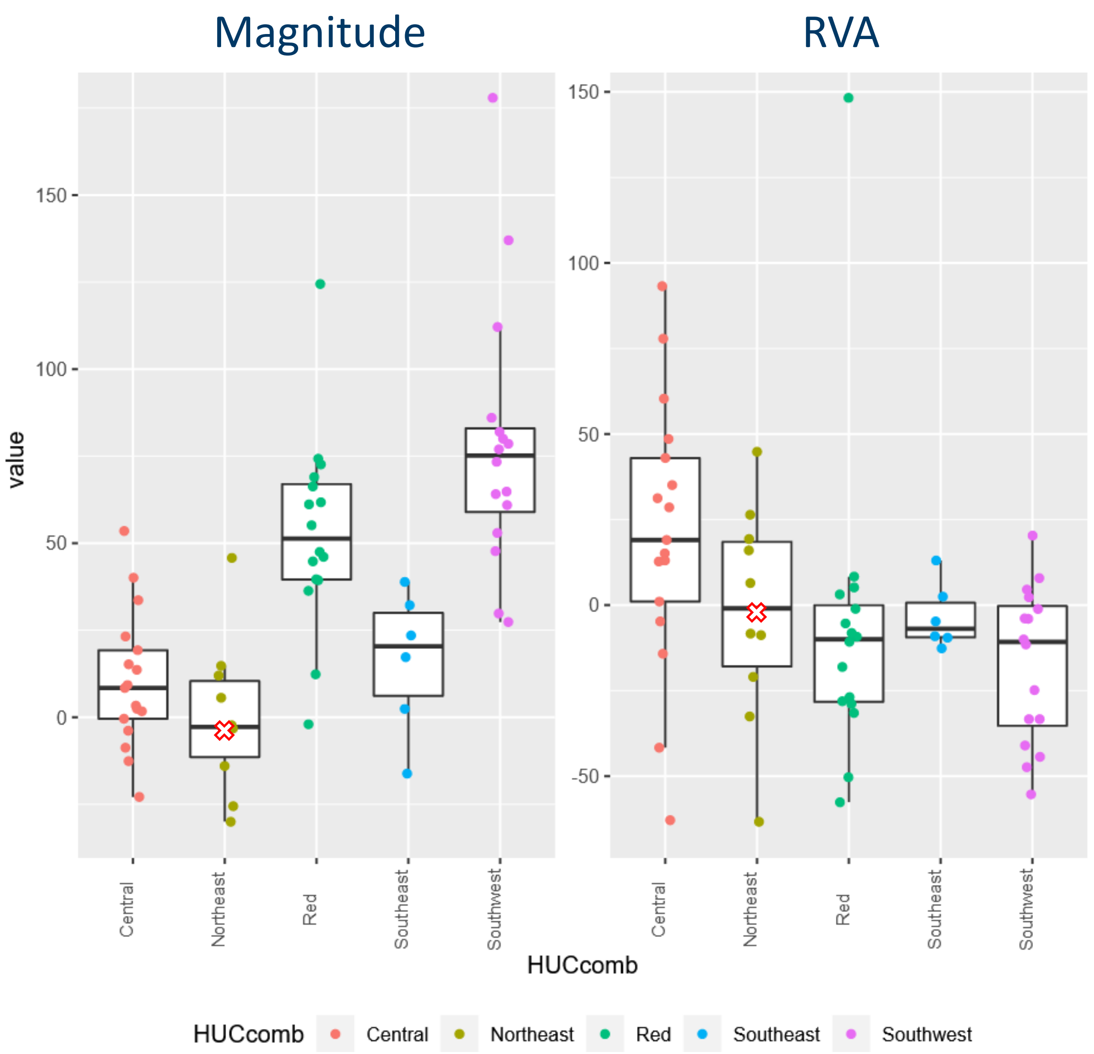


Peak Flows

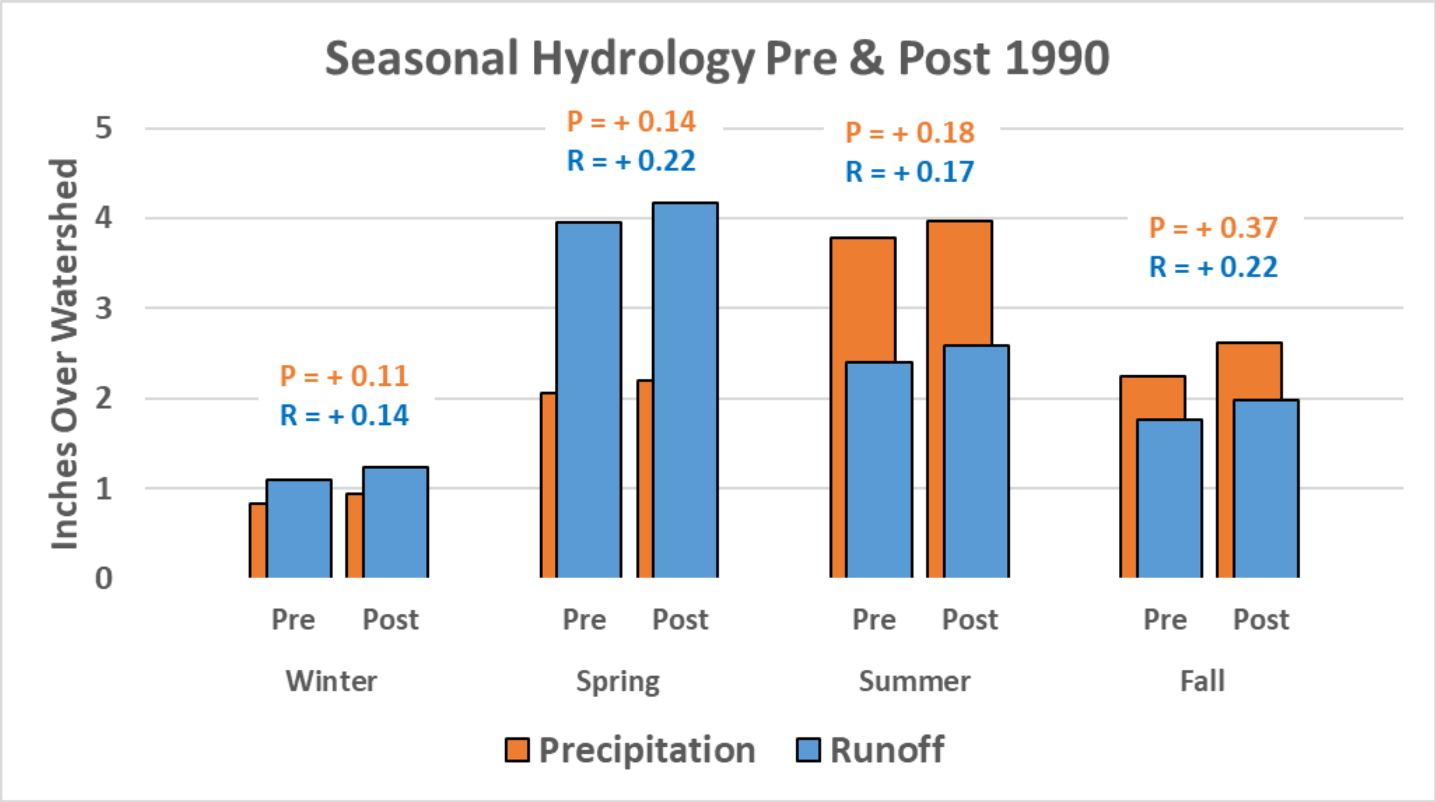


Annual Peak Discharge
Annual Instantaneous Peak Discharge (cfs)
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
1900
1920
1940
1960
1980
2000
2020
Pre 1990
Post 1990
25th Percentile
75th Percentile

Annual Peak Discharge



Seasonal Analysis



Discharge and Precipitation Averages – 1990 BP

	Discharge (in.)	Precip (in.)	D/P (%)
Pre 1990	9.27	26.75	0.35
Post 1990	10.02	29.17	0.34
Change	0.75	2.42	-0.003

Storage Considerations

1. Watershed hydrology has been considerably stable over the last 80 years
2. Whole system analysis likely not showing localized impacts
3. Metrics may indicate a shift in wetland function with altered base/low flows
4. Building resiliency through forest management and maintaining/restoring wetland function

DEPARTMENT OF NATURAL RESOURCES

THANK YOU!

Jason Carlson

Jason.Carlson@state.mn.us