Middleton's Stormwater Management Program 1975-2020 and effects of Climate Change and Urbanization

PURPOSE

- **Purpose of presentation is to show effectiveness of Middleton's stormwater management program over the period 1975-2020.**

- **Study shows how streamflow and water quality were affected by climate change and urbanization.**

- **Analysis provides areas where City should focus efforts to reduce flood peaks and decrease sediment and phosphorus loads.**

Middleton Stormwater Management Plan

-Middleton Water Resource Management Commission (MWRC)was formed in 1974.

-Purpose was to protect and enhance the water resources of Middleton.

-In 1979 a Stormwater Ordinance was developed to prevent flood peaks from increasing due to urbanization.

-The ordinance was modified in subsequent years to reduce sediment and phosphorus loads into Lake Mendota and to protect groundwater recharge.

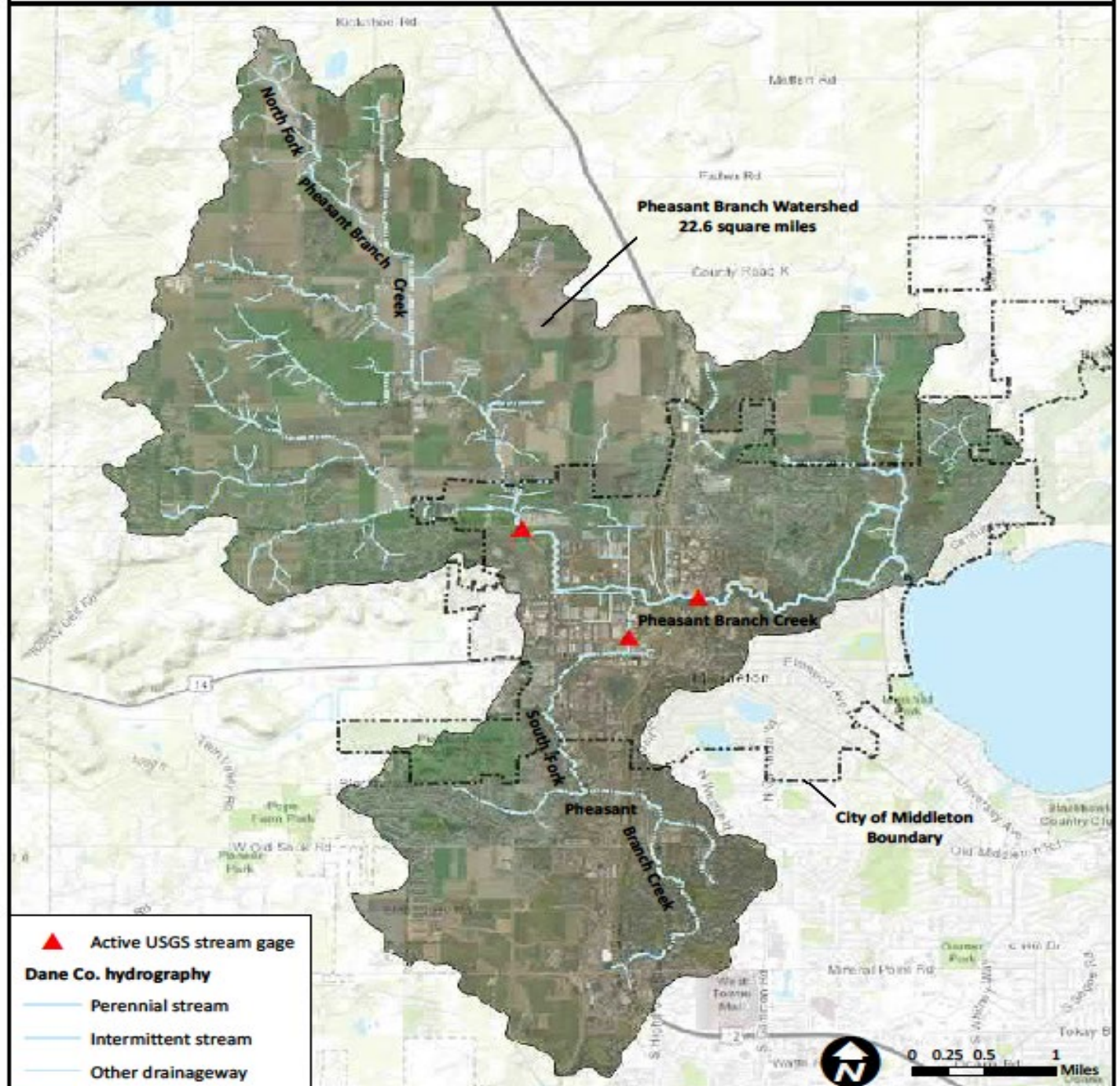
Middleton Stormwater Management Plan (cont'd)

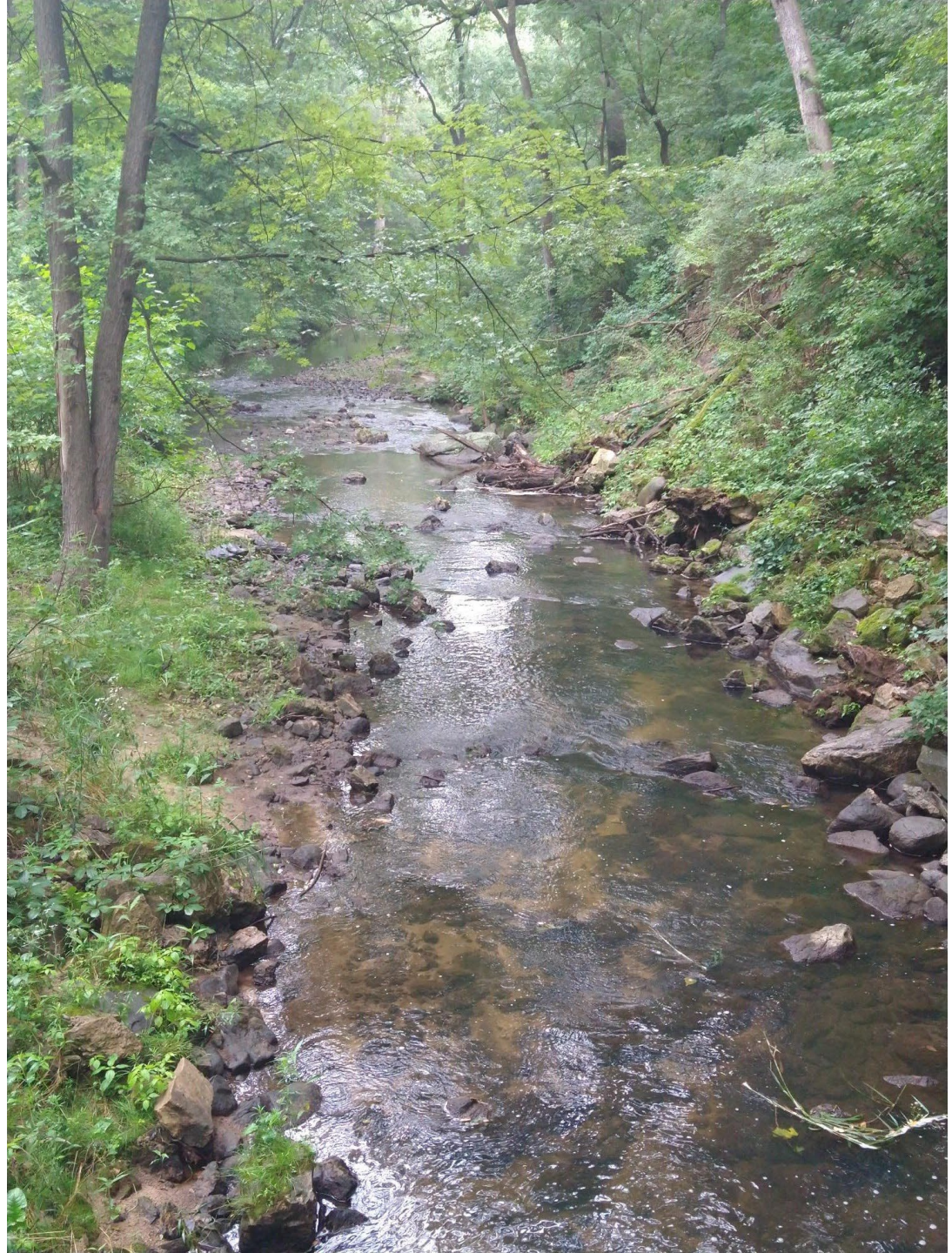
- To provide streamflow information for decision making a streamflow monitoring program was established with the U.S. Geological Survey in 1975.

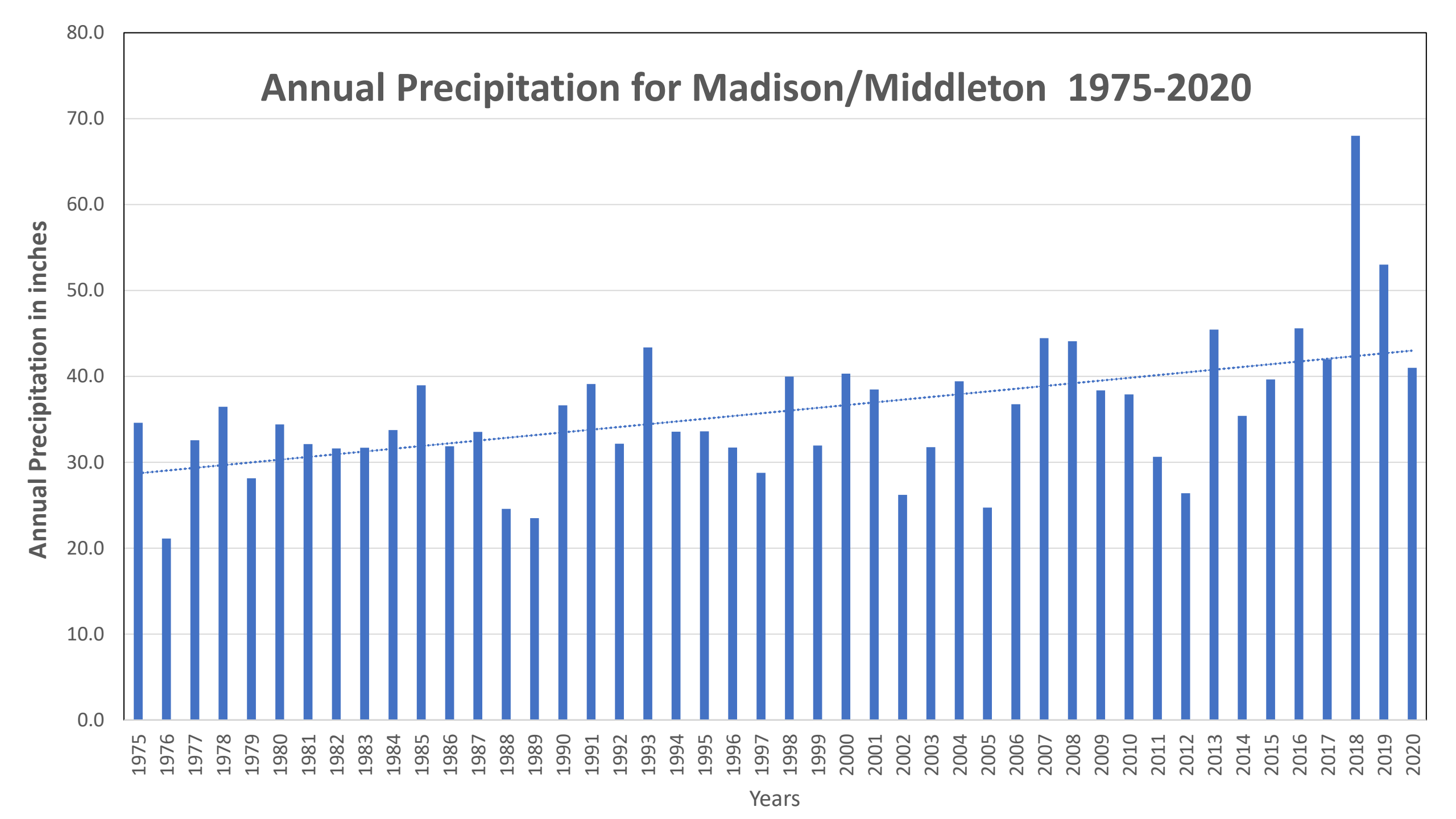
- On the mainstem, streamflow and sediment data has been collected since 1975 and phosphorus data since 1993.

- The South Fork and North Fork have gaging stations for the periods 1978-1981 and 2012-2020 with streamflow, sediment and phosphorus data collected.

Figure 1 - Pheasant Branch Creek Watershed






Annual Precipitation for Madison/Middleton 1975-2020
Annual Precipitation in inches
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
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
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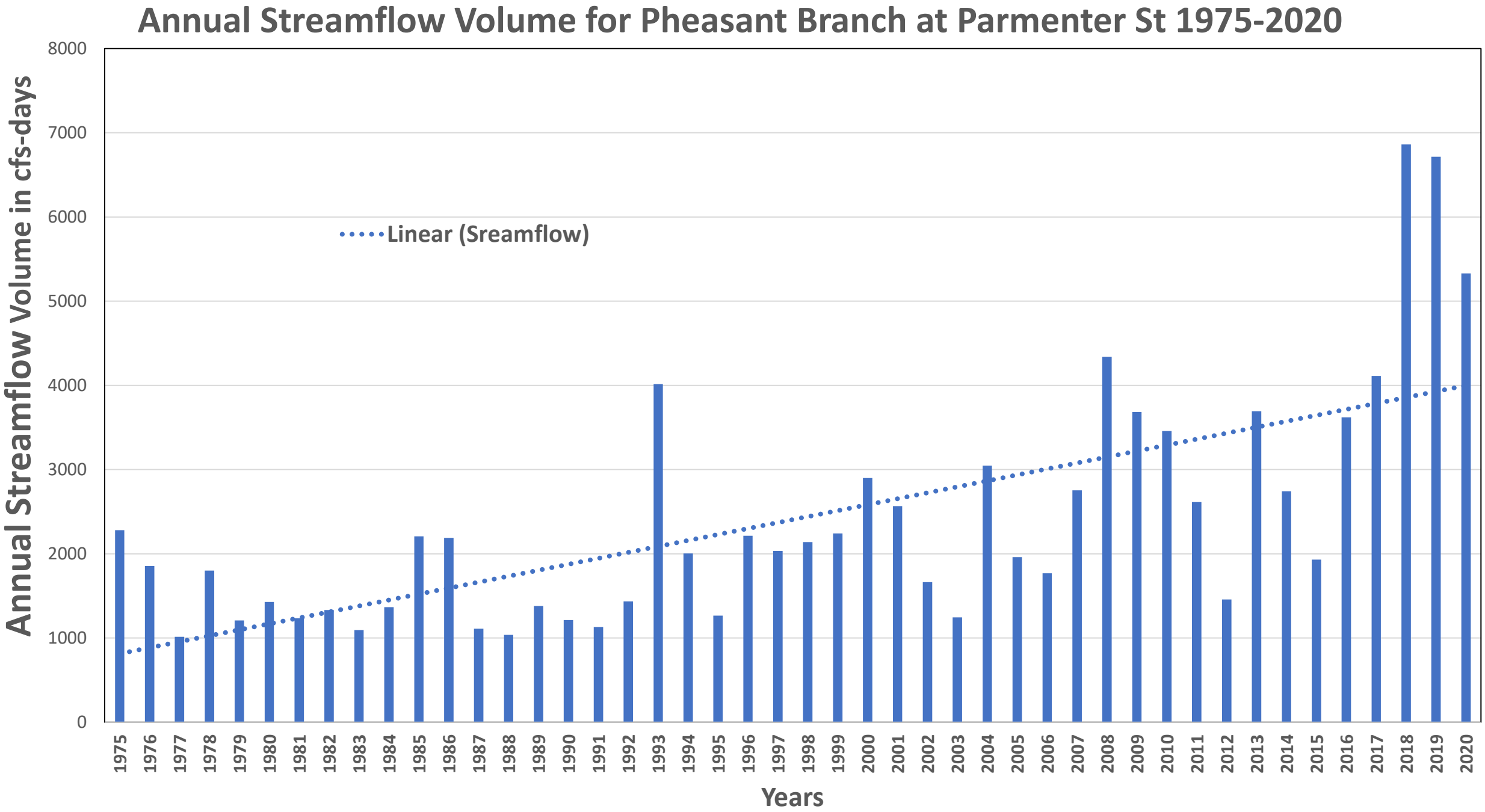
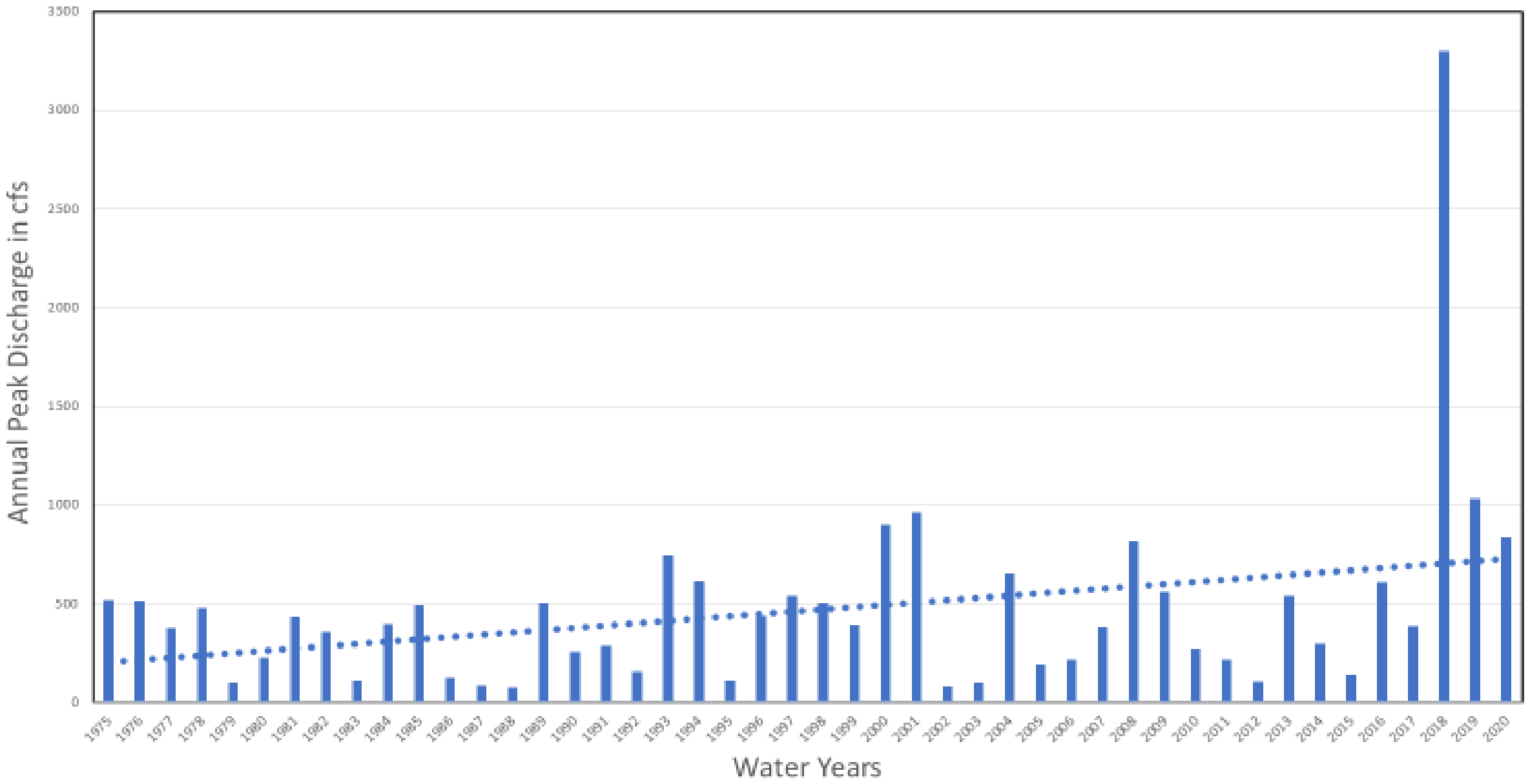
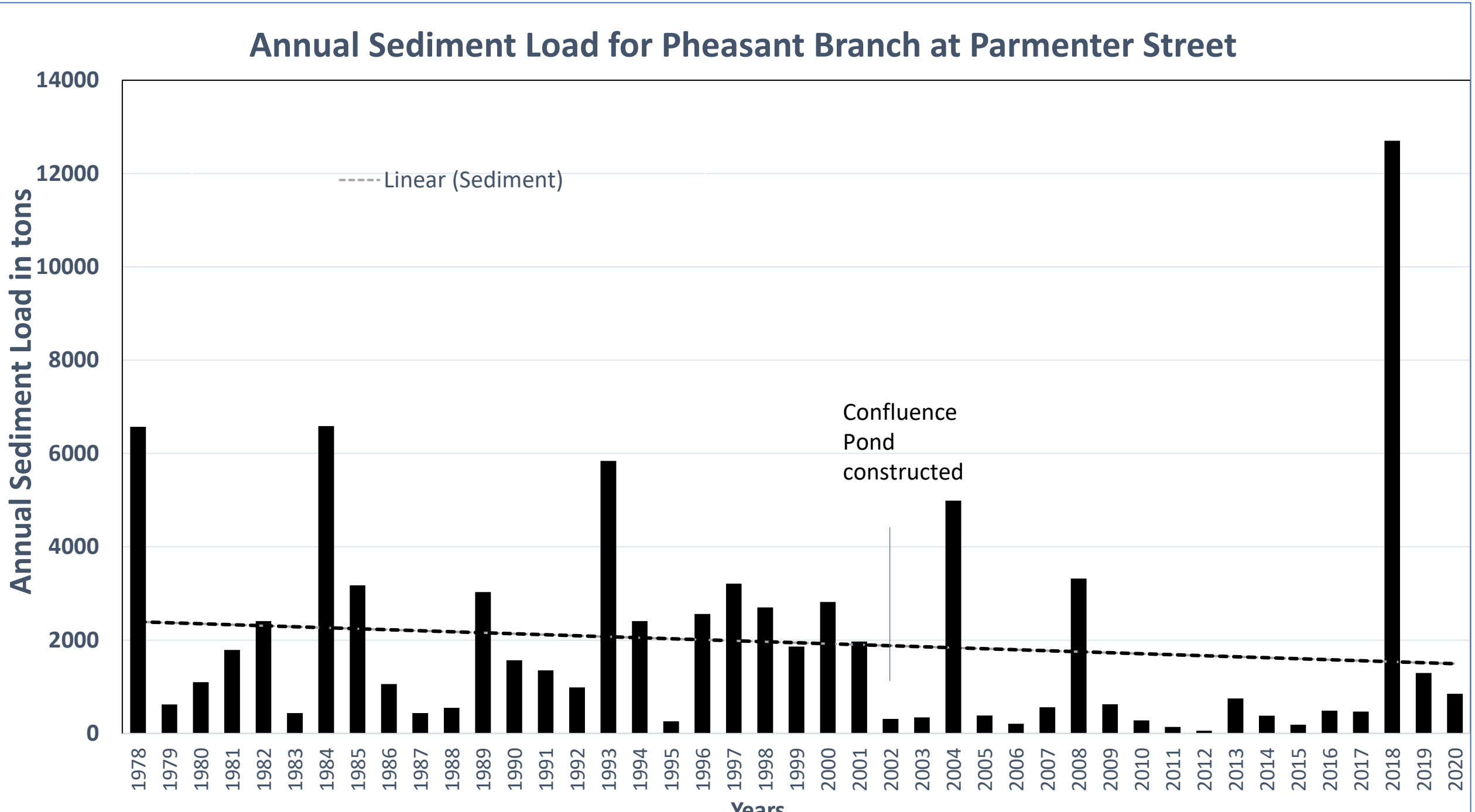
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Years

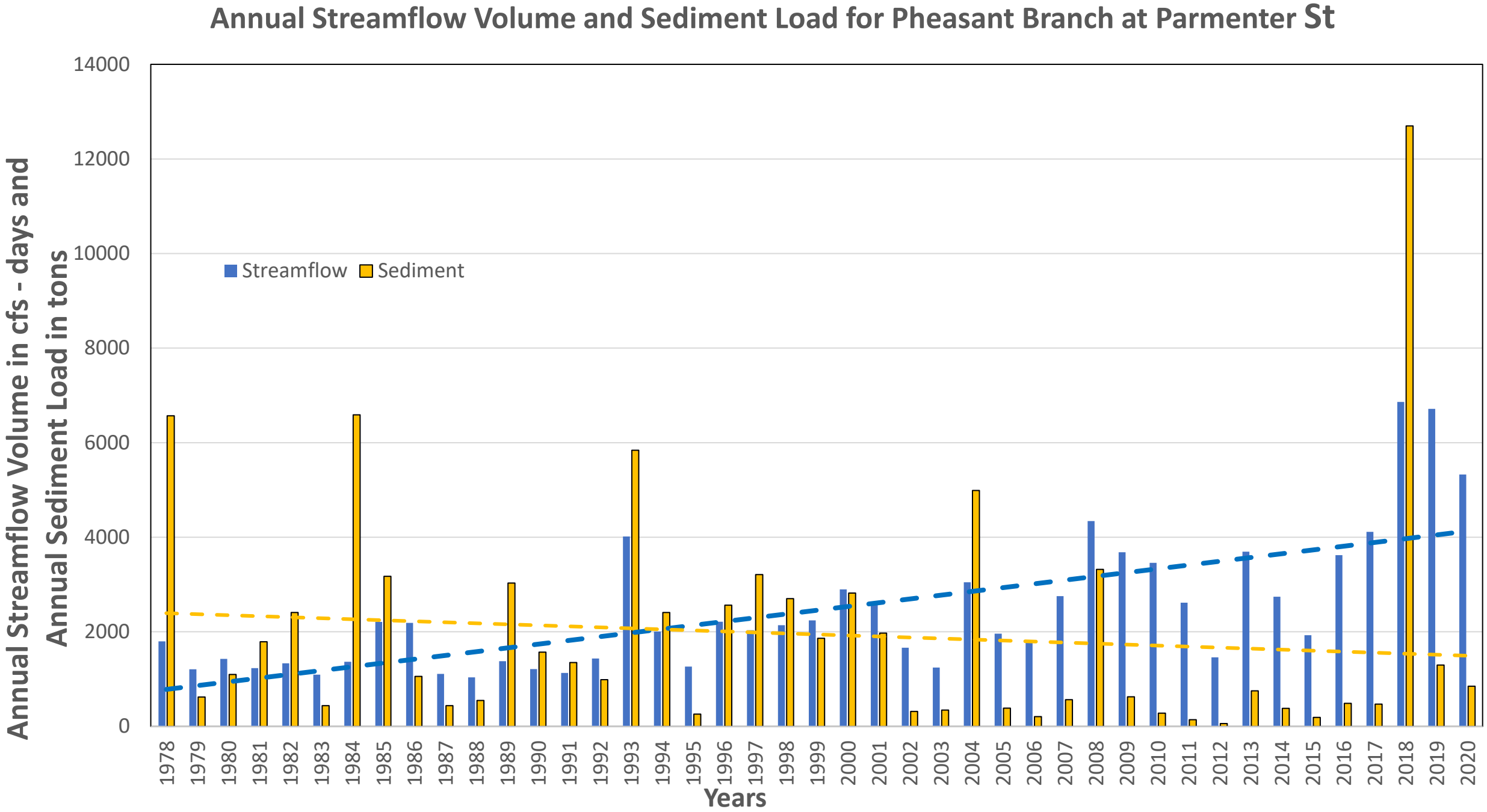

Annual Streamflow Volume for Pheasant Branch at Parmenter St 1975-2020
Annual Streamflow Volume in cfs-days
8000
7000
6000
5000
4000
3000
2000
1000
0
Linear (Sreamflow)
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Years

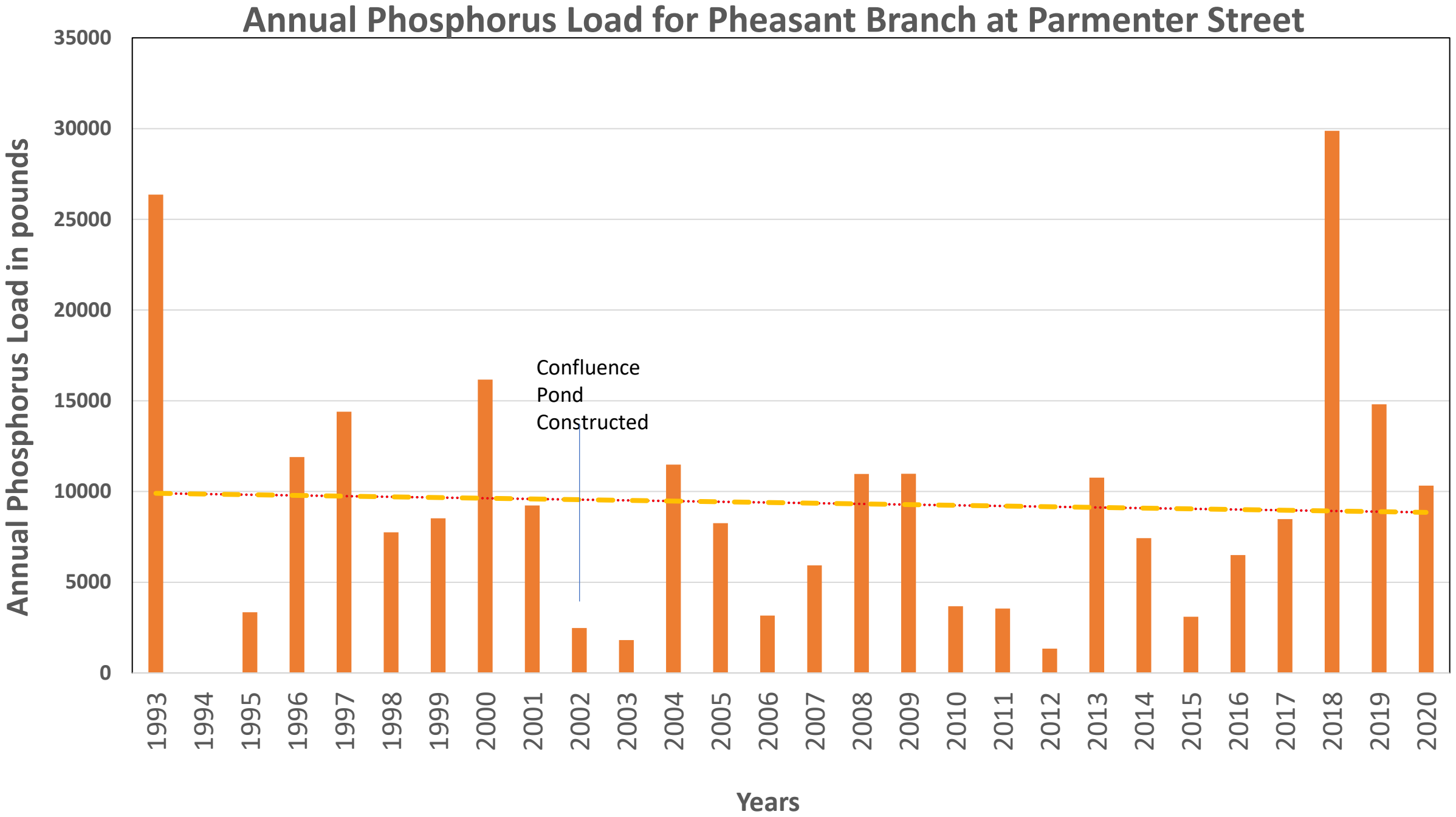

Annual Peak Discharge for Pheasant Branch at Parmenter St for the period 1975-2020
Annual Peak Discharge in cfs
3500
3000
2500
2000
1500
1000
500
0
1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Water Years

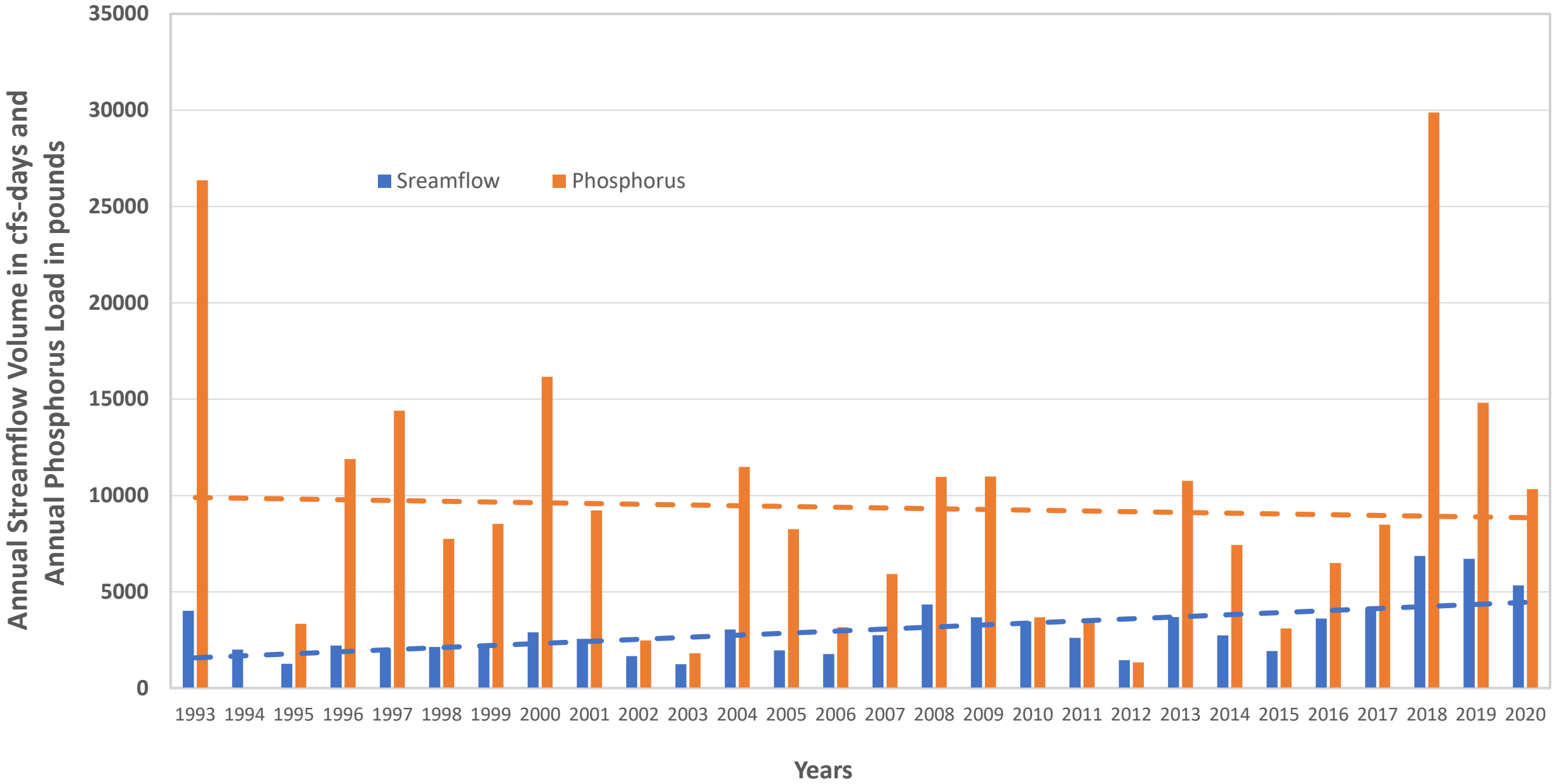
COMPARISON OF PRECIPITATION WITH STREAMFLOW CHARACTERISTICS FROM 1975-1989 TO 2004-2020

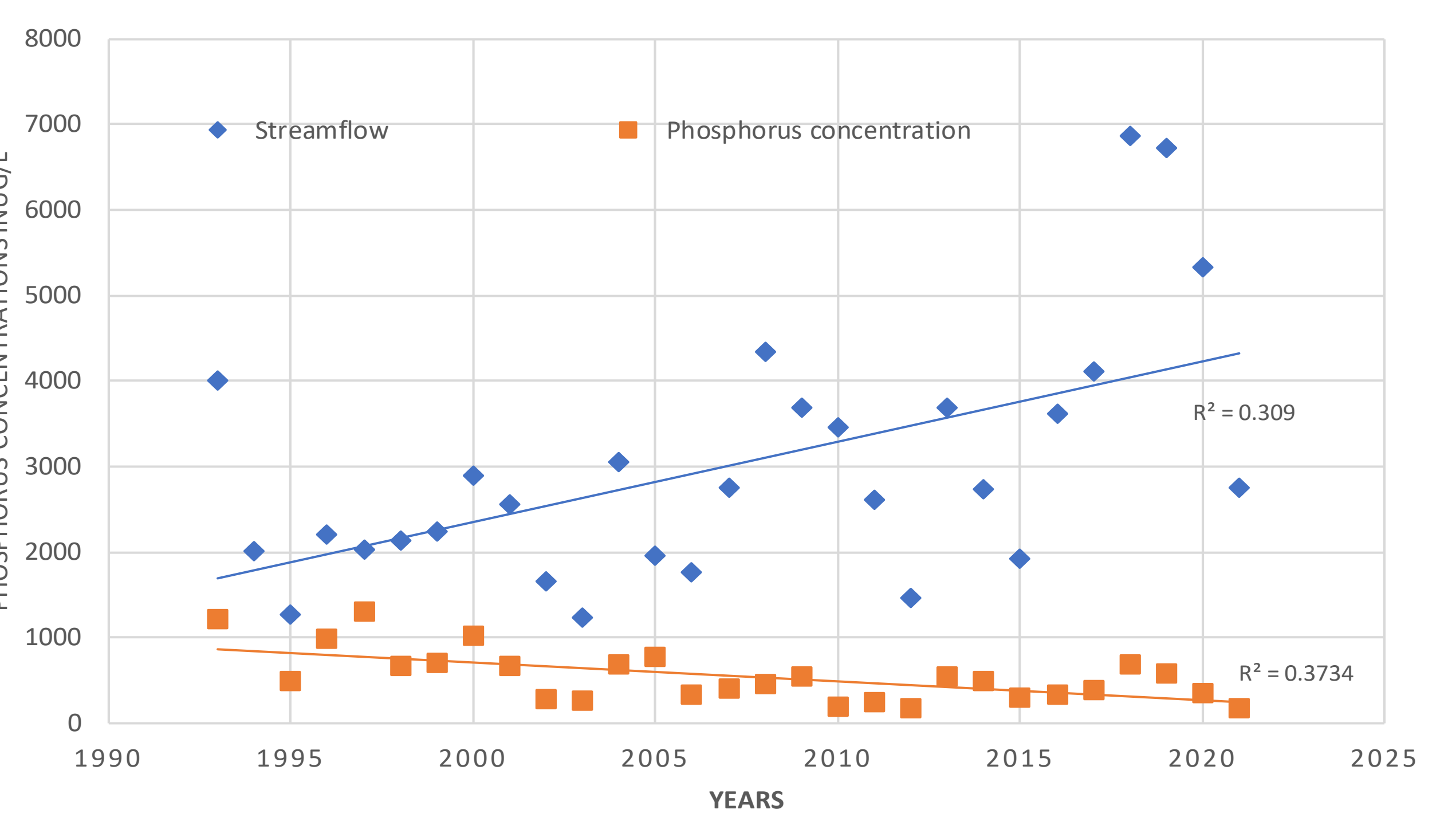
Period	Average Annual Precipitation inches	Average Annual Streamflow cfs-days	Average Annual Flood Peaks cfs
1975-1989	31.3	1500	319
1990-2004	35.1	2070	449
2005-2020	40.8	3560	626
Increase			
1974-89 to 2005-2020	30.3%	137%	96%


Annual Sediment Load for Pheasant Branch at Parmenter Street
Annual Sediment Load in tons
14000
12000
10000
8000
6000
4000
2000
0
Linear (Sediment)
Confluence Pond constructed
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
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Years


Annual Streamflow Volume and Sediment Load for Pheasant Branch at Parmenter St
Annual Streamflow Volume in cfs - days and Annual Sediment Load in tons
14000
12000
10000
8000
6000
4000
2000
0
Streamflow
Sediment
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
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Years

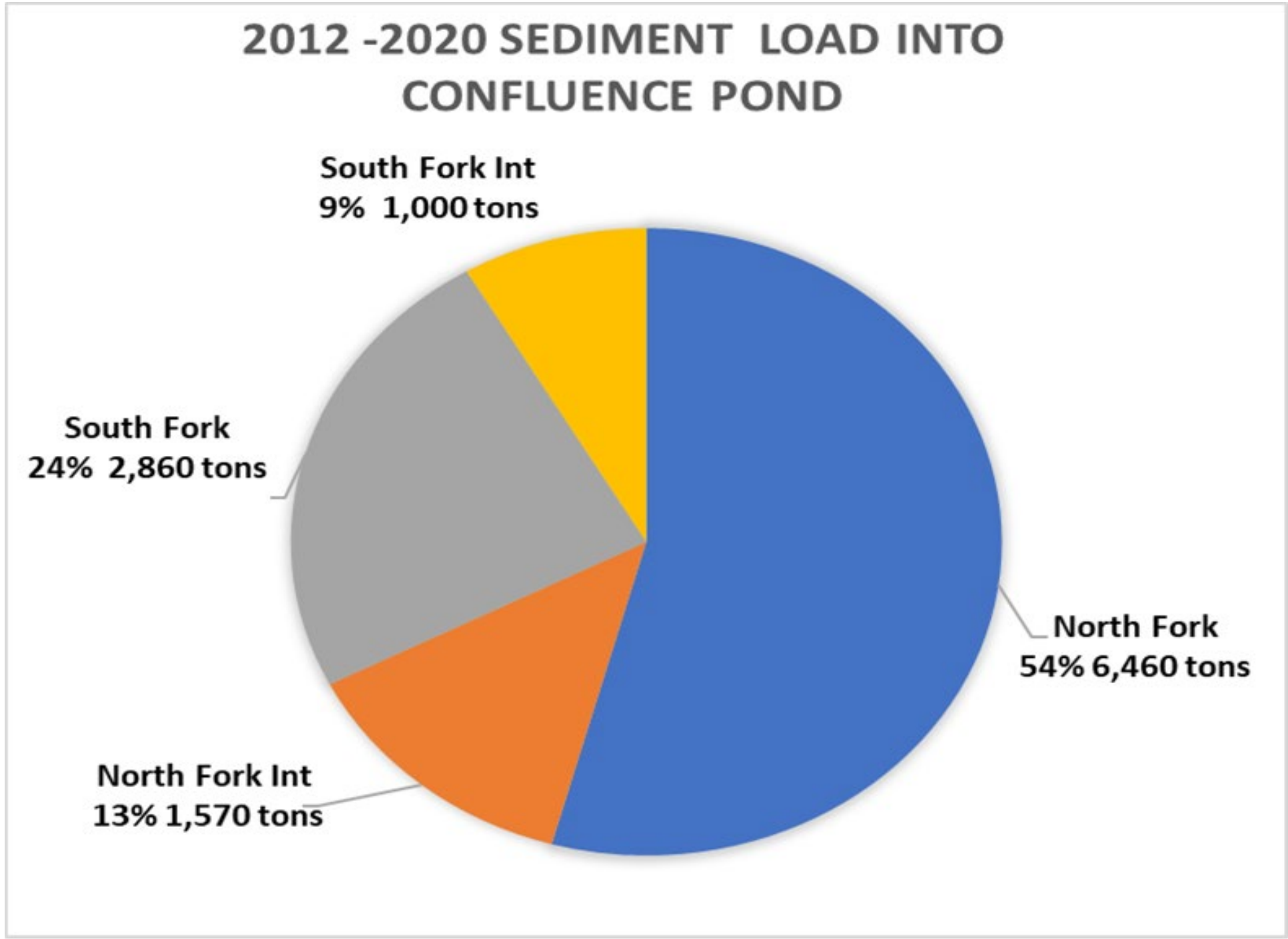

Annual Phosphorus Load for Pheasant Branch at Parmenter Street
Annual Phosphorus Load in pounds
35000
30000
25000
20000
15000
10000
5000
0
Confluence
Pond
Constructed
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Years


Annual Phosphorus Load and Streamflow Volume for Pheasant Branch at Parmenter St
Annual Streamflow Volume in cfs-days and Annual Phosphorus Load in pounds
35000
30000
25000
20000
15000
10000
5000
0
Sreamflow
Phosphorus
1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Years

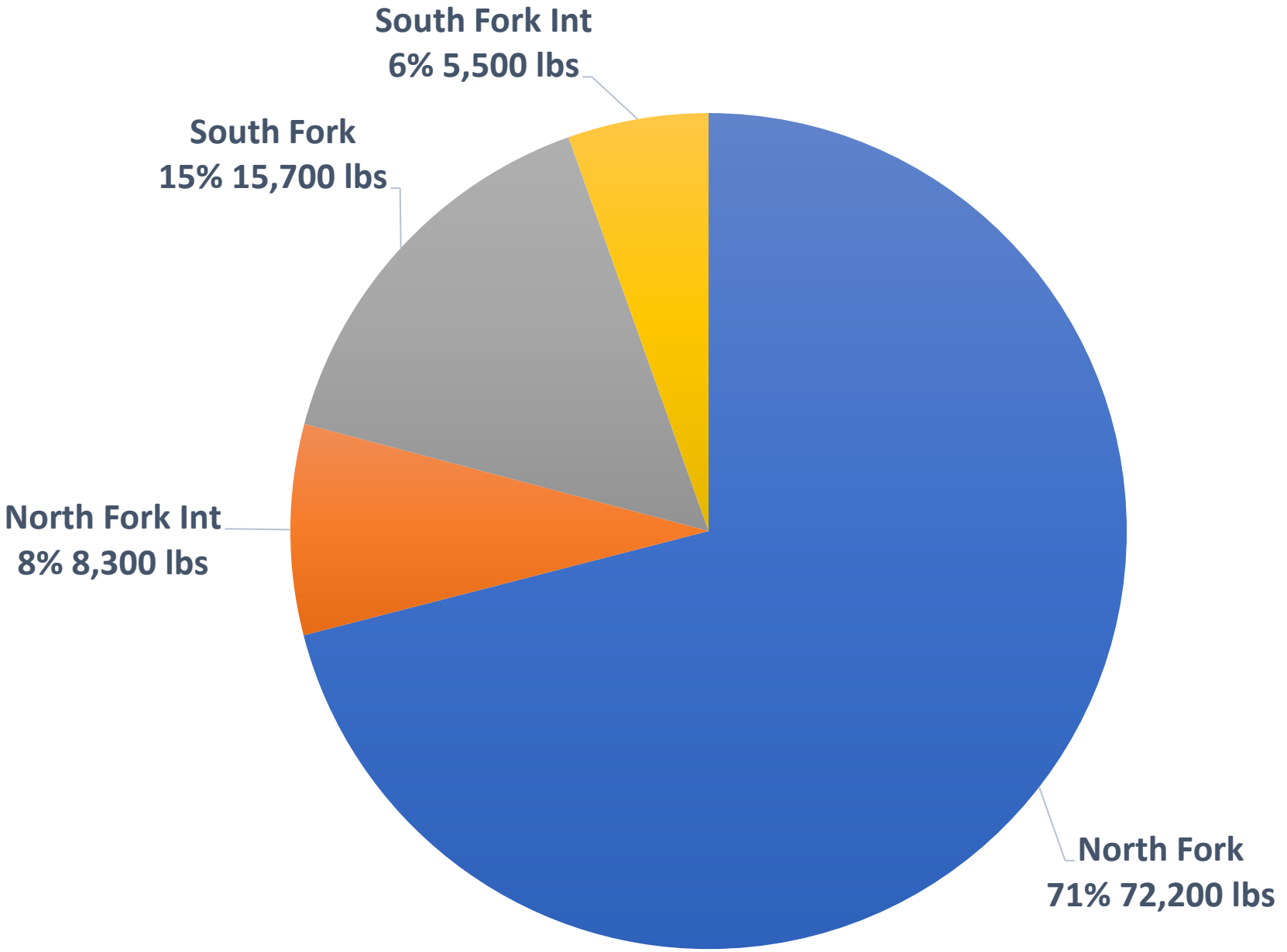

8000
7000
6000
5000
4000
3000
2000
1000
0
PHOSPHORUS CONCENTRATIONSUG/L
Streamflow
Phosphorus concentration
R² = 0.309
R² = 0.3734
1990
1995
2000
2005
2010
2015
2020
2025
YEARS

ESTIMATED SEDIMENT AND PHOSPHORUS LOADS TRAPPED IN CONFLUENCE POND 2012-2020

Year	Sediment Loads Inflow tons/yr	Outflow tons/yr	Trapped tons/yr	Percent Trapped	Phosphorus Loads Inflow lb./yr	Outflow lbs/yr	Trapped lbs/yr	Percent Trapped
2012	99	37.6	61.3	62.0	2040	1096	946	46.3
2013	979	640	340	34.7	11723	10008	1715	14.6
2014	840	303	537	63.9	7799	6950	848	10.9
2015	734	157	577	78.6	5042	2814	2228	44.2
2016	1688	179	1509	89.4	8926	5682	3244	36.3
2017	660	381	279	42.3	10562	7735	2827	26.8
2018	1423	508	915	64.3	16350	12127	4224	25.8
2019	3406	1046	2360	69.3	25146	19622	5599	22.2
2020	2063	687	1376	66.7	14602	9572	5030	34.4
Average 2012-2020	**1474**	**488**	**987**	**63.6%**	**11354**	**8401**	**2962**	**29.1%**


2012 -2020 SEDIMENT LOAD INTO CONFLUENCE POND
South Fork Int
9% 1,000 tons
South Fork
24% 2,860 tons
North Fork Int
13% 1,570 tons
North Fork
54% 6,460 tons

2012-2020 PHOSPHORUS LOAD INTO CONFLUENCE POND

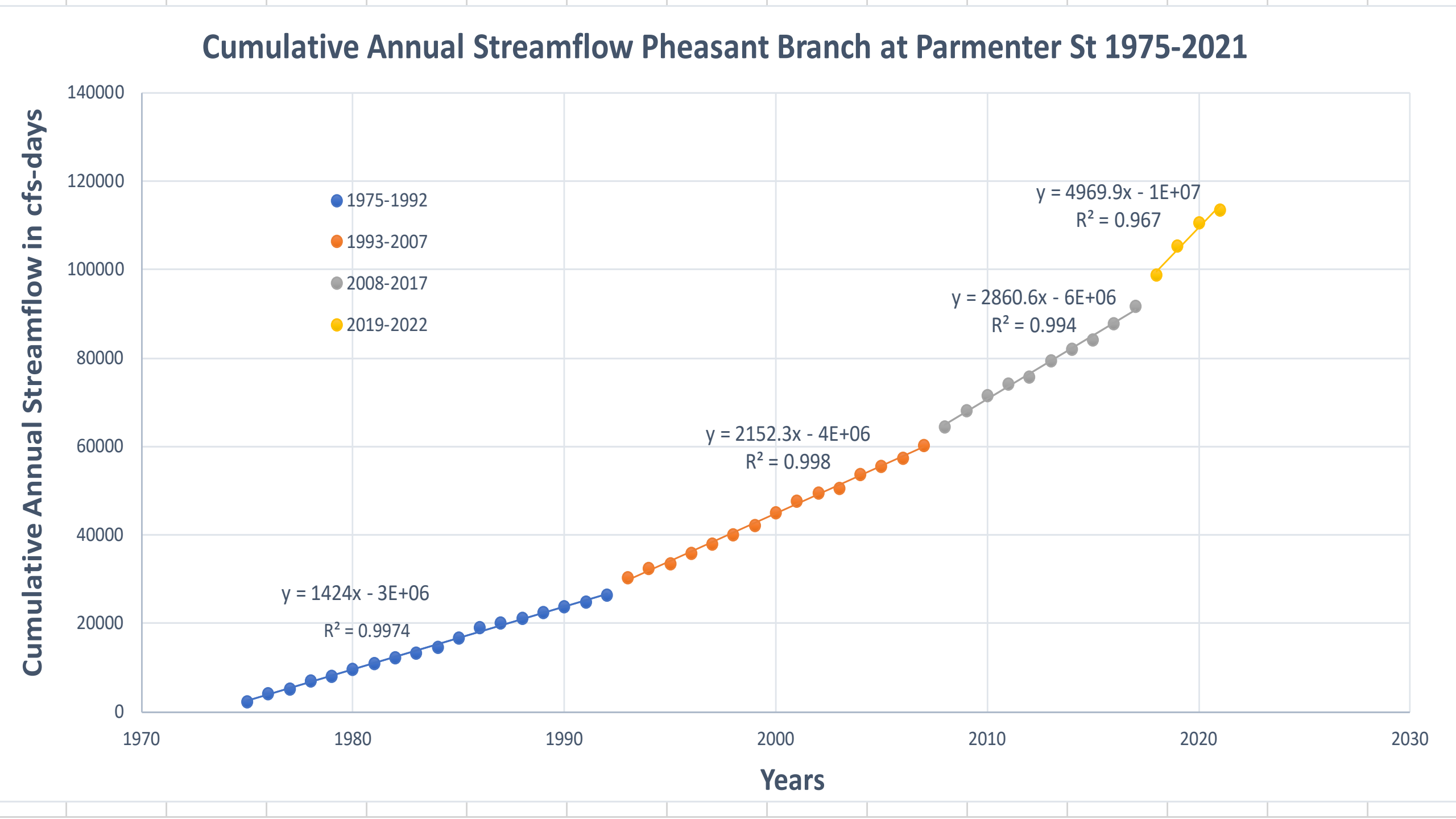


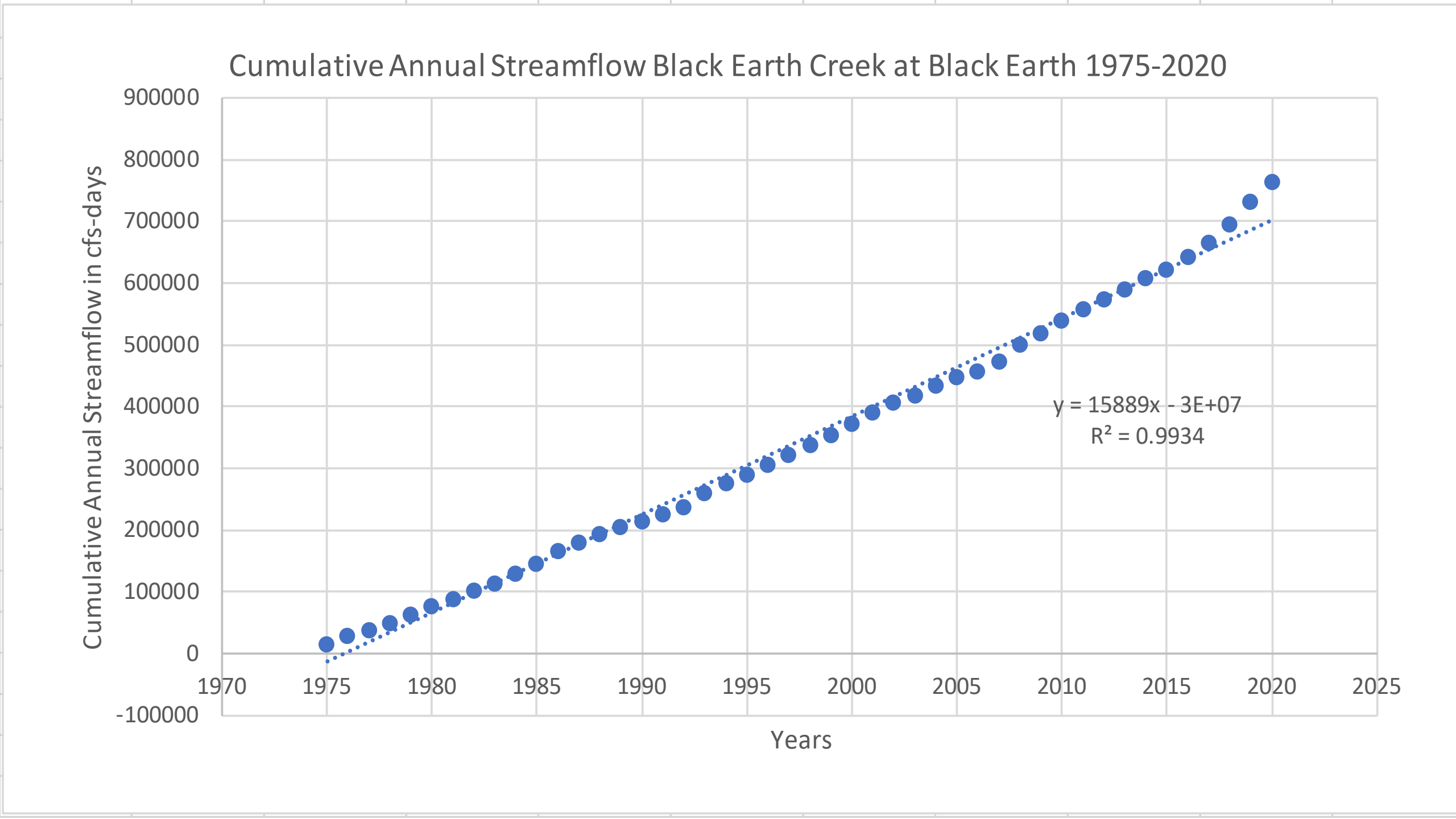
Changes in Precipitation and Annual Streamflow at Three Gaging Stations

Period	Average Annual Precipitation	Average Annual Streamflow		
		North Fork Pheasant Branch (rural)	South Fork Pheasant Branch (urban)	Pheasant Br downstream Confluence Pond
	inches	cfs/mi^2	cfs/mi^2	cfs/mi^2
1978-1981	32.8	24.4	19.5	17
2013-2020	44.1	64.5	143.0	49.5
Increase %	34.4%	164%	633%	191%

Changes in Precipitation and Flood Peaks at Three Gaging Stations

	Average Annual Precipitation	Average Annual Flood Peaks		
Period		North Fork Pheasant Branch (rural)	South Fork Pheasant Branch (urban)	Pheasant Br downstream Confluence Pond
	inches	cfs/mi^2	cfs/mi^2	cfs/mi^2
1978-1981	32.8	69	31	83
2013-2020	44.1	156	196	237
Increase %	34.4%	126%	532%	186%

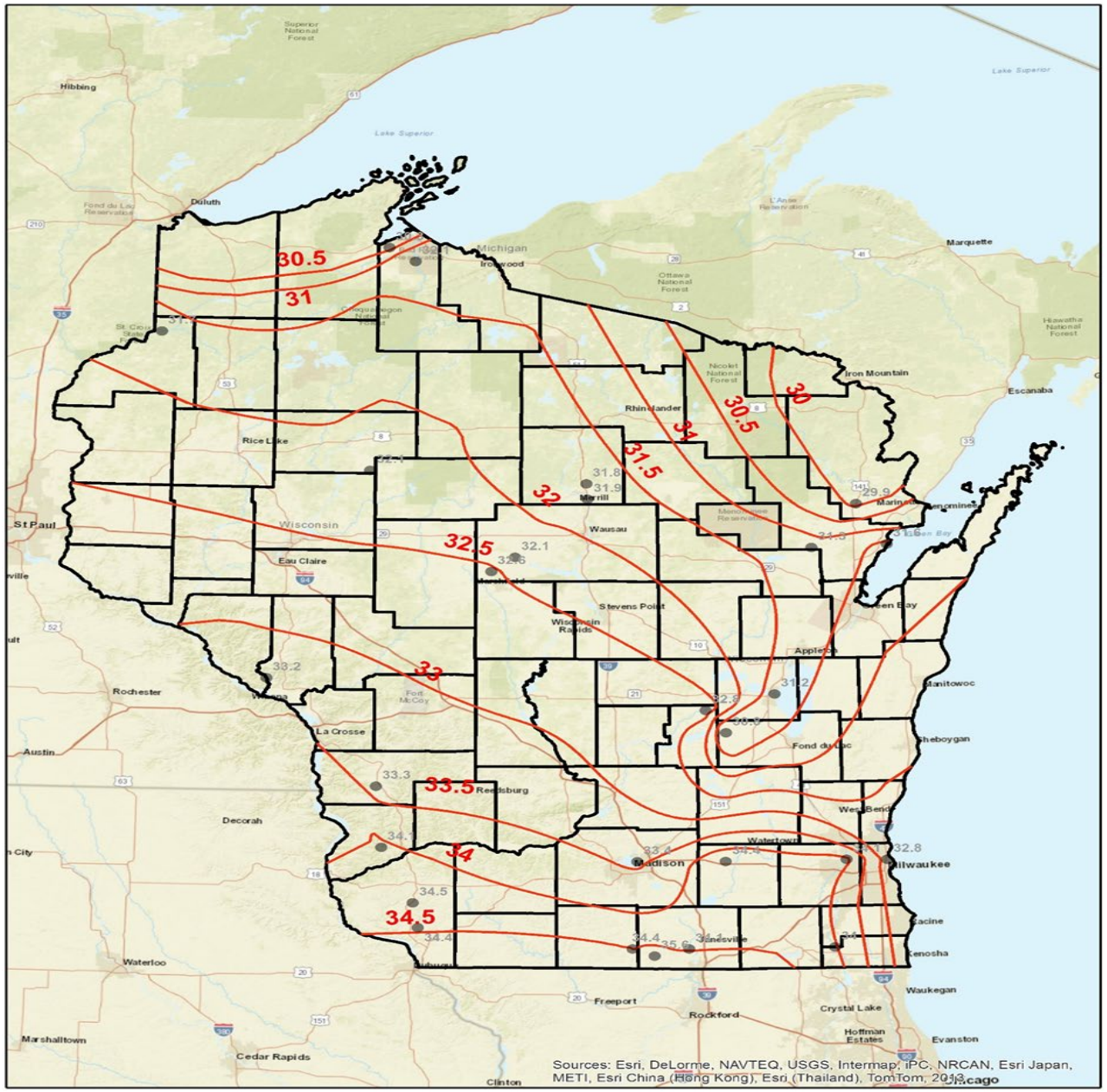

Cumulative Annual Streamflow Pheasant Branch at Parmenter St 1975-2021
Cumulative Annual Streamflow in cfs-days
140000
120000
100000
80000
60000
40000
20000
0
1970
1980
1990
2000
2010
2020
2030
Years
1975-1992
1993-2007
2008-2017
2019-2022
y = 1424x - 3E+06
R² = 0.9974
y = 2152.3x - 4E+06
R² = 0.998
y = 2860.6x - 6E+06
R² = 0.994
y = 4969.9x - 1E+07
R² = 0.967


Cumulative Annual Streamflow Black Earth Creek at Black Earth 1975-2020
Cumulative Annual Streamflow in cfs-days
900000
800000
700000
600000
500000
400000
300000
200000
100000
0
-100000
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
Years
y = 15889x - 3E+07
R² = 0.9934

Reasons for Increased Streamflow Volume

- **The increase in annual precipitation due to climate change**
- **Urbanization increased streamflow due to the increased impervious area prevented infiltration to groundwater. This is a bigger factor for flood peaks since groundwater infiltration generally goes back into the stream as baseflow.**
- **The increase in impervious area removes the loss of water to evapotranspiration. This hasn't received much attention and is not addressed in Middleton's Stormwater Ordinance.**

Average Annual Precipitation 1969-2008



Average Annual Runoff 1969-2008

Average Annual Water Budget for South Fork Pheasant Branch 1978-1982

	Runoff Values Prior to Urbanization	Est Runoff Values with Urbanization with Ordinace *
	inches	inches
Average Annual Precipitation in inches (P)	32.5	32.5
Groundwater Recharge in inches (GW)	8	8
Evapotranspiration in inches (ET)	23	13.8
Est Avg Annual Flow in inches (Q)		
Q=P-GW-ET	1.5	10.7
Recorded Avg Annual Flow	1.3	1.3
Increase in Avg Annual Flow		720%

	Average Annual Flow Volume		
Period	Average Annual Precipitation (inches)	North Fork Pheasant Branch (rural) (cfs-days/sq mi)	South Fork Pheasant Branch (urban) (cfs-days/sq mi)	Pheasant Branch at Parmenter Street (cfs-days/sq mi)
1978-1981	32.8	24.4	19.5	17
2013-2020	44.1	64.5	143	49.5
Increase %	34.4%	164%	633%	191%

Table 3. Comparison of average annual precipitation with average annual flow volume at three gaging stations for two periods.

Possible Changes to Storm Water Ordinance to Reduce Increased Runoff Volume due ET Loss

- **Require developer to provide solutions to reduce runoff volumes:**

-increase plants and trees in open spaces with high ET

-use green infrastructure to increase ET

-provide storage space around pond to accommodate increased runoff

-provide outlet structure to accommodate increased runoff

-require detailed rainfall runoff model that incorporates ET and GW to show how ET loss is compensated

Do nothing to the Ordinance and have city handle problems as they develops like Tiedeman and Stricker Ponds

SUMMARY

- Middleton's stormwater management program is effective in reducing sediment and phosphorus loads.
- Since 2002 the annual sediment load has decreased 56% and the annual phosphorus load decreased 48 %.
- The Confluence Pond has trapped 64 % of the sediment load, 16,000 tons and 29% of the phosphorus load 53,000 pounds.
- Climate change and urbanization have caused the annual flow to increase 136% and the annual flood peaks to increase 96%.
- A comparison on the urbanized South Fork to the rural North Fork showed annual flood peaks increase 632% for the South Fork compared to 182% for the North Fork.
- The North Fork contributes 15,700 lbs./yr. of phosphorus.
- The streamflow data collection program was critical for evaluating the effectiveness of the stormwater management program.

FUTURE CONSIDERATIONS

- To reduce flood peaks or minimize the increase due to climate change and urbanization more stringent controls will be required on the North Fork.
- To reduce flood peaks efforts should be made by Middleton with Madison to retrofit some of the existing development on the South Fork with flood retention features.
- To reduce phosphorus loads, future efforts should be concentrated on the North Fork since it has the largest load.
- If climate change continues Middleton should be prepared for continued repairs to Pheasant Branch.
- Add recommendation to Stormwater Ordinance to reduce flood volumes as a result of evapotranspiration loss.

THE END

http://digital.stormh20.com/november-2021

https://www.cityofmiddleton.us/278/Storm-Water-Study-Reports

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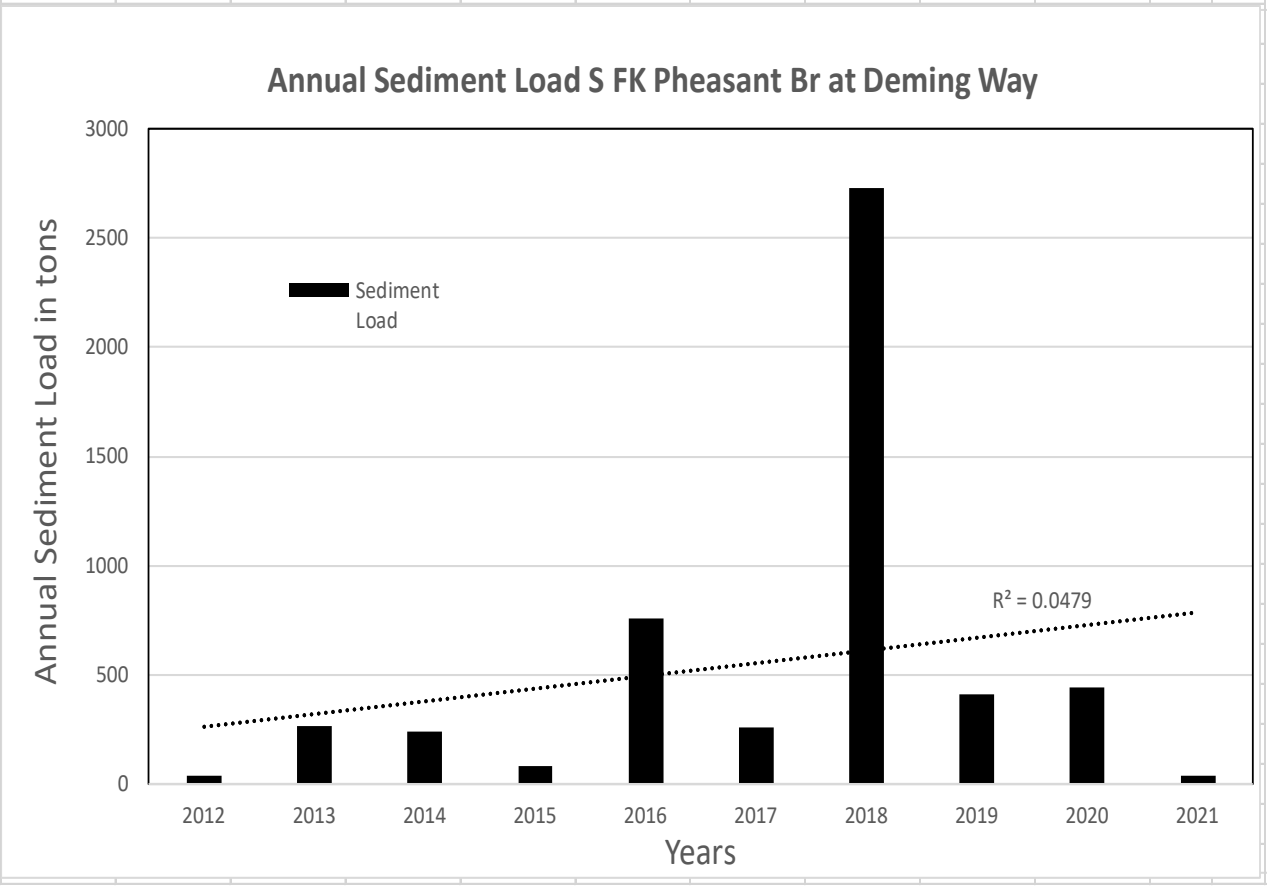
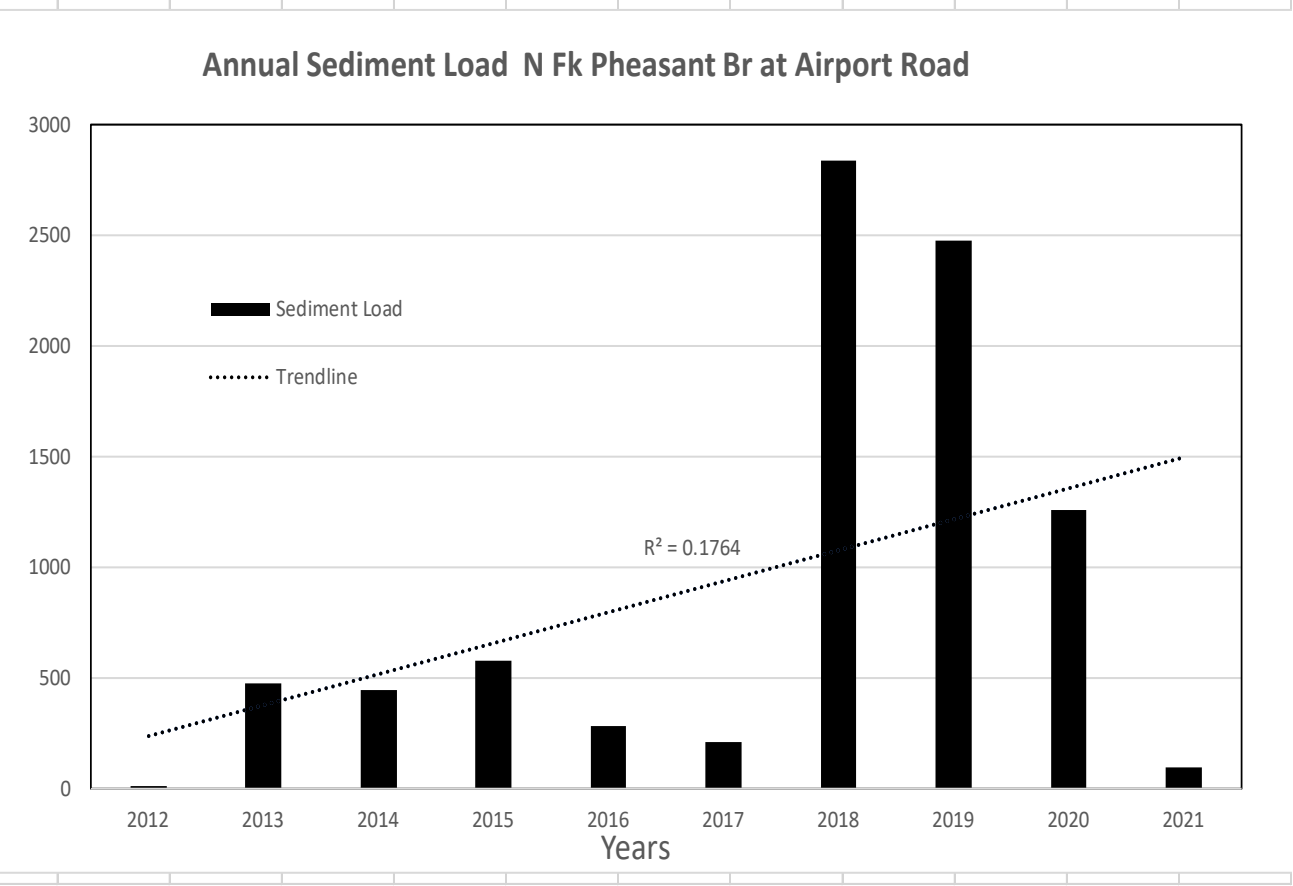
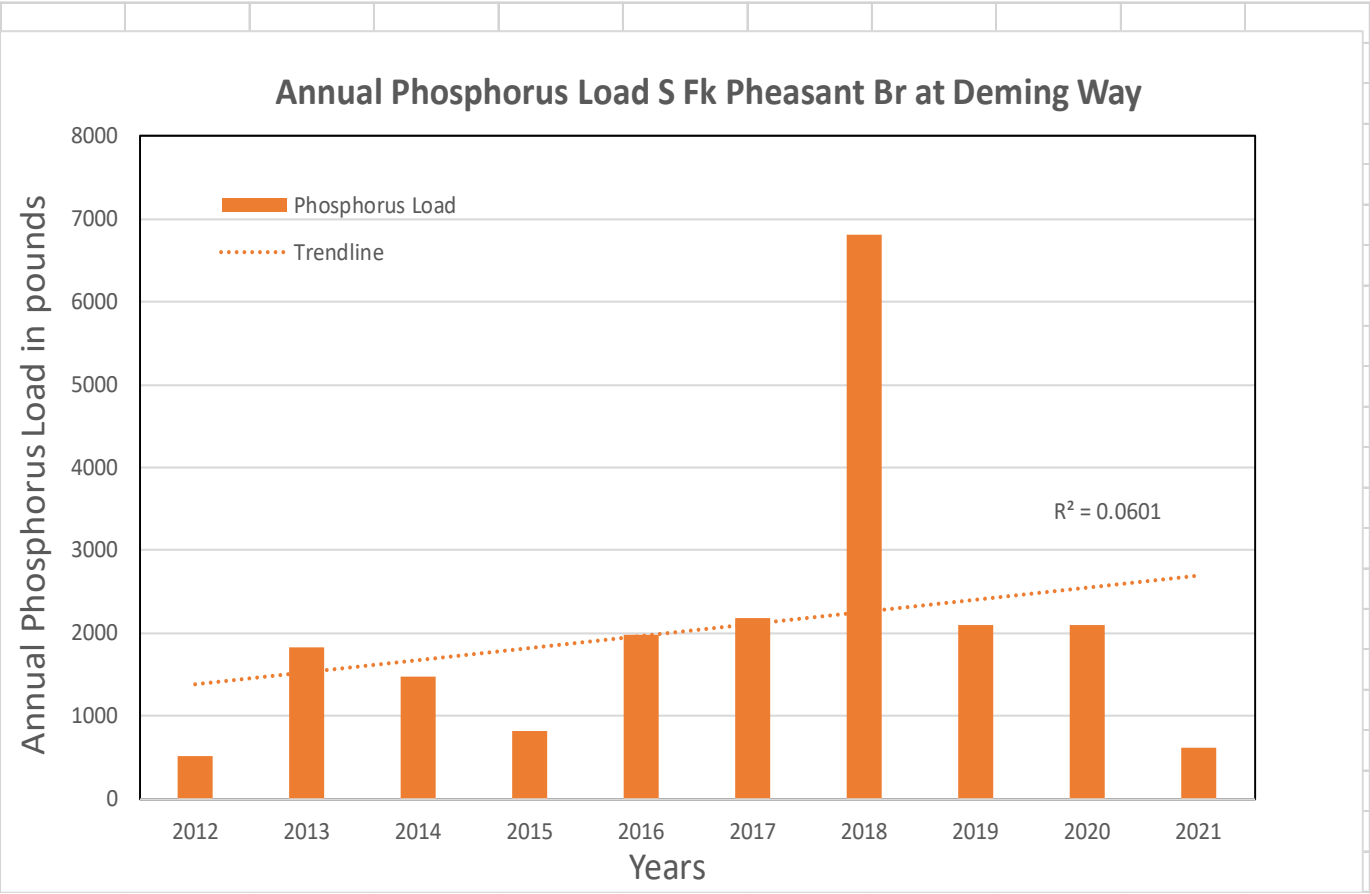
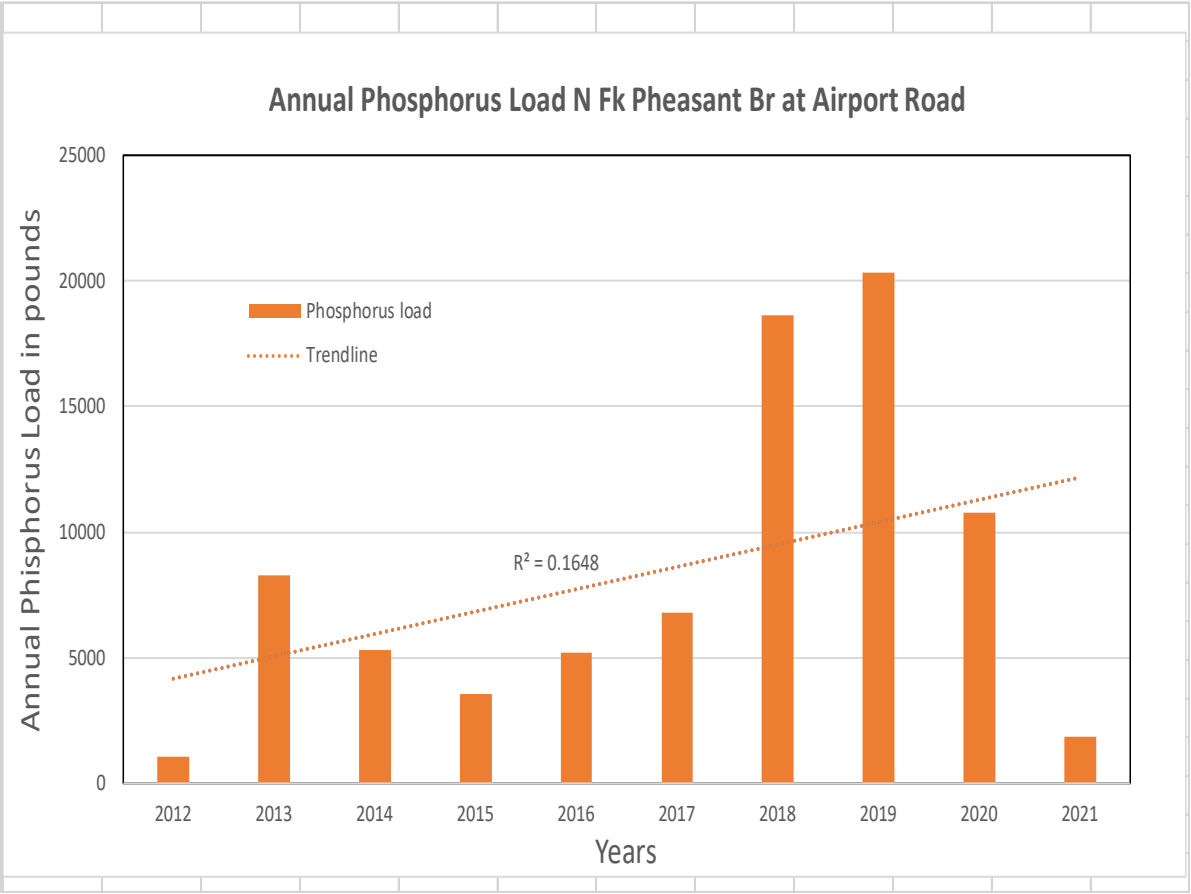

Annual Sediment Load S FK Pheasant Br at Deming Way
Annual Sediment Load in tons
3000
2500
2000
1500
1000
500
0
Sediment Load
R² = 0.0479
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
Years


Annual Sediment Load N Fk Pheasant Br at Airport Road
3000
2500
2000
1500
1000
500
0
Sediment Load
Trendline
R² = 0.1764
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
Years


Annual Phosphorus Load S Fk Pheasant Br at Deming Way
Annual Phosphorus Load in pounds
8000
7000
6000
5000
4000
3000
2000
1000
0
Phosphorus Load
Trendline
R² = 0.0601
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
Years


Annual Phosphorus Load N Fk Pheasant Br at Airport Road
Annual Phisphorus Load in pounds
25000
20000
15000
10000
5000
0
Phosphorus load
Trendline
R² = 0.1648
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
Years