Appendix A

Summary of Intensive Water Monitoring Station Data for 2003-2021 and Drainage Area Characteristics in the Lower Fox River Basin

for project report:

Water Quality Monitoring Coordination in the Lower Fox Basin

To:

Alliance for the Great Lakes

Performance Period: December 1, 2021 – June 30, 2022

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SUMMARY

- 14 L. Fox sub-basin intensive monitoring stations operated for 3+ years during 2004-21 period
    - Continuous flow, daily TSS (or SSC) and total phosphorus (TP) loads (Tables 2, 3; Fig 2, 3)
    - 81 total water years of daily loads; 60% of sub-basin area covered during this period
    - Inconsistent annual coverage: 48% (2004-2006) to low of 3% in 2010, to 21% in 2022
- Sites highly variable: mean annual yields (Tables 5-8), <u>need to capture *Spatial Variability*</u> (Fig 2-4)
    - Silver Creek: 0.06 t/ha TSS 0.54 kg/ha TP 0.36 kg/ha DP (66%)
    - Plum Creek: 1.64 t/ha TSS 2.98 kg/ha TP 0.82 kg/ha DP (27%)
    - Plum West: 0.74 t/ha TSS 2.23 kg/ha TP 1.10 kg/ha DP (50%)
- Highly variable annual precipitation and stream discharge during 2004-21 period (Table 4)
    - Annual Discharge: 75 mm in 2007 and 2009 to 545 mm in 2019
    - Site Max/Min Ratio of Yields at stations were typically:
        - Flow: 3.6 up to 4.6 Table 4
        - TSS: 7.8 up to 13.7 Table 5
        - TP: 4.3 up to 7.1 Table 6
        - DP: 3.9 up to 5.9 Table 7
    - Relative standard deviation of annual flow for individual stations was high (avg = 47%)
    - It's difficult to compare sites with different monitoring records → need for consistency
    - <u>Monitoring needs to capture this *Temporal Variability*</u>
- Annual stream flow varied considerably during 2004 to 2021 period, so how to "level the field"?
    - Analysis of flow-weighted concentrations greatly reduced annual variability relative to yields for a site (TP in Table 10, Fig 11):
        - Yields: Relative Std. deviation of TP (kg/ha) among years for all sites = 59%
        - Flow-weighted: Rel STD of TP (mg/L) between years for all sites = 21%
        - However, urban area and impervious surface contributions to yields and loads must be considered since runoff is higher than from Ag or natural areas. And urban proportions are increasing (i.e., likely diluting loads with more runoff).
- Sites highly variable: Flow-weighted Period mean concentrations (Table 8; Figs. 5, 11, 12)
    - Silver Creek: 22 mg/L TSS 0.20 mg/L TP 0.13 mg/L DP
    - Plum Creek: 547 mg/L TSS 0.99 mg/L TP 0.27 mg/L DP
    - Plum West: 286 mg/L TSS 0.86 mg/L TP 0.43 mg/L DP
- Analysis supports recommendation for consistency (e.g., keep Plum at D, and East at ZZ)
    - Need spatial coverage, wide variation in mean yields (TP: 0.54 to 2.98 kg/ha) and flow-weighted concentrations (TP: 0.20 to 0.99 mg/L; DP: 0.13 to 0.43 mg/L)
    - Silver Creek TSS yields very low. Why, what is the cause? But TP not as different
    - Station groups based on Flow-weighted period mean TP concentrations (Table 8), and confirmed with cluster analysis of TP, TSS and DP (where available):
        - Very high: Plum, Plum-West, Bower, Ash-Creamery
        - Moderately high: East ZZ, Apple, Baird, Ash-Grant
        - High: East River, Dutchman-Hansen, Duck at FF, Wequiock
        - Lower: Mahon, Silver
- GIS analysis: Drainage area Landcover (WISCLAND-2), minimum NDTI, slope, soil parameters (Table 12, Figures 7, 8, 9)

- Relationship to Flow, TSS, TP, and DP yields and flow-weighted concentrations
    - Most correlations low: e.g., overland slope, including Ag slopes (r^2 mostly < 0.1)
    - Highest r^2 with DP FWC: % Dairy (0.74) Wetland (0.53) Grassland (0.67)
    - Highest r^2 with TP FWC: % Dairy (0.63) Wetland (0.66) Grassland (0.58)
    - Highest r^2 with TP yields: % Dairy (0.38) Wetland (0.42) Grassland (0.41)
    - Correlations with % Dairy and % Ag are very similar; Dairy fraction of Ag not as good
- Cluster Analysis Dendograms created for L. Fox sub-basin using variables with highest r^2 relationships to TSS, TP and DP from Table 12 (dendograms of monitored drainage areas and remaining areas in Figure 10)
    - Two Methods typical: SAS Complete method, with Urban, Ag, Wetland, Grassland, and saturated soil conductivity variables, and SAS Average method with Ag and wetland
        - Results representative of other cluster methods/variable options that were valid
        - Four primary groups roughly correspond to yield and flow-concentration data of monitored areas: 1 highest, 4 lowest, and 2 and 3 somewhat similar
        - Results/method could help assess whether proposed spatial coverage is adequate
- WDNR Citizen Water Monitoring results vs Intensive stations (paired based on location, Fig 6)
    - Median TP (Citizen) vs Average annual <u>TP Yield</u>: $r^2 = 0.53$
    - Median TP (Citizen) vs Flow-weighted mean <u>TP concentration</u>: $r^2 = 0.60$
    - Good relationship, but Plum and Bower largely understated with Citizen median TP concentration relative to Intensive station yields and flow-weighted concentrations

NARRATIVE

This Appendix primarily focuses on water quality data from 14 stream monitoring stations in the Lower Fox sub-basin where continuous stream discharge, and daily loads of TSS (alternatively, Suspended Solids Concentrations, SSC) and total phosphorus (TP) were calculated by the USGS or UWGB at some time during the WY2004 to 2021 period (Figure 1). Edge-of-field monitoring locations are also shown in Figure 1, as well as WDNR citizen-based water monitoring stations. SSC was analyzed instead of TSS at Mahon and Wequiock UWGB stations, East River at CTH ZZ USGS station, and the Plum Creek USGS station after WY2021. In this document, the term TSS will also be used to represent SSC for purposes of simplicity, because the concentrations are nearly the same in local streams which have low proportions of suspended sand-size particles. Daily dissolved phosphorus (DP) loads were also calculated by the USGS for East River at ZZ, Ashwaubenon Creek at Grant, and Dutchman Creek at Hansen where extensive sample records of discrete dissolved phosphorus concentrations were available; whereas, the UWGB used regression analysis to estimate dissolved phosphorus loads at the remaining sites where DP samples were more limited. Each of the intensively monitored stations reported on here had at least three years of calculated daily discharge and loads, with a combined total of about 81 site-years of daily data. Approximately 60% of the Lower Fox sub-basin was monitored during the 2004 to 2021 period (excludes the area from overlapping nested watersheds; Table 1).

Except for Wequiock Creek, the USGS GCLAS software package was applied by UWGB (Mahon creek only) or the USGS (all other sites) at all intensive sites to calculate daily loads from continuous discharge and an extensive sampling record of discrete TSS and phosphorus concentrations (i.e., sample point to sample point integration, with virtual points added as needed). TSS and TP loads at Wequiock were calculated by the UWGB using continuous discharge, and continuous turbidity measurements which served as a surrogate for TSS and TP concentrations derived through regression analysis from discrete samples. The USGS/NEW Water, Dutchman Creek at Cyrus station (04085074) is not included in this analysis because it is not equipped with an automated sampler so daily GCLAS-derived loads are not available. Note that there are more sites with daily load data that go further back, including the USGS Bower Creek station where data were previously gathered from WY1991 to June 30, 1997, East River at the Monroe Street station (March 1985 to October 1986, see Hughes 1993), and Upper Bower Creek at Sunnyview Road (04085118, March 1985 to October 1986, see Hughes 1993).

Table 1 lists the stations, monitoring record, drainage area and percent areas of the 14 primary stream stations as they relate to either the Lower Fox sub-basin or only the portion within the sub-basin that drains directly to the Fox River. The stations and combined area that were monitored each USGS water year (October to September) are listed in Table 2 (includes overlapping nested areas) and Table 3 (overlapping areas not included in totals).

<u>Annual yields</u> of discharge (mm), TSS (t/ha), TP (kg/ha) and dissolved phosphorus (kg/ha) are listed by water year and monitoring station in Tables 4 to 7, respectively. Annual yield variations between the maximum and minimum for each stations monitoring record are listed at the bottom of these tables. The max/min ratios typically range by a factor of greater than three for discharge (2.0 to 4.6), >8 for TSS (3.0 to 13.7), >4 for TP (2.1 to 7.1) and >4 for dissolved phosphorus (1.6 to 5.9). Annual variations were quite high; therefore, data from a particular year is not likely to be representative for comparison purposes with other years or stations unless precipitation and runoff are accounted for (e.g., annual flow-weighted concentration), or data from that year can be contextualized within a longer data record.

The annual TSS and TP yield data from WY2004 to 2021 are also displayed on a temporal and spatial basis in Figure 2 and 3, respectively. Again, annual variation is high, as is the spatial coverage of monitoring stations. Tables 2 to 7, and Figures 2 and 3, show an inconsistent pattern of monitoring throughout the 2004 to 2021 period. For example, only 3% of the Lower Fox River sub-basin had intensive monitoring stations in 2010, compared to 48% from 2004 to 2006, and about 22% in 2021 (Tables 2 and 3). This monitoring approach may be related more to funding availability than to an overall monitoring strategy for the Lower Fox sub-basin, and it is inadequate given the highly variable nature of precipitation, and observed stream discharge and yields of TSS and phosphorus.

Average annual yields of stream discharge, TSS, TP and dissolved phosphorus are summarized in Table 8 (WY2004 to 2021). Average annual TSS and TP yields are shown in Figure 4. Average annual TSS yields varied from 0.06 t/ha at Silver Creek to as high as 1.64 t/ha at Plum Creek, with Plum West being the second highest at 0.74 t/ha. Average annual TP yields varied from 0.54 kg/ha at Silver Creek to as high as 2.98 kg/ha at Plum Creek, with Plum West being the second highest at 2.23 kg/ha. Average annual dissolved phosphorus yields varied from 0.31 kg/ha (52% of TP) at Duck Creek at CTH FF, to as high as 1.10 kg/ha (50% of TP) at Plum West.

<u>Flow-weighted concentrations</u> are based on dividing the total mass by the total discharge volume over the monitored period, within a single year, or events. Flow-weighted concentrations are useful because they account for the highly variable nature of annual precipitation and stream discharge, which greatly affect loads and yields; thereby, rendering site-to-site and year-to-year comparisons more useful than yield comparisons. Flow-weighted period mean TSS and phosphorus concentrations are summarized in Table 8, and displayed in Figure 5, where stations are ranked in descending order by TSS concentration. Flow-weighted period mean TSS concentrations varied from 22 mg/L at Silver Creek to as high as 550 mg/L at Plum Creek, with Plum West having the second highest at 290 mg/L. Flow-weighted period mean TP concentrations varied from 0.20 mg/L at Silver Creek to as high as 0.99 mg/L at Plum Creek, with Plum West having the second highest at 0.86 mg/L. Flow-weighted period mean dissolved phosphorus concentrations varied from 0.13 mg/L at Silver Creek to as high as 0.43 mg/L at Plum West.

Flow-weighted concentrations greatly reduced annual variability at individual stations compared to yields as evidenced by the reduction in relative standard deviations (std. deviation/mean; Tables 9 to 11, last two columns). For example, the relative standard deviation of TSS yields between years for all sites was 77%, compared to 48% with flow-weighted TSS concentrations. The relative standard deviation of TP yields between years for all sites was 59%, compared to 21% with flow-weighted TP concentrations. The relative standard deviation of DP yields between years for all sites was 49%, compared to 16% with flow-weighted DP concentrations.

Urban area and impervious surface contributions to yields and loads must also be considered when evaluating flow-weighted concentrations because runoff is higher than from agricultural or natural areas. Disparate land uses can affect the discharge yields, loads and concentrations. For example, areas with large percentages of impervious surfaces (e.g., urban areas) usually have much greater contributions to runoff compared to agricultural lands, thereby diluting the load with the increased water runoff and decreasing TSS and TP concentrations relative to agricultural areas. Urban area proportions are increasing in the Lower Fox sub-basin and thus can impact flow-concentration relationships.

The wide temporal and spatial variation in yields and flow-weighted concentrations (Tables 2-11, Fig 2-5) at the intensively monitored stations reveals why it is important to capture this variation rather than focusing on a small number of monitoring stations. In addition to capturing annual variations, having stations such as East at ZZ and Plum, which have been monitored intensely for 10 to 11 years (going on 12 to 13 years by end of WY2022), is critically important to tracking trends on a continuous basis rather than relying solely on before/after evaluation approaches.

WDNR Citizen Monitoring Stations: how does phosphorus data compare to intensive stations?

The locations of the WDNR citizen-based monitoring stations are shown in Figure 1. These sites were paired with data from the 14 intensely monitored stations which were nearest to these locations. In general, the relationship between median TP concentration from the citizen stations (median of all samples) and flow-weighted period mean TP concentration (mg/L) from the intensely monitored stations was fairly good (r^2 = 0.60, Figure 6). The relationship was not as good between the citizen station median TP concentration and the average annual TP yields (kg/ha) from the intensely monitored stations (r^2 = 0.53, Figure 6). Although this finding of a reasonable relationship between the two monitoring methods is good, it is also clear that for Plum and Bower, the WDNR May-Oct median TP concentrations from the citizen monitoring stations largely understates their relative importance to phosphorus load contributions.

Excessively high phosphorus concentrations from manure spills and runoff can be detected through low-flow monitoring, the May to October WDNR Citizen monitoring, and by screening for high TP/TSS ratios in event samples collected frequently at intensively monitored stations.

GIS Analysis

A GIS analysis of the stream monitoring sites was conducted with ARCMAP 10.5 to determine if: 1) landscape characteristics of the monitored drainage areas might explain possible patterns in water parameters such as flow, TSS and phosphorus yields and flow-weighted concentrations, and 2) whether there were similarities between landscape characteristics of both monitored and un-monitored areas. Results from the first part of this analysis are summarized in Table 12 where land cover classes and derivations thereof (WISCLAND-2, WDNR 2018), minimum Normalized-Difference Tillage Index (Sarah Kussow of Outagamie County LCD, 2022), overland slope (10 m DEM, WDNR) and soil parameters or derivations thereof like the NRCS curve number for corn crop (NRCS SSURGO) are listed for each the 14 primary monitoring station drainage areas (based on ARCMAP GIS analysis). R-squared statistics were also calculated for the relationships between landscape parameters and yields of flow, TSS, TP and dissolved phosphorus, as well as flow-weighted concentrations of TSS, TP and dissolved phosphorus (total mass/total water volume of the monitored period).

The relationships between the landscape characteristics and yields were moderate at best, with wetland and grassland, followed by dairy percentage being the best predictors of TSS and phosphorus yields (Table 12). The r^2 statistics for these characteristics were definitively higher for flow-weighted concentrations, especially with TP: 0.66 for wetland and 0.63 for dairy percentage. The relationships between the landscape characteristics and flow-weighted dissolved phosphorus concentrations were good, with r^2 statistics of 0.76 for agriculture, 0.74 for dairy, 0.66 for wetland and 0.58 for grassland percentage. The r^2 statistics for these characteristics were definitively higher for flow-weighted DP concentrations compared to DP yields.

Plots of the relationships between percent wetland and TSS and TP average annual yields, and period mean flow-weighted concentrations at intensive stream monitoring stations are shown in the upper and lower portions of Figure 7, respectively. Plots of the relationships between percent dairy and TSS and TP average annual yields, and period mean flow-weighted concentrations are shown in the upper and lower portions of Figure 8, respectively. Plots of the relationships between percent dairy and total and dissolved phosphorus average annual yields, and period mean flow-weighted concentrations are shown in the upper and lower portions of Figure 9, respectively. Again, the relationship with wetland and dairy percentages were definitively stronger with flow-weighted concentrations.

Surprisingly, mean overland slope for both the agricultural portion and the entire drainage area were not good predictors of yields or flow-weighted concentrations (r^2 mostly less than 0.1 for TP and TSS).

For the second part of this GIS analysis, a Cluster analysis was conducted with the SAS 9.4 statistical package to determine whether there were groups of monitored and un-monitored watersheds that had similar landscape characteristics. This procedure was done to see if monitored watersheds could represent areas that have not been monitored. The most predictive variables from Table 11 were employed to create dendogram clusters that were evaluated for general fitness (CCC, pseudo-F, and pseudo t-squared), and whether the clusters were similar to the ranking of flow-weighted concentrations and yields. Two cluster alternatives were generated which typified the valid clusters that were evaluated. In the first, the SAS Complete method was employed with WISCLAND-2 landcover classes (urban, agriculture, wetland, grassland, agriculture) and saturated soil hydraulic conductivity to create the Dendogram shown in Figure 10 (upper). The four primary groups shown in Figure 10 roughly correspond to yield and flow-concentration data of monitored areas shown in Figures 4 and 5: 1 highest, 4 lowest, and 2 and 3 somewhat similar. Unfortunately, nearly all of the un-monitored areas were in a single cluster that did not include a monitored area (group 3). In the second cluster alternative, the SAS Average method was employed with WISCLAND-2 agriculture and wetland landcover classes to create the Dendogram shown in Figure 10 (lower). Again, the four primary groups roughly corresponded to yield and flow-concentration data of monitored areas shown in Figures 4 and 5. With this cluster method, the Mahon station drainage areas was associated with the group 3 un-monitored area cluster.

References

Hughes, P.E. 1993. Hydrologic and water quality data for the East River Basin of Northeastern Wisconsin. U.S. Geological Survey Open File Report 89 245, Madison, WI. 91pp.

Figures and Tables

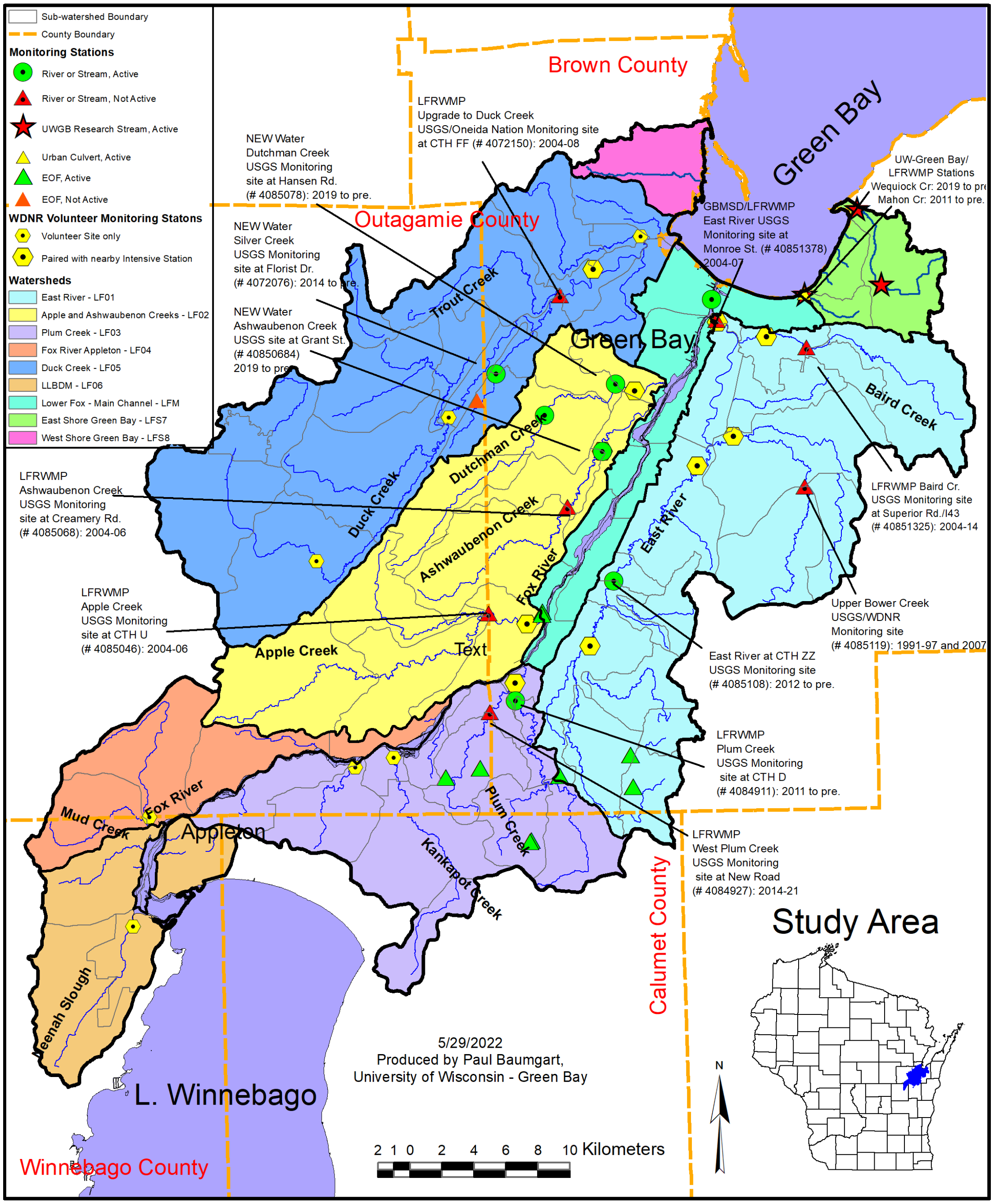


Figure 1. Water monitoring stations in the Lower Fox River sub-basin.

Table 1. Intensely monitored watershed stations in the Lower Fox sub-basin.

		LFox Sub-basin		to LFox outlet (not E/W or Duck)		
current in *Italics*	**Years**	**Area (km^2)**		**Area (km^2)**		
Apple	2004-06	117.7	7.1%	117.7	9.9%	
Duck_CTHFF	2004-08	262.7	15.8%			directly to Lower Bay
Baird	2004-14	53.8	3.2%	53.8	4.5%	
Bower	2007-09	36.0	2.2%	36.0	3.0%	
EastZZ	*2012-present*	*118.5*	*7.1%*	*118.5*	*10.0%*	
East	2004-07	368.2	22.2%	368.2	31.1%	
Plum	*2011-present*	*54.4*	*3.3%*	*54.4*	*4.6%*	
Plum_West	2014-21	24.4	1.5%	24.4	2.1%	
Silver	*2014-present*	*13.6*	*0.8%*	*13.6*	*1.1%*	to Lower Bay via Duck
Ash_Grant	*2019-present*	*64.2*	*3.9%*	*64.2*	*5.4%*	
Dutch_Hansen	*2019-present*	*67.0*	*4.0%*	*67.0*	*5.7%*	
Wequiock_NIC	*2019-present*	*30.4*	*1.8%*			directly to Lower Bay
Mahon	*2011-present**	*6.9*	*0.4%*			directly to Lower Bay
Ash_Creamery	2004-06	47.4	2.9%	not included in totals due to Ash-Grant		
Currently Monitored (WY2022)		**355.0**	**21.4%**	**317.7**	**26.8%**	No overlaps
Total Monitored since WY2004		**1,217.9**	**73.3%**	**917.9**	**77.5%**	with overlapping areas
Total Monitored since WY2004		***995.9***	***60.0%***	***695.9***	***58.8%***	*w/o Overlapping areas*
TOTAL		**1,661.2**		**1,184.1**		

*** High Bay levels after 2016 prevented event sampling at Mahon station near Bay outlet**

Table 2. Monitored watershed stations by year. Within Lower Fox sub-basin, and directly to Fox outlet. Area totals include overlapping areas within nested monitoring watersheds.

area (km^2)	117.7	47.4	262.7	53.8	36.0	368.2	*118.5*	*54.4*	24.4	*13.6*	*64.2*	*67.0*	*30.4*	*6.9*	**with Overlapping areas**			
	USGS	USGS	USGS	USGS	USGS	USGS	USGS	USGS	USGS	USGS	USGS	USGS	*UWGB*	*UWGB*	**Total**	**LFox-basin**	**to Outlet**	**to Outlet**
WYear	Apple	Ash_Crear	Duck_CTH	Baird	Bower	East	*EastZZ*	*Plum*	Plum_West	*Silver*	*Ash_Gran*	*Dutch_Ha*	*Wequiock*	*Mahon*	***(area km^2)***	***% area***	***(area km^2)***	***% area***
2004	1	1	1	1		1									849.8	51.2%	587.1	49.6%
2005	1	1	1	1		1									849.8	51.2%	587.1	49.6%
2006	1	1	1	1		1									849.8	51.2%	587.1	49.6%
2007			1	1	1	1									720.8	43.4%	458.1	38.7%
2008			1	1	1										352.6	21.2%	89.9	7.6%
2009				1	1										89.9	5.4%	89.9	7.6%
2010				1											53.8	3.2%	53.8	4.5%
2011				1				1						1	115.2	6.9%	108.3	9.1%
2012				1			1	1						1	233.7	14.1%	226.8	19.2%
2013				1			1	1						1	233.7	14.1%	226.8	19.2%
2014				1			1	1	1	1				1	271.6	16.4%	251.2	21.2%
2015							1	1	1	1				1	217.8	13.1%	197.3	16.7%
2016							1	1	1	1				1	217.8	13.1%	197.3	16.7%
2017							1	1	1	1				0	210.9	12.7%	197.3	16.7%
2018							1	1	1	1				0	210.9	12.7%	197.3	16.7%
2019							1	1	1	1	1	1	1	0	372.5	22.4%	328.5	27.7%
2020							1	1	1	1	1	1	1	0	372.5	22.4%	328.5	27.7%
2021							1	1	1	1	1	1	1	0	372.5	22.4%	328.5	27.7%
2022							1	1		1	1	1	1	0	348.1	21.0%	304.1	25.7%

Table 3. Monitored watershed stations by year. Within Lower Fox sub-basin, and directly to Fox outlet. Area totals do not include overlapping areas within nested monitoring watersheds.

area (km^2)	117.7	47.4	262.7	53.8	36.0	368.2	*118.5*	*54.4*	24.4	*13.6*	*64.2*	*67.0*	*30.4*	*6.9*	**without**	**Overlapping Areas**	
	USGS	USGS	USGS	USGS	USGS	USGS	USGS	USGS	USGS	USGS	USGS	USGS	*UWGB*	*UWGB*	**Total**	**LFox-basin**	**to Outlet**
WYear	Apple	Ash_Crea	Duck_CTH	Baird	Bower	East	*EastZZ*	*Plum*	Plum_West	*Silver*	*Ash_Gran*	*Dutch_Ha*	*Wequiock_*	*Mahon*	***(area km^2)***	***% area***	***% area***
2004	1	1	1	1		1									*796.0*	47.9%	*45.0%*
2005	1	1	1	1		1									*796.0*	47.9%	*45.0%*
2006	1	1	1	1		1									*796.0*	47.9%	*45.0%*
2007			1	1	1	1									*631.0*	38.0%	*31.1%*
2008			1	1	1										352.6	21.2%	7.6%
2009				1	1										89.9	5.4%	7.6%
2010				1											53.8	3.2%	4.5%
2011				1				1						1	115.2	6.9%	9.1%
2012				1			1	1						1	233.7	14.1%	19.2%
2013				1			1	1						1	233.7	14.1%	19.2%
2014				1			1	1	1	1				1	271.6	16.4%	21.2%
2015							1	1	1	1				1	217.8	13.1%	16.7%
2016							1	1	1	1				1	217.8	13.1%	16.7%
2017							1	1	1	1				0	210.9	12.7%	16.7%
2018							1	1	1	1				0	210.9	12.7%	16.7%
2019							1	1	1	1	1	1	1	0	372.5	22.4%	27.7%
2020							1	1	1	1	1	1	1	0	372.5	22.4%	27.7%
2021							1	1	1	1	1	1	1	0	372.5	22.4%	27.7%
2022							1	1		1	1	1	1	0	348.1	21.0%	25.7%

Table 4. Annual stream discharge (mm) of intensively monitoring stations in the Lower Fox sub-basin. Relative SD is the relative standard deviation (Std Dev/mean). Note high variability between years at individual stations, and between sites during some years when precipitation likely varied substantially on a spatial basis (e.g., Plum vs nearby Plum West and others in 2021, which affects TSS and TP yields even more in following tables).

WYear	Apple	Ashwaub Creamery	Baird	Duck	East River	Mahon	Bower	Plum	Plum West	Silver	East ZZ	Wequiock	Ashwaub Grant	Dutchman Hansen
2004	322	276	364	344	339									
2005	144	114	114	140	173									
2006	121	102	173	116	209									
2007			119	75	156		95							
2008			260	241			280							
2009			191				76							
2010			262											
2011			337			355		333						
2012			118			188		133			134			
2013			237			298		282			271			
2014			231			319		262	210	188	198			
2015						231		148	116	160	120			
2016						375		311	267	342	265			
2017								304	248	174	313			
2018								272	253	250	259			
2019		459						524	450	545	509	574	503	470
2020		460						440	369	386	448	401	514	462
2021		240						288	165	156	216	130	241	187
2022		X						X		X	X	X	X	X
mean	196	275	219	183	219	295	150	300	260	275	273	368	419	373
max	322	460	364	344	339	375	280	524	450	545	509	574	514	470
min	121	102	114	75	156	188	76	133	116	156	120	130	241	187
max/min	*2.7*	*4.5*	*3.2*	*4.6*	*2.2*	*2.0*	*3.7*	*3.9*	*3.9*	*3.5*	*4.2*	*4.4*	*2.1*	*2.5*
relative SD	56%	58%	39%	59%	38%	25%	75%	37%	41%	51%	46%	61%	37%	43%

Table 5. Annual TSS yields (t/ha) of intensively monitoring stations in the Lower Fox sub-basin. Relative SD is the relative standard deviation (Std Dev/mean). Note high variability between years at individual stations, and between sites during some years when precipitation likely varied substantially on a spatial basis (e.g., Plum vs nearby Plum West and others in 2021). Relative standard deviations of TSS at longer term stations were greater than with discharge (Table 4).

WYear	Apple	Ashwaub Creamery	Baird	Duck	East River	Mahon	Bower	Plum	Plum West	Silver	East ZZ	Wequiock	Ashwaub Grant	Dutchman Hansen
2004	0.931	0.705	0.733	0.359	0.495									
2005	0.117	0.204	0.097	0.107	0.065									
2006	0.162	0.067	0.177	0.031	0.135									
2007			0.120	0.036	0.139		0.154							
2008			0.230	0.106			0.932							
2009			0.067				0.068							
2010			0.196											
2011			0.240			0.330		1.284						
2012			0.069			0.128		0.646			0.325			
2013			0.096			0.110		1.197			0.211			
2014			0.175			0.201		2.144	0.536	0.020	0.729			
2015						0.150		0.581	0.263	0.016	0.082			
2016						0.183		1.628	0.837	0.085	0.417			
2017								1.097	1.009	0.016	0.750			
2018								1.678	0.800	0.028	0.468			
2019								2.759	0.820	0.087	0.666	0.359	0.488	0.310
2020								2.682	1.365	0.097	0.866	0.312	0.638	0.486
2021								2.342	0.326	0.128	0.207	0.056	0.180	0.120
2022								X		X	X	X	X	X
mean	0.40	0.33	0.20	0.13	0.21	0.18	0.38	1.64	0.74	0.06	0.47	0.24	0.44	0.31
max	0.93	0.70	0.73	0.36	0.49	0.33	0.93	2.76	1.36	0.13	0.87	0.36	0.64	0.49
min	0.12	0.07	0.07	0.03	0.06	0.11	0.07	0.58	0.26	0.02	0.08	0.06	0.18	0.12
max/min	*8.0*	*10.6*	*10.9*	*11.5*	*7.6*	*3.0*	*13.7*	*4.7*	*5.2*	*8.3*	*10.5*	*6.4*	*3.5*	*4.1*
relative SD	113%	103%	94%	105%	93%	43%	124%	46%	49%	75%	57%	67%	54%	60%

Table 6. Annual total phosphorus yields of intensively monitored stations in the Lower Fox sub-basin. Relative SD is the relative standard deviation (Std Dev/mean). Note high variability between years at individual stations, and between sites during some years when precipitation likely varied substantially on a spatial basis (e.g., Plum vs nearby Plum West and others in 2021). Relative standard deviations of total phosphorus at longer term stations were greater than with discharge (Table 4).

WYear	Apple	Ashwaub Creamery	Baird	Duck	East River	Mahon	Bower	Plum	Plum West	Silver	East ZZ	Wequiock	Ashwaub Grant	Dutchman Hansen
2004	1.89	2.02	2.34	1.29	1.63									
2005	0.59	0.82	0.53	0.57	0.46									
2006	0.51	0.53	0.73	0.35	0.68									
2007			0.51	0.19	0.53		0.75							
2008			1.16	0.54			2.50							
2009			0.68				0.35							
2010			1.31											
2011			1.01			1.02		2.54						
2012			0.39			0.26		1.13			0.75			
2013			0.72			0.43		2.37			1.10			
2014			1.10			0.53		3.44	1.09	0.27	1.46			
2015						0.58		1.33	0.87	0.25	0.50			
2016						0.58		2.97	2.20	0.48	1.54			
2017								2.48	2.48	0.27	2.07			
2018								3.14	2.42	0.55	1.68			
2019								4.69	3.58	1.31	2.69	1.52	1.95	1.38
2020								5.01	3.68	0.78	3.12	1.33	2.17	1.65
2021								3.65	1.51	0.41	1.18	0.33	1.03	0.61
2022								X		X	X	X	X	X
mean	1.00	1.12	0.95	0.59	0.83	0.57	1.20	2.98	2.23	0.54	1.61	1.06	1.72	1.21
max	1.89	2.02	2.34	1.29	1.63	1.02	2.50	5.01	3.68	1.31	3.12	1.52	2.17	1.65
min	0.51	0.53	0.39	0.19	0.46	0.26	0.35	1.13	0.87	0.25	0.50	0.33	1.03	0.61
max/min	*3.7*	*3.8*	*6.0*	*6.8*	*3.5*	*3.9*	*7.1*	*4.4*	*4.2*	*5.3*	*6.2*	*4.7*	*2.1*	*2.7*
relative SD	78%	70%	58%	72%	66%	45%	95%	41%	47%	66%	51%	61%	35%	45%

Table 7. Annual dissolved phosphorus yields of intensively monitored stations in the Lower Fox sub-basin. Relative SD is the relative standard deviation (Std Dev/mean). Daily dissolved phosphorus loads were calculated by the USGS for East River at ZZ, Ashwaubenon Creek at Grant, and Dutchman Creek at Hansen where extensive sample records of discrete dissolved phosphorus concentrations were available; whereas, the UWGB using regression analysis to estimate dissolved phosphorus loads at the remaining sites where dissolved phosphorus samples were more limited.

WYear	Apple	Ashwaub Creamery	Baird	Duck	East River	Mahon	Bower	Plum	Plum West	Silver	East ZZ	Wequiock	Ashwaub Grant	Dutchman Hansen
2004	0.62	0.89	0.93	0.61	0.66									
2005	0.34	0.47	0.26	0.30	0.22									
2006	0.24	0.34	0.36	0.21	0.31									
2007			0.23	0.10	0.22									
2008			0.57	0.31										
2009			0.41											
2010			0.71											
2011			0.58					0.73						
2012			0.21					0.35			0.27			
2013			0.45					0.72			0.59			
2014			0.60					0.73	0.52	0.18	0.48			
2015								0.47	0.46	0.18	0.29			
2016								0.86	1.02	0.31	0.75			
2017								0.82	1.06	0.19	1.00			
2018								0.83	1.13	0.37	0.89			
2019								1.36	2.11	0.90	1.59		1.25	0.92
2020								1.34	1.64	0.51	0.93		1.23	0.94
2021								0.80	0.90	0.22	0.72		0.77	0.45
2022								X		X	X		X	X
mean	0.40	0.56	0.48	0.31	0.35			0.82	1.10	0.36	0.75		1.08	0.77
max	0.62	0.89	0.93	0.61	0.66			1.36	2.11	0.90	1.59		1.25	0.94
min	0.24	0.34	0.21	0.10	0.22			0.35	0.46	0.18	0.27		0.77	0.45
max/min	*2.5*	*2.6*	*4.3*	*5.9*	*3.0*			*3.9*	*4.6*	*5.1*	*5.9*		*1.6*	*2.1*
relative SD	48%	51%	46%	62%	59%			37%	50%	70%	52%		25%	36%

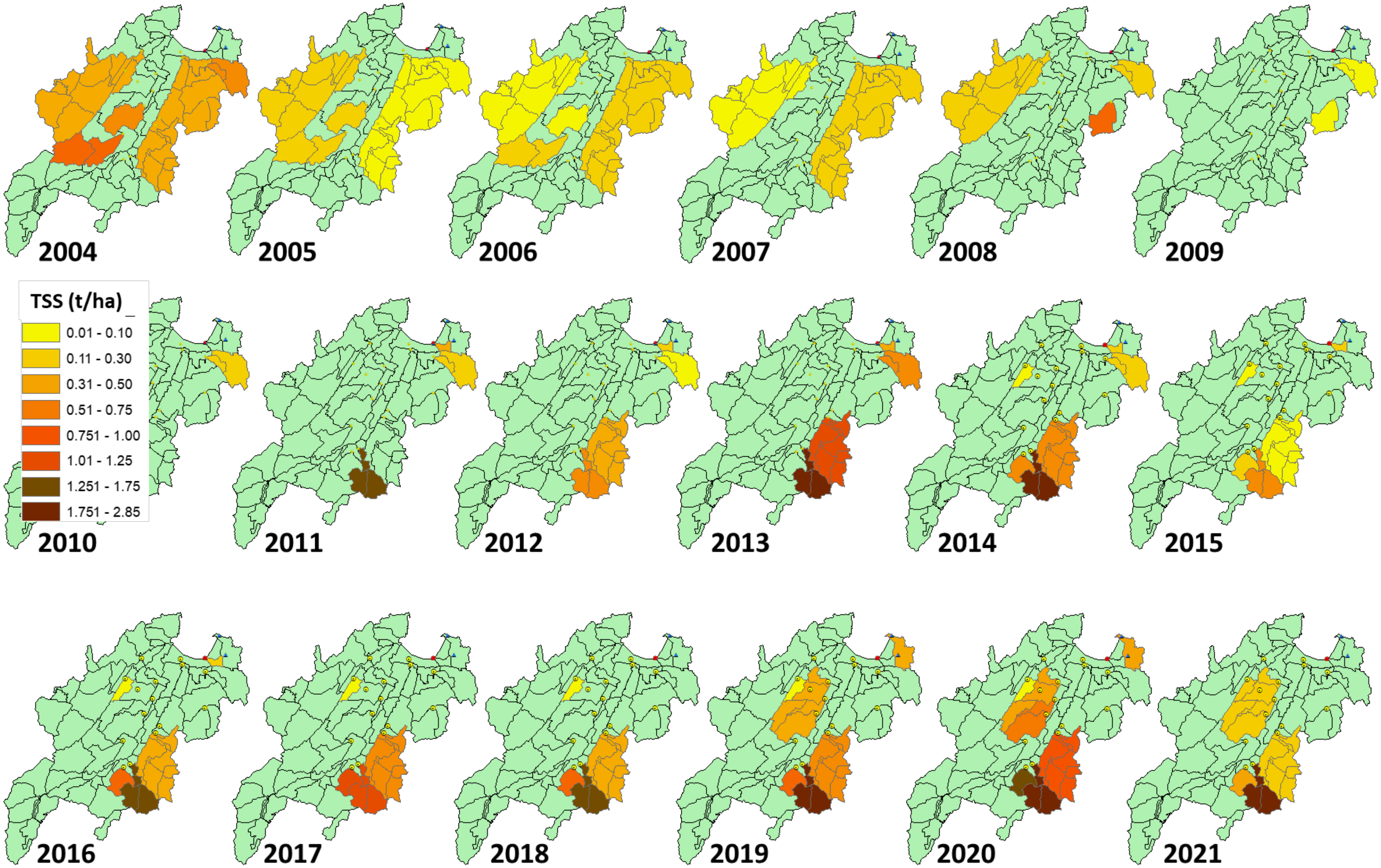


Figure 2. Annual TSS yields from stream monitoring stations during water years 2004 to 2021.

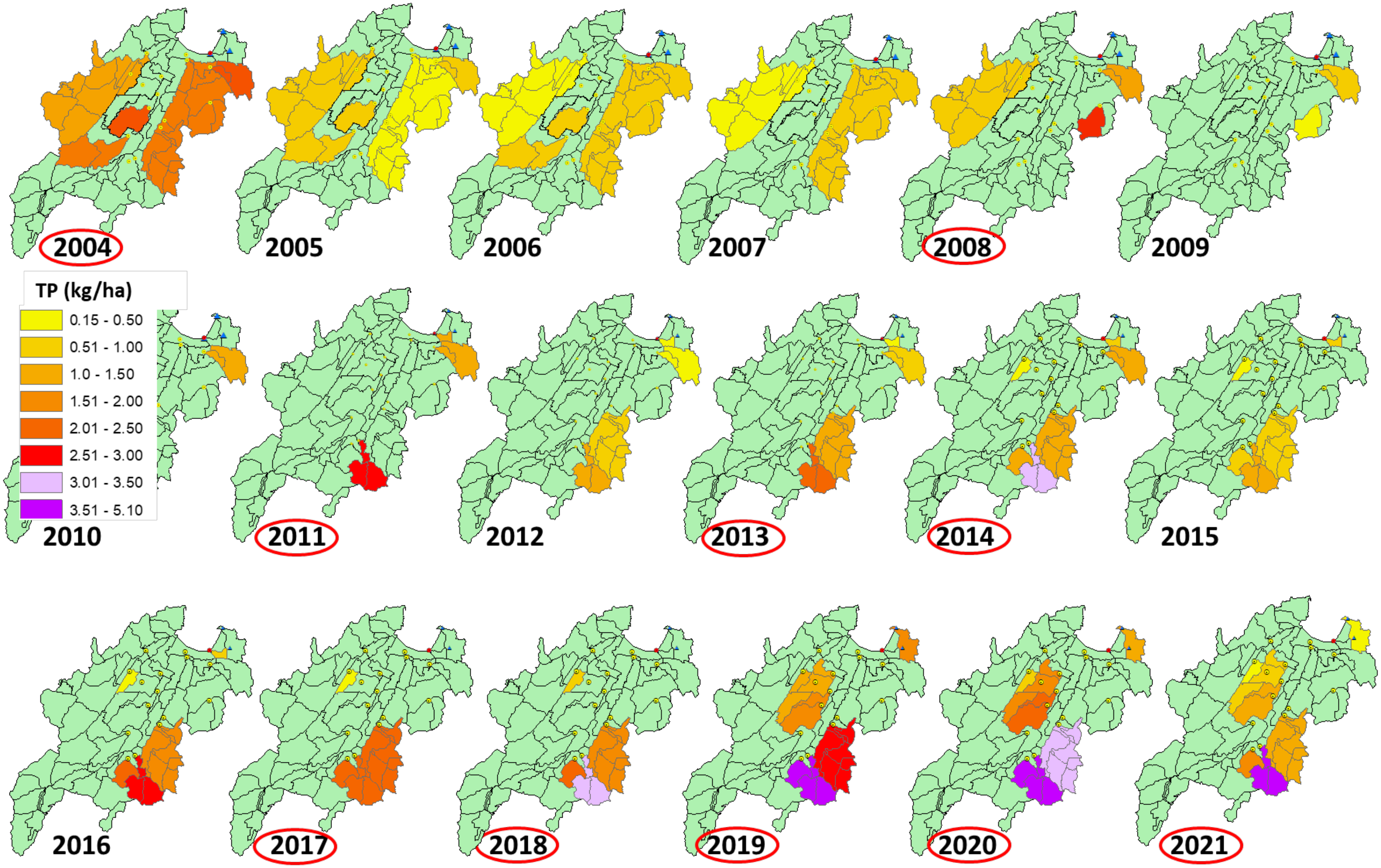


Figure 3. Annual total phosphorus (TP) yields from stream monitoring stations during water years 2004 to 2021. Years that tended to have higher TP yields are circled.

Table 8. Average annual yields and flow-weighted period mean concentrations of flow, TSS, total phosphorus (TP) and dissolved phosphorus at intensively monitored streams in Lower Fox sub-basin.

Stream	Flow (mm)	TSS (t/ha)	TP (kg/ha)	DP (kg/ha)	DP	Flow-weighted (mg/L) TSS	TP	DP	Water Years		USGS #
Apple	196	0.40	1.00	0.40	40.2%	206	0.509	0.204	3	2004-06	04085046
Ash-Creamery	164	0.33	1.12	0.56	50.3%	198	0.685	0.344	3	2004-06	04085068
Baird	219	0.20	0.95	0.48	50.8%	92	0.435	0.221	11	2004-14	040851325
Duck	183	0.13	0.59	0.31	52.0%	70	0.321	0.167	5	2004-08	04072150
East River	219	0.21	0.83	0.35	42.5%	95	0.377	0.160	4	2004-07	040851378
Mahon	295	0.18	0.57			62	0.192		6	2011-16	UWGB
Bower	150	0.38	1.20			256	0.798		3	2007-09	04085119
Plum	**300**	**1.64**	**2.98**	0.82	**27.5%**	**547**	**0.993**	0.273	11	2011-21	04084911
Plum West	260	0.74	2.23	**1.10**	49.6%	286	0.857	**0.425**	8	2014-21	04084927
Silver	275	0.06	0.54	0.36	66.1%	22	0.196	0.130	8	2014-21	04072076
East ZZ	273	0.47	1.61	0.75	46.7%	173	0.589	0.275	10	2012-21	04085108
Wequiock	368	0.24	1.06			66	0.288		3	2019-21	UWGB
Ash-Grant	419	0.44	1.72	1.08	63.0%	104	0.410	0.258	3	2019-21	040850684
Dutch-Hansen	373	0.31	1.21	0.77	63.6%	82	0.325	0.206	3	2019-21	04085078

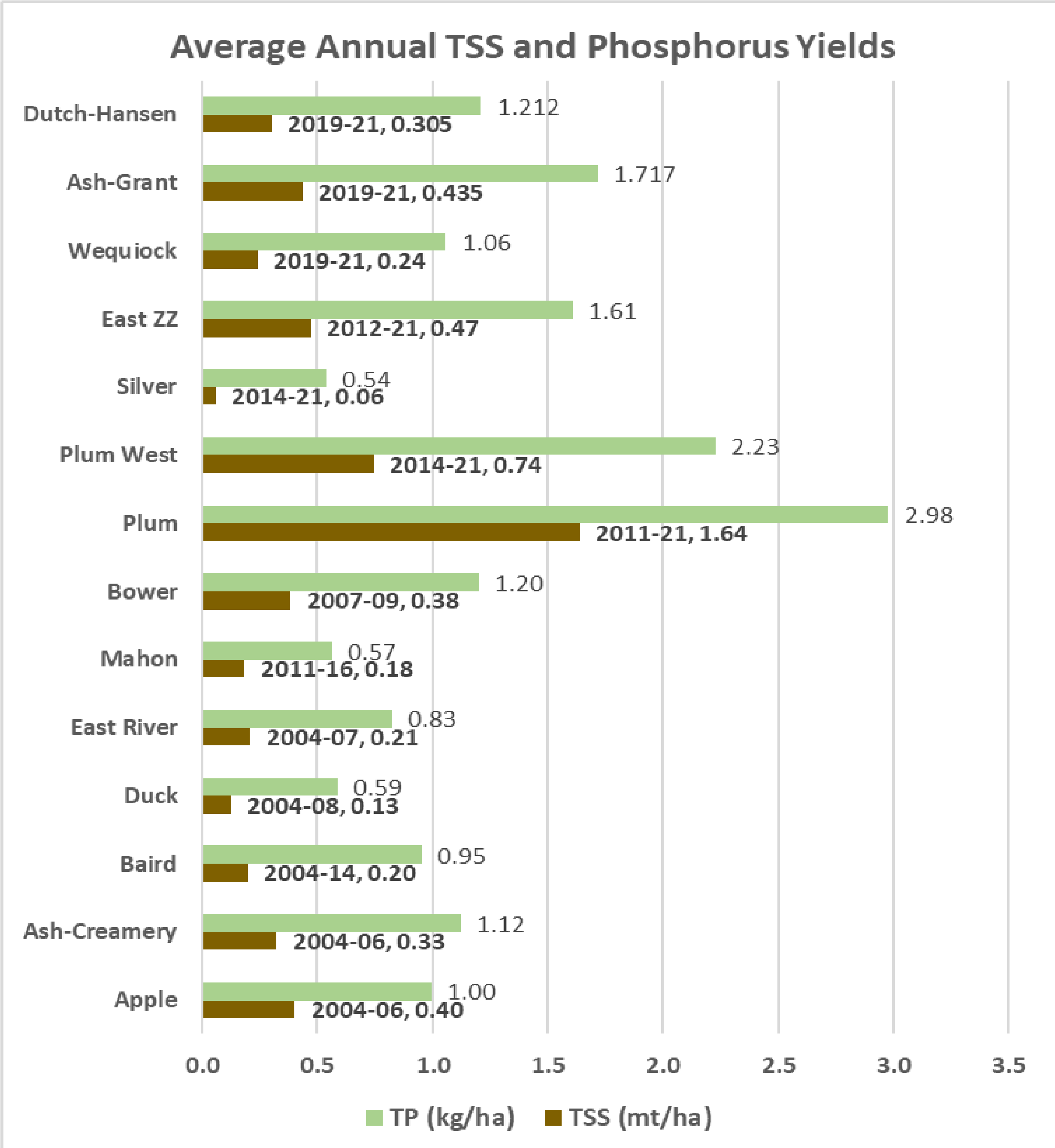


Figure 4. Average annual TSS and total phosphorus (TP) yields from the 14 primary stream monitoring stations in the Lower Fox sub-basin.

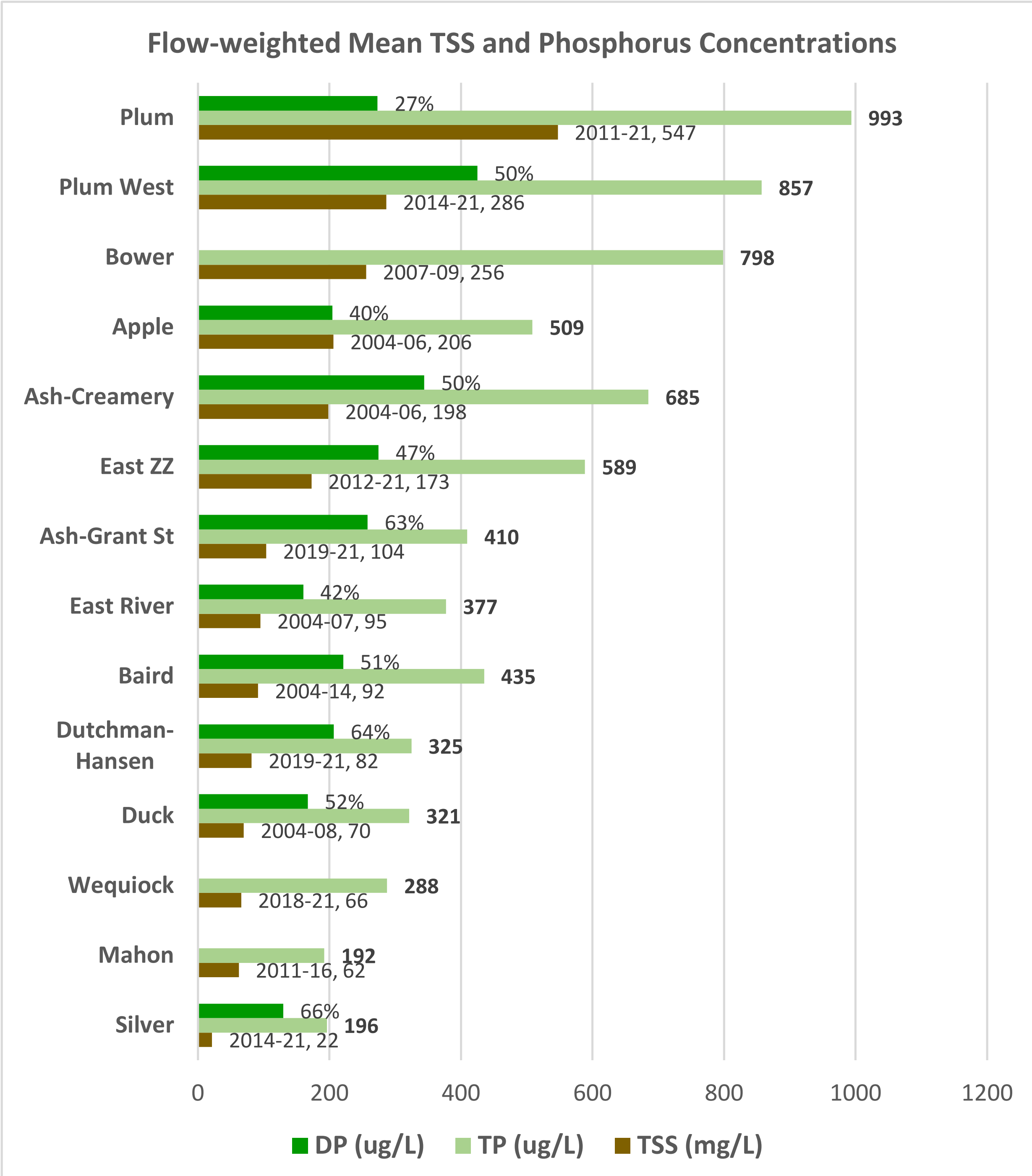


Figure 5. Flow-weighted period mean concentrations of TSS, total phosphorus (TP) and dissolved phosphorus (DP) during monitored period from the 14 primary stream monitoring stations. Ranked in descending order by TSS concentrations. These flow-weighted period mean concentrations compensate for annual discharge variations, so they are better suited for ranking the relative contributions of TSS and TP compared to yields shown in Figure 4.

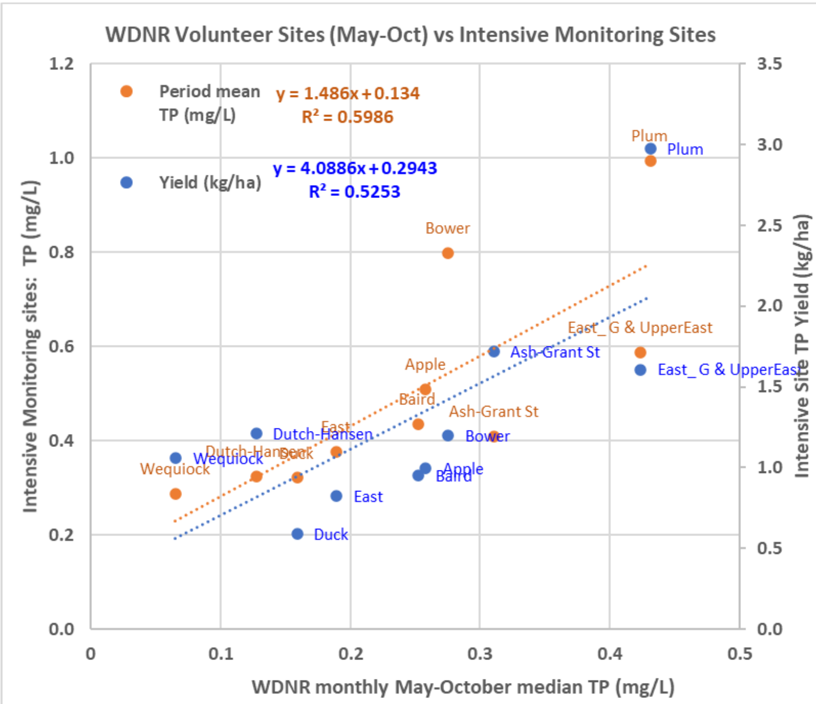


Figure 6. WDNR citizen water monitoring station median May-October total phosphorus concentrations (TP in mg/L) are compared to phosphorus yields and flow-weighted period mean concentrations at nearby intensely monitored stations. Note that flow-weighted mean concentrations are less biased to annual flow variations and different monitoring periods (e.g., Bower creek).

Table 9. Flow-weighted annual mean concentrations of TSS (mg/L) in intensive streams within the Lower Fox sub-basin. Concentrations less than 100 mg/L are in green and those greater than 300 mg/L are in red. Note the relatively low intra-annual variation for each stream, compared to annual yields listed in Table 5. As listed in the last two columns, the relative standard deviations of flow-weighted concentrations are lower than for yields (see also Table 5), both for individual streams (except Silver) and the combined average (48% compared to 77%). A standard deviation for only 3 values is normally not acceptable, but is useful for this particular comparative purpose.

	flow-weighted annual mean TSS concentrations (mg/L)																		Relative Std. Dev.	
	2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**TSS (mg/L)**	**TSS (t/ha)**
Apple	289	81	134																***65%***	113%
Ashwaub-Creamery	256	179	65																***57%***	103%
Baird	201	85	102	101	89	35	75	71	59	41	76								***52%***	94%
Duck	104	76	27	48	44														***51%***	105%
East River	146	37	65	89															***55%***	93%
Mahon								93	68	37	63	65	49						***30%***	43%
Bower				162	333	90													***64%***	124%
Plum								385	485	424	818	394	524	361	618	526	609	814	***30%***	46%
Plum West											255	226	314	407	316	182	369	197	***29%***	49%
Silver											11	10	25	9	11	16	25	82	***104%***	75%
East ZZ									243	78	367	69	157	240	180	131	193	96	***52%***	57%
Wequiock																63	78	43	***28%***	67%
Ashwaub-Grant St																97	124	75	***25%***	54%
Dutchman-Hansen																66	105	64	***30%***	60%
																		average	***48%***	***77%***

Table 10. Flow-weighted annual mean concentrations of total phosphorus (mg/L) in intensively monitored streams within the Lower Fox sub-basin. Concentrations less than 0.25 mg/L are in green and those greater than 0.50 mg/L are in red. Note the relatively low intra-annual variation for each stream, compared to annual yields listed in Table 6. As listed in the last two columns, the relative standard deviations of flow-weighted concentrations are much lower than for yields (see also Table 6), both for individual streams and the combined average (21% compared to 59%). A standard deviation for only 3 values is normally not acceptable, but is useful for this particular comparative purpose.

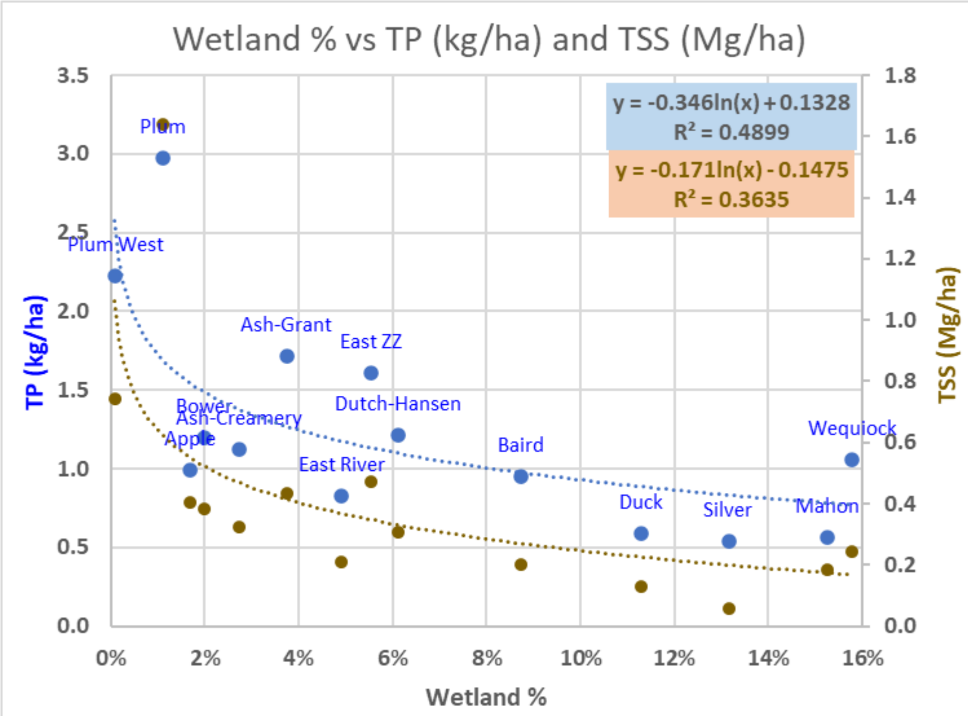
	flow-weighted annual mean total phosphorus concentrations (mg/L)																		Relative Std. Dev.	
	2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**TP (mg/L)**	**TP (kg/ha)**
Apple	0.59	0.41	0.42																***22%***	78%
Ashwaub-Creamery	0.73	0.72	0.52																***18%***	70%
Baird	0.64	0.46	0.42	0.43	0.45	0.35	0.50	0.30	0.33	0.30	0.48								***24%***	58%
Duck	0.38	0.40	0.30	0.25	0.23														***25%***	72%
East River	0.48	0.27	0.33	0.34															***26%***	66%
Mahon								0.29	0.14	0.14	0.16	0.25	0.15						***33%***	45%
Bower				0.78	0.89	0.46													***31%***	95%
Plum								0.76	0.85	0.84	1.31	0.90	0.96	0.82	1.16	0.89	1.14	1.27	***20%***	41%
Plum West											0.52	0.75	0.82	1.00	0.96	0.79	1.00	0.91	***19%***	47%
Silver											0.15	0.16	0.14	0.16	0.22	0.24	0.20	0.26	***25%***	66%
East ZZ									0.56	0.41	0.74	0.42	0.58	0.66	0.65	0.53	0.70	0.55	***19%***	51%
Wequiock																0.27	0.33	0.25	***15%***	61%
Ashwaub-Grant St																0.39	0.42	0.43	***5%***	35%
Dutchman-Hansen																0.29	0.36	0.32	***10%***	45%
																		average	***21%***	**59%**

Table 11. Flow-weighted annual mean concentrations of dissolved phosphorus (mg/L) in intensively monitored streams within the Lower Fox sub-basin. Concentrations less than 0.15 mg/L are in green and those greater than 0.35 mg/L are in red. Note the relatively low intra-annual variation for each stream, compared to annual yields listed in Table 7. As listed in the last two columns, the relative standard deviations of flow-weighted concentrations are much lower than for yields (see also Table 7), both for individual streams and the combined average (16% compared to 49%). A standard deviation for only 3 values is normally not acceptable, but is useful for this particular comparative purpose.

	flow-weighted annual mean dissolved phosphorus concentrations (mg/L)																		Relative Std. Dev.	
	2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**DP (mg/L)**	**DP (kg/ha)**
Apple	0.19	0.24	0.20																***12%***	48%
Ashwaub-Creamery	0.32	0.41	0.33																***14%***	51%
Baird	0.26	0.23	0.21	0.20	0.22	0.22	0.27	0.17	0.18	0.19	0.26								***15%***	46%
Duck	0.18	0.21	0.18	0.14	0.13														***21%***	62%
East River	0.19	0.13	0.15	0.14															***19%***	59%
Mahon																				
Bower																				
Plum								0.22	0.26	0.26	0.28	0.32	0.28	0.27	0.31	0.26	0.30	0.28	***10%***	37%
Plum West											0.25	0.40	0.38	0.43	0.45	0.47	0.44	0.54	***20%***	50%
Silver											0.10	0.11	0.09	0.11	0.15	0.17	0.13	0.14	***21%***	70%
East ZZ									0.20	0.22	0.24	0.24	0.28	0.32	0.34	0.31	0.21	0.33	***20%***	52%
Wequiock																				
Ashwaub-Grant St																0.25	0.24	0.32	***17%***	25%
Dutchman-Hansen																0.20	0.20	0.24	***11%***	36%
																		average	***16%***	**49%**

Table 12. GIS analysis of landscape characteristics for intensely monitored stream drainage areas in the Lower Fox sub-basin, with r^2 statistics of relationship to flow, yields and flow-weighted concentrations of TSS and phosphorus. Color scheme is green to yellow to red, where in general, green has the least and red has the greatest impact on soil erosion. R^2 statistics greater than 0.25 are highlighted, and highest R^2 are bolded.

	------------- WISCLAND-2 Land Cover from WDNR ---------------							WY2018	ALL	AG only	NRCS	Saturated			Dairy	Total
Monitoring Site	**Urban**	**Dairy**	**Cash_Crop**	**Grassland**	**Forest**	**Wetland**	**Quarry**	**min-NDTI**	**Slope%**	**Slope%**	**Curve#**	**Cond (mm/h)**	**USLE K-Fact**	**Clay_%**	**Fraction**	**Ag%**
APPLE	27.0%	45.6%	20.8%	1.3%	3.6%	1.7%	0.0%	0.128	1.69	1.42	84.4	33.7	0.37	27.04	68.7%	66.4%
ASH_CREAMERY	8.2%	61.2%	24.7%	0.2%	2.9%	2.7%	0.0%	0.113	1.21	1.05	84.7	32.9	0.37	27.01	71.2%	85.9%
ASH_GRANT	12.3%	56.7%	23.4%	0.6%	3.1%	3.7%	0.2%	0.116	1.33	1.05	84.3	34.8	0.37	25.65	70.8%	80.1%
BAIRD	8.8%	61.3%	16.5%	1.7%	3.0%	8.7%	0.0%	0.134	1.54	1.46	85.4	32.2	0.41	20.26	78.8%	77.7%
BOWER	1.7%	72.8%	19.7%	0.5%	3.4%	2.0%	0.0%	0.129	2.29	2.18	85.2	27.3	0.42	21.05	78.7%	92.5%
EAST	19.5%	53.4%	13.6%	1.3%	7.0%	4.9%	0.2%	0.132	2.85	2.39	84.2	40.6	0.38	19.98	79.7%	67.0%
EASTZZ	3.5%	64.9%	16.0%	1.2%	8.8%	5.6%	0.1%	0.129	3.02	2.61	84.0	33.6	0.38	19.85	80.3%	80.9%
DUCK_CTHFF	7.6%	42.0%	29.5%	2.4%	7.0%	11.3%	0.2%	0.106	1.90	1.70	84.0	51.9	0.37	14.26	58.8%	71.5%
SILVER	10.1%	47.3%	21.7%	3.1%	4.6%	13.2%	0.1%	0.173	2.25	2.05	83.1	74.1	0.33	18.18	68.6%	69.0%
PLUM	5.9%	61.5%	20.7%	0.7%	9.9%	1.1%	0.2%	0.123	2.76	2.06	84.8	32.1	0.37	19.16	74.8%	82.2%
PLUM_WEST	6.6%	75.7%	13.4%	0.5%	3.8%	0.1%	0.0%	0.138	2.82	2.72	84.8	24.6	0.40	25.42	85.0%	89.0%
DUTCH_HANSEN	24.1%	47.9%	16.0%	2.0%	3.7%	6.1%	0.1%	0.117	1.30	0.96	83.3	49.7	0.36	19.66	74.9%	64.0%
MAHON	33.8%	28.2%	10.2%	3.6%	8.9%	15.3%	0.0%	0.117	3.25	2.25	85.3	28.1	0.38	19.61	73.4%	38.4%
WEQUIOCK_NIC	8.0%	49.5%	20.8%	1.1%	4.6%	15.8%	0.1%	0.106	1.68	1.65	85.2	30.0	0.37	18.96	70.4%	70.3%
	linear correlations with average annual station Yields (r^2)															
Rsq Flow (mm)	0.039	0.046	0.027	0.010	0.005	0.065	0.055	0.022	0.012	0.049	0.033	0.004	0.183	0.003	0.000	0.069
Rsq TSS (Mg/ha)	0.078	0.184	0.001	0.238	0.150	**0.330**	0.050	0.005	0.082	0.043	0.044	0.137	0.008	0.021	0.085	0.152
Rsq TP (kg/ha)	0.159	0.376	0.004	0.410	0.043	**0.420**	0.019	0.005	0.039	0.034	0.031	0.187	0.030	0.075	0.190	0.301
Rsq dP (kg/ha)	0.066	**0.455**	0.082	0.393	0.006	0.362	0.039	0.032	0.007	0.004	0.048	0.271	0.052	0.178	0.243	0.381
Rsq dP%	0.010	0.072	0.018	0.210	**0.355**	0.309	0.028	0.052	0.245	0.143	0.325	0.323	0.154	0.003	0.048	0.054
	linear correlations with Flow-Weighted Period mean station Concentrations (r^2)															
Rsq TSS (mg/L)	0.120	0.298	0.000	0.346	0.077	**0.488**	0.004	0.002	0.076	0.060	0.088	0.202	0.069	0.060	0.107	0.266
Rsq TP (mg/L)	0.280	0.627	0.001	0.582	0.002	**0.663**	0.014	0.000	0.036	0.068	0.108	0.278	0.226	0.146	0.223	0.559
Rsq dP (mg/L)	0.177	0.737	0.049	0.666	0.021	0.525	0.237	0.054	0.014	0.031	0.287	0.543	0.236	0.358	0.271	**0.756**



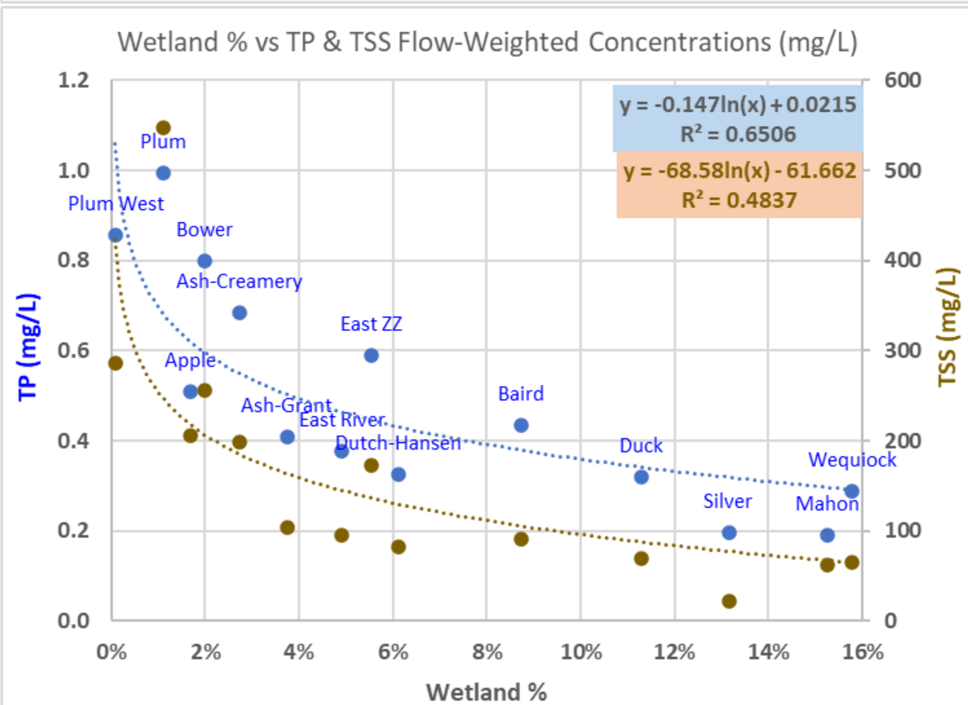


Figure 7. Wetland percent of total area versus TSS and total phosphorus (TP) average annual yields (upper) and period mean flow-weighted concentrations (lower) of intensive stream monitoring stations. The flow-weighted concentrations in the lower figure are typically better for site comparisons because they greatly reduce the variation caused by large fluctuations of annual discharge and improve correlations, especially when the monitoring periods are different.

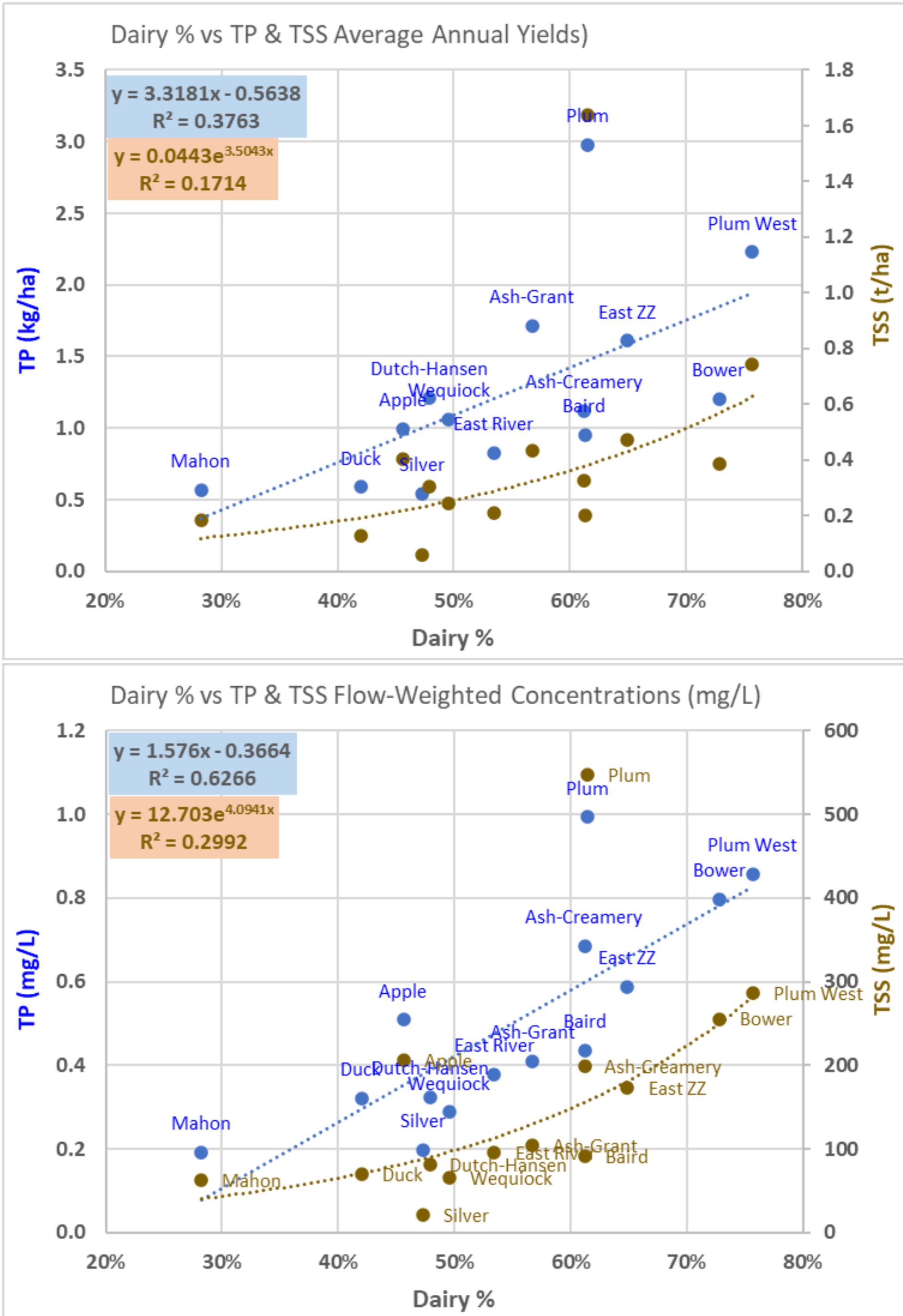
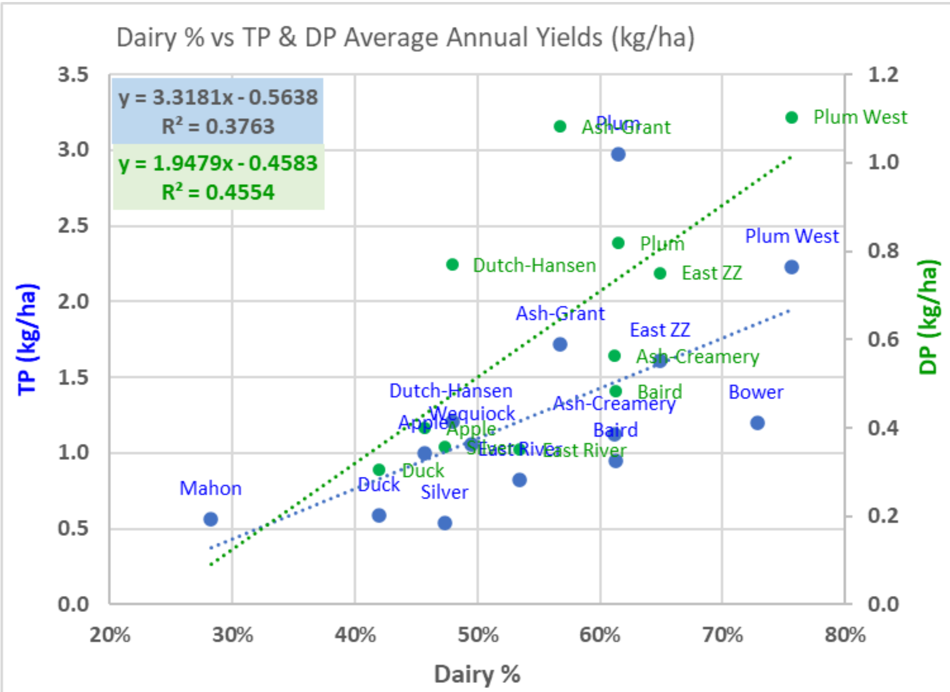


Figure 8. Dairy percent of total area versus TSS and total phosphorus (TP) average annual yields (upper) and period mean flow-weighted concentrations (lower) of intensive stream monitoring stations. Plum TSS and TP values are higher than the general trend lines. The flow-weighted concentrations in the lower figure are typically better for site comparisons because they greatly reduce the variation caused by large fluctuations of annual discharge and improve correlations (particularly for TP), especially when the monitoring periods are different.



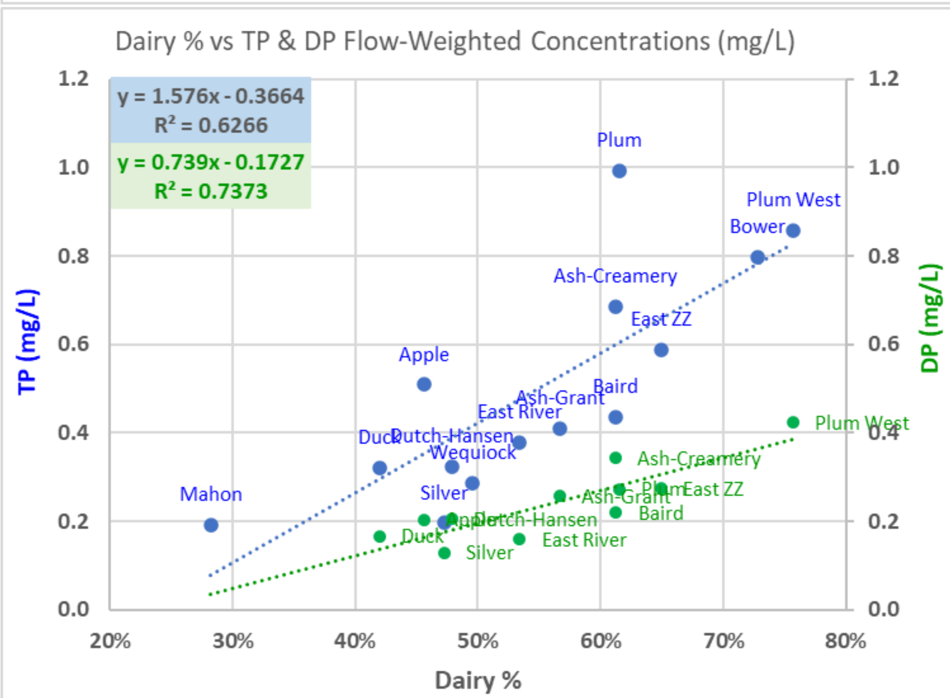


Figure 9. Dairy percent of total area versus total and dissolved phosphorus (DP) average annual yields (upper) and period mean flow-weighted concentrations (lower) of intensive stream monitoring stations. The flow-weighted concentrations in the lower figure are typically better for site comparisons because they greatly reduce the variation caused by large fluctuations of annual discharge and improve correlations, especially when the monitoring periods are different. The relationship of percent landcover in combined agriculture and flow-weighted concentrations was slightly greater ($r^2 = 0.76$) than percent dairy ($r^2 = 0.74$). However, the separation between the station labels was smaller and difficult to see, so it was not displayed in this figure.

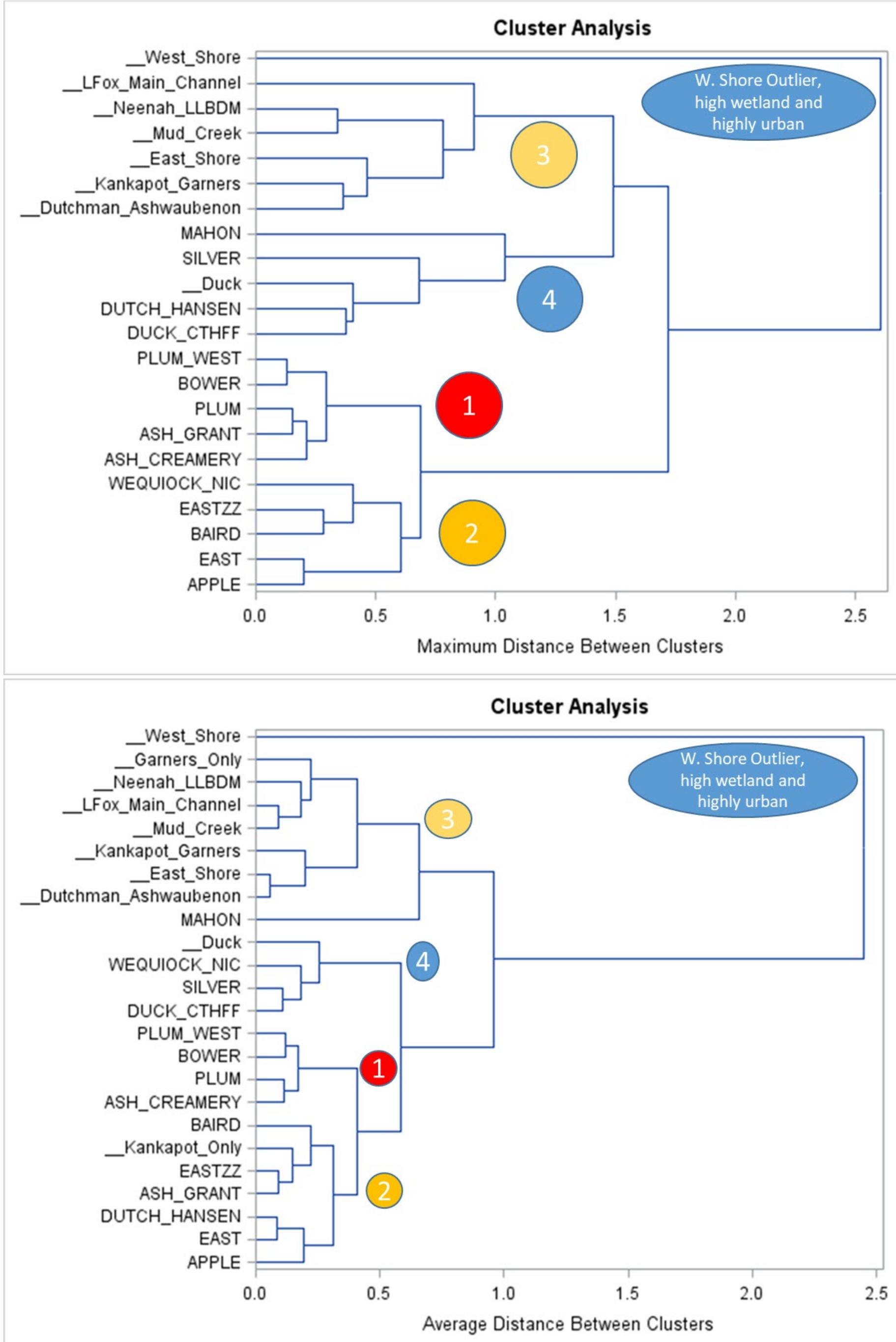
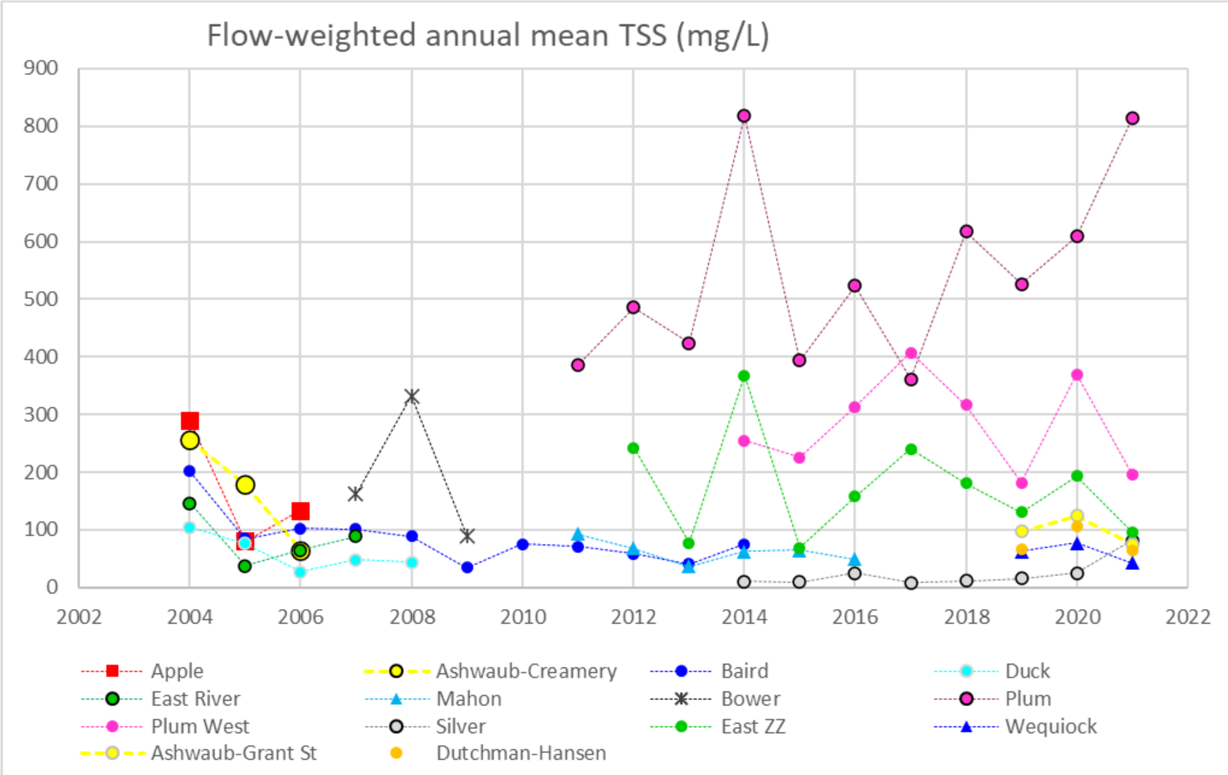


Figure 10. Cluster analysis dendograms of key WISCLAND-2 landcover classes, derivatives and soil property. SAS Complete method (upper), where percent urban, ag, wetland grassland and saturated conductivity variables identified four major clusters. An alternative valid dendogram (lower) based on the Average cluster method and percent ag and wetland also indicated four major clusters and was one of many dendograms which associated the Mahon monitoring station drainage area with unmonitored watersheds in group 3. No other stations represented watersheds in group 3 in any cluster alternatives that were evaluated. These two dendograms typified results from cluster method/variable alternatives that were deemed to be valid (total of 24 were evaluated). Clusters are similar to flow-weighted TSS and total phosphorus ranking. All CAPS = monitored; "__" = not monitored.



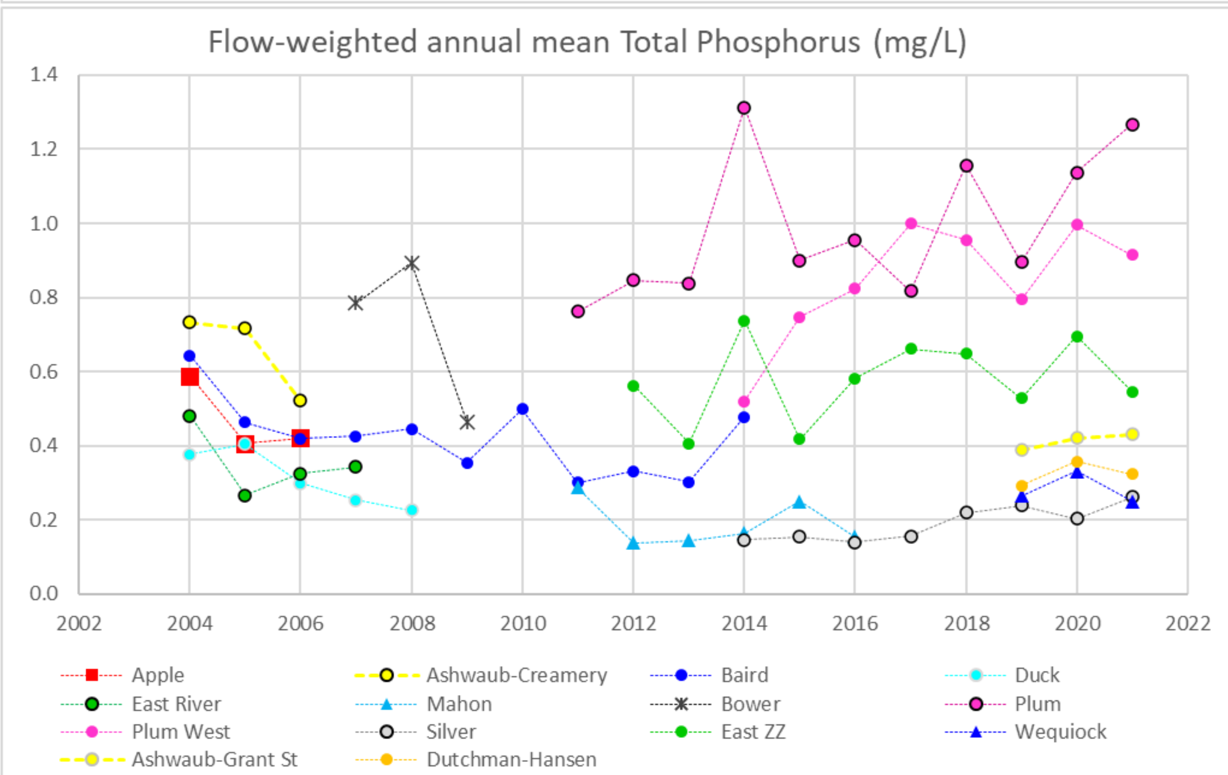


Figure 11. Flow-weighted annual mean TSS *(upper)* and total phosphorus *(lower)* concentrations for Lower Fox monitoring stations. Compared to annual yields, flow-weighted mean concentrations greatly reduce the variation caused by annual discharge variations, so easier to compare streams across different periods.

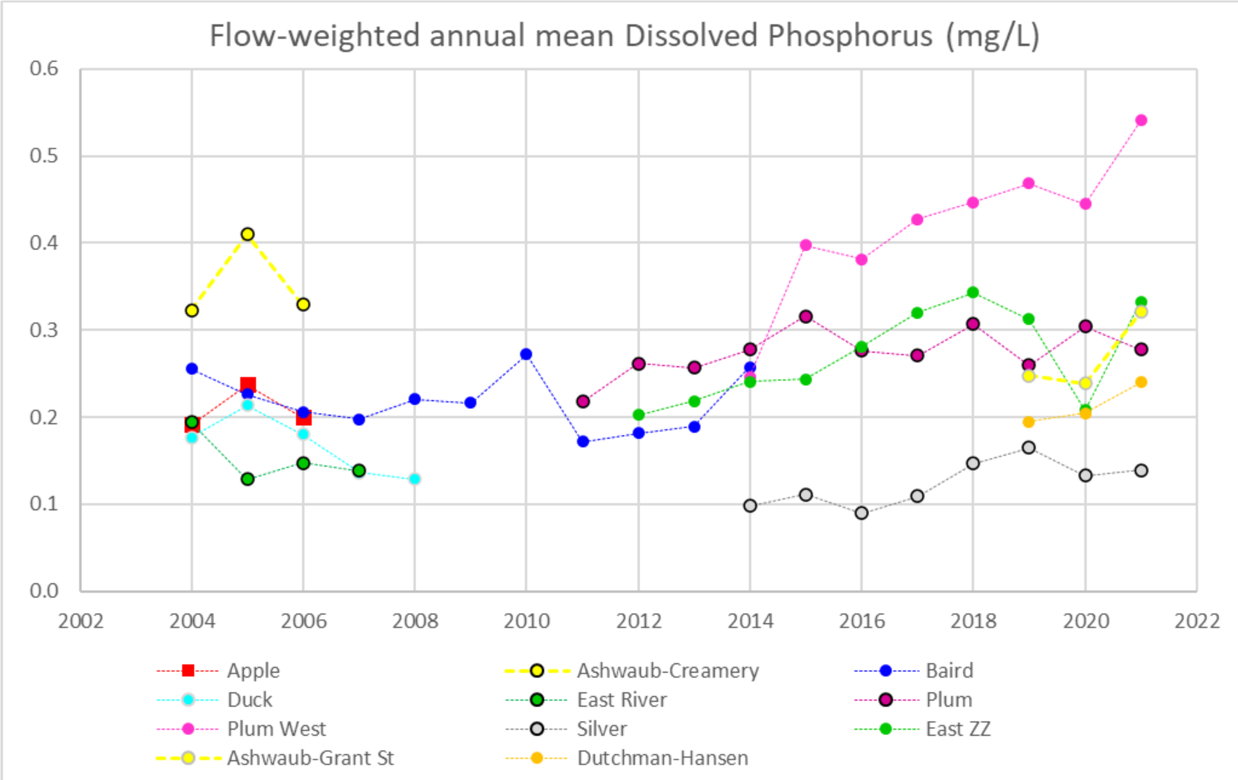
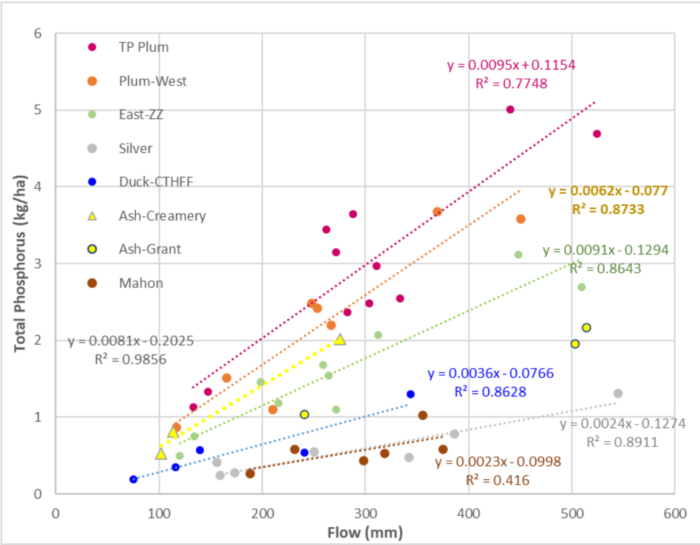


Figure 12. Flow-weighted annual mean dissolved phosphorus concentrations for Lower Fox monitoring stations. Compared to annual yields, flow-weighted mean concentrations greatly reduce the variation caused by annual discharge variations, so easier to compare streams across different periods.

OTHER Plots of Possible Interest

Annual Flow vs **TP** Relationships: Yields



Annual Flow vs **TP** Relationships: *Flow-weighted concentration*

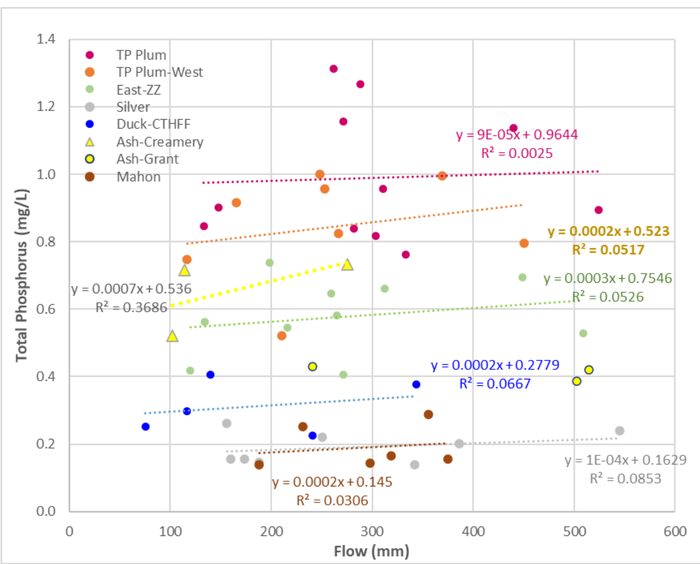
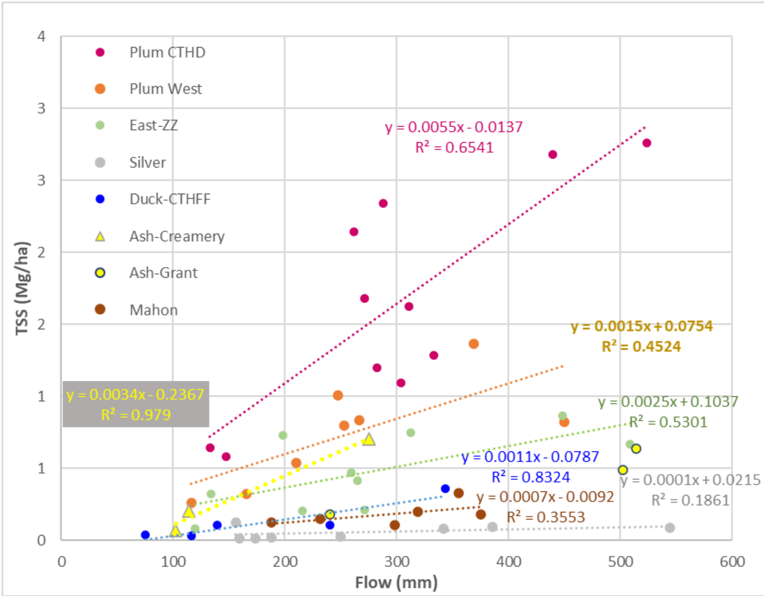


Table 13. Relationship between Flow (mm) and total phosphorus (TP) yields (upper) and flow-weighted period mean concentrations (lower). The lower figure shows that flow-weighted concentrations greatly reduce the variation caused by large fluctuations of annual discharge, which is better for site comparisons, especially when the monitoring periods are different (or precipitation is quite different). In both figures, each site displays a type of signature based on the relationship to flow: the difference being that the upper figure has a distinctly positive slope, whereas the slope in the lower figure is nearly zero, and the generally narrow range and average of flow-weighted TP seems well-suited to defining the site signature.

Annual Flow vs **TSS** Relationships: Yields



Annual Flow vs **TSS** Relationships: ***Flow-weighted concentration***

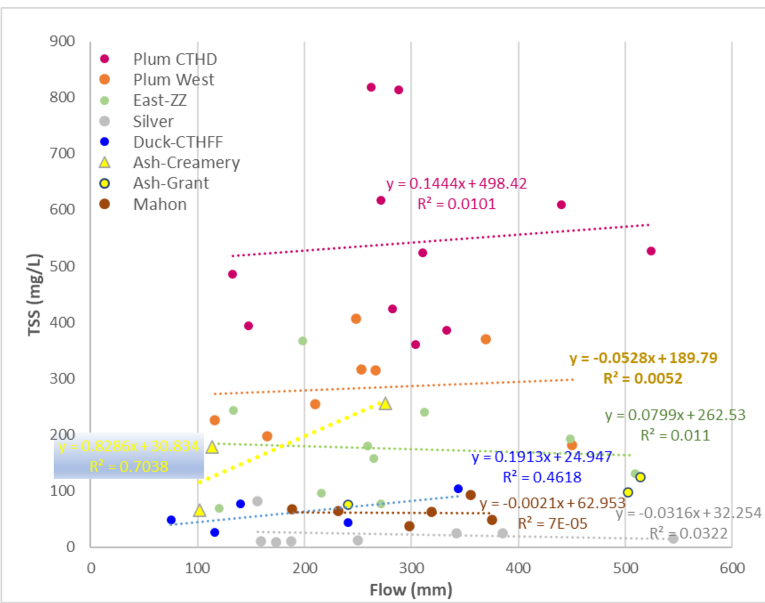
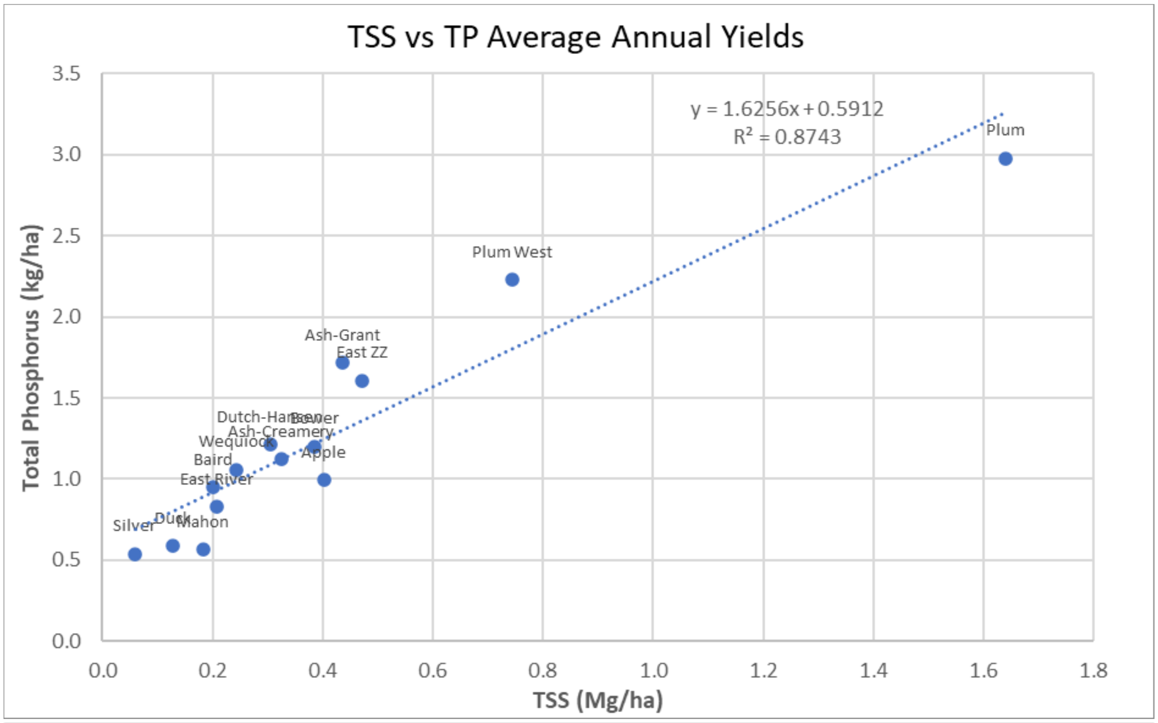


Table 14. Relationship between Flow (mm) and TSS yields (upper) and flow-weighted period mean concentrations (lower). The lower figure shows that flow-weighted concentrations greatly reduce the variation caused by large fluctuations of annual discharge, which is better for site comparisons, especially when the monitoring periods are different (or precipitation is quite different).



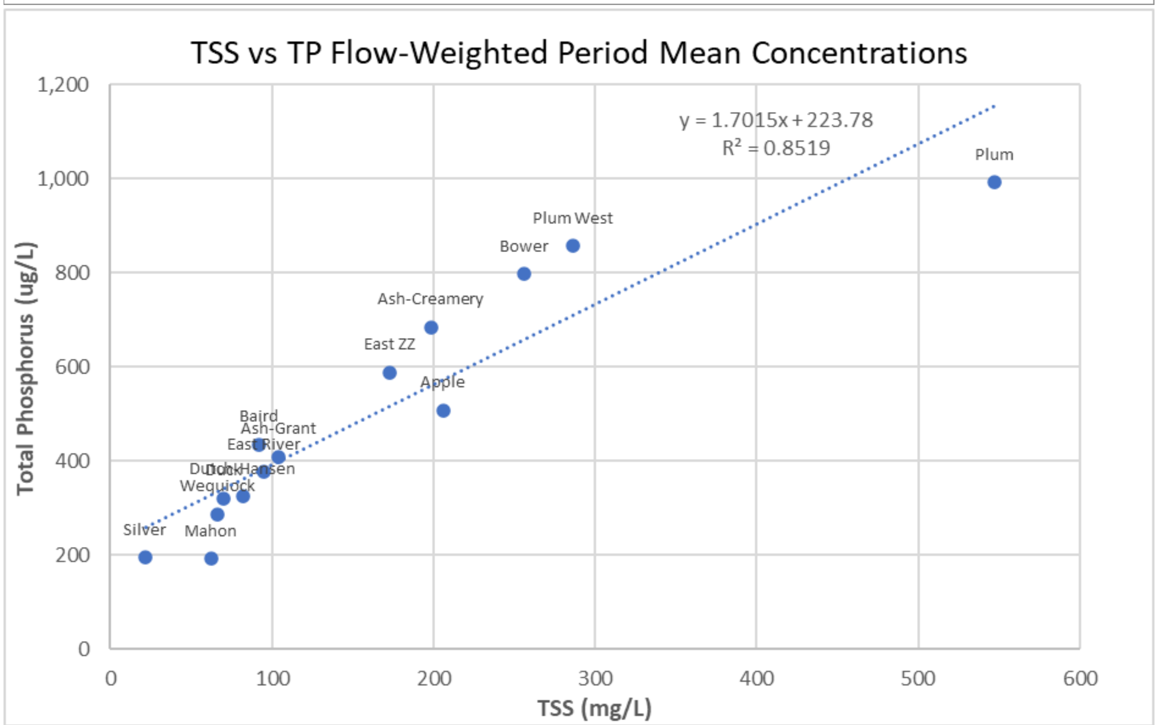
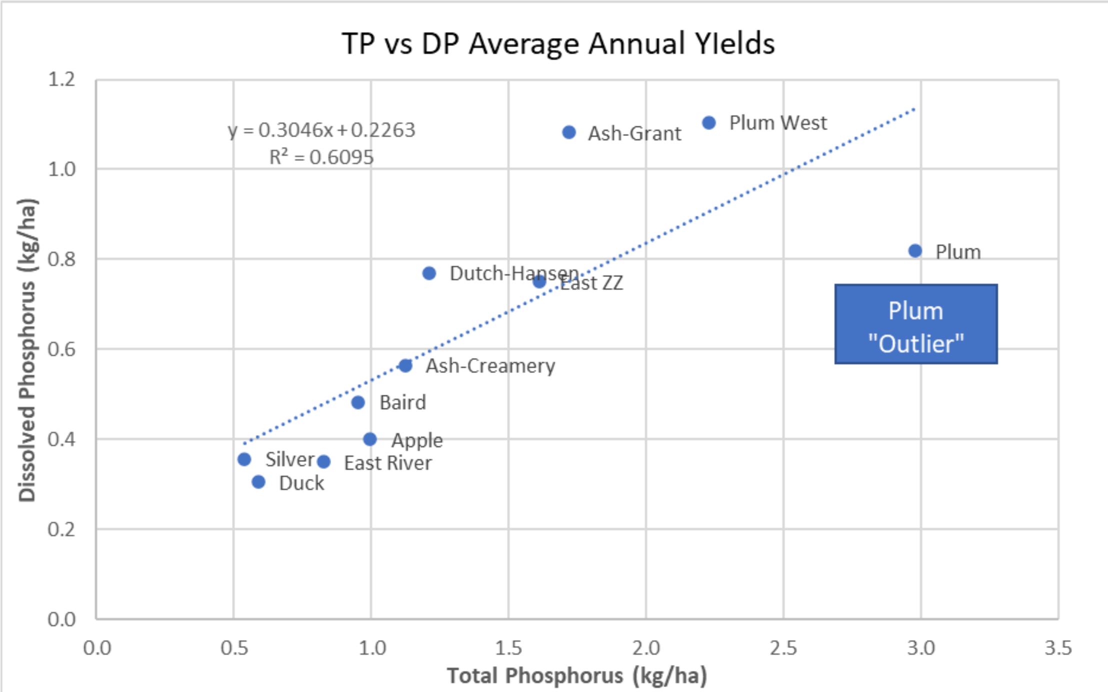


Figure 13. Average annual yield relationships between TSS and total phosphorus (upper) are compared to flow-weighted period mean concentration relationships (lower) at intensive stations in L. Fox sub-basin. The flow-weighted concentrations in the lower figure are typically better for site comparisons because they greatly reduce the variation caused by large fluctuations of annual discharge, especially when the monitoring periods are different (or precipitation is quite different). For example, average annual discharge was 164 mm at Ashwaubenon Creamery road station (2004-2006), compared to 419 mm at Ashwaubenon Hansen road station (2019-2021).



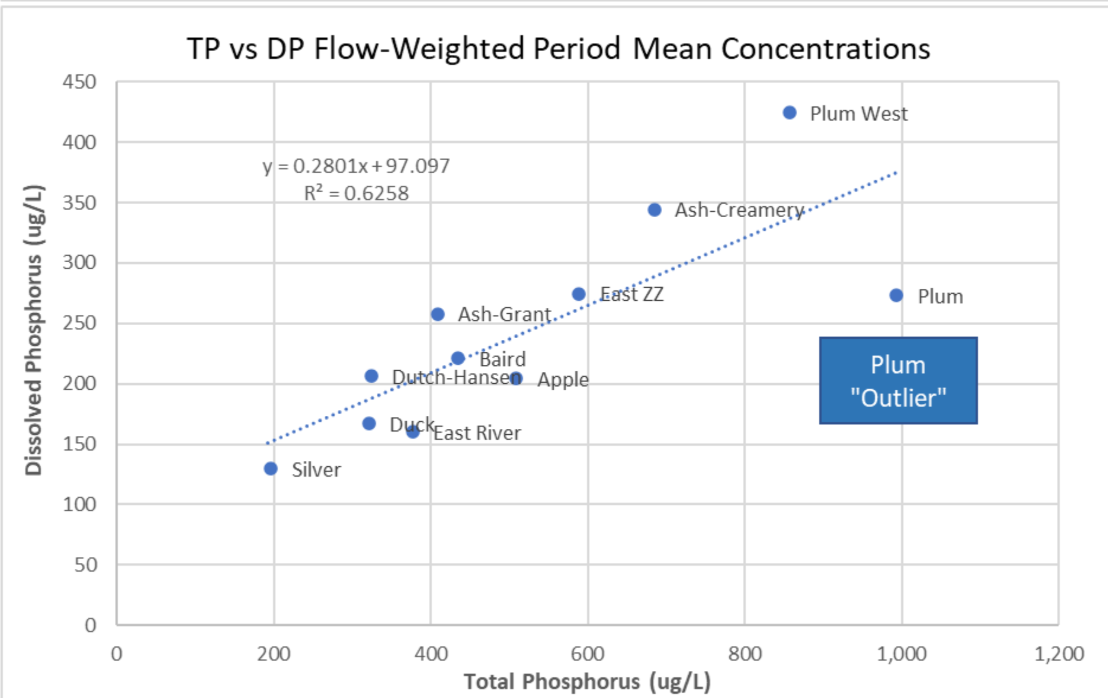
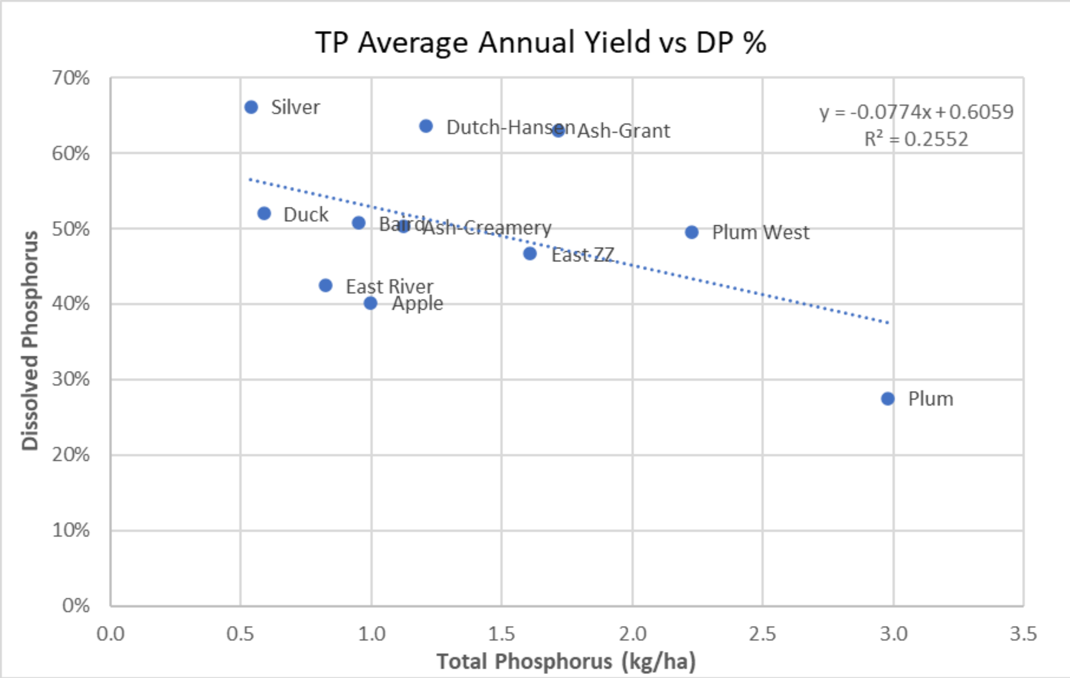


Figure 14. Average annual yield relationships between total and dissolved phosphorus (upper) are compared to flow-weighted period mean concentration relationships (lower) at intensive stations in L. Fox sub-basin. Apart from the Plum station, there was a good linear relationship between the two forms of phosphorus at these stations. The flow-weighted concentrations in the lower figure are better for site comparisons because they greatly reduce the variation caused by large fluctuations of annual discharge, especially when the monitoring periods are different (or precipitation is quite different). For example, average annual discharge was 164 mm at Ashwaubenon Creamery road station (2004-2006), compared to 419 mm at Ashwaubenon Hansen road station (2019-2021) (Table 8).



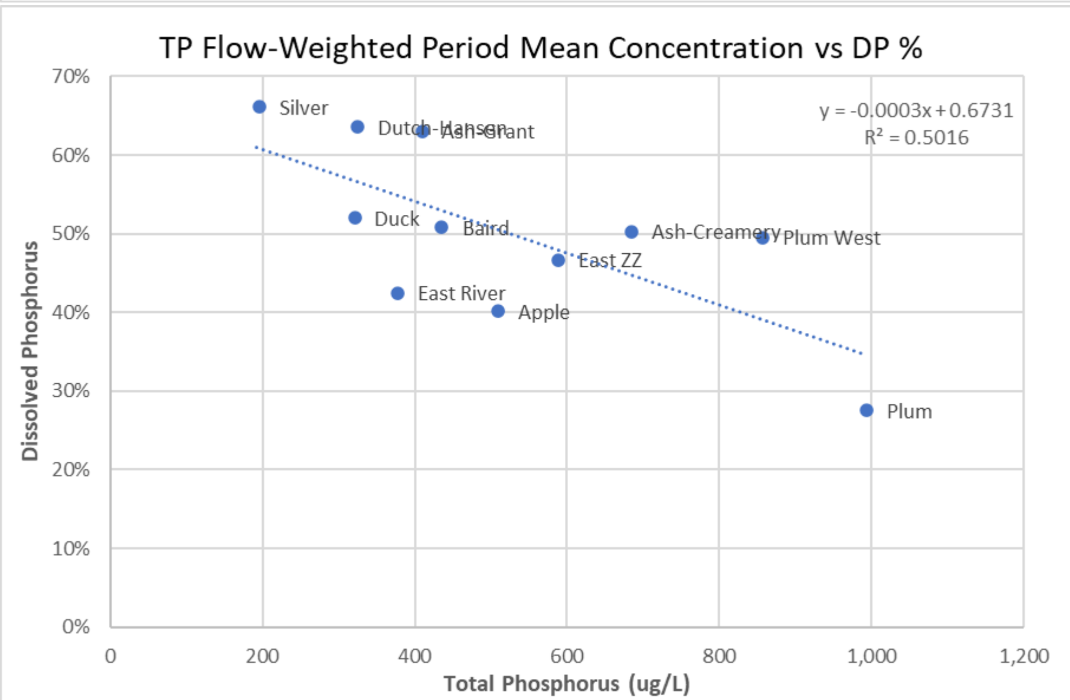


Figure 15. Average annual yield relationships between total phosphorus (TP) and percent dissolved phosphorus (DP) (upper) are compared to flow-weighted period mean concentration relationships (lower) at intensive stations in L. Fox sub-basin. In general, the percent DP decreased as flow-weighted period mean TP increased ($r^2 = 0.50$, lower figure). In addition, most stations have a DP fraction between 40 and 55%. The flow-weighted concentrations in the lower figure are better for site comparisons because they greatly reduce the variation caused by large fluctuations of annual discharge, especially when the monitoring periods are different (or precipitation is quite different). For example, average annual discharge was 164 mm at Ashwaubenon Creamery road station (2004-2006), compared to 419 mm at Ashwaubenon Hansen road station (2019-2021) (Table 8).