Appendix H.

Summary of NCWQR Data

Tables

Figures

A key part of the lower Sandusky TMDL is to examine nutrient and sediment loads in the basin, particularly given the observed increase of algal blooms in western Lake Erie. Recent analyses of water quality monitoring information indicate that dissolved phosphorus concentrations are on the rise. This observation is in spite of a downward trend in particulate phosphorus and suspended solids loads, due in large part to the success of erosion control efforts by the agricultural community. Increasing dissolved phosphorus concentrations are a significant concern because of its high bioavailability, which is a major contributor to algal growth problems.

Over the past thirty years, the National Center for Water Quality Research (NCWQR) at Heidelberg University has conducted one of the most comprehensive water quality monitoring programs found anywhere in the U.S. A part of their effort includes more than 30 years of intensive sampling at three locations in the Sandusky watershed (Honey Creek near Melmore, Sandusky River at Fremont, and Rock Creek at Tiffin). Several parameters measured relevant to the TMDL in the include flow, total suspended solids (TSS), nitrate plus nitrite (NN), total phosphorus (TP), and dissolved phosphorus (DP).

The purpose of this technical memorandum is to incorporate valuable information from the NCWQR program into the Sandusky source assessment. Water quality data is examined relative to hydrologic conditions with a focus on patterns related to source areas and delivery mechanisms. Key parts of this technical memo include:

- An analysis of hydrologic characteristics for the three monitoring locations shows that total flow in the watershed is dominated by storm-related runoff (i.e., surface- and inter-flow). This is consistent with the relatively high R-B flashiness index values for each site compared to other watersheds of similar size. Seasonally, the greatest flows occur from December through April Section H-1.
- A monthly analysis of the water quality data shows that the highest TSS, TP, NN, and DP loads occur from December through May/June, roughly coinciding with periods of greatest flows in the watershed Section H-2.
- Samples influenced by storm events were differentiated from those dominated by base flow conditions through hydrograph separation. Seasonal storm versus base load patterns were examined under a duration curve framework. TSS and TP storm loads were generally more than fifty percent greater than base flow loads across all zones and seasons; indicative of surface erosion processes. In contrast, storm loads for NN and DP were generally more than fifty percent greater only under moist conditions across all seasons; indicative of their dissolved nature and the role of interflow processes Section H-3.

H-1 Hydrology

Hydrology plays an important role in evaluating water quality. The hydrology of the Sandusky watershed is driven by local climate conditions. Basic hydrologic characteristics of this watershed (e.g., average annual flow and annual runoff) can be determined from flow records at the NCWQR monitoring sites. A quick analysis of the flow information offers some insight that can guide the water quality data review process. Table H-1 provides some initial summary information, both on the utility of certain flow metrics and on local watershed characteristics.

Total runoff, for example, often represents a starting point to understand key hydrologic processes in any given drainage. Common units are cubic feet per square mile or depth of runoff expressed as inches. Watershed specific differences can reflect factors such as increased impervious cover or diversions/withdrawals, as well as the influence of groundwater, wetlands, or lakes. The percentage of total runoff, which is either base flow or surface runoff, is another metric that can be used to evaluate the potential effect of stormwater in a watershed.

In addition to total runoff and percentage of base or surface flow, two other metrics (T_{Qmean} and Richards – Baker Flashiness Index) can help examine the effect of hydrology on water quality (Table H-2). These indicators have been used in studies that focused on evaluating regional patterns and trends in flow flashiness related to changes in land cover and land use (Baker, et al., 2004).

Table H-1. Summary statistics for several USGS in the Sandusky (WY 1984 – 2012)

Gage ID	Location	Area (mi^2)	Ann. avg. flow (cfs/ mi^2.)	Annual runoff Total (inches)	Base (%)	Surf. (%)
04197100	Honey Creek near Melmore	149	0.973	13.2	36%	64%
04197170	Rock Creek at Tiffin	34.6	0.965	13.1	24%	76%
04198000	Sandusky River at Fremont	1,251	1.025	13.9	30%	70%

Note: Ann. avg. flow = annual average flow; Base = baseflow; Surf. = surface flow.

Table H-2. Metric comparison of several USGS gages in the Sandusky watershed (WY 1984 – 2012)

Gage ID	Location	Area (mi^2)	Ann. avg. flow (cfs/ mi^2.) Median	Average	Metrics T_{Qmean}	R-B Flash
04197100	Honey Creek near Melmore	149	0.221	0.973	20.9	0.504
04197170	Rock Creek at Tiffin	34.6	0.182	0.965	15.5	0.843
04198000	Sandusky River at Fremont	1,251	0.315	1.025	22.8	0.380

Note: Ann. avg. flow = annual average flow; Base = baseflow; Surf. = surface flow.

R-B Flashiness is an indicator of the frequency and rapidity of short-term changes in stream flow. It is often a function of watershed size. T_{Qmean} represents the percentage of time that daily average flows exceed the annual average flow. A higher value represents hydrologic conditions that are closer to being normally distributed (generally, an indication of stable flow regimes). Conversely, lower T_{Qmean} values are typically associated with watersheds that may subjected to rapid changes. Again, reasons for differences in these two metrics should be considered in the water quality evaluation process.

Total flow for these three sites is dominated by storm-related runoff (i.e., surface- and inter-flow). This is consistent with the relatively high R-B flashiness index values for each site compared to other watersheds of similar size (Table H-2). Seasonally, the greatest flows occur from December through April (Figure H-1, Figure H-2, and Figure H-3).

Table H-3. Monthly precipitation

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
HC	1.76	1.69	2.23	1.73	1.10	0.84	0.59	0.37	0.21	0.37	0.84	1.47
RC	1.54	1.76	2.13	1.71	1.19	0.82	0.55	0.37	0.35	0.37	0.86	1.45
SR	1.78	1.80	2.18	1.73	1.31	0.99	0.68	0.39	0.29	0.39	0.83	1.53

Note: HC = Honey Creek; RC = Rock Creek; SR = Sandusky River.

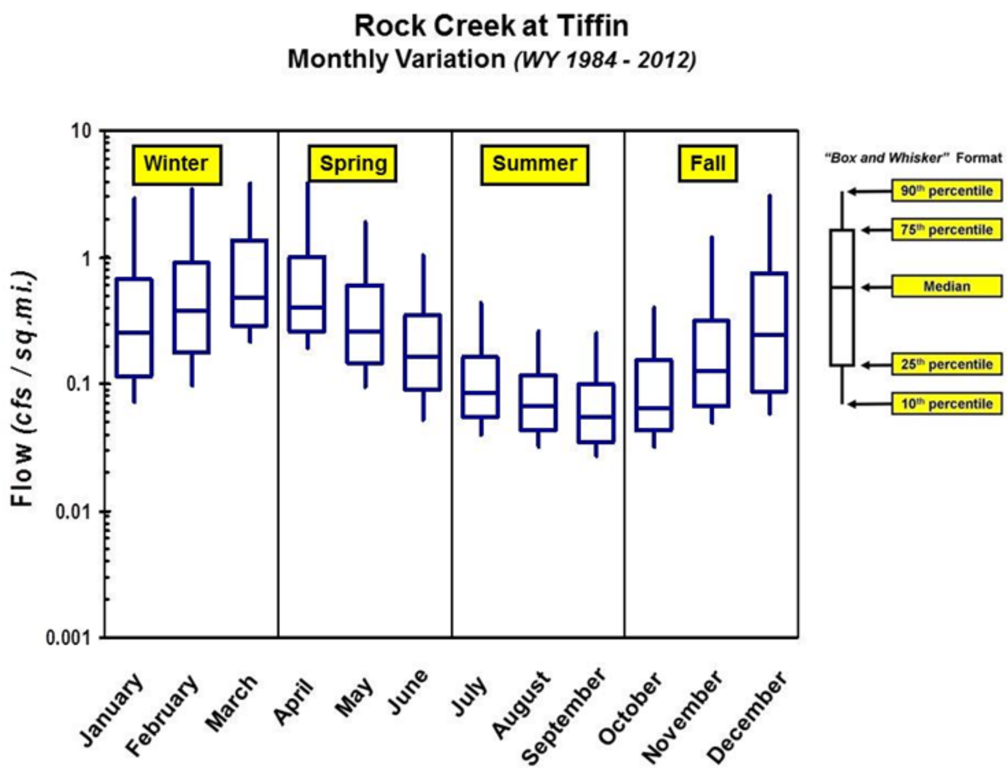

Figure H-1. Seasonal variation of Rock Creek flows.

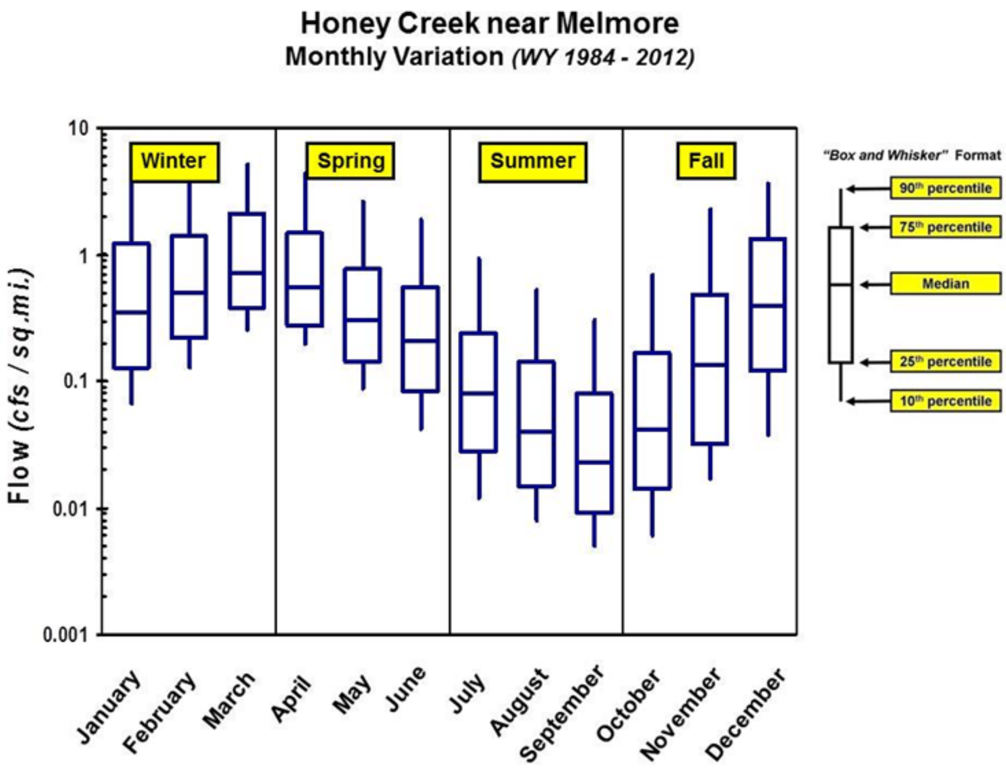

Figure H-2. Seasonal variation of Honey Creek flows.

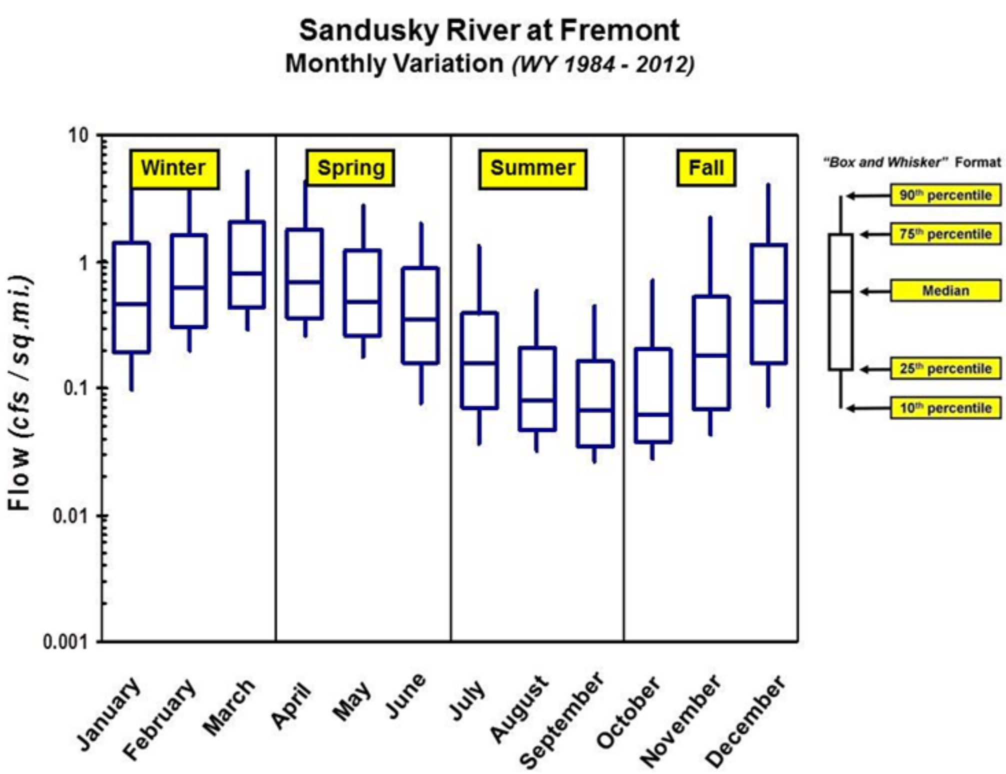

Figure H-3. Seasonal variation of Sandusky River flows.

Flow duration curves are another effective method to characterize hydrologic conditions and are an important component of an overall hydrologic analysis. Duration curves provide a quantitative summary that represents the full range of flow conditions, including both magnitude and frequency of occurrence (U.S. EPA 2007). Figure H-4 depicts flow duration curves for the three Sandusky watershed NCWQR sites. These duration curves are expressed as unit area flows (i.e., cfs per square mile) for direct comparison between sites.

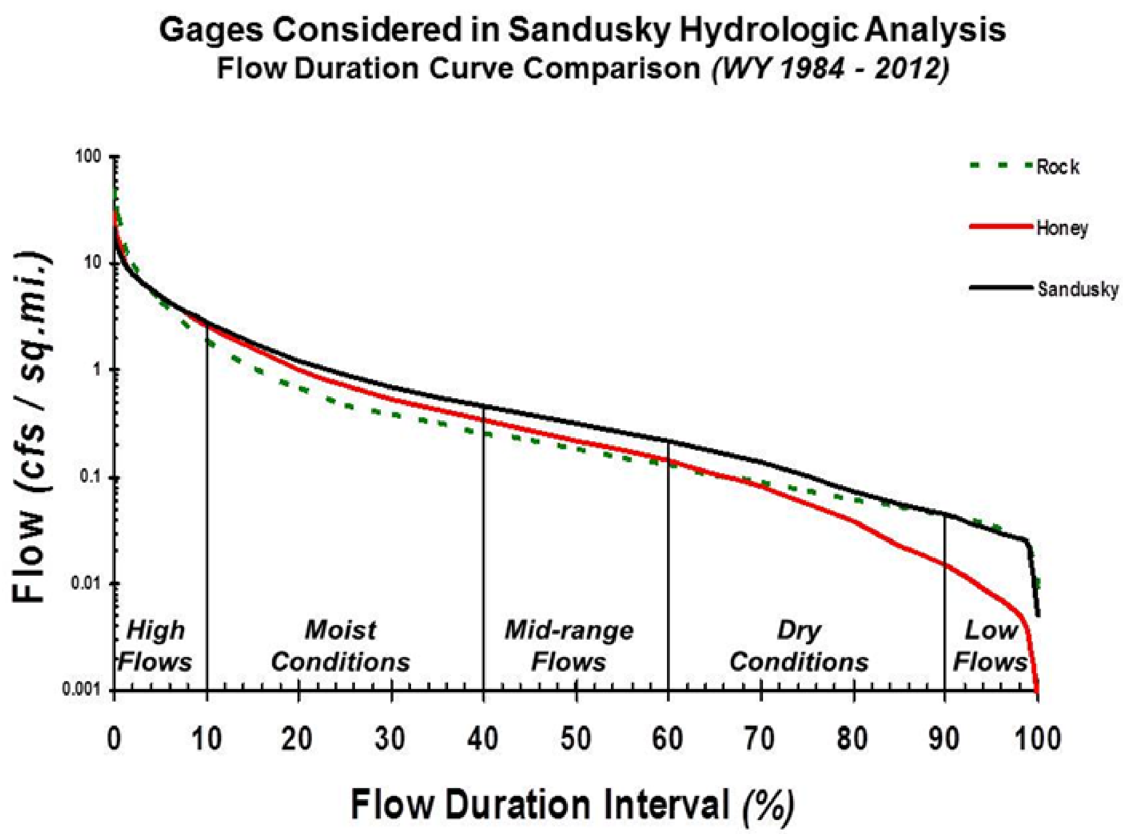

Figure H-4. Flow duration curve comparison of several Sandusky watershed USGS gages.

H-2 Water Quality

Water quality parameters examined in this assessment include dissolved phosphorus (DP), total phosphorus (TP), total suspended solids (TSS), and nitrate plus nitrite (NN). Table H-4 provides a general overview of water quality at each site with respect to annual average loads. Values are expressed as unit area (i.e., annual average divided by the drainage area) daily loads in order to make a relative comparison between sites.

Table H-4. Annual average unit area loads for NCWQR Sandusky watershed sites

Location	Area (mi^2)	Period of record	Unit area loads			
			mg/acre per day		grams/acre per day	
			DP	TP	TSS	NN
Rock Creek	34.6	10/1982 – 10/2012	470	5,027	3,363	30.3
Honey Creek	149	1/1976 – 10/2012	583	3,076	1,350	31.7
Sandusky River	1,251	10/1974 – 10/2012	500	2,994	1,555	32.8

Note: DP = dissolved phosphorus; mg = milligram; NO2+NO3 = nitrite plus nitrate; TP = total phosphorus; TSS = total suspended solids.

H-2.1 Seasonal Variation

Another important aspect of the water quality assessment is an examination of seasonal loading patterns. Table H-5 provides a tabular summary of the monthly variation in unit area loads for the Sandusky River at Fremont site (depicted graphically in Figure H-5, Figure H-6, Figure H-7, and Figure H-8). A monthly analysis of the water quality data shows that the highest DP, TP, TSS, and NN loads occur from December through May/June, roughly coinciding with periods of greatest flows in the watershed. This same monthly variation pattern is also reflected in water quality monitoring data collected for Honey and Rock Creeks.

Table H-5. Monthly water quality loading patterns -- Sandusky River

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Milligrams per acre per day												
DP	726	907	801	481	444	414	232	167	217	151	461	854
TP	3,775	4,952	5,456	4,252	3,259	3,761	1,457	753	813	395	1,828	3,607
Grams per acre per day												
TSS	1,454	2,402	2,833	2,289	1,867	2,736	907	369	380	124	663	1,347
NN	40.6	49.1	47.8	46.7	49.1	46.2	17.4	4.5	4.9	5.1	19.0	40.5

Note: DP = dissolved phosphorus; mg = milligram; NN = nitrite plus nitrate; TP = total phosphorus; TSS = total suspended solids.

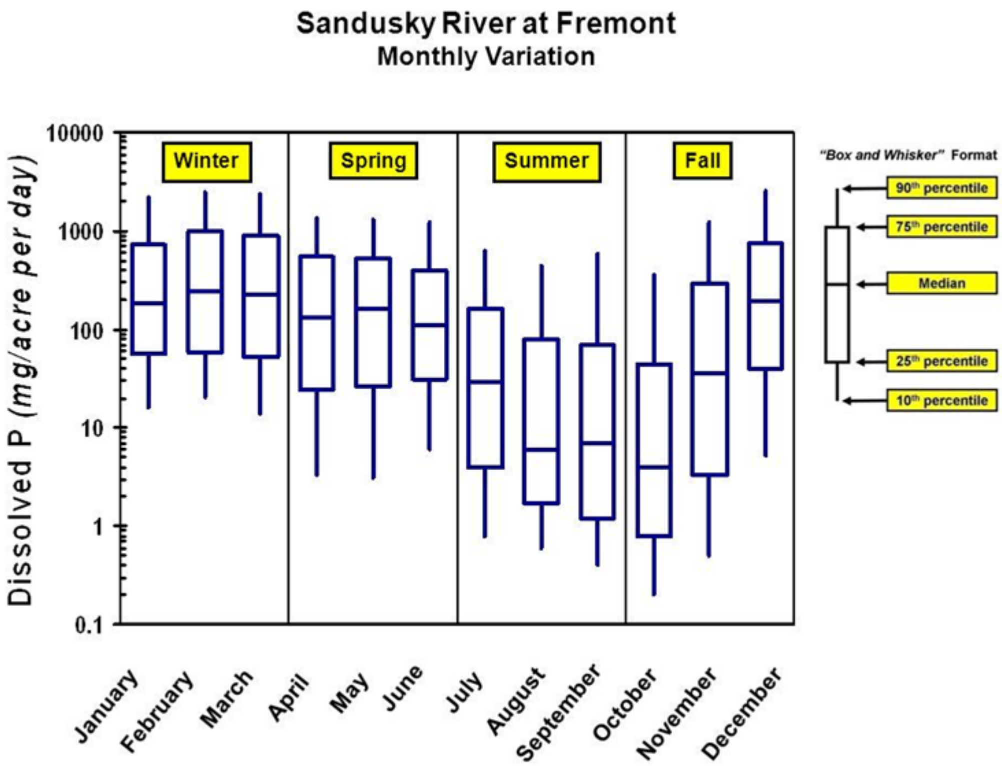

Figure H-5. Monthly variation of Sandusky River dissolved phosphorus.

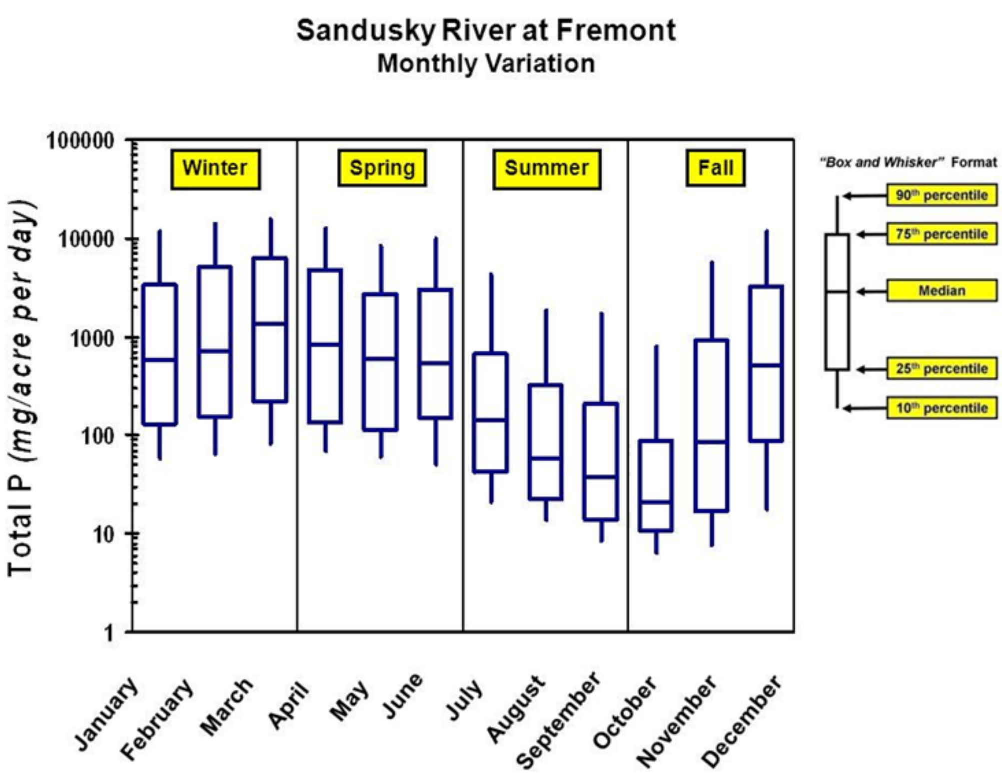

Figure H-6. Monthly variation of Sandusky River total phosphorus.

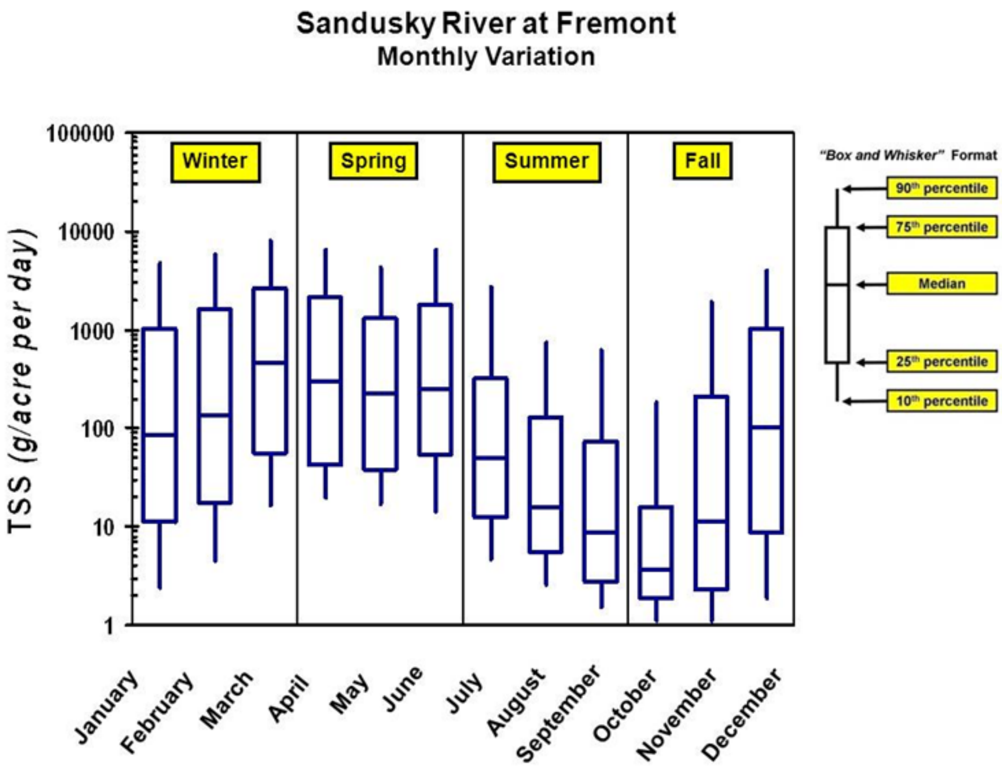

Figure H-7. Monthly variation of Sandusky River total suspended solids.

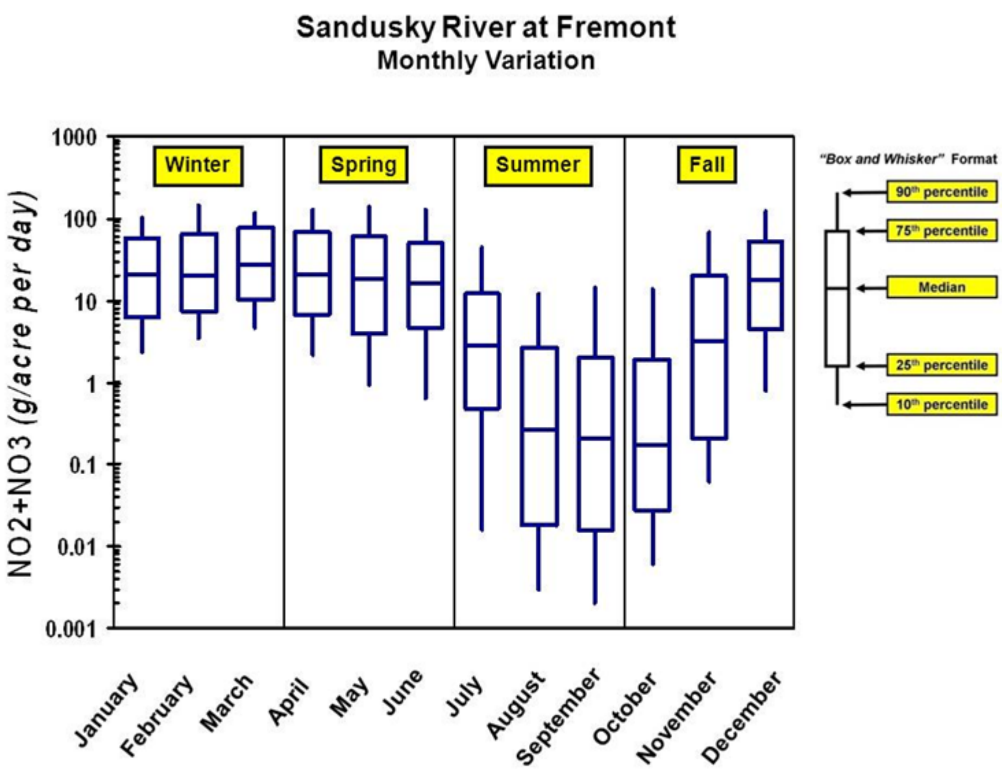

Figure H-8. Monthly variation of Sandusky River nitrite plus nitrate.

H-2.2 Long-Term Trends

Loading trends over the long-term were evaluated for each of the NCWQR sites. Generally, between the periods of 1974-1997 and 1998-2012, DP increased while TSS decreased (Table H-6). In Rock Creek, larger decreases in TP and NN also occurred whereas those two parameters only slightly changed for Honey Creek and the Sandusky River.

Table H-6. Loading trends for NCWQR Sandusky watershed sites

Parameter	Location	Unit area loads		Change (%)
		1974-1997	1998-2012	
DP	Rock Creek	333	623	87%
	Honey Creek	403	845	110%
	Sandusky River	395	645	63%
TP	Rock Creek	6,161	3,678	-40%
	Honey Creek	3,045	3,122	3%
	Sandusky River	2,978	3,019	1%
TSS	Rock Creek	4,435	2,089	-53%
	Honey Creek	1,572	1,018	-35%
	Sandusky River	1,722	1,311	-24%
NN	Rock Creek	37.2	22.1	-41%
	Honey Creek	32.2	30.9	-4%
	Sandusky River	32.6	33.0	1%

Note: DP = dissolved phosphorus; mg = milligram; NN = nitrite plus nitrate; TP = total phosphorus; TSS = total suspended solids.

H-3 Effects of Storm Events on Loads

Samples influenced by storm events were differentiated from those dominated by base flow conditions through hydrograph separation. Seasonal storm versus base load patterns were examined under a duration curve framework. TSS and TP storm loads were generally more than fifty percent greater than base flow loads across all zones and seasons; indicative of surface erosion processes. In contrast, storm loads for NN and DP were generally more than fifty percent greater only under moist conditions across all seasons; indicative of their dissolved nature and the role of interflow processes. These analyses are summarized in the following tables and figures.

Table H-7. Average storm flow load increase over base flow: Sandusky River - dissolved phosphorus

Season	Duration Curve Zone				
	High	*Moist*	*Mid-Range*	*Dry*	*Low*
Winter		95%			
Spring	50%	101%	114%	67%	
Summer		80%		72%	79%
Fall	228%	89%			
Notes: Only average load value increases over 50% noted. Shaded cell indicates greater than 50% increase in median value.					

Table H-8. Average storm flow load increase over base flow: Sandusky River - total phosphorus

Season	Duration Curve Zone				
	High	*Moist*	*Mid-Range*	*Dry*	*Low*
Winter	128%	164%	100%		
Spring	151%	204%	170%	69%	
Summer	141%	97%		78%	
Fall	418%	149%		95%	
Notes: Only average load value increases over 50% noted. Shaded cell indicates greater than 50% increase in median value.					

Table H-9. Average storm flow load increase over base flow: Sandusky River - total suspended solids

Season	Duration Curve Zone				
	High	***Moist***	***Mid-Range***	***Dry***	***Low***
Winter	184%	221%	198%		
Spring	210%	356%	313%	120%	
Summer	373%	108%		92%	60%
Fall	525%	298%	116%	213%	
Notes: Only average load value increases over 50% noted. Shaded cell indicates greater than 50% increase in median value.					

Table H-10. Average storm flow load increase over base flow: Sandusky River - nitrite plus nitrate

Season	Duration Curve Zone				
	High	***Moist***	***Mid-Range***	***Dry***	***Low***
Winter		69%			
Spring		96%	69%	86%	
Summer	282%	53%			97%
Fall	89%	68%			
Notes: Only average load value increases over 50% noted. Shaded cell indicates greater than 50% increase in median value.					

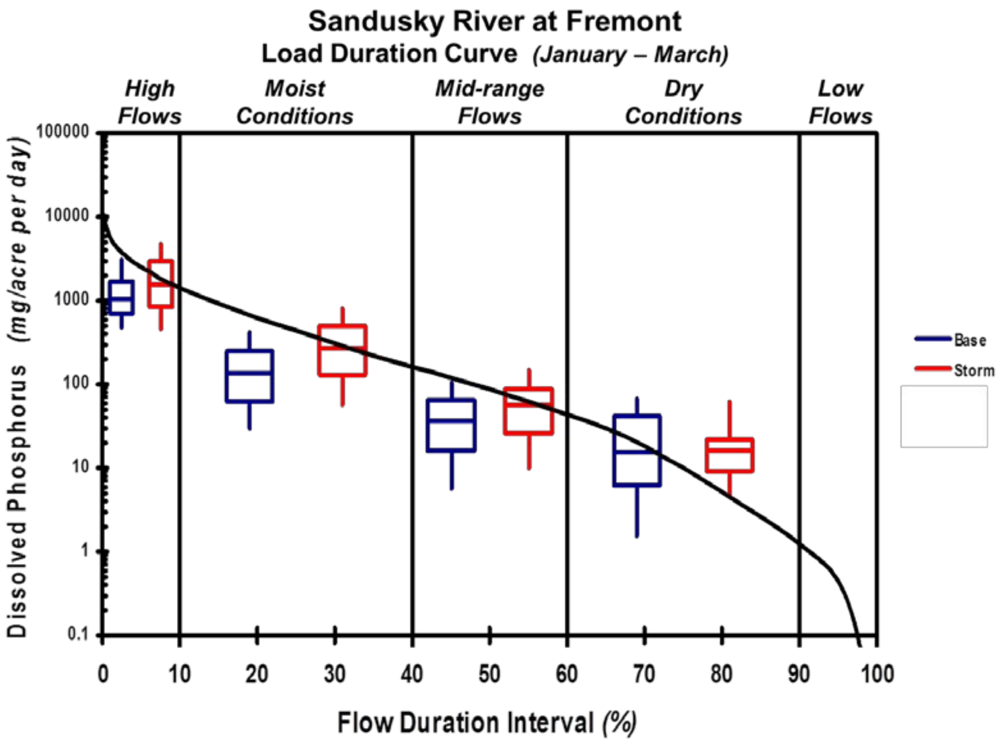

Figure H-9. Sandusky River (January through March): Dissolved phosphorus.

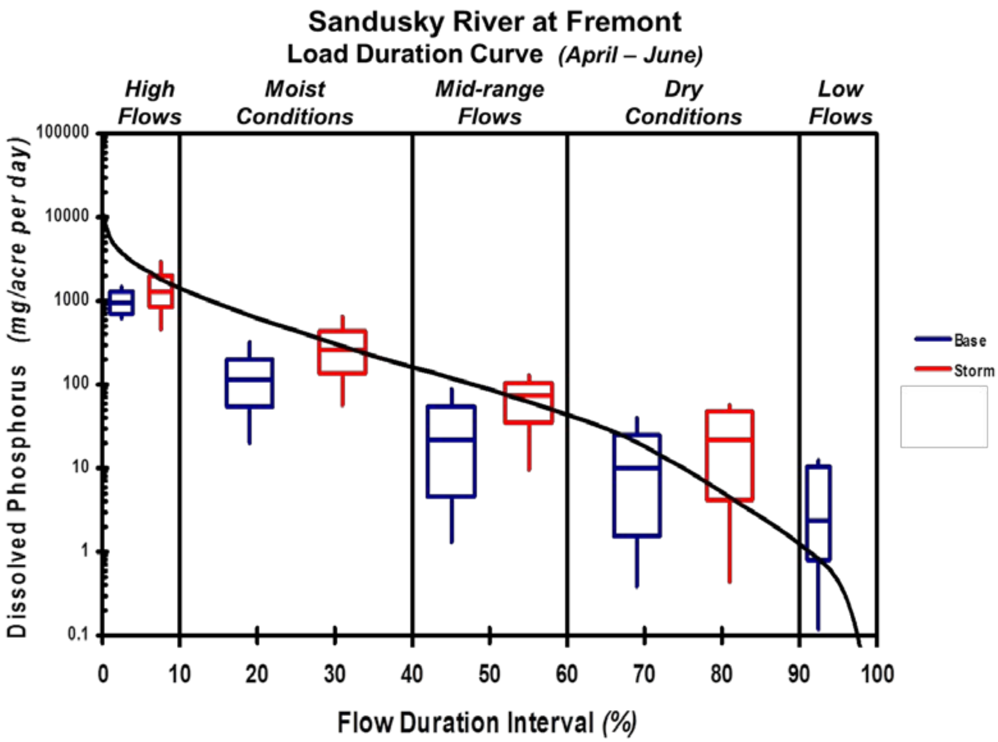

Figure H-10. Sandusky River (April through June): Dissolved phosphorus.

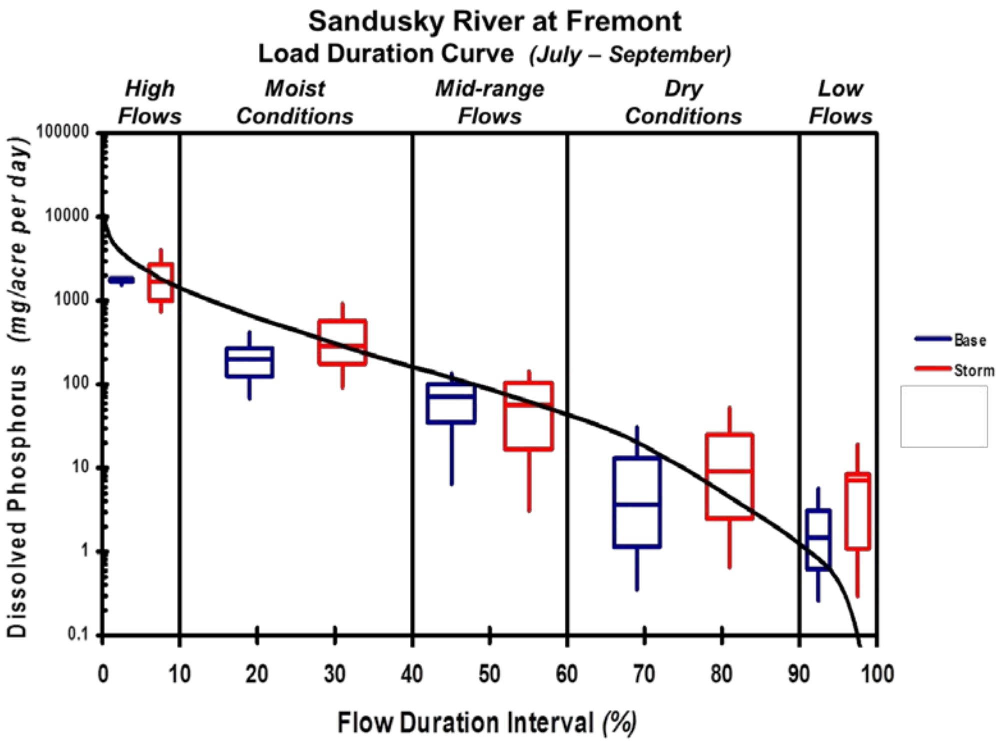

Figure H-11. Sandusky River (July through September): Dissolved phosphorus.

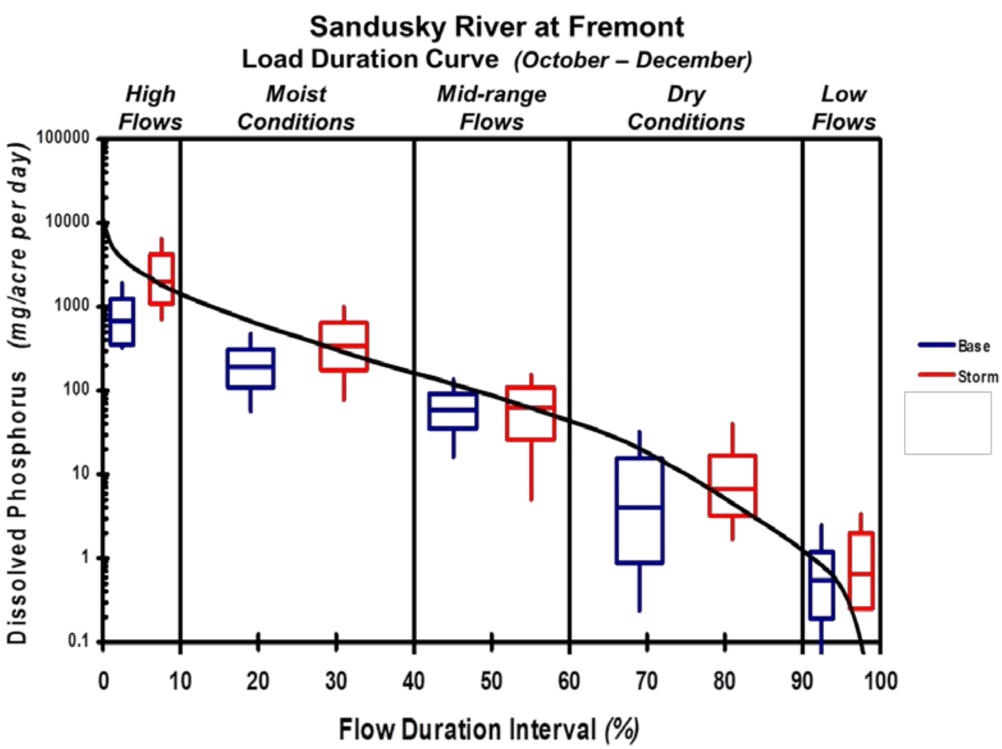

Figure H-12. Sandusky River (October through December): Dissolved phosphorus.

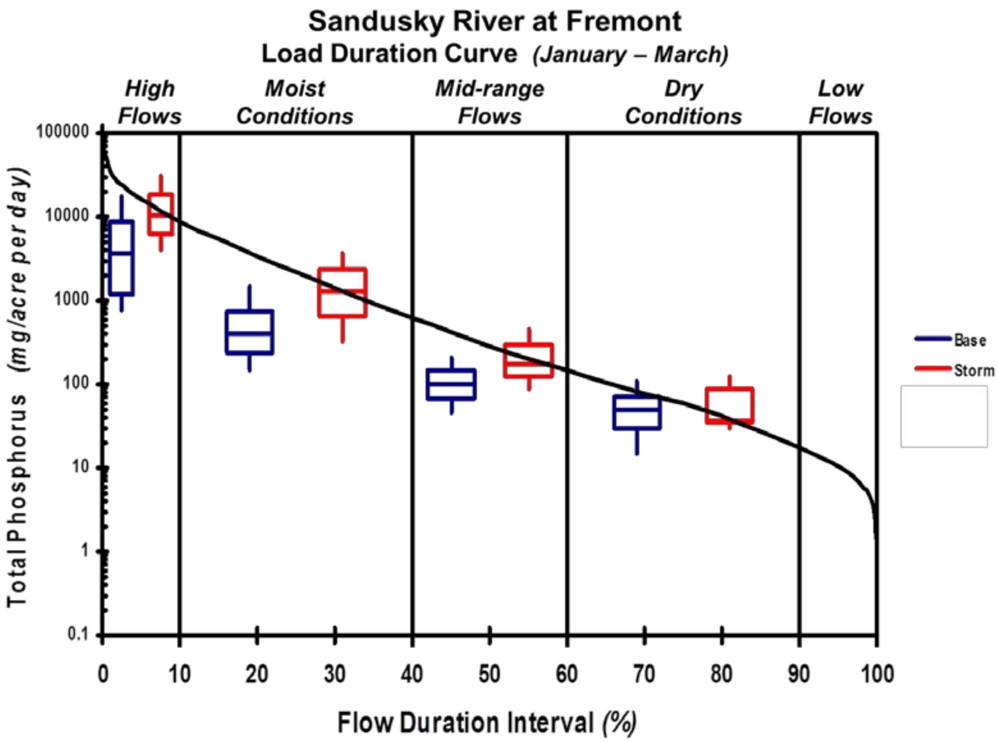

Figure H-13. Sandusky River (January through March): Total phosphorus.

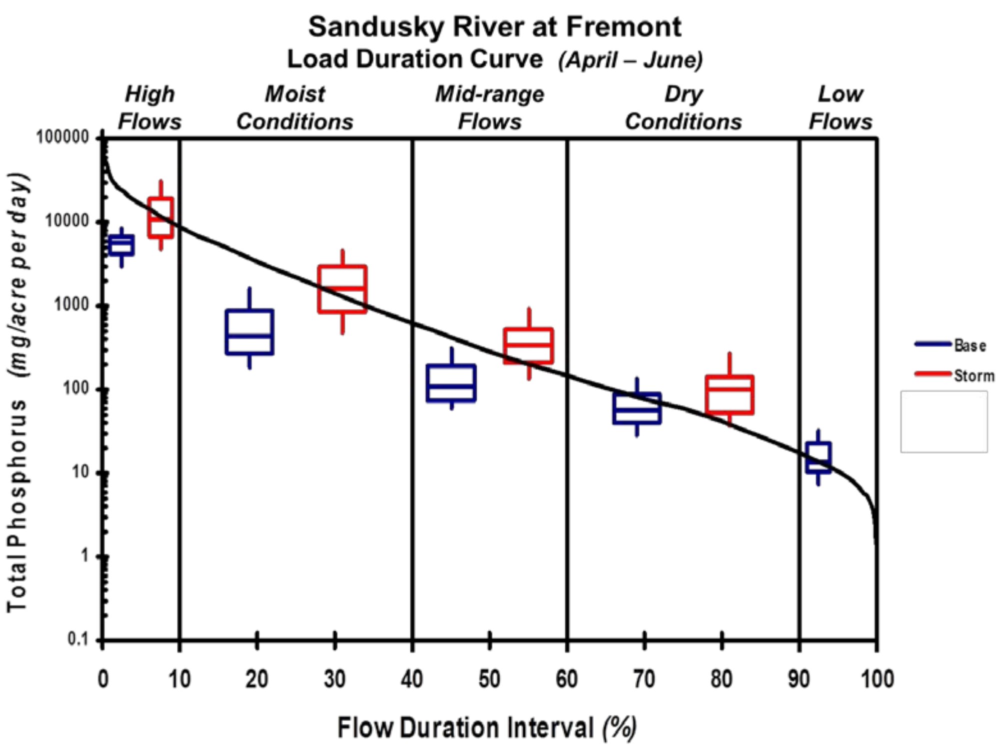

Figure H-14. Sandusky River (April through June): Total phosphorus.

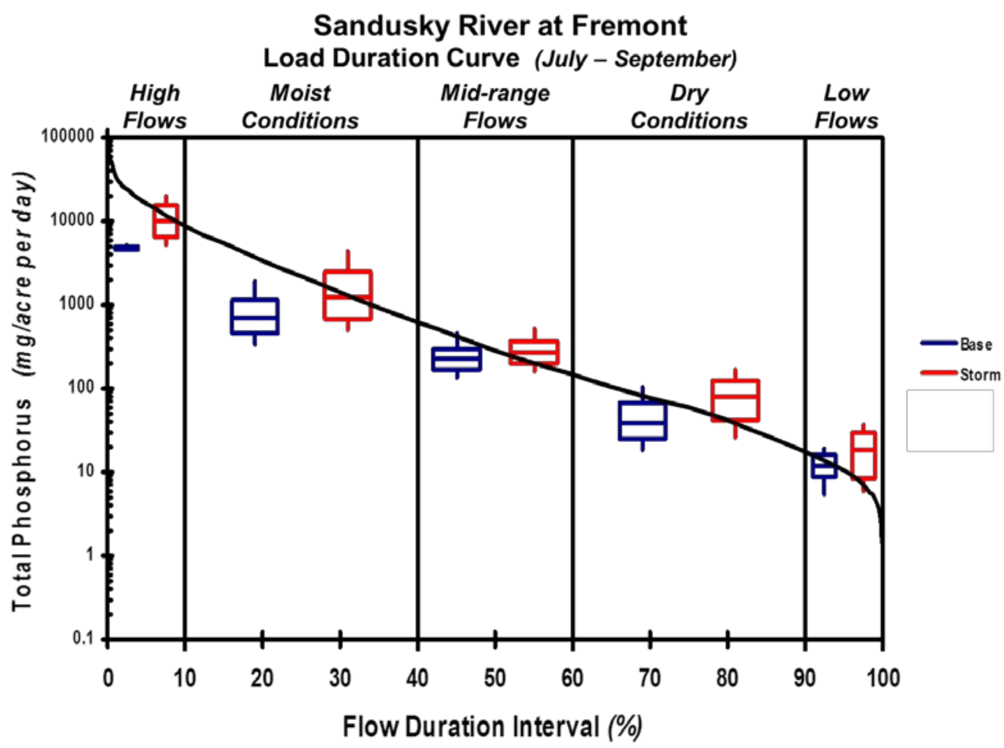

Figure H-15. Sandusky River (July through September): Total phosphorus.

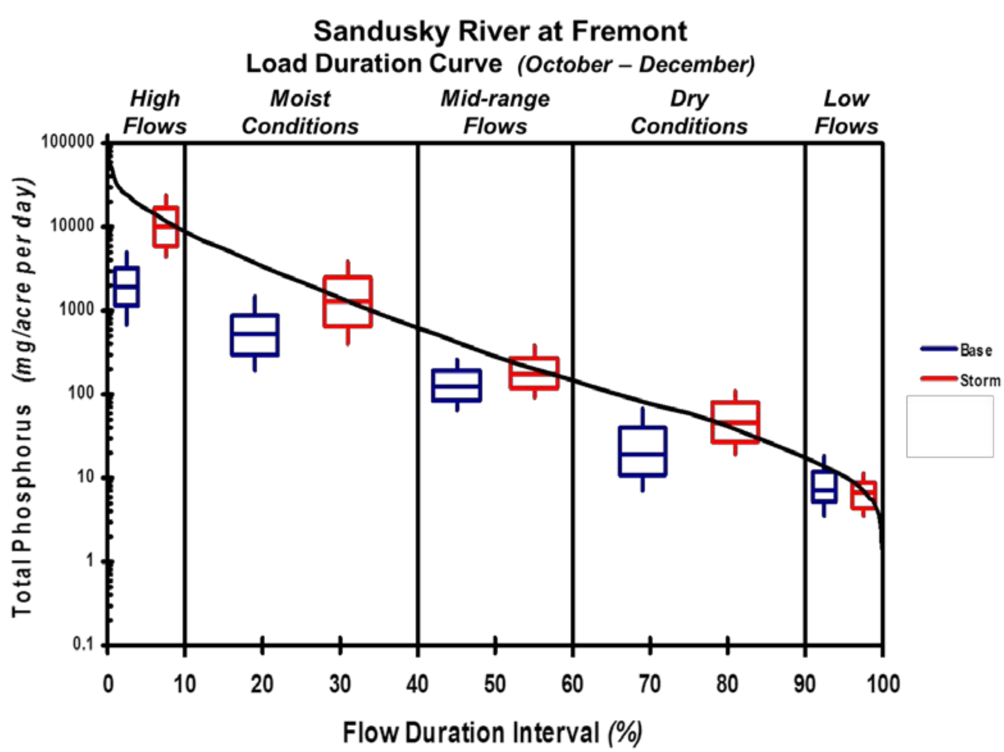

Figure H-16. Sandusky River (October through December): Total phosphorus.

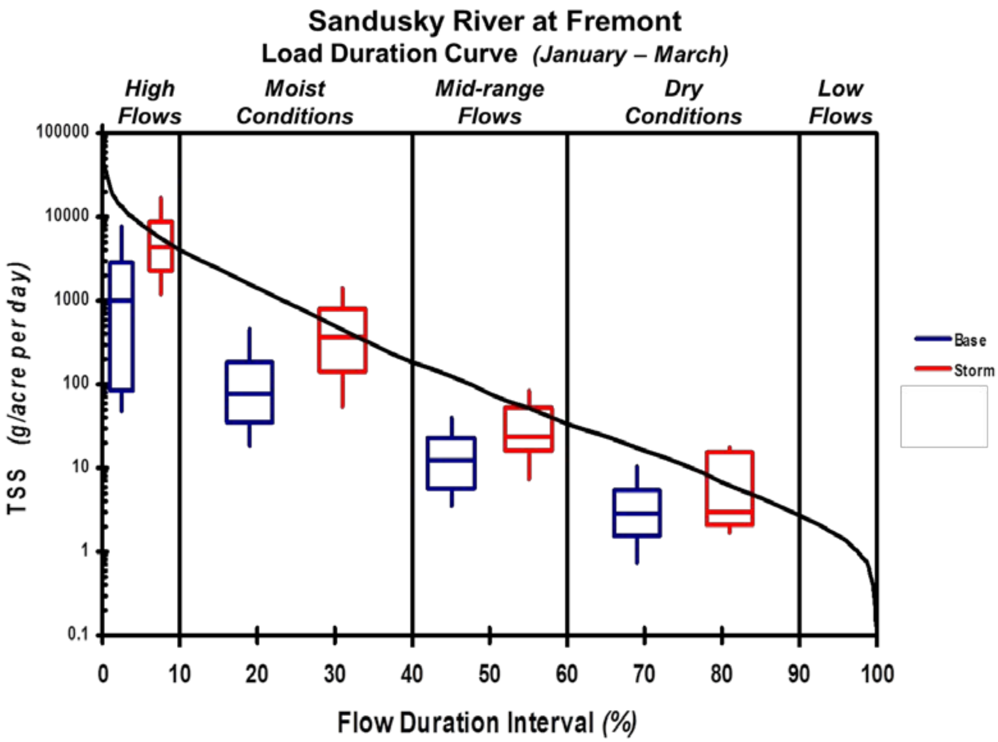

Figure H-17. Sandusky River (January through March): Total suspended solids.

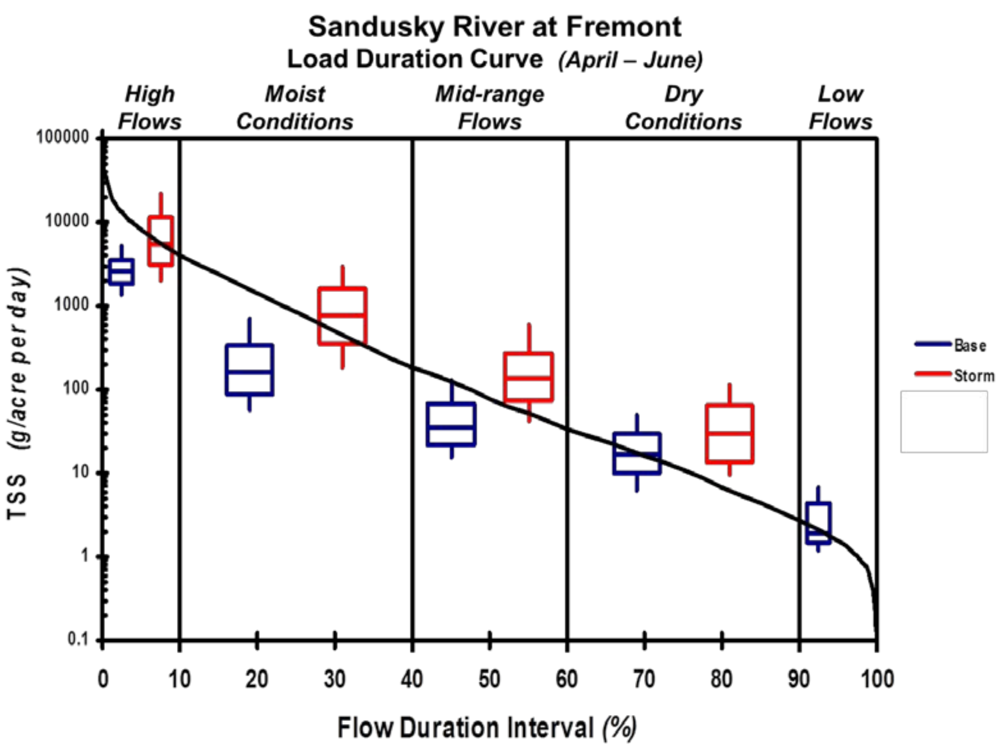

Figure H-18. Sandusky River (April through June): Total suspended solids.

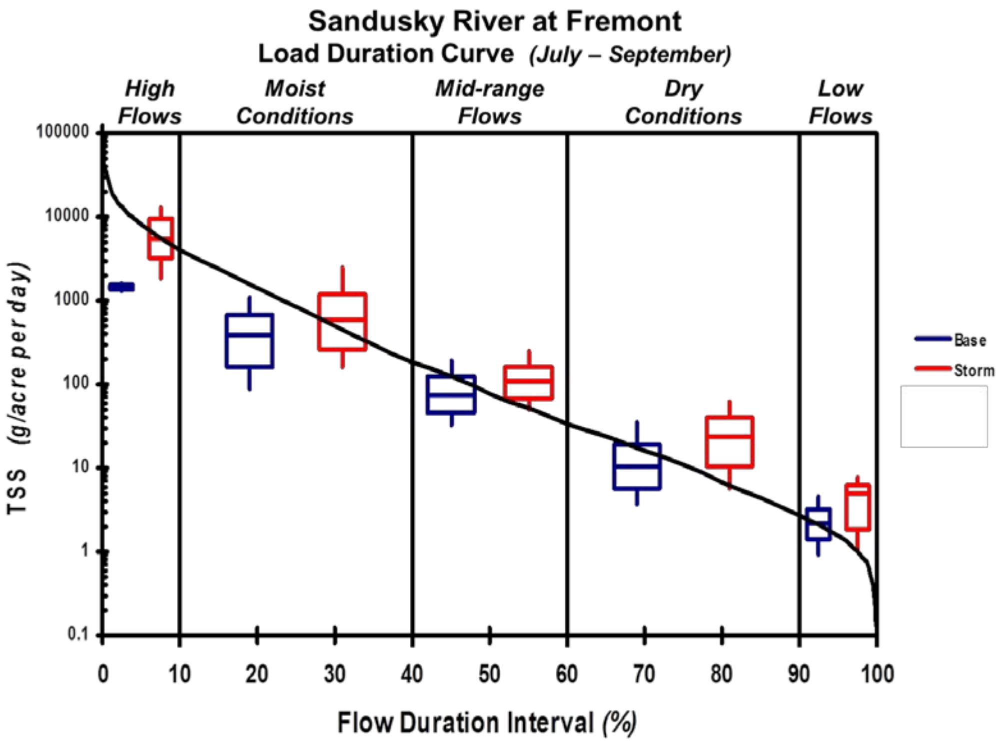

Figure H-19. Sandusky River (July through September): Total suspended solids.

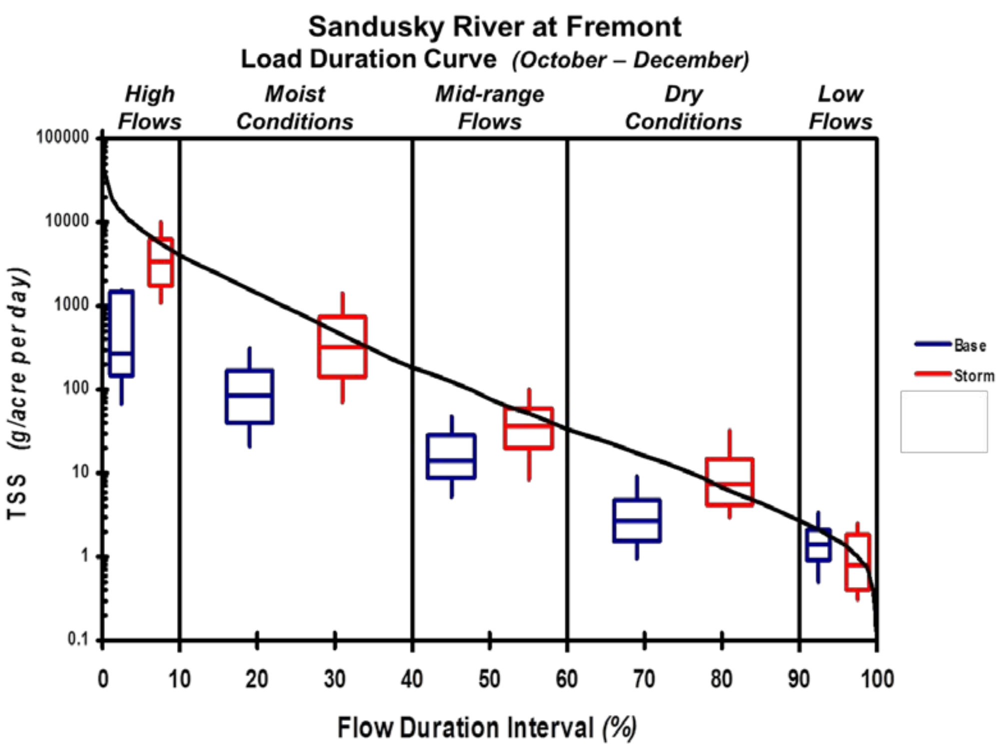

Figure H-20. Sandusky River (October through December): Total suspended solids.

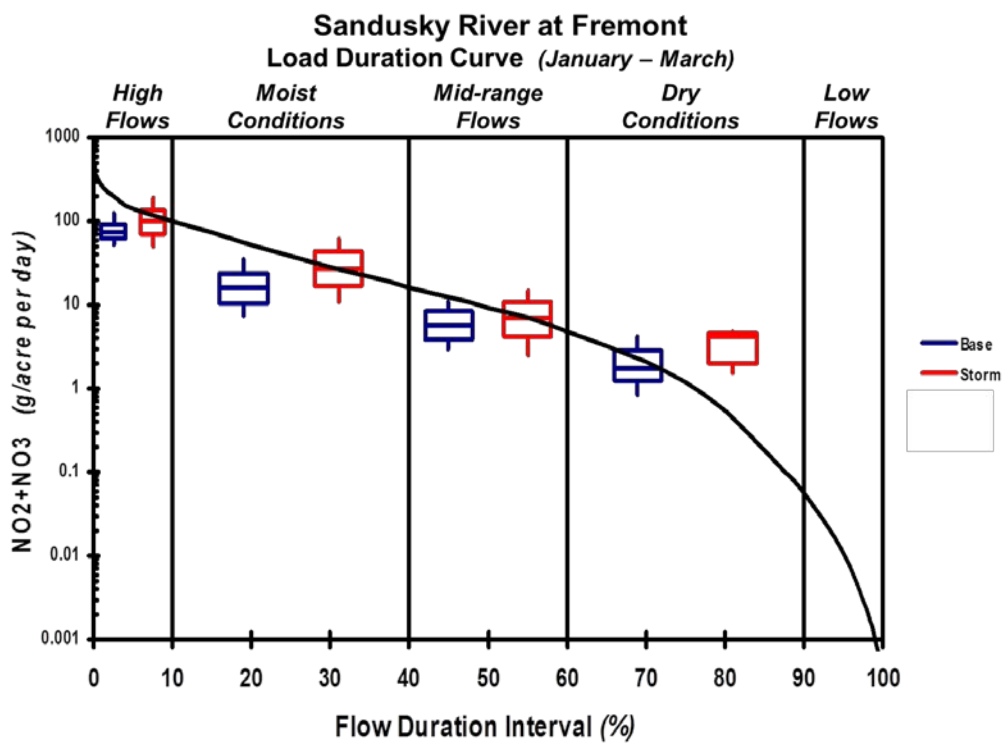

Figure H-21. Sandusky River (January through March): Nitrite plus nitrate.

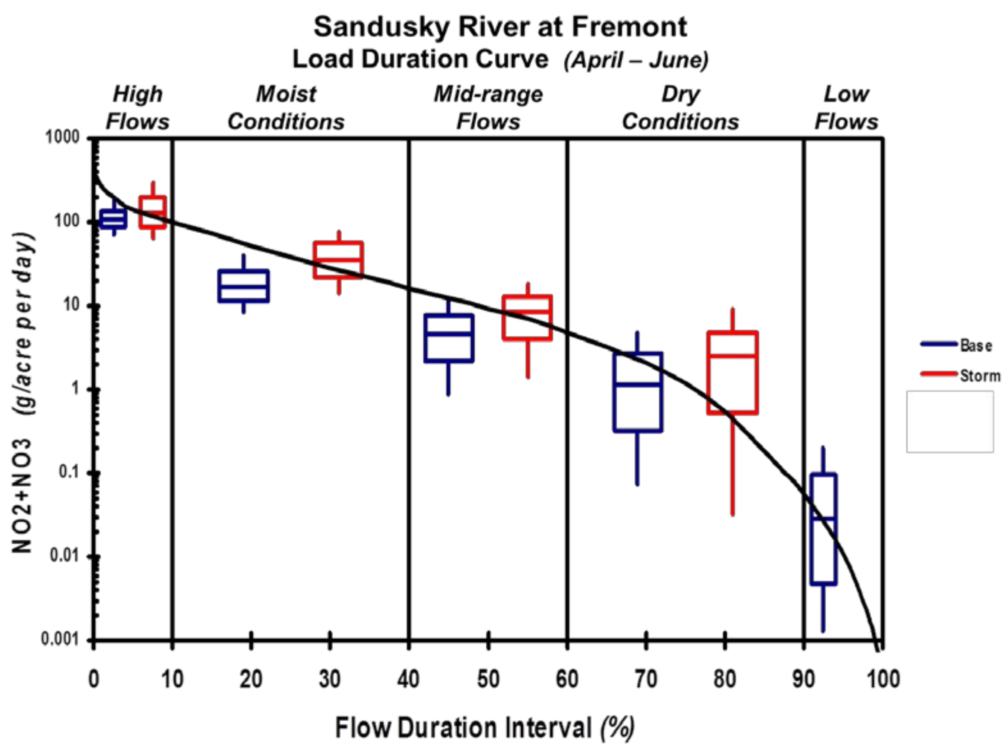

Figure H-22. Sandusky River (April through June): Nitrite plus nitrate.

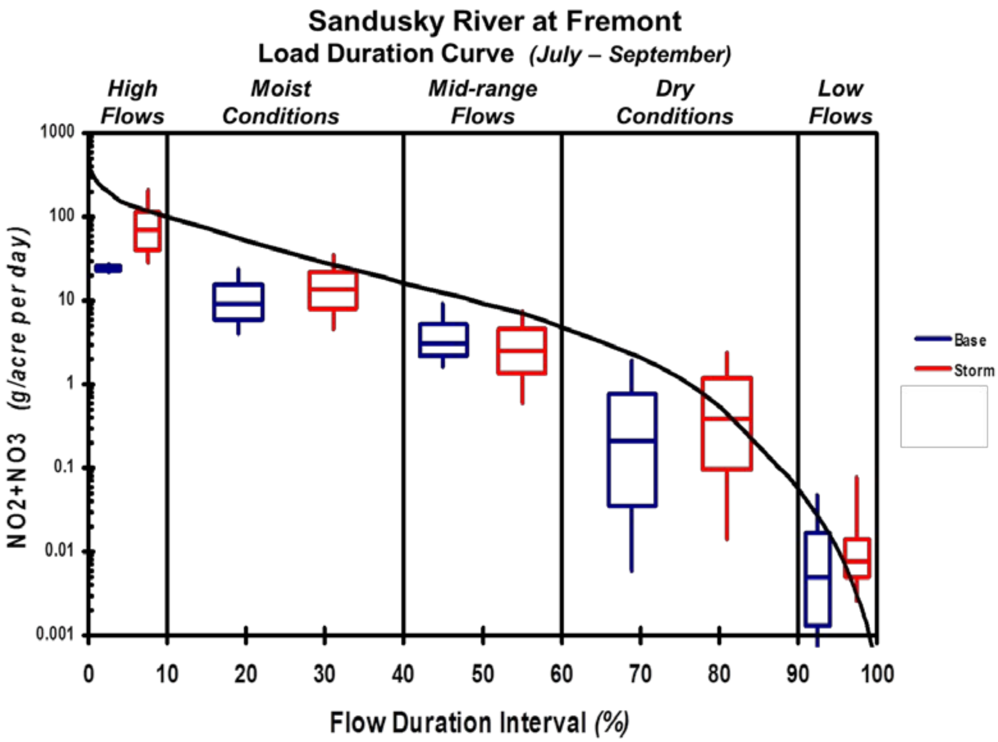

Figure H-23. Sandusky River (July through September): Nitrite plus nitrate.

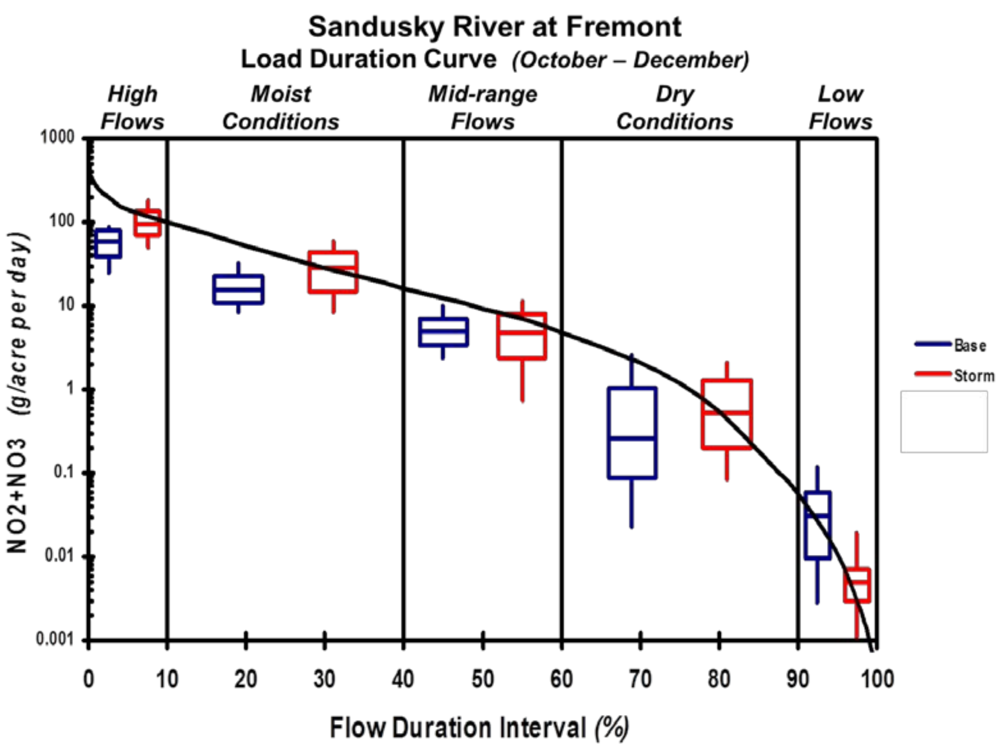

Figure H-24. Sandusky River (October through December): Nitrite plus nitrate.