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Reports from the Ohio Tributary Monitoring Program

Annual Loads of Sediment, Nutrients, and Chloride

This report presents information on the total amount of water and five water quality constituents transported annually in seven of the largest rivers within the state of Ohio, which together constitute the Ohio Tributary Monitoring Program. In addition, comparable values are provided for three smaller rivers or streams in Ohio and for the River Raisin in Michigan. The report covers water years[1] 1996 to 2001.

Stations

Basic information about the stations is shown in Table 1. More detailed information about the location of the monitoring stations, the sampling approach, and the analysis of samples is provided in a companion report: Program Description.

Table 1. Characteristics of the seven major Ohio Tributary Monitoring Program stations, and four additional stations included in this report.

River	Drainage Area above Station (sq.mi.)	Land use above station, by percent*			
		Agri-culture**	Urban	Wooded	Other***
River Raisin at Monroe, MI USGS 04176500	1,042				
Maumee R. at Waterville USGS 04193500	6,330	89.9	1.2	7.3	1.6
Sandusky R. near Fremont USGS 04198000	1,253	84.1	0.9	13.0	2.0
Rock Creek at Tiffin USGS 04197170	34.6	82.0	0.9	16.1	1.0
Honey Creek at Melmore USGS 04197100	149	85.6	0.6	12.5	1.3
Vermilion R. at Mill Hollow USGS 04199500	262				
Cuyahoga R. at Independence USGS 04208000	708	30.4	9.6	50.1	9.9

Table 1. Characteristics of the stations, continued

River	Drainage Area above Station (sq.mi.)	Land use above station, by percent*			
		Agri-culture**	Urban	Wooded	Other***
Grand R. at Painesville USGS 04212100	686	40.0	0.9	45.2	13.1
Muskingum R. at McConnelsville USGS 03150000	7,420	52.0	1.7	43.4	2.9
Scioto R. at Chillicothe USGS 03231500	3,854	80.2	4.6	12.9	2.3
Great Miami R. below Miamisburg USGS 03271601	2,685	82.1	4.7	10.3	2.9

* Source: ODNR Division of Real Estate and Land Management

** Includes open urban/suburban areas such as lawns

*** Includes shrub/scrub lands, open water, non-forested wetlands, barren ground

Methods

Annual discharge was calculated by summing up mean daily flows determined by the U.S. Geological Survey. Annual loads were calculated using AutoBeale, a computer implementation of the Beale Ratio Estimator. Information about this approach to load calculation can be found in Richards et al. (1996). Because the stations on the Scioto and Great Miami rivers did not begin operation until part way through the 1996 water year, annual loads were calculated for these stations beginning with WY1997.

Results

The resulting loads are shown in Table 2 on the following page. Q represents discharge, SS is suspended solids (sediment), TP is total phosphorus, SRP is soluble reactive phosphorus. Nitrate is expressed as nitrogen.

Discussion

The Beale Ratio Estimator provides an estimate of the uncertainty associated with its load estimates. For the calculations presented in Table 2, the sediment loads are typically accurate to about ±20% or better, total phosphorus ±10% or better, and the other constituents ±5% or better (95% confidence intervals).

As a general pattern, the annual discharge during the first three years was substantially greater than that during the last three years. The ratio ranges from 1.24 (Raisin) to 2.00 (Sandusky). A similar pattern is shown by the loads of sediment and total phosphorus, which have more extreme ratios, especially for the Ohio Lake Erie tributaries. For example, the ratio for the Sandusky River for sediment is 3.88, and for total phosphorus it is 3.13. Ratios for these three two-year periods show less

Table 2. Discharge and loads of sediment, nutrients and chloride at the seven major Ohio Tributary Monitoring Program stations, Water Years 1996 through 2001. Discharge is in million cubic meters and loads are in metric tons per year. One metric ton equals 1000 kg or 1.1 short tons.

River and year		Q	SS	TP	SRP	Nitrate	Chloride
Raisin	1996	670	54,911	115	10	3,090	24,115
	1997	835	67,784	168	20	4,311	28,659
	1998	885	85,682	200	23	3,440	27,991
	1999	666	75,195	118	20	3,608	23,535
	2000	552	79,038	111	21	2,985	22,394
	2001	707	83,443	140	30	3,704	30,415
Maumee	1996	5,124	883,201	1,896	207	41,582	158,475
	1997	6,886	1,330,604	2,877	427	42,580	171,080
	1998	6,531	1,162,024	2,927	508	29,855	134,049
	1999	4,080	518,811	1,272	215	25,711	120,210
	2000	3,352	618,243	1,188	202	27,003	118,289
	2001	3,771	337,091	935	260	26,142	146,466
Sandusky	1996	1,155	282,789	491	31	7,673	32,325
	1997	1,445	363,734	667	60	9,143	29,957
	1998	1,159	207,946	518	69	5,961	24,577
	1999	545	52,683	138	25	3,838	19,932
	2000	719	94,217	219	47	6,169	26,350
	2001	618	Station not in operation due to bridge repairs				
Honey Cr.	1996	134	21,040	51	5.2	915	3,271
	1997	168	43,555	86	8.7	902	3,418
	1998	152	22,736	66	10.5	728	2,644
	1999	60	2,395	12	2.8	331	1,798
	2000	106	11,841	46	9.7	692	2,214
	2001	60	3,256	14	4.9	358	2,152
Rock Cr.	1996	30.8	11,114	17.8	0.9	142	721
	1997	39.3	18,107	25.0	1.1	154	676
	1998	40.0	8,839	16.7	1.8	105	732
	1999	13.0	1,084	3.4	0.7	50	415
	2000	22.1	4,170	11.4	1.8	102	528
	2001	14.3	1,442	4.0	1.1	51	493
Vermilion	2001	105	12,900	23	4.4	388	5,091

Table 2. Discharge and loads of sediment, continued.

River and year		Q	SS	TP	SRP	Nitrate	Chloride
Cuyahoga	1996	1,025	255,142	293	28.0	1,894	130,712
	1997	1,156	206,009	240	24.9	1,674	109,690
	1998	777	103,089	161	24.4	1,408	87,881
	1999	568	100,035	146	29.6	1,329	101,584
	2000	746	143,839	186	35.1	1,367	116,365
	2001	591	97,454	144	41.4	1,380	123,632
Grand	1996	1,147	162,305	151	8.4	878	37,513
	1997	1,256	137,128	155	8.2	459	27,465
	1998	678	59,604	71	4.5	337	20,793
	1999	468	60,817	54	2.5	454	21,879
	2000	705	81,432	92	11.7	439	23,711
	2001	555	49,408	57	7.6	443	32,601
Muskingum	1996	10,285	1,214,738	2,114	155	20,364	304,153
	1997	8,250	654,732	1,360	120	15,380	251,325
	1998	6,609	565,548	1,063	145	10,202	186,355
	1999	6,031	442,637	901	125	10,305	219,876
	1999*	6,031	442,612	854	126	10,346	221,852
	2000*	Not	483,136	1,065	239	10,122	217,001
	2001*	Available	379,247	946	240	9,687	232,518
Scioto	1996	5,286	—	—	—	—	—
	1997	4,078	635,602	1,460	377	16,659	133,108
	1998	3,376	354,692	1,027	333	13,937	109,207
	1999	2,372	213,361	737	277	9,953	120,411
	2000	2,546	282,680	891	347	13,624	133,096
	2001	2,586	273,850	832	367	12,276	133,856
Great Miami	1996	3,836	—	—	—	—	—
	1997	2,952	336,988	1,070	393	13,937	116,356
	1998	2,420	235,353	938	362	11,587	102,118
	1999	1,750	71,130	533	259	7,412	95,636
	2000	1,560	161,422	591	271	9,374	97,149
	2001	1,925	216,381	737	356	9,801	110,519

* Loads calculated by the program Integrator, because mean daily flow data needed for the Beale Ratio Estimator are not available for this station after 1999. Loads for 1999 calculated by both programs are given to show that results are very similar.

marked differences for soluble reactive phosphorus, nitrate, and chloride, though in general the loads of these parameters also tend to be higher during the first period. These three parameters differ from total phosphorus and sediment in being dissolved constituents, and are less sensitive to the effects of rainfall variation from year to year.

There can be substantial differences in patterns shown by annual discharges and loads. For example, annual discharges for WY1996 and WY1998 are nearly identical for the Sandusky River, but the WY1996 sediment load is nearly half again as large as the WY 1998 load. This reflects the complex nature of the interaction between precipitation and the landscape, which is different for each parameter and changes systematically with the seasons and randomly among years, influenced by factors such as frozen ground in the winter, and timing and intensity of rainfall events relative to crop development or fertilizer application.

Annual loads of sediment are the largest, followed by loads of chloride, nitrate, total phosphorus, and soluble phosphorus in decreasing order. Very roughly, the loads of these constituents for the six year period reported herein are in the ratio SS : CL : NO3 : TP : SRP = 1500 : 700 : 60 : 5 : 1.

Annual loads of sediment and total phosphorus during 1997 and 1998 are among the largest seen in recent years, particularly for the Maumee and Sandusky Rivers. The two-year total phosphorus load for 1997-1998 from these two rivers is the largest since 1990-91. This appears to reflect natural variation, not relaxation of pollution prevention efforts. Whatever the cause, it may be a contributing factor to the renewed problems of anoxia in Lake Erie. If so, improvements may be on the way, because the 2000-2001 two-year load is the smallest since the drought year of 1988.

As would be expected, larger watersheds tend to have larger annual discharge and loads. However, the Ohio River tributaries have comparable total phosphorus loads, and the Muskingum has smaller soluble reactive phosphorus loads than the other two Ohio River tributaries, even though it has the largest drainage basin by far. Also, the Cuyahoga River has high chloride loads, considering its size and the size of its other loads. These discrepancies probably reflect the fact that the Scioto, Great Miami, and Cuyahoga rivers have much more urban land use than the others.

Comparisons between the stations are simplified when loads are expressed on a unit area basis. For some purposes, it is easier to compare water quality constituents using concentrations rather than loads. Other reports in this series present the monitoring results in these forms.

References

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[1] A water year runs from October 1 of one year to September 30 of the following year. The water year 1996, for example, extends from October 1, 1995 to September 30, 1996. Water years are used for water quality analyses because the late summer is usually a dry time with low flow, and this provides a natural break point for summing up annual flows and loads.