2.b. Loading Calculations, Annual Loads and Unit Area Loads

Introduction

A major objective of the tributary loading program is to determine the total amounts or loads of various pollutants that move past a monitoring station during a particular period of time, often one year. The sampling program used in these studies was specifically designed to provide accurate loading information for the Ohio rivers tributary to Lake Erie. This entails frequent sampling during periods of high stream flow.

Calculation of pollutant loading requires three kinds of information:

1. Stream flow data (**volume/time**)
2. Pollutant Concentration data (**amount/volume**)
3. Time data (**time**) (See Sample Time Window in Data Set Description)

These are used to calculate loads in the following manner:

volume/time x amount/volume x time = amount

Since the above variables are measured in differing units, a conversion factor must be used to produce an amount in appropriate units. For example:

$feet^3$/second x mg/L x days x conversion factor = metric tons

For the above equation the conversion factor is 0.002446. It is derived by multiplying:

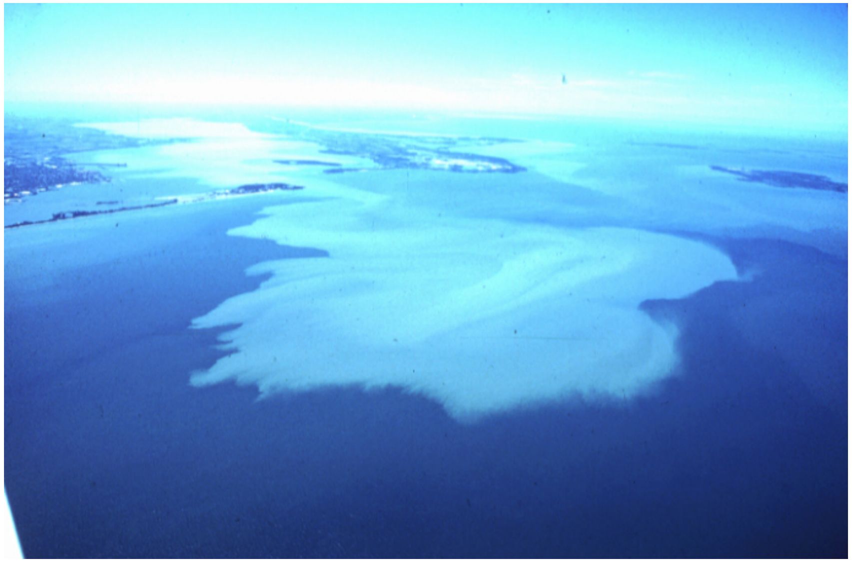
liters/$feet^3$ x sec/day x metric tons/mg = conversion factor

28.32 x 86,400 x 1×10^{-9} = 0.0024468

The units of the conversion factor are:

liters/$feet^3$ x seconds/day x metric tons/mg

Using dimensional analysis, it is evident that multiplying the units of the original data by the units of the conversion factor yields metric tons.



The above photo shows a plume of suspended sediment moving through Sandusky Bay, past Cedar Point and into Lake Erie. This sediment loading to Lake Erie was triggered by a large rainfall-runoff event in the Sandusky Watershed. The objective of the tributary loading program is to measure the amount of sediment and other pollutants that move out of watersheds, toward and/or into Lake Erie.

$feet^3$/second x milligrams/liter x days x liters/$feet^3$ x seconds/day x metric tons/ milligram = metric tons

Loading Calculations Using Excel Spreadsheets

The following modified spreadsheet illustrates the calculation of the total phosphorus load from the Grand River for the 1997 Water Year. From the Grand River data file, data from the columns Datetime, Time window, Flow and TP for the period from 10/01/1996 to 09/30/1997 were transferred onto a new worksheet as columns A,B, C, D. The conversion factor was added to column E. The loads for each sample were calculated by multiplying columns B*C*D*E and placing the product in Column F. The monitored load for the water year equals the sum of the sample load values in Column F. In the illustration below rows 9-420 were omitted. The total monitored load was 156.37 metric tons of total phosphorus. These calculations are done automatically within the Summary Report worksheet of the AnalysisTemplatev3 program.

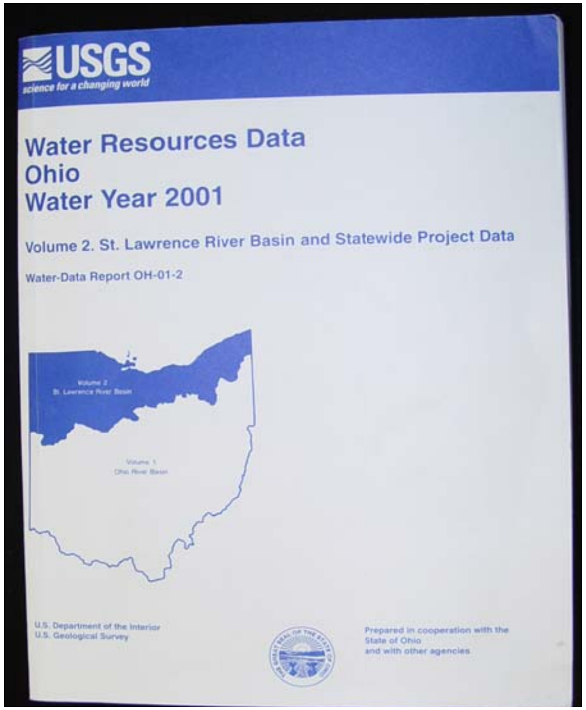
	A	B		C		D		E		F
1		**time**	**x**	**volume/time**	**x**	**amount/volume**	**x**	**conversion factor**	**=**	**amount**
2		days	x	ft^3/second	x	mg/L	x	seconds/day*L/ft^3*metric tons/mg	=	metric tons
3	Datetime	Time Window		Flow		TP				TP load
4	10/1/1996 20:00	1.00	*	1128.90	*	0.1068	*	0.0024468	=	0.2950
5	10/2/1996 20:00	1.00	*	716.44	*	0.0787	*	0.0024468	=	0.1380
6	10/3/1996 20:00	1.00	*	378.75	*	0.0586	*	0.0024468	=	0.0543
7	10/4/1996 20:00	1.00	*	260.00	*	0.0447	*	0.0024468	=	0.0284
8	10/5/1996 20:00	1.00	*	190.00	*	0.0399	*	0.0024468	=	0.0185
	Sample data for rows 9-420 were omitted from this illustration.									
421	9/29/1997 20:00	0.67	*	41.20	*	0.0426	*	0.0024468	=	0.0029
422	9/30/1997 20:00	1.00	*	53.10	*	0.0423	*	0.0024468	=	0.0055
423										
424	Total time, days	350.31						Total amount, metric tons		156.3718

Loading Adjustments

The loads calculated in the preceding manner represent what we call the monitored load. The monitored load generally needs to be adjusted for reasons listed below.

1. **Adjustments of provisional flow data to final flow data by the U.S. Geological Survey:** The provisional flow data are adjusted annually by the U.S. Geological Survey to correct for any deviations from the stage-discharge rating table that may have occurred. Major sources of deviations can occur from ice jams in the winter time or from "leaf dams" in the fall. The corrected flows are published as the average daily flow in the Water Quality Records for Ohio. The average daily flows generally represent an average of 15 minute recordings of stage. In instances where the USGS stage recording equipment failed to operate, the USGS estimates daily discharge based on monitored discharge at nearby stations. The resulting daily, monthly and annual discharges provide the best estimate of discharge at the sampling station.

2. **Unmonitored time:** The automatic samplers and pumping systems may fail to operate properly, resulting in an absence of samples to characterize loadings. Causes of these sampling problems include power outages, pump failures, and autosampler problems.



There are many methods of adjusting for flow corrections and for unmonitored time. One of the simplest is to use the final daily flow data as published by the USGS in their annual Water Resources Data for Ohio (or other states) volumes (upper right photo). If the monitored data is representative of the flow conditions for the year, the total monitored load can be adjusted by multiplying it times the ratio of the USGS final flow to the monitored flow for the time period. An example is shown below for the 1997 Water Year Total Phosphorus load for the Grand River (see loading calculation example on page 2 of this section):

Since 1998, the annual Water Resources Data Ohio reports are available in pdf format at http://oh.water.usgs.gov/AR/ar.html. Daily discharge data for the period of record may also be downloaded from the U. S. Geological Survey Web Site at http://nwis.waterdata.usgs.gov/oh/nwis/discharge.

Monitored TP load x USGS annual discharge/observed discharge from sampling program = Adjusted TP Load

156.4 metric tons x 1,260 million cubic meters/1,213 million cubic meters = 162.5 metric tons.

The adjusted TP load calculated in this way happens to match the 162 metric ton load derived from use of the Beale Ratio Estimator technique (see next page).

Loading Adjustments, continued

A second way to adjust the load is to compare the total monitored time (i.e., the sum of the sample time window) with the elapsed time. For the Grand River 1997 total phosphorus data, the elapsed time was 365 days and the total monitored time was 350.3 days. In this case the adjustment is made by multiplying the monitored load by the ratio of the elapsed time to the monitored time:

156.4 metric tons x 365/350.3 = 163.0 metric tons adjusted load

Again, the adjusted load is very close to the load adjustment attained by the Beale Ratio Estimator Technique. If the unmonitored time is longer, then the likelihood of the monitored time being representative of the unmonitored time is less likely.

The Summary Report worksheet of the AnalysisTemplatev3 program provides the total elapsed time, the total monitored time, the monitored load, and the monitored flow that can be used for the above adjustment techniques. The USGS final flow data can be obtained from the listed USGS sources.

Other adjustment procedures involve noting the USGS daily discharges for missed days and using a seasonal regression of concentration versus flow to estimate the concentrations for the missed days. Then the loads for the missed days can be calculated.

WQL Publications on Adjusted Loads and Load Estimation Techniques

Under contract with Region VIII of the U. S. EPA, Dr. R. Peter Richards of the WQL has prepared a detailed guidance document on the estimation of pollutant loads in rivers and streams. That document describes various current techniques for calculating loads. Although many of the techniques were developed to estimate loads based on many fewer samples than we produce, some techniques, such as the Beale Ratio Estimator technique, can still be used to advantage with our data sets.

Consequently, we use that technique to report annual loads for our monitoring stations.

Copies of those reports may be accessed by clicking on the name of the report you would like to see.

Richards, R.P. 1998. *Estimation of pollutant loads in rivers and streams: A guidance document for NPS programs*. Project report prepared under Grant X998397-01-0, U.S. Environmental Protection Agency, Region VIII, Denver. 108 p.

Loftus, T. and WQL Staff. 2004. The Ohio Tributary Monitoring Program: 2004 Annual Report. Prepared for the Ohio Department of Natural Resources, Division of Soil and Water Conservation.

Richards, R. Peter. 2001. Reports from the Ohio Tributary Monitoring Program, 1: Program Description. WQL Technical Report Series.

Richards, R. Peter. 2002. Reports from the Ohio Tributary Monitoring Program, 2: Annual loads of sediment, nutrients, and chloride. WQL Technical Report Series.

Richards, R. Peter. 2002. Reports from the Ohio Tributary Monitoring Program, 3: Unit-area loads of sediment, nutrients, and chloride. WQL Technical Report Series.

Richards, R. Peter. 2001. Reports from the Ohio Tributary Monitoring Program, 4: Time-weighted mean concentrations of pesticides. WQL Technical Report Series.

All of the above reports are also available at the WQL's website under publications http://www.heidelberg.edu/wql/publish.html#reports.

Related reports, journal articles and symposium proceedings may be found at http://www.heidelberg.edu/wql/publish.html.

Unit Area Loads

The annual adjusted load at a sampling station is greatly affected by the size of the watershed upstream from the sampling station. Thus the loads at the Maumee Station at Waterville, which drains 6,330 square miles, are much larger than at the Rock Creek Station in Tiffin, which drains 34.6 square miles. One way to compare the pollutant runoff from the two watersheds is to calculate the unit area loads. This involves dividing the total load by the watershed area. An example of the differences between total loads and unit area loads is shown below for suspended solids loads in the 2002 Water Year.

	Maumee River	Rock Creek
	6,330 mi^2	34.6 mi^2
Annual Adjusted load, metric tons	987,000 metric tons	9,870 metric tons
Unit area load, kilograms/hectare	602 kg/ha	1,122 kg/ha

In this example, the Maumee River exported 100 times more suspended sediment than the Rock Creek watershed during the 2002 Water Year. However the unit area export rate from Rock Creek was almost twice as high as for the Maumee River.

Unit area loads are used to compare pollutant export rates for watersheds when the issue is to identify those watersheds that are “critical areas” for pollutant load reduction consideration.

Unit area loads are automatically calculated in the “Summary Report of Loads and Concentrations” program of AnalysisTemplatev3. That report also includes an annualize unit area load in cases where loading calculations were done for periods in excess of - or less than - one year.

Time Period for Load Reporting

Although loads can be calculated for any time period, it is conventional to report loadings on an annual basis, usually using the Water Year rather than the Calendar Year. The Water Year is chosen by the U.S. Geological Survey as the primary way to report annual discharge volumes because the October 1 starting period is the time of the year when flooding events are least likely to occur. Thus annual variability in discharge is least likely to be impacted by short-term temporal vagaries of rainfall-runoff events. Also, by reporting loads on an annual basis, seasonal patterns of runoff are taken into account.

Annual variations in loading and associated unit area loads are often very large, due to annual variations in weather conditions, especially precipitation. Where long-term flow and loading studies are available, average annual loads and average annual unit area loads can be calculated and reported.