Appendix J. TMDL Development and Modeling Additional Information

J.1 Load duration curves for Yellow Creek and Tinkers Creek

Flow duration curves were developed for the USGS gages #04206220 Yellow Creek at Botzum, Ohio (0.5 mi upstream from mouth) and #04207200 Tinkers Creek at Bedford, Ohio (5.5 mi upstream from mouth). Load duration curves were created using these and the water quality targets described in Table 11 of Chapter 4. Figures J1 through J4 show the total phosphorus and fecal coliform load duration curves for these two gages and compares this allowable load with the existing observed load. The existing observed load was calculated using water quality samples collected from the Cuyahoga Valley National Park service and the Ohio EPA since 1991. Figure J1 shows a potential lower flow source of total phosphorus may be an issue on Yellow Ck while Figure J2 indicates that the observed fecal coliform samples do not indicate a bacteria problem for this tributary. Figure J3 indicates that Tinkers Ck may be enriched for phosphorus under all flow conditions; Figure J4 shows that exceedences of bacteria may only be occurring under wet weather conditions for Tinkers Ck. The relative contributions of the current total phosphorus load in Tinkers Ck is estimated in Figure J5.

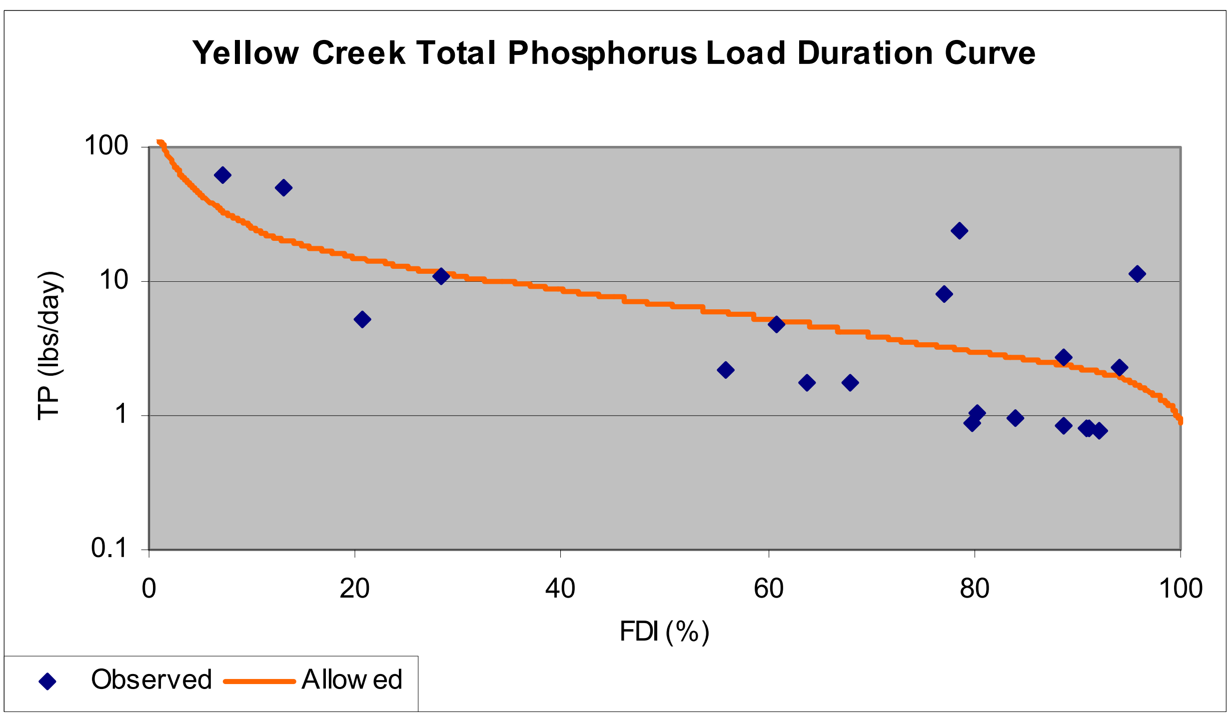

Figure J1. Comparison of allowable and observed total phosphorus loads for Yellow Ck

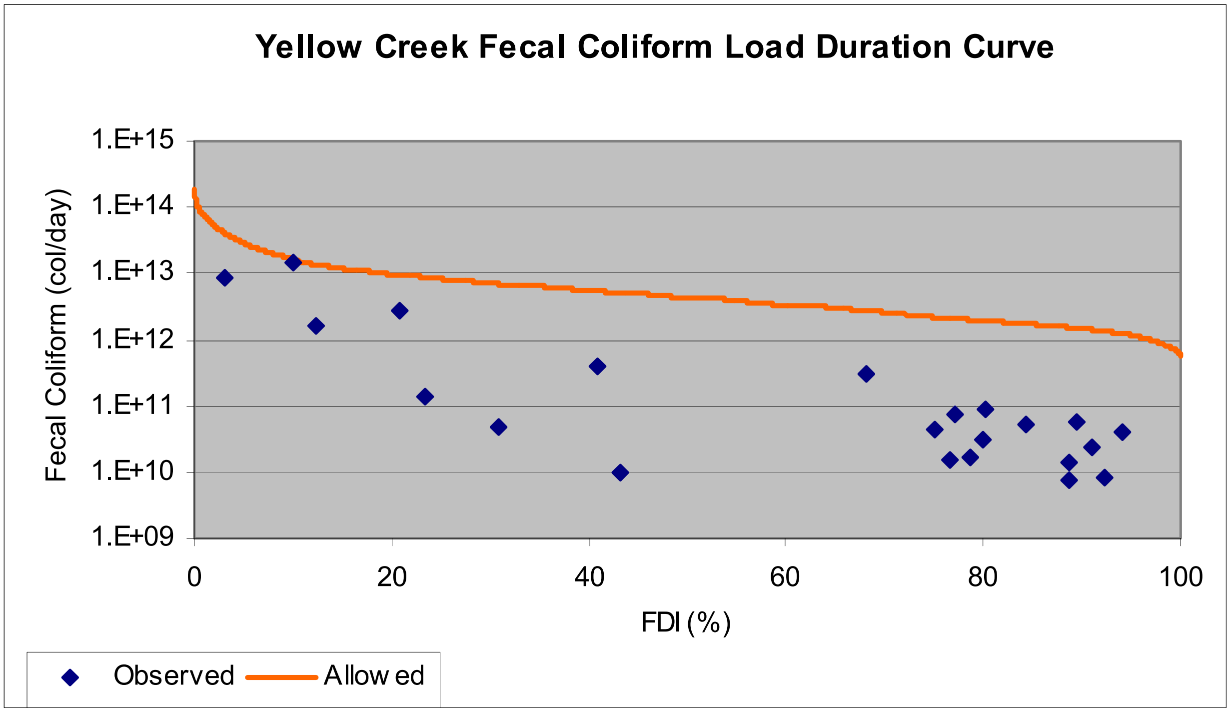

Figure J2. Comparison of allowable and observed fecal coliform loads for Yellow Ck

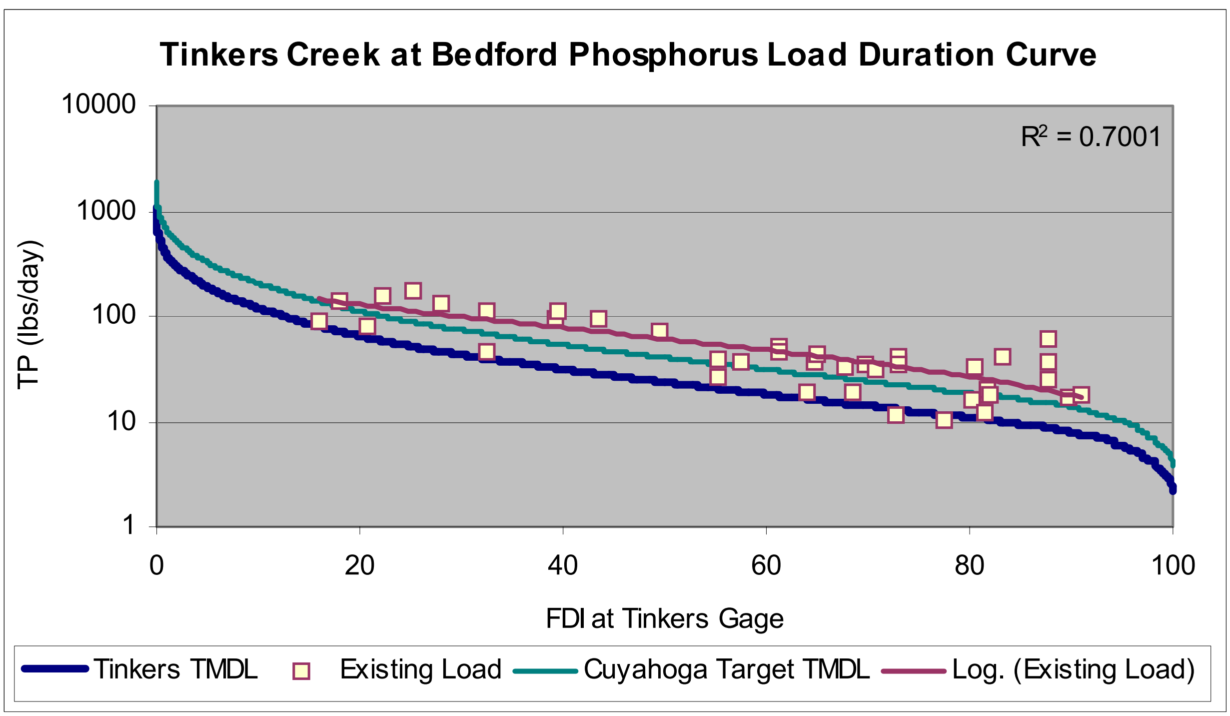

Figure J3. Comparison of allowable and observed phosphorus load in Tinkers Ck

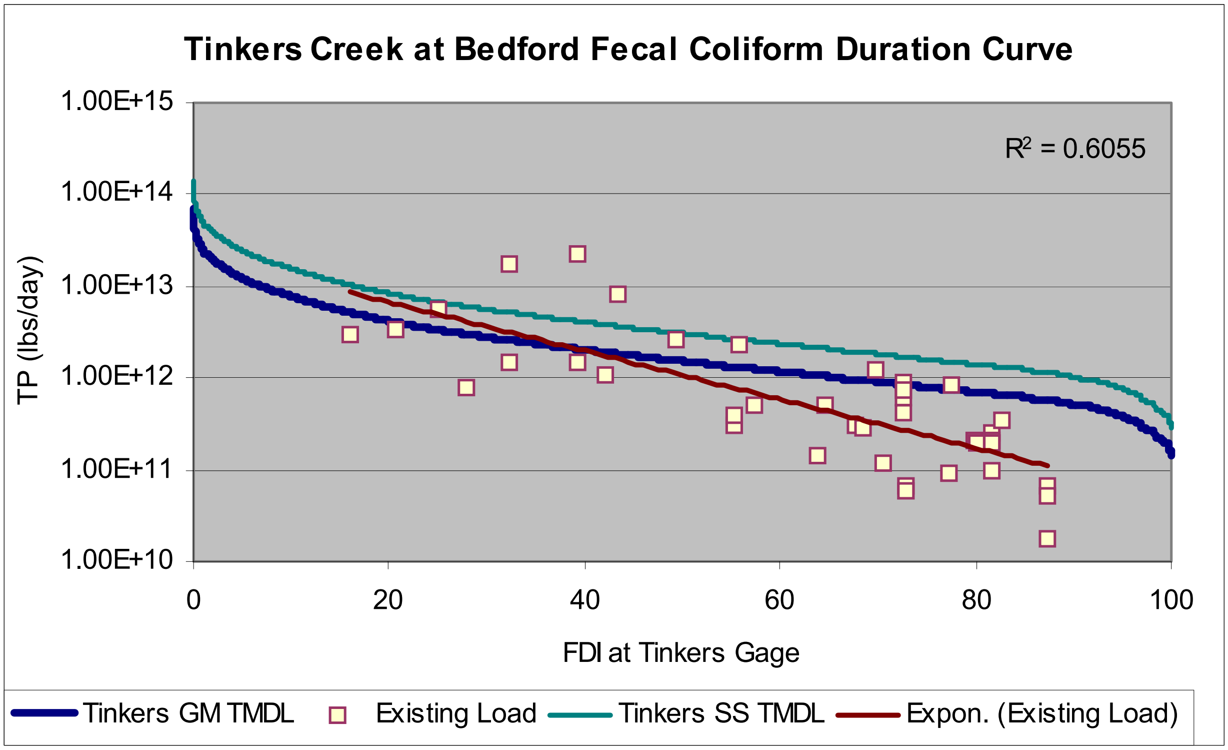

Figure 4 Comparison of allowable and observed fecal coliform load in Tinkers Ck. SS indicates single sample criteria of 2000 cfu/100 ml and GM the geometric mean criteria of 1000 cfu/100 ml

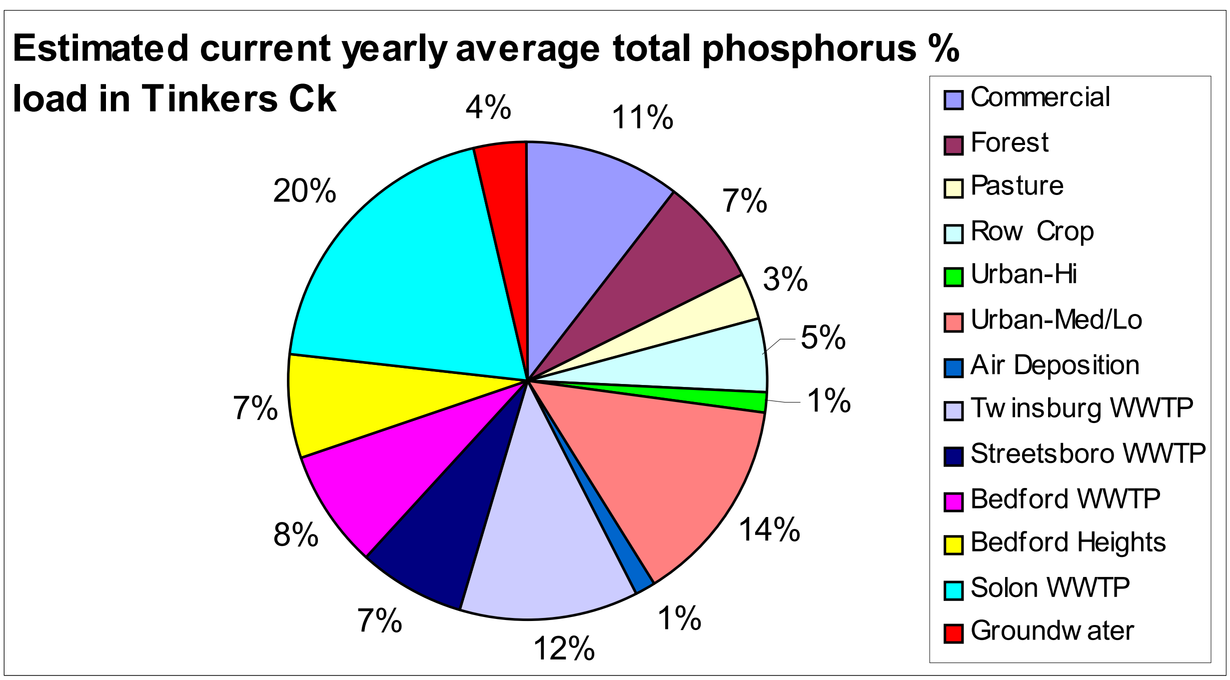

Figure 5 Estimate of the existing relative contributions of TP load for Tinkers Ck

J2. Additional Tributary Information

J.2.1 Brandywine Creek

Water quality duration curves are curves matching the observed concentration on a particular day with the flow duration interval applicable for the flow on that day. These curves are useful when you do not have the actual observed flow for a tributary. Instead you use the flow duration curve developed for a similar tributary and use the flow duration intervals based on the date of the collected sample. Water quality duration curves for total phosphorus and fecal coliform on Brandywine Ck just upstream of the mouth are shown in Figures J6 and J8. Figure J7 is included to reflect the closure of a discharge which was contributing to the total phosphorus load in Brandywine; note the steady decrease in total phosphorus over time.

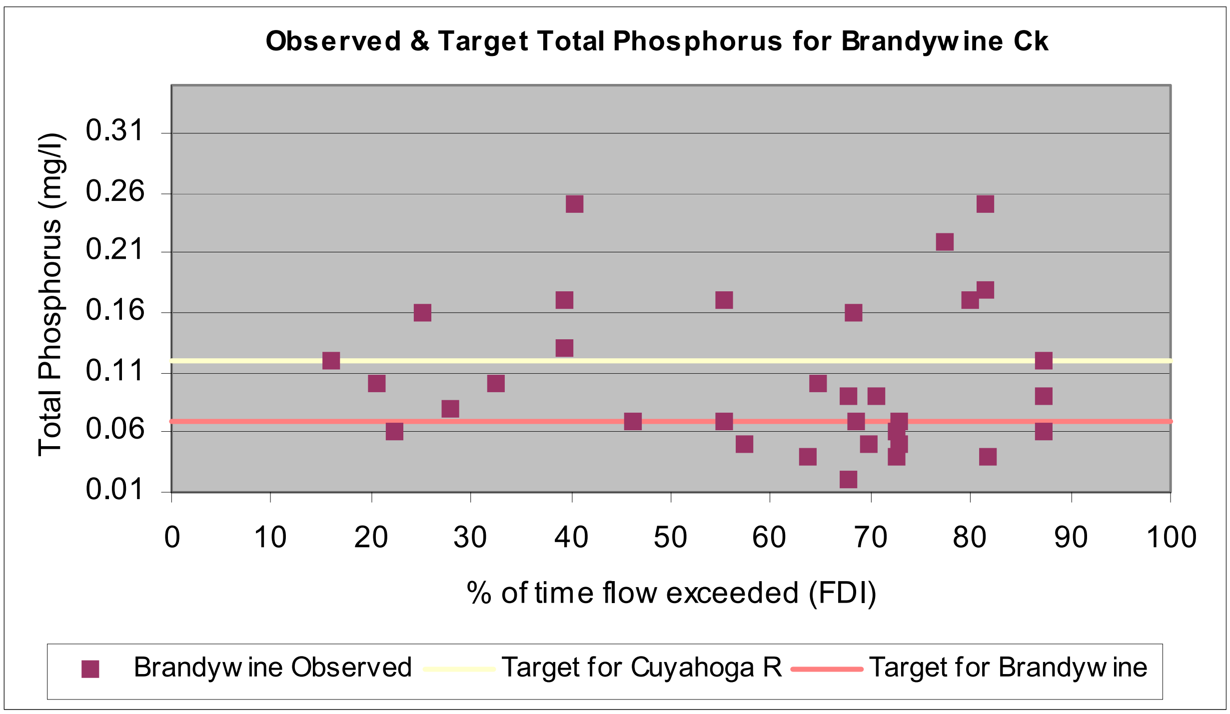

Figure 6 Total phosphorus water quality duration curve for Brandywine Ck

J.2.2 Little Cuyahoga River

Figures J9 and J10 indicate that the Little Cuyahoga River is not enriched for total phosphorus based on the observations to date but that fecal coliform is elevated. The elevated fecal coliform supports the probable affects of Akron's combined sewer overflow system. These curves were developed from data collected 0.3 miles upstream of the mouth.

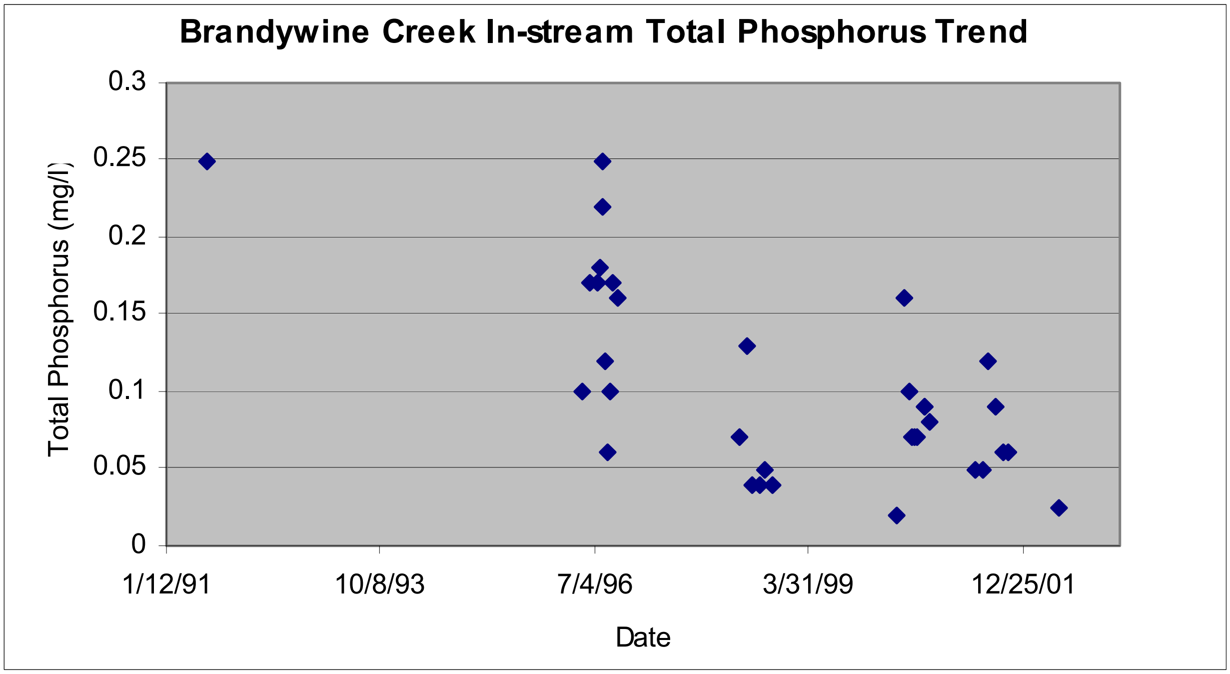

Figure J7. Temporal trends in total phosphorus concentrations for Brandywine Ck

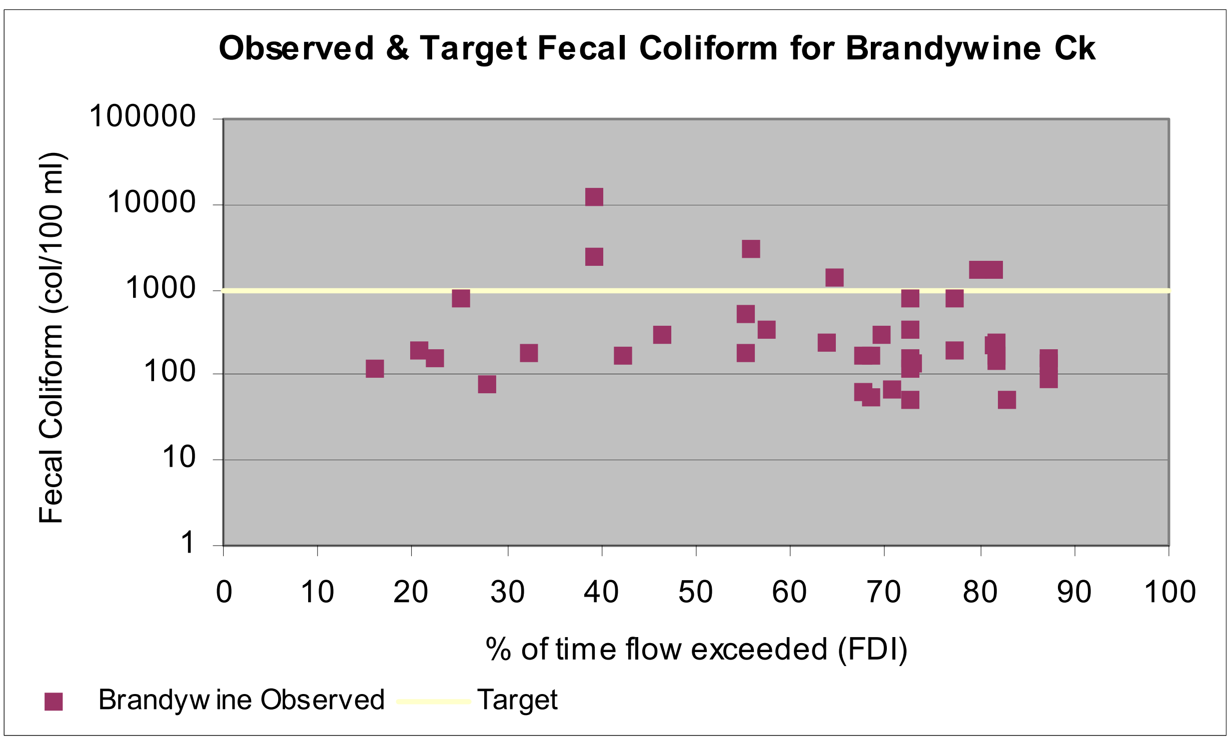

Figure J8. Water quality duration curve for fecal coliform in Brandywine Ck

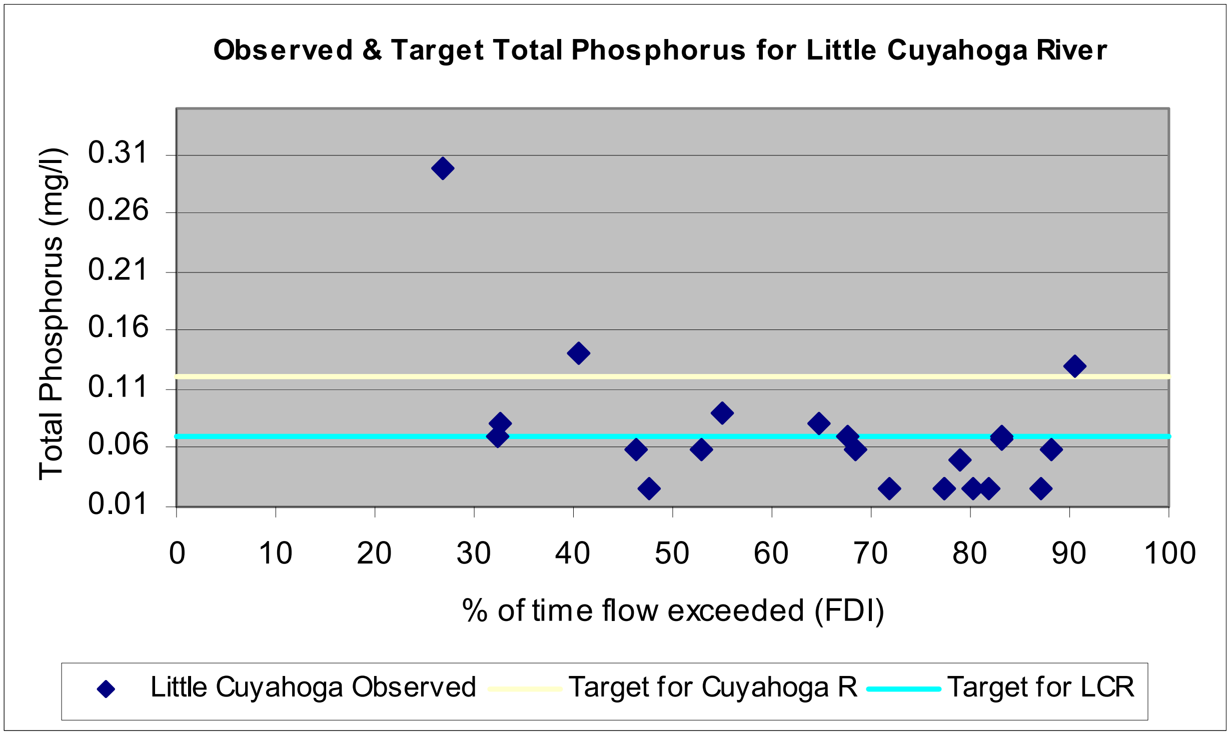

Figure 9 Total phosphorus water quality duration curve for the Little Cuyahoga R

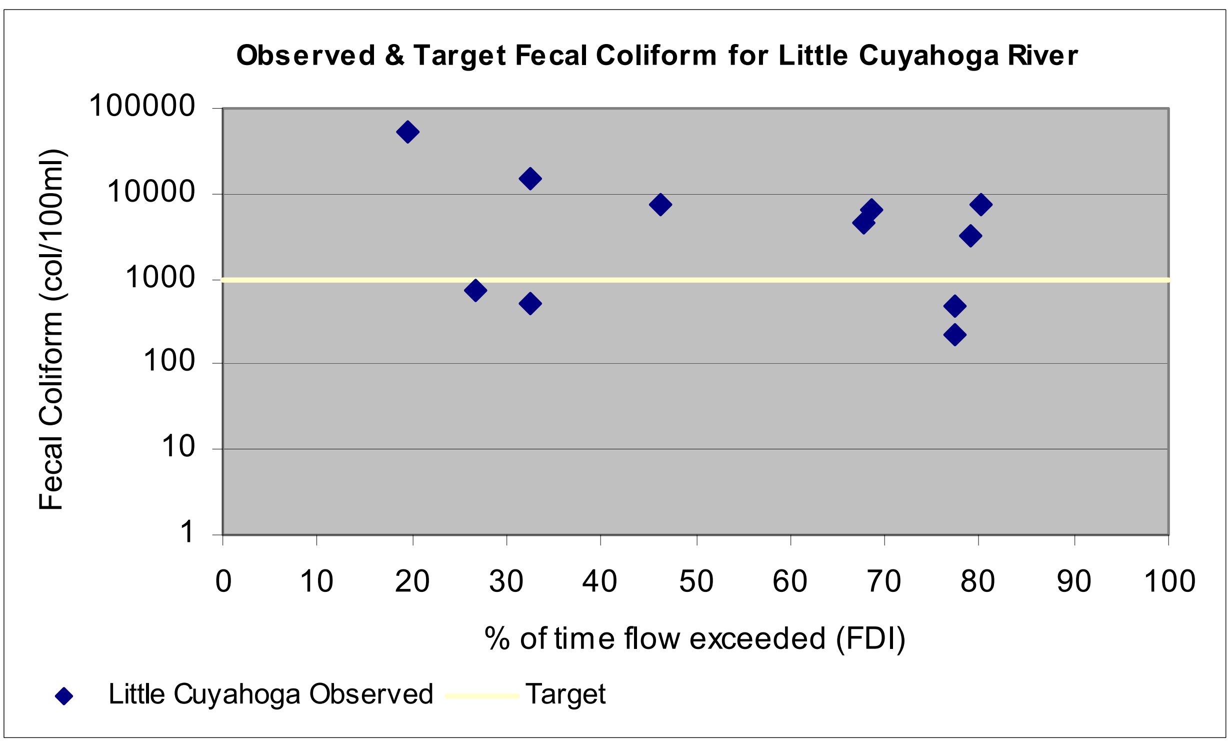

Figure 10 Fecal coliform water quality duration curve for the Little Cuyahoga R

J.2.3 Comparison of Total Phosphorus and Fecal Coliform Tributary Concentrations

The maximum, median, and minimum observed concentrations for total phosphorus and fecal coliform were calculated for each tributary where data was collected for the lower Cuyahoga TMDL. The chemistry data was provided by Ohio EPA and the CVNP personnel. Figures J11 and J12 depict how the tributaries compare for total phosphorus and fecal coliform respectively.

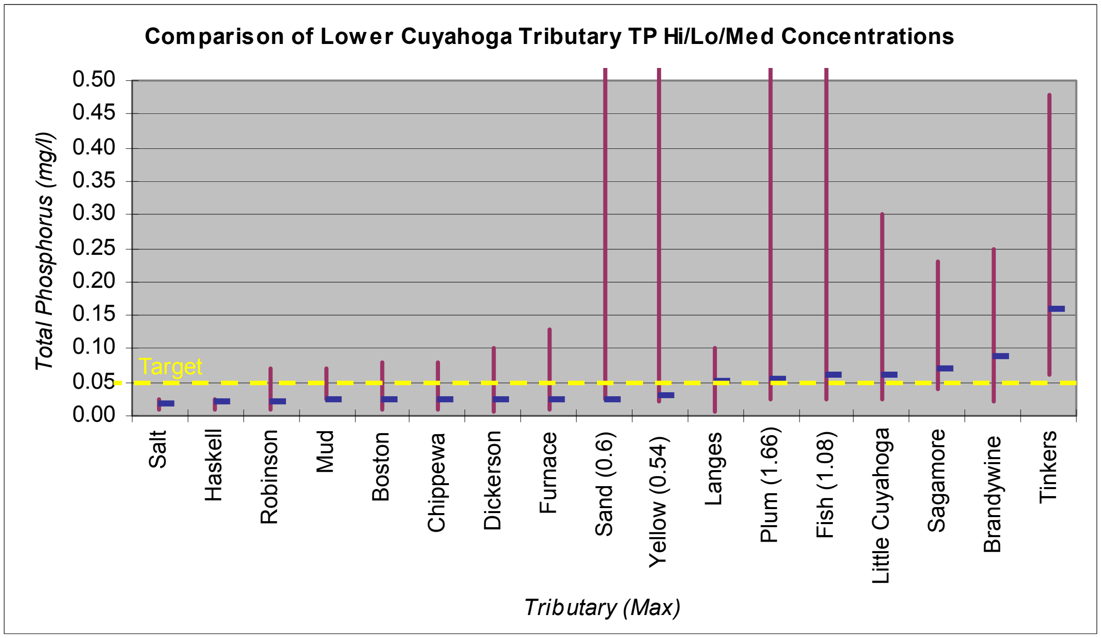

Figure J11. Total phosphorus tributary concentration comparison

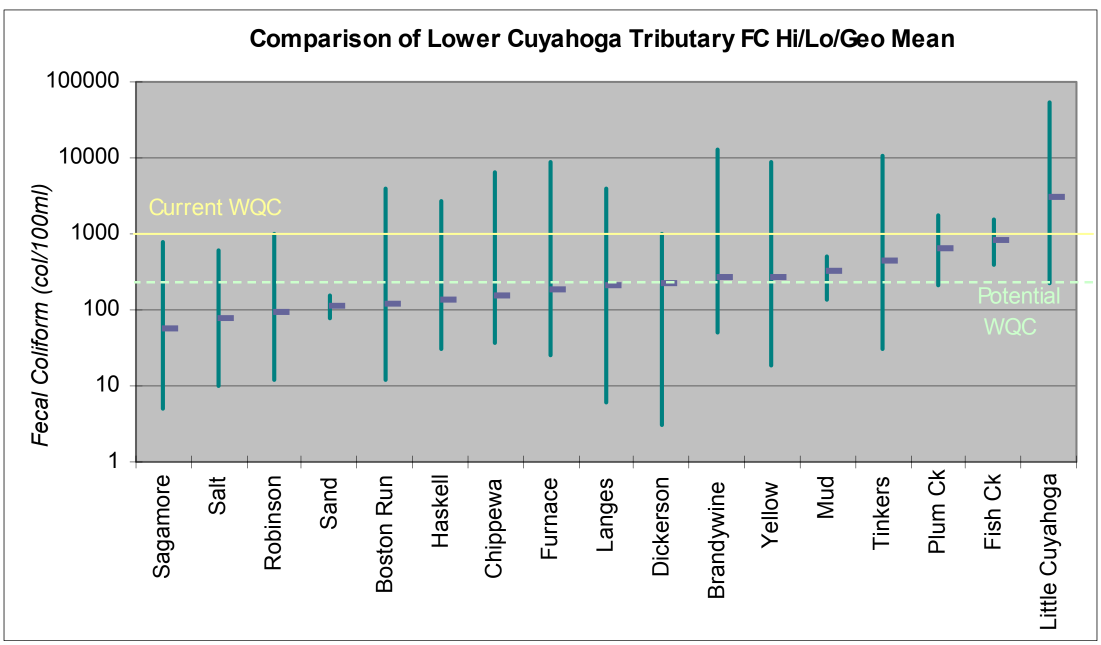

Figure J12. Fecal coliform tributary concentration comparision

J.3 Load Calculations by Source

J.3.1 Combined sewer overflows (CSOs)

J.3.1.1 Akron

The modeling the City of Akron had done to reflect their CSO system was summarized in appendices to their long term control plan (LTCP). The approach used by Akron's consultants involved modeling the system itself with the Stormwater Management Model (XP-SWMM) and the receiving streams' responses with the Water Quality Analysis Simulation Program (WASP). This modeling effort was fairly extensive and no additional modeling of the system was done specifically for the TMDL. Instead the results of the LTCP modeling were used based on information provided to the Ohio EPA by Akron.

The LTCP modeling was calibrated to data collected in 1994. The model then determined the existing typical loads, volumes, and frequency of overflows from the system for an average year per overflow in the system. In addition, the model predicted the effect of the LTCP implementation actions on volume and on the number of overflows per overflow.

This information needed to be adapted to the duration curve methodology in order to mesh with the TMDL approach. This entailed determining what flows (flow duration intervals) overflows were occurring at, their relative volume and quality. The calibration data collected in 1994 were used to determine this. A comparison of historic flow data collected at a now defunct USGS flow gage was compared to nearby active gages with sufficient period of records. The Tinkers Ck gage was reflective of the trends at the Little Cuyahoga gage (similar flow changes reflected). The dates of the 1994 CSO system sampling were paired with the flow duration intervals from the Tinkers Ck gage. The increase in flow at the Tinkers gage, adjusted by area, was also matched to the dates of the Akron CSO calibration data. The increase in flow data was ranked and summed; it was then used to determine the percentage of the total expected annual volume a particular storm event was expected to produce per overflow. Basically this was a method to determine the relative overflow volume contribution per storm and to relate this to a flow duration interval. For each monitored overflow event in 1994 an increase in stream flow was determined. This increase in flow was totaled for the year. The percent each individual storm event's contribution to this total was determined and associated with a flow duration interval. This percentage was applied to the total annual average volume per overflow as determined by the LTCP model results. Once each outfall's total annual volume was distributed per storm and associated with a flow duration interval, the LTCP modeling and the TMDL method could mesh. The total load per storm was determined based on the total volume per storm multiplied by the event mean concentration for fecal coliform and a value of 1.2 mg/l for total phosphorus. This phosphorus value was based on the literature gathered from various sources of expected CSO quality.

The expected loads from the Akron CSO system once the LTCP measures are in place were determined using the same method except that the predicted volumes and number of overflows were substantially reduced. The system is expected to have overflows only under high flows instead of the current situation where it triggers under almost any precipitation event. The LTCP has a suite of control methods which vary per outfall. Table J2 shows the expected total phosphorus loads after the LTCP actions are in place and gives an indication of the three different treatment methods Akron is proposing to use: Actiflo® treatment on large overflows, primary, settling, and disinfection on other overflows, and no treatment on small overflows. The table indicates which overflows will receive which treatment as well as indicating which overflows will remain after incorporation of the LTCP actions, at least based on the LTCP proposal as of December 2002.

J.3.1.2 Cleveland

Cleveland also performed modeling of their CSO system in order to propose a LTCP. Northeast Ohio Regional Sewer District personnel provided the results of this modeling to the Ohio EPA. No additional TMDL-specific CSO modeling was performed. The Cleveland CSOs are downstream of the Independence gage. The Independence gage has daily flow and water quality information; therefore, a detailed daily load analysis was done for that location. Upstream sources needed to be detailed as well. The downstream point of the lower Cuyahoga watershed upstream of the ship channel is Harvard Ave. Due to data and method limitations and given the detailed analysis upstream at Independence, an annual load analysis was appropriate at Harvard. The Cleveland LTCP analysis was performed to predict annual loads, and no data transformations needed to occur to mesh the TMDL method with the LTCP results. Table J1 shows the results of the Cleveland LTCP modeling for those CSOs that contribute to the Cuyahoga at Harvard Ave.

Table J1. Cleveland CSO contributions to the Cuyahoga R at Harvard

Receiving Water	Facilities Planning Area	CSO Outfalls	Annual CSO Volume (MG)	
			Baseline	after LTCP
Big Creek	Westerly	all	4.45	0.004
	Southerly	all	742.4	168.64
Cuyahoga River	Southerly	033	2.04	0.2
Mill Creek	Mill Creek & Southerly	all	516.89	14.26
Spring Creek	Southerly	all	13.49	0.52
Treadway Creek	Southerly	all	0.33	0.25
West Creek	Southerly	all	28.89	0.44
Total volume (MG/year):			1308	184
Total phosphorus load (lbs/year): *Used concentration of 0.48 mg/l as measured by Cleveland*				887
Fecal coliform load (cfu/year): *Used 1.85E+11 cfu/100 ml as determined by Cleveland:*				3.42000e+13

Table J2. Total phosphorus expected loads from the Akron CSO system after implementation of the LTCP

	Quality Achieved	Notes:		Quality Achieved	Notes:		Quality Achieved	Notes:
TP:	0.18 mg/l	a	TP:	1.2 mg/l	c	TP:	0.984 mg/l	e
Fecal:	200 cfu/100ml	b	Fecal:	500000 cfu/100ml	d	Fecal:	500 cfu/100ml	f

	Actiflo® Treatment				**Storage Basins (untreated)**					**Treatment Basins (settling/primary/disinfection)**					**TOTALs**	
CSO:	**#18**	**#40**	**#35**	**Bypass**	**#7**	**#14**	**#15**	**#22**	**#36**	**#3**	**#11**	**#12**	**#28**	**#29**	⇦ indicates a CSO	
#of Events:	*8*	*5*	*7*	*6*	*8*	*4*	*8*	*7*	*8*	*10*	*7*	*9*	*6*	*13*		
Volume (MG):	238.6	145.1	24.1	912	4.2	3.5	4.3	7.5	3.9	3.4	4.7	9.8	1.2	4.1	kg/event	lb/event
FDI	*TP Loads (kg/event):*				*TP Loads (kg/event):*					*TP Loads (kg/event):*						
0.001	56.96	41.18	5.99	240.42	6.68	7.18	6.84	12.42	6.21	4.2	6.38	12.41	1.73	4.77	413	911
0.002	39.54	28.59	4.16	166.91	4.64	4.99	4.75	8.63	4.31	2.91	4.43	8.62	1.20	3.31	287	633
0.004	18.03	13.04	1.90	76.12	2.12	2.27	2.17	3.93	1.97	1.33	2.02	3.93	0.55	1.51	131	289
0.028	11.53	8.33	1.21	48.66	1.35	1.45	1.39	2.51	1.26	0.85	1.29	2.51	0.35	0.97	84	184
0.049	10.69	7.73	1.12	45.11	1.25		1.28	2.33	1.16	0.79	1.2	2.33	0.32	0.90	76	168
0.032	10.47		1.10	44.18	1.23		1.26	2.28	1.14	0.77	1.17	2.28	0.32	0.88	67	148
0.05	8.96		0.94		1.05		1.08	1.95	0.98	0.66	1	1.95		0.75	19	43
0.095	6.40				0.75		0.77		0.70	0.47		1.39		0.54	11	24
0.082										0.36		1.08		0.41	1.9	4.1
0.136										0.32				0.36	0.7	1.5
0.108														0.30	0.3	0.7
0.117														0.30	0.3	0.7
0.175														0.29	0.3	0.6
														Total:	1092	2407
															kg/year	lb/year

Notes:

a: 85 % removal from Actiflo Kruger website

b: EMC = 500000 #col/100ml fecal; FC reduction from USEPA CSO Cl disinfection fact sheet (9/99) ave log reduction is 3-4 (500-50); 200/col safe estimate given high solids removal

c: Literature value

d: EMC = 500000 #col/100ml fecal

e: Assume urban SW more dilute than raw sewage so 50/50 organic/inorganic; primary settling will capture 35% of the organic resulting in a reduction of 18% TP.

f: Assume that disinfection not quite as effective as the actiflo since less solids/tss removal. Use log reduction of 4 as a conservative estimate.

J.3.2 Other Runoff

J.3.2.1 Total Phosphorus and Export Coefficients

The load from runoff for total phosphorus was assumed to be the difference between the observed load and the sum of all other sources. All other major sources were either known or could be estimated with reasonable certainty. Some intermittent or minor sources may not be known and therefore included in the runoff portion; however, this was thought to be acceptable as all sources would be accounted for regardless of their category and any unknown sources would be very minor and included in the load allocation portion (because they are unregulated) anyhow. In order to see if this calculated runoff load was reasonable, each year's total calculated runoff load was compared to the load expected to be produced using export coefficients.

Export coefficients are associated with different land uses and represent average annual unit-area loading rates. A range of export coefficients was determined from the literature. The area of a particular land use was multiplied by the range of export coefficients applicable to that land use. This was done for each land use in the watershed and the results were summed. This total represents the range (the minimum, median, and maximum) overland runoff load that would be expected in the watershed. These export coefficients do not take into account bank erosion, but they do take into account air deposition over each land use. The calculated runoff load was compared to the expected runoff load based on the export coefficients; this comparison is shown in Chapter 4, Figure 10. Note that there appears to be an unaccounted for source or other unknown/unaccounted for process occurring as the calculated runoff load generally slightly exceeds the maximum expected runoff load from the export coefficients. Figure 10 also indicates that the reductions in runoff loads being sought in this TMDL are achievable as these loads are around the runoff load expected for the medians of the export coefficients.

The range of export coefficients used in this study came from the following web sites which cite the original source(s) as well as give the export coefficients :

http://www.ecs.umass.edu/cee/rees/prjs/ExportCoef.htm

http://h2osparc.wq.ncsu.edu/lake/rec/spread1.html

http://lakes.chebucto.org/SWT/swt.html#usepa

http://www.epa.gov/owow/tmdl/techsupp.html
(Go to the Protocol for Developing Nutrient TMDLs PDF version hot button, Table 5-3)

Table J3 lists the land use and range of export coefficients used in this study. The sources for the ranges varied.

Table J3. Export Coefficients used in the Cuyahoga TMDL	kg/ha/yr		
	Export Coefficients Range:		
	Min	Median	Max
Commercial	0.69	0.8	0.91
Forest	0.005	0.2	1
Pasture	0.01	0.3	0.6
Row Crop	0.03	0.6	4.6
Urban-High	0.54	0.65	0.76
Urban-Med/Low	0.5	0.6	0.7
Air Deposition to Water/Wetlands	0.05	0.25	1

J.3.2.2 Fecal Coliform and the Fecal Tool Coliform Loading Estimation Tool

The Fecal Coliform Loading Estimation Tool (FCLET) is a spreadsheet tool that estimates the fecal coliform bacteria contribution from multiple sources. The tool estimates the monthly accumulation rate of fecal coliform bacteria on four land uses (cropland, forest, built-up, and pastureland), as well as the asymptotic limit for that accumulation should no washoff occur. The tool also estimates the direct input of fecal coliform bacteria to streams from grazing agricultural animals, wildlife, and failing septic systems. It has been used to support fecal coliform bacteria source quantification, model parameterization, and load allocation for TMDLs throughout the United States, and was developed by Tetra Tech, Inc., in conjunction with U.S. EPA Office of Science and Technology (Region 5, 2002).

The lower Cuyahoga TMDL used this tool to quantify the expected runoff load of bacteria. Septic system inputs were calculated separately and were not a part of this step. The inputs for FCLET came from a variety of sources; primarily from information found on the web. The US Agricultural Census provided farm animal information by county which was area-weighted adjusted by the portion of the county that was in the watershed. Ohio Department of Natural Resources and discussions with hunters and landowners provided information on the number of wildlife. Data on the number of dogs in the area was scarce; instead, an assumption of 1 dog per every 4 homes was made. The US Census provided information on the number of people and homes per county. Discussions with USDA and SWCD staff and the model defaults provided information on manure application methods and rates. The existing predicted bacteria loads from runoff based on FCLET are provided in Table J5. These values represent the expected load to the stream on the first and consecutive days of a rain event based on the month the event is occurring. These were incorporated into the TMDL LDC model by determining for each day in the study period if there had been a precipitation event (using precipitation data from weather gages), if this was the first day of the event or a consecutive day, and the month of the date of interest. Based on these factors the appropriate runoff value from FCLET was selected (or not if no precipitation).

Table J4. Explanation of FCLET Worksheets

Worksheet Name	**Purpose**
Land Use	Lists the distributions of built-up land, forestland, cropland, and pastureland in each subwatershed.
Animals	Lists the number of agricultural animals in each subwatershed (beef cattle, dairy cattle, swine, chickens, horses, sheep, turkeys, and other [user-defined]); the densities of wildlife by land use category (ducks, geese, deer, beaver, raccoons, muskrat, and other [user-defined]); and domestic pets (cats, dogs, etc.).
Manure Application	Calculates the fraction of the annual manure produced that is available for washoff based on the amount applied to cropland and pastureland in each month and the fraction of manure incorporated into the soil (for hog, beef cattle, dairy cattle, horse, poultry manure, and imported manure).
Grazing	Lists the days spent confined and grazing for beef cattle, dairy cattle, horses, sheep, and other animals. Beef and dairy cattle are assumed to have access to streams while grazing.
References	Lists literature and assumed values for manure content, wildlife densities, and built-up fecal coliform accumulation rates. These values are used in calculations in the remaining worksheets.
Wildlife	Calculates the fecal coliform bacteria produced by wildlife by land use category.
Cropland	Calculates the monthly rate of accumulation of fecal coliform bacteria on cropland from wildlife, hog, cattle, turkey, chickens, and imported manure.
Forest	Calculates the rate of accumulation of fecal coliform bacteria on forestland from wildlife.
Built-up	Calculates the rate of accumulation of fecal coliform bacteria on built-up land due to wildlife and domestic pets.
Pastureland	Calculates the monthly rate of accumulation of fecal coliform bacteria on pastureland from wildlife, cattle, and horse manure, and cattle, horse, sheep, and other grazing.
CATTLE IN STREAMS	Calculates the monthly loading and flow rate of fecal coliform bacteria from beef and dairy cattle.
SEPTIC IN STREAM	Calculates the loading and flow rate of fecal coliform bacteria from failing septic systems.
ACQOP&SQOLIM (for land uses)	Summarizes the monthly rate of accumulation of fecal coliform bacteria on the four land uses; calculates the build-up limit for each land use. Provides input parameters for the NPSM (ACQOP/MON-ACCUM and SQOLIM/MON-SQOLIM).
WILDLIFE IN STREAM	Calculates the monthly loading and flow rate of fecal coliform bacteria from wildlife.
FC Production Chart	Presents distribution of fecal coliform loading among sources.

Source: Region 5 TMDL Practitioners' Workshop; May 9, 2002; *Computer Session: Techniques for Developing Pathogen TMDLs Fecal Coliform Bacteria Source Quantification and Allocation*; Andrew Parker, Tetra Tech

Table J5. Fecal coliform expected runoff load for a rain event in a given month (from FCLET) to the Cuyahoga R at Independence

Month	Count/day	Count/day
1	1.91E+16	1.06E+16
2	2.25E+16	1.25E+16
3	9.49E+16	5.27E+16
4	8.15E+16	5.43E+16
5	3.22E+16	2.15E+16
6	1.03E+16	6890000000000000
7	6.94E+15	4620000000000000
8	3.16E+16	21100000000000000
9	7240000000000000	4.83E+15
10	15800000000000000	8.79E+15
11	16400000000000000	9.13E+15
12	19100000000000000	1.06E+16
	1st day of rain	consecutive days

J.3.3 Home and Semi-Public Sewage Disposal Systems (Septic)

The load from home and semi-public sewage disposal systems is referred to as the septic load in this report for simplicity. This load calculation is primarily based on the information presented in *Survey of Northeast Ohio Home Sewage Disposal Systems and Semi-Public Sewage Disposal Systems* (NOACA, 2001). This report was prepared for the Northeast Ohio Areawide Coordinating Agency (NOACA) in collaboration with several county and state agencies for the purpose of providing representative data on the performance of systems constructed since 1979 in the Northeast Ohio area.

Values presented in the report were generally based per county. These figures were adjusted based on the percent of county area that is within the watershed (referred to as HUC in Tables J6 and J7). Both the quality and quantity of the systems were estimated in the report. Table J6 presents the adjusted figures per system type based on the report, and Table J7 further refines these numbers to per capita figures so that appropriate flows and loadings could be calculated. Once the number and the type of quality achieve by the systems was estimated, the load was calculated using equations developed by Mandel (1993). These equations and the results are given in Table J7.

Table J6. Septic values from the NOACA study adjusted to county area within watershed

County	Area in HUC (ft2)	Total Area (ft2)	% of county in HUC	Estimated # of HSDS in county	New HSDS 1979-98	On+Offlots Total HSDS in HUC	Onlots New in HUC	Onlots ShrtCirct'd in HUC	Onlots Ponded in HUC	Offlots Total in county	Offlots Total in HUC	Offlots Failing in HUC	Total SPDS in county	SPDS Failing in HUC	'Direct' in county	'Direct' in HUC
Geauga	3875981429	11386085842	34.04%	33000	8504	11234	2895	376	3986	478	163	77	130	3	911	310
Cuyahoga	5277141963	12800440753	41.23%	14000	180	5772	74	148	856	3463	1428	495	89	10	976	402
Portage	5929891449	14051659257	42.20%	20000	9845	8440	4155	275	2345	838	354	167	*130*	7	474	200
Summit	7098087942	11706242378	60.64%	31330	8014	18997	4859	629	4367	810	491	491	*130*	11	523	317
Medina	176692533	11789289813	1.50%	20000	675	300	10	7	40	6440	97	47	197	1	330	5
Stark	198075706	16173449018	1.22%	*20000*	*675*	*245*	*8*	6	*33*	*6440*	79	37	*130*	1	608	7
Total:	22555871021	77907167060	28.95%	138330	27893	44987	12001	1441	11627	18469	2611	1314	806	33	3822	1242

Table J7. Loading calculations for septic systems in the Lower Cuyahoga watershed

2001 County Population	2001 HUC Population	People per Household	in HUC Summary							Per Capita (a)					
			Directs	Ponded On Failing Off	Short Circuited	On&Off Normal	On&Off Total	Failing SPDS	Normal SPDS	Directs	Ponded On Failing Off	Short Circuited	On&Off Normal	Failing SPDS	Normal SPDS
92180	31379	2.84	310	4062	376	6485	11234	3	41.5	881	11536	1069	18417	8	118
1380421	569096	2.39	402	1351	148	3870	5772	10	26.4	962	3229	353	9250	25	63
152743	64459	2.56	200	2512	275	5454	8440	7	47.4	512	6429	704	13961	19	121
544217	329986	2.45	317	4859	629	13192	18997	11	68.1	777	11903	1541	32321	26	167
155698	2334	2.74	5	88	7	200	300	1	1.9	14	239.8	18.9	549	3	5
377438	4622	2.49	7	70	6	162	245	1	0.6	19	173.9	14	403	2	1
							45206		TOTAL (a) :	3164	33513	3700	74902	83	476

total septic Q:	7685070 l/d	TP load:	10	111	9	0	0.3	0
	3.14 cfs	(lb/d)	a*d*e*F	a*d*e*F	F*a*d*(e-u)	absorbed		

(in summer)

	F =	0.0022046	
170 l/system/d	e =	1.5	g/d/percapita nonphospate detergent
from GWLF manual	u =	0.4	g/d/percapita
(from USEPA guidance)	d =	1	days/day

J.3.4 Reservoir Releases and Water Diversions

Lake Rockwell and Mogadore Reservoir are the two major reservoirs in the lower Cuyahoga watershed and serve the City of Akron as drinking water resources. The city has the ability to regulate flow out of both reservoirs. Mogadore Reservoir consistently releases approximately 5 MGD under most flow conditions. The Lake Rockwell release is more variable with a median annual release since 1996 of 30 MGD, a 5th percentile release of 3.5 MGD and a 95th percentile release of 395 MGD.

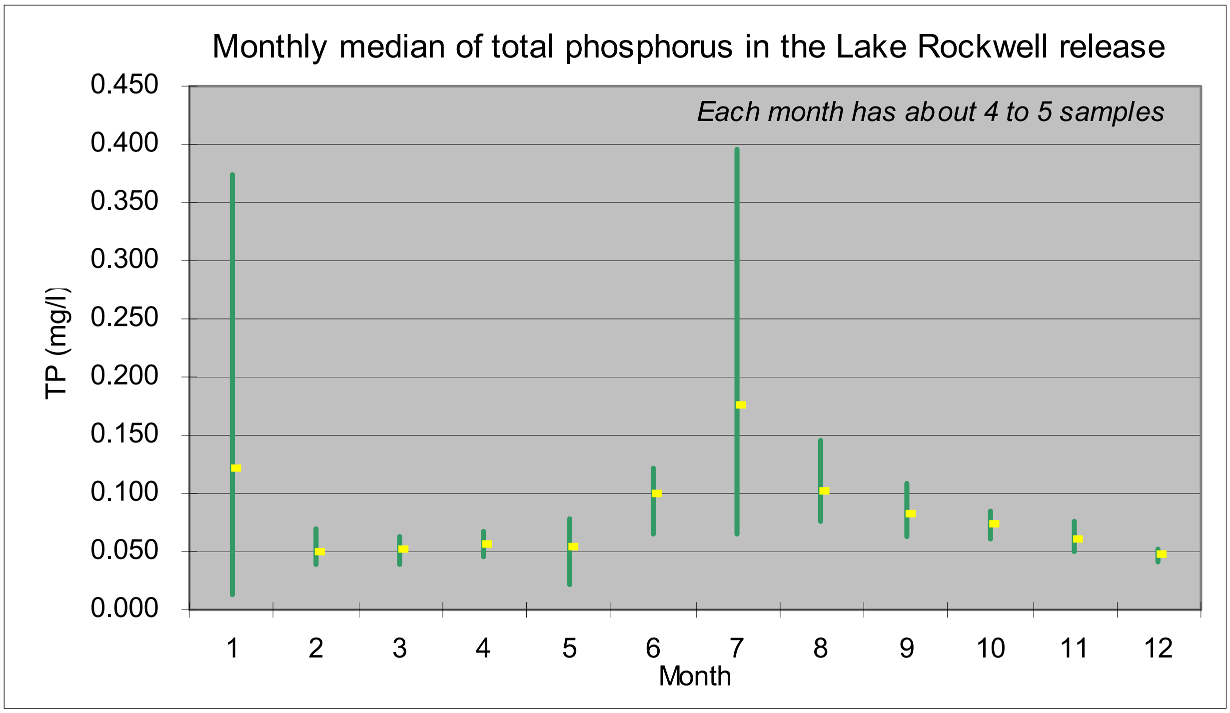

Figure 13 Monthly range of total phosphorus concentrations in the Lake Rockwell release since 1996. The yellow dashes are the median concentration, the low edge of the bar is the minimum value and the upper edge of the bar is the maximum value observed.

The City of Akron samples Lake Rockwell approximately monthly for nutrients and a few other parameters. The results of this sampling for total phosphorus are included in Figure J13 on a monthly basis. Fecal coliform sampling was not as extensive. The median of six samples was used to establish a fecal coliform quality for the reservoirs.

Some flow is diverted out of Lake Rockwell to service an area outside of the Lake Erie Basin. In order to account for this withdrawal, Akron diverts flow from the neighboring Tuscawarus basin and routes it back into the Lake Erie basin via the Ohio and Erie Canal in the Little Cuyahoga watershed. An additional flow diversion occurs near SR 82 (RM 20.8) from the Cuyahoga River to supply flow in the Ohio and Erie canal. This flow returns to the river downstream of Independence at around river mile 8.2.

J.3.5 Point Sources

The major point sources in the basin were included in the lower Cuyahoga TMDL development. This was any plant greater than 1 MGD design flow. No major industrial facilities are present in the lower Cuyahoga upstream of the ship channel only municipal facilities. The minor facilities were not included given the small contribution they make to the overall load to the lower Cuyahoga basin. This TMDL is a watershed-scale project; global issues are the primary focus. Small, minor NPDES facilities did not contribute significant load contributions in a global sense; however, they may have effects locally. The NPDES permit process should address these local issues, and these local effects and the appropriate treatment options would be more apparent in such a process which is on a much smaller scale.

Data from January 1, 1996 through June 30, 2002 were used in this analysis. The point source data came from each facility's monitoring records as reported to the agency. If a value was not available on a particular day (for example, flow or total phosphorus), the median of all sampled data for that facility and parameter was used instead.

J.3.6 Groundwater and the Hydrograph Separation and Analysis Program

The groundwater component of the flow budget in the lower Cuyahoga was determined using a USGS computer program for hydrograph separation and analysis (HYSEP). HYSEP is a computer program that can be used to separate a streamflow hydrograph into base-flow and surface-runoff components using daily mean stream discharge as input to the program. The base-flow component has traditionally been associated with groundwater discharge and the surface runoff component with precipitation that enters the stream as overland runoff. HYSEP includes three methods of hydrograph separation that are referred to in the literature as the fixed-interval, sliding-interval, and local minimum methods. These methods can be described conceptually as three different algorithms to systematically draw connecting lines between the low points of the streamflow hydrograph. The sequence of these connecting lines defines the base-flow hydrograph (USGS, 1996). The method used in the lower Cuyahoga TMDL analysis was the fixed-interval method, and the estimated groundwater discharge since 1996 is shown in Figure J14. For information regarding this method and for further information on HYSEP refer to http://pa.water.usgs.gov/reports/wrir96-4040.pdf.

The groundwater quality was based on the median values of relatively unimpacted 'reference' streams under low flow, non-runoff conditions. It was assumed that such streams would be primarily groundwater at these times and would give a reasonable approximation of the groundwater quality. USGS well data in the area was used as well. The data from these two sources were similar. Groundwater was assumed to be the natural background component of the TMDL flow and load allocation.

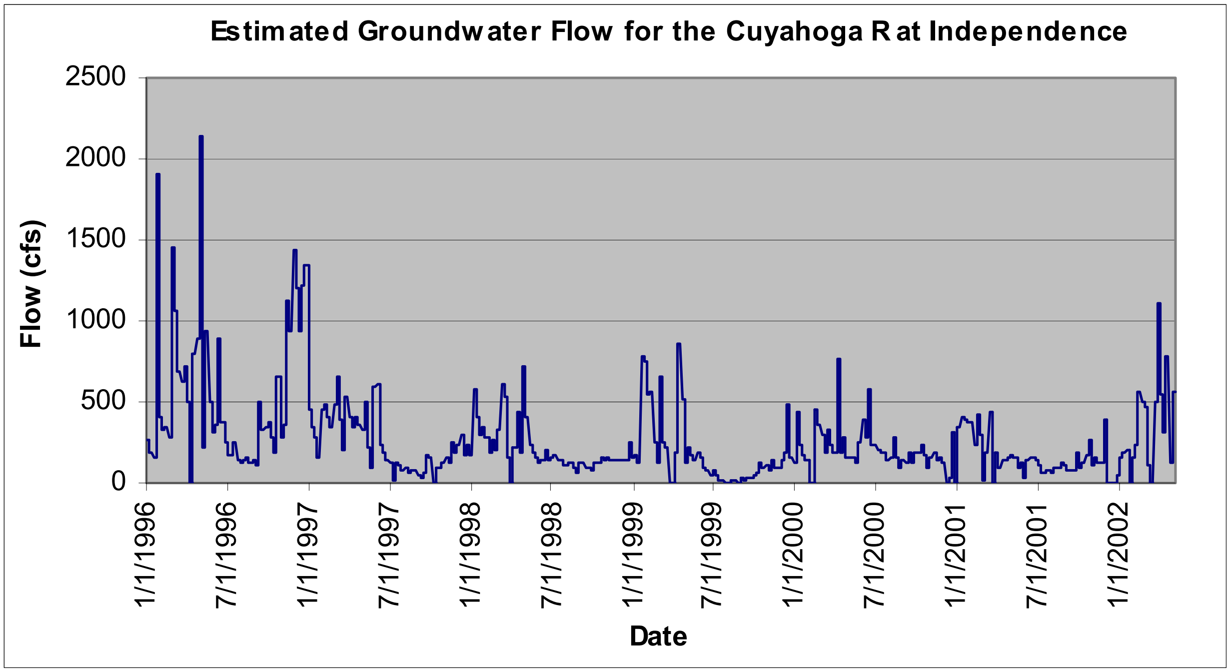

Figure 14 Groundwater discharge for the Cuyahoga River at Independence

J.3.7 Future Growth

The future growth component was determined as shown in Table J8.

Table J8. Future growth determination for the lower Cuyahoga TMDL

County	1990 Population	2000 Population	2015 Estimated Population	1990 to 2015 % growth	Relative county area in HUC	Estimated % growth
Cuyahoga	1412140	1393978	*1392900*	-1.36%	31	30.578
Summit	514990	542899	*557600*	8.27%	45	48.723
Portage	142585	152061	*160600*	12.63%	24	27.032
				Totals:	*100*	*106.33*

Notes: Added 3% to Summit to account for Medina and Stark land area.
See table below for determination of the relative county area in basin (HUC).
Population and estimated future population from the US Census Bureau.
Use 6% future growth estimator.

County	Area in HUC (ft^2)	relative county area in HUC
Cuyahoga	5277141963	31%
Portage	4006281449	24%
Summit	7098087942	42%
Medina	176692533.2	1%
Stark	198075706	1%
Total:	16756279593	100%

J.4 Seasonal and Annual Variations

Figure J15 shows the seasonal flow variations by monthly flow percentiles; highest flows occur in the February/March time period and the lowest flows occur between July and October. Figure J16 shows the water quality duration curve for total phosphorus at Independence broken out in two year increments. This shows there is some annual variation that occurs.

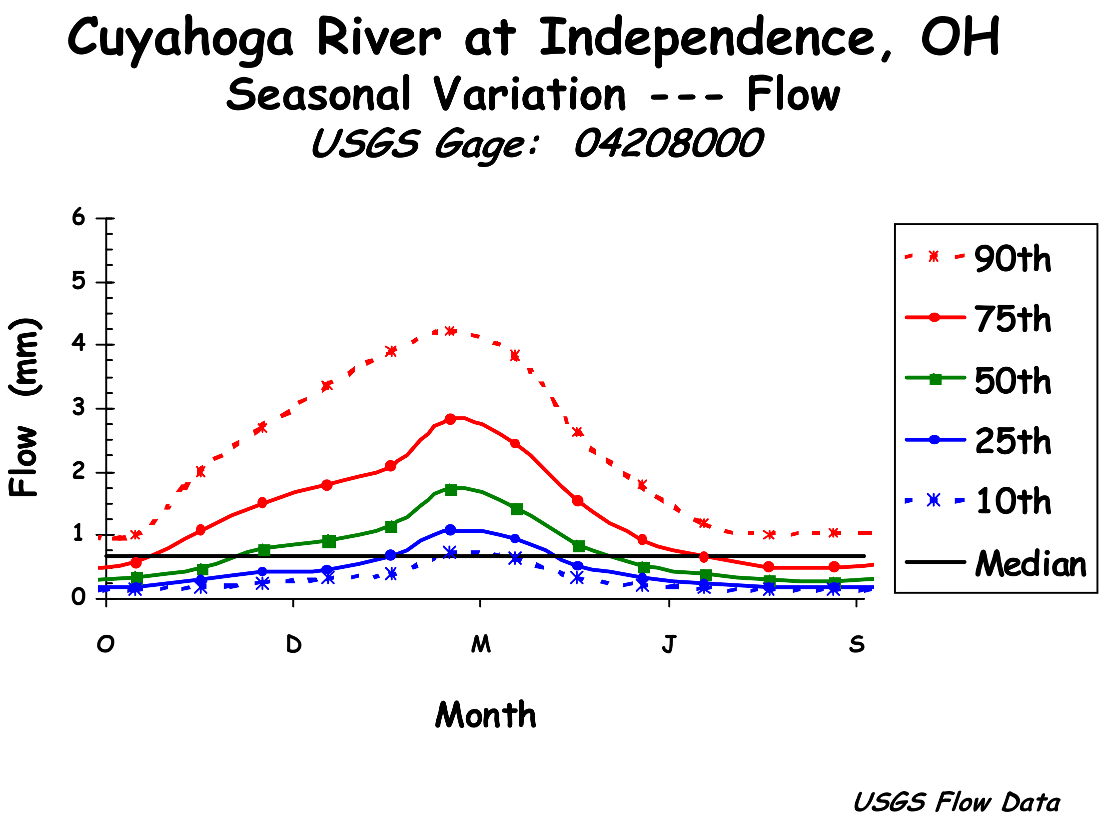

Figure 15 Seasonal flow variation for the Cuyahoga River at Independence

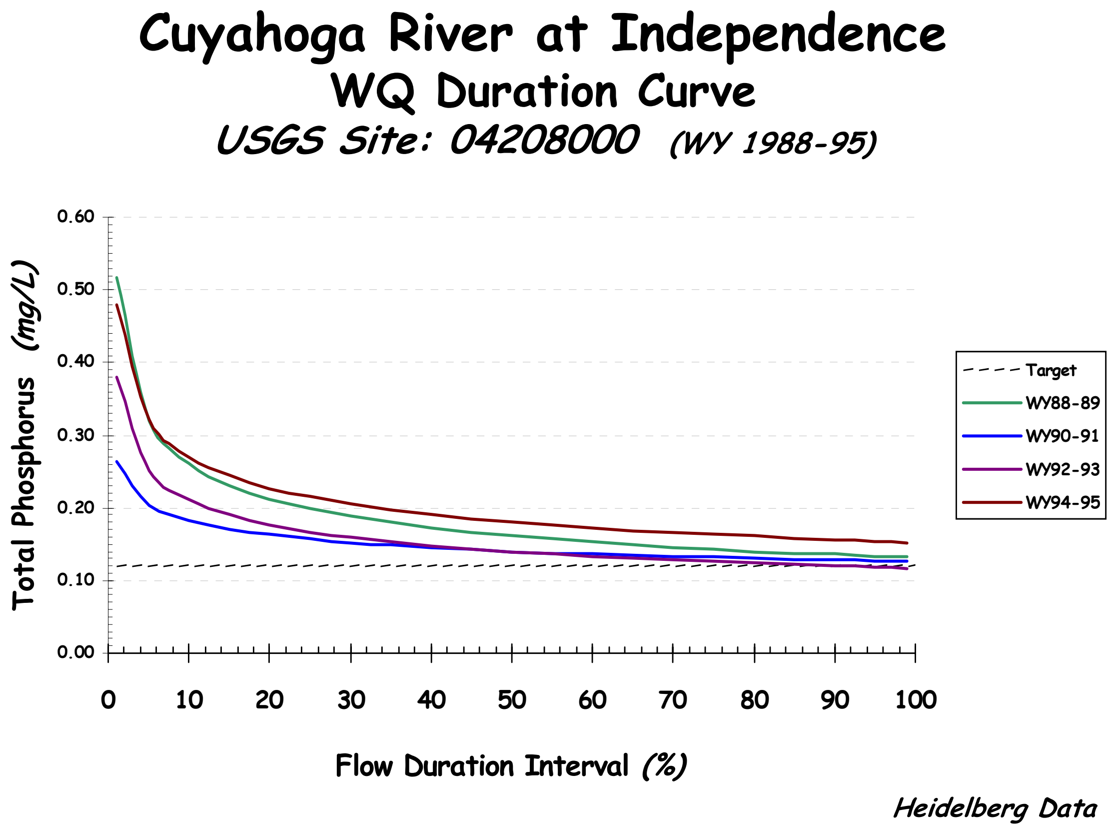

Figure 16 Annual variation in water quality for the Cuyahoga R at Independence

J.5 Comparison of Total Phosphorus Targets on the TMDL

Figure J17 shows the affect of varying the total phosphorus target on the TMDL and compares these various TMDLs with the existing loading for the Cuyahoga R at Independence. The targets are the from the report *Associations Between the Aquatic Biota, Habitat, and Nutrients in Ohio Rivers and Streams* (OEPA, 1999) and represent different percentiles of observed total phosphorus concentrations at sites attaining the designated use. The 95th % line on the graph represents the allowable load based on the 95th % total phosphorus concentration of the attaining sites; the 50th and 75th percentiles follow suit. The 50th% reference line (represented in cyan) is based on the 50th percentile concentration from only the least impacted reference sites.

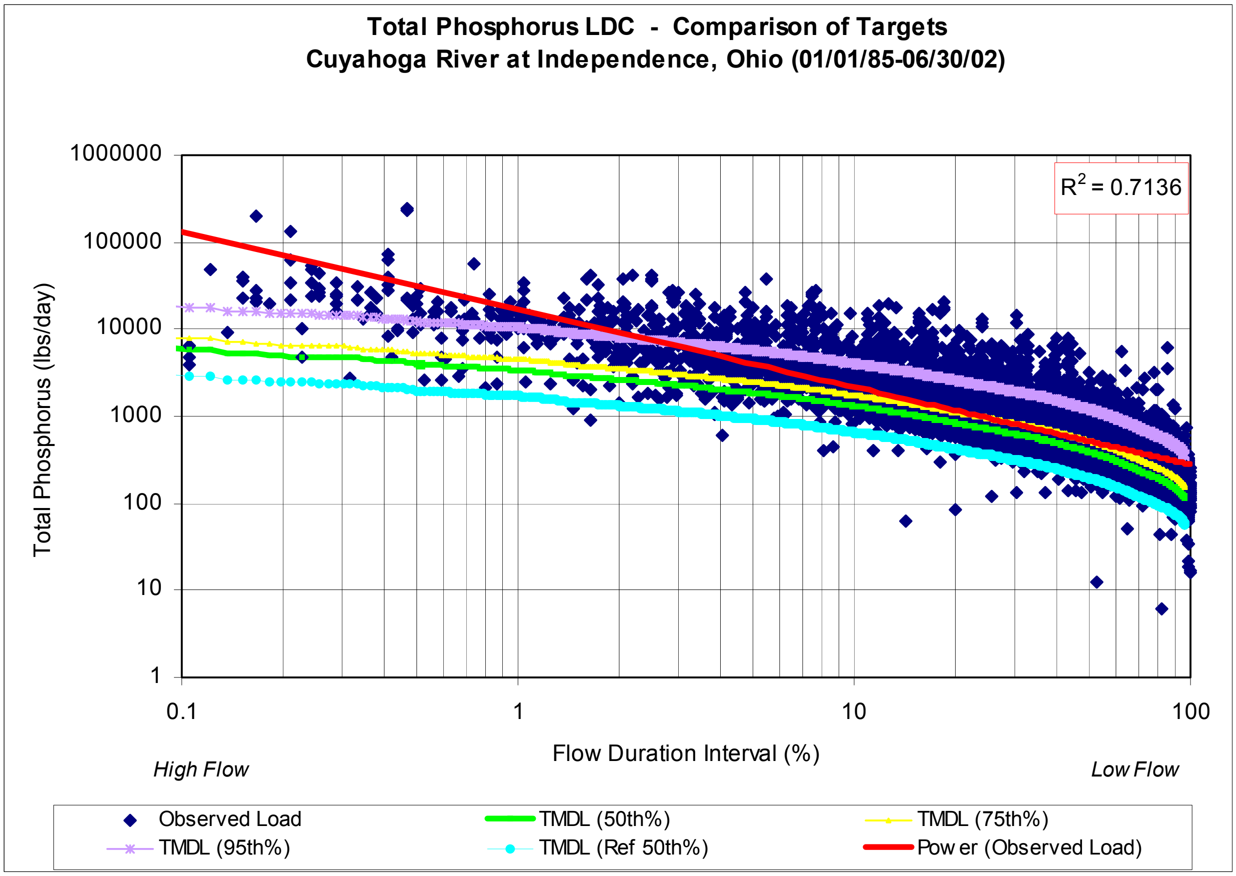

Figure 17 Comparison of total phosphorus TMDLs based on various targets

References

Mandel, R. 1993. The impact of septic systems on surface water quality. Unpublished M.S. dissertation. School of Civil & Environmental Engineering, Cornell University, Ithaca, NY.

NOACA. April, 2001. *Survey of Northeast Ohio Home Sewage Disposal Systems and Semi-Public Sewage Disposal Systems*; Cleveland, OH.

OEPA. 1999. Association Between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams. OEPA Technical Bulletin MAS/1999-1-1. Columbus, OH.

Region 5 TMDL Practitioners' Workshop. May 9, 2002. *Computer Session: Techniques for Developing Pathogen TMDLs Fecal Coliform Bacteria Source Quantification and Allocation*; Andrew Parker, Tetra Tech; Indianapolis, IN.

USGS. 1996. HYSEP: A Computer Program for Streamflow Hydrograph Separation and Analysis, Water Resource Investigations Report 96-4040. Lemoyne, PA.