Appendix J: Pathogen Modeling Details

This appendix explains the pathogen modeling method used to address the geometric mean portion of the recreational use criteria. Table J-1 shows the pathogen TMDL development. Pathogen modeling is carried out to determine existing conditions, TMDLs and acceptable allocations of an indicator parameter so that streams can meet their recreational use standards. Fecal coliform bacteria is the parameter the US EPA Bacteria Indicator Tool (BIT) calculates (US EPA, 2000). Because of this, fecal coliform bacteria is the indicator parameter used for the pathogen TMDL in this report. Fecal coliform bacteria loads are measured in colony forming units (cfu).

Table J-1. Summary of BIT bacteria TMDL development

Development step	Source		Method
Existing load	Point Source w/ NPDES		Product of discharger design flow and the fecal coliform average standard currently in place.
	Point Source w/o NPDES		Product of discharger design flow and the fecal coliform average standard.
	Surface runoff		Determined with the BIT tool and a spreadsheet watershed washoff model.
	HSTS		Population served by failing HSTS estimated via GIS and county Health Departments. Fecal coliform load based upon population estimate and a per capita loading rate.
	Cows in stream		Cattle in stream bacteria loads are determined using the BIT tool.
Calculation of loading capacity	-		Product of the average recreation season discharge volume from each sub-basin and the fecal coliform geometric mean concentration.
Suggested allocation	WLA	Point Sources w/ NPDES	Product of discharger design flow and the fecal coliform average standard currently in place.
		Point Sources w/o NPDES	Product of discharger design flow and the fecal coliform average standard.
		MS4	MS4s are allocated a portion of the total LA. MS4s allocations are the product of the percentage of the sub-basin area occupied by MS4s and the sub-basin surface runoff allocation.
	LA	Surface runoff	LA is equal to the sum of all WLAs (except for MS4 runoff) subtracted from the assimilative capacity.
		HSTS	Failing home sewage treatment systems are allocated a fecal coliform load of zero.
		Cows in stream	Cattle grazing in streams are allocated a fecal coliform load of zero.

Point sources with NPDES permits

Point source permittees discharging effluent that may contain pathogenic material are currently required to not exceed the recreational use standard for their receiving water. All of these point sources are identified in each pathogen TMDL watershed (Table J-2). The product of each facility's design flow and the fecal coliform geometric mean standard of 1000 cfu per 100 ml is used to calculate existing load.

Table J-2. Fecal coliform effluent concentration, flow and loads for NPDES point sources

14-Digit HUC	Sub-watershed	NPDES	Facility name	Fecal coliform (cfu/100ml)	Flow (MGD)	Load (cfu * 10^9 *day^{-1})
010	upper Middle Branch Nimishillen Ck	3PR00373	Cutty's Suset Campt STU 1	1000	0.070	2.65
		3PB00019	Hartville WWTP	1000	0.045	1.70
		3PV00123	Shady Knoll MHP	1000	0.006	0.23
030	East Branch Nimishillen Ck	3PR00279	Canaan Acres Christian	1000	0.014	0.53
		3PR00273	Cornerstone Foursquare WWTP[2]	1000	0.003	0.11
		3PR00336	Hot Laps Sports Bar Inc.	1000	0.004	0.15
		3PR00363	Louisville Health Center	1000	0.01625	0.62
		3PD00033	Louisville WWTP	1000	2.0	75.71
		3PG00108	Molly Stark Hospital WWTP	1000	0.10	3.79
		3PT00112	North Nimishillen Elem Sch	1000	0.006	0.23
040	West Branch Nimishillen Ck	3PG00082	Bob-O-Link Allt STP	1000	0.30	11.36
050	Sherrick Run†	3PT00113	Walker Elem Sch	1000	0.0075	0.28
060	lower mainstem Nimishillen Ck	3PE00000	City of Canton WPCF	1000	39	1476.31
		3IN00035	US Ceramic Tile Co.	1000	0.0148	0.56

† Sherrick Run is only part of this 14-digit HUC

Point sources without NPDES permits

Several non-permitted facilities with much lower effluent flow are known to exist in the subwatersheds modeled. These facilities have no NPDES permit and do not report their effluent quantity and quality values. Therefore effluent flow values were estimated. Like the permitted dischargers, these facilities were assumed to be continuously discharging fecal coliform effluent concentrations of 1000 cfu per 100 ml. Table J-3 shows these facilities, their assumed flow values and the calculated fecal coliform load for each.

Table J-3. Fecal coliform effluent concentration, flow and loads for point sources without an NPDES permit

14-Digit HUC	Sub-watershed	Facility name	Fecal coliform (cfu/100ml)	Flow (MGD)	Load (cfu * 10^9 *day^{-1})
030	East Branch Nimishillen Ck	Bud's Corner Tavern	1000	0.003	0.12
		Carriage House	1000	0.008	0.28
		Elm Inn	1000	0.004	0.15
		Robert Apartments	1000	0.006	0.22
		Thompson Dairyland	1000	0.006	0.22
		VFW	1000	0.003	0.12
		Northmark Inc	1000	0.003	0.12
040	West Branch Nimishillen Ck	Leno's Restaurant	1000	0.006	0.22
		North Market Home Sales	1000	0.003	0.12
		Whipple Center Building	1000	0.003	0.12
050	Sherrick Run†	Arvilla Well Services Inc	1000	0.003	0.12
		Roadside Tavern	1000	0.003	0.12
		True Vine Ministries	1000	0.003	0.12
060	lower mainstem Nimishillen Ck	Adams Fabricating	1000	0.003	0.12
		Barb Huff Apartments	1000	0.003	0.09
		Stanley Miller	1000	0.003	0.12

† Sherrick Run is only part of this 14-digit HUC

Surface runoff

Surface runoff of fecal coliform bacteria is determined by use of two tools. First the US EPA's BIT is employed to determine how much fecal coliform is accumulated on land. And second a washoff method is used to determine how much of that land accumulated bacteria is transported to the streams.

Bacteria Indicator Tool (BIT)

The USEPA Bacteria Indicator Tool (USEPA, 2000) requires three types of values: user-defined, default and literature. User-defined values are to be specific to the study area. User-defined values required by the tool are land use distribution, numbers of agricultural animals and wildlife densities. Default values are supplied by the tool, but it is suggested that they be modified to reflect patterns in the study area. Default values include the amount of each manure type applied each month, the amount of manure type that is incorporated into the soil and the time spent grazing and confined by livestock. Like default values, literature values are supplied by the tool, but they may be replaced with user values if better information is available for the study area. Literature values required by the tool are waste production/accumulation rates and fecal coliform bacteria content in animal waste, raw sewage and on built-up land uses.

Literature values are unchanged for each HUC because limited watershed-specific information is available that would better characterize the area. Values for the amount of time cattle spend in streams are limited only to those streams with evidence of cattle access as determined by Ohio EPA field staff. All other default values are left unchanged. User-defined values are determined via the following methods:

• The land use distribution is derived from the National Land Cover Dataset (NLCD) via GIS analysis. The NLCD is compiled from Landsat TM satellite imagery circa 2001 (Homer, 2004). NLCD information is reclassified to agree with the land use categories of BIT which are built-up, cropland, forest, pastureland and water.

• Populations of agricultural livestock and wildlife are derived from countywide figures. Information regarding the amount of livestock was obtained from Ohio Agricultural Statistics Service published data. Communication with the Stark County Natural Resources Conservation Service's District Conservationist took place in order to learn approximate locations of livestock farms in Stark County. The county total of livestock and basic livestock operations locations were combined to estimate the amount of livestock in each of the modeled watersheds.

• Information regarding wildlife populations was obtained from Ohio Department of Natural Resource census data. For the distribution of wildlife populations the total number of animals within the county was divided by the total number of acres of relevant land use in the county. The resulting animal densities (animals per acre) were used to estimate the wildlife populations within each watershed.

When all values are entered, BIT predicts the maximum surface accumulation rate of fecal coliform and the asymptotic limit of accumulation should no washoff occur. Additionally, BIT predicts the fecal coliform load contributed directly to the stream from livestock (cows) with stream access.

Washoff method

A spreadsheet method was used to estimate the pollutant loads from bacteria washoff. This method uses a combination of empirical data and literature or default values in each calculation. When all values were entered into BIT, the tool predicts the maximum surface accumulation rate of fecal coliform and the asymptotic limit of accumulation should no washoff occur. The maximum surface accumulation BIT output is used in this washoff method, however an on-land bacteria decay function is utilized. This decay function limits surface accumulation from exceeded the same asymptotic limit determined by BIT. In addition to the daily accumulation rate and decay function, this method requires daily runoff and a washoff coefficient as inputs. Daily runoff is estimated using the SCS curve-number method. The amount of on-land bacteria that washes off of a land use on any given day is based on a washoff equation used in the HSPF and SWMM models (Bicknell, 2001).

This method runs on a daily time step. For any given day whatever surface bacteria that does not get washed off from the prior day experiences a reduction due to the decay function. Then that day's bacteria are added to the accumulated material. If precipitation occurs then the SCS curve number determines how much runoff occurs in this land use. This runoff value is used in the washoff function for the land use. Some or all of the accumulated bacteria may wash off reducing that land use's total accumulated bacteria that will be accounted for the following day.

This method was carried out for the same four upland land uses considered in BIT (built-up, cropland, forest and pastureland) on a daily basis for ten recreational seasons

(1997-2006) for each watershed. The average total recreational season bacteria load was determined to represent the bacteria that wash off of the various land uses.

Home sewage treatment systems (HSTSs)

The number of HSTS and the percentage of those which are failing are determined via county supplied information and GIS analysis. These calculations were made without the use of BIT.

The Stark County Health Department supplied street addresses for all of the homes with HSTSs. Using GIS these addresses were able to be geo-coded and turned into spatial data. Simple GIS analysis was then used to determine how many HSTSs were in each subwatershed being considered for a bacteria TMDL (Map 4).

The percentage of failing HSTS and the bacteria loads contributing to the streams was determined based on information from health departments, field observations and GIS analysis. GIS analysis included data consisting of the age of houses in a watershed, population density and soil limitations. First GIS was used to find how many people lived in each watershed's area with HSTSs from the 2000 census block group level data (US Census Bureau, 2000). GIS analysis also determined the housing density, average age of houses (both also from 2000 census data) and percent of area with HSTS limited soils (data supplied from NEFCO, 2004) for each watershed. Of the HSTSs in the Nimishillen Creek watershed 21.7% are in areas with HSTS limited soils. One half of these systems were considered to be failing. The percent of systems failing was increased for each watershed with greater average age of houses and housing density. This manner of determining failure rates are estimates based on the best professional judgment of the Modeling and Assessment Section. Table J-4 shows the breakdown of the HSTS in each watershed. The watersheds which receive a bacteria TMDL are noted on this table. Table J-5 shows the percent of added failure rate for ranges of the average year houses were built and housing density.

For this TMDL, a HSTS considered failing is a one that is non-functional with untreated effluent being discharged to streams. Therefore if watershed has 57% HSTS failure rate it means that 57% of the fecal coliform bacteria that would normally be treated is being discharged to the streams. The wastewater flow rate used in this report is 40 gallons per HSTS plus 40 gallons per person using each system per day (Metcalf & Eddy, 1991). The wastewater quality concentration value used for this wastewater flow is 10 million cfu/100ml (US EPA, 2002). Therefore the existing failing HSTS load for each watershed is determined with the following factors: total HSTSs, the failure rate, the estimated number of persons served by failing systems, the wastewater flow rate and wastewater concentration.

Table J-4. HSTS GIS results and total % failure for each subwatershed

HUC	TMDL?	Watershed	Data	HSTS limited soil? NO	HSTS limited soil? Yes	Total HSTS	% failure of total
010	Yes	MB Nim. Cr. headwaters to below Swartz Ditch	HSTS	1052	450	1383	32.90%
			Ave. year house built	1968	1967		
			Ave. Housing density	82	83		
020-in part	No	MB Nim. Cr. below Swartz Ditch to above W. Branch [except E. Branch] MB only	HSTS	2361	385	2592	63.11%
			Ave. year house built	1968	1968		
			Ave. Housing density	674	520		
020-in part	No	Nim. Creek from confluence of Middle B and E. Branch to above W. Branch - mainstem only	HSTS	4		4	94.44%
			Ave. year house built	1949			
			Ave. Housing density	2309			
030	Yes	East Branch Nimishillen Creek	HSTS	2363	809	3006	48.39%
			Ave. year house built	1961	1960		
			Ave. Housing density	181	135		
040	No	West Branch Nimishillen Creek	HSTS	3916	406	4036	62.57%
			Ave. year house built	1967	1973		
			Ave. Housing density	727	376		
050-in part	Yes	Hurford Run only	HSTS	728	178	891	57.57%
			Ave. year house built	1964	1964		
			Ave. Housing density	488	177		
050-in part	Yes	Sherrick Run only	HSTS	528	398	901	68.83%
			Ave. year house built	1950	1954		
			Ave. Housing density	202	191		
060	Yes	Nimishillen Creek below Sherrick Run to Sandy Cr.	HSTS	961	453	1385	50.63%
			Ave. year house built	1960	1962		
			Ave. Housing density	211	111		

Note: The 050 partial watershed that drains to the mainstem has zero HSTS.

Table J-5. Increases in HSTS failure rates (included in Table 4.A.4)

For the watershed average homes built in year:				
1940 - 1949	1950 - 1959	1960 - 1969	1970 - 1979	1980 - 1990
38%	26%	17%	12%	7.5

For the watershed average housing density (houses/mi^2)					
80 - 149	150 - 299	300 - 499	500 - 999	1000 - 1999	2000 - 2999
4.5%	16%	29%	40.5%	52.5%	61.5%

Cows in streams

The BIT tool also determines how much fecal coliform is directly introduced to streams from livestock (cattle grazing in streams). The grazing practices employed for cattle is part of BITs user specified parameters.

Municipal separate storm sewer systems (MS4s)

MS4s are regulated municipalities that are required to have some type of NPDES permit for storm water runoff based on population and housing density. US Census GIS data are used to draw the MS4 boundaries for municipalities. These spatial data are cut by watershed and analyzed for land use using the same land use data employed for the BIT modeling. The amount urban land uses that are in the MS4 areas are compared to the total urban land use area for each watershed (Table J-6). The percentage of MS4 urban land uses to the total urban land uses in each watershed is determined. This percentage is taken away from the modeled fecal coliform urban land surface runoff (from washoff method explained above) and considered MS4 existing fecal coliform load. The recommended allocation of fecal coliform for MS4 lands is similarly calculated. Before surface runoff and MS4 fecal coliform allocations are made all other sources are first determined. The remaining loading capacity is allocated to surface runoff and MS4 load at the same ratio as these sources are calculated for existing loads. By doing this MS4 loads are required to be reduced the same percentage as the non-permitted surface runoff loads (see Chapter 5 of the main report for applications of this).

Table J-6. MS4s located throughout the 14-digit HUCs in the Nimishillen Creek watershed.

HUC-14	Watershed name	Municipal separate storm sewer systems (MS4)		
		Area of MS4 (mi^2)	Urban land that is MS4 (mi^2)*	Name
010	MB Nim Ck headwaters to below Swartz Ditch	0.49	0.34	Hartville Village
		0.13	0.10	Lake Township
020 in part	Middle Branch Nimishillen Creek below Swartz Ditch to above formation of mainstem	5.78	5.43	Canton City
		0.18	0.18	Nimishillen Township
		0.11	0.11	North Canton City
		9.29	6.73	Plain Township
020 in part	Nimishillen Ck below Middle Branch to above WB Nim Ck	2.29	2.26	Canton City
030	East Branch Nimishillen Creek	2.22	2.01	Canton City
		2.61	1.88	Canton Township
		5.01	3.15	Louisville City
		4.27	3.14	Nimishillen Township
		0.14	0.14	Plain Township
040	West Branch Nimishillen Creek	7.63	7.63	Canton City
		2.67	2.67	Greentown
		0.08	0.08	Hills and Dales Village
		8.47	8.47	Jackson Township
		0.31	0.31	Lake Township
		0.43	0.43	Meyers Lake Village
		5.72	5.72	North Canton City
		0.34	0.34	Perry Township
		5.36	5.36	Plain Township
		0.70	0.70	Tuscarawas Township
050 in part	Nim Ck below WB Ck to below Sherrick Run – mainstem only	0.34	0.30	Canton City
050 in part	Hurford Run	1.30	1.29	Canton City
		0.94	0.52	Canton Township
		3.30	3.03	Perry Township
050 in part	Sherrick Run	0.99	0.74	Canton City
		1.11	0.83	Canton Township
060	Nimishillen Ck below Sherrick Run to Sandy Cr.	0.17	0.11	Canton City
		3.01	2.18	Canton Township

* Based on the 2001 NLCD land use GIS data (Homer, 2004)

Loading capacity

Seasonal loading capacity for each watershed is determined by calculating the product of the seasonal stream flow and fecal coliform geometric mean concentration target. The seasonal stream flow is determined by averaging the 10 years of modeled hydrology for May through October 15. Stream flow was calculated by summing both the contribution of flow resulting from overland runoff and groundwater (baseflow) to the stream. Runoff was calculated concurrently with the existing bacteria overland washoff in the spreadsheet method used and described above. Baseflow for each subwatershed was calculated by applying a watershed area weighting factor to a near by USGS daily stream flow gage's baseflow. The baseflow of the gages was determined by applying a watershed area yield value. This value was determined by applying a stream flow separator method to the daily stream flow records of the Nimishillen Creek at North Industry gage (USGS 03118500) and the Middle Branch Nimishillen Creek at Canton gage (USGS 03118000). The geometric mean target is 1000 cfu per 100 ml for all primary recreational use streams and is described in Section 3.1.1 of the TMDL report. The loading capacity calculation accounts only for dilution as a means of assimilation. Not considering instream processing and decay of fecal coliform is a wasteload conservative measure representing an implicit margin of safety.