APPENDIX E

Details of the Technical Analyses (Modeling)

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E.1 Stream flow modeling

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E.1 Stream flow modeling

This appendix explains the use of GWLF to determine the amount of stream flow for watersheds with nutrient and bacteria modeling in the Tuscarawas TMDL report. Refer to the BasinSim 1.0: A Windows-Based Watershed Modeling Package, User's Guide, (Dai, 2000) for specific information about the model and this particular interface.

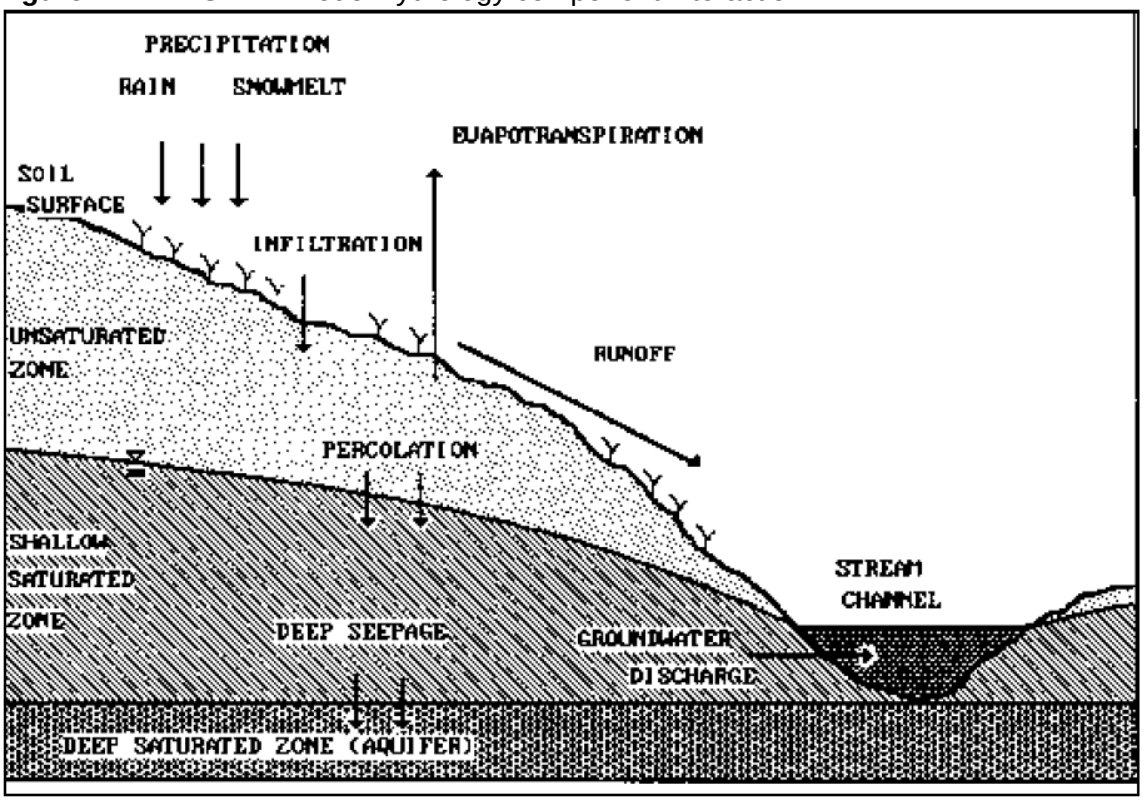
E.1.1 Model description

The Generalized Watershed Loading Function (GWLF) model is a mathematical model that estimates surface and groundwater flow as well as dissolved and total monthly nitrogen and phosphorus loads. GWLF is a mid-level watershed loading model that is a compromise between a simple, empirical export-coefficient model and a detailed, process-based mechanistic model. The hydrologic routines of the model operate on a daily time-step, while sediment and nutrient loads are calculated on a monthly basis. For the Tuscarawas River TMDL, GWLF is used to determine the phosphorus loads for watersheds impaired by nutrients. Stream flow estimates from GWLF are also used to determine the loading capacity of bacteria in watersheds that do not meet their recreational use attainment. This appendix only describes how the stream flow aspects of GWLF are determined for Tuscarawas River TMDL watersheds. Because the BasinSim user guide describes the mathematical process of this model in detail, very little of this is explained in this appendix (Dai, 2000).

Figure E.1.1.A shows the hydrologic model of GWLF. GWLF simulates runoff, groundwater recharge and stream flow by a water-balance method using measurements of daily precipitation and average temperature. Runoff is calculated using the Natural Resources Conservation Service's Runoff Curve Number method (USDA, 1986). This method determines the amount of precipitation that runs off the surface and is adjusted for the following: antecedent soil moisture before the precipitation event, growing or dormant season, detention potential and soil characteristics. Runoff curve numbers vary by land cover, use and soil type; the higher the runoff curve number the more runoff is produced. The predicted surface runoff flow is the quick response flow considered to include interflow and drainage from storm drains and field tiles.

Groundwater recharge is determined by tracking daily water balances in the unsaturated and shallow saturated zones. These zones act as reservoirs with inputs and outputs. The input to the unsaturated zone is the infiltrated water calculated as the amount of the precipitation received less the surface runoff. Water leaves this zone to the atmosphere via plant root uptake through transpiration and down to the shallow saturated zone through percolation. Transpiration is grouped with evaporation to make an evapotranspiration function. GWLF determines a daily potential evapotranspiration based on day length, temperature and cover coefficient of vegetation in each land use for each watershed. If there is enough available moisture in the unsaturated zone, the potential evapotranspiration will be lost to the atmosphere. If the available moisture in the unsaturated zone is less than that day's potential evapotranspiration, all water in that zone will go to the atmosphere. When the temperature is less than or equal to zero, there is no evapotranspiration. Percolation occurs daily when the unsaturated zone moisture volume exceeds the storage capacity (U*) after any evapotranspiration occurs. The shallow saturated zone receives the percolated water. This zone is treated as a linear reservoir; it can discharge water to the stream as baseflow or lose moisture to deep seepage. Each of these losses is determined by the product of the zone's moisture storage and a specific constant rate coefficient. The recession coefficient, *r*, determines baseflow and seepage coefficient, *s*, seepage from the shallow saturated zone.

Figure E.1.1.A GWLF Model hydrology component interaction



Stream flow is computed as the sum of the groundwater discharge from the shallow saturated zone (baseflow) and the surface runoff. The model computes the daily water balance and resulting stream flow.

E.1.2 Model setup

Many GWLF hydrology parameters require calibration with to a known stream flow gage. None of the 34 watersheds that require GWLF hydrology, for nutrient, bacteria and/or upstream TMDL modeling, have a USGS gage on them (except for gage # 03115973 on Schocalog Run which is within the Pigeon Creek watershed). Four stream flow gages are assumed to have representative watershed characteristics for the watersheds that require modeling (Table E.1.2.A). Weather data are determined based on the years available of stream flow data (Table E.1.2.B). Hydrology throughout this appendix is presented in cm/time over the watershed area. Table E.1.2.C provides the watershed area for the gage and TMDL watersheds in square CM and other units.

Table E.1.2.A USGS gage sites used as GWLF hydrology calibration watersheds

USGS gage used for GWLF hydrology calibration	Impaired watershed		Impaired	
	14-dig HUC	**Name**	**Nutrient**	**Pathogen**
Gage # 03115973 Schocalog Run at Copley Junction OH	010-010 partial	Tusc.River upst. Mogadore Rd.		X
	010-030 partial	Wolf Ck UT RM 11		X
	010-030 full	upper Wolf Creek	Modeled for upstream flow	
	010-040 full	Pigeon Creek	X	X
	010-050 full	Mid-Wolf		X
Gage # 03116200 Chippewa Creek at Easton OH	020-030 partial	Steel Ditch		X
	020-030 partial	Tommy Run		X
	020-040 full	Little Chippewa Ck	X	X
	020-050 full	River Styx	X	X
	020-060 partial	Mill Creek		X
	020-070 full	Red Run	X	X
	020-080 partial	Silver Creek	X	X
	030-120 full	Sippo Creek		X
Gage # 03123000 Sugar Creek above Beach City Dam at Beach City OH	030-050 full	Fox Run	X	
	030-070 full	Mudbrook Creek		X
	030-080 full	upper Newman Ck	X	X
	030-090 full	Orrville Ditch	X	X
	030-100 full	lower Newman Ck		X
	030-110 full	West Sippo Creek	X	X
	090-020 full	Pigeon Run		X
	090-040 partial	Small Mid Run		X
	090-030 partial	Tusc R. UT RM 83.7	X	X
	090-030 partial	Tusc R. UT RM 78.0		X
Gage # 03140000 Mill Creek near Coshocton OH	130-010 full	Stone Creek		X
	130-030 full	Oldtown Creek		X
	130-040 full	Beaverdam Creek		X
	180-030 full	Dunlap Creek		X
	180-040 partial	Blue Ridge Run		X
	180-050 full	Buckhorn Creek	X	X
	190-010 full	Evans Creek		X
	190-020 full	White Eyes Ck (not including E.F. & W.F.)		X
	190-030 partial	upper W. Fork White Eyes Creek		X
	190-030 full	Full W. Fork White Eyes Creek	Modeled for upstream flow	
	190-040 full	E.F. White Eyes Ck	X	X

Table E.1.2.B Additional information about calibration watersheds

USGS gage used for GWLF hydrology calibration	Gage record	Weather station ID /Name	Calibration period	Simulation years
Gage # 03115973 Schocalog Run at Copley Junction	October 1991 – September 2004	331541/ CHIPPEWA LAKE	April 1990 – March 2005	15
Gage # 03116200 Chippewa Creek at Easton	October 1960 – September 1981	331541/ CHIPPEWA LAKE	April 1960 – March 1982	22
Gage # 03123000 Sugar Creek above Beach City Dam at Beach City	January 1948 – September 1975	330493/ BEACH CITY LAKE	April 1950 – March 1976	26
Gage # 03140000 Mill Creek near Coshocton	January 1956 – September 2004	331905/ COSHO-CTON AG RES STN	April 1956 – March 2005	49

Table E.1.2.C Watershed areas

14-dig HUC	Name	Area (mi^2)	Area (cm^2)	14-dig HUC	Name	Area (mi^2)	Area (cm^2)
Gage 03115973	Schocalog Rn	3.65	9.453e+10	030-080 full	upper Newman Ck	12.41	3.214e+11
Gage 03116200	Chip Ck@ Easton	146.00	3.781e+12	030-090 full	Orrville Ditch	12.45	3.225e+11
Gage 03123000	Sugar Ck above Beach City Dam	160.00	4.144e+12	030-100 full	lower Newman Creek	14.46	3.744e+11
Gage 03140000	Mill Creek	27.20	7.045e+11	030-110 full	West Sippo Ck	11.61	3.006e+11
010-010 partial	Tusc.River upst. Mogadore Rd.	8.14	2.109e+11	090-020 full	Pigeon Run	9.54	2.470e+11
010-030 partial	Wolf Ck UT 11.	4.94	1.279e+11	090-040 part	Small Mid Run	3.50	9.059e+10
010-030 full	Upper Wolf Ck	29.06	7.527e+11	090-030 part	Tusc UT RM 83.7	9.11	2.360e+11
010-040 full	Pigeon Creek	24.87	6.441e+11	090-030 part	Tusc UT RM 78.0	5.26	1.362e+11
010-050 full	Mid-Wolf	9.91	2.568e+11	130-010 full	Stone Creek	38.87	1.007e+12
020-030 partial	Steel Ditch	12.16	3.150e+11	130-030 full	Oldtown Creek	19.23	4.981e+11
020-030 partial	Tommy Run	7.46	1.931e+11	130-040 full	Beaverdam Creek	21.96	5.687e+11
020-040 full	L. Chippewa Ck	32.18	8.334e+11	180-030 full	Dunlap Creek	26.59	6.887e+11
020-050 full	River Styx	29.55	7.654e+11	180-040 part	Blue Ridge Run	3.07	7.955e+10
020-060 partial	Mill Creek	7.45	1.930e+11	180-050 full	Buckhorn Creek	23.35	6.049e+11
020-070 full	Red Run	15.14	3.922e+11	190-010 full	Evans Creek	24.17	6.260e+11
020-080 part	Silver Creek	8.46	2.192e+11	190-020 full	White Eyes Ck (not including EF & WF)	20.49	5.306e+11
030-120 full	Sippo Creek	17.86	4.626e+11	190-030 part	upper W. Fork White Eyes Creek	11.85	3.069e+11
030-050 full	Fox Run	14.15	3.664e+11	190-030 full	full W. Fork White Eyes Creek	20.90	5.414e+11
030-070 full	Mudbrook Creek	9.15	2.370e+11	190-040 full	EF White Eyes Ck	12.58	3.259e+11

Initial input data

Hydrologic simulation in GWLF requires the following inputs: (1) daily precipitation in cm, (2) daily mean temperature in degrees C, (3) land use area in ha, (4) land use runoff curve numbers, (5) evapotranspiration cover coefficients, (6) vadose (unsaturated) zone soil water capacity (U*) in cm, (7) saturated-zone recession coefficient (*r)* and (8) seepage coefficient (*s*). The following paragraphs detail the source of each parameter.

- **Weather data** - Daily precipitation and mean temperature values used are from the Midwest Regional Climate Center weather stations. Table E.1.2.B above outlines which stations are used and the period they are applied. These stations are the best available data for the USGS gage watersheds, and have been partially determined based on model calibration (see next section).

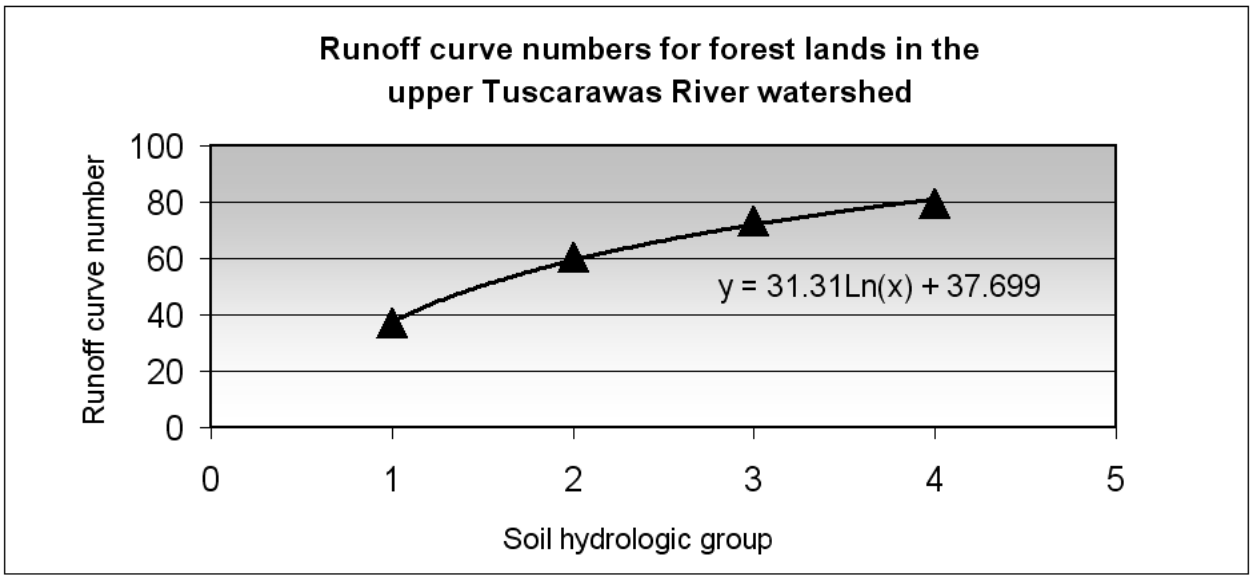
- **Land use** - Land use information is from the National Land Cover Dataset (USGS, 2000). The NLCD is compiled from Landsat™ satellite imagery and supplemented with ancillary data where available. The dataset includes 23 classes of land use in a grid with the resolution of 90 square meters per grid. NLCD data has been analyzed using ESRI ArcGIS™ on the basis of watershed boundary.

- **Runoff curve numbers** (CNs) are area-weighted averages for each land use that are used by GWLF. CNs, are based on the impermeability of a land use and are used by GWLF to determine surface runoff.

  The first step to determining CNs requires hydrologic response units (HRUs) to be created. By use of ESRI ArcGIS HRUs are based upon unique land use and soil hydrologic group pairings. The same land use data explained above is utilized in the creation of HRUs. For HRUs land use classes are grouped into 8 categories. The Natural Resource Conservation Service's State Soil Geographic (STATSGO) and Soil Survey Geographic Database (SSURGO) databases are used to learn all needed soils information. STATSGO is a generalized GIS database of soil parameters originally produced from more detailed soil survey data. The mapping scale for STATSGO is 1:250,000 (USDA, 1994). The newer, high-resolution data provided by SSURGO is not available for several counties in this watershed as a spatial GIS database. However, the higher resolution SSURGO tabular or attribute data does exist statewide (USDA, 2004). Because of this situation, the SSURGO attributes are generalized to relate to the STATSGO spatial data.

  The CNs used are based on Tables D-2, through D-5 of the BasinSim user's guide (Dai, 2000). That manual provides specific CNs for several classes of land use within each soil hydrologic group (A through D). In the creation of HRUs soil hydrologic groups are translated into a numeric value (i.e. A=1, D=4). The GIS analysis provides an overall area average soil hydrologic group value for each land use in each watershed. The HRUs soil hydrologic group value is interpolated on a land use specific curve to determine the CN. Interpolation is carried out by use of the curves created from the different CN values provided by the users guide for each land use type (Figure E.1.2.A).

Figure E.1.2.A Example of runoff curve number vs. soil hydrologic group, for forest land in the upper Tuscarawas watersheds. The points are the values provided by the user's guide.



- **ET cover coefficients** - Monthly evapotranspiration (ET) cover coefficients are referenced from the BasinSim user's guide for each land use (Dai, 2000).

- **U*** - The initial unsaturated (vadose) zone soil water capacity is set to10 cm. The BasinSim user's guide (Dai, 2000) recommends this value based upon a 100 cm rooting depth and a 0.1 cm/cm volumetric available water capacity (AWC). This value is used as a default because determination of the average watershed rooting depth and AWC is impractical.

- ***r*** - The saturated-zone recession coefficient for each gage is set based upon hydrograph analysis of the USGS gage daily flow stream gage records. For each gage periods of receding flow (from peak flow to baseflow) are identified and a recession coefficient is calculated. An analysis of all recession coefficients for a gage record is carried out and generally a value about the average and/or median is used for the initial recession coefficient. This method yielded coefficient values generally higher than the expected range outlined in the model's user guide.

- ***s*** - An initial seepage coefficient of zero is utilized as recommended by the BasinSim user's guide (Dai, 2000). This indicates no loss to deep storage.

The goal of this hydrology modeling is not to predict day-to-day or even month-to-month flow. Rather modeling attempts to depict seasonal and annual variation and to accurately represent average conditions. Therefore, the specific objectives of the GWLF simulations are to match the flow-duration interval of the predicted and observed flow, and to produce reasonable agreement between the predicted and observed average monthly flows.

E.1.3 Model calibration

Tables E.1.3.A summarizes the hydrologic input parameters used in the initial run of the GWLF models for the USGS gages. Table E.1.3.B shows initial runoff curve numbers used for each

land use for each gage. Figures E.1.3.A through E.1.3.H are plots of the pre-calibration results of the four USGS gages; there are two plots for each gage. The first plot shows the predicted (modeled) versus observed (gage) monthly flow of all the months modeled. These plots show a linear trendline with the equation describing the line and an R^2 value indicating the strength of the relationship. The dashed line on each of these plots shows one-to-one (slope = 1) line. This line helps illustrate how far from optimal each trendline is. The second plot for each gage shows the average of each month's total stream predicted (modeled) and observed (gage) results.

Table E.1.3.A Initial ground water (GW) parameter values for the gage watersheds

Gage number & name	GW variables		Monthly evapotranspiration cover coefficients											
			1	2	3	4	5	6	7	8	9	10	11	12
03115973 Schocalog Run at Copley Junction	U*	10	0.60	0.60	0.60	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.60	0.60
	r	0.566												
	s	0												
03116200 Chippewa Creek at Easton	U*	10	0.57	0.57	0.57	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.57	0.57
	r	0.253												
	s	0												
03123000 Sugar Ck ab Beach City Dam @Beach City	U*	10	0.56	0.56	0.56	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.56	0.56
	r	0.275												
	s	0												
03140000 Mill Creek near Coshocton	U*	10	0.55	0.55	0.55	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.55	0.55
	r	0.292												
	s	0												

U* – Unsaturated (vadose) zone soil water capacity in cm
r – Recession coefficient for the saturated-zone
s – Seepage coefficient

Table E.1.3.B Initial runoff curve numbers for the land uses of USGS gage watersheds

Land use	USGS Gages			
	03115973	03116200	03123000	03140000
Deciduous forest	65.64	72.34	70.06	69.46
Evergreen forest	65.85	72.41	69.72	69.79
Mixed forest	64.98	72.31	69.27	69.26
Urban and recreational grass	88.43	90.78	-	-
Pasture and hay	72.59	77.82	76.40	75.65
Row crops	79.15	84.26	83.36	81.20
Woody wetland	100.00	100.00	100.00	100.00
Emergent herbaceous wetland	100.00	100.00	100.00	100.00
Open water	100.00	100.00	100.00	100.00
Transitional	72.11	-	-	-
Low density residential	88.45	90.52	89.69	90.46
High density residential	88.43	90.51	89.66	-
Commercial	98.00	98.00	98.00	98.00
Quarry	-	87.00	87.00	-

Figure E.1.3.A Initial model stream flow results to gage stream flow results

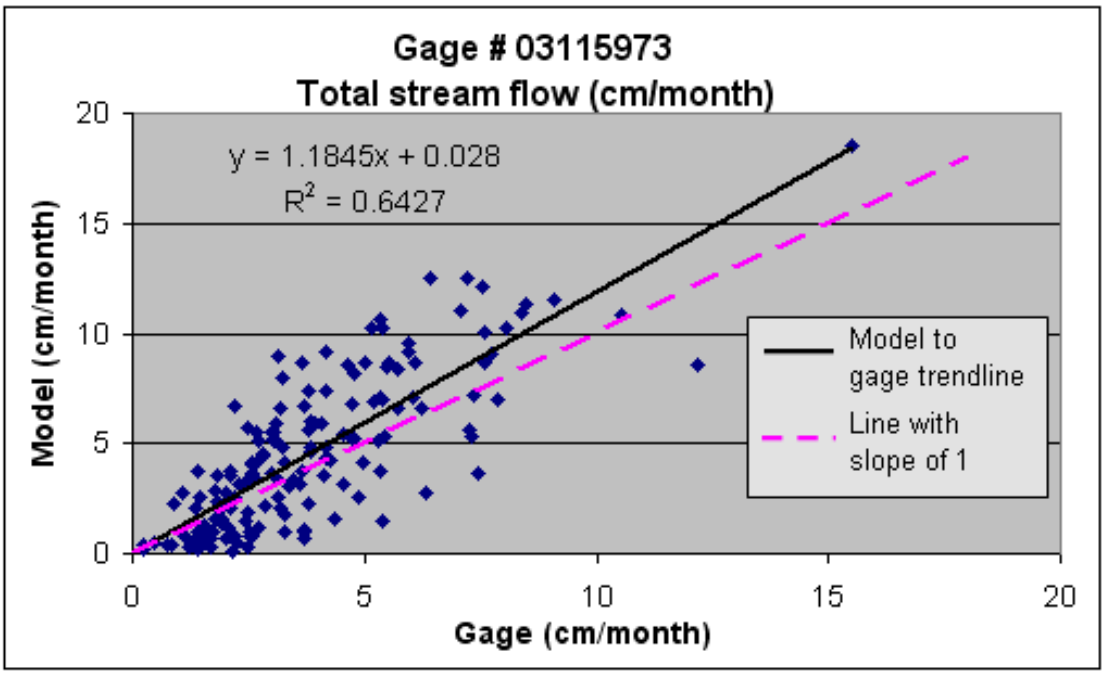


Figure E.1.3.B Initial model run average of each month's model results and gage stream flow

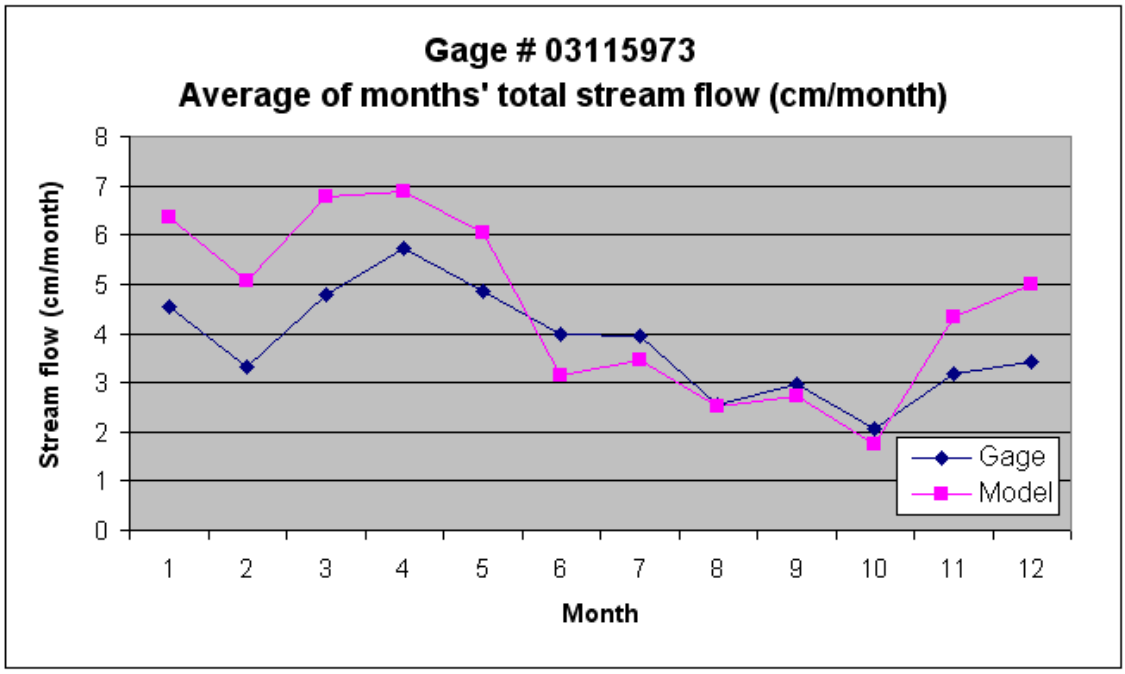


Figure E.1.3.C Initial model stream flow results to gage stream flow results

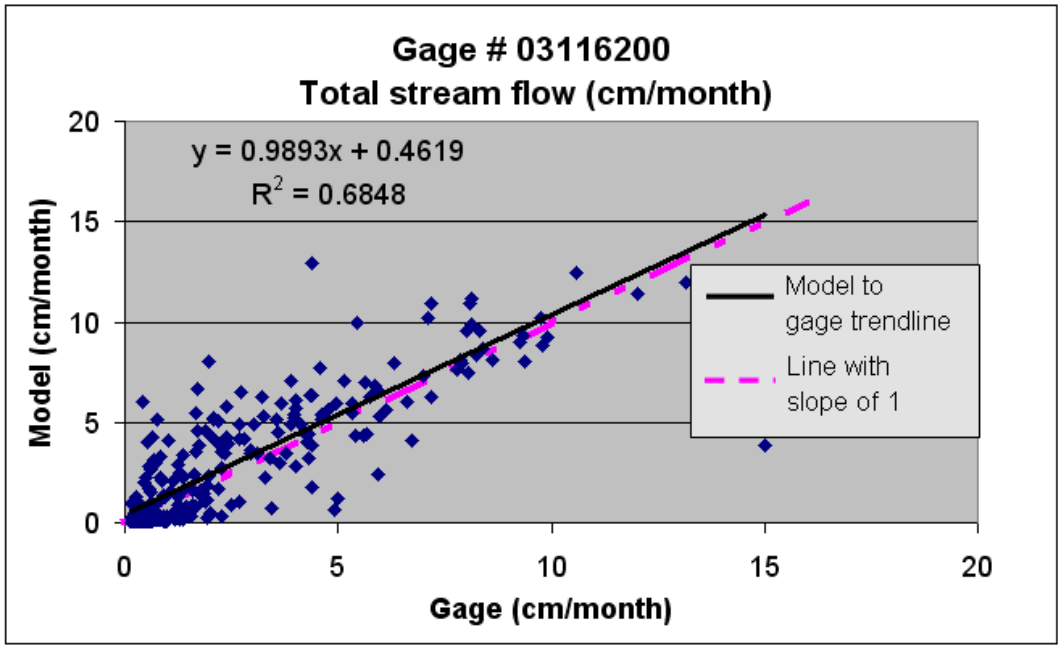


Figure E.1.3.D Initial model run average of each month's model results and gage stream flow

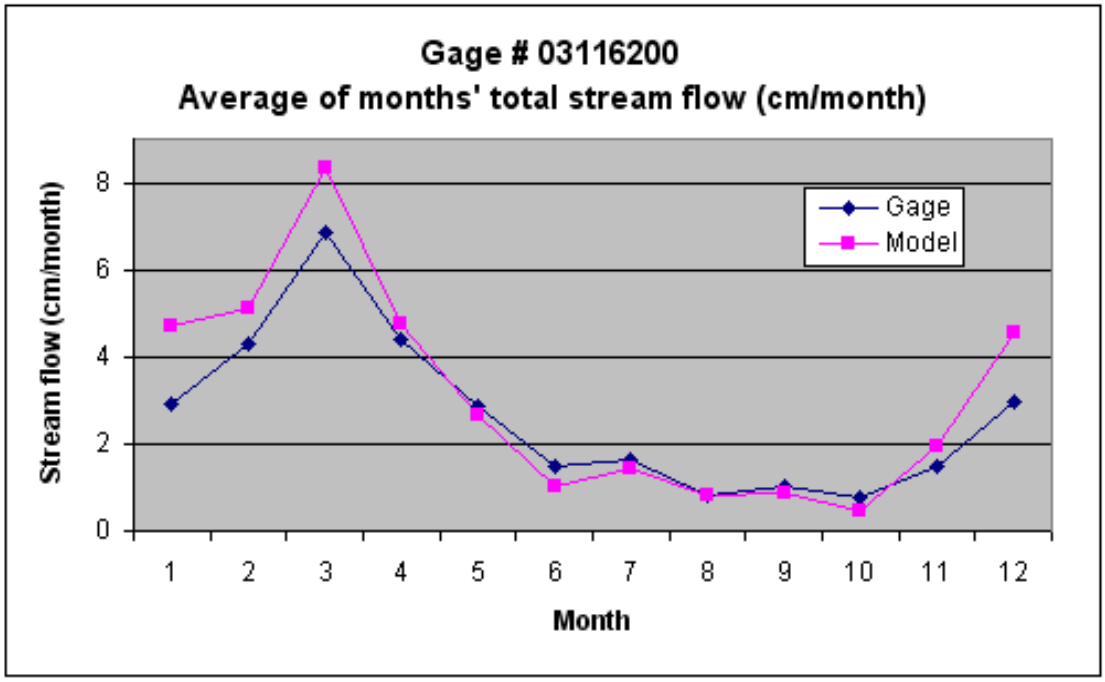


Figure E.1.3.E Initial model stream flow results to gage stream flow results

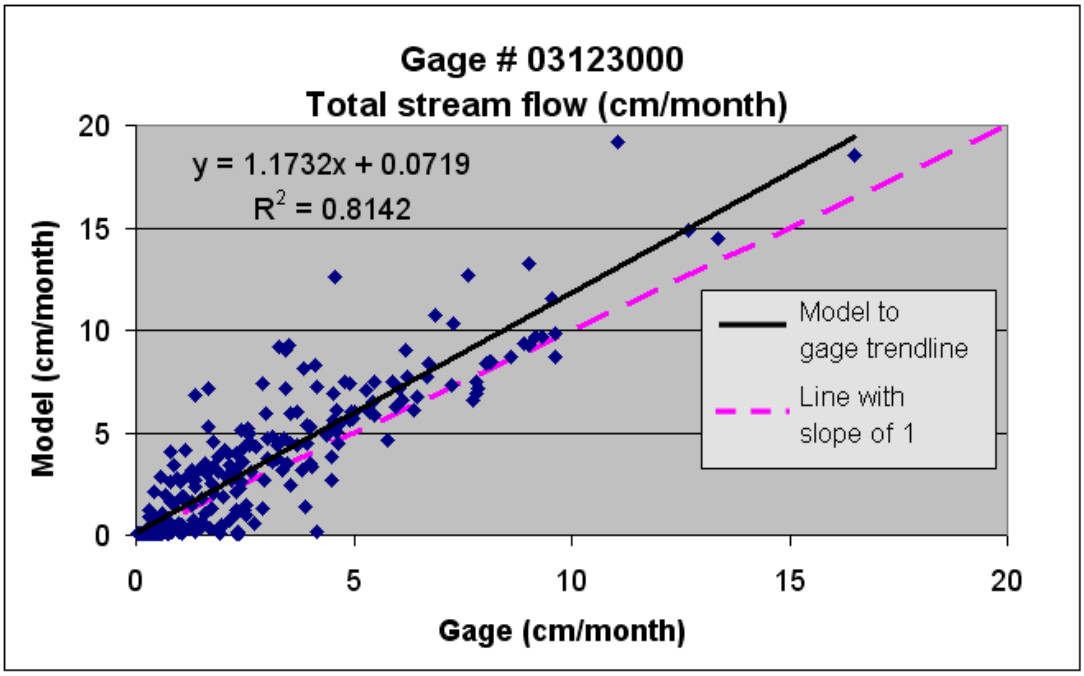


Figure E.1.3.F Initial model run average of each month's model results and gage stream flow

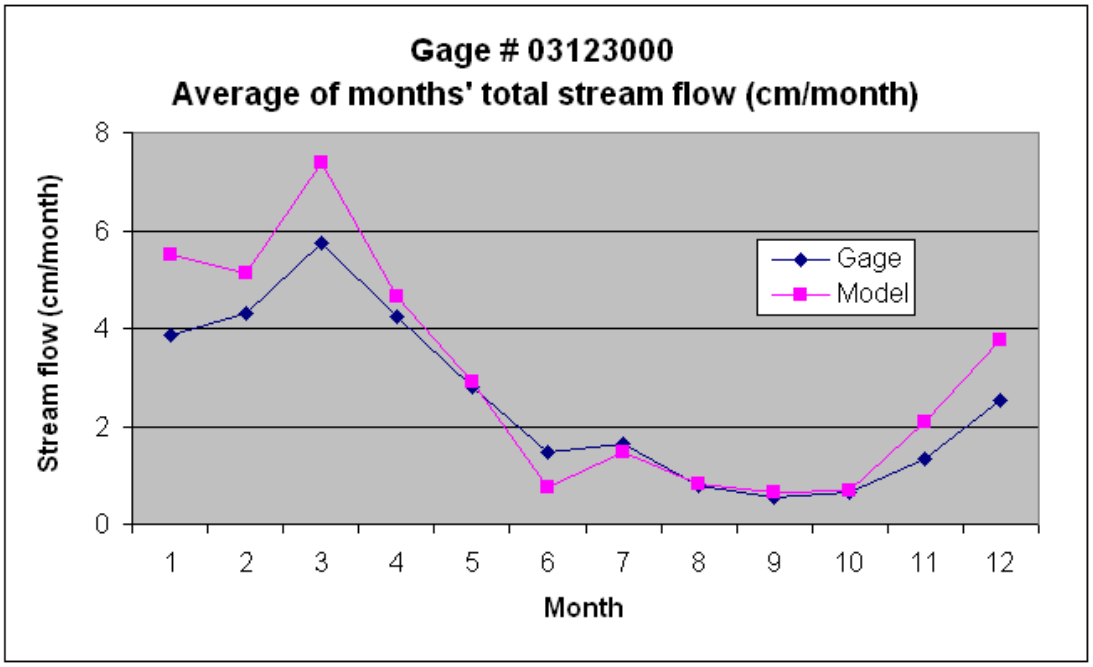


Figure E.1.3.G Initial model stream flow results to gage stream flow results

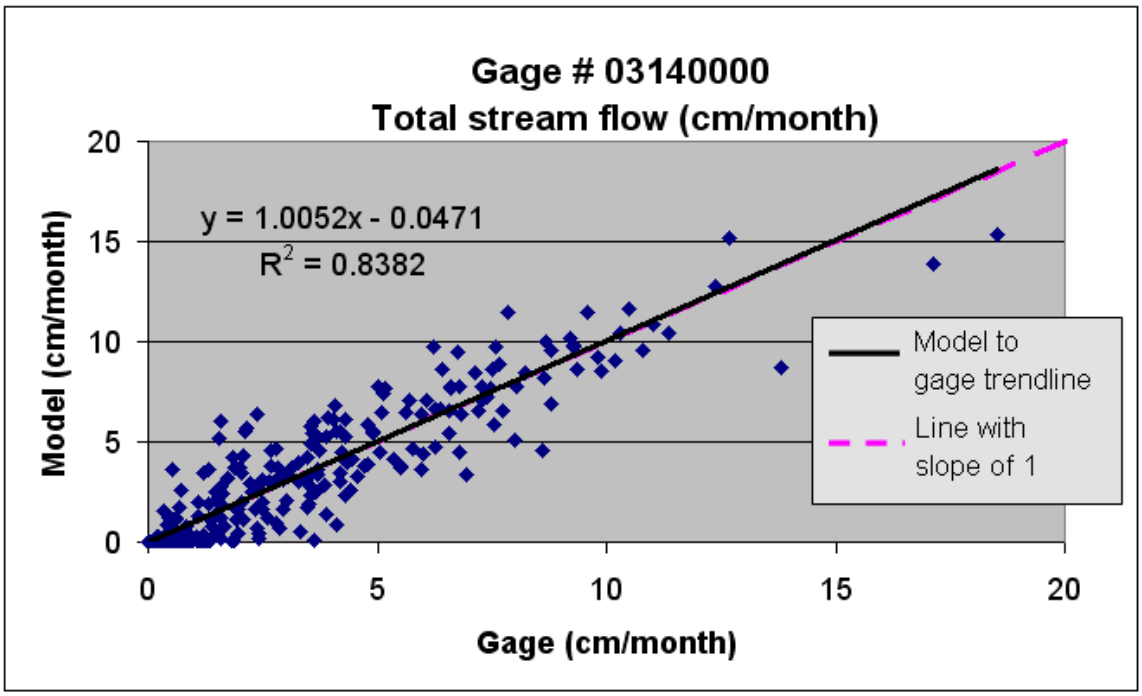
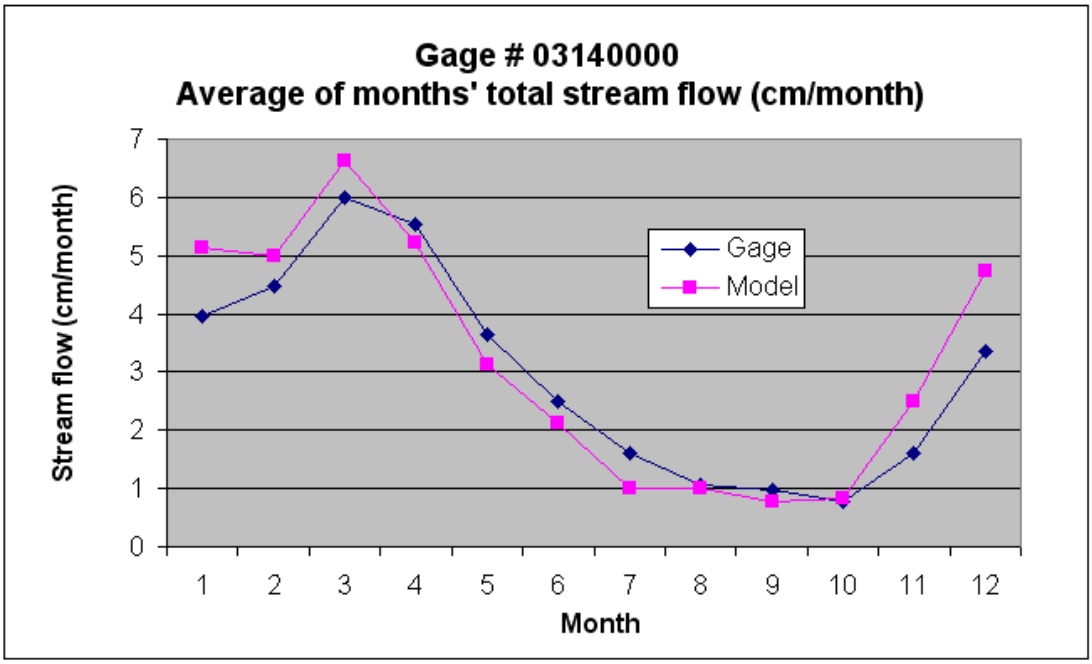


Figure E.1.3.H Initial model run average of each month's model results and gage stream flow



In the hydrology calibration procedure several plots and statistics, such as those shown above and many others, are analyzed to determine what changes can be made to input factors in order to improve the fit of the modeling results. Inputs are only changed within acceptable ranges given the setting of each modeled watershed. GWLF's hydrology modeling is driven by precipitation. Precipitation is first dealt with by GWLF as either runoff or infiltration into the shallow unsaturated (vadose) zone. Because the curve numbers for each land use is the only input that dictates runoff, it is first calibrated. The remaining inputs are adjusted as seen fit by each run's results. Several runs, modeling simulations, for each USGS gage watershed have been carried out. Refer to Tables E.1.3.C and E.1.3.D below for the modeling inputs used in the calibrated runs. Also Figures E.1.3.I through E.1.3.P show the post calibrated version of the same two plots for each gage as shown above for the initial runs. Table E.1.3.Q contains a pre and post calibration side-by-side comparison of the two statistics most in calibrating these gages.

Gage calibration explanations

The following is a narrative explanation of each gage's calibration.

Gage 03115973 – 15 runs

Figures E.1.3.A and E.1.3.B show clearly that the model in general predicted too much water making it to the stream; slope = 1.18. Also the correlation between predicted and observed flow was somewhat poor; R^2 =0.64. In looking at the initial input values it was clear that the recession coefficient, the function that dictates how much of the shallow saturated zone water is recessed into the stream each day, was extremely high. However with the recession coefficient lowered to 0.2, hydrologic response of the watershed was still too great; slope = 1.14. Some changes to evapotranspiration (ET) cover coefficients and runoff curve numbers were made. After several runs, however, the model was still over predicted stream flow. A seepage coefficient of 0.2 was added, and this took more water than desired out of the modeled stream flow. This coefficient was halved to 0.1 and it appeared to improve the hydrologic response, a slope of 0.95. However none of these changes improved the scatter of the modeling results. The first 9 model runs used weather station data from the Akron Canton Regional Airport station. While this station is closest to the gage it is south and east of the watershed. Since most weather in this part of the state moves west to east, as does this watershed's stream flow, an attempt to use a nearby gage that lies to the west was carried out. The Chippewa Lake gage was prepared for this time period and a model run with the same input parameters was performed. This brought about much improved hydrologic response; R^2 from 0.65 to 0.73 and slope from 0.95 to 0.99. At this point attempts were made to reduce the seepage coefficient since 0.1 is higher than generally expected from a headwaters stream. By increasing the runoff curve numbers and adjusting the ET cover coefficients the seepage coefficient was able to be lowered to 0.05 while maintaining good hydrologic response of the model R^2=0.74 and slope = 1.10. Figures E.1.3.I and E.1.3.J show the results of the calibrated model run.

Gage 03116200 – 24 runs

Figure E.1.3.C shows that the initial run of this watershed required improved correlation of predicted and observed hydrologic response (R^2=0.68). Examination of figure E.1.3.D shows the hydrologic response of the initial run of this watershed was too high December through March. Efforts to adjust the runoff curve numbers and ET cover coefficients were made providing some improvements. Similar to gage 03115973 the Akron Canton Regional Airport weather station was initially used for the temperature and precipitation data. In an attempt to improve the correlation of this gage's modeled hydrologic response to observed stream flow, the Chippewa Lake weather station was used. This created a significant improvement in both major statistics used for this calibration procedure; R^2 from 0.63 to 0.76 and slope from 0.87 to 0.92. Further attempts to improve the modeled watershed's hydrologic response were carried out.

Some improvements in the two statistics discussed here were achieved, however these changes brought about less desirable results in several other statistics. Generally, it seemed that while those additional changes more closely matched the total stream flow modeled to the gage they did so by increasing runoff and reducing baseflow (groundwater flow) to the stream to an unacceptable manner. Because of this, those additional changes were not kept.

Gage 03123000 – 8 runs

Figure E.1.3.E illustrates that while the initial run of this model showed acceptable correlation between predicted and observed flow (R^2 = 0.81), the model is consistently over-predicting the hydrologic response of the watershed (slope = 1.17). After some runoff curve number and ET cover coefficients adjustments were made, an attempt to lower the recession coefficient was made. This effort did not reduce the average hydrologic response in a desirable manner, and the recession coefficient was increased back to the original value. The next calibration run added a seepage coefficient of 0.1. This lowered the modeled streamflow to an acceptable level (slope = 0.98). Additional changes were attempted in following runs, however none yielded better results.

Gage 03140000 – 11 runs

Figure E.1.3.G shows that the initial run of this watershed's model is very well matched to the observed gage flow (R^2 = 0.84 and slope = 1.01). However an examination of the model's stream flow contributions from runoff and groundwater indicated very little runoff. Baseflow of groundwater to the stream appeared to be making up much of the lacking runoff averaging out to a good predicted to observed fit. All calibration attempts focused on increasing runoff and decreasing baseflow while still maintaining a good predicted to observed fit. Several adjustments to the recession and seepage coefficients and the unsaturated storage zone's water capacity were made. The best run that balanced the runoff and baseflow did not contain any changes to those inputs. Only adjustments in the runoff curve numbers and ET cover coefficients were needed to achieve a slightly decreased fit (R^2 = 0.82) and slope (0.92), but much more reasonable modeled watershed.

Table E.1.3.C Post calibration hydrologic-parameter values for the USGS gage watersheds

Gage number & name	Ground water variables		Monthly evapotranspiration cover coefficients											
			1	2	3	4	5	6	7	8	9	10	11	12
03115973 Schocalog Run at Copley Junction	U*	10	**0.80**	**0.75**	**0.80**	**0.89**	0.85	**0.80**	**0.75**	**0.78**	**0.78**	**0.8**	**0.78**	**0.80**
	r	**0.200**												
	s	**0.05**												
03116200 Chippewa Creek at Easton	U*	**15**	**0.60**	**0.60**	**0.70**	**0.75**	**0.85**	0.98	0.98	0.98	**0.85**	**0.75**	**0.65**	**0.60**
	r	**0.300**												
	s	0												
03123000 Sugar Creek above Beach City Dam at Beach City	U*	10	**0.60**	**0.60**	**0.60**	0.99	0.99	0.99	0.99	0.99	0.99	**0.92**	**0.60**	**0.60**
	r	0.275												
	s	**0.1**												
03140000 Mill Creek near Coshocton	U*	10	**0.80**	**0.75**	**0.80**	1.00	1.00	1.00	1.00	1.00	1.00	1.00	**0.8**	**0.65**
	r	0.292												
	s	0												

U* – Unsaturated (vadose) zone soil water capacity in cm
r – Recession coefficient for the saturated-zone
s – Seepage coefficient
Boldface values have been changed in calibration (compared to Table E.1.3.A)

Table E.1.3.D Post calibration runoff curve numbers for the land uses of USGS gage watersheds

Land use	USGS Gages			
	03115973	03116200	03123000	03140000
Deciduous forest	**70.00**	**86.80**	**76.00**	**82.00**
Evergreen forest	**72.00**	**86.90**	**74.00**	**83.00**
Mixed forest	**72.00**	**86.77**	**74.00**	**83.00**
Urban and recreational grass	88.43	90.78	-	-
Pasture and hay	**78.00**	**90.00**	**86.00**	**92.00**
Row crops	**83.00**	**95.00**	**91.00**	**95.00**
Woody wetland	100.00	100.00	100.00	100.00
Emergent herbaceous wetland	100.00	100.00	100.00	100.00
Open water	100.00	100.00	100.00	100.00
Transitional	**90.00**	-	-	-
Low density residential	**92.00**	**94.00**	**92.00**	**96.00**
High density residential	**95.00**	**98.00**	**98.00**	-
Commercial	98.00	98.00	98.00	98.00
Quarry	-	87.00	**89.00**	-

Boldface values have been changed in calibration (compared to Table E.1.3.B)

Figure E.1.3.I Post calibration model stream flow results to gage stream flow results

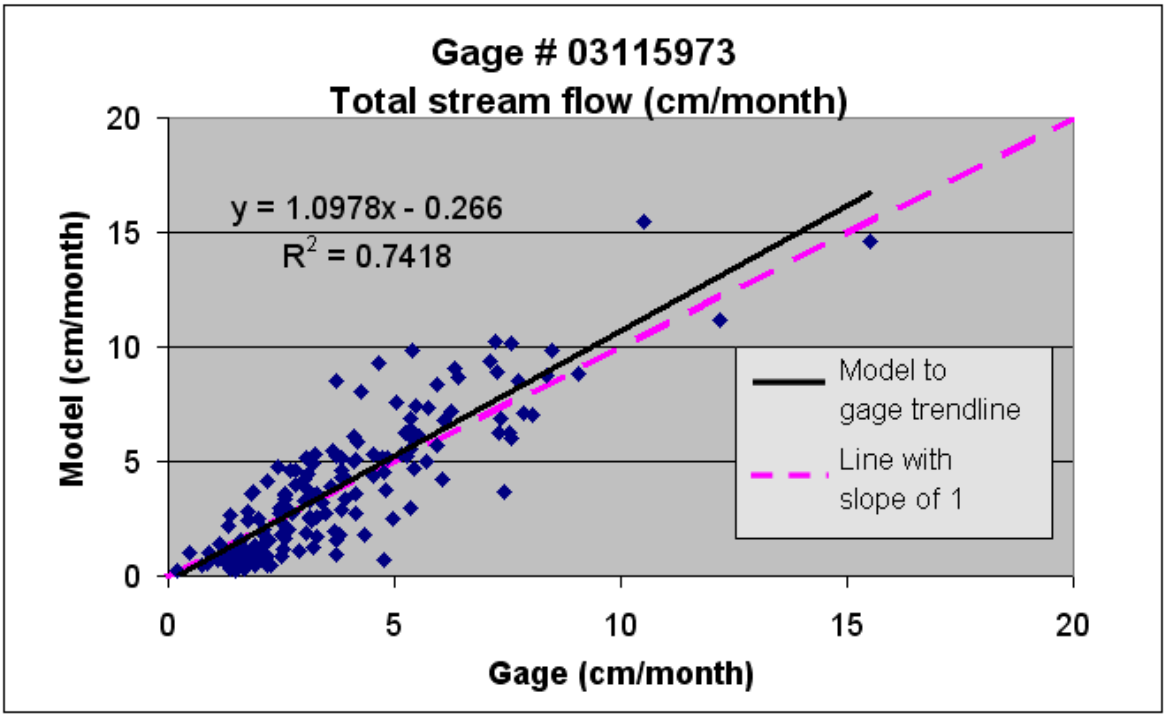


Figure E.1.3.J Post calibration average of each month's model results and gage stream flow

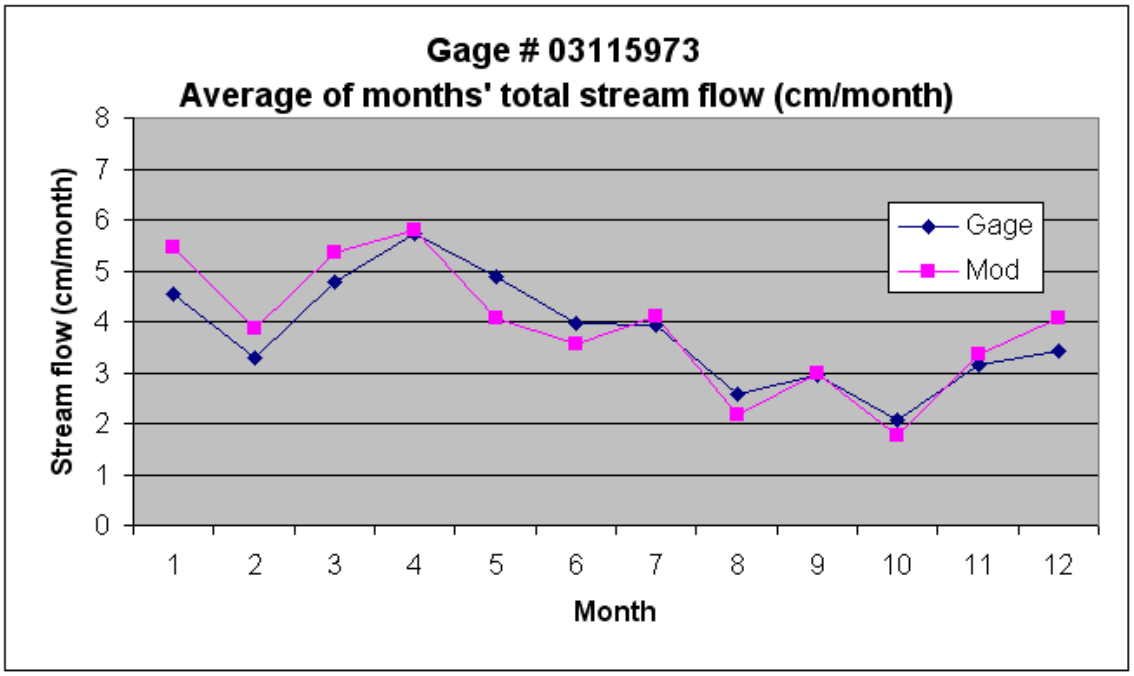


Figure E.1.3.K Post calibration model stream flow results to gage stream flow results

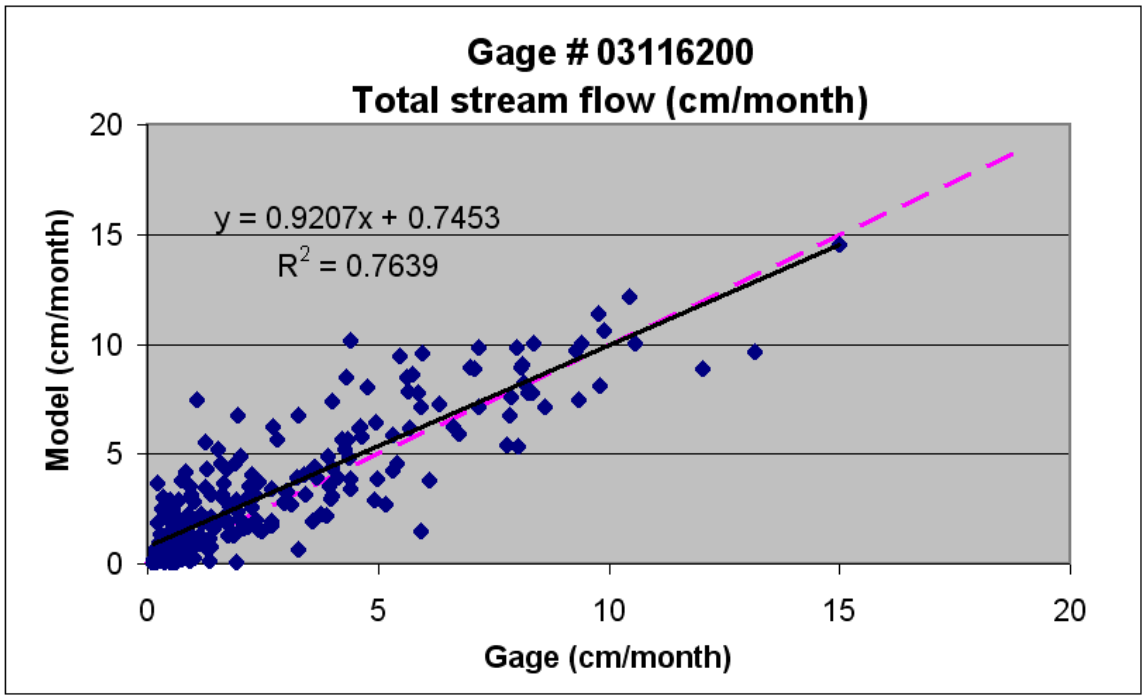


Figure E.1.3.L Post calibration average of each month's model results and gage stream flow

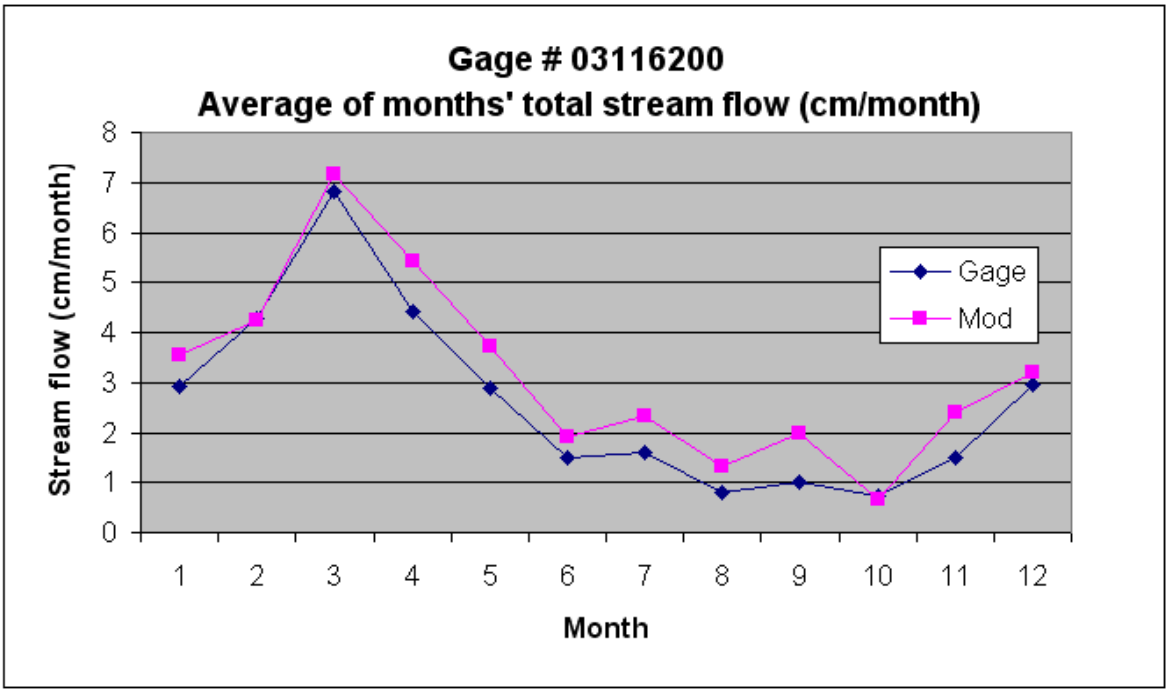


Figure E.1.3.M Post calibration model stream flow results to gage stream flow results

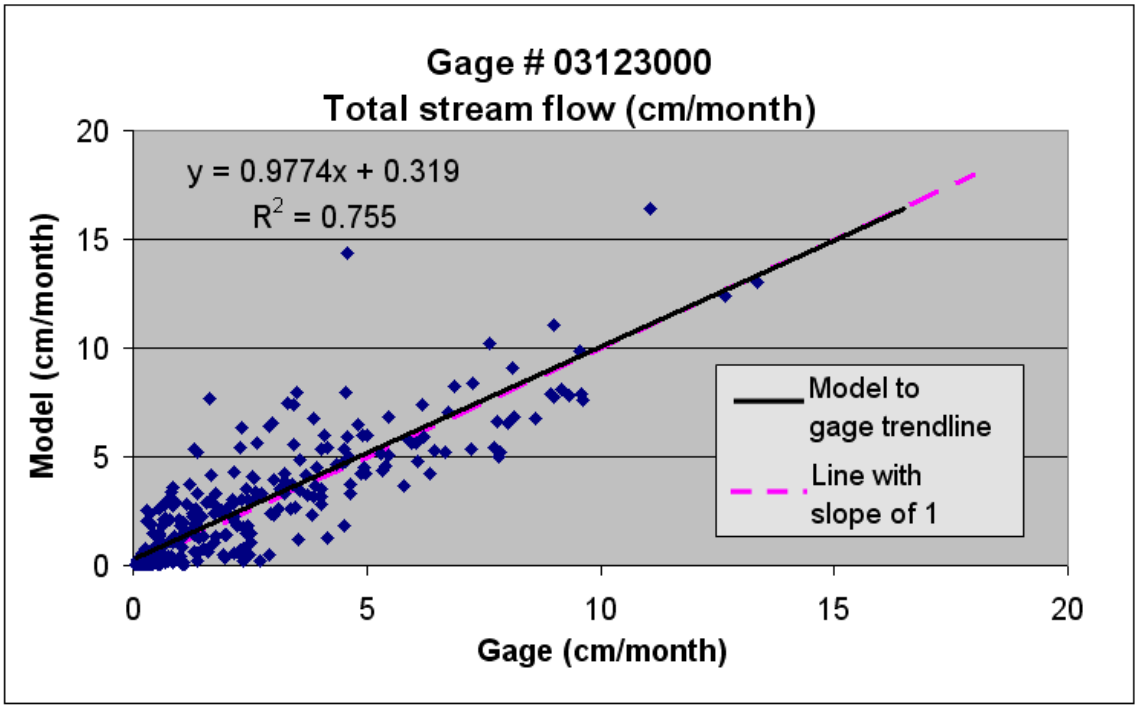


Figure E.1.3.N Post calibration average of each month's model results and gage stream flow

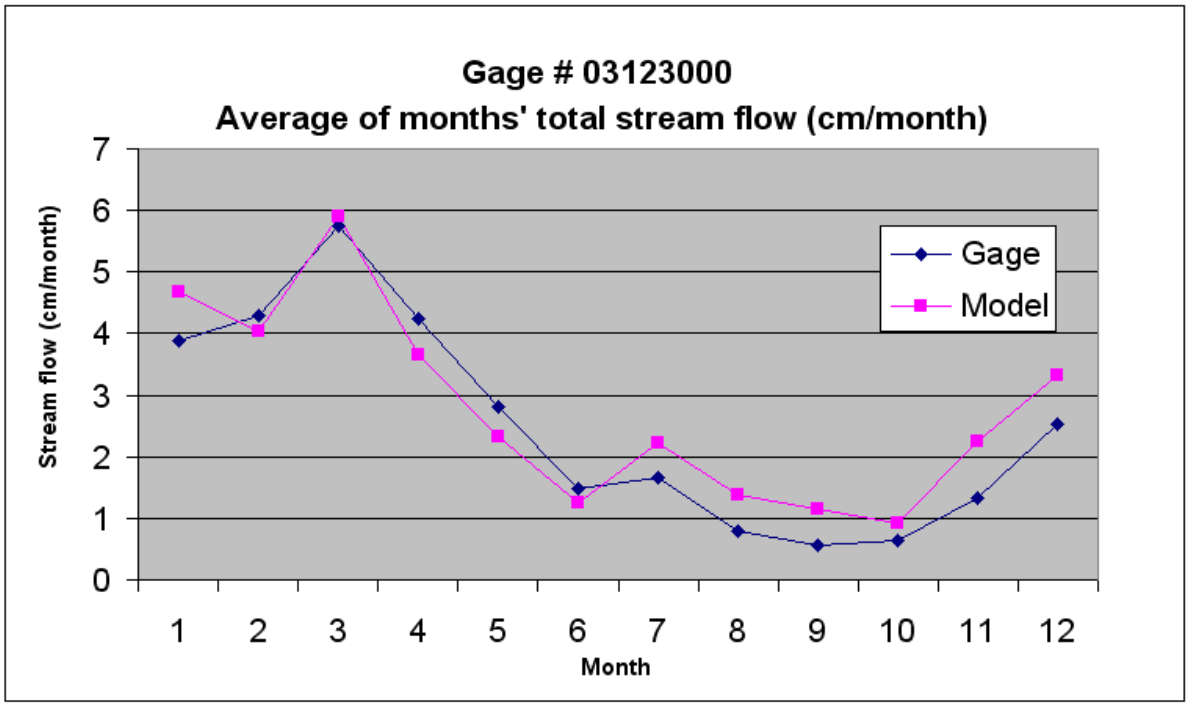


Figure E.1.3.O Post calibration model stream flow results to gage stream flow results

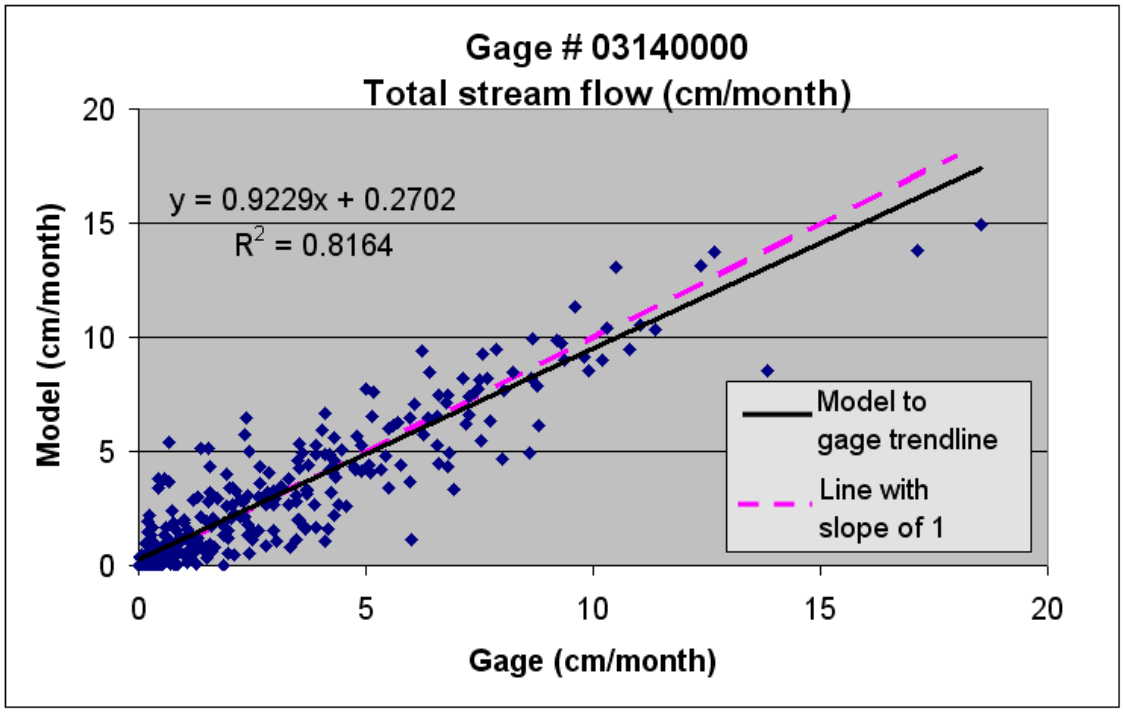


Figure E.1.3.P Post calibration average of each month's model results and gage stream flow

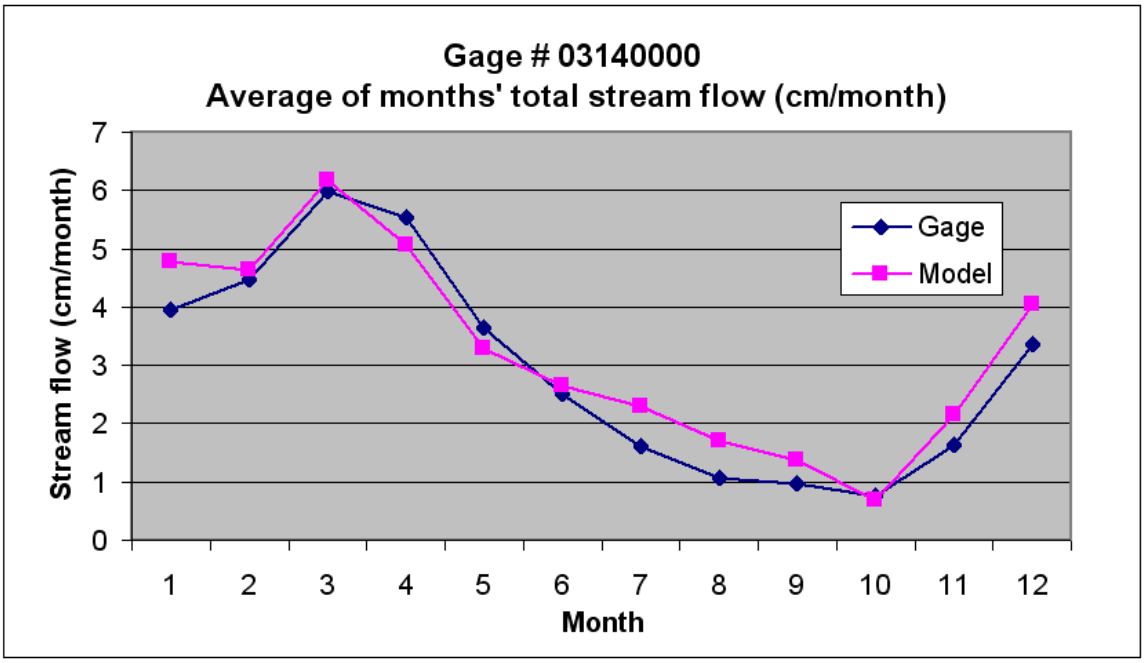


Table E.1.3.Q Comparison of simple statistics for each gage

Gage	Pre-calibration		Post-calibration	
	R^2	Slope	R^2	Slope
Gage # 03115973 Schocalog Run at Copley Junction	0.643	1.185	0.742	1.098
Gage # 03116200 Chippewa Creek at Easton OH	0.685	0.989	0.764	0.921
Gage # 03123000 Sugar Creek above Beach City Dam at Beach City	0.814	1.173	0.755	0.977
Gage # 03140000 Mill Creek near Coshocton OH	1.01	0.838	0.923	0.816

Model application
The four calibrated GWLF hydrology models are used in TMDL modeling of 34 subwatersheds of the Tuscarawas River watershed. All of the input parameters outlined above for calibrated gages are applied to the watersheds that each gage represents (for assignments see Table E.1.2.A). This includes the runoff curve number for each land use type. A few land use types exist in modeled watersheds that do not exist in their calibrated gage watersheds. A reasonable reference value based on the other runoff curve numbers in the watershed is used for these land uses. These are always very small amounts of land and make a negligible difference in runoff flow. All modeling for the TMDL is carried out for the 15 year period of April 1990 through March 2005. For most TMDL watersheds the same weather station is used for that watershed's calibrated gage. A few exceptions exist where a different weather station is close to or in a TMDL watershed. The 2nd through 15th year modeled stream flow is averaged for each of the 12 months. These average month stream flow values are used in the TMDL modeling efforts.

E.2 Nutrient modeling

This appendix explains the determination of the existing load of total phosphorus (total P) for each of the 12 modeled watershed. The existing load is the sum of the individual source loads. For the purpose of this report surface runoff, point sources, home sewage treatment systems (HSTS) and groundwater are considered as potential total P load sources. Table E.2.A shows a summary of the nutrient TMDL development. The hydrologic aspect of Generalized Watershed Loading Function (GWLF) model is explained in Appendix E.1. Generally the method of this modeling has inherent assumptions that result in uncertainty in the calculated loads. Every effort is made to base each assumption upon a justifiable rationale or value.

Table E.2.A Summary of nutrient TMDL development

Development step	Source		Method
Existing load	Point source		Discharger self-monitoring data used to estimate total P loading.
	Surface runoff		GWLF nutrient runs.
	Ground-water		GWLF nutrient runs.
	HSTS		Population served by failing HSTS is estimated via GIS and county Health Departments. Total P load based upon population estimate and a per capita loading rate.
Calculation of loading capacity	-		Product of the annual discharge volume from each sub-basin (GWLF hydrology) and the total P target concentration.
Allocation	WLA	Point Sources	Product of design flow rate and technology based effluent limitation of 1.0 mg TP/ml (or less depending on plant type).
		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	Surface runoff is equal to the sum of all WLAs, MOS and natural runoff subtracted from the assimilative capacity.
		Natural runoff	The expected background total P load is determined based on running GWLF considering all lands to be unmanaged.
		HSTS	Home sewage treatment systems are allocated a total P load of zero.
	Margin of safety		Five percent of the assimilative capacity is reserved for the margin of safety.

E.2.1 Surface runoff and groundwater, GWLF

The GWLF model is used to determine the total P load from runoff and groundwater. Computational steps the model carries out are not included in this appendix since the BasinSim user's guide, describes these in detail (Dai, 2000). Calibrated hydrologic parameters are used for each modeled watershed; refer to Appendix E.1 for details.

Required model inputs
Nutrient modeling in GWLF requires additional input parameters including values for the universal soil loss equation (USLE) and various nutrient concentrations in the water and soil. The following paragraphs detail the source of each input-parameter.

Soil factors

- **Rainfall-erosivity coefficients** for the dormant and growing seasons are referenced from the BasinSim user's guide Table B-14 and are 0.08 and 0.26, respectively (Dai, 2000). The same values are used for all modeled watersheds. The dormant season is considered November through March; growing season April through October.

- **K** - The USLE soil erodibility factor, K, is based upon an area-weighted average values from soil data. As required by GWLF a K value is calculated for each land use specific for each watershed. Geographical Information System (GIS) data is used to determine this soil property. The Natural Resource Conservation Service's State Soil Geographic (STATSGO) and Soil Survey Geographic Database (SSURGO) databases are both utilized for this report. STATSGO is a generalized GIS database of soil parameters originally produced from more detailed soil survey data. The mapping scale for STATSGO is 1:250,000 (USDA, 1994). The newer, high-resolution data provided by SSURGO is not available for several counties in this watershed as a spatial GIS database (USDA, 2004). However, the higher resolution SSURGO tabular (or attribute) data does exist statewide. Because of this situation, the SSURGO attributes are generalized to relate to the STATSGO spatial data. Since open water and urban land uses are not considered to have soil erosion, K factors for those land uses are set to 0. Values from 0.33 to 0.45 are determined for all other land uses.

- **LS** - An average slope and slope length for each land use in each watershed are required to determine the USLE slope length/steepness factor, LS. The slope is calculated using the National Elevation Dataset (NED) (USGS, 1996). The NED is analyzed using the Spatial Analyst extension of ArcGIS™. Average land use slope length within each watershed is determined using the two available soil databases in a similar manner outlined for the K factor. Knowing these two factors the slope length/steepness factor, LS, is determined using Tables 5.2 and 5.3 of *Predicting Rainfall Erosion Losses* (USDA, 2000).

- **C** - The USLE cover management factor, C, is referenced from Table 6 of *Predicting Rainfall Erosion Losses* (USDA, 2000). Extra detail is used in determining the C value for the row crop land use. The NRCS guidance breaks down C value by county and crop type. Because of this the row crop land use in each watershed is further broken down by county. State agriculture statistics are used to break down those areas by crop. C values are then assigned and area weighted to provide a specific row crop watershed value. This method created similar row crop C values for all watersheds; ranging from 0.107 to 0.113. A C value of 0.010 is used for all watersheds' pasture/hay land use. Wetland, open water and urban land uses are set to 1 for this factor effectively making this parameter not applicable to those land uses. Forest lands are assumed to have very low C and are set at 0.001.

- **P** - The USLE support practices factor, P, is set at 1 because no contour farming, cross-slope farming, strip-cropping, or terracing is known to occur in the watershed.

- **SDR** - The sediment delivery ratio (SDR) is referenced from Figure B-2 of the BasinSim user's guide (Dai, 2000). This factor is calculated based on watershed area.

Nutrient factors

- **Runoff total P**- The total P concentrations in surface runoff from different non-urban land uses are mostly referenced from the BasinSim user's guide (Dai, 2000). The urban build-up values are derived in the same manner. Both are shown in Table E.2.1.A. Different functions are used by GWLF in determining the load of total P from urban or rural (non-urban) land uses. Deviations from the user's guide are based on experience in modeling Ohio's watersheds by the Ohio EPA.

Table E.2.1.A Total P rural runoff and urban build-up values

Land use (rural)	Total P runoff value (mg/l)	Land use (urban)	Total P build-up value (mg/l)
Pasture/hay *	0.25	Commercial/Industrial/Transportation	0.0112
Row crops *	0.2	High-Density Residential	0.0112
Deciduous forest	0.008	Low-Density Residential	0.003
Emergent herb. wetlands	0	Quarries/Strip Mines/Gravel Pits	0
Evergreen forest	0.008		
Mixed forest	0.008		
Open water	0		
Transitional	0.15		
Urban / rec. grasses	0.15		
Woody wetlands	0		

***** These are the values for land uses without manure application (CAFO or otherwise)

- **Groundwater P** - Only one groundwater total P value can be used for each watershed. Data from Ohio EPA's Ambient Ground Water Monitoring Network is used for to determine this value. Table E.2.1.B shows these values. For most of the watersheds only data for buried aquifer wells are used. It is assumed these ambient monitoring sites are most similar to the ground water that is entering the streams. Since the Buckhorn Creek and East Fork White Eyes Creek watersheds both drain areas without recent glaciation a sandstone bedrock monitoring site in the area is used.

Table E.2.1.B Total P groundwater values

14-digit HUC	Watershed name	Ground water total P (mg/l)	Well name
010-040 full	Pigeon Creek	0.05	Rittman well field
020-040 full	Little Chippewa Ck	0.06	Orrville well field
020-050 full	River Styx	0.05	Rittman well field
020-070 full	Red Run	0.06	Orrville well field
020-080 part	Silver Creek	0.06	
030-050 full	Fox Run	0.05	Canal Fulton well field
030-080 full	upper Newman Ck	0.06	Orrville well field
030-090 full	Orrville Ditch	0.06	
030-110 full	West Sippo Creek	0.10	Massillon well field
090-030 part	Tusc R. unnamed tributary RM 83.7	0.06	Navarre well field
180-050 full	Buckhorn Creek	0.19	USDA Ag. Station (Cosh. County)
190-040 full	E.F. White Eyes Ck	0.19	

- **Soil P** - The model's user's guide provides a range of soil total P. The value in the middle of that range is used for all watersheds; 1266 mg/kg total P.

Special considerations modeling inputs

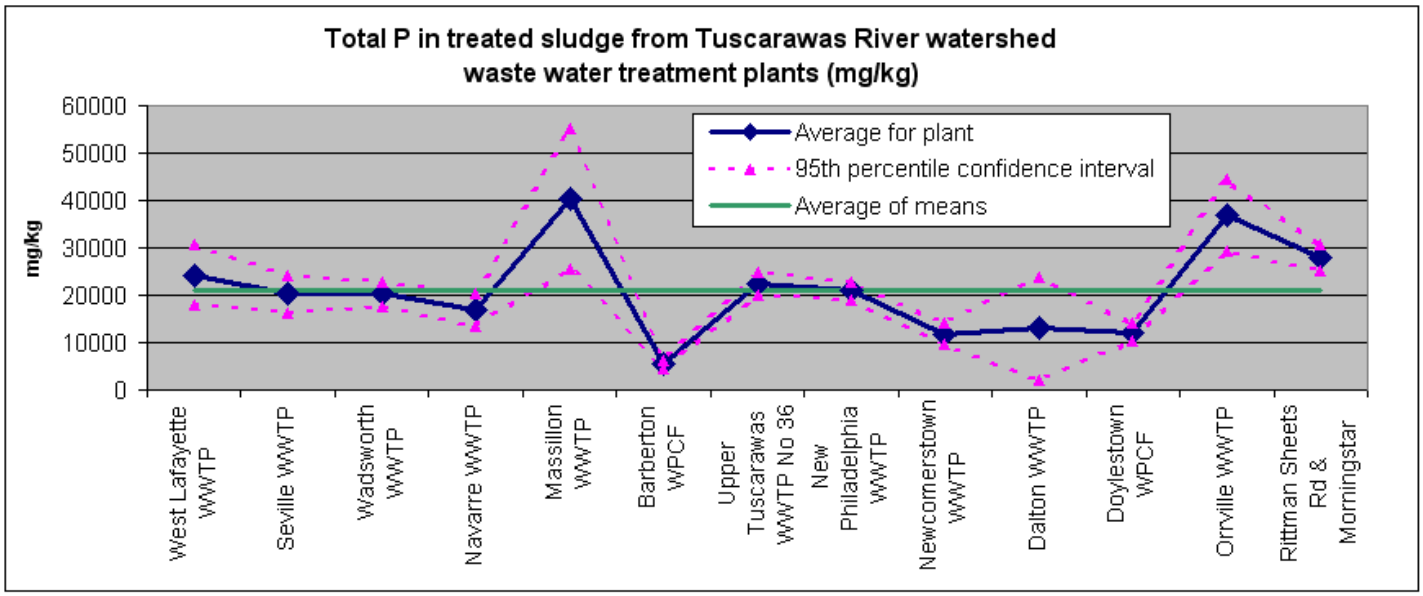
With the use of GIS, some additional modeling inputs became available. Field applied water treatment plant sewage sludge and various types of applied agriculture manure particularly are used to refine the concentration of total P in rural runoff. The two challenges for this type of input refinement involve determining where, geographically, to consider the additional inputs, and what total P runoff concentration should be used. The following paragraphs describe these inputs.

- **Sewage sludge** – **Distribution:** Ohio EPA is currently in the process of creating a GIS database showing all the fields that receive applications solid waste sludge from waste

water treatment plants. The Tuscarawas River watershed portion of this coverage is complete. These fields are compared against the nutrient modeled watersheds, and 10 of the 12 watersheds contain some area of application. The land use of these areas is broken up between row crop and pasture/hay (see Table E.2.1.D below).

- **Sewage sludge** – **Runoff concentration**: Figure E.2.1.A shows an analysis of self monitored total P in treated sewage sludge form Tuscarawas River watershed waste water treatment plants. The average of all the plant's averages is 20976.7 mg/kg. Treatment processes with an anaerobic digestion step causes relatively low mobility of phosphorus since it has been shown that, in this kind of sludge, a large part of mineral phosphorus is linked to organic compounds (Zhang, 1990). Therefore exported phosphorus is mostly under particulate form in runoff water. A concentration of 3.5 mg/L P was found in runoff water from a soil amended with a sludge containing 20 g P2O5/kg dry matter (Mostaghimi, 1992). This would yield a TP mg/kg concentration of 8733.6 a value lower than the average of all Tuscarawas River watershed sludge concentrations examined. However a concentration of 2.0 mg/L particulate P runoff from applied sludge containing 78 g P2O5/kg has been cited (Quilbé, 2005). This sludge would be 34061 mg/kg TP and more in-line with the sludge being applied in the Tuscarawas River basin. These two studies show the variability in sludge applied fields' runoff. Because of this the runoff from sewage sludge applied to row crop and pasture/hay land uses are assumed a total P concentration of 3.5 and 1.3 mg/l respectively.

Figure E.2.1.A Treated sludge total P concentrations



- **Concentrated animal feeding operations** (CAFO) – **Distribution:** There are two permitted CAFOs in the Tuscarawas River watershed located very close to one another. Both of these farms sit in the Orrville Ditch subwatershed; however manure from them is applied to fields in several surrounding subwatersheds. With the use of the CAFO permits, GIS data for these fields has been created. Using ESRI ArcGIS™ to analyze these data, the amount of area in each watershed receiving CAFO manure application is determined (Table E.2.1.D below).

- **Concentrated animal feeding operations** (CAFO) – **Runoff** c**oncentration:** When following best management practices (BMPs) of nutrient management, as dictated by CAFO permits, no manure should runoff from fields in which it is applied. Unexpected heavy rains occurring shortly after manure application resulting in runoff has been documented. Several other factors can impact when or if manure runoff will occur. Some of these factors include soil temperature (especially if freezing), snow cover, on-site manure storage and antecedent soil moisture availability. An aspect of nutrient management BMPs involve soil testing to determine nutrient needs. However soil tests are only required to occur once every 3 years for each field receiving applications. While these tests are used to determine a conservative total P application rate (to prevent over-application), soil tests are not performed before every application. If over-application does occur runoff water will have elevated total P even without soil and/or manure runoff (Sharpley, 2003). An examination of Ohio EPA complaint sampling from these two farms shows manure runoff containing a total P concentration as high as 12.1 mg/l (on 21 July 2004 in Stoll Ditch). Extremely high values like this only occur during large storms however. The GWLF model only allows for an annual total P concentration for each land use. Therefore CAFO monthly runoff concentrations must have all months considered. GWLF does adjust the amount of water runoff from a land use based on soil (unsaturated zone) antecedent moisture. The BasinSim user's guide references generally higher total P runoff from pasture/hay than from row crop land uses (Dai, 2000). An average total P concentration for CAFO row crops and CAFO pasture/hay land use of 1.7 and 4.1 mg/l is used.

- **Regular manure application** – **Distribution:** Since grazing livestock is common in the Tuscarawas River watershed (especially in Wayne County), runoff from manure applied land is taken into consideration. This is done by taking a portion of the remainder of row crops and pasture/hay (after CAFO and sewage sludge application areas have been removed). Table E.2.1.C shows the percentages used to determine these "regular manure" areas as well as the total percentages of all the special land uses. Table E.2.1.D shows the watershed breakdown of regular manure application areas as well as the other row crop and pasture/hay land use types.

- **Regular manure application** – **Runoff concentration:** Regular manure applications and grazing animals are almost fully unregulated. The BasinSim user's guide has limited reference values for grain crops with applied manure and grazed fields (Dai, 2000). The general runoff total P concentrations for regular manure applied row crop and pasture/hay land uses are 1.3 and 4.0 mg/l respectively. These values are only slightly lower than the values used for CAFO lands. The assumption for using these concentrations is that even though these lands are much less regulated and noticed by community members they still do not have the large volume of manure the CAFO lands must manage.

Table E.2.1.C Percentage used to determine "regular manure" areas and total percentages of all the special land uses

14-digit HUC	Watershed name	Percent (%) of remaining going to regular manure		Percent (%) of the modeled areas			
				Sludge	CAFO	Reg man.	No manure
010-040 full	Pigeon Creek	Row crop	1	0.4	0.0	1.0	98.6
		Pasture/hay	1	0.3	0.0	1.0	98.7
020-040 full	Little Chippewa Ck	Row crop	10	1.9	3.6	9.4	85.0
		Pasture/hay	40	1.7	5.2	37.2	55.8
020-050 full	River Styx	Row crop	10	4.4	0.0	9.6	86.0
		Pasture/hay	40	3.2	0.0	38.7	58.1
020-070 full	Red Run	Row crop	10	7.7	10.4	8.2	73.7
		Pasture/hay	40	9.1	19.1	28.7	43.1
020-080 part	Silver Creek	Row crop	10	11.2	0.0	8.9	79.9
		Pasture/hay	40	5.3	0.0	37.9	56.8
030-050 full	Fox Run	Row crop	10	9.7	3.0	8.7	78.6
		Pasture/hay	40	11.4	5.4	33.3	49.9
030-080 full	upper Newman Ck	Row crop	10	9.5	0.0	9.0	81.4
		Pasture/hay	40	8.2	0.0	36.7	55.1
030-090 full	Orrville Ditch	Row crop	10	0.0	21.6	7.8	70.5
		Pasture/hay	40	0.0	25.9	29.6	44.5
030-110 full	West Sippo Creek	Row crop	8	9.1	0.0	7.3	83.7
		Pasture/hay	25	9.4	0.0	22.7	68.0
090-030 part	Tusc R. UT @ RM 83.7	Row crop	5	5.0	0.0	4.8	90.3
		Pasture/hay	10	5.1	0.0	9.5	85.4
180-050 full	Buckhorn Creek	Row crop	8	1.9	0.0	7.8	90.3
		Pasture/hay	30	0.6	0.0	29.8	69.5
190-040 full	E. Fork White Eyes Ck	Row crop	8	0.0	0.0	8.0	92.0
		Pasture/hay	30	0.0	0.0	30.0	70.0

Table E.2.1.D Area distribution breakdown of special considerations land uses

14-digit HUC	Watershed name	Row crop (acres)				Pasture/hay (acres)			
		Sludge	CAFO	Regular manure	No manure	Sludge	CAFO	Regular manure	No manure
010-040 full	Pigeon Creek	2.2	0.0	4.9	482.9	3.3	0.0	12.8	1265.0
020-040 full	Little Chippewa Ck	49.1	95.9	248.7	2238.7	73.7	223.8	1595.4	2393.2
020-050 full	River Styx	68.5	0.0	149.1	1342.0	102.8	0.0	1226.3	1839.5
020-070 full	Red Run	112.3	151.9	119.1	1071.5	168.4	354.4	532.6	798.9
020-080 part	Silver Creek	35.0	0.0	27.7	249.4	52.5	0.0	371.8	557.7
030-050 full	Fox Run	117.6	36.2	106.2	955.6	176.4	84.5	516.1	774.1
030-080 full	upper Newman Ck	94.1	0.0	89.2	803.1	141.1	0.0	634.9	952.3
030-090 full	Orrville Ditch	0.0	207.9	75.4	678.3	0.0	485.2	555.6	833.4
030-110 full	West Sippo Creek	73.1	0.0	58.6	674.1	109.7	0.0	264.6	793.8
090-030 part	Tusc R. UT 83.7	31.8	0.0	30.4	577.1	47.7	0.0	88.7	798.3
180-050 full	Buckhorn Creek	9.6	0.0	40.0	460.4	14.5	0.0	663.2	1547.4
190-040 full	E.F. White Eyes Ck	0.0	0.0	25.5	293.1	0.0	0.0	500.2	1167.2

Background nutrient loads

Table E.2.A in the beginning of this appendix shows allocations made for natural runoff. This is a small total P load from each watershed that is expected to exist if no land management (use) were to be in place. This amount is calculated using GWLF with the assumption that all land use is deciduous forest. Also the soil total P concentration value, the single value for each

watershed that is used to figure how much total P contributes from eroded soil, is set to 873.4 mg/kg. This value is referenced form the BasinSim user's guide for soil eroding from a predominantly forest covered area (Dai, 2000).

E.2.2 Point sources

All permitted dischargers of treated effluent to waters of the state have been identified in the Tuscarawas River watershed. With the use of GIS the subwatersheds each permittee discharges to is also determined. Thirty-five dischargers have been identified in the eleven sub-watersheds modeled for nutrients. Point sources are calculated and summed separately from GWLF. The predominant source for the point source data is data supplied by the permitted dischargers to Ohio EPA per their permit requirements. Monitoring total P concentrations in effluent waters is not required by all discharges and some monitor total P infrequently. Since the GWLF output is examined on a monthly basis, a typical total P load is determined for each discharger for all 12 months. Total P load calculations from municipal separate storm sewer systems (MS4s) are discussed at the end of this section.

Discharges with regular total P effluent monitoring
An analysis of NPDES discharger data shows that four facilities regularly monitor the total P concentration in their effluent. A total P daily load is created for each of the 12 months of the year for these dischargers. This is done by first determining daily loads for every day total P is sampled at a facility. The facility's effluent discharge volume of the same day total P is sampled is used for this load. The median of each month's total P daily load is determined for the most recent five year period, so up to 60 months depending on data availability. An average of each of the twelve months' total P daily median load is determined. For instance, all of the median January daily total P loads are averaged to find a value for January. This is done to determine the total P daily load value for each of the twelve months of the year. Table E.2.2.A shows the facilities where this method is used and their determined daily total P load for each month.

Table E.2.2.A Daily total P loads for point sources with regular total P effluent monitoring data

NPDES/ County	Facility name	14-digit HUC	Daily total P effluent loads used in nutrient modeling (kg/day)											
			1	2	3	4	5	6	7	8	9	10	11	12
3IS00055/ SUMMIT	Adjusta- Post MFG Co Norton	010-040 full	0.04	0.09	0.05	0.04	0.10	0.11	0.02	0.04	0.09	0.04	0.07	0.07
3PD00017/ WAYNE	Orrville WWTP	020-040 full	23.0	20.9	23.9	33.4	27.2	20.8	15.6	14.6	19.8	25.5	21.5	20.1
3PD00047/ WAYNE	RITTMAN WWTP	020-050 full	5.41	5.02	5.93	6.65	6.80	7.02	8.75	7.34	7.21	5.98	7.13	5.96
3PB00014/ WAYNE	DOYLES-TOWN WPCF	020-080 part	5.16	2.14	5.89	3.93	2.86	4.89	1.64	3.20	2.30	3.35	3.85	1.56

Discharges without regular total P effluent monitoring data
The majority of permitted discharges have very limited or no effluent total P concentration monitoring. For these facilities an expected daily effluent flow volume for each of the twelve months is determined using the most recent five years of data. This is calculated by first finding the median of each month's daily flows. Then the average of each of the twelve months daily median flow is determined. This is a similar method as used in finding the expected daily total P load for the four facilities discussed in the previous paragraph. Total P effluent concentrations are estimated from Form 2C for many industrial discharges that do not regularly monitor this parameter. Industrial dischargers are required to complete the US EPA Form 2C whenever applying for NPDES renewal. This form requires monitoring of several parameters not typically

included in the discharger's normal monitoring schedule. For several small plants which only discharge non-contact cooling water, and have no other evidence in their permit files to indicate elevated total P concentrations, the groundwater total P concentration is used. This is the same groundwater concentration that is described above in E.2.1. Finally for the several waste water treatment plants that do not have any representative total P effluent sampling data a concentration of 3 mg/l is assumed. Table E.2.2.B shows the assumptions used in determining the total P effluent concentration for these permitted dischargers. Table E.2.2.C shows the daily total P effluent load for each month that is determined for use in the nutrient modeling.

Table E.2.2.B Total P effluent concentration assumptions made for point sources without regular monitoring data

HUC	NPDES/ County	County	Facility name	Total P (mg/l)	Explanation
010-040	3IE00007	Summit	PVS Chemical Inc OH	0.05	GW flow (2C is < detect)
	3IN00184	Summit	Roadway Express Inc Copley Terminal	1.1	2C report.
	3IR00102	Summit	Karman Rubber Co	0.05	Used GW (non-contact cooling)
	3PG00013	Summit	Ridgewood Place WWTP	3	Public waste facility
	3PH00004	Summit	Copley Square Water Co	3	Public waste facility
	3PR00184	Summit	Cavanaugh Bldg Corp	3	Public waste facility
	3PR00258	Summit	CVS Pharmacy	3	Public waste facility
	3PR00272	Summit	KPK Enterprises	3	Public waste facility
	3PR00309	Summit	Covenant Of Grace Church	3	Public waste facility
	3PR00322	Summit	Huth Enterprises Sawmill	3	Public waste facility
	3PR00331	Summit	Metropolitan Veterinary Hospital	3	Public waste facility
	3PR00358	Summit	Merchant Service Ctr	3	Public waste facility
	3PR00381	Summit	Copley Towne Center	3	Public waste facility
	3PT00038	Summit	Copley Fairlawn Middle School	3	Public waste facility
020-040	3IB00017	Wayne	Orrville Municipal Power	4.88	TP conc for outfall 005 on 2C *
	3ID00075	Wayne	Technocast Inc	0.06	Used GW concentration
	3IN00310	Wayne	Quality Castings Co	0.06	Used GW (non-cont. cooling)
	3IW00090	Wayne	Orrville WTP	0.06	Used GW
	3PR00144	Wayne	Apostolic Christian Home	3	Public waste facility
020-050	3IN00037	Medina	Hubbell Power Systems/ Ohio Wadsworth M.O.V. Plant	0.216	An old 2C value
	3IR00053	Medina	Goldsmith and Eggleton Inc	0.05	All flow is non-contact cooling.
	3IW00015	Medina	Wadsworth WTP	0.05	GW flow (2C is < detect)
	3PD00022	Medina	Wadsworth WWTP	3	Public waste facility
020-070	3PB00032	Wayne	Marshallville STP	3	Public waste facility
020-080	3PV00031	Wayne	Westview MHP	3	Public waste facility
030-050	3PR00280	Stark	Clay's Park Resorts Fox Run	3	Public waste facility
	3PR00288	Stark	Ohio Family Foundation INC.	3	Public waste facility
	3PV00099	Stark	Top-O-Hill MHP	3	Public waste facility
030-080	3PB00013	Wayne	Dalton WWTP	3	Public waste facility
	3PV00017	Wayne	Lincoln Terrace Estates MHP	3	Public waste facility
UT 83	3PT00100	Stark	PJ Lohr Elem Sch	3	Public waste facility

* Orrville Municipal Power receives some of their process water from the Orrville WWTP's effluent. Simple calculations are used to weight this plant's outfalls in order to determine its representative total P effluent concentration.

Table E.2.2.C Daily total P loads for point sources without regular total P effluent monitoring data

NPDES	Facility name	Daily total P effluent loads used in nutrient modeling (kg/day)											
		1	2	3	4	5	6	7	8	9	10	11	12
3IE00007	PVS Chemical Inc OH	0.11	0.11	0.11	0.11	0.11	0.10	0.10	0.09	0.11	0.10	0.11	0.11
3IN00184	Roadway Express Inc Copley Terminal	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67
3IR00102	Karman Rubber Co	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002
3PG00013	Ridgewood Place WWTP	0.15	0.18	0.17	0.18	0.16	0.16	0.18	0.15	0.18	0.18	0.17	0.16
3PH00004	Copley Square Water Co	1.46	1.50	1.50	1.47	1.48	1.45	1.44	1.42	1.38	1.39	1.38	1.44
3PR00184	Cavanaugh Bldg Corp	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
3PR00258	CVS Pharmacy	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003
3PR00272	KPK Enterprises	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
3PR00309	Covenant Of Grace Church	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001
3PR00322	Huth Enterprises Sawmill	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
3PR00331	Metropolitan Veterinary Hospital	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
3PR00358	Merchant Service Ctr	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
3PR00381	Copley Towne Center	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
3PT00038	Copley Fairlawn Middle School	0.24	0.08	0.10	0.09	0.09	0.05	0.04	0.04	0.06	0.06	0.06	0.09
3IB00017	Orrville Municipal Power	4.46	4.47	4.69	4.60	4.96	5.00	5.49	5.94	5.12	5.15	4.97	4.67
3ID00075	Technocast Inc	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
3IN00310	Quality Castings Co	0.02	0.01	0.02	0.01	0.03	0.01	0.02	0.01	0.03	0.01	0.01	0.02
3IW00090	Orrville WTP	.003	.002	.005	.004	.008	.003	.003	.003	.003	.002	.004	.005
3PR00144	Apostolic Christian Home	0.11	0.11	0.11	0.15	0.14	0.15	0.13	0.13	0.14	0.14	0.12	0.12
3IN00037	Hubbell Power Systems/ OH Wadsworth MOV Plant	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
3IR00053	Goldsmith and Eggleton Inc	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
3IW00015	Wadsworth WTP	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002
3PD00022	Wadsworth WWTP	35.5	38.5	40.0	43.3	39.7	34.4	29.6	28.0	28.0	27.4	28.3	33.8
3PB00032	Marshallville STP	1.01	1.22	1.24	1.15	0.95	0.73	0.69	0.94	0.89	0.84	0.89	1.08
3PV00031	Westview MHP	0.40	0.39	0.37	0.36	0.36	0.40	0.44	0.38	0.37	0.36	0.33	0.36
3PR00280	Clay's Park Resorts Fox Run	0.01	0.01	0.01	0.01	0.03	0.05	0.03	0.03	0.03	0.04	0.01	0.01
3PR00288	Ohio Family Foundation Inc.	0.08	0.06	0.07	0.07	0.08	0.12	0.15	0.10	0.08	0.06	0.06	0.06
3PV00099	Top-O-Hill MHP	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
3PB00013	Dalton WWTP	2.53	2.88	2.94	3.35	2.55	2.00	1.63	1.91	2.10	1.90	1.91	2.60
3PV00017	Lincoln Terrace Estates MHP	0.23	0.22	0.21	0.26	0.23	0.21	0.20	0.19	0.21	0.20	0.20	0.24
3PT00100	PJ Lohr Elem Sch	0.06	0.05	0.06	0.06	0.06	0.03	0.01	0.03	0.05	0.05	0.04	0.04

Municipal separate storm sewer systems (MS4s)

MS4s are regulated municipalities that are required to have a type of NPDES permit for storm water runoff based on population and density. The same US Census GIS data used to draw the MS4 boundaries for municipalities are used for nutrient modeling efforts. These spatial data are cut by watershed and analyzed for land use using the same land use data employed in the GWLF model predicting surface runoff. The amount of area with urban land uses that are in the MS4 area are compared to the total urban land use area for each watershed (Table E.2.2.D). 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 total P urban land use surface runoff (from GWLF and explained above) and considered MS4 existing total P load. The amount of allocated total P for MS4 lands is similarly calculated. Before surface runoff and MS4 total P 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 E.2.2.D MS4 municipalities in modeled watersheds

HUC-14	WS name	Municipal separate storm sewer systems (MS4)		
		Area of MS4 (mi^2)	Urban land that is MS4	Name
010-010 part	Tusc.River upst. Mogadore Rd.	1.40	85.1%	Suffield (Portage), Lake Twp (Stark), Hartville Village, Springfield Twp (Summit)
010-040 full	Pigeon Creek	9.61	99.6%	Akron
010-050 full	Mid-Wolf	4.12	99.5%	Barberton City, Norton City, Copley Twp (Summit) (very little)
020-050 full	River Styx	3.22	68.0%	Wadsworth
020-060 part	Mill Creek	0.16	53.1%	Doylestown Village, Wadsworth Twp (Medina), Wadsworth City
020-080 part	Silver Creek	0.90	89.4%	Chippewa Twp (Wayne), Doylestown Village, Norton City, Wadsworth Twp (Medina), Wadsworth City
030-070 full	Mudbrook Creek	1.02	86.0%	Jackson Township (Stark), Lawrence Twp (Stark) very small amount
030-100 full	lower Newman Ck	0.07	19.1%	Massillon City (small bit), Lawrence Twp (Stark) (small), Tuscarawas Twp (Stark) (small), Perry Twp (Stark)
030-110 full	West Sippo Creek	1.97	82.8%	Tuscarawas Twp (Stark), Massillon City
030-120 full	Sippo Creek	9.62	97.7%	Massillon City, Perry Twp (Stark), Jackson Twp (Stark)
090-030 part	Tusc R. UT RM 83.7	1.16	83.5%	Navarre Village
090-020 full	Pigeon Run	0.10	26.0%	Tuscarawas Twp (Stark)
130-030 full	Oldtown Creek	0.09	6.2%	New Philadelphia City
130-040 full	Beaverdam Creek	0.85	58.3%	New Philadelphia City

WS = watershed

E.2.3 Home sewage treatment systems

Home sewage treatment systems (HSTSs) for individual homes are not required to receive NPDES permits. In order to account for total P load from these sources, estimates are made for the amount of HSTSs and their type and condition. Detailed information about HSTSs is generally lacking because they are so numerous and installed and repaired over long periods of time.

All county health departments charged with regulating HSTSs in the Tuscarawas River watershed have been contacted for this report. Little specific information could be provided about the abundance of HSTSs with the exception of Coshocton County. That county's health department provided their own GIS data of the distribution of HSTSs. For the remaining counties the number of HSTS is determined via GIS analysis. The 1990 census GIS attribute (tabular) data included parameters outlining the percentage of private homes not on a public

sewage system. Census GIS data from 2000 do not contain this attribute information. Analyzing the spatial aspects of this 1990 census data allows for a watershed population, number of households, and percentage of HSTS households to be calculated. US Census Bureau blocks are the smallest geographic unit which is tabulated with 100% data. In urban areas blocks often correspond to actual city blocks bounded by streets. However in rural areas they can be much larger depending on density. Rural blocks can cover up to many square miles and may not have streets as boundaries. Analysis on census blocks is carried out by assuming each census block to be equally disturbed. The information calculated from 1990 census data is adjusted to 2000 census data. The rate of change from 1990 to 2000 population (positive or negative) is applied to each watershed's population number of homes and percentage of homes served by HSTSs. This HSTS abundance and use figures (Table E.2.3.A) are used to determine total P and bacteria (explained in Appendix E.3) loads.

Table E.2.3.A Calculated watershed HSTS and demographic data for the year 2000

HUC	Watershed name	HSTS homes	HSTS population	Persons/ HSTS	HSTS Failure rate (%)
010-010 partial	Tusc.River upst. Mogadore Rd.	1686	4766	2.83	30.06
010-030 partial	Wolf Ck UT RM 11	165	432	2.62	27.68
010-040 full	Pigeon Creek	2597	6775	2.61	31.35
010-050 full	Mid-Wolf	1425	3783	2.66	34.05
020-030 partial	Steel Ditch	283	717	2.54	31.63
020-030 partial	Tommy Run	292	867	2.97	31.63
020-040 full	Little Chippewa Ck	533	1526	2.86	30.25
020-050 full	River Styx	1315	3551	2.70	27.91
020-060 partial	Mill Creek	727	2093	2.88	28.19
020-070 full	Red Run	305	853	2.80	28.63
020-080 partial	Silver Creek	2433	6087	2.50	27.29
030-050 full	Fox Run	562	1551	2.76	28.44
030-070 full	Mudbrook Creek	793	2359	2.97	21.68
030-080 full	upper Newman Ck	567	1548	2.73	32.44
030-090 full	Orrville Ditch	253	740	2.92	28.48
030-100 full	Lower Newman Ck	798	2089	2.62	28.09
030-110 full	West Sippo Creek	966	2389	2.47	42.13
030-120 full	Sippo Creek	1604	4093	2.55	27.02
090-020 full	Pigeon Run	569	1458	2.56	30.37
090-030 partial	Tusc. R. UT RM 83.7	489	1186	2.43	29.57
090-030 partial	Tusc. R. UT RM 78.0	114	291	2.55	29.57
090-040 partial	Small Mid Run	23	56	2.47	26.08
130-010 full	Stone Creek	426	1070	2.51	56.17
130-030 full	Oldtown Creek	535	1301	2.43	26.26
130-040 full	Beaverdam Creek	907	2222	2.45	30.35
180-030 full	Dunlap Creek	303	762	2.52	25.91
180-040 partial	Blue Ridge Run	39	95	2.43	31.22
180-050 full	Buckhorn Creek	872	2021	2.32	48.14
190-010 full	Evans Creek	256	592	2.31	28.75
190-020 full	White Eyes Ck (not including E.F. & W.F.)	412	932	2.26	44.86
190-030 partial	upper W. Fork White Eyes Creek	248	539	2.17	23.32
190-040 full	E.F. White Eyes Ck	143	321	2.25	28.13

Health departments have been asked for estimates of known HSTS failure rates on the most specific level they could provide. Very little information however is known. Field efforts to investigate several tributaries with high fecal coliform and *E. coli* bacteria found several concentrated areas of failing and/or bypassed HSTSs. The percentage of failing HSTSs for this report is determined in general using US Census data on the years houses were built with refinement form field investigations. US Census data does not compile the years houses were built on the block geographic level discussed above, rather they use the next more course block group level. Similar to determining populations and homes served by HSTSs, a GIS analysis is carried out on these data. Assumptions are made about HSTS failure rates based on the years homes were built. Table E.2.3.B shows percentage of failing systems assigned to each year of home built. While various degrees of failing systems are possible (i.e. systems treating half or a quarter of the effluent adequately) these percentages are estimated to assist in calculating the cumulative number of fully non-functional systems. Table E.2.3.B also contains the additional failure rate increases and justifications for each increase. Table E.2.3.A above provides the failure rates used for each watershed's HSTSs.

Table E.2.3.B HSTS failure rates

HSTS failure rates for homes built in year:				
Pre-1940	'40-'49	'50-'69	'70-'89	'90-'00
40%	38%	35%	25%	2%
Increases in failure rates				
HUC	**Name**	**% Increased**	**Reason**	
010-010 part	Tusc.River upst. Mogadore Rd.	20	Field observations on Pontius Rd.	
030-110 full	West Sippo Creek	33.3	Septic effluent flowing out of Shady Groove complex	
130-010 full	Stone Creek	100	Many failed systems in the village of Stone Creek.	
180-050 full	Buckhorn Creek	75	Several failed systems observed in village of Wolf	
190-020 full	White Eyes Ck (dwst. E.F. & W.F.)	75	Ohio EPA documented orders with the village of Fresno	

Metcalf & Eddy, 1991, provides calculation of residential homes' waste water production by assuming 151.42 liters per residence plus 151.42 liters per resident in each residence each day (151.42 liters is 40 gallons). To determine HSTS pollutant flows, the amount of HSTS effluent flowing into streams, this flow equation is applied in each watershed using the demographic data on Table E.2.3.A. and multiplied by the failure rate. The failing HSTS flow volume is then multiplied (along with the proper conversion rates) by a reference total P concentration of 10 mg/l (USEPA, 2002). This provides a daily HSTS total P load.

E.3 Pathogen modeling

This appendix explains the pathogen modeling method used for most of the watersheds in this report. Table E.3.A shows the pathogen TMDL development. Pathogen modeling is carried out to determine acceptable allocations of an indicator parameter so that the streams can meet their recreational use standards. Recreational use standards concerned here, primary and secondary contact, are only in effect each year during the recreational season, May through 15 October. Fecal coliform bacteria is one of the two bacteria indicators currently used to determine recreational use attainment. Fecal coliform bacteria is also the parameter the US EPA Bacteria

Indicator Tool (BIT) calculates. Because of this, fecal coliform bacteria is the indicator parameter used for the pathogen TMDL in this report.

Table E.3.A Summary of pathogen TMDL development

Development step	Source		Method
Existing load	Point source		Product of discharger design flow and the fecal coliform average standard currently in place.
	Surface runoff		BIT tool with spreadsheet 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.
	Upstream load		Product of the recreation season discharge volume from any upstream drainage (GWLF hydrology) and the fecal coliform geometric mean concentration.
Calculation of loading capacity	-		Product of the recreation season discharge volume from each sub-basin (GWLF hydrology) and the fecal coliform geometric mean concentration.
Allocation	Upstream load		Product of the recreation season discharge volume from any upstream drainage (GWLF hydrology) and the fecal coliform geometric mean concentration.
	WLA	Point sources	Product of discharger design flow and the fecal coliform average standard currently in place.
		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) and upstream load subtracted from the assimilative capacity.
		HSTS	Home sewage treatment systems are allocated a fecal coliform load of zero.

E.3.2 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. The BIT tool also determines how much fecal coliform is directly introduced to streams from livestock (cattle grazing in 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 is 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 ™ satellite imagery circa 1992 (USGS, 2000). 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 is obtained from Ohio Agricultural Statistics Service published data. Information regarding wildlife populations is obtained from Ohio Department of Natural Resource census data. In each case, the total number of animals within a county is divided by the total number of acres of relevant land use in the county the livestock or wildlife would inhabit. The resulting animal densities (animals per acre) are used to estimate the animal populations within each 14-digit HUC.

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 is 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. This spreadsheet uses the most recent 14 years of precipitation data (1999-2005) from weather stations that most appropriately represent each watershed. A runoff curve number is applied to four of the land use types (no runoff is calculated for the water land use) within each watershed. The manner these runoff curve numbers are determined is described in Appendix E.1 (GWLF Hydrology). Runoff to streams is determined using precipitation data and the runoff curve number for land use in each watershed for every day. The US Soil Conservation Service's Curve Number Equation is used to determine this runoff. Note that adjustments to runoff curve numbers changing the detention parameter based on antecedent soil moisture, a function in place in GWLF, is not utilized in this method. The BIT output of the daily accumulation of fecal coliform bacteria colony forming units is used in this washoff method. This is added on to whatever fecal coliform is left over from the previous day (after washoff if any occurred) minus a decay rate that is in line with BIT's maximum storage (asymptotic limit) calculation. 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). In addition to the amount of accumulated fecal coliform, this equation uses the amount of runoff (water), and a different washoff (susceptibility) coefficient for urban and rural land uses. The daily bacteria washoff for each land use is summed for each watershed and each recreational season. The average seasonal load from this modeling is used as the existing fecal coliform in the TMDL report. No calibration efforts of this modeling have taken place.

E.3.2 Home sewage treatment systems (HSTSs)

The methods of determining the amount of HSTSs and their failure rates are estimated is described in Appendix E.2. Table E.2.3.A of that appendix provides the calculated population, amount of HSTSs and failure rates for each pathogen TMDL watershed. The same wastewater flow rate as used for failing HSTS total phosphorus is applied to fecal coliform bacteria. The concentration o f 1.00e7 colony forming units per 100 ml is referenced from USEPA's onsite waste management guidance (USEPA, 2002).

E.3.3 Point sources

Point source permittees that discharge effluent containing waste 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. Fecal coliform for NPDES dischargers' effluent are already required to meet the water quality standard for primary contact recreational use. Because of this, 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.

MS4s are determined in the same manner as in the nutrient modeled explained in Appendix E.2. This uses a proportion of the fecal coliform load from the surface runoff as determined by the BIT and washoff method described above. The percentage is determined by use of GIS. It is the percentage of each watershed's urban land use area that is within the MS4 boundary to its total area of urban land use (see Table E.2.3.B in Appendix E.2).