Appendix

D

LOADING ANALYSIS INFORMATION
UPPER MAHONING RIVER WATERSHED

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D1 Analysis Methods

About 62 percent of the sites evaluated in the upper Mahoning River watershed were impaired for aquatic life uses and 95 percent of the sites for recreation uses. Thirteen water quality stressors were identified as causing this impairment throughout the project area; however, only four were the focus of TMDL development, namely *E. coli*, sediment, habitat, and total phosphorus. The stressors that had no TMDLs developed mostly had one of the four stressors applied as a surrogate stressor (i.e., where sources are similar enough that source load reductions prescribed to address one stressor are very likely sufficient to address the other stressor). In other cases it is not practical to develop a TMDL for a particular stressor, such as when natural conditions are the cause of impairment. Additionally, there were seven nutrient impairments across five assessment units for which no TMDLs were developed, not due to impracticality, but rather limitations on staff resources. These impairments will be addressed in the future if needed (i.e., non-attainment of aquatic life uses persist). Table D-1 is a complete list of the assessment units and identified causes of the use impairments. This table also indicates what steps are taken, if any, in terms of TMDL development.

Table D-1. Summary of causes of impairment to aquatic life and recreational uses for the upper Mahoning River watershed and actions taken to address them.

Assessment Unit	Narrative Description	Causes of impairment	Action Taken
05030103 01 01	Beaver Run-Mahoning River	Nutrients	Total phosphorus TMDL
		Sedimentation / siltation	QHEI TMDL
Priority Points 5		*E. coli*	LDC TMDL - *E. coli*
05050103 01 02	Beech Creek	Habitat alterations	QHEI TMDL
		Nutrients	Not addressed
		Sedimentation / siltation	QHEI TMDL
Priority Points 6		*E. coli*	LDC TMDL - *E. coli*
05030103 01 03	Fish Creek-Mahoning River	Alteration in streamside / littoral cover	QHEI TMDL
		Habitat alterations	QHEI TMDL
		Fish kills	Not addressed
		Nutrients	Total phosphorus TMDL
		Flow alterations	QHEI TMDL
		Sedimentation / siltation	QHEI TMDL
Priority Points 8		*E. coli*	LDC TMDL - *E. coli*
05030103 02 01	Deer Creek	Nutrients	Total phosphorus TMDL
		Flow alterations	QHEI TMDL
Priority Points 8		*E. coli*	LDC TMDL - *E. coli*
05030103 02 02	Willow Creek	Alteration in streamside / littoral cover	QHEI TMDL
		Nutrients	Total phosphorus TMDL
		Sedimentation / siltation	QHEI TMDL
Priority Points 8		*E. coli*	LDC TMDL - *E. coli*
05030103 02 03	Mill Creek	Natural	Not addressed
		Nutrients	Not addressed
		Flow alterations	QHEI TMDL
		Sedimentation / siltation	QHEI TMDL
Priority Points 4		*E. coli*	LDC TMDL - *E. coli*

Assessment Unit	Narrative Description	Causes of impairment	Action Taken
05030103 02 04	Island Creek-Mahoning River	Nutrients	Not addressed
		Sedimentation / siltation	QHEI TMDL
Priority Points 6		*E. coli*	LDC TMDL - *E. coli*
05030103 03 01	Kale Creek	Habitat alterations	QHEI TMDL
		Natural	Not addressed
		Dissolved Oxygen	Not addressed
		Sedimentation / siltation	QHEI TMDL
		Turbidity	Not addressed (or QHEI)
Priority Points 6		*E. coli*	LDC TMDL - *E. coli*
05030103 03 02	Headwaters West Branch Mahoning River	Nutrients	Not addressed
		Organic enrichment	Not addressed
		Sedimentation / siltation	QHEI TMDL
Priority Points 9		*E. coli*	LDC TMDL - *E. coli*
05030103 03 03	Barrel Run	Flow alteration	QHEI TMDL
Priority Points 8		*E. coli*	LDC TMDL - *E. coli*
05030103 03 04 *Priority Points 3*	Kirwin Reservoir-West Branch Mahoning River	*E. coli*	LDC TMDL - *E. coli*
05030103 03 05	Town of Newton Falls-West Branch Mahoning River	Habitat alterations	QHEI TMDL
		Flow alterations	QHEI TMDL
		Sedimentation / siltation	QHEI TMDL
Priority Points 8		*E. coli*	LDC TMDL - *E. coli*
05030103 03 06	Charley Run Creek-Mahoning River	Flow alterations	QHEI TMDL
Priority Points 9		*E. coli*	LDC TMDL - *E. coli*
05030103 04 01	Headwaters Eagle Creek	Natural	Not addressed
Priority Points 5		*E. coli*	LDC TMDL - *E. coli*
05030103 04 02 *Priority Points 5*	South Fork Eagle Creek	*E. coli*	LDC TMDL - *E. coli*
05030103 04 03	Camp Creek-Eagle Creek	Nutrients	Total phosphorus TMDL
		Sedimentation / siltation	QHEI TMDL
Priority Points 8		*E. coli*	LDC TMDL - *E. coli*
05030103 04 04	Tinkers Creek	Habitat alterations	QHEI TMDL
		Nutrients	Total phosphorus TMDL
		Sedimentation / siltation	QHEI TMDL
Priority Points 6		*E. coli*	LDC TMDL - *E. coli*
05030103 04 05 *Priority Points 5*	Mouth Eagle Creek	*E. coli*	LDC TMDL - *E. coli*
05030103 04 06	Chocolate Run-Mahoning River	Habitat alterations	QHEI TMDL
		Nutrients	Not addressed
		Flow alterations	QHEI TMDL
		Sedimentation / siltation	QHEI TMDL
Priority Points 8		*E. coli*	LDC TMDL - *E. coli*

Stressors Selected for TMDL Development and Their Water Quality Targets

E. coli bacteria impair recreation uses since they indicate contamination by fecal material. *E. coli* are seldom pathogenic but a number of other fecal-based microorganisms are. These pathogenic organisms occur in a much lower abundance, so a statistical relationship is relied upon between *E. coli* bacteria and pathogenic organisms to determine a risk level associated with exposure to surface waters. The acceptable risk varies based on the level of use the water resources receives for recreation purposes. In this watershed, much of the Mahoning River has the potential for substantial recreation use and its quality is protected accordingly at the Primary Contact Recreation - A use. The criteria acceptable for *E. coli* is the geometric mean of the concentration of two or more samples taken during a single recreation season that does not exceed 126 colony forming units (CFUs) per 100 ml of sample. However, the majority of streams in the watershed are protected under a Primary Contact Recreation - B use where the geometric mean of two or more samples in a single recreation season is not to exceed 161 CFUs per 100 ml of sample.

Habitat provides refuge to organisms against predation and some environmental stressors. It also affords cover for certain predation strategies. The QHEI is a measure of habitat quality relative to presence or absence of structural features and flow conditions. Strong correlations exist between QHEI scores and some its component sub-metrics and the biological indices used in Ohio's water quality standards such as the Index of Biotic Integrity (IBI). Through statistical analyses of data for the QHEI and the biological indices, target values have been established for QHEI scores with respect to the various aquatic life use designations (Ohio EPA 1999). For the aquatic life use designation of warm water habitat (WWH) an overall QHEI score of 60 is targeted to provide reasonable certainty that habitat is not deficient to the point of precluding attainment of the biocriteria. An overall score of 75 is targeted for streams designated as exceptional warm water habitat (EWH) and a minimum score of 45 is targeted for modified warm water habitat (MWH) streams.

Sediment impairs aquatic life by damaging streambed habitat. Riffles and other areas comprised of coarser material become embedded with fine sediment effectively reducing or eliminating the important void spaces that provide cover to macroinvertebrates and fish as well as their eggs. Likewise, flow characteristics may be altered in such circumstances where interstitial and/or hyporheic flow is reduced or eliminated which has adverse results in the ecosystem. Sediment itself can be damaging to the aquatic ecosystem as it delivers pollutants and causes abrasion to organisms. The QHEI evaluates substrate quality and the degree of embeddedness. Along with substrate, the channel morphology metric and bank erosion and riparian zone metrics also indicate sediment problems in a stream. Bank erosion suggests the degree of internal sediment loading from the stream system based on the relative amount of bank failure while channel morphology indicates the system's capacity (or conversely its inability) to assimilate sediment loading. Table D-2 and D-3 show the QHEI targets used for the habitat and sediment TMDLs, respectively.

Table D-2. TMDL Targets for the overall QHEI score and the number of poor habitat attributes for habitat TMDLs in the upper Mahoning River basin.

	Overall QHEI Score	All Modified Attributes	
		High Influence Modified Attributes	All Other Modified Attributes
Range of Possibilities	12 to 100 points	- Channelized or No Recovery - Silt/Muck Substrate - Low Sinuosity - Sparse/No Cover - Max Pool Depth < 40 cm (wadeable streams only)	- Recovering Channel - Sand Substrate (boat sites) - Hardpan Substrate Origin - Fair/Poor Development - Only 1-2 Cover Types - No Fast Current - High/Moderate Embeddedness - Ext/Mod Riffle Embeddedness - No Riffle
Target	Overall score >= 60	Total number < 2	Total number < 5[1]
TMDL Points Assigned if Target is Satisfied	+ 1	+ 1	+ 1

1 The "Total number" is to include the high influence modified attributes.

Table D-3. TMDL Targets for QHEI metric scores for sediment TMDLs in the upper Mahoning River basin.

Sediment TMDL =	Substrate	+	Channel Morphology	+	Riparian Zone/Bank Erosion	
For WWH >=	13	+	14	+	5	>= 32

Nutrients impair aquatic communities by fostering excessive algae and plant growth which effects diurnal and seasonal dissolved oxygen concentrations. During peak production, typically mid to late summer, daily swings in dissolved oxygen can be substantial which causes stress on organisms, leading to avoidance or downstream drifting of macroinvertebrates, and/or changes in metabolic and/or growth rates and reproduction successes. Also, daily nighttime lows in dissolved oxygen concentration due to respiration of the massive body of plant biomass which is not compensated with oxygen produced through photosynthesis, can deplete dissolved oxygen to stressful or deadly conditions. On a seasonal basis, the large die-off of plant material occurs which supplies food for microbes which experience tremendous growth and consume much of the system's dissolved oxygen through respiration.

Excessive production also results in a shift in the aquatic community due to the changing food web and the fact that a relatively small set of organisms have a significant competitive advantage for acquiring food resources in a system with a food base dominated by primary production. Species that do not compete well under these conditions are typically locally extirpated.

Elemental phosphorus is one of three primary nutrients for plant growth. Phosphorus is also typically the limiting nutrient in freshwater ecosystems due, in part, to the fact that sources are limited to mineral materials and existing biomass (organic phosphorus) while the atmosphere provides a nearly limitless supply of nitrogen in the presence of nitrifying bacteria. Artificial fertilizers; however, add to the pool of phosphorus in the environment that otherwise would not be available (phosphorus being mined in other parts of the country). Since phosphorus has this status of typically being the limiting nutrient and the fact that it is relatively easy to manage in a watershed, it is the nutrient for which nutrient TMDLs are developed.

Correlation between ambient total phosphorus concentrations and the index of biotic integrity (IBI) shows a statistically significant relationship. Total phosphorus concentration targets have been developed for streams of differing watershed sizes and locations in Ohio based on ecoregions. Likewise targets vary based on the aquatic life use designation (or the expectation for biological performance). Table D-4 shows the concentration target values based on the categories just described.

Table D-4. Total phosphorus targets applicable to the upper Mahoning watershed.

Watershed size	EWH	WWH
Headwaters (drainage area < 20 mi^2)	-	0.08
Wadable (drainage area ≥ 20 mi^2 < 200 mi^2)	-	0.10
Small Rivers drainage area ≥ 200 mi^2 < 1000 mi^2)	0.10	-
Large Rivers (drainage area > 1000 mi^2)	0.15	-

The discharge from a eutrophic lake can be damaging to aquatic life due to the large amount of organic material and algae that is exported to downstream areas. Namely, dead or dying algae will provide a carbon source for decomposer bacteria that may proliferate and deplete dissolved oxygen levels through their respiration. Living algae that is exported can cause the conditions similar to what is observed in stream where primary production is high. Another problem to downstream receiving waters is the export of ammonia or concentrated nutrients that have accumulated in the hypolimnion (or chemolimnion) and are release through a bottom sluice where there deleterious impacts are realized downstream.

Total phosphorus, chlorophyll *a*, and Secchi disk transparency have historically been utilized as the primary indicators of eutrophication presented in lake TMDLs; however, total nitrogen, ammonia, dissolved oxygen, pH, and temperature have been listed within the draft Lake Habitat Criteria (these chemical based criteria are the same as those for the exceptional warmwater habitats) and evaluated in this TMDL. The reductions will reduce eutrophication to permissible levels that allow the lakes to meet Ohio's Lake Habitat Criteria. The criteria proposed for inland lakes are shown in Table D-5.

Table D-5. Ohio's Proposed Lake Habitat Criteria OAC Rule 3745-1-43 mixed layer depth median water quality standards (Table 43-12 in proposed rule, 2008).

Parameter Lake type	Form[1]	Units[2]	Statewide criteria	Ecoregional criteria				
				ECBP	EOLP	HELP	IP	WAP
Ammonia	T	mg/l	Table 43-4	--	--	--	--	--
Chlorophyll a[3]								
Dugout lakes	T	µg/l	8.0	--	--	--	--	--
Impoundments	T	µg/l	--	9.5	9.5	9.5	9.5	6.2
Natural lakes	T	µg/l	9.5	--	--	--	--	--
Upground reservoirs	T	µg/l	6.0	--	--	--	--	--
Dissolved oxygen[4] All lake types	T	mg/l	5.0 OMZM 6.0 OMZA	--	--	--	--	--
Nitrogen[3]								
Dugout lakes	T	µg/l	450	--	--	--	--	--
Impoundments	T	µg/l	--	815	790	815	815	350
Natural lakes	T	µg/l	650	--	--	--	--	--
Upground reservoirs	T	µg/l	1,150	--	--	--	--	--
pH All lake types	--	s.u.	a	--	--	--	--	--
Phosphorus[3]								
Dugout lakes	T	µg/l	24	--	--	--	--	--
Impoundments	T	µg/l	--	32	32	32	32	13
Natural lakes	T	µg/l	32	--	--	--	--	--
Upground reservoirs	T	µg/l	24	--	--	--	--	--
Secchi disk transparency[5]								
Dugout lakes	--	m	1.35	--	--	--	--	--
Impoundments	--	m	--	1.04	1.04	1.04	1.04	2.38
Natural lakes	--	m	1.04	--	--	--	--	--
Upground reservoirs	--	m	2.68	--	--	--	--	--
Temperature All lake types	--	--	b	--	--	--	--	--

1 T = total.
2 m = meters; mg/l = milligrams per liter (parts per million); µg/l = micrograms per liter (parts per billion); s.u. = standard units.
3 These criteria apply from May through October in the epilimnion of stratified lakes and throughout the water column in unstratified lakes.
4 For dissolved oxygen, OMZM means outside mixing zone minimum and OMZA means outside mixing zone minimum twenty-four-hour average. The dissolved oxygen criteria apply in the epilimnion of stratified lakes and throughout the water column in unstratified lakes.
5 These criteria apply as minimum values from May through October.
a pH is to be 6.5-9.0, with no change within that range attributable to human-induced conditions.
b At no time shall the water temperature exceed the average or maximum temperature that would occur if there were no temperature change attributable to human activities.

D1.1 Justification of Methods

E. coli Bacteria TMDLs

An underlying premise of the duration curve approach is correlation of water quality impairments to flow conditions. The duration curve alone does not consider specific fate and transport

processes. These processes may include sediment attenuation, plant uptake of nutrients, or chemical transformations.

The duration curve is most appropriate in cases where flow is a primary driver in pollutant delivery mechanisms, and other processes are a relatively insignificant part of the total loading. However, the duration curve method, by itself, is limited in the ability to track individual source loadings or relative source contributions within a watershed. Additional analysis is needed to identify pollutant contributions from different types of potential sources and activities.

The main advantage of the use of LDCs is the ability to discriminate loading based on flow. This method is appropriate since the sources of bacteria in Ohio streams can be differentiated by stream flow regime. The main shortcoming of this method is the lack of differentiation between various loading sources that may occur under the same flow regime, especially in regards to cows in stream versus poorly operating home sewage treatment systems. However, knowledge of the watershed is useful in discriminating these sources, where, if there is minimal access for livestock to streams and the presence of home septic systems is significant, loading estimates from this specific source and subsequent source controls can be appropriately applied.

Another justification for the selection of this method is that alternative methods to LDCs are mostly unreliable or prohibitive in terms of needed staff and funding resources to use them. For example, using a dynamic watershed model is time consuming and often yields similar results as those generated through simpler methods. More complicated modeling would also require more bacteria data than what is collected during routine surveys for calibration.

Ultimately, the decision to use load duration curves for bacteria TMDLs is reasonable since there is very little livestock in the watershed with which to confuse multiple low flow loading sources (home septic systems and livestock/manure). The investment needed to use more complicated bacteria models is not justified given the uncertainty associated with the information that would be gained and the fact that the modeling output from such an approach is not entirely necessary for effective management and/or control of the sources of bacteria.

Habitat and Sediment TMDLs

For decades the Ohio EPA has used the QHEI to help understand the causes of aquatic life use impairment as well as in assigning appropriate aquatic life uses to stream segments. The strong correlation between the paired scores of the QHEI and the Index of Biotic Integrity (IBI), an important biometric in Ohio's water quality standards, supports the idea that the QHEI is assessing aspects of the stream system that are relevant to biological performance. The reliability that the QHEI demonstrates in predicting biological performance (the basis for aquatic life use attainment) as well as the relative ease of its application is the reason it is selected as the basis for the sediment and habitat TMDLs.

In terms of TMDLs for sediment, the QHEI characterizes sediment problems with the substrate metric, which has several sub-metrics that deal with fine material (sediment). Despite not providing an absolute quantity (or load) of fine material, it does deal with the relative quantity expressed as a range in the percent of embeddedness of the channel and the percent of silt cover. Likewise the dominant substrate particle size (e.g., sands or silts) is marked and finer sized material score fewer points than coarser substrates. These connections are believed to be strong enough and the fact that they can reflect what is adversely impacting the biological community makes the QHEI suitable for developing sediment TMDLs. Also, many alternative methods for developing sediment TMDLs are problematic. An example is the use of total

suspended solids (TSS) as a surrogate for sedimentation (which is commonly done). Data gathered for modeling TSS (e.g., using GWLF, LSPC, or SWAT models) is often unreliable for calibration and validation since TSS demonstrates a high degree of variability both over space and time and is very sensitive to local disturbances which could significantly inflate the concentration well above what is representative of the system. Additionally, there are few models that adequately account for in-stream sediment dynamics (e.g., erosion and deposition processes) and those that do often require very high resource expenditures (e.g., much data collection) that are often not feasible (e.g., CONCEPTS).

Sediment TMDL targets and the qualitative habitat evaluation index (QHEI)
Numeric targets for sediment are based on metrics of the QHEI, specifically those that consider particular aspects of stream habitat closely related to and/or impacted by the sediment delivery and transport processes occurring in the system.

The QHEI sub-metrics used in the sediment TMDL are the substrate, channel morphology, and bank erosion and riparian zone. Table D-3 lists targets for each of these metrics.

- The substrate sub-metric evaluates the dominant substrate materials (i.e., based on texture size and origin) and the functionality of coarser substrate materials in light of the amount of silt cover and degree of embeddedness. This is a qualitative evaluation of the amount of excess fine material in the system and the degree to which the channel has assimilated (i.e., sorts) the loading.
- The channel morphology sub-metric considers sinuosity, riffle, and pool development, channelization, and channel stability. Except for stability each of these aspects are directly related to channel form and consequently how sediment is transported, eroded, and deposited within the channel itself (i.e., this is related to both the system's assimilative capacity and loading rate). Stability reflects the degree of channel erosion which indicates the potential of the stream as being a significant source for the sediment loading.
- The bank erosion and riparian zone sub-metric also reflects the likely degree of instream sediment sources. The evaluation of floodplain quality is included in this sub-metric which is related to the capacity of the system to assimilate sediment loads.

In summary, the reasonable connection between sedimentation and the QHEI, the strong correlation between QHEI score and biometrics, and the fact that other quantifiable indicators of sedimentation are typically problematic in their own right, justifies use of the QHEI for sediment TMDLs.

Total Phosphorus TMDLs (Generalized Watershed Loading Function (GWLF))
In-stream total phosphorus loading was based solely on estimates of its delivery from its surrounding watershed and known point source discharges. In-stream processes such as biological uptake, mineralization, re-suspension, or sediment fluxes are not accounted for in the load analysis. Point sources have a secondary role where the combined design discharge of all the facilities is less than ten percent of the average stream flow in the Mahoning River at the outlet of the project area. For this reason, nutrient management for point sources of phosphorus under low flow conditions is not the most appropriate approach for addressing nutrient problems in the watershed. Landscape loading is far more important in these parts of the project area where in the 04 ten-digit HUC the land runoff component of the overall loading is nearly 48 times greater than the point source dischargers. This ratio is over ten in the 01 ten digit HUC.

The GWLF model was chosen because of its widespread use in TMDLs and its ability to simulate the important processes of concern, specifically hydrology and nutrient export from the landscape to surface waters. However, because GWLF provides monthly pollutant load, it is commonly considered unfavorable for TMDLs since loads are required to be represented on daily timescales. To offset this setback and to create daily loads from monthly loads, hydrograph proportioning on a sliding monthly scale was done from the model output data.

A sliding monthly scale was done for the two drainages modeled, 30 day discharge values centered in time around the date in question were summed to obtain a sliding scale 30 day discharge. The daily discharge of this drainage was then divided by the 30 day discharge. The resulting unitless factor was multiplied by the monthly load representing the day in question time frame. The resultant is the daily total phosphorus load. Equation 1 provides the hydrograph proportioned daily load for given day (represented as ***i***) for a given GWLF monthly load increment (identified as ***j***).

Equation 1

$$DailyLoad_i = monthlyload_j \bullet \frac{DailyDischarge_i}{\sum_{i=-14}^{+15} DailyDischarge_i}$$

This method assumes that loading is directly proportional to daily discharge. In essence, water quality of the stream is considered steady state for the monthly timeframe given by GWLF. Error could be created by this assumption; however, the explicit margin of safety and the seasonal conglomeration of daily loads for analysis may mitigate this issue.

Total Phosphorus TMDLs (GWLF and BATHTUB)

The GWLF model was selected for reasons stated above. The BATHTUB model was selected because it does not have extensive data requirements, which would be largely unavailable, and also it can be used in conjunction with the non-point source loads calculated by GWLF. The BATHTUB model addresses the parameters of concern and has been used previously for reservoir TMDL applications therefore, use of more sophisticated lake models was not warranted based on the very limited water quality data with which they could be calibrated.

D1.2 Load Duration Curves (*E. coli* TMDLs)

Bacteria load reductions were determined through the use of load duration curves. This approach involves calculating the allowable loadings over the range of flow conditions expected to occur in the impaired stream by taking the following steps:

1. Generate a flow frequency table and plotting the data points to form a curve. The data reflect a range of natural occurrences from extremely high flows to extremely low flows. The period of record used January 1, 1987 to December 31, 2006 where daily average flows are used.

2. Translate into a load duration (or TMDL) curve by multiplying each flow value by the water quality standard/target for a particular contaminant, then multiplying by a conversion factor. The resulting points are plotted to create a load duration curve (LDC).

3. Convert water quality samples to loads by multiplying the sample concentration by the average daily flow on the day the sample was collected. Then, the individual loads are

plotted as points on the TMDL graph and can be compared to the water quality standard/target, or LDC.

4. Points plotting above the curve exceed the water quality standard/target and the daily allowable load. Those plotting below the curve represent compliance with standards and the daily allowable load. Further, it can be determined which types of flows contribute loads above or below the water quality standard/target (e.g., high flows versus low flows).

5. The area beneath the TMDL curve is interpreted as the loading capacity of the stream. The difference between this area and the area representing the current loading conditions is the load that must be reduced to meet water quality standards/targets.

6. The final step is to determine where reductions need to occur. Those exceedences at the right side of the graph occur during low flow conditions, and significant sources might include septic systems, illicit sewer connections, or animals depositing waste directly to the stream; exceedences on the left side of the graph occur during higher flow events, and potential sources include a variety of activities related to runoff.

Using the LDC approach allows Ohio EPA and local planners to determine which implementation practices are most effective for reducing loads based on flow regime. If loads are significant during wet weather events, implementation efforts can target those BMPs that will most effectively reduce storm water runoff.

Table D-6 lists the locations at which the various load duration curves were developed including the drainage area associated with each of those sites. The sites with LDC used to create bacteria TMDLs are all at what Ohio EPA calls sentinel sites. These sites are picked to represent HUC 12s and/or important drainage areas. The sites are sampled more frequently than the other survey sites. Water stage to stream discharge relationships are also created for each sentinel site. Knowing the stream discharge at each sampling of these sites allows for load calculations to be made without relying on the extrapolations to gages. Table D-6 shows the sentinel sites and their drainage area. In order to calculate the load duration curve, each site's full flow duration interval must be calculated. In order to determine the load duration curve for each LDC site, stream flows are extrapolated to a USGS gage (station # 03093000 Eagle Creek at Phalanx Station OH). A simple drainage area ratio of the LDC site to the USGS gage is applied to the gage flows to determine the LDC site's flows. The actual gage site is a sentinel site and no drainage area ratio is required for this site.

Table D-6. Description of the sentinel sites used for developing load duration curves for *E. coli* TMDLs including their drainage areas.

12-digit HUC	Stream and Location	River Mile	Drainage Area (sq. miles)	Station STORET Number	Recreation Use Designation
05030103-01-01	Beaver Run @ Center Rd	1.19	4.80	N01K24	PCR - B
05030103-01-01	Tributary to Mahoning River (97.11) at Georgetown Rd	1.15	4.30	N01K25	PCR - B
05030103-01-01	Mahoning River at Georgetown-Damascus Rd	97.69	19.14	N01K26	PCR - B
05030103-01-02	Little Beech Ck at a lane off of State Route 619	1.83	9.00	N01K13	PCR - B
05030103-01-02	Beech Ck at Vine St	3.54	17.40	N01K14	PCR - B
05030103-01-03	Mahoning River at Gaskill Dr in Alliance	84.99	90.00	N01S12	PCR - A
05030103-02-01	Deer Ck at Atwater Rd	2.90	33.84	300025	PCR - B
05030103-02-01	Deer Ck at Waterloo Rd	10.87	3.50	N01K12	PCR - B
05030103-02-02	Willow Ck at Notman Rd	3.74	7.20	300062	PCR - B
05030103-02-03	Mill Ck at Leffingwell Rd	3.64	19.10	300061	PCR - B
05030103-02-03	Turkey Broth Ck at State Route 534	3.36	4.90	N01K01	PCR - B
05030103-02-04	Island Ck at 12th Street Rd	2.65	4.20	N01K06	PCR - B
05030103-03-01	Kale Ck at Canal Rd (Newton Falls County Line Rd)	3.38	21.90	N02W07	PCR - B
05030103-03-02	West Branch Mahoning River at Newton Falls Rd at USGS Gage	20.94	21.80	300022	PCR - A
05030103-03-03	Barrel Run at Tallmadge Rd	3.65	10.20	N02K23	PCR - B
05030103-03-04	Silver Ck (Tributary to West Branch Mahoning River) at Calvin Rd	1.83	9.30	N02K20	PCR - B
05030103-03-04	Hinkley Ck at State Route 5	0.70	10.80	N02K22	PCR - B
05030103-03-05	West Branch Mahoning River at County Rd 114A South of Newton Falls	0.36	103.00	N02P12	PCR - A
05030103-03-06	Mahoning River downstream of dam and WWTP at Newton Falls	56.53	307.00	N02S12	PCR - A
05030103-04-01	Eagle Ck at State Route 700 upstream of Garrettsville	22.44	5.20	N02S02	PCR - B
05030103-04-01	Silver Ck at State Route 82 near Hiram	0.79	11.20	N02S03	PCR - B
05030103-04-02	South Fork Eagle Ck at State Route 303 at Windham	2.30	23.50	N02K06	PCR - B

12-digit HUC	Stream and Location	River Mile	Drainage Area (sq. miles)	Station STORET Number	Recreation Use Designation
05030103-04-03	Mahoning Ck downstream PM Estates MHP	0.70	3.70	N02K09	PCR - A
05030103-04-03	Eagle Ck at Hopkins Rd	15.04	36.00	N02K10	PCR - B
05030103-04-04	Tinker Ck at Nicholson Rd	2.50	11.20	N02K02	PCR - B
05030103-04-05	Eagle Ck at Gage near County Rd 114 downstream of Garrettsville[1]	5.60	97.60	N02P08	PCR - B
05030103-04-06	Mahoning River upstream of dam at Leavittsburg	45.73	542.00	N03S64	PCR - A
05030103-06-03	Mahoning River at Leavitt Rd at Leavittsburg	45.51	575.00	602280	PCR - A

1 This site coincides with the location of the USGS gage used for the unit area hydrograph to estimate flows at each of the other sentinel site locations

Table D-7. Location of the USGS gage for which unit area hydrographs are developed for other smaller watersheds (e.g., HUC12s) throughout the project area.

12-digit HUC	Stream and Location	River Mile	Drainage Area (sq. miles)	USGS gage description
05030103-04-05	Eagle Ck at Gage near County Rd 114 downstream of Garrettsville	5.60	97.60	USGS 03093000 Eagle Creek at Phalanx Station OH

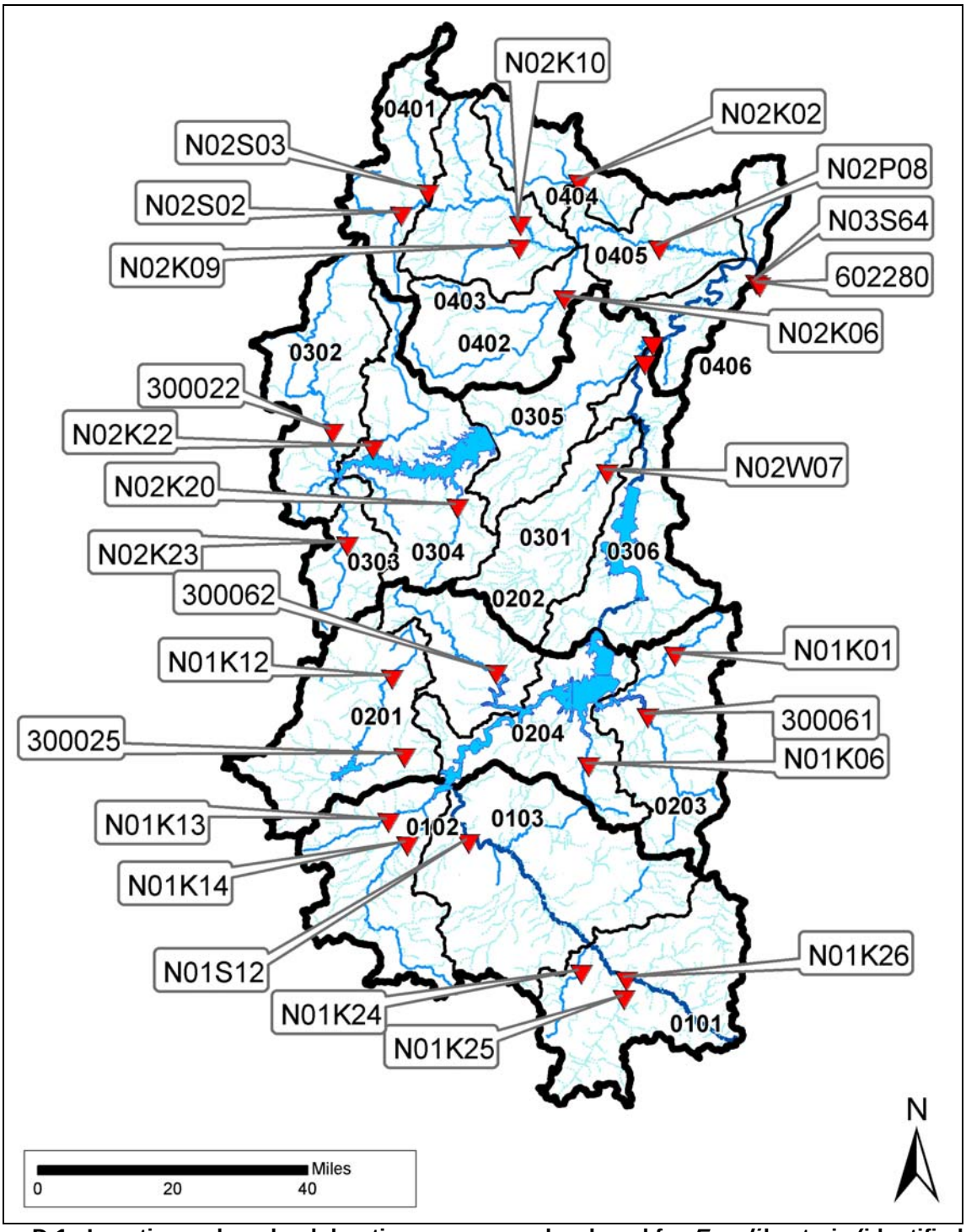

Figure D-1. Locations where load duration curves are developed for *E. coli* bacteria (identified by STORET number).

The load duration curves are grouped into five flow regimes noted with vertical lines and labels. These regimes are defined as the following:

High flow zone: Stream flows in the 0 to 5 exceedance percentile range; these are related to flood flows.

Wet weather zone:	Flows in the 5 to 40 exceedance percentile range; these are flows in wet weather conditions.
Normal range zone:	Flows in the 40 to 80 exceedance percentile range; this are the median stream flow conditions.
Dry weather zone:	Flows in the 80 to 95 exceedance percentile range; these are related to dry weather flows.
Low flow zone:	Flows in the 95 to 100 exceedance percentile range; related to drought conditions.

Figure D-2 is an example load duration curve to provide explanation of the various symbols used in the curve. The symbols are as follows: 1) water quality samples on the LDC curves are noted as diamonds; 2) samples taken when storm flow is greater than 50% of the flow are noted with the diamond with a red dot in the center (noted as ">50% SF in the figures legend), this flow condition is determined using the sliding-interval method for streamflow hydrograph separation contained in the USGS HYSEP program (Sloto, 1996) 3) box plots are shown for each flow regime with data where the center line of these boxes represents the median *E. coli* load for that flow regime, the top and bottom of the boxes represents the 75th and 25th percentiles respectively, and the upper and lower vertical bar tails are the maximum and minimum observed loads respectively.

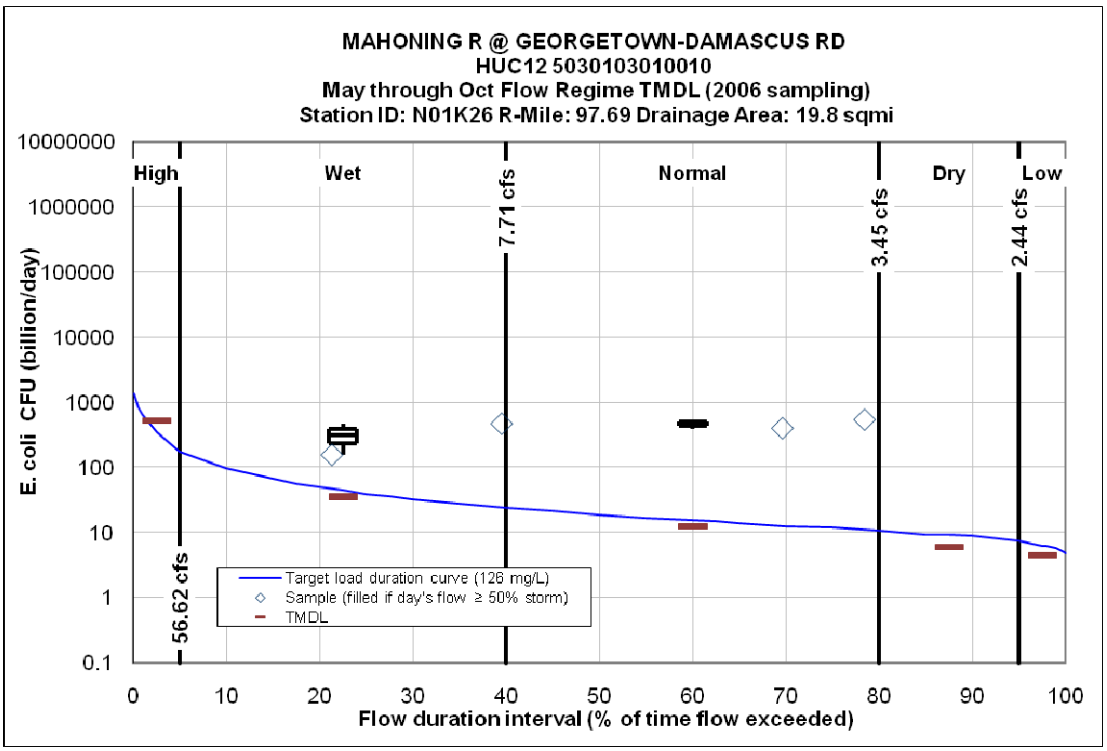

Figure D-2. *E. coli* LDC for HUC 05030103-01-01 Mahoning River.

All of the area beneath the TMDL curve is considered the *E. coli* loading capacity of the stream. The difference between this area and the area representing the current loading conditions is the load that must be reduced to meet water quality standards/targets. The final step to create an LDC, is to determine where reductions need to occur. Samples in exceedance at the right side of the graph occur during low flow conditions, and significant sources might include wastewater treatment plants, malfunctioning home sewage treatment systems, illicit sewer connections and/or animals depositing waste directly to the stream. Any exceedance on the left side of the

graph occurs during higher flow events and potential sources are likely land uses or management practices such as manure spreading or livestock production. These supply bacteria that are washed off upland areas with runoff. The LDC approach helps determine which implementation practices are most effective for reducing loads. Table D-8 shows various pollutant sources and the loads they are associated with.

Table D-8. Load duration curve flow zones and typical contributing sources.

Contributing Source Area	Duration Curve Zone				
	High	Wet weather	Normal	Dry	Low
Point source				M	H
Livestock direct access to streams				M	H
Home sewage treatment systems	M	M-H	H	H	H
Riparian areas		H	H	M	
Storm water: Impervious		H	H	H	
Combined sewer overflow (CSO)	H				
Storm water: Upland	H	H	M		
Field drainage: Natural condition	H	M			
Field drainage: Tile system	H	H	M-H	L-M	
Bank erosion	H	M			

H = high influence; M = moderate influence; L = low influence

Margin of Safety

The Clean Water Act requires that a TMDL include a margin of safety (MOS) to account for any lack of knowledge concerning the relationship between load and wasteload allocations and water quality. U.S. EPA guidance explains that the MOS may be implicit (i.e., incorporated into the TMDL through conservative assumptions in the analysis) or explicit (i.e., expressed in the TMDL as loadings set aside for the MOS).

An explicit 20% margin of safety was chosen based on an evaluation of a large data set and model results for the Paint Creek watershed in Ohio (Ohio EPA 2011). The target TMDL concentration with a 20% MOS normalized to the flow regimes, especially in the middle flow ranges, resulted in a seasonal geometric mean that did not exceed the water quality standard but was not unreasonably far below the standard (i.e. too stringent). In the high flow regimes, the 20% MOS is less conservative, but should still provide an adequate level of protection considering the likely reduction in recreation use during the highest flows and the variability of the flows and concentrations.

An implicit MOS is incorporated by not considering the die-off of pathogens as part of the TMDL calculations. The implicit MOS is also enhanced by the use of the geometric mean target (which is a seasonal target) to calculate daily loads. In addition, an explicit MOS has been applied as part of all of the bacteria TMDLs by reserving 20% of the allowable load because of the broad fluctuation of *E. coli* concentrations that occurs in nature and the relatively low numbers of data points available for this analysis.

Seasonality and Critical Conditions

The critical condition for pathogens is the summer dry period when flows are lowest, and thus the potential for dilution is the lowest. Growth rates are higher in the warmer months further making this a critical time of the year for bacteria contamination. Likewise, summer is the period

when the probability of recreational contact is the highest. For these reasons recreational use designations are only applicable in the period May through the end of October. Pathogen TMDLs are developed for the same time period in consideration of the critical condition, and for agreement with Ohio WQS.

The existing loads of *E. coli* from home sewage treatment systems or direct manure deposits from livestock are given a zero allocation because 1) properly functioning septic systems should not discharge pollutants and 2) proper livestock management should preclude such intense pollution of surface waters. The runoff loads are divided between runoff from MS4 areas and non-MS4 areas. Since runoff from MS4s is regulated by Ohio EPA, this allocation is considered a WLA. The non-MS4 runoff is a LA. This division is carried out simply by applying the land area ratio of each type (MS4 and non-MS4) to the remaining E. coli load allowed for each TMDL. Specific MS4s are subdivided and identified.

Allowance for Future Growth

Future growth is built in to the load duration curves because most of the point source dischargers receiving wasteload allocations for *E. coli* bacteria do not discharge at their design capacity. The wasteload allocations are based on the product of design flow, the target *E. coli* concentration and a conversion factor, therefore, this wasteload exceeds the current loading, provided the facilities are in compliance with the water quality based permit limit. There are no anticipated expansions in the waste water treatment plants in the TMDL project area. Likewise, based on observed population growth from 2000 to 2009 (U.S. Census Bureau, 2010) the project area is undergoing an overall negative growth. Portage and Geauga Counties, representing about half of the project area experienced marginal positive growth while the remaining counties had negative growth. Nonetheless an additional four percent of the TMDL is reserved for future growth.

D1.3 QHEI Analysis (Sediment and Habitat TMDLS)

The habitat and sediment TMDLs developed using the QHEI are simply the comparison of the existing index scores and/or inherent attributes, with targets for those scores and attributes. TMDLs are developed on a site-by-site basis and the needed improvement in the stream system is represented as the deviation from the QHEI targets, as opposed to a reduction in a particular stressor. Based on experience of staff from Ohio EPA, there is a correlation between a reduction in sediment loading (either from the watershed or from channel erosion) and movement towards meeting the sediment targets. More discussion regarding the QHEI targets and the established water quality goals for biological communities can be found in Section D-1.1.

QHEI data is collected on every site throughout the watershed in which biological attainment is determined. Figure D-3 represents the QHEI score for each sampling location vs. drainage area of the watershed up to the sampling location, where the biological attainment of an individual site is shown by color shading of the data points. This figure indicates that drainage area is not an important factor in determining QHEI scores in the upper Mahoning River watershed. Figure D-4 is a box and whisker plot of the three respective groups of fully, partially, and not attaining aquatic life sites. Non attaining sites have lower QHEI scores than the fully and partially attaining sites, based on ANOVA results (P value = 0.000) where the assumption of normally distributed data was satisfied (Anderson-Darling normality test =[Full (P=0.443), Non (P= 0.454), Partial (P=0.638)]). Details of the ANOVA are presented in Table D-9.

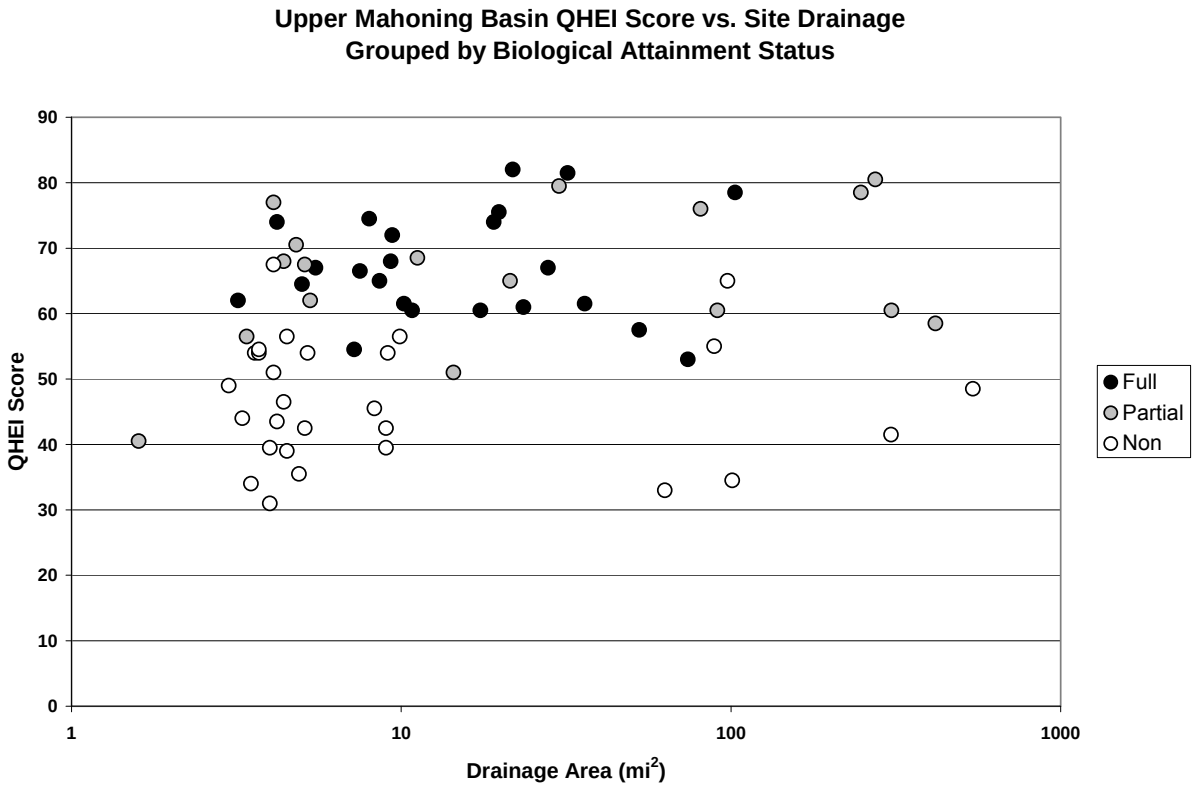

Figure D-3. QHEI Scores for the Upper Mahoning River vs. Drainage Area by Attainment Group

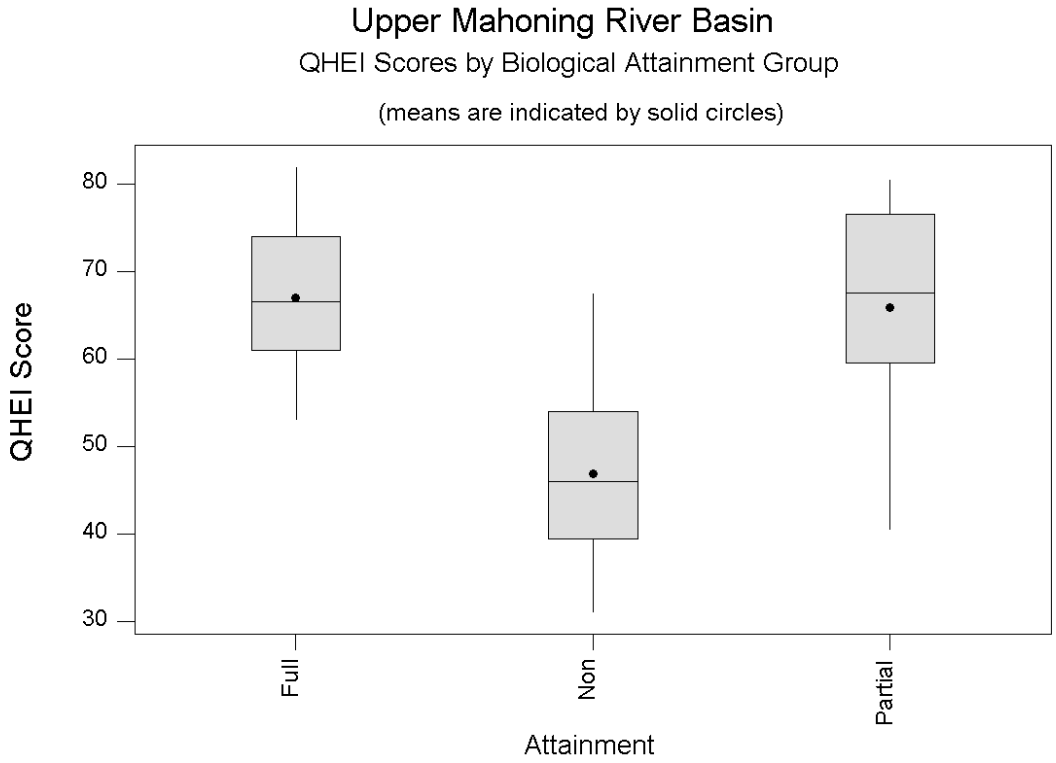

Figure D-4. Box-whisker plots of Upper Mahoning River Basin WWH QHEI scores by attainment group

Table D-9. One-way ANOVA of QHEI versus Attainment Status

```
Analysis of Variance for QHEI
Source     DF        SS        MS        F        P
Attainment  2    6419.7    3209.8    35.83    0.000
Error      65    5823.6      89.6
Total      67   12243.3

                             Individual 95% CIs For Mean
                             Based on Pooled StDev
Level       N      Mean     StDev  ------+---------+---------+---------+
Full       23    67.043     8.199                           (----*----)
Non        28    46.839     9.512  (----*---)
Partial    17    65.912    10.902                         (----*-----)
                                   ------+---------+---------+---------+
Pooled StDev =    9.465                 48.0      56.0      64.0      72.0
```

D1.4 Generalized Watershed Loading Function (GWLF) -Total Phosphorus TMDLS

Phosphorus TMDLs were developed for two watersheds (Figure D-5) within the upper Mahoning River watershed using the Generalized Watershed Loading Functions (GWLF) watershed model (Haith et al., 1992). The purpose of the modeling effort was to determine the nutrient loads from each significant source category (specifically agricultural runoff, septic systems, and point source dischargers) as well as the acceptable TMDL for total phosphorus. Ultimately, the GWLF output coupled with point source data were used to predict nutrient loads and hydraulic discharges of the stream reaches.

GWLF is a mid-range watershed model that provides monthly output of average nutrient concentrations and daily output for simulated stream flow at a geographical point defined by the user. This model does not simulate fate and transport processes within the stream system itself. Additionally, daily loads were developed by hydrograph proportioning of the monthly load (i.e., based on average monthly total phosphorus concentration, daily flow values, and total monthly flow volume) over a sliding monthly time period. This method presumes a steady loading rate proportioned to the stream flow which, effectively equalizes the total phosphorus concentration of the entire flow regime.

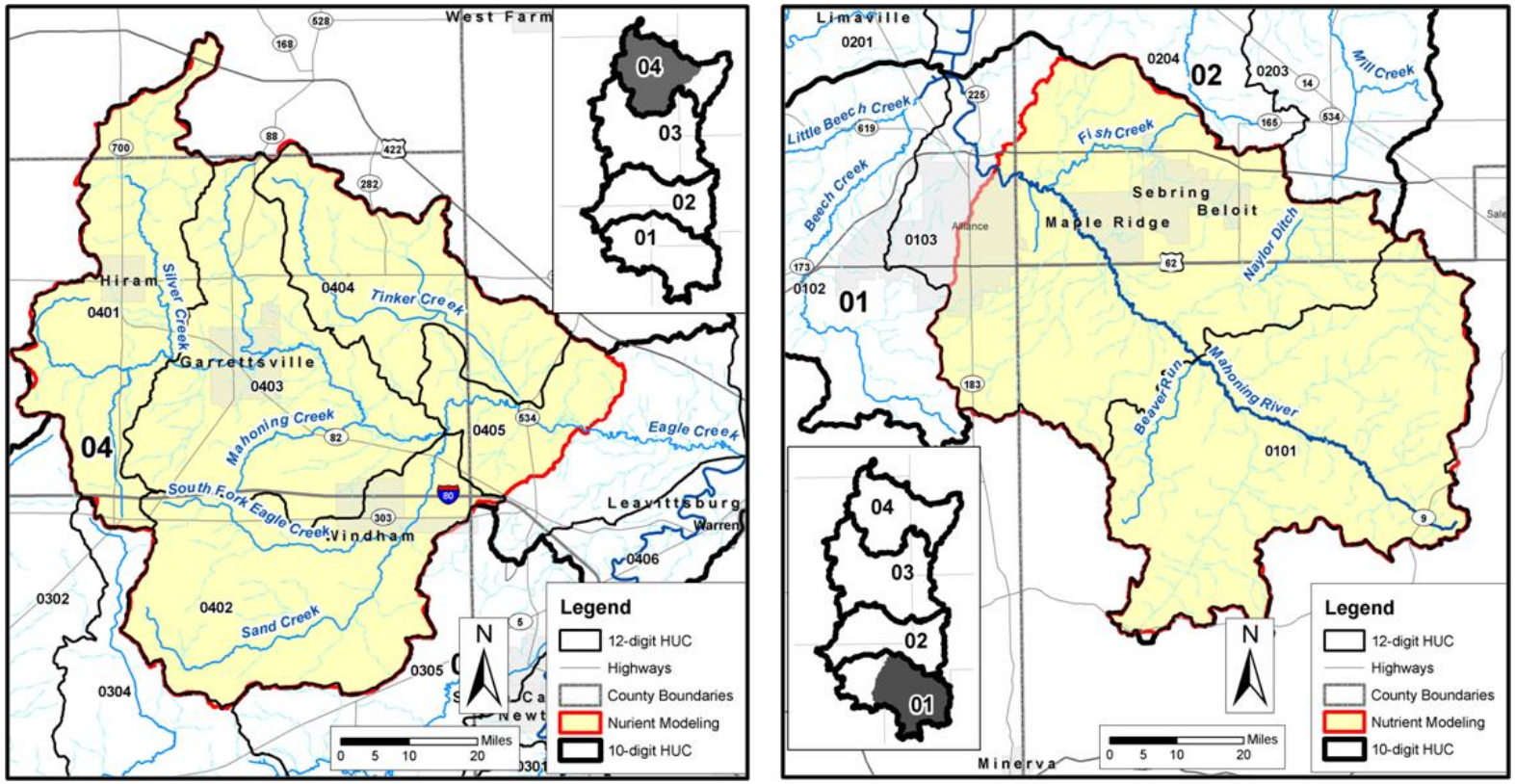

Figure D-5. Two areas where total phosphorus TMDL were developed using GWLF. The map on the left show the area draining to the Alliance gage while the right is for the Phalanx Station gage.

GWLF provides a simulation of precipitation-driven runoff and sediment delivery. Solids load, runoff, and ground water seepage are used to estimate particulate and dissolved phase pollutant delivery to a stream, based on pollutant concentrations in soil, runoff, and ground water (U.S. EPA, 2006).

GWLF simulates runoff and stream flow by a water-balance method, based on measurements of daily precipitation and average temperature. Precipitation is partitioned into direct runoff and infiltration using a form of the Natural Resources Conservation Service's (previously Soil Conservation Service [SCS]) Curve Number method (USDA, 1986). The Curve Number determines the amount of precipitation that flows off directly from various land uses and soil types, adjusted for antecedent soil moisture based on total precipitation in the preceding five days.

Stream flows may originate from surface runoff from precipitation events or from ground water pathways. The amount of water available to the shallow ground water zone is strongly affected by evapotranspiration, which GWLF estimates from available moisture in the unsaturated zone, potential evapotranspiration, and a cover coefficient. Potential evapotranspiration is estimated from a relationship to mean daily temperature and the number of daylight hours.

The user of the GWLF model must divide land uses into "rural" and "urban" categories, which determines how the model calculates loading of sediment and nutrients. For the purposes of modeling, "rural" land uses are those with predominantly pervious surfaces, while "urban" land uses are those with predominantly impervious surfaces. Monthly sediment delivery from each "rural" land use is computed from erosion and the transport capacity of runoff, whereas total erosion is based on the universal soil loss equation (USLE) (Wischmeier and Smith, 1978), with a modified rainfall erosivity coefficient that accounts for the precipitation energy available to detach soil particles (Haith and Merrill, 1987; U.S. EPA, 2006). For "urban" land uses, soil erosion is not calculated, and delivery of nutrients to the water bodies is based on an exponential accumulation and washoff formulation. Land use was determined for this project from The National Land Cover Dataset (STATSGO) GIS coverage. All nutrients loaded from urban land uses are assumed to move in association with solids. Nutrient loads from rural land uses may be dissolved (in runoff) or solid-phase (attached to sediment loading as calculated by the USLE).

GWLF requires three input files to simulate runoff and pollutant loads from each subwatershed. The weather file contains daily values of precipitation and average temperature. The nutrient file contains nitrogen and phosphorus concentrations of groundwater and runoff as well as build-up/wash off rates from urban areas. The transport file contains land use areas and parameters for estimating runoff, erosion, and evapotranspiration. This section of the report describes the modeling assumptions used to develop these three files for existing and natural conditions.

A phosphorus TMDL was developed for two drainage areas within the Upper Mahoning Watershed utilizing the Generalized Watershed Loading Functions (GWLF) watershed model (Haith et al., 1992). The purpose of the modeling effort was to determine the nutrient loads from each significant source category (specifically agricultural runoff, septic systems, and point source dischargers) as well as the acceptable TMDL for total phosphorus. The two drainage areas modeled were Mahoning River mainstem from the origination to the USGS gage in Alliance and Eagle Creek of the Mahoning from origination to the USGS gage at Phalanx Station. Hydrology and nutrients for each watershed were susbsequently modeled for each of the basins with GWLF. The non-point source model, GWLF, coupled with point source data were utilized to predict nutrient loads and hydraulic discharges of the stream reaches.

Modeled watersheds were designed to have end segments at USGS gage locations to allow calibration of the hydrology and nutrient model with potential data directly recorded at the respective gage. Actual discharge data was utilized for the Eagle Creek Gage drainage for modeling purposes since it was available from USGS. Because the Mahoning River at Alliance gage stage has not been rated since 1993, the calibration period for the hydrology of this watershed was calibrated from 1983 to 1993. It is estimated that small changes in the watershed characteristics have occurred from 1993 to 2006 eliminating concern of using this older data.

Evapotranspiration was the chosen variable of calibration for the hydrology model developed for the Upper Mahoning River at the USGS Mahoning Gage at Alliance. Once the hydrology modeled was calibrated, nutrient model results were compared to sample values collected by Ohio EPA at these locations. From the results of this effort a nutrient model simulating in-stream nutrient concentrations results was completed. These two nutrient models were utilized to determine reduction of load required to meet the TMDL targets for total phosphorus.

Twenty-three years of USGS record gage flow data from Eagle Creek and 13 years from the Mahoning Gage at Alliance drainage and two seasons of chemistry results from the Mahoning River basin survey were used to calibrate and compare model results. GWLF input parameters were assigned based on available monitoring data, default parameters suggested in the GWLF User's Manual (Haith et al., 1992), and the meteorological record from the Midwest Regional Climatic Center weather stations at Berlin Lake (330639) for the Upper Mahoning River upstream Alliance and Hiram (333780) for Eagle Creek upstream Phalanx Station gage. Default values were used for many parameters due to a lack of local data and to ensure the modeling results are consistent with previously validated studies. Experience and sensitivity analysis have proven these defaults to be acceptable values for most Ohio watersheds.

Transport Data

The National Land Cover Dataset (NLCD) is used as the land cover resource for this study and is described more fully in the Land Use section of this report. Evapotranspiration values from the GWLF manual were utilized and modified for calibration for this modeling effort. No actual data source was available for this parameter in this watershed.

Subwatershed Delineation

The first step in developing the transport files was to delineate sub-watersheds corresponding to the listed segments and major stream confluences. Each lake sub-watershed was outlined utilizing visual determination of topographic map drainage patterns and GIS spatial analysis. The new watershed was developed by clipping a 30-meter digital elevation model of the watershed and the National Hydrography Dataset stream coverage.

Land Use in the Upper Mahoning Watershed

Existing land use and land cover in the modeled drainage areas were determined from satellite imagery, digital aerial photography, and geographic information system (GIS) layers. Digital land use/land cover data were obtained from the National Land Cover Dataset (NLCD). The NLCD is compiled from Landsat ™ satellite imagery acquired between 1991 and 1993. The NLCD is a consistent representation of land cover for the conterminous United States generated from classified 30-meter resolution Landsat thematic mapper satellite imagery data.

The NLCD is classified into urban, agricultural, forested, water, and transitional land cover subclasses. NLCD information is reclassified to agree with the land use categories of GWLF. No

significant changes in land use in these watersheds have occurred since the land use data was collected therefore, no adjustment to this GIS coverage was done.

Runoff Curve Numbers

The GWLF model uses the curve number method to estimate runoff from each land use area. Area weighted curve numbers were developed for each subwatershed and land use based on the reported NRCS soil hydrologic groups. Soil hydrologic groups were used to account for the different infiltration rates of different soil types (e.g., higher infiltration for sands compared to clays).

The direct runoff fraction of precipitation in GWLF is calculated using the SCS Technical Release 55 (TR55) method based on land-use and soil hydrologic group (USDA, 1986). This method utilizes curve numbers for various land uses and soil characteristics which vary from 25 for undisturbed woodland with permeable soils, to 100, for essentially impervious surfaces. Land uses with higher curve numbers are assumed to have more surface runoff than those with lower curve numbers. The hydrologic soil group was determined from available soils data and curve numbers were calculated for each land use category/soil hydrologic group. Area weighted curve numbers (CN) assigned for the lakes watersheds are summarized in Table D-10.

Table D-10. Area weighted coefficient values for the SCS Curve Number (CN) method and RUSLE

		Eagle Creek @Phalanx Gage					Mahoning River @ Alliance Gage				
		Weighted C =		*0.019015*			*Weighted C =*		*0.016707*		
		SCS Method	ABVgage HRU	Weighted A	Area Sum	Total Landuse	SCS Method	HRU	Weighted A	Area Sum	Total Landuse
Land Use		CN	Weighted	KLSCP	Acres	Percent	CN	Weighted	KLSCP	Acres	Percent
Water	1	100.000	3.560	0.000212	375	0.6%	100.000	3.601	0.000568	429	0.8%
Urban	2	91.956	3.514	0.000190	5408	8.7%	91.699	3.417	0.000651	10258	18.0%
Other	3	91.978	3.523	0.000201	5228	8.4%	91.585	3.375	0.001039	1866	3.3%
Forest	4	77.739	3.592	0.000275	31356	50.2%	76.715	3.477	0.000416	13182	23.1%
Pasture	5	81.630	3.504	0.000200	6933	11.1%	81.228	3.447	0.000811	12438	21.8%
Cropland	6	86.666	3.420	0.012649	13099	21.0%	86.501	3.382	0.047544	18908	33.1%
Wetland	7	100.000	3.391	0.000278	65	0.1%	100.000	3.313	0.000497	8	0.0%
Total					62464	100%				57088	100%

Evapotranspiration Cover Coefficients

The portion of rainfall returned to the atmosphere is determined by GWLF based on temperature and the amount of vegetative cover. For urban land uses, the cover coefficient was calculated as (1 - impervious fraction). For all other land uses it was assumed that land had vegetative cover during the growing season (cover coefficient = 1) and limited vegetative cover during the dormant season (cover coefficient = 0.3). The cover coefficients were area-averaged to result in one coefficient value for the growing season (March-October) and one for the dormant season (November-February) as advised by the GWLF manual.

USGS Stream Stage/Discharge Gages

The United States Geological Survey has numerous stream stage gages within the Upper Mahoning Watershed. Table D-11 indicates the name and period of record for these stationary gages in this drainage. Because of the lack of Ohio EPA long-term data collection of stream flow in this area, the phosphorus modeling effort relies on stream flow data from the USGS gages.

Two stream reaches were determined to be nutrient impaired by the TSD and from statistical comparative analysis work within this TMDL. For modeling purposes, these modeling reaches were designed to end at USGS gages. USGS gage #03086500 Mahoning River at Alliance and

#03093000 Eagle Creek at Phalanx Station were chosen to be end stations for modeled watersheds. Data from these gages were obtained from the USGS internet data interface. Discharge data was collected for the Eagle Creek gage for 10 years prior and including 2007. However, stage data only was available for the Alliance gage on the Mahoning mainstem for the past ten years; therefore discharge data from 1983 to 1992 was used for model calibration. No large change in the watershed characteristics has occurred since that time frame to conditions in 1997.

Table D-11. USGS flow gaging stations in the Upper Mahoning River basin including the downstream Leavittsburg gage.

USGS Number	Location Period of Record Gage (discharge or gage ht. only)[1]
03086500	Mahoning R. at Alliance 1942-1992 (flow), 1992-2008 (gage ht.)
03087000	Beech Creek near Bolton 1944-1950 (flow)
03088000	Deer Creek at Limaville 1942-1950 (flow)
03091500	Mahoning R. at Pricetown 1930-2008 (flow)
03090500	Mahoning R. below Berlin Dam 1931-1990 (flow), 1990-2008 (gage ht.)
03092000	Kale Creek Near Pricetown 1942-1992 (flow), 1992-2008 (gage ht.)
03092090	West Br. Mahoning R. near Ravenna 1966-1992 (flow), 1992-2008 (gage ht.)
03092500	West Br. Mahoning R. near Newton Falls 1927-1980 (flow)
03093000	Eagle Creek at Phalanx Station 1927-2008 (flow)
03094000	Mahoning R. at Leavittsburg [2] 1941-2008 (flow)

1 Flow data include estimated discharge (cfs) and gage height. Real time USGS flow data are available at: http://waterdata.usgs.gov/oh/nwis/current?type=flow
2 This station is located immediately downstream from the Upper Mahoning River basin, and includes flow from Duck Creek.

Weather Data

The GWLF model uses daily values of precipitation and average temperature to estimate water inputs to the system as well as potential evapotranspiration rates. A ten year record of weather data from the National Midwest Regional Climate Center stations named Berlin Lake (330639) for the Upper Mahoning River upstream Alliance and Hiram (333780) for Eagle Creek upstream Phalanx Station gage were used as GWLF input. The weather station in which the Thiessen polygon covered the majority for the drainage area of the respective gage was chosen as the appropriate meteorological data source. Figure D-6 shows the weather station locations and their respective Thiessen polygons for aerial coverage of their data applicability.

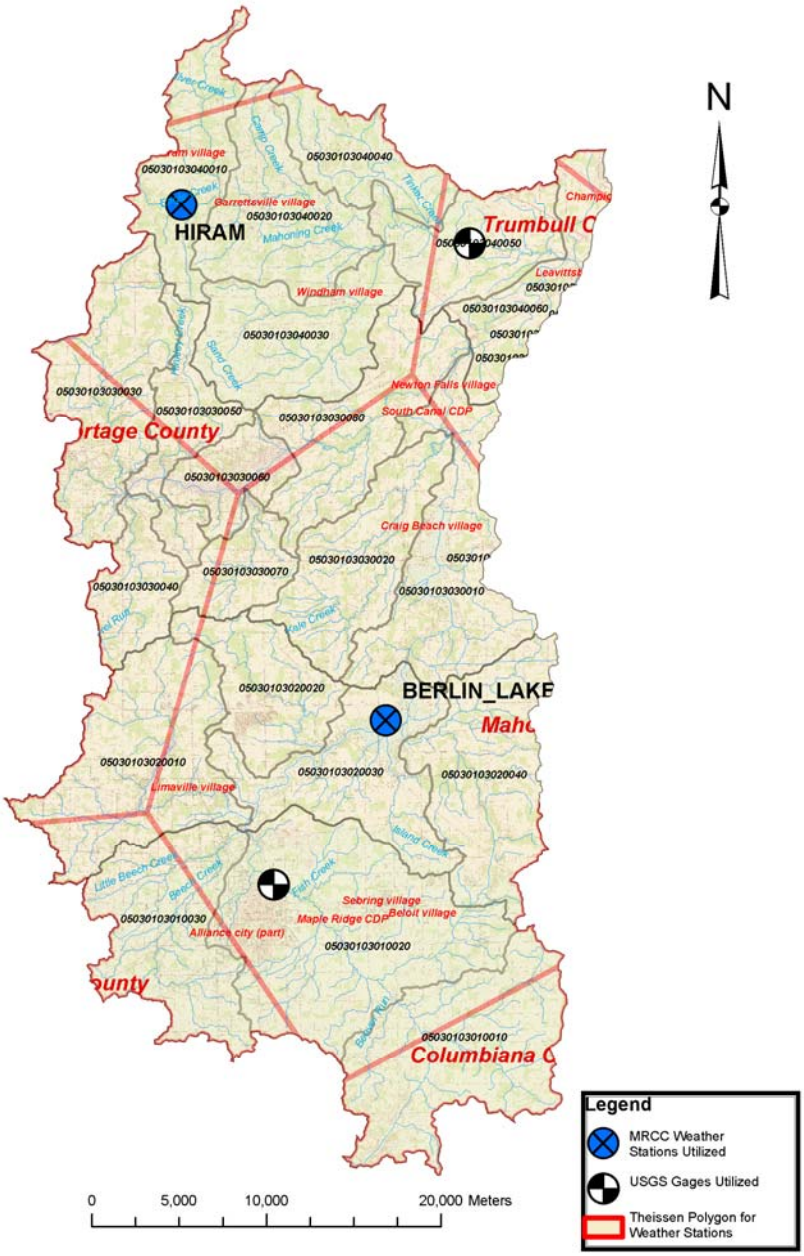

Figure D-6. Upper Mahoning River watershed emphasizing Alliance and Phalanx Station Road gages as well as weather stations coverage utilized to calibrate GWLF

GWLF Calibration

Calibration refers to the adjustment or fine-tuning of modeling parameters to reproduce known observations. Hydrologic calibration precedes water quality calibration because runoff is the transport mechanism by which nonpoint pollution occurs. Calibration efforts are often an iterative procedure of parameter evaluation and refinement as a result of altering simulated toward observed values of interest. Hydrologic calibration is based on ten years of simulation to evaluate parameters under a variety of climatic conditions. Water quality calibration usually spans only the time period in which ground-truthed water quality data exists for the watershed.

Significant stream discharge data existed at USGS gage sites for calibration; however, limited water quality data were available for this task. Calibration of modeled hydrology and nutrients were completed at the USGS gages of the Mahoning River at Alliance and Eagle Creek at Phalanx Station. Default values were used in GWLF for modeling parameters in which no site specific information was available. A comparison of the simulated and observed data is presented below.

Hydrologic Calibration

The GWLF model predicts flow volumes from runoff at daily intervals for the modeled watershed. Simulated flows were compared to observed discharge when available. Actual daily discharge data for the Eagle Creek gage, discharge data was available from 1998 to 2007 and utilized for modeling purposes. However, discharge data for the Mahoning River at Alliance did not exist for the modeling period of 1998 to 2007.

Since discharge data for the Mahoning River at Alliance was available prior to 1993, daily stream discharge values for the Mahoning River at Alliance were modeled by GWLF simulation from 1984 to 1993. Figure D-7 provides the trend of monthly total simulated flow in centimeters and actual USGS gage flow for the watershed area. This stage gage was no longer rated after 1993. Therefore, model calibration was completed on 10 years of available data from 1984 to 1993. Once discharge was properly modeled for this time frame, modeling was completed for ten years from 1998 to 2007.

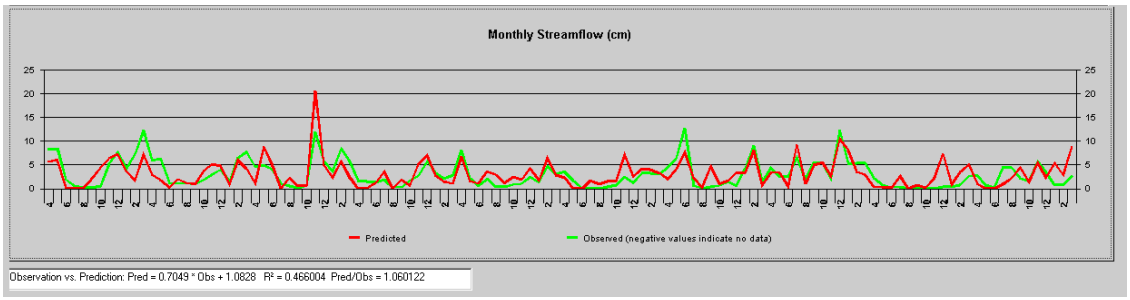

Figure D-7. Mahoning River at Alliance Gage hydrology simulation result after calibration (Gross Monthly Flow, r^2 = 0.466004, Predicted/Observed = 1.060122)

This figure also compares the known monthly flow volumes observed (green line) at the gage to the calibrated GWLF estimates (red line). GWLF was calibrated by adjusting the evapotranspiration in an iterative approach until the covariance was maximized and the predicted/observed statistic was most nearly the value of one. Fourteen calibration trials were completed to obtain an R^2 value of 0.46 and predicted/observed of 1.06. As can be observed by Figure D-8 and from the predicted/observed ratio, the model simulates the hydrology very well for the 1984 to 1993 period.

Nutrient Verification

During the 2006 and 2007 survey season of the Upper Mahoning watershed, Ohio EPA obtained 11 samples from the Mahoning River at the Alliance gage and 14 samples of Eagle Creek at the Phalanx Station gage which were analyzed for total phosphorus. This data was utilized to compare the GWLF ten year model run results to actual nutrient data. GWLF simulates the average monthly concentration for the modeled timeframe. Field data is collected as daily grab samples. Therefore, true calibration and verification could not be completed, but

comparison of the average monthly concentrations and the daily values could be accomplished as a basis for model adjustment and increased precision.

The most recent simulated average monthly concentrations are compared to daily observed concentrations as presented in Figure D-8 and D-9 for total phosphorus. Even with best efforts to increase model precision, variability does arise from observed to modeled values for a variety of reasons including assumptions in land use nutrient sources and lack of in-stream routing of nutrients. Additional error is possible in the model's inability to quantify settlement to and sorption of nutrients to bed sediments in-stream.

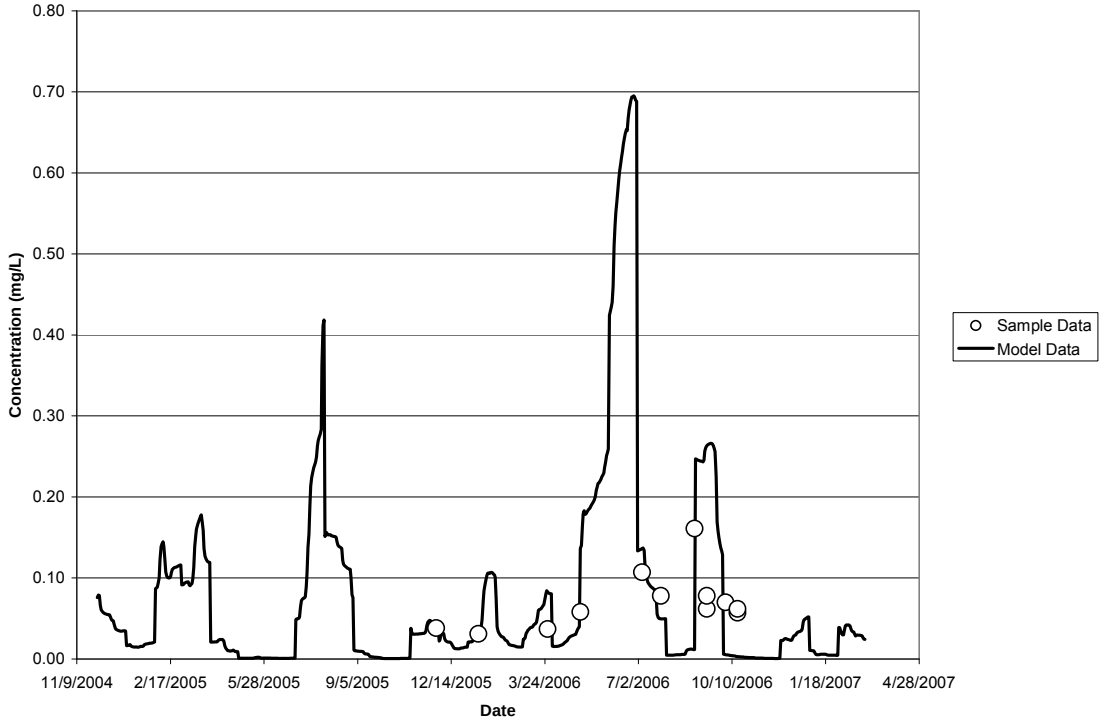

Figure D-8. Eagle Creek at Phalanx Station USGS gage - GWLF total phosphorus modeling result comparison to measured data after model calibration

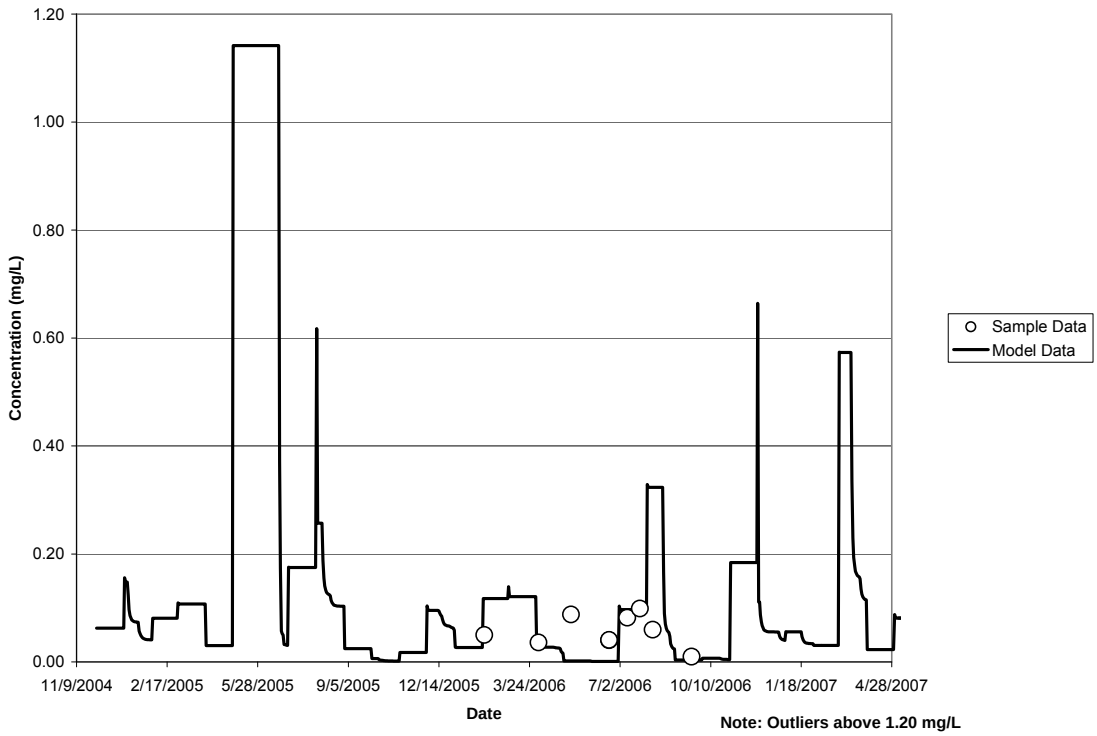

Figure D-9. Mahoning River at Alliance USGS gage - GWLF total phosphorus modeling result comparison to measured data after model calibration

Conversely, after iterative model adjustments, the average simulated monthly concentrations are similar in value to the observed concentrations at both gages. These positive comparisons of real and modeled data of nutrients validate modeling assumptions used to simulate the two upper Mahoning River drainage areas.

Margin of Safety

An explicit margin of safety of five percent of the calculated TMDL was used. Five percent is commonly used in TMDL development, and in this case, represents a reasonable margin of error in light of the predicted versus actual hydrology ratio being close to one and the fact that a well established and widely accepted mid range watershed model was used. The calibration for water quality presented nothing that warrants an explicit MOS that is higher than what is, and has up to now, been widely used in nutrient TMDLs.

Seasonality and Critical Conditions

The critical condition for nutrients loading is the growing season particularly when flows are low. In Ohio, this is most manifest in mid to late summer and early fall. Low flows have limited potential to dilute nutrient loads and the slow flow velocities and lower stream power better foster accumulation of filamentous and/or other types of algae. Nutrients impact the aquatic community by increasing algae and plant production leading to wide oscillations in diurnal dissolved oxygen concentrations and to seasonally low concentrations when this plant material dies and is consumed by microbes (creating tremendous continuous respiration in the system). The daytime/nighttime swings in dissolved oxygen concentrations is also believed to cause significant stress on aquatic life.

The most relevant nonpoint sources of phosphorus are seasonally loaded to the system. Fertilized cropland typically yields its highest loading when precipitation is high and crop cover is

low corresponding to spring and early summer. Livestock will have direct contact with streams in the warmer months and their impact is most severe when flow are low (low dilution) corresponding to late summer and early fall. Loading from non-discharging home septic systems is precipitation driven whereas direct discharging systems and other point sources typically discharge at a constant rate throughout the year.

However, as phosphorus readily attaches to sediment, detachment of adsorbed phosphorus in bottom sediments can lead to elevated instream concentrations regardless of the magnitude of short-term loads. As a result, it is the long-term, or chronic, phosphorus load that is directly related to the degradation of water quality. For this reason phosphorus TMDLs are developed to address nutrient loading during all times of the year and therefore, apply to all conditions, rather than a single critical condition.

Allowance for Future Growth

Future growth is built in to the load duration curves because most of the point source dischargers receiving wasteload allocations for total phosphorus do not discharge at their design capacity. The wasteload allocations are based on the product of design flow, the target total phosphorus concentration and a conversion factor, therefore, this wasteload exceeds the current loading, provided the facilities are in compliance with the water quality based permit limit. There are no anticipated expansions in the waste water treatment plants in the TMDL project area. Likewise, based on observed population growth from 2000 to 2009 (U.S. Census Bureau, 2010) the project area is undergoing an overall negative growth. Portage and Geauga Counties, representing about half of the project area experienced marginal positive growth while the remaining counties had negative growth. Nonetheless an additional four percent of the TMDL is reserved for future growth.

D1.5 GWLF and BATHTUB -Total Phosphorus TMDLS

GWLF Model Development

GWLF provides a simulation of precipitation-driven runoff and sediment delivery. Solids load, runoff, and ground water seepage are used to estimate particulate and dissolved phase pollutant delivery to a stream, based on pollutant concentrations in soil, runoff, and ground water (U.S. EPA, 2006).

GWLF simulates runoff and stream flow by a water-balance method, based on measurements of daily precipitation and average temperature. Precipitation is partitioned into direct runoff and infiltration using a form of the Natural Resources Conservation Service's (previously Soil Conservation Service [SCS]) Curve Number method (USDA, 1986). The Curve Number determines the amount of precipitation that flows off directly from various land uses and soil types, adjusted for antecedent soil moisture based on total precipitation in the preceding five days.

Stream flows may originate from surface runoff from precipitation events or from ground water pathways. The amount of water available to the shallow ground water zone is strongly affected by evapotranspiration, which GWLF estimates from available moisture in the unsaturated zone, potential evapotranspiration, and a cover coefficient. Potential evapotranspiration is estimated from a relationship to mean daily temperature and the number of daylight hours.

The user of the GWLF model must divide land uses into "rural" and "urban" categories, which determines how the model calculates loading of sediment and nutrients. For the purposes of modeling, "rural" land uses are those with predominantly pervious surfaces, while "urban" land

uses are those with predominantly impervious surfaces. Monthly sediment delivery from each "rural" land use is computed from erosion and the transport capacity of runoff, whereas total erosion is based on the universal soil loss equation (USLE) (Wischmeier and Smith, 1978), with a modified rainfall erosivity coefficient that accounts for the precipitation energy available to detach soil particles (Haith and Merrill, 1987; U.S. EPA, 2006). For "urban" land uses, soil erosion is not calculated, and delivery of nutrients to the water bodies is based on an exponential accumulation and washoff formulation. All nutrients loaded from urban land uses are assumed to move in association with solids. Nutrient loads from rural land uses may be dissolved (in runoff) or solid-phase (attached to sediment loading as calculated by the USLE).

GWLF requires three input files to simulate runoff and pollutant loads from each subwatershed. The weather file contains daily values of precipitation and average temperature. The nutrient file contains nitrogen and phosphorus concentrations of groundwater and runoff as well as build-up/wash off rates from urban areas. The transport file contains land use areas and parameters for estimating runoff, erosion, and evapotranspiration. This section of the report describes the modeling assumptions used to develop these three files for existing and natural conditions.

Transport Data

Land use, soil and weather data are critical components of hydrology functions of GWLF. The National Land Cover Dataset is used as the land cover resource for this study and is described more fully in the Land Use section of this report. Evapotranspiration values from the GWLF manual were utilized for this data since no actual data source was available.

Subwatershed Delineation

The first step in developing the transport files was to delineate sub-watersheds corresponding to the listed segments and major stream confluences. Each lake sub-watershed was outlined utilizing USGS online StreamStats watershed delineation tool. ArcGIS was utilized for spatial analysis of both reservoirs' watersheds. The results of this effort are presented in Figure D-10 and D-11 for Dale Walborn and Deer Creek Reservoirs, respectively. In Figure D-11, Deer Creek Reservoir drainage includes the entire Dale Walborn Reservoir watershed in addition to the watershed contributing area between both reservoirs.

Land Use in the Deer Creek Reservoir Watershed

Existing land use and land cover in the Deer Creek Reservoir watershed were determined from satellite imagery, digital aerial photography, and geographic information system (GIS) layers. Digital land use/land cover data were obtained from the National Land Cover Dataset (NLCD). The NLCD is compiled from Landsat ™ satellite imagery acquired between 1991 and 1993. The NLCD is a consistent representation of land cover for the conterminous United States generated from classified 30-meter resolution Landsat thematic mapper satellite imagery data.

The NLCD is classified into urban, agricultural, forested, water, and transitional land cover subclasses. NLCD information is reclassified to agree with the land use categories of GWLF. No significant changes in land use in these watersheds have occurred since the land use data was collected; therefore, no adjustment to this GIS coverage was made. Figure D-12 indicates the final land use coverage and data results are summarized in Table D-12. The Deer Creek watershed is predominantly rural with forested, pasture, and agricultural land use.

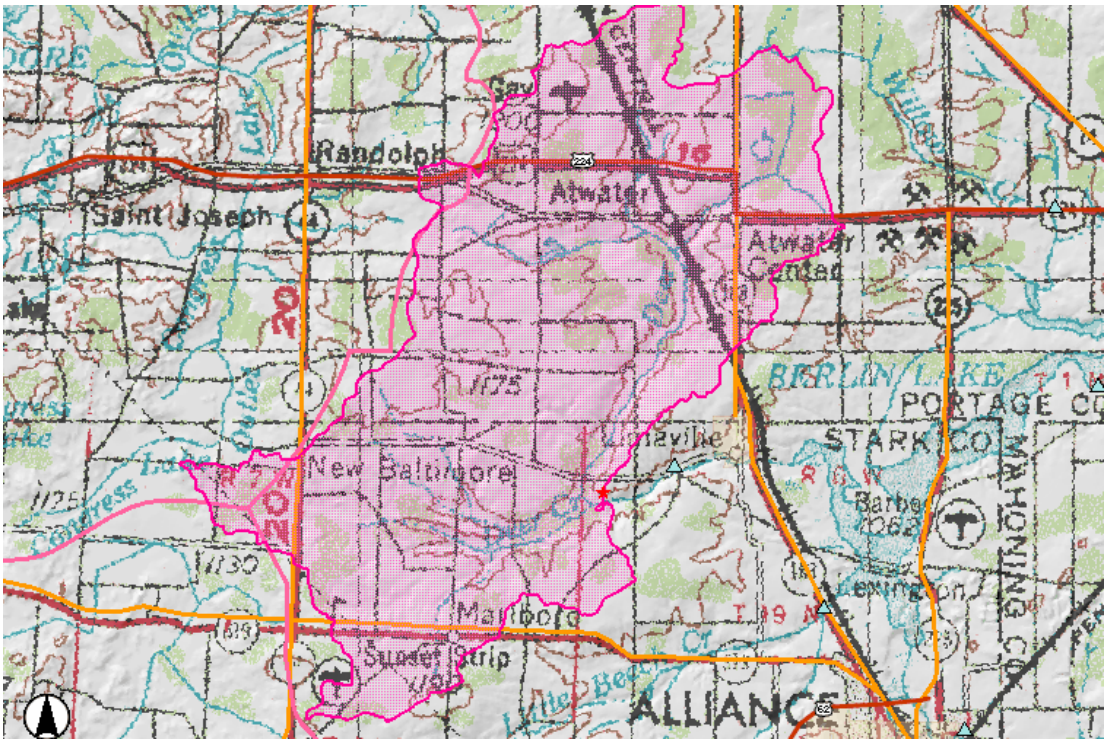

Figure D-10. Dale Walborn Reservoir Watershed (Source: StreamStats, USGS)

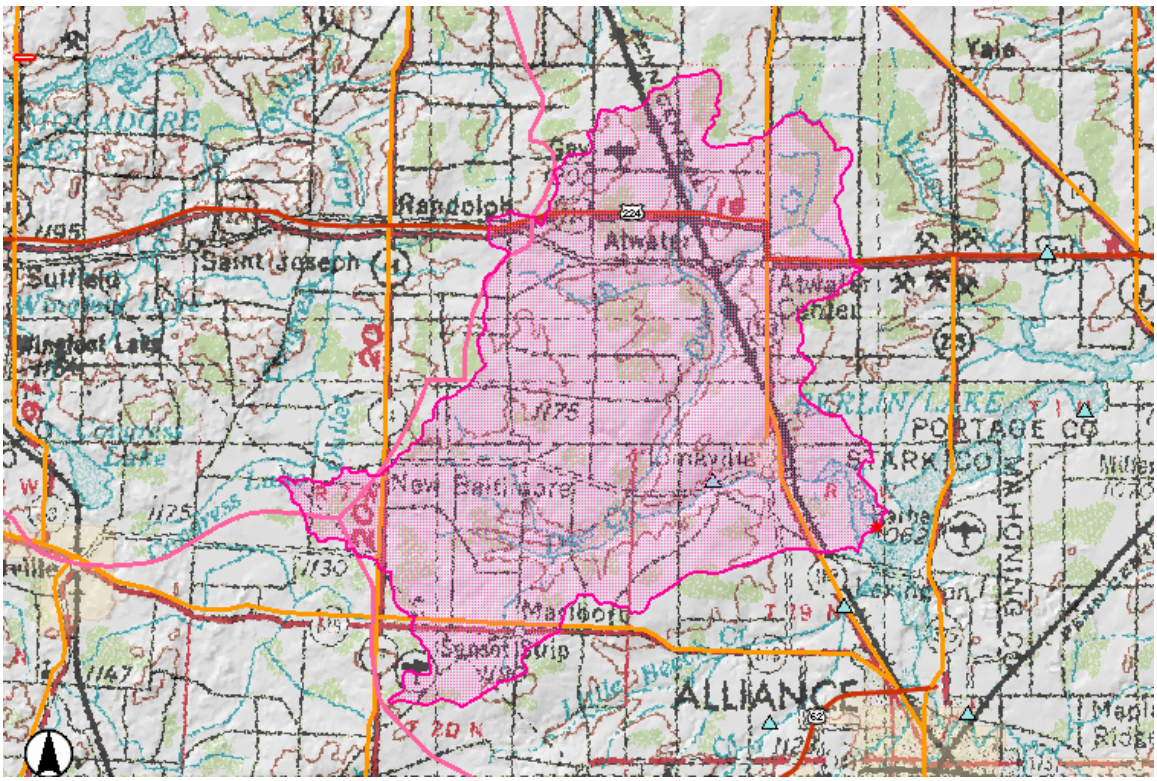

Figure D-11. Deer Creek Reservoir Watershed (Source: StreamStats, USGS)

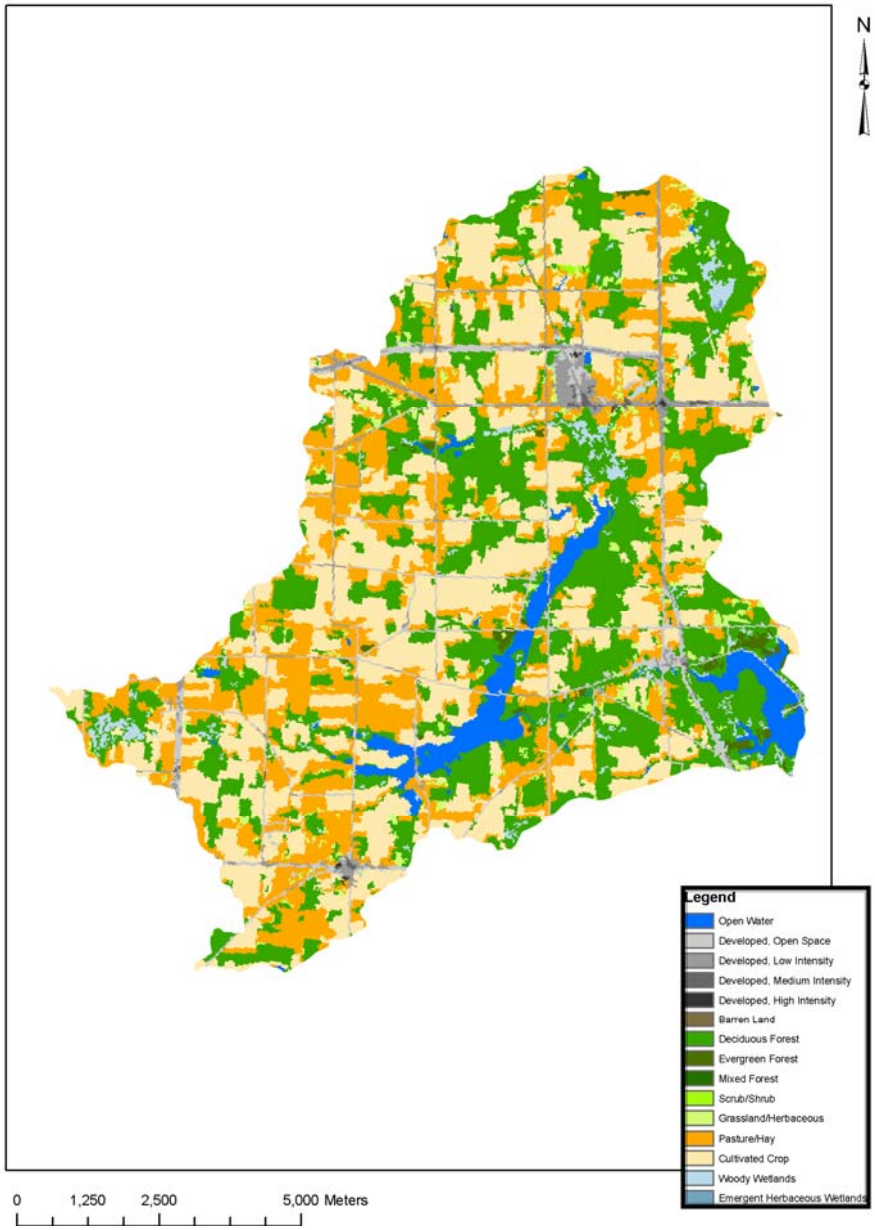

Figure D-12. Deer Creek and Dale Walborn Reservoir Land Use Map

Table D-12. Land Use Area and SCS Curve Numbers of Reservoir Drainage Basins

	Deer Creek Reservoir Area (ha)	Dale Walborn Reservoir Area (ha)	Deer Creek excluding Dale Walborn Area (ha)	SCS Curve Numbers
Water	423	294	129	100
Developed	682	565	116	91.7
Forest	2844	2164	680	76.7
Pasture	2491	2220	271	81.2
Crop	3007	2705	302	86.5
Wetland	163	133	30	100
Total	9609	8081	1528	

Runoff Curve Numbers

The GWLF model uses the curve number method to estimate runoff from each land use area. Area weighted curve numbers were developed for each subwatershed and land use based on the reported NRCS soil hydrologic groups. Soil hydrologic groups were used to account for the different infiltration rates of different soil types (e.g., higher infiltration for sands compared to clays).

The direct runoff fraction of precipitation in GWLF is calculated using the SCS Technical Release 55 (TR55) method literature based on land-use and soil hydrologic group (USDA, 1986). This method utilizes curve numbers for various land uses and soil characteristics which vary from 25 for undisturbed woodland with permeable soils, to, 100, for impervious surfaces. Land uses with higher curve numbers are assumed to have more surface runoff than those with lower curve numbers. The hydrologic soil group was determined from available soils data and curve numbers were calculated for each land use category/soil hydrologic group. Area weighted curve numbers assigned for the lakes watersheds are summarized in Table D-13.

Evapotranspiration Cover Coefficients

The portion of rainfall returned to the atmosphere is determined by GWLF based on temperature and the amount of vegetative cover. For urban land uses, the cover coefficient was calculated as (1 - impervious fraction). For all other land uses it was assumed that land had vegetative cover during the growing season (cover coefficient = 1) and limited vegetative cover during the dormant season (cover coefficient = 0.3). The cover coefficients were area-averaged to result in one coefficient value for the growing season (March-October) and one for the dormant season (November-February) as advised by the GWLF manual.

Soil Water Capacity and River Recession

Water stored in soil may evaporate, be transpired by plants, or infiltrate to ground water through the root zone. The amount of water that can be stored in soil (the soil water capacity) varies by soil type and rooting depth. Based on soil water capacities reported in the STATSGO database, soil types present in the watershed, and GWLF user's manual recommendations, a GWLF soil water capacity of 10 cm was used.

The GWLF model has three subsurface zones: a shallow unsaturated zone, a shallow saturated zone, and a deep aquifer zone. Behavior of the second two stores is controlled by a ground water recession and a deep seepage coefficient. The recession coefficient was set to 0.01 per day and the deep seepage coefficient to 0.

Weather Data

The GWLF model uses daily values of precipitation and average temperature to estimate water inputs to the system as well as potential evapotranspiration rates. A ten year record of weather data from the National Midwest Regional Climate Center stations named Louisville (#34728), Berlin (#330639), and Ravenna (#336949) were used as GWLF input. Figure D-13 indicates the lake and gage drainage areas as well as the weather station Thiessen polygons. The average temperature of the daily average temperature readings were used as well as a weighted average rainfall utilizing the Thiessen polygon method. Additional data from these stations was utilized for the BATHTUB model and will be discussed in subsequent sections of this report.

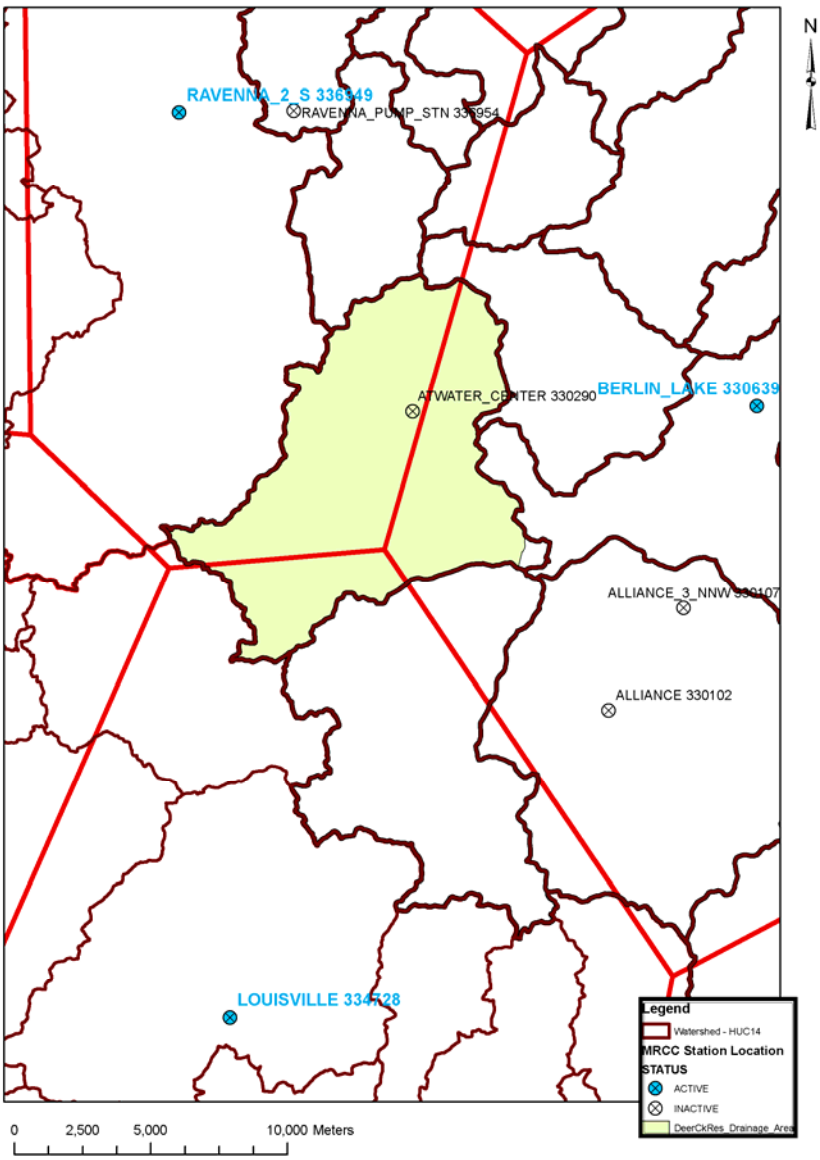

Figure D-13. Deer Creek Watershed and Thiess Polygons of the active MRCC weather stations

Nutrient Data

The GWLF model simulates nutrient runoff from rural land uses and washoff from urban land uses. In addition, soil is assumed to carry sorbed nutrients; groundwater also serves as a component of the total load. Because site-specific data were not available, soil nutrient concentrations are based on spatial distributions provided in the GWLF manual. Both the soil nitrogen and soil phosphorus concentrations were set to the average of the suggested range for the geographic area during model calibration. The soil nitrogen concentration is estimated to be 1400 mg/kg and the soil phosphorus concentration is estimated to be 1320 mg/kg. Nutrient modeling methods for the nutrient load allocations are provided in Table D-13.

Table D-13. Summary of nutrient TMDL development

Development step	Source	Method
Existing load	surface runoff	GWLF nutrient modeling and field data comparison
	ground-water	GWLF nutrient modeling
	point source	Product of discharger permit limit and the design flow of the facility is used to determine phosphorus loading
	HSTS	Population served by failing HSTS estimated via GIS and county Health Departments. Phosphorus 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 phosphorus target concentration.
Allocation	surface runoff	LA is equal to the sum of all WLAs and the MOS subtracted from the assimilative capacity.
	Point Sources	Product of design flow rate and technology based effluent limitation Total P of 1.0 mg /l (or less depending on plant type).
	natural runoff	The expected background phosphorus load is determined based on running GWLF considering all lands to be unmanaged.
	HSTS	Septic systems are allocated a phosphorus load of zero.
	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.
	MOS	Five percent of the assimilative capacity is reserved for the margin of safety.

Nutrient Concentrations for Rural Land Uses

GWLF requires a dissolved phase concentration for surface runoff from rural land uses. Particulate concentrations are taken as a general characteristic of area soils, determined by bulk soil concentration and an enrichment ratio indicating preferential association of nutrients with the more erodible soil fraction and not varied by land use. Dissolved and solid phase nutrient concentrations in runoff from each land use were set to GWLF default values and are summarized in Table D-14. Because site-specific data were not available, default values were chosen to estimate relative contributions from the pollutant sources.

Table D-14. Dissolved and solid phase nutrient concentrations for rural land uses

GWLF Land Use Group	Nitrogen		Phosphorus	
	Dissolved Phase (mg/L)	Solids Phase (mg/kg)	Dissolved Phase (mg/L)	Solids Phase (mg/kg)
Forest	0.25	3000	0.01	1276
Pasture	3.00	3000	0.25	1276
Row Crop	2.90	3000	0.26	1276
Barren/Transitional/Mines	0.65	3000	0.06	1276
Wetland	0.25	3000	0.01	1276

Buildup Washoff Rates from Urban Land Uses

GWLF simulates nutrient loads from developed land uses through a buildup/washoff formulation. Buildup rates for nitrogen and phosphorus are based on weighted averages of pervious and impervious default values suggested in the GWLF manual (Table D-15).

Table D-15. Pollutant buildup rates for urban land uses

Land use	Nitrogen build up (kg/ha-d)	Phosphorus build up (kg/ha-d)
Commercial/Industrial/Transportation	0.083	0.009
Low density residential	0.030	0.003

Groundwater Nutrient Concentrations

Groundwater nutrient concentrations were based on baseflow measurements reported in the GWLF manual for various levels of forested and agriculturally developed watersheds. Completely forested watersheds have values of 0.07 mg-N/L and 0.012 mg-P/L. Primarily agricultural watersheds have values of 0.71 mg-N/L and 0.104 mg-P/L. Intermediary values are also reported. Because the overwhelming majority of the land use for the watersheds studied were forest, concentrations for primarily forested areas were used as 0.34 mg-N/L and 0.013 mg-P/L.

Septic System Loading Data

The GWLF model requires an estimation of population served by septic systems to generate septic system nutrient loading rates. The number of home sewage treatment systems (HSTS) were determined via GIS analysis of census data. The number of HSTS in each 14-digit HUC is estimated based upon 1990 and 2000 census demographic information and adjusted to conditions expected in 2006 from population trends provided by the Ohio Department of Development. The Stark County Health Department estimated approximately 80 percent of the total number of systems in the Deer Creek reservoir watershed were failing. A failing system is assumed to short circuit the adsorption field and plant uptake zones and discharge directly to surface waters. The population served by normal and failing systems is summarized by subwatershed in Table D-16. HSTS pollutant loads are estimated as the product of the number of persons served by failing systems in each subwatershed, a per capita wastewater flow-rate and representative wastewater-quality information.

Table D-16. Population of lake drainage basins from GIS analysis of US Census Data 2005

Lake Drainage	Population (2005)	Houses (2005)
Dale Walborn Reservoir	9525	4267
Deer Creek Resevoir	18031	7615

Daily per capita mass loading rates and plant uptake rates for normal and failing systems were set to GWLF default values and are summarized in Table D-17. Using the default parameters suggested by the manual allows for an estimation of pollutant loading relative to other sources in the watershed. An overall failure rate of 75% allotted as 25% ponded, 25% short-circuited, and 25% straight pipe for GWLF usage. These value was used to simulate the failed and normally functioning systems within the watersheds and were developed by best professional judgment.

Table D-17. Septic system loading rates and plant uptake rates

Parameter	Nitrogen	Phosphorus
Loading Rate from Septic Tank Prior to Drainfield Treatment and Plant Uptake (grams/capita/day)	12	1.5
Growing Season Plant Uptake Rate (grams/capita/day)	1.6	0.4
Dormant Season Plant Uptake Rate (grams/capita/day)	0	0
Percent Additional Treatment in Soil Adsorption Field of Normal System (%)	0	100
Percent Additional Treatment in Soil Adsorption Field of Failing System (%)	0	0

Note that normal and failing systems are assumed to have equivalent tank effluent loading rates. In a normally functioning system, tank effluent is distributed over a soil adsorption field. Phosphorus is assumed to have the capability to be completely adsorbed to the soil particles and some nitrogen is taken up by plant roots during the growing season. The failing system bypasses both of these treatment mechanisms and is assumed to discharge pollutants at rates equivalent to the tank effluent values. This appears to be a valid assumption for the watershed studied because the overwhelming majority of homes are in very close proximity to receiving streams.

GWLF Calibration

Calibration refers to the adjustment or fine-tuning of modeling parameters to reproduce observations. Hydrologic calibration precedes water quality calibration because runoff is the transport mechanism by which nonpoint pollution occurs. In an ideal situation, calibration is an iterative procedure of parameter evaluation and refinement as a result of comparing simulated and observed values of interest and is based on several years of simulation to evaluate parameters under a variety of climatic conditions.

Limited flow and water quality data were available on the lake watershed drainages. Therefore, calibration of modeled hydrology and nutrients were completed at the USGS gage in Alliance on the Mahoning River mainstem Daily stage record was available for this site and utilized in calibration. Default values were used in GWLF for modeling parameters in which no site specific information was available. A comparison of the simulated and observed data is presented below. The calibrated GWLF model for the Alliance gage site was used as a basis for the Deer Creek GWLF model by changes only in land use, watershed area, population, and point source loadings.

Hydrologic Calibration

The GWLF model predicts flow volumes from runoff at monthly intervals. Simulated flows were compared to observed discharge at the USGS Alliance Gage during model calibration. Daily flows reported from April 1, 2000, through March 31, 2009, were summed by month for comparison with the GWLF simulation. Figure D-14 provides the trend of monthly total flow in centimeters for the watershed area.

This figure also compares the known monthly flow volumes observed at the gage to the calibrated GWLF estimates. GWLF was calibrated by adjusting the evapotranspiration in an iterative approach until the covariance was maximized and the predicted/observed statistic was most nearly the value of one. Multiple calibration runs were completed to obtain an R^2 value of 0.7049 and predicted/observed of 1.06. As can be observed by Figure D-14 and from the values of the comparison statistics, the model simulates the hydrology well.

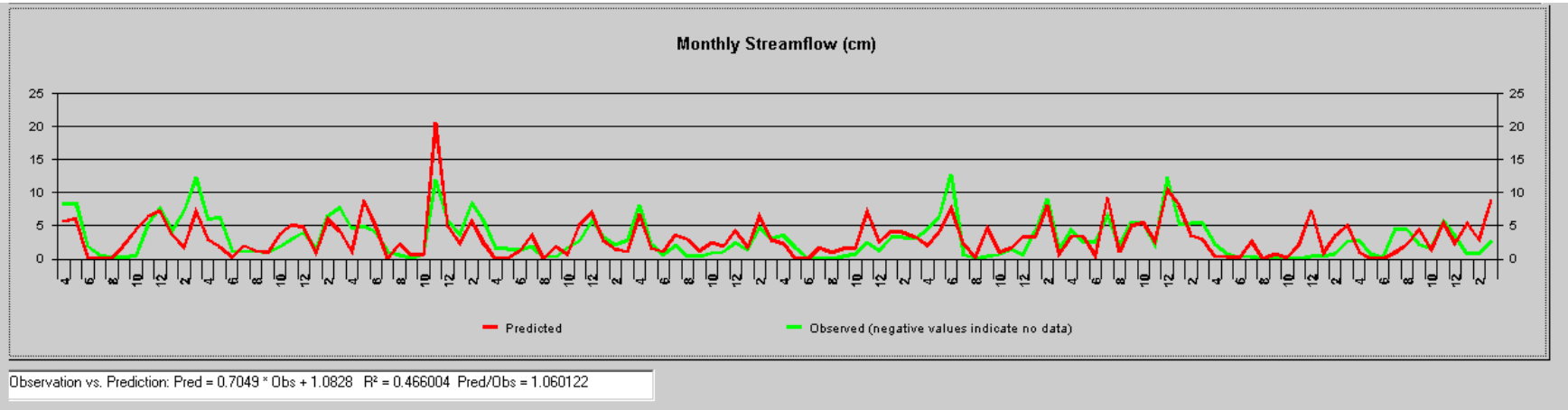

Figure D-14. Mahoning River @Alliance gage GWLF hydrology simulation result after calibration (Gross Monthly Flow, R^2 = 0.7049, Predicted/Observed.

Nutrient Verification

During the 2007 and 2008 survey season of the Deer Creek Reservoir watershed, Ohio EPA obtained seventeen samples from Deer Creek upstream of Deer Creek Reservoir at Atwater Road. This data was utilized to compare the GWLF ten year model run results to actual nutrient data. GWLF simulates the average monthly concentration for the modeled timeframe. Field data is collected as daily grab samples. Therefore, calibration could not be completed, but comparison of the average monthly concentrations and the daily values could be accomplished and used to influence model coefficient choices.

The lake algae growing season (modeling season) is from May to October. Samples were taken from various months throughout this season. Monthly values from the GWLF 10 year modeling work were compared to sample results in the respective month. Figure D-15 shows the results of the modeling effort as compared to the true sample results. Variability was minimized by reducing the variance of medians between the two groups in each month.

Model coefficients, when changed, influenced the entire modeling season; therefore, some months have more significant variability from modeled to sample results. September is the month with the largest variability. In both cases the average simulated monthly concentrations are similar in value with the observed concentrations. Variability does arise from observed to modeled values for a variety of reasons including assumptions in land use sources of nutrients and other modeling assumptions used to simulate Deer Creek watershed. In addition, a convoluted modeled daily concentration developed from gross monthly loading uniformly distributed to modeled daily flow as well as relatively small number of known concentrations from samples could create variability when comparing data sets.

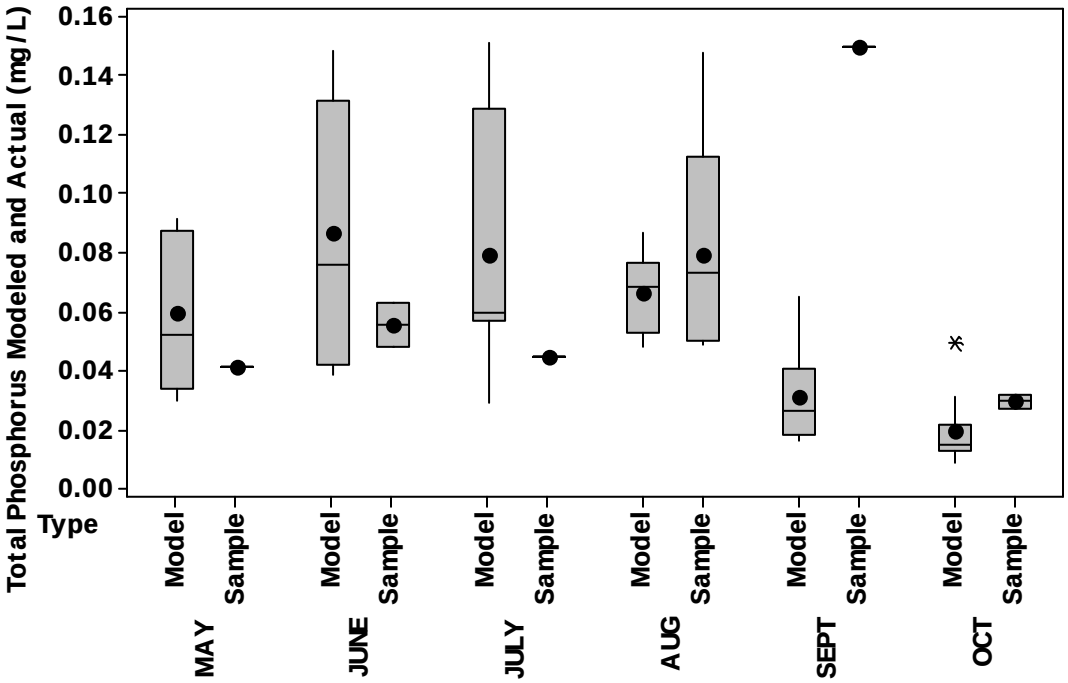

Figure D-15. Deer Creek just upstream of Deer Creek Reservoir at Atwater Road, comparison to sample total phosphorus data to GWLF model results for pseudo-calibration.

BATHTUB Model

The USACE BATHTUB model (Walker, 2004) was utilized to simulate nutrient response in Dale Walborn and Deer Creek Reservoirs based on input from the GWLF model. BATHTUB performs steady-state water and nutrient balance calculations in a spatially segmented hydraulic network, which accounts for pollutant transport and sedimentation (U.S. EPA, 2006). Eutrophication-related water quality conditions (e.g., phosphorus, nitrogen, chlorophyll *a*, and transparency) are predicted using empirical relationships previously developed and tested for reservoir applications (Walker, 1987).

BATHTUB has three primary input interfaces: global inputs, lake morphology, and watershed loading. Compared to other reservoir models, the BATHTUB model requires a moderate amount of site-specific data to configure and calibrate. Input data includes atmospheric loads of nutrients, tributary flows and concentrations, and global parameters such as evaporation rates and annual average precipitation. For lakes with low phosphorus residence times, the recommended critical condition is the period of increased sunlight, temperature and algal growth from May through September. Due to the effects of settling, the phosphorus residence time is often somewhat longer than hydraulic residence times.

The BATHTUB model was determined to be appropriate for use in this modeling effort because it addresses the parameters of concern and has been used previously for reservoir TMDL applications. The use of more sophisticated lake models was not warranted based on the very limited water quality data with which they could be calibrated.

Global and Lake Morphometric Data

The global inputs for each lake represent water balance contributions of precipitation and evaporation and phosphorus input from atmospheric deposition. Rainfall data was obtained from Midwest Regional Climatic Center weather stations in the local area of each waterbody. The area weighted Theissen polygon (Voronoi diagram) method was utilized to obtain average precipitation for each lake's drainage area. Solar radiation and barometric pressure were obtained from the Ohio Agricultural Research Development Center (OARDC) station in Wooster, Ohio. Seasonal lake evaporation was calculated using Penman's equation with a standard pan coefficient of 0.78, in conjunction with OARDC data.

The BATHTUB model requires basic lake morphometric data to assess residence time, net flow rate, and potential euphotic depth. Morphometric data, as presented in Table D-18, was collected from on-site sampling, GIS analysis, and the Ohio Department of Natural Resources dam safety inventory database. Because the lakes are spatially close, the two reservoirs were modeled as one waterbody with two segments with a channel connection. The model was developed assuming normal pool elevation throughout the growing season.

Atmospheric Deposition to Lakes

Atmospheric deposition can contribute a significant proportion of nutrient loads directly to a lake surface, particularly when the ratio of watershed area to lake surface area is low. The watershed to lake area ratios for Dale Walborn and Deer Creek Reservoir are (34:1) and (75:1); respectively. For both reservoirs, the water surface to watershed area ratio is very high, therefore, neither are expected to be significantly affected by direct atmospheric deposition of phosphorus. BATHTUB default values in units of $^{mg}/_{m^2 * yr}$ for total nitrogen (1000), inorganic nitrogen (500), total phosphorus (30) and ortho-phosphate (15) were used in the model simulation for each watershed because of the absence of site-specific data.

Table D-18. Deer Creek Reservoir and Dale Walborn Reservoir Morphometric Data

Lake Parameter	Deer Creek Reservoir	Walborn Reservoir	Units
Drainage Area	9609	8081	hectares[1]
Lake Area	127	231	hectares[2,3]
Volume	379	662	hectare-meter[2,3]
	3069	5366	acre-feet[2,3]
Maximum Depth	5.2	6.5	meters
Average Depth	3.0	2.9	meters
Relative Depth*	0.004	0.004	dimensionless
Development of Volume	1.73	1.32	dimensionless
Fetch	1801.0	5186.0	meters[4]
Maximum Width,Perpendicular to Fetch	698.1	550.3	meters[4]
Shoreline Length	12,813	20,009	meters[5]
Development of Shoreline	3.21	3.71	dimensionless[5]
Mean Annual Inflow	4577	3849	hectare-meter[6]
	37105	31204	acre-ft[6]
Mean Modeled Seasonal Inflow**	1699	1429	hectare-meter[6]
	13773	11582	acre-ft[6]
Average Hydraulic Residence Time	0.99	2.06	months[3,6]
Average Seasonal Surface Overflow Rate**	13.41	6.17	m/year[3,6]
Phosphorus Residence Time	0.396	0.695	months
BATHTUB Modeling Season**	5	5	months
Phosphorus Turnover Ratio	12.6	7.2	#/season

*maximum depth / lake diameter, if the lake area was a circle. Most lakes < 0.02.
** The season is defined as May through Sept.
[1] ArcGIS result
[2] ODNR Inventory Sheets
[3] Normal pool (principal spillway)
[4] ArcGIS using USGS 1:24000 topographic map
[5] National Hydrography Dataset (ArcGIS) values
[6] GWLF results

Inorganic Nutrient Fractions
BATHTUB requires an estimate of inorganic nutrient fractions for all loads to the modeled lake. The inorganic nutrient fractions for the watershed loads were approximated from the ratios of dissolved nutrient load to total nutrient load determined during the sampling events in 2007 and 2008 for Deer Creek Reservoir. Dale Walborn was assumed to be similar in the absence of samples. Atmospheric and groundwater recharge loads were assumed 100 percent inorganic.

Light Penetration in Lakes
The BATHTUB model requires average Secchi depth to determine the non-algal turbidity in the lake. A Secchi depth reading was collected by Ohio EPA during each limnology sampling visit to the respective lake in 2007 and 2008. The means of these readings were utilized to calibrate BATHTUB for Secchi visibility. The calibrated model was utilized to model the Secchi visibility for each lake from 1999 to 2008.

BATHTUB Calibration and Setup
The BATHTUB model for each lake was calibrated utilizing data collected during the sampling event at each water body in 2007 and 2008. Physical attributes of Dale Walborn were the only data collected. No depth integrated analytical samples were taken of this reservoir. The BATHTUB model allows calibration by total phosphorus, total nitrogen and/or chlorophyll *a*. All three parameters were utilized for calibration of the segmented lake model. BATHTUB offers the user several choices for nutrient sedimentation modeling which affects the predicted in-lake concentrations from loading rates and residence time.

For both lake watersheds, the segmented basin model represented the tributary inputs from GWLF. BATHTUB requires that lakes with a phosphorus turnover ratio of less than two per year must be modeled throughout an entire calendar year. Lakes with greater turnover ratios must only be modeled from May to September of each year. One sample results was included that was collected in October on Dale Walborn Reservoir because of the relevancy and BATHTUB flexibility allows for a growing season to be expanded from April to October if warranted (Walker, 1987, Report 4, pg. I-27). Turnover ratios for the modeled lakes can be found in Table D-18. For Dale Walborn and Deer Creek Reservoir, the monthly loads were summed over the May to October period, and average monthly flows were also taken from the GWLF output for this time period. The growing season was utilized because the phosphorus turnover ratio was greater than 2/season for both reservoirs.

Mean phosphorus concentrations were determined by dividing the GWLF gross nutrient mass by the gross volume of flow during this modeling season. Table D-19 indicates the selected BATHTUB options chosen during the BATHTUB modeling. Combined as one lake in two segments, the results of the GWLF model for each modeling season period from 1999 to 2008 were applied to BATHTUB to evaluate water quality/trophic conditions.

BATHTUB was compiled and ran using non-point source loads from each of the segment drainage areas. Once completed results of BATHTUB model run for the two segments and one channel were analyzed by load response curve using BATHTUB advanced user mode selection. Algae response load response curves were developed for total phosphorus, total nitrogen, and ortho-phosphate.

The BATHTUB model was then used as a diagnostic tool in order to estimate the phosphorus load reductions required to achieve the standards listed in Ohio's Lake Habitat Criteria. The calculated seasonal loads reflect the effects of varying climatic conditions observed during these

years. Therefore, the ten year average value for each parameter was utilized as influent loadings to develop the load reduction required to meet the in-lake water quality criteria.

Table D-19. Algorithms used within BATHTUB to simulate water quality in modeled lakes.

Process	Algorithm number	Algorithm description
Phosphorus balance	1	Second order, available phosphorus
Nitrogen balance	1	Second Order, available N
Chlorophyll *a* concentration	4	Linear function of phosphorus
Secchi depth	3	Function of total phosphorus
Phosphorus calibration	1	Decay rates
Nitrogen calibration	1	Decay Rates

Table D-20. Hypolimnetic and Metalimnetic Oxygen Depletion Rates utilized in BATHTUB Modeling

Location	Mean Concentration		
	Chlorophyll *a* (mg/m^3)	HODv (mg/m^3-day)	MODv (mg/m^3-day)
Epilimnion	25.23		
Metalimnion	21.25		143.77
Hypolimnion	14.90	201.18	

Note: Deer Creek Reservoir Mean Hypolimnetic Depth = 4.605 m

$$HOD_v = 240\frac{[C_a]^{0.5}}{H_d}$$ **Equation C1**

$$MOD_v = 0.4HOD_v(H_d)$$ **Equation C2**

Where: HOD_v = Hypolimneitc Oxygen Depletion Rate
MOD_v = Metalimnetic Oxygen Depletion Rate
C_a = Chlorophyll a Concentration (mg/m3)
H_d = Hypolimentic Depth (m)

Description of Target Endpoint

Ohio EPA has public noticed draft Lake Criteria rules in the Ohio Administrative Code (OAC Rule 3745-1-43). Comparison of the BATHTUB modeling results of the mixed layer water quality was compared to the draft lake water quality standard for Chlorophyll *a*, total phosphorus, total nitrogen, pH, dissolved oxygen, Sechhi disk transparency, and ammonia. Water quality of the mixed layer depth of both reservoirs was compared to the proposed standards for the respective parameters in the *Study Area and Preliminary Data Evaluation* of this report. As can be observed that section, data from Deer Creek Reservoir indicated that eutrophication cause and response variables exceeded the draft Lake Habitat Criteria values. Limited water quality data from Dale Walborn reservoir indicated that eutrophication response variables exceeded the criteria.

BATHTUB modeling was prepared for total phosphorus, chlorophyll a, and Secchi disk transparency. These parameters were chosen because BATHTUB is equipped to model eutrophication cause variables and Secchi disk transparency as the only response variable. In addition, Carlson's trophic state index (Carlson, 1977) was analyzed in the BATHTUB because this index is a classical guide for magnitude evaluation of eutrophication. Carlson's trophic state index uses algal biomass as the basis for trophic state classification. Three variables, chlorophyll pigments, Secchi depth, and total phosphorus, independently estimate algal biomass. The trophic index is a base two logarithmic transformation of Secchi depth; each 10-unit division of the index represents a halving or doubling of Secchi depth.

Target values for modeling purposes of these parameters were drawn directly from the draft Lake Habitat Criteria (OAC Rule 3745-1-43).

Margin of Safety

The Clean Water Act requires that a TMDL include a margin of safety (MOS) to account for any lack of knowledge concerning the relationship between load and wasteload allocations and water quality. U.S. EPA guidance explains that the MOS may be implicit (i.e., incorporated into the TMDL through conservative assumptions in the analysis) or explicit (i.e., expressed in the TMDL as loadings set aside for the MOS).

An explicit margin of safety of 5% is provided for the proposed reduction of influent total phosphorus to the combined lake system of Dale Walborn and Deer Creek Reservoirs. Five percent has been used in many other nutrient TMDLs and provides a reasonable level of assurance that the resulting allocations will meet water quality standards.

Seasonality and Critical Conditions

For lakes with low phosphorus residence times, the recommended critical condition is the period of increased sunlight, temperature and algal growth from May through September. Due to the effects of settling, the phosphorus residence time is often somewhat longer than hydraulic residence times.

Allowance for Future Growth

Future growth is built in to the load duration curves because most of the point source dischargers receiving wasteload allocations for total phosphorus do not discharge at their design capacity. The wasteload allocations are based on the product of design flow, the target total phosphorus concentration and a conversion factor, therefore, this wasteload exceeds the current loading, provided the facilities are in compliance with the water quality based permit limit. There are no anticipated expansions in the waste water treatment plants in the TMDL project area. Likewise, based on observed population growth from 2000 to 2009 (U.S. Census Bureau, 2010) the project area is undergoing an overall negative growth. Portage and Geauga Counties, representing about half of the project area experienced marginal positive growth while the remaining counties had negative growth. Nonetheless an additional four percent of the TMDL is reserved for future growth.

D2 Results

D2.1 *E. coli* TMDLs

TMDLs were developed in these three 12-digt HUCs for bacteria (*E. coli*), sediment and habitat (QHEI), and nutrients (total phosphorus). The results are presented for the applicable assessment units (i.e., 12-digit HUCs) in the following sub-sections.

D2.1.1 *E. coli* TMDLs - Headwaters Mahoning River (05030103-01)

E. coli TMDLs for the 01-01 twelve digit HUC are presented in Table D-21. Three sites were used in calculating the TMDLs and allocations to offer higher resolution of the level of abatement needed throughout the 41.1 square mile area. Sites are located on the Mahoning River at river mile 97.69; a tributary to the Mahoning River entering at river mile 97.11; and on Beaver Run. Meeting the prescribed allocations within these three area associated with the LDC points constitutes meeting the TMDL for the *E. coli* bacteria in the 01-01 twelve digit HUC.

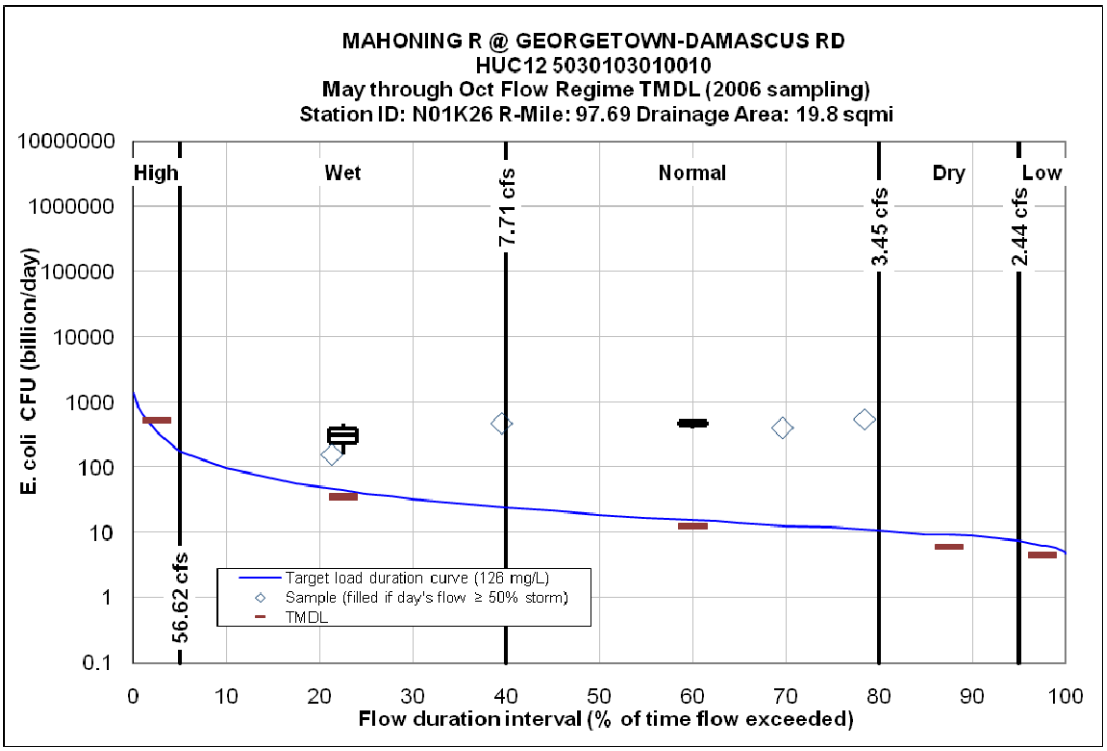

Figure D-16. Load duration curve for *E. coli* bacteria at sample location N01K26 on the Mahoning River at river mile 97.69 within the 01-01 twelve digit HUC.

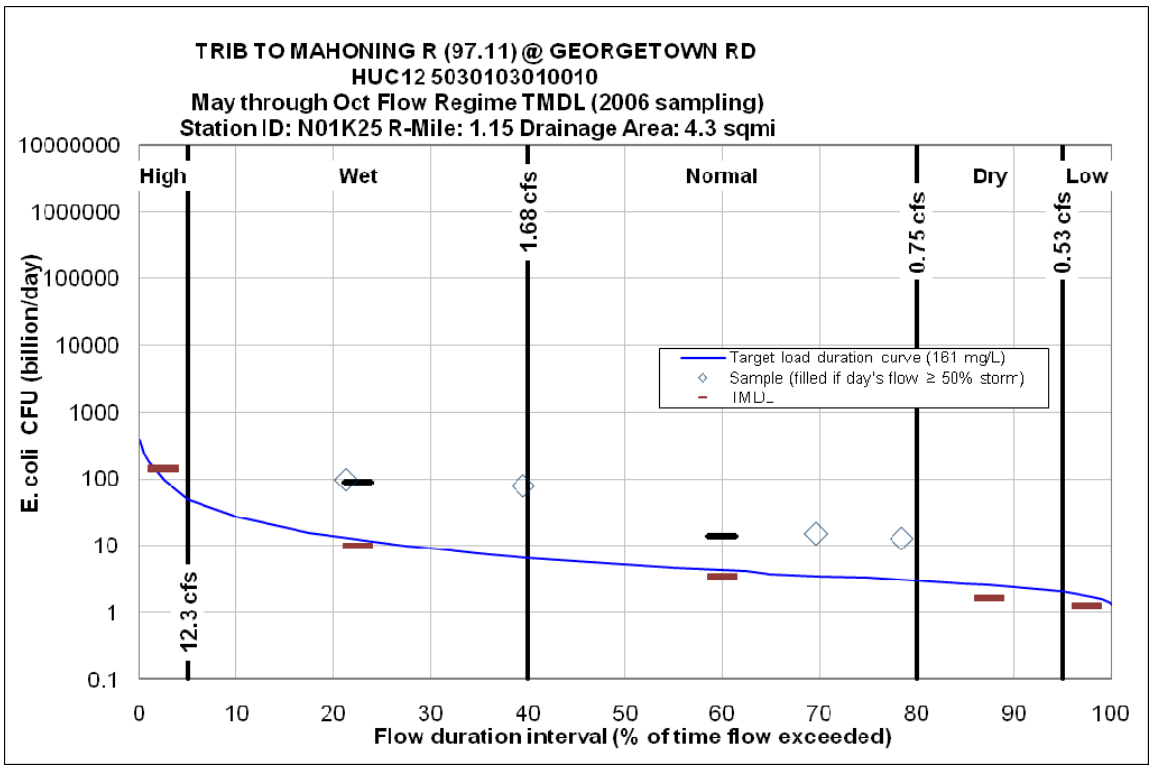

Figure D-17. Load duration curve for *E. coli* bacteria at sample location N01K25 on a tributary to Mahoning River at RM 97.11 (RM 1.15) within the 01-01 twelve digit HUC.

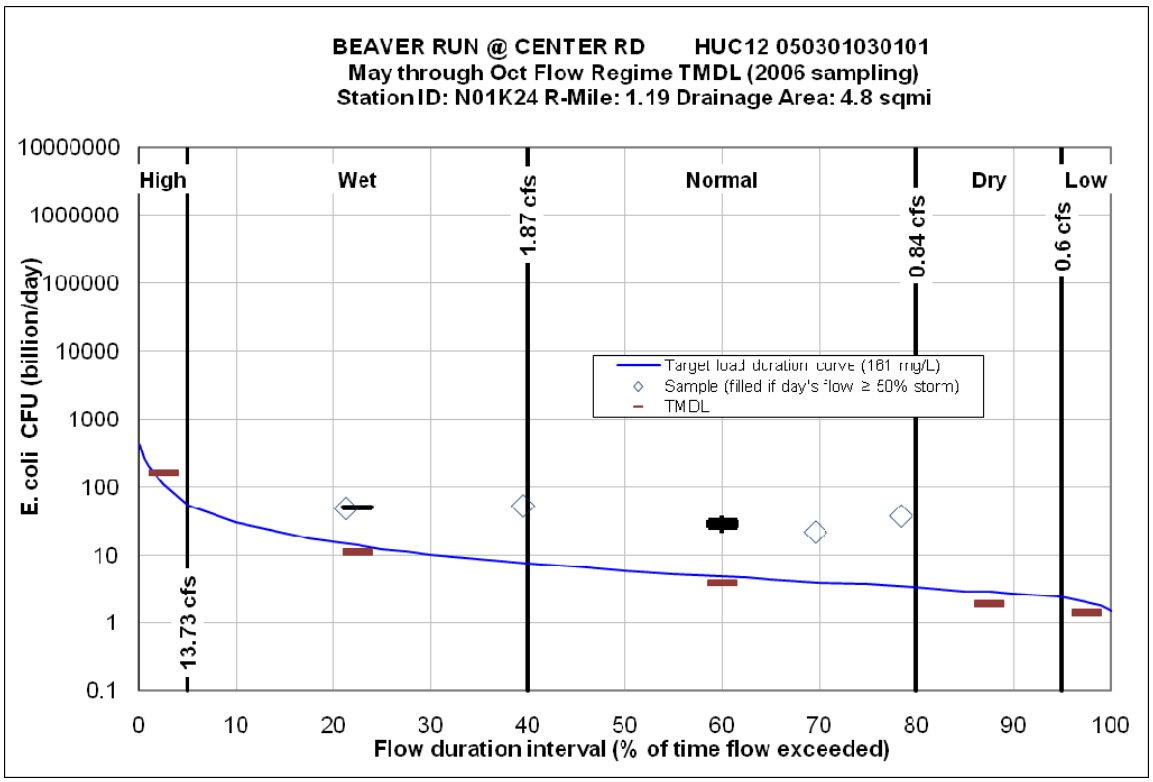

Figure D-18. Load duration curve for *E. coli* bacteria at sample location N01K24 on Beaver Run (RM 1.19) within the 01-01 twelve digit HUC.

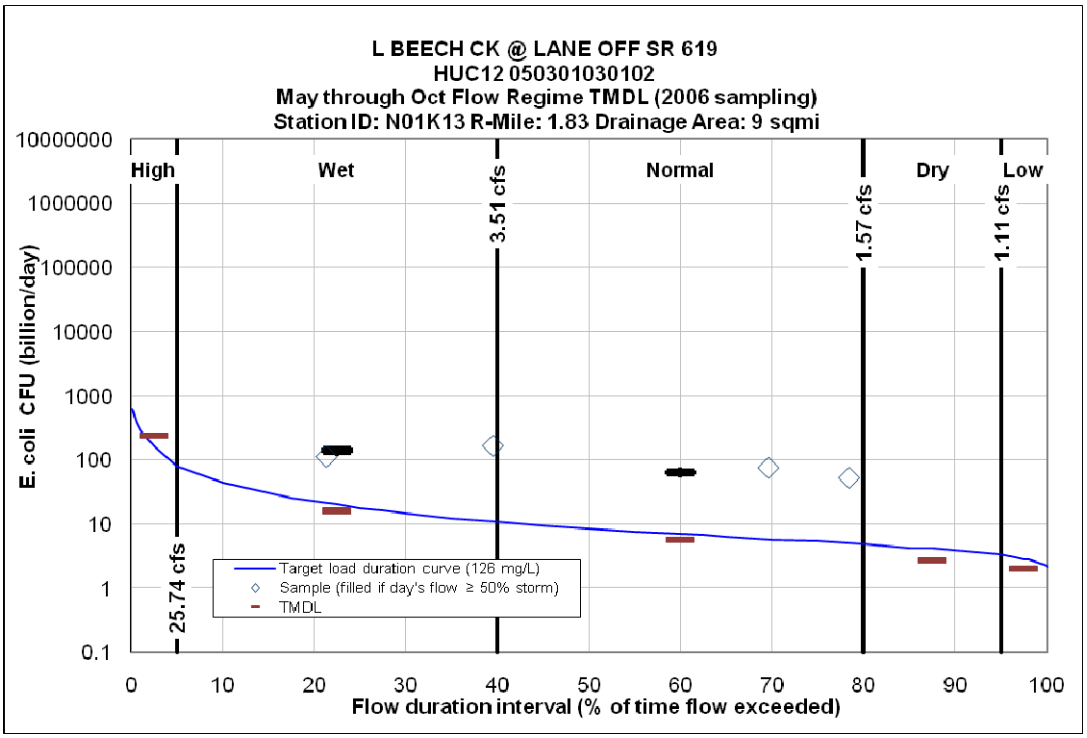

Figure D-19. Load duration curve for *E. coli* bacteria at sample location N01K13 on Little Beech Cr. (RM 1.83) within the 01-02 twelve digit HUC.

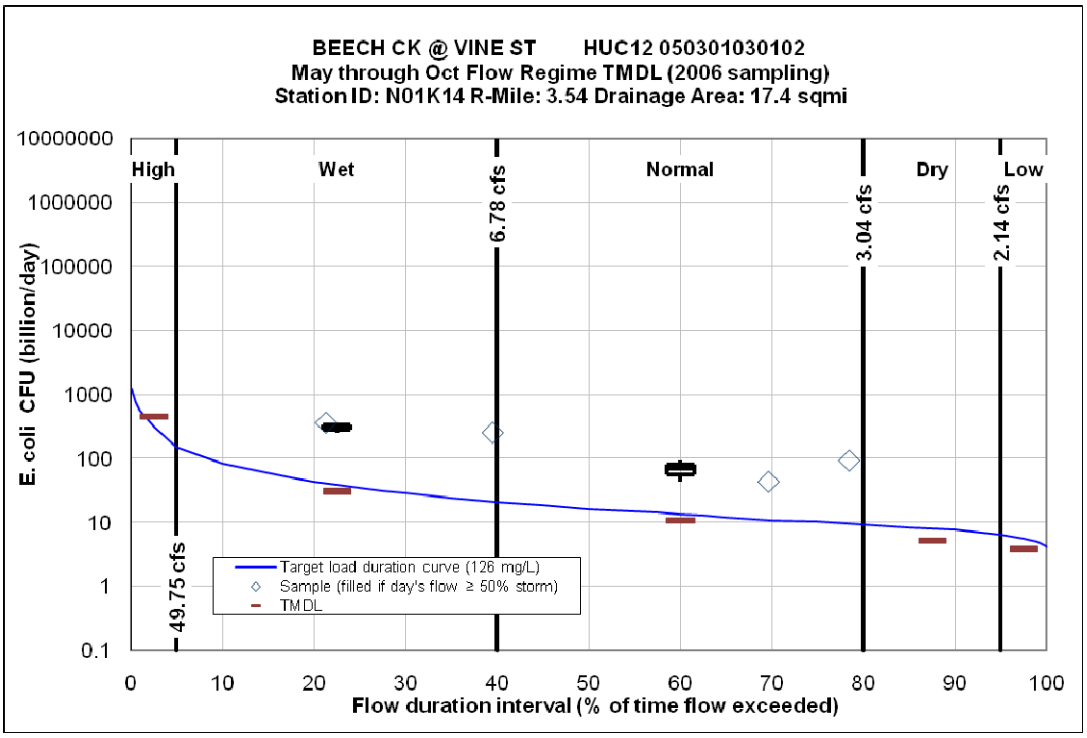

Figure D-20. Load duration curve for *E. coli* bacteria at sample location N01K14 on Beech Cr. (RM 3.54) within the 01-02 twelve digit HUC.

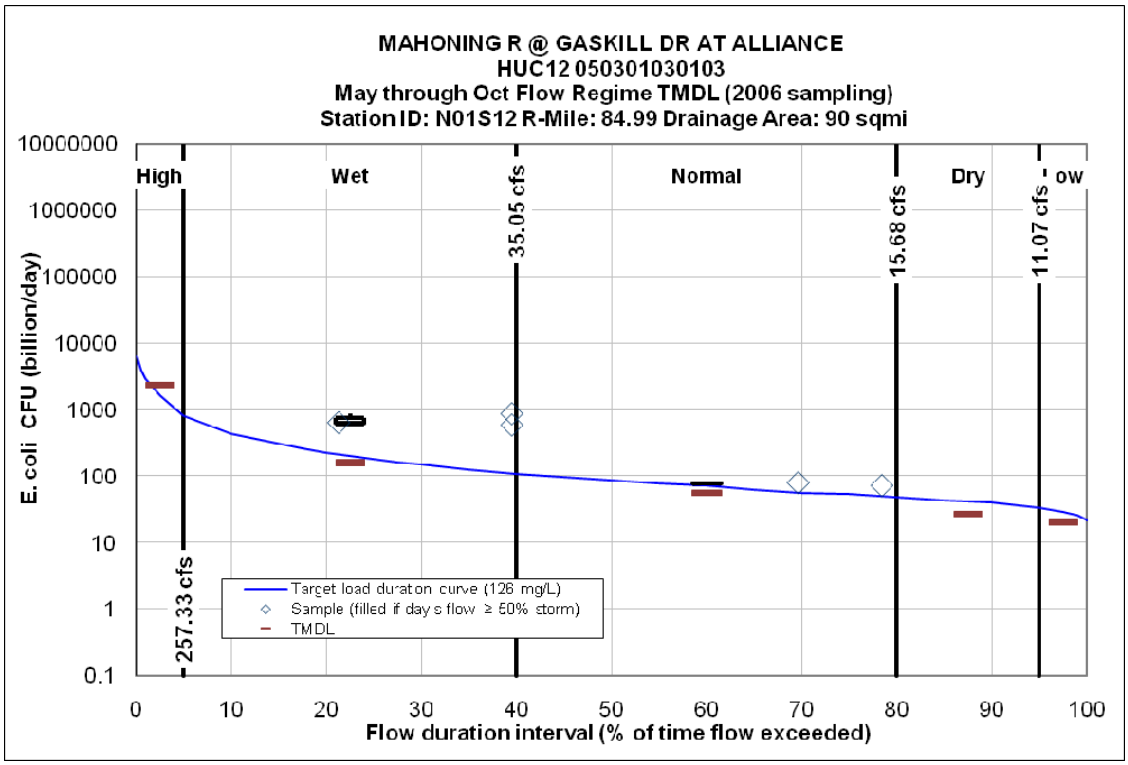

Figure D-21. Load duration curve for *E. coli* bacteria at sample location N01S12 on Mahoning River (RM 84.99) within the 01-03 twelve digit HUC.

Table D-21. *E. coli* TMDLs for the 05030103-01-01 12-digit HUC.

Flow Regime TMDL Allocation (billion/day)	Higher Flows	Wet Weather	Mid-Range Summer	Dry Weather	Low
Rec Season Interval	0-5%	5-40%	40-80%	80-95%	95-100%
N01K26 - Mahoning River (RM 97.69)					
Samples Collected		2	2		
Sample Median Load		310	466		
NPDES Point Source Existing Load	0.15	0.15	0.15	0.15	0.15
Margin of Safety (%)	20%	20%	20%	20%	20%
Margin of Safety (Load)	103.7	7.1	2.5	1.2	0.9
Included Upstream TMDL Allocation	0	0	0	0	0
Subwatershed % Reduction Required	No Data	88.5%	97.3%	No Data	No Data
LA (Non-Point Allocation)	518.33	35.48	12.38	5.87	4.36
Allowance for Future Growth (%)	4%	4%	4%	4%	4%
Allowance for Future Growth	25.92	1.78	0.63	0.30	0.23
WLA (NPDES Point/MS4 permits)	0.15	0.15	0.15	0.15	0.15
TMDL minus (MOS + Future Growth)	518.48	35.64	12.53	6.02	4.51
N01K25 - Tributary to Mahoning River at RM 97.11 (RM 1.15)					
Samples Collected		2	2		
Sample Median Load		89	14		
NPDES Point Source Existing Load	0.12	0.12	0.12	0.12	0.12
Margin of Safety (%)	20%	20%	20%	20%	20%
Margin of Safety (Load)	28.8	2.0	0.7	0.3	0.3
Included Upstream TMDL Allocation	0	0	0	0	0
Subwatershed % Reduction Required	No Data	88.9%	75.0%	No Data	No Data
LA (Non-Point Allocation)	143.76	9.77	3.38	1.55	1.14
Allowance for Future Growth (%)	4%	4%	4%	4%	4%
Allowance for Future Growth	7.19	0.49	0.17	0.08	0.06
WLA (NPDES Point/MS4 permits)	0.12	0.12	0.12	0.12	0.12
TMDL minus (MOS + Future Growth)	143.88	9.89	3.50	1.67	1.26
N01K24 - Beaver Run (RM 1.19)					
Samples Collected		2	2		
Sample Median Load		50	29		
NPDES Point Source Existing Load	0.00	0.00	0.00	0.00	0.00
Margin of Safety (%)	20%	20%	20%	20%	20%
Margin of Safety (Load)	32.1	2.2	0.8	0.4	0.3
Included Upstream TMDL Allocation	0	0	0	0	0
Subwatershed % Reduction Required	No Data	77.7%	86.6%	No Data	No Data
LA (Non-Point Allocation)	160.62	11.06	3.88	1.89	1.42
Allowance for Future Growth (%)	4%	4%	4%	4%	4%
Allowance for Future Growth	8.03	0.55	0.19	0.09	0.07
WLA (NPDES Point/MS4 permits)	0.00	0.00	0.00	0.00	0.00
TMDL minus (MOS + Future Growth)	160.62	11.06	3.88	1.89	1.42

Table D-22. *E. coli* wasteload allocations for the 05030103-01-01 12-digit HUC.

Regulated point source requirements	NPDES OEPA ID	Exist Flow Avg MGD	Dgn Flow Avg MGD	Conc Limit	WLA
Timashamie Family Campground	3PR00305	0.0039	0.0250	161.0	0.15
Paradise Lake Park Campground	3PR00325	0.02	0.02	161	0.12

Table D-23. *E. coli* TMDLs for the 05030103-01-02 12-digit HUC.

Flow Regime TMDL Allocation (billion/day)	Higher Flows	Wet Weather	Mid-Range Summer	Dry Weather	Low
Rec Season Interval	0-5%	5-40%	40-80%	80-95%	95-100%
N01K13 - Little Beech Cr. (RM 1.83)					
Samples Collected		2	2		
Sample Median Load		140	64		
Point Source Load	0.21	0.21	0.21	0.21	0.21
Margin of Safety (%)	20%	20%	20%	20%	20%
Margin of Safety (Load)	47.1	3.2	1.1	0.5	0.4
Included Upstream TMDL Allocation	0	0	0	0	0
Subwatershed % Reduction Required	No Data	88.4%	91.1%	No Data	No Data
LA (Non-Point Allocation)	235.48	15.99	5.48	2.52	1.83
Allowance for Future Growth (%)	4%	4%	4%	4%	4%
Allowance for Future Growth	11.78	0.81	0.28	0.14	0.10
WLA (NPDES Point/MS4 permits)	21%	21%	21%	21%	21%
TMDL minus (MOS + Future Growth)	**235.69**	**16.20**	**5.70**	**2.74**	**2.05**
N01K14 - Beech Cr. (RM 3.54)					
Samples Collected		2	2		
Sample Median Load		310	69		
Point Source Load	0.14	0.14	0.14	0.14	0.14
Margin of Safety (%)	20%	20%	20%	20%	20%
Margin of Safety (Load)	91.1	6.3	2.2	1.1	0.8
Included Upstream TMDL Allocation	0	0	0	0	0
Subwatershed % Reduction Required	No Data	89.9%	84.1%	No Data	No Data
LA (Non-Point Allocation)	455.50	31.18	10.85	5.13	3.83
Allowance for Future Growth (%)	4%	4%	4%	4%	4%
Allowance for Future Growth	22.78	1.57	0.55	0.26	0.20
WLA (NPDES Point/MS4 permits)	0.14	0.14	0.14	0.14	0.14
TMDL minus (MOS + Future Growth)	**455.65**	**31.32**	**11.00**	**5.28**	**3.97**

Table D-24. *E. coli* wasteload allocations for the 05030103-01-02 12-digit HUC.

Regulated point source requirements	NPDES OEPA ID	Exist Flow Avg MGD	Dgn Flow Avg MGD	Conc Limit cfu/100mL	WLA billion/day
Stark County Village Green Allot STP	3PG00087	0.0275	0.0200	126.0	0.10
Trilogy Alliance	3IN00347	0.0180	0.0000	0.0	0.00
Washington Elementary School	3PT00101	0.0050	0.0080	161.0	0.05
Marlington Local Schools	3PT00045	0.0213	0.0450	126.0	0.21

Table D-25. *E. coli* TMDLs for the 05030103-01-03 12-digit HUC.

Flow Regime TMDL Allocation (billion/day)	Higher Flows	Wet Weather	Mid-Range Summer	Dry Weather	Low
Rec Season Interval	0-5%	5-40%	40-80%	80-95%	95-100%
N01S12 - Mahoning River (RM 84.99)					
Samples Collected		3	2		
Sample Median Load		634	77		
NPDES Point Source Existing Load	8.57	8.57	8.57	8.57	8.57
Margin of Safety (%)	20%	20%	20%	20%	20%
Margin of Safety (Load)	471.3	32.4	11.4	5.5	4.1
Included Upstream TMDL Allocation	0	0	0	0	0
Subwatershed % Reduction Required	No Data	74.5%	26.0%	No Data	No Data
LA (Non-Point Allocation)	2,348.11	153.41	48.30	18.73	11.90
Allowance for Future Growth (%)	4%	4%	4%	4%	4%
Allowance for Future Growth	117.83	8.10	2.84	1.37	1.02
WLA (NPDES Point/MS4 permits)	8.57	8.57	8.57	8.57	8.57
TMDL minus (MOS + Future Growth)	2356.68	161.98	56.87	27.30	20.47

Table D-26. *E. coli* wasteload allocations for the 05030103-01-03 12-digit HUC.

Regulated point source requirements	NPDES OEPA ID	Exist Flow Avg MGD	Dgn Flow Avg MGD	Conc Limit cfu/100mL	WLA billion/day
Paradise Lake Park Campground	3PR00325	0.0200	0.0200	161.0	0.12
Timashamie Family Campground	3PR00305	0.0039	0.0250	161.0	0.15
Knox Elementary School - West Branch	3PT00123	0.0019	0.0070	126.0	0.03
Sebring WTP	3IV00182	0.0487	0.0500	0.0	0.00
West Branch Nursing Home LLC	3PR00458	0.0118	0.0118	126.0	0.06
Damascus WWTP	3PA00037	0.0547	0.0080	126.0	0.04
Country Squire Estates Ltd	3PV00130	0.0300	0.0100	126.0	0.05
Beloit WWTP	3PB00005	0.0689	0.1900	126.0	0.91
Tecumseh Village MHP	3PV00023	0.0019	0.0125	126.0	0.06
Sebring Landfill Facility	3IN00351	0.0180	0.0000	0.0	0.00
BP Amoco Oil Corp Bulk Plant Alliance	3IN00287	0.0009	0.0000	0.0	0.00
Sebring WWTP	3PC00011	0.7469	1.5000	126.0	7.15
Central Waste Inc	3IN00313	0.0045	0.0000	0.0	0.00
Alliance Tubular Products Co	3ID00043	1.7000	0.0694	0.0	0.00

D2.1.2 *E. coli* TMDLs - Deer Creek-Mahoning River (05030103-02)

TMDLs were developed in these four 12-digt HUCs for bacteria (*E. coli*), sediment and habitat (QHEI), and nutrients (total phosphorus). The results are presented for the applicable assessment units (i.e., 12-digit HUCs) in the following sub-sections.

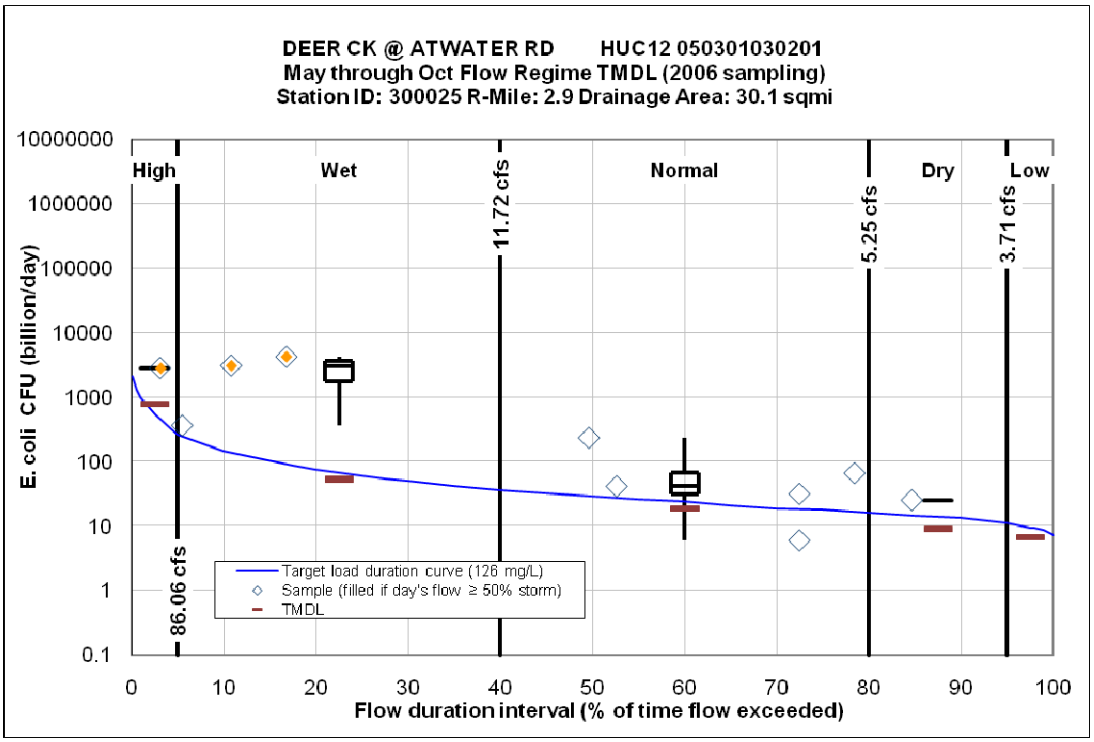

Figure D-22. Load duration curve for *E. coli* bacteria at sample location N01S12 on Deer Cr. (RM 2.90) within the 02-01 twelve digit HUC.

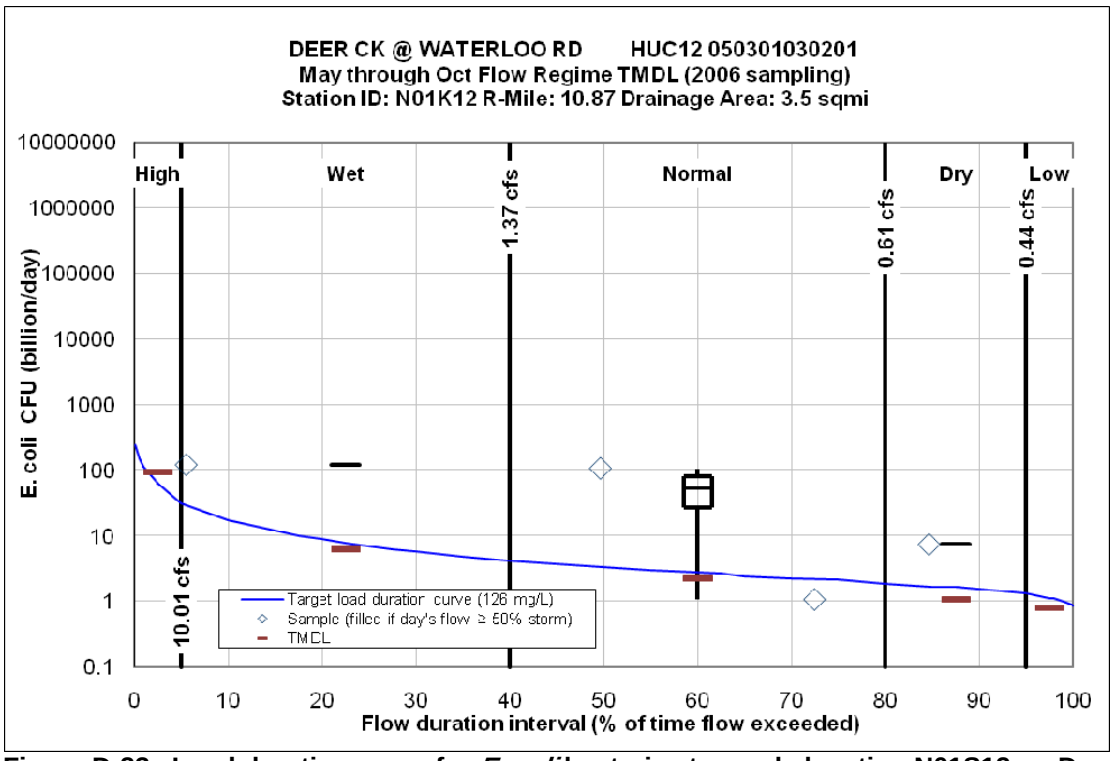

Figure D-23. Load duration curve for *E. coli* bacteria at sample location N01S12 on Deer Cr. (RM 10.87) within the 02-01 twelve digit HUC.

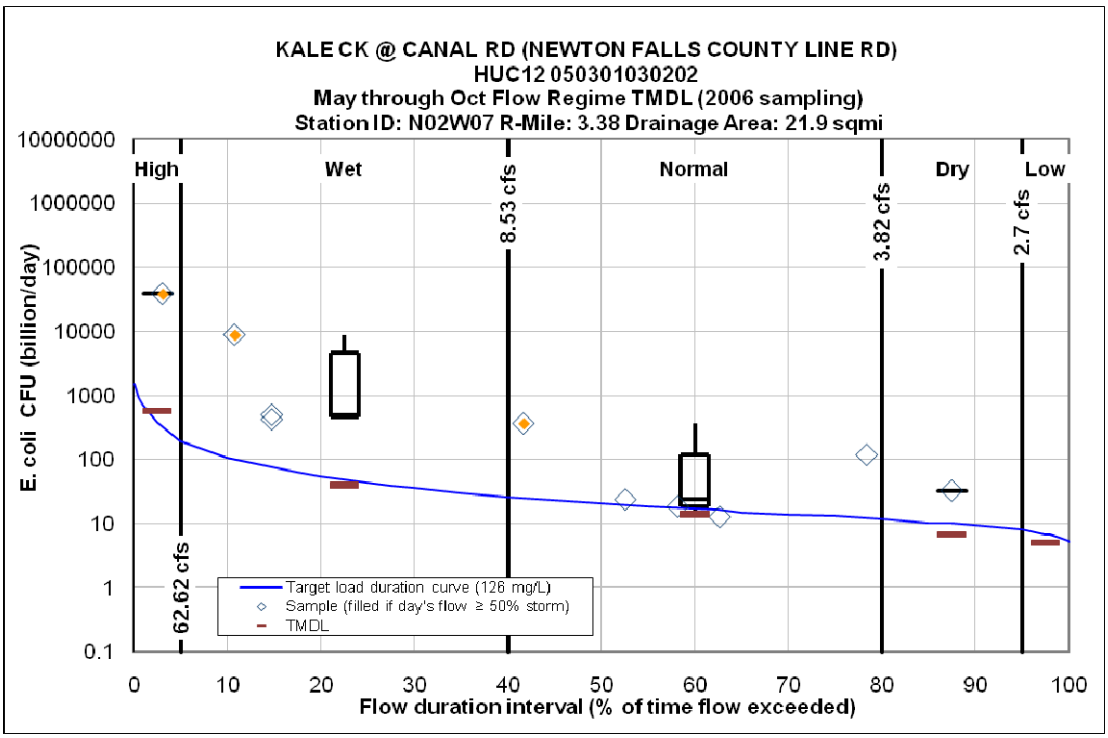

Figure D-24. Load duration curve for *E. coli* bacteria at sample location N02W07 on Kale Cr. (RM 3.38) within the 02-02 twelve digit HUC.

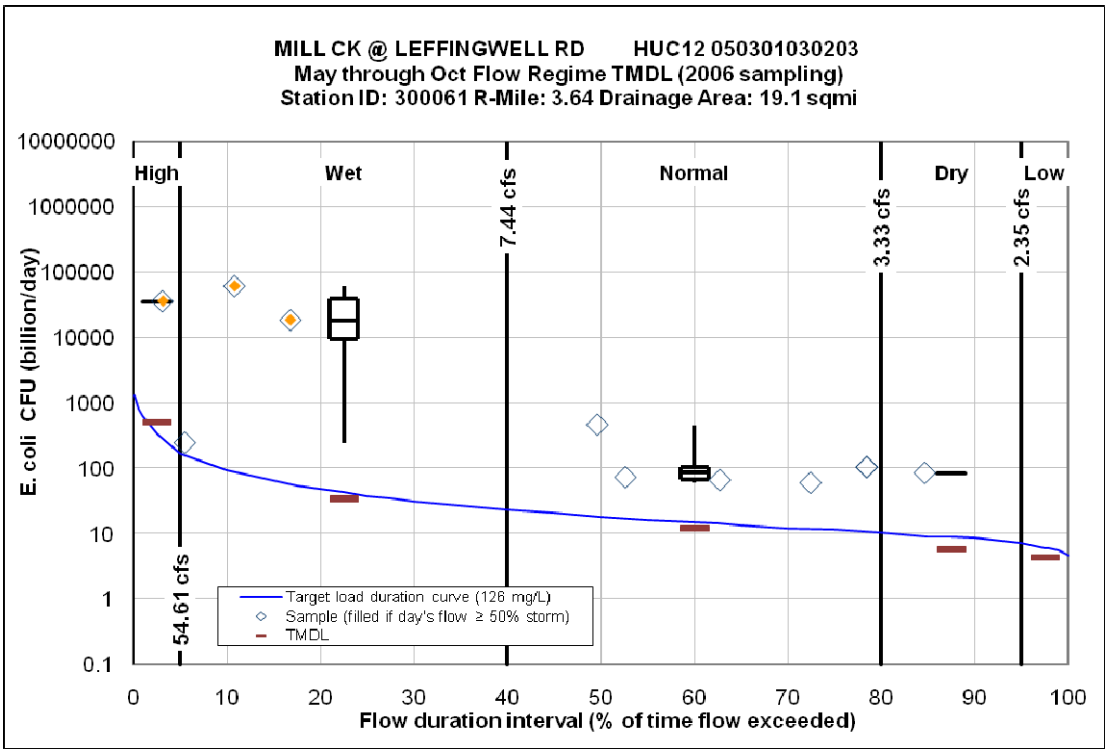

Figure D-25. Load duration curve for *E. coli* bacteria at sample location 300061 on Mill Cr. (RM 3.64) within the 02-03 twelve digit HUC.

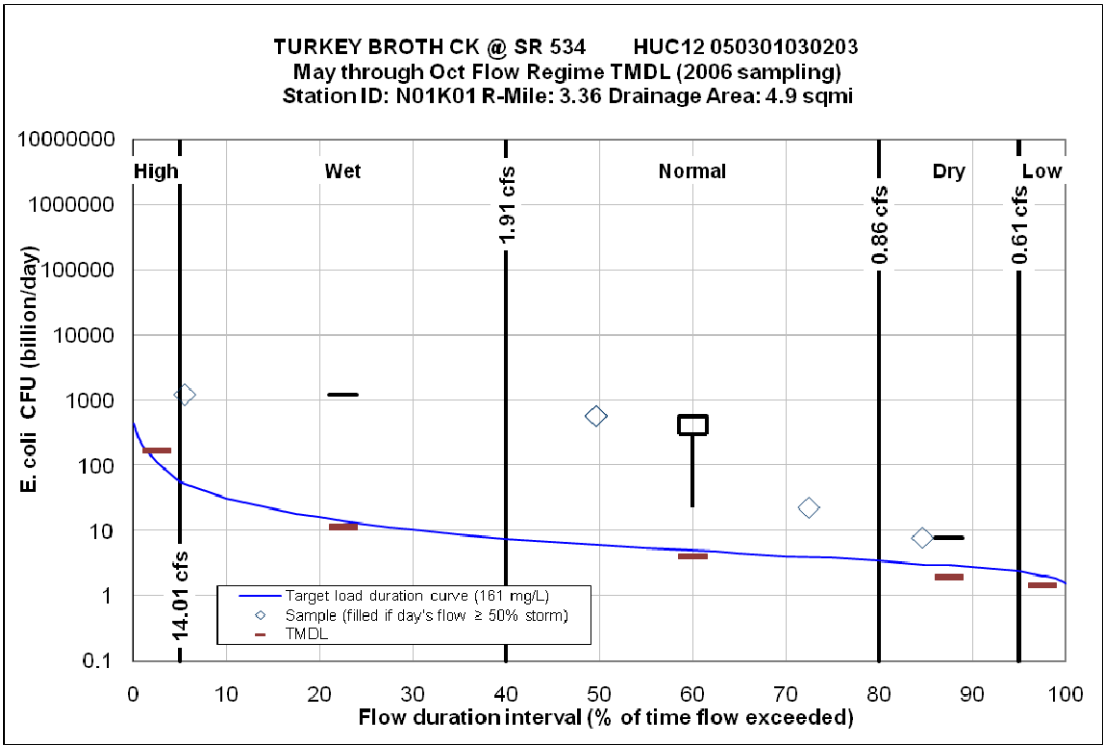

Figure D-26. Load duration curve for *E. coli* bacteria at sample location N01K01 on Turkey Broth Cr. (RM 3.36) within the 02-03 twelve digit HUC.

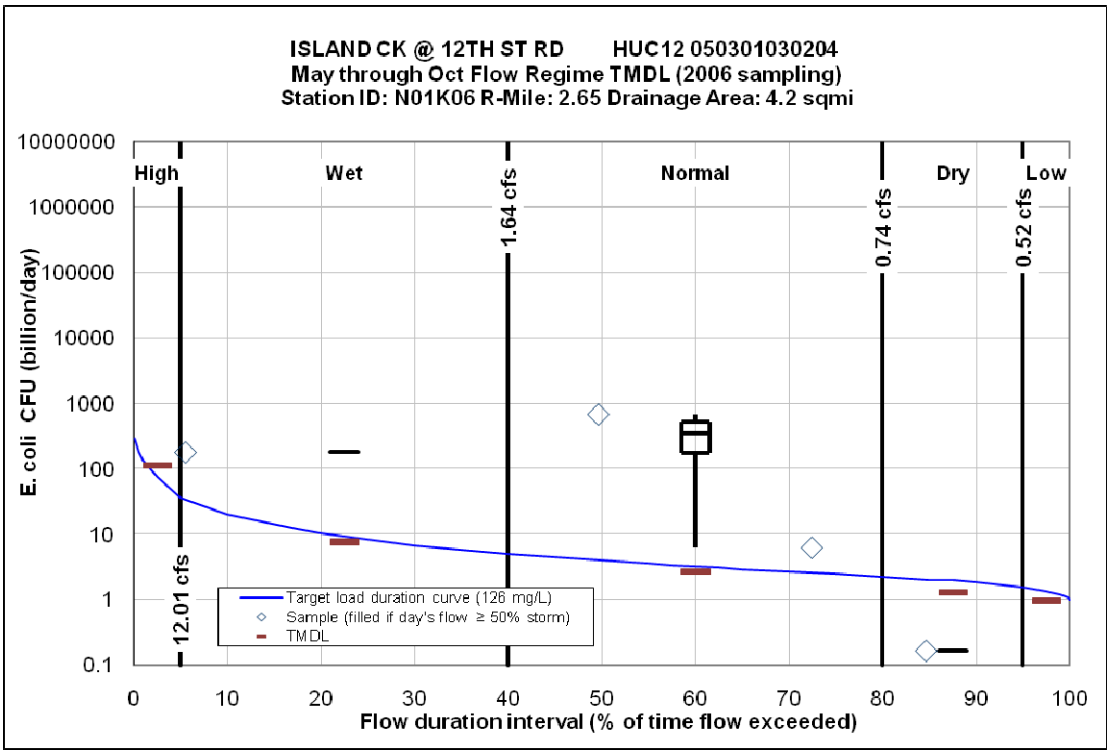

Figure D-27. Load duration curve for *E. coli* bacteria at sample location N01K06 on Island Cr. (RM2.65) within the 02-04 twelve digit HUC.

Table D-27. *E. coli* TMDLs for the 05030103-02-01 12-digit HUC.

Flow Regime TMDL Allocation (billion/day)	Higher Flows	Wet Weather	Mid-Range Summer	Dry Weather	Low
Rec Season Interval	0-5%	5-40%	40-80%	80-95%	95-100%
300025 - Deer Cr. (RM 2.90)					
Samples Collected	1	3	5	1	
Sample Median Load	2,819	3,085	42	25.4	
NPDES Point Source Existing Load	1.11	1.11	1.11	1.11	1.11
Margin of Safety (%)	20%	20%	20%	20%	20%
Margin of Safety (Load)	157.6	10.8	3.8	1.8	1.4
Included Upstream TMDL Allocation	0	0	0	0	0
Subwatershed % Reduction Required	72.0%	98.2%	54.2%	63.9%	No Data
LA (Non-Point Allocation)	787.07	53.07	17.93	8.04	5.75
Allowance for Future Growth (%)	4%	4%	4%	4%	4%
Allowance for Future Growth	39.41	2.71	0.95	0.46	0.34
WLA (NPDES Point/MS4 permits)	1.11	1.11	1.11	1.11	1.11
TMDL minus (MOS + Future Growth)	788.18	54.18	19.04	9.15	6.86
N01K12 - Deer Cr. (RM 10.87)					
Samples Collected		1	2	1	
Sample Median Load		120	54	7.4	
NPDES Point Source Existing Load	0.00	0.00	0.00	0.00	0.00
Margin of Safety (%)	20%	20%	20%	20%	20%
Margin of Safety (Load)	18.3	1.3	0.4	0.2	0.2
Included Upstream TMDL Allocation	0	0	0	0	0
Subwatershed % Reduction Required	No Data	94.7%	95.9%	85.4%	No Data
LA (Non-Point Allocation)	91.67	6.31	2.22	1.09	0.81
Allowance for Future Growth (%)	4%	4%	4%	4%	4%
Allowance for Future Growth	4.58	0.32	0.11	0.05	0.04
WLA (NPDES Point/MS4 permits)	0.00	0.00	0.00	0.00	0.00
TMDL minus (MOS + Future Growth)	91.67	6.31	2.22	1.09	0.81

Table D-28. *E. coli* wasteload allocations for the 05030103-02-01 12-digit HUC.

Regulated point source requirements	NPDES OEPA ID	Exist Flow Avg MGD	Dgn Flow Avg MGD	Conc Limit 0.0001	WLA 0
Pelican Grove Campground	3PR00373	0.0006	0.0008	126	0.004
Buckeye Packaging Co Inc	3PR00259	0.0013	0.0035	161	0.021
Custom Poly Bag Inc	3PR00389	0.0016	0.0015	161	0.009
Atwater WWTP	3PH00033	0.1074	0.2000	126	0.954
Waterloo K-12 Campus	3PT00079	0.0058	0.0200	161	0.122
Evrol LLC Atwater Terminal	3IG00025	0.0001	0.0001	0	0

Table D-29. *E. coli* TMDLs for the 05030103-02-02 12-digit HUC.

Flow Regime TMDL Allocation (billion/day)	Higher Flows	Wet Weather	Mid-Range Summer	Dry Weather	Low
Rec Season Interval	0-5%	5-40%	40-80%	80-95%	95-100%
300062 - Kale Cr. (RM 3.38)					
Samples Collected	1	5	5	2	
Sample Median Load	4,551	975	27	28.6	
NPDES Point Source Existing Load	0.00	0.00	0.00	0.00	0.00
Margin of Safety (%)	20%	20%	20%	20%	20%
Margin of Safety (Load)	37.7	2.6	0.9	0.4	0.3
Included Upstream TMDL Allocation	0	0	0	0	0
Subwatershed % Reduction Required	95.9%	98.7%	82.9%	92.3%	No Data
LA (Non-Point Allocation)	188.54	12.97	4.56	2.19	1.65
Allowance for Future Growth (%)	4%	4%	4%	4%	4%
Allowance for Future Growth	9.43	0.65	0.23	0.11	0.08
WLA (NPDES Point/MS4 permits)	-	-	-	-	-
TMDL minus (MOS + Future Growth)	188.54	12.97	4.56	2.19	1.65

Table D-30. *E. coli* TMDLs for the 05030103-02-03 12-digit HUC.

Flow Regime TMDL Allocation (billion/day)	Higher Flows	Wet Weather	Mid-Range Summer	Dry Weather	Low
Rec Season Interval	0-5%	5-40%	40-80%	80-95%	95-100%
300061 - Mill Cr. (RM 3.38)					
Samples Collected	1	3	6	1	
Sample Median Load	35,775	18,385	88	84.3	
NPDES Point Source Existing Load	0.00	0.00	0.00	0.00	0.00
Margin of Safety (%)	20%	20%	20%	20%	20%
Margin of Safety (Load)	100.0	6.9	2.4	1.2	0.9
Included Upstream TMDL Allocation	0	0	0	0	0
Subwatershed % Reduction Required	98.6%	99.8%	86.2%	93.1%	No Data
LA (Non-Point Allocation)	500.16	34.38	12.08	5.80	4.37
Allowance for Future Growth (%)	4%	4%	4%	4%	4%
Allowance for Future Growth	25.01	1.72	0.60	0.29	0.22
WLA (NPDES Point/MS4 permits)	-	-	-	-	-
TMDL minus (MOS + Future Growth)	500.16	34.38	12.08	5.80	4.37
N01K01 - Turkey Broth Cr. (RM 3.36)					
Samples Collected		1	3	1	
Sample Median Load		1,218	571	7.7	
NPDES Point Source Existing Load	0.15	0.15	0.15	0.15	0.15
Margin of Safety (%)	20%	20%	20%	20%	20%
Margin of Safety (Load)	32.8	2.3	0.8	0.4	0.3
Included Upstream TMDL Allocation	0	0	0	0	0
Subwatershed % Reduction Required	No Data	99.1%	99.3%	74.9%	No Data
LA (Non-Point Allocation)	163.81	11.13	3.82	1.78	1.30
Allowance for Future Growth (%)	4%	4%	4%	4%	4%
Allowance for Future Growth	8.20	0.56	0.20	0.10	0.07
WLA (NPDES Point/MS4 permits)	0.15	0.15	0.15	0.15	0.15
TMDL minus (MOS + Future Growth)	163.96	11.28	3.97	1.92	1.45

Table D-31. *E. coli* wasteload allocations for the 05030103-02-03 12-digit HUC.

Regulated point source requirements	NPDES OEPA ID	Exist Flow Avg MGD	Dgn Flow Avg MGD	Conc Limit	WLA
Western Reserve High School	3PT00143	0.0019	0	161.000	0.146268

Table D-32. *E. coli* TMDLs for the 05030103-02-04 12-digit HUC.

Flow Regime TMDL Allocation (billion/day)	Higher Flows	Wet Weather	Mid-Range Summer	Dry Weather	Low
Rec Season Interval	0-5%	5-40%	40-80%	80-95%	95-100%
N01K06 - Island Cr. (RM 2.65)					
Samples Collected		1	2	1	
Sample Median Load		181	346	0.2	
NPDES Point Source Existing Load	0.00	0.00	0.00	0.00	0.00
Margin of Safety (%)	20%	20%	20%	20%	20%
Margin of Safety (Load)	22.0	1.5	0.5	0.3	0.2
Included Upstream TMDL Allocation	0	0	0	0	0
Subwatershed % Reduction Required	No Data	95.8%	99.2%	None	No Data
LA (Non-Point Allocation)	109.99	7.57	2.66	1.28	0.96
Allowance for Future Growth (%)	4%	4%	4%	4%	4%
Allowance for Future Growth	5.50	0.38	0.13	0.06	0.05
WLA (NPDES Point/MS4 permits)	-	-	-	-	-
TMDL minus (MOS + Future Growth)	109.99	7.57	2.66	1.28	0.96

D2.1.3 *E. coli* TMDLs - West Branch Mahoning River-Mahoning River (05030103-03)

TMDLs were developed in these six 12-digt HUCs for bacteria (*E. coli*), sediment and habitat (QHEI), and nutrients (total phosphorus). The results are presented for the applicable assessment units (i.e., 12-digit HUCs) in the following sub-sections.

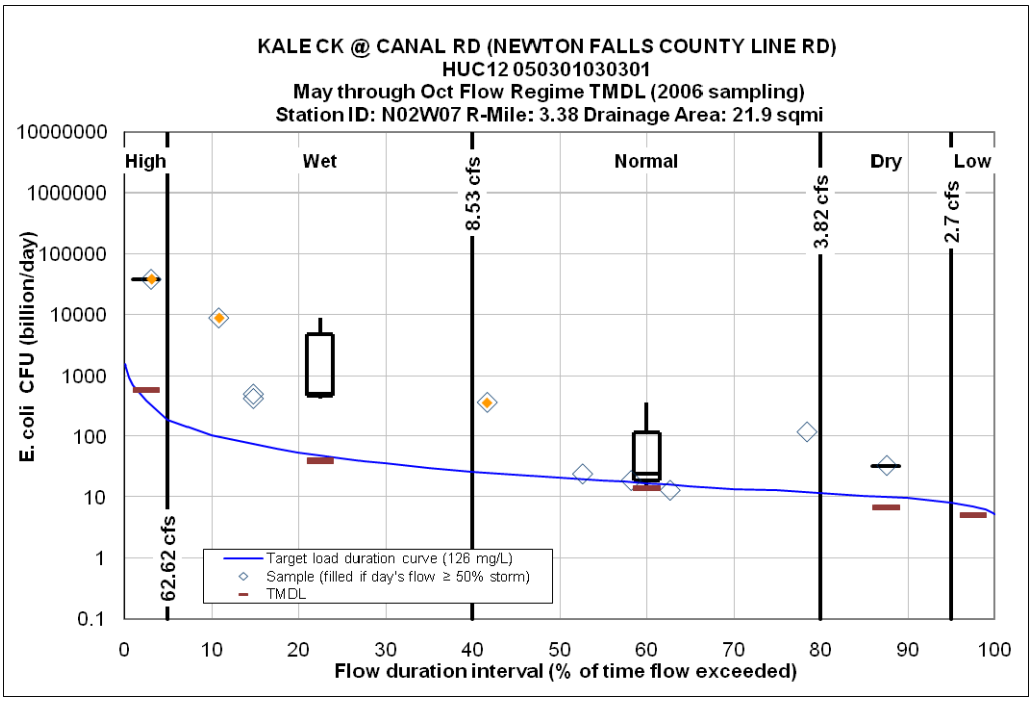

Figure D-28. Load duration curve for *E. coli* bacteria at sample location N02W07 on Kale Cr. (RM 3.38) within the 03-01 twelve digit HUC.

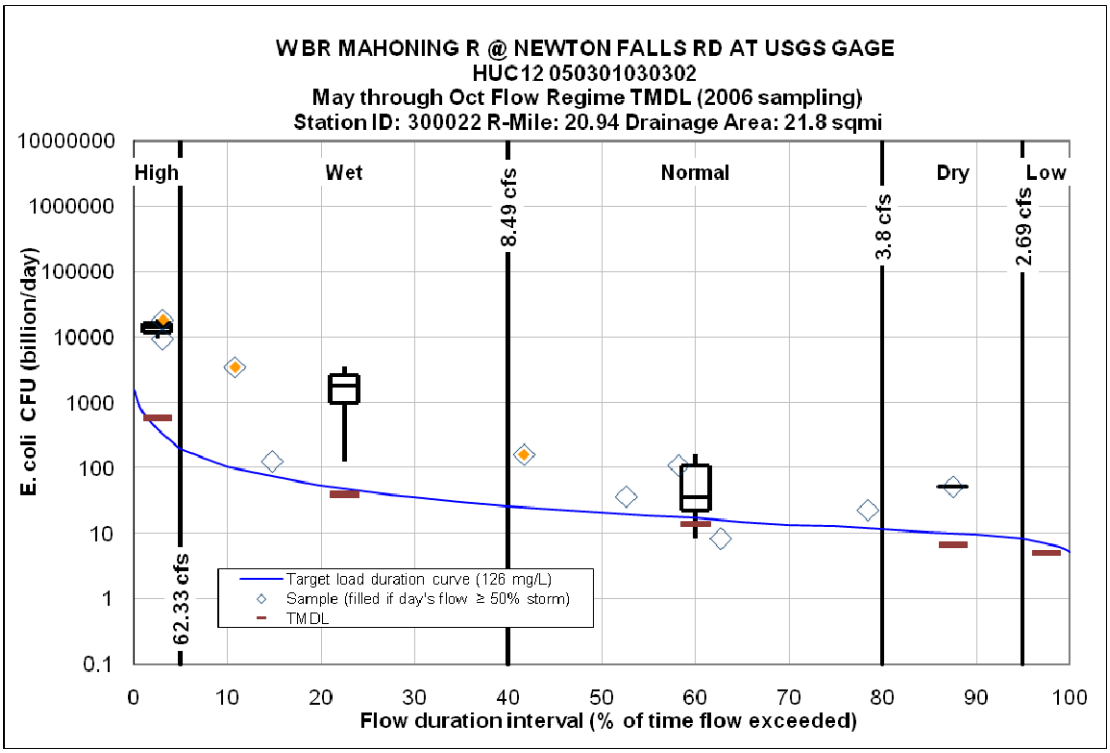

Figure D-29. Load duration curve for *E. coli* bacteria at sample location 300022 on West Branch Mahoning River (RM 20.94) within the 03-02 twelve digit HUC.

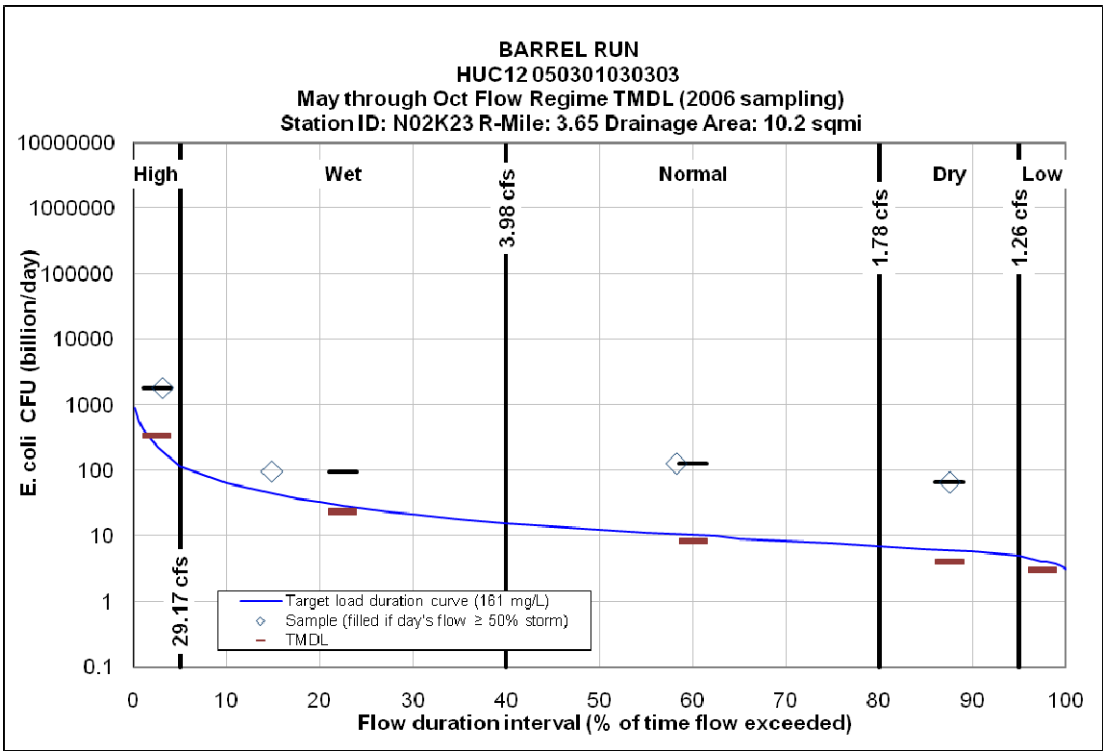

Figure D-30. Load duration curve for *E. coli* bacteria at sample location N02K23 on Barrel Run (RM 3.65) within the 03-03 twelve digit HUC.

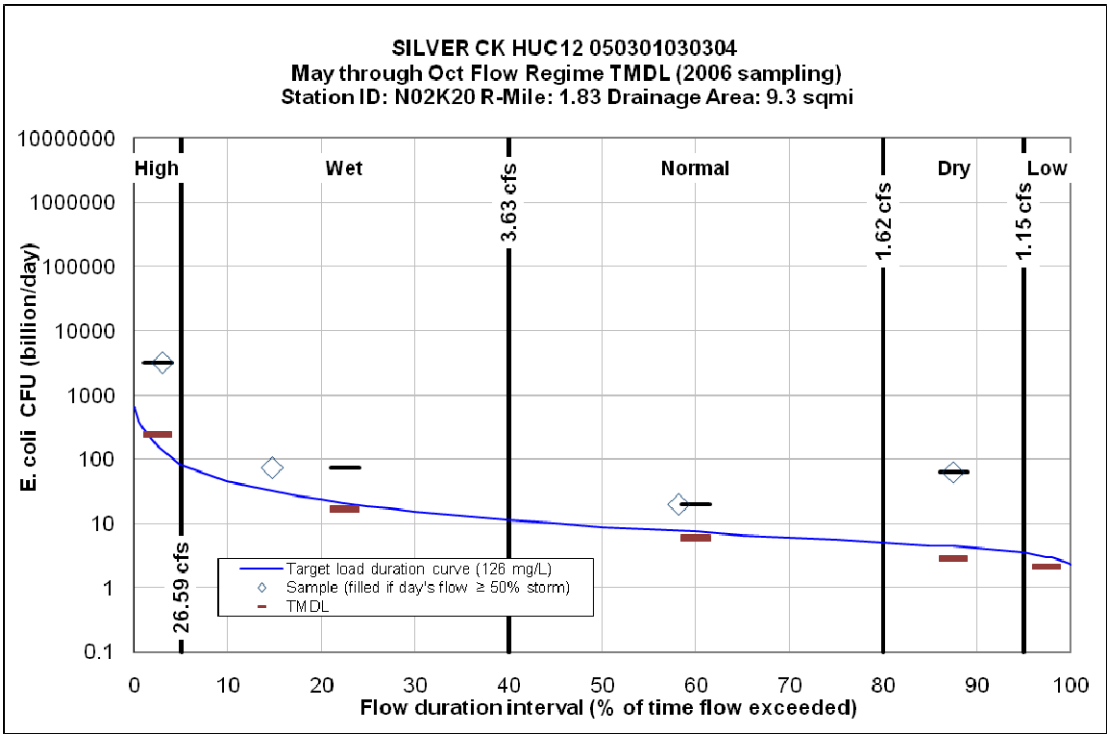

Figure D-31. Load duration curve for *E. coli* bacteria at sample location N02K20 on Silver Cr. (RM 1.83) within the 03-04 twelve digit HUC.

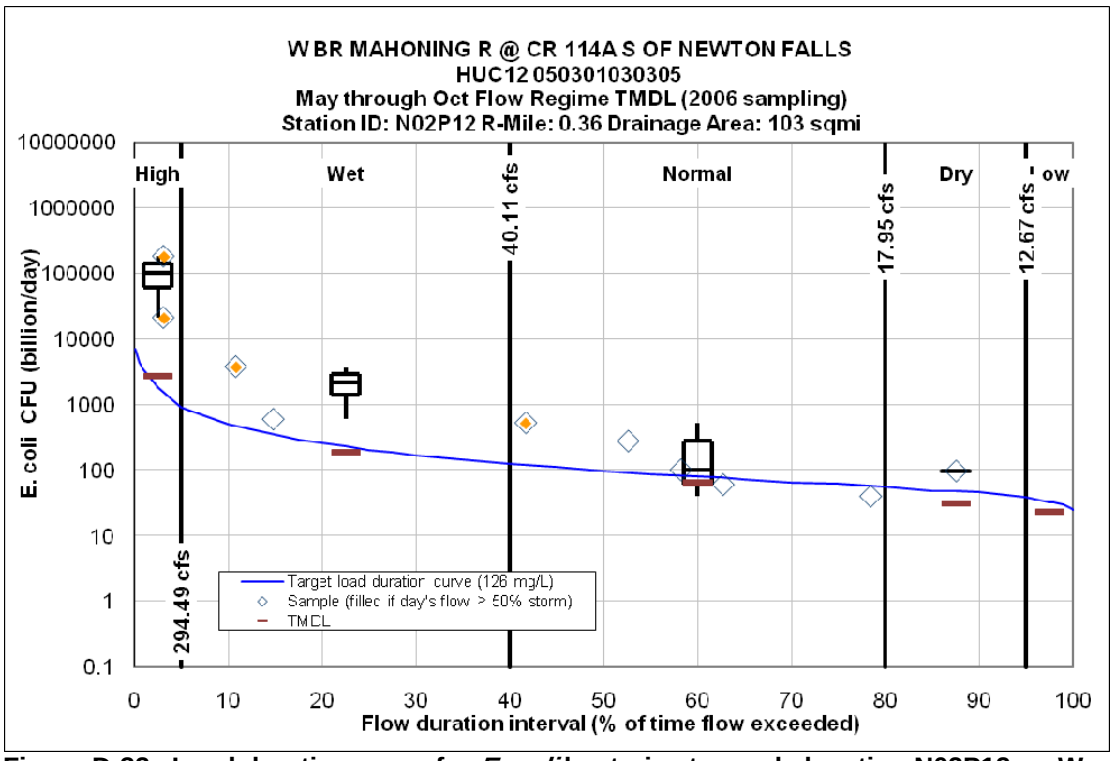

Figure D-32. Load duration curve for *E. coli* bacteria at sample location N02P12 on West Branch Mahoning River (RM 0.36) within the 03-05 twelve digit HUC.

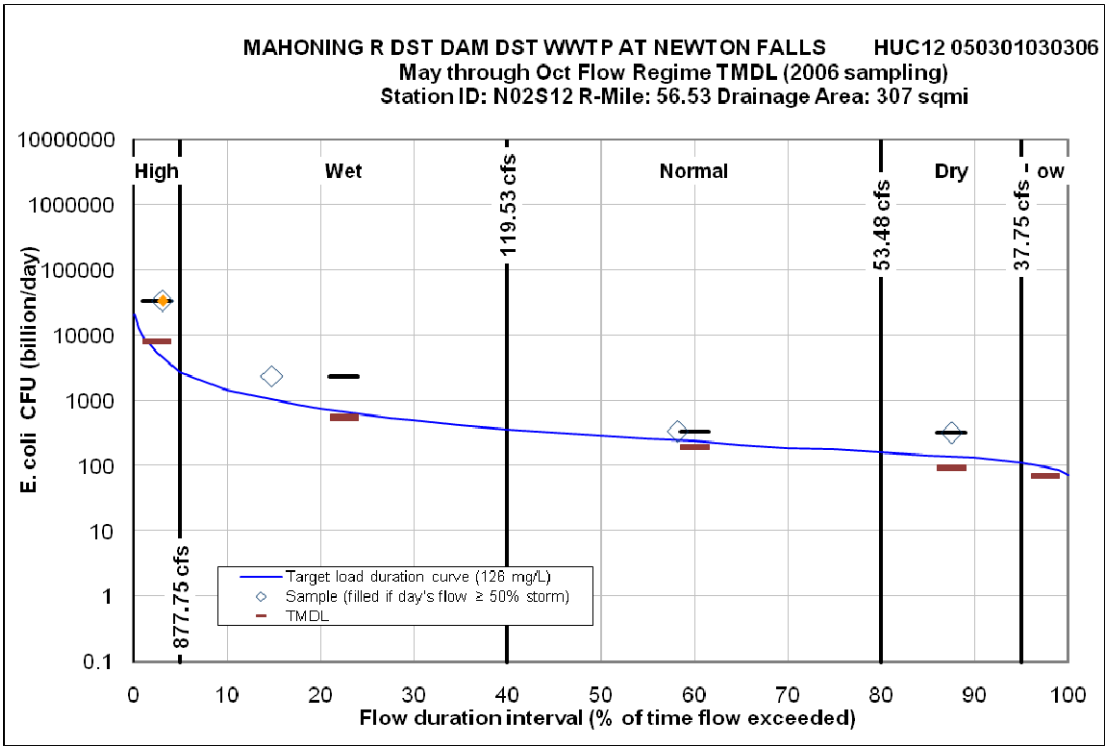

Figure D-33. Load duration curve for *E. coli* bacteria at sample location N02S12 on Mahoning River (RM 56.53) within the 03-06 twelve digit HUC.

Table D-33. *E. coli* TMDLs for the 05030103-03-01 12-digit HUC.

Flow Regime TMDL Allocation (billion/day)	Higher Flows	Wet Weather	Mid-Range Summer	Dry Weather	Low
Rec Season Interval	0-5%	5-40%	40-80%	80-95%	95-100%
N02W07 - Island Cr. (RM 2.65)					
Samples Collected	1	3	5	1	
Sample Median Load	38,456	501	24	32.9	
NPDES Point Source Existing Load	0.01	0.01	0.01	0.01	0.01
Margin of Safety (%)	20%	20%	20%	20%	20%
Margin of Safety (Load)	114.7	7.9	2.8	1.3	1.0
Included Upstream TMDL Allocation	0	0	0	0	0
Subwatershed % Reduction Required	98.5%	92.1%	42.1%	79.8%	No Data
LA (Non-Point Allocation)	573.47	39.42	13.82	6.65	4.97
Allowance for Future Growth (%)	4%	4%	4%	4%	4%
Allowance for Future Growth	28.67	1.97	0.69	0.33	0.25
WLA (NPDES Point/MS4 permits)	0.01	0.01	0.01	0.01	0.01
TMDL minus (MOS + Future Growth)	573.48	39.43	13.84	6.66	4.98

Table D-34. *E. coli* wasteload allocations for the 05030103-03-01 12-digit HUC.

Regulated point source requirements	NPDES OEPA ID	Exist Flow Avg MGD	Dgn Flow Avg MGD	Conc Limit	WLA
Nemenz Little Village Shoppe Inc	3PR00190	0	0.003	126	0.012067

Table D-35. *E. coli* TMDLs for the 05030103-03-02 12-digit HUC.

Flow Regime TMDL Allocation (billion/day)	Higher Flows	Wet Weather	Mid-Range Summer	Dry Weather	Low
Rec Season Interval	0-5%	5-40%	40-80%	80-95%	95-100%
300022 - Headwaters West Branch Mahoning River (RM 20.94)					
Samples Collected	2	2	5	1	
Sample Median Load	14,017	1,818	36	51.6	
NPDES Point Source Existing Load	0.00	0.00	0.00	0.00	0.00
Margin of Safety (%)	20%	20%	20%	20%	20%
Margin of Safety (Load)	114.2	7.8	2.8	1.3	1.0
Included Upstream TMDL Allocation	0	0	0	0	0
Subwatershed % Reduction Required	95.9%	97.8%	62.2%	87.2%	No Data
LA (Non-Point Allocation)	570.84	39.24	13.79	6.63	4.98
Allowance for Future Growth (%)	4%	4%	4%	4%	4%
Allowance for Future Growth	28.54	1.96	0.69	0.33	0.25
WLA (NPDES Point/MS4 permits)	-	-	-	-	-
TMDL minus (MOS + Future Growth)	570.84	39.24	13.79	6.63	4.98

Table D-36. *E. coli* TMDLs for the 05030103-03-03 12-digit HUC.

Flow Regime TMDL Allocation (billion/day)	Higher Flows	Wet Weather	Mid-Range Summer	Dry Weather	Low
Rec Season Interval	0-5%	5-40%	40-80%	80-95%	95-100%
N02K23 - Barrel Run (RM 3.65)					
Samples Collected	1	1	1	1	
Sample Median Load	1,833	96	126	65.2	
NPDES Point Source Existing Load	0.00	0.00	0.00	0.00	0.00
Margin of Safety (%)	20%	20%	20%	20%	20%
Margin of Safety (Load)	68.3	4.7	1.7	0.8	0.6
Included Upstream TMDL Allocation	0	0	0	0	0
Subwatershed % Reduction Required	81.4%	75.5%	93.5%	93.9%	No Data
LA (Non-Point Allocation)	341.31	23.48	8.26	3.97	2.99
Allowance for Future Growth (%)	4%	4%	4%	4%	4%
Allowance for Future Growth	17.07	1.17	0.41	0.20	0.15
WLA (NPDES Point/MS4 permits)	-	-	-	-	-
TMDL minus (MOS + Future Growth)	341.31	23.48	8.26	3.97	2.99

Table D-37. *E. coli* TMDLs for the 05030103-03-04 12-digit HUC.

Flow Regime TMDL Allocation (billion/day)	Higher Flows	Wet Weather	Mid-Range Summer	Dry Weather	Low
Rec Season Interval	0-5%	5-40%	40-80%	80-95%	95-100%
N02K20 - Silver Cr. (RM 1.83)					
Samples Collected	1	1	1	1	
Sample Median Load	3,232	74	20	62.9	
NPDES Point Source Existing Load	0.39	0.39	0.39	0.39	0.39
Margin of Safety (%)	20%	20%	20%	20%	20%
Margin of Safety (Load)	48.7	3.3	1.2	0.6	0.4
Included Upstream TMDL Allocation	0	0	0	0	0
Subwatershed % Reduction Required	92.5%	77.5%	70.5%	95.5%	No Data
LA (Non-Point Allocation)	243.14	16.36	5.51	2.45	1.73
Allowance for Future Growth (%)	4%	4%	4%	4%	4%
Allowance for Future Growth	12.18	0.84	0.29	0.14	0.11
WLA (NPDES Point/MS4 permits)	0.39	0.39	0.39	0.39	0.39
TMDL minus (MOS + Future Growth)	243.53	16.75	5.89	2.84	2.12

Table D-38. *E. coli* wasteload allocations for the 05030103-03-04 12-digit HUC.

Regulated point source requirements	NPDES OEPA ID	Exist Flow Avg MGD	Dgn Flow Avg MGD	Conc Limit	WLA
ODOT Rest Area 04-35 WWTP	3PP00033	0.0037	0.0200	126	0.095
Southeast High School	3PT00016	0.0153	0.0500	126	0.238
The Diamond Lodge	3PR00505	0.0100	0.0100	126	0.048
Gionino's Pizza	3PR00390	0.0002	0.0015	126	0.007

Table D-39. *E. coli* TMDLs for the 05030103-03-05 12-digit HUC.

Flow Regime TMDL Allocation (billion/day)	Higher Flows	Wet Weather	Mid-Range Summer	Dry Weather	Low
Rec Season Interval	0-5%	5-40%	40-80%	80-95%	95-100%
N02P12 - West Branch Mahoning River (RM 0.36)					
Samples Collected	2	2	5	1	
Sample Median Load	100,923	2,183	101	96.8	
NPDES Point Source Existing Load	1.57	1.57	1.57	1.57	1.57
Margin of Safety (%)	20%	20%	20%	20%	20%
Margin of Safety (Load)	539.4	37.1	13.0	6.2	4.7
Included Upstream TMDL Allocation	0	0	0	0	0
Subwatershed % Reduction Required	97.3%	91.5%	35.4%	67.7%	No Data
LA (Non-Point Allocation)	2,695.51	183.81	63.51	29.67	21.86
Allowance for Future Growth (%)	4%	4%	4%	4%	4%
Allowance for Future Growth	134.85	9.27	3.25	1.56	1.17
WLA (NPDES Point/MS4 permits)	1.57	1.57	1.57	1.57	1.57
TMDL minus (MOS + Future Growth)	2697.08	185.38	65.08	31.25	23.43

Table D-40. *E. coli* wasteload allocations for the 05030103-03-05 12-digit HUC.

Regulated point source requirements	NPDES OEPA ID	Exist Flow Avg MGD	Dgn Flow Avg MGD	Conc Limit	WLA
ODOT Rest Area 04-35 WWTP	3PP00033	0.0037	0.020	126	0.095
Southeast High School	3PT00016	0.0153	0.050	126	0.238
The Diamond Lodge	3PR00505	0.0100	0.010	126	0.048
Gionino's Pizza	3PR00390	0.0002	0.002	126	0.007
Maple Del Manor MHP	3PV00034	0.0267	0.040	126	0.191
Crest Rubber Co	3IR00015	0.1082	0.001	0	0
Countryside Estates	3PG00120	0.0263	0.035	126	0.167
Country Acres Campground 1	3PR00234	0.0027	0.010	126	0.048
Leisure Lake Park	3PR00265	0.8174	0.038	126	0.179
ODNR Beach Area W Branch SP	3PP00010	0.0039	0.100	126	0.477
Arnies West Branch Steak House	3PR00174	0.0008	0.003	126	0.016
Jolly Time MHP	3PV00085	0.0005	0.002	126	0.011
KMV III Ltd DBA Hamlet MHP	3PV00041	0.0164	0.020	126	0.095

Table D-41. *E. coli* TMDLs for the 05030103-03-06 12-digit HUC.

Flow Regime TMDL Allocation (billion/day)	Higher Flows	Wet Weather	Mid-Range Summer	Dry Weather	Low
Rec Season Interval	0-5%	5-40%	40-80%	80-95%	95-100%
N02S12 - Mahoning River (RM 56.53)					
Samples Collected	1	1	1	1	
Sample Median Load	34,210	2,370	340	323.2	
NPDES Point Source Existing Load	58.62	58.62	58.62	58.62	58.62
Margin of Safety (%)	20%	20%	20%	20%	20%
Margin of Safety (Load)	1607.8	110.5	38.8	18.6	14.0
Included Upstream TMDL Allocation	0	0	0	0	0
Subwatershed % Reduction Required	76.5%	76.7%	43.0%	71.2%	No Data
LA (Non-Point Allocation)	7,980.23	493.89	135.31	34.47	11.19
Allowance for Future Growth (%)	4%	4%	4%	4%	4%
Allowance for Future Growth	401.94	27.63	9.70	4.65	3.49
WLA (NPDES Point/MS4 permits)	58.62	58.62	58.62	58.62	58.62
TMDL minus (MOS + Future Growth)	8038.85	552.52	193.94	93.10	69.82

Table D-42. *E. coli* wasteload allocations for the 05030103-03-06 12-digit HUC.

Regulated point source requirements	NPDES OEPA ID	Exist Flow Avg MGD	Dgn Flow Avg MGD	Conc Limit	WLA
Alliance WWTP	3PD00000	5.2550	7.5000	126	35.77
Newton Falls STP	3PD00015	1.1084	1.5000	126	7.15
Sebring WWTP	3PC00011	0.7469	1.5000	126	7.15
Craig Beach WWTP	3PH00030	0.5271	1.0000	126	4.77
Atwater WWTP	3PH00033	0.1074	0.2000	126	0.95
Beloit WWTP	3PB00005	0.0689	0.1900	126	0.91
Alliance Tubular Products Co	3ID00043	1.7000	0.0694	0	0.00
Modern Management Solutions DBA All Seasons MHP	3PV00047	0.0353	0.0550	126	0.26
Sebring WTP	3IV00182	0.0487	0.0500	0	0.00
Marlington Local Schools	3PT00045	0.0213	0.0450	126	0.21
US Corp of Engineers Mill Creek R	3PN00000	0.0205	0.0300	126	0.14
Timashamie Family Campground	3PR00305	0.0039	0.0250	161	0.15
Western Reserve High School	3PT00143	0.0019	0.0240	161	0.15
Stark County Village Green Allot STP	3PG00087	0.0275	0.0200	126	0.10
Paradise Lake Park Campground STU	3PR00325	0.0200	0.0200	161	0.12
Waterloo K-12 Campus	3PT00079	0.0058	0.0200	161	0.12
Stark County Village Green Allot STP	3PG00087	0.0275	0.0200	126	0.10
North East Ohio Church of God Campground	3PR00437	0.0140	0.0140	126	0.07
Tecumseh Village MHP	3PV00023	0.0019	0.0125	126	0.06
West Branch Nursing Home LLC	3PR00458	0.0118	0.0118	126	0.06
Country Squire Estates Ltd	3PV00130	0.0300	0.0100	126	0.05
Washington Elementary School	3PT00101	0.0050	0.0080	161	0.05
Damascus WWTP	3PA00037	0.0547	0.0080	126	0.04
Washington Elementary School	3PT00101	0.0050	0.0080	161	0.05

Regulated point source requirements	NPDES OEPA ID	Exist Flow	Dgn Flow Avg MGD	Conc Limit	WLA
Knox Elementary School - West Branch	3PT00123	0.0019	0.0070	126	0.03
Green Acres Campground	3PR00221	0.0027	0.0050	126	0.02
Grace Community Church of Alliance	3PR00451	0.0050	0.0050	126	0.02
Circle Restaurant Inc	3PR00120	0.0014	0.0044	126	0.02
Ben's Restaurant and Bar	3PR00491	0.0037	0.0037	126	0.02
RC Sports Lounge	3PR00323	0.0005	0.0035	126	0.02
Buckeye Packaging Co Inc	3PR00259	0.0013	0.0035	161	0.02
Nemenz Little Village Shoppe Inc	3PR00190	0.0007	0.0025	126	0.01
Nemenz Food Mart	3PR00210	0.0008	0.0015	126	0.01
Custom Poly Bag Inc	3PR00389	0.0016	0.0015	161	0.01
Pelican Grove Campground	3PR00348	0.0006	0.0008	126	0.00
Pelican Grove Campground	3PR00373	0.0006	0.0008	126	0.00
Evrol LLC Atwater Terminal	3IG00025	0.0001	0.0001	0	0.00
Industrial Mining - City Stone	3IJ00067	0.3500	0.0000	0	0.00
Trilogy Alliance	3IN00347	0.0180	0.0000	0	0.00
Sebring Landfill Facility	3IN00351	0.0180	0.0000	0	0.00
BP Amoco Oil Corp Bulk Plant Alliance	3IN00287	0.0009	0.0000	0	0.00
Central Waste Inc	3IN00313	0.0045	0.0000	0	0.00
Trilogy Alliance	3IN00347	0.0180	0.0000	0	0.00
Alliance WWTP	3PD00000	5.2550	7.5000	126	35.77
Newton Falls STP	3PD00015	1.1084	1.5000	126	7.15
Sebring WWTP	3PC00011	0.7469	1.5000	126	7.15

D2.1.4 *E. coli* TMDLs Eagle Creek-Mahoning River (05030103-04)

TMDLs were developed in these six 12-digt HUCs for bacteria (*E. coli*), sediment and habitat (QHEI), and nutrients (total phosphorus). The results are presented for the applicable assessment units (i.e., 12-digit HUCs) in the following sub-sections.

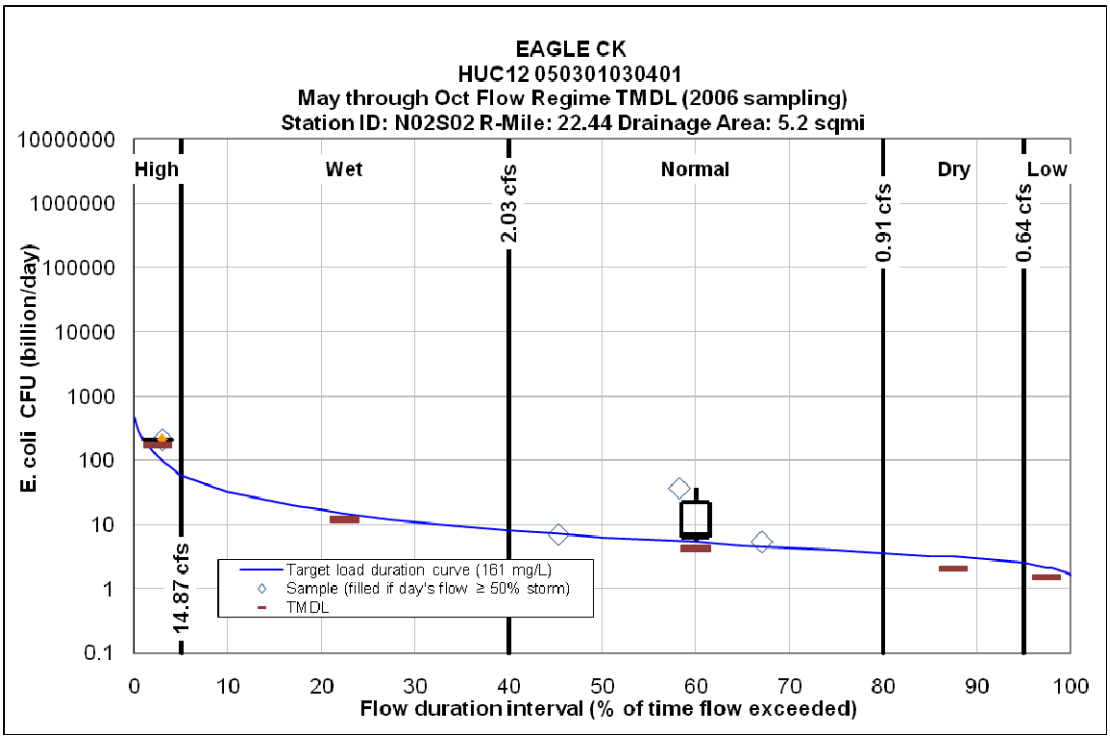

Figure D-34. Load duration curve for *E. coli* bacteria at sample location N02S02 on Eagle Cr. (RM 2.3) within the 04-01 twelve digit HUC.

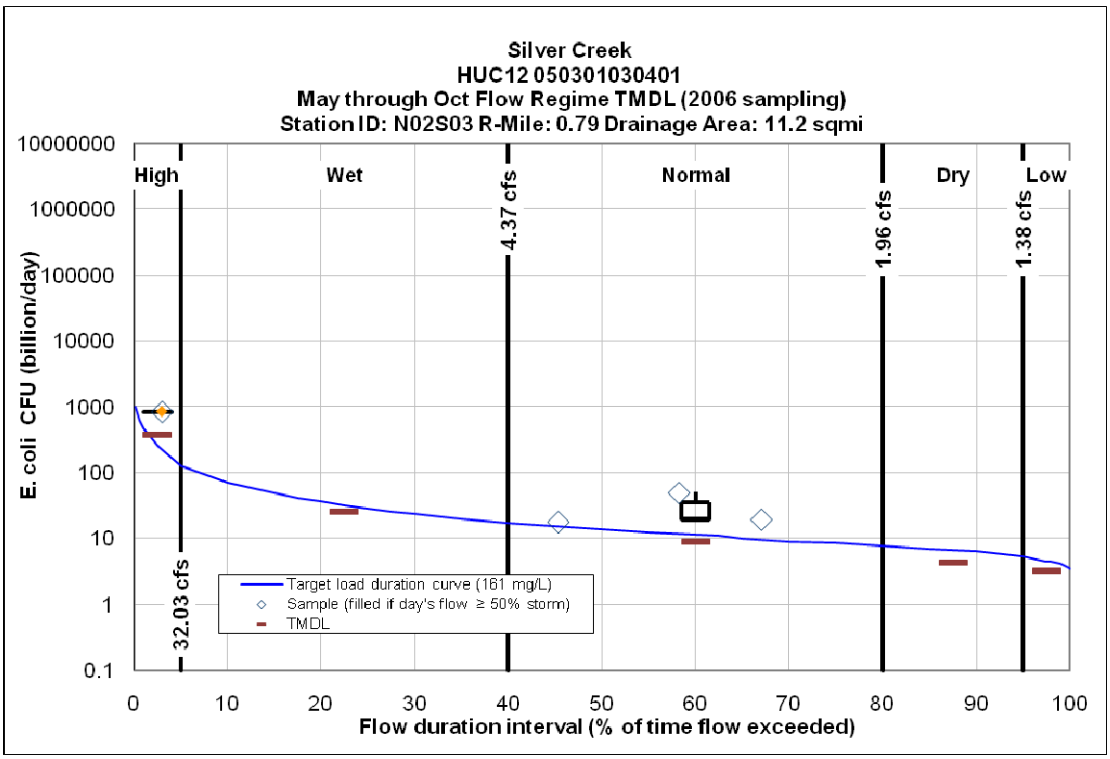

Figure D-35. Load duration curve for *E. coli* bacteria at sample location N02S03 on Silver Cr. (RM 0.79) within the 04-01 twelve digit HUC.

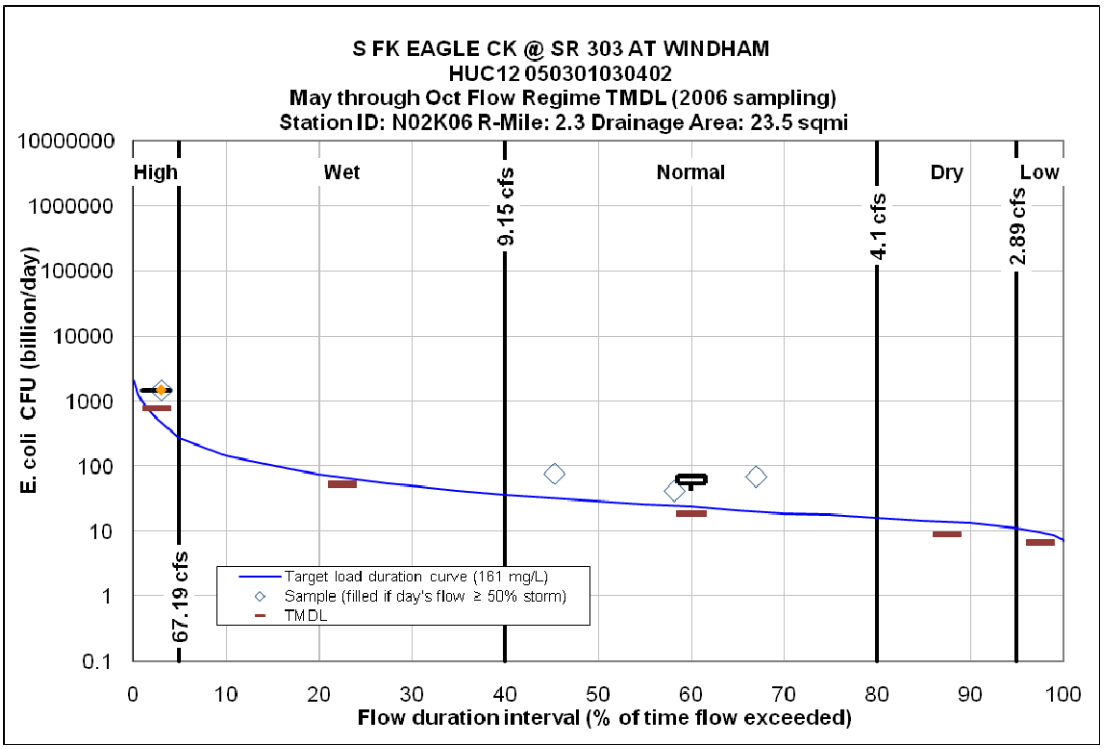

Figure D-36. Load duration curve for *E. coli* bacteria at sample location N02K06 on South Fork Eagle Cr. (RM 2.3) within the 04-02 twelve digit HUC.

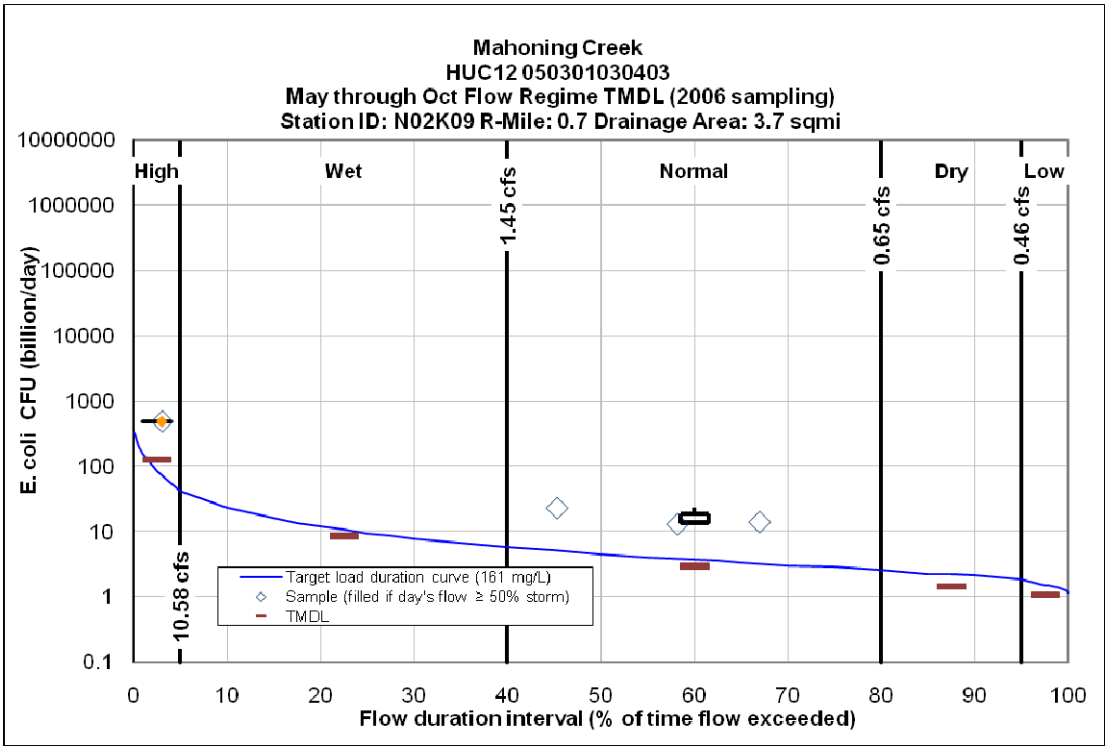

Figure D-37. Load duration curve for *E. coli* bacteria at sample location N02K09 on Mahoning Cr. (RM 0.7) within the 04-03 twelve digit HUC.

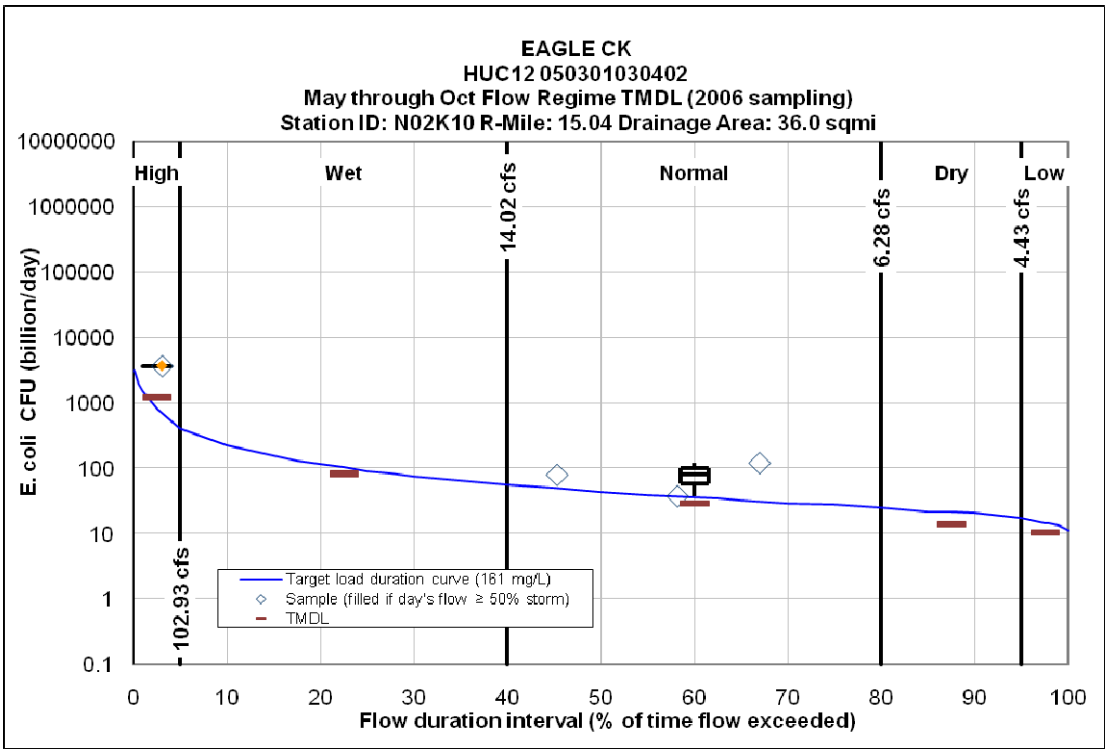

Figure D-38. Load duration curve for *E. coli* bacteria at sample location N02K10 on EagleCr. (RM 15.04) within the 04-03 twelve digit HUC.

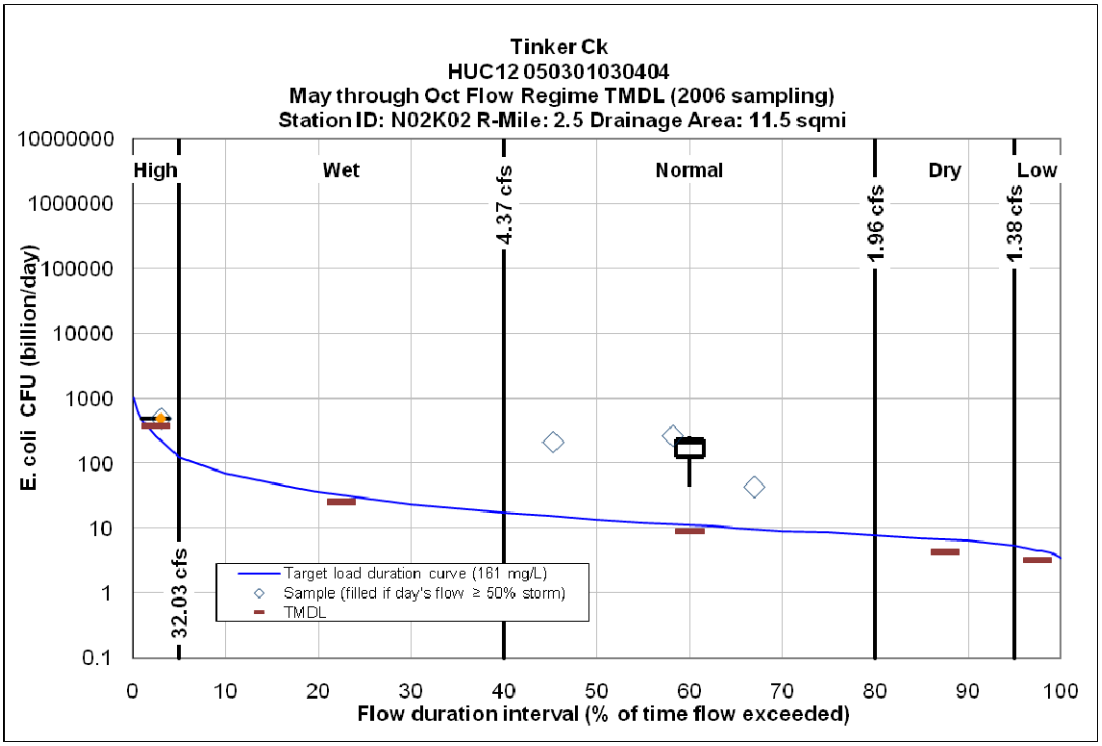

Figure D-39. Load duration curve for *E. coli* bacteria at sample location N02K02 on Tinker Cr. (RM 2.5) within the 04-04 twelve digit HUC.

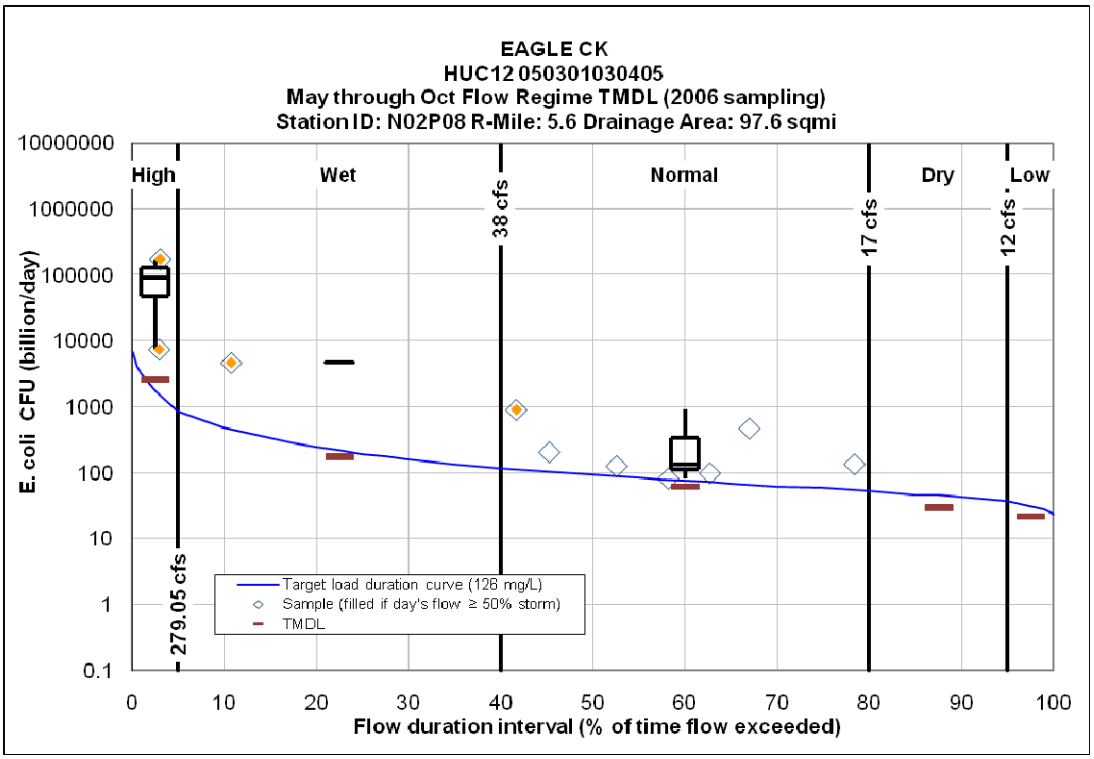

Figure D-40. Load duration curve for *E. coli* bacteria at sample location N02P08 on Eagle Cr. (RM 5.6) within the 04-05 twelve digit HUC.

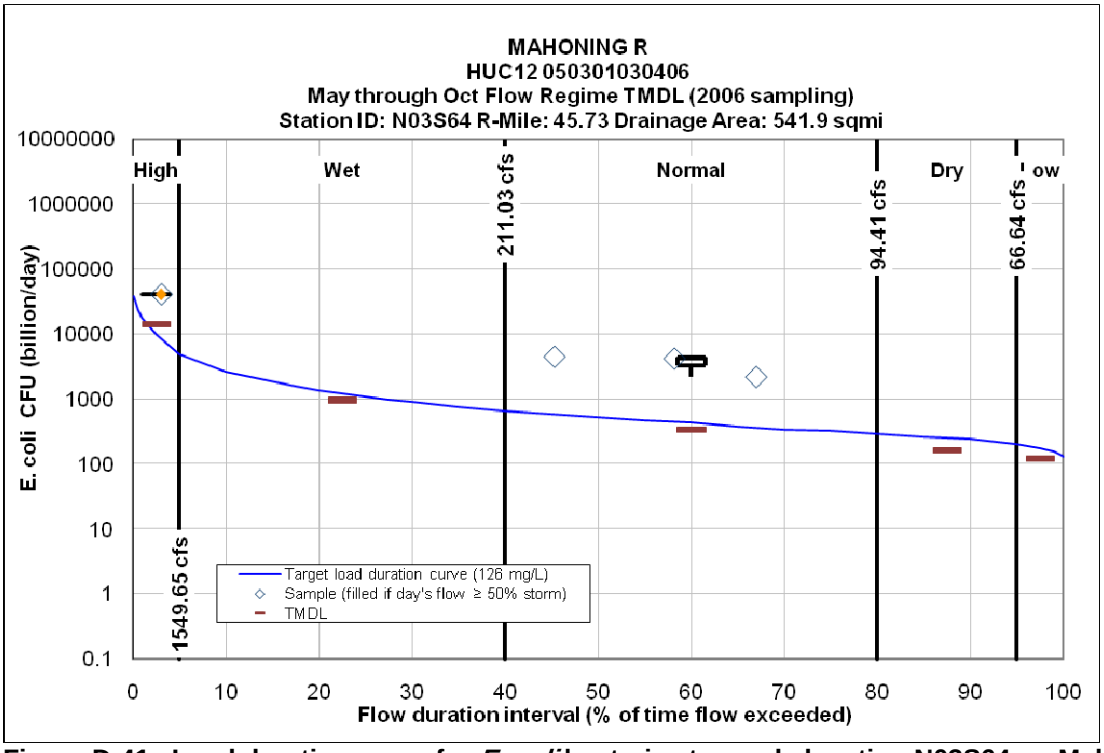

Figure D-41. Load duration curve for *E. coli* bacteria at sample location N03S64 on Mahoning River (RM 45.73) within the 04-06 twelve digit HUC.

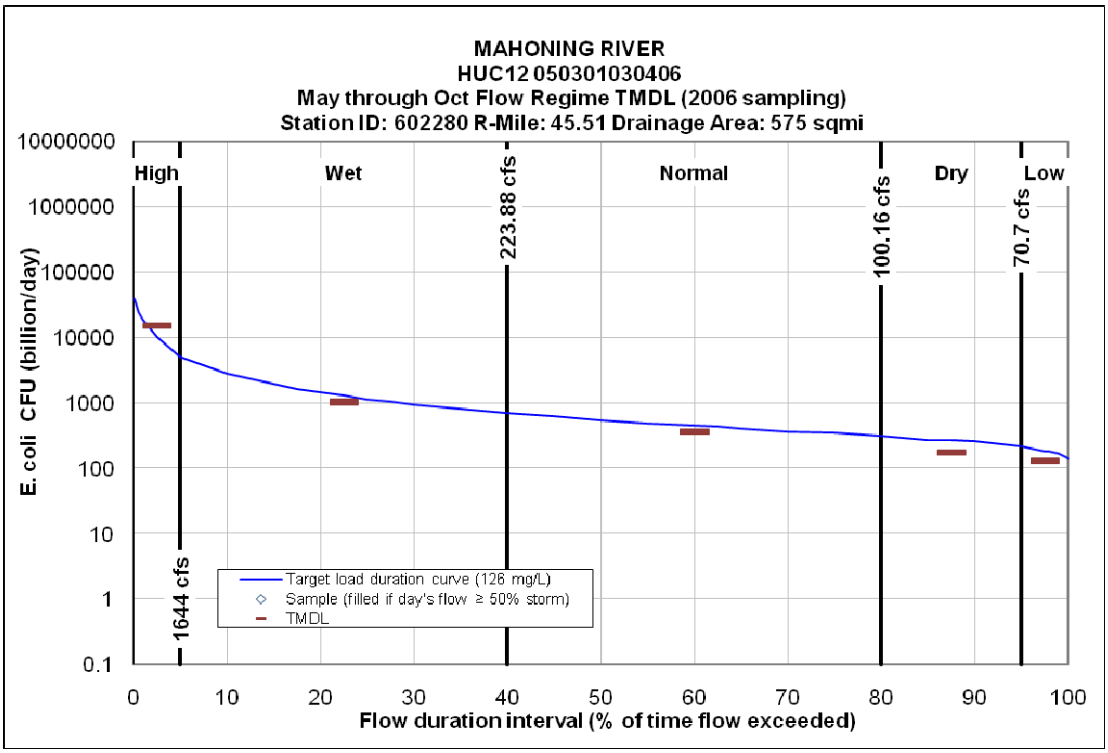

Figure D-42. Load duration curve for *E. coli* bacteria at sample location 602280 on Mahoning River (RM 45.51) within the 04-06 twelve digit HUC.

Table D-43. *E. coli* TMDLs for the 05030103-04-01 12-digit HUC.

Flow Regime TMDL Allocation (billion/day)	Higher Flows	Wet Weather	Mid-Range Summer	Dry Weather	Low
Rec Season Interval	0-5%	5-40%	40-80%	80-95%	95-100%
N02S02 - South Fork Eagle Cr. (RM 2.3)					
Samples Collected	1		3		
Sample Median Load	213		7		
NPDES Point Source Existing Load	0.06	0.06	0.06	0.06	0.06
Margin of Safety (%)	20%	20%	20%	20%	20%
Margin of Safety (Load)	34.8	2.4	0.8	0.4	0.3
Included Upstream TMDL Allocation	0	0	0	0	0
Subwatershed % Reduction Required	18.2%	No Data	40.5%	No Data	No Data
LA (Non-Point Allocation)	173.94	11.91	4.16	1.95	1.45
Allowance for Future Growth (%)	4%	4%	4%	4%	4%
Allowance for Future Growth	8.70	0.60	0.21	0.10	0.08
WLA (NPDES Point/MS4 permits)	0.06	0.06	0.06	0.06	0.06
TMDL minus (MOS + Future Growth)	174.01	11.97	4.22	2.02	1.51
N02S03 - Silver Cr. (RM 0.79)					
Samples Collected	1		3		
Sample Median Load	849		20		
NPDES Point Source Existing Load	1.22	1.22	1.22	1.22	1.22
Margin of Safety (%)	20%	20%	20%	20%	20%
Margin of Safety (Load)	74.9	5.2	1.8	0.9	0.7
Included Upstream TMDL Allocation	0	0	0	0	0
Subwatershed % Reduction Required	55.9%	No Data	54.2%	No Data	No Data
LA (Non-Point Allocation)	373.52	24.56	7.83	3.13	2.06
Allowance for Future Growth (%)	4%	4%	4%	4%	4%
Allowance for Future Growth	18.74	1.29	0.45	0.22	0.16
WLA (NPDES Point/MS4 permits)	1.22	1.22	1.22	1.22	1.22
TMDL minus (MOS + Future Growth)	374.74	25.78	9.04	4.35	3.28

Table D-44. *E. coli* wasteload allocations for the 05030103-04-01 12-digit HUC.

Regulated point source requirements	NPDES OEPA ID	Exist Flow Avg MGD	Dgn Flow Avg MGD	Conc Limit	WLA
Camp Asbury Central	3PR00220	0.0013	0.009	161	0.055
Custom Poly Bag Inc	3PR00389	0.0016	0	161	0.009
Hiram WWTP	3PB00020	0.1160	0	161	1.219

Table D-45. *E. coli* TMDLs for the 05030103-04-02 12-digit HUC.

Flow Regime TMDL Allocation (billion/day)	Higher Flows	Wet Weather	Mid-Range Summer	Dry Weather	Low
Rec Season Interval	0-5%	5-40%	40-80%	80-95%	95-100%
N02K06 - South Fork Eagle Cr. (RM 2.3)					
Samples Collected	1		3		
Sample Median Load	1,470		69		
NPDES Point Source Existing Load	2.74	2.74	2.74	2.74	2.74
Margin of Safety (%)	20%	20%	20%	20%	20%
Margin of Safety (Load)	157.3	10.8	3.8	1.8	1.4
Included Upstream TMDL Allocation	0	0	0	0	0
Subwatershed % Reduction Required	46.5%	No Data	72.4%	No Data	No Data
LA (Non-Point Allocation)	783.54	51.30	16.23	6.36	4.10
Allowance for Future Growth (%)	4%	4%	4%	4%	4%
Allowance for Future Growth	39.31	2.70	0.95	0.46	0.34
WLA (NPDES Point/MS4 permits)	2.74	2.74	2.74	2.74	2.74
TMDL minus (MOS + Future Growth)	786.28	54.04	18.97	9.11	6.84

Table D-46. *E. coli* wasteload allocations for the 05030103-04-02 12-digit HUC.

Regulated point source requirements	NPDES OEPA ID	Exist Flow Avg MGD	Dgn Flow Avg MGD	Conc Limit	WLA
Windham WWTP	3PC00019	0.349	0	161	2.74
Harbison Walker Refractories Windham Works	3IE00043	0	0	0	0

Table D-47. *E. coli* TMDLs for the 05030103-04-03 12-digit HUC.

Flow Regime TMDL Allocation (billion/day)	Higher Flows	Wet Weather	Mid-Range Summer	Dry Weather	Low
Rec Season Interval	0-5%	5-40%	40-80%	80-95%	95-100%
N02K09 - Mahoning Cr. (RM 0.7)					
Samples Collected	1		3		
Sample Median Load	490		14		
NPDES Point Source Existing Load	0.00	0.00	0.00	0.00	0.00
Margin of Safety (%)	20%	20%	20%	20%	20%
Margin of Safety (Load)	24.8	1.7	0.6	0.3	0.2
Included Upstream TMDL Allocation	0	0	0	0	0
Subwatershed % Reduction Required	74.7%	No Data	78.7%	No Data	No Data
LA (Non-Point Allocation)	123.81	8.54	2.99	1.45	1.10
Allowance for Future Growth (%)	4%	4%	4%	4%	4%
Allowance for Future Growth	6.19	0.43	0.15	0.07	0.06
WLA (NPDES Point/MS4 permits)	-	-	-	-	-
TMDL minus (MOS + Future Growth)	123.81	8.54	2.99	1.45	1.10

Table D-47 (cont.). *E. coli* TMDLs for the 05030103-04-03 12-digit HUC.

Flow Regime TMDL Allocation (billion/day)	Higher Flows	Wet Weather	Mid-Range Summer	Dry Weather	Low
Rec Season Interval	0-5%	5-40%	40-80%	80-95%	95-100%
N02K10 - Eagle Cr. (RM 15.04)					
Samples Collected	1		3		
Sample Median Load	3,682		80		
NPDES Point Source Existing Load	4.84	4.84	4.84	4.84	4.84
Margin of Safety (%)	20%	20%	20%	20%	20%
Margin of Safety (Load)	240.9	16.6	5.8	2.8	2.1
Included Upstream TMDL Allocation	0	0	0	0	0
Subwatershed % Reduction Required	67.3%	No Data	63.5%	No Data	No Data
LA (Non-Point Allocation)	1,199.70	77.97	24.25	9.12	5.62
Allowance for Future Growth (%)	4%	4%	4%	4%	4%
Allowance for Future Growth	60.23	4.14	1.45	0.70	0.52
WLA (NPDES Point/MS4 permits)	4.84	4.84	4.84	4.84	4.84
TMDL minus (MOS + Future Growth)	1204.54	82.81	29.09	13.96	10.46

Table D-48. *E. coli* wasteload allocations for the 05030103-04-03 12-digit HUC.

Regulated point source requirements	NPDES OEPA ID	Exist Flow Avg MGD	Dgn Flow Avg MGD	Conc Limit	WLA
Hiram WWTP	3PB00020	0	0	161.00	1.219
Blackbrook Valley Estates	3PG00093	0	0	161	0.183
Therm-O-Link Inc	3IQ00059	0	0	0.000	0
Western Reserve WWTP	3PG00121	0.022	0	161.000	0.134
Northern Ohio Multipurpose	3IH00073	0.350	0.350	0.000	0
Garrettsville WWTP	3PB00016	0.281	0.500	161	3.047
Homestead Manor MHP	3PV00103	0.030	0.030	161	0.183
Camp Asbury Central	3PR00220	0.001	0.009	161	0.055
Johnson Farm Recreational Camp	3PR00387	0.003	0.003	161	0.018

Table D-49. *E. coli* TMDLs for the 05030103-04-04 12-digit HUC.

Flow Regime TMDL Allocation (billion/day)	Higher Flows	Wet Weather	Mid-Range Summer	Dry Weather	Low
Rec Season Interval	0-5%	5-40%	40-80%	80-95%	95-100%
N02K02 - Tinker Cr. (RM 2.5)					
Samples Collected	1		3		
Sample Median Load	485		210		
NPDES Point Source Existing Load	0.00	0.00	0.00	0.00	0.00
Margin of Safety (%)	20%	20%	20%	20%	20%
Margin of Safety (Load)	74.9	5.2	1.8	0.9	0.7
Included Upstream TMDL Allocation	0	0	0	0	0
Subwatershed % Reduction Required	22.8%	No Data	95.7%	No Data	No Data
LA (Non-Point Allocation)	374.74	25.78	9.04	4.35	3.28
Allowance for Future Growth (%)	4%	4%	4%	4%	4%
Allowance for Future Growth	18.74	1.29	0.45	0.22	0.16
WLA (NPDES Point/MS4 permits)	-	-	-	-	-
TMDL minus (MOS + Future Growth)	374.74	25.78	9.04	4.35	3.28

Table D-50. *E. coli* TMDLs for the 05030103-04-05 12-digit HUC.

Flow Regime TMDL Allocation (billion/day)	Higher Flows	Wet Weather	Mid-Range Summer	Dry Weather	Low
Rec Season Interval	0-5%	5-40%	40-80%	80-95%	95-100%
N02P08 - Eagle Cr. (RM 5.6)					
Samples Collected	2	1	7		
Sample Median Load	89,391	4,644	137		
NPDES Point Source Existing Load	7.58	7.58	7.58	7.58	7.58
Margin of Safety (%)	20%	20%	20%	20%	20%
Margin of Safety (Load)	511.1	35.1	12.3	5.9	4.4
Included Upstream TMDL Allocation	0	0	0	0	0
Subwatershed % Reduction Required	97.1%	96.2%	54.8%	No Data	No Data
LA (Non-Point Allocation)	2,548.09	168.08	54.07	22.01	14.61
Allowance for Future Growth (%)	4%	4%	4%	4%	4%
Allowance for Future Growth	127.78	8.78	3.08	1.48	1.11
WLA (NPDES Point/MS4 permits)	7.58	7.58	7.58	7.58	7.58
TMDL minus (MOS + Future Growth)	2555.67	175.66	61.65	29.59	22.20

Table D-51. *E. coli* wasteload allocations for the 05030103-04-05 12-digit HUC.

Regulated point source requirements	NPDES OEPA ID	Exist Flow Avg MGD	Dgn Flow Avg MGD	Conc Limit	WLA 0.5
Hiram WWTP	3PB00020	0	0.200	161	1.219
Blackbrook Valley Estates	3PG00093	0	0.030	161	0.183
Therm-O-Link Inc	3IQ00059	0	0.000	0	0
Western Reserve WWTP	3PG00121	0	0.022	161	0.134
Northern Ohio Multipurpose	3IH00073	0.350	0.350	0	0
Garrettsville WWTP	3PB00016	0.281	0.500	161	3.047
Homestead Manor MHP	3PV00103	0.030	0.030	161	0.183
Camp Asbury Central	3PR00220	0.001	0.009	161	0.055
Johnson Farm Recreational Camp	3PR00387	0.003	0.003	161	0.018

Table D-52. *E. coli* TMDLs for the 05030103-04-06 12-digit HUC.

Flow Regime TMDL Allocation (billion/day)	Higher Flows	Wet Weather	Mid-Range Summer	Dry Weather	Low
Rec Season Interval	0-5%	5-40%	40-80%	80-95%	95-100%
602280 - Mahoning River (RM 5.6)					
Samples Collected					
Sample Median Load					
NPDES Point Source Existing Load	67.86	67.86	67.86	67.86	67.86
Margin of Safety (%)	20%	20%	20%	20%	20%
Margin of Safety (Load)	3011.3	207.0	72.6	34.9	26.2
Included Upstream TMDL Allocation	0	0	0	0	0
Subwatershed % Reduction Required	No Data	No Data	No Data	No Data	No Data
LA (Non-Point Allocation)	14,989	967	295	106	63
Allowance for Future Growth (%)	4%	4%	4%	4%	4%
Allowance for Future Growth	752.82	51.74	18.16	8.72	6.54
WLA (NPDES Point/MS4 permits)	67.86	67.86	67.86	67.86	67.86
TMDL minus (MOS + Future Growth)	15056.48	1034.85	363.24	174.36	130.78
N03S64 - Mahoning River (RM 45.73)					
Samples Collected	1		3		
Sample Median Load	41,086		4,239		
NPDES Point Source Existing Load	67.86	67.86	67.86	67.86	67.86
Margin of Safety (%)	20%	20%	20%	20%	20%
Margin of Safety (Load)	2838.5	195.1	68.5	32.9	24.7
Included Upstream TMDL Allocation	0	0	0	0	0
Subwatershed % Reduction Required	65.5%	No Data	91.9%	No Data	No Data
LA (Non-Point Allocation)	14,125	908	275	96	55
Allowance for Future Growth (%)	4%	4%	4%	4%	4%
Allowance for Future Growth	709.62	48.77	17.12	8.22	6.16
WLA (NPDES Point/MS4 permits)	67.86	67.86	67.86	67.86	67.86
TMDL minus (MOS + Future Growth)	14192.36	975.46	342.40	164.34	123.26

Table D-53. *E. coli* wasteload allocations for the 05030103-04-06 12-digit HUC.

Regulated point source requirements	NPDES OEPA ID	Exist Flow Avg MGD	Dgn Flow Avg MGD	Conc Limit	WLA
ODOT Rest Area 04-35 WWTP	3PP00033	0.004	0.020	126	0.0954
Southeast High School	3PT00016	0.015	0.050	126	0.2385
The Diamond Lodge	3PR00505	0.010	0.010	126	0.0477
Gionino's Pizza	3PR00390	0.000	0.002	126	0.0072
Maple Del Manor MHP	3PV00034	0.027	0.040	126	0.1908
Crest Rubber Co	3IR00015	0.108	0.001	0	0.0000
Countryside Estates	3PG00120	0.026	0.035	126	0.1669
Country Acres Campground 1	3PR00234	0.003	0.010	126	0.0477
Leisure Lake Park	3PR00265	0.817	0.038	126	0.1789
ODNR Beach Area W Branch SP	3PP00010	0.004	0.100	126	0.4770
Arnies West Branch Steak House	3PR00174	0.001	0.003	126	0.0159
Jolly Time MHP	3PV00085	0.001	0.002	126	0.0110
KMV III Ltd DBA Hamlet MHP	3PV00041	0.016	0.020	126	0.0954
Newton Falls STP	3PD00015	1.108	1.500	126	7.1544
RC Sports Lounge	3PR00323	0.000	0.004	126	0.0167
Craig Beach WWTP	3PH00030	0.527	1.000	126	4.7696
Industrial Mining - City Stone	3IJ00067	0.350	0.000	0	0.0000
Green Acres Campground	3PR00221	0.003	0.005	126	0.0238
Washington Elementary School	3PT00101	0.005	0.008	161	0.0488
North East Ohio Church of God Campground	3PR00437	0.014	0.014	126	0.0668
Ben's Restaurant and Bar	3PR00491	0.004	0.004	126	0.0174
US Corp of Engineers Mill Creek R	3PN00000	0.020	0.030	126	0.1431
Pelican Grove Campground	3PR00348	0.001	0.001	126	0.0038
Circle Restaurant Inc	3PR00120	0.001	0.004	126	0.0209
Nemenz Food Mart	3PR00210	0.001	0.002	126	0.0072
Modern Management Solutions DBA All Seasons MHP	3PV00047	0.035	0.055	126	0.2623
Alliance WWTP	3PD00000	5.255	7.500	126	35.7722
Grace Community Church of Alliance	3PR00451	0.005	0.005	126	0.0238
Stark County Village Green Allot STP	3PG00087	0.028	0.020	126	0.0954
Trilogy Alliance	3IN00347	0.018	0.000	0	0.0000
Paradise Lake Park Campground STU 1	3PR00325	0.020	0.020	161	0.1219
Timashamie Family Campground	3PR00305	0.004	0.025	161	0.1524
Knox Elementary School - West Branch	3PT00123	0.002	0.007	126	0.0334
Sebring WTP	3IV00182	0.049	0.050	0	0.0000
West Branch Nursing Home LLC	3PR00458	0.012	0.012	126	0.0560
Damascus WWTP	3PA00037	0.055	0.008	126	0.0382
Country Squire Estates Ltd	3PV00130	0.030	0.010	126	0.0477
Beloit WWTP	3PB00005	0.069	0.190	126	0.9062
Tecumseh Village MHP	3PV00023	0.002	0.013	126	0.0596
Sebring Landfill Facility	3IN00351	0.018	0.000	0	0.0000
BP Amoco Oil Corp Bulk Plant Alliance	3IN00287	0.001	0.000	0	0.0000
Sebring WWTP	3PC00011	0.747	1.500	126	7.1544
Central Waste Inc	3IN00313	0.005	0.000	0	0.0000

Regulated point source requirements	NPDES OEPA ID	Exist Flow	Dgn Flow	Conc Limit	WLA
Alliance Tubular Products Co	3ID00043	1.700	0.069	0	0.0000
Pelican Grove Campground	3PR00373	0.001	0.001	126	0.0038
Buckeye Packaging Co Inc	3PR00259	0.001	0.004	161	0.0213
Custom Poly Bag Inc	3PR00389	0.002	0.002	161	0.0091
Atwater WWTP	3PH00033	0.107	0.200	126	0.9539
Waterloo K-12 Campus	3PT00079	0.006	0.020	161	0.1219
Evrol LLC Atwater Terminal	3IG00025	0.000	0.000	0	0.0000
Nemenz Little Village Shoppe Inc	3PR00190	0.001	0.003	126	0.0121
Stark County Village Green Allot STP	3PG00087	0.028	0.020	126	0.0954
Trilogy Alliance	3IN00347	0.018	0.000	0	0.0000
Washington Elementary School	3PT00101	0.005	0.008	161	0.0488
Marlington Local Schools	3PT00045	0.021	0.045	126	0.2146
Western Reserve High School	3PT00143	0.002	0.024	126	0.1145
Hiram WWTP	3PB00020	0.116	0.200	161	1.2189
Blackbrook Valley Estates	3PG00093	0.064	0.030	161	0.1828
Therm-O-Link Inc	3IQ00059	0.033	0.000	0	0.0000
Western Reserve WWTP	3PG00121	0.022	0.022	161	0.1341
Northern Ohio Multipurpose	3IH00073	0.350	0.350	0	0.0000
Garrettsville WWTP	3PB00016	0.281	0.500	161	3.0473
Homestead Manor MHP	3PV00103	0.030	0.030	161	0.1828
Camp Asbury Central	3PR00220	0.001	0.009	161	0.0549
Johnson Farm Recreational Camp	3PR00387	0.003	0.003	161	0.0183
Windham WWTP	3PC00019	0.349	0.450	161	2.7425
Harbison Walker Refractories Windham Works	3IE00043	0.099	0.065	0	0.0000
Southington Local School Dist	3PT00134	0.002	0.024	126	0.1145
Arhaven Estates MHP	3PV00064	0.013	0.018	126	0.0835
PK Rentals	3GV00030	0.010	0.010	126	0.0477
William C Wilson	3GV00027	0.010	0.010	126	0.0477
Short Stop Truck Plaza	3PR00162	0.007	0.010	126	0.0477
Denman Tire Corp	3IR00002	0.057	0.130	0	0.0000
Warren No 3 WWTP	3PG00106	0.016	0.013	126	0.0596
Full Convenant Tabernacle Church	3GV00035	0.010	0.010	126	0.0477
Top of the Hill Store	3GV00019	0.010	0.010	126	0.0477
Ridge Ranch Campgrounds Sh	3PR00310	0.002	0.003	126	0.0143
Pleasant Park Mobile Court	3PV00067	0.021	0.023	126	0.1073
Delightful Auto Center	3GV00021	0.010	0.010	126	0.0477

D2.2 Habitat and Sediment TMDLs

D2.2.1 Habitat and Sediment TMDLs - Headwaters Mahoning River (05030103-01)

Table D-54. Sediment and Habitat TMDLs for the 05030103-01 10-digit HUC based on QHEI metrics and modified attributes.

Stream/River (Use)	River Mile[1]	Aquatic Life Use Attainment	Applicable TMDLs - Listed Cause[2] (B = bedload; H = habiteat)	Bedload TMDL						Habitat TMDL						
				Allocations			TMDL	% Deviation fromTarget[3]	Metrics with Substantial Deviation[4] (S = substrate; C = channel; R = riparian)	Allocations			Subscore			TMDL
				≥13	≥14	≥5	≥32			≥60 = 1pt	<2 = 1pt	<5 = 1pt				3
				QHEI Categories												
				Substrate	Channel	Riparian	Total Bedload Score			QHEI Score	# High Influence Atributes	Total # of Modified Attributes	QHEI	High Influence	# Modified Attributes	Total Habitat Score
Mahoning River (WWH)	102.24[H]	Full		17	14.5	3.5	35	-9%	---	62	1	1	1	0	1	**2**
	100.57[H]	Full		13	17.5	6.5	37	-16%	---	74.5	0	4	1	1	0	**2**
	97.69[H]	Full		15.5	16.5	2.5	34.5	-8%	---	75.5	0	3	1	1	1	**3**
	93.23[W]	Full		11	6	3.5	20.5	**36%**	---	57.5	1	4	0	0	0	0
	91.11[W]	Non	B / H	1	5	4	10	**69%**	S / C	33	3	6	0	0	0	0
	85.51[B]	Non	H	6.5	14	8.5	29	**9%**	S	55	1	6	0	0	0	0
	84.80[W]	Partial	B	15	7	4.5	26.5	**17%**	C	60.5	1	5	1	0	0	**1**
Beech Creek (WWH)	10.50[H]	Non	B / H	0.5	6.5	5	12	**63%**	S / C	31	5	6	0	0	0	0
	8.34[H]	Full		11.5	14	5.5	31	**3%**	---	65	0	5	1	1	0	**2**
	3.54[H]	Full		11	14	6.5	31.5	**2%**	---	60.5	1	5	1	0	0	**1**
Little Beech Creek (WWH)	1.83[H]	Non	B	11	6	1.5	18.5	**42%**	C / R	39.5	3	5	0	0	0	0
Fish Creek (WWH)	3.56[H]	Non	H	4.5	12	6.5	23	**28%**	S	49	2	6	0	0	0	0
	2.00[H]	Non	B	5.5	12	7	24.5	**23%**	S	56.5	2	5	0	0	0	0
	0.36[H]	Non	B	0	12	8.5	20.5	**36%**	S	42.5	1	6	0	0	0	0
Beaver Run (WWH)	1.19[H]	Partial	B	12.5	16	6.5	35	-9%	---	70.5	0	4	1	1	0	**2**

Stream/River (Use)	River Mile[1]	Aquatic Life Use Attainment	Applicable TMDLs - Listed Cause[2] (B = bedload; H = habiteat)	Bedload TMDL						Habitat TMDL						
				Allocations			TMDL	% Deviation fromTarget[3]	Metrics with Substantial Deviation[4] (S = substrate; C = channel; R = riparian)	Allocations			Subscore			TMDL
				≥13	≥14	≥5	≥32			≥60 = 1pt	<2 = 1pt	<5 = 1pt				3
				QHEI Categories												
				Substrate	Channel	Riparian	Total Bedload Score			QHEI Score	# High Influence Atributes	Total # of Modified Attributes	QHEI	High Influence	# Modified Attributes	Total Habitat Score
Naylor Creek (WWH)	3.63[H]	Non	H	6	5.5	3.5	15	**53%**	S / C	39	4	5	0	0	0	0
	1.35[H]	Non		5	10.5	4	19.5	**39%**	---	45.5	2	5	0	0	0	0
Trib. to Mahoning R. (RM 91.21) (WWH)	2.39[H]	Non		7	12	7	26	**19%**	---	54	2	5	0	0	0	0
Tributary to Mahoning River (RM 98.71) (WWH)	4.59 [H]	Partial	B	14.5	10.5	5	30	**6%**	C	62	2	5	1	0	0	**1**

1 H – Headwater site, W – Wading site, B – Boat site
2 Causes for which habitat TMDLs are developed include: habitat alteration; flow alteration; alteration in streamside vegetation.
3 Negative values shown in light grey are indicate where the minimum target is exceeded.
4 Deviations more than 20 to 25 percent of the target value are considered substantial. Deviations are not considered for sites that are not listed as impaired for sediment and/or habitat. D2.2.2 Habitat and Sediment TMDLs - Deer Creek-Mahoning River (05030103-02)

Table D-55. Sediment and Habitat TMDLs for the 05030103-02 10-digit HUC based on QHEI metrics and modified attributes.

Stream/River (Use)	River Mile[1]	Aquatic Life Use Attainment	Applicable TMDLs – Listed Cause[2] (B = bedload; H = habiteat)	Bedload TMDL						Habitat TMDL						
				Allocations			TMDL			Allocations			Subscore			TMDL
				≥13	≥14	≥5	≥32			≥60 = 1pt	<2 = 1pt	<5 = 1pt				3
				QHEI Categories												
				Substrate	Channel	Riparian	Total Bedload Score	% Deviation fromTarget	Metrics with Substantial Deviation[3] (S = substrate; C = channel; R = riparian)	QHEI Score	# High Influence Attributes	Total # of Modified Attributes	QHEI	High Influence	# Modified Attributes	Total Habitat Score
Mill Creek (WWH)	8.75[H]	Non		0.5	5	6	11.5	**64%**	S / C	39.5	3	5	0	0	0	0
	6.28[H]	Non	B	9.5	12.5	4.5	26.5	**17%**	S	56.5	2	4	0	0	0	0
	3.64[H]	Full		16.5	16.5	5	38	-19%	---	74	0	3	1	1	1	**3**
Turkey Broth Creek (WWH)	3.36[H]	Non	B / H	0.5	7	4	11.5	**64%**	S / C	35.5	4	5	0	0	0	0
Island Creek (WWH)	2.65[H]	Non	B	1	13	5.5	19.5	**39%**	S	43.5	1	5	0	0	0	0
Willow Creek (WWH)	8.13[H]	Non	B / H	6	6.5	5.5	18	**44%**	S / C	34	4	6	0	0	0	0
	3.74[H]	Full		4	12	8.5	24.5	**23%**	S	54.5	1	6	0	0	0	0
Deer Creek (WWH)	4.48[W]	Full	H	15	7.5	5.5	28	**13%**	C	67	1	6	1	0	0	**1**
	2.90[W]	Partial	H	15.5	15	7	37.5	-17%	---	79.5	0	4	1	1	0	**2**
Garfield Ditch (WWH)	0.66[H]	Non	B													
Tributary to Mill Creek at RM 3.67 (WWH)	1.10[H]	Non		14	8	3.5	25.5	**20%**	C	54.5	3	4	0	0	0	0

1 H – Headwater site, W – Wading site, B – Boat site
2 Causes for which habitat TMDLs are developed include: habitat alteration; flow alteration; alteration in streamside vegetation.
3 Negative values shown in light grey are indicate where the minimum target is exceeded.
4 Deviations more than 20 to 25 percent of the target value are considered substantial. Deviations are not considered for sites that are not listed as impaired for sediment and/or habitat.

D2.2.3 Habitat and Sediment TMDLs - West Branch Mahoning River-Mahoning River (05030103-03)

Table D-56. Sediment and Habitat TMDLs for the 05030103-03 10-digit HUC based on QHEI metrics (total score and substrate, riparian, and channel scores).

Stream/River (Use)	River Mile[1]	Aquatic Life Use Attainment	Applicable TMDLs - Listed Cause[2] (B = bedload; H = habiteat)	Bedload TMDL						Habitat TMDL						
				Allocations			TMDL	% Deviation fromTarget[3]	Metrics with Substantial Deviation[4] (S = substrate; C = channel; R = riparian)	Allocations			Subscore			TMDL
				≥13	≥14	≥5	≥32			≥60 = 1pt	<2 = 1pt	<5 = 1pt				3
				QHEI Categories												
				Substrate	Channel	Riparian	Total Bedload Score			QHEI Score	# High Influence Atributes	Total # of Modified Attributes	QHEI	High Influence	# Modified Attributes	Total Habitat Score
Mahoning River EOLP Ecoregion (WWH)	70.70[B]	Partial	H	17	13	7	37	-16%	Channel	78.5	0	4	1	1	0	**2**
	62.68[B]	Partial	H	20	14	5.5	39.5	-23%	---	80.5	0	2	1	1	1	**3**
	58.13[B]	Non	H	1	6	6.5	13.5	**58%**	S / C	41.5	2	6	0	0	0	0
	56.53[B]	Partial	H	12	9	4.5	25.5	**20%**	C	60.5	2	5	1	0	0	**1**
Kale Creek (WWH)	13.08[H]	Non	B / H	4.5	12	7.5	24	**25%**	S	51	1	7	0	0	0	0
	11.27[H]	Non	B	8.5	11.5	5	25	**22%**	S	54	0	6	0	1	0	**1**
	6.05[H]	Partial		1	12	6	19	**41%**	S	51	2	5	0	0	0	0
	3.70[W]	Partial		17	10	7.5	34.5	-8%	C	65	0	4	1	1	0	**2**
West Branch Mahoning River (WWH)	27.92[H]	Full		15	15	8.5	38.5	-20%	---	64.5	2	2	1	0	1	**2**
	24.35[H]	Full		14.5	17	6	37.5	-17%	---	72	0	2	1	1	1	**3**
	20.94[W]	Full		19	15.5	6	40.5	-27%	---	82	0	2	1	1	1	**3**
	11.39[W]	Partial	H	12	14	10	36	-13%	---	76	0	2	1	1	1	**3**
	3.15[B]	Non	H	0	6	5.5	11.5	**64%**	S / C	34.5	2	6	0	0	0	0
	0.40[B]	Full		14	14.5	10	38.5	-20%	---	78.5	0	1	1	1	1	**3**
Silver Creek	3.46[H]	Full		12	14	4	30	**6%**	---	67	0	4	1	1	0	**2**

Stream/River (Use)	River Mile[1]	Aquatic Life Use Attainment	Applicable TMDLs - Listed Cause[2] (B = bedload; H = habiteat)	Bedload TMDL						Habitat TMDL						
				Allocations			TMDL			Allocations			Subscore			TMDL
				≥13	≥14	≥5	≥32			≥60 = 1pt	<2 = 1pt	<5 = 1pt				3
				QHEI Categories												
				Substrate	Channel	Riparian	Total Bedload Score	% Deviation fromTarget[3]	Metrics with Substantial Deviation[4] (S = substrate; C = channel; R = riparian)	QHEI Score	# High Influence Atributes	Total # of Modified Attributes	QHEI	High Influence	# Modified Attributes	Total Habitat Score
(trib. to W. Branch) (WWH)	1.83[H]	Full		16	16	7	39	-22%	---	68	0	1	1	1	1	**3**
Hinkley Creek (WWH)	0.7[H]	Full		15	11	7.5	33.5	-5%	---	60.5	3	3	1	0	1	**2**
Barrel Run (WWH)	5.31[H]	Partial	H	14	12	7.5	33.5	-5%		67.5	1	5	1	0	0	**1**
	3.65[H]	Full		11	14	5.5	30.5	**5%**	---	61.5	0	6	1	1	0	**2**
Harmon Brook (WWH)	0.49[H]	Partial	B	14	15.5	6.5	36	-13%	---	77	0	3	1	1	1	**3**
Trib to West Branch Mahoning River at RM 0.01 (WWH)	2.10[H]	Non	B	9	14	7.5	30.5	**5%**	S	67.5	0	4	1	1	0	**2**
Trib to West Branch Mahoning River at RM 9.63 (WWH)	0.6[H]	Partial	H	8	8.5	3	19.5	**39%**	S / C	40.5	4	4	0	0	0	0

Stream/River (Use)	River Mile[1]	Aquatic Life Use Attainment	Applicable TMDLs - Listed Cause[2] (B = bedload; H = habiteat)	Bedload TMDL						Habitat TMDL						
				Allocations			TMDL			Allocations			Subscore			TMDL
				≥13	≥14	≥5	≥32			≥60 = 1pt	<2 = 1pt	<5 = 1pt				3
				QHEI Categories												
				Substrate	Channel	Riparian	Total Bedload Score	% Deviation fromTarget[3]	Metrics with Substantial Deviation[4] (S = substrate; C = channel; R = riparian)	QHEI Score	# High Influence Atributes	Total # of Modified Attributes	QHEI	High Influence	# Modified Attributes	Total Habitat Score
Trib to West Branch Mahoning River at RM 8.28 (WWH)	0.27[H]	Non	B / H	7	8	5.5	20.5	**36%**	S / C	42.5	2	7	0	0	0	0
Trib to Kale Creek at RM 5.29 (WWH)	1.08[H]	Partial	B	10	14	6.5	30.5	**5%**	S	56.5	1	5	0	0	0	0

1 H – Headwater site, W – Wading site, B – Boat site
2 Causes for which habitat TMDLs are developed include: habitat alteration; flow alteration; alteration in streamside vegetation.
3 Negative values shown in light grey are indicate where the minimum target is exceeded.
4 Deviations more than 20 to 25 percent of the target value are considered substantial. Deviations are not considered for sites that are not listed as impaired for sediment and/or habitat.

D2.2.4 Habitat and Sediment TMDLs - Eagle Creek-Mahoning River (05030103-04)

Table D-57. Sediment and Habitat TMDLs for the 05030103-04 10-digit HUC based on QHEI metrics (total score and substrate, riparian, and channel scores).

Stream/River (Use)	River Mile[1]	Aquatic Life Use Attainment	Applicable TMDLs - Listed Cause[2] (B = bedload; H = habiteat)	Bedload TMDL						Habitat TMDL						
				Allocations			TMDL	% Deviation fromTarget[3]	Metrics with Substantial Deviation[4] (S = substrate; C = channel; R = riparian)	Allocations			Subscore			TMDL
				≥13	≥14	≥5	≥32			≥60 = 1pt	<2 = 1pt	<5 = 1pt				3
				QHEI Categories												
				Substrate	Channel	Riparian	Total Bed-load Score			QHEI Score	# High Influence Attributes	Total # of Modified Attributes	QHEI	High Influence	# Modified Attributes	Total Habitat Score
Mahoning River EOLP Ecoregion (WWH)	54.73[B]	Partial		8	12	7.5	27.5	**14%**	S	58.5	1	5	0	0	0	0
	45.70[B]	Non		9	7	7.5	23.5	**27%**	S / C	48.5	2	6	0	0	0	0
Chocolate Run (WWH)	0.11[H]	Non	B / H	9	9.5	5	23.5	**27%**	S / C	46.5	2	4	0	0	0	0
Eagle Creek (WWH)	22.44[H]	Non		4.5	12	7.5	24	**25%**	S	54	1	5	0	0	0	0
	17.61[W]	Full		15	16	7.5	38.5	-20%	---	81.5	0	4	1	1	0	**2**
	15.04[W]	Full		13	12.5	8	33.5	-5%	---	61.5	0	4	1	1	0	**2**
	10.10[W]	Full		10	10.5	6.5	27	**16%**	S / C	53	0	6	0	1	0	**1**
	5.60[B]	Non		11	14.5	5.5	31	**3%**		65	0	4	1	1	0	**2**
Tinker Creek (WWH)	5.45[H]	Partial		10.5	17	5.5	33	-3%	S	68	0	2	1	1	1	**3**
	2.50[H]	Partial		14	11.5	5	30.5	**5%**		68.5	2	2	1	0	1	**2**

Stream/River (Use)	River Mile[1]	Aquatic Life Use Attainment	Applicable TMDLs - Listed Cause[2] (B = bedload; H = habiteat)	Bedload TMDL						Habitat TMDL						
				Allocations			TMDL	% Deviation fromTarget[3]	Metrics with Substantial Deviation[4] (S = substrate; C = channel; R = riparian)	Allocations			Subscore			TMDL
				≥13	≥14	≥5	≥32			≥60 = 1pt	<2 = 1pt	<5 = 1pt				3
				QHEI Categories												
				Substrate	Channel	Riparian	Total Bed-load Score			QHEI Score	# High Influence Atributes	Total # of Modified Attributes	QHEI	High Influence	# Modified Attributes	Total Habitat Score
Nelson Ditch (WWH)	0.4[H]	Non	B / H	5.5	6	5.5	17	**47%**	S / C	44	3	5	0	0	0	0
South Fork Eagle Creek (WWH)	3.86[H]	Full		9	13	8.5	30.5	**5%**	S	66.5	0	5	1	1	0	**2**
	2.30[W]	Full		10	14	8	32	0%	S	61	1	6	1	0	0	**1**
Camp Creek (CWH)	3.16[H]	Full		16	14	6.5	36.5	-14%	---	74	1	4	1	0	0	**1**
Silver Creek (trib. to Eagle Creek) (CWH)	2.26[H]	Full		11	12	6	29	**9%**	---	66	0	4	1	1	0	**2**
	0.79[H]	Full		12.5	7.5	6.5	26.5	**17%**	---	64	2	4	1	0	0	**1**
Mahoning Creek (WWH)	0.7[H]	Non	B	0	14	9	23	**28%**	S	54	1	5	0	0	0	0

1 H – Headwater site, W – Wading site, B – Boat site
2 Causes for which habitat TMDLs are developed include: habitat alteration; flow alteration; alteration in streamside vegetation.
3 Negative values shown in light grey are indicate where the minimum target is exceeded.
4 Deviations more than 20 to 25 percent of the target value are considered substantial. Deviations are not considered for sites that are not listed as impaired for sediment and/or habitat.

D2.3 Total Phosphorus TMDLs

Nutrients caused aquatic life uses impairments at nine sites in this 10-digit HUC. To address this, a watershed model was used for the entire 01-01 and part of the 01-02 twelve digit HUCs. Other nutrient impaired sites were not addressed.

Based on the watershed model, cropland is the largest source of total phosphorus to the watershed area producing 96.5% of the total load. All other sources are minimal in comparison and point sources comprise only 0.15% of the total phosphorus load.

D2.3.1 Total Phosphorus TMDLs - Headwaters Mahoning River (05030103-01)

Figure D-43 presents the seasonally grouped data for the Mahoning River at Alliance gage. Ten years of total phosphorus existing daily loads and TMDL values were grouped into seasonal categories. Seasons were grouped as follows: Spring – March, April, May; Summer – June, July, August; Autumn – September, October, November; Winter – December, January, February. Seasonally grouped daily values for existing loads and TMDLs were graphed in bar and whisker charts. Inter-quartile ranges and median are provided on these graphs. In addition, the 95th percent confidence interval of the median area presented as additional boxes within the inter-quartile range area. Data that fell outside the standard statistical 1.5 inter-quartile range test were eliminated from the data sets as outliers.

Table D-58 provides the median loads and the corresponding median TMDLs for each season. The need for load reduction was determined by a hypothesis test such that if the median of the existing load fell within the 95% confidence interval of the TMDL data set, no reduction in load was proposed. A null value for the hypothesis test indicates that the data sets are equivalent. If the median of the existing loading was higher than the TMDL's 95% confidence interval range of the median, reduction percentages and allocations are provided. Reductions were calculated by equating medians of the existing load and TMDL datasets assuring the translated data sets would be statistically similar with median hypothesis test.

The spring and summer seasons require reductions in total phosphorus as 46.5% and 96.0%, respectively. The median values for the existing total phosphorus load in autumn and winter fell within the 95% confidence interval of the median TMDL therefore no load reductions are required.

To assure point source discharges are allocated appropriate load reductions, effluent limits were set to 1 mg/L total phosphorus. Overall, point source loads comprise a small percent of the total phosphorus load; therefore, expensive reductions beyond 1 mg/L would not have a significant impact for total load reductions in the watershed. Table D-60 indicates this proposed concentration limit and associated discharge load allocated to the respective point source. These limits are proposed only during seasons in which loads reductions are needed to meet TMDL goals (i.e., spring and summer).

Other allocations were determined by fractioning the total TMDL load into allotments by equalizing percent reductions for each source beside point source dischargers and septic systems. A one hundred percent reduction is expected for failing septic systems for each season because failing systems is considered unacceptable practice (elimination of these sources is a goal for the TMDL). In addition, it is impractical to expect reductions from land types that consist of surface water, forest, wetland, and groundwater sources; therefore, no reductions were proposed for these sources.

Overall, source reductions of non-point sources are 46.1% and 99.7% for spring and summer loads, respectively. These reductions are projected to allow the water quality to meet TMDL targets. For point source loads, 22.9% is proposed for both spring and summer within this watershed. For septic systems, 100% reduction is proposed. Because of seasonal variation in the source loads, crop land is reduced in magnitude as shown in Table D-58.

For each source, an explicit 5% margin of safety was added to the TMDL value prior to determination of gross reductions needed. Failing septics was excluded for the MOS because of 100% reduction proposed. All source reduction percentages and loads can be viewed in Table D-58 for the Mahoning River at Alliance gage.

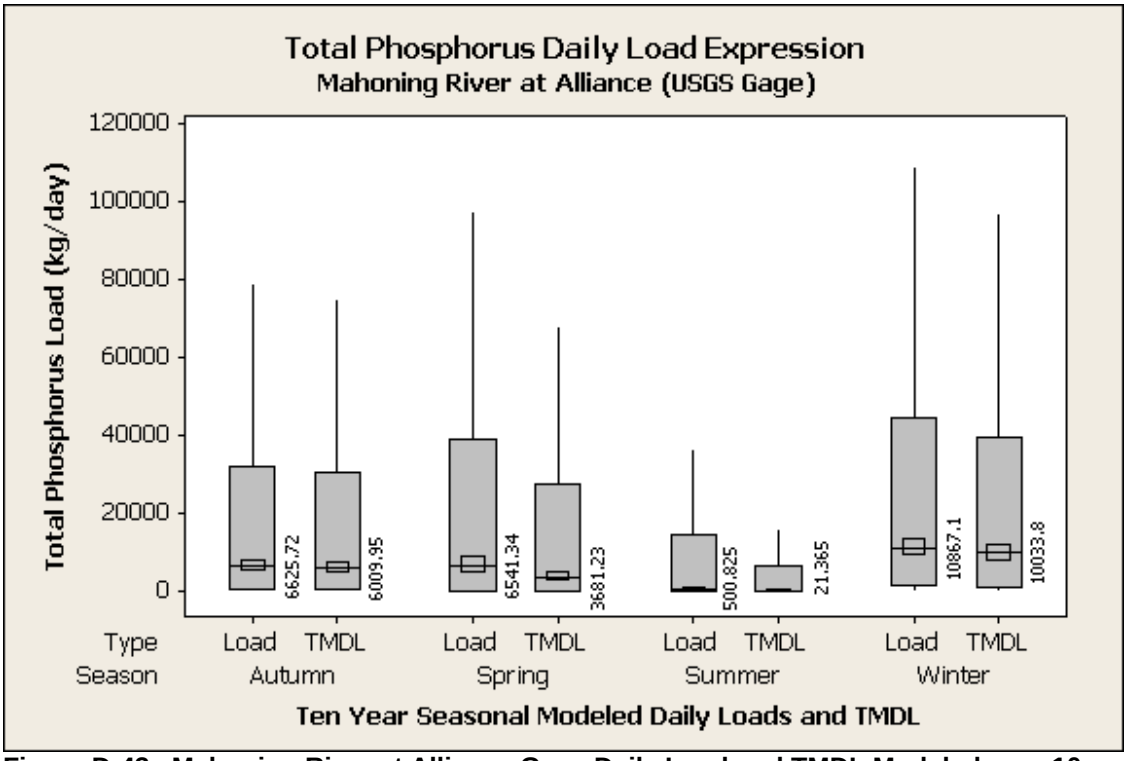

Figure D-43. Mahoning River at Alliance Gage Daily Load and TMDL Modeled over 10 years for Total Phosphorus (median 95% confidence interval range and values are presented).

Table D-58. Total annual loads and pollutant yields per the significant sources within the GWLF modeled area that employs the Alliance gage on the Mahoning River (HUCs 01 and 03).

Source	Area (ha)	Total P (kg/d)	kg/ha/day	lb/ac/day	% of Total
Cropland	7,701	13,942	1.811	1.615	96%
Urban	4,178	197	0.047	0.042	1%
Septic Systems	na	95	na	na	1%
Pasture	5,065	67	0.013	0.012	0.5%
Forest	5,368	50	0.009	0.008	0.3%
Water	175	32	0.185	0.165	0.2%
Other_Urban	760	25	0.034	0.030	0.2%
Point Source	na	21	na	na	0.1%
Wetland	3	18	5.925	5.286	0.1%
Groundwater	na	-	na	na	0.0%
TOTAL	**23,250**	**14,449**	**0.621**	**0.550**	**100%**

Table D-59. Median Existing and TMDL Loads with reductions needed for the Mahoning River and tributaries at the Alliance Gage Daily Load and TMDL Modeled over 10 years for Total Phosphorus.

Season of the Year	Median Existing Daily Load (kg/d)	Median Daily TMDL (kg/day)	TMDL MOS (%)	Total Reduction	
				(kg/d)	Percent
Spring	6,541	3,681	5%	3,044	47%
Summer	500	21	5%	480	96%
Autumn	6,625	6,009	0%	-	0%
Winter	10,867	10,033	0%	-	0%

Table D-60. Allocations and percent reductions for total phosphorus by source within the GWLF modeled area that employs the Alliance gage on the Mahoning River (HUCs 01 and 03).

SOURCE	Spring Load					Summer Load				
	Total P (kg/d)	TMDL (kg/d)	MOS (%)	Reduction (%)	Total Reduction (kg/d)	Total P (kg/d)	TMDL (kg/d)	MOS (%)	Reduction (%)	Total Reduction (kg/d)
Water	14.5	14.5	0%	0%	-	0.9	0.9	0%	0%	-
Urban	88.2	50	5%	46%	40.7	5.3	0	5%	100%	5.2
Other_Urban	11.4	6.5	5%	46%	5.3	0.7	0	5%	100%	0.7
Forest	22.4	22.4	0%	0%	-	1.3	1.3	0%	0%	-
Pasture	30.1	17.1	5%	46%	13.9	1.8	0	5%	100%	1.8
Cropland	6,249.9	3,543.9	5%	46%	2,883.2	373.3	0.1	5%	100%	373.2
Wetland	8.2	8.2	0%	0%	-	0.5	0.5	0%	0%	-
Groundwater	-	-	0%	0%	-	0	-	0%	0%	-
Point Source	21.4	18.5	5%	18%	2.9	21.4	18.5	5%	18%	2.8
Septic Systems	95	-	5%	100%	95	95.01	-	5%	100%	95
TOTAL	**6,541**	**3,681**		**44%**	**3041**	**500**	**21.4**		**95.7%**	**478.8**

Table D-61. Existing and proposed loading information, including wasteload allocations, for NPDES dischargers within the GWLF modeled area that employs the Alliance gage on the Mahoning River (HUCs 01 and 03).

Permit Number	Facility	Design Flow (mgd)	Existing Total Phosphorus Effluent Concentration (mg/l)	Existing Total Phosphorus Load (kg/day)	Proposed Total Phosphorus Effluent Concentration (mg/l)	Proposed Total Phosphorus Load - WLA (kg/day)
3PV00023	Tecumseh Village MHP	0.0125	3*	0.142	3	0.142
3PR00196	Dairy Kool	0.0011	3*	0.012	3	0.012
3PA00037	Damascus WWTP	0.08	3*	0.909	3	0.909
3IN00313	Central Waste Inc***	2.73	0.033	0.341	3	0.341
3PB00005	Beloit WWTP	0.190	3*	2.158	1	0.719
3PC00011	Sebring WWTP	1.50	3*	17.035	1	5.678
3PR00458	West Branch Nursing Home, LLC	0.012	3*	0.133	3	0.133
3PV00112	Arew Mobile Park	0.004	3*	0.045	3	0.045
3PR00305	Timashamie Family Campground	0.025	3*	0.284	3	0.284
3PR00325	Paradise Lake Park Campground STU 1	0.020	3*	0.227	3	0.227
3PT00123	Knox Elementary School - West Branch	0.0070	3*	0.079	3	0.079
TOTAL		**4.578**	**na**	**21.365**	**na**	**8.569**

* Indicates estimate utilized for TMDL purposes for those facilities in which no data exists.
*** Average discharge flow from sedimentation basin utilized for loading calculation.

D2.3.2 Total Phosphorus TMDLs - Deer Creek - Mahoning River (05030103-02)

Phosphorus reductions are needed to address eutrophic conditions in the Dale Walborn / Deer Creek reservoir systems as well as in-stream eutrophic conditions separate form this reservoir complex. The TMDLs and allocations for each of these environmental settings are different in terms of how the eutrophic conditions impact the aquatic community of the streams as well as the methods used to determine the allowable loading. The results of the analyses performed for the reservoir systems (i.e., BATHTUB – GWLF combination) are presented first followed by the load duration curves generated for the stream sites.

Reservoir Systems (Dale Walborn and Deer Creek)

Total Phosphorus
The median in-lake concentration of 32 µg/L (mg/m^3) corresponded to a ten year loading limit of 1,164,062 kg. The BATHTUB results comprise an entire years loading, therefore, the daily loading limit of total phosphorus to the combined lake system was found to be 319 kg/d (i.e., 1,164,062 kg-TP / 10 years / 365 days per year).

Total Nitrogen
The mean load response indicates an increase or decrease of total phosphorus loading will not influence the total nitrogen concentration of the mixed layer. Because the median total nitrogen concentration of the model results was within the proposed Ohio's Lake Habitat Criteria, reduction estimates and allocations are not proposed for total nitrogen.

Chlorophyll a
The median in-lake concentration of 9.5 µg/L (mg/m^3), corresponded to a ten year loading limit of 203125 kg. The BATHTUB results comprise an entire years loading, therefore, the daily loading limit of total phosphorus to the combined lake system was found to be 56 kg/d.

Secchi Disk Transparency
Using the mean Secchi disk transparency of at least 1.04 meters (as required by the Ohio Lake Habitat Criteria) a ten year loading limit of 210,937 kg was determined. The BATHTUB results comprise an entire years loading, therefore, the daily loading limit of total phosphorus to the combined lake system was found to be 58 kg/d.

A total reduction in the influent total phosphorus load to the combined lake system including the 5% margin of safety must be 70.8%.

Allocations for total phosphorus for the combined lake system of Dale Walborn and Deer Creek Reservoirs are presented in Table D-62. Reductions of 86.1% of total phosphorus loading are required for urban runoff, pasture runoff, and cropland runoff; whereas, a reduction of 100% and 57.9% are required for failing home sewage treatment systems and point source discharges, respectively. No reductions are proposed for forested area runoff, direct stream/lakewater atmospheric loadings, and wetland loadings because they are non-anthropogenic loadings. No reduction of nitrogen is proposed because the BATHTUB modeling results indicate total nitrogen mean values fall within the median total nitrogen limits in the proposed Ohio Lake Habitat Criteria rule.

Proposed individual point source limits and loadings are presented in Table D-64. A reasonable total phosphorus limit of 1.0 mg/L and the corresponding loading limits are provided on the table and previous allocations.

Table D-62. Existing Daily Load and Allowable Daily Load during Lake Growing Season for Ohio's Lake Habitat Criteria Attainment (Deer Creek and Dale Walborn Spatial Average water quality).

Modeled Response Parameter	Modeled Contaminant	10 Year Seasonal Mean Daily Modeled Contaminant Influent Load*	10 Year Modeled Concentration Load Response in Mixed Layer	Ohio EPA Proposed Mixed Layer WQ Standard Concentration	Allowable Influent Contaminant Load*	Margin of Safety		Required Reduction
Chlorophyll *a*	Phosphorus, Total	181 kg/day	27.4 µg/L	9.5 µg/L	56 kg/day	5%	3 kg/day	70.80%
Secchi Transparency	Phosphorus, Total	181 kg/day	0.7 m	1.04 m	58 kg/day	5%	3 kg/day	69.70%
Phosphorus, Total	Phosphorus, Total	181 kg/day	30 µg/L	32 µg/L	319 kg/day	5%	16 kg/day	0.00%
Nitrogen, Total	Phosphorus, Total	181 kg/day	672.8 µg/L	790 µg/L	181 kg/day	5%	9 kg/day	0.00%
Limiting Load and % Reduction	**Phosphorus, Total**				**56 kg/day**	**5%**	**3 kg/day**	**70.80%**

*Daily Loads for BATHTUB modeling season of May to September

Table D-63. Modeled Total Phosphorus Existing Load and TMDL Point and Non-Point Source Loads (kg/day) during Growing Season (May-September).

Reservoir		Water	Urban	Forest	Pasture	Cropland	Wetland	Home Sewage Treatment Systems	Point Sources	5% Margin of Safety	Total Daily Load
Deer Creek and Dale Walborn Reservoirs	**Existing**	2.16	0.68	0.52	0.72	148.23	25.51	0.61	2.46	---	181
	Allocation	2.16	0.09	0.52	0.1	20.04	25.51	0	1.61	2.78	53
	% Reduction	0.00%	86.10%	0.00%	86.10%	86.10%	0.00%	100.00%	57.90%	---	70.80%

Table D-64. Deer Creek Reservoir Watershed Point Source Discharge Total Phosphorus proposed Limit and Resulting Waste Load.

NPDES Permit Number	Type	Size	Facility Name	County	Total Phosphorus Concentration			Total Phosphorus Load	
					Existing (mg/L)	Proposed (mg/L)	Design Flow (mgd)	Existing (kg/d)	Proposed (kg/d)
3PR00389	Public	Minor	Custom Poly Bag Inc	Stark	3**	3.0	0.0015	0.017	0.017
3PT00079	Public	Minor	Waterloo K-12 Campus	Portage	3**	3.0	0.0200	0.227	0.227
3PH00033	Public	Minor	Atwater WWTP	Portage	2.14	1.0	0.2000	1.620	0.757
3IG00025	Industrial	Minor	Evrol LLC Atwater Terminal*	Portage	3**	3.0	0.0500	0.568	0.568
3PR00259	Public	Minor	Buckeye Packaging Co Inc	Stark	3**	3.0	0.0032	0.036	0.036

* Maximum daily flow in lieu of design flow
** Estimated because lack of historic data

D2.3.3 Total Phosphorus TMDLs - Eagle Creek-Mahoning River (05030103-04)

Three sites were impaired for nutrients in this 10-digit HUC that were addressed with the GWLF watershed loading model. The area covered by this modeling includes four entire 12-digit HUCs (01 through 04) and part of another one (05). Other nutrient impaired sites were not addressed.

Based on the watershed model, cropland is the largest source of total phosphorus to the producing 91.66% of the total load for the drainage. All other sources are minimal in comparison and point sources comprise only 2.81% of the total phosphorus load.

For Eagle Creek at Phalanx Station gage, the summer and autumn seasons required reductions of total phosphorus as 79.6% and 62.5%, respectively. Spring and winter values for total phosphorus existing load medians fell within the TMDL 95% confidence interval of the median which required no reductions in existing load.

Figure D-44 presents the seasonally grouped data (see Section 5.1.3 for months included in each of the seasons) for the Eagle Creek at Phalanx Station gage. The box and whisker plots in this figure are also explained in Section 5.1.3. Table D-65 provides the median loads and the corresponding median TMDLs for the seasons within this drainage. Again, decisions of needed reductions were made by visual median hypothesis test. Reductions are calculated as stated previously by equating medians of the existing load and TMDL groups.

The summer and autumn seasons require reductions in total phosphorus of non-point sources as 83.1% and 65.7%, respectively. The median values for the existing total phosphorus load in spring and winter fell within the 95% confidence interval of the median TMDL therefore no load reductions are required. Total load reductions and associated allocations were proposed for these seasons in Table D-66. Table D-66 also provides individual source loads and TMDL allocations with corresponding percent reductions.

For point source loads, 48.7% is proposed for both spring and summer within this watershed. To assure point source discharges are allocated appropriate load reductions, effluent limits were set to 1 mg/L total phosphorus. Overall, point source loads comprise a small percent of the total phosphorus load; therefore, expensive reductions beyond 1 mg/L would not have a significant impact for total load reductions in the watershed. Table D-67 indicates this proposed concentration limit and associated discharge load allocated to the respective point source. These limits are proposed only during seasons in which loads reductions are needed to meet TMDL goals (i.e., summer and autumn). For septic systems, 100% reduction is proposed.

Again, an explicit 5% margin of safety for each reduced source, except failing septics, was added to the TMDL value prior to determination of gross reductions needed. All source reduction percentages and loads can be viewed in Table D-68 for Eagle Creek at Phalanx Station gage

Table D-65. Median Existing and TMDL Loads with reductions needed for Eagle Creek and tributaries at Phalanx Station Gage Daily Load Daily Load and TMDL Modeled over 10 years for Total Phosphorus.

Season of the Year	Median Existing Daily Load (kg/d)	Median Daily TMDL (kg/day)	TMDL MOS (%)	Total Reduction	
				(kg/d)	Percent
Spring	26,360	27,402	0%	-	0%
Summer	27,325	5,872	5%	21,747	80%
Autumn	17,342	6,850	5%	10,834	62%
Winter	21,498	22,509	0%	-	0%

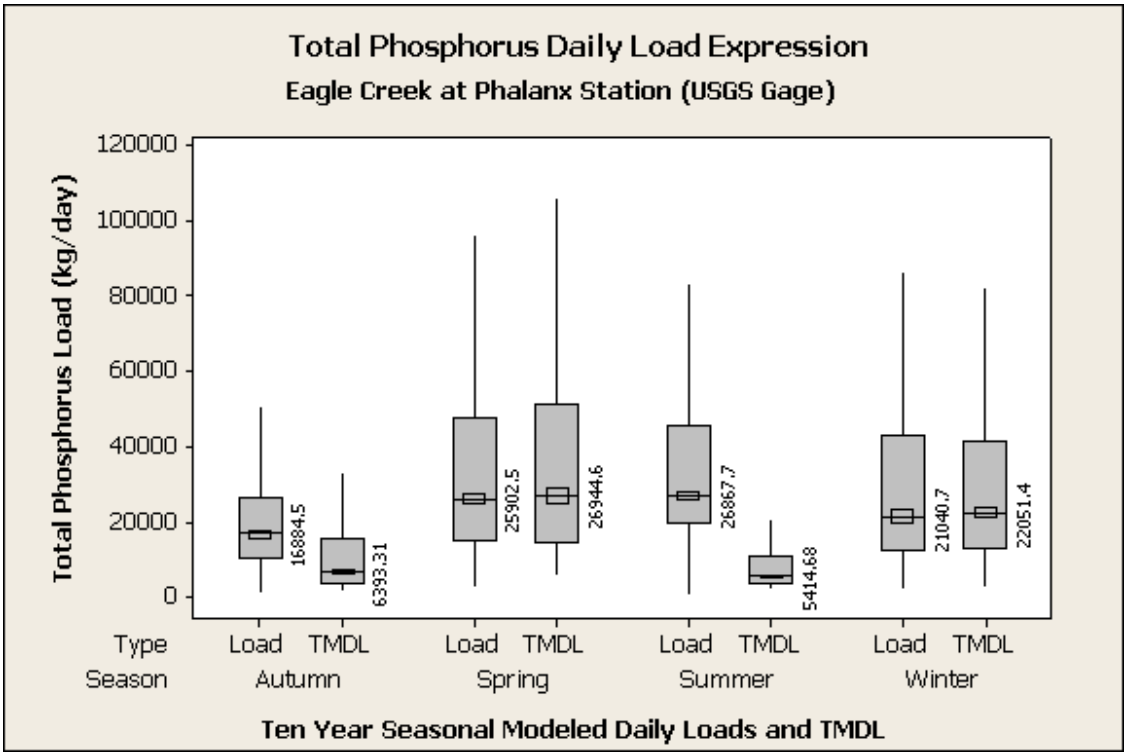

Figure D-44. Eagle Creek at Phalanx Station Gage Daily Load and TMDL Modeled over 10 years for Total Phosphorus (median 95% confidence interval range and values are presented).

Table D-66. Allocations and percent reductions for total phosphorus by source within the GWLF modeled area that employs the Phalanx Station gage on Eagle Creek (HUCs 01 through 05).

SOURCE	Spring Load					Summer Load					
	Total P (kg/d)	TMDL (kg/d)	MOS (%)	Reduction (%)	Total Reduction (kg/d)	Total P (kg/d)	TMDL (kg/d)	MOS (%)	Reduction (%)	Total Reduction (kg/d)	Total P (kg/d)
Water	74.3	74.3	0%	0%	-	46.6	46.6	0%	0%	-	74.3
Urban	272.7	48.4	5%	83%	226.7	171	61.8	5%	66%	112.3	272.7
Other_Urban	187.7	33.3	5%	83%	156.1	117.7	42.6	5%	66%	77.3	187.7
Forest	312	312	0%	0%	-	195.6	195.6	0%	0%	-	312
Pasture	98.4	17.5	5%	83%	81.8	61.7	22.3	5%	66%	40.5	98.4
Cropland	25,406.10	4,507.17	5%	83%	21,124.3	15929.9	5,755.87	5%	66%	10,461.82	25,406.10
Wetland	413.2	413.2	0%	0%	-	259.1	259.1	0%	0%	-	413.2
Groundwater	-	-	0%	0%	-	0	-	0%	0%	-	-
Point Source	10.4	9.126	5%	17%	1.7	10.45	9.126	5%	17%	5.1	10.4
Septic Systems	103.3	-	5%	100%	103.3	103.3	-	5%	100%	103.3	103.3
TOTAL	**26,878.1**	**5,414.7**		**79.9%**	**21694**	**16895**	**6,393.3**		**62.2%**	**10,800.32**	**26,878.1**

Table D-67. Existing and proposed loading information, including wasteload allocations for NPDES dischargers within the GWLF modeled area that employs the Phalanx Station gage on Eagle Creek (HUCs 01 through 05).

Permit Number	Facility	Design Flow (mgd)	Existing Total Phosphorus Effluent Concentration (mg/l)	Existing Total Phosphorus Load (kg/day)	Proposed Total Phosphorus Effluent Concentration (mg/l)	Proposed Total Phosphorus Load - WLA (kg/day)
3PB00016	Garrettsville WWTP	0.3560	3*	4.043	1	1.348
3PB00020	Hiram WWTP	0.20	3.26	2.468	1	0.757
3PV00103	Homestead Manor MHP	0.03	0.794	0.090	1	0.114
3PR00387	Johnson Farm Recreational Camp	0.0030	3*	0.034	3	0.034
3IH00073	Northern Ohio Multi Purpose	0.35	1**	1.325	1	1.325
3PX00004	Modern Management Solutions DBA PM Estates	0.05	3*	0.568	3	0.568
3PG00093	Blackbrook Estates MHP	0.030	3.51	0.399	3.51	0.399
3PR00220	Camp Asbury WWTP	0.0090	3*	0.102	3	0.102
3PG00121	Western Reserve WWTP	0.0132	3*	0.150	3	0.150
3PC00019	Windham WWTP	0.45	0.745	1.269	1	1.703
3PB00016	Garrettsville WWTP	0.3560	3*	4.043	3	4.043
TOTAL		**1.491**	**na**	**10.448**	**na**	**10.519**

* Indicates estimate utilized for TMDL purposes for those facilities in which no data exists.
** Total P concentration is limited by NPDES permit.

Table D-68. Total annual loads and pollutant yields per the significant sources within the GWLF modeled area that employs the Phalanx Station gage on Eagle Creek (HUCs 01 through 05).

Source	Area (ha)	Total P (kg/d)	kg/ha/day	lb/ac/day	% of Total
Cropland	5,301	15,159	2.860	2.551	97%
Urban	2,188	214	0.098	0.087	1%
Septic Systems	na	103	na	na	1%
Pasture	2,806	73	0.026	0.023	0.5%
Forest	12,689	54	0.004	0.004	0.3%
Water	152	35	0.231	0.206	0.2%
Other_Urban	2,116	28	0.013	0.012	0.2%
Wetland	26	20	0.758	0.676	0.1%
Point Source	na	10	na	na	0.1%
Groundwater	na	-	na	na	0.0%
TOTAL	**25,278**	**15,697**	**0.621**	**0.549**	**100%**

D3 References

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