Appendix

D

LOADING ANALYSIS INFORMATION
PAINT CREEK WATERSHED

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D1 Background

The aquatic beneficial life use is not adequately supported in areas of the Paint Creek watershed according to Ohio EPA's 2006 field survey (Ohio EPA, 2008). The aquatic life issues tend to be concentrated in the northwest region upstream Paint Creek Lake, with some clustered issues throughout the rest of the basin. Recreation beneficial use is not met in most of the Paint Creek watershed, with the exception of the Paint Creek mainstem between Paint Creek Lake and the Scioto River. The recreation use issues are throughout the basin's tributaries which are impacted by various sources controlled by seasonal variation and hydrology. The goal of the TMDL process is to achieve full attainment of the Water Quality Standards, especially attainment of the numerical biological, *E. coli*, and dissolved oxygen chemical criteria. The non-attainment of water quality standards is primarily due to nutrient and organic enrichment, suppressed dissolved oxygen due to eutrophication, sedimentation, habitat degradation, and *E. coli* concentrations above acceptable recreation use levels.

Nutrients rarely approach concentrations in the ambient environment that are toxic to aquatic life. US EPA (1976) concluded that "levels of nitrate nitrogen at or below 90 mg/L would not have [direct] adverse effects on warm water fish." However, nutrients, while essential to the functioning of healthy aquatic ecosystems, can exert negative effects at much lower concentrations by altering trophic dynamics, increasing algal and macrophyte production, increasing turbidity (via increased phytoplanktonic algal production), decreasing average dissolved oxygen concentrations, and increasing fluctuations in diel dissolved oxygen and pH. Such changes are caused by higher than normal nutrient concentrations and/or low stream corridor assimilative capacity resulting in shifts in species composition away from functional assemblages of intolerant species, benthic insectivores and top carnivores (e.g., darters, insectivorous minnows, redhorse, sunfish, and black basses) typical of high quality warm water streams towards less desirable assemblages of tolerant species, niche generalists, omnivores, and detritivores (e.g., creek chub, bluntnose minnow, white sucker, carp, green sunfish) typical of degraded warm water streams (OEPA, 1999).

Benthic substrate nutrient concentrations in the heavily farmed northwest region of the Paint Creek watershed are excessive in comparison with statewide data from unimpaired streams. Average phosphorus in-stream concentrations are typically excessive during the spring, and are continuously elevated below wastewater treatment facilities. Further, depressed dissolved oxygen levels, excessive algae, and trophic species shifts have been documented indicating nutrient enrichment problems.

The effects of nutrient enrichment are exacerbated by poor physical habitat; conversely, high quality habitat can mitigate those effects. High quality riverine habitats with intact riparian zones and natural channel morphology may decrease the potentially adverse effects of nutrients by assimilating excess nutrients directly into plant biomass (e.g., trees and macrophytes), by sequestering nutrients into invertebrate and vertebrate biomass, by "deflecting" nutrients into the immediate riparian zone during runoff events, and by reducing sunlight (a principal limiting factor in algal production) through shading (Mulholland, 1992). Also, high quality habitats minimize nutrient retention time in the water column during low flows because they tend to have high flow velocities in narrow low flow channels (e.g., unbraided vs. braided riffles), and coarse substrates with little potential for adsorption. Additionally, a healthy community of aquatic organisms typical of high quality habitats process and utilize nutrients very efficiently.

The habitat quality in the Paint Creek watershed ranges from poor to excellent. In general, however, the habitat quality is degraded in many of the headwater streams in the watershed. Headwater habitat quality is a critical component of the assimilative capacity for the protection of downstream uses; poor headwater habitat quality significantly reduces the capacity of a stream to assimilate nutrients and the effect of this is perpetuated throughout the stream system (citation needed).

Pathogen levels are also a concern in the Paint Creek basin, as recreation use impairment was identified at most sample sites. The group of bacteria known as *E. coli* is used as an indicator of the presence of various pathogens, such as *E. coli* O157:H7, cryptosporidium, and *Giardia lamblia*. The *E. coli* concentration data collected within a recreation season is used to calculate the group's statistical geometric mean, which is compared against Ohio's recreation use criteria. Class A waters are listed by ODNR as preferential canoe access recreation waters and must meet a seasonal geometric mean concentration of 126 cfu/100mL. Most of the other waters of the State are listed as Class B and must meet a seasonal geometric mean concentration of 161 cfu/100mL.

The geometric mean is used as the central tendency of the population due to the log-normal distributional nature of *E. coli* loadings, with the largest *E. coli* loadings typically dependent on pulsing short term high flow events. These short lived pulse loads of pathogens are typically during flows with less expected in-stream recreational activity in Ohio waters, although still a risk for high water sporting. Although the *E. coli* concentration levels dissipate in a few days after a high flow event, the stream bottom may be seeded with pathogens that can persist over six months. Other high loading events not necessarily in tandem with high stream flow include residual combined sewer releases, sludge lagoon failures, dense livestock with stream access, and loadings from failing straight-pipe septic systems. These types of loadings are not permitted due to the high potential for causing water borne illnesses from recreational contact with calm flowing waters. Typical sources of loadings are agricultural and residential washoff, permitted point sources, and wildlife.

Based on the 2006 results, a study was carried out to develop total maximum daily loads (TMDLs) for aquatic and recreation impairments as required by Section 303(d) of the Clean Water Act and the United States Environmental Protection Agency's Water Quality Planning and Management Regulations (Title 40 of the Code of Federal Regulations, Part 130). This TMDL report defines in-stream water quality conditions, potential point and nonpoint sources, pollutant targets, and pollutant reductions. Table D1-1 lists all the Paint Creek impairments and the methods used to address these impairments.

Table D1-1. Summary of impairment causes and actions taken for aquatic life and recreation uses for the Paint Creek watershed.

Assessment Unit (05060003)	Narrative Description	Causes of Impairment (Beneficial use in parentheses)	Action Taken
Headwaters Paint Creek (05060003 01)			
01 01 *Priority points: 3*	Headwaters Paint Creek	Insufficient data to assess (ALU[1])	No action necessary
		E. coli (RU[2])	Bacteria TMDL
01 02 *Priority points: 6*	East Fork Paint Creek	Dissolved oxygen (ALU)	Nutrient TMDL as surrogate
		Sedimentation/siltation (ALU)	Sediment TMDL
		Other flow regime alterations (ALU)	Habitat TMDL
		E. coli (RU)	Bacteria TMDL
01 03 *Priority points: 7*	Town of Washington Court House-Paint Creek	Dissolved oxygen (ALU)	Nutrient TMDL as surrogate
		Sedimentation/siltation (ALU)	Sediment TMDL
		Nutrient eutrophication biological indicators (ALU)	Nutrient TMDL
		Direct habitat alterations (ALU)	Habitat TMDL
		Other flow regime alterations (ALU)	Habitat TMDL
		E. coli (RU)	Bacteria TMDL
		Insufficient data to assess (PDWSU)	No action necessary
Sugar Creek (05060003 02)			
02 01 *Priority points: 5*	Headwaters Sugar Creek	Direct habitat alterations (ALU)	Habitat TMDL
		Nutrient eutrophication biological indicators (ALU)	Nutrient TMDL
		Dissolved oxygen (ALU)	Nutrient TMDL as surrogate
		E. coli (RU)	Bacteria TMDL
02 02 *Priority points: 6*	Camp Run-Sugar Creek	Nutrient eutrophication biological indicators (ALU)	Nutrient TMDL
		E. coli (RU)	Bacteria TMDL
Headwaters Rattlesnake Creek (05060003 03)			
03 01 *Priority points: 2*	Wilson Creek	Impairment unknown (ALU)	No action necessary
		Direct habitat alterations (ALU)	Habitat TMDL
		Organic enrichment (sewage) biological indicators (ALU)	Bacteria TMDL as surrogate
		Ammonia (total) (ALU)	Bacteria TMDL as surrogate
		E. coli (RU)	Bacteria TMDL
03 02 *Priority points: 1*	Grassy Branch	Other flow regime alterations (ALU)	Habitat TMDL
		No impairment (RU)	No action necessary
03 03 *Priority points: 3*	West Branch Rattlesnake Creek	Sedimentation/siltation (ALU)	Sediment TMDL
		Dissolved oxygen (ALU)	Habitat TMDL as surrogate

Assessment Unit (05060003)	Narrative Description	Causes of Impairment (Beneficial use in parentheses)	Action Taken
		E. coli (RU)	Bacteria TMDL
03 04 *Priority points: 7*	Headwaters Rattlesnake Creek	Direct habitat alterations (ALU)	Habitat TMDL
		Dissolved oxygen (ALU)	Habitat TMDL as surrogate
		E. coli (RU)	Bacteria TMDL
03 05 *Priority points: 7*	Waddle Ditch-Rattlesnake Creek	Direct habitat alterations (ALU)	Habitat TMDL
		Sedimentation/siltation (ALU)	Sediment TMDL
		E. coli (RU)	Bacteria TMDL
Lees Creek-Rattlesnake Creek (05060003 04)			
04 01 *Priority points: 4*	South Fork Lees Creek	Organic enrichment (sewage) biological indicators (ALU)	Bacteria TMDL as surrogate
		Dissolved oxygen (ALU)	Bacteria TMDL as surrogate
		Ammonia (total) (ALU)	Bacteria TMDL as surrogate
		E. coli (RU)	Bacteria TMDL
04 02 *Priority points: 0*	Middle Fork Lees Creek	No impairment (ALU)	No action necessary
		No impairment (RU)	No action necessary
04 03 *Priority points: 5*	Lees Creek	Other flow regime alterations (ALU)	Habitat TMDL
		Organic enrichment (sewage) biological indicators (ALU)	Bacteria TMDL as surrogate
		Dissolved oxygen (ALU)	Bacteria TMDL as surrogate
		E. coli (RU)	Bacteria TMDL
04 04 *Priority points: 3*	Walnut Creek	No impairment (ALU)	No action necessary
		E. coli (RU)	Bacteria TMDL
04 05 *Priority points: 0*	Hardin Creek	No impairment (ALU)	No action necessary
		No impairment (RU)	No action necessary
04 06 *Priority points: 3*	Fall Creek	Organic enrichment (sewage) biological indicators (ALU)	Not addressed
		Nutrient eutrophication biological indicators (ALU)	Not addressed
		No impairment (RU)	No action necessary
04 07 *Priority points: 4*	Big Branch-Rattlesnake Creek	No impairment (ALU)	No action necessary
		E. coli (RU)	Bacteria TMDL
Rocky Fork (05060003 05)			
05 01 *Priority points: 0*	South Fork Rocky Fork	No impairment (ALU)	No action necessary
		No data for assessment (RU)	No action necessary
05 02 *Priority points: 7*	Clear Creek	Organic enrichment (sewage) biological indicators (ALU)	Narrative of upgraded Hillsboro WWTP
		Other flow regime alterations (ALU)	Habitat TMDL
		E. coli (RU)	Bacteria TMDL
		Insufficient data to assess (PDWSU)	No action necessary

Assessment Unit (05060003)	Narrative Description	Causes of Impairment (Beneficial use in parentheses)	Action Taken
05 03 *Priority points: 5*	Headwaters Rocky Fork	No impairment (ALU)	No action necessary
		E. coli (RU)	Bacteria TMDL
05 04 *Priority points: 0*	Rocky Fork Lake-Rocky Fork	No data for assessment (ALU)	No action necessary
		No data for assessment (RU)	No action necessary
05 05 *Priority points: 10*	Franklin Branch-Rocky Fork	Nutrient eutrophication biological indicators (ALU)	Bacteria TMDL as surrogate
		E. coli (RU)	Bacteria TMDL
Indian Creek-Paint Creek (05060003 06)			
06 01 *Priority points: 11*	Indian Creek-Paint Creek	Natural conditions (flow or habitat) (ALU)	No action necessary
		Nutrient/eutrophication biological indicators (ALU)	Nutrient TMDL (Indian Creek only)
		Other flow regime alterations (ALU)	Habitat TMDL
		E. coli (RU)	Bacteria TMDL (Indian Creek only)
06 02 *Priority points: 11*	Farmers Run-Paint Creek	Organic enrichment (sewage) biological indicators (ALU)	Bacteria TMDL as surrogates
		E. coli (RU)	Bacteria TMDL
06 03 *Priority points: 2*	Cliff Creek-Paint Creek	No data for assessment (ALU)	No action necessary
		No impairment (RU)	No action necessary
Buckskin Creek-Paint Creek (05060003 07)			
07 01 *Priority points: 6*	Buckskin Creek	Nutrient/eutrophication biological indicators (ALU)	Bacteria TMDL as surrogate
		Other flow regime alterations (ALU)	Habitat TMDL
		E. coli (RU)	Bacteria TMDL
07 02 *Priority points: 3*	Upper Twin Creek	No impairment (ALU)	No action necessary
		E. coli (RU)	Bacteria TMDL
07 03 *Priority points: 4*	Lower Twin Creek	Insufficient data to assess (ALU)	No action necessary
		E. coli (RU)	Bacteria TMDL
07 04 *Priority points: 9*	Sulphur Lick-Paint Creek	Direct habitat alterations (ALU)	Habitat TMDL
		Sedimentation/siltation (ALU)	Sediment TMDL
		Dissolved oxygen (ALU)	Habitat TMDL as surrogate
		E. coli (RU)	Bacteria TMDL
Headwaters North Fork Paint Creek (05060003 08)			
08 01 *Priority points: 3*	Thompson Creek	No impairment (ALU)	No action necessary
		E. coli (RU)	Bacteria TMDL
08 02 *Priority points: 0*	Headwaters North Fork Paint Creek	No impairment (ALU)	No action necessary
		No impairment (RU)	No action necessary
08 03 *Priority points: 3*	Headwaters Compton Creek	No impairment (ALU)	No action necessary
		E. coli (RU)	Bacteria TMDL
08 04	Mills Branch-	No impairment (ALU)	No action necessary

Assessment Unit (05060003)	Narrative Description	Causes of Impairment (Beneficial use in parentheses)	Action Taken
Priority points: 4	Compton Creek	*E. coli* (RU)	Bacteria TMDL
08 05 *Priority points: 6*	Mud Run-North Fork Paint Creek	No impairment (ALU)	No action necessary
		E. coli (RU)	Bacteria TMDL
Little Creek-North Fork Paint Creek (05060003 09)			
09 01 *Priority points: 0*	Herrod Creek	No data for assessment (ALU)	No action necessary
		No data for assessment (RU)	No action necessary
09 02 *Priority points: 2*	Little Creek	No impairment (ALU)	No action necessary
		E. coli (RU)	Bacteria TMDL
09 03 *Priority points: 7*	Oldtown Run-North Fork Paint Creek	Organic enrichment (sewage) biological indicators (ALU)	Bacteria TMDL as surrogate
		Sedimentation/siltation (ALU)	Sediment TMDL
		E. coli (RU)	Bacteria TMDL
09 04 *Priority points: 4*	Biers Run-North Fork Paint Creek	No impairment (ALU)	No action necessary
		E. coli (RU)	Bacteria TMDL
Ralston Run-Paint Creek (05060003 10)			
10 01 *Priority points: 0*	Black Run	No impairment (ALU)	No action necessary
		No impairment (RU)	No action necessary
10 02 *Priority points: 5*	Ralston Run	Organic enrichment (sewage) biological indicators (ALU)	Bacteria TMDL as surrogate
		Sedimentation/siltation (ALU)	Sediment TMDL
		E. coli (RU)	Bacteria TMDL
10 03 *Priority points: 8*	City of Chillicothe-Paint Creek	No impairment (ALU)	No action necessary
		E. coli (RU)	Bacteria TMDL
Paint Creek (Paint Creek Lake dam to mouth)			
Large River *Priority points: 4*	Paint Creek Mainstem (Rocky Fork to mouth)	Dissolved oxygen (ALU)	Narrative
		No impairment (RU)	No action necessary

D2 Linkage Discussion

Total phosphorus to address nutrient enrichment

The aquatic life use designations for warm water and exceptional warm water habitats are impaired in several areas of the northern region of the Paint Creek watershed due to low dissolved oxygen caused by nutrients and algal/macrophyte decay in the water column and substrate. Some locations are listed as impaired directly by nutrient eutrophication as biological signatures of such stress are observed in the data. The sources of nutrients and organics that result in high oxygen consumption can be from row crop production, livestock, failing septic systems, permitted municipal and private point sources, sewer overflows, urban runoff and direct habitat alteration.

In freshwater systems, phosphorus is typically the nutrient that is in short supply relative to biological needs, which means that the productivity of aquatic plants and algae can be controlled by limiting the amount of phosphorus entering the water (Sharpley, 1999). Large diurnal swings in pH and dissolved oxygen may occur as excessive amounts of nutrients are metabolized by aquatic plants and algae. The extremes of the swings often exceed the state

water quality criteria established to protect fish and other aquatic organisms in their various life stages. The amount of phosphorus currently entering these waters exceeds the assimilative capacity of the receiving waters and must be addressed if these water quality problems are to be resolved. The sources of phosphorus loading and the speciation of phosphorus vary depending on the human activities and conditions in a specific watershed (U.S. EPA 2007).

Statewide total phosphorus (TP) targets for various size drainage area streams have been developed by Ohio EPA (1999) in order to address excessive nutrient enrichment impacting stream life. Phosphorus is selected as the nutrient to focus on for nutrient TMDLs because it is frequently the limiting nutrient to algal growth in the fresh water streams of Ohio. In effect, limiting the loading of phosphorus to streams reduces the impacts described above caused by excessive algal and aquatic plant life, thus addressing a stream's nutrient enrichment. Ohio EPA has clearly documented (Ohio EPA, 2007) how reducing TP loadings to streams mitigates in-stream nutrient enrichment.

Qualitative habitat assessment to address direct habitat alterations, sedimentation/siltation and flow alterations

Habitat alteration and sedimentation are causes of impairment at several assessment sites in the Paint Creek watershed. Poor habitat quality and an excessive amount of stream bed deposited sediment are environmental conditions, rather than a pollutant loads, so development of a load-based TMDL to address this cause of impairment is not possible.

The Qualitative Habitat Evaluation Index (QHEI) is a quantitative expression of a qualitative, visual assessment of habitat in free flowing streams and was developed by the Ohio EPA to assess available habitat for fish communities (Rankin, 1989, 1995). This tool provides a numeric value, which is assigned to a particular stream segment based on the quality of its habitat. The QHEI evaluates six general aspects of physical habitat that include channel substrate, instream cover, riparian characteristics, channel condition, pool/riffle quality, gradient and drainage area. Analysis of QHEI and biological response data by Ohio EPA (1999) determined the most sensitive aspects and breakpoint values for these aspects. Using these aspects/breakpoints as targets to directly address habitat impairment as a TMDL is an explicit method to mitigate impairment. This has been successfully employed by Ohio EPA (Ohio EPA, 2006, 2009, etc.).

Qualitative habitat assessment to address dissolved oxygen

In a few HUC 12 subwatersheds the Qualitative Habitat Evaluation Index (QHEI) TMDL method is used to address nutrient enrichment and dissolved oxygen caused impairments. Poor quality habitat with reduced or debilitated riparian zones (either no riparian zone is present or runoff bypasses the zone via field tiles) and simplified channel morphology generally exacerbate the deleterious effects of nutrients by reducing the riparian uptake and conversion of nutrients. Simplified morphology increases the retention time and sediment-water column interface via a wide channel and subsequent loss of low flow energy (e.g., increased intermittency). Retention of nutrients within the channel due to the diminished filtering time during overland flow events occurs as well. All of these factors allow for sunlight to stimulate nuisance growths of algae. These factors also interact to increase the retention of nutrients in the most available dissolved forms, attached to fine sediments (especially clays and silts) and in planktonic and attached algae (OEPA, 1999). In addition to phosphorus control, improvement of the stream corridor's habitat, although not a true "load", has a strong effect on rectifying dissolved oxygen levels not suitable for desired aquatic biology.

Pathogens (bacteria) to address recreational use impairments
Chronic *E. coli* concentration levels are direct evidence of recreation use impairment. Ohio standards are in place to protect against public health nuisances and recreational use of waterbodies. Recreation use of waterbodies is defined in OAC 3745-1-07 (4), which states "…use designations are in effect only during the recreation season, which is the period from May first to October thirty-first. These values serve as the targets used in the development of the TMDLs that address recreation use impairments. Therefore the use of *E. coli* to address recreational use impairment is adequate as it is dictated by state statute.

Pathogens (bacteria) to address nutrient enrichment (including dissolved oxygen and ammonia) and organic enrichment impairments
Organic enrichment as noted by biological indicators is also listed as a cause of aquatic impairment. Although there are criteria for BOD, the loading mechanisms of organic enrichment may be acute in nature which may not leave a significant marker in the water column chemistry. As with other previously mentioned pollutants, the OAC 3745-1-04 general water quality criteria explains that surface waters are to be "free from" substances entering waters as a result of human activity that will adversely affect aquatic life and/or create a public nuisance. Some of the organic enrichment issues were created by sporadic wastewater treatment, which also produced elevated levels of ammonia. Other areas have been affected by livestock feedlot and manure management problems. In both examples, correction of source issues diminishes all related pollutant loads to the waterbody. Therefore, depending on the source(s) of organic enrichment of an assessment unit, *E. coli*, TP, and/or NH_3-N TMDLs shall act as surrogate measures to address the 303(d) listing.

D3 Analysis Methods

The geology and impairment distribution of the Paint Creek watershed calls for different levels of analysis. The sites listed for nutrient and sediment related issues of the upper Paint Creek system with the compounding issues of the cities of Washington Court House and Greenfield wastewater treatment plants merits a detailed analysis to appropriately quantify source contributions. Due to resource constraints and the extent of impairments, the remainder of the basin is not subjected to the same level of analysis. The upper Paint Creek analysis also provides an in-depth quantification of *E. coli* loadings.

Establishing the relationship between the in-stream water quality targets and source loadings is a critical component of TMDL development. It allows for evaluation of management options that will achieve the desired source load reductions. The link can be established through a range of techniques, from qualitative assumptions based on sound scientific principles to sophisticated modeling techniques. The objective of this section is to present the approach taken to develop the linkage between sources and in-stream response for TMDL development in the Paint Creek watershed.

Tables D3-1 through D3-5 indicates how the applicable causes of impairment are addressed in each of the assessment units.

Table D3-1. Summary of causes of impairment and actions taken to address them in assessment units within the 05060003 01 and 05060003 02 ten-digit hydrologic units.

	Watershed Assessment Units				
	05060003 01			05060003 02	
Causes of Impairment	**01**	**02**	**03**	**01**	**02**
Aquatic Life Use					
Nutrient enrichment			D	D	D
Dissolved oxygen/organic enrichment		S^1	S^1	S^1	
Habitat alterations			D	D	
Sedimentation/siltation		D	D		
Flow regime alterations		S	S		
Recreation Use					
E. coli	D	D	D	D	D

D – direct	Means that TMDLs are calculated for this parameter.
S – surrogate	Means that TMDLs are calculated for a closely related cause and actions to reduce the impact of that cause should be sufficient to address this cause.
S^1 – surrogate LSPC	A TP TMDL using the LSPC model addresses this impairment.
Blank	Indicates that the assessment unit is not impaired for this cause.

Table D3-2. Summary of causes of impairment and actions taken to address them in assessment units within the 05060003 03 and 05060003 04 ten-digit hydrologic units.

	Watershed Assessment Units											
	05060003 03					05060003 04						
Causes of Impairment	**01**	**02**	**03**	**04**	**05**	**01**	**02**	**03**	**04**	**05**	**06**	**07**
Aquatic Life Use												
Nutrient enrichment											S^1	
Dissolved oxygen/organic enrichment	S^1		S^2	S^2		S^1		S^1			S^1	
Ammonia	S^1					S^1						
Habitat alterations	D	D		D	D							
Sedimentation/siltation			D		D							
Flow regime alterations								S				
Recreation Use												
E. coli (LDC)	D		D	D	D	D		D	D			D

D – direct	Means that TMDLs are calculated for this parameter.
S – surrogate	Means that TMDLs are calculated for a closely related cause and actions to reduce the impact of that cause should be sufficient to address this cause.
S^1 – surrogate LDC	An *E. coli* LDC TMDL is used to address this impairment.
S^2 – surrogate QHEI	A QHEI TMDL is used to address this impairment.
Blank	Indicates that the assessment unit is not impaired for this cause.

Table D3-3. Summary of causes of impairment and actions taken to address them in assessment units within the 05060003 05 and 05060003 06 ten-digit hydrologic units.

	Watershed Assessment Units							
	05060003 05					05060003 06		
Causes of Impairment	**01**	**02**	**03**	**04**	**05**	**01**	**02**	**03**
Aquatic Life Use								
Nutrient enrichment					S[1]	D		
Dissolved oxygen/organic enrichment		ne					S[2]	
Habitat alterations								
Sedimentation/siltation								
Flow regime alterations		S				S		
Recreation Use								
E. coli (LDC)		D	D		D	D	D	

D – direct	Means that TMDLs are calculated for this parameter.
S – surrogate	Means that TMDLs are calculated for a closely related cause and actions to reduce the impact of that cause should be sufficient to address this cause.
S[1] – surrogate LDC	An *E. coli* LDC TMDL is used to address this impairment.
S[2] – surrogate LDC	A TP TMDL using the LSPC model addresses this impairment.
Blank	Indicates that the assessment unit is not impaired for this cause.
ne	Narratively explained; impairment expected to be resolved.

Table D3-4. Summary of causes of impairment and actions taken to address them in assessment units within the 05060003 07 and 05060003 08 ten-digit hydrologic units.

	Watershed Assessment Units								
	05060003 07				05060003 08				
Causes of Impairment	**01**	**02**	**03**	**04**	**01**	**02**	**03**	**04**	**05**
Aquatic Life Use									
Nutrient enrichment	S[1]								
Dissolved oxygen/organic enrichment									
Ammonia									
Habitat alterations				D					
Sedimentation/siltation				D					
Flow regime alterations	S								
Recreation Use									
E. coli (LDC)	D	D	D	D	D		D	D	D

D – direct	Means that TMDLs are calculated for this parameter.
S – surrogate	Means that TMDLs are calculated for a closely related cause and actions to reduce the impact of that cause should be sufficient to address this cause.
S[1] – surrogate LDC	An *E. coli* LDC TMDL is used to address this impairment.
Blank	Indicates that the assessment unit is not impaired for this cause.

Table D3-5. Summary of causes of impairment and actions taken to address them in assessment units within the 05060003 09, 05060003 10 ten-digit hydrologic units and the Paint Creek large river unit.

	Watershed Assessment Units							
	05060003 09				05060003 10			Large River Unit
Causes of Impairment	**01**	**02**	**03**	**04**	**01**	**02**	**03**	**Paint Creek**
Aquatic Life Use								
Nutrient enrichment								ne
Dissolved oxygen/organic enrichment			S[1]			S[1]		
Ammonia								
Habitat alterations								
Sedimentation/siltation			D			D		
Flow regime alterations								
Recreation Use								
E. coli (LDC)		D	D	D		D	D	

D – direct	Means that TMDLs are calculated for this parameter.
S – surrogate	Means that TMDLs are calculated for a closely related cause and actions to reduce the impact of that cause should be sufficient to address this cause.
S[1] – surrogate LDC	An *E. coli* LDC TMDL is used to address this impairment.
Blank	Indicates that the assessment unit is not impaired for this cause.
ne	Narratively explained; impairment expected to be resolved.

D3.1 Loading Simulation Program in C++ (LSPC) method

D3.1.1 Justification of method

Establishing the relationship between the in-stream water quality targets and source loadings is a critical component of TMDL development. It allows for evaluation of management options that will achieve the desired source load reductions. The link can be established through a range of techniques, from qualitative assumptions based on sound scientific principles to sophisticated modeling techniques. The objective of this section is to present the approach taken to develop the linkage between sources and in-stream response for TMDL development in the Paint Creek watershed.

Selection of the appropriate approach or modeling technique requires consideration of the following: Expression of water quality criteria, Dominant processes, Source integration, Scale of analysis, TMDL scenario evaluation. Numeric criteria, such as those applicable here, require evaluation of magnitude, frequency, and duration. Thresholds of a numeric measure are often evaluated for frequency of exceedance (e.g., not to exceed more than once every 30 days). Acute standards typically require evaluation over short time periods and violations may occur under variable flow conditions. Chronic criteria require the evaluation of the response over a longer averaging period. The approach or modeling technique must permit representation of in-stream concentrations under a variety of flow conditions in order to evaluate critical periods for comparison to acute and chronic criteria.

The appropriate approach must also consider the dominant processes regarding pollutant loadings and in-stream fate. For the Paint Creek watershed, primary sources contributing to pathogen impairments include an array of nonpoint or diffuse sources as well as discrete direct inputs to the stream including permitted point source discharges, and direct deposition from

animals. Loading processes for nonpoint sources or land-based activities are typically rainfall driven and thus relate to surface runoff and subsurface discharge to a stream.

Key in-stream factors that must be considered include routing of flow, dilution, transport, and fate (decay or transformation) of pollutants.

Scale of analysis and waterbody type must also be considered in the selection of the overall approach. The approach should have the capability to evaluate watersheds at multiple scales, and be able to adequately represent the spatial distribution of sources and the delivery processes whereby pathogens are delivered throughout the stream network.

Based on the considerations, analysis of the monitoring data, review of the literature, characterization of the pathogen sources, the need to represent source controls to individual sources, and previous modeling experience, the Loading Simulation Program in C++ (LSPC) is selected to represent the source-response linkage in the upper Paint Creek watershed. LSPC is maintained by the US EPA Office of Research and Development in Athens, GA. Version 3.1 of the model was acquired from the developers, Tetra Tech, which incorporated in-stream nutrient processes.

LSPC 3.1 is a watershed modeling system that includes streamlined Hydrologic Simulation Program in Fortran (HSPF) algorithms for simulating hydrology, sediment, and general water quality on land as well as a simplified stream transport model and a more detailed stream nutrient processing model. A key data management feature of this system is that it uses a Microsoft Access database to manage model data and weather text files for driving the simulation. For each model run, it automatically generates comprehensive text-file output by subwatershed for all land-layers, reaches, and simulated modules, which can by expressed on hourly or daily intervals.

The LSPC model is essentially a re-coded C++ version of selected HSPF modules. LSPC's algorithms are identical to those of HSPF. HSPF has been used extensively throughout the United States for TMDL development. Refer to the HSPF User's Manual for a more detailed discussion of simulated processes and model parameters. While LSPC has the benefit of being streamlined, it does lack several of the special options available with HSPF. For the purposes of upper Paint Creek, LSPC contains the appropriate modules for the watershed's TMDL developments. For this modeling effort, benthic algae, zooplankton, pH and carbon are not used since HSPF representation is not fully developed into LSPC 3.1 for these components. Instead, water column algae was used to represent the total primary productivity of the reaches, the simulated minimum daily DO results are compared to the minimum standard, and pH was taken directly from field measurements in order to assess the potential of ammonia speciation and toxicity issues. The LSPC/HSPF demands greater user experience and time commitment than other comparable models. For this reason, LSPC analysis is limited to the Upper Paint Creek region. Although it is a complex model to run, the benefits of calibration and load quantification provide powerful insight to the interdependent constituents of a waterbody. LSPC also contains a TMDL module, where the user enters percent load reductions to point or diffused sources until water quality targets are achieved.

D3.1.2 Targets for LSPC modeling

E. coli

TMDL numeric targets for *E. coli* bacteria are derived from bacteriological water quality standards. The criterion for *E. coli* specified in §OAC 3745-1-07 are applicable outside the mixing zone and vary for waters that are classified as primary contact recreation (PCR). The Paint Creek mainstem from its river mile 71.16 downstream to its mouth, the North Fork Paint Creek from its river mile 37.39 to its mouth and the Rocky Fork from its river mile 18.05 to its mouth are all Class A streams in this watershed. This class indicates the most intensive use. The remainder of streams assessed in this watershed is Class B primary contact recreation streams. Class B streams support infrequent primary contact recreation activities. For Class A streams the criteria states that the geometric mean of more than one *E. coli* sample taken in each recreational season (May through October) shall not exceed 126 colony forming units (cfu) per 100 ml. For Class B the geometric mean of more than one *E. coli* sample taken in each recreational season shall not exceed 161 cfu per100 ml.

TMDLs are created for watersheds that drain to an assessment site that is not meeting the recreational use criterion described in the paragraph above. The criteria values are used as the TMDL targets for this impairment. If an LDC TMDL site is within a Class B stream section, but five river miles or closer upstream of a Class A designated section, then the Class A aspect of the criterion is applied to this TMDL.

Total phosphorus

While the Ohio EPA does not currently have statewide numeric criteria for phosphorus, potential targets have been identified in an Ohio EPA technical report titled “Association between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams”, (Ohio EPA, 1999). This document provides the results of a study analyzing the effects of nutrients on the aquatic assemblages of Ohio streams and rivers. The study reaches a number of conclusions and stresses the importance of habitat and other factors, in addition to instream nutrient concentrations, as having an impact on the health of biologic communities. The study also includes proposed targets for nitrate+nitrite concentrations and total phosphorus concentrations based on observed concentrations at reference sites. Reference sites are relatively not impacted sites that are used to define the expected or potential biological community.

Based on drainage areas, the Statewide total phosphorus average targets are WWH 0.08 mg/L for drainage areas under 20 sqmi, WWH 0.1 mg/L and EWH 0.05 mg/L for drainage areas between 20 and 200 sqmi, and WWH 0.17mg/L and EWH 0.1 mg/L for drainage areas between 200 and 1000 sqmi. It is important to note that these nutrient targets are not codified in Ohio’s water quality standards; therefore, there is a certain degree of flexibility as to how they can be used in a TMDL setting. Ohio’s standards also include narrative criteria that limit the quantity of nutrients that may enter state waters. Specifically, OAC Rule 3745-1-04 (E) states that all waters of the state, “…shall be free from nutrients entering the waters as a result of human activity in concentrations that create nuisance growths of aquatic weeds and algae.” In addition, OAC Rule 3745-1-04(D) states that all waters of the state, “…shall be free from substances entering the waters as a result of human activity in concentrations that are toxic or harmful to human, animal or aquatic life and/or are rapidly lethal in the mixing zone.” Excess concentrations of nutrients that contribute to non-attainment of biological criteria may fall under either OAC Rule 3745-1-04 (D) or (E) prohibitions.

D3.1.3 LSPC model setup, processes, data needs

The Loading Simulation Program in C++ (LSPC) version 3.1 (TetraTech, Inc, 2009) model is employed to address recreational use and nutrient enriched aquatic life use impairments in the upper Paint Creek subwatersheds.

Table D3-6 presents the modules from HSPF used in the LSPC dynamic watershed model. The user may refer to the HSPF User's Manual for a more detailed discussion of simulated processes and model parameters. For modeling nutrients available within land sources, the nutrient/agricultural soil interaction module is not available in LSPC V3.1 (MSTLAY, PEST, NITR, PHOS, and TRACER). Instead of allowing the model to speciate nutrients and/or pollutants through soil chemistry dynamics, values are entered for interflow and groundwater concentrations, and surface load buildup through the GQUAL (General Quality) module. The pervious and impervious land source outputs are then tracked with the RCHRES (Reach-Reservoir) module through the connected stream segments with the option of first order decay of the constituents. This simplified stream model is suitable for modeling pollutants like *E. coli*, contaminated sediment, metals, and chlorides for example. BOD and nutrients derived from the GQUAL land processes have the option of being converted to constituents controlled by the RQUAL (Reach Quality) module for in-stream interdependent dynamics. Table D3-7 presents the HSPF modules involved in the RCHRES and RQUAL modules. For the Paint Creek eutrophic modeling, benthic algae, zooplankton, pH, and carbon were not used since their HSPF representations are not fully developed in LSPC V3.1. Instead, water column algae (phytoplankton) are calibrated to represent the sole source of primary productivity of the reaches. Also, pH ranges are used directly from field measurements as representative through the summer in order to assess the potential of modeled total ammonia speciation and toxicity issues. The model representation of upper Paint Creek provides useful data for hydrology, point and diffused source pollutant/nutrient tracking, and dissolved oxygen levels.

Table D3-6. HSPF/LSPC pervious and impervious land constituents and required modules.

HSPF Section		Pervious Land (PERLND)													Impervious Land (IMPLND)							
● Required ◍ Recommended[1] ○ Optional		Adjusted Air Temp	Snow	Basic Hydrology	Soil Erosion	Soil Temperature	Water Temperature	Dissolved Oxygen	Carbon Dioxide	General WQ	Pesticides	Nitrogen	Phosphorus	Tracers	Adjusted Air Temp	Snow	Basic Hydrology	Solids	Water Temperature	Dissolved Oxygen	Carbon Dioxide	General WQ
PERLND	ATEMP	●	◍[3]	○	○	◍[3]	◍[3]	◍[3]	◍[3]	○	○	◍[3]	◍[3]	○								
	SNOW		●	○	○		○	○	○	○	○	○	○	○								
	PWATER			●	●		●	●	●	●	●	●	●	●								
	SEDMNT				●					●[2]	●	●	●									
	PSTEMP					●	◍	◍	◍		○[4]	◍	◍									
	PWTGAS						●	●	●													
	PQUAL									●												
	MSTLAY										●	●	●	●								
	PEST										●											
	NITR											●										
	PHOS												●									
	TRACER													●								
IMPLND	ATEMP														●	◍[3]	○	○	◍[3]	◍[3]	◍[3]	○
	SNOW															●	○	○	○	○	○	○
	IWATER																●	●	●	●	●	●
	SOLIDS																	●				●[2]
	IWTGAS																		●	●	●	
	IQUAL																					●

1 - Recommended module sections are required unless a timeseries of observed data or estimated values are available in place of the variables they simulate.
2 - Activate only if constituent being modeled is associated with sediment.
3 - ATEMP is recommended to adjust for any elevation differences between the observation site and the watershed.
4 - PSTEMP is required only if the first-order adsorption-desorption is selected instead of the equilibrium Freundlich approach.

Table D3-7. HSPF/LSPC RCHRES-GQUAL-RQUAL stream constituents and required modules.

HSPF Section		Free Flowing Reach or Reservoir (RCHRES)															
● Required ◍ Recommended[1] ○ Optional		Flow Routing	Conservative	Water Temperature	Sediment	General WQ	Pesticides	Dissolved Oxygen	BOD	Inorganic Phosphorus	Inorganic Nitrogen	Benthic Algae	Phytoplankton	Organic C, N & P	Zooplankton	pH	Carbon Dioxide	Total Inorganic Carbon
RCHRES	HYDR	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	ADCALC		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	CONS		●													◍	◍	◍
	HTRCH			●	◍[2]	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍
	SEDTRN				●	◍[3]	◍[3]	○[5]	○[5]	●[4]	●[4]	●[4]	●[4]	●[4]	●[4]	●[4]	●[4]	●[4]
	GQUAL					●	●											
RQUAL	OXRX							●	●	●	●	●	●	●	●	●	●	●
	NUTRX							○[6]	○[6]	●	●	●	●	●	●	●	●	●
	PLANK							○[6]	○[6]	○[6]	○[6]	●	●	●	●	●	●	●
	PHCARB															●	●	●

1 - Recommended module sections are required unless a timeseries of observed data or estimated values are available in place of the variables they simulate.
2 - Required only if using Toffaleti or Colby method for sand transport.
3 - Required only if constituent being modeled is sediment-associated; recommended if photolysis is considered to account for sediment shading.
4 - Required only if NH_4/PO_4 association with sediment is considered - otherwise, highly recommended.
5 - Required only if NUTRX is also active and sediment association is considered - otherwise, highly recommended.
6 - Consideration of entire nutrient and biological cycle is highly recommended.

Upper Paint Creek's seven HUC-12 subwatersheds are subdivided into 27 zones for the LSPC model as shown in Figure D3-1. The boundaries are selected to have data outlets that represent HUC-12 TMDL boundaries, chemistry/biology sample locations, and flow gaging stations. Subwatersheds 24-27 represent East Fork Paint Creek, 7-13 represent Sugar Creek, 14-23 represent Paint Creek upstream Sugar Creek, and 1-6 represent Paint Creek between Paint Creek Lake and Sugar Creek. In general, the higher ID numbers represent headwaters and each downstream ID is lower traveling to the mouth of each stream. Aquatic and recreation attainment status is listed for each zone in Table D3-8. Where there is an internal assessed tributary in a zone, the evaluation comes after the "/" following the main tributary assessment. Cumulative drainage area, subreach length, and slope are listed in the table for physical comparison of subwatersheds.

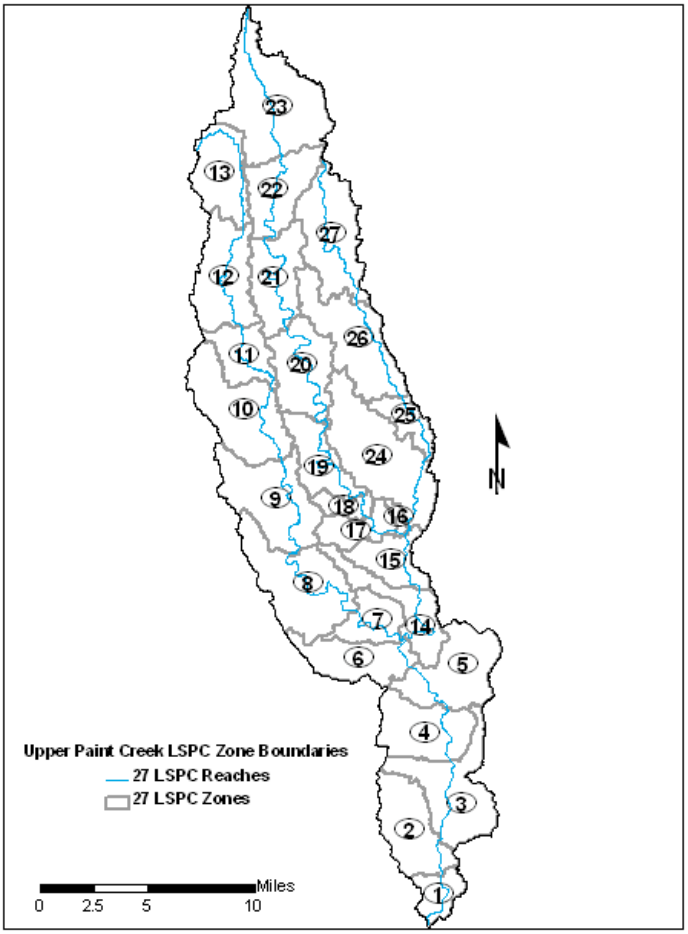


Figure D3-1. Upper Paint Creek subwatershed zones.

The subdivision into zones with areas generally averaging 10-20 square miles provides a simplified and manageable system for calibration and loading analysis with useful region specific results, but loses some ability to assess field scale issues. An example of local variability is the difference between East Fork Paint Creek's corridor at its wooded free flowing mouth versus its sluggish and unshaded characteristics a little further upstream at the US-22 crossing. On a watershed model level, these types of variances are averaged out for manageable assessment purposes. HSPF/LSPC falls into the lump sum model category, meaning that it does not keep track of each individual landuse block location or constituent travel between them. All transport mechanisms are "lumped" to the aggregate area of each landuse group and/or source. Resulting inputs to the stream from the aggregate sources are designed to enter at the upstream end of the reach instead of diffused along its course for simplification. As a consequence, there are tradeoffs in selecting the size of the subwatersheds and consequent subreaches if one is to use LSPC for both watershed and stream modeling. Spending time early to construct a well defined project scope for appropriate delineations is key to a successful watershed model. The Upper Paint Creek project attempts to deliver the needed end products without oversimplifying or overcomplicating the simulated processes. As a result, the smaller tributaries of Paint, Sugar, and East Fork are not modeled as separate zones. Although designed to simulate the main streams as a continuous linked system, a subwatershed of interest can be ran as a separate unit with some alterations to estimate loadings of a small tributary if it has a high percentage of the subwatershed area. The flexibility of running large scale or local tributary scenarios makes LSPC a powerful assessment tool.

Table D3-8. Paint Creek LSPC zone boundary data (* indicates no assessment of a reach / trib).

RCHID	Represented HUC-12	Name / Trib name	Drainage Mi^2	Length Miles	Slope ft/mile	RGID	Aquatic Attainment	Recreation Attainment
1	0602 Mouth	Paint lake influence	278	3.10	9.0	1	EWH - *	A - *
2	0602	Paint upst Paint Lake	274	2.01	12.9	1	EWH - *	A - *
3	0602	Paint dst Greenfield	263	4.18	8.9	1	EWH -Partial	A -Non
4	0601 Mouth	Paint SR-753	249	3.09	8.1	1	EWH -Full	A -Non
5	0601	Paint / Indian Ck	238	3.24	9.9	1	EWH - * / WWH - Partial	A - * / B - Non
6	0601	Paint / Wabash Ck	225	1.90	11.6	1	EWH - Full / WWH - Full	A - Non / B - *
7	0202 Mouth	Sugar at Paint Confluence	82	4.24	8.3	1	WWH - *	B - *
8	0202	Sugar Armbrust Rd	76	7.87	5.2	2	WWH - Full, upst - Full	B - Non
9	0202	Sugar US-22	59	7.47	3.5	2	WWH - Partial, upst - Full	B - Non
10	0201 Mouth	Sugar / Missouri Ditch	44	4.57	4.8	3	WWH - * / WWH - Full	B - * / B - Non
11	0201	Sugar Creamer Rd	29	5.03	4.4	3	WWH - Partial	B - Full
12	0201	Sugar McKillup Rd	22	6.24	5.1	3	WWH - Partial	B - Full
13	0201	Sugar Selsor Moon Rd	10	7.19	10.3	3	M WH - Full	B - Full
14	0601	Paint upst Sugar Ck	135	5.00	5.2	1	EWH - , upst EWH - Full	A - *
15	0601	Paint upst Pone Ck	126	3.43	4.1	2	EWH - Partial, upst WWH - *	A - Non
16	0103 Mouth	Paint upst East Fork	68	0.50	12.0	3	WWH - Partial	A - Non
17	0103	Paint Elm St	67	1.92	5.7	3	WWH - Partial	A - Non
18	0103	Paint upst WTP dam	62	1.51	8.6	1	WWH - *, dst dam - Full	B - *, dst dam A - Full
19	0103	Paint upst SR-41 YMCA	59	7.35	4.6	2	WWH - Partial, upst - Partial	B - Non, upst Non
20	0103	Paint Wildwood Rd	52	9.31	2.8	3	WWH - Partial	B - Non
21	0101 Mouth	Paint I-71	41	7.86	4.5	2	WWH - *	B - *
22	0101	Paint SR-323	30	6.13	4.1	2	WWH - Full	B - Non
23	0101	Paint / Phifer Ditch	21	8.10	12.8	3	WWH - * / M WH - *	B - * / B - *
24	0102 Mouth	East Fork / Big Run	52	4.75	3.2	3	WWH - Partial / WWH - Partial	B - Non / B - Non
25	0102	East Fork Bloomingburg	33	3.90	5.4	3	WWH - Full dst WWTP, upst-*	B - Non dst WWTP, upst-*
26	0102	East Fork Lewis Rd	29	6.02	5.3	3	WWH - Non	B - Non
27	0102	Vallery Ditch / W.Cathart	14	9.16	9.4	3	M WH - Full / WWH - Partial	B - Non / B - Non

Physical representation of the LSCP modeled watersheds

A subwatershed in LSPC gains its hydrologic and constituent properties through assignment to a characteristic group and the types of landuses it holds. The property group and associated landuses interact with the zone's physical layout and climate data to model the transport of constituents from storage to stream. Each zone relies on elevation mapping for overland slope, stream slope, and weather station data adjustment. Upper Paint Creek's change in land slope can be viewed in the elevation depiction of Figure D3-2 with the color scheme darkening as the elevation is lower. The mouth at Paint Creek Lake is at 773' above sea level, and highest point is at 1181'. Much of the land above Washington Court House is on near level glacial till, and several stream reaches have been channelized at some point to assist in draining fields for crop production. The watershed slope dips at the fringe of the unglaciated zone below Washington Court House, and the more dendritic tributary flows quicken. The increased slope of Paint Creek below Sugar Creek plays an important role in maintaining a healthy ecology in this exceptional stretch, despite the high phosphorus load.

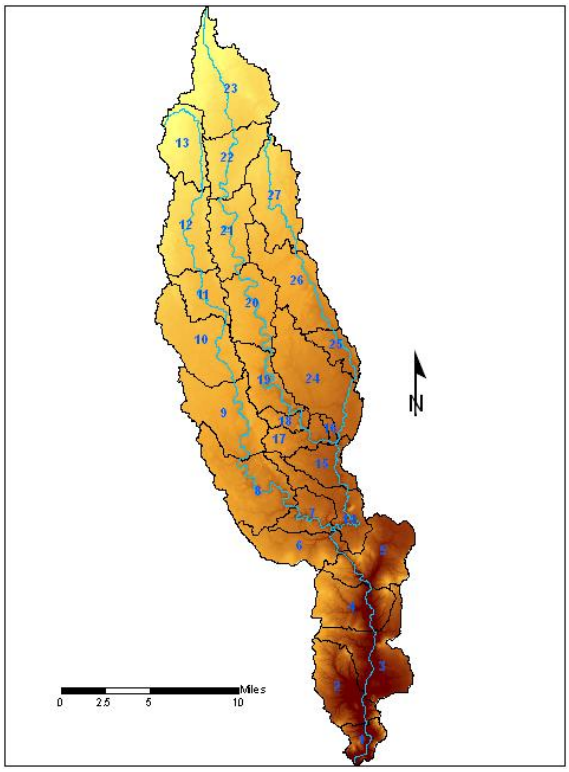


Figure D3-2. Paint Creek HSPF region model units, with elevation overlay (773' minimum shown dark, 1181' maximum shown light).

The hydrologic properties of the soils change in generally the same trend as the breaks in elevations. General soil complexes from the STATSGO database are mapped based on their drainage class in Figure. The drainage performance ranges from Class A soils with excellent drainage, Class D soils with very poor drainage. The Upper Paint Creek headwaters are a mix of Class C and Class B/D soils (the B/D designation means the soils of the area typically draining very poorly once wetted. The middle of the region (Jeffersonville to Bloomingburg to Washington Court House) is primarily made up of the Class B/D soils, with the exception of the thin zone of better draining Class B soils within the stream corridors. The soils of the south are primarily Class C soils. It should be noted that the STATSGO dataset is very generalized. The more detailed SSURGO soils database limits Class B soils to very thin stream corridors, unlike

the exaggerated Class B band in the STATSGO data. The remainder of the watershed is a mix of Class C and Class B/D soils (Figure D3-3, left half). In general, most of the soils within the glaciated area are drained by tiles and channel drainage improvements. The soils in this area are very productive once drained, but still hold considerable storm water in low spots and other less conductive locations. The soils in the southern region have a more general drainage hindrance, but the stream slopes are greater which diminishes some of the effect. Although there can be high variability in soils from one field to another, the effect tends to average out on a watershed scale. With review of the elevation and soil characteristics, the region can be split into three general soil/management groups for modeling hydrology and constituent transport. Table D3-9 lists the group assignments of each model zone. Group 3 is used to define characteristics of the central region, Group 4 characterizes the headwaters, and Group 5 characterizes the southern region. The LSPC GQUAL component provides hydrology and transport controls for each group, and using the three groups as assigned to the zones is sufficient to control the regional differences of the Paint Creek model.

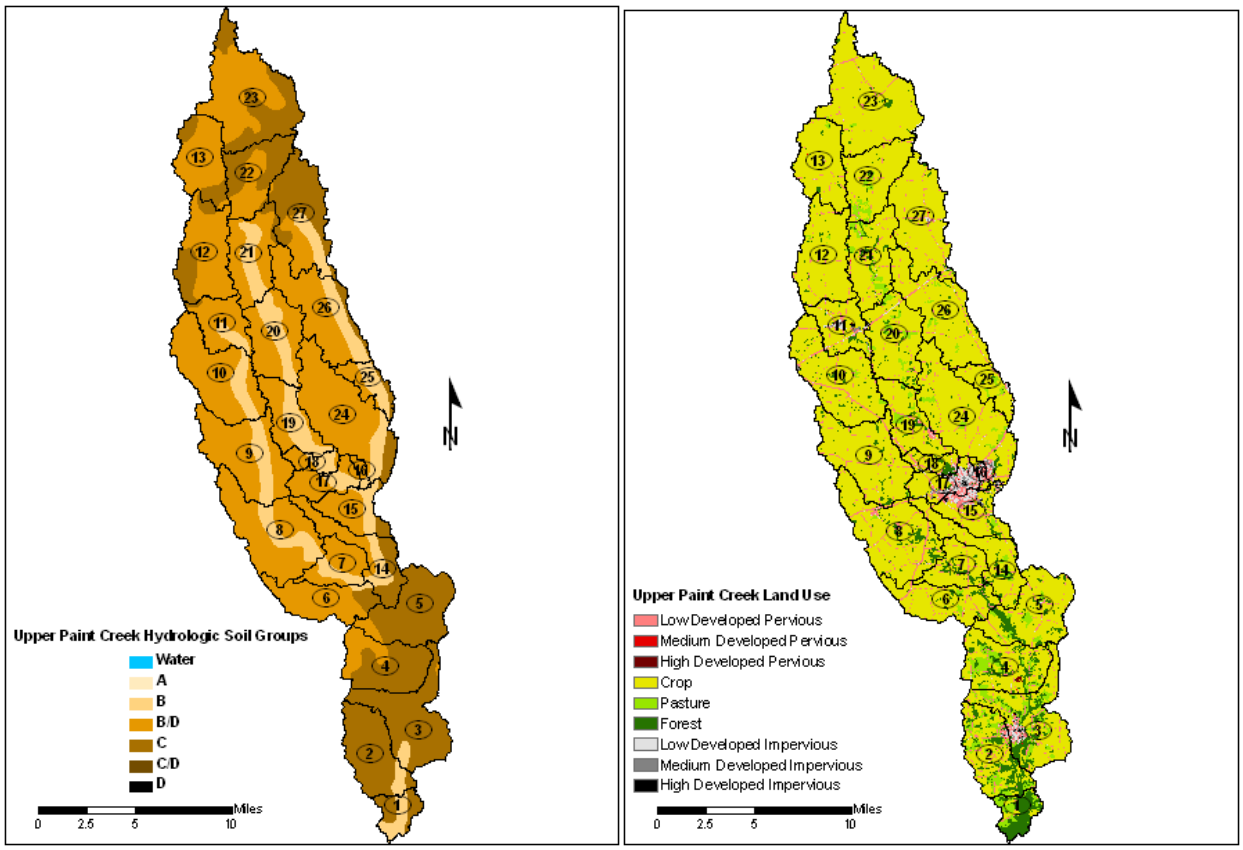


Figure D3-3. Paint Creek LSCP soil units (left) and landuse (right).

Table D3-9. Upper Paint Creek subwatershed zones mapping for LSPC simulation.

Zone	Group ID	Weather ID
1	5	1
2	5	1
3	5	1
4	5	1
5	5	1
6	5	1
7	3	1
8	3	1
9	3	3
10	3	3
11	4	3
12	4	3
13	4	3
14	3	1
15	3	1
16	3	3
17	3	3
18	3	3
19	3	3
20	4	3
21	4	3
22	4	3
23	4	3
24	3	3
25	4	3
26	4	3
27	4	3

Landuse raster data from the 2001 NLCD dataset (Homer, 2004) is used to map landuse types to zones (Figure D3-3, right half, above). In order to simplify the model representation, the several landuse types of NLCD are aggregated into a subset of nine similar usage types. Six of these deal with developed land which is further aggregated to two output types for reporting purposes. The reclassified landuses include impervious developed land (high, medium, low intensity), pervious developed (high, medium low intensity), crop (mostly corn and soy beans in the region), pasture (with livestock or fallow land), and forest (riparian tree lines to dense wooded areas). Each group assignment also has individual landuse controls. Paint Creek's land model of three groups and nine land uses results in 27 independent hydrology and constituent transport controls. Some variables can be adjusted on a monthly level, adding to the complexity of data management. Although the amount of data management multiplies with the addition of groups and landuses, it provides the option of more localized control if needed. It is best to focus calibration on the driving characteristics and leave the remaining controls with as similar properties as possible so useful subwatershed model results can be compared. Once group and landuse assignments are made, each zone's landuse specific constituent loadings are tracked and reported on an annual basis, while daily results are reported as the bulk constituent entering or leaving the zone. Landuse BOD, total phosphorus and total nitrogen estimates of surface, interflow, and groundwater sources are derived from Purdue and Ohio State Agricultural Extension information, the Virginia Patuxent basin model, professional judgment, and defaults built into LSPC. The resulting stream input loadings are then adjusted for timing and scale calibration.

Home sewage treatment systems, livestock and wildlife direct source representation of the LSCP modeled watersheds

Poorly performing home sewage treatment systems (HSTSs) and livestock and wildlife with direct point sources to streams are present throughout the Paint Creek watershed (Figure D3-4). This subsection outlines measures to include these sources in the LSPC TP and *E. coli* modeling.

US Census GIS block data available from the year 2000 is used as the base for determination of population and housing distribution for the subwatershed zones (ODD, 2003). The region has had low to negative population growth between 2000 and 2010 which allows for reliable use of the 2000 block data. The subwatershed boundaries are overlaid by the regional block data and population/housing is distributed by percent area coverage. Some final adjustments are made where a block region's population is not evenly distributed across a subwatershed(s). The resulting population data of Upper Paint Creek's LSPC zones are listed in Table D3-10. Further effort is made to delineate out the areas with sanitary sewer service and track the numbers of homes with HSTS (home septic treatment systems). Finally, the number of failing HSTS is determined by zone with the use of average county failure rates, site observations, aerial photography, and proximity to streams. An average failure rate of 20% homes is used as a base, and other adjustments are made to a zone's final failure rate. Aerator systems are assumed to have a 100% failure rate as recommended by USEPA, as they are often not properly maintained. The failing septic flow reaching the stream is assumed to be 17.5 gallons/day/person, assuming that one fourth of the standard 70 gallons/day/person usage has the potential for direct stream access and the rest contaminates ground seeps.

Figure D3-4. Septic flow leaching to a stream from a residential area (left) and cattle basking during summer low flow (right).

Table D3.10. Distribution of housing and population based on the US Census 2000 GIS block data.

SubWS	Name	Area Acres	SubWS Total Households	SubWS Total Population
1	Paint Creek - Paint Creek Lake	2599.39	35.8	106.4
2	**Paint Creek - Farmers Run**	**7174.17**	**628.1**	**1520.7**
3	**Paint Creek - City of Greenfield**	**8859.72**	**1739.1**	**4528.6**
4	Paint Creek - SR753 USGS Gage	7106.15	110.0	285.3
5	Paint Creek - Indian Creek	8165.71	162.4	439.2
6	Paint Creek - Wabash Creek	5871.92	85.0	244.5
7	Sugar Creek - Paint Creek Confluence	3842.40	81.6	212.5
8	**Sugar Creek - Armbrust Flow Site**	**10567.63**	**353.3**	**987.0**
9	Sugar Creek - Camp Run	9476.20	138.8	402.9
10	Sugar Creek - Missouri Ditch	9717.16	118.9	347.9
11	**Sugar Creek - Jeffersonville**	**4329.28**	**563.5**	**1409.2**
12	Sugar Creek - McKillup Rd	8004.34	53.9	159.0
13	Sugar Creek - Headwater	6237.01	36.6	89.0
14	Paint Creek - Pone Creek	5522.88	151.1	375.5
15	**Paint Creek - US35 WCH Bypass**	**4109.91**	**1485.0**	**3523.8**
16	**Paint Creek - City of Washington Court House**	**536.93**	**590.5**	**1287.2**
17	**Paint Creek - Elm Flow Site**	**3195.19**	**2966.3**	**7685.8**
18	**Paint Creek - WCH Drinking Water Intake**	**1629.68**	**393.4**	**850.1**
19	**Paint Creek - YMCA Flow Site**	**4955.22**	**296.9**	**818.9**
20	Paint Creek - Wildwood	7103.57	90.8	240.3
21	Paint Creek - Bookwalter	6480.12	111.3	315.6
22	Paint Creek - SR323	6289.77	31.6	81.0
23	Paint Creek - Headwater	13166.38	70.0	195.0
24	**EFork Paint Creek - US22 Flow Site**	**12091.69**	**812.8**	**2096.9**
25	**EFork Paint Creek - City of Bloomingburg**	**2739.84**	**88.8**	**249.6**
26	EFork Paint Creek - Brock Ditch	9387.98	80.6	235.9
27	**EFork Paint Creek - Headwater**	**8992.24**	**167.1**	**448.1**

The data is compiled using the Ohio EPA in-house spreadsheet SLA-PIT (Stream Load Allocation - Pathogen Indicator Tool). Refer to the Walnut Creek TMDL for further description of the process (Ohio EPA, 2010). It's base is built on USEPA's BIT (Bacteria Indicator Tool, originally developed to assist in HSPF inputs), with modifications to times of crop manure spreading, wildlife tracking, cattle stream access, HSTS failures, and the extended ability to simulate gross hydrology and fecal coliform washoff tracking for TMDL development. For Paint Creek, only the data compilation mechanisms of SLA-PIT are used, producing similar land loading data derived from BIT. The use of BIT only applies to calculating fecal coliform loadings which are translated into *E. coli* as explained later in this report.

SLA-PIT's livestock data is derived from USDA NASS census data, distributed to LSPC zones by percent county area and landuse type percentages. Livestock represented includes beef and dairy cattle, swine, horses, chickens, sheep, goats. The GIS data distribution is adjusted based on aerial photography and site observations. Livestock representation of zones is challenging as they are transient between fields through the summer, and population may swing from year to year. However, the approximation is meant to be compensating for the average effect of livestock over several years. Since land based livestock source data are assigned to one of the three defined LSPC characteristic groups, all the zone's individual results within a group are averaged. The timing and load of manure washoff's constituents is then adjusted later in calibration. Cattle with stream access are only represented in the zones if they were noted by field observations, or if it is obvious in aerial photography. Stream access also considers areas of riparian erosion which is washoff prone. In a similar method, wildlife data is derived from ODNR statistics, and distributed to LSPC zones by County area and landuse type percentages. The wildlife category considers ducks, geese, raccoons, beaver, canine, deer, and other ("other" uses bacteria ranges similar to canine). Each animal type has preferential habitat, and the landuse distribution percent is used to adjust county data more specifically. Once a zone has the animal counts established, they are treated as an average "unit wildlife" to represent the average concentration of bacteria from the animal group. The only constituent in wildlife

deposition modeled is bacteria. The estimates of failing HSTS, cattle, and wildlife that directly impact the stream are listed in Table D3-11.

The HSTS effluent reaching a stream is assumed to be 17.5 gallons/person/day, or 25% of the average 70 gallons/person/day (Metcalf & Eddy, 1991). The other 75% of the effluent is assumed to migrate to local ground water and/or contribute to the developed landuse load.

Table D3-11. Distribution of failing HSTS, cattle / unit wildlife, 24 hour average cattle / wildlife stream access.

Reach	Outlet Location	Drainage Mi^2	Length Miles	#HSTS Estimate	#HSTS Failing	#Grazed Cows Estimate	#Grazed Cows 24Hr Instream	#Unit Wildlife Estimate	#Unit Wildlife 24Hr Instream
1	Paint lake influence	278	3.10	36	7.2	177	0	205	10
2	Paint upst Paint Lake	274	2.01	150	30	310	0	181	6
3	Paint dst Greenfield	263	4.18	150	38	320	16	175	5
4	Paint SR-753	249	3.09	110	22	291	0	141	5
5	Paint / Indian Ck	238	3.24	162	104.5	114	0	126	4
6	Paint / Wabash Ck	225	1.90	85	21	38	6	81	3
7	Sugar at Paint Confluence	82	4.24	82	32.3	0	0	171	10
8	Sugar Armbrust Rd	76	7.87	353	126.7	8	0	238	10
9	Sugar US-22	59	7.47	139	35.8	7	0.34	140	5
10	Sugar / Missouri Ditch	44	4.57	119	31.8	80	4	149	8
11	Sugar Creamer Rd	29	5.03	25	9	30	2	122	9
12	Sugar McKillup Rd	22	6.24	54	14.8	18	0	71	3
13	Sugar Selsor Moon Rd	10	7.19	37	7.3	14	0	60	3
14	Paint upst Sugar Ck	135	5.00	75	19	55	0	123	5
15	Paint upst Pone Ck	126	3.43	75	15	16	0	108	6
16	Paint upst East Fork	68	0.50	10	2	0	0	44	2
17	Paint Elm St	67	1.92	75	15	0	0	75	4
18	Paint upst WTP dam	62	1.51	50	10	0	0	150	19
19	Paint upst SR-41 YMCA	59	7.35	297	99.4	96	5	112	5
20	Paint Wildwood Rd	52	9.31	50	14	161	8	126	6
21	Paint I-71	41	7.86	111	30.3	173	9	130	6
22	Paint SR-323	30	6.13	32	6.3	70	11	59	3
23	Paint / Phifer Ditch	21	8.10	70	14	20	0	88	4
24	East Fork / Big Run	52	4.75	125	29	113	0	124	5
25	East Fork Bloomingburg	33	3.90	15	3	47	0	54	3
26	East Fork Lewis Rd	29	6.02	81	16.1	50	0	77	3
27	Vallery Ditch / W.Cathart	14	9.16	167	45.4	20	3	75	5

The quantity of livestock stream load is normalized as a continuous 24 hour source. BIT calculates the in-stream cattle load monthly, which can be used to model temperature preference or availability. Livestock basking is represented in LSPC from May 1st to November 1st on an incremental basis. The BIT estimated May loading is used and is increased daily up to the peak August estimated value, and then decreased daily down to the October estimated value. The value is then incrementally reduced to a zero load by November 1st. The livestock in-stream load can also be considered to represent washoff prone feedlots adjacent to a stream. Wildlife is represented as a unit animal load normalized as a continuous 24 hour source. Pound for pound, geese have the highest fecal coliform output than other modeled warm blooded animals. Geese also occupy areas near water in urban and rural settings more than other animals. Other wildlife considered are ducks, deer, beaver, raccoons, and an “other” category represented as a dog. In order to estimate a unit load from various animals, first a habitat tendency is used to map ODNR county averages to the landuses of a subwatershed. Then an

estimated time spent in water of each species is applied to produce a stream count, and the loads are added to represent the 24 hour stream input.

NPDES point source representation of the LSCP modeled watersheds

NPDES permitted point sources have variable constituent data available for model representation. Self-monitoring data of point source facilities is reported to Ohio EPA as required by their permits. Ohio EPA also sampled several outfalls during the 2006 survey. Flow rate, temperature, and oxygen levels are typically tracked daily by point sources. Ammonia and BOD are typically recorded a few times a week. Other essential parameters for modeling eutrophication like phosphorus and nitrates may or may not be reported depending on permit requirements. Therefore, conservative estimates are needed for some point sources, while others can have more refined representations. Available data between 1995 and 2008 were used to develop constituent trends. If data trends are notably different between past and more recent years, the estimates are based on more current operations of facilities. The data is compiled into three month averages to account for seasonal variation of flow and chemistry (Jan-Mar, Apr-Jun, Jul-Sep, and Oct-Dec). All modeled point sources are built on a seasonal flow and temperature variation, but only a few have other seasonal constituent concentrations due to a lack of data. Annual concentrations are approximated for the smaller facilities with lesser reporting requirements. Table 3-12 reports derived annual averages of flow and chemistry for NPDES permitted facilities, HSTS, stream basking livestock, and stream basking wildlife. The regions two major facilities, Washington Court House and Greenfield, have enough data to develop daily flow and chemistry representation. Where daily data is not available, the record is patched with seasonal averages. An example using flow and total phosphorus export from Washington Court House WWTP and Greenfield WWTP are shown in Figure D3-5 and Figure D3-6 respectively.

Washington Court House's sanitary distribution system has infiltration problems which results in hydraulic overcharges within the system during storm events. The infiltration problem causes a wide range of flow and constituent strengths entering Paint Creek. Washington Court House is currently under orders to correct the performance issues of their sanitary system. Greenfield's WWTP has a 1.0 mg/L average phosphorus limit in place and has performed well. It had some operational issues in 2006 that led to organic enrichment and ammonia issues in Paint Creek. The model results indicate that the stream's ammonia levels were excessive during this time, and the facility issues have since been resolved. The appropriate representation of both facilities is useful for calibration and to compare the impacts of chronic nutrient levels at low flow verses high acute loadings coming from agricultural washoff. Although the majority of the EWH segment of Paint Creek below Washington Court House is in full attainment, the modeling of the intact stream corridor under high loading underlines the importance of stream gradient and habitat.

Table 3-12. NPDES existing point source annual flow and chemistry averages.

Entity	Flow	Temp	DO	$CBOD_5$	TSS	TP	NO_{3-2}	NH_{4-3}	ORN	Fecal	E. coli
Season	**cfs**	**C**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**#/100ml**	**#/100ml**
*** Washington WWTP 4PD00002 ***											
Winter	5.86	11.9	9.2	3.0	5.8	3.4	6.1	0.2	1.5	540	340
Spring	5.47	16.7	8.5	2.9	5.5	3.5	6.5	0.3	1.5	540	340
Summer	3.40	22.7	8.2	2.2	3.6	5.8	11.6	0.2	1.5	540	340
Fall	3.97	17.3	8.8	2.6	4.4	5.3	10.7	0.2	1.5	540	340
Washington WTP Paint Creek Intake OH2400714											
Winter	-2.91	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Spring	-2.91	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Summer	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Fall	-2.91	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
*** Greenfield WWTP 1PD00022 ***											
Winter	1.96	10.8	9.1	3.2	5.8	0.5	11.2	0.1	1.5	200	126
Spring	1.69	16.4	7.9	3.2	3.1	0.6	9.2	0.1	1.5	200	126
Summer	1.14	22.0	7.0	3.0	3.2	0.8	10.9	0.2	1.5	200	126
Fall	1.38	15.9	8.1	2.5	8.3	0.9	15.6	0.1	1.5	200	126
Jeffersonville WWTP 4PB00108											
Winter	0.39	4.9	9.6	5.0	18.4	2.7	7.0	3.0	1.5	256	161
Spring	0.29	14.8	7.4	5.0	18.4	2.7	7.0	1.0	1.5	256	161
Summer	0.26	19.5	7.3	5.0	18.4	2.7	7.0	1.0	1.5	256	161
Fall	0.27	7.9	9.2	5.0	18.4	2.7	7.0	3.0	1.5	256	161
Bloomingburg WWTP 4PB00025											
Winter	0.27	10.5	8.7	4.8	9.6	1.6	7.0	0.6	1.5	256	161
Spring	0.22	17.4	7.8	4.8	9.6	1.6	7.0	1.0	1.5	256	161
Summer	0.13	21.8	7.3	4.8	9.6	1.6	7.0	1.0	1.5	256	161
Fall	0.17	15.3	8.0	4.8	9.6	1.6	7.0	3.0	1.5	256	161
Washington WTP Backwash 4IW00017											
Winter	0.13	5.0	9.0	0.5	5.0	0.04	0.5	0.1	0.1	0	0
Spring	0.18	15.0	8.3	0.5	5.0	0.04	0.5	0.1	0.1	0	0
Summer	0.19	20.0	8.0	0.5	5.0	0.04	0.5	0.1	0.1	0	0
Fall	0.13	7.0	8.8	0.5	5.0	0.04	0.5	0.1	0.1	0	0
Prairie Knolls WWTP 4PV00115											
Winter	0.03	7.1	8.5	3.6	15.0	3.0	7.0	0.2	1.5	256	161
Spring	0.02	14.6	7.1	3.6	15.0	3.0	7.0	0.2	1.5	256	161
Summer	0.01	20.3	7.6	3.6	15.0	3.0	7.0	0.2	1.5	256	161
Fall	0.02	11.4	8.8	3.6	15.0	3.0	7.0	0.2	1.5	256	161
Miami Trace HS WWTP 4PT00121											
Winter	0.02	9.1	9.7	3.2	15.0	3.0	7.0	0.3	1.5	256	161
Spring	0.02	17.5	7.8	3.2	15.0	3.0	7.0	0.3	1.5	256	161
Summer	0.01	22.4	7.3	3.2	15.0	3.0	7.0	0.3	1.5	256	161
Fall	0.02	13.5	8.9	3.2	15.0	3.0	7.0	0.3	1.5	256	161
Flakes Ford WWTP 4PG00000											
Winter	0.02	9.9	7.9	5.3	15.0	3.0	7.0	1.5	1.5	200	126
Spring	0.02	14.5	7.7	5.3	15.0	3.0	7.0	1.5	1.5	200	126
Summer	0.01	19.9	6.6	5.3	15.0	3.0	7.0	1.5	1.5	200	126
Fall	0.01	14.6	7.0	5.3	15.0	3.0	7.0	1.5	1.5	200	126
24hr per capita unit Home Septic Treatment System (HSTS) effluent projected to reach a tributary											
Annual	2.7E-05	N/A	N/A	110	N/A	4	0.1	12	8	100000	63000
24hr unit stream basking livestock - season dependent, peak subwatershed livestock in August											
Summer	8.6E-06	N/A	N/A	22160	N/A	954	0.1	1554	3155	5E+07	3E+07
24hr unit basking wildlife (watershed avg concentration dependent on animals - goose, deer, raccoon, etc)											
Annual	var. E-07	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1E+07	7E+06

*Washington and Greenfield seasonal statistics are used to fill a daily modeling period record, sample data is used if available. All other point sources are modeled as seasonal blocks.

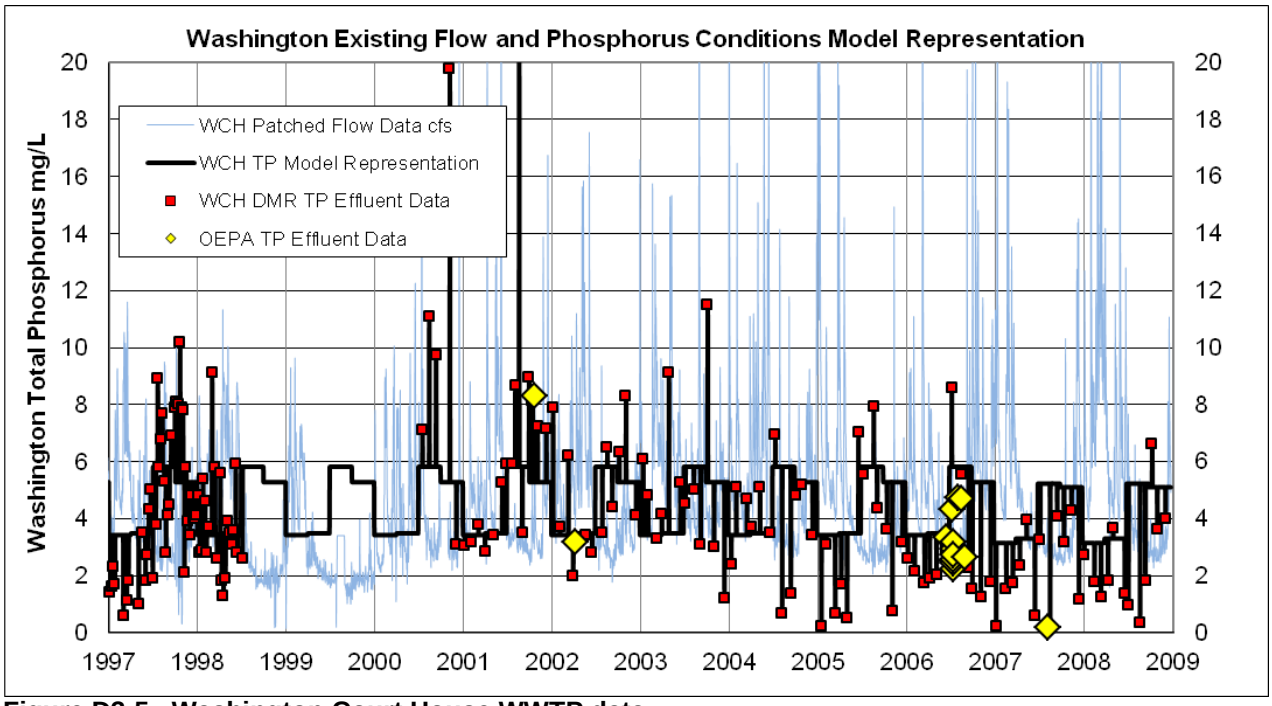


Figure D3-5. Washington Court House WWTP data.

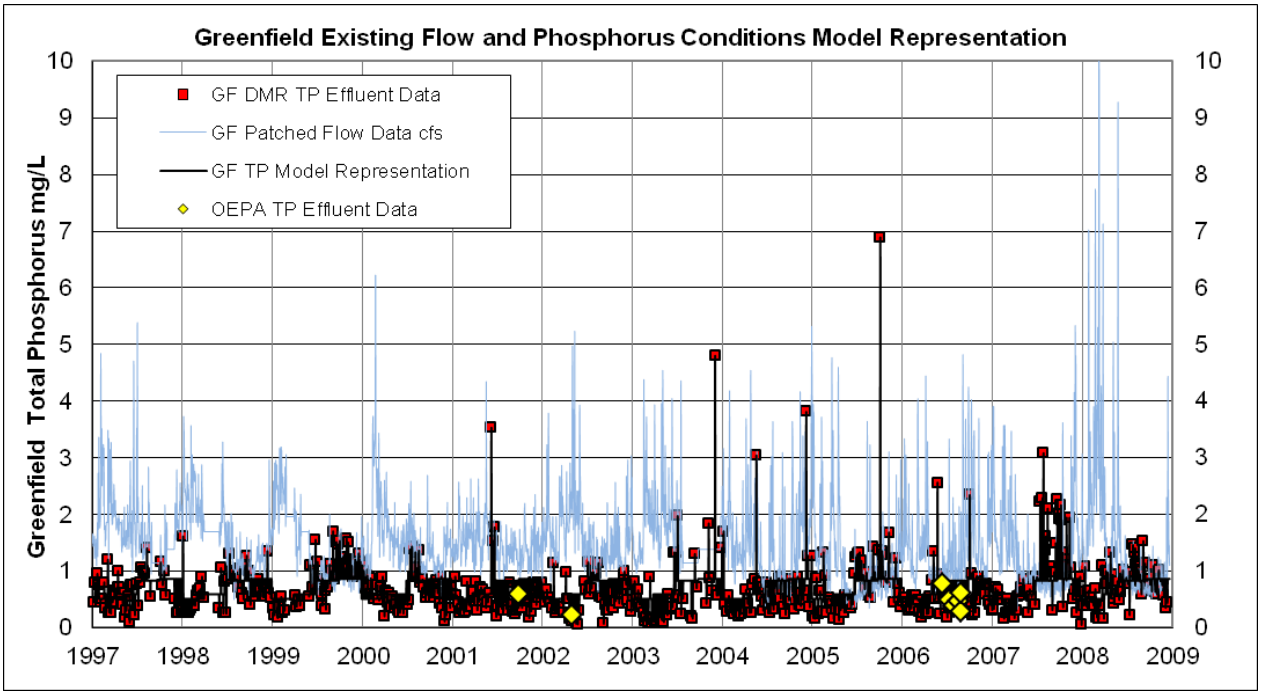


Table D3-6. Greenfield WWTP data.

The point sources take on a new loading characteristic in the model under baseline and simulation runs. Once the model is calibrated with the existing flows and loadings in place, the point sources are simulated to operate at permitted average design flows and baseline chemistry. Some constituents are still varied seasonally where appropriate, such as outfall temperature or where permit limits differ by season. By using design flows to determine

appropriate concentration limits and loadings for stream protection, the model takes in account the potential future growth design of each facility. The model is ran with the constituent levels as a baseline, and then constituents are adjusted through simulations until the desired effect is met locally and downstream (Table D3-13).

Table D3-13. NPDES baseline point source annual flow and chemistry averages.

Entity	Flow	Temp	DO	$CBOD_5$	TSS	TP	NO_{3-2}	NH_{4-3}	ORN	Fecal	E. coli
Season	**cfs**	**C**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**#/100ml**	**#/100ml**
Washington WWTP 4PD00002											
Winter	9.28	12.0	6.0	10.0	12.0	5.0	7.0	3.3	1.5	N/A	126
Spring	9.28	16.7	6.0	10.0	12.0	5.0	7.0	1.5	1.5	N/A	126
Summer	9.28	22.7	6.0	10.0	12.0	5.0	7.0	1.5	1.5	N/A	126
Fall	9.28	17.3	6.0	10.0	12.0	5.0	7.0	3.3	1.5	N/A	126
Washington WTP Paint Creek Intake OH2400714											
Winter	-2.91	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Spring	-2.91	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Summer	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Fall	-2.91	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Greenfield WWTP 1PD00022											
Winter	2.48	10.8	6.0	10.0	12.0	1.0	7.0	3.0	1.5	N/A	126
Spring	2.48	16.3	6.0	10.0	12.0	1.0	7.0	1.0	1.5	N/A	126
Summer	2.48	21.6	6.0	10.0	12.0	1.0	7.0	1.0	1.5	N/A	126
Fall	2.48	15.8	6.0	10.0	12.0	1.0	7.0	3.0	1.5	N/A	126
ASA Ethanol Bloomingburg LLC 4IN00196											
Winter	1.17	7.1	9.0	0.5	30.0	0.1	2.0	0.1	0.1	N/A	N/A
Spring	1.17	16.7	8.3	0.5	30.0	0.1	2.0	0.1	0.1	N/A	N/A
Summer	1.17	20.5	8.0	0.5	30.0	0.1	2.0	0.1	0.1	N/A	N/A
Fall	1.17	13.8	8.8	0.5	30.0	0.1	2.0	0.1	0.1	N/A	N/A
Jeffersonville WWTP 4PB00108											
Winter	0.77	3.9	7.0	10.0	12.0	3.0	7.0	3.0	1.5	N/A	161
Spring	0.77	14.6	8.0	10.0	12.0	3.0	7.0	1.0	1.5	N/A	161
Summer	0.77	19.4	8.0	10.0	12.0	3.0	7.0	1.0	1.5	N/A	161
Fall	0.77	6.9	7.0	10.0	12.0	3.0	7.0	3.0	1.5	N/A	161
Bloomingburg WWTP 4PB00025											
Winter	0.39	10.3	6.0	9.5	12.0	3.0	7.0	3.0	1.5	N/A	161
Spring	0.39	17.4	6.0	9.5	12.0	3.0	7.0	1.0	1.5	N/A	161
Summer	0.39	21.7	6.0	9.5	12.0	3.0	7.0	1.0	1.5	N/A	161
Fall	0.39	15.2	6.0	9.5	12.0	3.0	7.0	3.0	1.5	N/A	161
Washington WTP Backwash 4IW00017											
Winter	0.13	5.0	9.0	0.5	5.0	0.1	2.0	0.1	0.1	N/A	N/A
Spring	0.18	15.0	8.3	0.5	5.0	0.1	2.0	0.1	0.1	N/A	N/A
Summer	0.19	20.0	8.0	0.5	5.0	0.1	2.0	0.1	0.1	N/A	N/A
Fall	0.13	7.0	8.8	0.5	5.0	0.1	2.0	0.1	0.1	N/A	N/A
Prairie Knolls WWTP 4PV00115											
Winter	0.02	7.1	6.0	10.0	12.0	3.0	7.0	3.0	1.5	N/A	161
Spring	0.02	14.6	6.0	10.0	12.0	3.0	7.0	1.0	1.5	N/A	161
Summer	0.02	20.3	6.0	10.0	12.0	3.0	7.0	1.0	1.5	N/A	161
Fall	0.02	11.4	6.0	10.0	12.0	3.0	7.0	3.0	1.5	N/A	161
Flakes Ford WWTP 4PG00000											
Winter	0.02	9.8	5.0	10.0	12.0	3.0	7.0	3.0	1.5	N/A	126
Spring	0.02	14.4	5.0	10.0	12.0	3.0	7.0	3.0	1.5	N/A	126
Summer	0.02	19.7	5.0	10.0	12.0	3.0	7.0	3.0	1.5	N/A	126
Fall	0.02	14.8	5.0	10.0	12.0	3.0	7.0	3.0	1.5	N/A	126
24hr per capita unit Home Septic Treatment System (HSTS) effluent projected to reach a tributary											
Annual	2.7E-05	N/A	N/A	110	N/A	4	0.1	12	8	N/A	63000
24hr unit stream basking livestock - season dependent, peak subwatershed livestock in August											
Summer	8.6E-06	N/A	N/A	22160	N/A	954	0.1	1554	3155	N/A	3E+07
24hr unit basking wildlife (watershed avg concentration dependent on animals - goose, deer, raccoon, etc)											
Annual	var. E-07	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	7E+06

Stream reach representation of the LSCP modeled watersheds

Cross sections were measured in 2007 and 2008 at various locations within the upper Paint Creek region to aid in assessing the morphology of the stream reaches. Pebble counts were also conducted at several of these sites in order to estimate particle size distribution and channel roughness. The data was input into the Reference Reach V4.3L, part of the STREAM module maintained by ODNR. The spreadsheet was altered by adding a low flow reference, which represents dimensions of low flow levels that were noted while measuring the cross sections. Sites were selected to be representative of reach sections that would function like a run during mid-level flows. The Reference Reach Spreadsheet allows the input of estimated bankfull flow stage. Bankfull flow is a flow with a recurrence interval around every 1 to 1.5 years, and is thought to demonstrate an intact floodplain system if the flow does in fact begin to spill over its banks. It is also the flow level thought to be the most influential in dynamically changing channel form. The bankfull field estimates were noted based on recommendations such as, vegetation line changes, bank slump, flood plain connectivity, bank soil erosion patterns, and other signs of significant water level cuts. The bankfull stage is then used by the program to estimate parameters such as depth, area, flow, velocity, shear stress, and other useful hydraulic information. The spreadsheet also estimates a flood prone stage, which is a simple calculation of twice the maximum bankfull depth. The flood prone stage is left in the figures as a supplemental estimate, but is out of the scope of this project. The low flow stage line represents the water level at very low flow. Figure D3-7 shows a conceptualized version of these stream channel terms.

Of note is that several of the maintained streams have depths approaching a half foot, but this water is low velocity waters held back by instream vegetation, downstream bed rises, and over dredging. This type of cross section correlated well with many of the sites listed in the 303d list for dissolved oxygen issues. A site that shows signs of natural recovery after being channelized, Sugar Creek near McKillup Rd, is somewhat different from other measured reaches in that it has cut a deeper side channel, creating a secondary stage level within the now 12 feet deep ditch. As time goes on, the outer banks will begin to slump and an active bankfull floodplain may establish. However, in this stage of recovery the dispersed velocities are low enough to allow grasses to grow within the channel which in return slows flow more and holds decaying algae and plant material which causes DO violations. Grassed channels are excellent BMP structures for controlling the downstream export of sediment and bound chemical constituents. However, the use of grassed water ways are not appropriate for larger drainage areas that can be classified as WWH streams, as the nutrient load from the substrate sediments and the resulting DO issues tend to diminish the appropriate aquatic life. As the McKillup Rd site has a drainage area of 22 square miles, it does not function well for desired biological response as a grassed waterway and needs more concentrated velocity at lower flows. With the lack of gradient and stream energy in this region, it will take many years for Sugar Creek to naturally alter its overly deep ditch into a morphologically balanced reach. With regard to sites measured greater than 60 square miles, with the exception of the Elm Street site within Washington Court House, the low flow waters are free flowing at similar average depths, but are in better functional state for flow conveyance and channel forming energy. Figures D3-8 through D3-15 show the channels calculated for the LSPC modeled reaches.

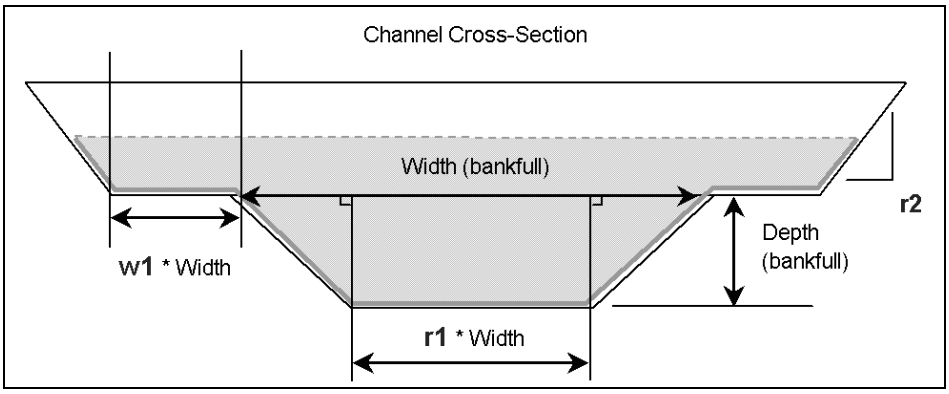
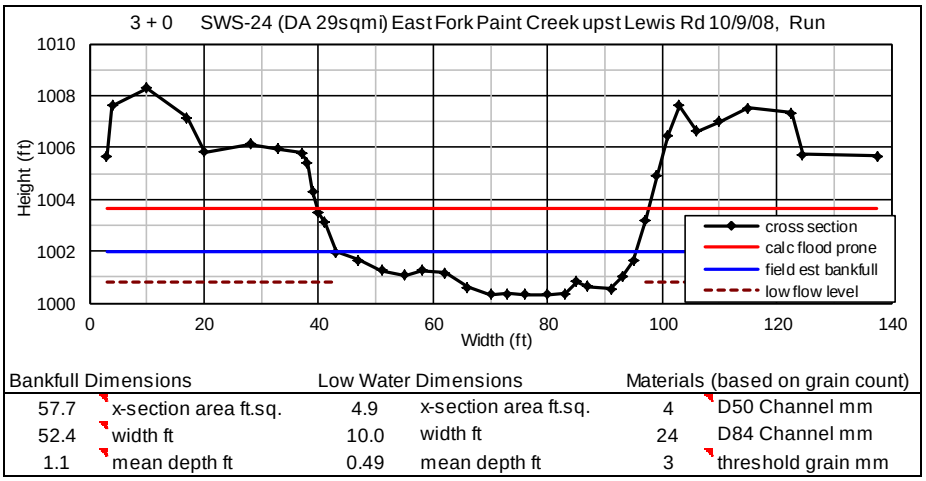
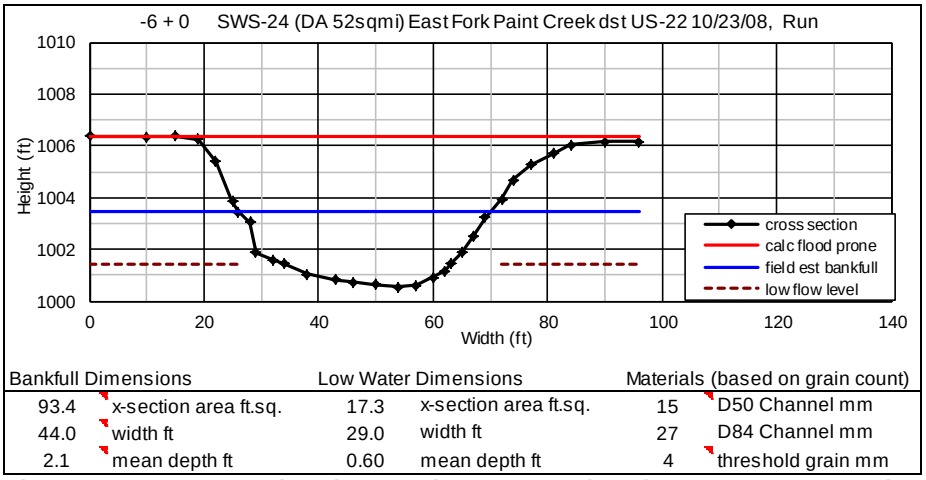


Figure D3-7. A conceptualized version stream channel terms.



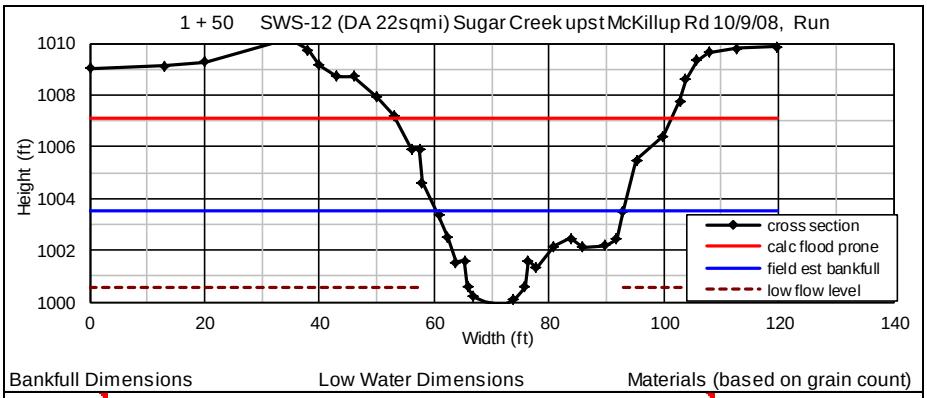
Bankfull Dimensions		Low Water Dimensions		Materials (based on grain count)	
57.7	x-section area ft.sq.	4.9	x-section area ft.sq.	4	D50 Channel mm
52.4	width ft	10.0	width ft	24	D84 Channel mm
1.1	mean depth ft	0.49	mean depth ft	3	threshold grain mm

Figure D3-8. East Fork Paint Creek cross section near Lewis Rd.



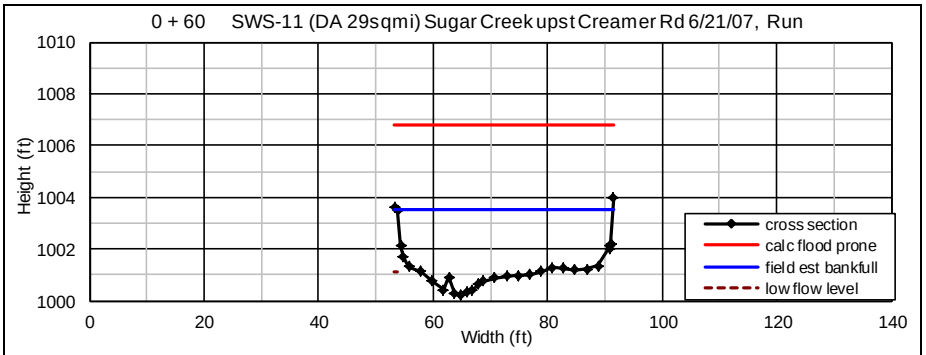
Bankfull Dimensions		Low Water Dimensions		Materials (based on grain count)	
93.4	x-section area ft.sq.	17.3	x-section area ft.sq.	15	D50 Channel mm
44.0	width ft	29.0	width ft	27	D84 Channel mm
2.1	mean depth ft	0.60	mean depth ft	4	threshold grain mm

Figure D3-9. East Fork Paint Creek cross section downstream US-22 (OEPA sentinel site).



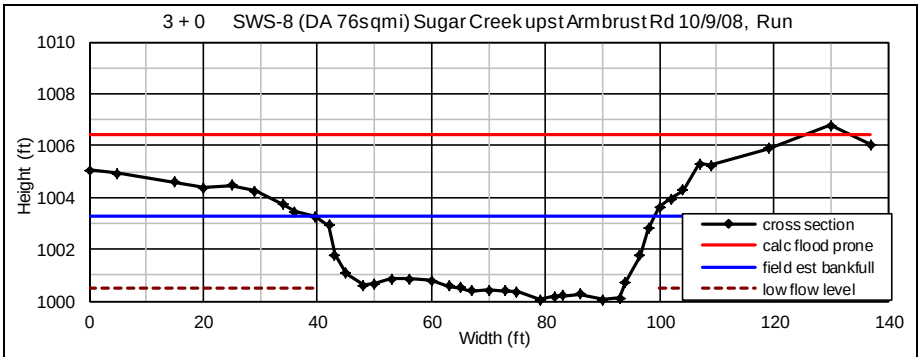
Bankfull Dimensions		Low Water Dimensions		Materials (based on grain count)	
65.6	x-section area ft.sq.	4.7	x-section area ft.sq.	13	D50 Channel mm
32.4	width ft	10.0	width ft	35	D84 Channel mm
2.0	mean depth ft	0.47	mean depth ft	6	threshold grain mm

Figure D3-10. Sugar Creek cross section near McKillup Rd.



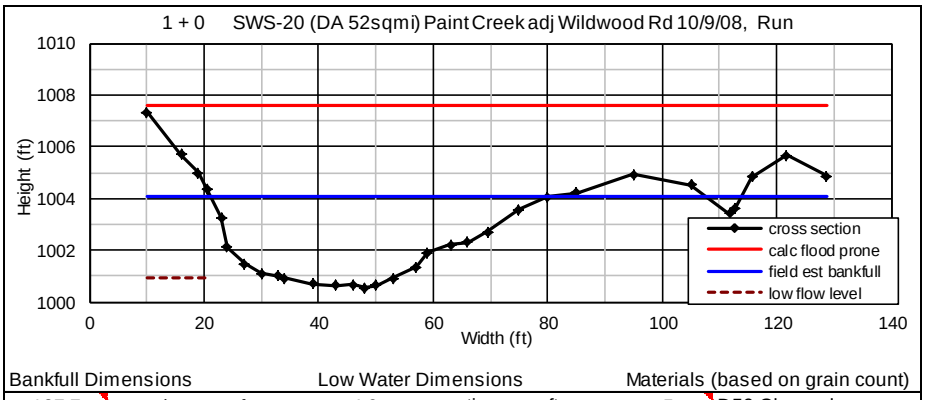
Bankfull Dimensions		Low Water Dimensions		Materials (based on grain count)	
92.5	x-section area ft.sq.	8.1	x-section area ft.sq.	---	D50 mm
37.6	width ft	21.0	width ft	---	D84 mm
2.5	mean depth ft	0.39	mean depth ft	6	threshold grain mm

Figure D3-11. Sugar Creek cross section near Creamer Rd.



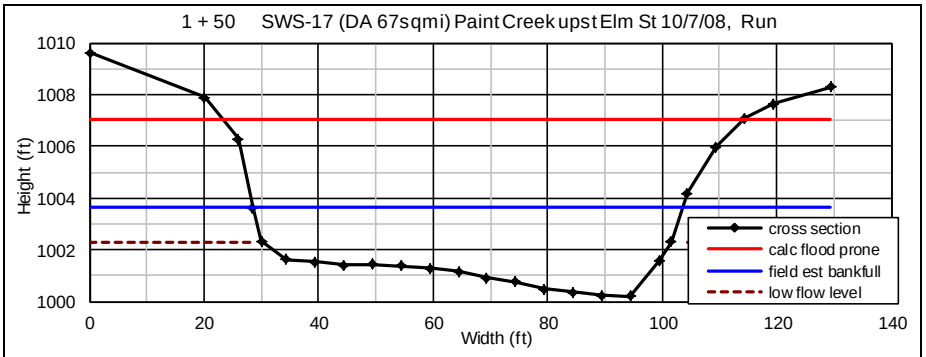
Bankfull Dimensions		Low Water Dimensions		Materials (based on grain count)	
148.5	x-section area ft.sq.	3.3	x-section area ft.sq.	13	D50 Channel mm
59.6	width ft	16.5	width ft	23	D84 Channel mm
2.5	mean depth ft	0.20	mean depth ft	7	threshold grain mm

Figure D3-12. Sugar Creek cross section near Armbrust Rd. (OEPA sentinel site).



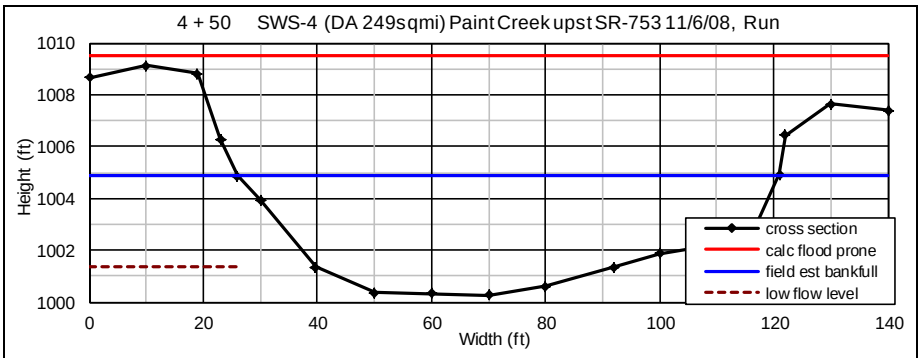
Bankfull Dimensions		Low Water Dimensions		Materials (based on grain count)	
137.7	x-section area ft.sq.	4.0	x-section area ft.sq.	5	D50 Channel mm
64.8	width ft	19.0	width ft	21	D84 Channel mm
2.1	mean depth ft	0.21	mean depth ft	3	threshold grain mm

Figure D3-13. Paint Creek cross section near Wildwood Rd.



Bankfull Dimensions		Low Water Dimensions		Materials (based on grain count)	
185.9	x-section area ft.sq.	88.3	x-section area ft.sq.	2.4	D50 Channel mm
75.2	width ft	71.6	width ft	7.2	D84 Channel mm
2.5	mean depth ft	1.23	mean depth ft	8	threshold grain mm

Figure D3-14. Paint Creek cross section upstream Elm St. / Washington Court House WWTP (OEPA sentinel site).



Bankfull Dimensions		Low Water Dimensions		Materials (based on grain count)	
321.5	x-section area ft.sq.	39.0	x-section area ft.sq.	31	D50 Channel mm
94.9	width ft	52.3	width ft	84	D84 Channel mm
3.4	mean depth ft	0.75	mean depth ft	16	threshold grain mm

Figure D3-15. Paint Creek cross section near SR-753 (USGS flow and OEPA ambient site).

Each delineated subwatershed is represented with a single stream assumed completely mixed, one-dimensional segments with a trapezoidal cross-section. Input parameters for the reaches include initial depth, length, depth, width, slope, Manning's roughness coefficient, and coefficients to describe the shape and of the stream channel. The National Hydrography Dataset (NHD) stream reach network is used to represent the model stream reach for each subwatershed. Longitudinal slopes are calculated based on DEM data and stream lengths measured from the original NHD stream coverage. In addition to stream slope and length, mean depths and channel widths are required to route flow and pollutants through the hydrologically connected subwatersheds. Free flowing bankfull stream depth and channel width for each reach are assigned using drainage area weighted regression curves developed jointly by ODNR and Ohio State University which characterize several studied Ohio streams. Tables D3-14 and D3-15 show the channel characteristics for each LSPC modeled reach.

The calculated cross sections compared to the field measurements generally agree, acknowledging a single field cross section measurement is typically not enough evidence to draw conclusions on the entire reach morphology. The regionally based cross section dimensions are best suited to represent the reach in a watershed scale model. Manning's roughness coefficients are based on representative literature values and are in general agreement compared to field estimates derived from the cross section measurement sites. The Washington Court House lowhead dam and other volume controls are represented as a reach with special properties. The length, width, maximum depth, infiltration rate, and control width are estimated to represent the average effect of the length of a reach.

The RGID component is an assignment of riparian effectiveness to limit light for algal control. A 3 value defines an open slow moving channel with little to no shading, typical of many of the ditched streams. A 2 value defines a stream reach with generally continuous 50% effective shading from the riparian cover. The 2 and 3 designations can be used in simulations where an open 3 reach is restored to a level 2 reach or vice versa. The level 1 designation is different in that it has over 50% effective shading, has better substrate and scouring velocities, and has a healthy connected floodplain typical of the subwatersheds near Paint Creek Lake. Table D3-8 above shows the RGID value assigned to each LSPC modeled reach.

Table D3-14. Channel characteristics LSPC modeled reaches 1-10, 13-16, 20-23 and 27.

Zone	Type	Length	BF Depth	BF Width	Slope	Manning
ID	ID	Miles	Feet	Feet	ft/ft	
1	1	3.1	5.6	145.3	0.0017	0.025
2	1	2.0	5.6	144.4	0.0024	0.035
3	1	4.2	5.6	142.1	0.0017	0.035
4	1	3.1	5.6	138.8	0.0015	0.035
5	1	3.2	5.6	136.5	0.0019	0.035
6	1	1.9	5.2	133.5	0.0022	0.035
7	1	4.2	3.9	88.6	0.0016	0.035
8	2	7.9	3.9	86.0	0.0010	0.035
9	2	7.5	3.6	77.8	0.0007	0.030
10	2	4.6	3.3	69.2	0.0009	0.030
13	3	7.2	2.3	37.7	0.0019	0.025
14	1	5.0	4.6	108.3	0.0010	0.030
15	2	3.4	4.6	105.6	0.0008	0.030
16	3	0.5	3.9	82.0	0.0023	0.025
20	3	9.3	3.6	73.5	0.0005	0.030
21	2	7.9	3.3	66.9	0.0008	0.030
22	2	6.1	3.0	59.4	0.0008	0.025
23	3	8.1	2.6	50.9	0.0024	0.025
27	3	9.2	2.3	43.6	0.0018	0.025

Table D3-15. Channel characteristics LSPC modeled reaches 11-12, 17-19 and 24-26.

Zone	Type	Length	Depth	Width	Control
ID	ID	Miles	Feet	Feet	Feet
11	3	5.0	0.25	20	20
12	3	6.2	0.25	15	15
17	3	1.9	0.5	70	50
18	1	1.5	0.5	70	50
19	2	7.3	0.125	15	15
24	2	4.7	0.17	15	15
25	3	3.9	0.17	15	15
26	3	6.0	0.25	15	15

Weather data for the LSCP modeled watersheds

Hourly weather data is the driving force of LSPC's hydrology components. The modeling processes needed for Paint Creek's desired results require an indepth weather model. Tetratech's Meteorological Data Analysis and Preparation Tool version 2.1 (MetAdapt) weather record patching software is used to create the information needed to simulate Paint Creek's hydrology. MetAdapt can import data in the NCDC (National Climatic Data Center) format which contains raw data, or in the EarthInfo format which is a dataset that has undergone a proprietary quality control process. Table D3-16 lists the types of parameters extracted and/or derived from raw weather station data by MetAdapt. Precipitation gage station selection should be controlled by proximity to the watershed, length and continuity of record, and quality of the measurements. Local precipitation gage stations typically report on a daily interval, which can be broken down into an hourly record by MetAdapt. In order to do this, MetAdapt can use a weather station that reports on an hourly basis for distribution, usually located at a major airport. The airport weather stations also provide the other necessary records, such as wind speed, cloud cover, temperature, and pressure.

The two precipitation gages selected to drive the model are in Midway (weather station 3) and Greenfield (weather station 1). Each zone is assigned to a weather station, which is listed in Table D3-9 above. The station's data gaps are patched with rainfall data from other nearby gages and disaggregated to an hourly distribution. The Dayton International Airport's weather logs are used to fill in the remaining parameters. Hourly solar radiation and potential evapotranspiration are usually not recorded, so MetAdapt creates hourly datasets for both using hourly distribution algorithms based on either the Hamon or Jenson method. The resulting hourly weather data is compiled into LSPC .air input files.

Table D3-16. Weather parameters used by the LSPC model.

Parameter Code		Description	Timestep
Water	HPCP	Precipitation (in/hr)	hourly
	PRCP	Precipitation (in/day)	hourly
	SNOW	Snowfall (in/day)	daily
	EVAP	Evaporation (in/day)	daily
	PEVT	Potential Evapotranspiration (in/hr)	hourly
Temperature	DPTC	Dewpoint Temp (Deg C)	hourly
	DPTP	Dewpoint Temp (Deg F)	hourly
	TMAX	Maximum Daily Temperature (Deg F)	daily
	TMIN	Minimum Daily Temperature (Deg F)	daily
	TMCD	Dry-Bulb Temperature (Deg C)	hourly
	TMPD	Dry-Bulb Temperature (Deg F)	hourly
	TMPW	Wet-Bulb Temperature (Deg F)	hourly
Air	WIND	Windspeed & Direction (mi/hr & Degrees)	hourly
	ALTP	Altimeter Pressure (mbar)	hourly
	PRES	Station Pressure (mbar)	hourly
	SLVP	Sea-Level Pressure (mbar)	hourly
	RHUM	Relative Humidity (%)	hourly
	HZVS	Haze/Visibility (miles)	hourly
Sky	TSKC	Cloud Cover (Tenths)	hourly
	TSCE	Cloud Cover (Tenths)	hourly
	CLHT	Ceiling Height (100 ft)	hourly
	SOL1	Clear Sky Solar Radiation (ly/hr)	hourly
	SOL2	Cloud Adjusted Solar Radiation (ly/hr)	hourly

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D3.1.4 LSPC model calibration and utilization

Model hydrology

The LSPC hydrology module considers several variables which control point source flows, soil infiltration, evapotranspiration, overland flow, stormwater recession rates, hydrograph routing, and deep groundwater loss among others. Figure D3-16 provides a pictorial view of how the LSPC model simulates these factors. Model calibration involves a necessary comparison of model results to gage flow data. The USGS gage on Paint Creek at SR-753 possesses a suitable record for model calibration. The calibration is built upon the US EPA publication (US EPA, 2000). The publication guides a user through controlling temperature, snow, pervious hydrology, impervious hydrology, and flow routing parameters.

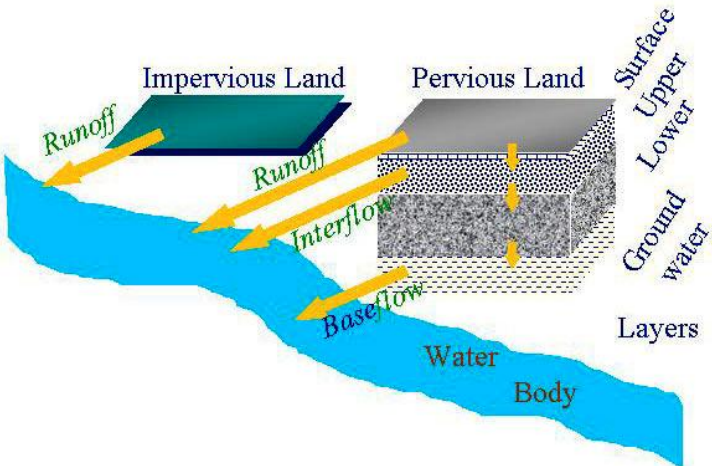


Figure D3-16. A pictorial view of how the LSPC model simulates hydrology.

The model is calibrated for storm flow characteristics using selected events in 2006 and 2003. Aggregate and seasonal flow characteristics use the 2000 to 2006 range for calibration. Criteria for calibration include completeness of weather data for a selected period, representation of low, average, and high flow years, and consistency of key model inputs for the selected period. Calibration involved adjustment of infiltration, subsurface storage, evapotranspiration, surface runoff, and interception storage parameters.

The model calibration was performed using the guidance of error statistics criteria specified in HSPEXP, temporal comparisons and comparisons of seasonal, high flows, and low flows. After adjusting the appropriate parameters within acceptable ranges, good correlations were found between model results and observed data. The hydrology model is validated with the 12 year period between 1997 and 2008, finding similar statistical patterns in the extended record.

The calibrated flow data is checked against both short term and long term patterns. The flow duration curve in Figure D3-17 indicates that the 2000-2006 calibrated flow data follows the same general recession pattern of the gage data. The percent cumulative flow trend in Figure D3-18 is useful to observe whether the modeled cumulative flow volume is within range with data derived from gage data. With the exception of a likely missed storm event (due to weather data records) during 2005, the two datasets generally agree with the trends and magnitude of continual flow patterns.

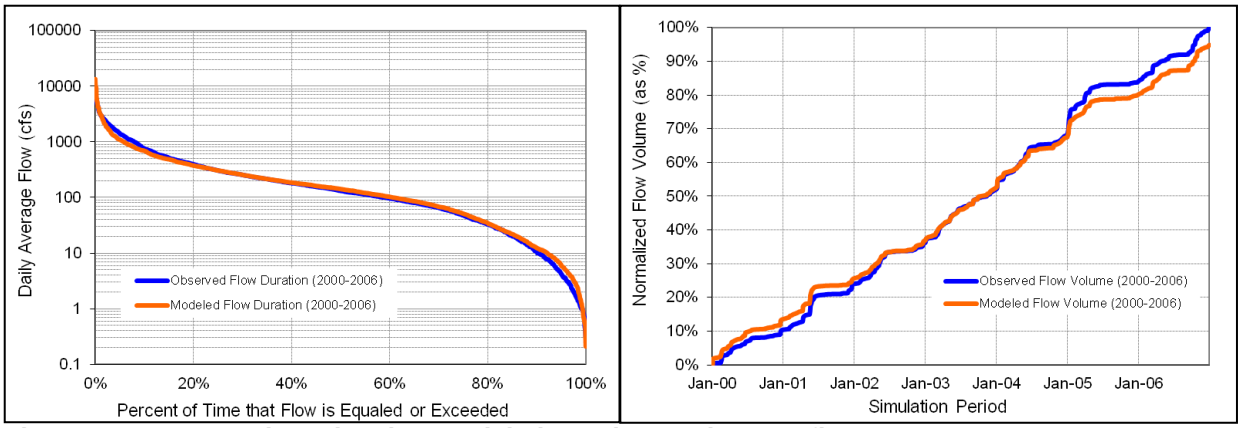


Figure D3-17. Two plots showing modeled vs. observed streamflow.

In order to study flows of the upper tributaries, OEPA established three sentinels sites in this region. Sentinel site water chemistry sampling is paired with a water stage measurement in order to correlate water level to flow, and pollutant concentration to load. All four sentinel sites provided flow-stage ratings with statistical R^2 values above 0.98.

Sugar Creek's sentinel site was established at Armbrust Road, representing 78 square miles of drainage. The site was found to be in aquatic full attainment, and provided important information on agriculture chemistry transport with distant point source contribution.

East Fork Paint Creek's sentinel site was established at US-22 on the west side of Washington Court House, representing 50 square miles of drainage. This site is in partial aquatic attainment due to sedimentation and dissolved oxygen issues. Much of East Fork is channelized for agricultural drainage and has little riparian cover.

Paint Creek's sentinel site was established at Elm Street just upstream Washington Court House's WWTP, representing a 67 square mile drainage area. This site is in partial aquatic attainment due to urban channelization, habitat alterations, eutrophication, and dissolved oxygen issues. This site was useful for observing deep urban channelization flow without constant point source influence. The Elm Street bridge's stream bed height is a control of flow (like a lowhead dam) through the deeper upstream reach, creating an often stagnant narrow pool of water. However, since Washington Court House's sanitary sewer line below this pool has infiltration issues and Washington Court House withdraws water upstream for its drinking water reservoir, it was not the best site to monitor low flow to use for other site estimates. Figures D3-18 and D3-19 show various modeled vs. observed flow plots for this assessment site. Points in blue are actual flow measurements used to develop the stage-flow relationship. Points in green are estimated flows during sampling events based on the relationship, which allow for an estimation of pollutant mass loading.

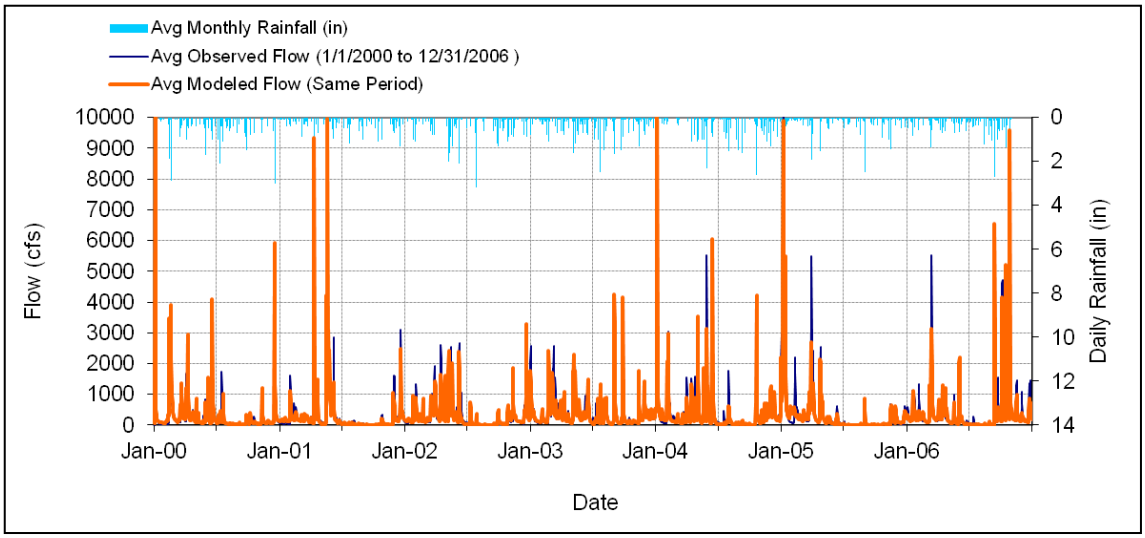


Figure D3-18. Modeled vs. observed flow with rainfall noted for the assessment site of the USGS gage on Paint Creek at SR-753.

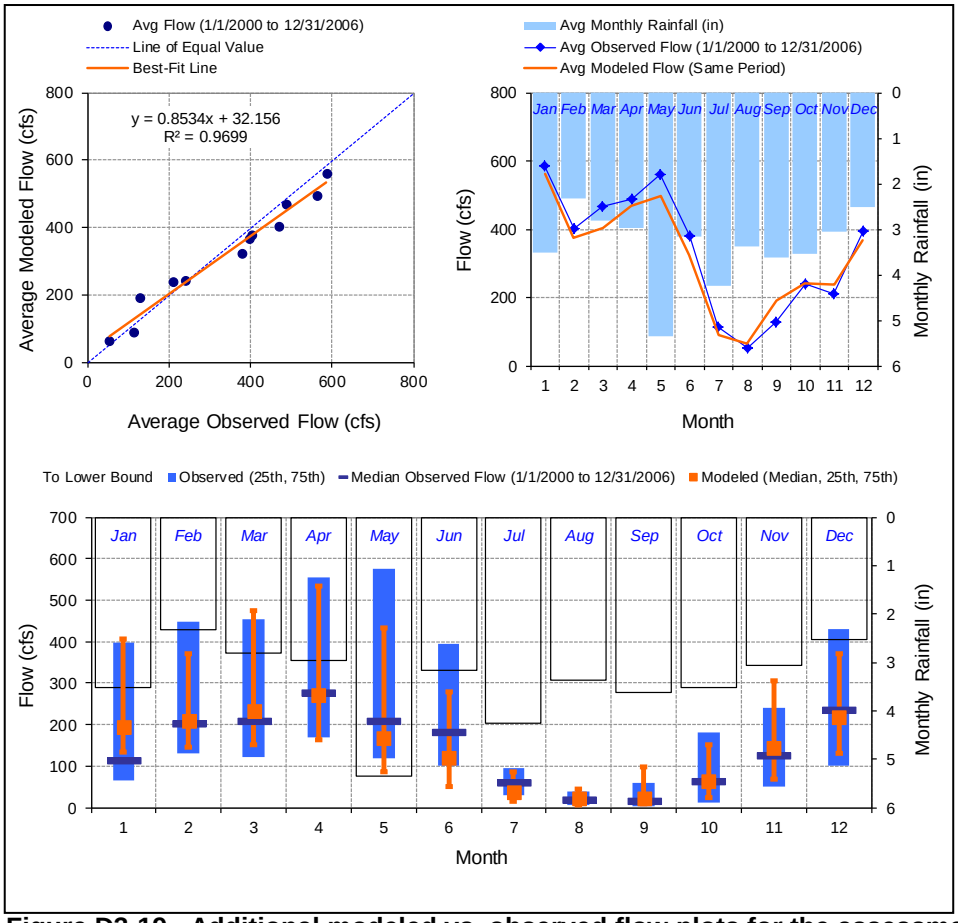


Figure D3-19. Additional modeled vs. observed flow plots for the assessment site of the USGS gage on Paint Creek at SR-753.

Table D3-17 shows summary statistics of the calibrated LSPC model at the USGS gage on Paint Creek at SR-753 assessment site. Note in the bottom half of this table that all of the error statistics that indicate how well the modeled flows match the observed gage flows are well within the recommended criteria. These recommendations come from US EPA 2000 and from TetraTech staff as presented to Ohio EPA modelers at past trainings.

Table D3-17. Summary statistics of the calibrated LSPC model at the USGS gage on Paint Creek at SR-753 assessment site.

LSPC Simulated Flow		Observed Flow Gage	
REACH OUTFLOW FROM SUBBASIN 4 7-Year Analysis Period: 1/1/2000 - 12/31/2006 Flow volumes are (inches/year) for upstream drainage area		OBSERVED FLOW 7-Year Analysis Period: 1/1/2000 - 12/31/2006 Flow volumes are (inches/year) for upstream drainage area	
Total Simulated In-stream Flow:	**17.37**	Total Observed In-stream Flow:	**18.31**
Total of simulated highest 10% flows:	**9.36**	Total of Observed highest 10% flows:	**10.20**
Total of Simulated lowest 50% flows:	**1.57**	Total of Observed Lowest 50% flows:	**1.46**
Simulated Summer Flow Volume (months 7-9):	**1.57**	Observed Summer Flow Volume (7-9):	**1.34**
Simulated Fall Flow Volume (months 10-12):	**3.89**	Observed Fall Flow Volume (10-12):	**3.90**
Simulated Winter Flow Volume (months 1-3):	**6.05**	Observed Winter Flow Volume (1-3):	**6.58**
Simulated Spring Flow Volume (months 4-6):	**5.86**	Observed Spring Flow Volume (4-6):	**6.49**
Total Simulated Storm Volume:	**10.46**	Total Observed Storm Volume:	**10.74**
Simulated Summer Storm Volume (7-9):	**1.11**	Observed Summer Storm Volume (7-9):	**0.86**
Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*	
Error in total volume:	-5.14	10	
Error in 50% lowest flows:	6.98	10	
Error in 10% highest flows:	-8.28	15	
Seasonal volume error - Summer:	16.81	30	
Seasonal volume error - Fall:	-0.20	30	
Seasonal volume error - Winter:	-7.99	30	
Seasonal volume error - Spring:	-9.75	30	
Error in storm volumes:	-2.59	20	
Error in summer storm volumes:	28.16	50	

An assessment site was established in 2008 for short term continuous stage measurement North of Washington Court House near the city's drinking water reservoir adjacent to SR-41. This site was part of the 2006 biology assessment and was found to be in partial attainment due to sedimentation, eutrophication, and dissolved oxygen issues. A continuous stream stage level recorder was installed in June of 2008 to monitor the agricultural drainage's flow coming into Washington Court House. Flows measured were used to construct a stage-flow rating, with a 0.98 R^2. However the stream flow became interstitial and provided no useful stage data between September and November, 2008 making the short record difficult for use of comparison to another long term gage. The observations of 2008 at several areas having interstitial pools with little through flow at the hottest time of the season captured the threshold of a critical low flow condition. The agriculture drainage channelization has altered the natural hydraulics in several areas, leaving low flows with little apparent velocity in stagnating reaches. Reaches were observed to be ditched deeper than downstream flow controls, which would not effectively increase channel drainage, but does diminish water quality in the summer. The deep ditching does not allow concentrated or interstitial transport at lower flows, but instead the reaches behave more like long pool segments. The soils of the area pond frequently and need artificial drainage for crop production, and likely are maintained to side on the error of too much

field drainage in most areas. Figure D3-20 shows this site's calculated flows, in blue, versus the USGS gage reported flows for the north of Greenfield gage.

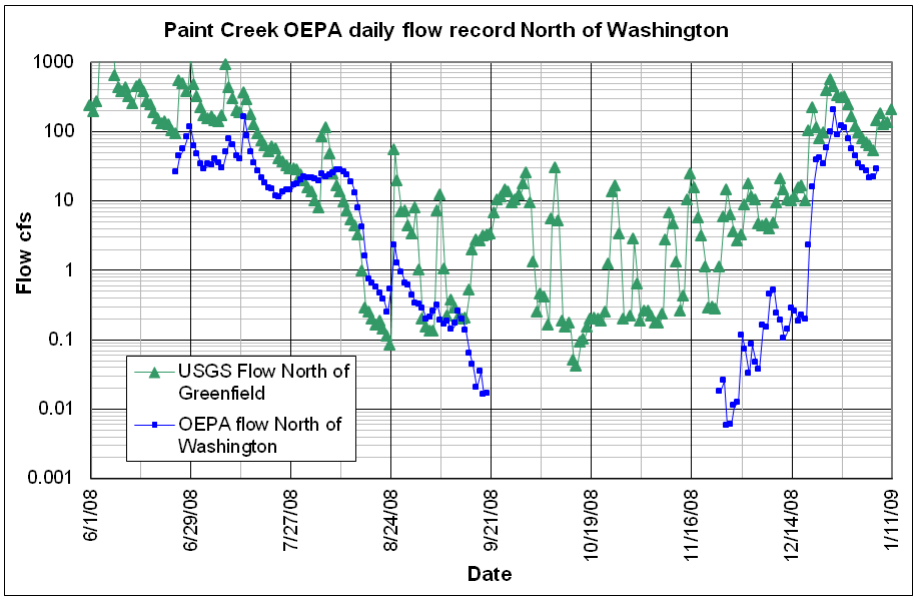


Figure D3-20. Paint Creek north of Washington Court House gaged flows vs. a downstream gage.

E. coli LSPC modeling background

The State of Ohio has until recently used fecal coliform as the pathogen indicator basis for recreation standard limits. The rules have changed to use *E. coli* as the pathogen indicator of choice, as recommended by US EPA. For assessment of general recreation season attainment, the geometric mean of daily *E. coli* concentration from May 1st to October 31st is used. While the metric is suitable to determine the overall health of a waterbody and the focus of TMDL development, there are other regulatory tools to consider. The integrated report does not consider maximum *E. coli* concentration violations as it did in the past for fecal coliform. However, a maximum *E. coli* standard is in effect to control localized sources known to have high pathogen content (CSOs, sludge lagoons, treatment operations, etc.). The maximum *E. coli* standard can also be used for assessment in public nuisance situations by the Department of Health or Ohio EPA (septic failures, manure storage failures, etc.). The *E. coli* TMDLs of this report focus on maintaining the recreation season geometric mean standard, with the understanding that all gross sources of pathogens are not permitted and do not receive any allocation.

Much research has led to several published reports and spreadsheet tools to estimate loadings of fecal coliform from sources. One of which is BIT (Bacteria Indicator Tool), a US EPA approved assessment spreadsheet which was originally designed to quantify source load inputs for HSPF. Discussion of the use of BIT to quantify fecal coliform sources is provided in Section D3.1.3. Unfortunately, there has not been as much work on quantifying *E. coli* loadings from sources, with a much smaller database of valid reference values. The same issue arises when calculating *E. coli* loads from NPDES permitted sources, where fecal coliform has been the reported parameter for years. The issue is overcome by the fact that *E. coli* itself is one of the organisms contained within the fecal coliform group of bacteria. The percent of fecal coliform that is *E. coli* can be highly variable depending on source and environment, but through analysis of sample data the ratio can be generalized. Ohio EPA developed a general in-stream fecal coliform – *E. coli* ratio using all paired data in Ohio, except for the Northeast region. The

variable ratio is calculated with a power function, *E. coli* = 0.403 * fecal coliform$^{1.028,}$ as it is based on a log scale. The use of power functions to describe the fecal coliform - *E. coli* relationship is common, such as the ratio developed by Virginia, *E. coli* = 0.988 * fecal coliform$^{0.919}$. The ratio is not linear due to specific properties of *E. coli* that other members of the fecal coliform group may not possess. *E. coli* appears to bind to fine sediments more readily, which results in a lower *E. coli* to fecal coliform ratio with high sediment load flows. Some *E. coli* strains are mobile through use of flagella and can sense poor growth environments. The survival response creates movement toward each other through chemical release sensing. The *E. coli* eventually clump together, which slows the decay rate. The phenomena would likely be successful in low flow waters, where conditions are steady enough to allow the organisms efficient location tracking. Due to the nature of *E. coli* agar testing without the use of an anticoagulant, a clumped group would appear as one colony forming unit, making the concentration appear to be less than actual. The estimation of living bacteria concentration in itself is difficult without a large amount of samples, adding to the complication of assessment. Fecal coliform and *E. coli* analysis are ran as two separate tests on different agar plates, which sometimes leads to results where *E. coli* concentration is higher than fecal coliform. This discrepancy is an indication of the inherent variability of lab analysis. Between high and low flow transport durations, the most consistent *E. coli* ratio with regard to fecal coliform appears to be around 200 to 1000 cfu/100ml. Many States have addressed the US EPA recommended *E. coli* standard of 126 cfu/100ml by using a correlated fecal coliform standard of 200 cfu/100ml. The ratio of the standards is approximate to the results of Virginia's FC – *E. coli* ratio.

The relationship between paired *E. coli* – fecal coliform samples taken in the Paint Creek basin is compiled for comparison to statewide results for determination of its suitability for *E. coli* source load estimation. The paired data is presented in Figure D3-21. 1023 paired samples were taken in the Paint Creek basin between 2006 and 2008, along with two ambient sites with data from 1999 to 2008. Samples with an *E. coli* detection at or below 60 cfu/100ml (about half of the Class A recreation standard 126 cfu/100ml) were omitted from the analysis. The high ratio variability at low fecal concentrations is not a significant representation issue since it occurs well below the standard. Paired samples with *E. coli* measuring higher than fecal coliform are left in the dataset to represent analytical error. The resulting equation for the Paint Creek basin is *E. coli* = 0.9375 * fecal coliform$^{0.9181}$, based on 726 paired samples. The general equation for Paint Creek turns out to provide similar results compared to Virginia's equation. Another relationship was developed using a subset of the data limited to 2008 data collection, which does not include many high sediment load events. 115 of the 204 collected paired samples were used in the same fashion as the main dataset, as presented in Figure D3-22. The resulting 2008 dataset equation *E. coli* = 0.8884 * fecal coliform$^{0.9824}$ provides similar results as the Paint Creek general equation, indicating the relationship holds over time and is most relevant during stable flows.

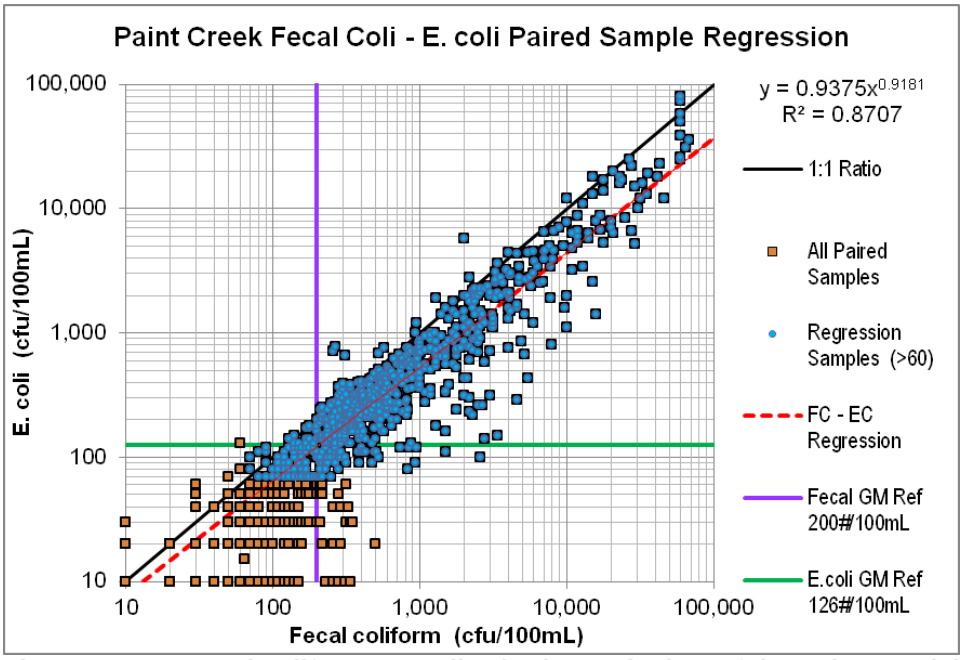


Figure D3-21. Fecal coliform- *E. coli* paired sample data of the Paint Creek basin

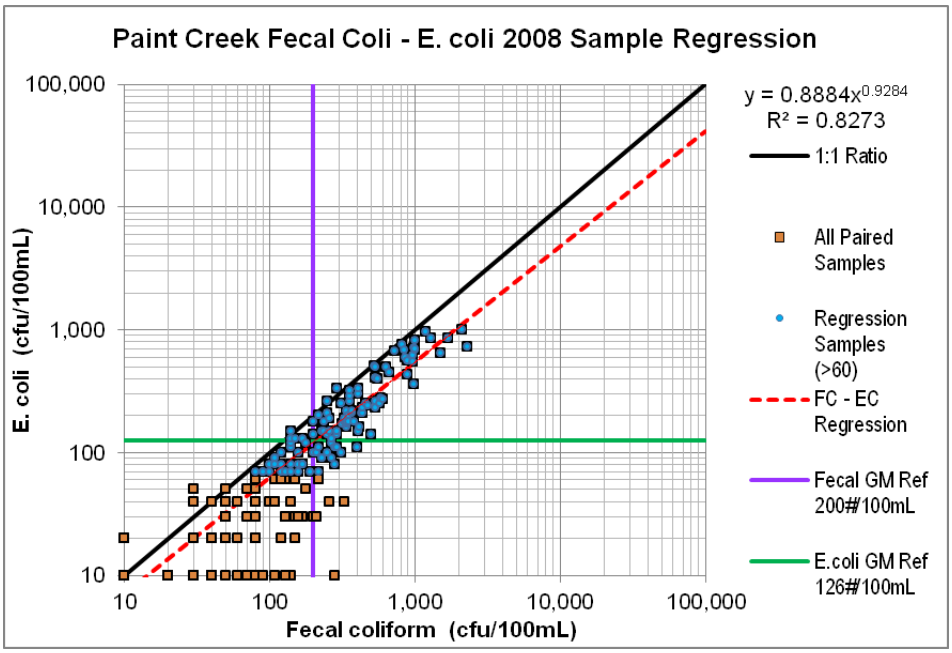


Figure D3-22. Fecal coliform- *E. coli* paired 2008 sample data of the Paint Creek basin

In-stream bacteria interactions are thought to be a major component to the FC-EC ratio variability. A power function relationship may provide erroneous *E. coli* results when applied to high magnitude fecal coliform sources. Therefore, a constant 63% of calculated fecal coliform source loads are used to represent generalized *E. coli* loading from all sources. The turbulent, low sediment stream waters that often generate this ratio keep the bacteria mixture in suspension without the effects of sediment absorption. The suspended mixture is assumed to best represent the general FC-EC ratio of nearby combined sources.

The land based sources for upper Paint Creek are assumed to be in conditions where the fecal coliform – *E. coli* ratio is not affected. BIT does calculate a loss of available source through disking in manure during crop/pasture applications. The undisked percent of manure remaining is assumed to not be affected by soil absorption. With the preservation assumptions, the land based fecal coliform accumulation, buildup, interflow, and groundwater rates are multiplied by 63% to populate the *E. coli* land parameters.

NPDES permitted wastewater plants are assigned the *E. coli* standard concentration as an average criteria depending on the recreation class of the stream. The existing representation of most point sources is simplified by derivation of fecal coliform concentration from the *E. coli* standard, with *E. coli* assuming 63% of the fecal coliform group. The exception is Washington Court House's representation since its self-monitoring effluent fecal coliform data contains significant spikes. Washington Court House WWTP's *E. coli* concentrations are calculated based on its average or daily fecal coliform values.

LSPC models landuse bacteria quantities through daily first order buildup rates and a buildup limit. BIT estimates these parameters through analysis of landuse type, typical urban/developed buildup values, livestock density, and wildlife density. It assumes all manure produced by feedlot livestock is spread over crop and pasture, and deposited in the same subwatershed it was generated. For Paint Creek, BIT is modified to eliminate manure spreading on most crop land during the growing season since a high percentage is in corn and soybean. Some manure application is still allocated to growing season crop land based on the percentage of cut forage grasses and wheat produced. Manure spreading is preferentially set to be greater during April, May, October, and November with more emphasis in the fall for field applications, while a continuous smaller load application is set to represent barn yard cleanings. LSPC stores this information based on the physical characteristic group a subwatershed is assigned. The 27 subwatershed load parameters estimated by BIT are averaged for each of the three physical groups for a calibration starting point. The groups use a first order equation to predict the amount of washoff from hourly rainfall. The approach is used in the urban SWMMS model, which uses a 0.5 in/hour rainfall coefficient to represent 90% flushing of the available load. LSPC uses the same approach for other land uses. 0.7, 0.65, and 0.8 in/hour coefficients are used for crop, pasture, and wooded landuses respectively.

E. coli calibration

HSPF/LSPC has two options for longitudinal in-stream pollutant modeling, the GQUAL and RQUAL stream modules. GQUAL is used to model pollutant transport that can be represented with advection, first order decay, temperature, and sediment interaction. The GQUAL stream model is sufficient for representing the in-stream processing of fecal coliform and *E. coli*. RQUAL is a nutrient specific stream model which simulates speciation of nutrients, metabolic processes of algae, and dissolved oxygen responses. RQUAL will be discussed in the nutrient section. Both stream models provide load and concentration reach data to the downstream reaches, which allows for spatial calibration and load tracking. Both models also depend on the temperature and sediment components of LSPC. The stream temperature model uses longwave radiation and conduction-convection heat transport coefficients as the basis for representation. The temperature simulation is used to adjust in-stream process rates The sediment module simulates sediment in suspension and within the bedload (Figure D3-23). The silt and clay transport model uses several physical characteristics for calibration, such as particle diameter, settling velocity, density, critical shear stress for deposition/scour, and erodibility. A velocity based power function is used to model sand transport. Sand, silt, and clay are assigned individual absorptive pollutant capacities, which is used to represent a pollutant's

affinity toward finer sediments and/or organic contents. Sediment calibration results are provided in the nutrient section.

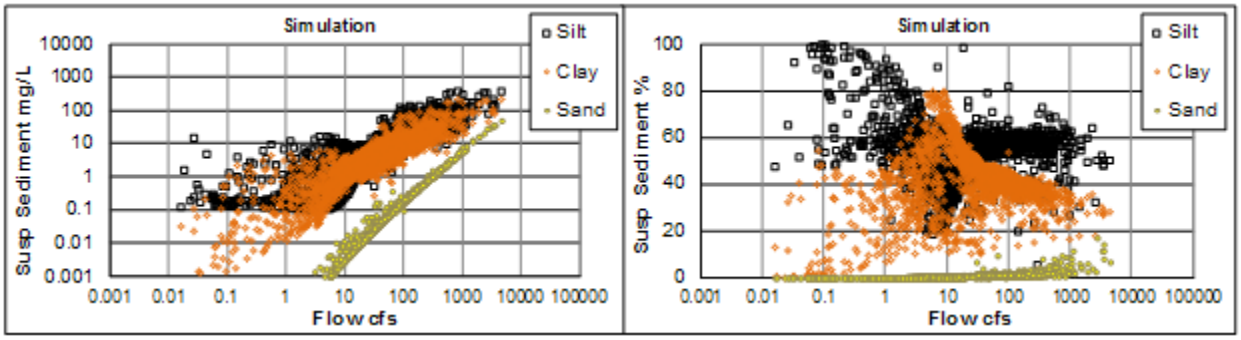


Figure D3-23. Sand, silt and clay simulation as suspended sediment concentration (left) and percent of total suspended sediment (right) in response to variable flows

The loss of in-stream suspended fecal coliform and *E. coli* is modeled as a first order decay. Both fecal coliform and *E. coli* are assigned an in-stream 0.72 cfu/day decay rate. The pathogen indicators enter the stream as inputs without preliminary sediment attachment, and sediment absorption begins within the turbulent mix of the stream. Once bound to sediment, the bacteria's advective transport alters and follows the sediment transport mechanisms. *E. coli* has more of an affinity and quicker rate of sediment absorption as opposed to the fecal coliform group as a whole. Bacteria decay rates differ once bound to sediment due to differences in toxicity, scavenging, food supply, and burial loss. *E. coli*'s sediment decay rates are calibrated to 3.06 cfu/day for suspended sediment and 5 cfu/day for bed sediment. The fecal coliform group's rates are calibrated to 1.02 and 2.04 cfu/day for suspended and bed sediment respectively. The varying transport mechanisms and decay rates result in *E. coli* concentrations generally diminishing quicker than the fecal coliform group. The variability in the export ratio is not as significant under high flows, which re-suspends the surviving bacteria in the scoured substrate. The simulated data of Paint Creek at SR-753 from 2000 to 2006 is plotted against the site's paired bacteria field data. The simulated paired data exhibits general agreement with the paired field data's variability due to sediment absorption and transport (Figure D3-24).

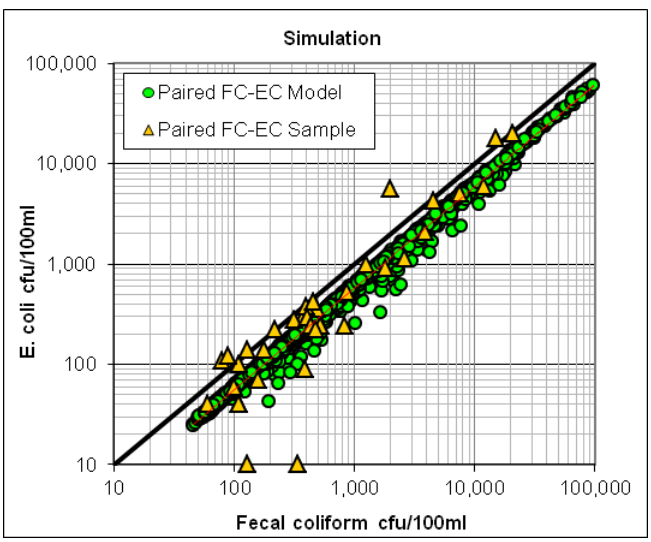


Figure D3-24. Sample and simulated fecal coliform – *E. coli* paired data in Paint Creek at SR-753 between 2000 and 2006.

Paint Creek at SR-753 is used as the main calibration point. It is located at a USGS gage and is an Ohio EPA ambient samples site. The calibration is an iterative process of adjusting parameters to control both low and high flow concentrations with consideration of seasonal changes and validation through the overall fit. The Ohio EPA sentinel sites Sugar Creek at Armbrust Road, East Fork Paint Creek at US-22, and Paint Creek at Washington Court House Elm Street are used as spatial validation points for further calibration adjustments. The calibration of fecal coliform and *E. coli* uses the weight of evidence approach. The variability in grab sample to daily average representation, rainfall/hydrology pattern errors, lab analysis issues, load characterization issues, and model parameter assumptions all contribute to error in the final product. All subwatershed unit output analysis omits daily *E. coli* simulation data at flows below 0.15 cfs, which is approximate to the annual 7Q10 of the basin's upper 20 sqmi drainages. The exclusion safeguards against using data when water quality standards generally do not apply and to disregard in-stream loading concentrations for continuous HSTS and livestock stream contributions. At near zero flows of small streams, livestock are not as likely to be contributing in stream and HSTS effluent may pool and dry. Several lines of evidence are used to assess the calibration fit in order to determine how useful the model results are for use in management decisions. Quantitative tests include direct comparison of grab samples to daily outputs through absolute error, and relative error. A load duration curve is a quasi-quantitative tool that compares sample ranges to the entire model dataset. Qualitative calibration looks at the overall model fit in ensuring that model data is within a realistic range based on season and hydrology timing through time series and flow/pollutant scatter plots. Another qualitative calibration issue is to ensure that modeled sources that vary from year to year, such as cattle density and movements between pastures which may not be reflected in sample data are represented as continuous sources to ensure an implicit margin of safety within the model.

The seven year existing condition daily *E. coli* simulation of Paint Creek at SR-753 is presented in Figure D3-25. The time series plot presents the recreation season simulation in black, and the off-season months in grey. The existing flow simulation should be referenced to review each year with regard to seasonal variability. Each recreation season's daily values are used to compute a seasonal geometric mean to compare to the Class A recreation standard 126 cfu/100ml. The geometric means are represented as brown lines on the graph, all of which indicate noncompliance every year. The 90th percentile of each season's dataset is also shown as a blue bar for general reference. The *E. coli* and fecal coliform simulations are further presented in flow-concentration scatterplots. The variability between the two pathogen indicators and respective simulations are shown to have strong ties with flow regime in the plots.

Of note are the base flow bacteria correlation up to 100cfs, and the increase in concentration from runoff events from 10cfs and up. Absolute and relative errors are provided four categories, low flow, transitional flow, high flow, and the entire sample group's pairings (Table D3-18). The categories' flow divides are determined by the site's 20th and 80th percent of flows exceeding. Absolute and relative errors are well accepted tools that describe the general fit of a model. Absolute error is defined as the summation of the absolute values of each sample value minus simulated value, divided by the count of samples. Relative error is defined as the summation of the same absolute values, divided by the sum of all the sample values, usually provided as a percent. The project's general *E. coli* relative error goal is 75%, which is expected to have more relative error than nutrient calibration (nutrient relative error is recommended as within 50% by US EPA). Field samples that resulted in non-detection (reported as <10 cfu/100ml by Ohio EPA DES) are not used for statistical analysis, but are depicted in the graphs as 10 cfu/100ml for visual reference. While the *E. coli* relative error within the low and transition flow regimes meet the requirement, the high flow results do not correlate as well to the grab samples. This is likely due to the nature of taking grab samples around peak flow events and the timing/magnitude of

the simulated routed flow peaks. However, as demonstrated via flow-concentration scatterplots, the simulated concentrations are well within range of what is expected. The load duration curve (Figure D3-26) provides review similar to a scatterplot, except that the load of *E. coli* is compared to sample data by flow regime. Each regime's simulation data is summarized by quartile boxplots, which encompass the range of sample data.

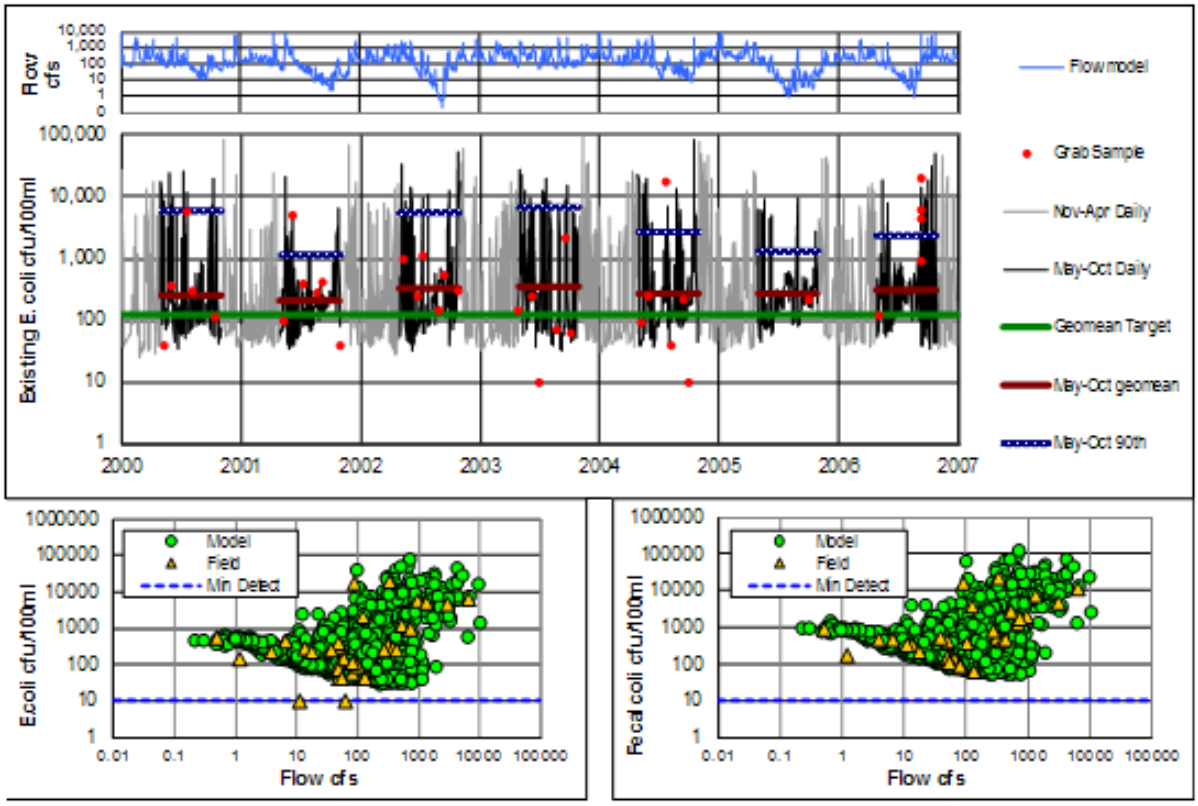


Figure D3-25. Fecal coliform and *E. coli* calibration of Paint Creek at SR-753

Table D3-18. Fecal coliform and *E. coli* calibration error statistics of Paint Creek at SR-753

Parameter	Instantaneous Samples per group	Low Q < 35cfs		Transition Q		375cfs < Runoff Q		Total Q range	
		Abs Err	Rel Err	Abs Err	Rel Err	Abs Err	Rel Err	Abs Err	Rel Err
E. coli	5 / 17 / 9	94.2	28%	855.9	60%	3896.2	143%	1615.7	99%
Fecal	6 / 18 / 9	103.0	23%	875.5	54%	7661.1	210%	2585.7	132%

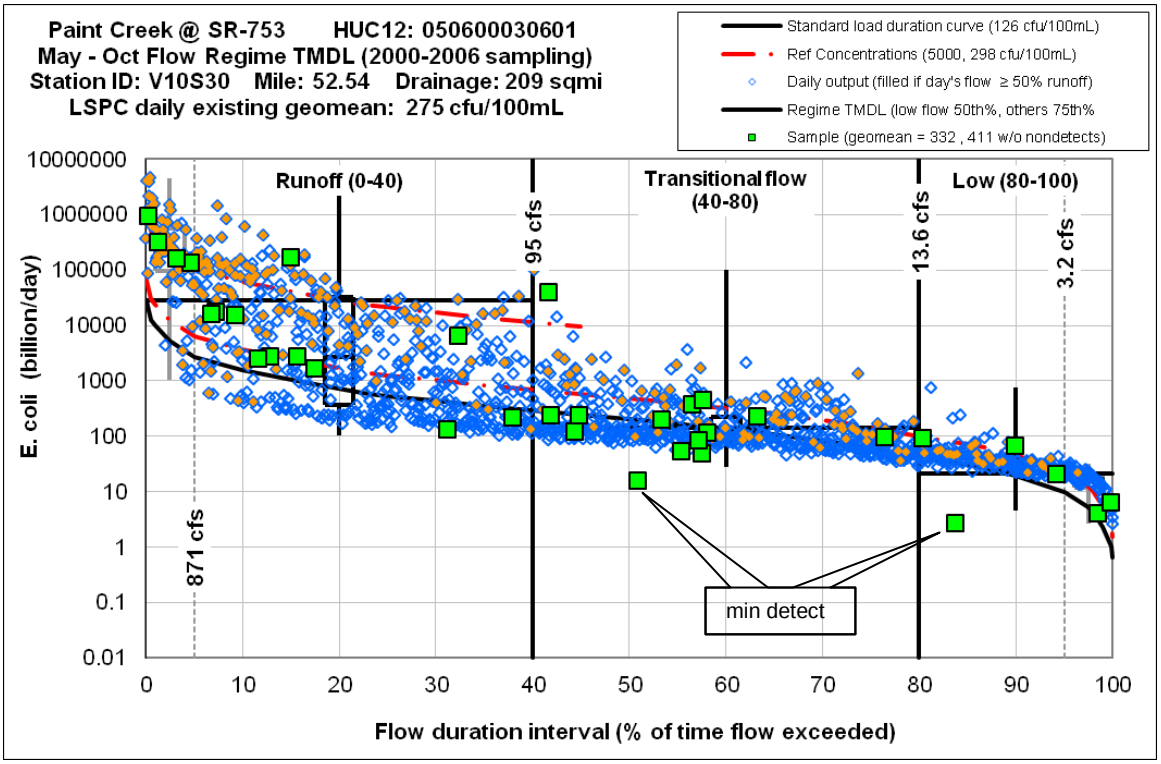


Figure D3-26. Sample and simulated *E. coli* data load duration curve comparison of Paint Creek at SR-753

The calibration plots and absolute/relative error statistics of the other three sentinel sites are provided in Figures D3-27 through D3-29 and Tables D3-19 through D3-21 respectively. Although the amount of samples quantities collected is just a fraction of the main Paint Creek site, they are still useful for comparison. The low flow regime relative errors of the Sugar and East Fork sites are higher due in part to the representation of the Jeffersonville and Bloomingburg WWTPs at a constant daily 161 cfu/100ml *E. coli* concentration. The lower flows of the small drainage area sites with constant load input representations are more prone to over predict concentrations. This is considered acceptable as a determination of potential year to year variable loading, another implicit margin of safety. Transitional flow relative errors are generally good for the three sites based on two to three samples. The high flow relative error is also within range, although just based on one sample. A better assessment of model performance in light of very low sample data is to ensure that simulation results are within expected ranges. The time series and scatter plots of the three sentinel sites indicate the model provides representative daily fecal coliform and *E. coli* data for the basin. Most of the other 22 model output points have a few *E. coli* grab samples for general comparison to the existing condition model simulation.

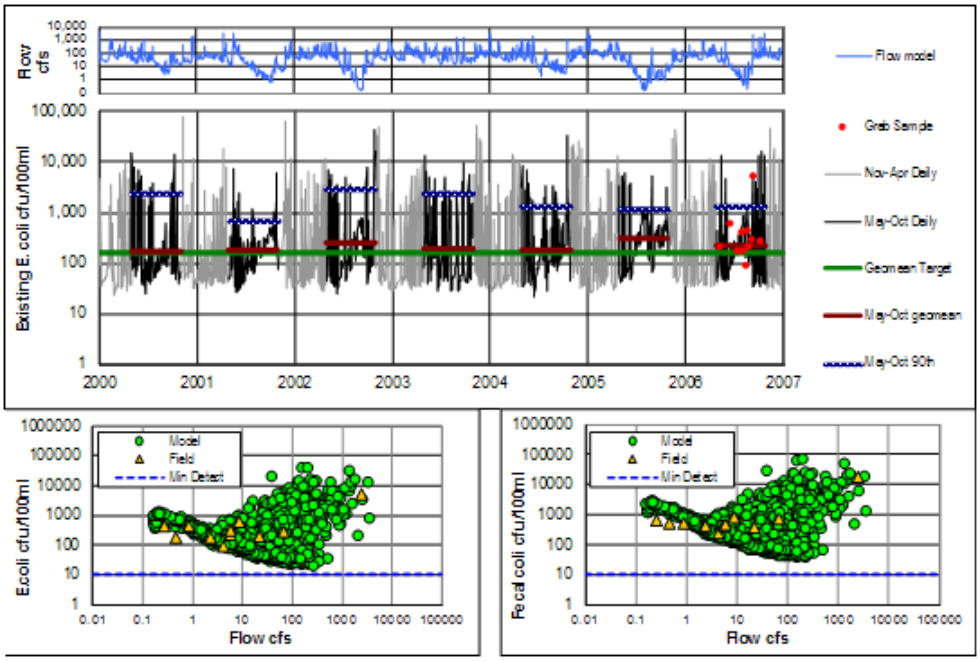


Figure D3-27. Fecal coliform and *E. coli* calibration of Sugar Creek at Armbrust Road

Table D3-19. Fecal coliform and *E. coli* calibration error statistics of Sugar Creek at Armbrust Road

Parameter	Instantaneous Samples per group	Low Q < 10cfs		Transition Q		115cfs < Runoff Q		Total Q range	
		Abs Err	Rel Err	Abs Err	Rel Err	Abs Err	Rel Err	Abs Err	Rel Err
E. coli	8 / 2 / 1	293.0	97%	146.3	61%	1852.3	35%	408.1	55%
Fecal	8 / 2 / 1	531.9	107%	116.5	22%	11218.0	62%	1427.8	68%

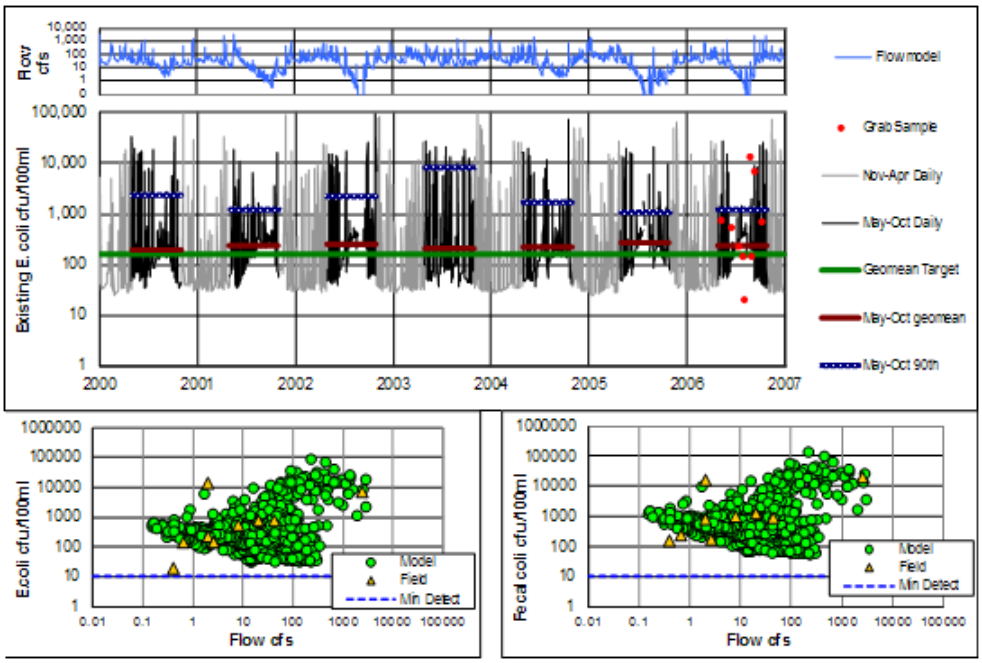


Figure D3-28. Fecal coliform and *E. coli* calibration of East Fork Paint Creek at US-22

Table D3-20. Fecal coliform and *E. coli* calibration error statistics of East Fork Paint Creek at US-22

Parameter	Instantaneous Samples per group	Low Q < 35cfs		Transition Q		375cfs < Runoff Q		Total Q range	
		Abs Err	Rel Err	Abs Err	Rel Err	Abs Err	Rel Err	Abs Err	Rel Err
E. coli	4 / 3 / 1	205.7	155%	465.1	71%	2264.1	32%	560.3	47%
Fecal	4 / 3 / 1	528.0	156%	693.2	68%	5828.4	29%	1252.5	41%

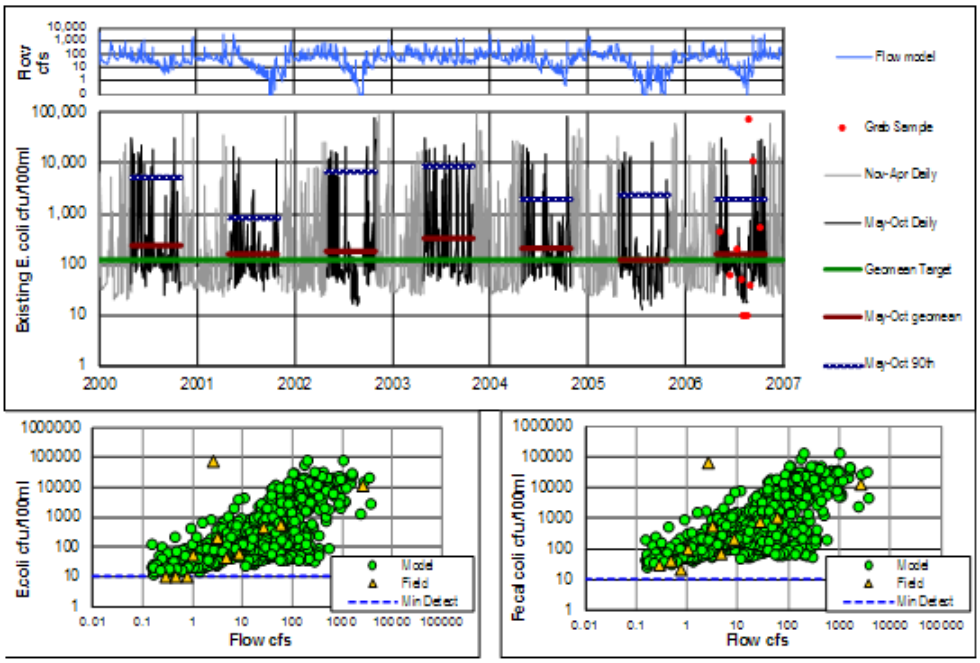


Figure D3-29. Fecal coliform and *E. coli* calibration of Paint Creek at Washington Court House Elm Street

Table D3-21. Fecal coliform and *E. coli* calibration error statistics of Paint Creek at Washington Court House Elm Street

Parameter	Instantaneous Samples per group	Low Q < 10cfs		Transition Q		100cfs < Runoff Q		Total Q range	
		Abs Err	Rel Err	Abs Err	Rel Err	Abs Err	Rel Err	Abs Err	Rel Err
E. coli	4 / 3 / 1	73.5	84%	509.8	80%	4319.2	39%	767.8	46%
Fecal	7 / 3 / 1	110.2	78%	1206.7	85%	13459.9	104%	1622.9	98%

E. coli LSPC modeling loading capacity development

The calibrated model is used to analyze the existing conditions both temporally and spatially. LSPC provides an annual load report for each land use source. Table D3-22 lists each modeled subwatershed's annual *E. coli* loads coming from different land uses and other non-point direct sources. The values are also summarized by HUC-12. The loads should be interpreted carefully, as the major concern of *E. coli* loading is during the recreation season. The recreation season loading from crop land is roughly 35% of the annual value, while pasture land contributes roughly 63% of its annual load during the recreation season. Livestock with stream access are modeled to only use the warmer waters of the recreation season, and the table values represent their entire contribution. Wildlife and failing HSTS have annual static representations, so half of the annual load contributes to the recreation season. The loadings from early spring that are still present in the water column and sediment bedload are another component of the complexity. Although, the high flows of May generally dampen the concentration of higher loads. Timing of deposition is also important to keep in mind while reviewing the scale of values. While pasture lands generate the highest recreation season loadings during storm events, it is the smaller in-stream loadings of livestock and HSTS that drive *E. coli* concentrations high during calmer flow periods.

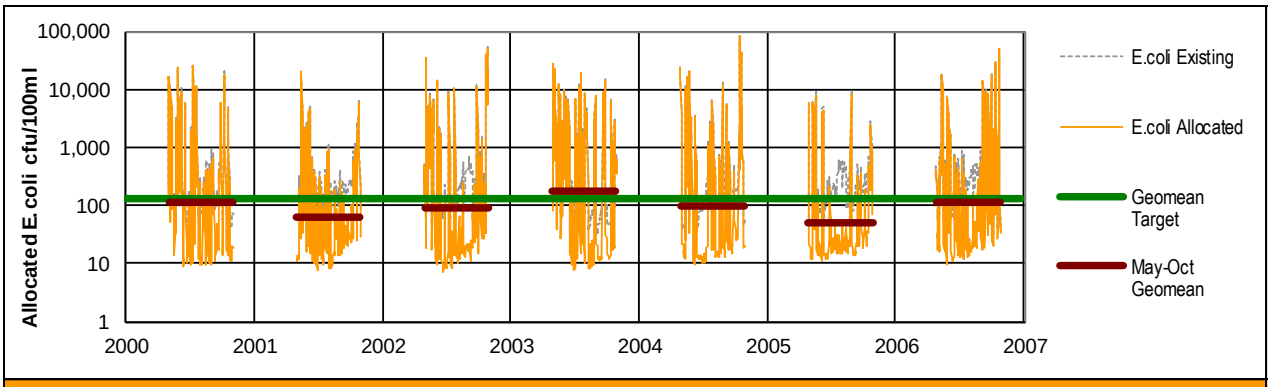
<u>The primary goal of the *E. coli* source reduction simulations is to meet the seasonal geometric mean annually under typical recreation season flow conditions.</u> As previously stated, the

collection of years demonstrate a range of annual climate variability, which ensures the consideration of low flow critical conditions and high flow overloadings to sensitive areas. In the case of *E. coli* assessment, the geometric mean calculation is a measure of a log normal distribution of concentrations. The statistical distribution represents the response to both continuous low flow loadings and periodic storm flow events with higher loadings. Each year's existing and load reduced daily concentrations are plotted as a time series, and each season's geometric mean is compared to the standard. An example simulation is depicted in Figure D3-30. A reference geometric mean of the combined seven recreation season's data also provided. The combined data provides a sense of the loading response of the 2000-'06 averaged hydrologic season.

The baseline model has the same settings as the existing model, with the exception of NPDES permitted point sources. The daily point source model flows are set to their respective average design flows, and the *E. coli* concentrations set to the receiving stream based average *E. coli* criteria. The point source representation incorporates the design incorporated future growth of each entity through increased baseline flow, and a conservative daily *E. coli* concentration set to the receiving stream's *E. coli* criteria. The Washington Court House and Greenfield daily *E. coli* baseline concentrations are an exception to this conservative option. Setting major discharger's limit to the water quality standard ensures downstream attainment, as could be demonstrated with a simple mass balance. However, the representation of a major discharger's effluent which contributes significantly to stream base flow distorts the assumed log-normal distribution of the daily recreations season concentrations. Since the low flow concentrations are biased high, it is not appropriate to reduce all other high flow sources down to the level to meet the lowest achievable geometric mean, which will remain inflated to near criteria concentration. From discharger self-monitoring reports, *E. coli* data between 2010 and 2011, Washington Court House and Greenfield have demonstrated the ability to meet 54 and 76 cfu/100ml median concentrations respectively. This more realistic representation is used to assist in simulating attainment of the recreation season standard. However, both facilities receive waste load allocations based on attaining a permitted 126 cfu/100ml average in the final loading simulation.

Table D3-22. Annual non-point *E. coli* loads from various diffused sources by model subwatershed and HUC-12

Annual non-point source load averages (washoff or direct) - billion cfu/year									
HUC-12	Sub-watershed	Area sqmi	Crop	Pasture	Developed	Wooded	Near/in-stream livestock	Near/in-stream Wildlife	Failing HSTS
050600030201 Sugar Creek headwaters	SWS-13	9.7	735,596	82,751	107	919	0.0	1.5	271.1
	SWS-12	12.5	935,635	112,282	178	1,410	0.0	1.6	664.1
	SWS-11	6.8	422,087	67,480	904	1,624	991.2	198.9	364.7
	SWS-10	15.2	339,192	256,467	555	3,454	2,643.1	112.1	1,416.3
	Total	44.2	2,432,510	518,980	1,745	7,406	3,634.3	314.0	2,716.1
050600030202 Lower Sugar Creek	SWS-9	14.8	340,548	44,223	317	3,861	225.5	10.6	1,581.0
	SWS-8	16.5	322,400	45,095	623	6,166	0.0	99.7	5,389.3
	SWS-7	6.0	117,924	0	120	3,541	0.0	160.1	1,281.9
	Total	37.3	780,872	89,318	1,060	13,568	225.5	270.3	8,252.2
050600030101 Paint Creek headwaters	SWS-23	20.6	1,533,750	121,437	358	2,180	0.0	1.7	594.0
	SWS-22	9.8	680,540	915,634	132	811	6,938.2	8.8	246.7
	SWS-21	10.1	645,732	1,062,150	242	4,032	5,716.5	14.5	1,306.9
	Total	40.5	2,860,022	2,099,221	732	7,023	12,654.7	25.0	2,147.6
050600030102 East Fork Paint Creek	SWS-27	14.1	1,025,770	95,017	522	1,164	1,982.3	55.8	1,855.1
	SWS-26	14.7	1,050,580	303,110	372	1,378	0.0	1.6	718.6
	SWS-25	4.3	291,310	283,878	167	368	0.0	21.3	737.9
	SWS-24	18.9	406,075	717,754	892	3,186	3,745.8	2.1	1,216.9
	Total	51.9	2,773,735	1,399,759	1,954	6,097	5,728.2	80.7	4,528.4
050600030103 Washington Paint Creek	SWS-20	11.1	729,197	995,406	337	2,773	5,306.0	71.4	564.3
	SWS-19	7.7	159,483	641,820	365	2,806	3,171.1	24.6	4,174.8
	SWS-18	2.5	46,844	0	289	2,094	0.0	24.6	364.0
	SWS-17	5.0	60,690	4,803	2,372	1,039	0.0	49.2	556.0
	SWS-16	0.8	6,385	0	546	170	0.0	1.3	76.0
	Total	27.2	1,002,599	1,642,029	3,909	8,883	8,477.1	171.2	5,735.2
050600030601 Miami Trace Paint Creek	SWS-15	6.4	92,820	82,684	1,614	1,780	0.0	160.1	1,281.9
	SWS-14	8.6	169,805	295,534	232	2,921	0.0	2.2	719.2
	SWS-6	9.2	723,499	135,831	260	2,467	3,729.9	6.2	920.0
	SWS-5	12.8	989,598	431,903	249	5,352	0.0	12.8	4,303.6
	SWS-4	11.1	689,442	1,107,330	304	6,438	0.0	2.2	869.1
	Total	48.1	2,665,164	2,053,282	2,659	18,959	3,729.9	183.4	8,093.8
050600030602 Greenfield Paint Creek	SWS-3	13.8	780,240	1,218,510	1,199	8,583	10,559.6	4.7	1,554.2
	SWS-2	11.2	600,438	1,219,060	544	9,256	0.0	9.3	1,276.4
	SWS-1	4.1	54,779	746,640	38	10,067	0.0	153.8	324.1
	Total	29.1	1,435,457	3,184,210	1,781	27,906	10,559.6	167.8	3,154.7



Sub-watershed E.coli results - Summer geometric mean concentration target < 126 cfu/100ml								
Year	2000	2001	2002	2003	2004	2005	2006	Combined
EC existing	258	207	318	344	260	271	305	277
EC allocate	111	65	89	174	94	51	109	92

Figure D3.30. Recreation season *E. coli* simulation of Paint Creek at SR-753. *E. coli* existing and allocated geometric means are listed for each simulated year.

After primary reduction analysis, the 2003 recreation season daily simulation was found to be an exception to the geometric mean goal. The 2003 season happens to be unique in that flow levels never dropped below the middle of the normal transitional flow levels. The simulated *E. coli* geometric mean is not representative in spirit of the recreation standard over its diminished range of flows. The six field samples collected in 2003 are agreeable to the simulated value range. The sample geometric mean is 120 cfu/100ml, which includes one <10 cfu/100ml below detection value. The simulated data is further assessed through comparison to the model's seven year daily dataset. Before and after reductions to meet the target for the other years at all the sites, the *E. coli* loadings of 2003 were mapped using load duration analysis (Figure D3-31) and found to have high flow *E. coli* loadings similar to the other six years. The load duration assessment will be further discussed in the *E. coli* load duration curve TMDL section, which is used to develop TMDLs for the remainder of the basin. The exclusion of the 2003 simulation as a geometric mean target does not imply that atypical years with excessive *E. coli* sample concentrations should be disregarded. A period of high flows with long duration could lead to failures in wastewater collection systems, manure retention systems, or other facilities under designed for high hydraulic loadings. Poorly designed and/or aging failure prone sources are not permitted and have an implicit zero TMDL allocation.

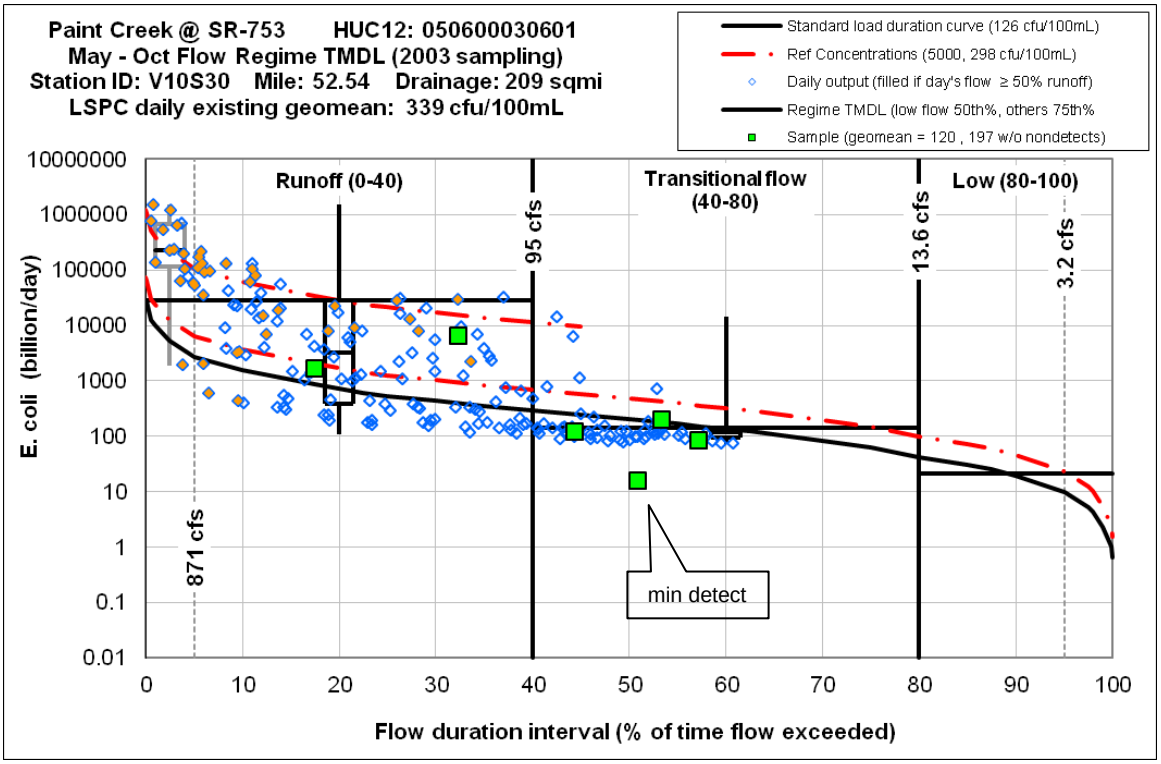
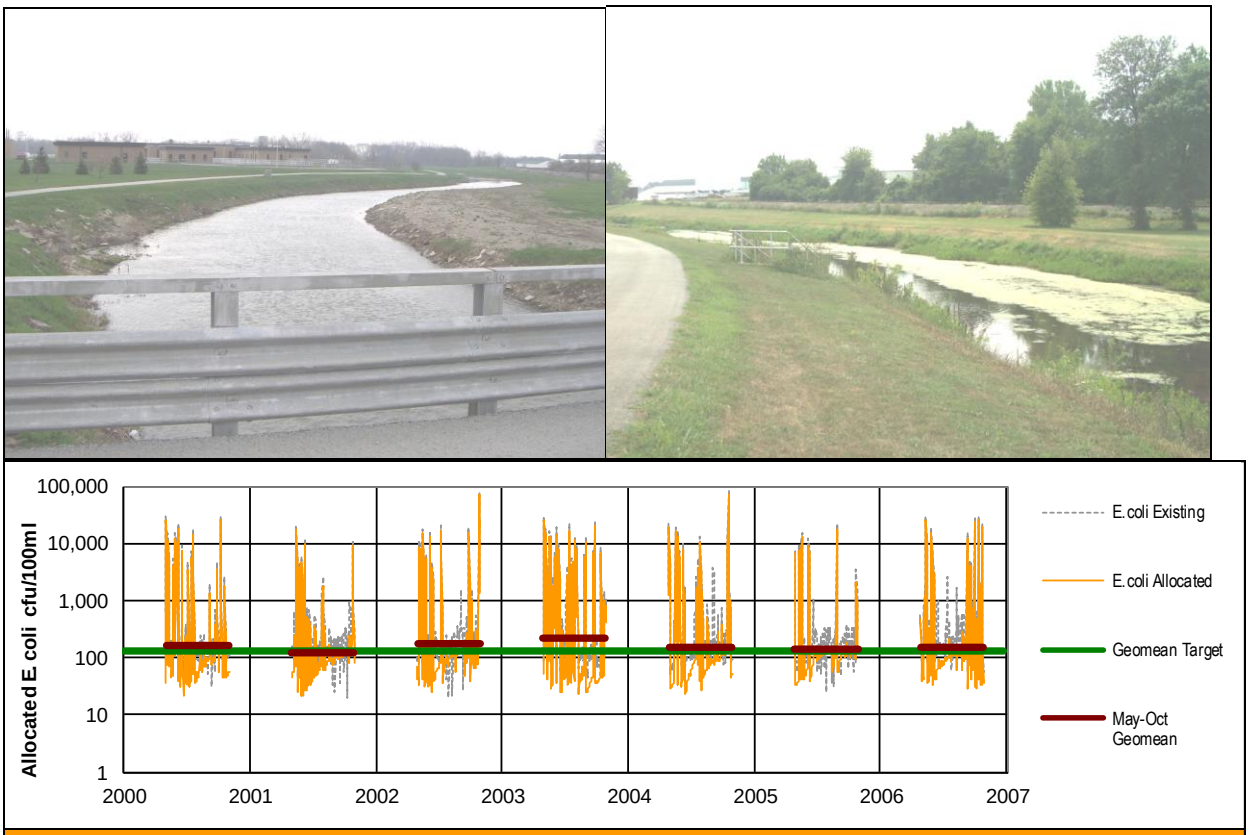


Figure D3-31. 2003 *E. coli* simulation and samples of Paint Creek upstream East Fork plotted within a load duration framework, depicting the abnormal skew toward high flow through the recreation season.

The Class-A Paint Creek reach between Washington Court House at Elm Street and East Fork Paint Creek is prone to high *E. coli* concentrations. The area is adjacent to Christman Memorial Park downstream of Elm Street and shares a maintained creek-side walking path. Two issues involving Washington Court House's treatment system have varying impacts in this area of frequent public use. A sanitary sewer main that is located under Paint Creek within the park boundary has infiltration issues. The infiltration causes treatment issues at the wastewater plant, which produces variable effluent results. Although the Washington Court House site has demonstrated low *E. coli* concentrations in recent years, several spikes of fecal coliform in the effluent occurred in the past due to the variable treatment performance. A sanitary sewer overflow bypasses to the wastewater plant's outfall, discharging raw sewage when storm waters enter the sanitary system. Neither of these issues is explicitly modeled, with the expectation that both infrastructure problems will be corrected. The middle section of Figure D3-32 is a simulation of the Washington Court House site set at 126 cfu/100ml, with all but the 2001 recreation season geometric means exceeding the standard. As previously stated, the static concentration source representation significantly contributes to the inflated geometric mean, but the low flow concentration average meets the standard due to mass balance mixing. However, since this reach has high potential for recreation and a strong chance for the presence of pathogens, an alternative solution to further load reduction is proposed. Relocation of the outfall to downstream of East Fork Paint Creek by construction of a 1800' sewer line will reduce the chances of pathogen contact near the park, as well as provide more initial dilution for the effluent.



Sub-watershed E.coli results - Summer geometric mean concentration target < 126 cfu/100ml								
Year	2000	2001	2002	2003	2004	2005	2006	Combined
EC existing	289	205	307	409	288	238	294	284
EC allocate	162	125	176	213	153	145	152	159

Figure D3-32. Paint Creek downstream of Elm Street with the Christman Park walking trail continuing streamside. The Washington Court House WWTP effluent discharge is adjacent to the WWTP facility (top left), and shown adjacent to the walking trail (top right). The *E. coli* simulation (bottom) presents existing and allocated loads generating seasonal geometric mean concentrations above the standard.

Washington Court House's incorporated limits are regulated by the NPDES MS4 permit 4GQ00027. Since the urban storm water load is a diffuse source as well as a permitted source, the load needs to be calculated as an entity separate from other developed or rural land loads. Washington Court House gained the MS4 status after the initial model was set up, so the MS4 land was not modeled as a unique land use. However, MS4 loads can be derived from subwatersheds 16, 17, and 18 (Paint Creek near the Washington Court House upland reservoirs, downstream to East Fork Paint Creek) developed lands which are mostly incorporated. 3.4 sqmi of the total incorporated 6.6 sqmi of Washington Court House are located within these model subwatersheds. Some additional developed lands adjacent to Washington Court House are within these boundaries, which are modeled as part of the MS4 to implicitly represent future incorporated expansion.

In order to quantify the individual MS4 daily loads, all other sources were shut off in the model. The resulting output is a quantification of several storm water generated load events. The remaining MS4 area draining to East Fork Paint Creek (1.3 sqmi) and below its confluence with Paint Creek (1.9 sqmi) cannot be analyzed in the same way. Both model subwatersheds 24

and 25 that contain Washington Court House's incorporated area respectively have a larger percentage of unincorporated urban land. The MS4 loads of these other two locations are calculated indirectly as a percentage of the total incorporated area multiplied by a percentage load derived from the simulated area upstream of East Fork. The generated washoff to the stream from the MS4 region is used to assist in reductions to meet the recreation season target, and for TMDL related permit development.

E. coli LSPC TMDL allocations, including margin of safety and allowance for future growth

LSPC analysis is used to simulate calibrated *E. coli* loadings with respect to the recreation season flow regime. The calibrated model is used to quantify necessary source load reductions to meet single season geometric mean criteria. Once criteria are met with the allocated model, simulated loadings are used to develop the TMDL.

LSPC's general point source and land based reduction controls can be used to control the simulated waterbody concentrations. The reduction controls work on the premise of removing a percentage of daily stream input loads, based on the simulated total available load. This applies to land based sources which have loading characteristics that vary monthly, as well as point sources that have a static baseline representation. In order to efficiently manage the production of various allocation simulations, land based and non-point direct sources are reduced by the same percentage for all subwatershed zones within a HUC-12. While this simplified approach is the basis for assigning HUC-12 reductions for load allocations, it may lead to future planning oversight since subwatershed zones contribute at different pollutant levels. Most notable is the case of HSTS, where more dense areas of failing systems are likely better targets for producing significant stream improvement. Watershed planners should refer to the existing annual loadings of the 27 subwatersheds to build efficiency in water quality projects.

Once *E. coli* concentration requirements are met for all 27 subwatershed zones, TMDLs can be derived on the HUC-12 level. The TMDLs, its sub-components, and a median export target are derived as follows:

<u>Total Maximum Daily Load (TMDL)</u>
<u>The *E. coli* TMDL is calculated as the 90th percentile of all recreation season allocated daily loads entering the stream from the simulated 2000-2006 period.</u> The TMDL serves as a benchmark for assessing improvement, where the 90th percentile of all future source load measurements are to be found acceptable. The TMDL is provided for both local HUC-12 specific and cumulative with upstream HUC-12 TMDLs. The 90th percentile TMDL is simply added to the downstream TMDL for quantity tracking. The formula "TMDL = MOS + AFG + ΣWLA + LA" defines the subcomponent quantities of the TMDL. The subcomponent targets are equally important to the overall TMDL, as the various listed load reductions and allocations control *E. coli* levels at a range of flow and load levels.

<u>Margin of Safety (MOS)</u>
Five percent of the TMDL is subtracted as an explicit margin of safety. This is incorporated into both local and cumulative TMDLs. The explicit margin of safety further ensures control of peak loadings which impact the *E. coli* seasonal geometric mean concentration. An implicit margin of safety is also incorporated into the model representation. The use of design flows and static daily maximum loads from direct sources (point and non-point) ensures that critical recreation periods of high use are assessed under the worst case loading condition. The static daily load of direct non-point sources represents an upper limit with respect to seasonal variation, which also incorporates an implicit safety factor. This compensates for alternating pasture usage and/or

changing HSTS impacts not reflected in the sample data. The use of a high level model with satisfactory calibration is in itself an implicit margin safety, by providing sufficient accuracy for management decisions.

Allowance for Future Growth (AFG)

Growth trends in the region's counties are -3 to 1% (ODD, 2003). Although significant development is not expected in the upper Paint Creek basin, a reserve for future growth is applied. The AFG is intended to account for new sources that would impact the low flow regime. The system is able to assimilate direct sources that discharge at 126cfu/100ml due to mass balance mixing. However, additional pollutant carrying flow sources are limited to safeguard against excessive pathogen and nutrient loading at sensitive low flows. The amount of additional flow is calculated as 10% of the stream's flow exceeded 90% of the time. The flow increase is multiplied by 126 cfu/100ml and a conversion factor to calculate the reserve load for future growth. This method allows for an accumulated 0.92 MGD effluent flow held at the *E. coli* limit for Paint creek upstream Paint Creek Lake. New sources that can discharge below the *E. coli* limit can be approved for more flow, as long as proper review indicates the TMDL requirements are met. Therefore, industrial sources that do not treat sanitary waste are not theoretically restricted by the *E. coli* TMDL. It should be noted that the municipal operations within the upper Paint Creek basin already have implicit reserve of future growth built into their current NPDES permits. These entities can also draw from the general reserve if necessary for further expansion. Each HUC-12 TMDL has a local reserve for future growth. Downstream HUC-12 TMDLs get the flow based reserve minus the reserve held by the upstream HUC-12(s). The total AFG is tracked with the cumulative TMDL. The total AFG of upper Paint Creek can be managed to allocate more where needed, but the AFG taken from other areas further limits their capacity to discharge increased *E. coli* loads.

Waste Load Allocation (WLA)

NPDES permitted sources receive a daily WLA. Each *E. coli* WLA is based on the appropriate *E. coli* concentration limit multiplied by the facility average design flow and a conversion factor. The exception is the Washington Court House MS4 WLA, with the incorporated limits involving three different HUC-12s. The MS4 permitted WLA is based on the 75th percentile of the storm water events' *E. coli* loads. The quantification of the storm flow loads are as described earlier. Each HUC-12 TMDL incorporates the sum of the local WLAs. Each point source's individual WLAs are listed in its associated HUC-12 TMDL table, which also includes the facilities existing average flow, average design flow, and average *E. coli* concentration limit. The cumulative TMDLs also incorporate the local HUC-12 WLAs, as well as the upstream WLAs. The individual WLAs are not relisted, but are referenced as an upstream allocated total if there are any.

Load Allocation (LA)

Non-point diffused sources receive a portion of the TMDL as a LA. The LA is the remaining portion of the TMDL after subtracting the MOS, AFG, and WLAs. Existing annual loads are provided in Table D3-22 and are discussed earlier in the report. The TMDL tables provide percent load reductions necessary to meet recreation season requirements. The percent reductions are applied to crop land, pasture land, developed land, forest land, near stream feedlots and/or livestock with stream access, stream accessing wildlife, and failing HSTS.

90th percentile and median Export May-October

While not part of the TMDL equation, the 90th percentile and median *E. coli* stream outlet load is provided as a tool for future sample assessments. Unlike the TMDL which is derived from input loads, the export load targets are based on the in-stream load that has undergone the effects of transport and decay. With regard to nested HUC-12 watersheds, the values are inherently

cumulative as the loads leaving system are impacted by the entire upstream system. These additional benchmark loads can be compared to future samples at the mouth of the HUC-12s.

Total phosphorus LSPC modeling background

Upper Paint Creek's 2006 biology assessment demonstrated the most concentrated aquatic impairments compared to the rest of the basin. The major cause of impairment was listed as nutrient cycle eutrophication, dissolved oxygen and/or both for various stream sites. As is typical for many low gradient agriculture area streams without point sources, observable water column phosphorus concentrations are well below healthy stream targets during the stable flows of summer. However, the conventional sampling does not measure the true load in a stream reach since much of the phosphorus driving eutrophication resides within the substrate or algae storage. With respect to eutrophication, periods of minimum dissolved oxygen are the primary stressor to the aquatic community. Since simply demonstrating that the water column samples of phosphorus is below target at low flows will not lead to remediating the stream system, a more detailed approach is warranted. Eutrophication can be controlled by limiting essential needs of algae. Phosphorus in the water and substrate is the limiting nutrient in freshwater systems, and can be controlled through source input reductions. Light intensity is another essential limiting factor in algae production, which habitat improvement can result positively in eutrophic control. Restoration of the stream habitat also helps to diminish the stream's nutrient input through capture and uptake.

Washington Court House's urban portion of Paint Creek exhibits aquatic and recreational issues related to flashy runoff, altered channel flow paths, sewer conveyance issues, and wastewater plant operations. Washington Court House and Ohio EPA are in communication on correcting stream infiltration and SSO issues near the wastewater plant. The sanitary sewer conveyance issues affect the dilution / overflow of the incoming waste, as well as the level of treatment the plant is capable of performing during variable weather and hydrologic conditions. The effluent is released into Paint Creek within the Elm Street city park area, along a paved walking trail. Upstream of the SSO region, Washington Court House draws drinking water from Paint Creek at Eyeman Park, and to a lesser extent from ground water. The water is pumped periodically to two linked upland reservoirs, and then pumped to the water treatment plant. Since the Eyeman Park area's water is protected for drinking water withdrawal, Paint Creek benefits as demonstrated by meeting aquatic criteria around the WTP dam. The remainder of Paint Creek within Washington Court House is impacted from wastewater strength, illicit discharges, urban and agricultural runoff, channelization, and the stream's low assimilative capacity due in part to a lack of riparian coverage.

Bloomingburg and Jeffersonville are two small cities with some commercial development. They are located along stretches of East Fork Paint Creek and Sugar Creek respectively, which are maintained for agricultural drainage through channelization practices. Both wastewater plants have undergone system upgrades since the 2006 survey, which are completed as of 2010. Also of note, ASA Ethanol was built just below Bloomingburg, which is designed for a significant non-contact process flow discharge capacity. The plant became operational in 2008 with infrequent processing, and is now consistently operating in 2011.

The city of Greenfield has also undergone wastewater plant improvements since the 2006 survey. The periodic organic and ammonia loading to Paint Creek has since been resolved. The city's current effluent limits are protective for Paint Creek's aquatic and recreation criteria.

The majority of the region's fertile soils are occupied by row crop agriculture. Field conservation methods are used in various areas, such as no-till practices, grass lined swales, and buffer

strips. Several stream reaches are channelized for field drainage, with variable levels of active maintenance and natural channel recovery. According to USDA NASS crop statistics, almost 200,000 acres of Fayette County's 260,500 acres of land area are in crop production (USDA, 2008). Current agricultural practices use some rotational crop practices with about half of the land in corn and the rest in soybeans.

Since the 1970's, farm lands have tended to become consolidated from 1200 to less than 500 owners in 2008. Much of the current agricultural practices now are on a large scale designed for crop efficiency. Livestock farming has diminished in the region, with remaining pastures tending to be reserved to marginal lands near streams. The livestock trend may have some small reversal if market forces make livestock production more profitable over crop, but the majority of area will likely stay in crop production.

With the changes to larger scale farming, field conservation practices, and declining livestock farming the effects can be measured in a decrease of suspended solids from typical growing season storm washoff. Water chemistry samples have been collected from an Ohio EPA ambient site in Paint Creek at the SR-753 crossing north of Greenfield for years. This data has been populated into a load duration curve (Figure D3-33) and broken down between 1976 to 1998 shown in light blue diamonds, and data after 1998 shown in dark blue diamonds. The effect of sediment erosion conservation practices may be confirmed by the data at mid to low flows, where the majority of samples collected after 1998 are below the Ohio EPA 5 mg/L total suspended solids detectable analysis limit. The same flow zone was impacted before 1998 by periodic unconsolidated sediment loads from washoff due to a higher percentage of tilled fields and unbuffered near-stream field sources.

The effect of conservation practices on phosphorus (Figure D3-34) and nitrogen (Figure D3-35) and levels at mid to low flows is less apparent in the SR-753 ambient data due to the high nutrient loadings from the Washington Court House WWTP. At higher flows, the data appears to indicate that phosphorus loading has decreased some likely due to sediment bound phosphorus reduction, and nitrate levels have increased some. It should be noted that the ambient data is taken as random instantaneous samples spaced apart monthly or quarterly, and may not be representative of the averaged day's nutrient load, especially involving storm flow dynamics.

Algae sampling was conducted at the SR-753 site on 9/3/2008, resulting in 1.8 ug/L water column chlorophyll-a and 161 mg/m^2 benthic chlorophyll-a. Another site was sampled downstream below the Greenfield WWTP, resulting in 0.8 ug/L water column chlorophyll-a and 313 mg/m^2 benthic chlorophyll-a. The benthic algae results are high (Miltner, 2010), but a healthy riparian corridor and natural moderate gradient enable Paint Creek to have enough assimilative capacity to maintain exceptional water habitat aquatic criteria around much of this area. Unfortunately, less data is available for the upper part of this stream system where there are documented aquatic life problems.

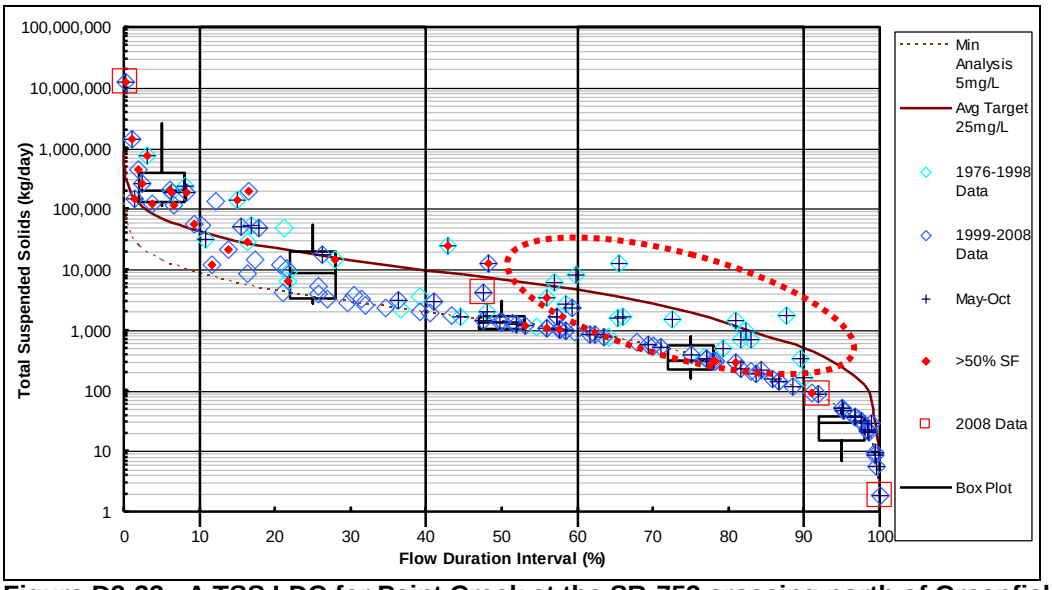


Figure D3-33. A TSS LDC for Paint Creek at the SR-753 crossing north of Greenfield.

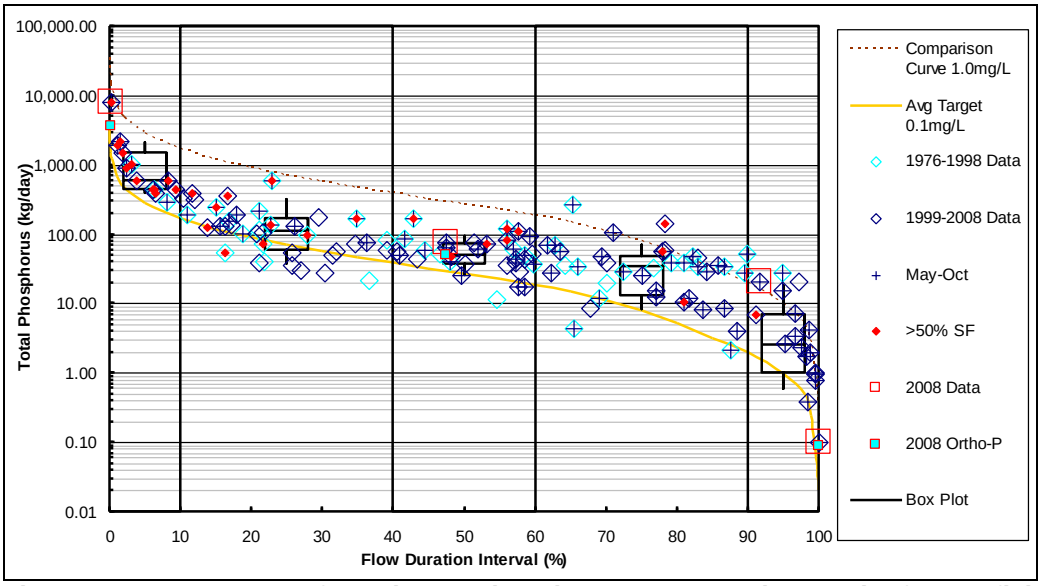


Figure D3-34. A TP LDC for Paint Creek at the SR-753 crossing north of Greenfield.

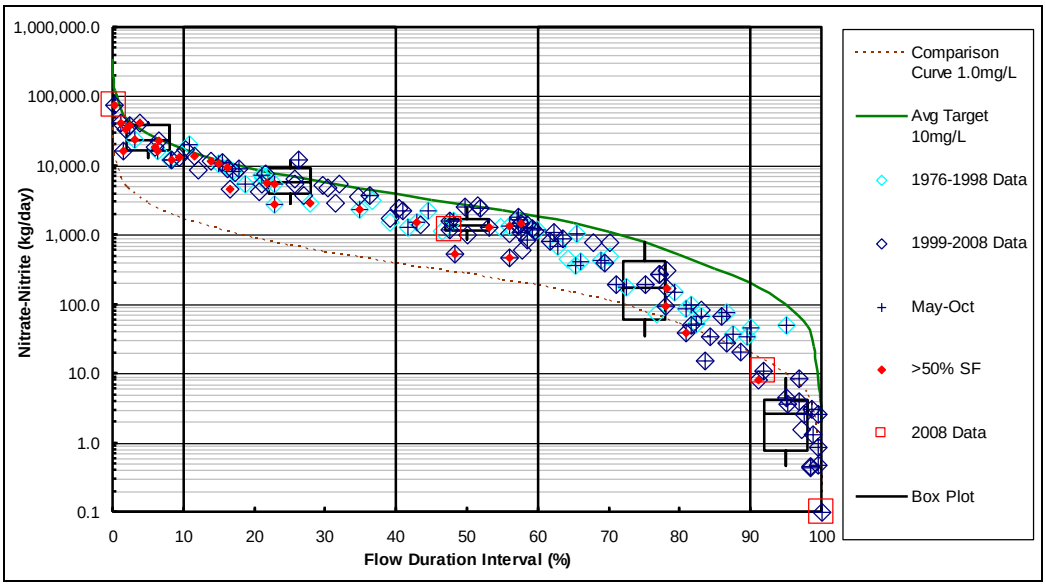


Figure D3-35. A Nitrate-nitrite LDC for Paint Creek at the SR-753 crossing north of Greenfield.

LSPC was selected for Upper Paint Creek analysis for two key reasons. The first is to assess the balance of effects between TP loadings and stream corridor structure in the control of eutrophic conditions. While total phosphorus concentrations are below guidance criteria in the water column during most of the low flow summer, there is considerable phosphorus bound to the substrate and within benthic algae. This condition is apparent in the agricultural areas, as well as within the urban setting of Washington Court House. Instead of deriving a target for the total resident load of TP within the channel corridor, a minimum DO criterion is used as the final measure of eutrophic condition control. The second key reason for using LSPC is to weigh the effects of Greenfield WWTP's effluent on the downstream impairment zone (listed as organic enrichment) in combination with the high phosphorus loading provided by Washington Court House and the upland loading contributions during rainfall events. Another aspect of the Greenfield area analysis is to understand why this EWH designated Paint Creek reach is mostly achieving full attainment despite being under a high phosphorus loading.

Critical Condition

Upper Paint Creek's waters are most sensitive to eutrophic nutrient levels during low flow summer conditions. This has been indicated with the findings of high benthic algae concentrations measured in 2008, and low dissolved oxygen measured in 2006. Meeting chemical and biological conditions under critical conditions is assured in three steps in this report. First, TP is analyzed to find the appropriate loading control level through meeting the association derived target. This section uses this control to assign TP TMDLs. Second the simulation assures that ammonia nitrogen (NH_3-N) water quality standards are met in all reaches. Since the model does not simulate pH, field pH data in combination with temperature simulation is used to derive the appropriate NH_3-N criteria. The simulation indicates that NH_3-N concentrations are acceptable with the condition that the TP TMDLs are met and all NPDES regulated sources meet their permitted NH_3-N limits. Third, the minimum DO criterion is used to determine if the corridor has enough assimilative capacity. A moving 30 day average of simulated daily minimum DO concentrations is used to indicate achievement of the criteria. Using a moving 30 day average safeguards against model anomalies (insufficient depth for algal growth, weather file discrepancies, etc.) and is generally comparable to the 10th percentile of grouped summer minimum DO concentrations. A review of the simulated concentrations achieved after the TP TMDL is met indicates that DO is still below criteria in some of the

channelized low gradient reaches. Instead of further reducing TP loads below the association based target, increase in DO concentrations are simulated through improving the stream corridor. The channel improvement is based on the findings of the QHEI submetrics. The reach definitions are adjusted to improve lacking natural stream components, specifically riparian shade and typical riffle/run dynamics. Updating reach shade level is straight forward in the model. Improved channel flow is represented by altering the cross sections that are initially set to behave as flood plain disconnected agricultural ditches. The reach definitions are changed to regional values based on drainage area. As stream corridor functioning has a strong effect on eutrophic conditions, the QHEI submetrics are indeed a critical condition and must be addressed. The Habitat/Bedload TMDL section provides the improved minimum DO simulations for the impaired reaches of this section. Note that the targets of the Habitat/Bedload TMDLs are the driving force for biologic improvement, and the simulated DO effects are intended to demonstrate the strength of a healthy stream corridor.

Seasonality and Total Phosphorus Concentration Target

The LSPC analysis simulates daily TP and other associated constituents daily from January 2000 through December 2006. This assessment captures a wide range of seasonal conditions, as each model year had characteristic hydrologic conditions. In particular, the analysis revealed the highest average concentrations (and load) occur during the spring. This higher seasonal load acts to seed the local and far-field substrate and water column of reaches with sufficient TP and TN to drive algal productivity into the summer. Impounded areas are susceptible to eutrophic problems much earlier than free flowing streams due to increased retention capacity. Large storms during summer act to both scour productive substrates as well as refuel nutrient levels for local and downstream growth. Fall and winter conditions tend to produce less average nutrient loadings, but can produce large acute loads in response to large storms and suitable soil conditions. As previously discussed the average 0.1 mg/L TP concentration is linked strongly to biological success. In order to protect base flow conditions through the year, the average concentration target is imposed on four seasonal periods. The winter group is defined as January – March, spring as April – June, summer as July – September, and fall as October – December. The higher average concentration of spring is a main driver of addressing nutrient loading seasonality and transport control. Summer also has a unique seasonality issue in that WWTP effluent concentrations contribute a much larger percentage of the low flow condition.

Total phosphorus calibration

The RQUAL stream model is an HSPF module that specializes in eutrophic processing. The total nitrogen (TN), TP, and BOD loads of groundwater, interflow, and surface runoff of crop, pasture, urban and forest land uses are subdivided into specific chemical species. GQUAL BOD is translated to BOD5. Total Nitrogen is translated into NO_{3+2}, NH_3-N, sediment related particulate NH_3-N, and organic reactive nitrogen. Total Phosphorus is translated into PO_4, sediment related particulate PO_4, and organic reactive phosphate. Model point sources are directly set to release the appropriate RQUAL parameters. RQUAL also supplements the land based process model by addition of monthly DO contributions within interflow and groundwater. The interaction of components and range of values capable of representing processes is complex. The reader is referred to the HSPF and LSPC manuals, and the US EPA, 1985. Both documents are heavily relied upon for calibration. The following is a brief description of the processes in RQUAL used in the upper Paint Creek eutrophication model.

BOD fate is modeled through a temperature controlled decay rate, and by settling of organic matter. Oxygen demand of organics in the substrate (SOD) is also represented through similar equations in addition to release rate controls based on water column DO concentration and

scouring. Physical DO reaeration is controlled with stream depth and velocity equations similar to Streeter-Phelps equations or by wind influence equations for impounded reaches.

Nitrification is controlled through transfer rate equations for conversion from NH_3-N to NO_2 and finally to NO_3, all of which are dependent on temperature. Denitrification is also represented with a transfer rate equation from NO_3 to N, which is dependent on a low DO threshold and temperature. Particulate NH_3-N and PO_4 bound to substrate sediment can be released to the water column through benthal release rate equations, which relies on a user defined constant bed concentration adsorbed to sand, silt, and clay sediment partitions. Adsorption coefficients are used to control the transfer of NH_3-N and PO_4 to or from the suspended sediment partition groups.

Algae are modeled as a single composite species, which aids to streamlining the calibration process. However, it should be noted that the many species have different needs and behaviors which change over the growing season. Dominant species grow in significant masses as the appropriate seasonal conditions are reached. A system that can be modeled as a simplified one dimensional system minimizes the need to address the species variation, and therefore a single representation is suitable for this study. The algae module contains further controls for DO, nitrogen, and phosphorus for conversions to milligrams of biomass. Algae cell makeup is controlled by a user defined percentage of carbon and by the biomass conversion formulas. A cell's chlorophyll-a to phosphorus ratio is user defined, as it may vary widely with different species of algae. The cell is made up of refractory and labile percentages, which are used to release appropriate nutrient speciation to the water column. Algae concentrations are primarily controlled by a maximum unit growth rate, which can be achieve if all environmental conditions are optimum. Physical processes controlling growth include light base extinction based on water depth, the concentration of suspended sediment that contributes to light reduction, and algae self-shading that also reduce light due to overgrowth. Nutrient uptake by algae is controlled by Michaelis-Menten equations, which considers three nitrogen-phosphorus conditions and uses the most restrictive nutrient condition for available growth. Algal growth is sensitive to temperature, and thresholds are set to halt growth at maximum and minimum temperatures. An optimum temperature between the two extremes is used to extrapolate the level of contribution to growth. Algae effects decline in DO concentrations through respiration and death. The unit respiration and death rates are selected to best represent the overall effect of the multiple species. The death rate is able to increase when anaerobic conditions exist. The increased death rate is also triggered by excessive concentrations of algae which make light and nutrient capture difficult. Algal loss is also controlled through physical processes. The nature of a channels riparian shade has strong effect on growth levels. Each reach group is set to represent the typical amount of shade a reach receives. Algae transport is different from the primary LSPC constituent transport model. Algal growth and retention is expected to occur along the side channel zones of the stream, which produces longer retention times. The retention and transport is controlled through the definition of algae concentrations that will stay in a reach for both very high and lows, which are used in a flow scour equation.

Paint Creek at SR-753 is the main calibration site, as it is located at a USGS gage and possesses monthly/quarterly long term Ohio EPA sample data. The fairly strong hydrology calibration was discussed earlier. This section provides another view of the representation of hydrology. The simulated and gage records are compared on the sample days. The absolute and relative errors of daily flow are shown in Table D3-17 above. This information is provided to supplement the sediment and nutrient calibration issues, which may contain error anomalies due to the weather file representation. Therefore a high relative error in flow may produce conditions where nutrient concentrations are simulating short term conditions not confirmed by

the USGS gage. Relative and absolute errors are provided in four categories: the total record, low flows below 80% annual flow exceedance, high flow above 20% annual flow exceedance, and for transitional flows between the two extremes. The breakdown is important to review the calibration in light of the importance of seasonal/critical conditions for each parameter. US EPA provides generally expected relative errors for eutrophic related parameters as a guide for calibration. Erosion should be within 10-35%, sediment transport within 20-50%, nutrients within 50%, and dissolved oxygen within 15%. As mentioned in the *E. coli* section, relative area is only as useful as the representation of the field data set. Field data are collected as grab samples which may or may not represent the average of the day and/or the length of a reach. Scatter plots of model and field data are provided for each parameter as another line of evidence. The scatter plots generally indicate that the simulated concentrations are within range of what field data indicates. Once the model found an initial state of calibration for the SR-753 site, the model was validated with the East Fork, Sugar Creek, and Paint Creek Elm St sentinel sites. The model was then iteratively calibrated and validated until general agreement was found at all sites. Figures D3-36 through D3-39 shows the suspended solids, TP, nitrate-nitrite and ammonia calibration results.

The sediment model is described in the *E. coli* section, as both GQUAL and RQUAL stream modules depend on its output. The clay, silt, sand sediments are treated separately to control nutrient adsorption rates, and therefore TSS calibration is rather important. TSS is difficult to model for various reasons. The major problem with Upper Paint Creek sediment calibration is the Ohio EPA minimum detection limit of 5 mg/L. The detection limit makes model comparison impossible at low flow and during other seasonal conditions with low TSS. The silt and clay fractions are still significant at lower flows and interact with constituents via adsorption and light defraction. Sampling the true daily load of TSS at high flows is another challenge. Without the aid of automated sampling equipment it is difficult and resource prohibitive to collect peak load samples at the right time or frequency. Also, TSS is not necessarily well mixed during high flow transport, with larger particles traveling closer to the substrate. Field erosion modeling is also difficult in that classic methods simulate detachment, but do not consider losses from recapture in depressions. The model is calibrated to represent the sediment loads that reach the stream to compensate for this. Sediment transport is also complex, and relies on an understanding of soil types and channel characteristics. Between erosion and sediment transport, the calibration goal was to achieve a relative error below 75% for transitional flows. In general, TSS relative error performed best during transitional flows, likely due to better sample representation of the daily average. Sample data above minimum detection limits was lacking for low flows. High flow relative errors are higher, most likely due to missing the peak / average condition of the day through grab sampling. However, a comparison of all three ranges in a scatter plot demonstrates the simulated TSS is well within range of what is to be expected across the flow conditions and seasonal effects.

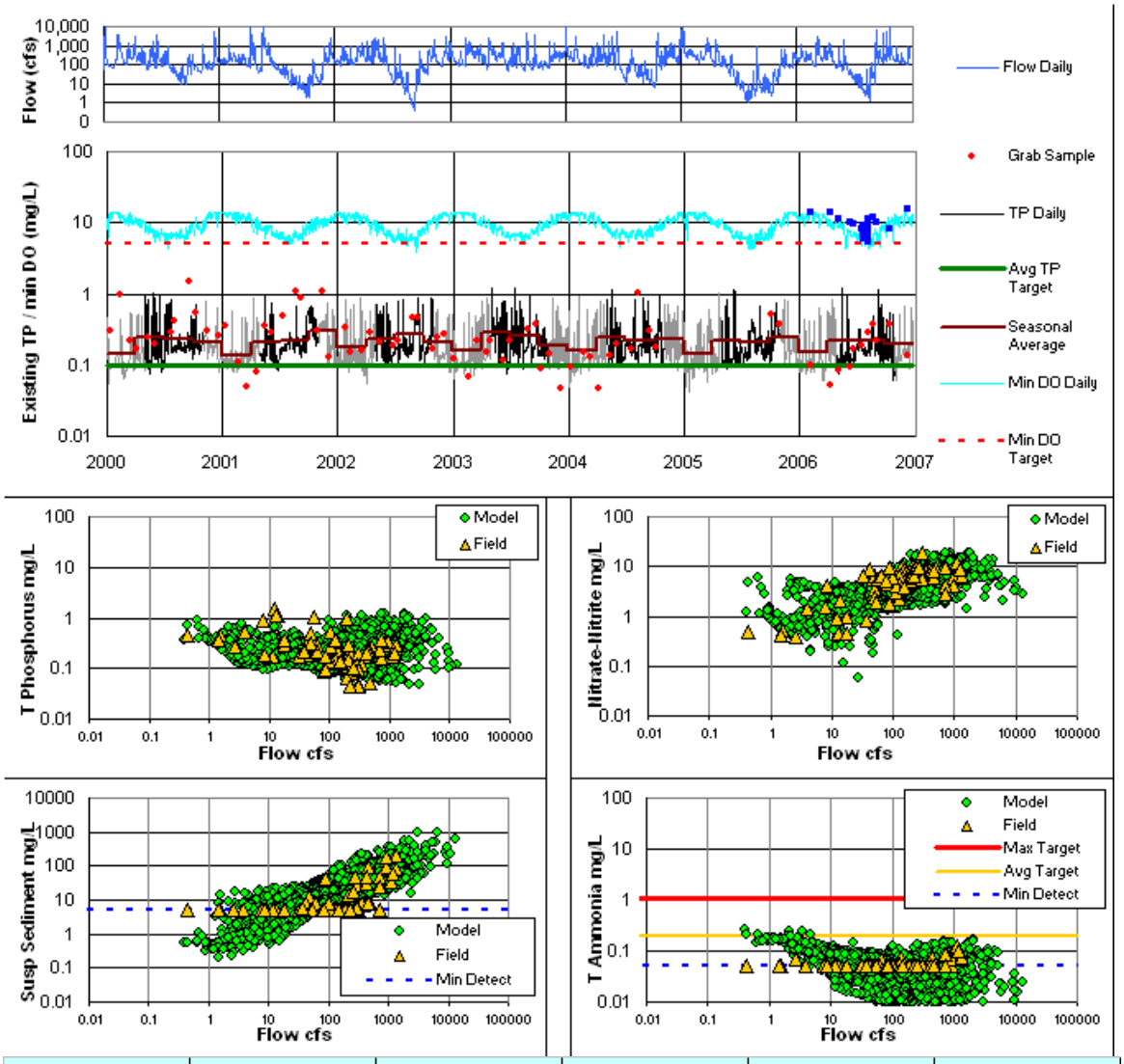
Total phosphorus results are representative of field data. TP transport is strongly related to TSS transport due to adsorption. Therefore, the TP model suffers the same field data representation problems as TSS at high flow. High flow TP was calibrated in consideration of the high flow event dataset of 6/2/08-6/4/08, which was sampled closer to peak concentration. The other high flow TP samples are likely less than the daily average due to sample timing. With regard to low and transitional flow modeling, the calibration was able to encompass a wide range of impacts. These include effluent loading, channel condition, and algal growth.

The nitrate-nitrite (NO_{3+2}) results were much more representative at high flow. NO_{3+2} does not bind to sediment and stays at high concentrations after a storm peak. Therefore, it is much easier to collect representative high flow grab samples. Transitional flow NO_{3+2} concentration

simulation also performed well, responding to seasonal tile drainage, effluent loadings, algal uptake and other processes. Low flow NO_{3+2} calibration was not as successful as TP, although not a significant issue. Some sites performed better than others, likely due to better representation of conditions suitable for denitrification. Side channel uptake by vegetation during tile drainage or local riparian washoff may be another reason for the elevated low flow concentration simulation, as this process is not built into the model. Regardless, TP is the limiting nutrient and the driver of algal productivity during low flow conditions. The overly protective calibration of NO_{3+2} levels can be considered an implicit margin of safety in that it assures proper representation of TP as limiting.

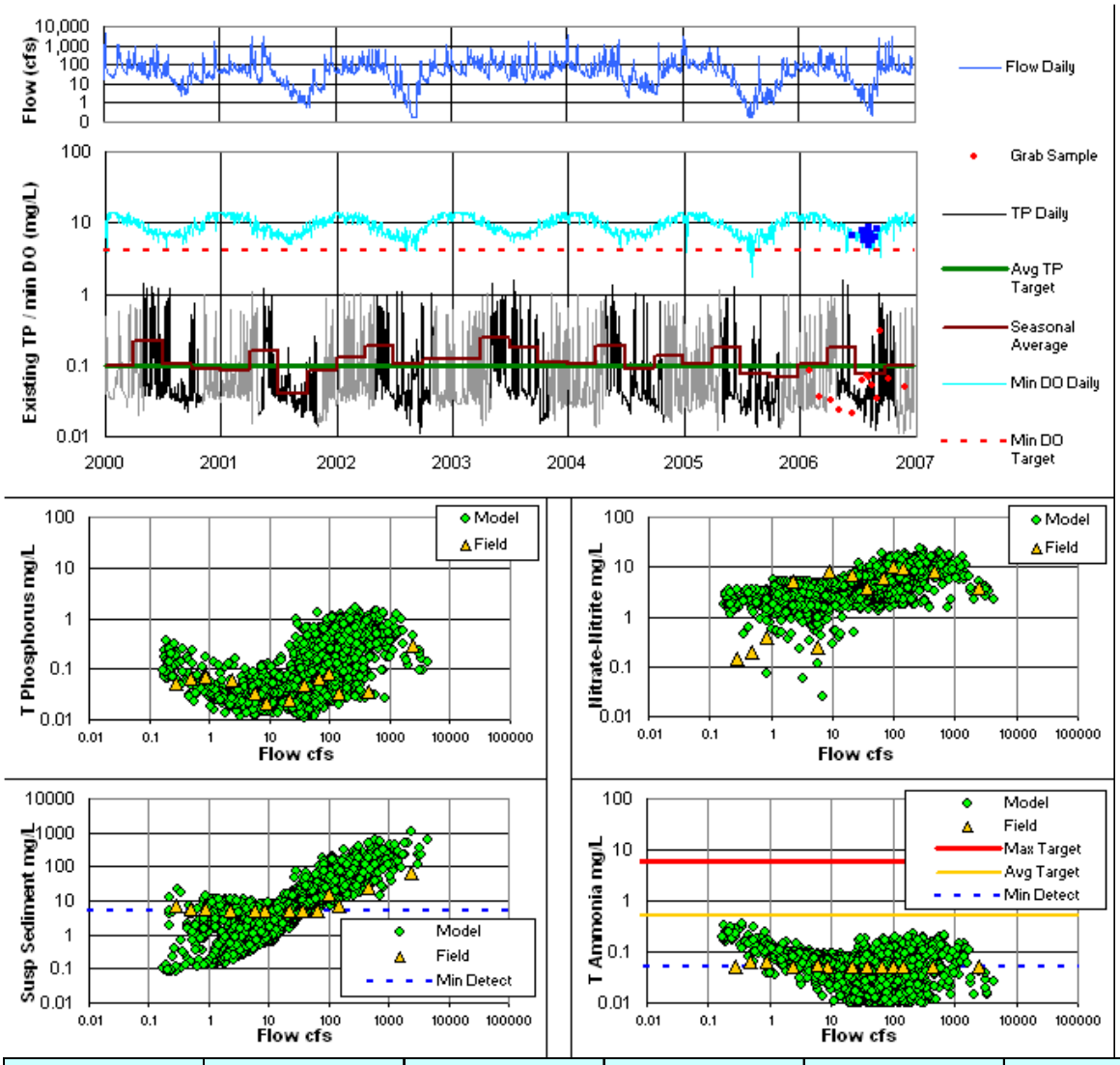
Ammonia nitrogen (NH_3-N) has a similar minimum detection limit issue as TSS. Ohio EPA NH_3-N samples are analyzed with a minimum detection limit of 0.05 mg/L. Due to significant improvement of WWTPs through the 80's and 90's, NH_3-N levels are typically below detection during stable flow conditions. With a restrictive field dataset, relative error analysis is a weaker metric of calibration. The scatter plots demonstrate that increases in simulated NH_3-N concentrations are validated by being within range of detectable NH_3-N field data. Elevated NH_3-N concentrations during low flow conditions are often caused by localized sources. The sources include improper treatment of WWTP effluent, household septic tanks, livestock feedlot drainage and direct deposition, and other nuisance sources. The NH_3-N simulation is successful in capturing noted field issues, demonstrating agricultural related source contributions and acute WWTP operational issues.

Dissolved oxygen calibration relied mainly on short term hourly readings at logger deployment sites. Equipment was deployed twice for 48 hour records in July and August 2006. The minimum values recorded by the equipment generally just before dawn is used to calibrate the minimum DO simulation. The calibration is well within relative error expectations for the four main sites, as well as a Paint Creek site upstream of Washington Court House at SR-41, and downstream of Washington Court House at Miami-Trace Rd. However, it should be noted that the field dataset is very small. The daily simulation also provides a maximum DO value, which can be used to verify the daily range. Field staff typically measure DO as a point measurement when taking grab samples. These measurements and data collected from the hourly loggers generally agree in range the simulated early morning minimum and afternoon maximum DO concentrations. All hourly DO data and DO point measurements are included in the figures to demonstrate that field data is at or above the depicted daily minimum DO simulation.



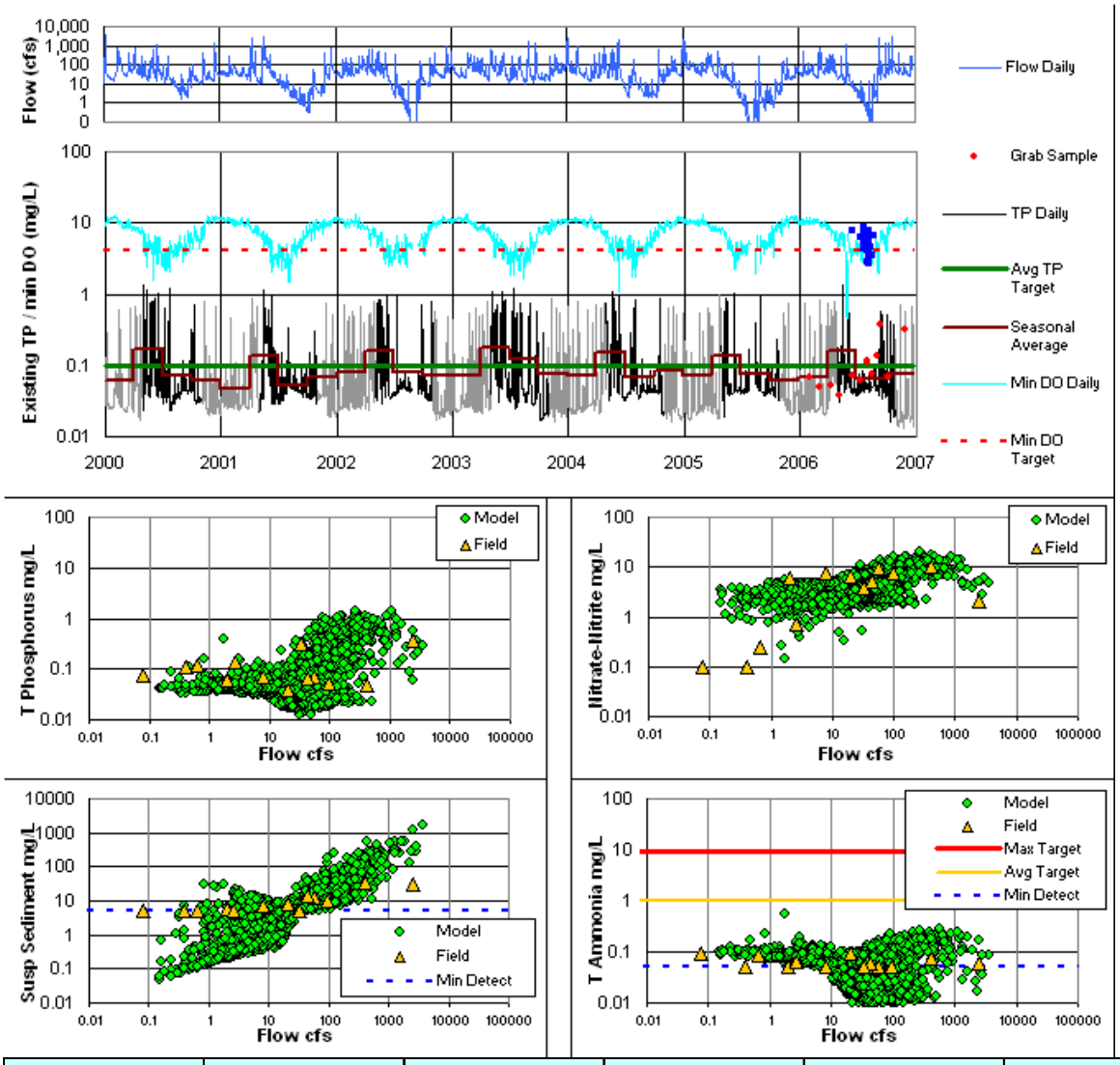
Parameter	Samples per group	Low Q < 35cfs		Transition Q		375cfs < Runoff Q		Total Q range	
		Abs Err	Rel Err	Abs Err	Rel Err	Abs Err	Rel Err	Abs Err	Rel Err
DO_{min}	3 / 0 / 0	0.07	1%	-	-	-	-	-	-
TP	14 / 42 / 15	0.32	57%	0.15	62%	0.24	105%	0.20	67%
NO_x	14 / 42 / 15	1.5	94%	2.3	35%	4.0	55%	2.5	44%
TSS	0 / 14 / 15	-	-	15.5	100%	43.3	69%	29.9	75%
Flow	14 / 43 / 18	8.1	57%	66.5	39%	782.1	72%	227.3	63%

Figure D3-36. Suspended solid, TP, NO_{3+2}, and NH_3-N calibration results of Paint Creek at SR-753.



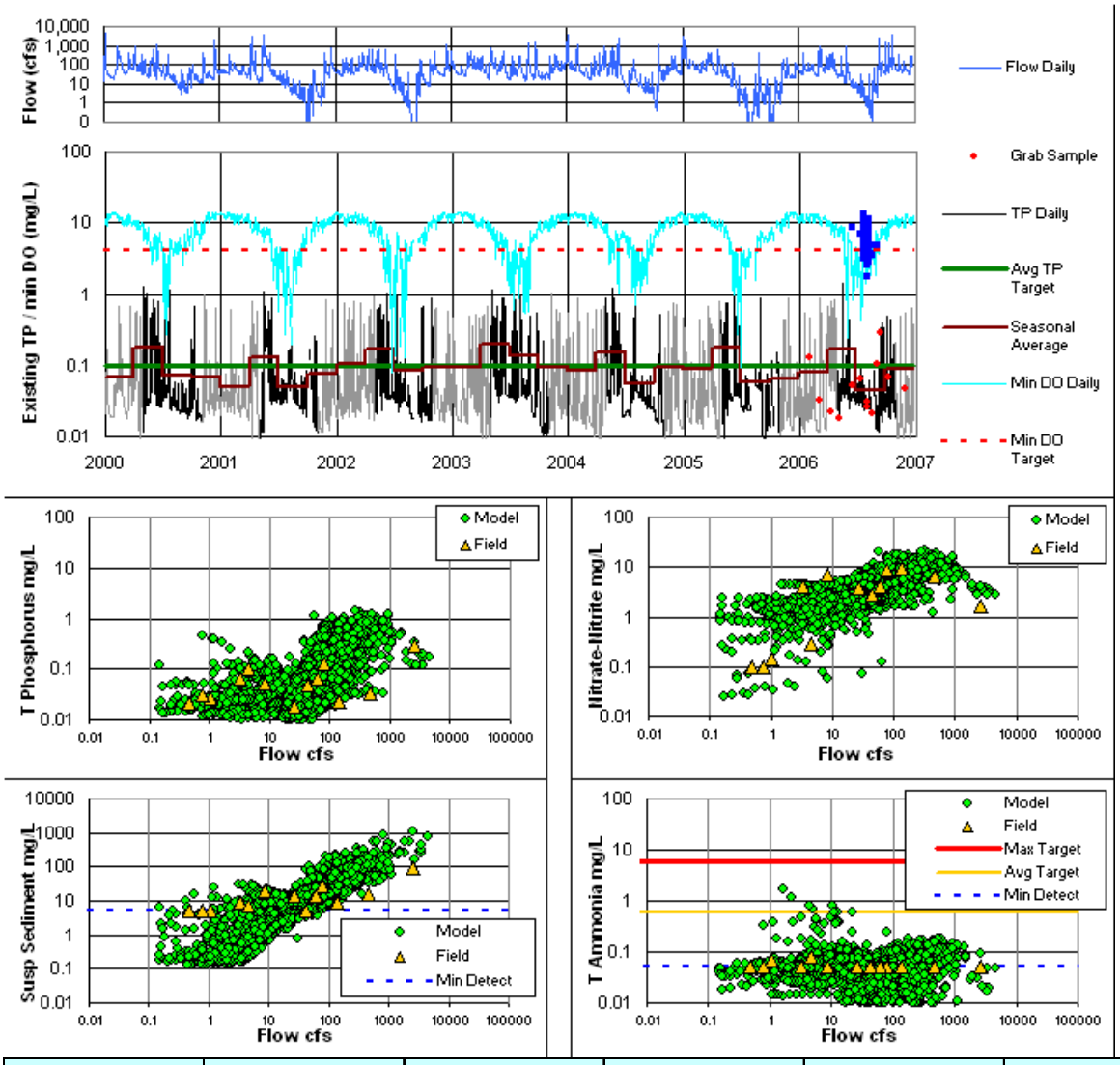
Parameter	Samples per group	Low Q < 10cfs		Transition Q		115cfs < Runoff Q		Total Q range	
		Abs Err	Rel Err	Abs Err	Rel Err	Abs Err	Rel Err	Abs Err	Rel Err
DO_{min}	3 / 0 / 0	0.21	4%	-	-	-	-	-	-
TP	6 / 4 / 2	0.04	77%	0.03	53%	0.10	63%	0.05	65%
NO_x	6 / 4 / 2	2.6	109%	3.0	45%	1.3	20%	2.5	56%
TSS	3 / 1 / 2	5.7	90%	4.9	31%	508.5	1321%	173.2	928%

Figure D3-37. Suspended solid, TP, NO_{3+2}, and NH_3-N calibration results of Sugar Creek at Armbrust Rd.



Parameter	Samples per group	Low Q < 5cfs		Transition Q		75cfs < Runoff Q		Total Q range	
		Abs Err	Rel Err	Abs Err	Rel Err	Abs Err	Rel Err	Abs Err	Rel Err
DO_{min}	2 / 0 / 0	0.27	6%	-	-	-	-	-	-
TP	4 / 5 / 2	0.06	55%	0.10	86%	0.11	53%	0.09	67%
NO_x	4 / 5 / 2	2.5	141%	2.8	43%	1.7	35%	2.5	56%
TSS	1 / 4 / 2	5.7	95%	5.7	54%	559.2	2868%	163.8	1318%

Figure D3-38. Suspended solid, TP, NO_{3+2}, and NH_3-N calibration results of East Fork Paint Creek at US-22



Parameter	Samples per group	Low Q < 10cfs		Transition Q		100cfs < Runoff Q		Total Q range	
		Abs Err	Rel Err	Abs Err	Rel Err	Abs Err	Rel Err	Abs Err	Rel Err
DO_{min}	3 / 0 / 0	0.29	9%	-	-	-	-	-	-
TP	6 / 4 / 2	0.03	51%	0.05	81%	0.06	39%	0.04	56%
NO_x	6 / 4 / 2	1.8	95%	1.8	37%	2.1	38%	1.9	53%
TSS	3 / 3 / 2	11.2	96%	7.1	39%	499.0	978%	131.6	548%

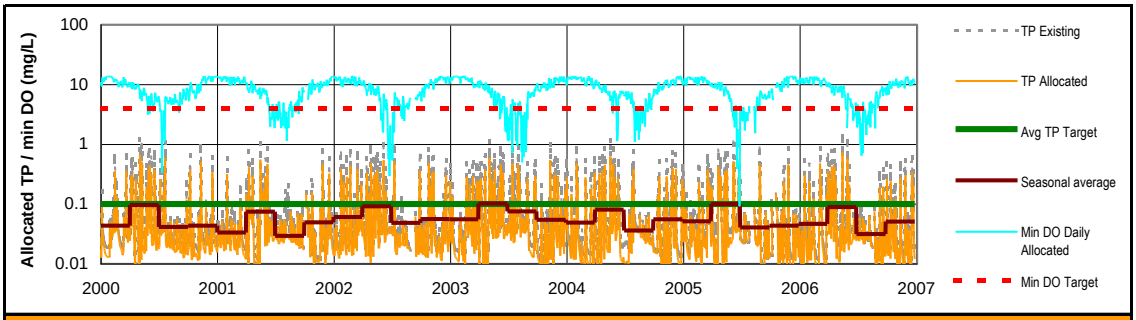
Figure D3-39. Suspended solid, TP, NO_{3+2}, and NH_3-N calibration results of Paint Creek at Elm Street (Washington Court House).

Total phosphorus LSPC modeling loading capacity development

The calibrated model is used to analyze the existing conditions both temporally and spatially. LSPC provides an annual load report for each land use source.

The primary goal of the TP source reduction simulations is to meet the average 0.1mg/L target for each season group's average. Daily TP data is averaged from 2000-2006 for each season to compare against lowered loads and concentrations generated by the LSPC TMDL module. As previously stated, the collection of years demonstrate a range of annual climate variability, which ensures the consideration of low flow critical conditions and high flow overloadings to

sensitive areas. Each season's existing and load allocated daily concentrations are plotted as a time series, and each season's average is compared to the target. An example simulation is depicted in Figure D3-40. The minimum DO and maximum NH_3-N simulation statistics are also compared to their respective criteria in a table inset in this figure.



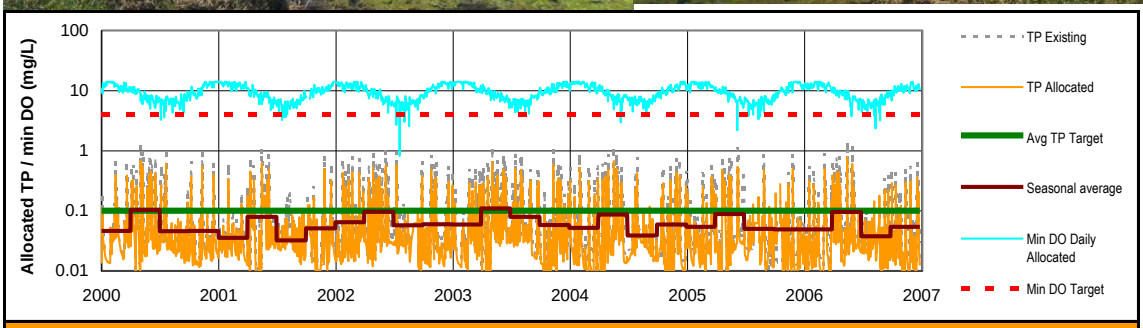
Sub-watershed seasonal TP, May-October DO, and annual NHx results				
TP < 0.1	January - March	April - June	July - September	October - November
TP existing	0.08	0.17	0.07	0.08
TP allocated	0.05	0.09	0.04	0.05

Min oxygen / max ammonia criteria		Existing concentrations		TMDL concentrations	
DO Summer min criteria	> 4	DO 30 day min existing	2.3	DO 30 day min result	2.7
NH_x Annual max criteria	< 5.9	NH_x max existing level	1.63	NH_x max result	1.26

Figure D3-40. TP allocation control module with NO_{2+3} and DO response levels for the Paint Creek Elm Street, Washington Court House assessment site

The baseline model has the same settings as the existing model, with the exception of NPDES permitted point sources. The daily point source model flows are set to their respective average design flows, and the nutrient and other permitted concentrations set to targets or pre-existing limits. The point source representation incorporates the design incorporated future growth of each entity through increased baseline flow, and a conservative daily TP concentration set to their current or proposed effluent limit.

Figure D3-40 above depicts the allocation of phosphorus at the Paint Creek Elm Street (Washington Court House) site. Note that the existing summer TP average is already meeting the 0.1 mg/L target. As discussed previously, water column TP sample data provides only one part of the TP loading in a stream corridor. This particular reach is impounded at less than two inches depth at low flow via channelization and a restrictive substrate control under the Elm Street Bridge. The reach substrate is overlain with dense fine sediment and organic material, which contains a TP reservoir for algal uptake. In order to address the TP component of this reach's eutrophic state, the higher spring TP concentration becomes the focus for resident load control. The simulated load reductions drops the spring TP concentration from 0.17 mg/L to 0.09 mg/L, and all four seasons are meeting the target. Ammonia concentration also decreases in response to less algal respiration/death. However, minimum DO is still below the 4 mg/L criteria rising from the existing 2.3 mg/L to 2.7 mg/L. This is evidence that the sediment and algal derived organic retention have a major impact on this reach, in combination with a lack of shade with compounds the impairment. Figure D3-41 demonstrates the eutrophic response to providing natural shade to the reach, and creating run-like flow through this Washington Court House public park. In combination with TP allocations, minimum DO concentration rises to 5.7 mg/L, and maximum NH_3-N concentration significantly drops to 0.37 mg/L.



Sub-watershed seasonal TP, May-October DO, and annual NHx results						
TP < 0.1	January - March		April - June	July - September	October - November	
TP existing	0.08		0.17	0.07	0.08	
TP allocated	0.05		0.09	0.05	0.05	
Min oxygen / max ammonia criteria			Existing concentrations		TMDL concentrations	
DO Summer min criteria	> 4		DO 30 day min existing	2.3	DO 30 day min result	5.7
NH_x Annual max criteria	< 5.9		NH_x max existing level	1.63	NH_x max result	0.37

Figure D3-41. Post TP allocation control module with NO_{2+3} and DO response levels, after stream reach improvement simulation (bottom), Paint Creek upstream of Elm Street adjacent to Washington Court House city park (upper left), and Elm Street Bridge looking downstream (upper right).

The model provides several insights to the state of Upper Paint Creek. The state of channelization and lack of connected riparian zones for buffering and shade are dominant features in the northern area. The interaction of agriculture channel maintenance practices and WWTP effluent use is important. As indicated in the TMDL tables, the Jeffersonville WWTP's TP limit can be increased from 1 mg/L to 2 mg/L, and Bloominburg's TP limit from 1.5 mg/L to 2 mg/L if the habitat and bedload TMDLs are carried out to the extent of improving minimum DO levels above criteria. The excessive TP loading is too large for the adjacent reach to handle, but the downstream reach below the East Fork confluence is functional. This indicates that the relocation of the Washington Court House WWTP outfall downstream to the East Fork confluence will spare the adjacent reach (as well as remove a pathogen source adjacent to the city park lands as stated in the E. coli section). However, the downstream waters are sensitive to NH_3-N concentrations since the elevated algal productivity creates high pH levels. The model indicates that in-stream NH_3-N criteria will be met if the Washington Court House WWTP average effluent limit is reduced to 1.0 mg/L. The WWTP is currently operating well below this proposed effluent limit. Paint Creek minimum DO concentrations below the East Fork confluence down to Paint Creek Lake meet EWH criteria due to a stronger gradient, a more natural channel, and an intact flood plain connected riparian corridor. This confirmation of Paint Creek's general EWH chemical criteria attainment along this corridor demonstrates that habitat

is a major factor in controlling eutrophic conditions. The data also confirms that the acute operational issues of the Greenfield WWTP in 2006 are the primary source of impairment due model and field data confirmed spikes in NH_3-N and also organic enrichment within the channel substrate. Greenfield WWTP's current NH_3-N effluent limits are acceptable to meet in-stream water quality criteria.

LSPC's general point source and land based reduction controls can be used to preferentially alter the simulated waterbody concentrations. The reduction controls work on the premise of removing a percentage of daily stream input loads, based on the simulated total available load. This applies to land based sources which have loading characteristics that vary monthly, as well as point sources that have a static baseline representation. In order to efficiently manage the production of various allocation simulations, land based and non-point direct sources are reduced by the same percentage for all subwatershed zones within a HUC-12. While this simplified approach is the basis for assigning HUC-12 reductions for load allocations, it may lead to future planning oversight since subwatershed zones contribute at different pollutant levels. Most notable is the case of HSTS, where more dense areas of failing systems are likely better targets for producing significant stream improvement. Watershed planners should refer to the existing annual loadings of the 27 subwatersheds to build efficiency in water quality projects.

Once TP concentration requirements are met for all 27 subwatershed zones, TMDLs can be derived on the HUC-12 level. The TMDLs, its sub-components, and a median export target are derived as follows:

Total phosphorus LSPC TMDL allocations, including margin of safety and allowance for future growth

LSPC analysis is used to simulate calibrated TP, NH_3-N and NO_{3+2} loadings with respect to the annual flow regime. The calibrated model is used to quantify necessary source load reductions to meet average season targets. Once criteria are met with the allocated model, simulated loadings are used to develop the TMDL.

Total Maximum Daily Load (TMDL)

The TP TMDL is calculated as the 90th percentile of all allocated daily loads entering the stream from the simulated 2000-2006 period. The TMDL serves as a benchmark for assessing improvement, where the 90th percentile of all future source load measurements are to be found acceptable. The TMDL is provided for both local HUC-12 specific and cumulative with upstream HUC-12 TMDLs. The 90th percentile TMDL is simply added to the downstream TMDL for quantity tracking. The formula "TMDL = MOS + RFG + ΣWLA + LA" defines the subcomponent quantities of the TMDL. The subcomponent targets are equally important to the overall TMDL, as the various listed load reductions and allocations control TP levels at a range of flow and load levels.

Margin of Safety (MOS)

Five percent of the TMDL is subtracted as an explicit margin of safety. This is incorporated into both local and cumulative TMDLs. The explicit margin of safety further ensures control of peak loadings which impact the TP averages of the four season groups. An implicit margin of safety is also incorporated into the model representation. The use of design flows and static daily maximum loads from direct sources (point and non-point) ensures that critical recreation periods of high use are assessed under the worst case loading condition. The static daily load of direct non-point sources represents an upper limit with respect to seasonal variation, which also incorporates an implicit safety factor. This compensates for alternating pasture usage and/or changing HSTS impacts not reflected in the sample data. The use of a high level model with

satisfactory calibration is in itself an implicit margin safety, by providing sufficient accuracy for management decisions.

Allowance for Future Growth (AFG)

Growth trends in the region's counties are -3 to 1%. Although significant development is not expected in the upper Paint Creek basin, a reserve for future growth is applied. The reserve is intended to account for new sources that would impact the low flow regime. The system is able to assimilate direct sources that discharge at 1.0 mg/L due to mass balance mixing. However, additional pollutant carrying flow sources are limited to safeguard against excessive nutrient loading at sensitive low flows. The amount of additional flow is calculated as 10% of the stream's flow exceeded 90% of the time. The flow increase is multiplied by 1.0 mg/L and a conversion factor to calculate the reserve load for future growth. New sources that can discharge below this TP limit can be approved for more flow, as long as proper review indicates the TMDL requirements are met. Therefore, industrial sources that do not treat phosphorus containing waste are not theoretically restricted by the total phosphorus TMDL. It should be noted that the municipal operations within the upper Paint Creek basin already have implicit reserve of future growth built into their current NPDES permits. These entities can also draw from the general reserve if necessary for further expansion. Each HUC-12 TMDL has a local reserve for future growth. Downstream HUC-12 TMDLs get the flow based reserve minus the reserve held by the upstream HUC-12(s). The total reserve is tracked with the cumulative TMDL. The total reserve of upper Paint Creek can be managed to allocate more where needed, but the reserve taken from other areas further limits their capacity to discharge increased TP loads.

Waste Load Allocation (WLA)

NPDES permitted sources receive a daily WLA. Each TP WLA is based on the appropriate TP concentration limit multiplied by the facility average design flow and a conversion factor. The exception is the Washington Court House MS4 WLA, with the incorporated limits involving three different HUC-12s. The MS4 permitted WLA is based on the 75th percentile of the stormwater events' TP loads. The quantification of the storm flow loads are as described earlier. Each HUC-12 TMDL incorporates the sum of the local WLAs. Each point source's individual WLAs are listed in its associated HUC-12 TMDL table, which also includes the facilities existing average flow, average design flow, and average TP concentration limit. The cumulative TMDLs also incorporate the local HUC-12 WLAs, as well as the upstream WLAs. The individual WLAs are not relisted, but are referenced as an upstream allocated total if there are any.

Load Allocation (LA)

Non-point diffused sources receive a portion of the TMDL as a LA. The LA is the remaining portion of the TMDL after subtracting the MOS, AGR, and WLAs. Existing annual loads are provided in Table and are discussed earlier in the report. The TMDL tables provide percent load reductions necessary to meet recreation season requirements. The percent reductions are applied to crop land, pasture land, developed land, forest land, near stream feedlots and/or livestock with stream access, stream accessing wildlife, and failing HSTS.

90th percentile annual export

While not part of the TMDL equation, the 90th percentile TP export from a HUC-12 waterbody is provided as a tool for future sample assessments. Unlike the TMDL which is derived from input loads, the export load targets are based on the in-stream load that has undergone the effects of transport and eutrophication processes. With regard to nested HUC-12 watersheds, the values are inherently cumulative as the loads leaving system are impacted by the entire upstream

system. These additional benchmark loads can be compared to future samples at the mouth of the HUC-12s.

D3.2 Habitat and sediment method (Qualitative Habitat Evaluation Index)

D3.2.1 Justification of method

Poor habitat quality is an environmental condition, rather than a pollutant load, so development of a load-based TMDL for habitat is not possible. Nonetheless, habitat is an integral part of stream ecosystems and has a significant impact on aquatic community assemblage and consequently on the potential for a stream to meet the biocriteria within Ohio's water quality standards (see below). In addition, US EPA acknowledges that pollutants, conditions or other environmental stressors can be subject to the development of a TMDL to abate those stressors in order to meet water quality standards (US EPA, 1991). Thus, sufficient justification for developing habitat TMDLs is established.

The Qualitative Habitat Evaluation Index (QHEI) was developed by the Ohio EPA (Ohio EPA, 1989) with one of the objectives being to create a means for distinguishing impacts to the aquatic community from pollutant loading versus poor stream habitat. The design of the QHEI in conjunction with its statistically strong correlation to the biocriteria makes it an appropriate tool for developing habitat TMDLs.

D3.2.2 Targets for QHEI modeling

The QHEI assigns a numeric value to an individual stream segment (typically 150-200 m in length) based on the quality of its habitat. The actual number values of the QHEI scores do not represent the quantity of any physical properties of the system but provide a means for comparing the relative quality of stream habitat. However, even though the numeric value is derived qualitatively, subjectivity is minimized because scores are based on the presence and absence and relative abundance of unambiguous habitat features. Reduced subjectivity was an important consideration in developing the QHEI and has since been evidenced through minimal variation between scores from various trained investigators at a given site as well as consistency with repeated evaluations (Ohio EPA, 1989). The QHEI evaluates six general aspects of physical habitat that include channel substrate, instream cover, riparian characteristics, channel condition, pool/riffle quality, and gradient. Within each of these categories or submetrics, points are assigned based on the ecological utility of specific stream features as well as their relative abundance in the system. Demerits (i.e., negative points) are also assigned if certain features or conditions are present that reduce the overall utility of the habitat (e.g., heavy siltation and embedded substrate). These points are summed within each of the six submetrics to give a score for that particular aspect of stream habitat. The overall QHEI score is the sum of all of the submetric scores.

Since its development the QHEI has been used to evaluate habitat at most biological sampling sites and currently there is an extensive database that includes QHEI scores and other water quality variables. Strong correlations exist between QHEI scores and its component submetrics 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 aquatic life use designations of warmwater habitat (WWH) and exceptional warmwater habitat (EWH), respective overall QHEI scores of 60 and 75 are

targeted to provide reasonable certainty that habitat is sufficient to support biological community expectations.

One of the strongest correlations found through these statistical analyses described above is the negative relationship between the number of "modified attributes" and the IBI scores. Modified attributes are features or conditions that have low value in terms of habitat quality and therefore are assigned relatively fewer points or negative points in the QHEI scoring. A subgroup of the modified attributes shows a stronger impact on biological performance; these are termed high influence modified attributes.

In addition to the overall QHEI scores, targets for the maximum number of modified and high influence modified attributes have been developed. For streams designated as WWH, there should no more than four modified attributes, of which no more than one should be a high influence modified attribute. For EWH streams, there should be no more than two modified attributes and zero high influence attributes. Table D3-23 lists modified and high influence modified attributes and provides the QHEI targets used for this habitat TMDL.

Table D3-23. QHEI targets for the habitat TMDL.

	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
Targets	**WWH**	Overall score ≥ 60	Total number < 2	Total number < 5[1]
	EWH	Overall score ≥ 75	Total number < 0	Total number < 35[1]
TMDL Points if Target Satisfied	+1		+1	+1

[1] Total number of modified attributes includes those counted towards the high influence modified attributes.

For simplicity, a pass/fail distinction is made to determine whether each of the three targets is being met. Targets are set for: 1) the total QHEI score; 2) maximum number of all modified attributes; and 3) maximum number of high influence modified attributes only. If the minimum target is satisfied, then that category is assigned a "1", if not, it is assigned a "0". To satisfy the habitat TMDL, the stream segment in question should achieve a score of three.

The QHEI is also used to develop the bedload (sediment) TMDL. Numeric targets for sediment are based on the metrics of the QHEI. Although QHEI evaluates the overall quality of stream habitat, some of the component metrics consider particular aspects of stream habitat that are closely related to and/or impacted by the sediment delivery and transport processes occurring in the system

The QHEI metrics used in the bedload TMDL are the substrate, riparian, and channel metrics. All of these evaluate stream attributes related to substrate quality and the amount of fines in the sediment. Substrate is a QHEI category that measures the type, origin, quality, and degree of embeddedness of stream substrates. Degree of embeddedness refers to the extent to which gravel, cobble, and boulders are surrounded, buried by, or covered by fine materials such as sand or silt. The riparian QHEI category evaluates riparian width, quality, and bank erosion. The channel QHEI category describes stream physical morphology including sinuosity and extent of development. Each of these factors influences the degree to which siltation affects a stream, and cumulatively serves as its numeric target.

The targets were established based on a paired analysis of IBI scores with corresponding values of these QHEI metrics. The targets are set at the fiftieth percentile of the site that achieves a minimum IBI score of 40, which is meant to reflect a warmwater habitat fish community. Table D3-24 summarizes the sediment TMDL targets that are used to address sedimentation.

Table D3-24. Sediment (bedload) TMDL targets

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

The sedimentation scores can be thought of as a “concentration”, as they measure the current amount of sediment in the stream. This means that the load allocations (LAs) and wasteload allocations (WLAs) are the same as the loading capacity (e.g., score = 32).

D3.2.3 QHEI modeling

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).

There is an implicit margin of safety applied to the habitat TMDLs based on conservative target values used. The targets from the *Association Between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams* (Ohio EPA 1999) are conservative because attainment of aquatic life uses has been demonstrated even when the targets are not met.

Critical Conditions

The critical condition for the habitat and sediment TMDLs is the summer dry period when environmental stress upon aquatic organisms is the greatest. It is during this period that the presence of high-quality habitat features, such as deep pools and unembedded substrate, is essential to provide refuge for aquatic life. QHEI scores, the basis of the habitat and sediment TMDLs, are assessed during the summer field season. The habitat and sediment TMDLs are therefore reflective of the critical condition.

Allowance for Future Growth

Since no explicit loads are calculated for the habitat and sediment TMDLs, no future growth load can be allotted.

Stream habitat and sediment relationship to dissolved oxygen depletion

As indicated in the phosphorus TMDL section, the load reductions may need to work in concert with channel improvements to control localized eutrophication and oxygen depletion. Model reaches that cannot meet acceptable oxygen depletion levels through meeting phosphorus targets are further assessed through alteration of stream reach characteristics. Two primary types of channels were identified that cause issues with oxygen depletion. The first is stream reaches that have been channelized and going through the early stages of recovery. The streams have slumped banks which begin to fill in low benches, and offer a suitable foothold for aquatic vegetation that acts to delay the transfer of flow and pollutants downstream. Many have no riparian cover, which promote the growth of in-channel plants. These reaches within the Paint Creek system are notable by their capacity to hold a substrate load of fine sediments which contain phosphorus, BOD, and ammonia in particulate forms. Stream reaches that are not being maintained may correct their own issues through channel morphology dynamics over a long period of time. Other actively maintained channels need to be cleared more frequently to help both peak flow and pollutant dissipation of WWH corridors. There are several types of hydraulic channel designs that also take water quality into consideration, but the subject is out of scope for this report. The second type of stream channel has an obvious maintenance history and were dug or scoured unnecessarily deep. These sections may reside in one project zone with the hope of better peak drainage, but downstream channel structure or bridges act as the primary control of further increases of peak drainage. As with the first type of stream reach, these deeper reaches act as a sink that collects fine sediments and associated pollutants. The benthic reserve of phosphorus is enough to fuel massive algal blooms even when there is little apparent phosphorus in the water column. Therefore, the excessive low flow depth of a long reach serves no purpose for appropriate stream habitat or for effective increases in peak flow drainage.

The comparison of oxygen improvement and QHEI scores in these impaired reaches is not intended to provide definitive linkage between habitat and biology scoring. In fact, a reach with an ample supply of dissolved oxygen may not have suitable in-stream habitat to support population diversity. Likewise, a reach with exceptional habitat qualities may have depressed oxygen levels that are not eutrophic in nature, such as the case with point sources with BOD issues. Another discrepancy in direct comparison is in the scale of what each group represents. The model's oxygen levels are generated on a reach scale defined by aggregate stream characteristics, while the field QHEI assessment is generally confined to the shorter zone of biology assessment sites. With all these issues aside, there is a general agreement of insufficiency in QHEI metrics and dissolved oxygen levels in this size of agriculturally dominant streams.

The model reaches are defined as discussed for the model under existing conditions. For small drainage areas (<30sqmi), the addition of riparian shading to a channelized reach may be enough to keep minimum oxygen levels in check under normal hydrologic circumstances. The model simulates this through decreasing the available daily light available to the reach, which suppresses algal productivity. For other channelized reaches of larger drainage areas and/or significant point sources involved, a retrofit hydraulic design to improve water quality is needed to improve oxygen levels. This involves the removal of the volume maintaining reach representation and updating reach parameters with typical Ohio stream dimensions. It is indicative that using one of these two model methods (or both) represent similar needed

improvements dictated by the metric deficiencies of the bedload and habitat TMDLS. However, neither method indicates the actual ground scale efforts of work needed for localized site improvements, only a general indication of reach level improvement needed for TMDL quantification. Because of this uncertainty of scale, no attempt was made to model reach oxygen improvements specifically based on range QHEI percent deviations. For implementation on the local scale, the county soil and water district staff can provide help for voluntary improvement efforts.

Another issue that needs further effort is if habitat restoration alone could delist a reach from past eutrophic signatures in the biology data. If habitat restoration of a stream is conducted and a biologic survey indicates that the reach is in full attainment as a result, the phosphorus reductions listed by a TMDL may not be as demanding. This would not always be the case, as TMDLs are also used to protect downstream areas and the habitat/phosphorus controls may need to coexist. However, the lessened need to reduce phosphorus would be beneficial to point sources. For example, Jeffersonville has been allocated a load developed by using the minimum 1.0 mg/L guideline due to the eutrophic issues of Sugar Creek surrounding Creamer Rd. If the reach is constructed to be free flowing at low flow and shade provided in key areas, a biologic assessment may demonstrate that the phosphorus load's indirect issues are under control. The effort in proper channel maintenance with water quality in mind may lead to less expensive wastewater treatment.

D3.3 Load duration curve pathogen modeling (*E. coli*)

D3.3.1 Justification of method

Much of the watershed is impacted by elevated E. coli concentrations. A load duration curve approach using Ohio EPA sample data directly is selected for source load analysis and TMDL development. The duration curve (US EPA, 2007) approach allows for characterizing water quality concentrations (or water quality data) at different flow regimes. The method provides a visual display of the relationship between stream flow and loading capacity. Using the duration curve framework, the frequency and magnitude of water quality standard exceedances, allowable loadings, and size of load reductions are easily presented and can be better understood.

An empirical method of determining most TMDL bacteria loading and reductions is utilized in this report via load duration curves (LDCs). This method is appropriate since the sources of bacteria in Ohio streams can be differentiated by stream flow regime. The main advantage of the use of LDCs is in this methods ability to divide loads based on flow. The main shortcoming of this method is its lack of being able to differentiate various loads that may occur in the same flow regime (such as cows in stream and poorly operating home sewage treatment systems during periods of low flow).

D3.3.2 Targets for LDC pathogen modeling

The targets for this modeling is the exact same as applied for the LSPC *E. coli* modeling explained above in the D3.1.2 subsection. The includes the same rule that applies Class A recreation use criteria to Class B designated assessed stream sites that are five miles of less upstream of a Class A designated stream reach.

D3.3.3 LDC pathogen modeling

To create TMDL LDCs, the flow duration for each TMDL site is determined. This involves calculating the flow expected for the full range of exceedance percentile. Since this beneficial use is only applicable to the recreation season, May through October, the stream flows used to calculate this range of exceedance percentile is only that of flows occurring May through October. Exceedance percentile stream flows are the probability that a given flow magnitude is exceeded. This normalizes the flows to a range of natural occurrences from extremely high flows (zero exceedance percentile) to extremely low flows (100). The flow curve is converted into a load duration curve by taking the product of each flow values, the water quality geometric mean standard and a conversion factor. These values, in *E. coli* counts per day are the TMDL for each flow condition. The resulting points are plotted to create a LDC.

The water quality samples for each impaired site are converted into loads by taking the product of the *E. coli* sample result, the flow at the time the sample was collected and a conversion factor. Each calculated load is plotted as a point on the LDC plot and is then compared to the water quality TMDL load. Points that plot above the LDC represent deviations from the water quality standard and the daily allowable load. Points that plot below the curve represent samples in compliance with standards and the daily allowable load.

Water quality samples on the LDC curves are noted as diamonds. 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).

Box plots are shown for each flow regime with observed data. 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. The upper and lower vertical bar tails are the maximum and minimum observed loads respectively.

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.

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 D3-25 shows various pollutant sources and the flows contributing to their occurrence.

Table D3-25. Load duration curve flow zones and typical contributing sources

Contributing Source Area	Duration Curve Zone				
	High	Moist	Mid-Range	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

LDCs are developed at the most downstream assessment site in a HUC 12s that has impairment of recreational use. Table D3-26 shows the sentinel and non-sentinel sites and their drainage area. In order to determine each LDC's flow interval, stream flows are extrapolated to a representative USGS gage. A simple drainage area ratio of the LDC site's watershed to the USGS gage's is then applied to the gage flows. If significant effluent flow is expected to be altering a watershed's flow interval then the extra flow is added to the flow record prior to calculating the flow duration interval.

Table D3-26. LDC *E. coli* TMDL sites and their drainage areas.

12-Digit HUC	Stream Name	Class	Location	River Mile	Drainage Area (Sq. mi.)
05060003 03 01	Wilson Ck	B	Downstream Sabina WWTP	2.8	18.4
05060003 03 03	West Br Rattlesnake Ck	B	Downstream Wilson Ck	2.8	41.6
05060003 03 04	Rattlesnake Ck	B	Milledgeville-Octa Rd.	35.36	34
05060003 03 05	Rattlesnake Ck	B	W of New Martinsburg, upst Zimmerman Rd.	15	125
05060003 04 01	S Fork Lees Ck	B	Hixon Rd	1.6	15.9
05060003 04 03	Lees Ck	B	Monroe Rd E of Leesburg	1.16	73
05060003 04 04	Walnut Ck	B	Walnut Ck Rd.	4.2	5.7
05060003 04 07	Rattlesnake Ck	B	Centerfield Rd.	7.55	209
05060003 05 02	Clear Ck	B	Dst Hillsboro WWTP	6.6	25.1
05060003 05 03	Rocky Fk	A	SR 124, upst Rocky Fk Lake, DST WWTP	17.53	39
05060003 05 05	Rocky Fk	A	Browning Rd nr Barretts Mill	3.03	140
05060003 07 01	Trib. to Buckskin Ck	B	McCann Rd.	0.18	2.7
05060003 07 02	Upper Twin Ck	A*	Upper Twin Creek Rd.	2.0	12.2
05060003 07 03	Lower Twin Ck	A*	Farm off Lower Twin Rd.	2.2	15.0
05060003 07 04	Massie Run	A*	US RT 50 W of Bainbridge	0.1	4.9
05060003 08 01	Thompson Ck	A*	Thompson Ck	3.3	8.0
05060003 08 03	Compton Ck	B	Washington Waterloo Rd.	11.2	19.9
05060003 08 04	Compton Ck	A*	Dogtown Rd.	1.1	59.0
05060003 08 05	N Fk Paint Ck	A	Good Hope-New Holland Rd.	26.7	51.0
05060003 09 02	Little Ck	A*	Little Creek Rd nr Rogers Rd.	1.0	22.7
05060003 09 03	N Fk Paint Ck	A	Downstream Frankfort WWTP	14.1	163.4
05060003 09 04	N Fk Paint Ck	A	Poke Hollow Rd.	2.28	231.0
05060003 10 02	Ralston Run	A*	Turner Rd.	2.8	5.2
05060003 10 03	Owl Ck	A*	Upstream US RT 50	0.35	6.5

* The TMDL for these watersheds are developed based on Class A recreation use criteria because the assessment site is within 5 river miles of a Class A segment.

Modeling condition, margin of safety and future growth

In order to use the LDCs developed for bacteria TMDLs an additional flow adjustment must be made. To account for all expected future growth in the watershed, TMDLs require that permitted public waste water treatment facilities be allocated at their full permitted design flow. Because of this the additional flow must be added into the flow duration curve. Since this flow is expected no matter what the flow regime of the stream, the additional flow is added across all flow conditions. Adjustments that are made for additional future growth are discussed below.

An explicit margin of safety (MOS) is computed in the Paint Creek TMDLs. The MOS is used to reserve assimilative capacity and accounts for uncertainty in the LDC approach and in monitoring information. A 20% MOS is applied to account for broad fluctuations of *E. coli* concentrations that occur in nature and the relatively low number of data points available for this analysis. For LDC TMDLs, US EPA (2007) recommends this type of MOS for two reasons: 1) allocations will not exceed the load associated with the minimum flow in each regime; and 2) recognition that the uncertainty associated with effluent limits and water quality may vary across different flow 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 and mortality rates lower 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 this uses criteria.

Permitted dischargers with NPDES permits that currently require disinfection (mostly WWTPs), are given WLAs equivalent to the product of their design flow, the target *E. coli* concentration and a conversion factor. Since these facilities operate no matter what the stream flow, their WLA is the same for all five flow regimes. The target bacteria concentration is set to the recreation use criteria, outlined above, applicable to the stream the effluent is discharged to. The exception to this is if the discharge point is within five river miles of a more restrictive primary contract recreation class. In these cases the criteria for the more restrictive class is applied to the discharge.

The allocated loads of *E. coli* from home sewage treatment systems or direct manure deposits from livestock for the TMDLs are set to zero. This is because properly functioning HSTSs and proper livestock management should preclude *E. coli* and other pathogenic materials from being discharged to waters of the state.

The load remaining after the MOS and NDPES point source loads are allocated is 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 on the bacteria TMDL tables.

As explained in the LSPC discussion, population projections for this watershed show insignificant growth. Because of this, a relatively low allowance for future growth (AFG) is reserved from the TMDL load, 2%.

D4 Results

This section summarizes TMDLs results.

D4.1 LSPC modeled recreation and aquatic life use results

This subsection outlines the nutrient and bacteria TMDL results for the watersheds that were modeled using the LSPC modeling approach. Tables D4-1 through D4-9 show the TMDL total and allocated loads for each HUC 12 receiving an *E. coli* TMDL via the LSPC method. These tables also include the percent reduction required for the various landuses. The terminology on these tables is explained on in Section D3.1.4. Tables D4-10 through D4-15 show the same information for the total phosphorus TMDLs. After several of these tables narrative management scenarios are provided.

Table D4-1. Paint Creek headwaters *E. coli* TMDL.

***E. coli* requirements for HUC-12 050600030101**							
***E. coli* Recreation Season TMDL components and target export load - billion cfu/day**							
TMDL components	TMDL	MOS	LA	Σ WLA	AFG	90th% target export	
HUC-12 / sub-watershed	1579.1	79.0	1499.4	0.00	0.74	4942.6	
Cumulative watershed	1579.1	79.0	1499.4	0.00	0.74		
Non-point source LA reductions (% of existing recreation season load contribution)							
Washoff / direct source	Crop	Pasture	Developed	Wooded	D-Livestock	D-HSTS	D-Wildlife
Percent reduction	0%	0%	0%	0%	100%	100%	0%
Point source NPDES WLA							
Facility Name	NPDES OEPA ID		Existing MGD	Dgn Q MGD	Limit C cfu/100mL	WLA billion/day	
None	N/A		N/A	N/A	N/A	N/A	

Table D4-2. East Fork Paint Creek *E. coli* TMDL.

***E. coli* requirements for HUC-12 050600030102**							
***E. coli* Recreation Season TMDL components and target export load - billion cfu/day**							
TMDL components	TMDL	MOS	LA	Σ WLA	AFG	90th% target export	
HUC-12 / sub-watershed	1118.8	55.9	1031.8	30.37	0.76	1389.0	
Cumulative watershed	1118.8	55.9	1031.8	30.37	0.76		
Non-point source LA reductions (% of existing recreation season load contribution)							
Washoff / direct source	Crop	Pasture	Developed	Wooded	D-Livestock	D-HSTS	D-Wildlife
Percent reduction	0%	0%	0%	0%	100%	100%	0%
Point source NPDES WLA							
Facility Name	NPDES OEPA ID		Existing MGD	Dgn Q MGD	Limit C cfu/100mL	WLA billion/ day	
Bloomingburg WWTP	4PB00025		0.13	0.25	161	1.524	
ASA Ethanol Industrial	4IN00196		Industrial	0.758	0	0.000	
Washington CH MS4 (1.3sqmi)	4GQ00027		Stormwater	Stormwater	0	28.847	

Table D4-3. Paint Creek below Millbrook to East Fork Paint Creek *E. coli* TMDL.

***E. coli* requirements for HUC-12 050600030103**							
***E. coli* Recreation Season TMDL components and target export load - billion cfu/day**							
TMDL components	TMDL	MOS	LA	Σ WLA	AFG	90th% target export	
HUC-12 / sub-watershed	644.0	32.2	529.0	81.49	1.33	9047.6	
Cumulative watershed	2223.1	111.2	2028.3	81.49	2.06		
Non-point source LA reductions (% of existing recreation season load contribution)							
Washoff / direct source	Crop	Pasture	Developed	Wooded	D-Livestock	D-HSTS	D-Wildlife
Percent reduction	30%	30%	0%	0%	100%	100%	0%
Point source NPDES WLA							
Facility Name	NPDES OEPA ID	Existing MGD	Dgn Q MGD	Limit C cfu/100mL	WLA billion/ day		
Prairie Knolls MHP	4PV00115	0.01	0.015	161	0.091		
Miami Trace High School	4PT00121	0.01	Abandoned	0	0.000		
WCH WTP Intake	OH2400714	Withdrawal	0	N/A	N/A		
Washington CH WTP Backwash	4GW00002	Intermittent	0.1008	0	0.000		
BP Amoco Stormwater	4IN00171	Stormwater	0	0	0.000		
Washington Court House WWTP	4PD00002	3.03	6	126	28.618		
Washington Court House SSO	4PD00002	Variable	Variable	0	0.000		
Washington CH MS4 (3.4sqmi)	4GQ00027	Stormwater	Stormwater	N/A	52.778		
Upstream allocation unit WLAs	None	N/A	N/A	N/A	0.000		

Table D4-4. Alternate Paint Creek below Millbrook to East Fork Paint Creek *E. coli* TMDL (Washington Court House WWTP outfall relocated to discharge below East Fork Paint Creek).

***E. coli* requirements for HUC-12 050600030103**							
***E. coli* Recreation Season TMDL components and target export load - billion cfu/day**							
TMDL components	TMDL	MOS	LA	Σ WLA	AFG	90th% target export	
HUC-12 / sub-watershed	1027.9	51.4	899.7	75.49	1.33	12345.5	
Cumulative watershed	2607.0	130.4	2399.0	75.49	2.06		
Non-point source LA reductions (% of existing recreation season load contribution)							
Washoff / direct source	Crop	Pasture	Developed	Wooded	D-Livestock	D-HSTS	D-Wildlife
Percent reduction	0%	0%	0%	0%	100%	100%	0%
Point source NPDES WLA							
Facility Name	NPDES OEPA ID	Existing MGD	Dgn Q MGD	Limit C cfu/100mL	WLA billion/day		
Prairie Knolls MHP	4PV00115	0.01	0.015	161	0.091		
Miami Trace High school WWTP	4PT00121	Abandoned	0	0	0.000		
WCH WTP Intake	OH2400714	Withdrawal	0	N/A	N/A		
Washington CH WTP Backwash	4GW00002	Intermittent	0.1008	0	0.000		
BP Amoco Stormwater	4IN00171	Stormwater	0	0	0.000		
Washington Court House SSO	4PD00002	Variable	Variable	0	0.000		
Washington CH MS4 (3.4sqmi)	4GQ00027	Stormwater	Stormwater	N/A	75.397		
Upstream allocation unit WLAs	None	N/A	N/A	N/A	0.000		

Table D4-5. Sugar Creek headwaters through Missouri Ditch *E. coli* TMDL.

***E. coli* requirements for HUC-12 050600030201**							
***E. coli* Recreation Season TMDL components and target export load - billion cfu/day**							
TMDL components	TMDL	MOS	LA	Σ WLA	AFG	90th% target export	
HUC-12 / sub-watershed	738.5	36.9	697.8	3.05	0.71	1097.1	
Cumulative watershed	738.5	36.9	697.8	3.05	0.71		
Non-point source LA reductions (% of existing recreation season load contribution)							
Washoff / direct source	Crop	Pasture	Developed	Wooded	D-Livestock	D-HSTS	D-Wildlife
Percent reduction	0%	0%	0%	0%	100%	0%	0%
Point source NPDES WLA							
Facility Name	NPDES OEPA ID	Existing MGD	Dgn Q MGD	Limit C cfu/100mL	WLA billion/day		
Jeffersonville WWTP	4PB00108	0.35	0.5	161	3.047		

Table D4-6. Sugar Creek below Missouri Ditch to Paint Creek *E. coli* TMDL.

***E. coli* requirements for HUC-12 050600030202**							
***E. coli* Recreation Season TMDL components and target export load - billion cfu/day**							
TMDL components	TMDL	MOS	LA	Σ WLA	AFG	90th% target export	
HUC-12 / sub-watershed	1147.7	57.4	1089.9	0.00	0.39	5199.7	
Cumulative watershed	1886.4	94.3	1788.0	3.05	1.10		
Non-point source LA reductions (% of existing recreation season load contribution)							
Washoff / direct source	Crop	Pasture	Developed	Wooded	D-Livestock	D-HSTS	D-Wildlife
Percent reduction	0%	0%	0%	0%	100%	100%	0%
Point source NPDES WLA							
Facility Name	NPDES OEPA ID	Existing MGD	Dgn Q MGD	Limit C cfu/100mL	WLA billion/day		
Upstream allocation unit WLAs	Various	N/A	N/A	N/A	3.047		

Table D4-7. Paint Creek downstream East Fork Paint Creek to upstream City of Greenfield *E. coli* TMDL.

***E. coli* requirements for HUC-12 050600030601**							
***E. coli* Recreation Season TMDL components and target export load - billion cfu/day**							
TMDL components	TMDL	MOS	LA	Σ WLA	AFG	90th% target export	
HUC-12 / sub-watershed	856.4	42.8	771.5	42.05	0.03	30815.6	
Cumulative watershed	6085.0	304.3	5597.2	179.57	3.96		
Non-point source LA reductions (% of existing recreation season load contribution)							
Washoff / direct source	Crop	Pasture	Developed	Wooded	D-Livestock	D-HSTS	D-Wildlife
Percent reduction	0%	0%	0%	0%	100%	100%	0%
Point source NPDES WLA							
Facility Name	NPDES OEPA ID	Ex Flow Avg MGD	Dgn Q MGD	Limit C cfu/100 mL	WLA billion/day		
Washington CH MS4 (1.9sqmi)	4GQ00027	Stormwater	Stormwater	N/A	41.831		
Flakes Ford WWTP	4PG0000	0.01	0.01375	126	0.066		
Proposed Good Hope WWTP	N/A	0.00	0.032	126	0.153		
Upstream unit WLA (Paint)	Various	N/A	N/A	N/A	104.106		
Upstream unit WLA (East Fork)	Various	N/A	N/A	N/A	30.371		
Upstream unit WLA (Sugar)	Various	N/A	N/A	N/A	3.047		

Table D4-8. Alternate Paint Creek downstream East Fork Paint Creek to upstream City of Greenfield *E. coli* TMDL (Washington Court House WWTP outfall relocated to discharge below East Fork Paint Creek).

***E. coli* requirements for HUC-12 050600030601**							
***E. coli* Recreation Season TMDL components and target export load - billion cfu/day**							
TMDL components	TMDL	MOS	LA	Σ WLA	AFG	90th% target export	
HUC-12 / sub-watershed	856.4	42.8	742.9	70.67	0.03	32168.3	
Cumulative watershed	6468.9	323.4	5962.0	179.57	3.96		
Non-point source LA reductions (% of existing recreation season load contribution)							
Washoff / direct source	Crop	Pasture	Developed	Wooded	D-Livestock	D-HSTS	D-Wildlife
Existing load to stream	2,665,164	2,053,282	1,722	18,959	3729.9	7349.4	103
Percent reduction	0%	0%	0%	0%	100%	100%	0%
Target annual load	2,665,164	2,053,282	1,722	18,959	0.0	0.0	103
Point source NPDES WLA							
Facility Name	NPDES OEPA ID	Ex Flow Avg MGD	Dgn Q MGD	Limit C cfu/100mL	WLA billion/ day		
Washington Court House WWTP	4PD00002	3.03	6	126	28.618		
Washington CH MS4 (1.9sqmi)	4GQ00027	Stormwater	Stormwater	N/A	41.831		
Flakes Ford WWTP	4PG0000	0.01	0.01375	126	0.066		
Proposed Good Hope WWTP	N/A	0.00	0.032	126	0.153		
Upstream unit WLA(Paint)	Various	N/A	N/A	N/A	75.488		
Upstream unit WLA(EFork)	Various	N/A	N/A	N/A	30.371		
Upstream unit WLA(Sugar)	Various	N/A	N/A	N/A	3.047		

Table D4-9. Paint Creek upstream City of Greenfield to Paint Creek Lake *E. coli* TMDL and organic enrichment TMDL using *E. coli* as a surrogate.

***E. coli* requirements for HUC-12 050600030602**							
***E. coli* Recreation Season TMDL components and target export load - billion cfu/day**							
TMDL components	TMDL	MOS	LA	Σ WLA	AFG	90th% target export	
HUC-12 / sub-watershed	203.5	10.2	185.2	7.63	0.44	37044.6	
Cumulative watershed	6288.5	314.4	5782.7	187.05	4.39		
Non-point source LA reductions (% of existing recreation season load contribution)							
Washoff / direct source	Crop	Pasture	Developed	Wooded	D-Livestock	D-HSTS	D-Wildlife
Percent reduction	0%	0%	0%	0%	100%	100%	0%
Point source NPDES WLA							
Facility Name	NPDES OEPA ID	Existing MGD	Dgn Q MGD	Limit C cfu/100mL	WLA billion/day		
MMM Bluerock Quarry	4IJ00021	Stormwater	Stormwater	0	0.000		
Greenfield WWTP	1PD00022	0.99	1.6	126	7.631		
Upstream allocation unit WLA	Various	N/A	N/A	N/A	179.420		

Table D4-10. Paint Creek headwaters total phosphorus TMDL.

Total Phosphorus requirements for HUC-12 050600030101 (Paint Creek Headwaters)							
Total Phosphorus Annual TMDL components and target export load - kg/day							
TMDL components	TMDL	MOS	LA	Σ WLA	AFG	90th% target export	
HUC-12 / sub-watershed	315.9	15.8	299.4	0.00	0.73	237.3	
Cumulative watershed	315.9	15.8	299.4	0.00	0.73		
Non-point source LA reductions (% of existing recreation season load contribution)							
Washoff / direct source	Crop	Pasture	Developed	Wooded	D-Livestock	D-HSTS	D-Wildlife
Percent reduction	45%	0%	0%	0%	100%	100%	0%
Point source NPDES WLA							
Facility Name	NPDES OEPA ID	Ex Flow Av MGD	Dgn Q MGD	Limit C mg/L	WLA kg/day		
None	N/A	N/A	N/A	N/A	0.000		

Table D4-11. East Fork Paint Creek TMDLs for dissolved oxygen stresses using total phosphorus as a surrogate parameter.

Total Phosphorus requirements for HUC-12 050600030102 (East Fork Paint Creek)							
Total Phosphorus Annual TMDL components and target export load - kg/day							
TMDL components	TMDL	MOS	LA	Σ WLA	AFG	90th% target export	
HUC-12 / sub-watershed	471.0	23.6	370.1	76.15	1.19	330.3	
Cumulative watershed	471.0	23.6	370.1	76.15	1.19		
Non-point source LA reductions (% of existing recreation season load contribution)							
Washoff / direct source	Crop	Pasture	Developed	Wooded	D-Livestock	D-HSTS	D-Wildlife
Percent reduction	45%	0%	0%	0%	100%	100%	0%
Point source NPDES WLA							
Facility Name	NPDES OEPA ID	Ex Flow Av MGD	Dgn Q MGD	Limit C mg/L	WLA kg/day		
Stardust Dairy CAFO	4IK00027	Stormwater	N/A	N/A	0.000		
Bloomingburg WWTP*	4PB00025	0.13	0.25	1.5	1.420		
ASA Ethanol Industrial	4IN00196	0.35	0.758	0.1	0.287		
Washington CH MS4(1.3sqmi,20%area)	4GQ00027	Stormwater	N/A	N/A	74.440		

*The model indicates that dissolved oxygen depletion on East Fork Paint Creek in areas between its mouth and the Bloomingburg WWTP can be effectively lessened through appropriate channel maintenance. If the channel modifications efforts are proven to increase pollutant flushing without degrading the stream banks or floodplain connectivity, Bloomingburg WWTP can discharge phosphorus at an average 2.0 mg/L. This concentration is within range of current operations and facilities, and will provide a 1.893 kg/day WLA. Refer to the Habitat/QHEI TMDL section

Table D4.12. Paint Creek between East Fork and I-71 TMDLs for nutrient enrichment and dissolved oxygen stresses using total phosphorus as a direct (nutrient enrichment) and surrogate (dissolved oxygen) parameter.

Total Phosphorus requirements for HUC-12 050600030103 (Paint Creek upst East Fork)							
Total Phosphorus Annual TMDL components and target export load - kg/day							
TMDL components	TMDL	MOS	LA	Σ WLA	AFG	90th% target export	
HUC-12 / sub-watershed	276.3	13.8	186.3	73.04	3.16	426.1	
Cumulative watershed	591.9	29.6	485.4	73.04	3.89		
Non-point source LA reductions (% of existing recreation season load contribution)							
Washoff / direct source	Crop	Pasture	Developed	Wooded	D-Livestock	D-HSTS	D-Wildlife
Percent reduction	60%	0%	0%	0%	100%	100%	0%
Point source NPDES WLA							
Facility Name	NPDES OEPA ID	Ex Flow Av MGD	Dgn Q MGD	Limit C mg/L	WLA kg/day		
Prairie Knolls MHP	4PV00115	0.01	0.01	3	0.114		
Miami Trace High School	4PT00121	0.01	Abandoned	0	0.000		
Washington Court House WTP Intake	OH2400714	With-drawal	N/A	N/A	N/A		
Washington Court House WTP Backwash	4GW00002	Inter-mittent	0.1008	N/A	N/A		
BP Amoco Stormwater	4IN00171	Storm-water	N/A	N/A	N/A		
Washington CH MS4(Paint upst EF)	4GQ00027	Storm-water	N/A	N/A	27.504		
Washington Court House SSO	4PD00002	SSO	N/A	0	0.000		
Washington CH WWTP (outlet as is)*	4PD00002	3.03	6	1	22.712		
Washington CH WWTP(reloc outlet)*	4PD00002	3.03	6	variable 4-2	45.425		

*The relocation of the Washington Court House WWTP 001 outfall from its current location to 2000 feet downstream at the East Fork Paint Creek confluence is a beneficial option for controlling both localized eutrophication and pathogen issues within this city park zone. Although the next downstream assessment site is in Partial attainment (EWH criteria), it has been listed as a natural flow/habitat issue since the site's biologic indices strongly meet WWH criteria it is near the EWH/WWH boundary. For the purpose of this TMDL, it is sufficient to eliminate the outfall as a major eutrophication source of Paint Creek upstream East Fork. In order to ensure that phosphorus loading to Paint Lake does not increase due to further development of Washington Court House, the current average phosphorus load estimate is used as this optional outfall relocation TMDL. Based on downstream biologic assessment and model results, the current average concentration (~4mg/L based on 2005 to 2010 DMR data) is an acceptable level with current average flow discharge. This requirement is within range of current operation and facilities with the exception that work needs done on the sewer network's I/I problems. However, the WWTP must maintain the allocated WLA as future development occurs. This will result in an average 2 mg/L permit limit when the Washington Court House WWTP is treating its design 6 MGD average flow capacity. Note that a future assessment of Paint Lake's eutrophic level may indicate that more phosphorus load reduction is required.

Table D4-13. Sugar Creek upstream Creamer Rd. TMDLs for nutrient enrichment and dissolved oxygen using total phosphorus as a direct (nutrient enrichment) and surrogate (dissolved oxygen) parameter.

Total Phosphorus requirements for HUC-12 050600030201 (Sugar Creek Headwaters)							
Total Phosphorus Annual TMDL components and target export load - kg/day							
TMDL components	TMDL	MOS	LA	Σ WLA	AFG	90th% target export	
HUC-12 / sub-watershed	349.7	17.5	329.4	1.89	0.86	272.9	
Cumulative watershed	349.7	17.5	329.4	1.89	0.86		
Non-point source LA reductions (% of existing recreation season load contribution)							
Washoff / direct source	Crop	Pasture	Developed	Wooded	D-Livestock	D-HSTS	D-Wildlife
Percent reduction	45%	0%	0%	0%	100%	0%	0%
Point source NPDES WLA							
Facility Name		NPDES OEPA ID	Ex Flow Av MGD	Dgn Q MGD	Limit C mg/L	WLA kg/day	
Jeffersonville WWTP*		4PB00108	0.35	0.5	1.0	1.893	

*The model indicates that dissolved oxygen depletion on Sugar between Creamer Rd area and the Jeffersonville WWTP can be effectively lessened through appropriate channel maintenance. If the channel modifications efforts are proven to increase pollutant flushing without degrading the stream banks or floodplain connectivity, Jeffersonville WWTP can discharge phosphorus at an average 2.0 mg/L. This concentration is within range of current operations and facilities, and will provide a 3.785 kg/day WLA. Refer to the Habitat/QHEI TMDL section.

Table D4-14. Sugar Creek between US-22 and Ford Rd. total phosphorus TMDL.

Total Phosphorus requirements for HUC-12 050600030202 (Partial zone, Sugar Ck upst US-22)							
Total Phosphorus Annual TMDL components and target export load - kg/day							
TMDL components	TMDL	MOS	LA	Σ WLA	AFG	90th% target export	
HUC-12 / sub-watershed	117.6	5.9	111.6	0.00	0.10	324.8	
Cumulative watershed	471.5	23.6	445.0	1.89	0.96		
Non-point source LA reductions (% of existing recreation season load contribution)							
Washoff / direct source	Crop	Pasture	Developed	Wooded	D-Livestock	D-HSTS	D-Wildlife
Percent reduction	45%	0%	0%	0%	100%	100%	0%
Point source NPDES WLA							
Facility Name		NPDES OEPA ID	Ex Flow Av MGD	Dgn Q MGD	Limit C mg/L	WLA kg/day	
Upstream subwatershed WLAs		N/A	N/A	N/A	N/A	1.893	

Table D4-15. Indian Creek total phosphorus TMDL.

Total Phosphorus requirements for HUC-12 050600030601 (Partial zone, Indian Creek only)							
Total Phosphorus Annual TMDL components and target export load - kg/day							
TMDL components	TMDL	MOS	LA	Σ WLA	AFG	90th% target export	
HUC-12 / sub-watershed	308.9	15.4	293.2	0.24	0.02	45.6	
Cumulative watershed	308.9	15.4	293.2	0.24	0.02		
Non-point source LA reductions (% of existing recreation season load contribution)							
Washoff / direct source	Crop	Pasture	Developed	Wooded	D-Livestock	D-HSTS	D-Wildlife
Percent reduction	45%	0%	0%	0%	100%	0%	0%
Point source NPDES WLA							
Facility Name		NPDES OEPA ID	Ex Flow Av MGD	Dgn Q MGD	Limit C mg/L	WLA kg/day	
Proposed Good Hope WWTP		N/A	0.00	0.032	2	0.242	

D4.2 Habitat and sediment (QHEI) results

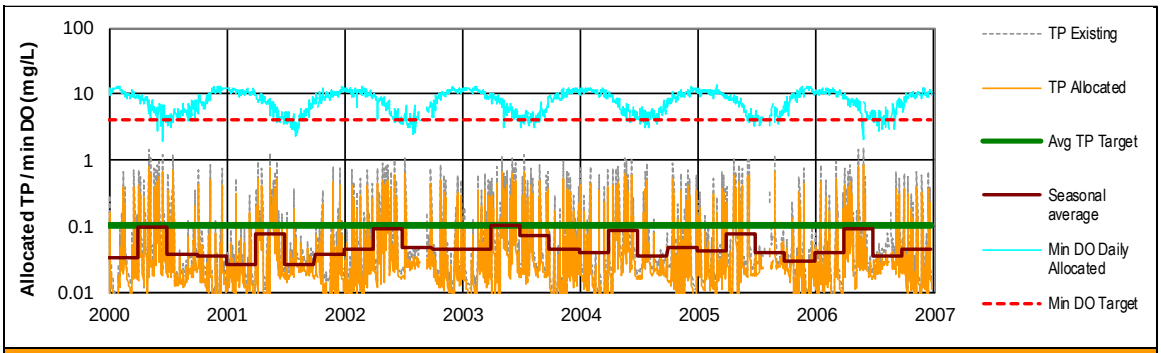
This subsection includes tables D4-16 through D4-39 showing the results from the habitat and sediment TMDLs. Figures D4-1 through D4-6 show phosphorus reduction, channel shading, and channel modifications considerations that have been calculated for the habitat HUCs that were part of the LSPC modeling.

Table D4-16. Paint Creek headwaters bedload and habitat TMDL.

Bedload and Habitat Daily Load Requirements - HUC12 - 050600030101							
Paint Creek dst SR-323 RM 96.0							
Bedload TMDL (WWH designation)				Habitat TMDL (WWH designation)			
Substrate	Channel	Riparian	TMDL	QHEI	Mod Attrib	High Impact	TMDL
Target ≥ 13	Target ≥ 14	Target ≥ 5	Target ≥ 32	Target ≥ 60	Target < 5	Target < 2	Target = 3
12.5	13.5	7.5	33.5 (None% deviation)	65.5	6	0	1 Below

Table D4-17. East Fork Paint Creek headwaters bedload and habitat TMDL (see related oxygen information).

Bedload and Habitat Daily Load Requirements - HUC12 - Upper 050600030102							
East Fork Paint Creek at Lewis Rd RM 8.6							
Bedload TMDL (WWH designation)				Habitat TMDL (WWH designation)			
Substrate	Channel	Riparian	TMDL	QHEI	Mod Attrib	High Impact	TMDL
Target ≥ 13	Target ≥ 14	Target ≥ 5	Target ≥ 32	Target ≥ 60	Target < 5	Target < 2	Target = 3
6	8.5	3.5	18 (44% deviation)	44	8	1	2 Below
Vallery Ditch at RM 2.3							
Bedload TMDL (MWH designation)				Habitat TMDL (MWH designation)			
Substrate	Channel	Riparian	TMDL	QHEI	Mod Attrib	High Impact	TMDL
Target ≥ ?	Target ≥ ?	Target ≥ ?	Target ≥ ?	Target ≥ ?	Target < ?	Target < ?	Target = 3
13.5	11	3.5	-	56	6	1	-
William Cathart Ditch at RM 0.2							
Bedload TMDL (WWH designation)				Habitat TMDL (WWH designation)			
Substrate	Channel	Riparian	TMDL	QHEI	Mod Attrib	High Impact	TMDL
Target ≥ 13	Target ≥ 14	Target ≥ 5	Target ≥ 32	Target ≥ 60	Target < 5	Target < 2	Target = 3
12	10	4	26 (19% deviation)	50	6	2	3 Below

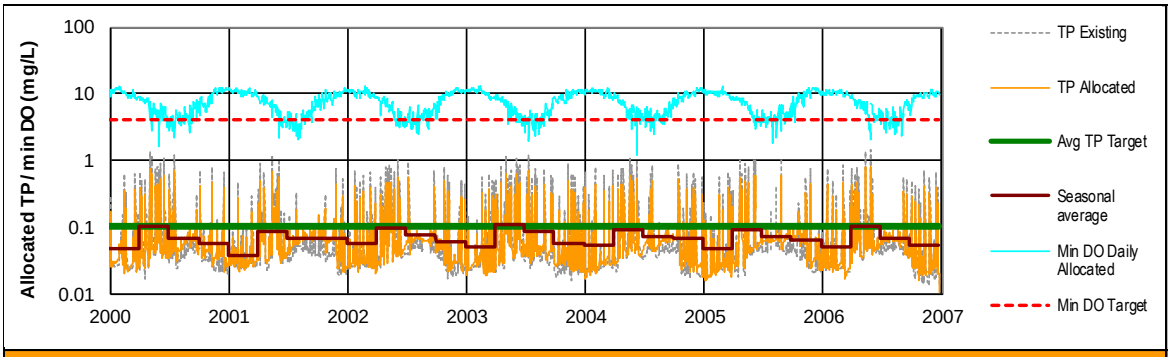


Sub-watershed seasonal TP, May-October DO, and annual NHx results						
TP < 0.1	January - March		April - June	July - September	October - November	
TP existing	0.06		0.15	0.07	0.07	
TP allocated	0.04		0.09	0.04	0.04	
Min oxygen / max ammonia criteria			Existing concentrations		TMDL concentrations	
DO Summer min criteria	> 4		DO 30 day min existing	2.7	DO 30 day min result	4.0
NH_x Annual max criteria	< 12.6		NH_x max existing level	0.29	NH_x max result	0.29

Figure D4-1. East Fork Paint Creek headwaters bedload and habitat TMDL – HSPF results for East Fork Paint Creek upstream Lewis Rd with phosphorus reduction and channel shading.

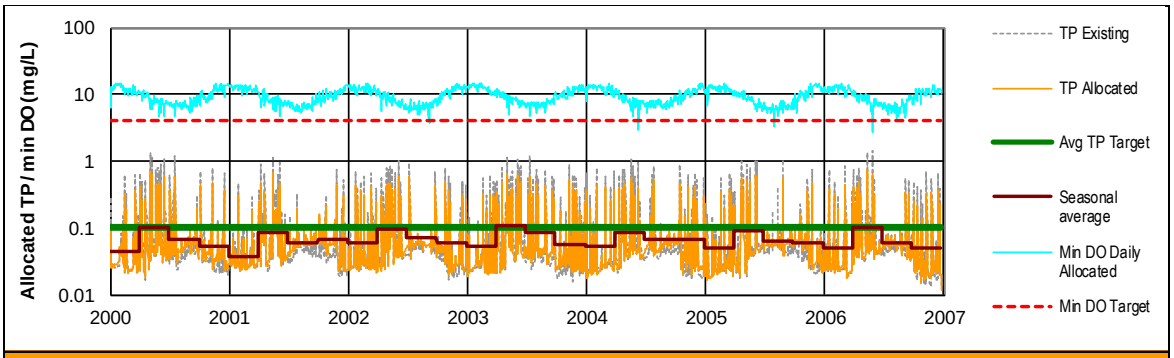
Table D4-18. East Fork Paint Creek bedload and habitat TMDL (see related oxygen information).

Bedload and Habitat Daily Load Requirements - HUC12 - Lower 050600030102							
East Fork Paint Creek at US-22 RM 0.72							
Bedload TMDL (WWH designation)				**Habitat TMDL (WWH designation)**			
Substrate	Channel	Riparian	TMDL	QHEI	Mod Attrib	High Impact	TMDL
Target ≥ 13	Target ≥ 14	Target ≥ 5	Target ≥ 32	Target ≥ 60	Target < 5	Target < 2	Target = 3
12.5	12	7	31.5 (2% deviation)	63	5	0	1 Below
East Fork Paint Creek at Matthews Rd RM 5.1							
Bedload TMDL (WWH designation)				**Habitat TMDL (WWH designation)**			
Substrate	Channel	Riparian	TMDL	QHEI	Mod Attrib	High Impact	TMDL
Target ≥ 13	Target ≥ 14	Target ≥ 5	Target ≥ 32	Target ≥ 60	Target < 5	Target < 2	Target = 3
7	12	4.5	23.5 (27% deviation)	56	7	1	2 Below
Big Run at Lewis Rd RM 1.8							
Bedload TMDL (WWH designation)				**Habitat TMDL (WWH designation)**			
Substrate	Channel	Riparian	TMDL	QHEI	Mod Attrib	High Impact	TMDL
Target ≥ 13	Target ≥ 14	Target ≥ 5	Target ≥ 32	Target ≥ 60	Target < 5	Target < 2	Target = 3
12	7	4	23 (28% deviation)	43	6	3	3 Below



Sub-watershed seasonal TP, May-October DO, and annual NHx results						
TP < 0.1	January - March		April - June	July - September		October - November
TP existing	0.07		0.16	0.08		0.07
TP allocated	0.05		0.10	0.07		0.06
Min oxygen / max ammonia criteria			Existing concentrations		TMDL concentrations	
DO Summer min criteria		> 4	DO 30 day min existing	3.4	DO 30 day min result	3.8
NH_x Annual max criteria		< 9.1	NH_x max existing level	0.53	NH_x max result	0.28

Figure D4-2. East Fork Paint Creek bedload and habitat TMDL – HSPF results for East Fork Paint Creek between Lewis Rd and Matthews Rd with phosphorus reduction and channel shading



Sub-watershed seasonal TP, May-October DO, and annual NHx results					
TP < 0.1	January - March	April - June	July - September	October - November	
TP existing	0.07	0.16	0.08	0.07	
TP allocated	0.05	0.10	0.07	0.06	
Min oxygen / max ammonia criteria		Existing concentrations		TMDL concentrations	
DO Summer min criteria	> 4	DO 30 day min existing	3.4	DO 30 day min result	6.1
NH_x Annual max criteria	< 9.1	NH_x max existing level	0.53	NH_x max result	0.24

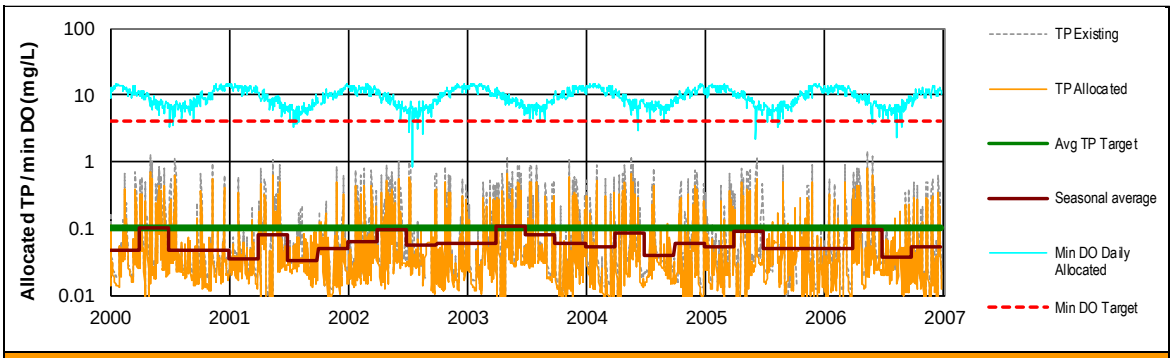
Figure D4-3. East Fork Paint Creek bedload and habitat TMDL – HSPF results for East Fork Paint Creek between Matthews Rd and Paint Creek with phosphorus reduction and channel modifications (minimum DO criteria met with Bloomingburg WWTP discharging 2 mg/L TP average, pending habitat improvements and aquatic attainment).

Table D4-19. Paint Creek North of Washington Court House bedload and habitat TMDL.

Bedload and Habitat Daily Load Requirements - HUC12 - Upper 050600030103							
Paint Creek adjacent to YMCA Washington CH off SR-41 RM 73.3							
Bedload TMDL (WWH designation)				Habitat TMDL (WWH designation)			
Substrate	Channel	Riparian	TMDL	QHEI	Mod Attrib	High Impact	TMDL
Target ≥ 13	Target ≥ 14	Target ≥ 5	Target ≥ 32	Target ≥ 60	Target < 5	Target < 2	Target = 3
12.5	13.5	4	30 (6% deviation)	66	5	0	1 Below
Paint Creek at Bloomingburg-New Holland Rd RM 75.3							
Bedload TMDL (WWH designation)				Habitat TMDL (WWH designation)			
Substrate	Channel	Riparian	TMDL	QHEI	Mod Attrib	High Impact	TMDL
Target ≥ 13	Target ≥ 14	Target ≥ 5	Target ≥ 32	Target ≥ 60	Target < 5	Target < 2	Target = 3
11.5	17	10	38.5 (-% deviation)	77	4	0	Achieved
Paint Creek adjacent to Wildwood Rd RM 79.86							
Bedload TMDL (WWH designation)				Habitat TMDL (WWH designation)			
Substrate	Channel	Riparian	TMDL	QHEI	Mod Attrib	High Impact	TMDL
Target ≥ 13	Target ≥ 14	Target ≥ 5	Target ≥ 32	Target ≥ 60	Target < 5	Target < 2	Target = 3
14.5	11.5	3.5	29.5 (8% deviation)	62	7	0	1 Below

Table D4-20. Paint Creek Washington Court House bedload and habitat TMDL (see related oxygen information).

Bedload and Habitat Daily Load Requirements - HUC12 - Lower 050600030103							
Paint Creek 0.3 miles downstream Washington CH WWTP RM 69.35							
Bedload TMDL (WWH designation)				**Habitat TMDL (WWH designation)**			
Substrate	Channel	Riparian	TMDL	QHEI	Mod Attrib	High Impact	TMDL
Target ≥ 13	Target ≥ 14	Target ≥ 5	Target ≥ 32	Target ≥ 60	Target < 5	Target < 2	Target = 3
12	5.5	3.5	21 (34% deviation)	40.5	7	2	3 Below
Paint Creek at Elm Street RM 69.52							
Bedload TMDL (WWH designation)				**Habitat TMDL (WWH designation)**			
Substrate	Channel	Riparian	TMDL	QHEI	Mod Attrib	High Impact	TMDL
Target ≥ 13	Target ≥ 14	Target ≥ 5	Target ≥ 32	Target ≥ 60	Target < 5	Target < 2	Target = 3
11.5	5	3.5	20 (38% deviation)	38	6	2	3 Below
Paint Creek at Eyeman Park Drive dst lowhead dam RM 71.16							
Bedload TMDL (WWH designation)				**Habitat TMDL (WWH designation)**			
Substrate	Channel	Riparian	TMDL	QHEI	Mod Attrib	High Impact	TMDL
Target ≥ 13	Target ≥ 14	Target ≥ 5	Target ≥ 32	Target ≥ 60	Target < 5	Target < 2	Target = 3
15	14	3.5	32.5 (-% deviation)	64.5	1	0	Achieved

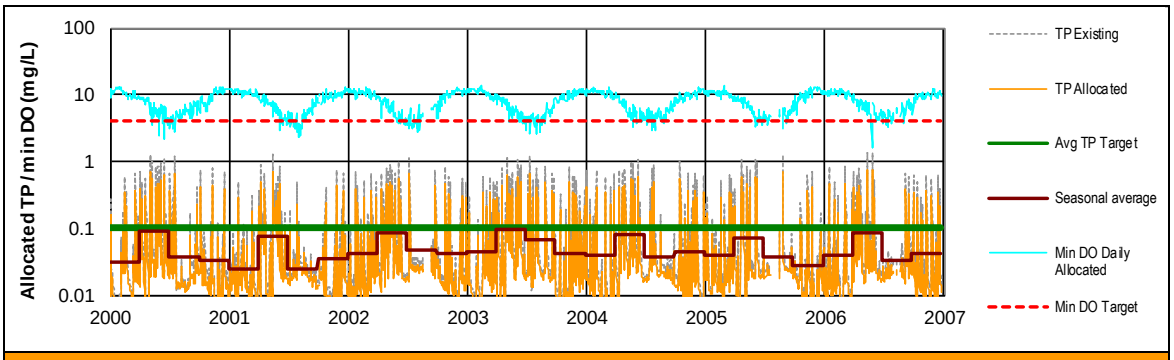


Sub-watershed seasonal TP, May-October DO, and annual NHx results						
TP < 0.1	January - March		April - June	July - September		October - November
TP existing	0.08		0.17	0.07		0.08
TP allocated	0.05		0.09	0.05		0.05
Min oxygen / max ammonia criteria			Existing concentrations		TMDL concentrations	
DO Summer min criteria		> 4	DO 30 day min existing	2.3	DO 30 day min result	5.7
NH_x Annual max criteria		< 5.9	NH_x max existing level	1.63	NH_x max result	0.37

Figure D4-4. Paint Creek Washington Court House bedload and habitat TMDL – HSPF results for Paint Creek upstream of Washington Court House's WWTP with phosphorus reduction and channel modifications.

Table D4-21. Sugar Creek headwaters bedload and habitat TMDL (see related oxygen information).

Bedload and Habitat Daily Load Requirements - HUC12 - 050600030201							
Sugar Creek at McKillup Rd RM 29.21							
Bedload TMDL (WWH designation)				Habitat TMDL (WWH designation)			
Substrate	Channel	Riparian	TMDL	QHEI	Mod Attrib	High Impact	TMDL
Target ≥ 13	Target ≥ 14	Target ≥ 5	Target ≥ 32	Target ≥ 60	Target < 5	Target < 2	Target = 3
14.5	11.5	4	30 (6% deviation)	60	6	0	1 Below
Sugar Creek at Selsor Moon Rd RM 36.9							
Bedload TMDL (MWH designation)				Habitat TMDL (MWH designation)			
Substrate	Channel	Riparian	TMDL	QHEI	Mod Attrib	High Impact	TMDL
Target ≥ ?	Target ≥ ?	Target ≥ ?	Target ≥ ?	Target ≥ ?	Target < ?	Target < ?	Target = 3
12	9	3	-	38	7	3	-

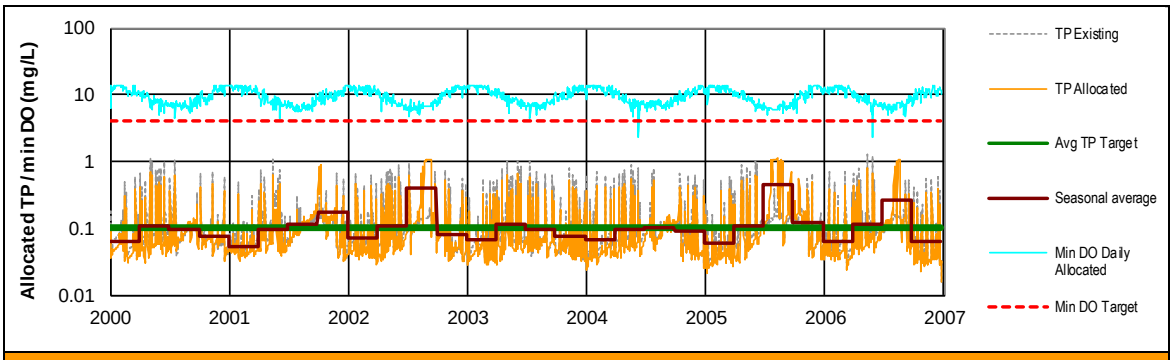


Sub-watershed seasonal TP, May-October DO, and annual NHx results						
TP < 0.1	January - March		April - June	July - September	October - November	
TP existing	0.06		0.15	0.06	0.06	
TP allocated	0.04		0.08	0.04	0.04	
Min oxygen / max ammonia criteria			Existing concentrations		TMDL concentrations	
DO Summer min criteria	> 4		DO 30 day min existing	3.1	DO 30 day min result	4.0
NH_x Annual max criteria	< 13		NH_x max existing level	0.30	NH_x max result	0.30

Figure D4-5. Sugar Creek headwaters bedload and habitat TMDL – HSPF results for Sugar Creek near McKillup Rd with phosphorus reduction and channel shading.

Table D4-22. Sugar Creek between Missouri Ditch and McKillup Rd bedload and habitat TMDL (see related oxygen information).

Bedload and Habitat Daily Load Requirements - HUC12 - Lower 050600030201							
Missouri Ditch at Harmony Rd RM 1.6							
Bedload TMDL (WWH designation)				Habitat TMDL (WWH designation)			
Substrate	Channel	Riparian	TMDL	QHEI	Mod Attrib	High Impact	TMDL
Target ≥ 13	Target ≥ 14	Target ≥ 5	Target ≥ 32	Target ≥ 60	Target < 5	Target < 2	Target = 3
9	11	4.5	24.5 (23% deviation)	50	6	1	2 Below
Sugar Creek at Creamer Rd RM 24.21							
Bedload TMDL (WWH designation)				Habitat TMDL (WWH designation)			
Substrate	Channel	Riparian	TMDL	QHEI	Mod Attrib	High Impact	TMDL
Target ≥ 13	Target ≥ 14	Target ≥ 5	Target ≥ 32	Target ≥ 60	Target < 5	Target < 2	Target = 3
11.5	10	3	24.5 (23% deviation)	48.5	7	1	2 Below



Sub-watershed seasonal TP, May-October DO, and annual NHx results				
TP < 0.1	January - March	April - June	July - September	October - November
TP existing	0.09	0.17	0.13	0.10
TP allocated	0.06	0.11	0.22	0.10

Min oxygen / max ammonia criteria		Existing concentrations		TMDL concentrations	
DO Summer min criteria	> 4	DO 30 day min existing	2.2	DO 30 day min result	6.2
NH_x Annual max criteria	< 7.3	NH_x max existing level	0.26	NH_x max result	1.10

Figure D4-6. Sugar Creek between Missouri Ditch and McKillup Rd bedload and habitat TMDL – HSPF results for Sugar Creek near Creamer Rd with phosphorus reduction, channel shading, and channel modifications (minimum DO criteria met with Jeffersonville WWTP discharging 2 mg/L TP average, pending habitat improvements and aquatic attainment).

Table D4-23. Sugar Creek from mouth to Missouri Ditch bedload and habitat TMDL.

Bedload and Habitat Daily Load Requirements - HUC12 - 050600030202							
Sugar Creek at Armbrust Rd RM 4.24							
Bedload TMDL (WWH designation)				**Habitat TMDL (WWH designation)**			
Substrate	Channel	Riparian	TMDL	QHEI	Mod Attrib	High Impact	TMDL
Target ≥ 13	Target ≥ 14	Target ≥ 5	Target ≥ 32	Target ≥ 60	Target < 5	Target < 2	Target = 3
17	15.5	6	38.5 (-% deviation)	76	2	0	Achieved
Sugar Creek at Mark Rd RM 5.4							
Bedload TMDL (WWH designation)				**Habitat TMDL (WWH designation)**			
Substrate	Channel	Riparian	TMDL	QHEI	Mod Attrib	High Impact	TMDL
Target ≥ 13	Target ≥ 14	Target ≥ 5	Target ≥ 32	Target ≥ 60	Target < 5	Target < 2	Target = 3
17	15.5	6.5	39 (-% deviation)	73	2	0	Achieved
Sugar Creek at US-22 RM 11.9							
Bedload TMDL (WWH designation)				**Habitat TMDL (WWH designation)**			
Substrate	Channel	Riparian	TMDL	QHEI	Mod Attrib	High Impact	TMDL
Target ≥ 13	Target ≥ 14	Target ≥ 5	Target ≥ 32	Target ≥ 60	Target < 5	Target < 2	Target = 3
15	14.5	5.5	35 (-% deviation)	69	1	0	Achieved
Sugar Creek at Ford Rd RM 18.48							
Bedload TMDL (designation)				**Habitat TMDL (designation)**			
Substrate	Channel	Riparian	TMDL	QHEI	Mod Attrib	High Impact	TMDL
Target ≥ 5	Target ≥ 2	Target ≥ 13	Target ≥ 14	Target ≥ 5	Target < 32	Target < 60	Target = 3
14.5	10.5	5	30 (6% deviation)	60.5	5	1	1 Below

Table D4-24. Paint Creek between East Fork and Sugar Creek bedload and habitat TMDL.

Bedload and Habitat Daily Load Requirements - HUC12 - Upper 050600030601							
Paint Creek at Flakes Ford Rd RM 63.3							
Bedload TMDL (EWH designation)				**Habitat TMDL (EWH designation)**			
Substrate	Channel	Riparian	TMDL	QHEI	Mod Attrib	High Impact	TMDL
Target ≥ 15	Target ≥ 15	Target ≥ 5	Target ≥ 35	Target ≥ 75	Target < 2	Target < 1	Target = 3
15.5	15	5.5	36 (-% deviation)	68.5	4	0	2 Below
Paint Creek adjacent Creek Rock Bridge RD RM 67.1							
Bedload TMDL (EWH designation)				**Habitat TMDL (EWH designation)**			
Substrate	Channel	Riparian	TMDL	QHEI	Mod Attrib	High Impact	TMDL
Target ≥ 15	Target ≥ 15	Target ≥ 5	Target ≥ 35	Target ≥ 75	Target < 2	Target < 1	Target = 3
12.5	10	7	29.5 (16% deviation)	61	8	0	2 Below

Table D4-25. Wilson Creek bedload and habitat TMDL.

Bedload and Habitat Daily Load Requirements - HUC12 - 050600030301							
Wilson Creek dst Sabina WWTP RM 2.8							
Bedload TMDL (WWH designation)				**Habitat TMDL (WWH designation)**			
Substrate	Channel	Riparian	TMDL	QHEI	Mod Attrib	High Impact	TMDL
Target ≥ 13	Target ≥ 14	Target ≥ 5	Target ≥ 32	Target ≥ 60	Target < 5	Target < 2	Target = 3
15	7	4	26 (19% deviation)	44	7	3	3 Below
Wilson Creek at Polk Rd RM 3.8							
Bedload TMDL (WWH designation)				**Habitat TMDL (WWH designation)**			
Substrate	Channel	Riparian	TMDL	QHEI	Mod Attrib	High Impact	TMDL
Target ≥ 13	Target ≥ 14	Target ≥ 5	Target ≥ 32	Target ≥ 60	Target < 5	Target < 2	Target = 3
7	8	4	19 (41% deviation)	43	7	3	3 Below
Tributary to Wilson Creek at US-22 RM 0.4							
Bedload TMDL (WWH designation)				**Habitat TMDL (WWH designation)**			
Substrate	Channel	Riparian	TMDL	QHEI	Mod Attrib	High Impact	TMDL
Target ≥ 13	Target ≥ 14	Target ≥ 5	Target ≥ 32	Target ≥ 60	Target < 5	Target < 2	Target = 3
6.5	7.5	4.5	18.5 (42% deviation)	33.5	10	3	3 Below

Table D4-26. Grassy Branch habitat TMDL as a surrogate for flow alteration.

Bedload and Habitat Daily Load Requirements - HUC12 - 050600030302							
Grassy Branch at Marchant-Luttrell RM 8.7							
Bedload TMDL (WWH designation)				**Habitat TMDL (WWH designation)**			
Substrate	Channel	Riparian	TMDL	QHEI	Mod Attrib	High Impact	TMDL
Target ≥ 13	Target ≥ 14	Target ≥ 5	Target ≥ 32	Target ≥ 60	Target < 5	Target < 2	Target = 3
9	6	3	18 (44% deviation)	33	9	4	3 Below

Table D4-27. West Branch Rattlesnake Creek sediment and habitat TMDL as surrogate for dissolved oxygen.

Bedload and Habitat Daily Load Requirements - HUC12 - 050600030303							
West Branch Rattlesnake Creek dst Wilson Ck RM 2.8							
Bedload TMDL (WWH designation)				**Habitat TMDL (WWH designation)**			
Substrate	Channel	Riparian	TMDL	QHEI	Mod Attrib	High Impact	TMDL
Target ≥ 13	Target ≥ 14	Target ≥ 5	Target ≥ 32	Target ≥ 60	Target < 5	Target < 2	Target = 3
10	8	3.5	21.5 (33% deviation)	46.5	8	0	2 Below
West Branch Rattlesnake Creek at SR-729 RM 4.3							
Bedload TMDL (WWH designation)				**Habitat TMDL (WWH designation)**			
Substrate	Channel	Riparian	TMDL	QHEI	Mod Attrib	High Impact	TMDL
Target ≥ 13	Target ≥ 14	Target ≥ 5	Target ≥ 32	Target ≥ 60	Target < 5	Target < 2	Target = 3
11.5	11.5	5	28 (13% deviation)	53	7	2	3 Below

Table D4-28. Rattlesnake Creek habitat TMDL and habitat as a surrogate for dissolved oxygen TMDL.

Bedload and Habitat Daily Load Requirements - HUC12 - 050600030304							
Rattlesnake Creek at SR-729 RM 31.5							
Bedload TMDL (WWH designation)				Habitat TMDL (WWH designation)			
Substrate	Channel	Riparian	TMDL	QHEI	Mod Attrib	High Impact	TMDL
Target ≥ 13	Target ≥ 14	Target ≥ 5	Target ≥ 32	Target ≥ 60	Target < 5	Target < 2	Target = 3
11.5	8.5	7	27 (16% deviation)	49	7	1	2 Below
Rattlesnake Creek at Milledgville-Octa Rd RM 35.4							
Bedload TMDL (WWH designation)				Habitat TMDL (WWH designation)			
Substrate	Channel	Riparian	TMDL	QHEI	Mod Attrib	High Impact	TMDL
Target ≥ 13	Target ≥ 14	Target ≥ 5	Target ≥ 32	Target ≥ 60	Target < 5	Target < 2	Target = 3
13	12	7	32 (0% deviation)	58	8	1	2 Below
Rattlesnake Creek at US-35 RM 38.1							
Bedload TMDL (WWH designation)				Habitat TMDL (WWH designation)			
Substrate	Channel	Riparian	TMDL	QHEI	Mod Attrib	High Impact	TMDL
Target ≥ 13	Target ≥ 14	Target ≥ 5	Target ≥ 32	Target ≥ 60	Target < 5	Target < 2	Target = 3
11.5	11.5	4.5	27.5 (14% deviation)	59.5	8	0	2 Below

Table D4-29. Rattlesnake Creek upstream Lee's Creek bedload and habitat TMDL.

Bedload and Habitat Daily Load Requirements - HUC12 - 050600030305							
Rattlesnake Creek at Zimmerman Rd RM 15.0							
Bedload TMDL (WWH designation)				Habitat TMDL (WWH designation)			
Substrate	Channel	Riparian	TMDL	QHEI	Mod Attrib	High Impact	TMDL
Target ≥ 13	Target ≥ 14	Target ≥ 5	Target ≥ 32	Target ≥ 60	Target < 5	Target < 2	Target = 3
17	15	7.5	39.5 (-% deviation)	71	4	0	Achieved
Rattlesnake Creek at Snow Hill Rd RM 24.0							
Bedload TMDL (WWH designation)				Habitat TMDL (WWH designation)			
Substrate	Channel	Riparian	TMDL	QHEI	Mod Attrib	High Impact	TMDL
Target ≥ 13	Target ≥ 14	Target ≥ 5	Target ≥ 32	Target ≥ 60	Target < 5	Target < 2	Target = 3
14.5	11	4.5	30 (6% deviation)	52	5	1	2 Below

Table D4-30. South Fork Lee's Creek bedload and habitat TMDL.

Bedload and Habitat Daily Load Requirements - HUC12 - 050600030401							
Tributary to Tributary to South Fork Lees Creek at Careytown Rd RM 0.2							
Bedload TMDL (WWH designation)				Habitat TMDL (WWH designation)			
Substrate	Channel	Riparian	TMDL	QHEI	Mod Attrib	High Impact	TMDL
Target ≥ 13	Target ≥ 14	Target ≥ 5	Target ≥ 32	Target ≥ 60	Target < 5	Target < 2	Target = 3
11	14	4.5	29.5 (8% deviation)	50.5	6	1	2 Below

Table D4-31. Lee's Creek bedload and habitat TMDL.

Bedload and Habitat Daily Load Requirements - HUC12 - 050600030403							
Tributary to Lees Creek at Thomas Rd RM 1.3							
Bedload TMDL (WWH designation)				Habitat TMDL (WWH designation)			
Substrate	Channel	Riparian	TMDL	QHEI	Mod Attrib	High Impact	TMDL
Target ≥ 13	Target ≥ 14	Target ≥ 5	Target ≥ 32	Target ≥ 60	Target < 5	Target < 2	Target = 3
17	17.5	3.5	38 (-% deviation)	66	2	0	Achieved

Table D4-32. Fall Creek bedload and habitat TMDL.

Bedload and Habitat Daily Load Requirements - HUC12 - 050600030406							
Fall Creek dst SR-138 RM 7.5							
Bedload TMDL (WWH designation)				Habitat TMDL (WWH designation)			
Substrate	Channel	Riparian	TMDL	QHEI	Mod Attrib	High Impact	TMDL
Target ≥ 13	Target ≥ 14	Target ≥ 5	Target ≥ 32	Target ≥ 60	Target < 5	Target < 2	Target = 3
7.5	16.5	5.5	29.5 (8% deviation)	58.5	6	1	2 Below

Table D4-33. Clear Creek bedload and habitat TMDL.

Bedload and Habitat Daily Load Requirements - HUC12 - 050600030502							
Clear Creek at Selph Rd RM 5.4							
Bedload TMDL (EWH designation)				Habitat TMDL (EWH designation)			
Substrate	Channel	Riparian	TMDL	QHEI	Mod Attrib	High Impact	TMDL
Target ≥ 15	Target ≥ 15	Target ≥ 5	Target ≥ 35	Target ≥ 75	Target < 2	Target < 1	Target = 3
14	8.5	4.5	27 (23% deviation)	59	7	1	3 Below
Clear Creek dst Hillsboro WWTP RM 6.6							
Bedload TMDL (EWH designation)				Habitat TMDL (EWH designation)			
Substrate	Channel	Riparian	TMDL	QHEI	Mod Attrib	High Impact	TMDL
Target ≥ 15	Target ≥ 15	Target ≥ 5	Target ≥ 35	Target ≥ 75	Target < 2	Target < 1	Target = 3
12.5	17	5.5	35 (0% deviation)	71.5	5	1	3 Below
Moberly Branch at US-62 RM 0.9							
Bedload TMDL (WWH designation)				Habitat TMDL (WWH designation)			
Substrate	Channel	Riparian	TMDL	QHEI	Mod Attrib	High Impact	TMDL
Target ≥ 13	Target ≥ 14	Target ≥ 5	Target ≥ 32	Target ≥ 60	Target < 5	Target < 2	Target = 3
15.5	13	4	32.5 (-% deviation)	66	6	1	1 Below

Table D4-34. Paint Creek between Sugar Creek and SR-753 bedload and habitat TMDL.

Bedload and Habitat Daily Load Requirements - HUC12 - Lower 050600030601							
Paint Creek at SR 753 RM 52.54							
Bedload TMDL (EWH designation)				Habitat TMDL (EWH designation)			
Substrate	Channel	Riparian	TMDL	QHEI	Mod Attrib	High Impact	TMDL
Target ≥ 15	Target ≥ 15	Target ≥ 5	Target ≥ 35	Target ≥ 75	Target < 2	Target < 1	Target = 3
17.5	17	7	41.5 (-% deviation)	78.5	3	0	1 Below
Indian Creek at Miami Trace Rd RM 1.6							
Bedload TMDL (WWH designation)				Habitat TMDL (WWH designation)			
Substrate	Channel	Riparian	TMDL	QHEI	Mod Attrib	High Impact	TMDL
Target ≥ 13	Target ≥ 14	Target ≥ 5	Target ≥ 32	Target ≥ 60	Target < 5	Target < 2	Target = 3
16.5	11	4.5	32 (0% deviation)	61.5	5	1	1 Below
Paint Creek at Miami Trace Rd RM 58.75							
Bedload TMDL (EWH designation)				Habitat TMDL (EWH designation)			
Substrate	Channel	Riparian	TMDL	QHEI	Mod Attrib	High Impact	TMDL
Target ≥ 15	Target ≥ 15	Target ≥ 5	Target ≥ 35	Target ≥ 75	Target < 2	Target < 1	Target = 3
17.5	17.5	6	41 (-% deviation)	83	2	0	1 Below
Wabash Creek at New Martinsburg Rd RM 0.8							
Bedload TMDL (designation)				Habitat TMDL (designation)			
Substrate	Channel	Riparian	TMDL	QHEI	Mod Attrib	High Impact	TMDL
Target ≥ 5	Target ≥ 2	Target ≥ 13	Target ≥ 14	Target ≥ 5	Target < 35	Target < 60	Target = 3
10.5	17	4	31.5 (2% deviation)	67	2	0	Achieved

Table D4-35. Paint Creek between Paint Lake and SR-753 bedload and habitat TMDL.

Bedload and Habitat Daily Load Requirements - HUC12 - 050600030602							
Paint Creek adjacent Washington St downstream Greenfield RM 48.7							
Bedload TMDL (EWH designation)				Habitat TMDL (EWH designation)			
Substrate	Channel	Riparian	TMDL	QHEI	Mod Attrib	High Impact	TMDL
Target ≥ 15	Target ≥ 15	Target ≥ 5	Target ≥ 35	Target ≥ 75	Target < 2	Target < 1	Target = 3
15.5	17	8.5	41 (-% deviation)	83	0	0	Achieved

Table D4-36. Sulphur Lick sediment and habitat TMDLs as a surrogate for dissolved oxygen.

Bedload and Habitat Daily Load Requirements - HUC12 - 050600030704							
Sulphur Lick at Spargersville Rd RM 1.5							
Bedload TMDL (WWH designation)				Habitat TMDL (WWH designation)			
Substrate	Channel	Riparian	TMDL	QHEI	Mod Attrib	High Impact	TMDL
Target ≥ 13	Target ≥ 14	Target ≥ 5	Target ≥ 32	Target ≥ 60	Target < 5	Target < 2	Target = 3
7	12	5.5	24.5 (23% deviation)	50.5	7	2	3 Below

Table D4-37. Buckskin Creek bedload and habitat TMDL.

Bedload and Habitat Daily Load Requirements - HUC12 - 050600030701							
Tributary to Buckskin Creek RM 0.2							
Bedload TMDL (WWH designation)				Habitat TMDL (WWH designation)			
Substrate	Channel	Riparian	TMDL	QHEI	Mod Attrib	High Impact	TMDL
Target ≥ 13	Target ≥ 14	Target ≥ 5	Target ≥ 32	Target ≥ 60	Target < 5	Target < 2	Target = 3
11.5	11.5	3.5	26.5 (17% deviation)	50.5	6	1	2 Below

Table D4-38. Oldtown Run bedload and habitat TMDL.

Bedload and Habitat Daily Load Requirements - HUC12 - 050600030903							
Oldtown Run at Clarksburg Pike RM 1.3							
Bedload TMDL (WWH designation)				Habitat TMDL (WWH designation)			
Substrate	Channel	Riparian	TMDL	QHEI	Mod Attrib	High Impact	TMDL
Target ≥ 13	Target ≥ 14	Target ≥ 5	Target ≥ 32	Target ≥ 60	Target < 5	Target < 2	Target = 3
10	9.5	5	24.5 (23% deviation)	56.5	7	1	2 Below

Table D4-39. Ralston Run bedload and habitat TMDL.

Bedload and Habitat Daily Load Requirements - HUC12 - 050600031002							
Ralston Run at Turner Rd RM 2.8							
Bedload TMDL (WWH designation)				Habitat TMDL (WWH designation)			
Substrate	Channel	Riparian	TMDL	QHEI	Mod Attrib	High Impact	TMDL
Target ≥ 13	Target ≥ 14	Target ≥ 5	Target ≥ 32	Target ≥ 60	Target < 5	Target < 2	Target = 3
4.5	13	5.5	23 (28% deviation)	44.5	8	4	3 Below

D4.3 Pathogen LDC method results

A summary of the bacteria TMDLs, wasteload allocation, load allocation, margin of safety, and allowance for future growth at each hydrologic condition is presented in Table D4-40.

Table D4-40. TMDL summary table (*E. coli* loads are expressed in billions of organisms per day).

Hydrologic Condition	High flows	Wet weather	Normal range	Dry weather	Low
Flow Duration Interval	0-5%	5-40%	40-80%	80-95%	95-100%
Wilson Ck Dst Sabina WWTP		**HUC12: 05060003 03 01**			
Total Maximum Daily Load	588.4	74.2	13.4	1.8	0.5
Wasteload Allocation	2.32	2.32	2.32	1.42	0.42
Load Allocation	456.6	55.6	8.1	0	0
Margin of Safety	117.7	14.8	2.7	0.4	0.1
Allowance for future growth	11.77	1.48	0.27	0.04	0.01
Total load reduction required	No Data	65.8%	61.9%	93.0%	No Data
W Br Rattlesnake Ck downstream Wilson Ck		**HUC12: 005060003 03 03**			
Total Maximum Daily Load	1330.3	167.8	30.2	4.0	1.2
Wasteload Allocation	2.32	2.32	2.32	2.32	0.92
Load Allocation	1035.3	128.6	21.2	0.8	0
Margin of Safety	266.1	33.6	6.0	0.8	0.2
Allowance for future growth	26.61	3.36	0.60	0.08	0.02
Total load reduction required	No Data	None	None	80.2%	No Data
Rattlesnake Ck @ Milledgeville-Octa Rd.		**HUC12: 05060003 03 04**			
Total Maximum Daily Load	1087.3	137.1	24.7	3.3	0.9
Wasteload Allocation	3.64	3.64	3.64	2.54	0.74
Load Allocation	844.4	103.3	15.6	0	0
Margin of Safety	217.5	27.4	4.9	0.7	0.2
Allowance for future growth	21.75	2.74	0.49	0.07	0.02
Total load reduction required	No Data	None	31.4%	None	No Data
Rattlesnake Ck W of New Martinsburg, upst Zimmerman Rd.		**HUC12: 05060003 03 05**			
Total Maximum Daily Load	3997.3	504.2	90.8	12.1	3.5
Wasteload Allocation	5.96	5.96	5.96	5.96	2.76
Load Allocation	3111.9	387.3	64.9	3.4	0
Margin of Safety	799.5	100.8	18.2	2.4	0.7
Allowance for future growth	79.95	10.08	1.82	0.24	0.07
Total load reduction required	No Data	52.1%	43.8%	88.0%	No Data
S Fk Lees Ck @ Hixon Rd		**HUC12: 05060003 04 01**			
Total Maximum Daily Load	508.5	64.1	11.5	1.5	0.4
Wasteload Allocation	0.00	0.00	0.00	0.00	0.00
Load Allocation	396.6	50.0	9.0	1.2	0.3
Margin of Safety	101.7	12.8	2.3	0.3	0.1
Allowance for future growth	10.17	1.28	0.23	0.03	0.01
Total load reduction required	96.5%	99.7%	No Data	91.6%	No Data
Lees Ck @ Monroe Rd E of Leesburg		**HUC12: 05060003 04 03**			
Total Maximum Daily Load	2200.8	83.9	13.0	4.8	4.0
Wasteload Allocation	2.44	2.44	2.44	2.44	2.44
Load Allocation	1714.1	63.0	7.7	1.3	0.7
Margin of Safety	440.2	16.8	2.6	1.0	0.8
Allowance for future growth	44.02	1.68	0.26	0.10	0.08
Total load reduction required	97.2%	86.7%	None	None	None

Table D4-40 (cont.). TMDL summary table (*E. coli* loads are expressed in billions of organisms/day).

Hydrologic Condition	High flows	Wet weather	Normal range	Dry weather	Low
Walnut Ck @ Walnut Ck Rd.		**HUC12: 05060003 04 04**			
Total Maximum Daily Load	182.3	23.0	4.1	0.6	0.2
Wasteload Allocation	0.00	0.00	0.00	0.00	0.00
Load Allocation	142.2	17.9	3.2	0.4	0.1
Margin of Safety	36.5	4.6	0.8	0.1	0.03
Allowance for future growth	3.65	0.46	0.08	0.01	0.003
Total load reduction required	100.0%	100.0%	No Data	85.6%	No Data
Rattlesnake Ck @ Centerfield Rd.		**HUC12: 05060003 04 07**			
Total Maximum Daily Load	6683.4	843.0	151.9	20.1	5.9
Wasteload Allocation	2.44	2.44	2.44	2.44	2.44
Load Allocation	5210.6	655.1	116.0	13.3	2.2
Margin of Safety	1,336.7	168.6	30.4	4.0	1.18
Allowance for future growth	133.67	16.86	3.04	0.40	0.12
Total load reduction required	97.5%	88.2%	None	None	None
Clear Ck Dst Hillsboro WWTP		**HUC12: 05060003 05 02**			
Total Maximum Daily Load	517.4	69.0	30.6	25.2	24.4
Wasteload Allocation	18.89	18.89	18.89	18.89	18.89
Load Allocation	384.7	34.9	5.0	0.8	0.2
Margin of Safety	103.5	13.8	6.1	5.0	4.88
Allowance for future growth	10.35	1.38	0.61	0.50	0.488
Total load reduction required	99.8%	98.4%	No Data	None	No Data
Rocky Fk @ SR 124, upst Rocky Fk Lake, DST WWTP HUC12: 05060003 05 03					
Total Maximum Daily Load	606.2	60.9	14.3	7.7	6.8
Wasteload Allocation	1.48	1.48	1.48	1.48	1.48
Load Allocation	471.3	46.0	9.7	4.5	3.8
Margin of Safety	121.2	12.2	2.9	1.5	1.35
Allowance for future growth	12.12	1.22	0.29	0.15	0.135
Total load reduction required	99.8%	99.6%	No Data	89.7%	No Data
Rocky Fk @ Browning Rd nr Barretts Mill		**HUC12: 05060003 05 05**			
Total Maximum Daily Load	1764.3	324.8	84.3	37.8	29.2
Wasteload Allocation	20.62	20.62	20.62	20.62	20.62
Load Allocation	1355.6	232.7	45.2	8.9	2.1
Margin of Safety	352.9	65.0	16.9	7.6	5.83
Allowance for future growth	35.29	6.50	1.69	0.76	0.583
Total load reduction required	95.9%	70.2%	None	None	None
Trib. to Buckskin Ck (@ RM 12.25) @ McCann Rd. HUC12: 05060003 07 01					
Total Maximum Daily Load	53.6	5.4	1.3	0.7	0.6
Wasteload Allocation	0.00	0.00	0.00	0.00	0.00
Load Allocation	41.8	4.2	1.0	0.5	0.5
Margin of Safety	10.7	1.1	0.3	0.1	0.12
Allowance for future growth	1.07	0.11	0.03	0.01	0.012
Total load reduction required	No Data	No Data	57.8%	45.4%	No Data

Table D4-40 (cont.). TMDL summary table (*E. coli* loads are expressed in billions of organisms/day).

Hydrologic Condition	High flows	Wet weather	Normal range	Dry weather	Low
Upper Twin Ck @ Upper Twin Creek Rd W of Bourneville HUC12: 05060003 07 02					
Total Maximum Daily Load	189.6	19.0	4.5	2.4	2.1
Wasteload Allocation	0.00	0.00	0.00	0.00	0.00
Load Allocation	147.9	14.9	3.5	1.9	1.6
Margin of Safety	37.9	3.8	0.9	0.5	0.42
Allowance for future growth	3.79	0.38	0.09	0.05	0.042
Total load reduction required	No Data	No Data	82.2%	81.9%	No Data
Lower Twin Ck @ Farm off Lower Twin Rd. HUC12: 05060003 07 03					
Total Maximum Daily Load	233.1	23.4	5.5	3.0	2.6
Wasteload Allocation	0.00	0.00	0.00	0.00	0.00
Load Allocation	181.9	18.3	4.3	2.3	2.0
Margin of Safety	46.6	4.7	1.1	0.6	0.52
Allowance for future growth	4.66	0.47	0.11	0.06	0.052
Total load reduction required	No Data	No Data	61.6%	None	No Data
Massie Run @ US RT 50 W of Bainbridge HUC12: 05060003 07 04					
Total Maximum Daily Load	76.2	7.6	1.8	1.0	0.8
Wasteload Allocation	0.00	0.00	0.00	0.00	0.00
Load Allocation	59.4	6.0	1.4	0.7	0.6
Margin of Safety	15.2	1.5	0.4	0.2	0.17
Allowance for future growth	1.52	0.15	0.04	0.02	0.017
Total load reduction required	No Data	No Data	68.6%	89.7%	No Data
Thompson Ck @ Wissler Rd. HUC12: 05060003 08 01					
Total Maximum Daily Load	110.0	14.3	2.6	0.6	0.3
Wasteload Allocation	0.00	0.00	0.00	0.00	0.00
Load Allocation	85.8	11.1	2.0	0.4	0.3
Margin of Safety	22.0	2.9	0.5	0.1	0.07
Allowance for future growth	2.20	0.29	0.05	0.01	0.007
Total load reduction required	No Data	No Data	58.7%	65.7%	No Data
Compton Ck @ Washington Waterloo Rd. HUC12: 05060003 08 03					
Total Maximum Daily Load	349.7	45.4	8.2	1.7	1.1
Wasteload Allocation	0.00	0.00	0.00	0.00	0.00
Load Allocation	272.8	35.4	6.4	1.4	0.8
Margin of Safety	69.9	9.1	1.6	0.3	0.21
Allowance for future growth	6.99	0.91	0.16	0.03	0.021
Total load reduction required	No Data	No Data	44.6%	53.7%	No Data
Compton Ck @ Dogtown Rd. HUC12: 05060003 08 04					
Total Maximum Daily Load	811.5	105.4	19.0	4.0	2.5
Wasteload Allocation	0.14	0.14	0.14	0.14	0.14
Load Allocation	632.8	82.0	14.6	3.0	1.8
Margin of Safety	162.3	21.1	3.8	0.8	0.49
Allowance for future growth	16.23	2.11	0.38	0.08	0.049
Total load reduction required	No Data	No Data	38.7%	61.7%	No Data
N Fk Paint Ck @ Good Hope-New Holland Rd. HUC12: 05060003 08 05					
Total Maximum Daily Load	701.5	91.1	16.4	3.5	2.1
Wasteload Allocation	0.76	0.76	0.76	0.76	0.76
Load Allocation	546.4	70.3	12.0	1.9	0.9
Margin of Safety	140.3	18.2	3.3	0.7	0.43
Allowance for future growth	14.03	1.82	0.33	0.07	0.043
Total load reduction required	98.3%	36.3%	18.4%	None	No Data

Table D4-40 (cont.). TMDL summary table (*E. coli* loads are expressed in billions of organisms/day).

Hydrologic Condition	High flows	Wet weather	Normal range	Dry weather	Low
Little Ck @ Little Creek Rd nr Rogers Rd.		**HUC12: 05060003 09 02**			
Total Maximum Daily Load	376.3	41.3	6.7	1.5	0.3
Wasteload Allocation	0.00	0.00	0.00	0.00	0.00
Load Allocation	293.5	32.2	5.2	1.2	0.3
Margin of Safety	75.3	8.3	1.3	0.3	0.07
Allowance for future growth	7.53	0.83	0.13	0.03	0.007
Total load reduction required	No Data	No Data	60.7%	None	No Data
N Fk Paint Ck downstream Frankfort WWTP			**HUC12: 05060003 09 03**		
Total Maximum Daily Load	2708.3	297.0	48.2	10.9	2.6
Wasteload Allocation	1.81	1.81	1.81	1.81	1.81
Load Allocation	2110.7	229.8	35.8	6.7	0.2
Margin of Safety	541.7	59.4	9.6	2.2	0.51
Allowance for future growth	54.17	5.94	0.96	0.22	0.051
Total load reduction required	No Data	No Data	72.6%	None	No Data
N Fk Paint Ck @ Poke Hollow Rd.			**HUC12: 05060003 09 04**		
Total Maximum Daily Load	3834.1	425.2	73.5	20.7	8.9
Wasteload Allocation	6.10	6.10	6.10	6.10	6.10
Load Allocation	2984.5	325.5	51.2	10.0	0.9
Margin of Safety	766.8	85.0	14.7	4.1	1.79
Allowance for future growth	76.68	8.50	1.47	0.41	0.179
Total load reduction required	No Data	96.0%	None	None	No Data
Ralston Run @ Turner Rd.			**HUC12: 05060003 10 02**		
Total Maximum Daily Load	80.8	8.1	1.9	1.0	0.9
Wasteload Allocation	0.14	0.14	0.14	0.14	0.14
Load Allocation	62.9	6.2	1.3	0.7	0.6
Margin of Safety	16.2	1.6	0.4	0.2	0.18
Allowance for future growth	1.62	0.16	0.04	0.02	0.018
Total load reduction required	No Data	No Data	46.7%	38.8%	No Data
Owl Ck upst US RT 50			**HUC12: 05060003 10 03**		
Total Maximum Daily Load	101.0	10.1	2.4	1.3	1.1
Wasteload Allocation	0.00	0.00	0.00	0.00	0.00
Load Allocation	78.8	7.9	1.9	1.0	0.9
Margin of Safety	20.2	2.0	0.5	0.3	0.22
Allowance for future growth	2.02	0.20	0.05	0.03	0.022
Total load reduction required	No Data	No Data	69.4%	54.4%	No Data

Figures D4-7 through D4-30 show the *E. coli* load duration curves. Tables D4-41 through D4-64 show the detailed allocations for each HUC 12.

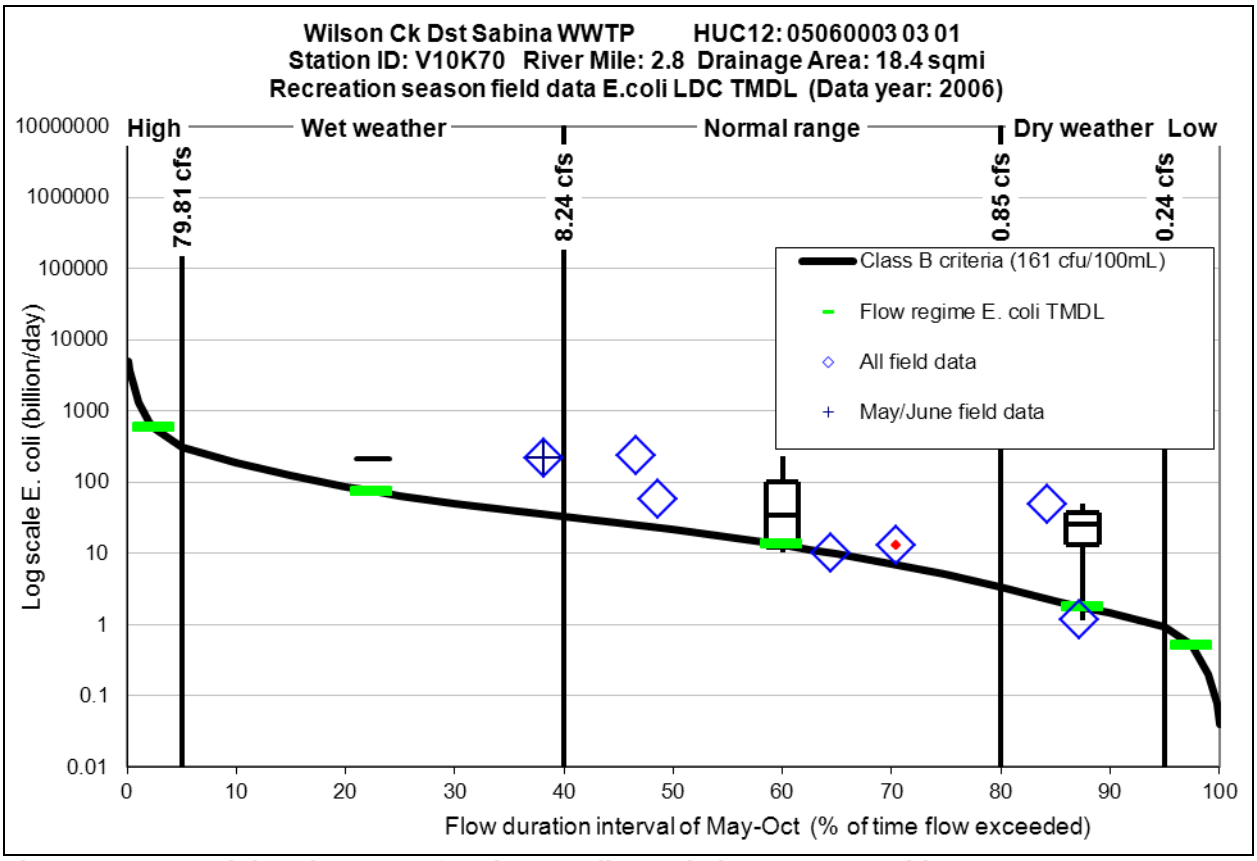


Figure D4-7. Load duration curve for site on Wilson Ck downstream Sabina WWTP HUC12: 05060003 03 01.

Table D4-41. Headwaters Rattlesnake Creek E coli TMDLs and surrogate TMDLs for organic enrichment and ammonia (HUC: 05060003 03 01).

Flow regime TMDL analysis (*E. coli* in billion organisms/day)	High flows	Wet weather	Normal range	Dry weather	Low
Flow duration regime interval	0-5%	5-40%	40-80%	80-95%	95-100%
Samples per regime		1	4	2	
Median sample load	No data	216.8	35.1	25.2	No data
WLA - Sabina STP - 1PB00038	2.32	2.32	2.32	1.42	0.42
LA	456.6	55.6	8.1	0	0
MOS	117.7	14.8	2.7	0	0
AFG	11.77	1.48	0.27	0.04	0.01
TMDL	No Data	65.8%	61.9%	93.0%	No Data
Total load reduction required	588.4	74.2	13.4	1.8	0.5

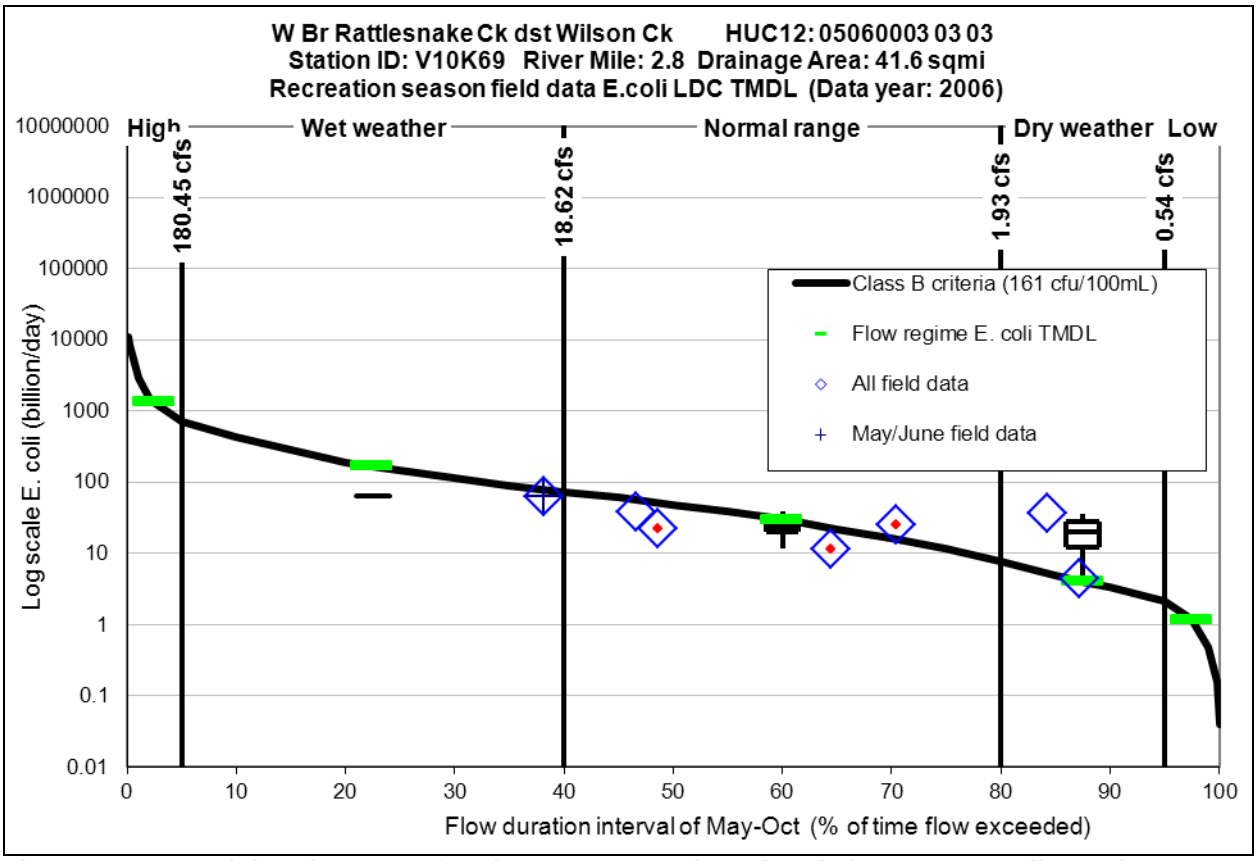


Figure D4-8. Load duration curve for site on W Br Rattlesnake Ck downstream Wilson Ck HUC12: 005060003 03 03.

Table D4-42. TMDL table for site on W Br Rattlesnake Ck downstream Wilson Ck HUC12: 005060003 03 03.

Flow regime TMDL analysis (*E. coli* in billion organisms/day)	High flows	Wet weather	Normal range	Dry weather	Low
Flow duration regime interval	0-5%	5-40%	40-80%	80-95%	95-100%
Samples per regime		1	4	2	
Median sample load	No data	63.7	24.0	20.2	No data
WLA- Sabina STP - 1PB00038	2.32	2.32	2.32	2.32	0.92
LA	1035.3	128.6	21.2	0.8	0
MOS	266.1	33.6	6.0	0.8	0.2
AFG	26.61	3.36	0.60	0.08	0.02
TMDL	1330.3	167.8	30.2	4.0	1.2
Total load reduction required	No Data	None	None	80.2%	No Data

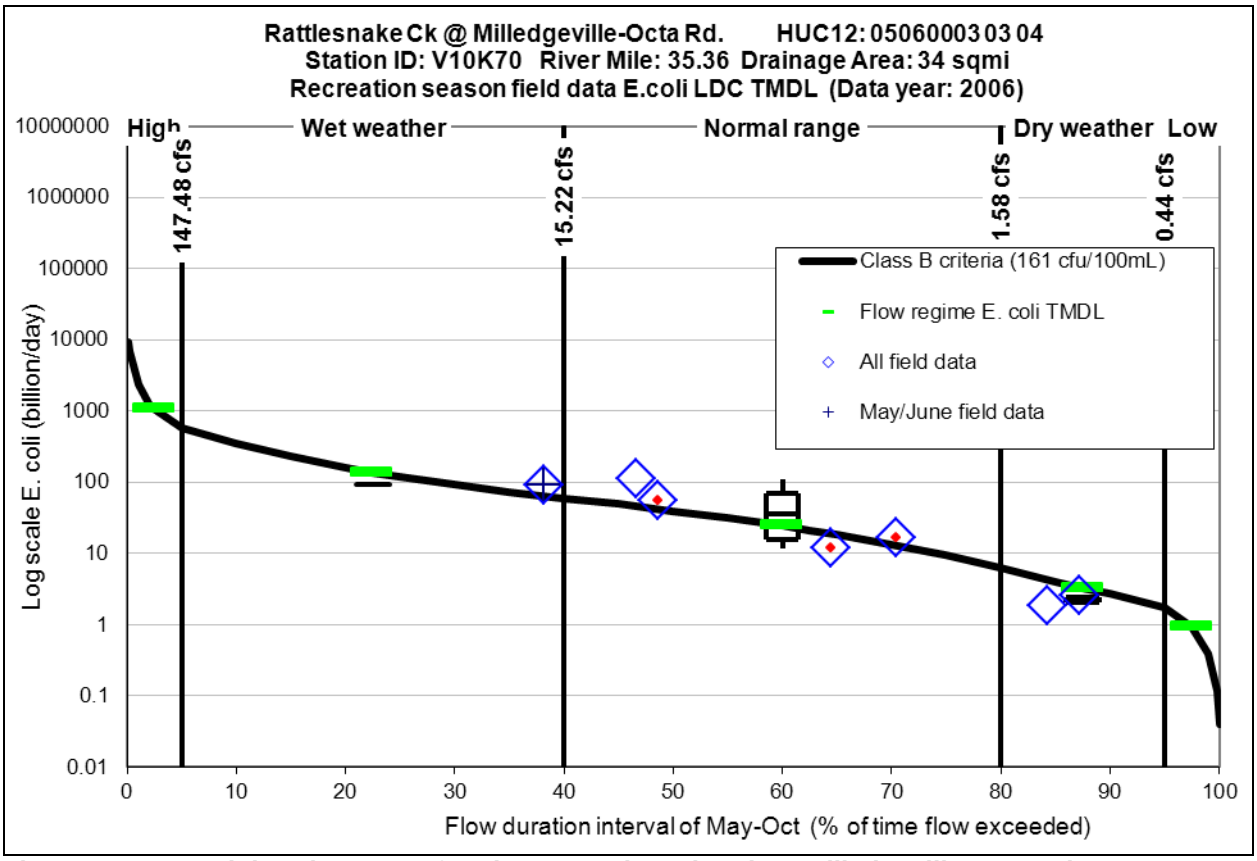


Figure D4-9. Load duration curve for site on Rattlesnake Ck @ Milledgeville-Octa Rd. HUC12: 05060003 03 04.

Table D4-43. TMDL table for site on Rattlesnake Ck @ Milledgeville-Octa Rd. HUC12: 05060003 03 04.

Flow regime TMDL analysis (*E. coli* in billion organisms/day)	High flows	Wet weather	Normal range	Dry weather	Low
Flow duration regime interval	0-5%	5-40%	40-80%	80-95%	95-100%
Samples per regime		1	4	2	
Median sample load	No data	92.2	36.0	2.2	No data
WLA	3.64	3.64	3.64	2.54	0.74
South Solon WWTP - 4PA00002	0.60	0.60	0.60	0.42	0.12
Rattlesnake SD #1 WWTP - 4PH00007	3.05	3.05	3.05	2.12	0.62
Rockies Express Pipeline - 4GH00006	0.00	0.00	0.00	0.00	0.00
LA	844.4	103.3	15.6	0	0
MOS	217.5	27.4	4.9	0.7	0.2
AFG	21.75	2.74	0.49	0.07	0.02
TMDL	1087.3	137.1	24.7	3.3	0.9
Total load reduction required	No Data	None	31.4%	None	No Data

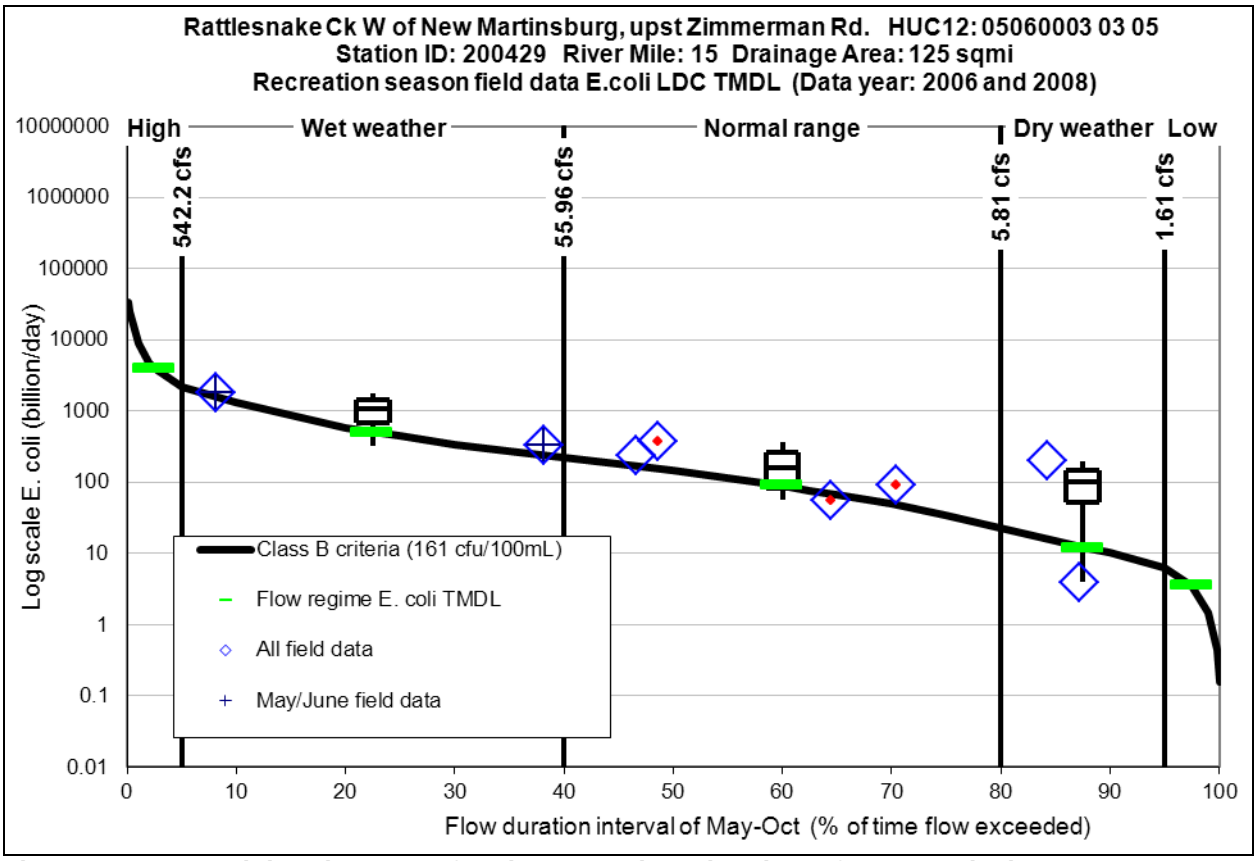


Figure D4-10. Load duration curve for site on Rattlesnake Ck W of New Martinsburg, upst Zimmerman Rd. HUC12: 05060003 03 05.

Table D4-44. TMDL table for site on Rattlesnake Ck W of New Martinsburg, upst Zimmerman Rd. HUC12: 05060003 03 05.

Flow regime TMDL analysis (*E. coli* in billion organisms/day)	High flows	Wet weather	Normal range	Dry weather	Low
Flow duration regime interval	0-5%	5-40%	40-80%	80-95%	95-100%
Samples per regime		2	4	2	
Median sample load	No data	1,052.5	161.7	100.4	No data
WLA	5.96	5.96	5.96	5.96	2.76
Sabina STP - 1PB00038	2.32	2.32	2.32	2.32	1.07
South Solon WWTP - 4PA00002	0.60	0.60	0.60	0.60	0.28
Rattlesnake SD #1 WWTP - 4PH00007	3.05	3.05	3.05	3.05	1.41
LA	3111.9	387.3	64.9	3.4	0.0
MOS	799.5	100.8	18.2	2.4	0.7
AFG	79.95	10.08	1.82	0.24	0.07
TMDL	3997.3	504.2	90.8	12.1	3.5
Total load reduction required	No Data	52.1%	43.8%	88.0%	No Data

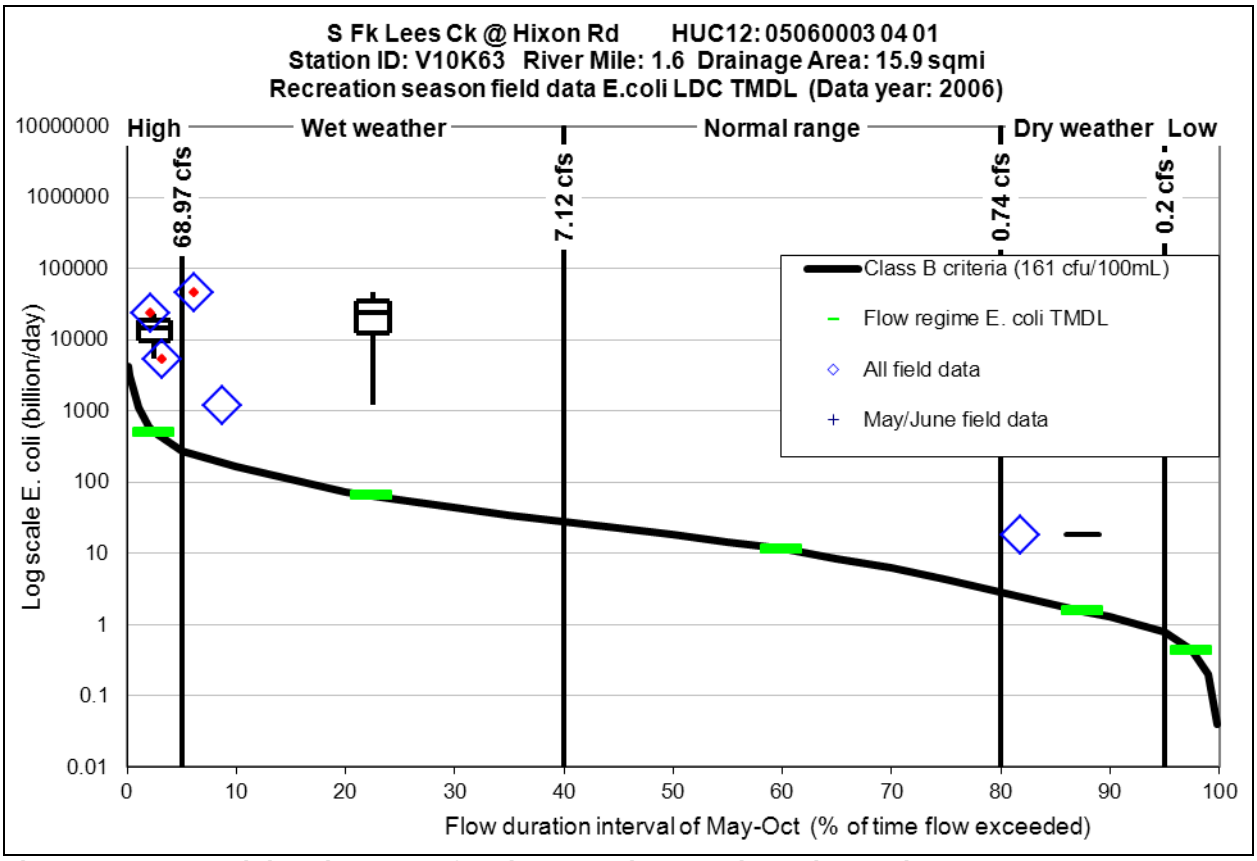


Figure D4-11. Load duration curve for site on S Fk Lees Ck @ Hixon Rd HUC12: 05060003 04 01.

Table D4-45. Rattlesnake Creek E. coli TMDLs and surrogate TMDLs for organic enrichment, ammonia and dissolved oxygen (HUC: 05060003 04 01).

Flow regime TMDL analysis (*E. coli* in billion organisms/day)	High flows	Wet weather	Normal range	Dry weather	Low
Flow duration regime interval	0-5%	5-40%	40-80%	80-95%	95-100%
Samples per regime	2	2		1	
Median sample load	14,384.3	23,821.8	No data	18.4	No data
WLA	0.00	0.00	0.00	0.00	0.00
LA	396.6	50.0	9.0	1.2	0.3
MOS	101.7	12.8	2.3	0.3	0.1
AFG	10.17	1.28	0.23	0.03	0.01
TMDL	508.5	64.1	11.5	1.5	0.4
Total load reduction required	96.5%	99.7%	No Data	91.6%	No Data

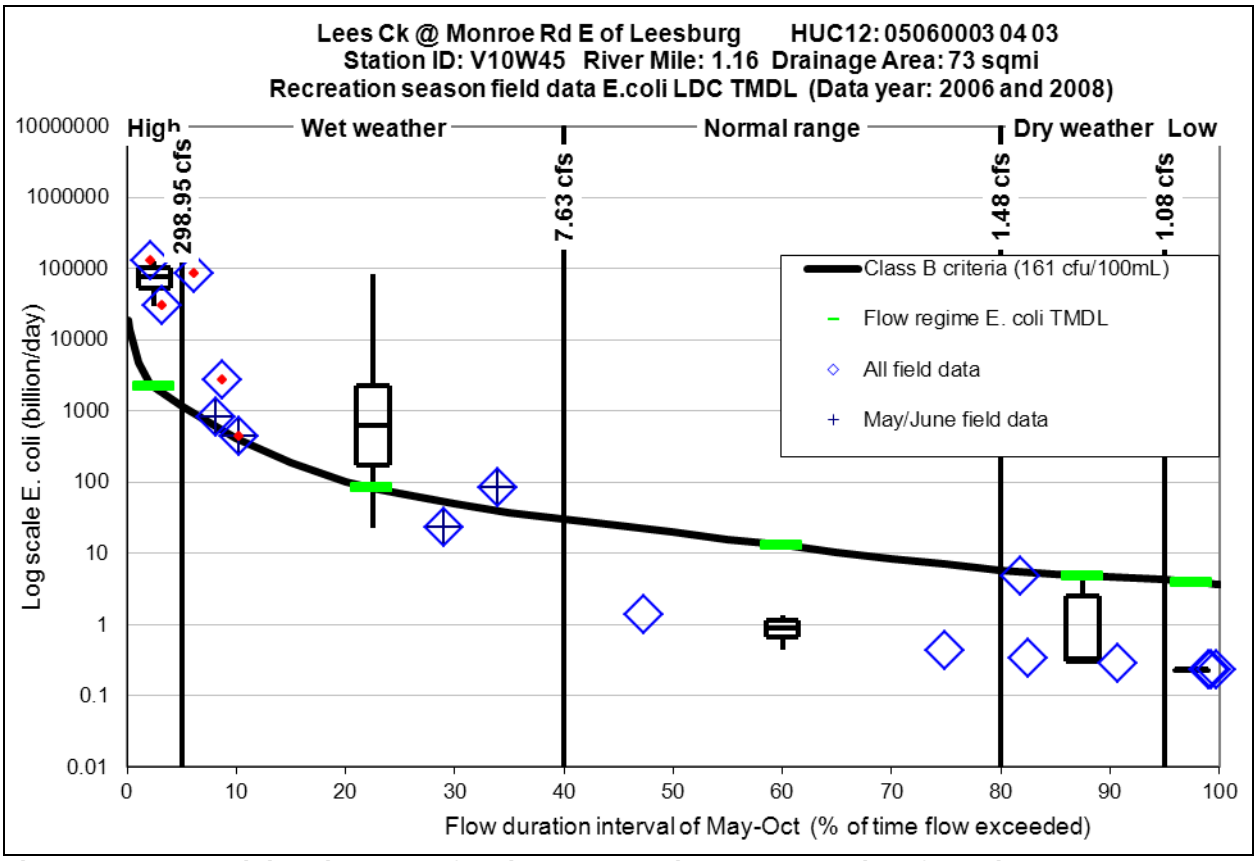


Figure D4-12. Load duration curve for site on Lees Ck @ Monroe Rd E of Leesburg HUC12: 05060003 04 03.

Table D4-46. Rattlesnake Creek *E. coli* TMDLs and surrogate TMDLs for organic enrichment, ammonia and dissolved oxygen (HUC: 05060003 04 03).

Flow regime TMDL analysis (*E. coli* in billion organisms/day)	High flows	Wet weather	Normal range	Dry weather	Low
Flow duration regime interval	0-5%	5-40%	40-80%	80-95%	95-100%
Samples per regime	2	6	2	3	3
Median sample load	78,230.0	630.9	0.9	0.3	0.2
WLA Leesburg WWTP - 1PB00106	2.44	2.44	2.44	2.44	2.44
LA	1714.1	63.0	7.7	1.3	0.7
MOS	440.2	16.8	2.6	1.0	0.8
AFG	44.02	1.68	0.26	0.10	0.08
TMDL	2200.8	83.9	13.0	4.8	4.0
Total load reduction required	97.2%	86.7%	None	None	None

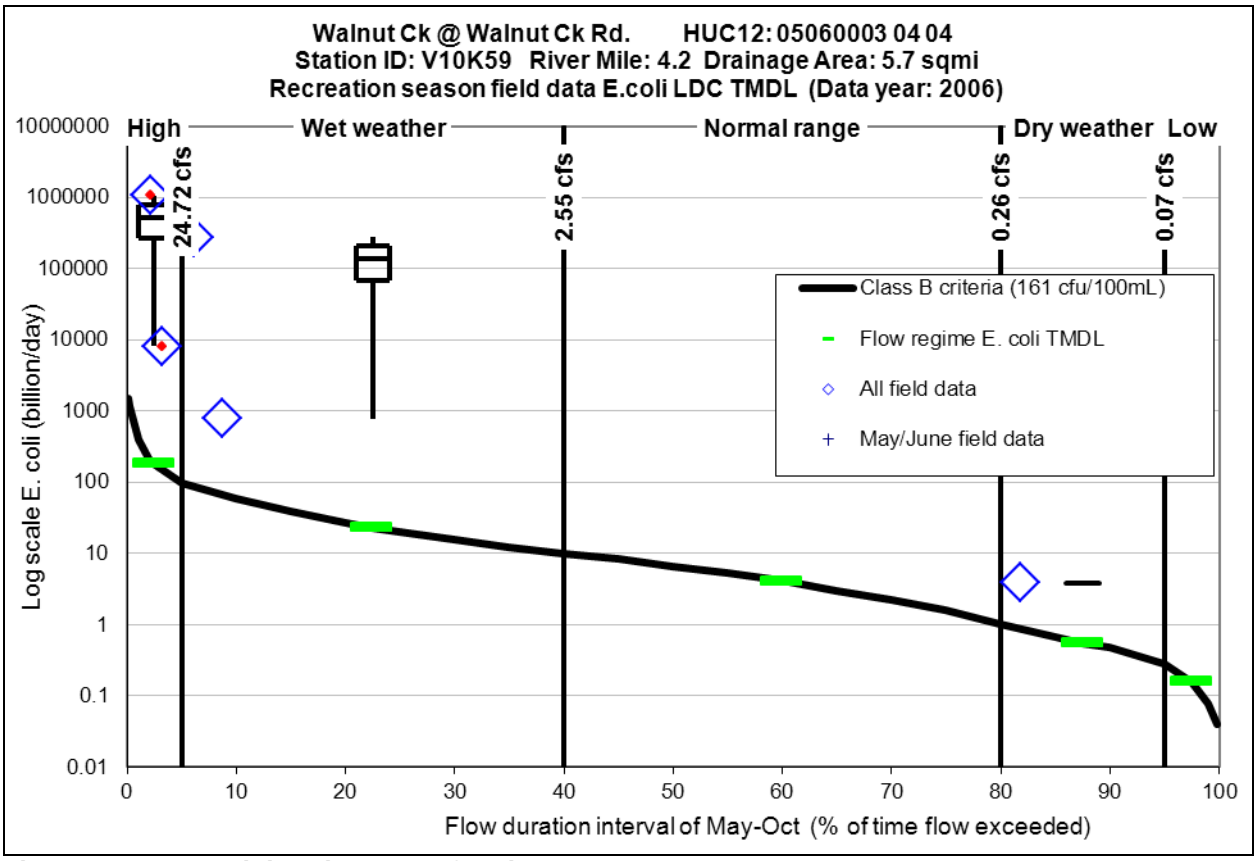


Figure D4-13. Load duration curve for site on Walnut Ck @ Walnut Ck Rd. HUC12: 05060003 04 04.

Table D4-47. TMDL table for site on Walnut Ck @ Walnut Ck Rd. HUC12: 05060003 04 04.

Flow regime TMDL analysis (*E. coli* in billion organisms/day)	High flows	Wet weather	Normal range	Dry weather	Low
Flow duration regime interval	0-5%	5-40%	40-80%	80-95%	95-100%
Samples per regime	2	2		1	
Median sample load	528,581.6	137,303.4	No data	3.8	No data
WLA	0.00	0.00	0.00	0.00	0.00
LA	142.2	17.9	3.2	0.4	0.1
MOS	36.5	4.6	0.8	0.1	0.03
AFG	3.65	0.46	0.08	0.01	0.003
TMDL	182.3	23.0	4.1	0.6	0.2
Total load reduction required	100.0%	100.0%	No Data	85.6%	No Data

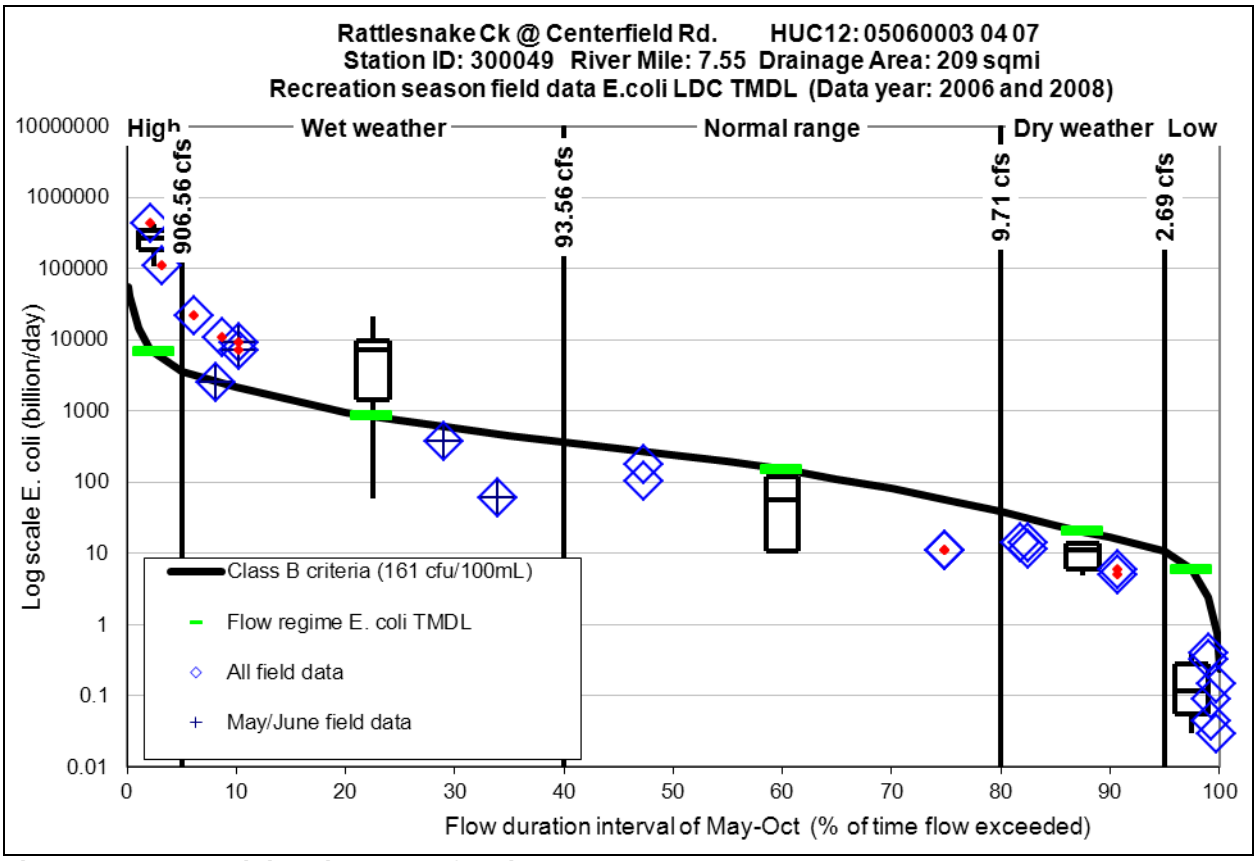


Figure D4-14. Load duration curve for site on Rattlesnake Ck @ Centerfield Rd. HUC12: 05060003 04 07.

Table D4-48. TMDL table for site on Rattlesnake Ck @ Centerfield Rd. HUC12: 05060003 04 07.

Flow regime TMDL analysis (*E. coli* in billion organisms/day)	High flows	Wet weather	Normal range	Dry weather	Low
Flow duration regime interval	0-5%	5-40%	40-80%	80-95%	95-100%
Samples per regime	2	7	4	5	6
Median sample load	265,219	7,150.4	56.2	11.2	0.1
WLA Leesburg WWTP - 1PB00106	2.44	2.44	2.44	2.44	2.44
LA	5210.6	655.1	116.0	13.3	2.2
MOS	1,336.7	168.6	30.4	4.0	1.18
AFG	133.67	16.86	3.04	0.40	0.12
TMDL	6683.4	843.0	151.9	20.1	5.9
Total load reduction required	97.5%	88.2%	None	None	None

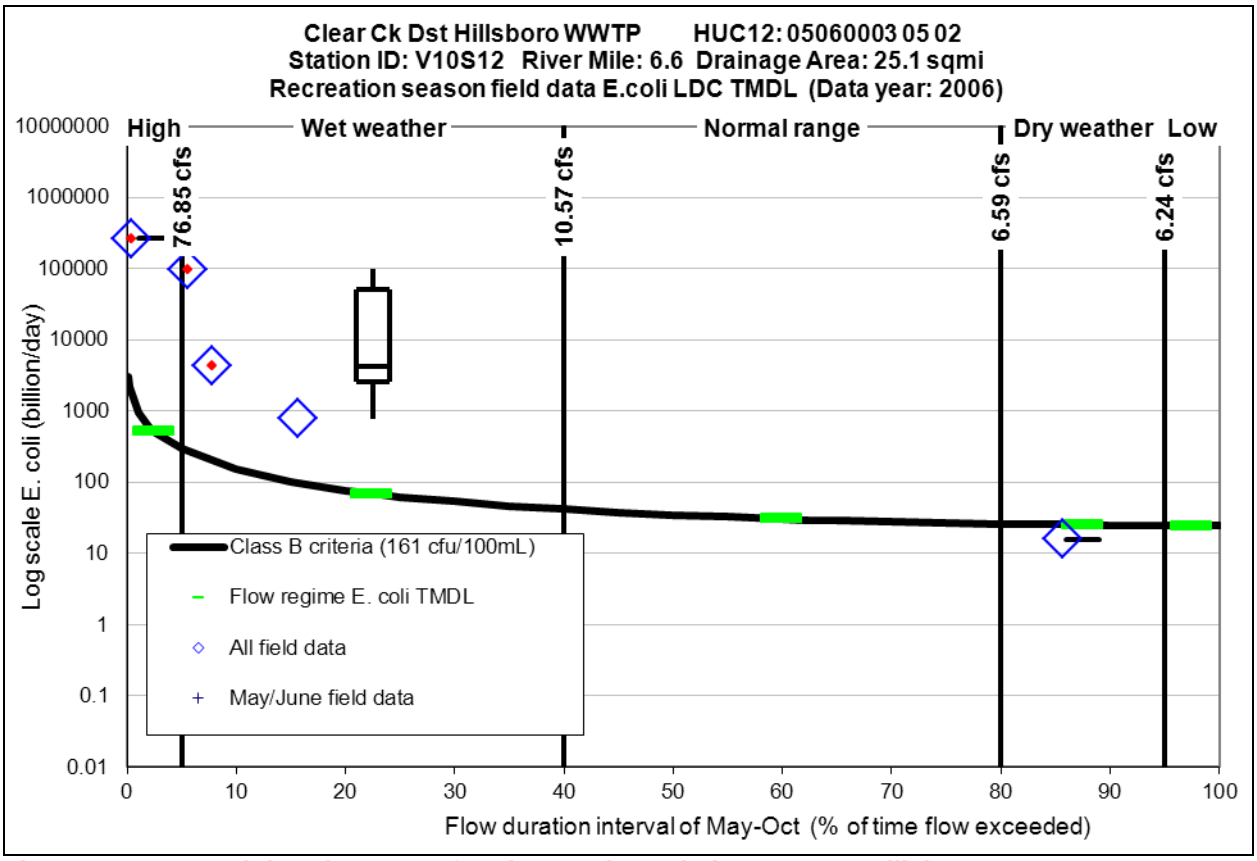


Figure D4-15. Load duration curve for site on Clear Ck downstream Hillsboro WWTP HUC12: 05060003 05 02.

Table D4-49. TMDL table for site on Clear Ck downstream Hillsboro WWTP HUC12: 05060003 05 02.

Flow regime TMDL analysis (*E. coli* in billion organisms/day)	High flows	Wet weather	Normal range	Dry weather	Low
Flow duration regime interval	0-5%	5-40%	40-80%	80-95%	95-100%
Samples per regime	1	3		1	
Median sample load	264,761.7	4,299.1	No data	15.7	No data
Total WLA	18.89	18.89	18.89	18.89	18.89
Hillsboro STP- 1PC00100	18.89	18.89	18.89	18.89	18.89
BP Amoco #69544 - 1IN00255	0.00	0.00	0.00	0.00	0.00
LA	384.7	34.9	5.0	0.8	0.2
MOS	103.5	13.8	6.1	5.0	4.88
AFG	10.35	1.38	0.61	0.50	0.488
TMDL	517.4	69.0	30.6	25.2	24.4
Total load reduction required	99.8%	98.4%	No Data	None	No Data

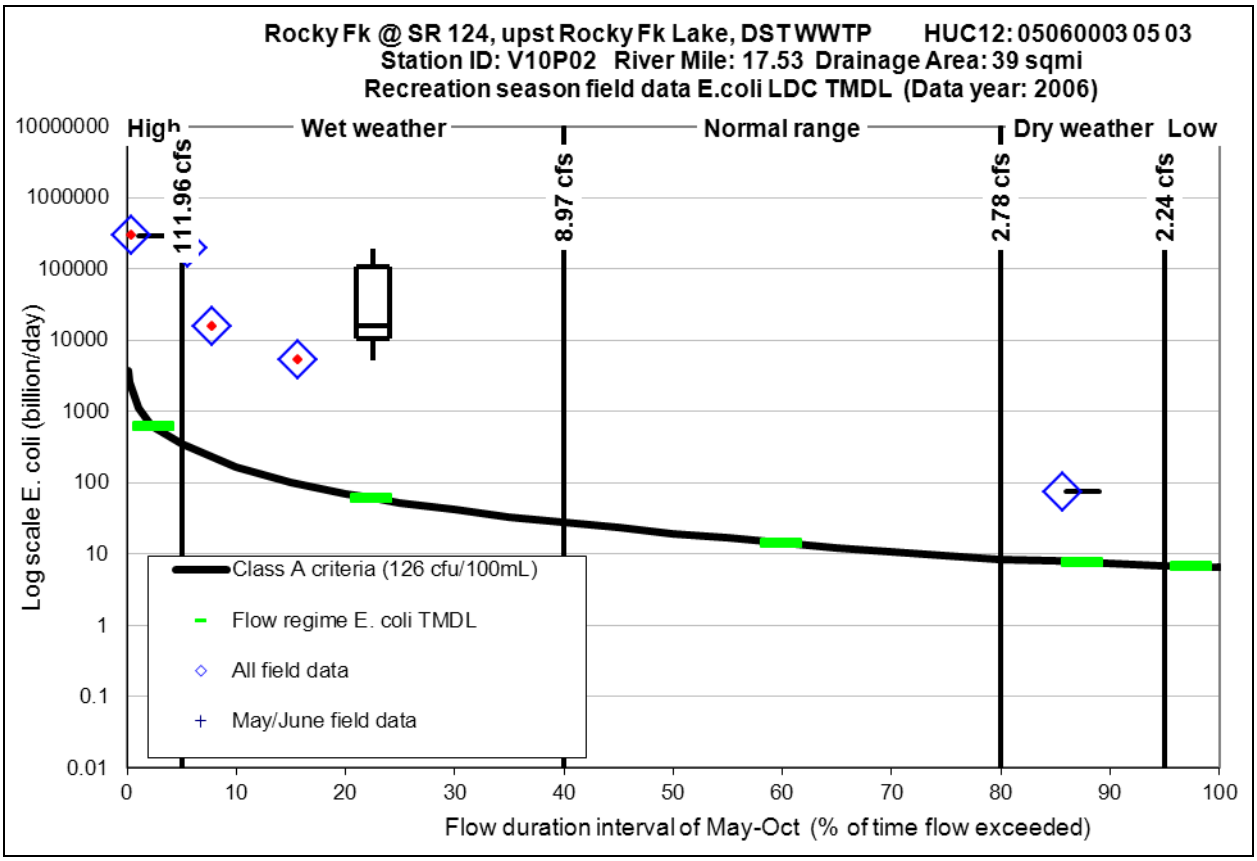


Figure D4-16. Load duration curve for site on Rocky Fk @ SR 124, upst Rocky Fk Lake, DST WWTP HUC12: 05060003 05 03.

Table D4-50. TMDL table for site on Rocky Fk @ SR 124, upst Rocky Fk Lake, DST WWTP HUC12: 05060003 05 03.

Flow regime TMDL analysis (*E. coli* in billion organisms/day)	High flows	Wet weather	Normal range	Dry weather	Low
Flow duration regime interval	0-5%	5-40%	40-80%	80-95%	95-100%
Samples per regime	1	3		1	
Median sample load	292,914	15,685	No data	74.8	No data
Total WLA	1.48	1.48	1.48	1.48	1.48
Rocky Fork Lake WWTP - 1PS0015	1.43	1.43	1.43	1.43	1.43
Pleasant Acres MHP - 1PV00127	0.05	0.05	0.05	0.05	0.05
LA	471.3	46.0	9.7	4.5	3.8
MOS	121.2	12.2	2.9	1.5	1.35
AFG	12.12	1.22	0.29	0.15	0.135
TMDL	606.2	60.9	14.3	7.7	6.8
Total load reduction required	99.8%	99.6%	No Data	89.7%	No Data

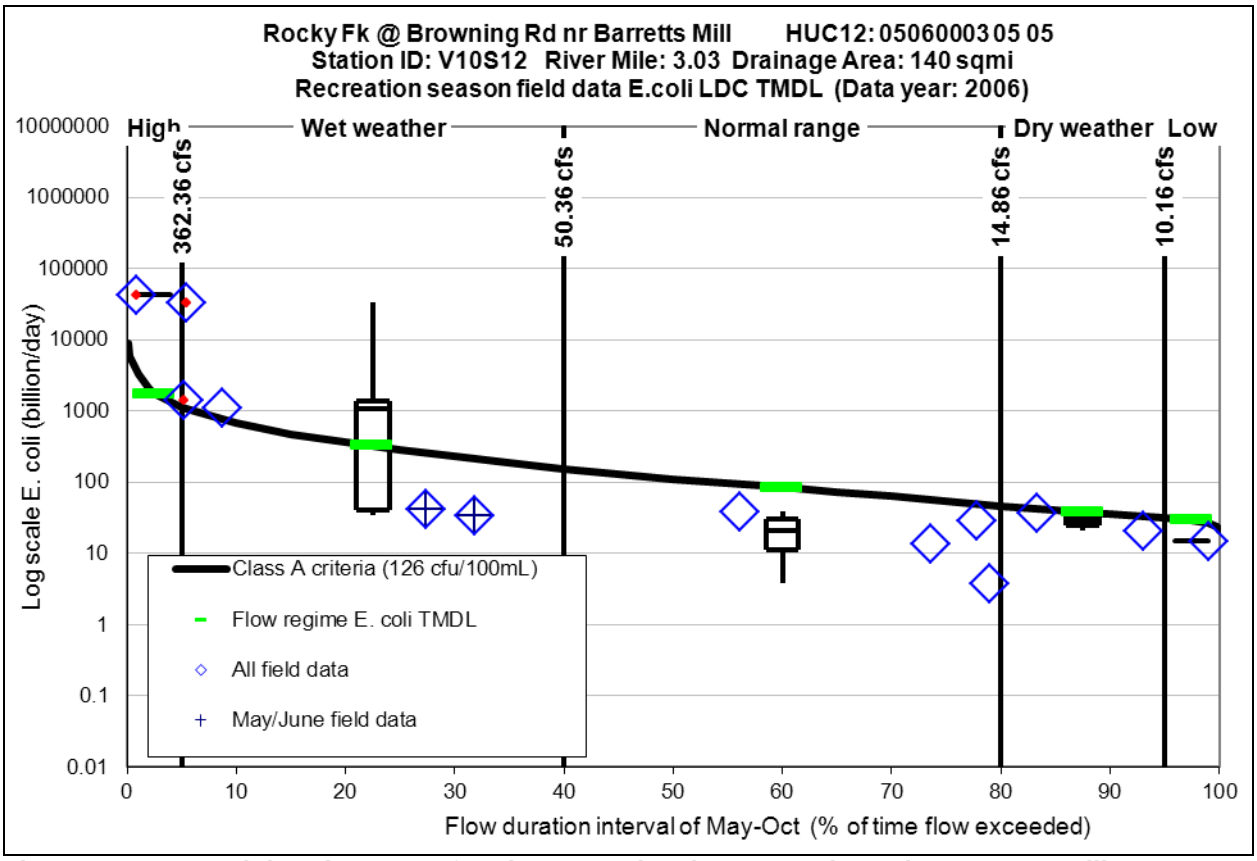


Figure D4-17. Load duration curve for site on Rocky Fk @ Browning Rd nr Barretts Mill HUC12: 05060003 05 05.

Table D4-51. Rocky Fork E. coli TMDLs and surrogate TMDLs for organic enrichment and nutrient enrichment (HUC12: 05060003 05 05).

Flow regime TMDL analysis (*E. coli* in billion organisms/day)	High flows	Wet weather	Normal range	Dry weather	Low
Flow duration regime interval	0-5%	5-40%	40-80%	80-95%	95-100%
Samples per regime	1	5	4	2	1
Median sample load	42,651	1,089	20.7	28.5	14.8
Total WLA	20.62	20.62	20.62	20.62	20.62
Rocky Fork Truck Stop - 1PZ00038	0.02	0.02	0.02	0.02	0.02
Hickory Hills Lake Co - 1PX00063	0.10	0.10	0.10	0.10	0.10
Country Home MHP - 1PV00093	0.04	0.04	0.04	0.04	0.04
Babington Camp & Park - 1PV00087	0.10	0.10	0.10	0.10	0.10
Rocky Fork Lake WWTP - 1PS0015	1.43	1.43	1.43	1.43	1.43
Pleasant Acres MHP - 1PV00127	0.05	0.05	0.05	0.05	0.05
Hillsboro STP - 1PC00100	18.89	18.89	18.89	18.89	18.89
BP Amoco #69544 - 1IN00255	0.00	0.00	0.00	0.00	0.00
LA	1355.6	232.7	45.2	8.9	2.1
MOS	352.9	65.0	16.9	7.6	5.83
AFG	35.29	6.50	1.69	0.76	0.583
TMDL	1764.3	324.8	84.3	37.8	29.2
Total load reduction required	95.9%	70.2%	None	None	None

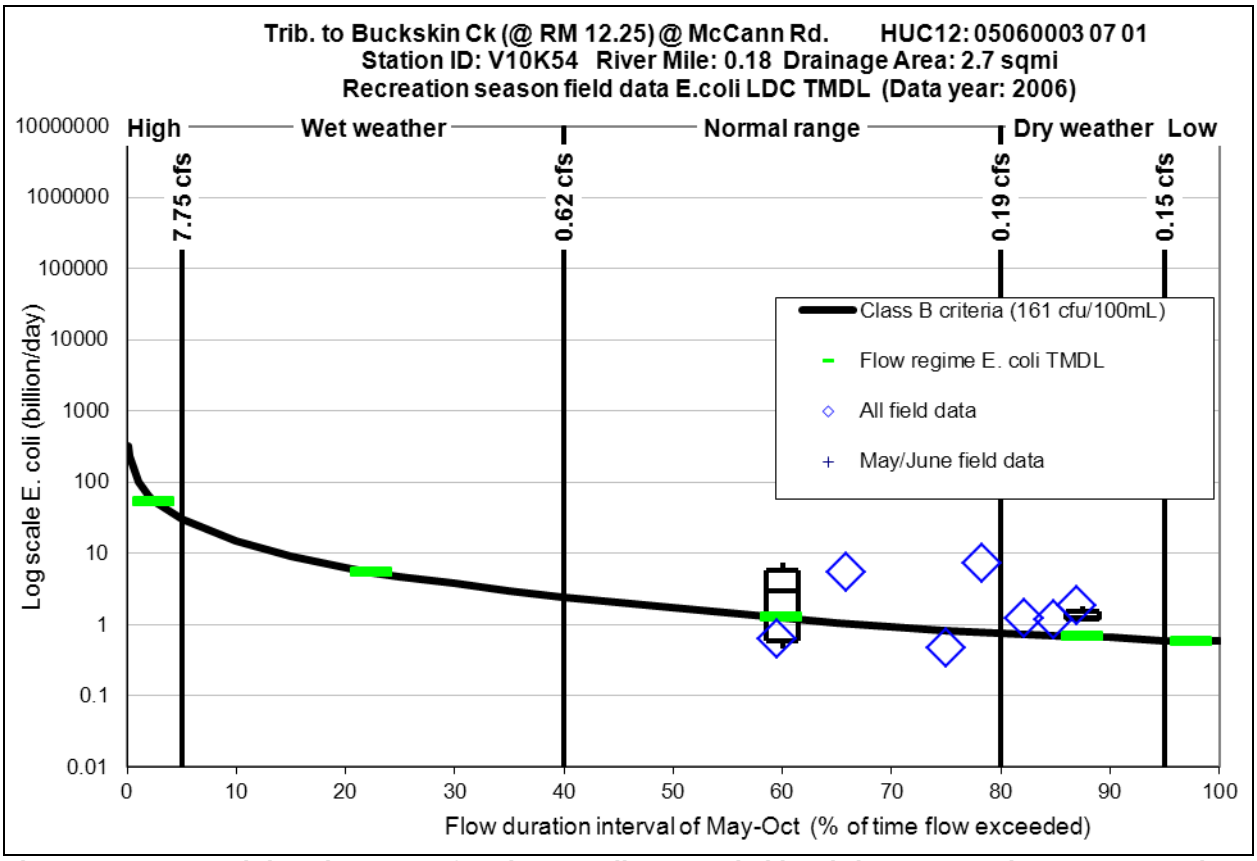


Figure D4-18. Load duration curve for site on Trib. to Buckskin Ck (@ RM 12.25) @ McCann Rd. HUC12: 05060003 07 01.

Table D4-52. Paint Creek E. coli TMDLs and surrogate TMDLs for nutrient enrichment .

Flow regime TMDL analysis (*E. coli* in billion organisms/day)	High flows	Wet weather	Normal range	Dry weather	Low
Flow duration regime interval	0-5%	5-40%	40-80%	80-95%	95-100%
Samples per regime			4	3	
Median sample load	No data	No data	3.0	1.2	No data
WLA	0.00	0.00	0.00	0.00	0.00
LA	41.8	4.2	1.0	0.5	0.5
MOS	10.7	1.1	0.3	0.1	0.12
AFG	1.07	0.11	0.03	0.01	0.012
TMDL	53.6	5.4	1.3	0.7	0.6
Total load reduction required	No Data	No Data	57.8%	45.4%	No Data

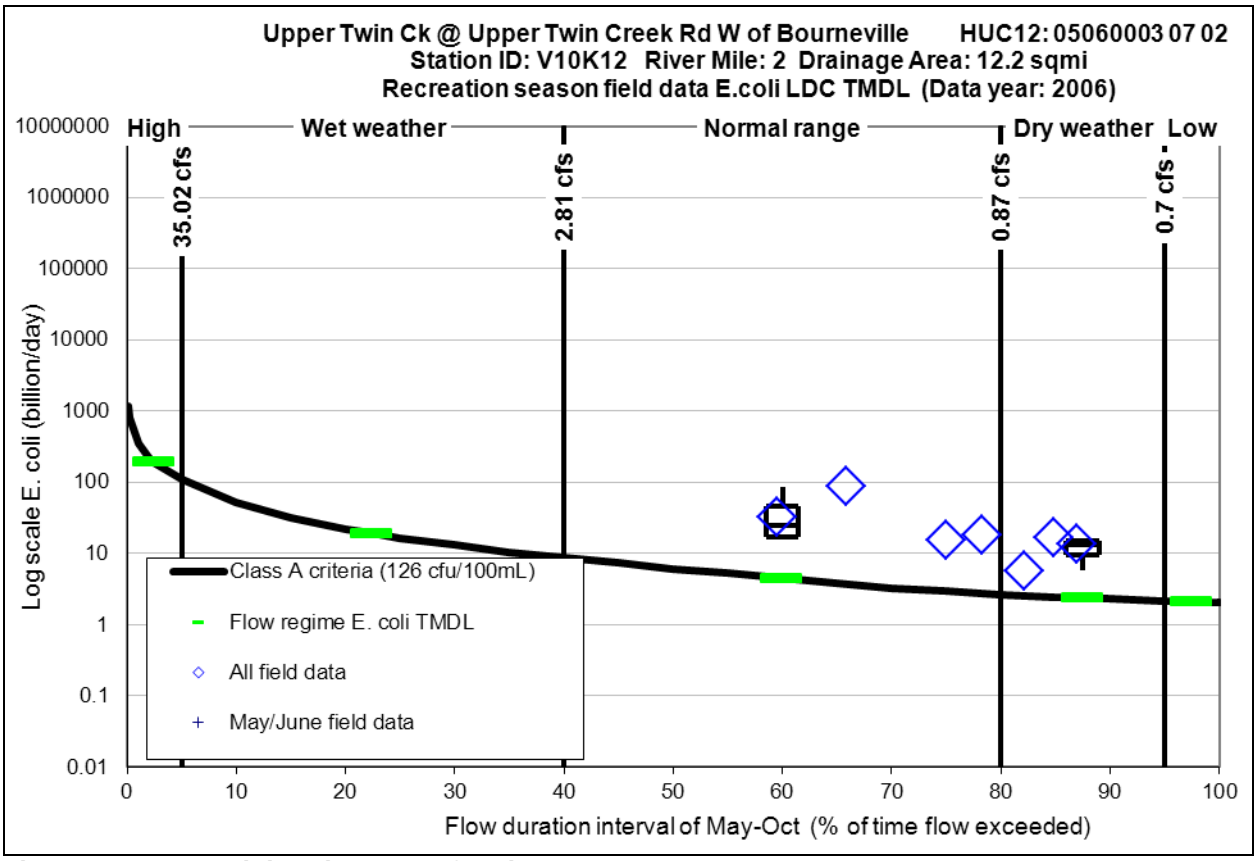


Figure D4-19. Load duration curve for site on Upper Twin Ck @ Upper Twin Creek Rd W of Bourneville HUC12: 05060003 07 02.

Table D4-53. TMDL table for site on Upper Twin Ck @ Upper Twin Creek Rd W of Bourneville HUC12: 05060003 07 02.

Flow regime TMDL analysis (*E. coli* in billion organisms/day)	High flows	Wet weather	Normal range	Dry weather	Low
Flow duration regime interval	0-5%	5-40%	40-80%	80-95%	95-100%
Samples per regime			4	3	
Median sample load	No data	No data	25.1	13.2	No data
WLA	0.00	0.00	0.00	0.00	0.00
LA	147.9	14.9	3.5	1.9	1.6
MOS	37.9	3.8	0.9	0.5	0.42
AFG	3.79	0.38	0.09	0.05	0.042
TMDL	189.6	19.0	4.5	2.4	2.1
Total load reduction required	No Data	No Data	82.2%	81.9%	No Data

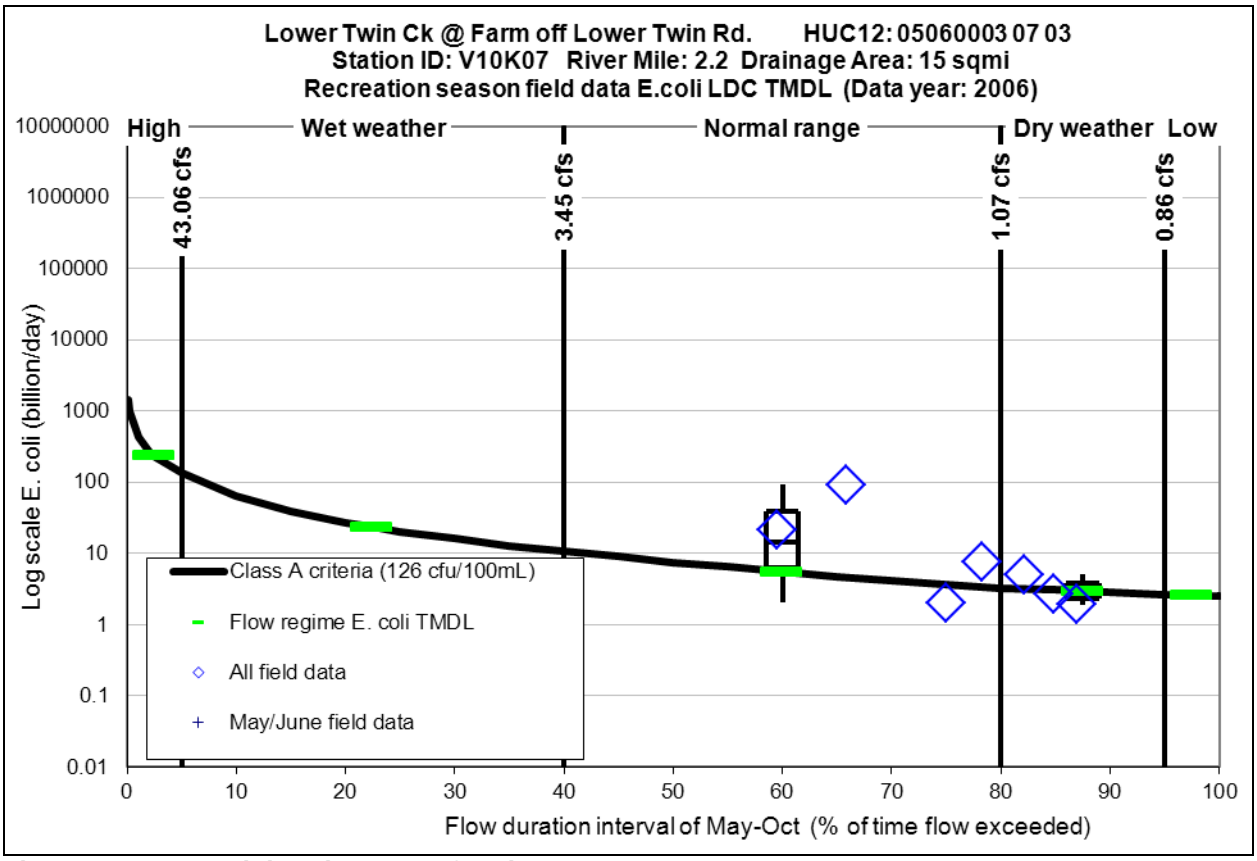


Figure D4-20. Load duration curve for site on Lower Twin Ck @ Farm off Lower Twin Rd. HUC12: 05060003 07 03.

Table D4-54. TMDL table for site on Lower Twin Ck @ Farm off Lower Twin Rd. HUC12: 05060003 07 03.

Flow regime TMDL analysis (*E. coli* in billion organisms/day)	High flows	Wet weather	Normal range	Dry weather	Low
Flow duration regime interval	0-5%	5-40%	40-80%	80-95%	95-100%
Samples per regime			4	3	
Median sample load	No data	No data	14.3	2.7	No data
WLA	0.00	0.00	0.00	0.00	0.00
LA	181.9	18.3	4.3	2.3	2.0
MOS	46.6	4.7	1.1	0.6	0.52
AFG	4.66	0.47	0.11	0.06	0.052
TMDL	233.1	23.4	5.5	3.0	2.6
Total load reduction required	No Data	No Data	61.6%	None	No Data

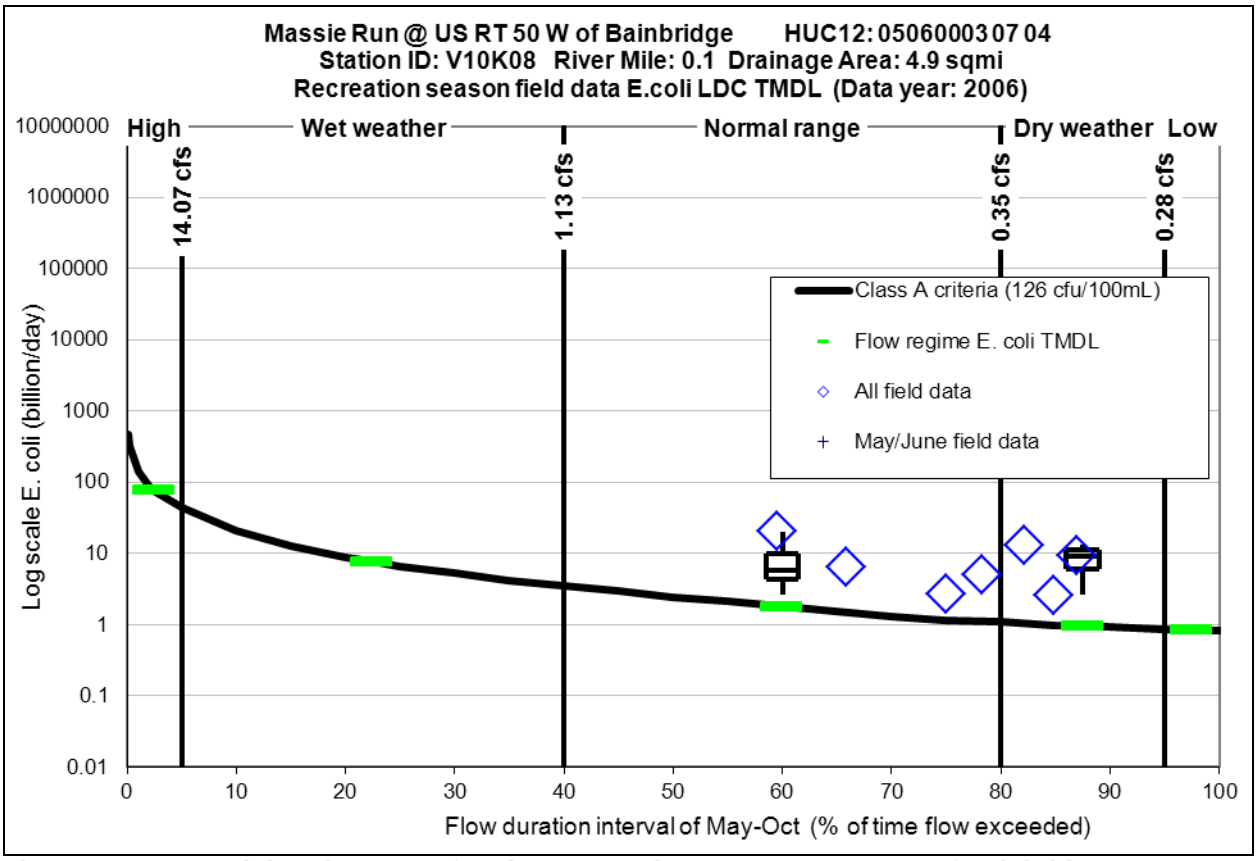


Figure D4-21. Load duration curve for site on Massie Run @ US RT 50 W of Bainbridge HUC12: 05060003 07 04.

Table D4-55. TMDL table for site on Massie Run @ US RT 50 W of Bainbridge HUC12: 05060003 07 04.

Flow regime TMDL analysis (*E. coli* in billion organisms/day)	High flows	Wet weather	Normal range	Dry weather	Low
Flow duration regime interval	0-5%	5-40%	40-80%	80-95%	95-100%
Samples per regime			4	3	
Median sample load	No data	No data	5.7	9.3	No data
WLA	0.00	0.00	0.00	0.00	0.00
LA	59.4	6.0	1.4	0.7	0.6
MOS	15.2	1.5	0.4	0.2	0.17
AFG	1.52	0.15	0.04	0.02	0.017
TMDL	76.2	7.6	1.8	1.0	0.8
Total load reduction required	No Data	No Data	68.6%	89.7%	No Data

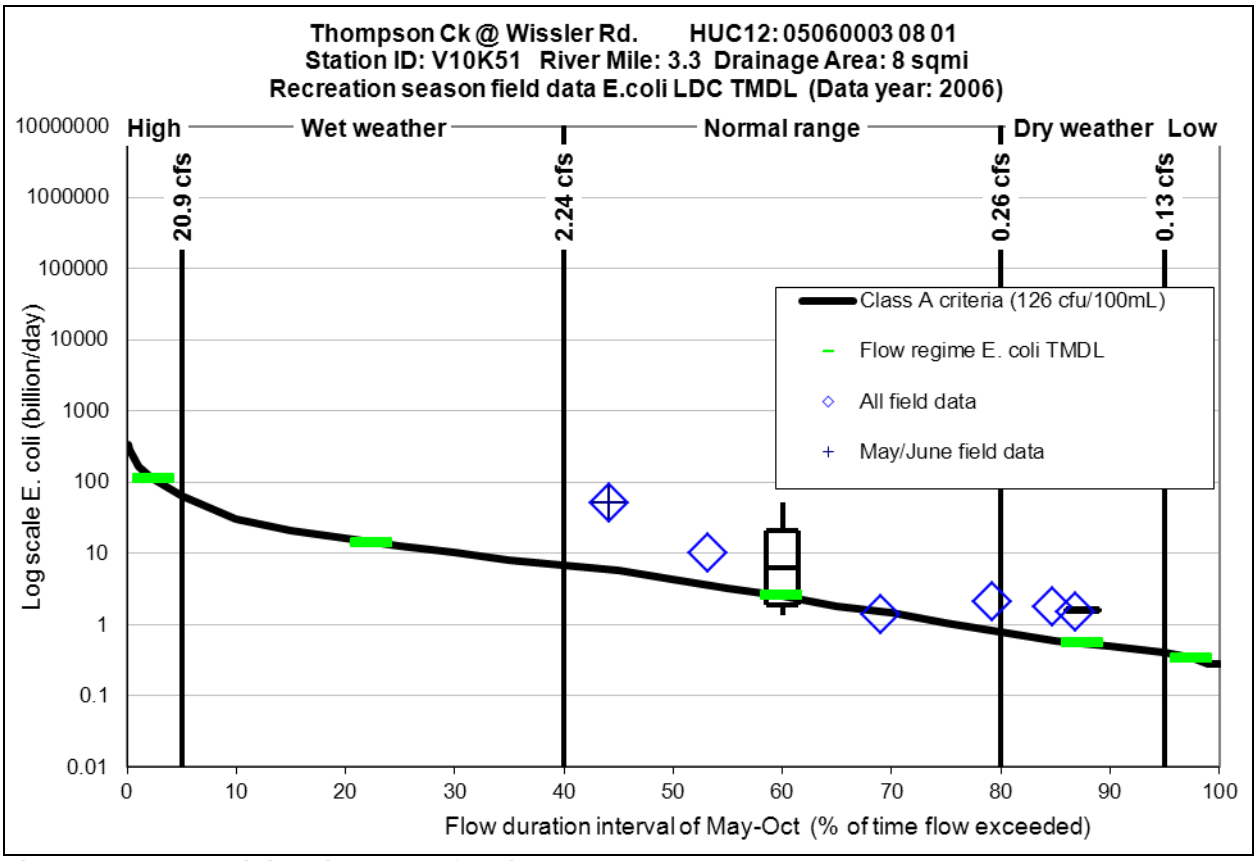


Figure D4-22. Load duration curve for site on Thompson Ck @ Wissler Rd. HUC12: 05060003 08 01.

Table D4-56. TMDL table for site on Thompson Ck @ Wissler Rd. HUC12: 05060003 08 01.

Flow regime TMDL analysis (*E. coli* in billion organisms/day)	High flows	Wet weather	Normal range	Dry weather	Low
Flow duration regime interval	0-5%	5-40%	40-80%	80-95%	95-100%
Samples per regime			4	2	
Median sample load	No data	No data	6.2	1.6	No data
WLA	0.00	0.00	0.00	0.00	0.00
LA	85.8	11.1	2.0	0.4	0.3
MOS	22.0	2.9	0.5	0.1	0.07
AFG	2.20	0.29	0.05	0.01	0.007
TMDL	110.0	14.3	2.6	0.6	0.3
Total load reduction required	No Data	No Data	58.7%	65.7%	No Data

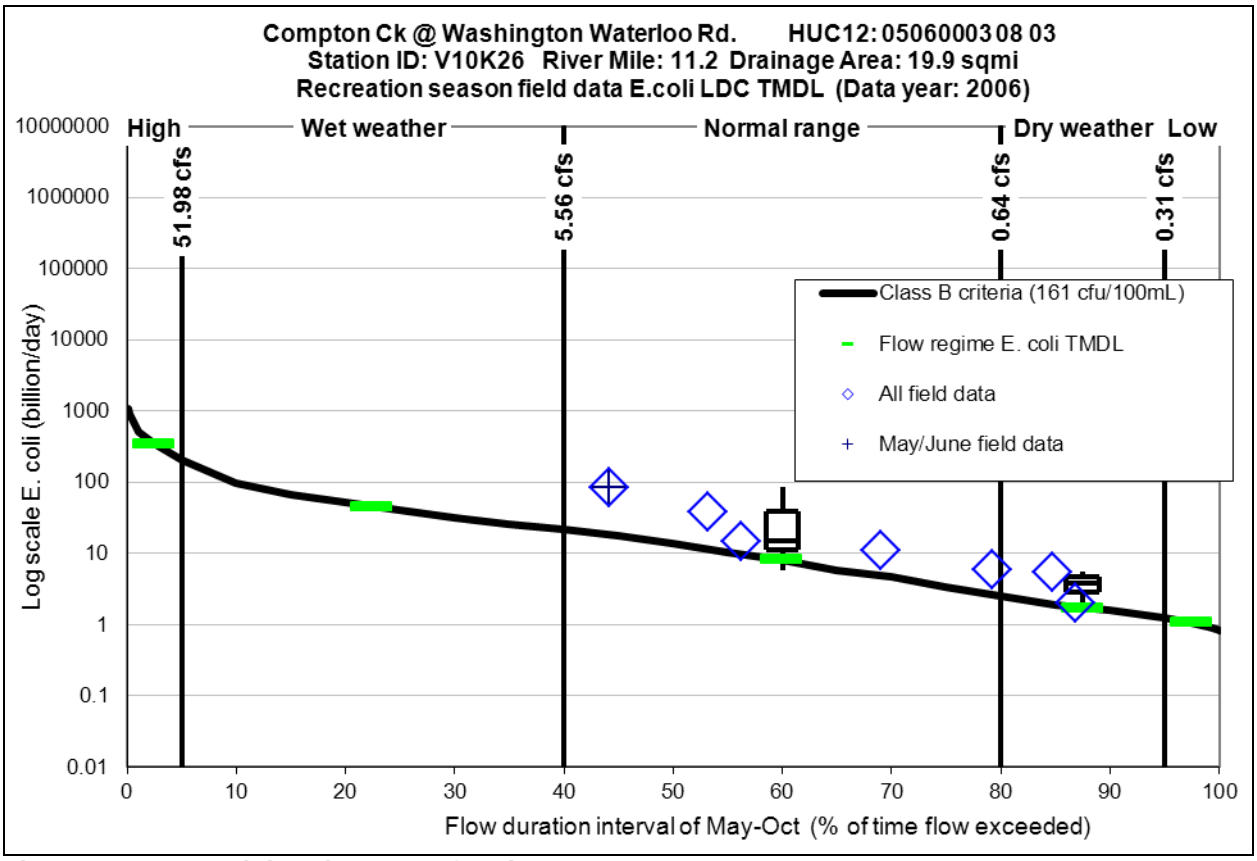


Figure D4-23. Load duration curve for site on Compton Ck @ Washington Waterloo Rd. HUC12: 05060003 08 03.

Table D4-57. TMDL table for site on Compton Ck @ Washington Waterloo Rd. HUC12: 05060003 08 03.

Flow regime TMDL analysis (*E. coli* in billion organisms/day)	High flows	Wet weather	Normal range	Dry weather	Low
Flow duration regime interval	0-5%	5-40%	40-80%	80-95%	95-100%
Samples per regime			5	2	
Median sample load	No data	No data	14.7	3.7	No data
WLA	0.00	0.00	0.00	0.00	0.00
LA	272.8	35.4	6.4	1.4	0.8
MOS	69.9	9.1	1.6	0.3	0.21
AFG	6.99	0.91	0.16	0.03	0.021
TMDL	349.7	45.4	8.2	1.7	1.1
Total load reduction required	No Data	No Data	44.6%	53.7%	No Data

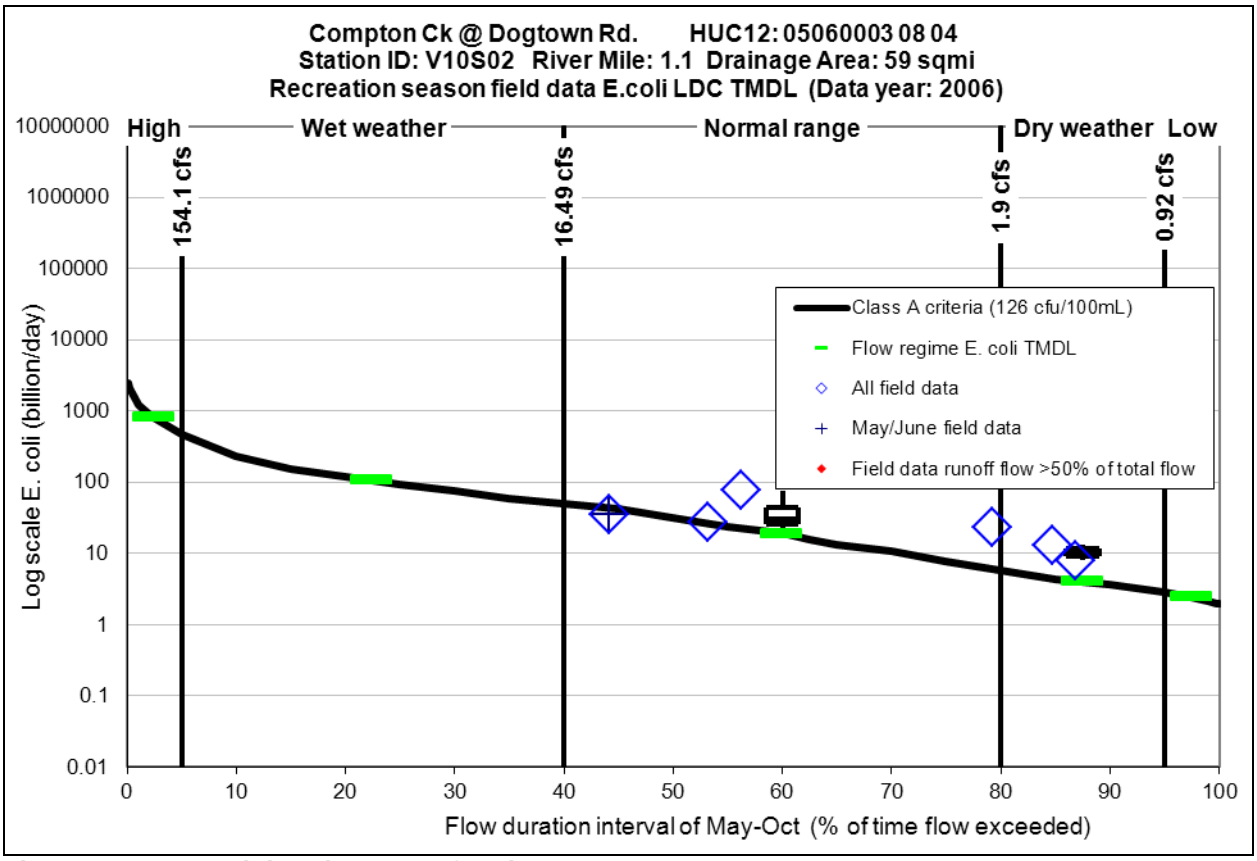


Figure D4-24. Load duration curve for site on Compton Ck @ Dogtown Rd. HUC12: 05060003 08 04.

Table D4-58. TMDL table for site on Compton Ck @ Dogtown Rd. HUC12: 05060003 08 04.

Flow regime TMDL analysis (*E. coli* in billion organisms/day)	High flows	Wet weather	Normal range	Dry weather	Low
Flow duration regime interval	0-5%	5-40%	40-80%	80-95%	95-100%
Samples per regime			4	2	
Median sample load	No data	No data	30.9	10.5	No data
Total WLA	0.14	0.14	0.14	0.14	0.14
Petro Environmental Tech Cell Div - 4IN00150	0.00	0.00	0.00	0.00	0.00
Pine Tree Court Apts 1 - 4PW00004	0.14	0.14	0.14	0.14	0.14
LA	632.8	82.0	14.6	3.0	1.8
MOS	162.3	21.1	3.8	0.8	0.49
AFG	16.23	2.11	0.38	0.08	0.049
TMDL	811.5	105.4	19.0	4.0	2.5
Total load reduction required	No Data	No Data	38.7%	61.7%	No Data

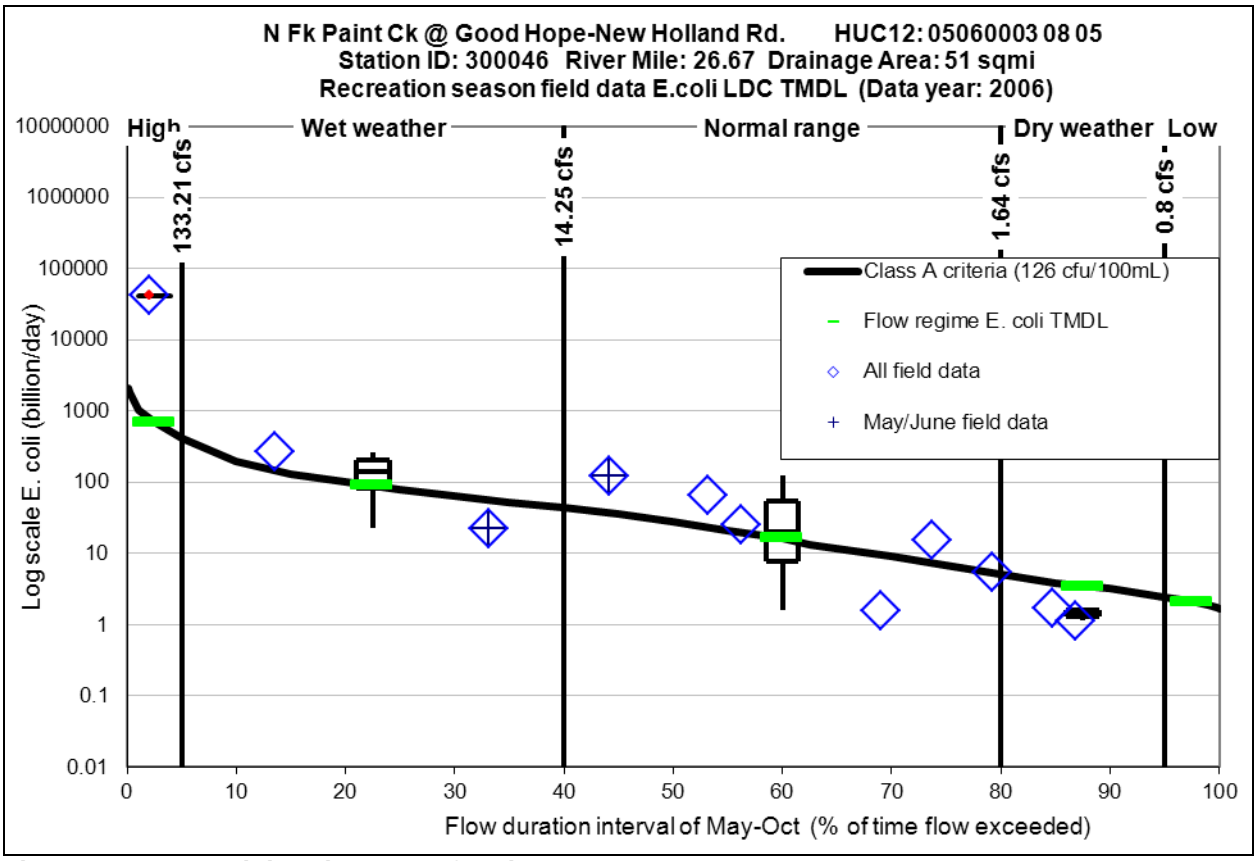


Figure D4-25. Load duration curve for site on N Fk Paint Ck @ Good Hope-New Holland Rd. HUC12: 05060003 08 05.

Table D4-59. TMDL table for site on N Fk Paint Ck @ Good Hope-New Holland Rd. HUC12: 05060003 08 05.

Flow regime TMDL analysis (*E. coli* in billion organisms/day)	High flows	Wet weather	Normal range	Dry weather	Low
Flow duration regime interval	0-5%	5-40%	40-80%	80-95%	95-100%
Samples per regime	1	2	6	2	
Median sample load	41,572	142.8	20.1	1.4	No data
WLA New Holland WWTP - 4PB00028	0.76	0.76	0.76	0.76	0.76
LA	546.4	70.3	12.0	1.9	0.9
MOS	140.3	18.2	3.3	0.7	0.43
AFG	14.03	1.82	0.33	0.07	0.043
TMDL	701.5	91.1	16.4	3.5	2.1
Total load reduction required	98.3%	36.3%	18.4%	None	No Data

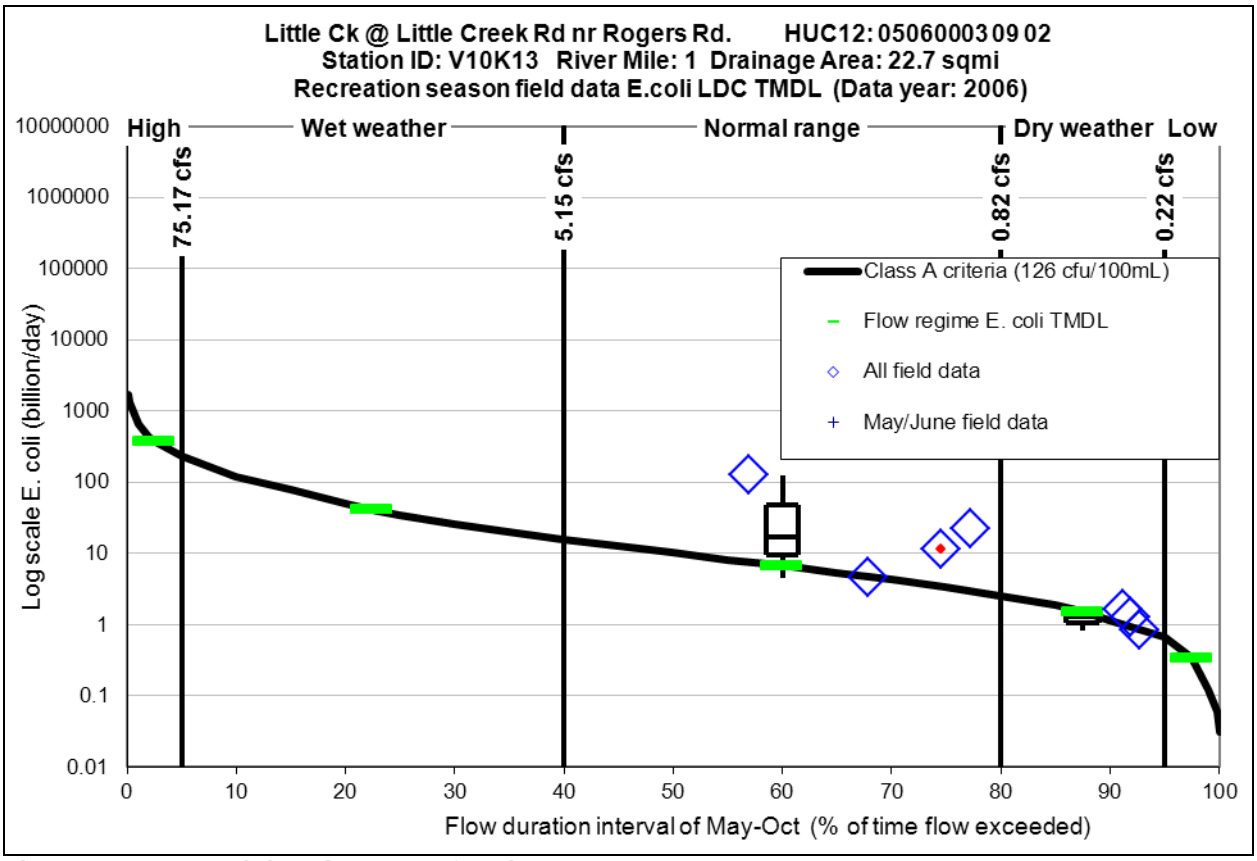


Figure D4-26. Load duration curve for site on Little Ck @ Little Creek Rd nr Rogers Rd. HUC12: 05060003 09 02.

Table D4-60. TMDL table for site on Little Ck @ Little Creek Rd nr Rogers Rd. HUC12: 05060003 09 02.

Flow regime TMDL analysis (*E. coli* in billion organisms/day)	High flows	Wet weather	Normal range	Dry weather	Low
Flow duration regime interval	0-5%	5-40%	40-80%	80-95%	95-100%
Samples per regime			4	3	
Median sample load	No data	No data	17.0	1.3	No data
WLA	0.00	0.00	0.00	0.00	0.00
LA	293.5	32.2	5.2	1.2	0.3
MOS	75.3	8.3	1.3	0.3	0.07
AFG	7.53	0.83	0.13	0.03	0.007
TMDL	376.3	41.3	6.7	1.5	0.3
Total load reduction required	No Data	No Data	60.7%	None	No Data

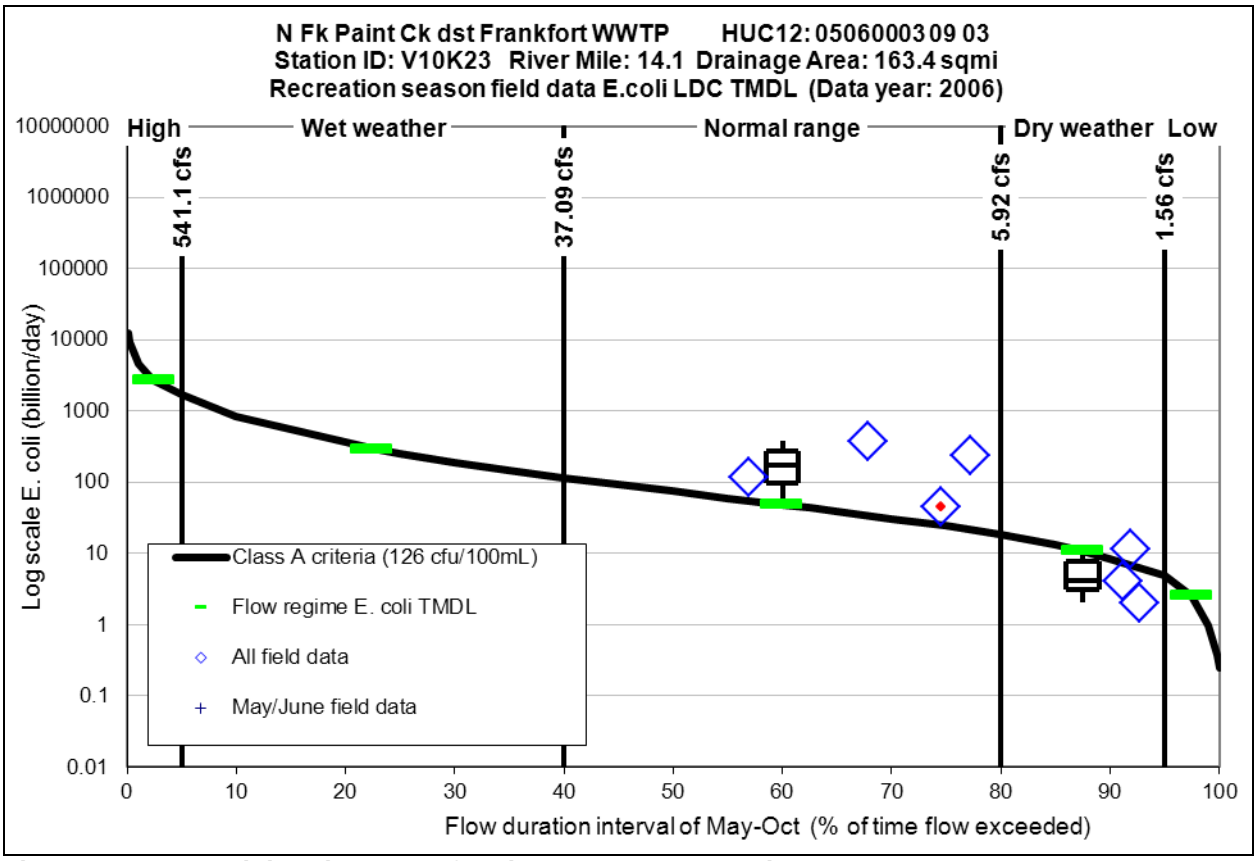


Figure D4-27. Load duration curve for site on N Fk Paint Ck downstream Frankfort WWTP HUC12: 05060003 09 03.

Table D4-61. North Fork Paint Creek *E. coli* TMDLs and surrogate TMDL for organic enrichment (HUC: 05060003 09 03).

Flow regime TMDL analysis (*E. coli* in billion organisms/day)	High flows	Wet weather	Normal range	Dry weather	Low
Flow duration regime interval	0-5%	5-40%	40-80%	80-95%	95-100%
Samples per regime			4	3	
Median sample load	No data	No data	175.7	4.1	No data
Total WLA	1.81	1.81	1.81	1.81	1.81
Frankfort WWTP - 0PB00014	0.91	0.91	0.91	0.91	0.91
Melvin Stone Co - 0IN00217	0.00	0.00	0.00	0.00	0.00
Petro Environmental Tech Cell Div - 4IN00150	0.00	0.00	0.00	0.00	0.00
Pine Tree Court Apts 1 - 4PW00004	0.14	0.14	0.14	0.14	0.14
New Holland WWTP - 4PB00028	0.76	0.76	0.76	0.76	0.76
LA	2110.7	229.8	35.8	6.7	0.2
MOS	541.7	59.4	9.6	2.2	0.51
AFG	54.17	5.94	0.96	0.22	0.051
TMDL	2708.3	297.0	48.2	10.9	2.6
Total load reduction required	No Data	No Data	72.6%	None	No Data

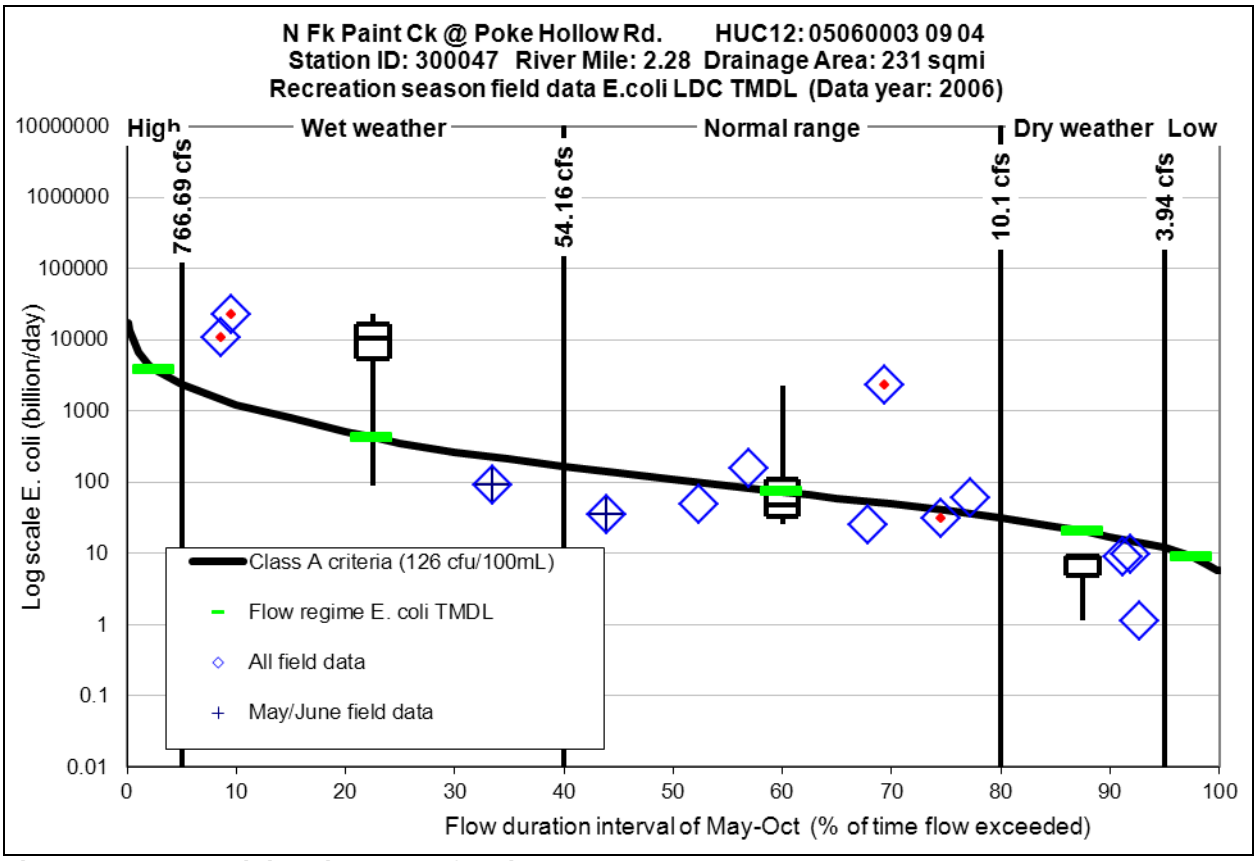


Figure D4-28. Load duration curve for site on N Fk Paint Ck @ Poke Hollow Rd. HUC12: 05060003 09 04.

Table D4-62. TMDL table for site on N Fk Paint Ck @ Poke Hollow Rd. HUC12: 05060003 09 04.

Flow regime TMDL analysis (*E. coli* in billion organisms/day)	High flows	Wet weather	Normal range	Dry weather	Low
Flow duration regime interval	0-5%	5-40%	40-80%	80-95%	95-100%
Samples per regime		3	7	3	
Median sample load	No data	10,534.7	48.6	8.8	No data
Total WLA	6.10	6.10	6.10	6.10	6.10
Frankfort WWTP - 0PB00014	0.91	0.91	0.91	0.91	0.91
Melvin Stone Co0IN00217	0.00	0.00	0.00	0.00	0.00
Petro Environmental Tech Cell Div - 4IN00150	0.00	0.00	0.00	0.00	0.00
Pine Tree Court Apts 1 - 4PW00004	0.14	0.14	0.14	0.14	0.14
New Holland WWTP - 4PB00028	0.76	0.76	0.76	0.76	0.76
Pleasant Valley Regional SD - 0PQ00002	4.29	4.29	4.29	4.29	4.29
LA	2984.5	325.5	51.2	10.0	0.9
MOS	766.8	85.0	14.7	4.1	1.79
AFG	76.68	8.50	1.47	0.41	0.179
TMDL	3834.1	425.2	73.5	20.7	8.9
Total load reduction required	No Data	96.0%	None	None	No Data

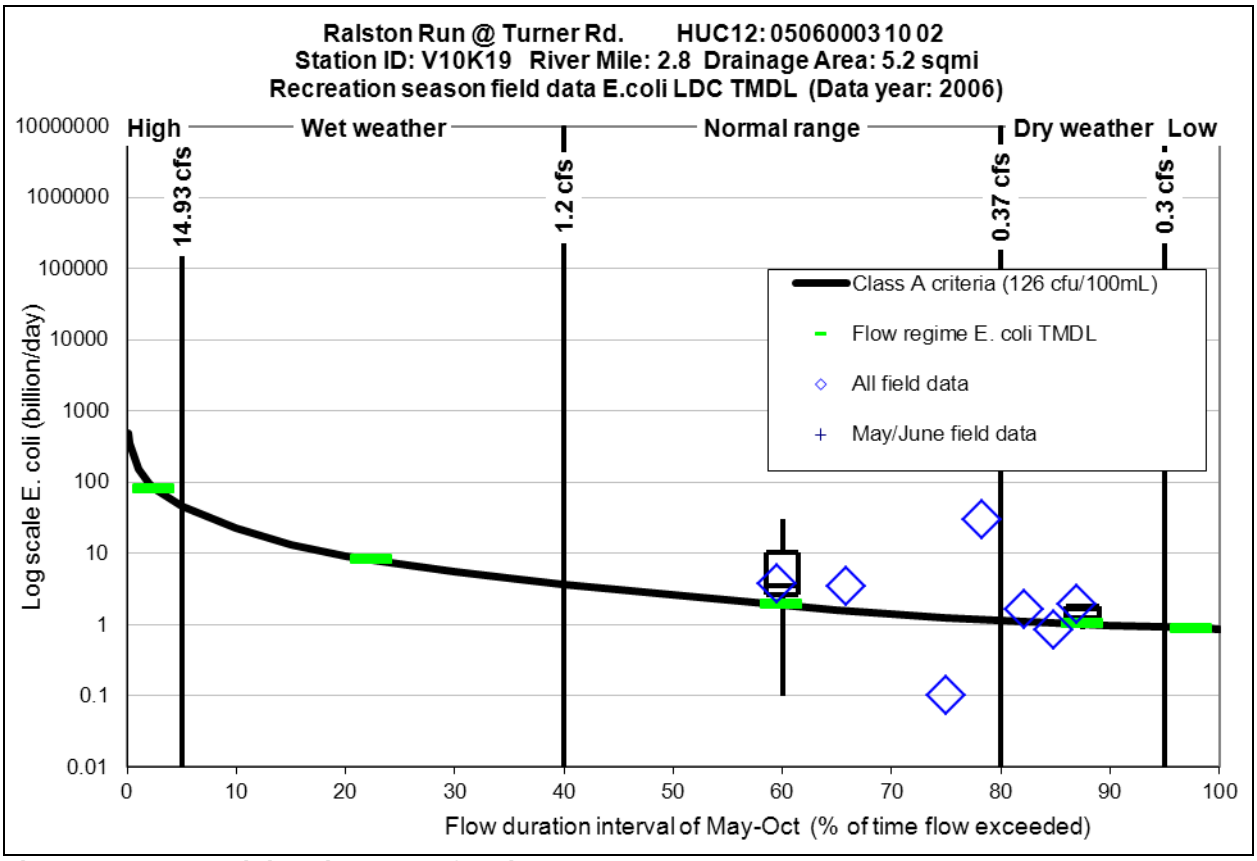


Figure D4-29. Load duration curve for site on Ralston Run @ Turner Rd. HUC12: 05060003 10 02.

Table D4-63. Paint Creek below lower Twin Creek to Scioto River *E. coli* TMDLs and surrogate TMDL for organic enrichment (HUC12: 05060003 10 02).

Flow regime TMDL analysis (*E. coli* in billion organisms/day)	High flows	Wet weather	Normal range	Dry weather	Low
Flow duration regime interval	0-5%	5-40%	40-80%	80-95%	95-100%
Samples per regime			4	3	
Median sample load	No data	No data	3.6	1.7	No data
WLA Huntington Local School District-0PT00007	0.14	0.14	0.14	0.14	0.14
LA	62.9	6.2	1.3	0.7	0.6
MOS	16.2	1.6	0.4	0.2	0.18
AFG	1.62	0.16	0.04	0.02	0.018
TMDL	80.8	8.1	1.9	1.0	0.9
Total load reduction required	No Data	No Data	46.7%	38.8%	No Data

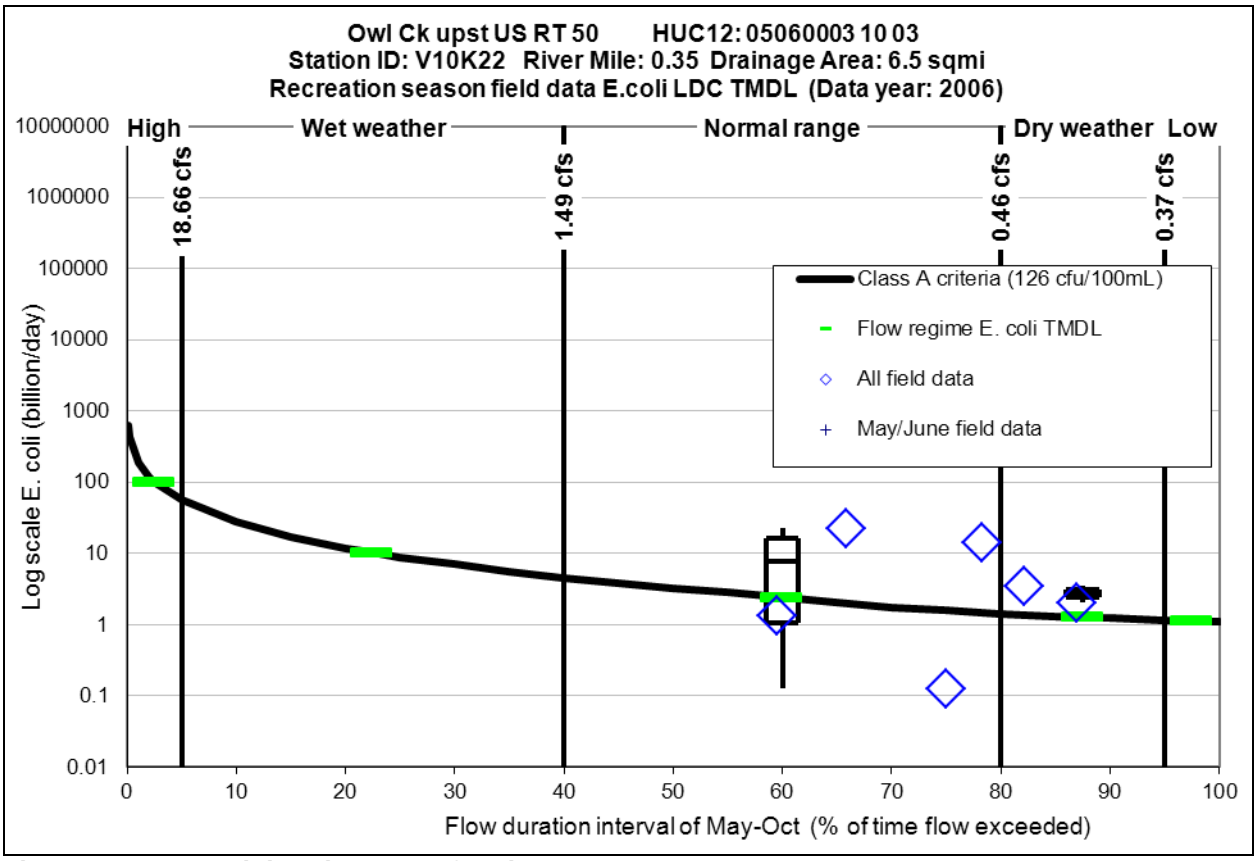


Figure D4-30. Load duration curve for site on Owl Ck upstream US RT 50 HUC12: 05060003 10 03.

Table D4-64. TMDL table for site on Owl Ck upstream US RT 50 HUC12: 05060003 10 03.

Flow regime TMDL analysis (*E. coli* in billion organisms/day)	High flows	Wet weather	Normal range	Dry weather	Low
Flow duration regime interval	0-5%	5-40%	40-80%	80-95%	95-100%
Samples per regime			4	2	
Median sample load	No data	No data	7.8	2.8	No data
WLA	0.00	0.00	0.00	0.00	0.00
LA	78.8	7.9	1.9	1.0	0.9
MOS	20.2	2.0	0.5	0.3	0.22
AFG	2.02	0.20	0.05	0.03	0.022
TMDL	101.0	10.1	2.4	1.3	1.1
Total load reduction required	No Data	No Data	69.4%	54.4%	No Data

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