Appendix

D

LOADING ANALYSIS INFORMATION OTTAWA RIVER WATERSHED

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D1 Background

The Ottawa River watershed was evaluated in 2010 for its ability to support aquatic life and recreation use. In each case, portions of the Ottawa River watershed were found to fall short of the goals set forth by the Clean Water Act. As a result of these findings, this study was carried out to identify pollutant loads that are contributing to non-attainment of water quality goals and quantify any needed reductions of pollutants in order to meet water quality goals. Table D-1 below lists impaired locations alongside associated causes of impairment and the actions taken to address these impairments.

Table D-1. Summary of impairments and methods used to address impairments.

Assessment Unit (04100007)	**Narrative Description**	**Causes of Impairment** (Beneficial use in parentheses)	**Action Taken**
Upper Ottawa River (04100007 03)			
03 01 *Priority points: 2*	Upper Hog Creek	No impairment (ALU)	No action necessary
		No data (RU)	No action necessary
03 02 *Priority points: 5*	Middle Hog Creek	No impairment (ALU)	No action necessary
		Bacteria (RU)	*E. coli* TMDL
03 03 *Priority points: 9*	Little Hog Creek	Dissolved oxygen (ALU)	Total phosphorus TMDL
		Nutrients (ALU)	
		Organic enrichment (sewage) biological indicators (ALU)	
		Total suspended solids (ALU)	Sediment TMDL
		Sedimentation/siltation (ALU)	
		Direct habitat alterations (ALU)	Habitat TMDL
		Bacteria (RU)	*E. coli* TMDL
03 04 *Priority points: 9*	Lower Hog Creek	Nutrients (ALU)	Total phosphorus TMDL
		Nutrient/eutrophication biological indicators (ALU)	
		Sedimentation/siltation (ALU)	Sediment TMDL
		Bacteria (RU)	*E. coli* TMDL
03 05 *Priority points: 11*	Lost Creek	Fish kills (ALU)	Not addressed in this report
		Nutrients (ALU)	Total phosphorus TMDL
		Organic enrichment (sewage) biological indicators (ALU)	
		Bacteria (RU)	*E. coli* TMDL
		Insufficient data to assess use (PDWSU)	No action necessary

Assessment Unit (04100007)	**Narrative Description**	**Causes of Impairment** (Beneficial use in parentheses)	**Action Taken**
03 06 *Priority points: 8*	Lima Reservoir-Ottawa River	Dissolved oxygen (ALU)	Total phosphorus TMDL
		Nutrients (ALU)	
		Nutrient/eutrophication biological indicators (ALU)	
		Excess algal growth (ALU)	
		Low flow alterations (ALU)[1]	
		Organic enrichment (sewage) biological indicators (ALU)	$CBOD_5$ TMDL
		Ammonia (total) (ALU)	Not addressed in this report[2]
		Direct habitat alterations (ALU)	Habitat TMDL
		Other anthropogenic substrate alterations (ALU)	Sediment TMDL
		Sedimentation/siltation (ALU)	
		Unknown (ALU)	No action necessary
		Bacteria (RU)	*E. coli* TMDL
		Insufficient data to assess use (PDWSU)	No action necessary
Middle Ottawa River (04100007 04)			
04 01 *Priority points: 6*	Little Ottawa River	Biochemical oxygen demand (ALU)	Total phosphorus TMDL
		Nutrients (ALU)	
		Organic enrichment (sewage) biological indicators (ALU)	
		Direct habitat alterations (ALU)	Sediment TMDL
		Bacteria (RU)	*E. coli* TMDL
04 02 *Priority points: 10*	Dug Run-Ottawa River	Dissolved oxygen (ALU)	Total phosphorus TMDL
		Nutrient/eutrophication biological indicators (ALU)	
		Nutrients (ALU)	
		Organic enrichment (sewage) biological indicators (ALU)	$CBOD_5$ TMDL
		Fish-passage barrier (ALU)[3]	Not addressed in this report
		Unknown (ALU)	No action necessary
		Bacteria (RU)	*E. coli* TMDL

Assessment Unit (04100007)	**Narrative Description**	**Causes of Impairment** (Beneficial use in parentheses)	**Action Taken**
04 03 *Priority points: 7*	Honey Run	Dissolved oxygen (ALU)	Total phosphorus TMDL
		Nutrients (ALU)	
		Direct habitat alterations (ALU)	Habitat TMDL
		Bacteria (RU)	*E. coli* TMDL
		Insufficient data to assess use (PDWSU)	No action necessary
04 04 *Priority points: 3*	Pike Run	No impairment (ALU)	No action necessary
		Bacteria (RU)	*E. coli* TMDL
04 05 *Priority points: 5*	Leatherwood Ditch	No impairment (ALU)	No action necessary
		Bacteria (RU)	*E. coli* TMDL
04 06 *Priority points: 6*	Beaver Run-Ottawa River	No impairment (ALU)	No action necessary
		Bacteria (RU)	*E. coli* TMDL
Lower Ottawa River (04100007 05)			
05 01 *Priority points: 5*	Sugar Creek	No impairment (ALU)	No action necessary
		Bacteria (RU)	*E. coli* TMDL
05 02 *Priority points: 9*	Plum Creek	Fish kills (ALU)	Not addressed in this report
		Dissolved oxygen (ALU)	Total phosphorus TMDL
		Biochemical oxygen demand (ALU)	
		Nutrient/eutrophication biological indicators (ALU)	
		Ammonia (total) (ALU)	
		Organic enrichment (sewage) biological indicators (ALU)	
		Sedimentation/siltation (ALU)	Sediment and habitat TMDLs
		Unknown (ALU)	Not addressed in this report
		Bacteria (RU)	*E. coli* TMDL
05 03 *Priority points: 6*	Village of Kalida-Ottawa River	No impairment (ALU)	No action necessary
		Bacteria (RU)	*E. coli* TMDL

ALU = aquatic life use RU = recreation use PDWSU = public drinking water supply use

[1] Only addressed problems where lowhead dams exacerbate nutrient enrichment. Lowhead dams place a physical restriction on the macroinvertebrate community that is not addressed by the proposed technique.

[2] Impairment linked to permit exceedances from a point source near the time of sampling based on a mechanical error at the facility; repetition of the error is not expected. Current permit limits considered protective of aquatic life.

[3] A fish passage barrier is not a load-regulated impairment and thus a TMDL is inappropriate.

D2 Linkage Discussion

D2.1 Dissolved Oxygen

The purpose of this linkage discussion is to link the cause of impairment to aquatic life (dissolved oxygen) to the sources that trigger the impairment. Dissolved oxygen (DO) is a dynamic parameter of water chemistry that directly affects the survival of aquatic life. Identifying DO as a dynamic parameter acknowledges that it is affected by multiple components of the ecosystem including: temperature, re-aeration, nutrient enrichment, and oxidation of organic matter. Ottawa River watershed assessment sites were noted as having DO violations (OAC 3745-1-07). In the Ottawa River watershed two cases are identified that contribute to DO violations: nutrient enrichment/eutrophication *and* organic enrichment (sewage).

D2.1.1 Nutrient Enrichment and Nutrient Eutrophication

Nutrients rarely approach concentrations in the ambient environment that are toxic to aquatic life, and are essential to the functioning of healthy aquatic ecosystems at appropriate concentrations. However, nutrient concentrations in excess of the needs of a balanced ecosystem (nutrient enrichment) can exert negative effects by causing excess primary production (Sharpley *et al.* 1999). The excess primary production causes negative effects including large diel fluctuations of DO and potential for minimum DO violations when respiration and decomposition of dead algae (eutrophication) is high. Such changes shift fish species composition away from functional assemblages comprised of intolerant species, benthic insectivores and top carnivores typical of high quality streams towards less desirable assemblages of tolerant species, niche generalists, omnivores and detritivores typical of degraded streams (Ohio EPA 1999a). Such a shift in community structure lowers the diversity of the system; the IBI and ICI scores reflect this shift and a stream may be precluded from achieving its aquatic life use designation.

Phosphorus is selected as the focal point for nutrient TMDLs because it is typically the limiting nutrient to algal growth in the fresh water systems (Mcdowell *et al*. 2009). Therefore, by limiting the loading of phosphorus to streams, the impacts caused by nutrient enrichment will be mitigated. Ohio EPA developed statewide total phosphorus (TP) targets for streams on the basis of basin size in order to address nutrient enrichment impacting aquatic life (Ohio EPA 1999a). Ohio EPA has implemented phosphorus limitation in other watersheds and clearly documented how reducing TP loadings to streams mitigates in-stream nutrient enrichment (Ohio EPA 2007). All impaired streams receive a TMDL for total phosphorus. In some cases the TMDL is based on a specified critical condition where certain sources are not mentioned. An example is the TMDL for the mainstem of the Ottawa River that does not result in allocations for the industrial storm water discharges and CSOs. The selected critical condition is such that these sources do not directly contribute a nutrient load during the low flow condition.

D2.1.2 Organic Enrichment

The other case of loading that causes DO violations is organic enrichment from external sources. The result is conditions similar to eutrophication where DO is depressed by the oxidation of organic matter. The difference between the two causes is the source of the organic matter: in-stream production vs. external loading. In the case of the Ottawa River, biological indicators for organic enrichment are listed as a cause of impairment when linked to external sources of organic matter. The presence of certain sources is common where impairments are indicated including: Combined Sewer Overflows (CSOs), Sanitary Sewer Overflows (SSOs), and non-point sources (includes failing on-lot home sewage treatment systems (HSTS)). Other sources contribute to external organic loading exist including industrial storm water permits and continuous point source discharges (includes HSTS with NPDES permit); however these are ubiquitous to the watershed (not limited to occurring in impaired areas) and are not indicated as a source stimulating organic enrichment. In one case a TMDL is computed directly to address organic enrichment but in most instances surrogate TMDLs for a different pollutant address the reduction necessary to account for organic enrichment. As some of the sources of organic load are not attributed to organic enrichment they are not accounted for with an allocation in a TMDL.

Four tributaries (Little Hog Creek, Lost Creek, Little Ottawa River and Plum Creek) and two Ottawa River mainstem areas have impairment partially attributed to organic enrichment. In the case of the tributaries surrogate TMDLs for phosphorus represent the reduction needed in the sources causing enrichment. The tributaries are associated with enrichment from CSOs, SSOs, and on-lot HSTS. Nutrient enrichment is also indicated in each of these watersheds and the nutrient impairment is addressed with a TMDL for total phosphorus. SSOs are prohibited and thus receive no wasteload; in phosphorus TMDLs they are not included thus indicating no wasteload is allocated for SSOs. The only way to achieve zero load is to eliminate the discharge. Tributary CSOs only occur in one instance for the village of Columbus Grove and Plum Creek. Columbus Grove is on a schedule to separate the sewer system and as such for the purposes of the TMDL the CSOs are treated as SSOs and given zero load for the surrogate parameter phosphorus. On-lot HSTS (occurring in all impaired tributaries) are part of the non-point source load but by definition are meant to treat and assimilate all pollutants on the site. Systems commonly fail with an Ohio Department of Health survey from 2012 (ODH 2013) survey indicating that some 31% of the systems statewide are failing. As a convention these systems are considered to contribute no load to the streams but load is reserved in the form of an allowance for future growth in the case that correction of a failing system requires issuing an NPDES permit. The attribution of no load to these systems is again accounted for with the zero allocation for phosphorus. The source of impairment for mainstem sites is attributed to loads from the city of Lima CSOs. This source is dealt with explicitly with a TMDL for $CBOD_5$ in a specified critical condition. A summary of where organic enrichment occurs and how the sources are addressed is presented in Table D-2.

Table D-2. Summary of organic enrichment sources and how the source is covered by a TMDL.

Nested Subwatershed (04100007)	CSOs	SSOs	HSTS
03 03	NP	NP	PZ
03 05	NP	NP	PZ
03 06	**PA**	PZ	PZ
04 01	NP	PZ	PZ
04 02	**PA**	PZ	PZ
05 02	PZ	PZ	PZ

NP - Not present as a source of impairment
PA - Present - receives WLA
PZ - Present - load is zero

D2.2 Habitat Alteration and Sedimentation/Siltation

Habitat alteration and sedimentation are both common causes of impairment in the Ottawa River 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 (Ohio EPA 1989a; Rankin 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, in-stream cover, riparian characteristics, channel condition, pool/riffle quality, gradient and drainage area. Analysis of QHEI and biological response data by Ohio EPA (1999a) 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.

D2.3 Pathogens (Bacteria) Recreation Use Impairments

Elevated bacteria loading is the cause of recreation use impairment in the Ottawa River watershed. The proportion of pathogenic organisms present in assessed waters is generally small compared to non-pathogenic organisms. For this reason most pathogenic organisms are difficult to isolate and identify. Additionally, pathogenic organisms are highly varied in their characteristics and type which also makes them difficult to measure. Nonpathogenic bacteria that are associated with pathogens transmitted by fecal contamination are more abundant and are, therefore, monitored as surrogates because of the greater ease in sampling and measuring. These bacteria are called indicator organisms. Ohio has promulgated water quality standards for the geometric mean concentration for *E. coli* bacteria (OAC 3745-1-07). These values serve as the targets used in the development of the TMDLs that address recreation use impairments. Therefore *E. coli* is used to address recreation use impairment.

D3 Analysis Methods

D3.1 Dissolved Oxygen

D3.1.1 Nutrient Enrichment and Eutrophication

<u>Target Development</u>

Phosphorus is considered to control the degree of enrichment and as a result targets discussed in this section are for phosphorus. Ohio Administrative Code (OAC) includes 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.

The narrative rules establish the authority of the Ohio EPA to impart nutrient limits for watersheds where biological attainment is not met. However, numerical criteria have not been established. Ohio EPA staff developed a document, *Association between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams* (Ohio EPA 1999), that relates total phosphorus concentrations to attainment of stream biology. This report was used for the water quality targets for the Ottawa River watershed TMDLs: 0.1 mg/l based on wadeable streams in Ohio (200 mi^2 > drainage area > 20 mi^2) designated as warmwater habitat. 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 regarding their use in TMDL development.

Load Duration Curves (LDCs)

Justification for Use of Nutrient LDCs

Nutrients can be modeled explicitly in a detailed manner such as in the model QUAL2K, also used in this report. However, use of a model with this complexity is time consuming and for adequate calibration, more data is needed than what is collected in a routine field survey. In many cases where there are none or few permitted dischargers it in not feasible to collect the additional data to allow for the development of more complex models.

An empirical method of determining TMDL nutrient loading and reductions is utilized with load duration curves (LDCs). This method is appropriate since nutrient sources in Ohio streams can be differentiated by streamflow regime. The main advantage of the use of LDCs is in this method's ability to differentiate loads based on flow regime. 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). However in smaller tributaries, sources and how their contributions differ between flow regimes are fairly straight forward. In-stream processes and interactions between sources are simplified at this scale mitigating the primary weakness of the technique.

Critical Condition and Seasonality

Nutrient impairments that manifest as effects on the aquatic community are exacerbated by times of low flow where sunlight and temperatures are also not limiting. These conditions are associated with summer months when precipitation is typically the lowest, temperatures are the highest and daylight is the longest. These are the times that algae is least likely to be limited by anything other than nutrient availability. The result is the ability to reduce stress on aquatic communities by restricting algal growth by limiting nutrients. In systems where high nutrient inputs are not associated with these critical conditions there is still a link to aquatic life communities. Nutrients that are assimilated to the system during flow regimes outside of the critical condition can be released during the critical condition creating an internal nutrient source. This is especially true with phosphorus which often enters waters bound to sediment that can accumulate on the streambed. LDCs have the added benefit of providing the opportunity to allocate nutrient loads at all flow regimes, more completely managing their effects.

Development of Load Duration Curves

To create LDCs for the development of TMDLs, the flow duration for each TMDL site is determined. This involves calculating the flow expected for the full range of exceedance percentile. 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 (0% exceedance percentile) to extremely low flows (100% exceedance percentile). The flow curve is converted into a load duration curve by taking the product of the flow, the water quality target (0.1 mg/l for WWH) and a conversion factor. The load in kilograms per day is 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 total phosphorus concentration, 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 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 and Crouse 1996).

Box plots are shown for each flow regime with observed data. The center line of these boxes represents the median TP 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; these are the median streamflow 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 total phosphorus 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. The likelihood of a source affecting the stream varies by flow regime and likely sources in the five flow regimes are indicated in Table D-3.

Table D-3. 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

Most sites with LDCs developed to be TMDLs are at what Ohio EPA refers to as sentinel sites. These sites are picked to represent nested subwatersheds and/or important drainage areas. The sites are sampled more frequently than the other survey sites. Water stage to stream discharge rating curve relationships are also created for each sentinel site. Knowing the stream discharge at each sampling of these sites allows for load calculations to be made without relying on the extrapolations to stream gages. Some additional non-sentinel sites are also utilized to create LDCs for TMDLs. These assessment sites were found to be impaired by nutrient enrichment, but do not have a sentinel site representing them. Table D-4 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 USGS gage (station # 04187100 Ottawa River at Lima, OH). A drainage area ratio of the LDC site's watershed to the USGS gage's is then applied to the gage flows.

Table D-4. LDC total phosphorus TMDL sites and their drainage areas.

Nested Subwatershed	Stream Name	Class	Location	River Mile	Drainage Area (Sq. mi.)
04100007 03 04	Hog Creek	WWH	Swaney Rd	0.27	73.7
04100007 03 03	Mud Run	WWH	Bluffton-Bentley Rd	0.65	6.7
04100007 03 03	Little Hog Creek	WWH	Peevee Rd	3.62	12.1
04100007 03 05	Lost Creek	WWH	East High Street	0.35	5.8
04100007 03 06	Zurmehly	WWH	Ft Amanda Road	0.03	3.3
04100007 04 01	Little Ottawa	WWH	Ft Amanda Road	0.03	16.4
04100007 04 03	Honey Run	WWH	Cremeans Rd	3.58	10.9
04100007 05 02	Plum Creek	WWH	TR-O	8.12	22.0

Margin of Safety and Allowance for Future Growth

In order to use the LDCs for TMDLs an additional flow adjustment must be made. To account for expected future growth in the watershed, TMDLs require that permitted public waste water treatment facilities be allocated at their full permitted design flow. 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 used for Ottawa River TMDLs derived from nutrient LDCs. The MOS is used to account for uncertainty in the response of the waterbody to loading reductions. A 5% MOS is applied to account for unknown factors of the assimilative capacity and limited data available for this analysis. For LDC TMDLs, U.S. 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.
2) Recognition that the uncertainty associated with effluent limits and water quality may vary across different flow conditions.

Population projections for this watershed show insignificant growth in in the area contained in the watershed (U.S. Census Bureau 2012). Because of this, a relatively low allowance for future growth (AFG) of 2% is reserved from the TMDL.

Allocations

Each NPDES discharger on a tributary where downstream aquatic life use is impaired due to nutrient-related causes is assigned a wasteload allocation (WLA) for total phosphorus based on the design flow of the facility and water quality target applicable to its receiving water. Sanitary sewer overflows and failing on-lot household sewage treatment systems are present in some watersheds that are impaired by nutrients. Each is a source of nutrients but does not appear as part of the allocations, indicating that they receive zero wasteload allocation. CSOs from Columbus Grove appear in the table but because of the scheduled complete sewer separation for the community also received zero load in the allocations. Industrial facilities with individual permits for storm water discharges are not considered to be sources phosphorus. The result is that the allocation for these facilities is accounted for based on the allocation included for either the load allocation or the municipal separate storm sewer system (MS4) allocation. Allocations are listed in the TMDL table that corresponds with each sampling site in Section D4.1. Recommended permit limits for TP, based on TMDL wasteload allocations, are also included in the section.

Total phosphorus NPDES permit limit recommendations in the Ottawa River watershed account for empirical in-stream phosphorus decay, or reincorporation, based on samples taken in the Hog Creek mainstem between Ada WWTP and the Hog Creek at Swaney Road LDC site. Average in-stream phosphorus concentrations decreased at a rate of 0.06 mg/L/ river mile; therefore, an allowance is made for increased phosphorus discharge based on the distance in river miles travelled to the impaired site.

Validation of Drainage Area Yield Relationship

The LDC method requires that the hydrology of the site is accurately represented by the relationship between the gage flow and the site flow. A series of flow measurements made at the Sugar Creek at CR-16 O were used to determine the accuracy of predicted streamflow measurements using drainage area-weighted flow data from the Ottawa River USGS stream gage station 04187100. Measurements were made at a range of flow levels (from interstitial or 0.0 cfs to 146 cfs actual measured flow) during the sampling season of 2010 (Table D-5). Measured flows were compared with USGS daily average flows, for the day that the flow measurement was made, via a comparison to a 1-to-1 line that represents perfect agreement between the two values (Figure D-1).

Table D-5. Sugar Creek @ CR-16O measured flows versus predicted flows.

Date	Measured Flow	Drainage Area Yield Predicted Flow
9/14/2010	0.0	3.97
7/28/2010	2.25	13.6
3/24/2010	9.24	33.04
5/12/2010	145.67	185.6

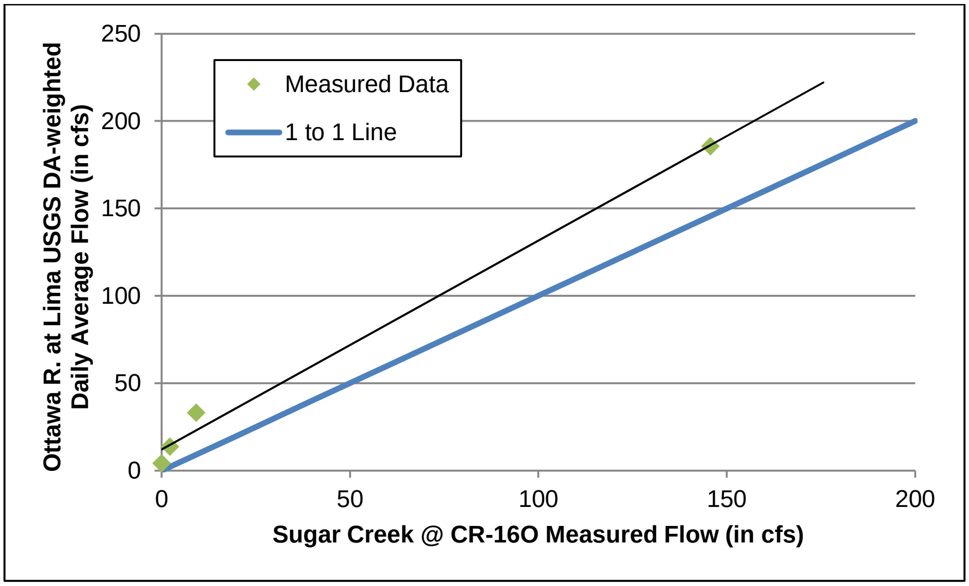

Figure D-1. Regression of Sugar Creek at CR-16O measured flows vs. Ottawa River at Lima USGS drainage area weighted daily average flows.

QUAL2K

Justification for Use of QUAL2K

While TP LDCs are adequate in many situations for developing nutrient TMDLs, in other cases there are complicating factors including: large interactive point source dischargers and changing stream dynamics. The large point sources are exacerbated at a specific critical condition and warrant more effort to discern the impact at that critical condition. These situations limit the effectiveness of an empirical approach such as a LDC that examines a continuum of streamflow conditions. In this case the Ottawa River mainstem is not attaining aquatic life use (ALU) from RM 43.4 to 28.9 with a common cause of DO from nutrient enrichment *and* flow alterations (lowhead dams). Stream dynamics in this reach change drastically as the river moves from agricultural land use upstream from the city of Lima to urban/suburban land use within the city of Lima then back to an agricultural land use downstream from the city of Lima but with flow added by point sources within the city of Lima. Methods like LDCs do not account for the changing morphology of the stream especially when changes are this drastic. QUAL2K is an in-stream kinetics water quality model that allows more exact representation of the processes that affect water quality. Once calibrated and validated the model can be used to simulate critical stream conditions and compare strategies for

remediation. QUAL2K was developed by Chapra and others (2008). The model is supported by U.S. EPA and is recommended for the development of TMDLs.
The strengths and weaknesses of QUAL2K also help to justify the use of the model in this scenario. QUAL2K explicitly grows algae, which are grown based on the availability of resources they need with nutrients being one of the major resources. This allows the nutrients to become dynamic in the system which allows for nutrient loading to be looked at not only as a mass balance, but also as from the standpoint of how the system responds to nutrient inputs. One weakness of QUAL2K is the inability to represent nonpoint source loads that are more important when streamflow is not dominated by point sources. The critical condition limits the exposure to the limitation because it is a time when point sources dominate the flow. However residual impacts from sources occurring outside of the critical condition are not fully accounted for. The bigger weakness in this scenario is that the model is for steady-state flow conditions. It is rare in nature and for wastewater treatment plants to be observed as a true steady state condition. Flow is a major parameter for determining concentrations and determining how long reactions have to occur so uncertainty in this area of the model can cause significant problems. Sampling for calibration and validation data at conditions that are nearly steady flow is a means to mitigate the problem

Critical Condition and Seasonality

Nutrient impairments that manifest as effects on the aquatic community are exacerbated by times of low flow where sunlight and temperatures are also not limiting. These conditions are associated with summer months when evapotranspiration and temperatures are the highest and daylight is the longest. These are the times that algae is least likely to be limited by anything other than nutrient availability. The result is the ability to reduce stress on aquatic communities by restricting algal growth through nutrient limitation. The conditions are always linked to dry weather conditions. Several NPDES permitted dischargers have separate permit conditions for treated flows that are linked to increased volume due to the influence of storm water. The QUAL2K model does not address these flows and they are not considered linked to the nutrient impairment that is observed in the impaired portions of the Ottawa River downstream from the major point sources.

QUAL2K Description

QUAL2K is a one-dimensional, steady-state model that is used to simulate dissolved oxygen (DO), carbonaceous biological oxygen demand (CBOD), algae as chlorophyll-a, organic and inorganic phosphorus, and the nitrogen series. The model considers stream re-aeration from the atmosphere and sediment oxygen demand among other processes. The study area is divided into a sequence of reaches (Figure D-2) and within each reach there exists 1 - 4 elements where physical/chemical processes are simulated as a steady-state (invariant with time) phenomenon. Each reach is a river segment that has stable hydraulic characteristics (e.g. consistent slope, velocity, bottom width, etc.). While both the mainstem and tributaries can be modeled as interacting segments; the tributaries were considered as fixed inputs. The entire course of elements for all reaches is considered a series of linked, “completely mixed reactors.” Each element is treated as a separate system which has initial external inputs (from the previous element, baseflow additions, tributary, and wastewater inflow) and internal chemical reactions that either increase or decrease the modeled constituents.

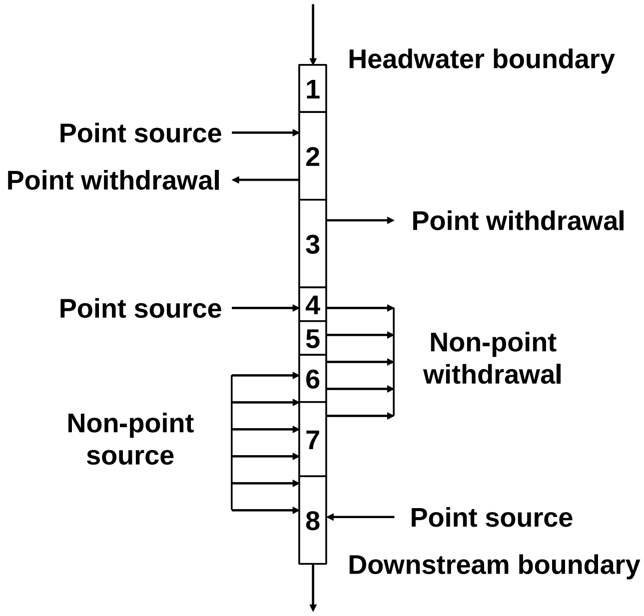

Figure D-2. General segmentation scheme for the QUAL2K model showing reaches (numbered), boundary locations, and lateral inputs (or withdrawals). In this simplified scheme, tributaries are considered as fixed, point source inputs.

The Ottawa River (Lima) study area was divided into 17 reaches with a headwater boundary established at Thayer Road (RM 45.97) and a downstream boundary established at the crossing of Piquad Road (RM 25.8) (Figure D-3). Reaches have similar hydraulic characteristics or are controlled by a hydraulic structure such as a lowhead dam. Reach setup is critical in order to develop accurate hydrology for the modeled segment.

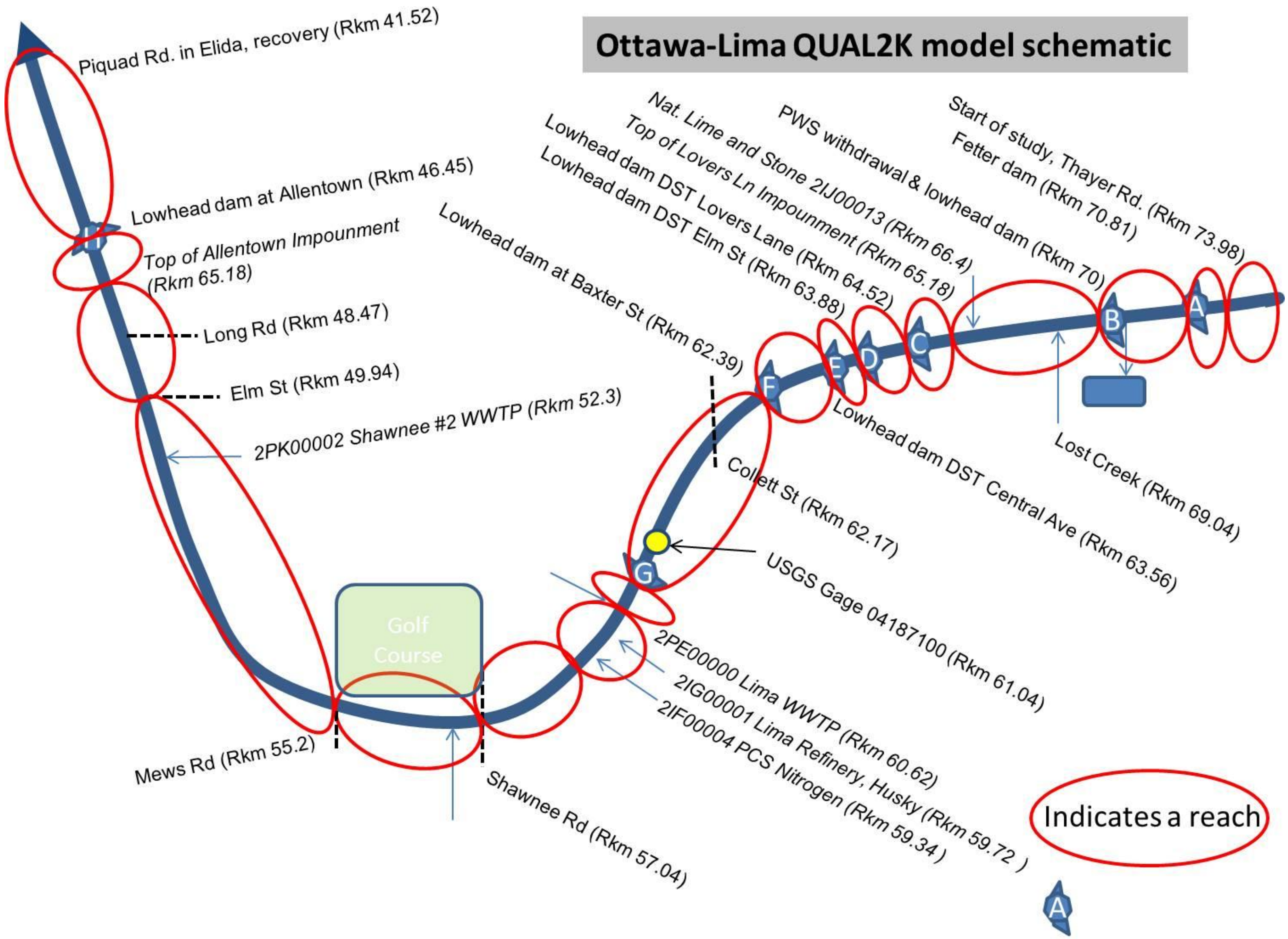

Figure D-3. QUAL2K model segmentation for Ottawa River from river mile 25.8 – 45.97.

Flow is an explicit component of the model and additions (point sources including tributaries) or withdrawals of flow are modeled conservatively. Different methods are used to model the stream hydraulics by QUAL2K: rating curves for free flowing reaches and weir equations for impounded reaches. Rating curves for depth and velocity are used to describe stream hydraulic characteristics—velocity and depth—as a function of channel flow (Q). The functional relationship for velocity (U) and depth (H) is described as:

$$U = aQ^b$$

$$H = \alpha Q^\beta$$

The coefficients (a and α) and exponents (b and β) are established from field survey. At a minimum, three field surveys are needed to establish reliable coefficients and exponents through a linear, least-squares regression analysis. Each survey produces one plotting point for fitting a linear model. Only one time-of-travel field survey was performed for this TMDL, therefore the exponents b (0.45) and β (0.55) were established near the midpoints of ranges provided in Chapra (2008). A sharp crested weir equation is used to describe hydraulic characteristics for reaches that are controlled by dams:

$$H_h = \frac{Q_i}{1.83\,B_w}^{2/3}$$

where B_w represents the width of the weir, Q_i represents the element flow and the output is H_h or the head at some point induced by the weir. Based on these two different methods the model predicts the average depth of an element as well as the velocity. Time of travel is then computed from the average velocity of the element.

Temperature is a critical component of any model that is used to represent chemical interactions. QUAL2K uses temperature controlled rate equations to model nearly all reactions dictating the interaction of chemical constituents.

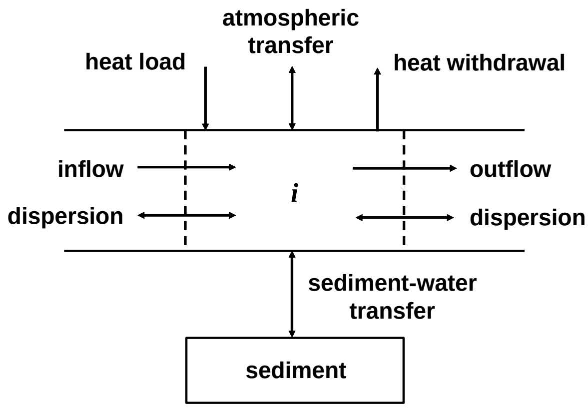

Figure D-4. Components of the heat balance in a modeled element (Chapra et al 2008).

The heat balance for a single element *i* that is carried out in the model is controlled by heat transfer rates between many sources and sinks represented in Figure D-4. Model inputs such as: shade, cloud cover, point source temperatures, and numerous heat transfer rate constants are used to dictate temperature. Temperature affects the reaction rates in the model using the equation:

$k(T) = k(20)\theta^{T-20}$ (Chapra et al 2008)

where k(T) reaction rate at a specified temperature (T), k(20) is a standardized reaction rate at 20^{o}C and θ is the temperature coefficient for the reaction. In the above equation the most aptly used temperature coefficient is θ = 1.07 which represents roughly a doubling of a reaction rate for every 10^{o}C. Temperature and stream hydrology are critical pieces of information for the modeled chemical constituents that are the target of the modeling. Their importance is stressed in the calibration of the model.

Chemical constituents take on two forms in the model: conservative substances (not subject to reaction) and model variables (subject to chemical interaction). Conservative substances are important for providing mass balance checks on the system but the real purpose of using a complex model such as QUAL2K is to accurately represent variables subject to interaction. The following are all modeled as variables by QUAL2K: nutrients (phosphorus and nitrogen), chlorophyll-a (from benthic algae and phytoplankton), organic carbon, CBOD, pH and alkalinity.

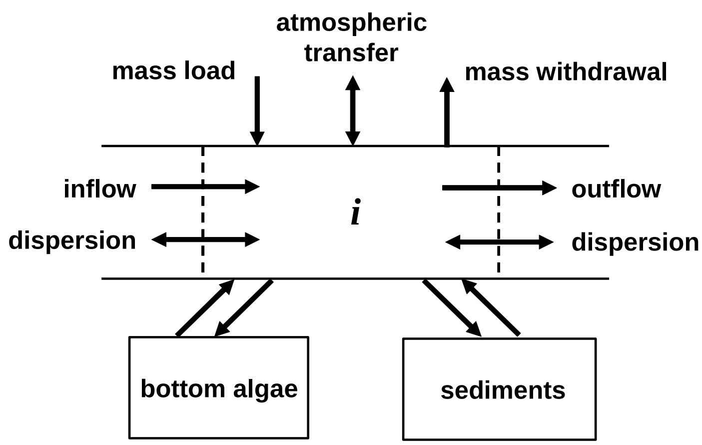

Figure D-5. General mass balance showing interactions between various pools for variables.

Variables are subject to interaction between various different pools in a system represented in Figure D-5. Different pools can act as either sources or sinks changing concentrations; more detailed descriptions of the equations for the interactions of variables are presented in Chapra et al. (2008, pages 31 – 77). The interaction of variables is complex in nature and further discussion is unnecessary in the context of this report.

QUAL2K Calibration

The interactions that are modeled by QUAL2K are not constant from one system to another which makes calibration of the model necessary. The data used for calibration were collected on September 14, 2011. The data collected included: hydrology (flow and time of travel [TOT]), Datasonde measurements (temperature, dissolved oxygen, pH and conductivity), stream chemistry (nutrients, CBOD, TSS, etc.), phytoplankton (chlorophyll *a*, or Chl-a) and benthic algae (Chl-a). A subset of these components is presented in order to show the level of accuracy with which the model was able to match measured stream conditions.

Hydrology

As stated above flow is an important component of the model because it dictates many other processes, such as dilution and heat transfer. Two sites on the modeled reach have enough data to represent daily average flows: Piquad Road (RM 25.75) and upstream Lima upstream dam at USGS gage (RM 37.93). Flow is conservatively modeled and flow inputs are as daily averages; therefore, flow measurements representing a single point in time could not be used to calibrate model flows. As you can see in Figure D-6 the flow was underestimated at both calibration points. The cause is likely linked to several factors: unstable flows observed during the field survey, uncertainty in flow measurements and uncertainty in discharger inputs. It is expected to see such errors in modeled data and is the reason why model results must also be validated to ensure constituents corroborate to field data measurements.

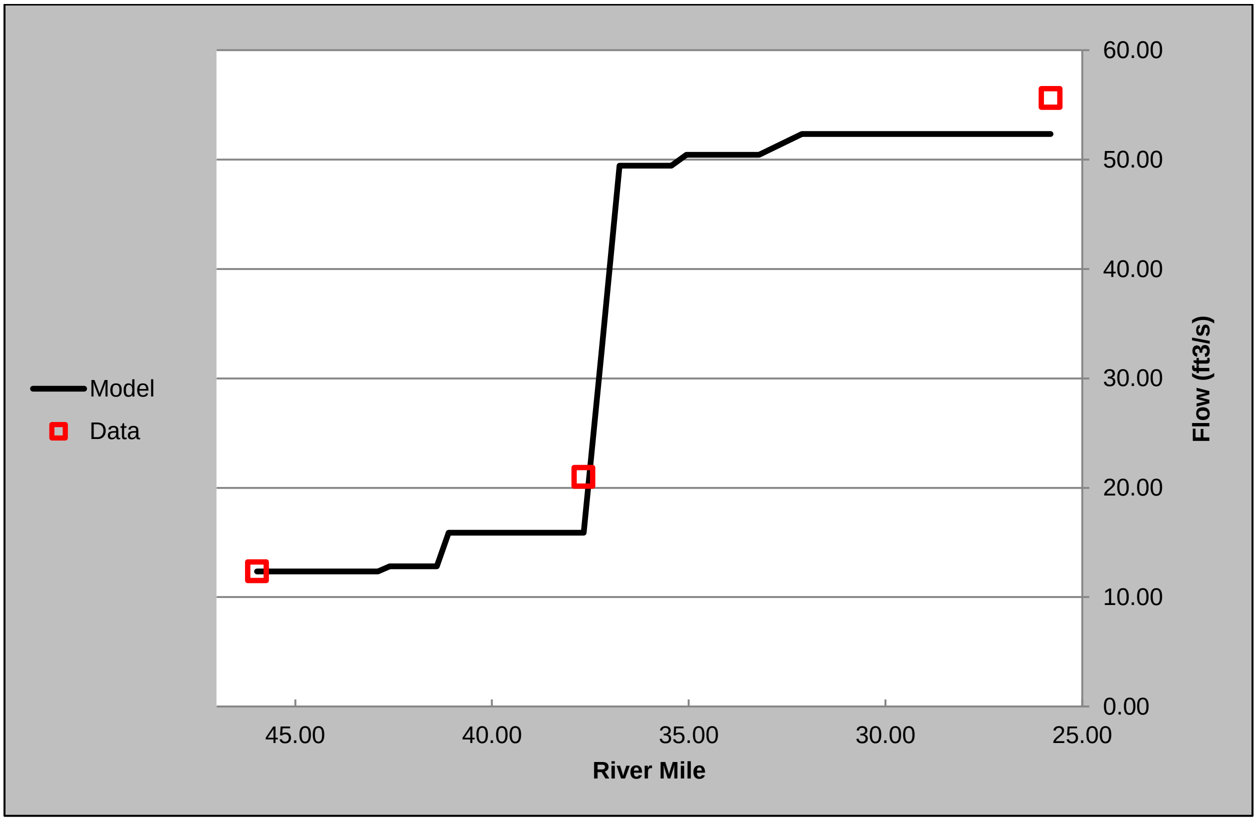

Figure D-6. Flow calibration plot; flows are generally underestimated in the model.

Time of travel (TOT) is an important model output because it dictates the amount of time chemical reactions have to take place in a given reach. The calibration data set is used to adjust hydrologic parameters (rating curves and weir coefficients) so that TOT can well represent measured field data. Field data are measured by dumping rhodhamine dye at one point and measuring it at another; the time in which the highest concentration of die is captured at the second point represents the average TOT of the reach. Figure D-7 shows the calibration for TOT of the modeled stream segment. As a result of how the model is calibrated for TOT, error is minimized, assuring that the model accurately represents the amount of time reactions have to take place in a given reach.

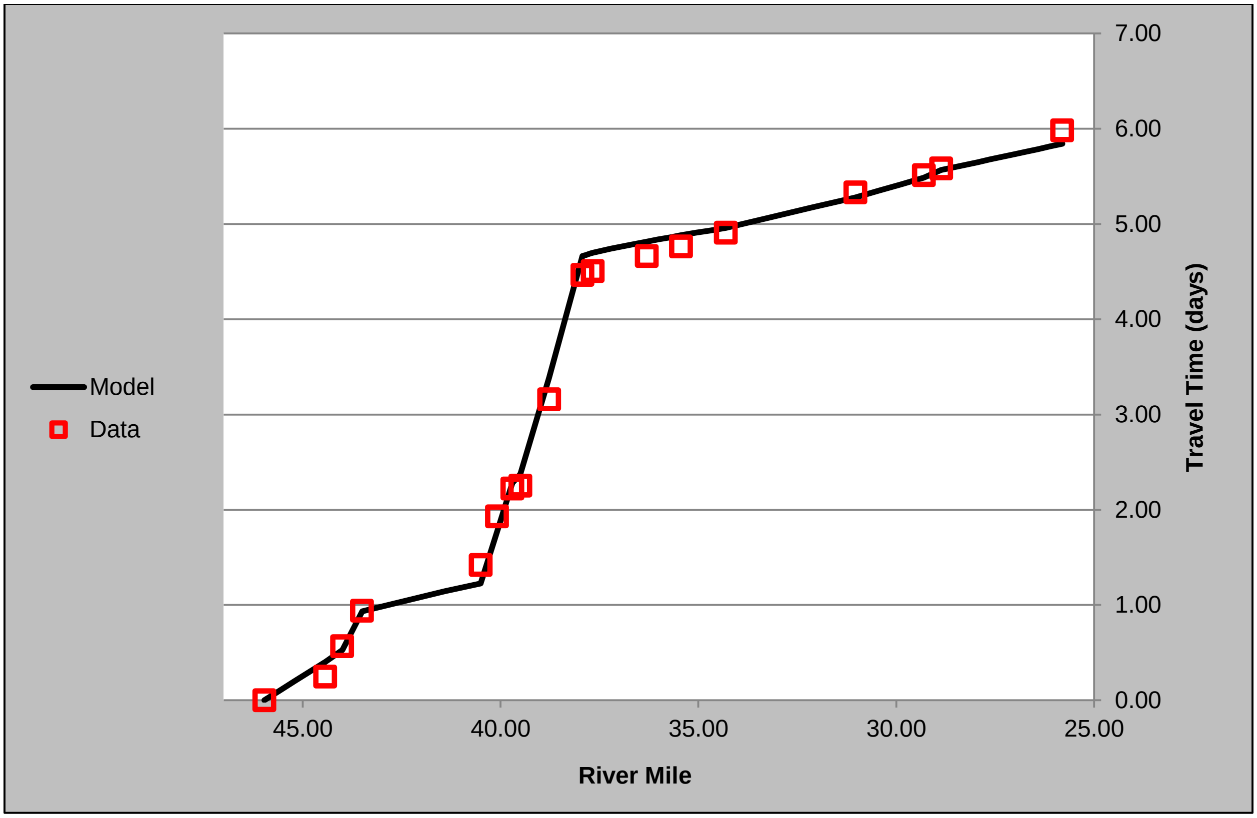

Figure D-7. Calibration of time of travel for modeled stream segment.

Temperature

Temperature is dependent on stream flow (amount of water) and the length of time that the water is exposed to certain local stream conditions (TOT). It is also important as a driving factor for chemical reactions. The result of these two conditions is that hydrology calibration has to be done before temperature and temperature calibration has to be completed before chemical and biological constituents can be calibrated. The environmental conditions that are most important to temperature calibration are: air temperature, dew point temperature (involved with evaporation calculations), shade as a function of time of day and cloud cover. These conditions are set based on observations of the day that the model represents. The calibration parameters are the rates dictating how heat transfer occurs between the different sources and sinks of heat within the system.

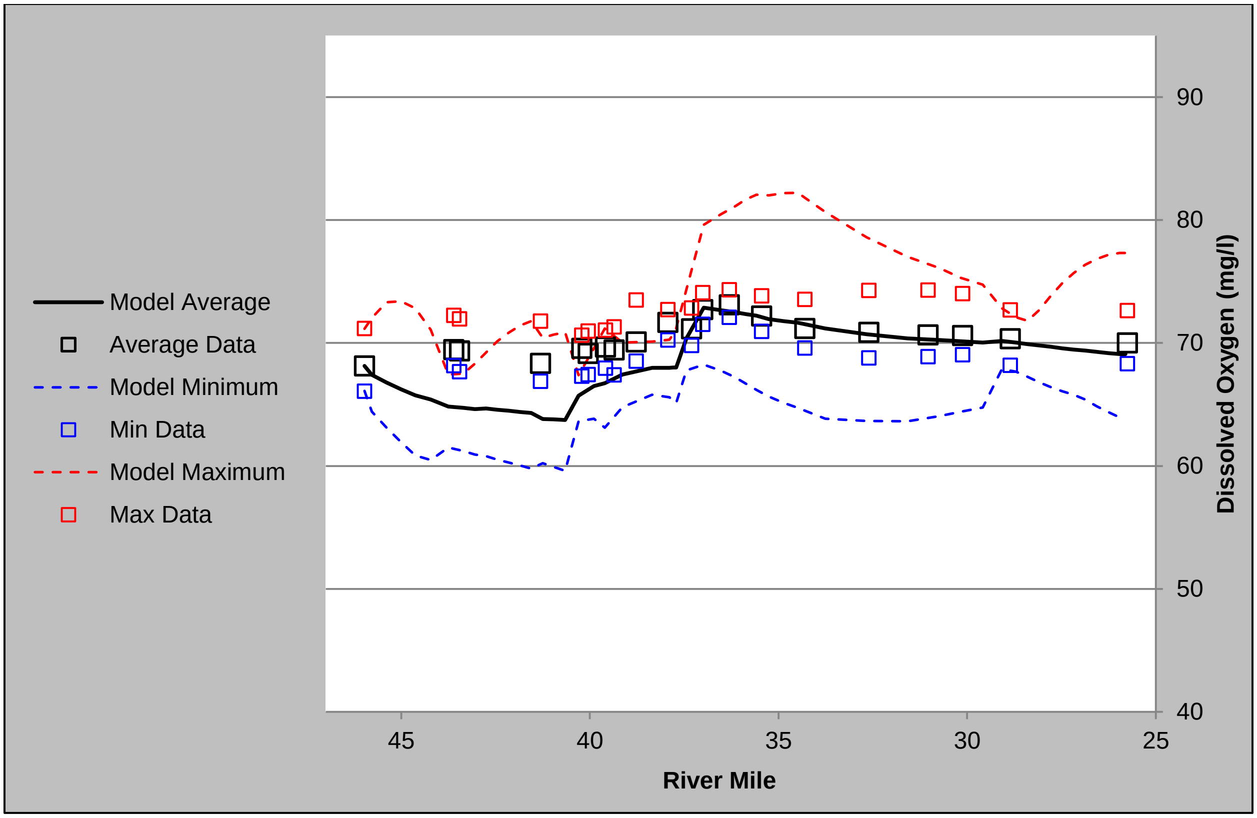

Figure D-8. Temperature calibration plot from modeled stream segment.

As seen in Figure D-8 the average temperatures were well represented by the model; however minimum and maximum temperatures are generally under/over-estimated respectively. Rates were adjusted to balance these differences but it was not possible to achieve a better fit for minimum and maximum values.

Algae/Dissolved Oxygen/Nutrients Calibration

The rest of the parameters are interactive with each other to a degree that makes it impossible to isolate and calibrate them separately. The important external factors that could be controlled were external sources of the constituent such as point sources and tributaries. These constituents change and/or are transformed and lost due to in-stream interaction and reaction. Phosphorus is tracked in four different pools in the stream system: Inorganic phosphorus, organic phosphorus, phytoplankton internal phosphorus and benthic algae internal phosphorus (lost from system to further reaction downstream). The total phosphorus is then the sum of all components except the benthic algae component. Figure D-9 presents the model calibration results for stream phosphorus.

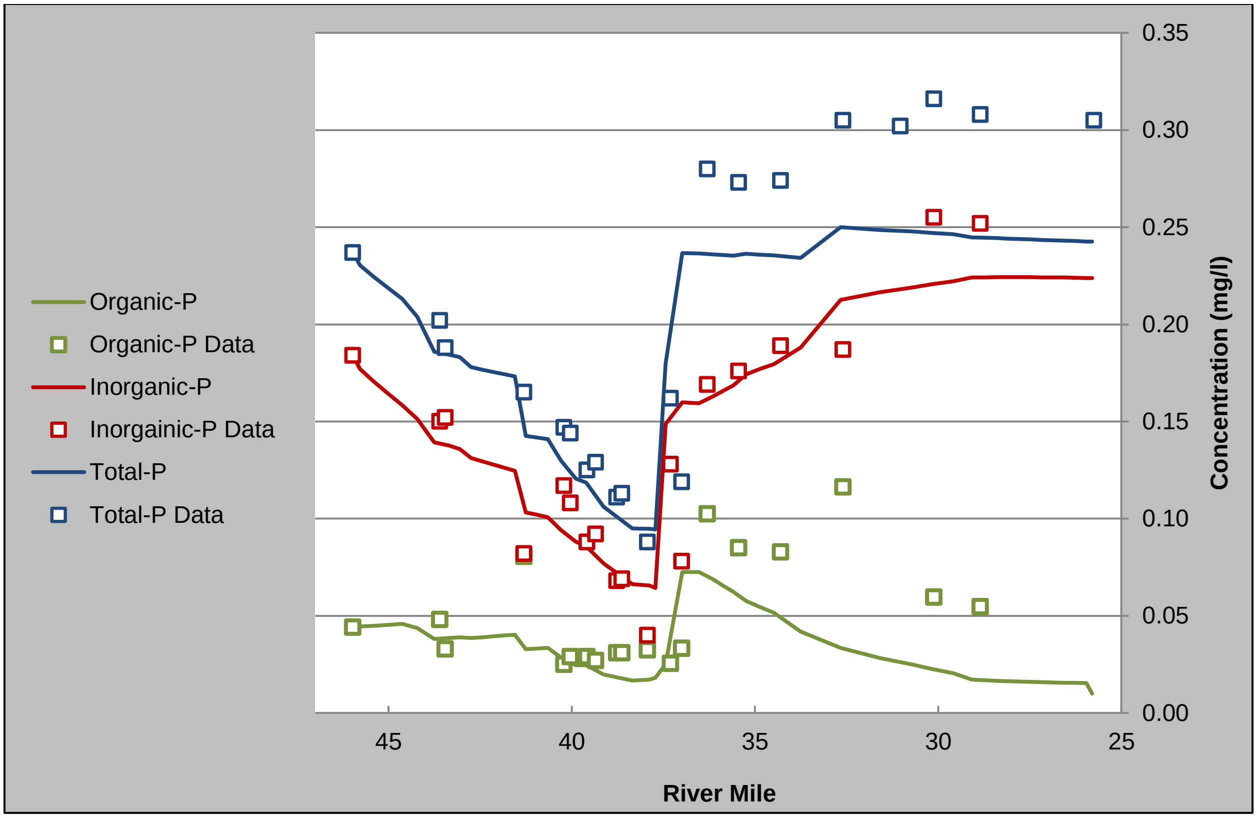

Figure D-9. Phosphorus calibration plot representing total phosphorus, inorganic phosphorus and organic phosphorus.

Phosphorus concentrations are well represented prior to the discharges from three major point sources at which time they are consistently underestimated. Possible reasons for the discrepancy include: grab samples of effluent vs. composite samples in stream and unsteady flows observed on the day samples were collected. A notable field observation is that under the conditions of the calibration, the stream reach upstream from the final lowhead dam in the city of Lima acts as a phosphorus sink. Immediately downstream from the last lowhead dam in the city of Lima three point sources discharge (Lima WWTP, Lima Refining Company and PCS Nitrogen) with two of those having concentrations of phosphorus which are greater than the concentrations in the stream (Lima WWTP and PCS Nitrogen). The result is significantly higher in-stream phosphorus levels downstream from the point sources than upstream.

Nitrogen components modeled include: organic nitrogen, ammonia nitrogen, nitrate nitrogen, phytoplankton internal nitrogen, and benthic algae internal nitrogen. Nitrogen species are presented in Figure D-10.

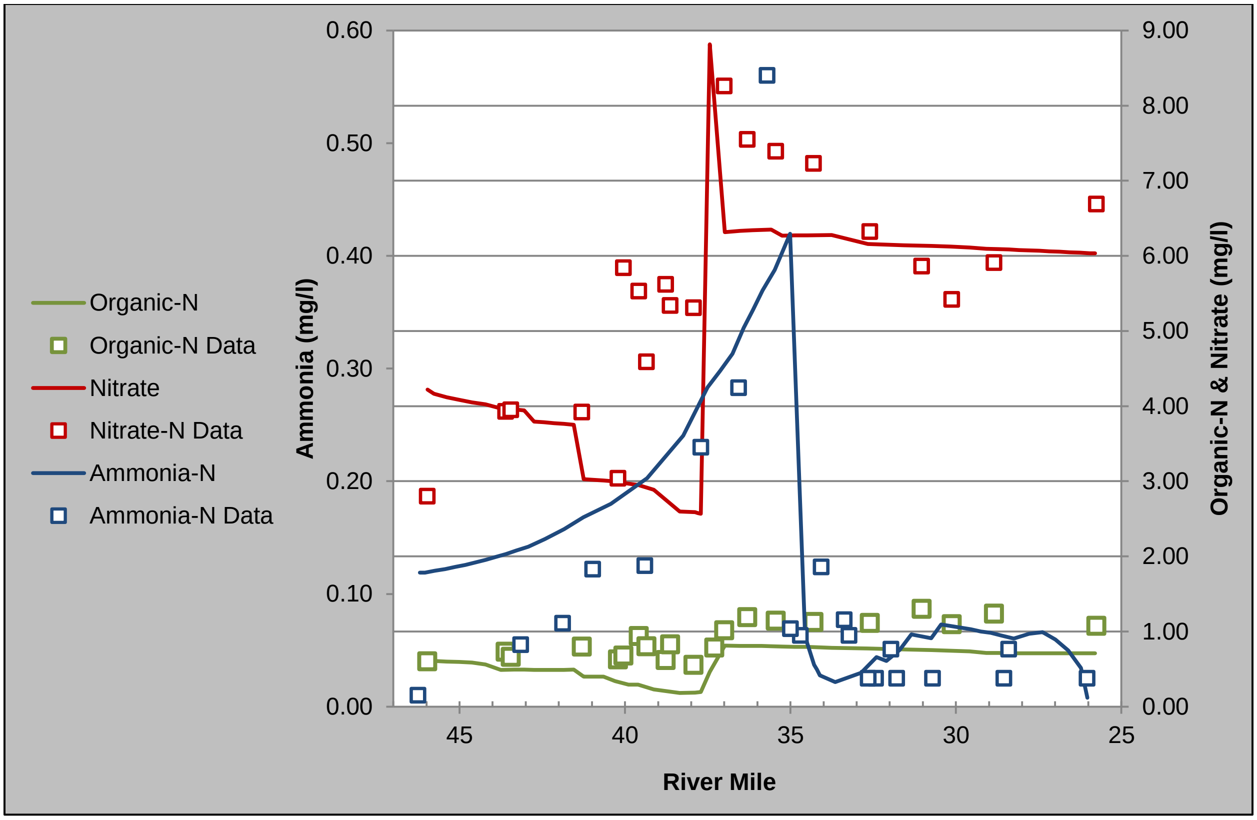

Figure D-10. Summary of calibration of nitrogen species.

Nitrogen species seem to be predicted well by the model and trends are followed well. Among other factors algae species respond to nutrient availability in the stream. In streams that are stressed by nutrient enrichment, the ability to accurately model algae growth is a key component of representing the degradation processes. QUAL2K models two primary algal groups: benthic algae and phytoplankton. These two groups interact and compete for nutrients and light availability. Field data for the algal groups are chlorophyll-a analyses of filtered water samples (phytoplankton) and rock scraping (benthic algae). The model results are also presented as level of chlorophyll-a; not directly as algal biomass. Many user defined parameters influence algae growth including: algal growth rates, maximum nutrient uptake rates, cell quotas for nutrients, respiration rates, and death rates. It is important to note that for this model algal abundance was observed to differ between lotic (flowing water) and lentic reaches (still water, in this instance dam pools). As a result reach specific growth rates were applied to achieve adequate algal abundance in different stream reaches. Algae growth directly impacts nutrient levels but more importantly dissolved oxygen. Dissolved oxygen is affected by the amount of dissolved oxygen present as well as the rates dictating growth (photosynthesis) and respiration. In the model it is possible to achieve a good fit for average dissolved oxygen values with poorly fit minimum and maximum values. This is an indicator that rates dictating photosynthesis and respiration are not properly balanced. Figures D-11 and D-12 are calibration plots for algae and dissolved oxygen, respectively.

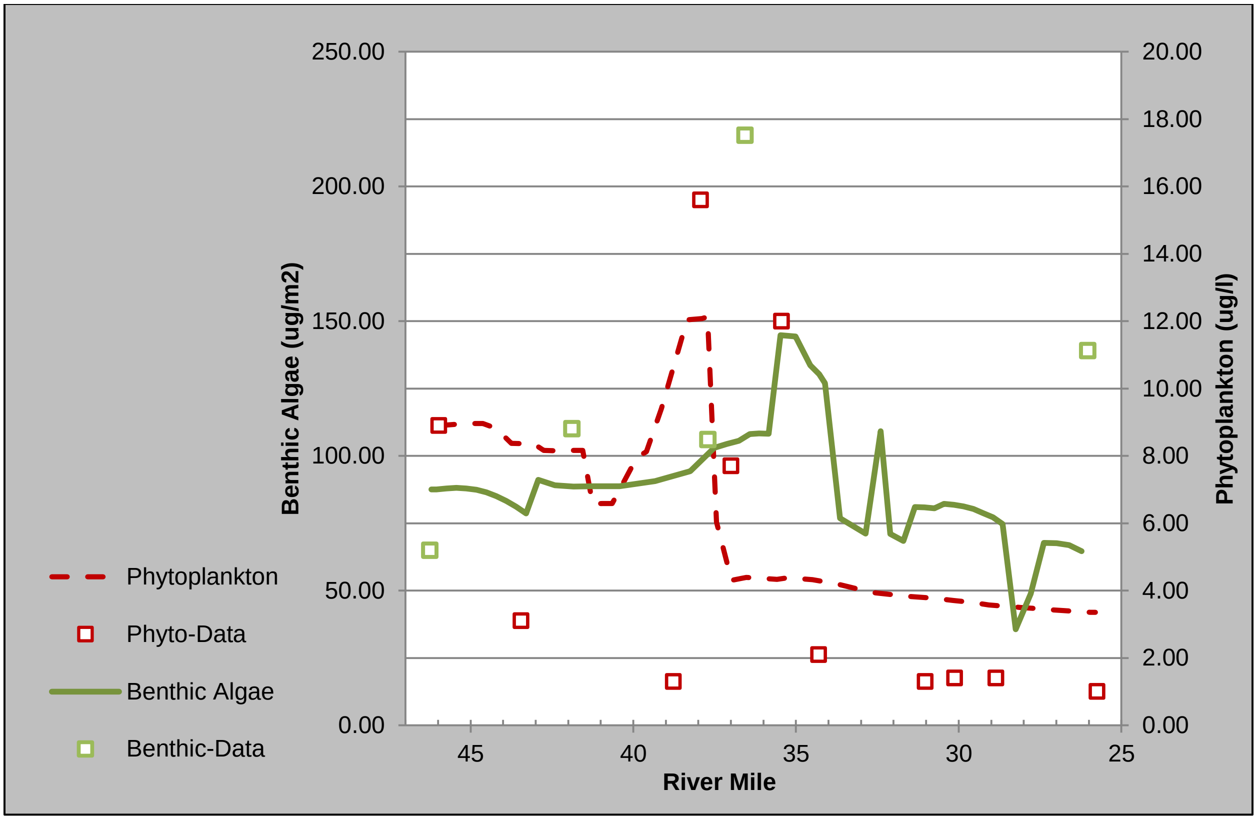

Figure D-11. Benthic algae and phytoplankton calibration plots.

The model is predicting algae values in the correct range but error is still easily discernible in many places. Potential sources of this error are more linked with the error in the collection of the data. Algae data change readily from day to day and even throughout the day. The result is that algae samples do not always represent the environmental condition precisely. However the field data did represent a condition where the relative abundance of the different types of algae varies between sections. In the upstream section of the river the phytoplankton dominate due to mostly pooled and sluggish conditions that are observed. Once the major point sources discharge the streamflow increases dramatically and the lowhead dams that cause the pooled conditions cease; as a result the stream tends to grow more benthic algae compared to phytoplankton.

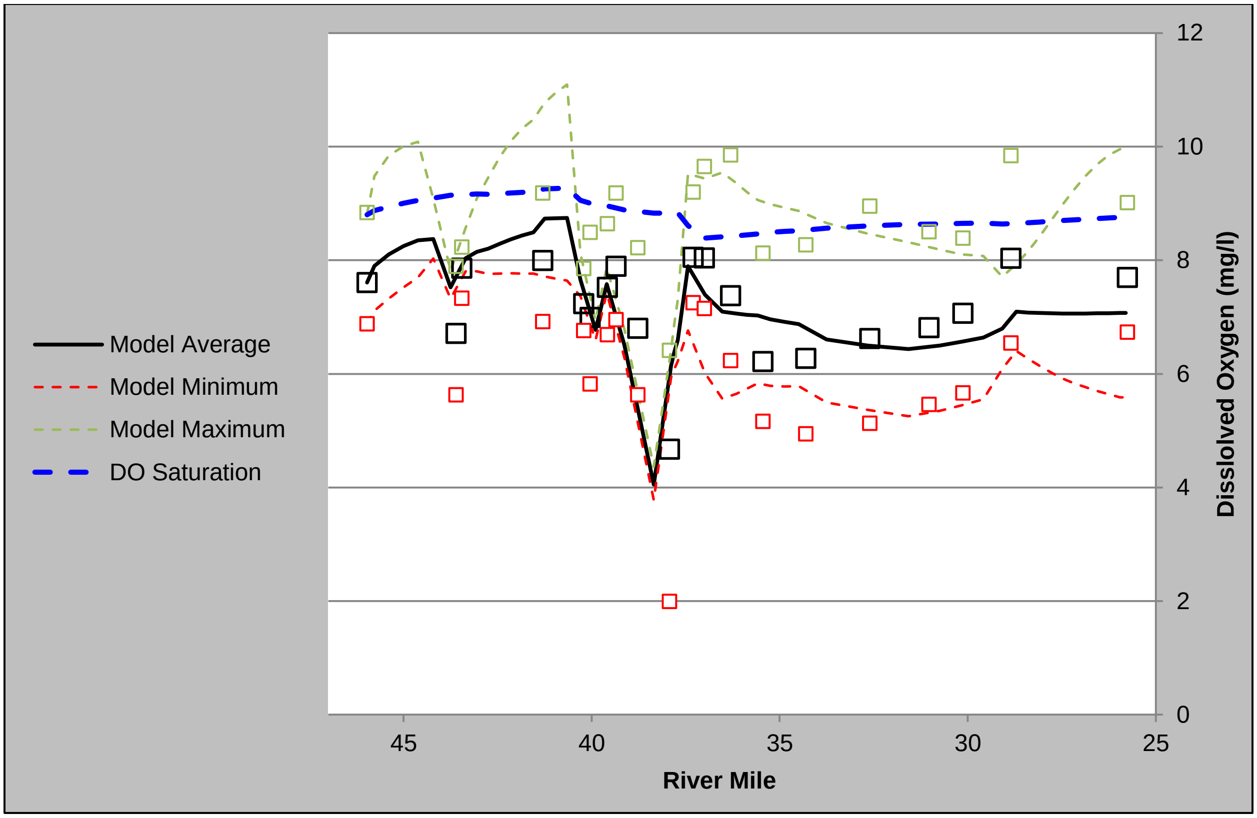

Figure D-12. Dissolved oxygen calibration plot.

Because of the weaknesses of calibrating to direct indicators of primary productions (algae abundance) dissolved oxygen becomes very important. Dissolved oxygen is heavily impacted by primary production and as a result can be used to determine when algae growth rates are at a proper level. The final adjustments to rates affecting algae were made based on the influence on dissolved oxygen concentrations in the system. The dissolved oxygen model had a very good fit with observed data which is amongst the most robust of the field data collected as observations are recorded hourly for 24 hours.

Best professional judgment is used in order to determine when a model has achieved "calibrated" status. Best professional judgment in this case could be defined as the point at which appreciable model improvements were not possible by adjusting rates and other model inputs. Based on the results presented above, it is judged that the model was adequately calibrated.

<u>QUAL2K Validation</u>

Validation establishes the robustness of the model; in other words, how effective the model is at representing different conditions. In validation the rates and fixed environmental conditions that were specified to calibrate the model are left unchanged. The variable conditions include: chemistry inputs, flows and weather, are updated to a different point in time. The same field data collected for calibration were again collected for this point in time. The model is executed and model outputs are compared to the field data. Field data were collected on July 13, 2011 for model validation. Major differences in environmental condition were present in this survey, notably: flows were more stable (but of similar magnitude) and the Lima Refining Company was not discharging through its duration. Figures D-13 through D-18 present the same graphs for stream flow, TOT, temperature, phosphorus species, nitrogen species and dissolved oxygen.

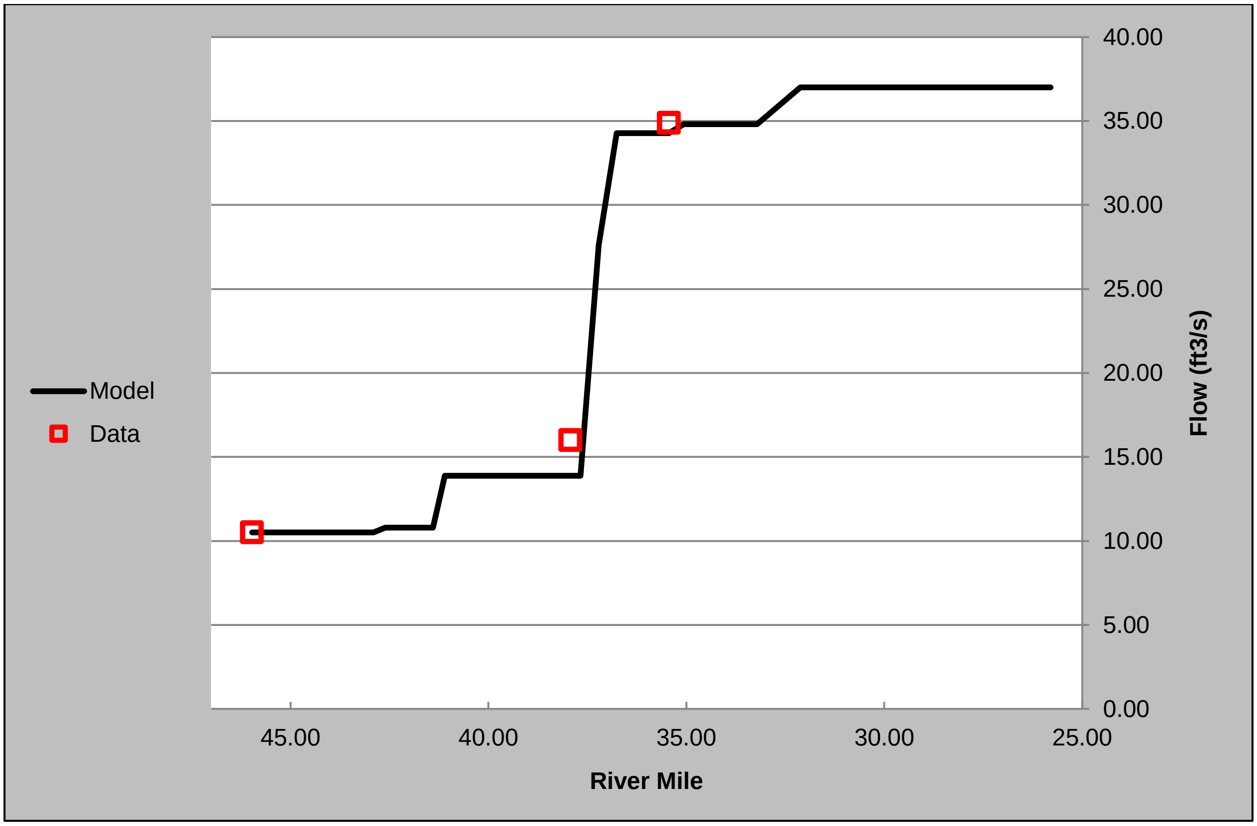

Figure D-13. Flow validation took place at two key points: at the USGS gage (RM 37.93), which is upstream from major point source discharges, and at Shawnee Rd (RM 35.3), which is downstream from the major point source discharges.

Notable differences that become apparent in the two datasets for modeling include: higher inputs from a tributary upstream from the city of Lima (Lost Creek) and lower flow downstream from the city of Lima due to the lack of discharge from the Lima Refining Company. The model fit the collected data better for the validation model than the calibration model, which is largely attributed to the more stable flows that were observed during the survey.

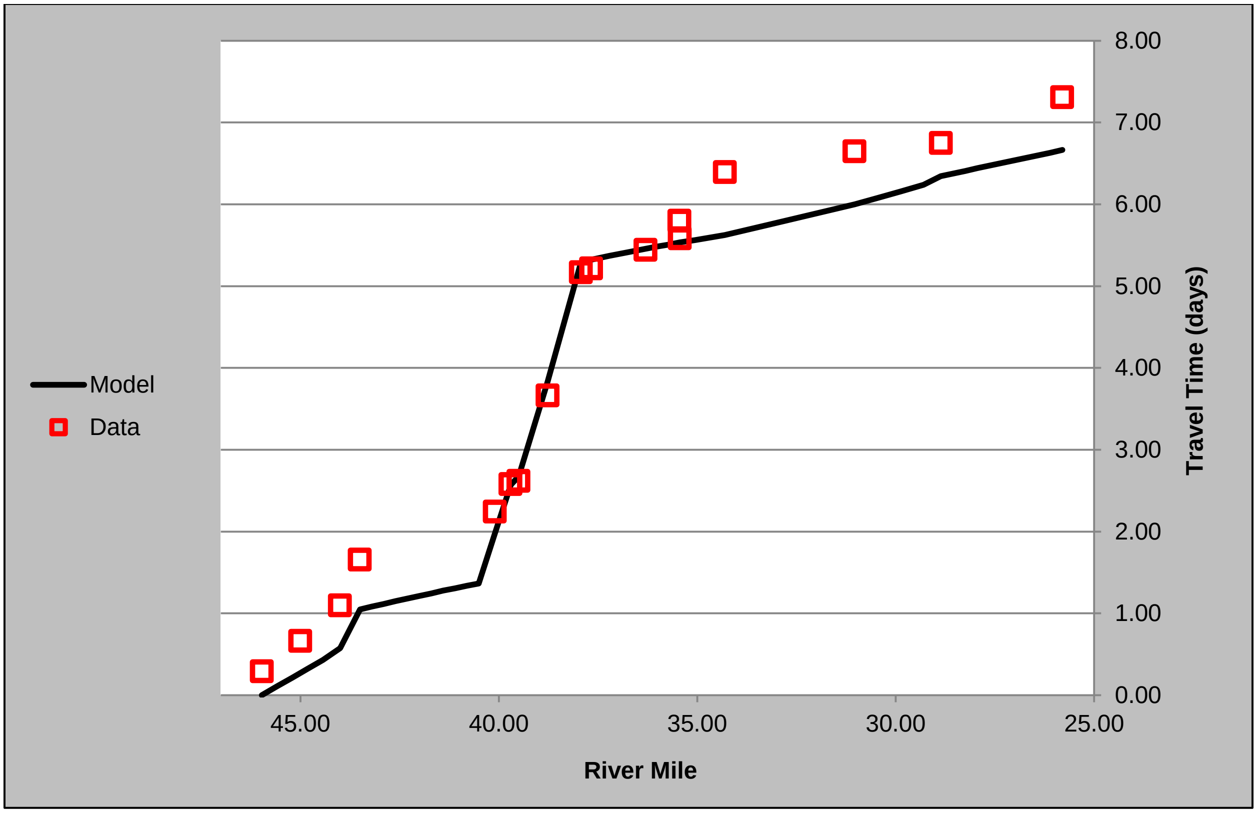

Figure D-14. Time of travel validation plot.

The TOT in the validation model is less precise than the calibration model but for the most part the data was well represented by trends and magnitude. These differences can be expected because it is difficult to predict how TOT will change based on small changes in hydrology. The model was calibrated very precisely for the TOT data from the previous survey and thus small deviations are not that alarming.

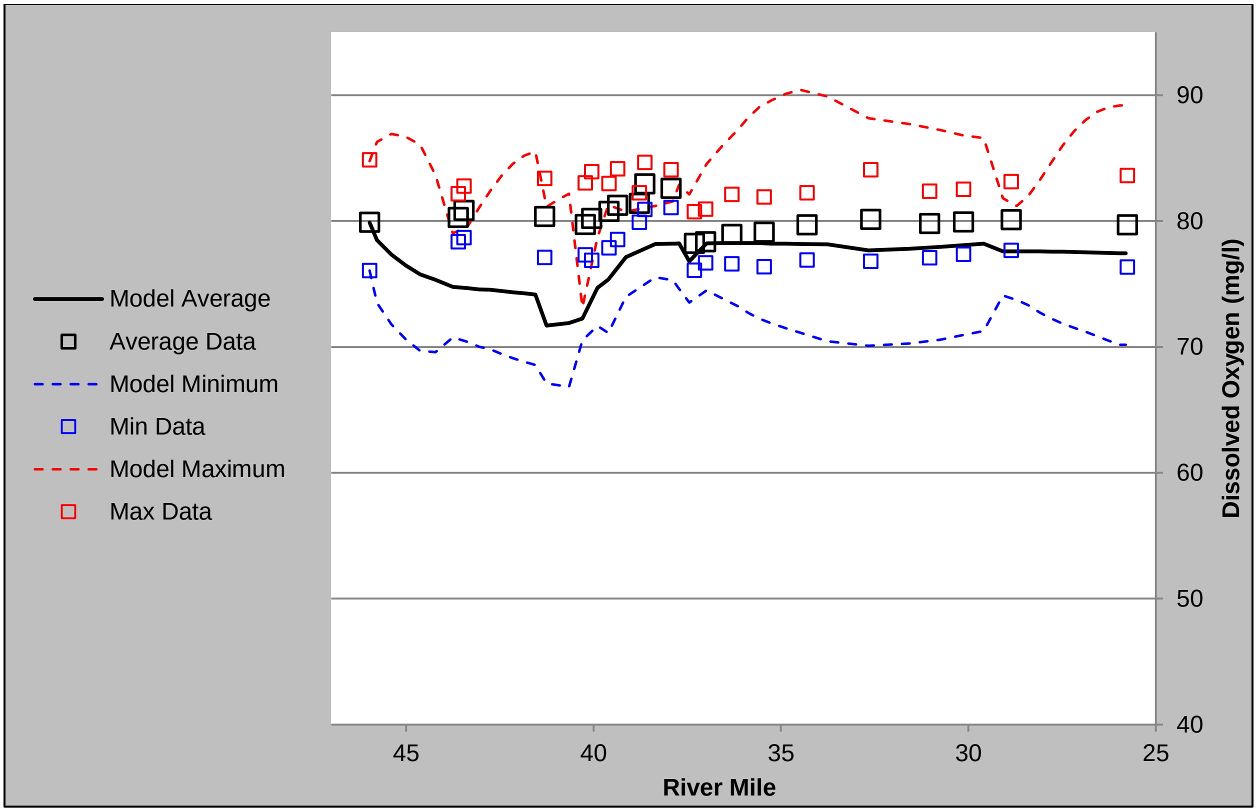

Figure D-15. Temperature validation plot.

The modeled temperature fit the observed data in a very similar fashion as the calibration data. Based on this observation it can be noted that this component of the model is very robust as it transfers from one condition to another.

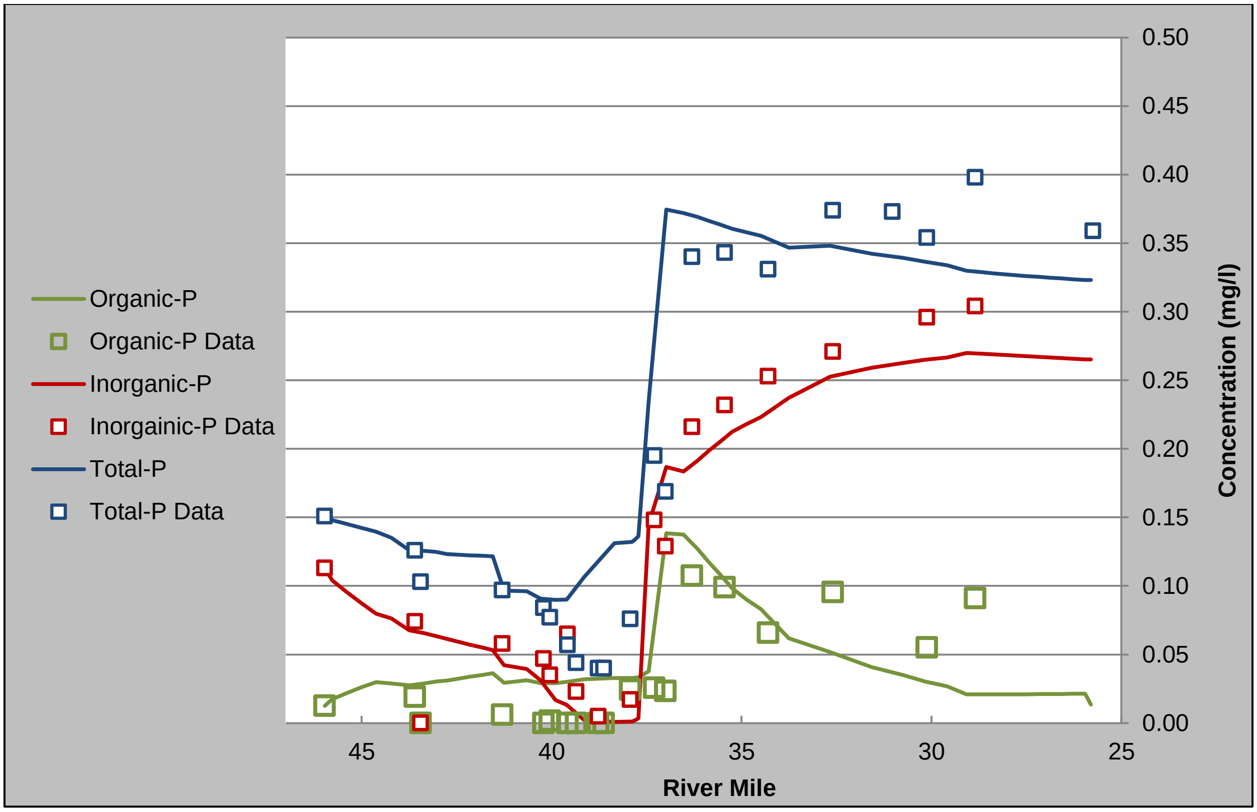

Figure D-16. Phosphorus species validation data.

Model fit is slightly worse upstream from the major point sources and is predicted slightly better downstream from the major point sources. The model improvements downstream from the dischargers are likely caused by improved quality of data from the July survey. The survey benefitted from more steady flows as identified earlier and the major NPDES discharges were sampled with a composite sampler, better representing the actual phosphorus load from the source.

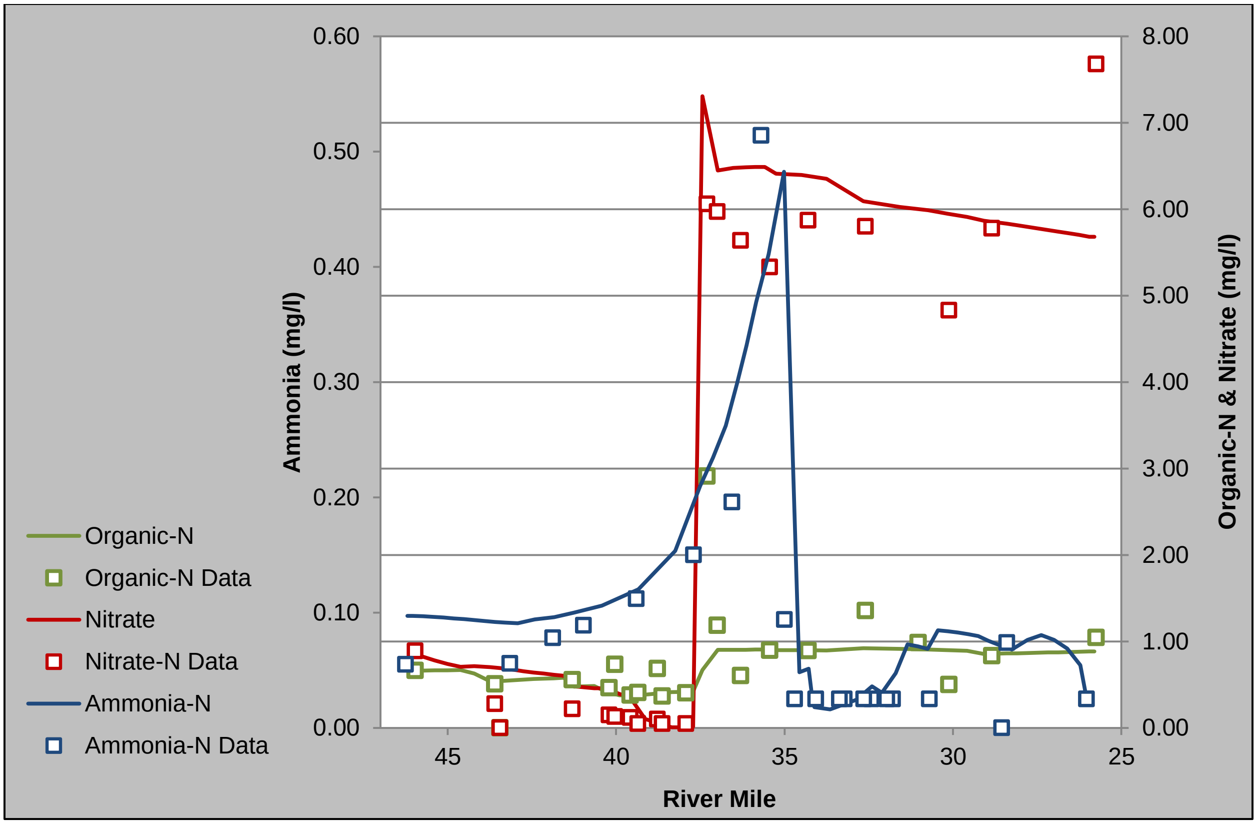

Figure D-17. Nitrogen species data validation.

Again the magnitude and trends observed in the validation data were well represented by the model. As mentioned earlier nutrients are an important part of the model because they are a major factor driving primary production. The validation survey collected little chlorophyll data to directly represent algae abundance so dissolved oxygen is relied on as an indicator of how well the model represents primary production.

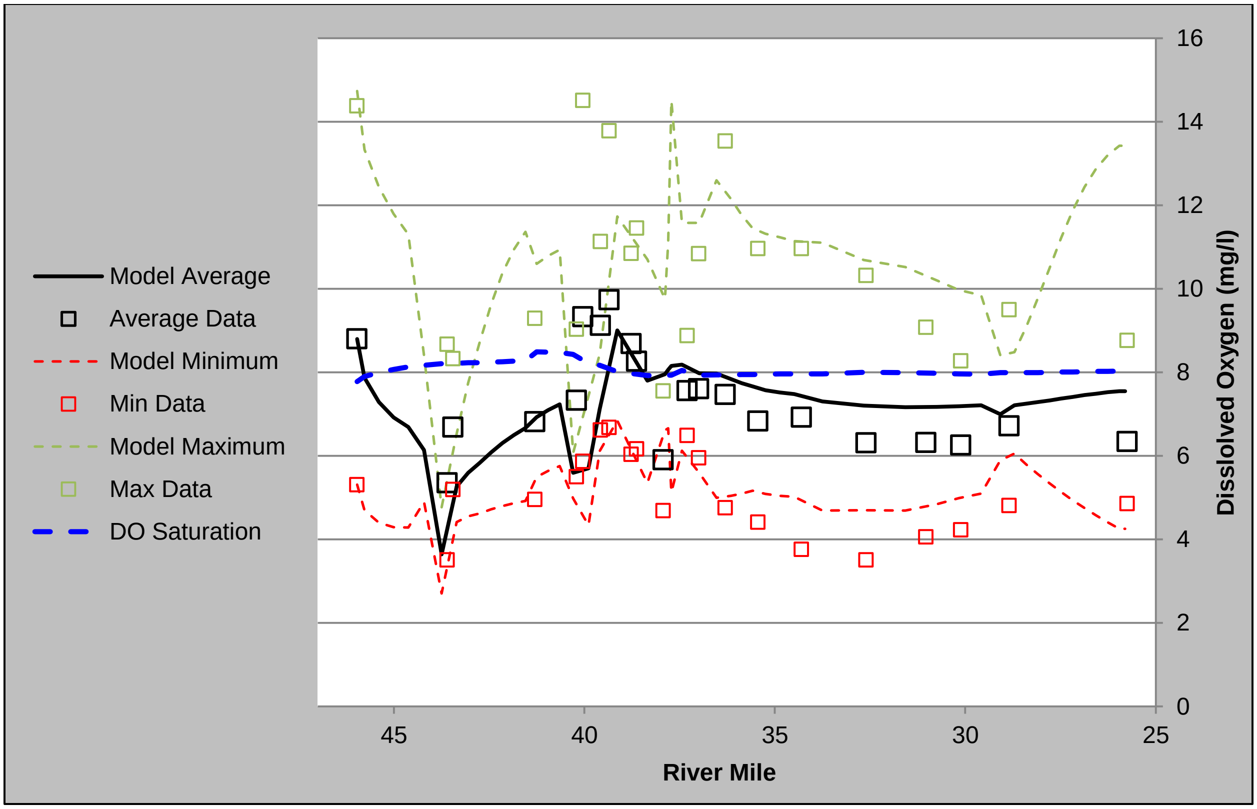

Figure D-18. Dissolved oxygen plot for validation model.

The model fit the measured dissolved oxygen data well. Primary production influences dissolved oxygen values through photosynthesis (maximum) and respiration (minimum). The fit of these values is an indirect indicator that primary production is accurately represented by the model. Fit of the average dissolved oxygen is an indicator that the minimum and maximum values (respiration vs. photosynthesis) are properly balanced.

As mentioned previously, during the time validation data was collected one of the major point source discharges, Lima Refining Company, was not discharging. Even with this major difference validation model results show a reasonable fit to field data collected during a different time of year with different stream inputs. It is the opinion of the Ohio EPA staff that the validation model represents a model that is robust in its ability to represent different conditions in the Ottawa River from river mile 25.8 – 45.97. The model is now considered able to predict conditions where field data were not observed to validate model results. A scenario was developed in order to represent critical field conditions. Then a TMDL was calculated to identify the scenario where nutrient enrichment will no longer cause biological impairment.

<u>Model Summary</u>

Error between model predictions and measured data is an important measure to describe the effectiveness of the modeling effort. Model error can be defined as:

$$Error(\%) = \frac{x_{obs} - x_{model}}{x_{obs}} * 100$$

$$x_{obs} = field\ data\ observed$$
$$x_{model} = model\ predicted\ data$$

As a tool to help discuss the errors associated with the model, the error is examined as relative error, which is the absolute value of the error. Two parameters are discussed based on the relevance to the modeling effort: total phosphorus and average dissolved oxygen. In the calibration model, the relative error for the two parameters is 12.52% and 7.46%, respectively. Much of the error in the total phosphorus is biased to the stream locations downstream from the major point sources in the watershed. Inaccuracies in adapting effluent grab samples as representative of daily discharge and non-steady state flows are contributing to errors downstream from the major point sources. Dissolved oxygen seems to be well represented by the model. The validation model was similarly analyzed and relative error was 50.01% for total phosphorus and 16.27% for dissolved oxygen. Further critique of the error shows a major bias of error to the region where lowhead dams are abundant. The extreme errors are not associated with extreme concentrations (relative to others observed in the stream). However, the measured total phosphorus concentrations are small in this reach and small magnitude errors lead to large percent errors. To demonstrate the impact of these errors on the relative error calculations, the values were excluded from the analysis and the percent error for the rest of the stream was 14.54%. Also, the stream the model fit downstream improved dramatically in the validation model compared to the calibration model, largely attributed to composite chemistry data collected at the major point sources.

Margin of Safety and Allowance for Future Growth

With the available information the model was calibrated and validated to the best possible fit of field data. However due to weaknesses in the model and field data collection model error is inevitable. In order to determine what margin of safety is adequate to protect aquatic life a quantification of the standard error present in the model was applied. The purpose of the margin of safety is to be protective of the use that is addressed by the modeling effort (aquatic life). As a result the under prediction errors are used to establish a margin of safety. The calibration model had a maximum under prediction of 21.8% and the validation model had a maximum under prediction of 17.3% for total phosphorus. Phosphorus is ultimately used as the target in the stream; therefore, the margin of safety is based on error in predicting phosphorus concentrations. To ensure protection of aquatic life the margin of safety is set as the more conservative value from the calibration model, 21.8%.

Population projections for this watershed show insignificant growth in the area contained in the watershed (U.S. Census Bureau 2012). Because of this, a relatively low allowance for future growth (AFG) of 2% is reserved from the TMDL. No future plans for expansion are known of at this time for any of the industrial facilities that are receiving allocations from this TMDL.

Allocations

The QUAL2K model is suited for low flow steady-state conditions and thus allocations are based on the impact of pollutant sources in that condition. The most important in the low flow critical condition (when nutrients are most likely to cause impairment) are point source discharges. The modeled reach contains many point source discharges including: National Lime and Stone Company, Lima WWTP, Lima Refining Company, PCS Nitrogen and Shawnee #2 WWTP. These sources all receive an allocation for phosphorus based on the QUAL2K model results. Storm event-related sources such as CSOs, SSOs and industrial storm water discharges do not receive an allocation from this modeling exercise because they do not occur as a source in the critical condition. The critical condition is designed to be protective of the biological life in the stream from nutrient related impairments.

Modeling with QUAL2K

Critical Conditions

A set of critical conditions was constructed to represent the existing load at permitted limits in the critical condition for nutrients affecting aquatic life. The point sources do not typically discharge at these levels; thus, this scenario represents a condition that is a greater load than the load that is currently impairing the stream. The critical flow condition is dictated by the cause of impairment that is being modeled. According to Ohio Administrative Code 3745-2-05, if the cause of impairment is an average water quality criterion, in this instance dissolved oxygen, 7Q10 flows should be used for modeling and wasteload allocations (WLAs). The 7Q10 flow is the flow regime representing the annual minimum 7 day average flow on a 10 year recurrence interval (Straub 1997). In this instance the final WLA is for total phosphorus because it is identified as the limiting nutrient for algal growth and associated eutrophication impacts.

Also associated with the critical condition are the weather conditions that have the greatest impact on the impairing cause. In this case, because algal production increases with temperature and light exposure, a long summer day with minimal cloud cover is used. The weather data from the validation model represented such a condition and to limit the exposure of the model to error, July 13, 2011 data were used with the exception of eliminating the cloud cover. Point source discharges were added to the system at design effluent flows with permit limits established as constituent concentrations. The purpose of this approach is to maximize the loading potential and potential impact of the point sources on the system. In some instances the facility is required to monitor total phosphorus in its effluent. These samples were used to calculate an average projected effluent quality for the facility. The headwater chemistry dictating the background water quality was based on an average of samples collected by Ohio EPA and was biased to low flow samples (storm event samples were excluded).

TMDL Scenario

The TMDL scenario uses the same environmental conditions as the critical condition. However, changes are made to ensure that the nutrient targets are met in the stream. The primary target is 0.1 mg/l phosphorus from the *Associations* document (Ohio EPA 1999a); however, as the model is developed; situations could arise where flexibility in the target should be exercised. The most important goal of the TMDL is to achieve the narrative criteria that are codified as state law. Two options were implemented in the model to achieve nutrient targets:

1) Removal of dams that exacerbate nutrient enrichment.
2) Reduction of point source loads.

Based on upstream nutrient TMDLs from load duration curves, it was assumed that the headwater inputs into the stream are meeting the *Associations* target for phosphorus but all other parameters remain the same from the critical condition model. Similarly the only parameter that was adjusted for point sources is the phosphorus concentration. Based on the concentrations necessary to meet the targets in the model, wasteload allocations were completed for the different point sources discharging in the modeled reach. The TMDL using QUAL2K was computed differently than in the LDC approach because it treats the stream segment as a continuum. Therefore the nutrient TMDL for the impaired reach of the Ottawa mainstem is the sum of the inputs that contribute to the stream through the entire segment. The allocations were completed by reserving a portion of this load as a margin of safety and an allowance for future growth.

D3.1.2 Organic Enrichment (CSOs)

Combined Sewer Overflow (CSO) Targets

CSOs are unique from other point source discharges as they are intermittent in nature and discharge occurrences are linked exclusively to wet weather events. Discharge quality is also variable depending on when the sample is taken (temporally) and where the sample was taken (spatially). During the wet weather events that trigger a CSO discharge the streamflow also changes rapidly both temporally and spatially. The variability present within the system makes capturing and quantifying a specific water quality based target difficult. As a result, Ohio EPA has relied on a target that limits the number of discharges that occurs in a year as opposed to the quality of any single discharge. The target that is being negotiated for the city of Lima is a combined sewer system that overflows an average of five times per year (MWH Global, Inc. 2012). The nature of CSO mitigation means that these will likely be the highest flows that the CSOs discharge when there is the most potential for dilution. Also mitigation will likely capture the first flush from the sewer system that is generally higher in pollutant concentration from sediment that accumulated in sewer lines. These factors combine to limit the impact of the remaining CSO discharges on stream aquatic life.

Justification for Modeling Method

The use of predictive modeling is necessary to perform loading analysis when data are limited and the critical condition is not easily monitored. However, when large datasets are available direct observations can be used to perform a loading analysis. As required by the NPDES permit for the city of Lima WWTP, the city reports the following for five CSO discharge stations: overflow occurrences, overflow volume and carbonaceous biological oxygen demand 5-day ($CBOD_5$) concentration of the discharge. Modeling done for the city of Lima's draft long term control plan indicates these five stations account for the majority of the overflow volume discharged to the Ottawa River (MWH Global, Inc. 2012). The large dataset available from the city of Lima is favorable to perform a loading analysis using observed data by developing an empirical model.

Critical Condition and Seasonality

The target for this TMDL (five occurrences per year) makes it necessary to define what constitutes an occurrence. Exploring the nature of CSOs is necessary to define what an occurrence is, which leads into the definition of the critical condition for this TMDL. CSOs occur in a manner that is both spatially and temporally variable. To explain the spatial distribution of CSO impacts a short discussion of why CSOs occur is warranted. There are two scenarios that can cause a CSO to occur:

1) The wastewater treatment plant is overwhelmed and additional flow must be bypassed.
2) The piping network is overwhelmed at some point and must be allowed to overflow to relieve pressure.

The city operates the network to ensure that the maximum amount of flow reaches the treatment plant. However, once the network reaches capacity overflows can occur at 19 permitted locations to reduce stress on the system. It is still possible that the upstream overflows occur without the occurrence of a downstream overflow. The result of the spatial variability of CSOs is the definition of an occurrence. An overflow from any combination of points within the system in a 24 hour period is counted as one occurrence. For example, the piping network is locally overwhelmed and an overflow occurs at an upstream relief point; this counts as one occurrence. A contrasting example is a large precipitation event occurs and the capacity of the treatment plant is overwhelmed as well as the piping network and all 19 permitted locations report an overflow; this still counts as one occurrence. Distribution of discharge locations begins to explain the spatial variability in impairments caused by CSO occurrences. Impairment is also influenced by variability in the stream system and is exacerbated by locations where settling is maximized (i.e., dam pools).

Temporal distribution of events refers to occurrences being discrete events. The temporal distribution can take on greater meaning in that occurrences are more frequent seasonally. Local peaks in May and November identify a degree of seasonality for CSO occurrences in late spring and early fall (Figure D-19).

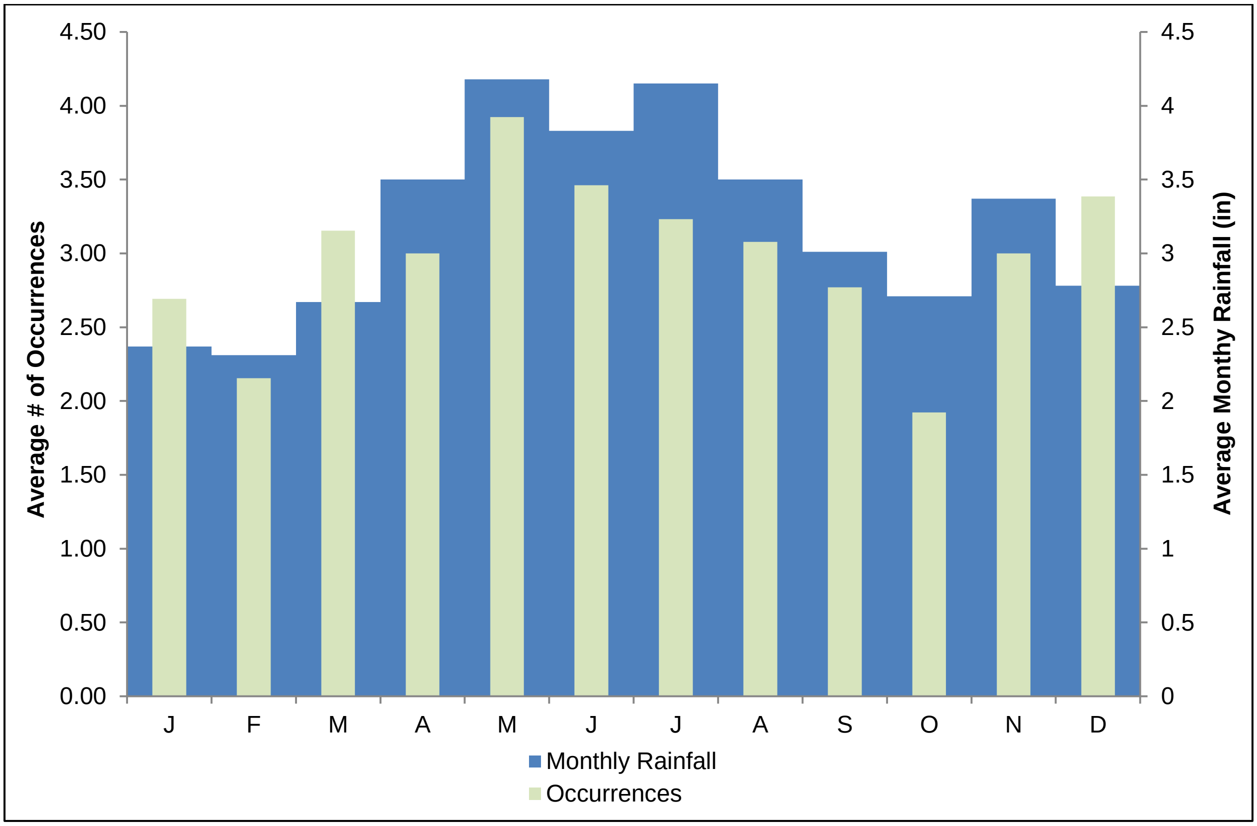

Figure D-19. Historical average monthly precipitation for Lima, Oh and average number of CSO discharge occurrences based on 13 years (1999 – 2011) of observed data.

Now that there is a better understanding of where, when and why CSOs occur, the critical condition as it applies to developing a TMDL can be discussed. The critical condition can take on two meanings with regard to CSOs:

1) The condition in which an occurrence is induced.
2) The condition in which aquatic life is impaired by the occurrence.

Based on the above discussion, we assume these two conditions do not occur simultaneously. As a result it is not possible to develop a TMDL scenario where the load of a pollutant is addressed in the same flow condition the aquatic life is impaired by the load. The critical condition argument is based on the residual impact of CSO loads on dissolved oxygen through organic enrichment. However, mitigation strategies will likely reduce the risk of exposure to acute toxicity impacts from CSOs. The result is the definition of the critical condition that was used to conduct the loading analysis: The critical condition for TMDL calculations is the five CSO occurrences that are the most difficult to eliminate. For the purposes of the TMDL these are assumed to be the largest events with regard to total volume discharged.

These two conditions vary both spatially and temporally. Occurrences are induced by both the volume and intensity of a precipitation event. CSO occurrences have local peaks in May and November with the highest number of occurrences occurring in May based on 13 years of data (Figure D-19). These peaks represent the temporal distribution of occurrences. However, the aquatic life is indicated to be impaired by organic enrichment, which is exacerbated by low flows and warm temperatures. These conditions are typically associated with summer months. From Figure D-19 it can be observed that occurrences remain high through summer months but summer occurrences are associated with high intensity rains and temporary high flows.

Model Development

An empirical model uses monitoring data as a baseline for what reduction needs to take place in order to meet the target. The number of occurrences is the basis of the target but occurrences alone do not carry enough information to prescribe a reduction in pollution. The preference is to use a parameter such as overflow volume so something is not only known about the occurrence of the discharge but also the size of the discharge. Based on this logic an event size can be selected that if all smaller events are eliminated the average number of events in a given year will meet the target of five per year. The purpose of the empirical model is to analyze the data and determine the overflow volume that can occur and eliminate all but five occurrences per year. Based on the information from the empirical model and statistical analysis of other pollutant sources, allocations for the TMDL were completed using a mass balance.

Allocations

The target of five occurrences per year is not load-based; therefore, a surrogate parameter must be chosen. $CBOD_5$ is chosen as the parameter to be used because it is an indicator of organic loading and is commonly monitored so source contributions can be characterized. The allocations can be discussed based on the following categories: point sources, CSOs, nonpoint sources and MS4.

Point Sources: Point sources received an allocation based on the current permit limit and the design capacity of the treatment plant. The city of Lima is unique from the other point sources because they have a distinct design capacity and permit limit for wet weather flows. Since critical condition is the 5 most extreme wet weather events of the year they are allocated based on the wet weather limits.

CSOs: Monitoring data from 5 permitted CSO discharge locations were characterized to determine the $CBOD_5$ concentration of a "typical" CSO discharge (Figure D-20). The figure presents box plots for the individual discharge locations as well as for all values combined. The box plots represent the median as the center value, the 25^{th} and 75^{th} percentile as the bound of the upper and lower boxes respectively, and lines extending to the maximum and minimum values. The plots exclude outliers that are identified as points that lie outside of 2 times the inner-quartile range (75th percentile – 25th percentile).

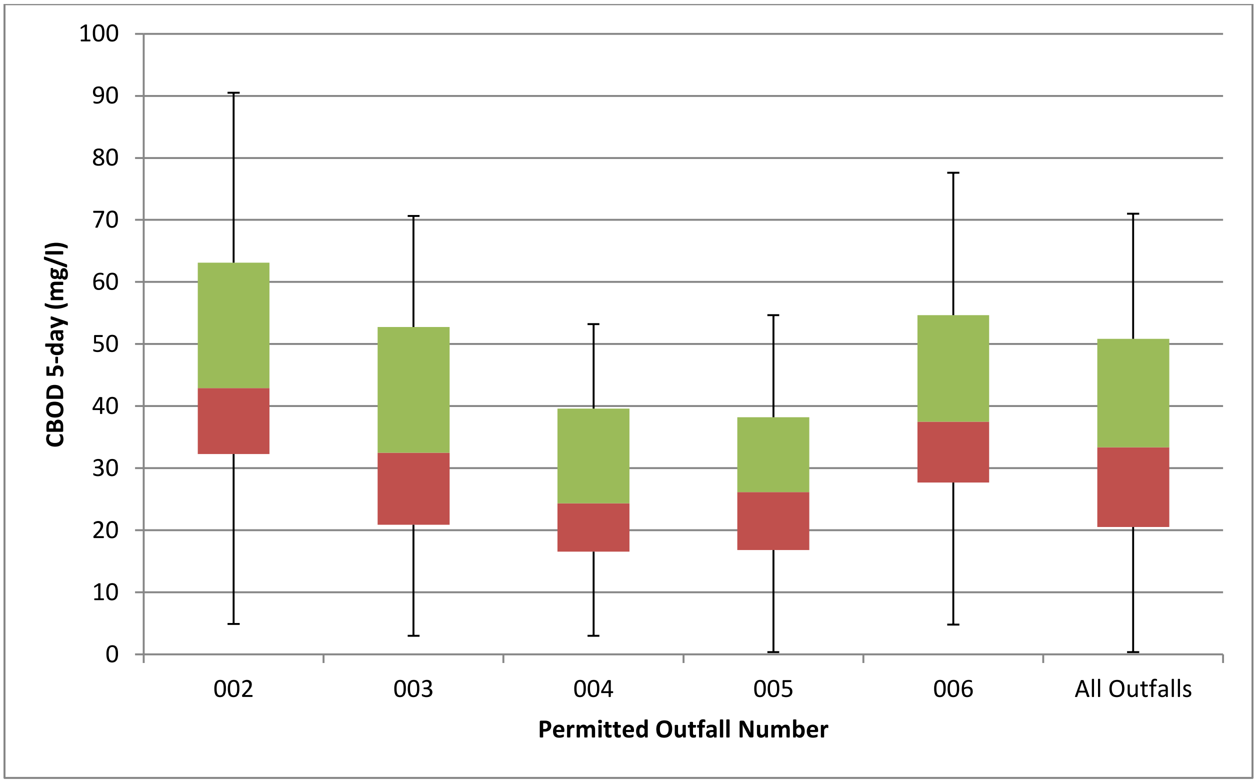

Figure D-20. Characterization of all CBOD 5-day samples collected by the city of Lima over a 13 year (1999 – 2011) period of record. The box and whisker plots represent the minimum (lower whisker), the 25th percentile (lower bound of red box), the median (intersection of the red and green boxes), the 75th percentile (upper bound of green box), and the maximum (upper whisker).

As a conservative measure the 75th percentile value for all outfalls' CBOD5 concentration was used to allocate the CSOs. Once the empirical model described above established the overflow volume that will eliminate all but five overflows per year, the remaining events were categorized. Also due to the mitigation process the discharge events that still occur should be reduced by the volume eliminated by mitigation. Again as a conservative measure the 75th percentile value of the remaining overflow volume was used to compute the allocation.

Non-point Sources: Nonpoint sources were allocated based on the background water quality determined from a statistical analysis of reference sites (Ohio EPA 1999b). Again the 75th percentile value for the $CBOD_5$ was used and also the 75th percentile of the streamflow (measured during discharge events) from a USGS gage located near the end of the study reach.

MS4: The MS4 allocation is included in the TMDL as a point source. It is computed by using a GIS analysis to determine what portion of the watershed is contained within a permitted MS4 area—in this case the city of Lima. The percentage is then used to allocate a fraction of the nonpoint source load to the MS4 area.

Industrial Storm Water NPDES: These are regulated storm water discharges from industrial facilities. The primary purpose is to protect streams from pollutants that the facility may unnaturally enhance in storm water runoff. The facilities are not supposed to increase a conventional pollutant. As a result the facilities are allocated at background loads and are considered to be included within the MS4 allocation or load allocation based on the location of the facility.

Notable from Figure D-20, the $CBOD_5$ samples have a high variability and visual differences depending on the location from which they were collected. Samples collected at individual stations had an averaged having a range 26.8 mg/l $CBOD_5$ between the 25th and 75th percentile values.

$CBOD_5$ is the chemical measure of organic enrichment of a water body. Based on the impairment to aquatic life by organic enrichment NPDES dischargers were allocated a limit of $CBOD_5$ based on their current permit limits for the final outfall at the design discharge. Associated with the city of Lima WWTP NPDES permit are CSO discharges that will receive an allocation using the 75th percentile of their discharge $CBOD_5$ concentration and 75th percentile flow that is expected during the occurrence of a discharge. The load allocation will be based on the 75th percentile of the average daily streamflow on the days that the allocated discharge events occurred and the 75th percentile of the background CBOD 5-day concentration.

Two nested subwatersheds contain impairments from organic enrichment that result from the city of Lima CSOs: 03 06 (Lima Reservoir/Ottawa River) and 04 02 (Dug Run/Ottawa River). All CSO discharges are within the 03 06 nested subwatershed and therefore one allocation table was constructed under the premise that addressing CSO impacts in the upstream nested subwatershed will protect the downstream use. Other sites that included organic enrichment as a cause are linked to sanitary sewer overflow sources or the Village of Columbus Grove's CSOs. These impaired sites are addressed separately from this TMDL calculation.

Margin of Safety and Allowance for Future Growth

Conservative assumptions provide an implicit margin of safety in a model. In this loading analysis many conservative assumptions were made including using the 75th percentile values for the following:

1) $CBOD_5$ concentration of the pollutant in the CSO discharge
2) CSO discharge volume
3) Background $CBOD_5$ concentration
4) Streamflow corresponding to occurrences

The model does have limitations however, such as:

1) Uses flow data from all CSO discharge locations; however, the five used are expected to account for the majority of the volume discharged.
2) CSO discharges are treated as a continuous daily discharge but in reality occur over a shorter time period (the flow volume in million gallons is treated as a flow rate, million gallons per day).

While conservative assumptions imply an implicit margin of safety (MOS) an additional 20% explicit MOS is used to account for additional model uncertainty. The explicit MOS is applied to both mitigation value (eliminated overflow volume) and the TMDL allocations for $CBOD_5$. If assumptions were made less conservatively, the explicit MOS would have had to be higher to account for the variability in the data driving the model and flows that are not explicitly included in the model development.

There is no indication of expected population growth in Allen or Hardin counties where the Ottawa River watershed is located (U.S. Census Bureau 2012). Allen County, which contains the majority of the watershed, is actually expecting a negative population shift. Therefore; a low but reasonable allowance for future growth of 2% is used.

Model Validation

According to the city of Lima's draft long-term control plan, 41 occurrences are expected in a typical rainfall year with a total overflow volume of 407.6 million gallons. Based on 13 years of reported data there was an average of 36 occurrences per year. This assumes that minor CSOs that do not report flow do not discharge as separate occurrences. While it is not possible to accurately report total volume because of limited overflow volume data, an average of 402.9 million gallons per year is discharged from five stations that report overflow volume. Agreement between the two different approaches provides some certainty that the data used to perform the loading analysis are sufficient.

D3.2 Habitat and Sediment Bedload Analysis, QHEI Method

Target Development

Habitat

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 some its component sub-metrics and the biological indices used in Ohio's water quality standards such as the Index of Biotic Integrity (IBI). Through statistical analyses of data for the QHEI and the biological indices, target values have been established for QHEI scores with respect to the various aquatic life use designations (Ohio EPA 1999a). For the aquatic life use designation of warmwater habitat (WWH) an overall QHEI score of 60 is targeted to provide reasonable certainty that habitat is not deficient to the point of precluding attainment of the bio-criteria (Table D-7).

Many of the sites in the Ottawa River study area that are listed as impaired due to habitat are designated as modified warmwater habitat (MWH). Targets for habitat do not exist for these streams but standards for biological indices are established making it possible for the sites to be assessed for attainment. There is a reasonable expectation that, even in MWH systems where lower biological standards are in place, habitat that is degraded to some extent will influence biological attainment. The method for establishing habitat targets involved determining the percent reduction in standards for biological indices. The sites in the Ottawa River assessment area that were both MWH and listed as impaired by habitat are headwater streams. To develop QHEI targets for these systems differences a ratio of expectations for biological indices between WWH and MWH for these sites was used. The percent reduction in the two biological indices, index of biological integrity (IBI) and invertebrate community index (ICI), are 28.6% and 35.3% respectively. The percent reduction calculated for the IBI results in a higher relative score for the metrics (i.e., QHEI of 43 vs. 39) used in habitat TMDLs. The higher QHEI value is chosen to err on the side of protective of aquatic life. The ratio was applied to the metrics used to establish habitat targets for MWH which are presented in Table D-7.

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 (Table D-6). 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 sub-group of the modified attributes shows a stronger impact on biological performance; these are termed "high influence modified attributes" (Table D-6).

Table D-6. Itemization of "modified attributes" for computing the habitat TMDL.

High Influence Modified Attributes	Moderate Influence Modified Attributes	
• Channelized or no recovery • Silt/muck substrate • Low sinuosity • Sparse/no cover • Maximum pool depth < 40 cm (wadeable streams only)	• Recovering channel • Heavy/moderate silt cover • Sand substrate (boat sites) • Hardpan substrate origin • Fair/poor development • Low sinuosity • Only 1-2 cover types	• Intermittent and poor pools • No fast current • High/moderate overall embeddedness • High/moderate riffle embeddedness • No riffle

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 4 modified attributes of which no more than 1 should be a high influence modified attribute (Table D-7). For simplicity, a pass/fail distinction is made telling whether each of the three targets are 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 (Table D-7). Using the same methodology describe above for setting MWH targets for overall QHEI scores number of high and moderate influence attributes are adjusted. The difference is that these targets are increased, as opposed to reduced which is the case for overall QHEI scores.

Table D-7. QHEI-based targets for the sediment TMDL.

Habitat TMDL Targets			
	Target		
QHEI Category	*WWH*	*MWH*	*Score*
QHEI Score	≥ 60	≥ 43	+ 1
High Influence #	≤ 1	≤ 2	+ 1
Total # Modified	≤ 4	≤ 6	+ 1

Habitat TMDL ►	+ 3

Sediment

The QHEI is also used in developing the sediment TMDL for this project. Numeric targets for sediment are based upon sub-metrics of the QHEI. Although the QHEI evaluates the overall quality of stream habitat, some of its component sub-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 sub-metrics used in the sediment TMDL are the substrate, channel morphology, and bank erosion and riparian zone. Table D-8 lists targets for each of these metrics for WWH aquatic life use designation.

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

Similarly to the MWH targets derived for habitat, MWH targets for sediment TMDLs also had to be derived. The same logic was followed and percent reduction in the standards for IBI scores in headwater streams were used (Table D-8).

Table D-8. QHEI-based targets for the habitat TMDL.

Sediment TMDL Targets		
	Target	
QHEI Category	*WWH*	*MWH*
Substrate	≥ 13	≥ 9
Channel	≥ 14	≥ 10
Riparian	≥ 5	≥ 4
Sediment TMDL ►	≥ 32	≥ 23

Justification for Use of QHEI Methods

Habitat

A consequence of habitat degradation not being a pollutant per se is that methods used to conduct traditional loading analyses are incompatible. The QHEI score does have a strong correlation to biological criteria and thus serves as a useful target if habitat is to be eliminated as a factor limiting aquatic life.

Sediment

The rationale for using the QHEI for development of the sediment TMDL is largely due to the problems linked to other methods of evaluating sediment loading and the limited reliability that results. For example, the measurement of total suspended solids (TSS) is commonly used as a loading parameter; however, gathering data that is reliable for calibration and validation is often uncertain. This uncertainty rests in the fact that TSS demonstrates a high degree of variability both over space and time and is sensitive to local disturbances.

Finally, the QHEI has a strong relationship with the bio-criteria in Ohio's water quality standards, whereas TSS has a relatively weak correlation with biological performance, which is probably related to the variability and unreliability of TSS measures. The QHEI measures the end result of high sediment loading (either from the landscape or in-stream sources) as it impacts the biological community.

<u>Critical Conditions and Seasonality</u>

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

Habitat is generally a relatively static condition of a stream. Exceptions include major modifications made by humans (or animals such as beavers) or changes in the hydrology or sediment loading of the watershed, which is typically a human-caused situation. Because habitat is relatively static, seasonality has little meaning. Specifically, absent a major disturbance, habitat quality does not change across the seasons but rather over much longer timescales (years to decades). Finally, there is no seasonal "loading" associated with habitat but instead habitat evolves through changes in morphology and riparian vegetation. However, in terms of sediment, seasonality does have meaning. For example, agricultural areas yield the highest loads when fields have minimal vegetative cover and runoff events occur. This corresponds to the spring pre-plant season. In-stream sources of sediment from bed or bank erosion are also seasonally loaded when flows are highest and banks are saturated. When stream banks are saturated, they are more susceptible to erosion through slip failure. As with upland loads, spring is an important time as well as mid to late fall.

<u>Margin of Safety</u>

Despite the fact that a numerical value within a QHEI score 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 1989b). The consistency of the method reduces uncertainty and thus implicitly implying a margin of safety (MOS).

Additional implicit MOS is incorporated into the habitat and sediment TMDLs through the use of conservative target values. The target values were developed though comparison of paired IBI and QHEI evaluations. Using an IBI score of 40 as representative of the attainment of WWH, individual components of the QHEI were analyzed to determine their magnitude at which WWH attainment is probable (Ohio EPA 1999a). However, attainment can occur at levels lower than the established targets. The difference between the habitat and sediment targets and the levels at which attainment actually occurs is an implicit MOS.

Allocations

In quantifying the sediment and habitat TMDLs for the Ottawa River watershed, only sites with either ALU partial or non-attainment were considered. Sites having full attainment were excluded and hence do not appear in tables. Further, of these sites, only those with causes identified as siltation/sedimentation and/or habitat alteration were considered for sediment TMDLs. Correspondingly, only those sites with habitat alteration, sedimentation/siltation, turbidity, and/or flow alteration (non-natural) were considered for a habitat TMDL.

D3.3 Pathogens

Target Development

Recreation use was not supported in multiple assessment units where the geometric mean of at least one stream sampling site did not meet its water quality standard. Twenty sites were sampled as a part of the Ohio EPA's monitoring and assessment in 2010 to determine recreation use attainment, and all 20 (100%) were found to be in non-attainment.

This study was carried out to develop *E. coli* total maximum daily loads (TMDL) 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 report defines in-stream bacteria conditions, potential sources, bacteria targets and needed reductions and recommends implementation strategies.

TMDL numeric targets for *E. coli* bacteria are derived from bacteriological water quality standards. The criteria for *E. coli* specified in OAC 3745-1-07 are applicable outside the effluent mixing zone and vary for waters determined as primary contact recreation (PCR). Furthermore, this criterion designates streams that support frequent primary contact recreation—Class A streams. The Ottawa River mainstem is designated as Class A. All other sites sampled in the watershed lie within 5 river miles of the Ottawa River mainstem and are held to the Class A standard in order to protect downstream Class A recreation use on the Ottawa River. For Class A streams, the standard states that the geometric mean of more than one *E. coli* sample taken in each recreational season (May 1 through October 31) shall not exceed 126 colony-forming units (cfu) per 100 ml.

A Class B PCR target curve is also depicted on each LDC plot because of local interest and for informational purposes only. The dashed line on each LDC curve represents the TMDL curve as it would appear if the mainstem of the Ottawa River were designated as Class B (vs. Class A) for recreation use and a standard of 161 cfu per 100 mL (vs. 126 cfu per 100 mL) were used for all LDC sites. Adoption of the more lenient Class B standards would not affect the attainment status of any non-attaining subwatersheds, based on 2010 sampling results. In order to avoid potential confusion, because the Class B standard was not used to establish TMDLs, calculations related to a Class B recreation use standard are not included in any associated TMDL tables.

Justification for Use of LDCs

Many modeling techniques for bacteria are time consuming and are often found by Ohio EPA to yield results that are difficult to properly calibrate. For adequate calibration, this type of modeling requires additional bacteria data that are not collected during routine surveys. An empirical method of determining 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 streamflow regime. The main advantage of the use of LDCs is in this methods ability to divide loads based on flow.

Critical Conditions and Seasonality

Critical conditions for bacteria are difficult to define as they vary by source. The critical conditions are often defined by flow regime and likely sources during different flow regimes were identified in Table D-3. The variability in critical conditions for different bacteria sources is a strong reason for the use of LDCs because they are able to cover multiple flow regimes. Seasonality is important for bacteria TMDLs since water quality standards for *E. coli* only apply to the recreation season. As stated in the previous section this is the time between May 1 and October 31. Samples for assessment are only collected in this timeframe and hydrology used to determine flow intervals is only from this time period.

LDC Development

Of the 20 sites found to be in recreation use non-attainment during the summer of 2010, a subset of eleven sampling locations was established on the mainstem and tributary streams within the watershed, and these sites were used for further study of the causes of recreation use non-attainment in non-attaining nested sub-watersheds (12-digit hydrologic units). These eleven sites included three sites on the mainstem of the Ottawa River and eight tributary sites. Nested subwatersheds addressed by these LDCs are shown in Table D-9.

Table D-9. Nested subwatersheds that are represented by LDC sites.

Load Duration Curve Site	Nested Subwatershed Location (04100007)	Nested Subwatersheds Represented (04100007)
Hog Ck. (RM 0.27) N of Lafayette @ Swaney Rd.	03 04 [1]	03 02 03 04
Lost Ck. (RM 0.35) @ E. High St., lower crossing	03 05	03 05
Ottawa R. (RM 35.44) at Lima @ Shawnee Rd.	03 06	03 03 03 06
Little Ottawa R. (RM 0.03) at Fort Amanda Rd.	04 01	04 01
Ottawa R. (RM 29.26) @ Copus Rd.	04 02	04 02 (excluding Honey Run)
Honey Run (RM 0.9) @ Wapak Rd.	04 02	04 02 (Honey Run only)
Ottawa R. (RM 3.67) @ US-224	04 03	04 03 04 06
Pike Run (RM 0.84) Lima-Gomer Rd.	04 04	04 04
Leatherwood Ditch (RM 1.67) @ Putnam CR-U	04 05	04 05
Sugar Creek (RM 0.6) @ CR-O	05 01	05 01
Plum Ck. (RM 0.19) W. of Kalida @ SR-114	05 02	05 02

[1] This LDC includes nested subwatershed 03 01 if data collected in the future show impairment.

For a given impaired site, each hydrologic condition (high flows, wet weather conditions, normal range conditions, dry weather conditions or low flows) was assigned a target bacteria loading rate (cfu/day) by multiplying the Class A *E. coli* water quality standard, 126 cfu/100 ml, by the median flow of each hydrologic class at that site and a constant, used to convert cubic feet per second to milliliters per day: $T = Q_m * S * C$; where T = target bacteria load, Q_m = median flow for a specific hydrologic class, S = water quality standard (126 cfu/100 ml) and C = a unit conversion constant (cubic feet per second to milliliters per day). Median observed bacteria loads in each hydrologic condition were compared to the median target value in that condition, after incorporating a margin of safety and allowance for future growth, in order to quantify needed reductions.

Margin of Safety and Allowance for Future Growth

An explicit margin of safety (MOS) is computed in the Ottawa River 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 fluctuations of *E. coli* concentrations that occur in nature and the relatively low number of data points available for this analysis. For LDC TMDLs, U.S. 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.
2) Recognition that the uncertainty associated with effluent limits and water quality may vary across different flow conditions.

Population projections for this watershed show insignificant growth (U.S. Census Bureau 2012). As a result, a relatively low allowance for future growth is reserved from the TMDL load—2%.

Allocations

Each sanitary discharger is assigned a wasteload allocation (WLA) based upon the design flow of the treatment facility and the water quality standard applicable to its receiving water. These WLAs are listed in the TMDL table that corresponds with each sampling site in Section D5. Because any facility operates at most times at some fraction of its design flow, the WLA for these facilities includes reserve capacity up to the design flow.

The Lima WWTP is unique as a point source in that they receive many allocations based on the wet weather design capacity. When operating in wet weather conditions the plant has in its most recent permit a schedule to increase the capacity up to 70 MGD compared to the dry weather design capacity of 18.5 million gallons per day. The difference in these two operational conditions results in significant increase in total load at the high flow condition. The result is a need to account for the load of the wet weather design condition in the *Wet Weather* and *High* flow ranges. As a result the Lima WWTP receives a higher WLA in the specified flow regimes when wet weather plant operation is expected.

The wasteload allocation for each facility is accounted for in each downstream site’s LDC in the watershed; for example, the WLA for Lima WWTP is included in the LDC of the most immediate downstream site, *Ottawa River @ Shawnee Rd (RM 35.44)*, as well as *Ottawa River @ Copus Rd (RM 29.26)* and *Ottawa River @ US-224 (RM 3.67)*.

Allocations for the regulated MS4 in this watershed were determined based on the area of the MS4 draining to each assessment location. Townships, municipalities, and urbanized areas as documented in geographic information system (GIS) database files were used to determine the total regulated area for the MS4. These areas were then used to calculate WLAs based on the proportion of the upstream drainage area located within the MS4 boundaries. Storm water runoff was assumed to occur during *High*, *Wet Weather* and *Normal Range* flow conditions.

In many cases in the Ottawa River and its tributaries, there is a scenario in which low flows the point sources dominate the stream flow. As a result the streams ability to assimilate pathogen loads is decreased and the TMDL is exceeded. There is more certainty at this flow condition as to the source of the load (point sources). These sources are given limits that they are required to meet through the NPDES permitting process. As a result there is less uncertainty that needs to be accounted for with an explicit margin of safety. Where these cases occur a footnote is included with the allocations table in Section D4.3 and the MOS is reduced to 10% in the lowest flow regime.

The load duration curve method was selected to assign in-stream pollutant loads at a given site to one or several potential pollutant sources (see U.S. EPA 2007). In a load duration curve, patterns of impairment can be examined and addressed relative to the flow conditions under which they occur, and this allows a set of potential pollutant sources specific to a given site to be highlighted (see Table D-3). Under the highest flow conditions, point sources are likely to be masked by in-stream dilution; therefore high pollutant levels in these conditions are associated with precipitation wash-off or erosion of contaminated land surfaces. Impairments under normal range flows can be caused by a mixture of point and nonpoint sources. Under the lowest flow conditions, recreation use impairments are generally attributable to sources not associated with runoff events, such as a failing HSTS, point source discharge or in-stream livestock.

D4 Results

D4.1 Nutrients/Eutrophication/Dissolved Oxygen – Total Phosphorus

D4.1.1 Nutrient Enrichment and Eutrophication

Load Duration Curves

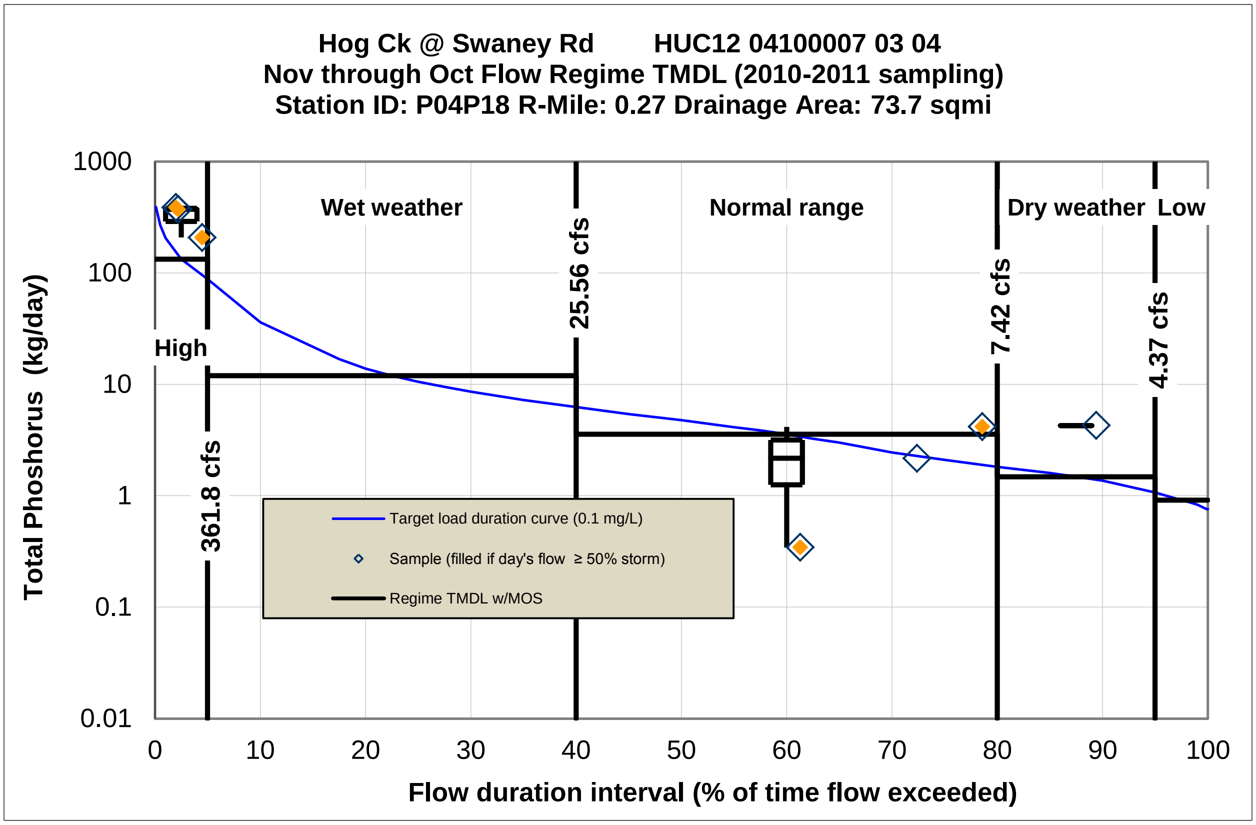

Figure D-21. Total phosphorus load duration curve: Hog Ck @ Swaney Rd.

Table D-10. Total phosphorus TMDL table: Hog Ck @ Swaney Rd.

TMDL and duration intervals	High 0-5%	Wet weather 5-40%	Normal range 40-80%	Dry weather 80-95%	Low 95-100%
Samples Per Regime	3	0	3	1	0
Median Sample load	372	N/A	1.75	2.91	N/A
Total Load Reduction Required	**66.9%**	No Data	**NA**	**67.0%**	No Data
Total Maximum Daily Load	132.99	12.01	3.56	1.48	0.91
***Margin of Safety: 5%**	6.65	0.60	0.18	0.07	0.04
Allowance for future growth: 2%	2.66	0.24	0.07	0.03	0.02
Load Allocation	122.83	10.32	2.46	0.53	0.01
Wasteload Allocation Total	0.85	0.85	0.85	0.85	0.85
Ada WWTP 2PB00050	0.85	0.85	0.85	0.85	0.85

Values were adjusted for rounding; *MOS reduced to 4% in low flow regime.

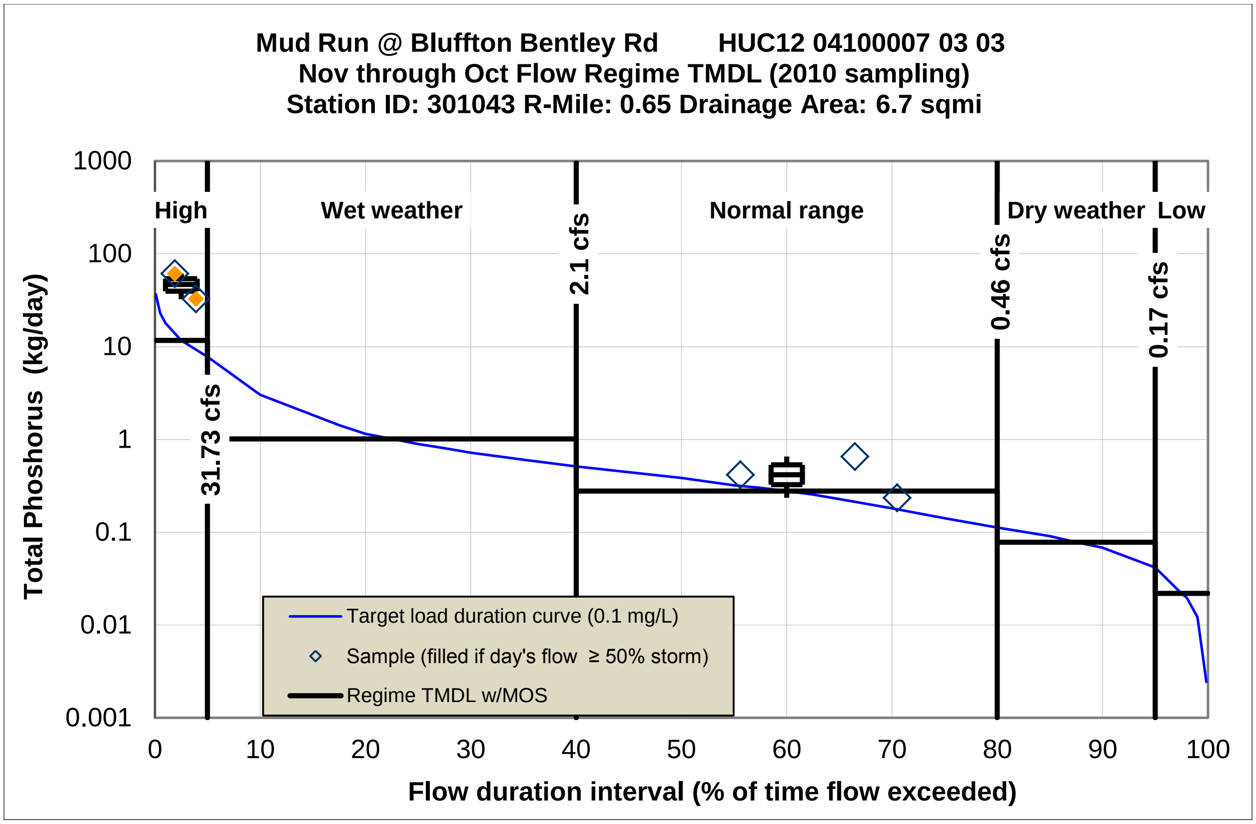

Figure D-22. Total phosphorus load duration curve: Mud Run @ Bluffton Bentley Rd.

Table D-11. Total phosphorus TMDL table: Mud Run @ Bluffton Bentley Rd.

TMDL and duration intervals	High 0-5%	Wet weather 5-40%	Normal range 40-80%	Dry weather 80-95%	Low 95-100%
Samples Per Regime	2	0	3	0	0
Median Sample load	47	N/A	0.42	N/A	N/A
Total Load Reduction Required	**76.9%**	No Data	**37.7%**	No Data	No Data
Total Maximum Daily Load	11.66	1.01	0.28	0.08	0.02
Margin of Safety: 5%	0.58	0.05	0.01	0.004	0.001
Allowance for future growth: 2%	0.23	0.02	0.01	0.002	0.0004
Load Allocation	10.84	0.94	0.26	0.07	0.02
Wasteload Allocation Total	0.00	0.00	0.00	0.00	0.00

Values were adjusted for rounding.

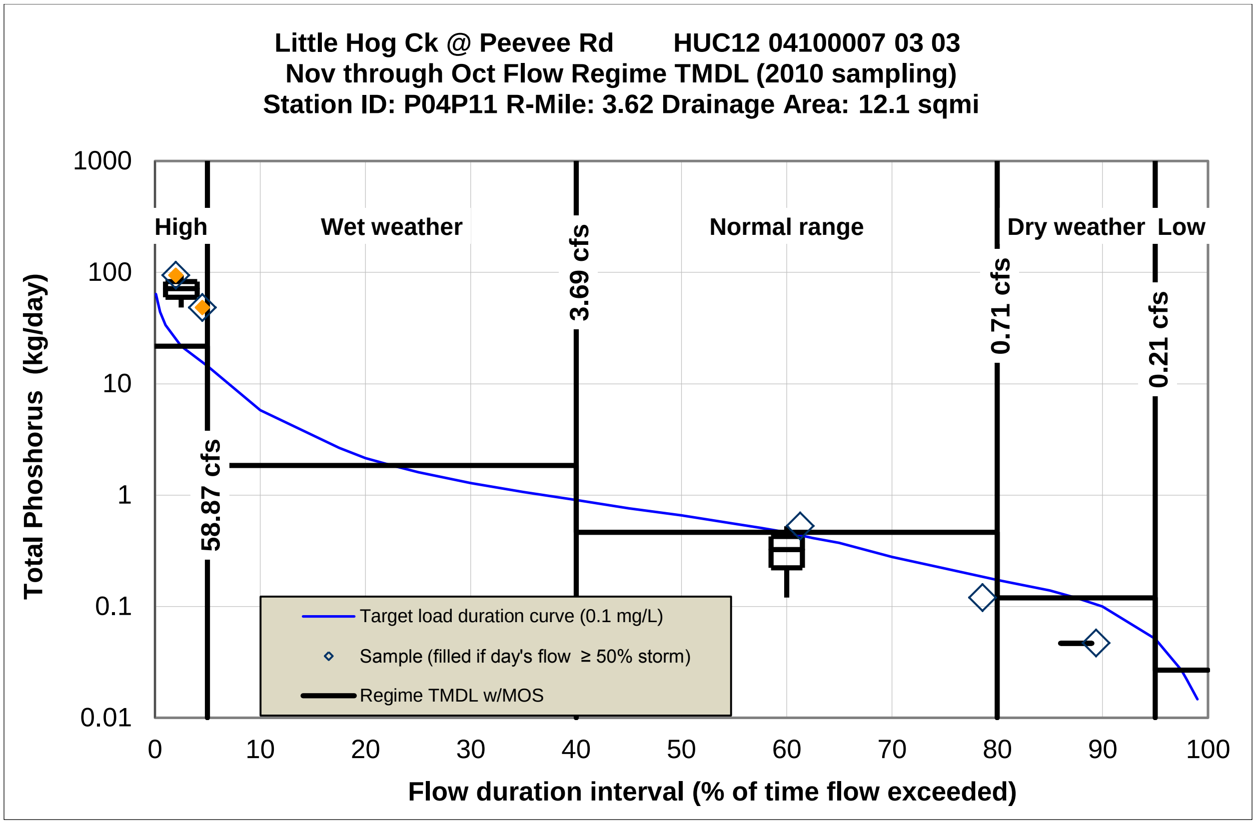

Figure D-23. Total phosphorus load duration curve: Little Hog Ck @ Peevee Rd.

Table D-12. Total phosphorus TMDL table: Little Hog Ck @ Peevee Rd.

TMDL and duration intervals	High 0-5%	Wet weather 5-40%	Normal range 40-80%	Dry weather 80-95%	Low 95-100%
Samples Per Regime	2	0	2	1	0
Median Sample load	71	N/A	0.32	0.05	N/A
Total Load Reduction Required	**71.7%**	No Data	**N/A**	**N/A**	No Data
Total Maximum Daily Load	21.70	1.85	0.46	0.12	0.03
Margin of Safety: 5%	1.09	0.09	0.02	0.01	0.001
Allowance for future growth: 2%	0.43	0.04	0.01	0.002	0.001
Load Allocation	20.18	1.72	0.43	0.11	0.03
Wasteload Allocation Total	0.00	0.00	0.00	0.00	0.00

Values were adjusted for rounding.

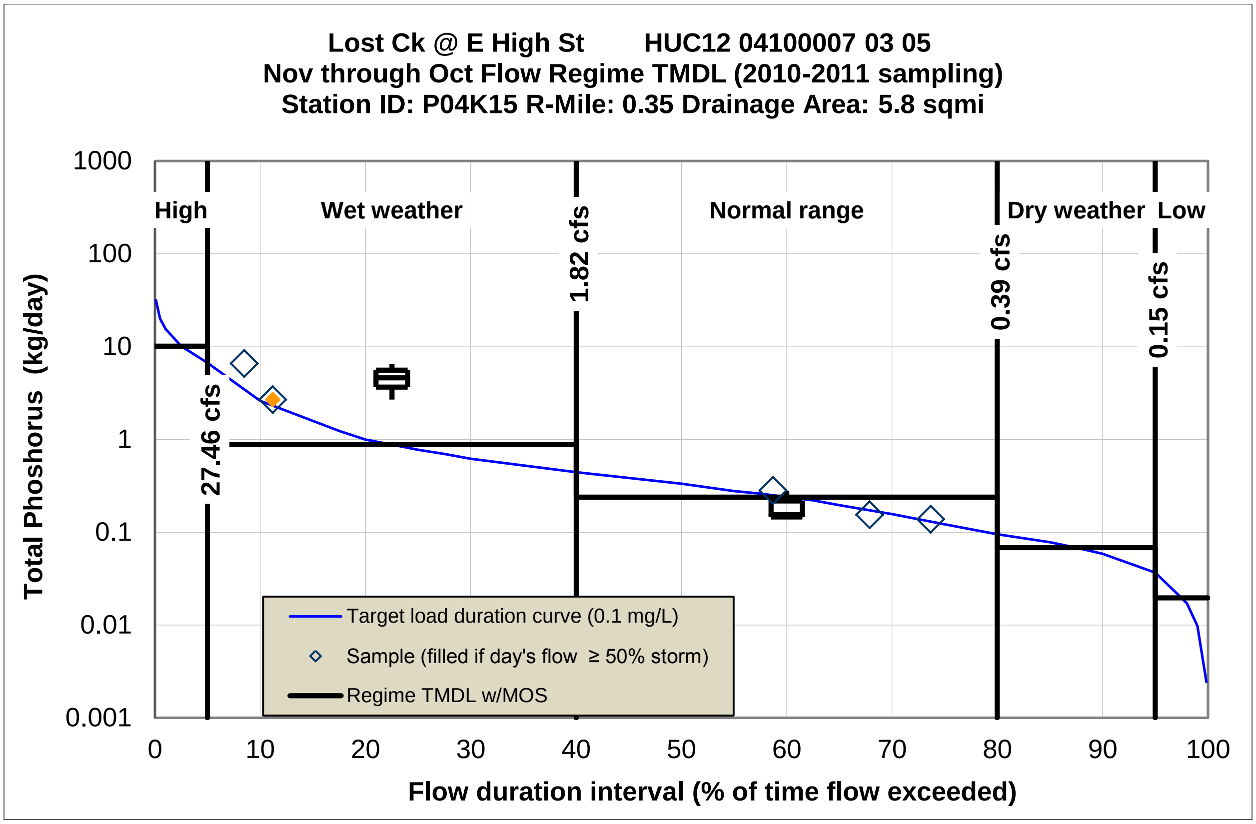

Figure D-24. Total phosphorus load duration curve: Lost Ck @ Reservoir Rd.

Table D-13. Total phosphorus TMDL table: Lost Ck @ Reservoir Rd.

TMDL and duration intervals	High 0-5%	Wet weather 5-40%	Normal range 40-80%	Dry weather 80-95%	Low 95-100%
Samples Per Regime	0	2	3	0	0
Median Sample load	N/A	5	0.15	N/A	N/A
Total Load Reduction Required	No Data	82.4%	N/A	No Data	No Data
Total Maximum Daily Load	10.09	0.88	0.24	0.07	0.02
Margin of Safety: 5%	0.50	0.04	0.01	0.003	0.001
Allowance for future growth: 2%	0.20	0.02	0.00	0.001	0.0004
Load Allocation	6.94	0.60	0.17	0.07	0.01
Wasteload Allocation Total	2.44	0.21	0.06	0.00	0.00
Lima MS4	2.44	0.21	0.06	0.00	0.00

Values were adjusted for rounding.

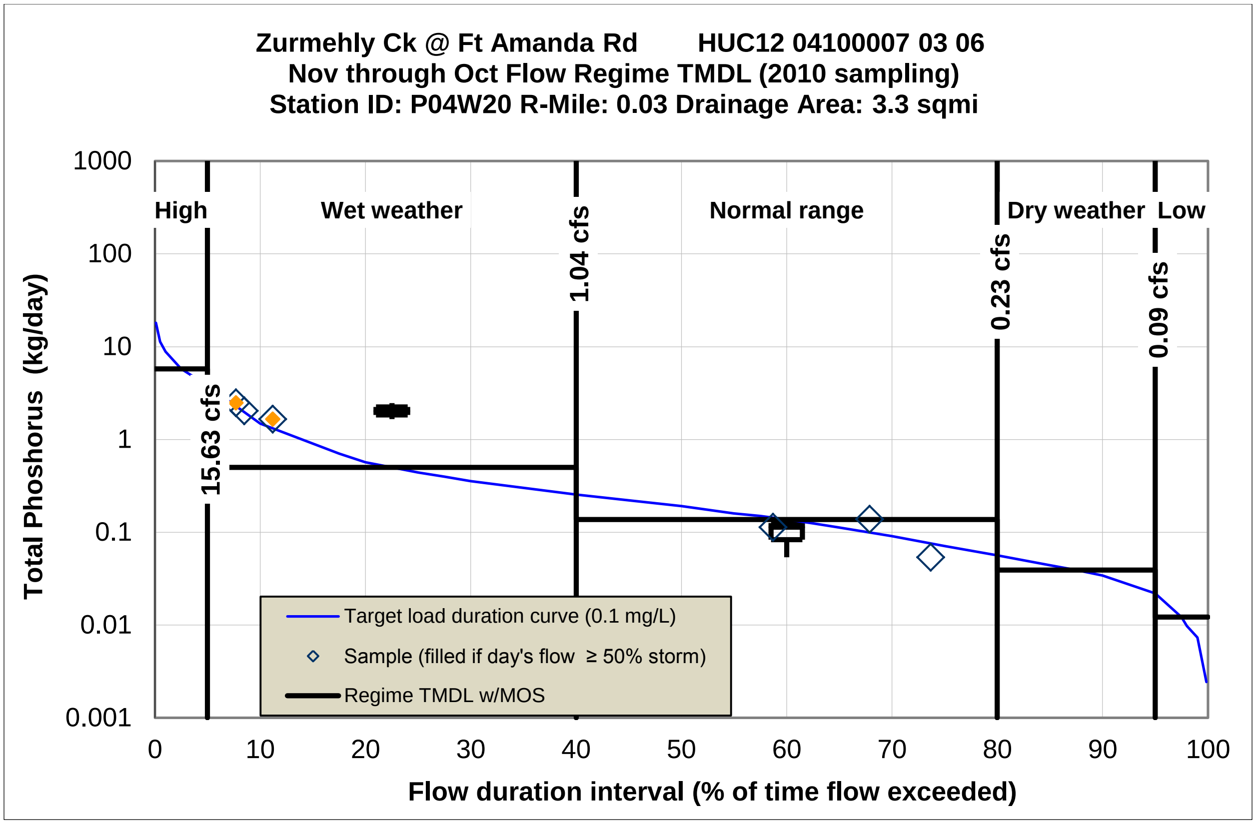

Figure D-25. Total phosphorus load duration curve: Zurmehly Creek @ Ft. Amanda Rd.

Table D-14. Total phosphorus TMDL table: Zurmehly Creek @ Ft. Amanda Rd.

TMDL and duration intervals	High 0-5%	Wet weather 5-40%	Normal range 40-80%	Dry weather 80-95%	Low 95-100%
Samples Per Regime	0	3	3	0	0
Median Sample load	N/A	2	0.11	N/A	N/A
Total Load Reduction Required	No Data	**77.1%**	**NA**	No Data	No Data
Total Maximum Daily Load	5.74	0.50	0.14	0.04	0.01
Margin of Safety: 5%	0.29	0.02	0.01	0.00	0.00
Allowance for future growth: 2%	0.11	0.01	0.00	0.00	0.00
Load Allocation	3.04	0.26	0.07	0.04	0.01
Wasteload Allocation Total	2.30	0.20	0.05	0.00	0.00
Lima MS4	2.30	0.20	0.05	0.00	0.00

Values were adjusted for rounding.

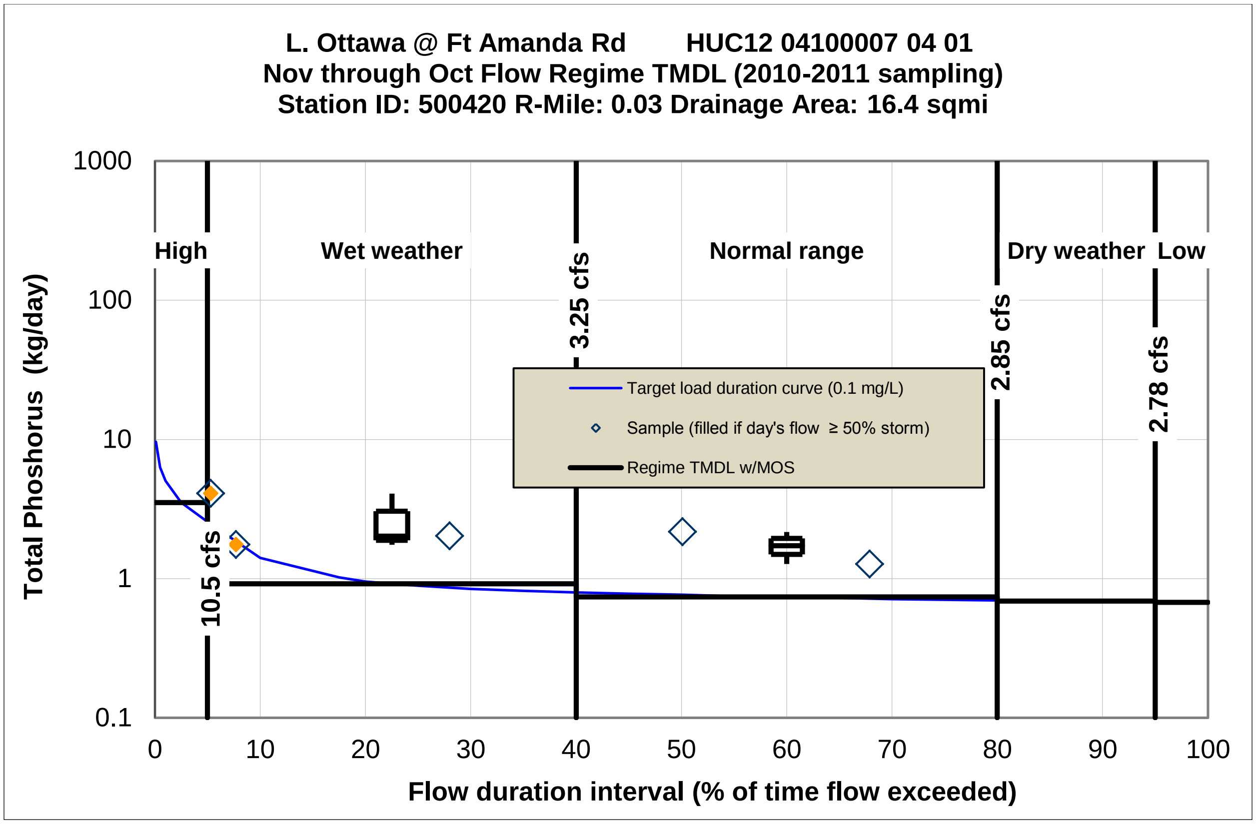

Figure D-26. Total phosphorus load duration curve: Little Ottawa River @ Ft. Amanda Rd.

Table D-15. Total phosphorus TMDL table: Little Ottawa River @ Ft. Amanda Rd.

TMDL and duration intervals	**High 0-5%**	**Wet weather 5-40%**	**Normal range 40-80%**	**Dry weather 80-95%**	**Low 95-100%**
Samples Per Regime	0	3	2	0	0
Median Sample load	N/A	2	1.72	N/A	N/A
Total Load Reduction Required	No Data	**57.8%**	**60.1%**	No Data	No Data
Total Maximum Daily Load	3.52	0.92	0.74	0.69	0.68
Margin of Safety: 5%	0.18	0.05	0.04	0.03	0.03
Allowance for future growth: 2%	0.07	0.02	0.01	0.01	0.01
Load Allocation	1.95	0.18	0.06	0.04	0.02
Wasteload Allocation Total	1.33	0.67	0.63	0.61	0.61
Lima MS4	0.72	0.07	0.02	0.00	0.00
Cridersville WWTP 2PB00048	0.61	0.61	0.61	0.61	0.61

Values were adjusted for rounding.

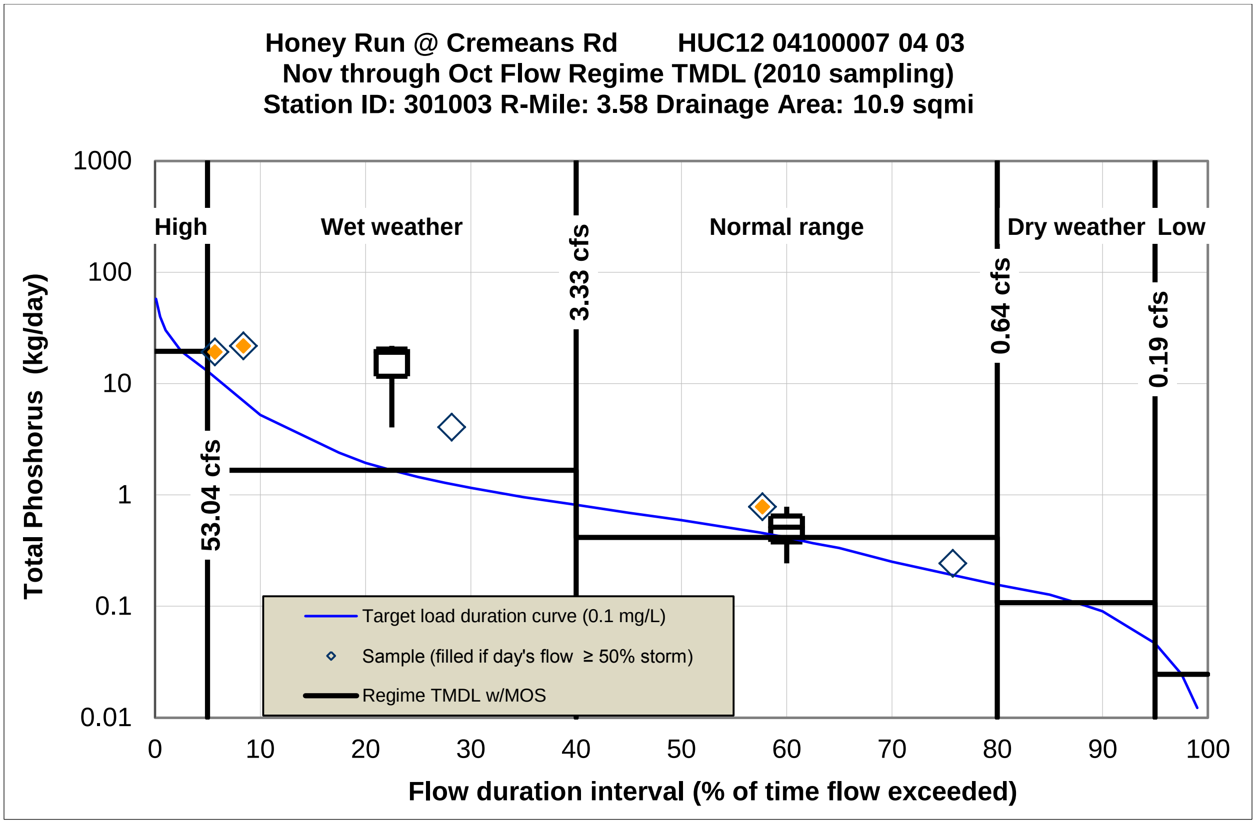

Figure D-27. Total phosphorus load duration curve: Honey Run @ Cremeans Rd.

Table D-16. Total phosphorus TMDL table: Honey Run @ Cremeans Rd.

TMDL and duration intervals	High 0-5%	Wet weather 5-40%	Normal range 40-80%	Dry weather 80-95%	Low 95-100%
Samples Per Regime	0	3	2	0	0
Median Sample load	N/A	19	0.51	N/A	N/A
Total Load Reduction Required	No Data	72.6%	N/A	No Data	No Data
Total Maximum Daily Load	19.55	1.66	0.42	0.11	0.02
Margin of Safety: 5%	0.98	0.08	0.02	0.01	0.001
Allowance for future growth: 2%	0.39	0.03	0.01	0.002	0.0005
Load Allocation	18.18	1.55	0.39	0.10	0.02
Wasteload Allocation Total	0.00	0.00	0.00	0.00	0.00

Values were adjusted for rounding.

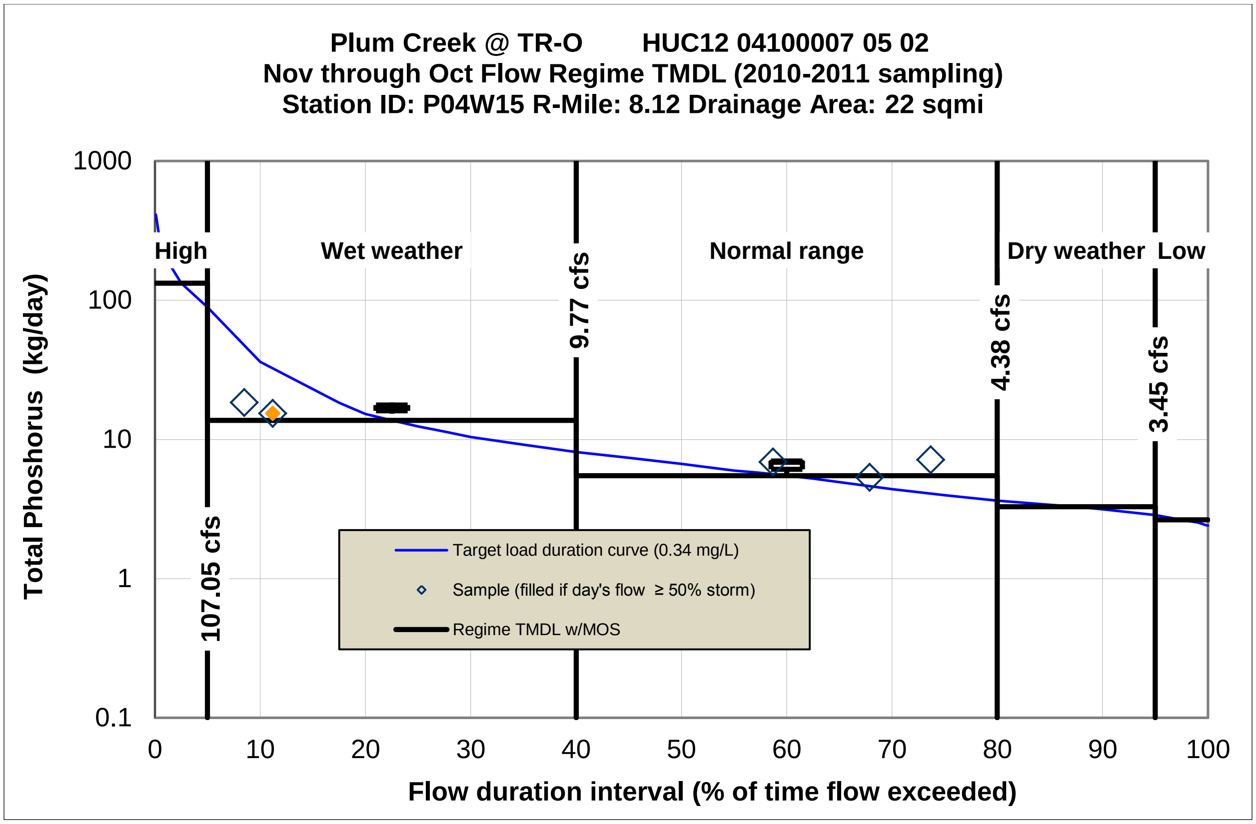

Figure D-28. Total phosphorus load duration curve: Plum Creek @ TR-O.

Table D-17. Total phosphorus TMDL table: Plum Creek @ TR-O.

TMDL and duration intervals	High 0-5%	Wet weather 5-40%	Normal range 40-80%	Dry weather 80-95%	Low 95-100%
Samples Per Regime	0	2	3	0	0
Median Sample load	N/A	17	6.87	N/A	N/A
Total Load Reduction Required	No Data	24.5%	25.4%	No Data	No Data
Total Maximum Daily Load	132.54	13.70	5.51	3.29	2.65
Margin of Safety: 5%	6.63	0.69	0.28	0.16	0.13
Allowance for future growth: 2%	2.65	0.27	0.11	0.07	0.05
Load Allocation	120.79	10.27	0.50	0.10	0.010
Wasteload Allocation Total	2.47	2.47	4.62	2.96	2.46
Columbus Grove WWTP 2PC00004	2.16	2.16	2.16	2.16	2.16
Columbus Grove CSOs	0.00	0.00	0.00	0.00	0.00
Cairo Sulfur Products 2IF00008	0.30	0.30	0.30	0.30	0.30

Values were adjusted for rounding.

D4.1.2 Tributary Discharger Total Phosphorus NPDES Permit Recommendations

Table D-18. NPDES discharger total phosphorus limit recommendations for tributary dischargers.

Nested Subwatershed	Ohio Permit Number	Facility Name	Design Flow (MGD)	Recommended Permit Limit (mg/L TP)
05 02	2IF00008	Cairo Sulfur Products	0.0735	1.0
04 01	2PB00048	Cridersville WWTP	0.80	0.57
03 02	2PB00050	Ada WWTP	2.0	0.84
05 02	2PC00004	Columbus Grove WWTP	0.82	1.2

Nutrient load reduction, specifically in the form of total phosphorus, is necessary in tributaries to the Ottawa River where 1) aquatic life use did not achieve full attainment of designated goals, and 2) said non- or partial attainment of aquatic life use goals were attributed to nutrient enrichment or related causes. In the streams where this situation occurs, a load reduction is required from nonpoint sources as well as a wasteload reduction that is required from point source dischargers in order to meet in-stream total phosphorus targets. Recommended total phosphorus permit limits for NPDES dischargers in Ottawa River tributary locations were established via the load duration curve method in order for in-stream total phosphorus concentrations not to exceed a WWH target concentration of 0.1 mg/L total phosphorus. Permit limits as listed in Table D-18 have been adjusted upward to allow for an observed degree of in-stream phosphorus decay to occur between the NPDES facility and the impaired stream site, as outlined in Section D3.1.2.

QUAL2K

The Ottawa River downstream from Lima is strongly dominated by point source effluent. Figure D-29 shows that 94.9% of the river at the end of the modeled reach is sourced as effluent.

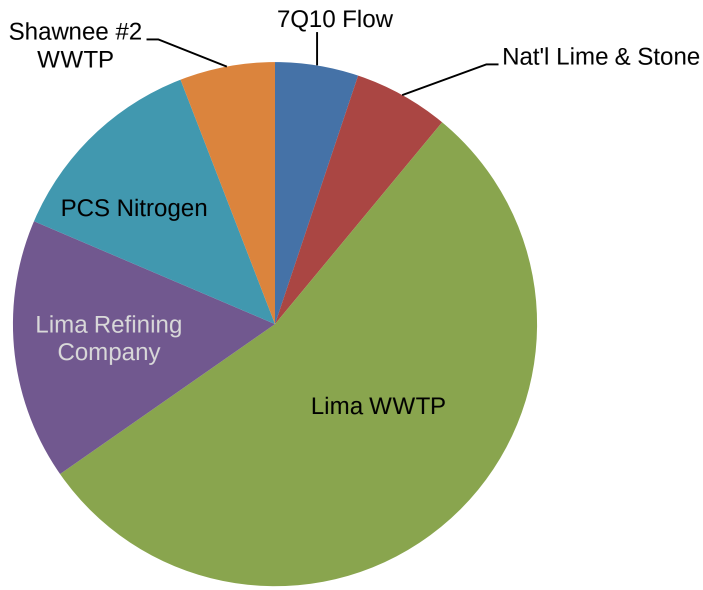

Figure D-29. Components making up the streamflow at the end of the modeled reach.

The dominance of the effluent components demonstrates the importance of effluent quality on aquatic life in the stream. This means that if aquatic life is impaired by chemical constituents at critical low flows the burden of improvement is placed firmly upon the point source community. A TMDL scenario is proposed to improve aquatic life in the Ottawa River by limiting the availability of phosphorus to the algal community that is driving eutrophication.

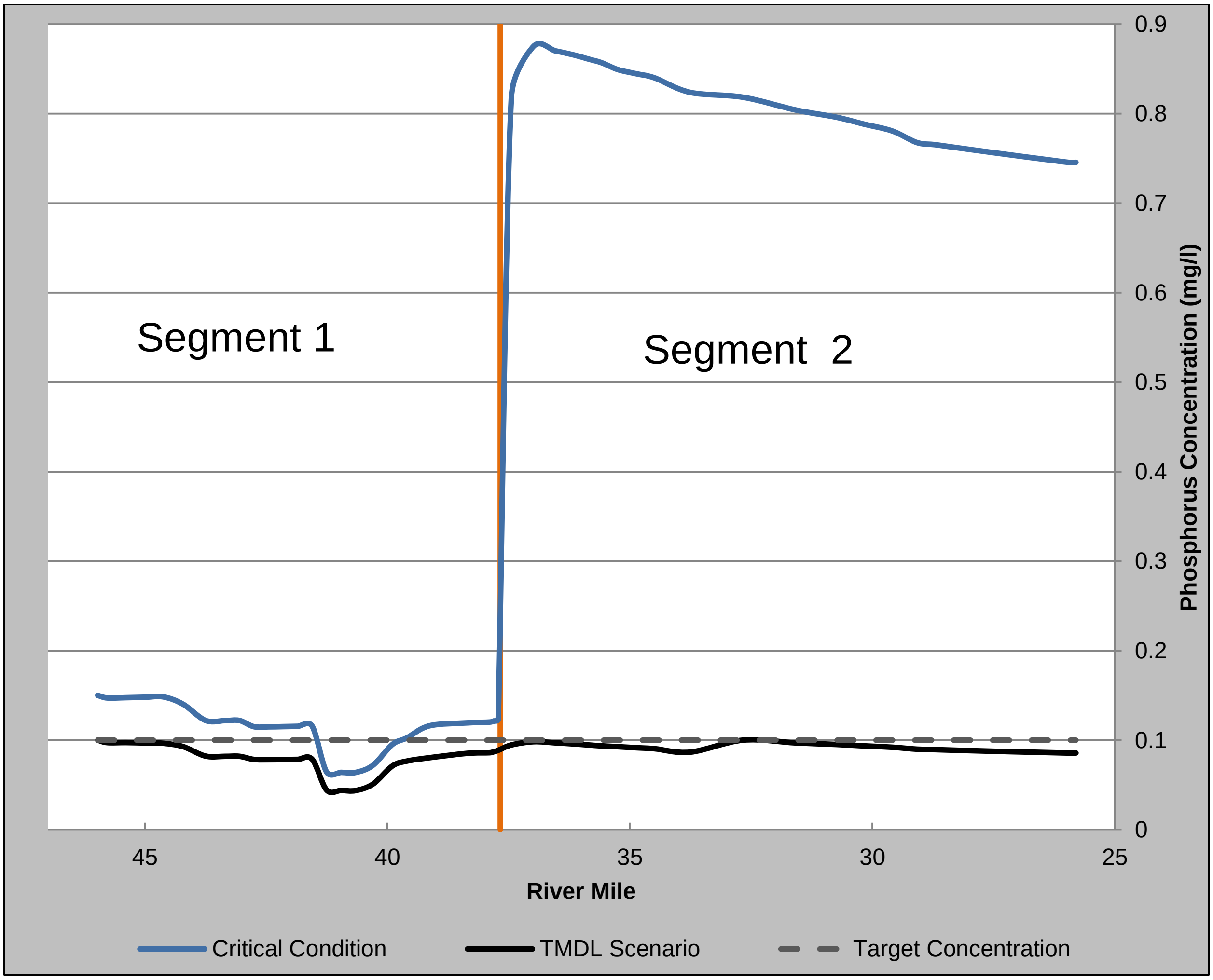

Figure D-30. QUAL2K output of the critical condition and TMDL scenario for total phosphorus in the Ottawa River in Lima.

The critical condition is not a TMDL scenario but it is shown here for comparison to the TMDL scenario. A line representing the in-stream target concentration is also plotted in Figure D-30. The TMDL in this instance is total P load that is discharged to the stream. Unlike with the LDC analysis for nutrients there is not a location where in-stream target total phosphorus concentrations have to be met. The reason is that the QUAL2K model looks at the entire system and decisions for allocations are based on the response of the entire system. The model represents a system where the total phosphorus is contained in three major pools within the water column:

1) Inorganic pool
2) Organic pool
3) Algal pool

These pools are interactive where the algal fraction of phosphorus is released to the organic pool when algae dies; the organic fraction is then hydrolyzed into the inorganic pool which is then available for incorporation back to the algal fraction. Phosphorus is also released from sediments through desorption and hydrolysis from the organic matter that drives sediment oxygen demand. Figure D-30 has two different segments identified where the three pools behave differently:

> Segment 1: This segment extends from the start of the modeled reach (RM 28.6) to where the city of Lima WWTP discharges to the stream (RM 37.67). The stream segment can be described for the critical condition as a segment that is dominantly lentic in nature. Lentic systems have high cumulative time of travel and deep water columns providing ideal conditions for phytoplankton growth. The result is that the algal fraction of TP dominates and low water column concentrations of inorganic phosphorus that increases the rate of desorption from sediments. Ultimately TP concentrations in the water column increase until they reach an equilibrium concentration during the critical condition.
>
> Segment 2: Segment two begins at the point where the Lima WWTP discharges to the Ottawa River (RM 37.67); followed immediately by the point source discharges of the Lima Refining Company and PCS Nitrogen. The stream segment represents a lotic system which is dominated by point source discharges (Figure D-29). The model predicts decay of total phosphorus concentrations in this segment where the effluent components of inorganic and organic phosphorus pools dominate the TP concentration. Upstream processes are completely masked in this reach by the dominance of effluent in the stream.

The two segments have different sources and factors that contribute to in-stream water quality. By isolating the two segments it will be easier to make decisions about where changes need to be made in order to meet water quality targets. The first step is to adjust the starting water quality of the current critical conditions model to reflect upstream TMDL implementation meeting water quality standards. The next step is to alter the hydrology of the upper segment so the water quality target is maintained. Lowhead dams are common in the segment therefore hydrology can be altered with their removal. This has two desirable effects: the time of travel is decreased (less time for reactions to take place) and benthic algae can compete with phytoplankton for resources (no longer light limited). The net result of a dam removal in this critical condition is lowering the water column concentration of total phosphorus. For water quality targets to be consistently met throughout the upper segment three dams had to be removed: A, F and G (from Figure D-3). The water quality in the second segment is strictly controlled by point source inputs from: Lima WWTP, Lima Refining Company, PCS Nitrogen, and Shawnee #2 WWTP. These point sources have two effects: increasing flow and contribution of pollutants. In this segment water quality targets are met by reducing pollutant contributions from point sources. The scenario in which the water quality target is met for the entire stream segment is presented in Figure D-30. The TMDL and allocations are presented in Table D-19. Recommended permit limits that were used to develop these allocations are in Table D-19; the limits are specific to the critical condition in which nutrients most severely affect aquatic life in the stream.

Table D-19. TMDL and supporting allocations for the modeled stream reach.

	Conc. (mg/l)	Yield (kg/mi^2/day)	Load (kg/day)
Load (nonpoint source)	-	0.000267	**0.04**
Wasteload (total point sources)			**10.58**
2IJ00013 (National Lime & Stone)	0.015	-	0.11
2PE00000 (Lima WWTP)	0.0762	-	5.33
2IG00001 (Lima Refining Company)	0.0762	-	1.58
2IF00004 (PCS Nitrogen)	0.0762	-	1.25
2PK00002 (Shawnee #2 WWTP)	0.305	-	2.31
Margin of Safety: 21.8%	-	-	**3.03**
Allowance for future growth: 2%	-	-	**0.28**
TMDL = LA + WLA + MOS + AFG			13.93

The purpose of the allocations in this TMDL is to protect the aquatic life of the stream in the modeled reach. The TMDL does not address overall loads that may affect downstream aquatic life use which are influenced by different flow regimes. An example that this TMDL does not address is total phosphorus loading that may be affecting large end point ecosystems; in this case downstream dam pools and Lake Erie.

D4.1.3 Organic Enrichment (CSOs)

The initial modeling step was to determine what size of CSO discharge would have to be eliminated in order to meet the targets that are set by Ohio EPA for CSO impact mitigation. In order to have an average of 5 discharges per year for a 13 year period of record all but 65 occurrences would have had to been eliminated. If all events that discharged less than 26.1 million gallons were eliminated over the 13 years of record the target would have been met (Figure D-31). When the explicit MOS is applied to the empirical model the mitigation value is adjusted to 31.3 MG. By including the explicit MOS the mitigation value is adjusted upward providing a higher degree of certainty that the target of averaging five discharges per year will be met. The inclusion of this margin of safety increases the certainty that the target of five discharge occurrences is met over the long term. Based on the inclusion of the MOS, 45 discharge occurrences would have occurred. If the assumption is made that the remaining discharges are reduced by the mitigation value the 75th percentile of the remaining overflows would be 32.6 MG.

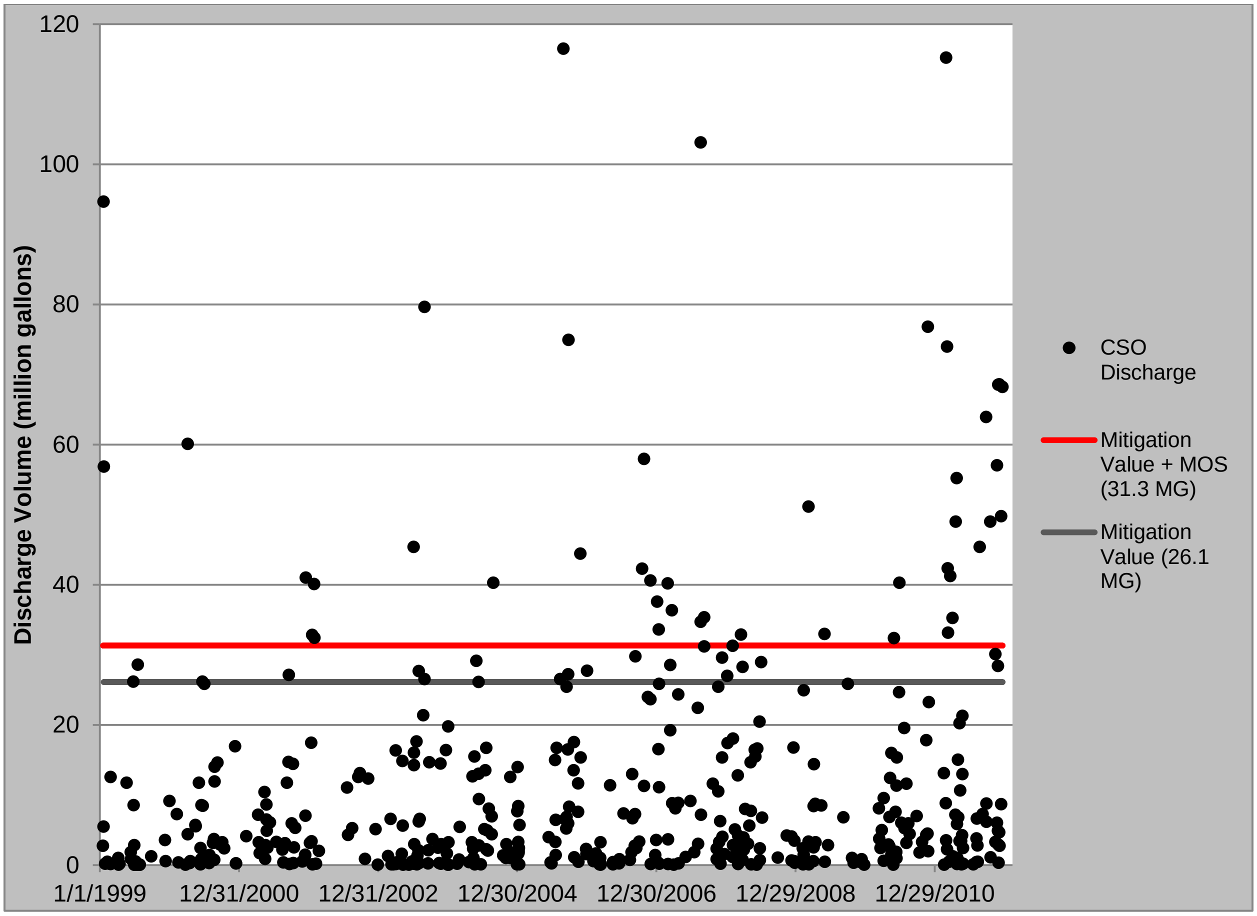

Figure D-31. All CSO total discharge volume at five major CSO discharges in the city of Lima with a mitigation target that would limit CSO discharges to an average of five per year.

The 38 discharges that are greater than the mitigation value (+ MOS) were all matched with the average daily flow as reported by the USGS gaging station immediately downstream from the last CSO discharge. The gage was only in operation for three years (23%) of the study duration but captured 21 of the discharge events (46.7%). The 75th percentile value of streamflow during the 21 events was 1650 cfs. An analysis of reference sites for wadeable streams (<200 mi^2 drainage area) in the Eastern Corn Belt Plains Ecoregion yielded a 75th percentile $CBOD_5$ value of 2.0 mg/l (Ohio EPA 1999b). With these results the TMDL can be calculated and the pollutant sources can be allocated based on:

$$TMDL = WLA + LA + MOS + AFG$$

The results of the allocations are presented in Table D-20. The allocations apply to the scenario where an average of five discharge events occurs annually. The allocations are a conservative estimate of the existing loading scenario that occurs during these events.

Table D-20. TMDL allocations for the nested subwatershed 03 06 (Lima Reservoir-Ottawa River).

	$CBOD_5$ Load (kg/day)
Total Maximum Daily Load	**20,676.45**
Margin of Safety: 20%	**3,389.58**
Allowance for future growth: 2%	**338.96**
Load Allocation	**5,253.72**
Wasteload Allocation Total	**11,694.19**
Lima MS4	1,263.14
County Line Invest. LLC 2PW00018	0.14
Ada WWTP 2PB00050	93.38
Colonial Golfer's Club 2PR00195	0.35
LaFayette WWTP 2PA00049	4.67
National Lime & Stone Co 2IJ00013	62.25
Lima Combined Sewer Overflows[1]	3,336.50
Lima Sanitary Sewer Overflows	0
PCS Nitrogen 2IF00004	186.31
Lima Refinery 2IG00018	1,293.00
Lima WWTP 2PE00000	5,454.45

[1]Includes outfalls: 002, 003, 004, 005, 006, 007, 008, 009, 033, 034, 035, 036, 037

Implementation of this scenario would result in a total overflow volume discharged to the Ottawa River being reduced by 81.1%. It would be expected that the pollutant load reduction will be greater than this value; since the mitigation strategy should capture the first flush of the sewers and the remaining occurrences are when the highest degree of dilution is available. It is beyond the capacity of the modeling method to comment further on pollutant load reductions. The modeling method does two things: identifies discharge occurrences that will remain after mitigation and conservatively allocate a $CBOD_5$ load to events that remain.

D4.2 Habitat Alteration and Sediment

The set of tables presented below highlight the portions of the Ottawa River watershed where impacts to stream habitat negatively affect the potential for a given stream to meet its aquatic life use designation. The sediment TMDL approach (Table D-21) breaks the QHEI into three categories that directly impact the sedimentation of a stream: Substrate (the material that the stream bed is comprised of), Channel (the architecture of the stream), and Riparian (the presence and quality of vegetation along the stream bank). This table indicates the amount, in percent, that a site's score deviates from the target and highlights the portion of the sediment condition which contributes the most to impairment.

In the case of the sediment-impacted sites in this watershed, riparian alterations contribute the least to sedimentation problems. Only at Ottawa River RM 43.45 and 38.63 does the riparian zone contribute to a poor sediment score. The more significant impairments within the sediment category are attributable to substrate- and channel-related metrics, with an equal number of sites having one of these two categories listed as the main impairment.

Table D-21. Characterization of the sediment TMDL using QHEI metrics for sites with impairment due to sedimentation/siltation and/or habitat alteration in the Ottawa River (Lima) TMDL study area.
Note: ALU designation in parentheses. Grouped by nested subwatershed; all sites are located within the 8-digit hydrologic unit 04100007.

Stream/River	River Mile	QHEI Categories			Total Sediment Score	Deviation from Target (%)	Main Impairment Category
		Substrate	Channel	Riparian			
03 03 L. Hog Creek – Ottawa River							
L. Hog Ck WWH)	3.62	4	12	5.5	21.5	32.8	substrate
03 04 Hog Creek – Ottawa River							
Hog Ck (WWH)[1]	3.80	20	12.5	6.5	39	---	channel
03 06 Ottawa River							
Ottawa R (WWH)	43.45	11	10	4	25	21.9	channel
Ottawa R (WWH)	42.61	6	10	10	26	18.8	substrate
Ottawa R (WWH)	38.63	10	6.5	3	19.5	39.1	channel
Ottawa R (WWH)	37.91	8.5	11	4	23.5	26.6	substrate
04 01 Little Ottawa River							
L. Ottawa R (WWH)	1.85	6.5	17	5.5	29	9.4	substrate
04 03 Ottawa River							
Honey Run (MWH-C)[2]	3.58	8.5	8	8.5	25	---	channel
05 02 Plum Ck – Ottawa River							
Plum Creek (MWH-C)	8.12	5	7.5	4	16.5	28.3	substrate
Target (MWH)		**≥ 9**	**≥ 10**	**≥ 4**	**≥ 23**		
Target (WWH)		**≥ 13**	**≥ 14**	**≥ 5**	**≥ 32**		

[1] Substrate assessed based on data collected at RM 0.3 because data were unavailable at RM 3.8; the land use and channel characteristics between the two sites do not differ substantially.
[2] The site meets the overall sediment score; however, two of the sub-metrics do not meet the target and are considered to be influencing the attainment status.

Table D-22. Characterization of the habitat TMDL using QHEI metrics for sites with impairment due to habitat alteration, sedimentation/siltation, turbidity, and/or flow alteration (non-natural) in the Ottawa River (Lima) TMDL study area.
Note: ALU designation in parentheses. Grouped by nested subwatershed; all sites are located within the 8-digit hydrologic unit 04100007.

Stream/River	River Mile	QHEI Score	# of High Influence Attributes	Total # of Modified Attributes	Sub-score			Total Habitat Score
					QHEI	High Influence	Modified	
03 03 L. Hog Creek – Ottawa River								
L. Hog Ck (WWH)	3.62	45.5	1	6	0	1	0	1
03 06 Ottawa River								
Ottawa R (WWH)	43.45	49	1	5	0	0	0	0
Ottawa R (WWH)	42.61	58	2	8	0	0	0	0
Ottawa R (WWH)	38.63	48.5	2	8	0	0	0	0
Ottawa R (WWH)	37.91	63.5	1	6	1	1	0	2
04 03 Ottawa River								
Honey Run (MWH-C)	3.58	50.5	3	10	1	0	0	1
05 02 Plum Creek – Ottawa River								
Plum Creek (MWH-C)	8.1	36	2	10	0	0	0	0
Target (MWH)		**≥ 43 = 1 pt**	**< 2 = 1 pt**	**< 6 = 1 pt**				**3 pts**
Target (WWH)		**≥ 60 = 1 pt**	**< 2 = 1 pt**	**< 5 = 1 pt**				**3 pts**

Some of the sites with the most severe impacts to sediment-related aquatic life habitat metrics, as indicated by the percent deviation from the target, include Ottawa River at RM 38.63 (Collett St.), 39.1%; Little Hog Creek at RM 3.62 (Peevee Rd.), 32.8%; and the Ottawa River at RM 37.91 (downstream dam adjacent Lima WWTP), 26.6%.

As described earlier, the habitat TMDL considers the final QHEI score and the frequency of modified attributes for a given site (Table D-22). A total habitat score of zero represents low overall QHEI and too many high and moderate influence modified attributes. Ottawa River mainstem sites at river miles 38.6 (at Collett St.), 42.6 (at Roush Rd.) and 43.45 (downstream Metzger Rd. dam) each fail to meet QHEI score or modified attributes targets, indicating the need for significant habitat improvement. The Ottawa River at river mile 37.91 (just downstream dam at Lima WWTP) provides relatively better habitat but exhibits too many moderate influence habitat modifications to meet QHEI targets, and Little Hog Creek at RM 3.62 (Pevee Rd.) needs overall QHEI score improvement and a diminution of modified habitat attributes.

D4.3 Bacteria

In the sequence of figures and tables below, the load duration curve for each site (Figures D-32 through D-42) is shown followed by the TMDL table for that site (Tables D-23 through D-33).

In general, the greater required reductions in *E. coli* loading, in terms of both the amount of reduction needed and the geographic spread of needed reduction exist under *High* and *Wet Weather* streamflow conditions. Reductions in nonpoint source contributions of *E. coli* are recommended to reduce loading under these streamflow conditions.

Among many possibilities, some typical nonpoint sources of *E. coli* include manure spreading, stream bank erosion, and washoff from livestock feeding operations. Scenarios where high *E. coli* loads exist under normal range flow conditions, or high loads occur under all conditions, can be attributed to a mixture of point and nonpoint sources. Site investigation using digital mapping, aerial photography or an on-the-ground visit can help further develop priorities for implementation based on the LDC evidence for either point or nonpoint sources of *E. coli*.

In many locations, *E. coli* loading needs to be reduced under *Dry Weather* conditions. High *E. coli* loading under dry weather conditions is indicative of a concentrated or point source contribution of *E. coli* to the stream.

General examples of bacteria point sources include combined sewer overflows (CSOs), municipal separate storm sewer systems (MS4s) or poorly operating wastewater treatment plants. High bacteria levels under low flow conditions may also indicate leaking sewer lines or failing home sewage treatment systems.

Necessary nonpoint source reductions ranged from 16.4% in dry weather to 98.5% in several instances of various flow conditions.

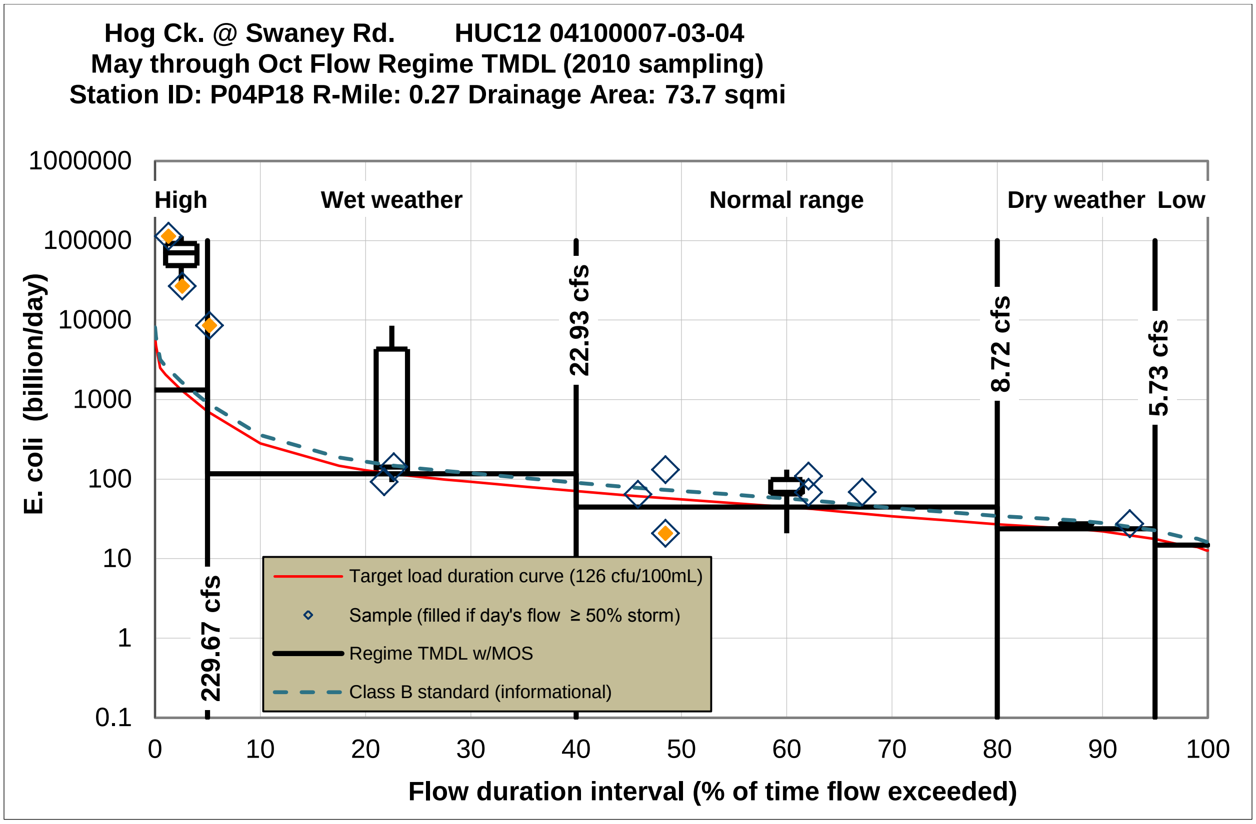

Figure D-32. *E. coli* load duration curve: Hog Creek @ Swaney Rd.

Table D-23. *E. coli* TMDL table: Hog Creek @ Swaney Rd.

TMDL and duration intervals	High 0-5%	Wet weather 5-40%	Normal range 40-80%	Dry weather 80-95%	Low 95-100%
Samples Per Regime	2	3	6	1	0
Median Sample load	69550	131	53.68	14.61	N/A
Total Load Reduction Required	**98.5%**	**36.2%**	**49.0%**	**32.5%**	No Data
Total Maximum Daily Load	1314.73	116.34	44.61	23.64	14.77
Margin of Safety: 20%*	262.95	23.27	8.92	4.73	1.48
Allowance for future growth: 2%	26.29	2.33	0.89	0.47	0.30
Load Allocation	1013.30	78.56	22.60	6.25	0.81
Wasteload Allocation Total	12.19	12.19	12.19	12.19	12.19
Ada WWTP 2PB00050	12.19	12.19	12.19	12.19	12.19

Values were adjusted for rounding.
*10% in Low flow regime

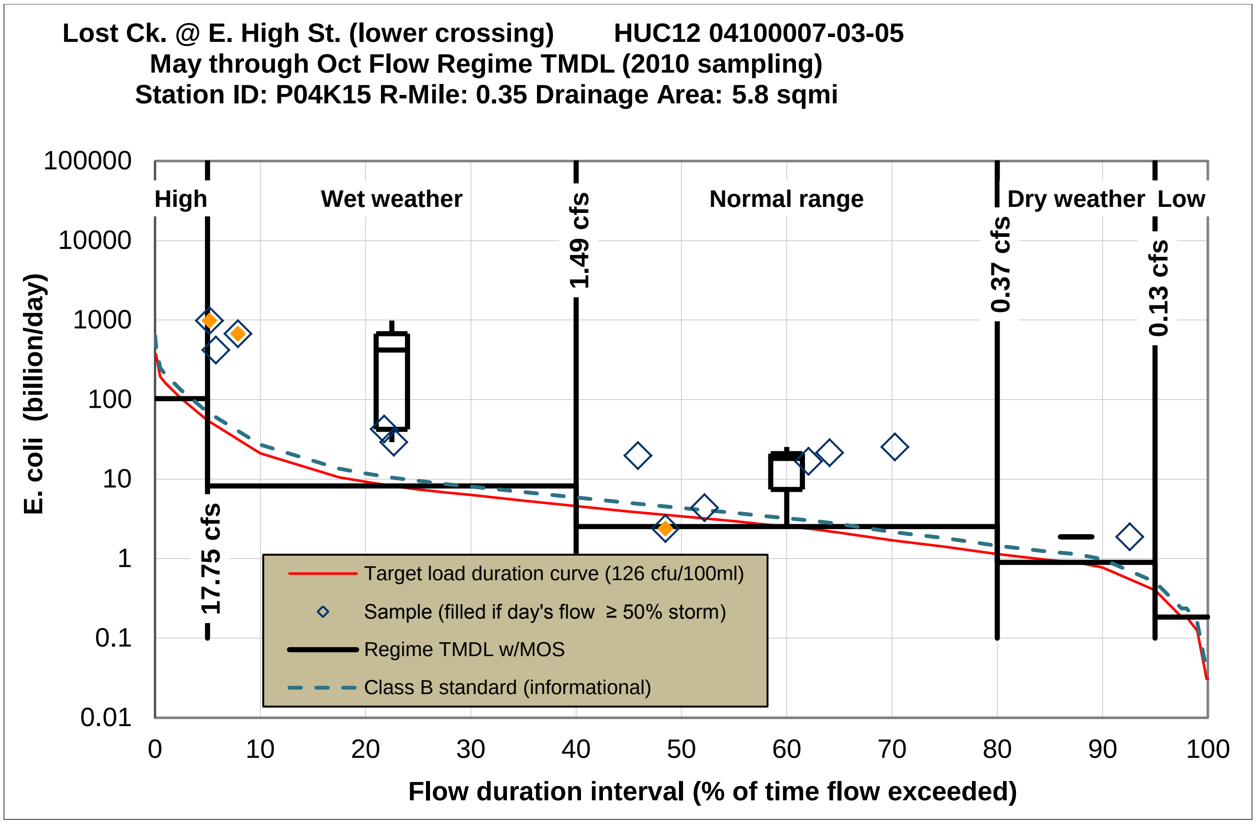

Figure D-33. *E. coli* load duration curve: Lost Creek @ E. High St.

Table D-24. *E. coli* TMDL table: Lost Creek @ E. High St.

TMDL and duration intervals	High 0-5%	Wet weather 5-40%	Normal range 40-80%	Dry weather 80-95%	Low 95-100%
Samples Per Regime	0	5	6	1	0
Median Sample load	N/A	419	18.15	1.87	N/A
Total Load Reduction Required	No Data	**98.5%**	**89.1%**	**62.8%**	No Data
Total Maximum Daily Load	102.44	8.17	2.53	0.89	0.18
Margin of Safety: 20%*	20.49	1.63	0.51	0.18	0.02
Allowance for future growth: 2%	2.05	0.16	0.05	0.02	0.00
Load Allocation	59.12	4.70	1.45	0.68	0.15
Wasteload Allocation Total	20.78	1.67	0.52	0.01	0.01
Lima MS4	20.77	1.65	0.51	0.00	0.00
County Line Invest. LLC 2PW00018	0.01	0.01	0.01	0.01	0.01

Values were adjusted for rounding.
*10% in Low flow regime

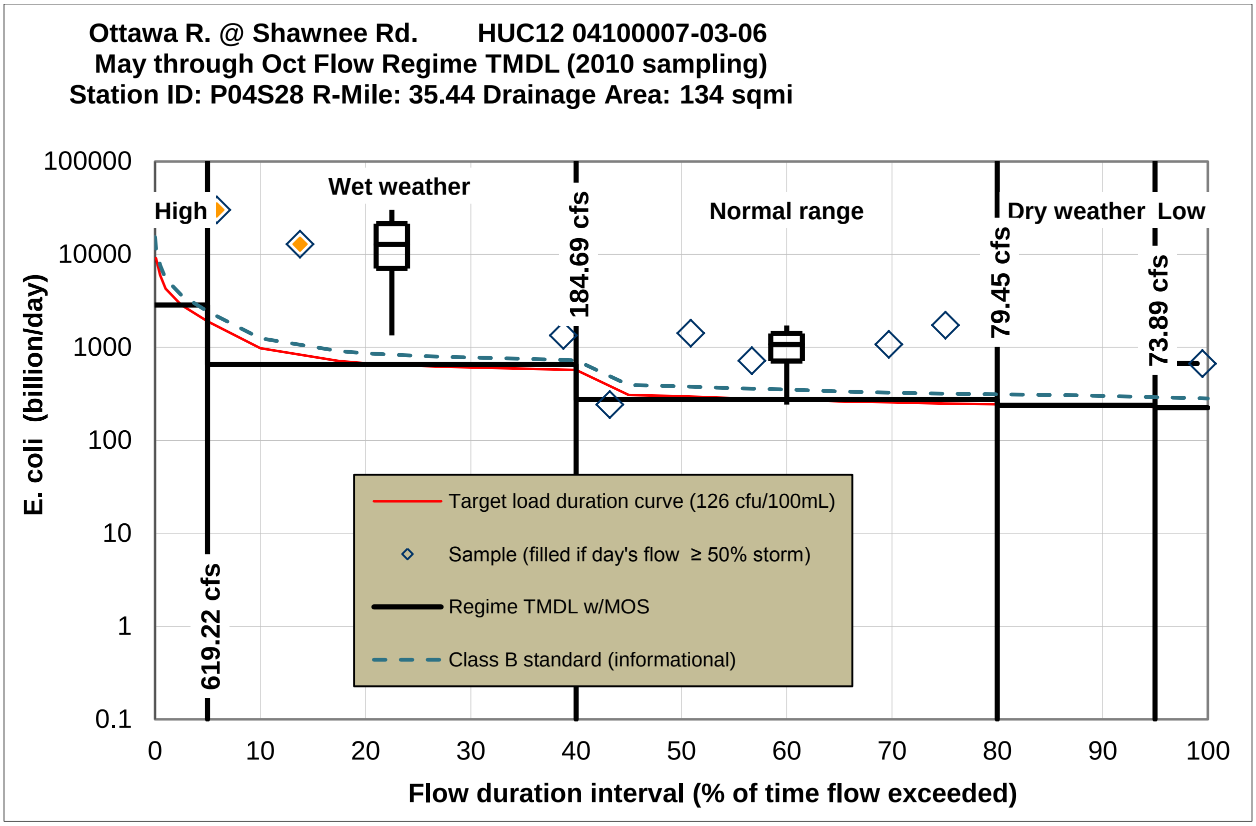

Figure D-34. *E. coli* load duration curve: Ottawa R. @ Shawnee Rd.

Table D-25. *E. coli* TMDL table: Ottawa R. @ Shawnee Rd.

TMDL and duration intervals	High 0-5%	Wet weather 5-40%	Normal range 40-80%	Dry weather 80-95%	Low 95-100%
Samples Per Regime	0	4	4	1	0
Median Sample load	N/A	5279	1166.20	613.31	N/A
Total Load Reduction Required	No Data	**93.4%**	**83.6%**	No Data	**73.8%**
Total Maximum Daily Load	2866.00	654.64	275.78	238.45	224.54
Margin of Safety: 20%	573.20	130.93	55.16	47.69	44.91
Allowance for future growth: 2%	57.32	13.09	5.52	4.77	4.49
Load Allocation	1479.07	81.93	41.52	22.15	11.30
Wasteload Allocation Total	758.57	430.85	175.74	166.50	166.50
Lima MS4	346.94	19.21	9.73	0.00	0.00
County Line Invest. LLC 2PW00018	0.01	0.01	0.01	0.01	0.01
Ada WWTP 2PB00050	12.19	12.19	12.19	12.19	12.19
Colonial Golfer's Club 2PR00195	0.05	0.05	0.05	0.05	0.05
LaFayette WWTP 2PA00049	0.48	0.48	0.48	0.48	0.48
National Lime & Stone Co 2J00013	9.54	9.54	9.54	9.54	9.54
PCS Nitrogen 2IF00004	17.84	17.84	17.84	17.84	17.84
Lima Refinery 2IG00018	38.16	38.16	38.16	38.16	38.16
Lima WWTP 2PE00000	333.87	333.87	88.24	88.24	88.24

Values were adjusted for rounding.

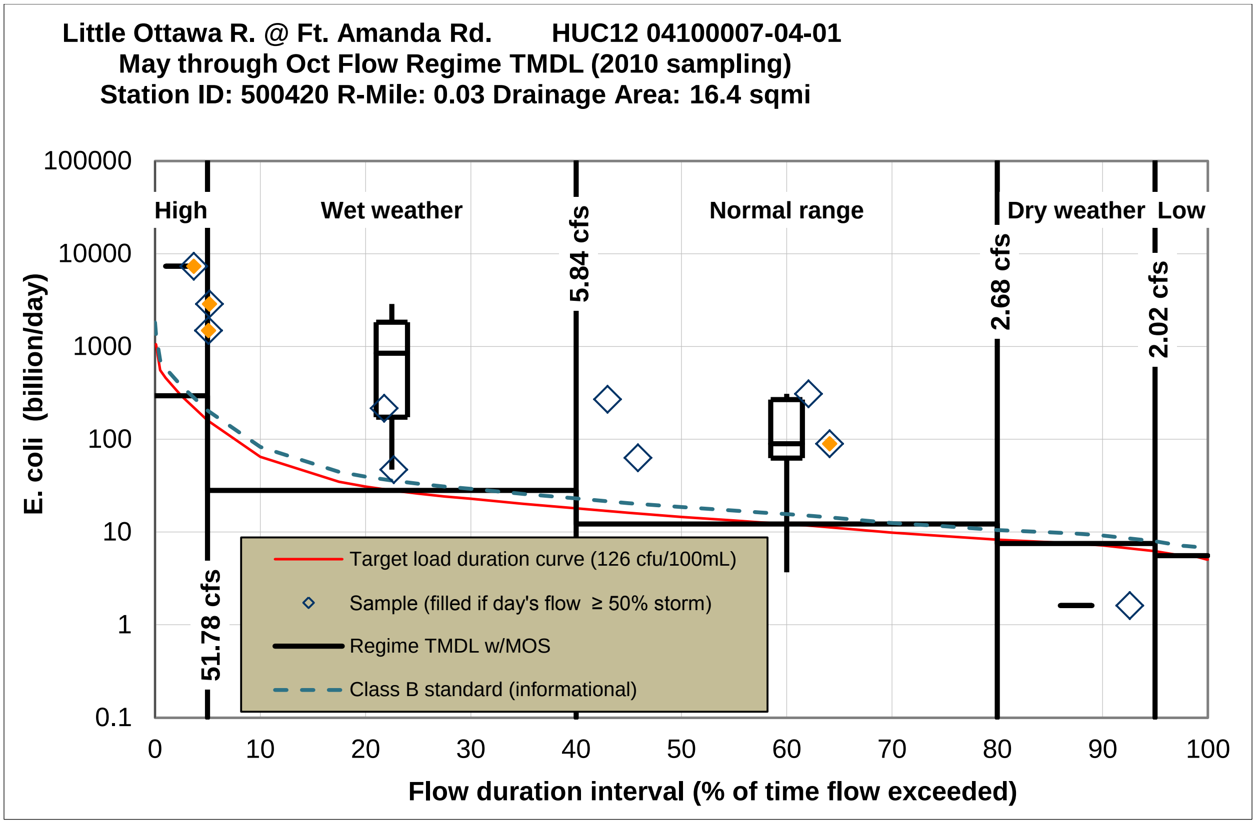

Figure D-35. *E. coli* load duration curve: Little Ottawa River @ Ft. Amanda Rd.

Table D-26. *E. coli* TMDL table: Little Ottawa River @ Ft. Amanda Rd.

TMDL and duration intervals	High 0-5%	Wet weather 5-40%	Normal range 40-80%	Dry weather 80-95%	Low 95-100%
Samples Per Regime	1	4	5	1	0
Median Sample load	7336	850	89.57	1.61	N/A
Total Load Reduction Required	**96.9%**	**97.4%**	**89.4%**	N/A	No Data
Total Maximum Daily Load	294.46	28.14	12.21	7.55	5.58
Margin of Safety: 20%*	58.89	5.63	2.44	1.51	0.56
Allowance for future growth: 2%	5.89	0.56	0.24	0.15	0.11
Load Allocation	164.11	12.47	3.39	1.02	0.03
Wasteload Allocation Total	65.57	9.49	6.13	4.88	4.88
Lima MS4	60.98	4.90	1.54	0.00	0.00
Cridersville WWTP 2PB00048	4.88	4.88	4.88	4.88	4.88

Values were adjusted for rounding.
*10% in Low flow regime

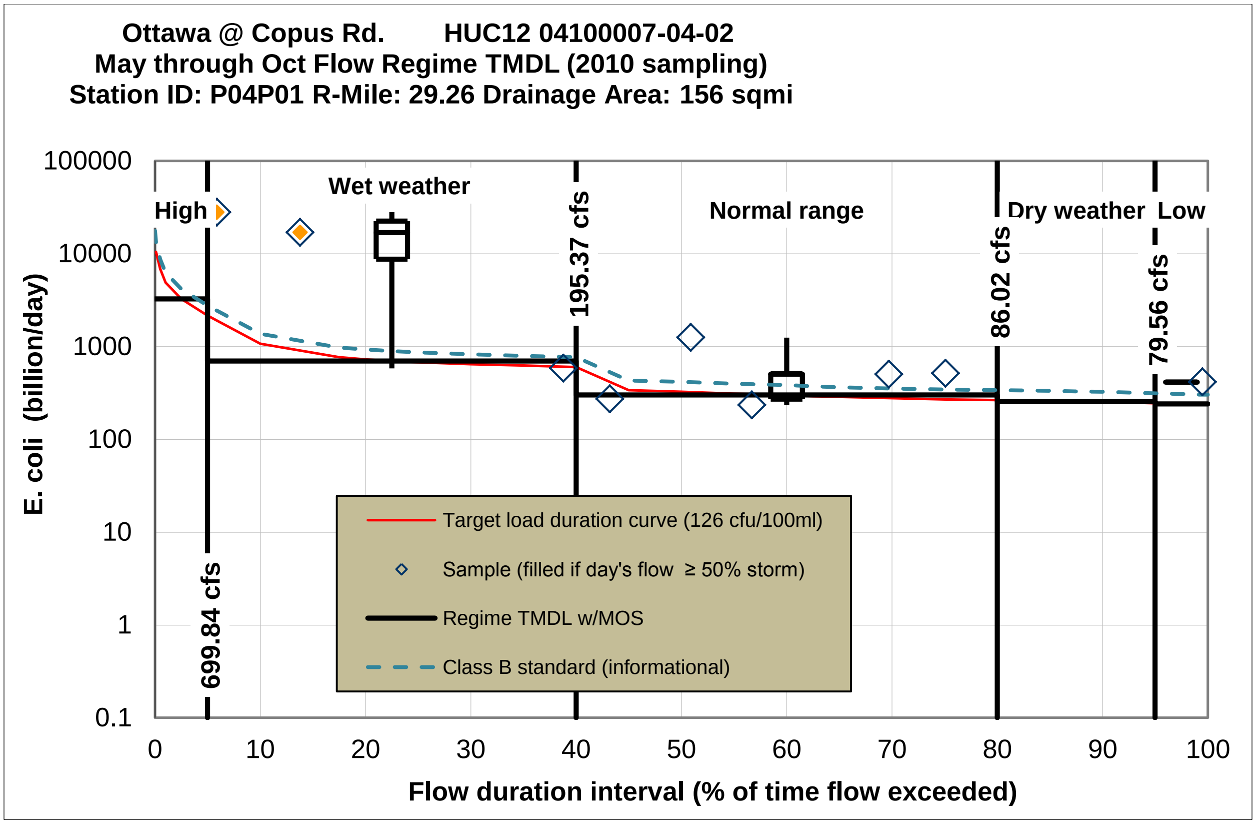

Figure D-36. ***E. coli*** **load duration curve: Ottawa R. @ Copus Rd.**

Table D-27. *E. coli* TMDL table: Ottawa R. @ Copus Rd.

TMDL and duration intervals	High 0-5%	Wet weather 5-40%	Normal range 40-80%	Dry weather 80-95%	Low 95-100%
Samples Per Regime	0	3	5	0	1
Median Sample load	N/A	16933	504.95	N/A	415.25
Total Load Reduction Required	No Data	**96.8%**	**53.5%**	No Data	**54.5%**
Total Maximum Daily Load	3268.6	701.28	300.96	257.65	241.50
Margin of Safety: 20%*	653.72	140.26	60.19	51.53	24.15
Allowance for future growth: 2%	65.37	14.03	6.02	5.15	4.83
Load Allocation	1467.41	85.68	39.71	23.77	11.89
Wasteload Allocation Total	1082.10	461.32	195.04	177.19	177.19
Lima MS4	659.27	38.49	17.84	0.00	0.00
County Line Invest. LLC 2PW00018	0.01	0.01	0.01	0.01	0.01
Ada WWTP 2PB00050	12.19	12.19	12.19	12.19	12.19
Colonial Golfer's Club 2PR00195	0.05	0.05	0.05	0.05	0.05
LaFayette WWTP 2PA00049	0.48	0.48	0.48	0.48	0.48
National Lime & Stone Co 2IJ00013	9.54	9.54	9.54	9.54	9.54
PCS Nitrogen 2IF00004	17.84	17.84	17.84	17.84	17.84
Lima Refinery 2IG00018	38.16	38.16	38.16	38.16	38.16
Lima WWTP 2PE00000	333.87	333.87	88.24	88.24	88.24
Cridersville WWTP 2PB00048	4.88	4.88	4.88	4.88	4.88
Shawnee #2 WWTP 2PK00002	9.54	9.54	9.54	9.54	9.54

Values were adjusted for rounding.

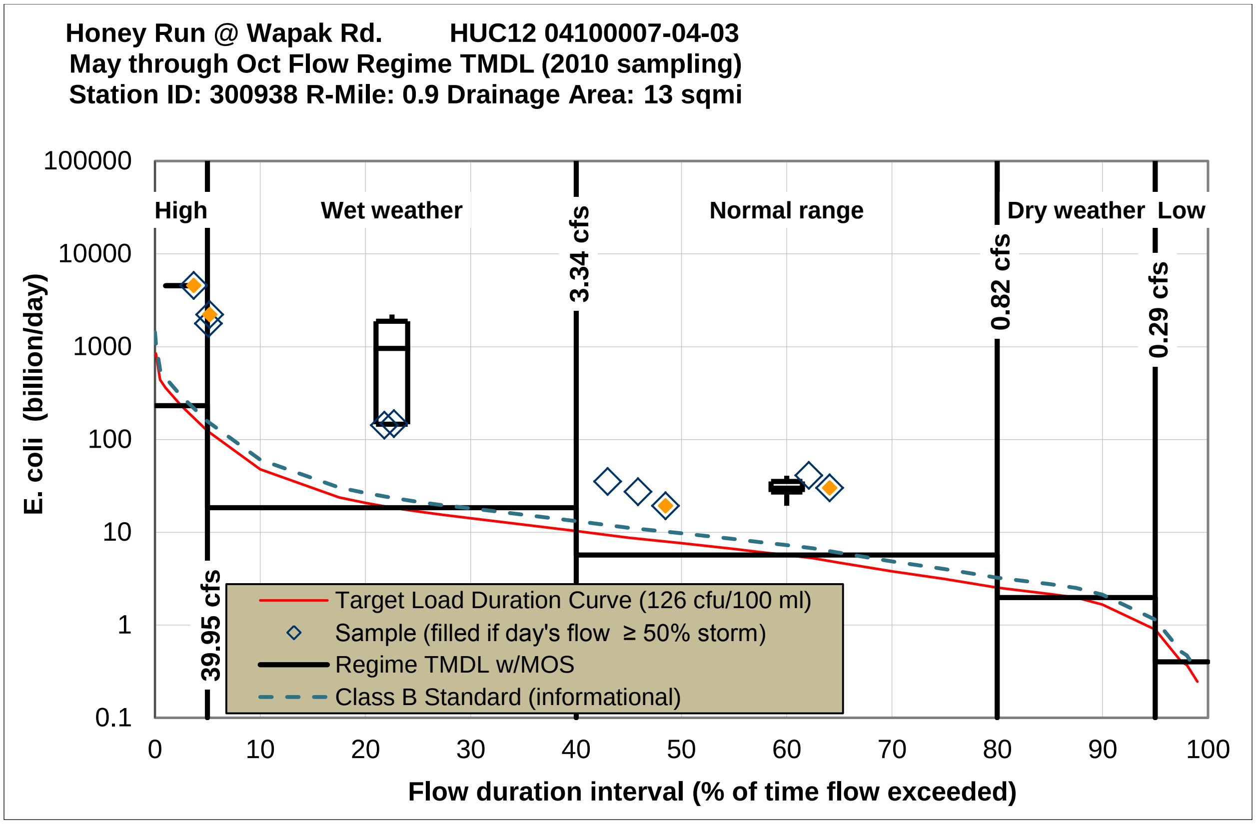

Figure D-37. *E. coli* load duration curve: Honey Run @ Wapak Rd.

Table D-28. *E. coli* TMDL table: Honey Run @ Wapak Rd.

TMDL and duration intervals	High 0-5%	Wet weather 5-40%	Normal range 40-80%	Dry weather 80-95%	Low 95-100%
Samples Per Regime	1	4	5	0	0
Median Sample load	4547	960	29.95	N/A	N/A
Total Load Reduction Required	**96.0%**	**98.5%**	**85.2%**	No Data	No Data
Total Maximum Daily Load	230.58	18.37	5.67	1.97	0.40
Margin of Safety: 20%	46.12	3.67	1.13	0.39	0.08
Allowance for future growth: 2%	4.61	0.37	0.11	0.04	0.01
Load Allocation	179.86	14.33	4.42	1.54	0.31
Wasteload Allocation Total	0.00	0.00	0.00	0.00	0.00

Values were adjusted for rounding.

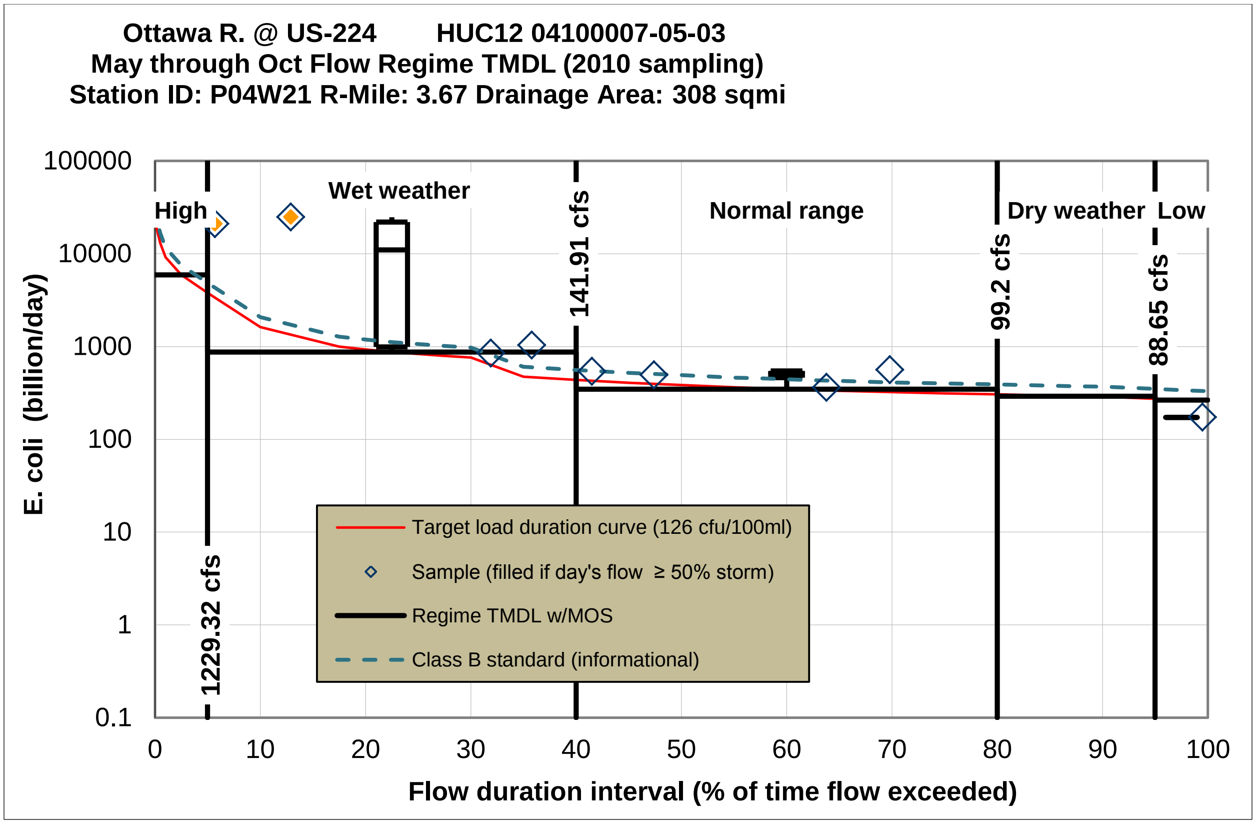

Figure D-38. *E. coli* load duration curve: Ottawa R. @ US-224.

Table D-29. *E. coli* TMDL table: Ottawa R. @ US-224.

TMDL and duration intervals	High 0-5%	Wet weather 5-40%	Normal range 40-80%	Dry weather 80-95%	Low 95-100%
Samples Per Regime	0	4	4	0	1
Median Sample load	N/A	11058	517.41	N/A	172.91
Total Load Reduction Required	No Data	**93.8%**	**47.5%**	No Data	N/A
Total Maximum Daily Load	5906.76	876.22	348.31	292.58	266.13
Margin of Safety: 20%*	1181.35	175.24	69.66	58.52	53.23
Allowance for future growth: 2%	118.14	17.52	6.97	5.85	5.32
Load Allocation	3414.12	197.29	61.06	30.96	10.35
Wasteload Allocation Total	1192.46	486.17	210.63	197.23	197.23
Lima MS4	749.59	43.31	13.40	0.00	0.00
County Line Invest. LLC 2PW00018	0.01	0.01	0.01	0.01	0.01
Ada WWTP 2PB00050	12.19	12.19	12.19	12.19	12.19
Colonial Golfer's Club 2PR00195	0.05	0.05	0.05	0.05	0.05
LaFayette WWTP 2PA00049	0.48	0.48	0.48	0.48	0.48
National Lime & Stone Co 2IJ00013	9.54	9.54	9.54	9.54	9.54
PCS Nitrogen 2IF00004	17.84	17.84	17.84	17.84	17.84
Lima Refinery 2IG00018	38.16	38.16	38.16	38.16	38.16
Lima WWTP 2PE00000	333.87	333.87	88.24	88.24	88.24
Shawnee #2 WWTP 2PK00002	9.54	9.54	9.54	9.54	9.54
Elida WWTP 2PB00046	2.38	2.38	2.38	2.38	2.38
American #2 WWTP 2PH00006	5.72	5.72	5.72	5.72	5.72
American Bath STP 2PH00007	7.15	7.15	7.15	7.15	7.15
National Lime & Stone Co Rimer 2IJ00053	4.77	4.77	4.77	4.77	4.77
Cridersville WWTP 2PB00048	4.88	4.88	4.88	4.88	4.88

Values were adjusted for rounding.

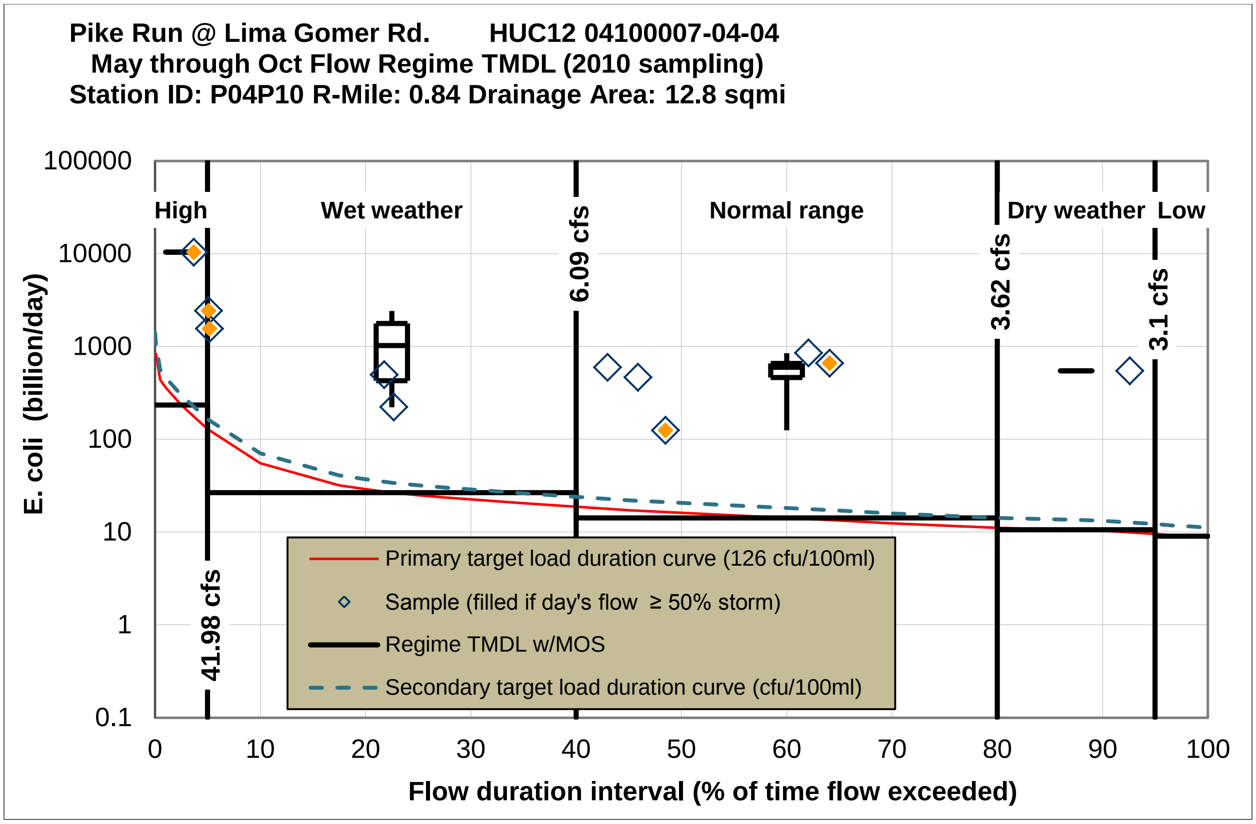

Figure D-39. *E. coli* load duration curve Pike Run @ Lima-Gomer Rd.

Table D-30. *E. coli* TMDL table Pike Run @ Lima-Gomer Rd.

TMDL and duration intervals	High 0-5%	Wet weather 5-40%	Normal range 40-80%	Dry weather 80-95%	Low 95-100%
Samples Per Regime	1	4	5	1	0
Median Sample load	10398	1026	597.41	547.61	N/A
Total Load Reduction Required	98.2%	98.0%	98.1%	98.5%	No Data
Total Maximum Daily Load	234.75	26.70	14.24	10.60	9.06
Margin of Safety: 20%*	46.95	5.34	2.85	2.12	0.91
Allowance for future growth: 2%	4.69	0.53	0.28	0.21	0.18
Load Allocation	121.40	9.43	2.73	1.12	0.82
Wasteload Allocation Total	61.70	11.39	8.38	7.15	7.15
Lima MS4	54.54	4.24	1.23	0.00	0.00
American Bath STP 2PH00007	7.15	7.15	7.15	7.15	7.15

Values were adjusted for rounding.

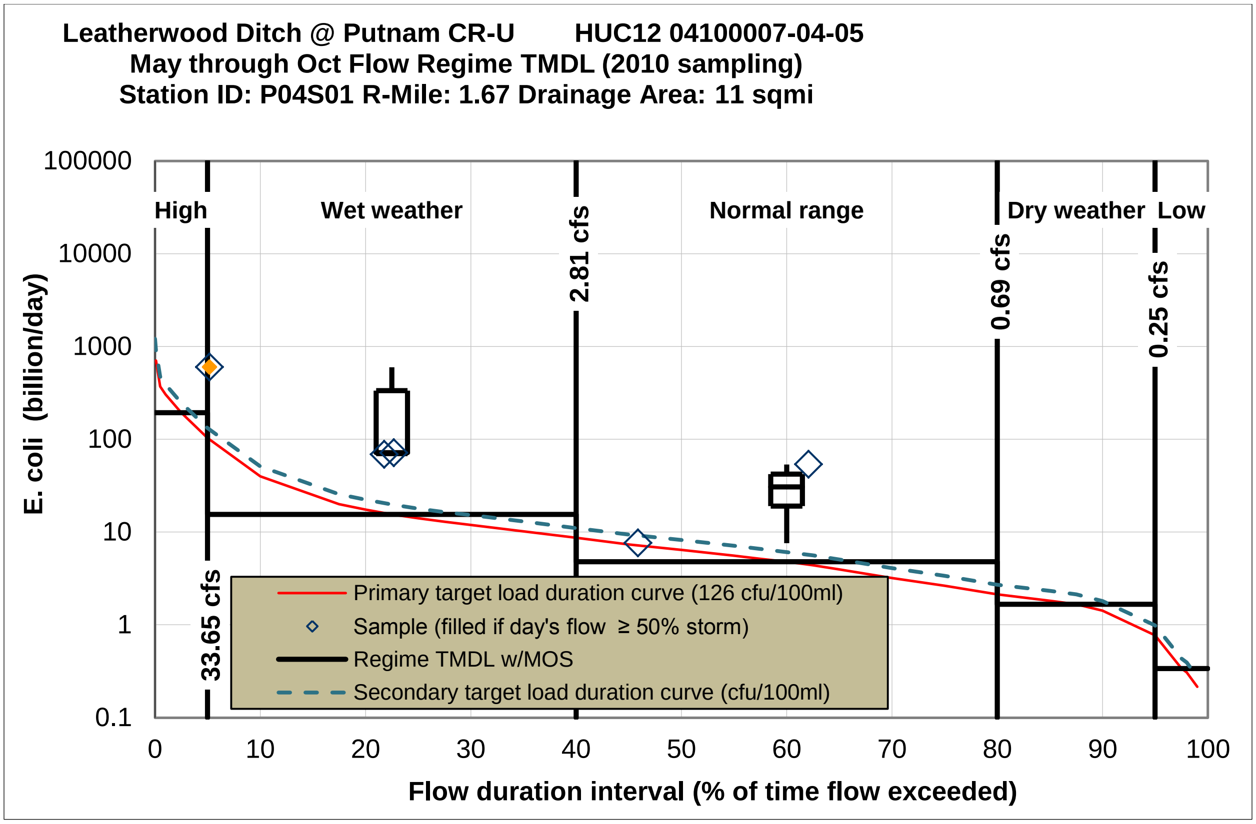

Figure D-40. *E. coli* load duration curve: Leatherwood Ditch @ Putnam CR-U.

Table D-31. *E. coli* TMDL table: Leatherwood Ditch @ Putnam CR-U.

TMDL and duration intervals	High 0-5%	Wet weather 5-40%	Normal range 40-80%	Dry weather 80-95%	Low 95-100%
Samples Per Regime	0	3	2	0	0
Median Sample load	N/A	72	30.60	N/A	N/A
Total Load Reduction Required	No Data	**83.1%**	**87.8%**	No Data	No Data
Total Maximum Daily Load	194.21	15.48	4.78	1.66	0.34
Margin of Safety: 20%	38.84	3.10	0.96	0.33	0.07
Allowance for future growth: 2%	3.88	0.31	0.10	0.03	0.01
Load Allocation	151.48	12.07	3.73	1.30	0.26
Wasteload Allocation Total	0.00	0.00	0.00	0.00	0.00

Values were adjusted for rounding.

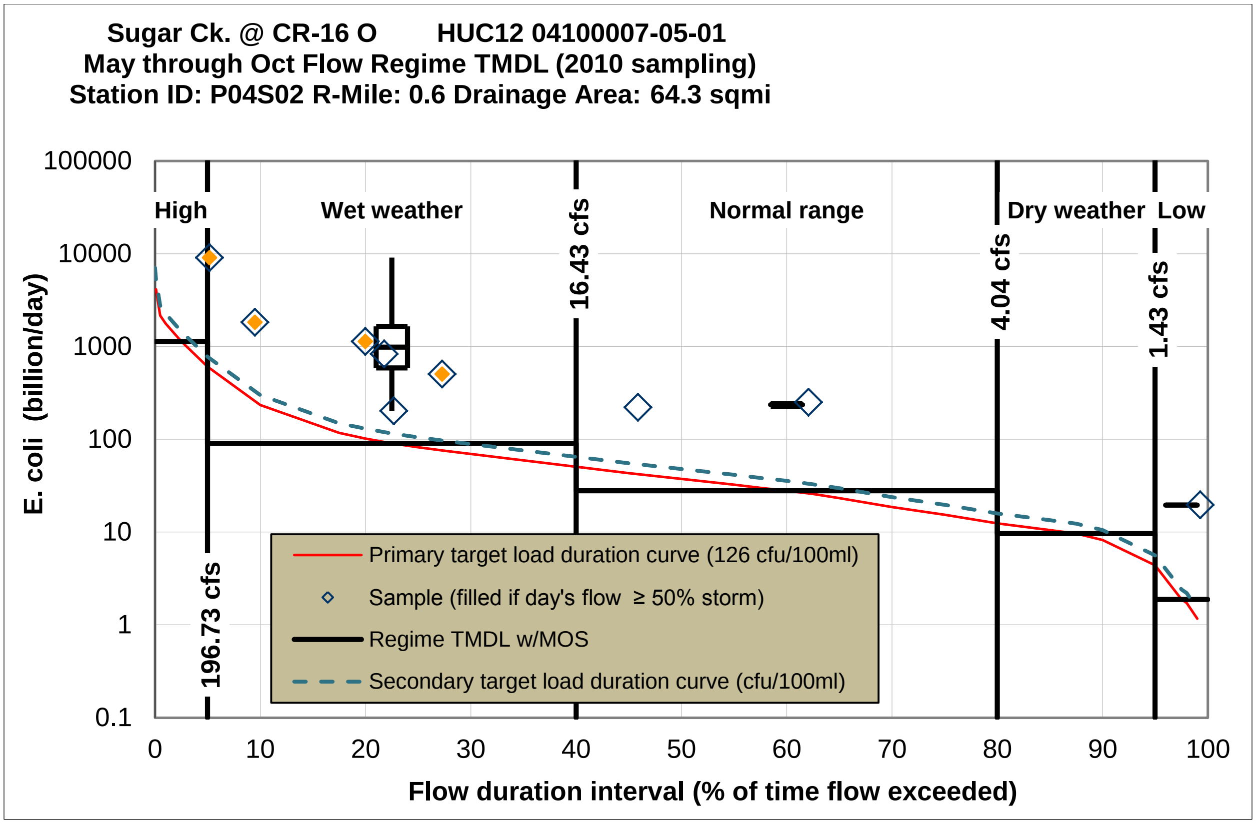

Figure D-41. ***E. coli*** **load duration curve: Sugar Creek @ CR-O.**

Table D-32. ***E. coli*** **TMDL table: Sugar Creek @ CR-O.**

TMDL and duration intervals	High 0-5%	Wet weather 5-40%	Normal range 40-80%	Dry weather 80-95%	Low 95-100%
Samples Per Regime	0	6	2	0	1
Median Sample load	N/A	982	235.36	N/A	19.60
Total Load Reduction Required	No Data	**92.8%**	**90.8%**	No Data	**91.6%**
Total Maximum Daily Load	1135.60	90.45	27.90	9.62	1.88
Margin of Safety: 20%	227.12	18.09	5.58	1.92	0.38
Allowance for future growth: 2%	22.71	1.81	0.56	0.19	0.04
Load Allocation	868.05	69.14	21.33	7.50	1.46
Wasteload Allocation Total	17.72	1.41	0.44	0.00	0.00
Lima MS4	17.72	1.41	0.44	0.00	0.00

Values were adjusted for rounding.

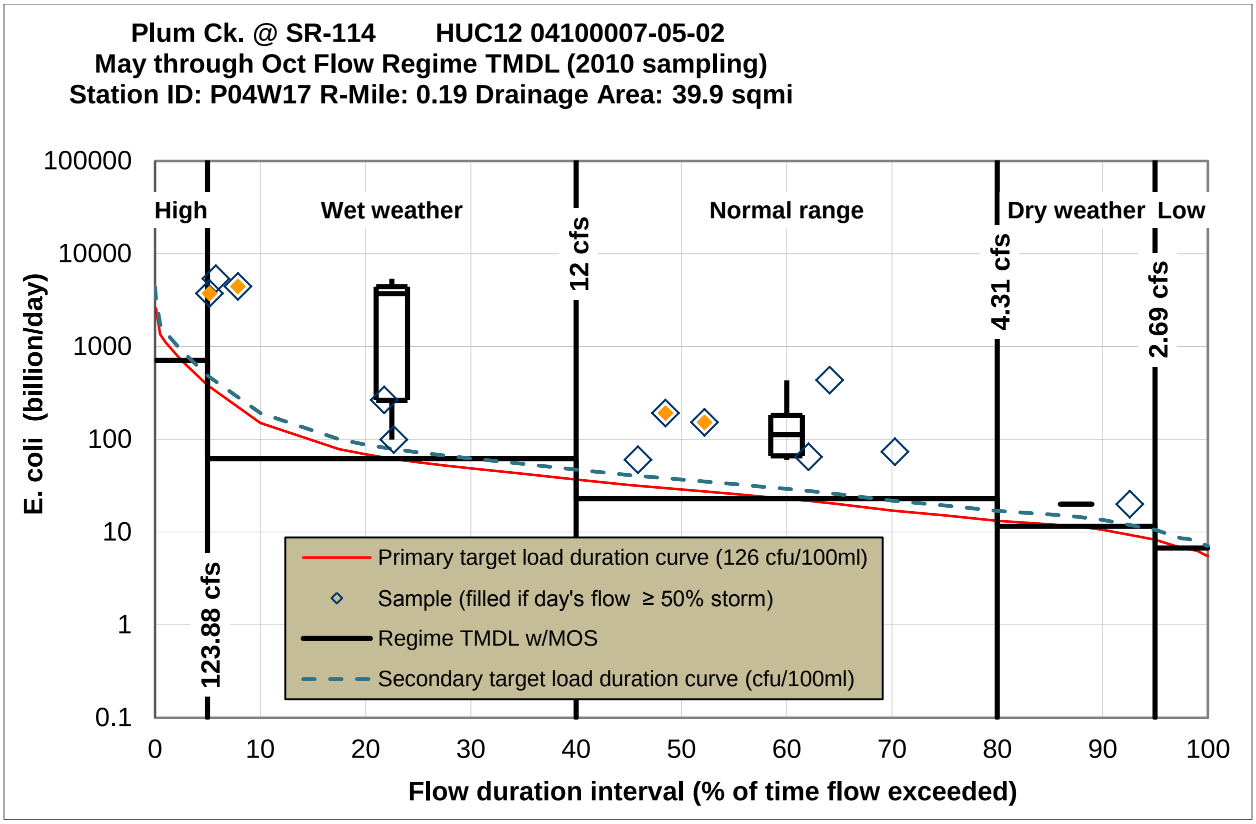

Figure D-42. *E. coli* load duration curve: Plum Creek @ SR-114.

Table D-33. *E. coli* TMDL table: Plum Creek @ SR-114.

TMDL and duration intervals	High 0-5%	Wet weather 5-40%	Normal range 40-80%	Dry weather 80-95%	Low 95-100%
Samples Per Regime	0	5	6	1	0
Median Sample load	N/A	3720	112.33	19.99	N/A
Total Load Reduction Required	No Data	**98.7%**	**84.1%**	**55.0%**	No Data
Total Maximum Daily Load	710.22	61.68	22.87	11.53	6.72
Margin of Safety: 20%*	142.04	12.34	4.57	2.31	0.67
Allowance for future growth: 2%	14.20	1.23	0.46	0.23	0.13
Load Allocation	549.68	43.82	13.55	4.70	1.62
Wasteload Allocation Total	4.29	4.29	4.29	4.29	4.29
Columbus Grove WWTP 2PC00004	3.91	3.91	3.91	3.91	3.91
Cairo Sulfur Products 2IF00008	0.38	0.38	0.38	0.38	0.38

Values were adjusted for rounding.
*10% in Low flow regime

D5 Implementation Phases

Causes of impairment in the Ottawa River are numerous. These causes clearly act together to stress the aquatic life in the stream. Meeting biological water quality standards in the impaired section (RM 28.9 – 43.4) of the Ottawa River will require a major commitment from local stakeholders. Several modeling techniques are used to determine TMDLs for different pollutants that are identified as stressors to the stream system. These modeling techniques are not interactive and several focus on a specific critical condition (*i.e.*, QUAL2K nutrients and CSO model). The interactions between these conditions are difficult to represent in a model; therefore, it is not known exactly how changes in one critical condition will affect the aquatic life in a different critical condition. One of the most plaguing stressors in the system is nutrient enrichment, which is exacerbated at low flows when point sources have the ability to dominate the system. Modeling results predict that to meet nutrient water quality targets substantial measures would have to be taken to reduce point source loads of phosphorus.

However when considering nutrient targets Ohio EPA has issued guidance (2000) for how flexibility in nutrient targets can be addressed:

> *"Intermediate nutrient targets are available to complement the biological criteria and to help evaluate the impact of nutrient loadings. These target concentrations are identified in a technical report (Ohio EPA 1999). The values in the technical report represent 'no affect or no impact' based concentrations that have been associated with measured biological criteria and aquatic life use attainment. In most situations, higher concentrations can reasonably be expected to carry an increasing risk of impaired biological communities and failure to attain the respective aquatic life use. However, the values in the technical report are only suggested guidelines, and a variety of factors must be considered in selecting a specific nutrient target used in the TMDL process. These factors include:*
>
> > <u>*Some waters attain aquatic life criteria at higher concentrations*</u> *– this fact is evident in the technical report (Ohio EPA 1999) and requires that a variety of physical and hydrological factors be evaluated on a case-by-case basis prior to setting a target level.*
> >
> > <u>*Location of project with respect to ecoregion*</u> *– consult the technical report (Ohio EPA 1999) and assess if higher or lower targets may be appropriate.*
> >
> > <u>*Stream habitat condition*</u> *– unusually low or high physical habitat quality will influence nutrient impacts on aquatic life; adjust the targets accordingly.*
> >
> > <u>*Streamflow conditions*</u> *– impairment of the aquatic life use caused by nutrients is exacerbated on wastewater effluent dominated streams (high percentage of wastewater during low flow periods).*
>
> *Because the values in the technical report are initial target concentrations only and are not codified in regulations, there is a certain degree of flexibility as to how they can be used in a TMDL setting. A TMDL must be flexible in its consideration of load reduction, habitat improvements, the degree of wastewater effluent flow predominance, and other features that determine attainment of biological criteria. As provided in paragraph (E) of rule 3745-2-12, TMDL nutrient targets may allow for a phased reduction towards the selected target in recognition of such factors as habitat restoration efforts, technical feasibility, treatment costs,*

> *and the possibility of achieving aquatic life use attainment at concentrations in excess of the target value."*

In the Ottawa River, flexibility will be exercised. The possibility of the stream supporting its designated aquatic life use at higher nutrient levels is supported by the reach immediately downstream from the modeled reach. In this reach nutrient levels remain elevated but aquatic life is in full attainment of its designated use. Interactions between causes of impairment are also not readily represented in the modeling techniques used to develop TMDLs. Therefore, implementation phases are proposed where all causes are gradually mitigated until biological life attainment is observed. If biological attainment is achieved before the final implementation phase, the nutrient TMDL can be recalculated. Allocations will be adjusted to represent the condition where biological life standards are achieved in the stream. If biological life standards are achieved before complete implementation of the CSO LTCP, the TMDL will not be recalculated because impairments are not only linked to biological life, but also to recreation use.

The QUAL2K model was used to present the predicted impacts on in-stream water quality. Certain variables can be adjusted in the model representing different phases of implementation. The two that were focused on are removal of lowhead dams and different discharge concentrations for point source discharges. One option that is not going to be looked at as a variable is CSO discharges. These scenarios are built on the assumption that CSO impact is difficult to predict and mitigation of CSOs are a large part of what is needed to achieve attainment in the river. CSOs do not directly impact the stream at the same critical condition that is used to assess nutrient loads, meaning CSOs do not discharge during the 7Q10 low flow critical condition; however, their impacts do linger as increased sediment oxygen demand. The QUAL2K model does not adequately address these impacts, which limits its effectiveness and encourages a flexible implementation approach.

Implementation Phases

Phases are chosen based on the potential of improving water quality of the Ottawa River by taking phases that methodically reduce pollutant loads or other stresses. The QUAL2K model was used to demonstrate the impact each phase will have on nutrient enrichment in the Ottawa River.

Phase 1:
In this phase it is expected that the CSO long term control plan (LTCP) will have been adopted for the city of Lima and resulting compliance schedules are met. The Lima WWTP is the only major discharger in the modeled reach that currently has a permit limit for total phosphorus. The first phase recommends the institution of a regulatory framework to limit the discharge of phosphorus to the Ottawa River. All major dischargers to the Ottawa River receive a wasteload allocation that is equal to the facilities' design (municipal WWTP) or average (industrial) flows and a concentration of 1.0 mg/l total phosphorus. A minor reduction from existing loads during critical condition is expected in this phase because PCS Nitrogen will reduce its total phosphorus permit limit to 1.0 mg/l from an average discharge of 1.5 mg/l.

Phase 2:
The second phase assumes that the Ottawa River is still impaired by nutrients after the implementation of the first phase and with progression of the LTCP implementation. In this phase the point source discharges of phosphorus will be further limited at two facilities if attainment of biological criteria has not been documented. If the discharger currently has the

potential to discharge at or above 1.0 mg/l at low flows, the limit in this phase stays at 1.0 mg/l total phosphorus. If the point source has the potential with current technology to discharge at levels below 1.0 mg/l total phosphorus, the wasteload allocation is limited to that value. Nutrients as addressed by the TMDL are treated as chronic pollutants (not acutely toxic) and limits are proposed as chronic pollutant limits (Table D-34).

Table D-34. Proposed total phosphorus limits for major NPDES facilities for the second implementation phase via the QUAL2K model.

Facility	Design Flow (MGD)	Total Phosphorus Concentration (mg/l)
Lima WWTP (2PE00000)	18.50	0.500
Lima Refinery (2IG00001)	5.49	0.700
PCS Nitrogen (2IF00004)	3.74	1.000
Shawnee #2 WWTP (2PK00002)	2.00	1.000

Also, while not a traditional pollutant, a study shows lowhead dams have a major impact on the stream environment (Santucci *et al.* 2005). The study identifies how physical channel alteration affects certain aquatic species disproportionately. The result is algal growth that is unchecked by typical macroinvertebrate grazing, which fuels the food chain for insectivorous fishes. The result is the effects of nutrient enrichment being exacerbated in dam pools. Reaches of the river impacted by the lowhead dams are also indicated as being impacted by nutrient enrichment. Dam removal causes two changes that reduce the impact of nutrients at low flows:

1) Nutrient retention from flow regimes outside the critical condition is reduced.
2) Reduction in travel time through the reach decreases production of phytoplankton in the reach.

Based on these observations two dams are recommended to be removed in the second implementation phase to reduce the impact of nutrient impairment in the Ottawa River. The two dams that are recommended to be removed are the Fetter Road dam and the Erie Railroad (RR) dam near the Lima WWTP. The Erie RR dam is thought to be interactive with the City's CSOs by exacerbating their impacts during the low flow critical condition. Additional stress would be alleviated on certain parts of the aquatic community because lotic conditions will be restored in the old dam impoundment.

Phase 3:

The nature of a LTCP for mitigating CSO impacts to a stream is that the implementation takes place in multiple phases over an extended timeframe. Biology will again be reassessed and impacts associated with the CSOs should be reduced. At this point the impact of nutrient enrichment in the low flow critical condition should become more pronounced. If nutrient impacts to aquatic life are still determined to be a cause of impairment downstream from point sources, it will be necessary to take steps to reduce the nutrient loads from the point sources. Generally Ohio EPA does not allocate loads to point sources based on effluent total phosphorus concentration of lower than 0.5 mg/l (Ohio EPA 2000). However, case-by-case evaluation of loads can allow for lower limits, if necessary to alleviate nuisance conditions, justifying the next implementation phase. In the third implementation phase, the four major point sources are allocated based on effluent total phosphorus concentrations of 0.5 mg/l.

Also recommended with the phased approach to implementation is an additional dam removal. In this phase, the Baxter Street dam is recommended to be removed. The Baxter Street dam is again interactive with the CSO discharges in the city of Lima and its removal will add to water quality improvements upstream from the major point source discharges.

Phase 4:
The final implementation phase is intended for the situation in which, even after complete implementation of the LTCP for the city of Lima CSOs and a modest lowering of nutrient limits, biological life is still observed to be impaired in the Ottawa River by nutrient enrichment. The TMDL scenario where the water quality target is met is implemented. This scenario was developed earlier in the appendix but is again presented to show the progression of nutrient reduction to achieve biological life water quality standards.

Results

The implementation phases were developed into QUAL2K model runs that represent the potential impact the phase will have on nutrient concentrations in the Ottawa River. Potential impact is used because this is a worst-case loading scenario, where sources discharge at the level allocated to them. This is typically not the case as dischargers implement new technologies that keep them from exceeding a limit, leaving typical concentrations at some level below the limit. For example, the city of Lima WWTP currently has a limit of 1.0 mg/l for total phosphorus but has an average projected effluent quality of 0.511 mg/l, which is a conservative estimate of the 75th percentile of the discharge quality. Total phosphorus results from the QUAL2K model run are presented in Figure D-43 below.

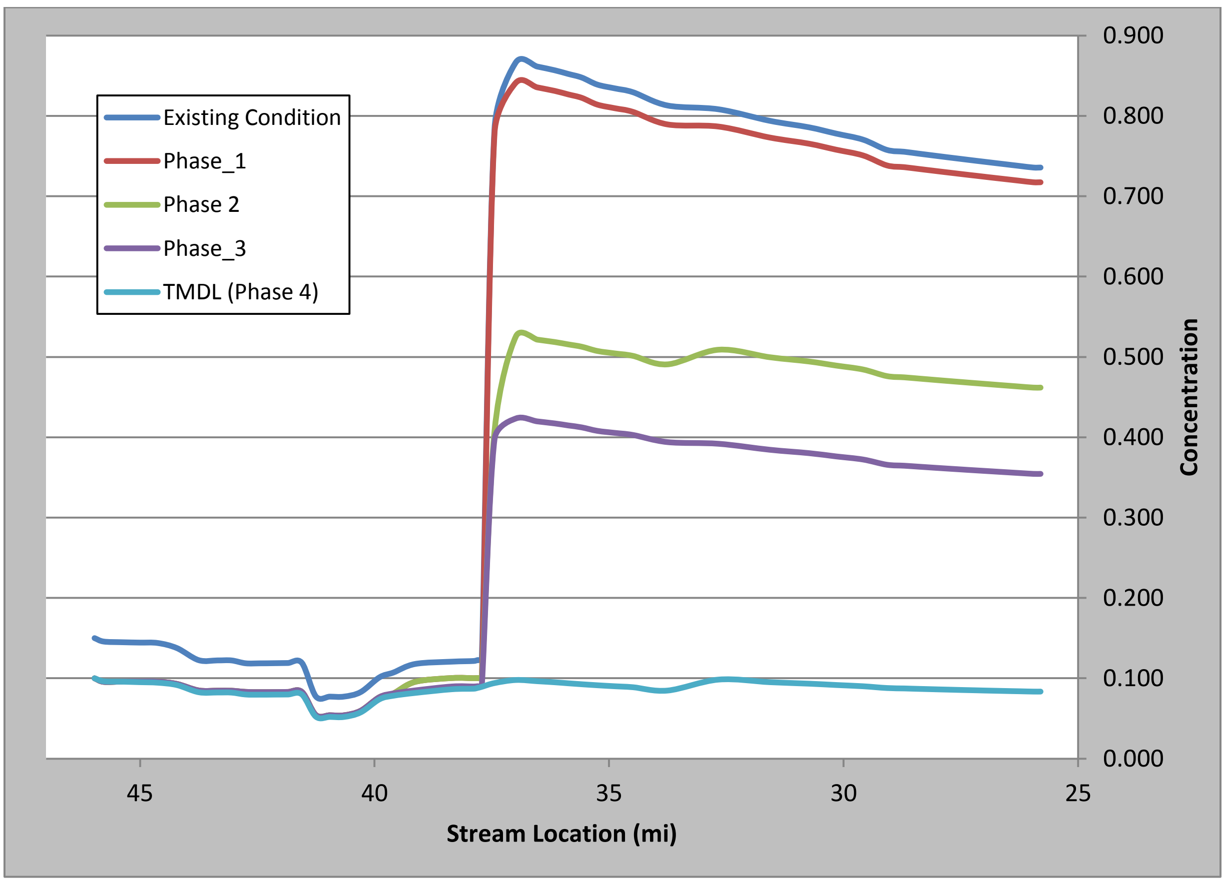

Figure D-43. Water column total phosphorus concentrations under different loading phases progressing toward TMDL implementation.

The figure shows how the permitted loads decrease the predicted water column total phosphorus concentrations with each successive implementation phase. It is proposed that the biology is assessed between each intermediate phase, having allowed time for the biology to recover, to determine when biological criteria are attained. These scenarios represent a critical condition for nutrient impairment when background flows provide limited dilution. Figure D-44 presents the loads allocated to each individual major point source for the proposed implementation phases. TMDL allocations from each implementation phase are summarized in Table D-35.

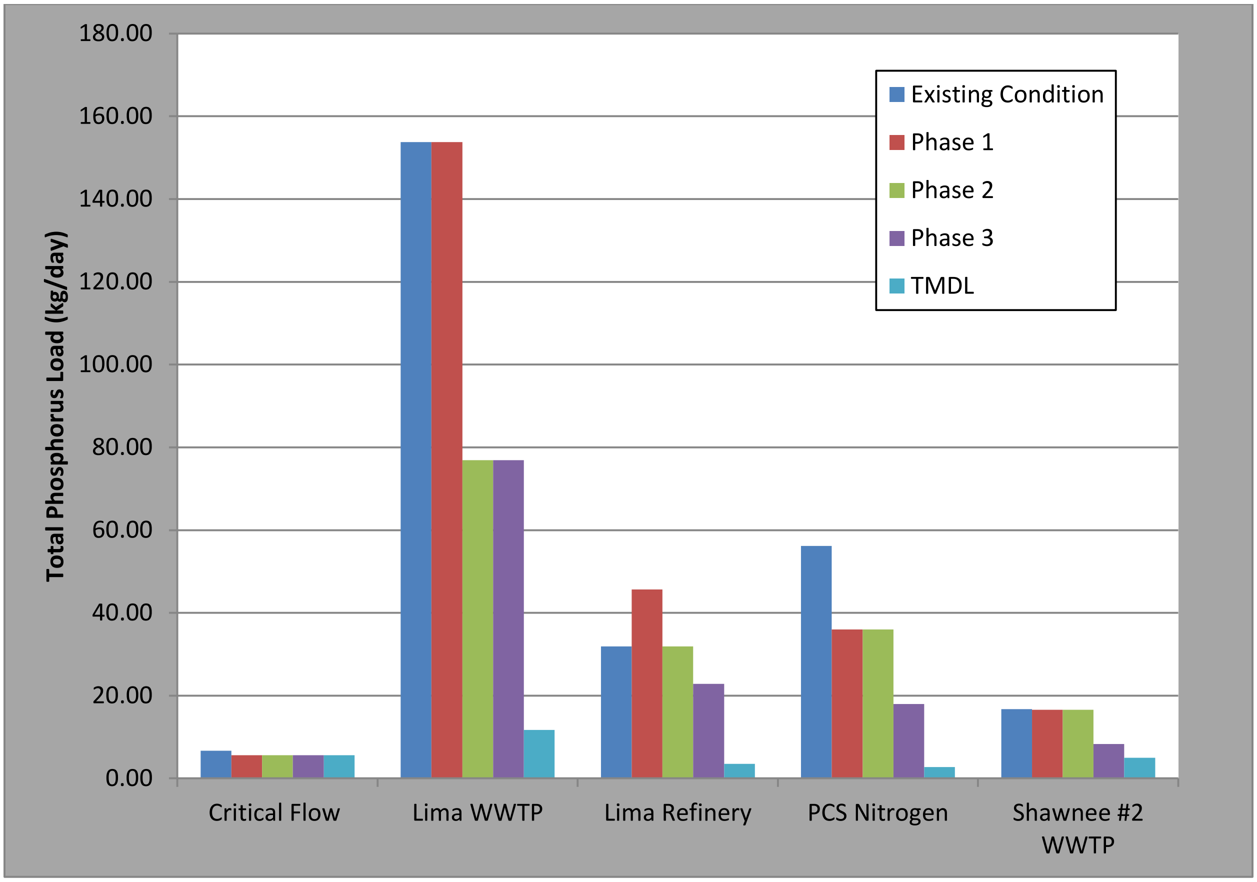

Figure D-44. Loads allocated to each individual major point source for the proposed implementation phases

Table D-35. Summary of allocations for Ottawa River from successive implementation phases.

	Conc. (mg/l)	**Yield** (kg/mi²/day)	**Load** (kg/day)	**Conc.** (mg/l)	**Yield** (kg/mi²/day)	**Load** (kg/day)
	Existing Load			**Phase 1**		
Load (nonpoint source)	-	0.000267	**0.04**	-	0.000267	**0.04**
Total Wasteload (point source)			**114.17**			**112.49**
2IJ00013 (Nat'l Lime & Stone)	0.015	-	0.11	0.015	-	0.11
2PE00000 (Lima WWTP)	1.0	-	69.93	1.0	-	69.93
2IG00001 (Lima Refining Co.)	0.699	-	14.51	1.0	-	20.75
2IF00004 (PCS Nitrogen)	1.556	-	22.00	1.0	-	14.14
2PK00002 (Shawnee #2 WWTP)	1.008	-	7.62	1.0	-	7.56
Margin of Safety[1] =	-	-	**-**	-	-	-
Allowance for future growth[2]	-	-	**-**	-	-	-
TMDL = LA+WLA+MOS+AFG			80.01			72.09
	Phase 2			**Phase 3**		
Load (nonpoint source)	-	0.000267	**0.04**	-	0.000267	**0.04**
Total Wasteload (point source)			**71.30**			**56.30**
2IJ00013 (Nat'l Lime & Stone)	0.015	-	0.11	0.015	-	0.11
2PE00000 (Lima WWTP)	0.5	-	34.97	0.5	-	34.97
2IG00001 (Lima Refining Co.)	0.7	-	14.53	0.5	-	10.38
2IF00004 (PCS Nitrogen)	1.0	-	14.14	0.5	-	7.07
2PK00002 (Shawnee #2 WWTP)	1.0	-	7.56	0.5	-	3.78
Margin of Safety[1]	-	-	**-**	-	-	**-**
Allowance for future growth[2]	-	-	**-**	-	-	**-**
TMDL = LA+WLA+MOS+AFG			56.34			13.93
	TMDL (Phase 4)					
Load (nonpoint source)	-	0.000267	0.04			
Total Wasteload (point source)			10.58			
2IJ00013 (Nat'l Lime & Stone)	0.015	-	0.11			
2PE00000 (Lima WWTP)	0.0762	-	5.33			
2IG00001 (Lima Refining Co.)	0.0762	-	1.58			
2IF00004 (PCS Nitrogen)	0.0762	-	1.25			
2PK00002 (Shawnee #2 WWTP)	0.305	-	2.31			
Margin of Safety[1]	-	-	3.03			
Allowance for future growth[2]	-	-	0.28			
TMDL = LA+WLA+MOS+AFG			13.93			

[1] Margin of safety is not applied to implementation phases because loading is not based on a water quality target.

[2] Allowance for future growth not applied to implementation phases because loading is not based on a water quality target.

The loading phases outlined start by imposing universal total phosphorus limits at 1.0 mg/l, which reduces the existing load by 2.75%. Phase 2 limits two point sources based on the ability of the point source to meet the limit with current technology or with technology that was needed for Phase 1, which reduces the existing load by 37.27%. Phase 3 limits the four major point sources based on an effluent limit of 0.5 mg/l total phosphorus. This would reduce the existing load by 50.74%. The final phase when the TMDL is implemented reduces the existing load by 91.42%. These implementation phases will help to alleviate the burden of phosphorus load reductions while allowing other mitigation strategies to improve water quality. The result is that the implementation may not need to proceed to completion if biological criteria are met, in which case the TMDL can be recalculated.

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