State of Ohio
Environmental Protection Agency

Division of Surface Water

Total Maximum Daily Loads for the Stillwater River Watershed

The Stillwater River, downstream of Webster, Darke County

Final Report
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Ted Strickland, Governor
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Acknowledgments

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A large number of local stakeholders and volunteers were instrumental in completing the 2004 TMDL. Ohio EPA acknowledges the continuing importance of their work in this next phase of Stillwater River restoration.

Executive Summary

The Clean Water Act requires States to identify waters that do not meet water quality standards. The Ohio Environmental Protection Agency (Ohio EPA) identified the Stillwater River watershed as impaired, citing failure to meet water quality goals established for aquatic life and recreation beneficial uses. Ohio EPA completed a TMDL to address impairments of the aquatic life use in 2004. This report revisits the total phosphorus loading analysis in the 2004 TMDL.

Ohio EPA decided to recompile the 2004 Stillwater River TMDL watershed model to ensure an accurate model to support the Miami Conservancy District (MCD) nutrient trading program and to address concerns raised by some point source dischargers in the watershed. By incorporating a finer resolution, more sophisticated techniques and more robust data, the revised model is a more accurate representation of the watershed. Thus, it provides a more reliable tool for predicting how much pollution the watershed can handle and still maintain water quality standards.

The Stillwater River drains approximately 673 square miles in eastern Indiana and western Ohio, flowing into the Great Miami River at Dayton. Agriculture comprises over 80 percent of the landuse, and Darke County has the second highest concentration of animal feeding operations (AFOs) in Ohio.

The most pervasive problems facing streams in the basin is habitat destruction through channelization. Channelization is the removal of trees from stream banks coupled with deepening, and often straightening, the stream course. It is a direct cause of sedimentation, and greatly magnifies the effects of introduced nutrients. This latter problem is especially troublesome in the northern portion of the basin where large amounts of synthetic and organic fertilizers are applied to the land. The other pervasive problem in the watershed is organic and nutrient enrichment, primarily from land-applied animal manure and secondarily from failing septic systems and municipal wastewater treatment works.

In the new analysis, total phosphorus loads are lower for four point sources and higher for one. Permit limits for total phosphorus are no longer recommended for five communities. A few small communities will be encouraged to connect to larger wastewater systems, and these larger wastewater systems will be encouraged to allow the connection. Several specific areas need to eliminate or repair home sewage treatment systems. Among non-point sources, the TMDL results suggest that the farm community is most responsible for phosphorus reductions given the high loads of organic (manure) and synthetic fertilizer applied to the watershed.

The following recommendations are suggested to affect full recovery of aquatic life uses:

- Establish comprehensive nutrient management plans for all animal feeding operations
- Encourage the use of best demonstrated technologies for managing animal waste through cost sharing and other incentive programs
- Increase the number and width of vegetated filter strips on maintained ditches through cost sharing and other incentive programs
- Increase the number of agricultural acres in no-till or conservation tillage through cost sharing and other incentive programs
- Restore stream habitat in agricultural areas
- Establish a Darke County Sewer District.

1.0 Introduction

The Clean Water Act (CWA) Section 303(d) requires States, Territories, and authorized Tribes to list and prioritize waters for which technology-based limits alone do not ensure attainment of water quality standards. Lists of these waters (the section 303(d) lists) are made available to the public and submitted to the U.S. Environmental Protection Agency (USEPA) in every even-numbered year.

The Clean Water Act and USEPA regulations require that Total Maximum Daily Loads (TMDLs) be developed for all waters on the section 303(d) lists. In the simplest terms, a TMDL can be thought of as a cleanup plan for a watershed that is not meeting water quality standards. A TMDL is defined as a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards and an allocation of that quantity among the sources of the pollutant. Ultimately, the goal of Ohio's TMDL process is full attainment of Water Quality Standards (WQS), which would subsequently lead to the removal of the waterbodies from the 303(d) list.

The Ohio Environmental Protection Agency (Ohio EPA) identified the Stillwater River watershed as a priority impaired water on several 303(d) lists, citing impairments of the aquatic life and recreation beneficial uses. Ohio EPA completed a TMDL to address impairments of the aquatic life use in 2004 (Ohio EPA, 2004); the report was approved by U.S. EPA on June 15, 2004. TMDLs for the recreation use impairments have not been completed. This report revisits the loading analysis for total phosphorus completed for the 2004 TMDL report.

Table 1.1 summarizes the TMDL status of impairments identified in the Stillwater River watershed as reported in Ohio's 2008 303(d) list (Ohio EPA, 2008). Both the 2009 and 2004 reports cover the entire Stillwater River watershed, comprised of six watershed and one large river assessment units: 05080001 090, 100, 110, 120, 130, 140, and the mainstem of the Stillwater River (see Table 1.1 and Figure 1.1).

Based on the 1999 biological and water quality survey of the Stillwater River basin, the primary causes of impairment in the Stillwater River watershed are organic and nutrient enrichment, ammonia and habitat degradation. The Stillwater River mainstem is impaired only by an impoundment formed by a dam that is currently being removed.

TMDLs were calculated for organic/nutrient enrichment and habitat in 2004. The total phosphorus loads are recalculated in this report; the 2004 analyses for other impairments remain intact.

1.1 Why Revisit This TMDL?

Ohio EPA decided to recompile the Stillwater River TMDL watershed model to ensure as accurate a model as possible to support the Miami Conservancy District (MCD) nutrient trading program and to address concerns raised by some point source dischargers in the watershed. As part of the trading program, MCD has measured and compiled more than three years of data which provide additional "ground-truthing" for the simulation model and suggest that the 2004 version could be improved.

The 2009 version of the model incorporates several improvements, such as the following:

- Better resolution in the analysis because a finer watershed scale was used – this is analogous to "more pixels" in a photograph, which results in a clearer picture
- More sophisticated routing of sewage inputs within the model
- More robust calibration of the watershed hydrology and chemistry in the model
- More realistic manure application rates based on livestock inventory data.

Altogether, the revised model is a more accurate representation of the watershed, so it provides a more reliable tool for predicting how much pollution the watershed can handle and still maintain water quality standards. The differences in the 2004 and 2009 TMDL results are discussed in Section 4.5 and illustrated in Table 4.10 and Figures 4.3 and 4.4.

1.2 Change in Watershed Numbering System

In 2008, federal government agencies completed a project to redraw all hydrologic unit boundaries for Ohio according to a new coding method. This project was part of a nationwide initiative to develop a nationally consistent dataset of watershed coding numbers (the Watershed Boundary Dataset). The former coding method uses 11 digits and 14 digits, respectively, to describe larger and smaller watersheds. In the new method, 11-digit codes have been converted to 10-digit codes, and 14-digit codes have been converted to 12-digit codes. In addition, to make the size of the smaller watersheds more consistent across the state, some of the small hydrologic units were combined or split. To do this, each hydrologic unit boundary was meticulously examined and redrawn, if necessary, to follow ridge lines more closely.

Near the borders of the state of Ohio, the old codes were not consistent with neighboring states. Therefore, those hydrologic units were renumbered in some cases to better line up with neighboring states' hydrologic unit codes. Many hydrologic units were also renamed to standardize naming across the state.

The original Stillwater River TMDL and Ohio's 303(d) lists were completed using the old coding. The new analysis in this report and future Ohio 303(d) lists use the new coding. Thus, a way to bridge the conversion is needed. Table 1.2 shows the old 11- and 14-digit codes and names as well as the new 10- and 12-digit codes and names.

1.3 Public Involvement

Public involvement is key to the success of water restoration projects, including TMDL efforts. From the beginning, Ohio EPA has invited participation in all aspects of the TMDL program. The Ohio EPA convened an external advisory group in 1998 to assist the Agency with the development of the TMDL program in Ohio. The advisory group issued a report in July 2000 to the Director of Ohio EPA on their findings and recommendations. The Stillwater River watershed TMDL project was completed using the process endorsed by the advisory group.

The 2004 Stillwater River TMDL project was the culmination of an extensive outreach effort involving many local stakeholders and led by the Systemic Inquiry Group of The Ohio State

University's Ohio Agricultural Research and Development Center. Through the years, there has also been significant local activity to develop watershed restoration plans.

Table 1.1. Summary of causes of aquatic life use impairment (from 2008 303(d) list) and actions taken to address impairments for the Stillwater River watershed.

Assessment Unit	**Narrative Description**	**Causes of Impairment**	**Action Taken**
05080001 090	Stillwater R. (headwaters to above Swamp Creek) *Priority Points: 0*	Nutrients Organic enrichment/DO	2009 TMDL for total P; 2004 TMDL for others
		Direct habitat alteration	Analysis in 2004 TMDL (approved)
05080001 100	Stillwater R. (above Swamp Cr. to above Greenville Cr.) *Priority Points: 3*	Nutrients Organic enrichment/DO	2009 TMDL for total P; 2004 TMDL for others
		Siltation Direct habitat alteration	Analysis in 2004 TMDL (approved)
		Other inorganics	Not addressed
		Bacteria	Not addressed
05080001 110	Greenville Cr. (headwaters to below West Branch) *Priority Points: 3*	Organic enrichment/DO	2009 TMDL for total P; 2004 TMDL for others
		Direct habitat alteration	Analysis in 2004 TMDL (approved)
		Bacteria	Not addressed
05080001 120	Greenville Cr. (below W. Branch to Stillwater River) *Priority Points: 3*	Organic enrichment/DO	2009 TMDL for total P; 2004 TMDL for others
		Bacteria	Not addressed
05080001 130	Stillwater River (below Greenville Cr. to above Ludlow Cr.) *Priority Points: 3*	Organic enrichment/DO	2009 TMDL for total P; 2004 TMDL for others
		Direct habitat alteration	Analysis in 2004 TMDL (approved)
		Bacteria	Not addressed
05080001 140	Stillwater River (above Ludlow Cr. to Great Miami River) *Priority Points: 3*	Unionized ammonia	Not addressed
		Nutrients Organic enrichment/DO	2009 TMDL for total P; 2004 TMDL for others
		Direct habitat alteration	Analysis in 2004 TMDL (approved)
		Bacteria	Not addressed
05080001	Stillwater River mainstem *Priority Points: 0*	Direct habitat alteration Other flow regime alterations	Analysis in 2004 TMDL (approved)

Consistent with Ohio's current Continuous Planning Process (CPP), the draft TMDL report will be available for public comment from June 9 through July 10, 2010. A copy of the draft report was posted on Ohio EPA's web page (www.epa.state.oh.us/dsw/tmdl/index.html). A summary of the comments received and the associated responses is included in Appendix D.

Continued public involvement is critical to the success of any TMDL project. Ohio EPA will continue to support the implementation process and will facilitate, to the fullest extent possible, restoration actions that are acceptable to the communities and stakeholders in the study area and to Ohio EPA.

1.4 Organization of Report

This report is organized as follows:

- Section 1 provides context for this project relative to the Clean Water Act, Ohio's 303(d) list, and past TMDL work
- Section 2 describes the project area and is largely unchanged from the 2004 TMDL (changes shown in *italics*).
- Section 3 outlines the problem statement and is mostly unchanged from the 2004 TMDL (changes shown in *italics*).
- Section 4 describes the new analysis of the total phosphorus loading in the watershed.
- Section 5 discusses strategies to restore the Stillwater River watershed.
- Appendix A contains Tables 1.1 and 1.2 from the 2004 report, which could be useful in understanding the analysis in this report.
- Appendix B contains data collected in the Englewood dam area during 2008.
- Appendix C contains the details of the new loading analysis.
- Appendix D contains the comments received during the public review period and Ohio EPA's responses.

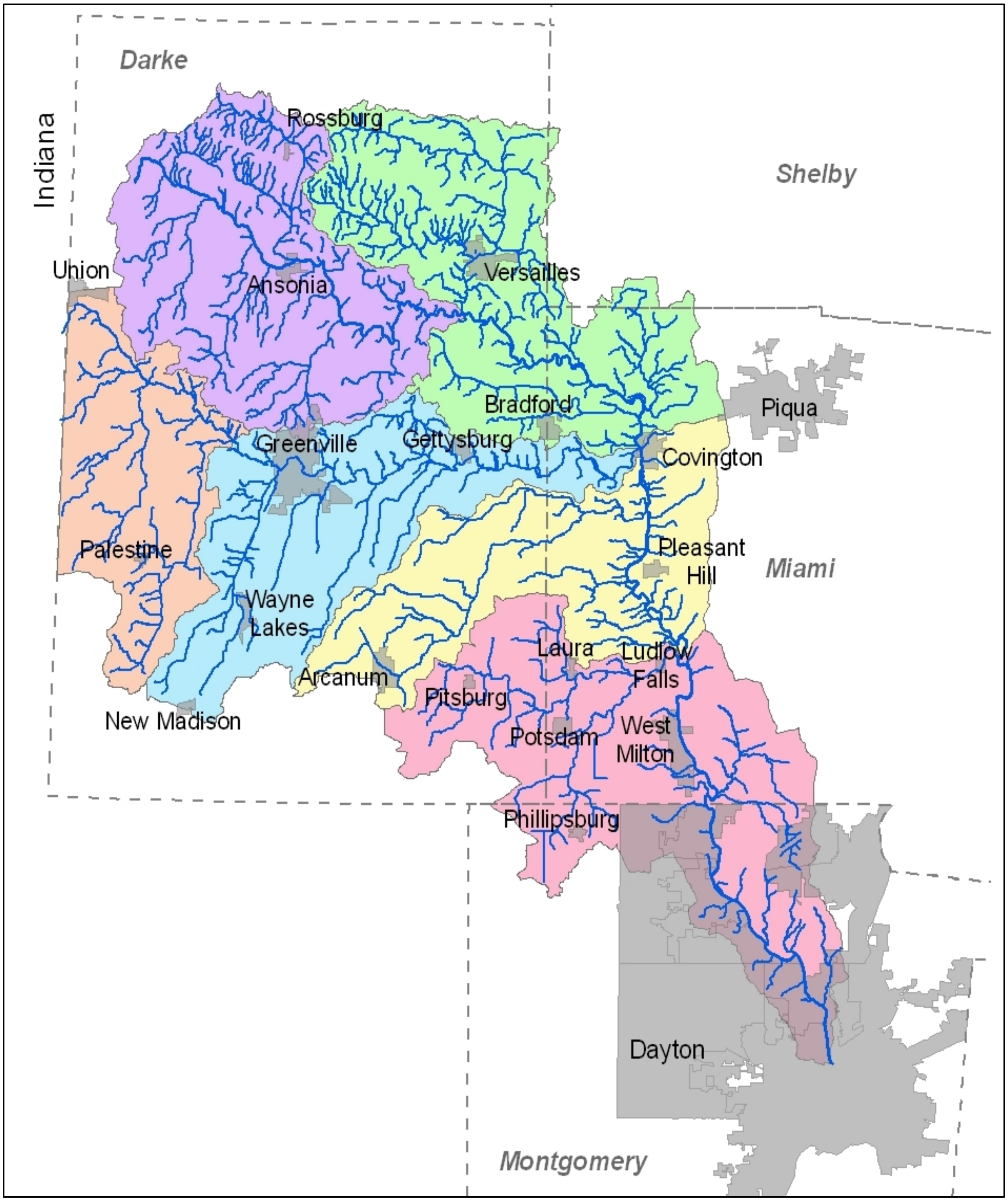

Figure 1.1. Stillwater River watershed in western Ohio.

Table 1.2. Crosswalk between Old and New Watershed Coding Numbers (Hydrologic Unit Code (HUC) numbers. The smaller (unshaded) watershed units are nested within the larger units (shaded).

Old Number	Old Name	New Number	New Name
05080001090	**Stillwater R. (headwaters to above Swamp Creek)**	**0508000109**	**Headwaters Stillwater River**
05080001090010	Stillwater River above S. Fk. Stillwater R.	050800010902	Headwaters Stillwater River
05080001090020	South Fork Stillwater River	050800010901	South Fork Stillwater River
05080001090030	Stillwater River below S. Fk. to above Woodington Run	050800010905	Woodington Run-Stillwater River
05080001090040	Woodington Run	050800010905	Woodington Run-Stillwater River
05080001090050	Stillwater River below Woodington Run to above above Boyd Cr. [except N. Fk. Stillwater R.]	050800010905	Woodington Run-Stillwater River
05080001090060	North Fork Stillwater River	050800010903	North Fork Stillwater River
05080001090070	Boyd Creek	050800010904	Boyd Creek
05080001090080	Stillwater River below Boyd Cr. to above Swamp Cr.	050800010906	Town of Beamsville-Stillwater River
05080001100	**Stillwater R. (above Swamp Cr. to above Greenville Cr.)**	**0508000112**	**Swamp Creek-Stillwater Creek**
05080001100010	Swamp Creek above Indian Cr.	050800011202	Swamp Creek
05080001100020	Indian Creek	050800011201	Indian Creek
05080001100030	Swamp Creek below Indian Cr. to Stillwater Cr.	050800011202	Swamp Creek
05080001100040	Stillwater Creek below Swamp Cr. to above Granville Cr. [except Trotters Cr. & Harris Cr.]	050800011205	Town of Covington-Stillwater River
05080001100050	Trotters Creek	050800011203	Trotters Creek
05080001100060	Harris Creek	050800011204	Harris Creek
05080001110	**Greenville Cr. (headwaters to below West Branch)**	**0508000110**	**Headwaters Greenville Creek**
05080001110010	Greenville Creek above Dismal Cr.	050800011004	Headwaters Greenville Creek
05080001110020	Dismal Creek	050800011001	Dismal Creek
05080001110030	Kraut Creek	050800011002	Kraut Creek
05080001110040	Greenville Creek below Dismal Cr. to above West Branch [except Kraut Cr.]	050800011004	Headwaters Greenville Creek
05080001110050	West Branch Greenville Creek	050800011003	West Branch Greenville Creek
05080001120	**Greenville Cr. (below W. Branch to Stillwater River)**	**0508000111**	**Mud Creek-Greenville Creek**
05080001120010	Greenville Creek below West Branch to above Bridge Cr. [except Mud Cr.]	050800011102	Bridge Creek-Greenville Creek
05080001120020	Mud Creek	050800011101	Mud Creek

Table 1.2. Crosswalk between Old and New Watershed Coding Numbers (Hydrologic Unit Code (HUC) numbers. The smaller (unshaded) watershed units are nested within the larger units (shaded).

Old Number	Old Name	New Number	New Name
05080001120030	Bridge Creek	050800011102	Bridge Creek-Greenville Creek
05080001120040	Greenville Creek below Bridge Cr. to Stillwater R. [except Dividing Branch]	050800011103	Dividing Branch-Greenville Creek
05080001120050	Dividing Branch	050800011103	Dividing Branch-Greenville Creek
05080001130	**Stillwater River (below Green-ville Cr. to above Ludlow Cr.)**	**0508000113**	**Painter Creek-Stillwater River**
05080001130010	Stillwater River below Greenville Cr. to above Painter Cr.	050800011303	Canyon Run-Stillwater River
05080001130020	Painter Creek [except L. Painter Cr.]	050800011302	Painter Creek
05080001130030	Little Painter Creek	050800011301	Little Painter Creek
05080001130040	Stillwater River below Painter Cr. to above Ludlow Cr.	050800011303	Canyon Run-Stillwater River
05080001140	**Stillwater River (above Ludlow Cr. to Great Miami River)**	**0508000114**	**Ludlow Creek-Stillwater River**
05080001140010	Ludlow Creek [except Hog Run & Brush Cr.]	050800011402	Ludlow Creek
05080001140020	Hog Run	050800011402	Ludlow Creek
05080001140030	Brush Creek	050800011401	Brush Creek
05080001140040	Stillwater River below Ludlow Cr. to above Brush Cr.	050800011404	Jones Run-Stillwater River
05080001140050	Brush Creek	050800011403	Brush Creek
05080001140060	Stillwater River below Brush Cr. to Englewood Retarding Structure	050800011405	Mill Creek-Stillwater River
05080001140070	Stillwater River below Englewood Retarding Struc. to G. Miami R.	050800011406	Town of Irvington-Stillwater River

2.0 Study Area Description

Ohio EPA completed a comprehensive biological, chemical, and physical assessment of the water quality conditions in the Stillwater River watershed in 1999. This assessment formed the basis for the 2004 TMDL. In 2008, Ohio EPA returned to the Stillwater River to assess the current conditions around the Englewood dam, prior to its removal. The text in this chapter is from the 2004 TMDL; the 2008 assessment is described in Appendix B. Changes from the 2004 report are shown in italics.

The Stillwater River flows 67 miles from its headwaters in Indiana and northern Darke County to a confluence with the Great Miami River in Dayton (Figure 2.1). The Stillwater River flows in a generally eastward direction through Darke County into western Miami County where it turns southward to Montgomery County. Major tributaries include: Greenville Creek, Ludlow Creek, Painter Creek, Swamp Creek and North Fork Stillwater River. The watershed covers approximately 673 square miles with about 32 square miles in Randolph County Indiana, and is drained by 280 miles of streams, but many of those stream miles have been physically modified to maintain drainage for row crop agriculture. Historically, almost one-third of the watershed may have been wetlands, but tile drainage and stream channelization have reduced this to one-half of one percent. Agriculture composes over 80 percent of the landuse, and Darke County has the second highest concentration of animal feeding operations (AFOs) in Ohio.

The topography of the Stillwater River watershed has been influenced by glaciation which left distinctive land forms and thick deposits of silt, sand, and gravel. This aquifer was designated as a Sole Source Aquifer by U.S. EPA. Designation requires extra review for any federally funded projects proposed for the surface above the aquifer. The watershed lies completely with in the Eastern Cornbelt Plains ecoregion which is characterized by level to gently sloping land and relatively low gradient streams. Most of the upland area is covered with a glacial drift of varying thicknesses over limestone bedrock. Downstream from the village of West Milton the valley narrows and deepens until reaching the Englewood Dam. The limestone bedrock is closer to the surface in this area and becomes the anchor for the dam at either end. This lower part of the river downstream from West Milton lies above a highly productive sand and gravel aquifer which is the water supply for three-fourths of the watershed's population of 66,266. Smaller pockets of sand and gravel aquifers are found in isolated areas of the watershed. These aquifers do not reflect current surface water flow patterns but are apparently part of an ancient river system known as the Teays River which was eliminated by glaciation. Soils tend to be poorly drained due to high clay content especially in the upland areas.

The concentration of livestock/poultry operations (218 in 1997) in the watershed produces more than 121,258 tons of solid manure annually. Based on the number of various animal types inventoried in the watershed, this waste produces about 2220 tons N/yr, 1665 tons P_2O_5/yr, and 1480 tons K_2O/yr, with a total annual value of \$2.5 million. With a P_2O_5, application rate of 60 lbs./acre, nearly 150,000 acres are needed to utilize the yearly phosphorus production. Although twice this much cropland exists in the watershed, considerations of time of year, crop type, distance to streams and dwellings, availability of non-owned land for spreading, and hauling distance from the livestock/poultry facility, all combine to reduce the actual amount of useable acreage. The 121,258 tons, moreover, only account for the solid portion of the manure. When the liquid portion is added to the manure total, the figure increases to nearly 277,500 tons yearly. For the watershed as a whole, this amounts to 757 tons of manure per square mile, with individual drainage areas ranging from as little as 63 tons/mi^2 to more than 1250 tons/mile^2. This amounts to an average of about 222 gallons of manure per acre per year.

2.1 Biological and Water Quality Summary

Biological and water quality conditions vary widely in the Stillwater River basin from the best of the best to the worst of the worst measured within Ohio (Table 2.1). The stream segments with the highest biological and water quality are the lower Stillwater River mainstem from Covington to the confluence with the Great Miami River, and Greenville Creek and its tributaries originating from the Farmersville Moraine. The reason the lower Stillwater River is in such good condition is because the riparian forest is intact, development within the adjacent flood plain is largely agricultural and the agriculture practiced there employs conservation measures. The Stillwater River has the largest population of river redhorse in Ohio. River redhorse are listed as Special Interest on the Ohio Division of Wildlife Endangered Species list because of their comparative rarity and declining abundance in Ohio. Water quality and reasonably intact biological communities are maintained in Greenville Creek and its tributaries by groundwater-augmented baseflow.

The stream segments having the poorest water quality and the most degraded biological communities are, in order of severity of impairment, Painter Creek, the North Fork Stillwater, Swamp Creek, Indian Creek, the Stillwater River mainstem upstream from Ansonia, Ballinger Run, and Mill Creek. Painter Creek is degraded by Arcanum's failed sewage collection and treatment system. Swamp Creek, the North Fork Stillwater and the Stillwater mainstem are impacted by habitat destruction and organic enrichment from land-applied manure, Indian Creek from the preceding factors plus failing septic systems, Ballinger Run by organic enrichment from combined sewer overflows (CSOs) and Mill Creek from deicing chemicals used at the Dayton-Cox International Airport.

The most pervasive problem facing streams in the basin is habitat destruction through channelization. Almost the entire stream network in Darke County has previously been channelized. Channelization is the removal of trees from stream banks coupled with deepening, and often straightening, the stream course. Channelization always results in long-term aquatic life use impairment, especially for sport fishing, is a direct cause of sedimentation and greatly magnifies the effects of introduced nutrients. This latter problem is especially troublesome in the northern portion of the basin where large amounts of manure are applied to the land. Because the streams are maintained in a channelized state with little or no riparian buffer, organic matter and nutrients are able to enter unimpeded during storm events. The absence of a shading riparian canopy allows full sunlight to reach the stream and cause algal blooms. The algal blooms then result, either through decomposition or respiration, in dissolved oxygen depletion to below levels needed to sustain higher aquatic life. Further complicating matters is the loss or diminution of sustained stream flow in channelized headwaters, especially those less than 10 mi^2, as the whole point of channelization is to expedite drainage. The upshot being, from a pollution loadings standpoint, that less flow for a given drainage area means less assimilative capacity.

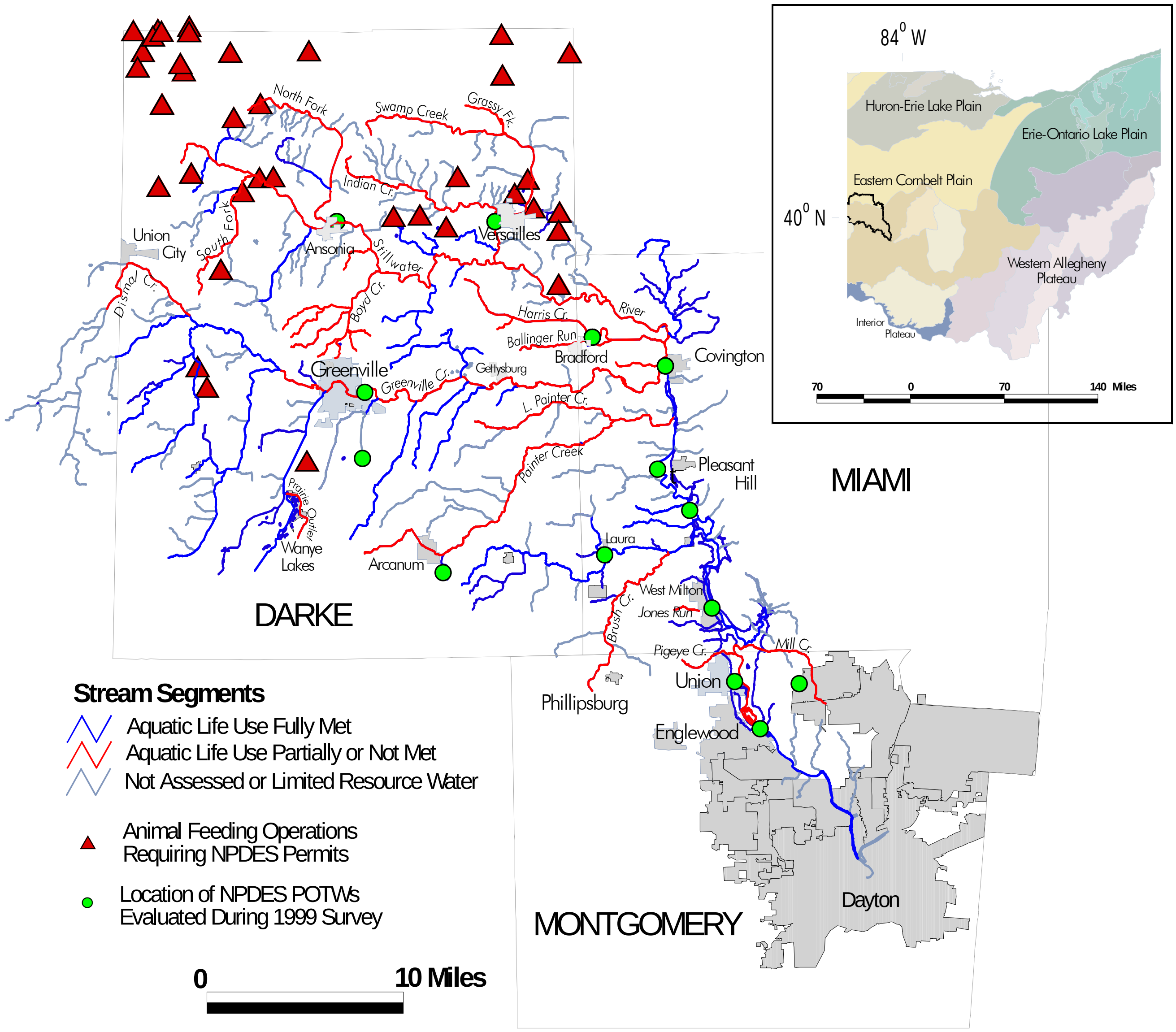

Figure 2.1 - Geographic location of the Stillwater River watershed in Ohio, principal cities within the watershed, and waterbody segments with impaired aquatic life uses in relation to NPDES permitted facilities

The other pervasive problem facing the basin, as mentioned in the previous paragraph, is organic enrichment. Organic enrichment in the Stillwater basin comes primarily from land-applied animal manure and failing septic systems. That organic enrichment is a problem in the basin was evidenced by biological and water quality results (*e.g.*, high fecal coliform bacteria and *E. coli* counts, high biochemical oxygen demand, wide diel oxygen swings, poor to very poor biological scores, and fish kills occurring in streams with sustained flow). Although channelized streams are expected to have less biological and water quality integrity compared to natural streams, channelized streams are expected to be free from nuisance conditions (*e.g.*, mats of decaying algae), safe for recreational contact (*i.e.*, fecal matter should not be present), and should have sufficient water quality to harbor aquatic life. Swamp Creek and its tributaries, the North Fork, and the Stillwater River upstream from Ansonia were similarly impacted from excess organic enrichment from land-applied manure. Failing septic systems caused noticeable water quality impacts and biological impairment in Indian Creek, Greenville Creek downstream from Gettysburg, the Wayne Lakes area, and to Ludlow Creek or its tributaries near Phillipsburg and Pittsburgh.

The existing problems should not, however, overshadow successes. Most of the point source problems along the Stillwater mainstem have been abated and considerable recovery has occurred since 1982 (see Figure 2.1 for locations). Now, the existing threat from point sources is that population growth will over-run treatment capacity. *See Table 2.2 for performance at time of monitoring. Table 4.7 contains updated information used in the 2009 modeling and offers additional insight on actual flows versus design flows for individual facilities.*

The other area of success has been in the implementation of agricultural best management practices. Conversion of farmed acres to no-till, filter strips, and conservation easements have collectively resulted in improved biological communities for the entire Stillwater mainstem downstream from Ansonia.

2.2 Individual Waterbody Summaries

Stillwater River[1]

Approximately sixty-six miles of the Stillwater River were assessed for the status of aquatic life uses and attainability of those uses. The Stillwater River is designated Warmwater Habitat (WWH) from its headwaters to Biesner Road (RM 57.0), and Exceptional Warmwater Habitat (EWH) from Biesner Road to the confluence with the Great Miami River. The WWH designation is not attainable upstream from Woodington Run/Ansonia (RM 61.8) as the river there is under active channel maintenance. Therefore, the appropriate and attainable aquatic life use designation is Modified Warmwater Habitat (MWH). The WWH designated segment should be extended downstream to Shroeder Road (RM 52.0) as the stream between RMs 57 and 52 has been previously channelized and has not recovered enough warmwater habitat attributes, either over time or due to proximity to the actively maintained headwaters, to make EWH a realistic use. Based on these adjusted use recommendations, the attainment status for the sixty-six miles of Stillwater River mainstem are 3.3 miles not attaining, 8.2 miles partially attaining and 55.0 miles fully attaining aquatic life uses. Aquatic life use impairment in the headwaters upstream from Ansonia is being caused by organic enrichment from land applied manure combined with

[1] *All of the beneficial use changes discussed here were implemented on July 21, 2002. The TMDL is based on the new use designations.*

poor habitat. Impairment downstream from Ansonia is being caused by a combination of organic and nutrient enrichment from CSOs (Ansonia), wastewater loadings (Ansonia and Versailles) and manure (North Fork and Swamp Creek), and by the downstream footprint resulting from keeping the headwaters maintained in a channelized state.

In 1999, a small reach of partial attainment also existed in and downstream from the Englewood dam pool. The impairment in the dam pool was caused by nutrient enrichment and siltation. The impairment downstream of the dam was due to a combination of being immediately downstream from the Englewood dam and wastewater loadings from the treatment plant.

In 2008, biological assessments completed upstream of the impoundment, within the impoundment, and downstream of both the impoundment and Englewood WWTP. The 2008 assessment (see Appendix B) showed that there is minimal nutrient enrichment downstream of the Englewood WWTP as observed using dissolved oxygen traces and benthic algae sampling (chlorophyll a). See Section 5 for information on the status of the dam.

Greenville Creek

The entire thirty-four miles of Greenville Creek in Ohio are designated Exceptional Warmwater Habitat. That use designation is appropriate for all segments except for the reach flowing through Greenville, which has been channelized and is maintained *de facto* by hard urban surfaces. The appropriate aquatic life use designation for this reach, based on demonstrated biological performance and habitat quality is Warmwater Habitat. Adjusting for this recommendation, 11.1 miles fully attain, 20.2 miles partially attain, and 3.2 miles do not attain aquatic life uses. The single most important factor responsible for impairing the aquatic life uses in Greenville Creek is habitat degradation. Portions of the creek upstream from Greenville have been recently channelized to accommodate development, most of the tributaries have been channelized and consequently are a source of sediment, and as previously mentioned, the creek in and downstream from Greenville has been altered. The collective effect of all this contributes to the impairment immediately downstream from the Greenville WWTP. Organic and nutrient enrichment from the Greenville WWTP and, more importantly, onsite sewage disposal (septic tanks) is the primary cause of impairment further downstream from Greenville.

Mill Creek

Mill Creek is designated WWH. This use was fully met in the lower 0.5 miles of the creek, and not met in the remaining 2.1 miles assessed. The biological communities remain impaired by releases of deicing chemicals used at the Cox-Dayton International Airport.

Ludlow Creek

Ludlow Creek is designated WWH. That designation is appropriate except for the channelized and actively maintained headwaters where a Modified Warmwater Habitat (MWH) designation is appropriate. When MWH is considered for the headwaters upstream from the Darke County line, the aquatic life uses are fully met.

Brush Creek

Brush Creek is designated WWH. That use designation was not met at RM 7.1 due to organic enrichment, presumably from on-site sewage disposal. The impact at RM 7.1 was likely exacerbated by the drought. The site sampled at RM 0.4 fully met WWH.

Painter Creek

Painter Creek has an unconfirmed EWH use designation from its confluence with the Stillwater River to the Darke County line (RM 5.5), and a MWH designation upstream from there. The EWH use has not been demonstrated; therefore, the appropriate aquatic life use is WWH. Given these designations, of the approximately eighteen miles assessed, 1.5 miles were in full attainment, 8.0 miles did not attain, and 5.5 miles partially attained their respective aquatic life use designations. The eight mile reach of non-attainment was caused by gross organic enrichment from the failing sewage collection and treatment system in Arcanum.

Harris Run and Ballinger Run

Harris Run and Ballinger Run are both designated WWH, and that designation has been confirmed for the portion of both streams in Miami County. However, both streams are actively maintained for drainage in Darke County where a MWH use designation is appropriate. The RM at the Darke-Miami county line for Harris Run is 5.2 and 1.7 for Ballinger Run. So designated, there were 4.2 miles of partial attainment and 1.0 mile of full attainment in Harris Run, and 3.0 miles of non-attainment in Ballinger Run. Bradford CSOs continued to be the main source of impairment to both Ballinger Run and Harris Creek.

Trotters Creek and Tributaries

Trotters Creek has an unconfirmed WWH aquatic life use designation. The fish and macroinvertebrate community downstream from Rike Road (RM 1.7) met expectations for EWH and should be so designated. Upstream from Rike Road, WWH is the appropriate aquatic life use.

Of the tributaries to Trotters Creek assessed, a WWH aquatic life use is appropriate for Sigmon Ditch and Bennett Ditch. Orr Ditch, Apple Ditch and Rudy Ditch should be resampled during a non-drought year to be properly designated as the macroinvertebrate samples were collected during the height of the drought.

Swamp Creek and Tributaries

Swamp Creek is designated MWH upstream from RM 6.5 and WWH downstream from that point. Of the 12.1 miles assessed, 5.6 miles fully attained, 4.2 miles partially attained, and 2.3 miles did not attain their respective use designations. The main cause of impairment was organic and nutrient enrichment, with conditions being so enriched as to result in critically low dissolved oxygen concentrations and fish kills. The source of the organic and nutrient enrichment is land applied manure.

Indian Creek is similarly impaired by organic and nutrient enrichment, but failing septic systems are an additional source of enrichment. Indian Creek is designated WWH and that designation has been confirmed for the lower 1.9 miles (Conover Road) of stream. Upstream, the creek is an actively maintained drainage ditch and therefore should be designated MWH. So designated, 4.1 miles - the entire assessed portion being proposed for MWH - were not attaining, and the lower 2.0 miles were partially attaining the WWH aquatic life use designation.

The tributary to Swamp Creek at RM 3.54 is actively maintained for drainage and should be designated as MWH. So designated, the 1.0 mile reach assessed was meeting its aquatic life use. Grassy Fork is a maintained ditch and should be designated MWH. The MWH aquatic life use was not met due to drought related stresses.

Boyd Creek and Tributaries

The entire Boyd Creek drainage network is a series of maintained drainage ditches that should be designated MWH. Based on the MWH aquatic life use, Boyd Creek fully attained at RM 0.8, and partially attained at RM 3.5. The two tributaries to Boyd Creek (confluences at RM 2.46 and 2.67) did not attain due to very poor qualitative macroinvertebrate scores. The macroinvertebrate community from the tributary at RM 2.46 may have been limited by the drought, but the tributary at RM 2.67 was impaired by organic enrichment, most likely from failing onsite sewage disposal. On-site disposal was also the reason for partial attainment in Boyd Creek.

North Fork Stillwater River and Sycamore Ditch

The North Fork is appropriately designated MWH. All eleven miles evaluated did not attain the MWH aquatic life use due to organic and nutrient enrichment from land-applied manure. Sycamore Ditch met MWH.

Woodington Run

Biological communities in Woodington Run met expectations for WWH at RM 4.9 and partially met expectations at RM 1.1. The limiting component at RM 1.1 was the bug community, which was evaluated as “fair” because of effects from nutrient enrichment. Because the fish community met WWH at both sites, the physical stream habitat has recovered some function since being channelized, and because the macroinvertebrate community was impaired beyond simply the effects of habitat, a WWH aquatic life use is recommended for Woodington Run.

South Fork Stillwater River

Biological communities in the South Fork met expectations for WWH at RM 0.4, did not meet based on one qualitative bug sample at RM 1.3, and partially met expectations at RM 3.0. Habitat function was admittedly worse than that for Woodington Run, but as the fish community met WWH, and the fish community is generally the more limiting component when habitat is the issue, a WWH aquatic life use is recommended for the South Fork.

Other Tributaries

Numerous other nameless and undesignated tributaries were assessed to determine the appropriate aquatic life use designation (see Table 2.1). The rationale for assigning a designation in all cases was based on demonstrated biological performance not confounded by water quality impacts, or potential biological performance based on habitat quality in the absences of a direct water quality problem where such a problem existed.

Table 2.1 Aquatic life use attainment status for stations sampled in the Stillwater River basin July-September, 1999. The Index of Biotic Integrity (IBI), Modified Index of well being (MIwb), and Invertebrate Community Index (ICI) are scores based on the performance of the biotic community. The Qualitative Habitat Evaluation Index (QHEI) is a measure of the ability of the physical habitat to support a biotic community. *All uses shown as proposed were implemented on July 21, 2002.*

River Mile Fish/Invert.	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes & Sources
Stillwater River (14-200) *WWH/MWH proposed*						
65.8	30	NA	MG	31	Partial/Full	
65.0	18*	NA	F	31	NON/NON	Organic enrichment - AFOs
63.8	40	NA	MG	37	Full/Full	
63.0	34	5.3*	F*	38	NON/NON	Organic enrichment - AFOs.
61.1/61.8	25	7.0	30	34	NON/Full	
				WWH		
60.2	-	-	38		(Full)	
58.8	30*	7.8^{ns}	32^{ns}	43	Partial	Organic enrichment - CSOs
58.1	38	9.0	-	47	Full	
57.9	37^{ns}	8.3	MG^{ns}	48	Full	
57.0	-	-	34^{ns}	-	(Full)	
				EWH /WWH Proposed		
54.4	43	7.8^{ns}	-	44	NON/Full	
				EWH		
52.0/51.2	46^{ns}	9.0^{ns}	44^{ns}	73	Full	
47.8	48	9.6	38*	74	Partial	Sedimentation and nutrient enrichment
44.1	47	10.2	42^{ns}	73	Full	
41.4	50	9.2^{ns}	36*	75	Partial	Sedimentation and nutrient enrichment
37.7	51	9.3^{ns}	44^{ns}	82	Full	
33.5	-	-	48		(Full)	
32.1	54	10.1	52	81	Full	27.9 58 9.9 E
81	Full		25.1	59	10.4	46 86 Full
22.8/21.2	58	9.7	48	73	Full	18.0 57 9.8 E
75	Full		16.0	59	10.1	44^{ns} 81 Full
11.4	52	9.8	48	77	Full	
8.9	28*	7.5	--	52	Partial	Hydromodification - impoundment
8.8	--	--	40*	--	(NON)	Hydromodification, organic enrichment
8.6	53	10.3	MG*	88	Partial	Hydromodification, organic enrichment
5.0	59	10.5	46	86	Full	
1.2	55	10.5	46	86	Full	

Table 2.1. Continued.

River Mile Fish/Invert.	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes & Sources
Pigeye Creek 14-201 WWH						
0.6	36^{ns}	NA	F^{*}	36	Partial	Organic enriched - septic/livestock
Mill Creek 14-202 WWH						
2.6	$\underline{22}^{*}$	NA	F^{*}	47	NON	Toxics (deicers) - Dayton Airport
1.2	$\underline{26}^{*}$	NA	G	57	NON	Toxics (deicers) - Dayton Airport
0.3	44	NA	52	50	Full	
Brush Creek 14-203 EWH/WWH - Proposed						
0.1	41	NA	G	63	Full	
Jones Run 14-204 WWH						
0.4	28^{*}	NA	G	57	Partial	Organic enrichment, sewer line leak
Rocky Run (14-205) WWH						
0.5	-	-	G	-	Full	
Opossum Run 14-206 WWH - EWH proposed						
0.8	46^{ns}	NA	E	70	Full	
Painter Creek 14-208 MWH						
16.9/17.9	28	NA	F	28	Full	
16.2/15.5	$\underline{16}^{*}$	NA	$\underline{10}^{*}$	32	NON	Organic enrichment - CSOs.
14.7	$\underline{12}^{*}$	NA	$\underline{4}^{*}$	28	NON	Toxics (NH_4) - CSOs & sewage lagoon
9.7/8.9	$\underline{24}$	$\underline{5.6}^{*}$	26	41	NON	Organic enrichment - CSOs
			EWH /WWH - proposed			
3.4/4.4	33^{*}	6.8^{*}	G	78	NON/Partial	Organic enrichment - CSOs
0.7/1.1	33^{*}	6.3^{*}	44	63	NON/Partial	Organic enrichment - CSOs
Little Painter Creek 14-209 MWH - proposed						
0.4	34	NA	F*	44	Partial	Organic enrichment - livestock
Ludlow Creek 14-210 MWH - Proposed						
12.6	34	NA	MG	51	Full	
				WWH		
6.4	36^{ns}	7.9^{ns}	VG	60	Full	
3.5	44	8.1^{ns}	VG	77	Full	
2.9	42	8.1^{ns}	-	78	Full	
2.3	40	7.9^{ns}	40	76	Full	

Table 2.1. Continued.

River Mile Fish/Invert.	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes & Sources
Brush Creek 14-211 WWH						
7.1	38[ns]	NA	VP[*]	41	NON	Organic enrichment - on-site sewerage
0.4	40	NA	VG	76	Full	
Hog Run 14-213 WWH						
0.2	48	NA	MG	70	Full	
Baker Ditch LRW - Proposed						
0.6	-	-	VP	-	NON	Dry ditch
Feitshams Ditch LRW - Proposed						
0.6	-	-	F	-	Full	
Brown Ditch LRW - Proposed						
0.4	-	-	F	-	Full	
Heller Ditch 14-217 MWH - proposed						
0.1	26	NA	MG	43	Full	
Harris Run 14-218 WWH						
3.8/5.2	35[*]	NA	44	31	Partial	Sedimentation
2.0	30[*]	NA	G	58	Partial	Organic enrichment - CSOs
0.9	42	NA	38	73	Full	
Ballinger Run 14-219 MWH - proposed						
2.8	20[*]	NA	-	30	(NON)	
				WWH		
1.4	25[*]	NA	0[*]	57	NON	Organic enrichment, toxics - CSOs
0.6	34[*]	NA	32[ns]	62	Partial	Organic enrichment - CSOs
Greenville Creek 14-220 EWH -						
33.0/34.3	52	NA	58	76	Full	
30.2	48[ns]	9.1[ns]	42[ns]	61	Full	
28.9	45[*]	8.4[*]	50	49	Partial	Hydromodification - channelization
26.5	48[ns]	7.9[*]	46	57	Partial	Hydromodification - channelization
24.6	50	8.5[*]	50	72	Partial	Hydromodification – channelization

Table 2.1. Continued.

River Mile Fish/Invert.	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes & Sources
Greenville Creek - Continued EWH - /WWH-proposed						
23.2/22.6	37[ns]	8.2[ns]	-	49	NON/Full	Hydromodification - Impounded
21.7/22.3	47	8.5	42	72	Partial/Full	
19.6	39[ns]	7.5[*]	34[ns]	45	NON/Partial	Hydromod. - urban, org. enrich.
19.3	*34*	*7.4*	*F*	-		
19.2	-	-	30[*]	-	(NON)/(NON)	Hydromod., org. enrich. - sewer line
18.3	36[ns]	7.2[*]	F[*]	53	NON/Partial	Hydromod, org. enrich., WWTP
				EWH -		
16.2	37[*]	8.6[*]	54	71	Partial	organic enrichment - WWTP
13.7	46[ns]	9.6	E	81	Full	
10.8	48[ns]	8.9[*]	50	86	Partial	Organic enrichment - on-site sewerage
6.1	46[ns]	9.1[ns]	44[ns]	84	Full	
3.7	38[*]	8.2[*]	-	75	NON	Organic enrichment - on-site sewerage
1.4	55	10.5	46	76	Full	
0.1	-	-	50	-	(Full)	
McQuay Ditch 14-221 WWH						
1.6/0.5	36[ns]	NA	VG	56	Full	
Poplar Ditch 14-222 WWH						
0.6	52	NA	G	61	Full	
Bolton Run 14-223 WWH						
0.6	50	NA	MG	45	Full	
Dividing Branch 14-224 WWH						
0.4	-	-	VG	-	Full	
2.4/3.1	48	NA	MG	41	Full	
Bridge Creek 14-225 WWH Existing						
1.4/0.2	38[ns]	NA	54	39	Full	
Mud Creek 14-226 WWH						
6.1	54	NA	40	58	Full	
4.7	51	NA	58	46	Full	
2.1/0.1	42	NA	54	35	Full	

Table 2.1. Continued.

River Mile Fish/Invert.	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes & Sources
Prairie Outlet 14-227 WWH						
0.8	36^{ns}	NA	28^{*}	40	Partial	Organic enrich. - on site sewerage
W. Br. Greenville Cr 14-228 WWH						
10.2/10.7	42	NA	F^{*}	37	Partial	Hydromodification
7.4	52	NA	G	43	Full	
5.3/5.8	56	NA	G	50	Full	
0.3	44	9.1	G	78	Full	
Spring Branch 14-229 WWH						
0.3	48	NA	MG	57	Full	
Kraut Creek 14-230 WWH						
5.9	54	NA	E	62	Full	
4.4	50	NA	-	52	Full	
0.6	42	8.8	VG	70	Full	
N. Fk. Kraut Creek 14-231 WWH						
2.1	42	NA	E	69	Full	
0.8	46	NA	G	56	Full	
Dismal Creek 14-232 WWH						
3.8/4.7	$\underline{27}^{*}$	NA	42	44	NON	Hydromodification
2.2/1.8	35^{*}	NA	MG	53	Partial	Org. enrich. - land application
0.1	36^{ns}	NA	36	48	Full	
Trotters Creek 14-234 WWH						
0.3/0.9	48	9.4	VG	74	Full	
Swamp Creek 14-235 MWH						
12.1	-	-	F	-	(Full)	
8.9	$\underline{27}$	NA	28	33	Full	
6.5	$\underline{17}^{*}$	$\underline{4.8}^{*}$	30	35	NON	Organic enrichment - AFOs
				WWH		
4.5	32^{*}	6.5^{*}	G	42	Partial	Organic enrichment - AFOs
2.9	27^{*}	7.2^{*}	42	40	Partial	Organic enrichment - AFOs; hydromod
2.3	34^{*}	7.1^{*}	26^{*}	34	NON	Organic enrichment - AFOs; hydromod
2.0/1.6	32^{*}	6.4^{*}	34^{ns}	43	Partial	Organic enrichment - AFOs; hydromod
0.3	42	6.7^{*}	42	49	Partial	Organic enrichment - AFOs; hydromod

Table 2.1. Continued.

River Mile Fish/Invert.	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes & Sources
Indian Creek 14-236 MWH - proposed						
5.2/6.1	32	NA	P*	38	NON	Organic enrichment - AFOs; hydromod
3.1/2.0	20*	NA	32	30	NON	Organic enrichment - on-site sewerage
				WWH		
0.5	41	NA	F*	47	Partial	Organic enrichment - on-site sewerage
Boyd Creek 14-237 MWH - proposed						
3.5	34	NA	F*	45	Partial	
0.8	40	NA	F	55	Full	
N. Fk. Stillwater R. 14-238 MWH						
10.5	12*	NA	VP*	22	NON	Organic enrichment - AFOs
8.3	-	-	VP*	-	NON	Organic enrichment - AFOs
4.4	20*	NA	F	25	NON	Organic enrichment - AFOs
0.4	27	NA	12*	36	NON	Organic enrichment - AFOs
Woodington Run 14-239 WWH						
4.9	42	NA	G	52	Full	
1.1	44	NA	F*	51	Partial	Hydromod, enrichment
S. Fk. Stillwater R. 14-240 WWH						
5.5	36[ns]	NA	F*	30	Partial	Hydromod, enrichment
1.3	-	-	F*	-	(NON)	Hydromod, enrichment
0.4	38[ns]	NA	MG	40	Full	
Sycamore Ditch 14-241 MWH - proposed						
0.2	24	NA	F*	35	Full	
Trib. to Kraut Creek 14-245 WWH						
0.2	46	NA	F*	55	Partial	Unknown
Trib. to Ludlow Cr. 14-247 MWH - proposed						
0.4	26	NA	MG	42	Full	

Table 2.1. Continued.

River Mile Fish/Invert.	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes & Sources
Trib Stillwater 32.6 14-250 WWH - proposed						
0.6	34*	NA	G	64	Partial	Organic enrichment - on-site sewerage
Bitch Run (trib to Mud Creek @ RM 2.1) 14-251 WWH - proposed						
0.1	42	NA	-	51	(Full)	
Lake Branch Ditch 14-252 WWH						
4.1	46	NA	P*	30	NON	Organic enrichment - on-site sewerage
0.7	54	NA	54	56	Full	
Trib. to Harris C. 14-253 WWH - proposed						
0.2	34*	NA	VP*	44	NON	Unknown
Sigmon Ditch 14-254 WWH - proposed						
1.2	40	NA	G	56	Full	
Bennett Ditch 14-256 WWH - proposed						
0.6	42	NA	P*	56	NON	Organic enrichment - livestock
Trib. to Swamp Creek 14-259 MWH - proposed						
0.6	28	NA	24	37	Full	
Grassy Fork 14-260 MWH - proposed						
0.9	-	-	P*	-	(NON)	Drought & habitat
Trib. to Stillwater @ RM 38.3 14-261 WWH - proposed						
0.7	28*	NA	P*	71	NON	Organic enrichment - livestock
Trib Stillwater 51.0 14-262 WWH - proposed						
1.3	42	NA	G	54	Full	
2.2	-	-	F*	-	(Partial)	Hydromodification - channelization
Trib to trib to Stillwater 51.0/2.4 WWH - proposed						
0.3	44	NA	-	44	(Full)	
Trib. to Boyd (2.67) 14-264 MWH - proposed						
0.5	30	NA	VP*	26	NON	Hydromodification - channelization

Table 2.1. Continued.

River Mile Fish/Invert.	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes & Sources
Trib. to Boyd (2.46) 14-265 MWH - proposed						
1.2/1.7	30	NA	VP*	46	NON	Hydromodification - channelization
Trib to Stillwater 14-266 MWH - proposed						
0.4	-	-	F*	-	(NON)	Hydromodification - channelization
Trib Stillwater 55.4 14-267 MWH - proposed						
0.8	<u>26</u>	NA	P*	47	NON	Organic enrichment - on-site sewerage
Trib Stillwater 14-268 MWH - proposed						
0.3	-	-	F	-	(Full)	
Trib SF Stillwater 14-269 MWH - proposed						
1.6	32	NA	F*	29	Partial	Hydromodification - channelization
Trib Stillwater 64.9 14-270 MWH - proposed						
0.3	36	NA	-	42	(Full)	
1.1	30	NA	-	21	(Full)	

Index-Site Type	Biological Criteria Eastern Corn Belt Plains (ECBP) EWH	WWH	MWH
IBI-Headwaters	50	40	24
IBI-Wading	50	40	24
IBI-Boat	48	42	30
MIwb-Wading	9.4	8.3	6.2
MIwb-Boat	9.6	8.5	6.6
ICI	46	36	22

a The Modified Index of Well-being is not applicable (NA) to headwater site types.
b A qualitative narrative evaluation used when quantitative data were not available or unreliable due to current velocities less than 0.3 fps flowing over the artificial substrates (P = Poor, F = Fair, MG = Marginally Good, G = Good, VG = Very Good, E = Exceptional).
c Use attainment status based on one organism group is parenthetically expressed.
A Boat sampling method
D Wading method
* Indicates significant departure from applicable biocriteria (>4 IBI or ICI units, or >0.5 MIwb units). Underlined scores are in the Poor or Very Poor range.
ns Nonsignificant departure from biocriteria ($\leq$4 IBI or ICI units, or $\leq$0.5 MIwb units).
d Modified Warmwater Habitat criteria for channel modified habitats.

Table 2.2. Summary of performance and impacts to receiving waters for NPDES dischargers evaluated in the 1999 survey of the Stillwater River Basin

NPDES Discharger	**Flow (mgd) Design /Median/ 95th**	**Toxicity Bioassay /Biosample**	**Receiving Water Impairment**
Ansonia (1PB00005)	0.35/0.12/0.27	NA/ND	Slight from CSOs
Arcanum (1PB00000)	0.40/0.36/0.94	Acute/Acute	Extreme from CSOs and WWTP
Bradford (1PB00008)	0.24/0.21/0.38	NA/Acute (CSOs)	Severe from CSOs; moderate organic enrichment from WWTP
Covington (1PB00013)	0.75/0.29/0.51	None/ND	None
Englewood (1PD00001)	2.50/1.31/3.14	Acute and chronic/ND	Slight due to organic enrichment
Greenville (1PD00005)	3.50/2.14/3.24	None/ND	Slight due to organic enrichment
Pleasant Hill (1PB00026)	0.20/0.10/0.16	NA/ND	None
Union (1PB00030)	1.00/0.58/1.19	Acute/ND	None
Versailles (1PB00033)	0.38/0.28/0.53	NA/ND	Slight impact to Stillwater due to organic enrichment
West Milton (1PC00011)	1.20/0.6*/1.6*	None/ND	Minimal - small decrease in macroinvertebrate scores

* 1999 data were not available for West Milton.

3.0 Problem Statement

Only minor changes from the 2004 Stillwater TMDL report have been made. Changes are shown in italics.

The Stillwater River basin (USGS Catalogue Number 05080001) is located in the Eastern Cornbelt Plains of west-central Ohio (Figure 2.1). Agriculture, both row crop and livestock production, dominates the landscape, and in so doing is responsible for most of the miles of stream impairment. Much of the stream network has been modified and is maintained in a modified state to facilitate rapid drainage for rowcrop production; consequently, habitat alterations are a major cause of impairment. Manure from concentrated animal feeding operations (CAFOs) is applied to fields within the watershed. Direct runoff of manure to the streams and leaching of manure through the tile networks result in organic and nutrient enrichment as another major cause of impairment. Because the stream network is maintained for drainage, little or no riparian buffer exists on most headwater streams to filter errant manure.

Agriculture is not the only source of impairment; various stream segments in the Stillwater River basin are not meeting water quality standards for aquatic life use due to municipal point sources or onsite wastewater systems. The specific stream segments appearing either on the most recent §303(d) list or recently identified as not fully meeting aquatic life uses, their respective waterbody identification numbers, segment length, aquatic life use status, and causes and sources of impairment are listed Table 1.1. The geographic locations and place names of the stream segments and their proximity to sources of pollution are shown in Figure 2.1. For more detailed information on sources and locations of pollution in the Stillwater River basin please refer to Ohio EPA (2001). Based on results of a 1999 intensive water and biological quality survey of the Stillwater River Basin (Ohio EPA 2001), the following stream segments currently appearing on the §303(d) list are now fully meeting their aquatic life uses:

> Stillwater River (Greenville Creek to Ludlow Creek; OH57 37);
> Greenville Creek (Headwaters to West Branch Greenville Creek OH57 32);
> Mud Creek (OH57 28).

For the remaining segments and those newly identified, regardless of the source, two causes organic enrichment and habitat alteration, ultimately effect most of the impairment. Other causes listed are, in most cases, secondary consequences of the primary causes. For example, nutrient enrichment often co-occurs with organic enrichment as organic matter is often high in nutrient content and those nutrients are remineralized through microbial decomposition. Habitat alterations, specifically channelization to promote agricultural drainage, exacerbates deleterious effects from nutrient enrichment through loss of shading, filtration, the stream channel-flood plain connection, homogenization of stream substrates, and decreased nutrient spiral length (Newbold et al. 1983). Similarly, habitat alteration promotes siltation. Because the various causes listed are interrelated and occur on a watershed scale, the TMDL for the Stillwater River basin is not pollutant specific *per se*, although segment specific causes, sources and loads are addressed in this report, rather it is the watershed scale approach *in toto* to achieve restoration of aquatic life uses. It encompasses broadly prescriptive agricultural best management practices (BMPs), farm-specific BMPs, county-wide efforts to address failing on-site sewage disposal, suburban storm water control, adoption of objective criteria for agricultural drainage maintenance (*i.e*., hydromodification), and upgrades to publicly owned sewage collection and treatment systems.

Enriched streams suffer from excessive aquatic plant growth and large daily swings in dissolved oxygen (DO). Excess phosphorus in lotic systems will stimulate aquatic plant growth and maintenance to high levels of production (measured as biomass/time and/or biomass/area). These plants include phytoplankton, benthic algae (periphyton), filamentous algae, and aquatic macrophytes. Within a diel period (i.e., 24-hour period), stimulation in plant growth will produce supersaturated levels of DO during the diurnal period (i.e., daytime). During the nocturnal period (i.e., nighttime), high respiration rates from these same plants will consume enough DO to reduce ambient DO to very low (hypoxic) levels. Plant respiration can occur from both from living and dead plant material.

Phosphorus is typically regarded as the limiting nutrient for aquatic plant growth in Ohio rivers and streams. Controlling for phosphorus in upstream sources (e.g., animal manure, WWTP effluent) typically yields corresponding reductions in nitrogen and carbon. Therefore, total phosphorus is selected as a target parameter for calculating the total maximum daily load (TMDL).

3.1 Applicable Water Quality Standards and Water Quality Numeric Targets

Ohio Water Quality Standards: Designated Aquatic Life Uses
The Ohio Water Quality Standards (WQS; Ohio Administrative Code 3745-1) consist of designated uses and chemical, physical, and biological criteria protective of those uses, and an antidegradation policy as outlined in OAC 3745-1-05. Use designations consist of two broad groups, aquatic life and non-aquatic life uses. In applications of the Ohio WQS to the management of water resource issues in Ohio's rivers and streams, the aquatic life use criteria frequently result in the most stringent protection and restoration requirements, hence their emphasis in biological and water quality reports. Also, an emphasis on protecting for aquatic life generally results in water quality suitable for all uses.

The five different aquatic life uses currently defined in the Ohio WQS are described as follows:

1) *Warmwater Habitat (WWH)* - this use designation defines the "typical" warmwater assemblage of aquatic organisms for Ohio rivers and streams; *this use represents the principal restoration target for the majority of water resource management efforts in Ohio.*

2) *Exceptional Warmwater Habitat (EWH)* - this use designation is reserved for waters which support "unusual and exceptional" assemblages of aquatic organisms which are characterized by a high diversity of species, particularly those which are highly intolerant and/or rare, threatened, endangered, or special status (*i.e.,* declining species); *this designation represents a protection goal for water resource management efforts dealing with Ohio's best water resources.*

3) *Coldwater Habitat (CWH)* - this use is intended for waters which support assemblages of cold water organisms and/or those which are stocked with salmonids with the intent of providing a put-and-take fishery on a year round basis which is further sanctioned by the Ohio DNR, Division of Wildlife; this use should not be confused with the Seasonal Salmonid Habitat (SSH) use which applies to the Lake Erie tributaries which support periodic "runs" of salmonids during the spring, summer, and/or fall.

4) *Modified Warmwater Habitat (MWH)* - this use applies to streams and rivers which have been subjected to extensive, maintained, and essentially permanent hydromodifications such that the biocriteria for the WWH use are not attainable *and where the activities have been sanctioned and permitted by state or federal law;* the representative aquatic assemblages are generally composed of species which are tolerant to low dissolved oxygen, silt, nutrient enrichment, and poor quality habitat.

5) *Limited Resource Water (LRW)* - this use applies to small streams (usually <3 $mi.^2$ drainage area) and other water courses which have been irretrievably altered to the extent that no appreciable assemblage of aquatic life can be supported; such waterways generally include small streams in extensively urbanized areas, those which lie in watersheds with extensive drainage modifications, those which completely lack water on a recurring annual basis (*i.e.,* true ephemeral streams), or other irretrievably altered waterways.

Chemical, physical and biological criteria are generally assigned to each use designation in accordance with the broad goals defined by each. As such the system of use designations employed in the Ohio WQS constitutes a tiered approach of graduated levels of protection. This hierarchy is especially apparent for parameters such as dissolved oxygen, NH_3-N, temperature and the biological criteria. For other parameters such as heavy metals, the technology to construct an equally graduated set of criteria has been lacking, thus the same water quality criteria may apply to two or three different use designations.

Ohio Water Quality Standards: Non-Aquatic Life Uses

In addition to assessing the appropriateness and status of aquatic life uses, each biological and water quality survey also addresses non-aquatic life uses such as recreation, water supply, and human health concerns as appropriate. The recreation uses most applicable to rivers and streams are the Primary Contact Recreation (PCR) and Secondary Contact Recreation (SCR) uses. The criterion for designating the PCR use is simply having a water depth of at least one meter over an area of at least 100 square feet or where canoeing is a feasible activity. If a water body is too small and shallow to meet either criterion the SCR use applies. The attainment status of PCR and SCR is determined using bacterial indicators (*e.g.,* fecal coliforms, *E. coli)* and the criteria for each are specified in the Ohio WQS.

Water supply uses include Public Water Supply (PWS), Agricultural Water Supply (AWS) and Industrial Water Supply (IWS). Public Water Supplies are simply defined as segments within 500 yards of a potable water supply or food processing industry intake. The Agricultural Water Supply (AWS) and Industrial Water Supply (IWS) use designations generally apply to all waters unless it can be clearly shown that they are not applicable. An example of this would be an urban area where livestock watering or pasturing does not take place, thus the AWS use would not apply. Chemical criteria are specified in the Ohio WQS for each use and attainment status is based primarily on chemical-specific indicators. Human health concerns are additionally addressed with fish tissue data, but any consumption advisories are issued by the Ohio Department of Health are detailed in other documents.

The determination of use attainment status and assignment of probable causes and sources of impairment are the underpinnings of this TMDL. The identification of impairment in rivers and streams is straightforward - the numerical biological criteria are used to judge aquatic life use attainment and impairment (partial and non-attainment). The rationale for using the biological criteria, within a weight of evidence framework, has been extensively discussed elsewhere (Karr *et al*. 1986; Karr 1991; Ohio EPA 1987a,b; Yoder 1989; Miner and Borton 1991; Yoder 1991; Yoder 1995). Describing the causes and sources associated with observed impairments relies on an interpretation of multiple lines of evidence including water chemistry data, sediment data, habitat data, effluent data, land use data, and biological results (Yoder and Rankin 1995). Thus the assignment of principal causes and sources of impairment to stream segments appearing on the §303d list represent the association of impairments (as judge by aquatic life use status) with stressor and exposure indicators. The reliability of the identification of probable causes and sources is increased where many such prior associations have been identified, or have been experimentally or statistically linked together. The ultimate measure of success in water resource management is the restoration of lost or damaged ecosystem attributes including aquatic community structure and function.

The establishment of instream numeric targets is a significant component of the TMDL process. The numeric targets serve as a measure of comparison between observed instream conditions and conditions that are expected to restore the designated uses of the segment. The TMDL identifies the load reductions and other actions that are necessary to meet the target, thus resulting in the attainment of applicable water quality standards, ultimately judge by attainment of designated aquatic life uses.

<u>Biocriteria</u>

Full restoration of aquatic life uses is the stated goal of this TMDL, and numeric biocriteria are used to judge attainment of aquatic life use designations. After the control strategies have been implemented, biological measures including the IBI, ICI, QHEI and MIwb will be used to validate biological improvement and biocriteria attainment. The current attainment of the biocriteria along with the applicable standards is listed in Section 2.2, Table 2.1.

<u>Organic Enrichment</u>

Organic enrichment is not explicitly listed in Ohio water quality standards, but falls under the general water quality criteria of Ohio Administrative Code (OAC) 3745-1-04 applicable to all waters of the state, wherein, to every extent practical and possible as determined by the director, these waters shall be:

> (A) Free from suspended solids or other substances that enter the waters as a result of human activity and that will settle to form putrescent or otherwise objectionable sludge deposits, or that will adversely affect aquatic life;
>
> (C) Free from materials entering the waters as a result of human activity producing color, odor or other conditions in such a degree as to create a nuisance;
>
> (D) 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;
>
> (E) Free from nutrients entering the waters as a result of human activity in concentrations that create nuisance growths of aquatic weeds and algae;

(F) Free from public health nuisances associated with raw or poorly treated sewage.

Dissolved Oxygen

Apart from nuisance conditions, organic enrichment also results in dissolved oxygen concentrations insufficient to support aquatic life uses. One measurable endpoint of this TMDL is to attain the D.O. water quality criterion at all times including summer, low flow critical conditions. The D.O. criteria for the Warmwater Habitat segments are a 5.0 mg/l average over a 24-hour period and a 4.0 mg/l minimum. For the Exceptional Warmwater Habitat segments the criteria is a 6.0 mg/l average over a 24-hour period and a 5.0 mg/l minimum.

Ammonia-N

Ammonium ions are another by-product of organic enrichment and are toxic to aquatic life. Water quality standards for ammonia nitrogen are based on aquatic life use designation, pH and temperature. The standards are tabularized and can be found in OAC 3745-1-07, Tables 7-2 through 7-8.

Sedimentation and Habitat

Habitat alteration and siltation were identified as causes of impairment. OAC 3745-1-04 states that all waters of the state shall be free from suspended solids and other substances that enter the waters as a result of human activity and that will settle to form objectionable sludge deposits, or that will adversely affect aquatic life. However, no statewide numeric criteria have been developed specifically for sediment, TSS or habitat. Instead, target Qualitative Habitat Evaluation Index (QHEI) scores, based on reference data sites for some of the aquatic life use designations, can be used as surrogates. The QHEI measures several or more aspects of six physical habitat variables. The variables are: substrate, instream cover, riparian characteristics, channel characteristics, pool/riffle quality and gradient and drainage area. The habitat attributes derived from the QHEI can be used to assess overall potential to support aquatic life, and which attributes are potentially the most limiting, and so, provide narrative targets for restoration (see Ohio EPA 1999).

Nutrients

Numeric targets are derived directly or indirectly from state narrative or numeric water quality standards (OAC 3745-1). In Ohio, applicable biocriteria are appropriate numeric targets (see Table 2.1). Determinations of current use attainment are based on a comparison of a stream's biological scores to the appropriate criteria, just as the success of any implementation actions resulting from the TMDLs will be evaluated by observed improvements in biological scores.

Ohio EPA currently does not have statewide numeric criteria for nutrients but potential targets have been identified in a technical report entitled *Association Between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams* (OEPA, 1999). This document provides the results of a study analyzing the effects of nutrients on the aquatic assemblages of Ohio streams and rivers. The study reaches a number of conclusions and stresses the importance of habitat and other factors, in addition to instream nutrient concentrations, as having an impact on the health of biologic communities. The study also includes proposed targets for nitrate+nitrite concentrations and total phosphorus concentrations based on observed concentrations at reference sites. Reference sites are relatively unimpacted sites that are used to define the expected or potential biological community within an ecoregion. The total phosphorus targets are shown in Table 3.1. It is important to note that these nutrient targets are not codified in Ohio's water quality standards; therefore, there is a certain degree of flexibility as to how they can be used in a TMDL setting.

Ohio's standards also include narrative criteria which limits the quantity of nutrients which may enter waters. Specifically, OAC 3745-1-04 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, and shall be free from floating debris, oil, scum and other floating materials entering the waters as a result of human activity in amounts sufficient to be unsightly or cause degradation.

3.2 Pollutant Assessment

Ohio EPA (2001) provides a detailed source inventory of both pollutants and pollution. See Figure 2.1 for an overview of significant point source locations.

3.3 Linkage Analysis

Rationale for the numerical targets appearing in Table 3.1 is as follows:

Biological index scores. Invertebrate Community Index (ICI), and Index of Biotic Integrity (IBI). Numeric standards for biological communities in Ohio streams are codified in OAC 3745-1-07, Table 7-17. Numeric scores by which stream communities are judged and compared to water quality standards are given by multimetric biological indexes. The Invertebrate Community Index (ICI) is used to measure stream macroinvertebrate communities and the Index of Biotic Integrity for fish communities. The use of multimetric indexes is well accepted and widely employed (Karr 1981, Leonard and Orth 1986, Fausch et al.1984, Yoder and Smith 1995, DeShon 1995, Davis and Simon 1995).

Ammonia-nitrogen. Ammonia-nitrogen is given as a target value for the prevention of acute and chronic toxicity. The relationship between temperature, pH and ammonia toxicity is so well documented as to be codified into state law OAC 3745-1-07, Tables 7-3 through 7-8. Rationale for stratification by aquatic life uses is given in Ohio EPA (1997).

Dissolved oxygen. Target values for dissolved oxygen are the minimum concentrations, both instantaneous and average, needed to support a given aquatic life use. As with ammonia-nitrogen, the relationship between the target value and response indicator (*i.e.*, biological communities) is so well demonstrated as to be codified in to state law; OAC 3745-1-07, Table 7-1. Rationale for stratification by aquatic life uses is given in Ohio EPA (1995).

Fecal coliforms. The target values and measured values listed in Table 3.1 are used as indicators only to help identify sites where organic enrichment is the primary cause of aquatic life use impairment. The water quality standard and attendant rationale for fecal coliform applies to human health.

Total Kjeldahl Nitrogen (TKN). Target values for TKN are derived from Ohio EPA (1999) and simply approximate the upper bounds (*i.e.*, 90^{th} percentiles) from a population of reference sites. TKN is not associated with biological index scores, however, TKN is linearly related to ammonia-nitrogen and biochemical oxygen demand, and so is used here simply as an indicator of organic enrichment.

Nutrient parameters (NOx-N, TP). Target values for nutrient parameters are based on Ohio EPA (1999), and Miltner and Rankin (1998). In brief, Ohio EPA (1999) lists percentile ranges of common water quality and chemistry parameters for minimally impacted reference sites stratified by ecoregion and stream size. Ohio EPA (1999) also lists percentile ranges of those same parameters measured in streams throughout Ohio with corresponding measured aquatic communities with narrative ranges of excellent, good, fair and poor. Miltner and Rankin (1998) demonstrated a significant association between nutrient concentrations and biological index scores and provided thresholds values for TP and NOx-N corresponding to designated aquatic life uses. For either approach, percentile range or statistical association, significant variability exists between causal and response variables. In the case of the percentile approach, median and 90^{th} percentile values for TP and NOx-N vary by an order of magnitude at reference sites, and excellent aquatic communities are frequently measured (25% of samples) at sites having nutrient concentrations exceeding the 90^{th} percentile reference site concentrations. And nutrients accounted for, at best, 16% of the variation in biological index scores in Miltner and Rankin (1998). The large variation between causal and response variables does not obviate any relationship which may exist, or imply that any relationship for any given stream is necessarily weak. Rather, the variability is simply a manifestation of the number of biotic and abiotic factors controlling biological communities in streams. Chief among those factors, and one that can be anthropogenically influenced, is habitat.

Habitat. Ohio EPA uses the Qualitative Habitat Evaluation Index (QHEI; as detailed in Rankin 1995) to measure habitat quality in steams. Several habitat attributes measured by the QHEI are strongly correlated with poor biological community performance. Those attributes are collectively called High Influence Modified Attributes (HIMA) as the attributes are characteristic of hydromodification, primarily channelization for agricultural drainage. Target values in Table T correspond to statistically significant relationships between QHEI scores and biological index scores, and statistically significant thresholds for the number of HIMAs found in a given stream segment that will likely preclude biological communities from meeting a given aquatic life use designation (Ohio EPA 1999). These relationships are described in detail in Rankin (1995) and Ohio EPA 1999.

3.4 Source Identification

The major source of habitat destruction is stream channelization for agricultural drainage. The major sources of oxygen demanding substances and nutrients during the critical low-flow period, in order of greatest contribution to aquatic life use impairment is the land application of animal waste originating from animal feeding operations, municipal wastewater treatment plants, and on-site wastewater management (septic) systems.

Table 3.1. Numeric targets for biological, habitat and water quality parameters and measured values by stream segment for the Stillwater River, 999. Where biological impairment exists, bold font denotes deviation from target value.

WBID River URM	LRM	ICI Min	IBI Min	QHEI[‡]	HIMA[a†]	Ammonia-N* Max[†]	Ammonia-N* Max[‡]	D.O. Min[†]	D.O. Min[‡]	TKN[‡b]	Fecal Col[‡◊]	NO_x-N[‡b]	TP[‡b]
MWH		22	24	45	≤3	7.3	1.2	3.0	4.0	4.0	1000	3.0	0.30
WWH		32	36	60	≤1	7.3	0.8	4.0	5.0	1.0	1000	1.0	0.08
EWH		42	46	75	0	4.5	0.8	5.0	6.0	1.0	1000	0.5	0.05
OH57 45 Stillwater River (Headwaters to North Fork) MWH													
67.6	57.9	**16**	**18**	**36**	**4**	0.38	0.08	3.4	4.3	0.11	315	0.65	0.16
OH57 43 Stillwater River (North Fork to Swamp Creek) WWH													
57.9	45.8	**24**	**34**	61	1	0.29	0.11	4.3	**4.8**	0.23	506	0.69	**0.17**
OH57 37 Stillwater River (Swamp Creek to Greenville Creek) EWH													
45.8	32.4	42	46	77	0	0.11	0.06	6.0	6.4	0.32	480	0.52	0.37
OH57 14 Stillwater River (Greenville Cr. To Ludlow Cr.) EWH													
32.4	21.0	**40**	50	81	0	0.08	0.06	5.5	6.7	**2.79**	118	**3.28**	**0.32**
OH57 1 Stillwater River (Brush Creek to Great Miami R.) EWH - Englewood Dam Pool													
14.2	0.0	**40**	**28**	**52**	**2**	0.12	0.07	7.1	7.1	0.59	30	0.49	0.15
OH57 1 Stillwater River (Brush Creek to Great Miami R.) EWH													
14.2	0.0	-	53	85	0	0.13	0.06	5.3	6.5	0.64	55	0.55	0.19
OH57 3 Mill Creek WWH													
5.7	0.0	**22**	**22**	**51**	**4**	0.50	0.09	4.3	5.6	**2.45**	438	0.48	0.08
OH57 4 Brush Creek WWH													
6.0	0.0	36	41	63	0	0.05	0.05	2.0	2.0	1.47	10	0.26	0.05

Table 3.1. Continued.

WBID River URM	LRM	ICI Min	IBI Min	QHEI‡	HIMA[a†]	Ammonia-N* Max†	Ammonia-N* Max‡	D.O. Min†	D.O. Min‡	TKN[‡b]	Fecal Col[‡◊]	NO_x-N[‡b]	TP[‡b]
MWH		22	24	45	≤3	7.3	1.2	3.0	4.0	4.0	1000	3.0	0.30
WWH		32	36	60	≤1	7.3	0.8	4.0	5.0	1.0	1000	1.0	0.08
EWH		42	46	75	0	4.5	0.8	5.0	6.0	1.0	1000	0.5	0.05
OH5716 Opossum Run EWH													
2.0	0.0	48	46	70	0	0.07	0.06	6.4	6.4	0.66	285	0.23	0.06
OH57 18 Painter Creek MWH													
19.7	5.5	**4**	**12**	**32**	**5**	6.17*	**1.20**	**1.9**	**2.8**	0.10	**4249**	2.22	0.36
OH57 18.x Painter Creek WWH (new segment based on use designation break)													
5.5	0.0	36	**33**	78	0	0.14	0.09	5.0	5.0	0.68	150	0.78	0.17
OH57 19 Little Painter Creek MWH													
5.2	0.0	**20**	34	**44**	**2**	0.25	0.13	4.8	4.8	1.13	170	0.59	0.07
OH57 7 Ludlow Creek WWH													
13.5	0.0	32	36	67	3	0.15	0.06	3.5	4.4	1.96	891	0.40	0.11
OH57 8 Brush Creek WWH													
8.0	0.0	**0**	38	**57**	**3**	0.09	0.06	3.3	3.3	**3.51**	140	0.64	0.20
OH57 10 Hog Run WWH													
2.3	0.0	32	48	70	1	0.10	0.07	5.6	5.6	10.51	135	0.64	1.53
OH57 20 Heller Ditch MWH													
4.1	0.0	32	26	43	4	0.08	0.06	4.5	4.5	0.43	250	0.56	0.07

Table 3.1. Continued.

WBID River URM	LRM	ICI Min	IBI Min	QHEI‡	HIMA[a†]	Ammonia-N* Max†	Ammonia-N* Max‡	D.O. Min†	D.O. Min‡	TKN[‡b]	Fecal Col[‡◊]	NO_x-N[‡b]	TP[‡b]
MWH		22	24	45	≤3	7.3	.2	3.0	4.0	4.0	1000	3.0	0.30
WWH		32	36	60	≤1	7.3	0.8	4.0	5.0	1.0	1000	1.0	0.08
EWH		42	46	75	0	4.5	0.8	5.0	6.0	1.0	1000	0.5	0.05
OH57 38 Harris Creek WWH													
9.1	0.0	36	**30**	**40**	**3**	0.19	0.12	5.6	5.9	0.89	**2633**	0.50	0.31
OH57 39 Ballinger Run WWH													
4.6	0.0	**0**	**25**	59	1	3.06*	0.53	4.3	6.0	**3.14**	**48193**	1.42	1.26
OH57 32 Greenville Creek (Headwaters to West Branch) EWH													
40.5	24.3	42	**45**	**64**	**1**	0.09	0.05	5.6	6.7	0.42	336	0.27	0.13
OH57 26 Greenville Creek (West Br. To Dividing Br.) WWH													
24.3	15.2	**26**	36	**56**	**2**	0.75	0.18	4.8	5.9	**2.23**	**1436**	0.48	**0.49**
OH57 21 Greenville Creek (Dividing Br. To Stillwater R.) EWH													
15.2	0.0	44	**37**	80	0	0.07	0.05	6.0	7.1	**1.89**	84	0.35	**0.28**
OH57 22 Mcquay Ditch WWH													
3.2	0.0	44	36	56	2	0.31	0.11	3.5	3.5	2.06	6043	0.56	0.13
OH57 23 Poplar Ditch WWH													
2.4	0.0	44	52	61	2	0.05	0.05	7.3	7.3	1.98	2550	0.32	0.11
OH57 24 Bolton Run WWH													
3.5	0.0	32	50	45	3	0.19	0.10	4.8	4.8	0.21	2050	0.29	0.15

Table 3.1. Continued.

WBID River URM	LRM	ICI Min	IBI Min	QHEI‡	HIMA^{a†}	Ammonia-N* Max†	Ammonia-N* Max‡	D.O. Min†	D.O. Min‡	TKN$^{\ddagger b}$	Fecal Col$^{\ddagger\diamond}$	NO_x-N$^{\ddagger b}$	TP$^{\ddagger b}$
MWH		22	24	45	≤3	7.3	1.2	3.0	4.0	4.0	1000	3.0	0.30
WWH		32	36	60	≤1	7.3	0.8	4.0	5.0	1.0	1000	1.0	0.08
EWH		42	46	75	0	4.5	0.8	5.0	6.0	1.0	1000	0.5	0.05
OH57 25 Dividing Branch WWH													
7	0.0	32	48	41	3	0.06	0.05	4.3	4.3	0.28	845	0.46	0.11
OH57 27 Bridge Creek WWH													
4.6	0.0	54	38	39	3	0.18	0.10	8.6	8.6	0.99	1215	0.35	0.14
OH57 28 Mud Creek WWH													
8.0	0.0	40	42	58	3	0.34	0.06	2.5	2.5	0.30	1070	0.25	0.08
OH57 29 Prairie Outlet WWH													
2.0	0.0	**28**	36	**40**	**5**	0.15	0.09	5.2	5.2	**1.20**	**10846**	0.30	0.10
OH57 30 West Branch WWH													
11.4	0.0	38	44	57	3	0.05	0.05	6.8	7.1	0.66	724	0.23	0.07
OH57 31 Spring Branch WWH													
0.5	0.0	32	48	57	1	0.05	0.05	7.4	7.4	0.60	155	0.22	0.10
OH57 33 Kraut Creek WWH													
7.0	0.0	44	42	66	1	0.06	0.05	6.5	8.1	0.61	358	0.32	0.07
OH57 34 North Fork Kraut Creek WWH													
2.7	0.0	38	46	56	1	0.05	0.05	8.3	8.3	0.72	390	0.22	0.11

Table 3.1. Continued.

WBID River URM	LRM	ICI Min	IBI Min	QHEI[‡]	HIMA[a†]	Ammonia-N* Max[†]	Ammonia-N* Max[‡]	D.O. Min[†]	D.O. Min[‡]	TKN[‡b]	Fecal Col[‡◊]	NO_x-N[‡b]	TP[‡b]
MWH		22	24	45	≤3	7.3	1.2	3.0	4.0	4.0	1000	3.0	0.30
WWH		32	36	60	≤1	7.3	0.8	4.0	5.0	1.0	1000	1.0	0.08
EWH		42	46	75	0	4.5	0.8	5.0	6.0	1.0	1000	0.5	0.05
OH57 35 Dismal Creek WWH													
9.5	0.0	32	**27**	**48**	**3**	0.32	0.12	**2.8**	**4.2**	0.37	604	0.47	0.36
OH57 40 Trotters Creek WWH													
4.8	0.0	44	48	74	0	0.11	0.10	2.8	2.8	0.10	1265	0.24	0.12
OH57 41 Swamp Creek MWH													
13.8	6.5	28	**17**	**34**	**3**	0.26	0.08	**2.5**	**2.8**	0.12	**2383**	0.76	0.32
OH57 41.x Swamp Creek WWH (new segment based on use designation break)													
6.5	0.0	**26**	**27**	**40**	**3**	0.45	0.14	**3.6**	**4.9**	**1.24**	**8635**	0.80	**0.69**
OH57 42 Indian Creek MWH													
5.2	0.0	**12**	**20**	**38**	**4**	1.55	0.14	**1.4**	**2.7**	0.17	797	0.72	0.16
OH57 44 Boyd Creek MWH													
3.3	0.0	**20**	34	45	2	0.13	0.10	4.9	4.9	0.63	**1118**	0.47	0.16
OH57 46 North Fork Stillwater River MWH													
7.7	0.0	**0**	**12**	**31**	**4**	3.22*	0.29	**2.2**	**3.3**	0.18	**1024**	1.10	**0.42**
OH57 47 Woodington Run WWH													
3.4	0.0	**22**	42	**51**	**2**	0.06	0.05	**3.4**	**4.1**	0.10	247	0.41	0.16

Table 3.1. Continued.

WBID River		ICI	IBI			Ammonia-N*		D.O.					
URM	LRM	Min	Min	QHEI[‡]	HIMA[a†]	Max[†]	Max[‡]	Min[†]	Min[‡]	TKN[‡b]	Fecal Col[‡◊]	NO_x-N[‡b]	TP[‡b]
MWH		22	24	45	≤3	7.3	1.2	3.0	4.0	4.0	1000	3.0	0.30
WWH		32	36	60	≤1	7.3	0.8	4.0	5.0	1.0	1000	1.0	0.08
EWH		42	46	75	0	4.5	0.8	5.0	6.0	1.0	1000	0.5	0.05
OH57 48 South Fork Stillwater River WWH													
7.0	0.0	**20**	38	**44**	**3**	0.25	0.09	5.3	5.3	0.11	325	0.66	0.13
OH57 7.1 Trib. To Ludlow Creek (Rm 11.80) MWH													
4.35	0.0	32	26	42	3	0.16	0.07	6.1	6.1	3.50	29000	0.41	0.20
OH57 37.1 Trib. To Stillwater R. (Rm 32.60) WWH													
2.4	0.0	38	**34**	64	0	0.08	0.06	7.0	7.0	**3.08**	**30225**	0.27	0.13
OH57 28.2 Lake Branch Ditch WWH													
5.55	0.0	54	54	56	1	0.06	0.05	5.8	5.8	0.53	5100	0.31	0.11
OH57 41.1 Trib. To Swamp Creek (Rm 3.54) MWH													
5.11	0.0	24	24	56	4	0.28	0.11	1.4	1.4	0.39	90	1.09	0.42
OH57 37.2 Trib. To Stillwater R. (Rm 38.30) WWH													
2.43	0.0	**12**	**28**	**37**	0	0.71	0.25	**1.5**	**1.5**	0.11	**10535**	0.88	0.42
OH57 48.1 Trib. To S. Fk. Stillwater R. (Rm 0.94) MWH													
4.78	0.0	**20**	32	**29**	**5**	0.05	0.05	4.4	4.4	0.10	85	0.60	0.16

[‡] Table values are the segment average.
[†] Table values are the extreme (maximum or minimum) value
[a] HIMA - High Influence Modified Habitat Attributes
[b] Target values are adopted from Ohio EPA (1999; *i.e.*, the Associations Report).
* Specific numeric water quality exist in OAC 3745-1-07, Tables 7-3 through 7-8; target values are guidelines based on the 75th percentile values of temperature (24°C) and field pH (8.1) from all samples collected during the 1999 Stillwater survey.
[◊] Specific numeric water quality exist in OAC 3745-1-07, Table 7-2; target values are based on Primary Contact Recreation.

4.0 Load Development and Allocation

Relative to the 2004 TMDL, the revised TMDL development effort considers the following improvements:

1) Spatial resolution of the modeling analysis was increased by using a smaller watershed unit. In the 2004 report, if an impairment existed in the larger watershed unit, responsibility for load reductions was assigned to all of the sectors in the entire unit. Using the same technique on smaller watershed units allows for a more discrete analysis. Model boundaries now exactly match 12-digit HUC boundaries. Aquatic life use (ALU) designation and attainment were determined for each 12-digit HUC. Refer to Section 1.2 and Table 1.2 for discussion of watershed unit size.

2) ALU impairment was now assessed at both the subbasin (i.e., HUC 12) and the reach segment level. The latter assessment was included to determine if an NPDES discharger would receive a load reduction or not. Load reduction decisions for NPS, MS4 stormwater, and home sewage treatment systems (HSTS) were still made at the subbasin level.

3) HSTS contributions were simulated as a point-source with the assumption that all failing systems were indirect contributions to the stream. For this model version, all WWTP and HSTS were built *inside* the model input and routed through each HUC.

4) As previously done, calibration of hydrology was again made to three USGS continuous flow gauges within the watershed. However, daily, monthly, seasonal, and yearly comparisons were made. In this version, model comparison diagnostics were improved according to recommendations by Moriasi et al. (2007). Further, an independent subset of observed flow data was used for hydrology *validation*.

5) Calibration of nutrients (total phosphorus and nitrate-nitrite) was performed at the long-term Ohio EPA ambient monitoring location. Further, a general comparison of model loads to Miami Conservancy District (MCD) observed daily loads for total phosphorus, ortho-phosphate, and nitrate-nitrite was also made. In the first version (April 2004), no systematic calibration of model chemistry was made.

6) Model realism for manure application rates was improved in this version to address concerns raised in the 2004 report results. Manure application rates were determined based on a 2003 Darke and Miami County livestock inventory (MVRPC 2003a, 2003b). Hence, for each model subunit, the manure application rate matches the expected manure yield from the total animal count per subbasin reported in the livestock inventory. Further, model crop yields match 2000-2007 NASS reported yields for corn, soybean, and winter wheat.

7) Model channel dimensions and baseflow recession are more realistic in this version. Channel bankfull width and depth were derived from a regional curve developed for the middle latitudes of Ohio (D. Mecklenberg, 2008; personal communication). Also, the baseflow recession coefficient derived from the long-term flow record for each of the three USGS gauges was applied to each of the corresponding drainage systems.

4.1 Method of Calculation

Nutrient and organic enrichment and habitat degradation were the primary causes of impairment for the Stillwater River TMDL according to the 2001 TSD. This report revision addresses the enrichment aspect as a cause of impairment using the following methodology:

1) Determine load contributions from nonpoint source activities originating on the watershed landscape, primarily from the intensive animal feeding operations and row-crop agriculture.

2) Account for load contributions arising from all wastewater sources in the watershed (namely those dischargers having conduit loads exceeding 0.02 MGD).

3) Determine load contributions from MS4 stormwater zones using the model-generated overland flow nutrient load.

4) Estimate load contributions from residential septic systems (or onsite sewage systems) – an atypical point-source of nutrient and organic enrichment – as a component of total load reduction strategy.

4.1.1 Estimating Loads from SWAT

Nutrient loading and flow in the Stillwater River watershed from the major pollution sectors – agricultural NPS, HSTS, stormwater, and WWTP – was simulated using the Soil and Water Assessment Tool (SWAT). SWAT is a river basin-scale model developed by the USDA ARS at the Blackland (Texas) Research Center (Arnold et al. 1998; Srinivasan, R. et al. 1998). The particular version used was ArcSWAT v.2.1.4a (12/06/2008) which is the most recent version of the model coupled with the ESRI ArcMap interface. SWAT is a physically based model that operates on a daily time step (continuously) and efficiently over several years. It is not designed to simulate single-event flooding. SWAT has been used extensively in the USA for TMDL applications (e.g., Wisconsin, Illinois, Texas, Ohio – Black R and Wabash R watersheds) and has been accepted by USEPA as a modeling strategy for TMDL load development (USEPA 1999).

The model geometry consists of one complete watershed that is composed of 44 subbasin units (see Figure 4.1). These subbasins were based on the 12-digit USGS Hydrologic Unit Code (HUC) boundaries. There are total of 27 12-digit HUCs in the watershed but for particular HUCs with major stream confluences, the HUC was subdivided into two or three subunits. Each TMDL assessment unit (AU) comprises one of the 44 SWAT subbasins. Within each subbasin are an array of hydrologic representative units (HRUs), one main channel (that enables connection of subbasin to another), and one tributary channel that connects to a main channel. HRUs are unique combination of soil map unit (and associated textural and physical attributes) and land use/management. Both HRUs and tributary channels are soley attributional in nature and possess no specific geographic location.

Multiple point source discharges were simulated within a single basin; however, each effluent contribution was deposited into the reach at the beginning of the SWAT subbasin unit. On the basis of average design flow exceeding 0.02 MGD, 22 wastewater dischargers were included in the revised Stillwater SWAT model (Tables 4.1 and 4.7). For dischargers with average design flows below 0.02 MGD, no load reductions were considered and the facility would be allowed to discharge at design flow and PEQ-average total phosphorus concentration.

No in-stream impoundments were simulated in this model version. Englewood Reservoir has no control structures (other than an indirect regulation through a fixed height spillway) and water flows continuously. Daily precipitation data was compiled for the entire model period for 13 stations (data obtained from Miami Conservancy District) distributed within and beyond the watershed boundary. Evapotranspiration was simulated using the Priestly-Taylor method (1972) which is a simpler form of the Penman-Monteith (Penman, 1965). The selected method better reproduced average magnitudes expected for Ohio (shown in Brown, 1994).

The Stillwater River watershed, like most medium-sized agricultural operations in the eastern Midwest, has a complex mixture of agricultural management practices. In consultation with a regional nutrient management specialist, the USDA District Conservationist for Darke County, and the Stillwater SWCD watershed coordinator, a detailed, realistic set of scenarios were developed for this simulation. The scenarios comprise varying crop rotation, tillage practice, fertilizer type, and fertilizer application rate (Table 4.2). Each of the scenarios is portrayed in detail in Appendix C.3.

Detailed information on livestock types and numbers was provided by the Stillwater Watershed Project (the stakeholder group representing this watershed) from the 2003 Darke and Miami County livestock inventory (MVRPC 2003a, 2003b). This information was used to calibrate manure loads by amount for each of the 44 model subbasins. A simplifying assumption was made that the rate or yield (i.e., mass per area) of applied manure per model subbasin was solely a function of the numbers located within the same subbasin. While estimates of manure application rate were the best possible without having a farm-by-farm survey made available to the Ohio EPA, some subbasin estimates may be higher than actual due to export of poultry manure outside the watershed domain (Joint SWCD Board, personal communication; 2009). However, the SWCD board also commented that poultry manure may also be imported into the watershed domain but were unsure if it would offset exports.

4.1.2 Calibration of Flow Hydrology

This version of the SWAT model was calibrated for hydrology using three US Geological Survey hydrologic gauges that exist within the watershed. Station biographies are depicted in Table 4.3. The SWAT model was executed over the period January 1999 to July 2008 (about 9.5 years). The model calibration phase extended from 2001-2007 and the model validation phase was for the individual years 2000 and 2008. The period 2001-2007 was chosen for calibration because it included both low and high annual streamflow amounts. The calibration process progressed in a downstream direction by first adjusting parameters in the Bradford drainage system. Once the best match was obtained for this gage, these parameters were held constant and then adjustments to parameters in the Pleasant Hill interim drainage were made. The process concluded with parameter adjustments only for the Englewood interim drainage. The sequence of adjustments is documented in Appendix C.1.a.

For calibrating hydrology, comparisons were made for:

1) Daily: total streamflow (surface runoff + baseflow) using a graphical technique (percent exceedence probability curve), a dimensionless model evaluation statistic (Nash-Sutcliffe efficiency index or E_{NS}), and an error index (percent bias or PBIAS).

2) Annual: total streamflow, surface runoff, baseflow, and baseflow ratio (baseflow divided by total streamflow) using graphical techniques (cross-plots and histogram), dimensionless statistics (E_{NS} and the average relative difference), a regression statistic (coefficient of determination or R^2), and simple univariate measures (mean, standard deviation).

3) Seasonal: total streamflow, surface runoff, baseflow, and baseflow ratio using graphical techniques (cross-plots and histogram), dimensionless statistics (E_{NS} and the average relative difference), and simple univariate measures (mean, standard deviation). Seasonal boundaries were defined relative to typical meteorological divisions as: winter (January, February), spring (March through June), summer (July through September), and autumn (October through December).

4) Monthly: surface runoff, baseflow, and baseflow ratio using graphical techniques (cross-plots and histogram), dimensionless statistics (E_{NS} and the average relative difference), and simple univariate measures (mean, standard deviation).

Baseflow separation from total streamflow was made using the USGS PART method (Rutledge 1998). Baseflow recession coefficients were computed using the filter produced by Arnold and Allen (1999). For monthly comparisons, some care should be exercised in interpreting baseflow estimates as baseflow separation algorithms are least robust at this temporal discretization.

E_{NS} and PBIAS are described in Moriasi et al. (2007) and Van Liew et al. (2007). All calibration and validation results are reported in Appendix C.1.b – C.1.d for each of the three drainage systems (one for each USGS gauge). Performance goals for E_{NS}, PBIAS, and average relative difference statistics are included adjacent to the result reported for this study. Ranges of values reported from numerous studies for calibration and validation of total streamflow and surface runoff, among other parameters, are reported in Moriasi et al. (2007; their Table 1). In general, model simulation of streamflow can be judged as “satisfactory” if $E_{NS} > 0.50$ and PBIAS ± 25 percent (Moriasi et al. 2007). In this calibration, generally all three drainage systems meet or exceed these performance ratings.

4.1.3 Calibration of Total Phosphorus and Nitrate-Nitrite

For this version, SWAT nutrient loads were calibrated using observed data measured from Ohio EPA's long-term ambient monitoring site at Stillwater River at Pleasant Hill. A total of 88 nutrient grab samples were taken from the same location as the USGS flow gauge from the period 2000-2008. Model parameters were adjusted in three areas: 1) fertilizer application rate and timing, 2) surface management such as incorporation by tillage and residue management, and 3) instream processes (Appendix C.2.a). Graphical and numerical comparisons are shown in Appendix C.2.b and c. Nitrate loads were better predicted than total phosphorus loads as the trace was fairly well matched. Several of the high magnitude loads were overpredicted (by 7-50 times) for total phosphorus but low magnitude loads were fairly well matched. Matching loads for single events in time (mass per day) is difficult if stormflow peaks are not calibrated.

For chemistry calibration, there is insufficient observed data to generate model statistics sufficient for comparing to monthly (only aggregation published) performance standards identified in Moriasi et al. (2007).

The provision of measured daily concentrations of nutrients from Miami Conservancy District (MCD) sampling allowed for additional comparison of model generated loads at Stillwater River at Englewood (Appendix C.2.d through f). While MCD sampling is ongoing, this comparison extended from period April 2005 to July 2008. When examining the time trace, ortho-phosphorus, nitrate, and total nitrogen were fairly well matched. However, as with the Pleasant Hill location, total phosphorus loads were over predicted for several high magnitude events (Appendix C.2.d). When comparisons were done on an annual basis, the match of model predicted to observed MCD loads approximate a 1:1 relationship with some years (for example, 2007 and 2008 for total phosphorus) matching more closely than other years (2006) (Appendix C.2.e and f).

4.2 Critical Conditions and Seasonality

The critical condition is defined as the set of environmental conditions that, if controls are designed to be protective of them, will ensure attainment of objectives for all other conditions. The argument that the critical condition for meeting a total phosphorus target applies to the entire year was established in the previous version (April 2004) of this TMDL. Here nutrient sources in the Stillwater River watershed arose primarily from wet weather conditions and most of the mass inputs occurred from November through June. However, the most severe eutrophy was observed in the low flow (summer) period. Hence, we applied the total P target to all seasons of the year.

Seasonality was addressed in the Stillwater River TMDL by using the calibrated SWAT model to simulate *daily* loadings over the period 2002-2007. In this model scenario, WWTP facilities were programmed to discharge at average design flow with total phosphorus concentrations set at average projected effluent quality (PEQ), or 2.5 mg-P/L when total phosphorus monitoring was not available in a facility's discharge monitoring report (DMR). The daily loadings were then aggregated to seasonal sums for each year of the simulation and the average of these sums (n = 6) was considered as the existing load for each model subunit. Existing loads, target (TMDL) loads, and percent reductions were developed by season: winter (Dec/Jan/Feb), spring

(Mar/Apr/May), summer (Jun/Jul/Aug), and autumn (Sep/Oct/Nov). Seasonality in model input was produced from observed daily precipitation and minimum/maximum temperatures, daily point source loadings, and crop management schedules. Crop management schedules included the rate and timing of synthetic dry and organic (manure) fertilizer. Thus, estimated loads are therefore reflective of seasonal changes in weather, treatment facility operating practices, and agricultural management practices.

4.3 Margin of Safety

An implicit margin of safety was incorporated into this TMDL through various aspects of the loading characterization, as follows:

1) The modeling approach employed a detailed simulation model (SWAT) employed over a fine HUC resolution representing land surface. Certain model parameters were selected for each of the model subunits (44 total) providing a finer spatial resolution of physical process representation. Model parameters adjusted by subunit include:
    a. hydrology:
        i. baseflow recession factor
        ii. soil moisture evaporation rate
        iii. runoff curve number
        iv. groundwater "evaporation" parameters
        v. available water capacity for soil
    b. chemistry:
        i. fertilizer application (both manure and synthetic)
        ii. crop rotation
        iii. tillage type, if any

    In addition the model employs 10 m land cover (USGS NLCD 2001) and digital elevation models, and NRCS SSURGO soil survey database. The latter having a much finer spatial resolution than the customarily used STATSGO soil database.

2) Some of the high nutrient loads are overestimated by the model, after weeks of chemistry calibration there was no success in reducing these very high loads. Hence, the total load reduction would be slightly overestimated and can be considered an implicit MOS.

3) Conservative calculations are used to estimate loads from point source dischargers. The PEQ-average is much higher than the median or mean of daily concentrations (loads), thus providing a "worst case" estimate of the load.

4) If multiple aquatic life use designations exist on a mainstem segment within a given 12-digit HUC, the most restrictive use designation applies. Also, non- or partial-attainment status determined *from only one* organism group is considered impaired. Downstream beneficial uses are protected, in the case of nutrient impairment – aquatic life use (ALU). Protection of downstream use was operationalized at the 12-digit HUC level. Even though a specific HUC was not impaired for ALU and for causes due to nutrient and/or organic enrichment, it could be assigned an allocation to protect the downstream,

contiguous HUC if that downstream HUC was impaired. If both the specific HUC and downstream HUC were impaired, then the most restrictive total phosphorus target would be applied.

5) The selected nutrient targets are conservative. A conservative assumption implicit in target development is in the selection of the median to represent the total phosphorus target that corresponds to an unimpaired biological community. Because Ohio EPA's evaluation of phosphorus data for generating target values is based on measured performance of aquatic life and because full attainment can be observed at concentrations above this target (reinforcing the concept that habitat and other factors play an important role in supporting fully functioning biological communities), water quality attainment can occur at levels higher than the target. The difference between the actual level where attainment can be achieved and the selected target is an implicit margin of safety.

4.4 TMDL Calculations

4.4.1 Target Estimation

Allowable TMDL loads considered concentrations based on target concentrations defined in Ohio EPA (1999) and *incremental* streamflow predicted by the SWAT model. Incremental streamflow was computed by subtracting the inflow from a given HUC – the inflow arising from one or two upstream HUCs. For headwater HUCs (i.e., no inflow), the total flow at its outlet is both an incremental and cumulative flow.

Target total phosphorus concentrations were defined by Ohio EPA (1999) as a function of drainage basin size and aquatic life use designation (Table 4.4). Assignment of target is based on the mainstem segment that drains each particular HUC. Figure 4.2 shows the assignment for each of the 44 model subbasin units; also shown is total P target, the ALU for each segment assigned a use, and point-based biological sampling results.

Table 4.5 also lists the impairment status, the use being protected (type and whether the downstream use was protected), and the total phosphorus target (in mg-P/L).

The TMDL (the load limit) and existing stressor loads were defined on a seasonal basis from daily model simulations of a 6-year period (2002-2007 inclusively). The seasons are: WI winter = December-January-February, SP spring = March-April-May, SU summer = June-July-August, AU autumn = September-October-November. In Table 4.5 distributed by season and 12-digit HUC, the allowable total phosphorus load (i.e., TMDL) and the net existing load are portrayed. Also shown in Table 4.5 are the total percentage reduction expected for each HUC and the distribution of responsibility for the load reduction by two categories: 1) NPDES discharge and HSTS and 2) nonpoint source (including MS4 stormwater).

There were no allowances for future growth made in the current TMDL equation. Englewood is bounded by incorporated cities that limit growth. Growth is unlikely in Greenville as sewer extensions are discouraged. Pittsburg is unlikely to grow even though sewer extensions are in development. West Milton plans to expand their WWTP and subsume a few surrounding unsewered areas; that would result in increased effluent flow. Union WWTP appears to be the destination of the Philipsburg area sewer region. The Union WWTP plans expansion but intends to land apply as much effluent as possible.

Stressor or impairment sectors are defined as: point source discharge, non-point source discharge (limited to manure-fertilizer and synthetic-fertilizer applied to agricultural row crop), residential septic systems (on-site sewage disposal), and municipal stormwater discharge. Load estimations were defined for each of these sectors to determine the relative accountability in meeting the TMDL. The existing net load, derived from SWAT daily simulations, and TMDL allowance for each sector is portrayed in Table 4.6.

4.4.2 Protection of Downstream Uses

Load allocations and wasteload allocations are prescribed to model subunits that have a non- or partial-attainment (aquatic life use) status. Attainment status is derived from point-based biological sampling listed in Table 2.1. The status of points co-located on the mainstem segment passing through HUC12 is used as the primary determinant. Also, the worst-case status would be applied.

If the HUC12 is not impaired based on above but if the next downstream HUC12 is impaired, then the existing HUC would be assigned a target according to this downstream attainment status. Further, the downstream use is only protected by the adjacent upstream HUC.

For cases where the current HUC12 is impaired and the next downstream HUC12 is also impaired, the most restrictive impairment will be applied. This condition is labeled “impaired but protecting downstream use” and appears in Table 4.5 (label = “yd”), Table 4.1 (…protecting… in column labeled 2009 ambient target), and Figure 4.2.

The only aquatic life-use impairment considered for the Stillwater TMDL total P model is “non” or “partial” and that caused by “nutrient enrichment and/or organic enrichment.” Also, attainment status defined by only one organism group [(non) or (partial)] is also considered impaired (MOS). A minimum of one non-attaining sample site (in Table 2.1) is needed for a HUC to receive an impaired status.

Protection of downstream beneficial use is supported in 40CFR 131.10(b), OAC 3745-2-08, OAC 3645-1-05(D)(3)(b), and OAC 3645-1-05(D)(5)(a). Specifically, the language states in:

a) 40CFR 131.10(b) states that “…the State shall take into consideration the water quality standards of downstream waters and shall ensure that its water quality standards provide for the attainment and maintenance of the water quality standards of downstream waters.”
b) OAC 3745-2-08 requires mixing zone demonstrations to consider the downstream use.
c) OAC 3645-1-05(D)(3)(a) and (b) affords protection to downstream lakes, reservoirs, wetlands, exceptional warmwater habitats, …, etc. from any net increase in the discharge of regulated pollutants [paragraph (a)] and nutrients [paragraph (b)].

4.4.3 Point Source Discharge (Wasteload Allocation)

Observed daily wastewater loads for 22 NPDES dischargers above a 0.02 MGD average design flow (ADF) were included in the SWAT model (from Table 4.1). Nutrient loads (including all species of nitrogen and phosphorus) were calculated for these entities according to procedures outlined in Appendix C.4). Unique, daily quantities of flow and load, as reported from a facility's DMR, were used in the simulation. All (both above and below 0.02 MGD ADF) NPDES facilities that discharge into the Stillwater River system are portrayed in Table 4.7. The ADF and existing flow (using a PEQ-average calculation of conduit flow) are both shown for comparison. Some facilities were included in the model strictly for determining a precise flow balance. Facilities that discharge on an intermittent basis (e.g., sand and gravel operations, campgrounds) were easily accommodated in the SWAT daily simulation.

Wasteload allocations for all facilities shown in Table 4.7 are portrayed in Table 4.8. Allocations were distributed seasonally; the calculated allowable total phosphorus concentration was computed using the facility's ADF. In HUCs that were not impaired for organic or nutrient enrichment or for segments not impaired downstream of a given discharger, no load reduction was computed. These facilities could be expected to discharge at design flow and PEQ-average total phosphorus concentrations. Also, facilities that are designed below 0.02 MGD ADF would be allowed to discharge at their ADF and PEQ-average total phosphorus concentration (or 2.5 mg-P/L if no phosphorus DMR information exists). These small facilities were not part of the SWAT simulation so their wasteload allocation was taken from the larger non-point source load allocation.

4.4.4 Nonpoint Source Contributions (Load Allocation)

Based on biological assessments, measured in-stream nutrient concentrations, and observed nutrient-related nuisance conditions, the sector labeled "non-point source discharge" focussed on the rate and timing of organic manure and synthetic fertilizer applied to cropland. Detailed agricultural management scenarios were developed for each SWAT model sub-basin within each assessment unit to portray the load generation as accurately as possible. Appendix C.3 documents each of the six possible management scenarios for selected model subunits. The rate or yield (i.e., mass per area) of applied manure per model subunit was solely a function of the numbers (housed in AFOs) located within the same subunit. Manure application rates were established according to the Darke and Miami SWCD 2002-2003 livestock inventories. A generic manure type was applied in all instances; the composition of this type represented the average concentration of nitrogen and phosphorus species (e.g., mineralized P or ortho-P) for beef cattle, dairy cattle, swine, and poultry. Numerical values of net existing loads from agriculture fertilizer sources and their respected load allocations are portrayed by season in Table 4.6.

4.4.5 Stormwater (Wasteload Allocation)

An assessment of the nutrient contributions from identified stormwater-generating communities was made in this TMDL. Jurisdictions required to meet stormwater discharge guidelines under the Small Municipal Separate Storm Sewer System (MS4) program (i.e., Phase II) include the

Greenville Urban Cluster and the Dayton Urbanized Area. The Greenville Urban Cluster occupies parts of HUCs -09-04, -09-06, -11-01, and -11-02 within the 8-digit HUC 05080001. All HUCs within the Dayton Urbanized Area are not impaired. Because MS4 allocations are land surface derived, their contribution was a component of the SWAT simulated nonpoint source load; the amount of the existing load was based on the percentage land area occupied by MS4 within each model subunit. Net existing and wasteload allocations for MS4 stormwater zones are portrayed by season in Table 4.6.

4.4.6 Home Sewage Treatment Systems (Load Allocation)

A total number and number of failing home sewage treatment systems (HSTS) were assigned to each model subunit based on procedures developed in the first version (April 2004) of the Stillwater TMDL. To summarize, the total number of systems was taken from 1990 US Census Bureau block group under parameter: type of sewage system. Then the number of people using a septic system was determined by US Census 2000 block group data on average size of household and number of households. The per capita mass loading rate was taken from the US EPA design manual for on-site wastewater treatment and disposal systems (USEPA 2002; their Table 3-7). Several geographic factors were considered that might predict whether the septic system was functioning or failing – age of house, soil permeability, and soil drainage class. For this approach, no directly connected HSTS-to-stream scenario was considered under failing systems. All failing systems were considered either ponded or improperly designed leach field. Under the SWAT simulation, the septic discharge from failing systems was input into the top of each mainstem segment within each HUC and subsequently processed within the channel. Net existing and load allocations for HSTS are portrayed by season in Table 4.6.

4.4.7 Combined Sewer Overflows

Known combined sewer overflows (CSO) regions have existed for the communities of Ansonia, Arcanum, and Bradford prior to the completion of the first Stillwater TMDL. These discharges have now been remediated or will be remediated within the next 1-1.5 years so that their load exceedence can be completely remediated by NPDES regulatory authority.

Ansonia’s NPDES permit included a schedule to completely separate their sewers and eliminate all overflows by July 2010. They once had 10 permitted CSO outfalls for which they were required to report flow occurrence, flow rate, duration of flow, TSS, and CBOD. As of the writing of this report, Ansonia’s entire system has been separated; items remaining including capping or removing of overflow structures.

Arcanum’s NPDES permit included a schedule to completely separate their sewers from stormwater flow and eliminate all overflows by May 2010. They once had 3 permitted CSO outfalls and were required to report flow occurrence, flow rate, duration of flow, TSS, and CBOD. Arcanum began construction in February 2009 on the third (and final) phase of sewer separation. The current project will separate the remaining 25 percent of the collection system and eliminate the remaining 3 CSO outfalls. By February 2010, their system will be entirely separated.

Bradford's NPDES permit included a schedule to completely separate their sewers and eliminate all overflows by January 2013. They currently have two permitted CSO outfalls and are required to report flow occurrence, flow volume, fecal coliform, TSS, and CBOD. As of this report writing, Bradford has completed 85 percent of their sewer separation and two CSO outfalls remain.

4.4.8 Summary of Load Allocations

Table 4.9 presents a summary of the TMDL, load allocations, and wasteload allocations organized by 12-digit HUC and season, expressed in terms of seasonal loads. Table 4.9a presents the same information expressed in terms of daily loads. The following general statements can be made about this TMDL analysis:

1) The goal of this analysis, in employing a deterministic water quality model such as SWAT, was to provide refined numerical load allocations over geographic space and time. In this report, load allocations were distributed by season of year and by assessment unit, including an allocation for the entire drainage basin.

2) Expressed as a percentage and magnitude of the TMDL, the non-point source discharge (agriculture fertilizer) was allocated the highest magnitude load for each of the seasons and for each of the 12-digit HUC assessment units.

3) Exceedence of total phosphorus goals occurs for every season for nearly all of the impaired assessment units.

4.5 Comparing the 2009 Results to the 2004 Results

This report revisits the loading analysis for total phosphorus completed for the 2004 TMDL report. The 2009 version of the model incorporates several improvements, such as the following:

- Better resolution in the analysis because a finer watershed scale was used
- More sophisticated routing of sewage inputs within the model
- More robust calibration of the watershed hydrology and chemistry in the model
- More realistic manure application rates based on livestock inventory data.

Altogether, the revised model is a more accurate representation of the watershed, so it provides a more reliable tool for predicting how much pollution the watershed can handle and still maintain water quality standards.

However, the many changes mean that a detailed comparison of results is not possible. A general comparison of results is provided in Table 4.10, showing the 2004 and 2009 results in terms of percent reduction required to meet the TMDL. Only annual results can be compared because seasons were defined differently in the two TMDLs. The structure of table illustrates the better resolution in the 2009 analysis. Note that in the 2009 analysis, some of the smaller watersheds are shown as not impaired. In the coarser 2004 analysis, these areas were grouped with the surrounding impaired areas and many received load reductions.

Figures 4.3 and 4.4 illustrate the differences in the results of the 2004 and 2009 TMDLs. In the two maps, "needed percent reduction" is the percent decrease in the amount of the existing total phosphorus load needed to meet water quality goals. A greater needed percent reduction means that the stream is further from the goal.

Table 4.11 shows the impact on point sources. In the new analysis, total phosphorus loads are lower for four point sources and higher for one. Permit limits for total phosphorus are no longer recommended for five communities. A few small communities will be encouraged to connect to larger wastewater systems, and these larger wastewater systems will be encouraged to allow the connection. Several specific areas need to eliminate or repair home sewage treatment systems.

Figure 4.1. Location of USGS 12-digit HUC boundaries within the Stillwater River watershed. All 12-digit HUC watersheds are located withing the 8-digit HUC 05080001 and the corresponding label shows only the 10-digit and 12-digit numeric couplets (i.e., last 4 digits of the 12-digit code). Simulation model subunit number is depicted as a red label (in parentheses). Background map shows county boundary.

Figure 4.2 Map of Stillwater River watershed showing aquatic life use designation (by reach), aquatic life use attainment (by point location), and assignment of aquatic life use impairment (by 12-digit HUC). The numerical label for each HUC is the total phosphorus target (in mg-P/L) obtained from the *Associations* document (Ohio EPA 1999) conditioned by drainage area and use designation for the mainstem segment in each HUC.

For use designation, EWH = exceptional warmwater habitat, WWH = warmwater habitat, MWH = modified warmwater habitat, and LRW = limited resource water. For use attainment, (full) or (non) implies only one organism group (i.e., fish or macroinvertebrates) was used in determining attainability. Use attainability decisions were obtained from the 2001 Stillwater TSD; for the lower HUC (05080001-14-06) use attainability was refined from 2008 biological sampling in the upper reach of the mainstem segment.

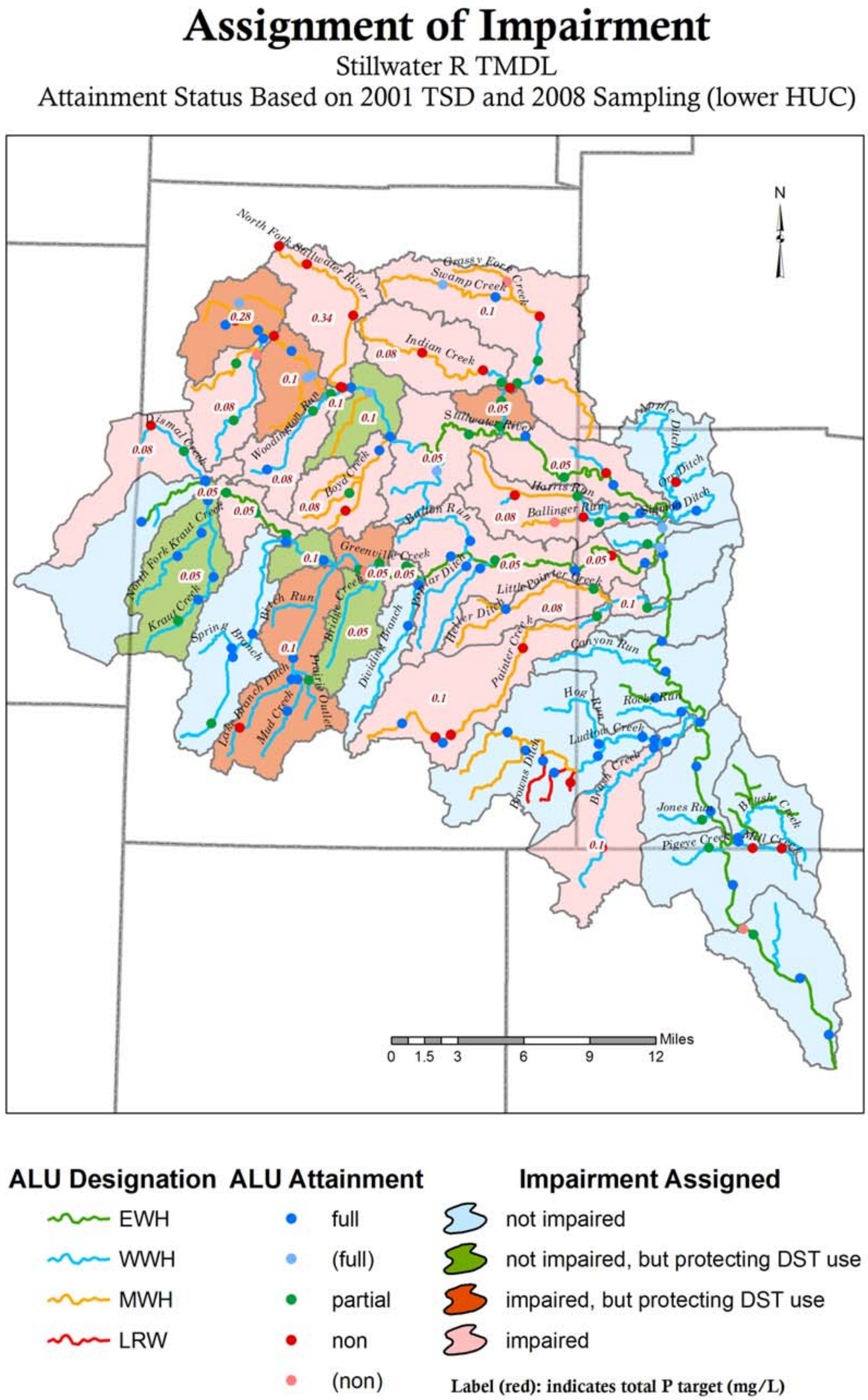
Assignment of Impairment
Stillwater R TMDL
Attainment Status Based on 2001 TSD and 2008 Sampling (lower HUC)
N
Miles
0 1.5 3 6 9 12
North Fork Stillwater River
Grassy Fork Creek
Swamp Creek
Indian Creek
Stillwater River
Woodington Run
Boyd Creek
Dismal Creek
North Fork Kraut Creek
Kraut Creek
Spring Branch
Birch Run
Bridge Creek
Greenville Creek
Ballou Run
Harris Run
Ballinger Run
Little Painter Creek
Painter Creek
Canyon Run
Dividing Branch
Mud Creek
Prairie Outlet
Hog Run
Rocky Run
Ludlow Creek
Brush Creek
Jones Run
Pigeye Creek
Mill Creek
ALU Designation
EWH
WWH
MWH
LRW
ALU Attainment
full
(full)
partial
non
(non)
Impairment Assigned
not impaired
not impaired, but protecting DST use
impaired, but protecting DST use
impaired
Label (red): indicates total P target (mg/L)

Figure 4.3 Needed percent reduction in total phosphorus load for meeting water quality goals: 2004 TMDL. (Refer to Section 4.5 and Table 4.10 for more detail.)

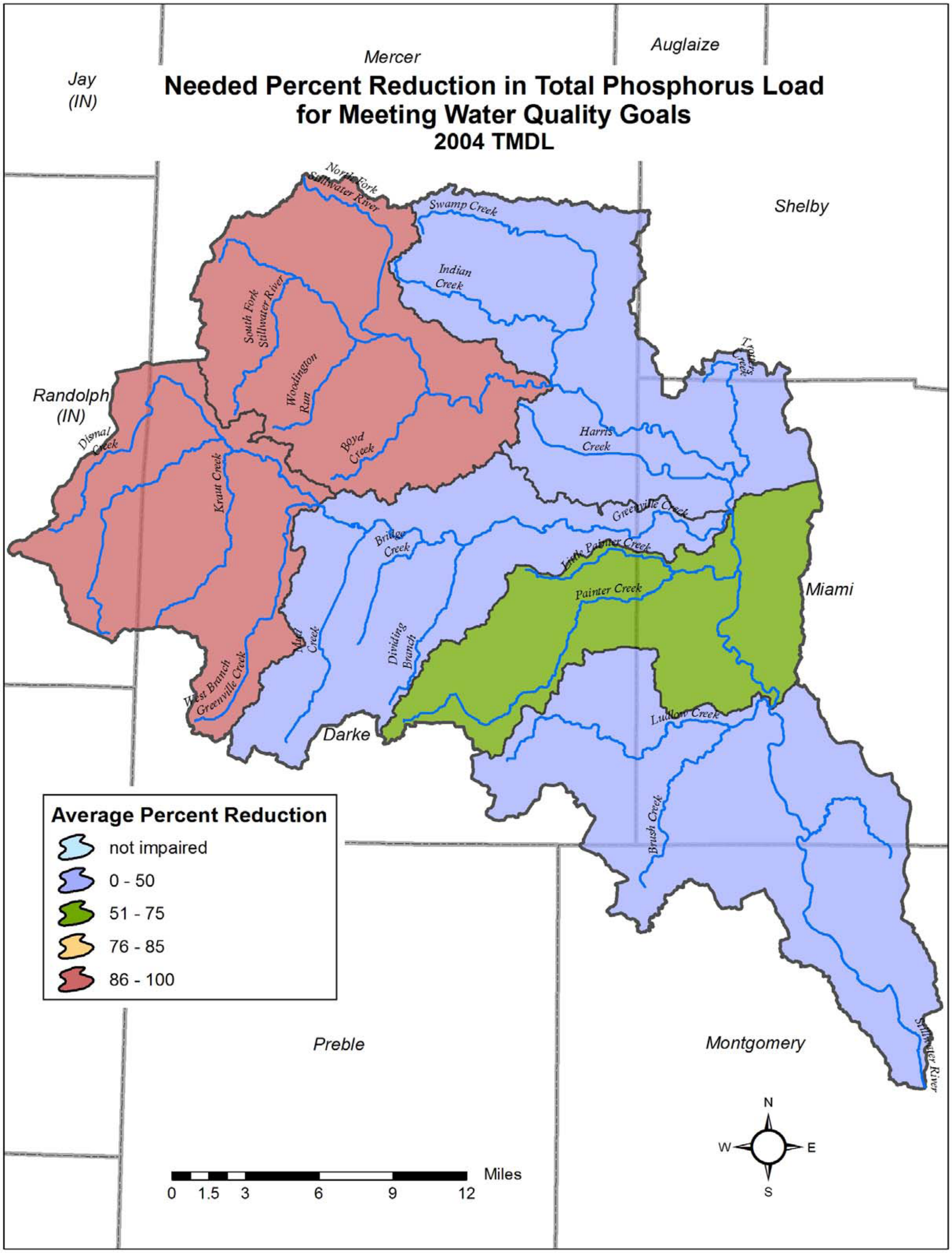

Figure 4.4 Needed percent reduction in total phosphorus load for meeting water quality goals: 2009 TMDL. (Refer to Section 4.5 and Table 4.10 for more detail.)

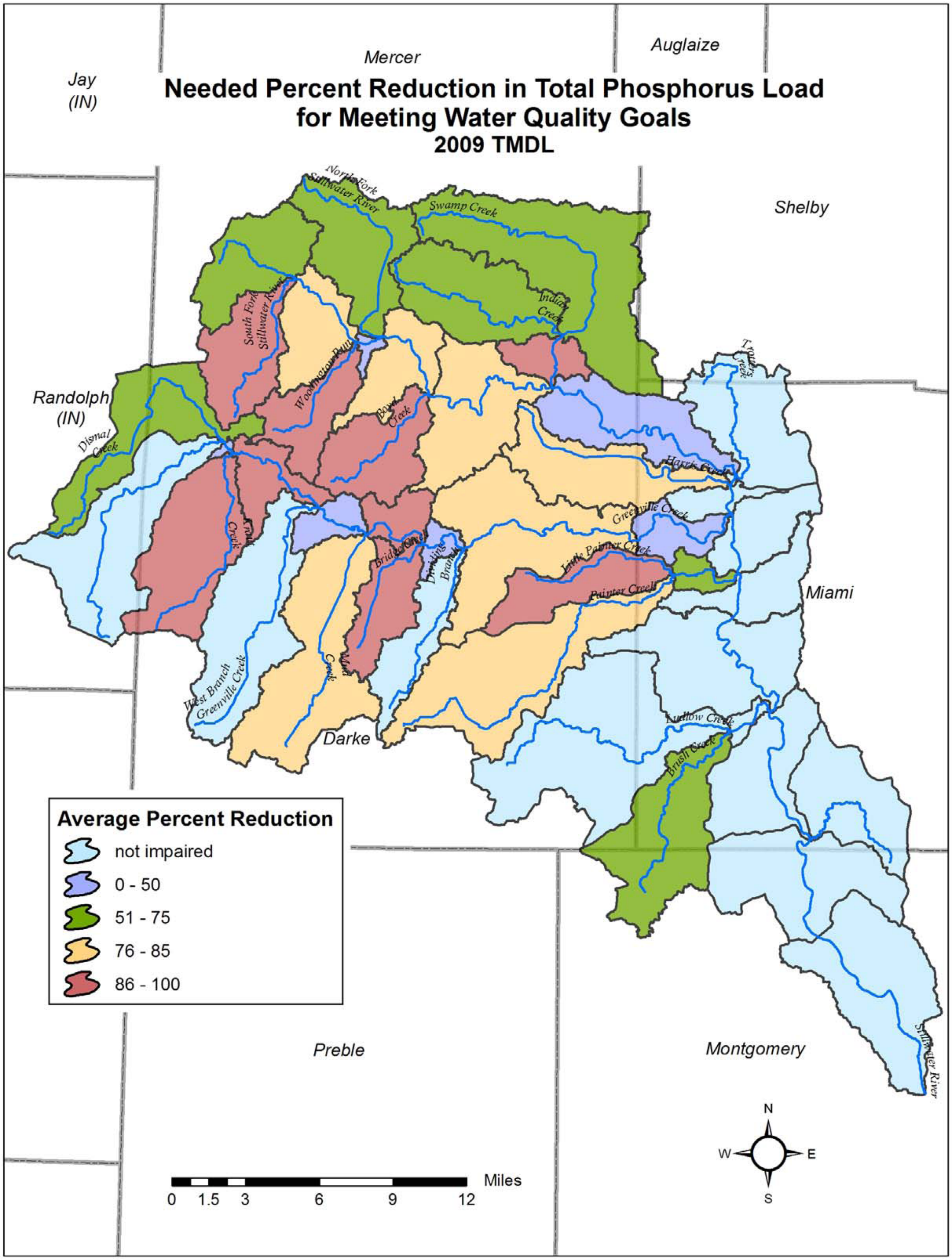

Table 4.1. Status of NPDES permit dischargers included in 2009-version of Stillwater TMDL SWAT model. Organized by 12-digit HUC. For ambient target, information in parentheses indicates the aquatic life-use designation as MWH=modified warmwater habitat, WWH=warmwater habitat, EWH=exceptional warmwater habitat, and river size as H=headwater, W=wading, S=small river. When "protecting" is shown, indicates the downstream aquatic life-use/river size being protected. "Flow accounting only" indicates the facility was included in the simulation model for hydrology mass balance but no phosphorus is discharged.

Facility #	Facility Name	Station	2004 ambient target (mg-P/L)	2004 effluent limit (mg-P/L)	2009 ambient target (mg-P/L)
05080001-09-04: Boyd Creek					
1PG00090	Rolin Acres Subdivision WWTP	001	none	none	0.08 (MWH, H protecting EWH, W)
1PW00045	Northtowne Apts	001	none	none	0.08 (MWH, H protecting EWH, W)
05080001-09-05: Woodington Run-Stillwater River					
1PB00005	Ansonia STP	001	0.1 (WWH, W)	0.6	0.05 (WWH, W protecting EWH, W)
05080001-11-01: Mud Creek					
1IJ00015	Shamrock Materials Ft Jefferson Limestone	001	none	none	flow accounting only
05080001-11-02: Bridge Creek-Greenville Creek					
1PD00005	Greenville WWTP	001	0.17 (WWH, S)	0.55	0.05 (WWH, W protecting EWH, W)
1PV00094	Sherwood Forest MHP	001	none	none	0.05 (WWH, W protecting EWH, W)
05080001-11-03: Dividing Branch-Greenville Creek					
1IJ00044	CF Poeppelman Inc *	001	none	none	flow accounting only
05080001-12-02: Swamp Creek					
1PB00033	Versailles WWTP	001	0.17 (WWH, S)	1.03	0.05 (WWH, W protecting EWH, W)
05080001-12-03: Trotters Creek					
1IN00178	Hartzell Propeller Inc Service Center *	001	none	none	flow accounting only
05080001-12-04: Harris Creek					
1PB00008	Bradford WWTP	001	0.17 (WWH, S)	1.03	0.08 (WWH, H)
05080001-13-02: Painter Creek					
1PB00000	Arcanum STP	001	0.17 (WWH, S)	0.79	0.1 (WWH, W)
05080001-13-03: Canyon Run-Stillwater River					
1IJ00061	Milton Materials LLC *	001	none	none	flow accounting only
1IJ00061	Milton Materials LLC *	002	none	none	flow accounting only
1IJ00061	Milton Materials LLC *	003	none	none	flow accounting only
1PB00026	Pleasant Hill STP	001	0.17 (WWH, S)	0.79	none: not impaired
1PB00013	Covington WWTP	001	0.17 (WWH, S)	0.79	none: not impaired
05080001-14-02: Ludlow Creek					
1IJ00048	Barrett Paving Materials Inc	001	none	none	flow accounting only
1PB00045	Laura WWTP	001	none	none	none: not impaired
05080001-14-04: Jones Run-Stillwater River					
1PC00011	West Milton WWTP	001	0.3 (WWH, L)	0.57	none: not impaired
1PV00004	Pine Brook Estates	001	none	none	none: not impaired
05080001-14-05: Mill Creek-Stillwater River					
1II00029	Dayton International Airport Terminal	002	none	none	flow accounting only

Table 4.1. Status of NPDES permit dischargers included in 2009-version of Stillwater TMDL SWAT model. Organized by 12-digit HUC. For ambient target, information in parentheses indicates the aquatic life-use designation as MWH=modified warmwater habitat, WWH=warmwater habitat, EWH=exceptional warmwater habitat, and river size as H=headwater, W=wading, S=small river. When "protecting" is shown, indicates the downstream aquatic life-use/river size being protected. "Flow accounting only" indicates the facility was included in the simulation model for hydrology mass balance but no phosphorus is discharged.

Facility #	Facility Name	Station	2004 ambient target (mg-P/L)	2004 effluent limit (mg-P/L)	2009 ambient target (mg-P/L)
1II00029	Dayton International Airport Terminal	003	none	none	flow accounting only
1PB00030	Union STP	001	0.3 (WWH, L)	0.57	none: not impaired
1PB00030	Union STP	002	0.3 (WWH, L)	0.57	none: not impaired
05080001-14-06: Town of Irvington-Stillwater River					
1IN00216	APS Materials Inc *	001	none	none	flow accounting only
1PD00001	Englewood WWTP	001	0.3 (WWH, L)	0.57	none: not impaired

Table 4.2. Enumeration of Management Scenario Options

Crop Rotation	Tillage	Fertilizer Type
‣ Corn-Soybean (C-S) ‣ Corn-Soybean-Winter Wheat (C-S-C-S-Wh) ‣ Corn-Soybean-Winter Wheat-Perennial Grass (C-S-Wh-G-G-G-G)	‣ generic no-till mixing ‣ field cultivator ‣ chisel plow	‣ synthetic dry (as function of time of year): 28-00-00, anhydrous ammonia, 10-34-60, 18-46-00, 00-46-00, 00-00-60 ‣ dry manure (nutrient amounts of beef, swine, dairy, and chicken averaged to a generalized manure type)

Other variations include:
1) Time of year for planting, tillage, fertilizer, and harvest (with or without full removal).
2) Fertilizer rate (kg/day).
3) Curve number for each scenario.

Table 4.3. Hydrologic Stations Used in Stillwater River TMDL Modeling Study

Station ID	Station Name	Drainage Area (mi^2)	Period of Record
03265000	Stillwater River at Pleasant Hill OH	503	Oct 1916 – present
03266000	Stillwater River at Englewood OH	650	Oct 1925 – present
03264000	Greenville Creek near Bradford OH	193	Oct 1930 – Sep 2000; Oct 2002 – present

Table 4.4. Target total phosphorus concentrations defined for Ohio (based on Ohio EPA 1999) as a function of aquatic life use designation and drainage basin area.

Watershed Type	Drainage Area Range (mi^2)	Concentration (mg-P/L)		
		EWH	WWH	MWH
Headwater	0 – 20	0.05	0.08	0.34
Wading	20 – 200	0.05	0.10	0.28
Small River	200 – 1000	0.10	0.17	0.25

Table 4.5. Distribution of TMDL allowance and existing loads by HUC 12 and season. Designation of impairment (y=impaired, yd=impaired but protecting downstream use, nd=not impaired but protecting downstream use) and the use being protected (D=ALU listed is for the downstream HUC). NetTotP(avg kg/seas) is net existing load supplied by the specific HUC (NPS and PS contributions) once upstream loads are subtracted. pct PS+HSTS refers to the percentage of existing load occupied by point sources (PS) and home sewage treatment systems (HSTS). pct NPS refers to the percentage of existing load occupied by NPS and MS4 stormwater zones (where exists). pct red (tot) refers to the total reduction of existing load (by kg/seas) required to meet P-TMDL. Blue color reference defines the net existing load is below TMDL (i.e., no reduction needed).

HUC-12	HUC-12 NAME	model sub#	season	Impaired	Protecting Use	P-target (mg-P/L)	P-TMDL (avg kg/seas)	NetTotP (avg kg/seas)	pct PS+HSTS	pct NPS	pct red (total)
05080001-09-01	South Fork Stillwater River	18	Wi	y	WWH, H	0.08	444	3588	0.02	0.98	0.88
			Sp				360	3965	0.02	0.98	0.91
			Su				178	2709	0.03	0.97	0.94
			Au				126	1618	0.05	0.95	0.93
05080001-09-02	Headwaters Stillwater River	20	Wi	yd	MWH, W (D)	0.28	1635	2671	0.02	0.98	0.39
			Sp				1273	3098	0.02	0.98	0.59
			Su				698	1658	0.03	0.97	0.58
			Au				581	1297	0.05	0.95	0.55
05080001-09-03	North Fork Stillwater River	22	Wi	y	MWH, H	0.34	2596	5365	0.01	0.99	0.52
			Sp				2073	5688	0.01	0.99	0.64
			Su				1012	3685	0.02	0.98	0.73
			Au				722	2325	0.04	0.96	0.69
05080001-09-04	Boyd Creek	3	Wi	y	WWH, H	0.08	456	3544	0.04	0.96	0.87
			Sp				416	3657	0.04	0.96	0.89
			Su				139	1895	0.13	0.87	0.93
			Au				159	1382	0.13	0.87	0.88
05080001-09-05	Woodington Run	37	Wi	y	WWH, H	0.08	357	2433	0.03	0.97	0.85
			Sp				328	2576	0.03	0.97	0.87
			Su				110	874	0.09	0.91	0.87
			Au				125	1061	0.09	0.91	0.88
05080001-09-05	Woodington Run-Stillwater River (lower)	26	Wi	nd	WWH, W (D)	0.1	429	2303	0.02	0.98	0.81
			Sp				395	2333	0.02	0.98	0.83
			Su				94	473	0.05	0.95	0.80
			Au				118	1117	0.04	0.96	0.89
05080001-09-05	Woodington Run-Stillwater River (middle)	1	Wi	y	WWH, W	0.1	52	-19	0.53	0.47	0.00
			Sp				47	-111	0.52	0.48	0.00
			Su				19	-121	0.79	0.21	0.00
			Au				25	598	0.79	0.21	0.96
05080001-09-05	Woodington Run-Stillwater River (upper)	38	Wi	yd	WWH, W (D)	0.1	453	1666	0.02	0.98	0.73

Table 4.5. Distribution of TMDL allowance and existing loads by HUC 12 and season. Designation of impairment (y=impaired, yd=impaired but protecting downstream use, nd=not impaired but protecting downstream use) and the use being protected (D=ALU listed is for the downstream HUC). NetTotP(avg kg/seas) is net existing load supplied by the specific HUC (NPS and PS contributions) once upstream loads are subtracted. pct PS+HSTS refers to the percentage of existing load occupied by point sources (PS) and home sewage treatment systems (HSTS). pct NPS refers to the percentage of existing load occupied by NPS and MS4 stormwater zones (where exists). pct red (tot) refers to the total reduction of existing load (by kg/seas) required to meet P-TMDL. Blue color reference defines the net existing load is below TMDL (i.e., no reduction needed).

HUC-12	HUC-12 NAME	model sub#	season	Impaired	Protecting Use	P-target (mg-P/L)	P-TMDL (avg kg/seas)	NetTotP (avg kg/seas)	pct PS+HSTS	pct NPS	pct red (total)
			Sp				332	1787	0.02	0.98	0.81
			Su				156	757	0.04	0.96	0.79
			Au				151	714	0.06	0.94	0.79
05080001-09-06	Town of Beamsville-Stillwater River	17	Wi	y	EWH, W	0.05	372	1247	0.05	0.95	0.70
			Sp				282	1235	0.04	0.96	0.77
			Su				127	14937	0.12	0.88	0.99
			Au				117	263	0.19	0.81	0.56
05080001-10-01	Dismal Creek	24	Wi	y	WWH, H	0.08	790	3311	0.02	0.98	0.76
			Sp				586	2789	0.03	0.97	0.79
			Su				393	1115	0.07	0.93	0.65
			Au				284	929	0.08	0.92	0.69
05080001-10-02	Kraut Creek	23	Wi	nd	EWH, W (D)	0.05	553	5862	0.02	0.98	0.91
			Sp				530	5298	0.02	0.98	0.90
			Su				229	2280	0.06	0.94	0.90
			Au				170	2270	0.04	0.96	0.93
05080001-10-04	Headwaters Greenville Creek (lower)	25	Wi	y	EWH, W	0.05	189	1732	0.02	0.98	0.89
			Sp				175	1282	0.02	0.98	0.86
			Su				71	588	0.07	0.93	0.88
			Au				54	647	0.05	0.95	0.92
05080001-10-04	Headwaters Greenville Creek (middle)	43	Wi	nd	EWH, W (D)	0.05	10	-212	0.02	0.98	0.00
			Sp				8	-252	0.02	0.98	0.00
			Su				4	-61	0.04	0.96	0.00
			Au				2	-57	0.05	0.94	0.00
05080001-11-01	Mud Creek	12	Wi	yd	WWH, W (D)	0.1	1477	7368	0.04	0.96	0.80
			Sp	yd	WWH, W (D)	0.1	1426	7041	0.04	0.96	0.80
			Su	yd	WWH, W (D)	0.1	622	2671	0.10	0.90	0.77
			Au	yd	WWH, W (D)	0.1	453	2741	0.10	0.90	0.83
05080001-11-02	Bridge Creek-Greenville Creek (lower)	42	Wi	yd	EWH, W (D)	0.05	190	3468	0.85	0.15	0.95
			Sp			0.05	191	3380	0.86	0.14	0.94
			Su			0.05	133	3824	0.95	0.05	0.97

Table 4.5. Distribution of TMDL allowance and existing loads by HUC 12 and season. Designation of impairment (y=impaired, yd=impaired but protecting downstream use, nd=not impaired but protecting downstream use) and the use being protected (D=ALU listed is for the downstream HUC). NetTotP(avg kg/seas) is net existing load supplied by the specific HUC (NPS and PS contributions) once upstream loads are subtracted. pct PS+HSTS refers to the percentage of existing load occupied by point sources (PS) and home sewage treatment systems (HSTS). pct NPS refers to the percentage of existing load occupied by NPS and MS4 stormwater zones (where exists). pct red (tot) refers to the total reduction of existing load (by kg/seas) required to meet P-TMDL. Blue color reference defines the net existing load is below TMDL (i.e., no reduction needed).

HUC-12	HUC-12 NAME	model sub#	season	Impaired	Protecting Use	P-target (mg-P/L)	P-TMDL (avg kg/seas)	NetTotP (avg kg/seas)	pct PS+HSTS	pct NPS	pct red (total)
			Au			0.05	118	3664	0.93	0.07	0.97
05080001-11-02	Bridge Creek-Greenville Creek (middle)	41	Wi	nd	EWH, W (D)	0.05	265	2626	0.06	0.94	0.90
			Sp			0.05	246	2384	0.06	0.94	0.90
			Su			0.05	107	1012	0.21	0.79	0.89
			Au			0.05	80	948	0.15	0.85	0.92
05080001-11-02	Bridge Creek-Greenville Creek (upper)	14	Wi	nd	WWH, W (D)	0.1	217	449	0.04	0.96	0.52
			Sp			0.1	202	224	0.04	0.96	0.10
			Su			0.1	80	104	0.12	0.88	0.23
			Au			0.1	62	174	0.09	0.91	0.64
05080001-11-03	Dividing Branch-Greenville Creek (lower)	32	Wi	y	EWH, W	0.05	141	57	0.1	0.9	0.00
			Sp			0.05	102	-200	0.1	0.9	0.00
			Su			0.05	36	-202	0.1	0.9	0.00
			Au			0.05	36	14	0.1	0.9	0.00
05080001-11-03	Dividing Branch-Greenville Creek (middle)	39	Wi	y	EWH, W	0.05	680	4644	0.03	0.97	0.85
			Sp			0.05	653	4620	0.03	0.97	0.86
			Su			0.05	258	1363	0.11	0.89	0.81
			Au			0.05	191	1669	0.08	0.92	0.89
05080001-11-03	Dividing Branch-Greenville Creek (upper)	40	Wi	y	EWH, W	0.05	54	-572	0.03	0.97	0.00
			Sp			0.05	48	-636	0.03	0.97	0.00
			Su			0.05	14	-423	0.11	0.89	0.00
			Au			0.05	13	-317	0.08	0.92	0.00
05080001-12-01	Indian Creek	19	Wi	y	WWH, H	0.08	617	2014	0.04	0.96	0.69
			Sp			0.08	471	2407	0.03	0.97	0.80
			Su			0.08	238	976	0.08	0.92	0.76
			Au			0.08	209	661	0.16	0.84	0.68
05080001-12-02	Swamp Creek (lower)	27	Wi	yd	EWH, W (D)	0.05	113	1488	0.73	0.27	0.92
			Sp			0.05	88	1386	0.69	0.31	0.94
			Su			0.05	47	977	0.86	0.14	0.95

Table 4.5. Distribution of TMDL allowance and existing loads by HUC 12 and season. Designation of impairment (y=impaired, yd=impaired but protecting downstream use, nd=not impaired but protecting downstream use) and the use being protected (D=ALU listed is for the downstream HUC). NetTotP(avg kg/seas) is net existing load supplied by the specific HUC (NPS and PS contributions) once upstream loads are subtracted. pct PS+HSTS refers to the percentage of existing load occupied by point sources (PS) and home sewage treatment systems (HSTS). pct NPS refers to the percentage of existing load occupied by NPS and MS4 stormwater zones (where exists). pct red (tot) refers to the total reduction of existing load (by kg/seas) required to meet P-TMDL. Blue color reference defines the net existing load is below TMDL (i.e., no reduction needed).

HUC-12	HUC-12 NAME	model sub#	season	Impaired	Protecting Use	P-target (mg-P/L)	P-TMDL (avg kg/seas)	NetTotP (avg kg/seas)	pct PS+HSTS	pct NPS	pct red (total)
			Au			0.05	45	1263	0.92	0.08	0.96
05080001-12-02	Swamp Creek (upper)	21	Wi	y	WWH, W	0.1	1468	6193	0.26	0.74	0.76
			Sp			0.1	1130	5302	0.22	0.78	0.79
			Su			0.1	568	1797	0.44	0.56	0.68
			Au			0.1	500	1317	0.65	0.35	0.62
05080001-12-04	Harris Creek	16	Wi	y	WWH, H	0.08	558	2121	0.19	0.81	0.74
			Sp			0.08	430	2175	0.18	0.82	0.80
			Su			0.08	202	16858	0.38	0.62	0.99
			Au			0.08	185	955	0.48	0.52	0.81
05080001-12-05	Town of Covington-Stillwater River (upper)	4	Wi	y	EWH, W	0.05	329	250	0.09	0.91	0.00
			Sp			0.05	249	-46	0.08	0.92	0.00
			Su			0.05	112	-1637	0.18	0.82	0.00
			Au			0.05	109	-405	0.29	0.71	0.00
05080001-13-01	Little Painter Creek	11	Wi	y	WWH, H	0.08	386	2041	0.03	0.97	0.81
			Sp			0.08	391	3028	0.02	0.98	0.87
			Su			0.08	98	906	0.08	0.92	0.89
			Au			0.08	92	813	0.08	0.92	0.89
05080001-13-02	Painter Creek (lower)	31	Wi	y	WWH, W	0.1	125	301	0.03	0.97	0.58
			Sp			0.1	96	99	0.03	0.97	0.04
			Su			0.1	39	183	0.06	0.94	0.79
			Au			0.1	31	213	0.07	0.93	0.86
05080001-13-02	Painter Creek (upper)	10	Wi	y	WWH, W	0.1	1278	4920	0.08	0.92	0.74
			Sp			0.1	1281	6809	0.06	0.94	0.81
			Su			0.1	315	1888	0.18	0.82	0.83
			Au			0.1	301	1900	0.18	0.82	0.84
05080001-14-01	Brush Creek (Ludlow Creek)	2	Wi	y	WWH, W	0.1	1136	3333	0.09	0.91	0.66
			Sp			0.1	978	3797	0.08	0.92	0.74
			Su			0.1	430	1371	0.21	0.79	0.69
			Au			0.1	447	1922	0.14	0.86	0.77

Table 4.6. Distribution of existing loads and TMDL allowance by sector (e.g., HSTS vs. PS) within each HUC 12 and season. For each HUC, values are reported by season in row order as WI, SP, SU, and AU. All magnitudes reported in average kg/season (N = 6 years).

			Existing Net Load - by sector				TMDL (allowance) - by sector			
HUC-12	HUC-12 NAME	sub#	MS4 (avg kg/seas)	NPS (avg kg/seas)	HSTS (avg kg/seas)	PS (avg kg/seas)	NPS (avg kg/seas)	HSTS (avg kg/seas)	PS (avg kg/seas)	MS4 (avg kg/seas)
05080001-09-01	South Fork Stillwater River	18		3516	58	14	435	7	2	0
				3886	64	15	353	6	1	0
				2628	66	16	173	4	1	0
				1537	65	16	120	5	1	0
05080001-09-02	Headwaters Stillwater River	20		2618	53	0	1603	33	0	0
				3036	62	0	1248	25	0	0
				1608	50	0	677	21	0	0
				1232	65	0	552	29	0	0
05080001-09-03	North Fork Stillwater River	22		5312	54	0	2570	26	0	0
				5631	57	0	2052	21	0	0
				3611	74	0	992	20	0	0
				2232	93	0	693	29	0	0
05080001-09-04	Boyd Creek	3	174	3228	100	42	415	13	5	22
			180	3331	103	43	379	12	5	20
			84	1564	174	73	114	13	5	6
			62	1140	127	53	131	15	6	7
05080001-09-05	Woodington Run	37		2360	73	0	346	11	0	0
				2499	77	0	318	10	0	0
				796	79	0	100	10	0	0
				966	95	0	114	11	0	0
05080001-09-05	Woodington Run-Stillwater River (lower)	26		2257	46	0	420	9	0	0
				2286	47	0	387	8	0	0
				450	24	0	90	5	0	0
				1072	45	0	113	5	0	0
05080001-09-05	Woodington Run-Stillwater River (middle)	1		0	0	0	52	0	0	0
				0	0	0	47	0	0	0
				0	0	0	19	0	0	0
				126	14	459	5	1	19	0
05080001-09-05	Woodington Run-Stillwater River (upper)	38		1633	33	0	444	9	0	0
				1751	36	0	326	7	0	0
				726	30	0	149	6	0	0
				671	43	0	142	9	0	0
05080001-09-06	Town of Beamsville-Stillwater River	17	0.02	1185	62	0	354	19	0	0
			0.02	1185	49	0	270	11	0	0

Table 4.6. Distribution of existing loads and TMDL allowance by sector (e.g., HSTS vs. PS) within each HUC 12 and season. For each HUC, values are reported by season in row order as WI, SP, SU, and AU. All magnitudes reported in average kg/season (N = 6 years).

			Existing Net Load - by sector				TMDL (allowance) - by sector			
HUC-12	HUC-12 NAME	sub#	MS4 (avg kg/seas)	NPS (avg kg/seas)	HSTS (avg kg/seas)	PS (avg kg/seas)	NPS (avg kg/seas)	HSTS (avg kg/seas)	PS (avg kg/seas)	MS4 (avg kg/seas)
			0.22	13145	1792	0	111	15	0	0
			0.00	213	50	0	95	22	0	0
05080001-10-01	Dismal Creek	24		3245	66	0	775	16	0	0
				2705	84	0	568	18	0	0
				1037	78	0	366	28	0	0
				855	74	0	262	23	0	0
05080001-10-02	Kraut Creek	23		5745	108	9	533	10	9	0
				5192	98	8	511	10	8	0
				2143	126	10	205	13	10	0
				2179	84	7	156	6	7	0
05080001-10-04	Headwaters Greenville Creek (lower)	25		1697	35	0	185	4	0	0
				1257	26	0	172	4	0	0
				546	41	0	66	5	0	0
				615	32	0	52	3	0	0
05080001-10-04	Headwaters Greenville Creek (middle)	43		0	0	0	10	0	0	0
				0	0	0	8	0	0	0
				0	0	0	4	0	0	0
				0	0	0	2	0	0	0
05080001-11-01	Mud Creek	12	157	6942	268	0	1392	54	0	32
			150	6623	268	0	1342	54	0	30
			53	2349	268	0	547	62	0	12
			55	2418	268	0	400	44	0	9
05080001-11-02	Bridge Creek-Greenville Creek (lower)	42	311	209	23	2925	11	1	160	17
			283	190	22	2885	11	1	163	16
			114	77	28	3605	3	1	126	4
			153	103	26	3381	3	1	109	5
05080001-11-02	Bridge Creek-Greenville Creek (middle)	41	191	2278	74	84	140	7	90	19
			173	2067	67	76	121	7	92	18
			62	738	99	113	1	7	92	7
			62	743	66	76	1	1	91	5
05080001-11-02	Bridge Creek-Greenville Creek (upper)	14	11	420	18	0	203	9	0	5
			5	210	9	0	190	8	0	5
			2	90	13	0	69	10	0	2
			4	154	16	0	55	6	0	1
05080001-11-03	Dividing Branch-Greenville Creek (lower)	32		51	6	0	127	14	0	0

Table 4.6. Distribution of existing loads and TMDL allowance by sector (e.g., HSTS vs. PS) within each HUC 12 and season. For each HUC, values are reported by season in row order as WI, SP, SU, and AU. All magnitudes reported in average kg/season (N = 6 years).

			Existing Net Load - by sector				TMDL (allowance) - by sector			
HUC-12	HUC-12 NAME	sub#	MS4 (avg kg/seas)	NPS (avg kg/seas)	HSTS (avg kg/seas)	PS (avg kg/seas)	NPS (avg kg/seas)	HSTS (avg kg/seas)	PS (avg kg/seas)	MS4 (avg kg/seas)
				0	0	0	102	0	0	0
				0	0	0	36	0	0	0
				13	1	0	33	4	0	0
05080001-11-03	Dividing Branch-Greenville Creek (middle)	39		4504	138	1	659	20	1	0
				4481	138	1	633	19	1	0
				1213	149	1	229	28	1	0
				1535	133	1	175	15	1	0
05080001-11-03	Dividing Branch-Greenville Creek (upper)	40		0	0	0	54	0	0	0
				0	0	0	48	0	0	0
				0	0	0	14	0	0	0
				0	0	0	13	0	0	0
05080001-12-01	Indian Creek	19		1933	81	0	593	25	0	0
				2335	72	0	457	14	0	0
				898	78	0	219	19	0	0
				555	106	0	175	33	0	0
05080001-12-02	Swamp Creek (lower)	27		402	23	1063	31	2	81	0
				430	20	936	27	1	59	0
				137	18	823	7	1	40	0
				101	25	1137	4	1	41	0
05080001-12-02	Swamp Creek (upper)	21		4583	1579	31	1086	374	7	0
				4136	1144	23	881	244	5	0
				1006	775	15	318	245	5	0
				461	839	17	175	319	6	0
05080001-12-04	Harris Creek	16		1718	121	281	452	32	74	0
				1784	118	274	352	23	54	0
				10452	1930	4476	125	23	54	0
				497	138	320	96	27	62	0
05080001-12-05	Town of Covington-Stillwater River (upper)	4		227	21	1	299	28	1	0
				0	0	0	249	0	0	0
				0	0	0	112	0	0	0
				0	0	0	109	0	0	0
05080001-13-01	Little Painter Creek	11		1980	61	0	374	12	0	0
				2967	61	0	383	8	0	0

Table 4.6. Distribution of existing loads and TMDL allowance by sector (e.g., HSTS vs. PS) within each HUC 12 and season. For each HUC, values are reported by season in row order as WI, SP, SU, and AU. All magnitudes reported in average kg/season (N = 6 years).

			Existing Net Load - by sector				TMDL (allowance) - by sector			
HUC-12	HUC-12 NAME	sub#	MS4 (avg kg/seas)	NPS (avg kg/seas)	HSTS (avg kg/seas)	PS (avg kg/seas)	NPS (avg kg/seas)	HSTS (avg kg/seas)	PS (avg kg/seas)	MS4 (avg kg/seas)
				834	73	0	90	8	0	0
				748	65	0	85	7	0	0
05080001-13-02	Painter Creek (lower)	31		292	9	0	122	4	0	0
				96	3	0	93	3	0	0
				172	11	0	37	2	0	0
				198	15	0	29	2	0	0
05080001-13-02	Painter Creek (upper)	10		4526	210	183	1176	55	48	0
				6400	218	190	1204	41	36	0
				1548	181	158	258	30	26	0
				1558	183	159	247	29	25	0
05080001-14-01	Brush Creek (Ludlow Creek)	2		3033	300	0	1034	102	0	0
				3494	304	0	900	78	0	0
				1083	288	0	339	90	0	0
				1653	269	0	384	63	0	0

Table 4.7. Average design flow (in MGD), total P concentration from average PEQ within a DMR, and existing conduit flow (in MGD) for all NPDES facilities within the Stillwater River watershed. Color assignments defined at bottom of table.

HUC-12	HUC- 12	Model Subbasin#	Ohio EPA Facility #	Facility Name	Station	Average Design Flow (MGD)	Total P (PEQ-avg) (mg-P/L)	Existing Flow (PEQ-avg) (MGD)
05080001-09-01	South Fork Stillwater River	18	1PT00095	Mississinawa Valley Local Sch Dist Office	001	0.01982	2.5	0.006
05080001-09-04	Boyd Creek	3	1PG00090	Rolin Acres Subdivision WWTP	001	0.024	2.5	0.027
05080001-09-04	Boyd Creek	3	1PW00045	Northtowne Apts	001	0.030	2.5	0.007
05080001-09-04	Boyd Creek	3	1PT00108	Woodland Hts Elem Sch	001	0.01	2.5	0.006
05080001-09-04	Boyd Creek	3	1PZ00111	Darke Co MRDD Ditch Maintenance and Co Garage	001	no discharge	0	0.002
05080001-09-05	Woodington Run-Stillwater River (middle)	1	1PB00005	Ansonia STP	001	0.35	1.39	0.375
05080001-10-01	Dismal Creek	24	1PB00031	Union City STP	001	land application	0	land application
05080001-10-02	Kraut Creek	23	1PX00058	Wildcat Woods Campground	001	0.01	2.5	0.005
05080001-11-01	Mud Creek	12	1IJ00015	Shamrock Materials Ft Jefferson Limestone	001	intermittent	0	intermittent
05080001-11-02	Bridge Creek-Greenville Creek (lower)	42	1PD00005	Greenville WWTP	001	3.5	3.68	2.494
05080001-11-02	Bridge Creek-Greenville Creek (middle)	41	1PV00094	Sherwood Forest MHP	001	0.051	4.22	0.051
05080001-11-02	Bridge Creek-Greenville Creek (middle)	41	1GH00001	Andersons Marathon Ethanol Greenville Operations	001	no design flow	0	no flow
05080001-11-02	Bridge Creek-Greenville Creek (middle)	41	1IN00240	Markwith Tool Co Inc	001	0.0045	0	0.0004
05080001-11-02	Bridge Creek-Greenville Creek (middle)	41	1PG00104	Darke Co Criminal Justice Ctr	001	0.01	2.5	0.002
05080001-11-02	Bridge Creek-Greenville Creek (middle)	41	1PG00105	Darke Co Home	001	0.01	2.5	0.008
05080001-11-03	Dividing Branch-Greenville Creek (lower)	32	1IJ00044	CF Poeppelman Inc	001	intermittent	0	intermittent
05080001-11-03	Dividing Branch-Greenville Creek (middle)	39	1IS00131	Norcold Inc	001	0.01	0	0.003
05080001-11-03	Dividing Branch-Greenville Creek (middle)	39	1IX00043	Gettysburg WTP	001	intermittent	0	intermittent
05080001-11-03	Dividing Branch-Greenville Creek (middle)	39	1PR00112	Greenville Country Club	001	0.0015	2.5	0.001
05080001-12-02	Swamp Creek (lower)	27	1PB00033	Versailles WWTP	001	0.75	5.56	0.443
05080001-12-02	Swamp Creek (upper)	21	1PX00057	Cottonwood Lakes Campground	001	0.005	2.5 (seasonal)	0.001

Table 4.7. Average design flow (in MGD), total P concentration from average PEQ within a DMR, and existing conduit flow (in MGD) for all NPDES facilities within the Stillwater River watershed. Color assignments defined at bottom of table.

HUC-12	HUC- 12	Model Subbasin#	Ohio EPA Facility #	Facility Name	Station	Average Design Flow (MGD)	Total P (PEQ-avg) (mg-P/L)	Existing Flow (PEQ-avg) (MGD)
05080001-12-03	Trotters Creek	30	1IN00178	Hartzell Propeller Inc Service Center	001	0.0216 (intermittent)	0	0.033
05080001-12-04	Harris Creek	16	1PB00008	Bradford WWTP	001	0.24	3.96	0.297
05080001-12-04	Harris Creek	16	1IZ00010	Bradford WTP	001	0.17	0	0.088
05080001-12-05	Town of Covington-Stillwater River (upper)	4	1PX00014	Stillwater Golf Estates	001	0.0075	2.5	0.0094
05080001-13-02	Painter Creek (upper)	10	1PB00000	Arcanum STP	001	0.4	1.52	0.510
05080001-13-02	Painter Creek (upper)	10	1PT00115	Franklin Monroe Elem Sch	001	0.002	2.5	0.0024
05080001-13-03	Canyon Run-Stillwater River (lower)	33	1IJ00061	Milton Materials LLC	001	intermittent	0	intermittent
05080001-13-03	Canyon Run-Stillwater River (lower)	33	1IJ00061	Milton Materials LLC	002	intermittent	0	intermittent
05080001-13-03	Canyon Run-Stillwater River (lower)	33	1IJ00061	Milton Materials LLC	003	intermittent	0	intermittent
05080001-13-03	Canyon Run-Stillwater River (lower)	33	1PB00026	Pleasant Hill STP	001	0.2	3.56	0.140
05080001-13-03	Canyon Run-Stillwater River (upper)	35	1PB00013	Covington WWTP	001	0.75	5.21	0.478
05080001-13-03	Canyon Run-Stillwater River (upper)	35	1PR00103	Birdless Ltd	001	0.003	2.5	0.001
05080001-14-02	Ludlow Creek (lower)	9	1IJ00048	Barrett Paving Materials Inc	001	intermittent	0	intermittent
05080001-14-02	Ludlow Creek (lower)	9	1PV00123	Le-O-Na Falls MHP	001	0.0075	2.5	0.0003
05080001-14-02	Ludlow Creek (upper)	36	1PB00045	Laura WWTP	001	0.06	5.79	0.050
05080001-14-02	Ludlow Creek (upper)	36	1PT00101	Franklin Monroe High School	001	0	0	0.003
05080001-14-04	Jones Run-Stillwater River	8	1PC00011	West Milton WWTP	001	1.2	2.67	0.884
05080001-14-04	Jones Run-Stillwater River	8	1PV00004	Pine Brook Estates	001	0.025	2.5	0.017
05080001-14-05	Mill Creek-Stillwater River	6	1II00029	Dayton International Airport Terminal	002	intermittent	0	intermittent
05080001-14-05	Mill Creek-Stillwater River	6	1II00029	Dayton International Airport Terminal	003	intermittent	0	intermittent
05080001-14-05	Mill Creek-Stillwater River	6	1PB00030	Union STP	001	1.0	1.98	0.801
05080001-14-05	Mill Creek-Stillwater River	6	1II00029	Dayton International Airport Terminal	001	intermittent	0	intermittent

Table 4.7. Average design flow (in MGD), total P concentration from average PEQ within a DMR, and existing conduit flow (in MGD) for all NPDES facilities within the Stillwater River watershed. Color assignments defined at bottom of table.

HUC-12	HUC- 12	Model Subbasin#	Ohio EPA Facility #	Facility Name	Station	Average Design Flow (MGD)	Total P (PEQ-avg) (mg-P/L)	Existing Flow (PEQ-avg) (MGD)
05080001-14-05	Mill Creek-Stillwater River	6	1II00029	Dayton International Airport Terminal	004	intermittent	0	intermittent
05080001-14-05	Mill Creek-Stillwater River	6	1II00029	Dayton International Airport Terminal	005	intermittent	0	intermittent
05080001-14-05	Mill Creek-Stillwater River	6	1II00029	Dayton International Airport Terminal	007	intermittent	0	intermittent
05080001-14-05	Mill Creek-Stillwater River	6	1IM00006	Wright Bros Aero Inc	001	intermittent	0	intermittent
05080001-14-05	Mill Creek-Stillwater River	6	1IM00006	Wright Bros Aero Inc	002	intermittent	0	intermittent
05080001-14-05	Mill Creek-Stillwater River	6	1IM00009	UPS-Cartage Services Dayton Hub	001	intermittent	0	intermittent
05080001-14-05	Mill Creek-Stillwater River	6	1PX00052	Sugar Grove Bible Church	001	0.004	2.5	0.001
05080001-14-06	Town of Irvington-Stillwater River	5	1IN00216	APS Materials Inc	001	intermittent	0	intermittent
05080001-14-06	Town of Irvington-Stillwater River	5	1PD00001	Englewood WWTP	001	2.5	2.48	1.908

Legend

- NPDES facility discharges to impaired segment and ADF > 0.02 MGD.
- NPDES facility included for flow accounting only.
- NPDES facility ADF < 0.02; may discharge to an impaired segment.
- HUC 12 unit not impaired.
- Net existing load is below TMDL; no reduction needed.
- Estimated effluent concentration.

Table 4.8. Wasteload allocations for NPDES dischargers in Stillwater River watershed. Allocations are distributed by season (defined in text) and listed as an average daily load (in kg-P/d) or as an average concentration (in mg-P/L). Color assignments defined at bottom of table.

				TMDL allow (avg kg/d)				TMDL allow (avg mg/L) ADF			
HUC12	**Facility #**	**Facility Name**	**Station**	**WI**	**SP**	**SU**	**AU**	**WI**	**SP**	**SU**	**AU**
05080001-09-01	1PT00095	Mississinawa Valley Local Sch Dist Office	001	0.19	0.19	0.19	0.19	2.50	2.50	2.50	2.50
05080001-09-04	1PG00090	Rolin Acres Subdivision WWTP	001	0.23	0.23	0.23	0.23	2.50	2.50	2.50	2.50
05080001-09-04	1PW00045	Northtowne Apts	001	0.03	0.03	0.03	0.04	0.29	0.26	0.28	0.33
05080001-09-04	1PT00108	Woodland Hts Elem Sch	001	0.01	0.01	0.01	0.01	0.29	0.26	0.28	0.33
05080001-09-04	1PZ00111	Darke Co MRDD Ditch Maintenance and Co Garage	001	0	0	0	0	0	0	0	0
05080001-09-05	1PB00005	Ansonia STP	001	1.84	1.84	1.84	0.25†	1.39	1.39	1.39	0.19
05080001-10-01	1PB00031	Union City STP	001								
05080001-10-02	1PX00058	Wildcat Woods Campground	001	0.09	0.09	0.09	0.09	2.50	2.50	2.50	2.50
05080001-11-01	1IJ00015	Shamrock Materials Ft Jefferson Limestone	001	0	0	0	0	0	0	0	0
05080001-11-02	1PD00005	Greenville WWTP	001	2.09	2.08	1.61	1.41	0.16	0.16	0.12	0.11
05080001-11-02	1PV00094	Sherwood Forest MHP	001	0.82	0.82	0.82	0.82	4.22	4.22	4.22	4.22
05080001-11-02	1GH00001	Andersons Marathon Ethanol Greenville Operations	001	0	0	0	0	0	0	0	0
05080001-11-02	1IN00240	Markwith Tool Co Inc	001	0	0	0	0	0	0	0	0
05080001-11-02	1PG00104	Darke Co Criminal Justice Ctr	001	0.09	0.09	0.09	0.09	2.50	2.50	2.50	2.50
05080001-11-02	1PG00105	Darke Co Home	001	0.09	0.09	0.09	0.09	2.50	2.50	2.50	2.50
05080001-11-03	1IJ00044	CF Poeppelman Inc	001	0	0	0	0	0	0	0	0
05080001-11-03	1IS00131	Norcold Inc	001	0	0	0	0	0	0	0	0
05080001-11-03	1IX00043	Gettysburg WTP	001	0	0	0	0	0	0	0	0
05080001-11-03	1PR00112	Greenville Country Club	001	0.014	0.014	0.014	0.014	2.50	2.50	2.50	2.50
05080001-12-02	1PB00033	Versailles WWTP	001	1.06	0.76	0.51	0.53	0.37	0.27	0.18	0.19
05080001-12-02	1PX00057	Cottonwood Lakes Campground	001	0.10	0.06	0.06	0.08	5.12	3.26	3.28	4.31
05080001-12-03	1IN00178	Hartzell Propeller Inc Service Center	001	0	0	0	0	0	0	0	0
05080001-12-04	1PB00008	Bradford WWTP	001	0.97	0.69	0.69	0.80	1.07	0.76	0.75	0.88
05080001-12-04	1IZ00010	Bradford WTP	001	0	0	0	0	0	0	0	0

Table 4.8. Wasteload allocations for NPDES dischargers in Stillwater River watershed. Allocations are distributed by season (defined in text) and listed as an average daily load (in kg-P/d) or as an average concentration (in mg-P/L). Color assignments defined at bottom of table.

				TMDL allow (avg kg/d)				TMDL allow (avg mg/L) ADF			
HUC12	Facility #	Facility Name	Station	WI	SP	SU	AU	WI	SP	SU	AU
05080001-12-05	1PX00014	Stillwater Golf Estates	001	0.07	0.07	0.07	0.07	2.50	2.50	2.50	2.50
05080001-13-02	1PB00000	Arcanum STP	001	0.62	0.45	0.33	0.32	0.41	0.30	0.22	0.21
05080001-13-02	1PT00115	Franklin Monroe Elem Sch	001	0.006	0.004	0.003	0.003	0.67	0.49	0.36	0.35
05080001-13-03	1IJ00061	Milton Materials LLC	001								
05080001-13-03	1IJ00061	Milton Materials LLC	002								
05080001-13-03	1IJ00061	Milton Materials LLC	003								
05080001-13-03	1PB00026	Pleasant Hill STP	001								
05080001-13-03	1PB00013	Covington WWTP	001								
05080001-13-03	1PR00103	Birdless Ltd	001								
05080001-14-02	1IJ00048	Barrett Paving Materials Inc	001								
05080001-14-02	1PV00123	Le-O-Na Falls MHP	001								
05080001-14-02	1PB00045	Laura WWTP	001								
05080001-14-02	1PT00101	Franklin Monroe High School	001								
05080001-14-04	1PC00011	West Milton WWTP	001								
05080001-14-04	1PV00004	Pine Brook Estates	001								
05080001-14-05	1II00029	Dayton International Airport Terminal	002								
05080001-14-05	1II00029	Dayton International Airport Terminal	003								
05080001-14-05	1PB00030	Union STP	001								
05080001-14-05	1II00029	Dayton International Airport Terminal	001								
05080001-14-05	1II00029	Dayton International Airport Terminal	004								
05080001-14-05	1II00029	Dayton International Airport Terminal	005								
05080001-14-05	1II00029	Dayton International Airport Terminal	007								
05080001-14-05	1IM00006	Wright Bros Aero Inc	001								
05080001-14-05	1IM00006	Wright Bros Aero Inc	002								
05080001-14-05	1IM00009	UPS-Cartage Services Dayton Hub	001								
05080001-14-05	1PX00052	Sugar Grove Bible Church	001								

Table 4.8. Wasteload allocations for NPDES dischargers in Stillwater River watershed. Allocations are distributed by season (defined in text) and listed as an average daily load (in kg-P/d) or as an average concentration (in mg-P/L). Color assignments defined at bottom of table.

				TMDL allow (avg kg/d)				TMDL allow (avg mg/L) ADF			
HUC12	**Facility #**	**Facility Name**	**Station**	**WI**	**SP**	**SU**	**AU**	**WI**	**SP**	**SU**	**AU**
05080001-14-06	1IN00216	APS Materials Inc	001								
05080001-14-06	1PD00001	Englewood WWTP	001								

Notes:
†: The Village of Ansonia is allocated a reduced total P load for AU because NPS loads increase significantly in this same season. These NPS loads stem from increased manure/fertilizer inputs in October and November of each year. Whereas in WI, SP, and SU there is no load reduction, all sectors experience a load reduction in AU for HUC 05080001-09-05 (middle).

Legend

- NPDES facility discharges to impaired segment and ADF > 0.02 MGD.
- NPDES facility included for flow accounting only.
- NPDES facility ADF < 0.02; may discharge to an impaired segment.
- HUC 12 unit not impaired.
- Net existing load is below TMDL; no reduction needed.
- Estimated effluent concentration.

Table 4.9. Summary of TMDL, load allocations (LA), and wasteload allocations (WLA) organized by 12-digit HUC (subbasin model unit) and season. Expressed as average kg-P/season.

HUC-12	Waterbody Name	Model Subunit #	Season	TMDL (avg kg/seas)	LA (avg kg/seas)	WLA (avg kg/seas)
05080001-09-01	South Fork Stillwater River	18	Wi	444	442	2
			Sp	360	359	1
			Su	178	177	1
			Au	126	125	1
05080001-09-02	Headwaters Stillwater River	20	Wi	1635	1635	0
			Sp	1273	1273	0
			Su	698	698	0
			Au	581	581	0
05080001-09-03	North Fork Stillwater River	22	Wi	2596	2596	0
			Sp	2073	2073	0
			Su	1012	1012	0
			Au	722	722	0
05080001-09-04	Boyd Creek	3	Wi	456	428	28
			Sp	416	390	25
			Su	139	127	12
			Au	159	146	13
05080001-09-05	Woodington Run	37	Wi	357	357	0
			Sp	328	328	0
			Su	110	110	0
			Au	125	125	0
05080001-09-05	Woodington Run-Stillwater River (lower)	26	Wi	429	429	0
			Sp	395	395	0
			Su	94	94	0
			Au	118	118	0
05080001-09-05	Woodington Run-Stillwater River (middle)	1	Wi	52	52	0
			Sp	47	47	0
			Su	19	19	0
			Au	25	6	19
05080001-09-05	Woodington Run-Stillwater River (upper)	38	Wi	453	453	0
			Sp	332	332	0
			Su	156	156	0
			Au	151	151	0
05080001-09-06	Town of Beamsville-Stillwater River	17	Wi	372	372	0
			Sp	282	282	0
			Su	127	127	0
			Au	117	117	0
05080001-10-01	Dismal Creek	24	Wi	790	790	0
			Sp	586	586	0
			Su	393	393	0
			Au	284	284	0
05080001-10-02	Kraut Creek	23	Wi	553	543	9
			Sp	530	521	8
			Su	229	218	10
			Au	170	163	7
05080001-10-04	Headwaters Greenville Creek (lower)	25	Wi	189	189	0
			Sp	175	175	0
			Su	71	71	0
			Au	54	54	0
05080001-10-04	Headwaters Greenville Creek (middle)	43	Wi	10	10	0
			Sp	8	8	0

Table 4.9. Summary of TMDL, load allocations (LA), and wasteload allocations (WLA) organized by 12-digit HUC (subbasin model unit) and season. Expressed as average kg-P/season.

HUC-12	Waterbody Name	Model Subunit #	Season	TMDL (avg kg/seas)	LA (avg kg/seas)	WLA (avg kg/seas)
			Su	4	4	0
			Au	2	2	0
05080001-11-01	Mud Creek	12	Wi	1477	1445	32
			Sp	1426	1396	30
			Su	622	610	12
			Au	453	444	9
05080001-11-02	Bridge Creek-Greenville Creek (lower)	42	Wi	190	13	177
			Sp	191	12	179
			Su	133	4	130
			Au	118	4	114
05080001-11-02	Bridge Creek-Greenville Creek (middle)	41	Wi	265	147	110
			Sp	246	128	110
			Su	107	8	99
			Au	80	2	92
05080001-11-02	Bridge Creek-Greenville Creek (upper)	14	Wi	217	212	5
			Sp	202	198	5
			Su	80	79	2
			Au	62	61	1
05080001-11-03	Dividing Branch-Greenville Creek (lower)	32	Wi	141	141	0
			Sp	102	102	0
			Su	36	36	0
			Au	36	36	0
05080001-11-03	Dividing Branch-Greenville Creek (middle)	39	Wi	680	680	1
			Sp	653	652	1
			Su	258	257	1
			Au	191	190	1
05080001-11-03	Dividing Branch-Greenville Creek (upper)	40	Wi	54	54	0
			Sp	48	48	0
			Su	14	14	0
			Au	13	13	0
05080001-12-01	Indian Creek	19	Wi	617	617	0
			Sp	471	471	0
			Su	238	238	0
			Au	209	209	0
05080001-12-02	Swamp Creek (lower)	27	Wi	113	32	81
			Sp	88	28	59
			Su	47	7	40
			Au	45	5	41
05080001-12-02	Swamp Creek (upper)	21	Wi	1468	1461	7
			Sp	1130	1125	5
			Su	568	563	5
			Au	500	493	6
05080001-12-04	Harris Creek	16	Wi	558	484	74
			Sp	430	375	54
			Su	202	148	54
			Au	185	123	62
05080001-12-05	Town of Covington-Stillwater River (upper)	4	Wi	329	327	1
			Sp	249	249	0
			Su	112	112	0
			Au	109	109	0

Table 4.9. Summary of TMDL, load allocations (LA), and wasteload allocations (WLA) organized by 12-digit HUC (subbasin model unit) and season. Expressed as average kg-P/season.

HUC-12	Waterbody Name	Model Subunit #	Season	TMDL (avg kg/seas)	LA (avg kg/seas)	WLA (avg kg/seas)
05080001-13-01	Little Painter Creek	11	Wi	386	386	0
			Sp	391	391	0
			Su	98	98	0
			Au	92	92	0
05080001-13-02	Painter Creek (lower)	31	Wi	125	125	0
			Sp	96	96	0
			Su	39	39	0
			Au	31	31	0
05080001-13-02	Painter Creek (upper)	10	Wi	1278	1231	48
			Sp	1281	1245	36
			Su	315	288	26
			Au	301	276	25
05080001-14-01	Brush Creek (Ludlow Creek)	2	Wi	1136	1136	0
			Sp	978	978	0
			Su	430	430	0
			Au	447	447	0

Table 4.9a. Summary of TMDL, load allocations (LA), and wasteload allocations (WLA) organized by 12-digit HUC (subbasin model unit) and season. Expressed as average kg-P/day.

HUC-12	Waterbody Name	Model Subunit#	season	TMDL (avg kg/d)	LA (avg kg/d)	WLA (avg kg/d)
05080001-09-01	South Fork Stillwater River	18	Wi	4.92	4.90	0.02
			Sp	3.91	3.90	0.02
			Su	1.94	1.93	0.01
			Au	1.39	1.37	0.01
05080001-09-02	Headwaters Stillwater River	20	Wi	18.12	18.12	0.00
			Sp	13.84	13.84	0.00
			Su	7.58	7.58	0.00
			Au	6.39	6.39	0.00
05080001-09-03	North Fork Stillwater River	22	Wi	28.77	28.77	0.00
			Sp	22.53	22.53	0.00
			Su	11.00	11.00	0.00
			Au	7.93	7.93	0.00
05080001-09-04	Boyd Creek	3	Wi	5.05	4.74	0.31
			Sp	4.52	4.24	0.28
			Su	1.51	1.38	0.13
			Au	1.75	1.60	0.14
05080001-09-05	Woodington Run	37	Wi	3.95	3.95	0.00
			Sp	3.56	3.56	0.00
			Su	1.19	1.19	0.00
			Au	1.38	1.38	0.00
05080001-09-05	Woodington Run-Stillwater River (lower)	26	Wi	4.75	4.75	0.00
			Sp	4.29	4.29	0.00
			Su	1.02	1.02	0.00
			Au	1.29	1.29	0.00
05080001-09-05	Woodington Run-Stillwater River (middle)	1	Wi	0.58	0.58	0.00
			Sp	0.51	0.51	0.00
			Su	0.21	0.21	0.00
			Au	0.27	0.06	0.21
05080001-09-05	Woodington Run-Stillwater River (upper)	38	Wi	5.02	5.02	0.00
			Sp	3.61	3.61	0.00
			Su	1.69	1.69	0.00
			Au	1.66	1.66	0.00
05080001-09-06	Town of Beamsville-Stillwater River	17	Wi	4.13	4.13	0.00
			Sp	3.06	3.06	0.00
			Su	1.38	1.38	0.00
			Au	1.28	1.28	0.00
05080001-10-01	Dismal Creek	24	Wi	8.76	8.76	0.00
			Sp	6.37	6.37	0.00
			Su	4.27	4.27	0.00
			Au	3.12	3.12	0.00
05080001-10-02	Kraut Creek	23	Wi	6.13	6.02	0.10
			Sp	5.76	5.66	0.09
			Su	2.49	2.37	0.11
			Au	1.87	1.79	0.08
05080001-10-04	Headwaters Greenville Creek (lower)	25	Wi	2.09	2.09	0.00
			Sp	1.91	1.91	0.00
			Su	0.77	0.77	0.00
			Au	0.60	0.60	0.00
05080001-10-04	Headwaters Greenville Creek (middle)	43	Wi	0.11	0.11	0.00

Table 4.9a. Summary of TMDL, load allocations (LA), and wasteload allocations (WLA) organized by 12-digit HUC (subbasin model unit) and season. Expressed as average kg-P/day.

HUC-12	Waterbody Name	Model Subunit#	season	TMDL (avg kg/d)	LA (avg kg/d)	WLA (avg kg/d)
			Sp	0.08	0.08	0.00
			Su	0.05	0.05	0.00
			Au	0.03	0.03	0.00
05080001-11-01	Mud Creek	12	Wi	16.36	16.02	0.35
			Sp	15.50	15.17	0.33
			Su	6.76	6.63	0.13
			Au	4.98	4.88	0.10
05080001-11-02	Bridge Creek-Greenville Creek (lower)	42	Wi	2.10	0.14	1.96
			Sp	2.07	0.13	1.94
			Su	1.45	0.04	1.41
			Au	1.30	0.05	1.25
05080001-11-02	Bridge Creek-Greenville Creek (middle)	41	Wi	2.94	1.63	1.22
			Sp	2.68	1.39	1.20
			Su	1.16	0.09	1.08
			Au	0.88	0.02	1.02
05080001-11-02	Bridge Creek-Greenville Creek (upper)	14	Wi	2.40	2.35	0.06
			Sp	2.20	2.15	0.05
			Su	0.87	0.85	0.02
			Au	0.68	0.67	0.02
05080001-11-03	Dividing Branch-Greenville Creek (lower)	32	Wi	1.56	1.56	0.00
			Sp	1.11	1.11	0.00
			Su	0.39	0.39	0.00
			Au	0.40	0.40	0.00
05080001-11-03	Dividing Branch-Greenville Creek (middle)	39	Wi	7.54	7.53	0.01
			Sp	7.10	7.09	0.01
			Su	2.80	2.80	0.01
			Au	2.10	2.09	0.01
05080001-11-03	Dividing Branch-Greenville Creek (upper)	40	Wi	0.60	0.60	0.00
			Sp	0.52	0.52	0.00
			Su	0.16	0.16	0.00
			Au	0.14	0.14	0.00
05080001-12-01	Indian Creek	19	Wi	6.84	6.84	0.00
			Sp	5.12	5.12	0.00
			Su	2.58	2.58	0.00
			Au	2.29	2.29	0.00
05080001-12-02	Swamp Creek (lower)	27	Wi	1.26	0.36	0.90
			Sp	0.95	0.31	0.64
			Su	0.51	0.08	0.43
			Au	0.50	0.05	0.45
05080001-12-02	Swamp Creek (upper)	21	Wi	16.27	16.19	0.08
			Sp	12.28	12.23	0.05
			Su	6.17	6.12	0.05
			Au	5.49	5.42	0.07
05080001-12-04	Harris Creek	16	Wi	6.19	5.36	0.82
			Sp	4.67	4.08	0.59
			Su	2.19	1.61	0.58
			Au	2.03	1.35	0.68
05080001-12-05	Town of Covington-Stillwater River (upper)	4	Wi	3.64	3.62	0.02
			Sp	2.71	2.71	0.00
			Su	1.22	1.22	0.00

Table 4.9a. Summary of TMDL, load allocations (LA), and wasteload allocations (WLA) organized by 12-digit HUC (subbasin model unit) and season. Expressed as average kg-P/day.

HUC-12	Waterbody Name	Model Subunit#	season	TMDL (avg kg/d)	LA (avg kg/d)	WLA (avg kg/d)
			Au	1.20	1.20	0.00
05080001-13-01	Little Painter Creek	11	Wi	4.27	4.27	0.00
			Sp	4.25	4.25	0.00
			Su	1.07	1.07	0.00
			Au	1.01	1.01	0.00
05080001-13-02	Painter Creek (lower)	31	Wi	1.39	1.39	0.00
			Sp	1.04	1.04	0.00
			Su	0.43	0.43	0.00
			Au	0.34	0.34	0.00
05080001-13-02	Painter Creek (upper)	10	Wi	14.16	13.64	0.53
			Sp	13.93	13.54	0.39
			Su	3.42	3.13	0.29
			Au	3.31	3.03	0.28
05080001-14-01	Brush Creek (Ludlow Creek)	2	Wi	12.59	12.59	0.00
			Sp	10.63	10.63	0.00
			Su	4.67	4.67	0.00
			Au	4.91	4.91	0.00

Table 4.10. Comparison of % load reduction between 2004 TMDL and 2009 (current) TMDL organized by assessment unit. For the 2004 TMDL (Ohio EPA 2004), allocations were made to 11-digit HUC whereas in the 2009 TMDL allocations were made to 12-digit HUC. All assessment units exist in the 05080001 8-digit HUC. Value of % load reduction represents average of four seasonal reductions and applies to NPS, HSTS, MS4, and WWTP (2009 only) sectors. Percent load reductions for the WWTP sector in the 2004 TMDL were based on best available technology and were approximately 70% for each assessment unit. For purposes of average % reduction, a "not impaired" HUC was considered as 0% reduction. Sub# refers to the name of the given area in the model.

2004 TMDL			**2009 TMDL**			
11-digit extension	**11-digit HUC name**	**average % reduction**	**10- and 12-digit extension**	**10- and 12-digit HUC name**	**sub#**	**average % reduction**
-090	**Stillwater R. (headwaters to above Swamp Creek)**	**88**	**-09**	**Headwaters Stillwater River**	**--**	**72**
			-09-01	South Fork Stillwater River	18	91
			-09-02	Headwaters Stillwater River	20	53
			-09-03	North Fork Stillwater River	22	64
			-09-04	Boyd Creek	3	89
			-09-05	Woodington Run	37	87
			-09-05	Woodington Run-Stillwater River (lower)	26	84
			-09-05	Woodington Run-Stillwater River (middle)	1	24
			-09-05	Woodington Run-Stillwater River (upper)	38	78
			-09-06	Town of Beamsville-Stillwater River	17	76
-100	**Stillwater R. (above Swamp Cr. to above Greenville Cr.)**	**29**	**-12**	**Swamp Creek-Stillwater Creek**	**--**	**40**
			-12-01	Indian Creek	19	73
			-12-02	Swamp Creek (lower)	27	94
			-12-02	Swamp Creek (upper)	21	71
			-12-03	Trotters Creek	30	not impaired
			-12-04	Harris Creek	16	83
			-12-05	Town of Covington-Stillwater River (lower)	28	not impaired

Table 4.10. Comparison of % load reduction between 2004 TMDL and 2009 (current) TMDL organized by assessment unit. For the 2004 TMDL (Ohio EPA 2004), allocations were made to 11-digit HUC whereas in the 2009 TMDL allocations were made to 12-digit HUC. All assessment units exist in the 05080001 8-digit HUC. Value of % load reduction represents average of four seasonal reductions and applies to NPS, HSTS, MS4, and WWTP (2009 only) sectors. Percent load reductions for the WWTP sector in the 2004 TMDL were based on best available technology and were approximately 70% for each assessment unit. For purposes of average % reduction, a "not impaired" HUC was considered as 0% reduction. Sub# refers to the name of the given area in the model.

2004 TMDL			**2009 TMDL**			
11-digit extension	**11-digit HUC name**	**average % reduction**	**10- and 12-digit extension**	**10- and 12-digit HUC name**	**sub#**	**average % reduction**
			-12-05	Town of Covington-Stillwater River (middle)	29	not impaired
			-12-05	Town of Covington-Stillwater River (upper)	4	0
-110	**Greenville Cr. (headwaters to below West Branch)**	**92**	**-10**	**Headwaters Greenville Creek**	**--**	**42**
			-10-01	Dismal Creek	24	72
			-10-02	Kraut Creek	23	91
			-10-03	West Branch Greenville Creek	13	not impaired
			-10-04	Headwaters Greenville Creek (lower)	25	89
			-10-04	Headwaters Greenville Creek (middle)	43	0
			-10-04	Headwaters Greenville Creek (upper)	44	not impaired
-120	**Greenville Cr. (below W. Branch to Stillwater River)**	**1**	**-11**	**Mud Creek-Greenville Creek**	**--**	**49**
			-11-01	Mud Creek	12	80
			-11-02	Bridge Creek-Greenville Creek (lower)	42	96
			-11-02	Bridge Creek-Greenville Creek (middle)	41	90
			-11-02	Bridge Creek-Greenville Creek (upper)	14	37
			-11-03	Dividing Branch	15	not impaired
			-11-03	Dividing Branch-Greenville Creek (lower)	32	0

Table 4.10. Comparison of % load reduction between 2004 TMDL and 2009 (current) TMDL organized by assessment unit. For the 2004 TMDL (Ohio EPA 2004), allocations were made to 11-digit HUC whereas in the 2009 TMDL allocations were made to 12-digit HUC. All assessment units exist in the 05080001 8-digit HUC. Value of % load reduction represents average of four seasonal reductions and applies to NPS, HSTS, MS4, and WWTP (2009 only) sectors. Percent load reductions for the WWTP sector in the 2004 TMDL were based on best available technology and were approximately 70% for each assessment unit. For purposes of average % reduction, a "not impaired" HUC was considered as 0% reduction. Sub# refers to the name of the given area in the model.

2004 TMDL			2009 TMDL			
11-digit extension	**11-digit HUC name**	**average % reduction**	**10- and 12-digit extension**	**10- and 12-digit HUC name**	**sub#**	**average % reduction**
			-11-03	Dividing Branch-Greenville Creek (middle)	39	85
			-11-03	Dividing Branch-Greenville Creek (upper)	40	0
-130	**Stillwater River (below Green-ville Cr. to above Ludlow Cr.)**	**75**	**-13**	**Painter Creek-Stillwater River**	**--**	**38**
			-13-01	Little Painter Creek	11	87
			-13-02	Painter Creek (lower)	31	57
			-13-02	Painter Creek (upper)	10	81
			-13-03	Canyon Run-Stillwater River (lower)	33	not impaired
			-13-03	Canyon Run-Stillwater River (middle)	34	not impaired
			-13-03	Canyon Run-Stillwater River (upper)	35	not impaired
-140	**Stillwater River (above Ludlow Cr. to Great Miami River)**	**40**	**-14**	**Ludlow Creek-Stillwater River**	**--**	**10**
			-14-01	Brush Creek (Ludlow Creek)	2	71
			-14-02	Ludlow Creek (lower)	9	not impaired
			-14-02	Ludlow Creek (upper)	36	not impaired
			-14-03	Brush Creek	7	not impaired
			-14-04	Jones Run-Stillwater River	8	not impaired
			-14-05	Mill Creek-Stillwater River	6	not impaired
			-14-06	Town of Irvington-Stillwater River	5	not impaired

Table 4.11. Comparison of recommended total phosphorus limits between 2004 and 2009 TMDLs for NPDES facilities. Organized by 12-digit HUC. Facilities discharging below 0.02 MGD (ADF) not included in table.

Facility #	Facility Name	Station	2004 effluent limit (mg-P/L)	2009 effluent limit (mg-P/L) (as average of 4 seasons)	Change Occurred
05080001-09-04: Boyd Creek					
1PG00090	Rolin Acres Subdivision WWTP	001	none	2.5 recommended (subsumed into NPS load)	
1PW00045	Northtowne Apts	001	none	0.29 recommended (possible connect ot major or subsumed into NPS load)	
05080001-09-05: Woodington Run-Stillwater River					
1PB00005	Ansonia STP	001	0.6	1.0	less restrictive limit
05080001-11-01: Mud Creek					
1IJ00015	Shamrock Materials Ft Jefferson Limestone	001	none	none (no TP discharged)	
05080001-11-02: Bridge Creek-Greenville Creek					
1PD00005	Greenville WWTP	001	0.55	0.14 (1.0 initially)	more restrictive limit
1PV00094	Sherwood Forest MHP	001	none	4.22 recommended (subsumed into NPS load)	
05080001-11-03: Dividing Branch-Greenville Creek					
1IJ00044	CF Poeppelman Inc *	001	none	none (no TP discharged)	
05080001-12-02: Swamp Creek					
1PB00033	Versailles WWTP	001	1.03	0.25 (1.0 initially)	more restrictive limit
05080001-12-03: Trotters Creek					
1IN00178	Hartzell Propeller Inc Service Center *	001	none	none (no TP discharged)	
05080001-12-04: Harris Creek					
1PB00008	Bradford WWTP	001	1.03	0.87 (1.0 initially)	more restrictive limit
05080001-13-02: Painter Creek					
1PB00000	Arcanum STP	001	0.79	0.29 (1.0 initially)	more restrictive limit
05080001-13-03: Canyon Run-Stillwater River					
1IJ00061	Milton Materials LLC *	001	none	none (no TP discharged)	
1IJ00061	Milton Materials LLC *	002	none	none (no TP discharged)	
1IJ00061	Milton Materials LLC *	003	none	none (no TP discharged)	
1PB00026	Pleasant Hill STP	001	0.79	none: not impaired	limit removed
1PB00013	Covington WWTP	001	0.79	none: not impaired	limit removed
05080001-14-02: Ludlow Creek					
1IJ00048	Barrett Paving Materials Inc	001	none	none (no TP discharged)	
1PB00045	Laura WWTP	001	none	none: not impaired	
05080001-14-04: Jones Run-Stillwater River					
1PC00011	West Milton WWTP	001	0.57	none: not impaired	limit removed
1PV00004	Pine Brook Estates	001	none	none: not impaired	
05080001-14-05: Mill Creek-Stillwater River					
1II00029	Dayton International Airport Terminal	002	none	none (no TP discharged)	
1II00029	Dayton International Airport Terminal	003	none	none (no TP discharged)	
1PB00030	Union STP	001	0.57	none: not impaired	limit removed

Table 4.11. Comparison of recommended total phosphorus limits between 2004 and 2009 TMDLs for NPDES facilities. Organized by 12-digit HUC. Facilities discharging below 0.02 MGD (ADF) not included in table.

Facility #	Facility Name	Station	2004 effluent limit (mg-P/L)	2009 effluent limit (mg-P/L) (as average of 4 seasons)	Change Occurred
05080001-14-06: Town of Irvington-Stillwater River					
1IN00216	APS Materials Inc *	001	none	none (no TP discharged)	
1PD00001	Englewood WWTP	001	0.57	none: not impaired	limit removed

5.0 Strategies for Restoration

Restoration methods to bring an impaired waterbody into attainment with water quality standards generally involve an increase in the waterbody's capacity to assimilate pollutants, a reduction of pollutant loads to the waterbody, or some combination of both. As described in Section 2, the causes of impairment in the Stillwater River are primarily nutrient enrichment, sedimentation, and stream habitat degradation. Therefore, an effective restoration strategy would include habitat improvements and reductions in pollutant loads, potentially combined with some additional means of increasing the assimilative capacity of the stream.

In advance of the 2004 TMDL, a workgroup sponsored by the Stillwater Watershed Project (see www.stillwatershed.org) developed a list of potential restoration strategies. These strategies were screened and evaluated using selected criteria (including feasibility, acceptability, sustainability, economical, reasonable assurance, and measurability) to identify the actions that could be used to achieve the TMDL restoration targets. The workgroup's menu of strategies were as follows (listed in no particular order):

- Stormwater management plans
- Reduce the use of agricultural and residential fertilizers and pesticides
- Riparian buffers; agricultural erosion control (bioremediation)
- Erosion control in urban/residential areas
- Septic system management and maintenance
- Public education for appreciation of watersheds and water quality
- Increase no-till farming practices
- Point source controls - permit effluent limitations (numerical restrictions and/or BMPs)
- Limit and reuse point source discharge water
- Encourage all livestock producers to manage their operations in accordance with manure nutrient management plans
- Encourage all livestock producers to participate in the Livestock Environmental Assurance Program (LEAP)
- Develop criteria for implementation of ditch maintenance program
- Develop Home Sewage Treatment System (HSTS) plans (proposed in the 2004 TMDL and subsequently completed in 2004)
- Health Department "manifest program" for septic tank handlers (part of CWA Section 319 grant)
- Establish Darke County Sewer District
- Establish pilot performance standards program with 10-15 producers that links payments for best management practices to load reductions in small stream segments.

The following additional strategies should be considered in reducing the nonpoint source contribution of phosphorus to the Stillwater River watershed:

- Market and transporting quantities of manure product outside the Stillwater River drainage basin to other watersheds not having any substantial production of animal manure; solicit subsidies and grants to reduce expenses in transportation of manure product outside of watershed

- Examine and adjust differences between rates and timing (i.e., time of year) of manure vs. synthetic fertilizer in selected headwater sub-basins through human interaction with the SWAT model by adjusting management strategies.

- Improve terrestrial and bank habitat with inclusion of woody trees and other perennials to improve nutrient uptake (assimilation) and reduce sediment export from uplands to channels.

- Explore crop-rotation and tillage practice scenarios to reduce overland sediment transport and overall nutrient yields through interaction with the SWAT model by adjusting management strategies.

Use of a physically-based daily simulation model will facilitate the Miami Conservancy District (MCD) trading program and can potentially answer questions on agricultural-specific load contribution, headwaters versus lower reach lower load distributions, and acute versus chronic load-producing events.

Founded in 1990 (and first funded in 1993), the Stillwater Watershed Project has been implementing best management practices (BMPs) for the control of erosion and nutrient runoff, purchase of conservation easements, and education within the watershed. This effort has been funded through a combination of grants from Ohio EPA (CWA Section 319), Ohio DNR (Watershed Management, Streambanking, Manure Nutrient Management, Geographic Information Systems and Watershed Coordinator), and USDA (Water Quality Incentive Program). More than $2 million have been spent within the watershed with 69 percent going directly to landowners for BMP installation and/or conservation easements. In addition to these grants, Ohio EPA's Division of Environmental & Financial Assistance (DEFA) has established a linked deposit low interest loan program for agricultural equipment and practices within the watershed.

In recent years, grants received by the Stillwater Watershed Project have locally implemented water quality improvement projects, produced measurable improvements in land management practices, and improved local awareness and understanding of the issues associated with nonpoint source pollution. Examples include replacing more than 500 failing on-site home sewage treatment systems and implementing nutrient reduction farm practices throughout the watershed. Specifically, grant amounts devoted to water quality improvements in the Watershed include:

1. Removal of Englewood low dam: $899,548
2. CWA Section 319 ($777,000 total)
    a. FFY 1993: $200,000
    b. FFY 1995: $120,000
    c. FFY 1997: $229,000
    d. FFY 2000: $228,000

Since 2001 the Project has been the recipient of a watershed coordinator grant to gradually shift personnel funding from reliance on grants to local support. Ohio EPA has provided $400,000 per year that is matched by $400,000 from ODNR to support local watershed planning efforts. As part of the grant requirements, an update of the Watershed Action Plan (WAP) that incorporated recommendations from the 2004 TMDL was completed and state endorsed in 2006. Periodic updates are completed and prepared by the Stillwater watershed coordinator who is funded in part by Ohio EPA and ODNR watershed coordinator grant funds. The Stillwater Watershed Plan serves as a primary means of TMDL implementation.

In 2002 the Miami County Health Department received a CWA Section 319 grant to inventory and upgrade residential septic systems throughout the county including the Stillwater watershed. One requirement of the grant was completion of a HSTS plan for the county. The Darke County Health Department received a CWA Section 319 grant to complete an inventory and assessment of all septic systems. Both counties have approved HSTS plans, so low-interest loans through Ohio EPA's DEFA could be available to homeowners for septic system upgrades and repairs.

Ohio EPA is taking an iterative, adaptive approach to implementation for this TMDL project. NPDES permits will be issued such that:

- Reasonable reductions of total phosphorus and instream monitoring of phosphorus and other TMDL parameters will be required;
- Enough time will be incorporated into the permit process to allow for nonpoint source controls to become effective and for additional data to be collected;
- Trends in instream concentrations will be tracked, and the NPDES permits will include an option for permit modifications should data indicate instream total phosphorus levels have achieved stable and desirable levels or that the use designations are being fully met.

Generally, implementation of BMPs relies on voluntary and incentive programs such as government cost-sharing. Therefore, the implementation plan should show: 1) there is reasonable assurance that nonpoint source controls will be implemented and maintained; or 2) nonpoint source reductions are demonstrated through an effective monitoring program. Long-term watershed water quality monitoring will also be important in evaluating the effectiveness of BMPs.

5.1 Reasonable Assurances

Reasonable assurances provide a level of confidence that the wasteload allocations and load allocations in TMDLs will be implemented by Federal, State, or local authorities and/or by voluntary action. The stakeholders will develop and document a list that differentiates the enforceable and non-enforceable selected actions necessary to achieve the restoration targets. Reasonable assurances for planned point source controls, such as wastewater treatment plant upgrades and changes to NPDES permits, will be a schedule for implementation of planned NPDES permit actions. For non-enforceable actions (certain nonpoint source activities), assurances would include 1) demonstration of adequate funding; 2) process by which agreements/arrangements between appropriate parties (e.g., governmental bodies, private landowners) will be reached; 3) assessment of the future of government programs which contribute to implementation actions; and 4) demonstration of anticipated effectiveness of the actions. It will be important to coordinate activities with those governmental entities that have jurisdiction and programs in place to implement the nonpoint source actions (e.g., county soil and water conservation district offices, county health departments, local Natural Resource Conservation Service offices of the U.S. Department of Agriculture, municipalities, and local governmental offices).

A summary of the regulatory, non-regulatory, and incentive based actions applicable to or recommended for the Stillwater watershed:

Regulatory:

- phosphorus limits for specific NPDES dischargers where aquatic life use attainment downstream of the effluent is impaired
- any new requirements that may be developed for household sewage treatment systems (statewide)
- sewage sludge disposal standards to regulate sludge application rates (statewide)
- phase I and II stormwater requirements

Non-regulatory:

- incorporation of the recommendations of the 2009 TMDL into the watershed action plan
- the Stillwater Watershed Joint Board of Supervisors to promote the watershed action plan and other activities contributing to the goals of the TMDL project
- periodic stream monitoring to measure progress
- removal of the dam at Englewood

Incentive-based:

- 319-funded projects for the entire Stillwater watershed which support the goals of this TMDL
- 319-funded (in part) watershed coordinator to promote watershed improvement activities
- various loan opportunities for WWTP, septic system, agriculture practices and riparian/habitat improvements
- A pilot program to test tying conservation payments to performance standards for reducing loads in impaired stream segments with 10-15 farmers

Agriculture related projects under CWA Section 319 grants are now focused on 12-digit HUCs and the expectation is that all available resources, not just CWA Section 319 dollars, will be used in that watershed. Under current USEPA guidance, program-type grants or single BMP demonstration projects are not fundable.

5.2 Implementation Plan

The five strategies developed for implementing the 2004 Stillwater River watershed TMDL remain relevant today: 1) animal waste management, 2) drainage and channelization management, 3) on-site sewage management, 4) urban issues, and 5) point source controls. The process used to generate ideas for implementing the 2004 TMDL is described in that report (Ohio EPA, 2004).

Past recommendations (2004 TMDL) were incorporated into the 2006 endorsed WAP. Recommendations in the 2009 TMDL should be considered for inclusion when the WAP is revised. The WAP will contain more specific details on the agreements reached with cooperating landowners and government officials.

Animal Waste Management
Animal waste is a significant contributor to nonpoint source pollution in the Stillwater watershed. Darke County has one of the highest concentrations of confined animal feeding operations in the state with a number of facilities covered under the ODA/Ohio EPA permitting programs. Implementation actions include the voluntary development of manure nutrient management plans, promotion of evolving technologies for safe land application of manure, grid soil sampling of lands proposed for manure application, establishment of vegetated filter strips, building of manure storage facilities according to NRCS specifications, exclusion of livestock from streams with alternate water supplies, and certification of manure applicators. Assessment units were ranked based on total phosphorus reduction required and willingness of landowner participation.

Currently, any animal feeding operation needs to have a manure nutrient management plan when applying for funds through the Soil and Water Office and Stillwater Watershed Project. The Stillwater Watershed Project has held manure nutrient management field days to encourage producers to develop a manure nutrient management plan and apply manure at the proper levels and time frames. Also, there has been an increase in filter strips since the Stillwater was selected to receive Conservation Security Program funds. Finally, Stillwater Watershed Project has been using the MCD Water Quality Trading program and Water Pollution Control Loan Fund to implement no-till cultivation and work with producers to implement cover crops.

Drainage and Channelization Management
Most, if not all, of the tributary streams in the Stillwater watershed have been channelized at some time. A significant number have been maintained in this condition to allow for drainage of crop fields to maintain productivity. The watersheds of these streams do deliver significant amounts of sediment and nutrients to downstream segments and need to be managed to maximize the length of time between maintenance activities. Implementation actions include development of criteria for ditch management programs that assess the need for and process to be followed in maintenance, the use of newer technologies such as two-stage or over-wide ditches, conservation planning to reduce sediment and nutrients entering the ditch and watershed wide stormwater control standards.

To best achieve water quality goals in the Stillwater River watershed, agricultural ditches should become more efficient at storing and assimilating more sediment and nutrient loads. A promising approach that will likely allow for years of improved capacity to treat nonpoint sources of sediment and nutrients is development of floodplain storage on bench structures. Bench structures become densely vegetated with herbaceous plants and grasses which help to sort and store sediment from the main channel. The plants and microbes living in the bench substrate utilize available nutrients in the water. Habitat improvements are also realized through increased variation in flow and channel shape as small meanders develop between the benches.

Such an approach to drainage ditch construction and maintenance is predicated on wide channel bottoms. The wider bottoms also require a small loss of land at the elevation of the field and more excavation work. Compensation for these costs are likely to include a substantially larger conveyance capacity resulting in fewer occasions where fields flood and improved subsurface drainage outlet freeboard. In essence, these improvements to drainage capacity are likely to be among the most efficient water quality improvements that can be made as well. Stream restoration, however, provides the greatest improvements in water quality and largest increase in conveyance capacity, although the significantly larger costs associated with restoration may preclude widely using this approach.

During the work for the 2004 TMDL, the subcommittee planned to develop a ranking system for streams identified as impaired because of poor habitat quality. This system uses factors such as the deviation from expected QHEI scores, drainage area, and probability of BMP adoption by adjacent landowners to rank streams for implementation actions. The ranking exercise indicated a number of management practices have been put in place (e.g., filter strips) in impaired segments since TMDL data were collected. These sites, where landowner cooperation is available, would be good sites for additional monitoring. The stream segments of West Branch of Greenville Creek and South Fork were to be targeted for management efforts initially because of high ratings on the criteria of QHEI, drainage size, and social capacity. County and township officials would educate about innovative ditch maintenance procedures such as two-stage ditches. These same officials would be consulted on development of criteria for beginning drainage maintenance activities and the identification of particular drainage problems.

<u>On-site Sewage Management</u>
Septic systems impact water quality in the Stillwater River watershed through failed, faulty, or discharging systems and improper disposal of wastes (septage) from septic systems. Implementation actions to address these sources of pollution would include oversight of septic tank waste haulers, identification of faulty septic systems, elimination of on-site septic systems through extension of municipal sanitary sewers, and public education about septic system maintenance.

The Miami County Health Department has an approved HSTS plan, is implementing a Section 319 grant, and is instituting an Ohio EPA DEFA linked deposit low interest loan program. The Darke County Health Department received a 319 grant for inventory of on-site systems in the Darke County portion of the watershed and upgrade of some systems along with an education component. A HSTS plan for the county was developed to make the county eligible for the linked deposit program. The 2004 subcommittee recommended the establishment of a county wide sewer district for Darke County, making it easier to extend sewers to currently unsewered areas.

<u>Urban Issues</u>
Urban related issues are not as major a problem in the Stillwater watershed as they are in more urbanized areas. Greenville is the only community in the Darke and Miami County portions of the watershed included in the Phase II stormwater regulations that became effective in 2003. In Montgomery County the cities of Englewood and Clayton as well as Butler and Union

Townships are included. The City of Dayton has stormwater regulations enacted as part of its Phase I stormwater permit which includes the Cox International Airport. Nutrients are contributed to the river through normal permitted discharge and through discharges from combined sewer overflows (CSOs). As NPDES permits are renewed limits will be established for phosphorus and nitrogen to levels that supplement reductions from nonpoint sources. Requirements for best available control technology will be the primary mechanism used for reaching the desired limits. Three communities have combined sewers with documented water quality problems from the overflows. All of these communities have begun to or plan to begin elimination of the overflows as part of schedules established with Ohio EPA. All of the municipal sludge management plans will also be updated to meet 40 CFR 503 requirements to ensure that land application of sludge does not impact on water quality.

Point Source Controls

Considering the size of the discharge, the type of treatment facility, and the likely financial impact of the high cost/pound of reduction at small facilities, phosphorus reductions are not proposed for a number of small facilities that discharge to impaired segments. Their TMDL allowances (wasteload allocations) are set equal to their existing allowable discharges, while the required phosphorus reductions in these segments will be achieved by the nonpoint source sector within their respective 12-digit HUC. These facilities include Mississinawa Valley Local School District, Rolin Acres Subdivision, Northtowne Apartments, Woodland Heights Elementary School, Wildcat Woods Campground, Sherwood Forest Mobile Home Park, Darke County Criminal Justice Center, Darke County Home, Greenville Country Club, Cottonwood Lakes Campground, Stillwater Golf Estates, and Franklin Monroe Elementary School.

Several of the above facilities have options for their wastewater that would be beneficial for meeting the goals of the TMDL. Northtowne Apartments and the Woodland Heights Elementary School are candidates for connecting to the Greenville wastewater treatment plant. The Franklin Monroe Elementary School will be connecting to the new Pitsburg wastewater treatment plant.

For three of the facilities that discharge to impaired segments, the Greenville, Versailles, and Bradford wastewater treatment plants, the TMDL is recommending adaptive implementation with provisions for water quality trading. Adaptive implementation is an iterative process that makes progress toward water quality goals while using new data and information to reduce uncertainty and adjust implementation activities.

The first step of the implementation process is reducing existing phosphorus discharges to meet a 1.0 mg/l monthly average effluent limit. For these plants, this is a substantial reduction in phosphorus discharge that ranges from 73 percent (Greenville) to 82 percent (Versailles). Considering the magnitude of these reductions, implementation will allow time for evaluating improvements in biological performance. Time will also allow the facilities to evaluate participation in a water quality trading program as a compliance option for meeting the TMDL allocations (seasonal average concentration) of 0.11 – 0.16 mg/l (Greenville), 0.18 – 0.37 mg/l (Versailles), 0.75 – 1.07 mg/l (Bradford).

Considering that the Village of Arcanum operates a lagoon treatment system, implementation will require a phosphorus reduction to a monthly average of 1.0 mg/l, but no lower. Additional phosphorus reductions assigned to Arcanum will be achieved by the nonpoint source sector within their 12-digit HUC.

Data show that the Ansonia's lagoon wastewater treatment system is currently able to achieve the 1.0 mg/l year-round phosphorus allocation assigned to it in the TMDL.

5.3 Removal of the Lowhead Dam at Englewood

Removal of the lowhead dam at Englewood (not the flood control structure) will improve instream and riparian habitat and thus provide an interconnection between channel and riparian zone. This interconnection has been lacking due to the dam/impoundment. The flow-through structure (Englewood flood reserve) is immediately downstream of the dam/impoundment; this concrete channel likely eliminates recovery of the impoundment effects and thus propagating the impact into the Englewood WWTP mixing zone (which is just downstream of the flow-through structure).

Removal of the dam will improve flow velocity and scour once-embedded substrates free of silt and clay; subsequently, cleaner substrates will improve macroinvertebrate ecology and, in turn, improve fishery ecology.

Dam removal is underway. A phased approach to lowering the 10 ft dam was designed to assure minimal bank and substrate erosion. Phase I reduced the dam height from 10 ft to 7.5 ft and included riparian plantings (in spring 2009) and building a bridge for a footpath over an inlet tributary. Phase II and III will be combined and completed in summer 2009, completely removing the dam. These phases also include installation of rock veins to serve as a series of riffle structures.

See Appendix B for biological assessments completed upstream of the impoundment, within the impoundment, and downstream of both the impoundment and Englewood WWTP. Appendix B also shows that there is minimal nutrient enrichment downstream of the Englewood WWTP as observed by DO traces and benthic algae sampling (chlorophyll a).

5.4 Process for Monitoring and Revision

The effectiveness of actions implemented based on the TMDL recommendations should be validated through ongoing monitoring and evaluation. Information derived from water quality analyses can guide changes to the implementation strategy to more effectively reach the TMDL goals. Additionally, monitoring is required to determine if and when formerly impaired segments meet applicable water quality standards (WQS).

This section of the report provides a general strategy for continued monitoring and evaluation and lists parties who can potentially carry out such work. It highlights past efforts and those planned to be carried out in the future by the Ohio EPA and others. It also outlines a process by which changes to the implementation strategy can be made if needed.

Evaluation and Analyses
Aquatic life are impaired in the watershed, so monitoring that evaluates the river system with respect to these uses is a priority to the Ohio EPA. The degree of impairment of aquatic life use is exclusively determined through the analysis of biological monitoring data. Ambient conditions causing impairment include agricultural land uses, home sewage treatment systems and point source discharges. This report sets targets values for these parameters, which should also be measured through ongoing monitoring.

A serious effort should be made to determine if and to what degree the recommended implementation actions have been carried out. This should occur within an appropriate timeframe following the completion of this TMDL report and occur prior to measuring the biological community, water quality or habitat.

Past and Ongoing Water Resource Evaluation
Ohio EPA monitored the watershed in 1999 (Ohio EPA, 2001) and the area around the Englewood dam was reassessed in 2008 (Appendix B). The Ohio EPA is scheduled to perform biological, water quality, habitat, and sediment chemistry monitoring in the watershed in 2019 (Ohio EPA, 2008). Ohio EPA also maintains a long-term chemistry monitoring station at Pleasant Hill, near with the U.S. Geological Survey stream flow gaging station.

WWTPs have been completing ambient monitoring according to NPDES permits and will continue to do so. The Miami Conservancy District is sampling ambient nutrients (continuously from April 2005 to the present) on the Stillwater River at Englewood.

Potential and Future Evaluation
Ohio EPA is unaware of any future plans for additional monitoring and evaluation by other entities.

Recommended Approach for Gathering and Using Available Data
Early communications should take place between the Ohio EPA and any potential collaborators to discuss research interests and objectives. Through this, areas of overlap should be identified and ways to make all parties research efforts more efficient should be discussed. Ultimately important questions can be addressed by working collectively and through pooling resources, knowledge, and data.

Revision to the Implementation Approach
An adaptive management approach will be taken in the Stillwater River watershed. Adaptive management is recognized as a viable strategy for managing natural resources (Baydack et al., 1999) and this approach is applied on federally-owned lands. An adaptive management approach allows for changes in the management strategy if environmental indicators suggest that the current strategy is inadequate or ineffective. The recommendations put forth for the Stillwater River watershed largely center on agricultural BMPs, improving home sewage treatment systems, and phosphorus reductions. If chemical water quality does not show improvement and/or water bodies are still not attaining water quality standards after the implementation plan has been carried out, then a TMDL revision would be initiated. The Ohio EPA would initiate the revision if no other parties wish to do so.

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Appendix A: Tables from 2004 Stillwater River TMDL

Table 1.1. Names of impaired stream segments and the miles impaired, and associated causative pollutants and pollutant sources in the Stillwater River basin identified in the 1992, 1998 and 2002 §305b assessment cycles.

AQUATIC LIFE USE STATUS

Segment	URM	LRM	FULLY	THREAT	PARTIAL	NON	Unassessed	**Causes†**		**Sources†**	
Stillwater River (Headwaters to North Fork) MWH											
OH57 45								Other habitat alterations	M	Channelization - Agriculture	M
2002	67.6	57.9	7	0	0	2.67	0	Organic enrichment/DO	H	Hydromodification - Agriculture	M
								Nutrients	M	Confined Animal Feeding Operations	H
Stillwater River (Headwaters to North Fork) MWH											
OH57 45								Other habitat alterations	H	Channelization - Agriculture	M
1998	67.6	57.9	0	0	0	9.67	9.67	Nutrients	M	Hydromodification - Agriculture	M
										Nonirrigated crop production	H
Stillwater River (Headwaters to North Fork) MWH											
OH57 45								Organic enrichment/DO	H	Combined Sewer Overflow	M
1992	67.6	57.9	0	0	9.67	0	9.67			Municipal Point Sources	H
Stillwater River (North Fork to Swamp Creek) WWH/EWH											
OH57 43								Nutrients	H	Channelization - Agriculture	H
2002	57.9	45.8	8.09	0	4	0	0			Hydromodification - Agriculture	H
										Confined Animal Feeding Operations	M
Stillwater River (Swamp Creek to Greenville Creek) EWH											
OH57 37								Nutrients	H	Channelization - Agriculture	H
2002	45.8	32.4	12.5	0	1	0	0			Hydromodification - Agriculture	H
										Confined Animal Feeding Operations	M

† Magnitude of causes and sources are given as follows: H - High, M - Moderate, S - Slight, T - Threat

Table 1.1. Continued.

Segment	URM	LRM	FULLY	THREAT	PARTIAL	NON	Unassessed	Causes†		Sources†	
				AQUATIC LIFE USE STATUS							
Stillwater River (Swamp Creek to Greenville Creek) EWH											
OH57 37								Organic enrichment/DO	H	Combined Sewer Overflow	M
1992	45.8	32.4	5.5	0	8	0	13.5			Municipal Point Sources	H
Stillwater River (Greenville Cr. To Ludlow Cr.) EWH											
OH57 14								Other habitat alterations	H	Source Unknown	H
1992	32.4	21	8.6	0	2.8	0	11.4	Cause Unknown	H	Dam construction - Development	H
										Hydromodification - Development	H
Stillwater River (Brush Creek to Great Miami R.) EWH											
OH57 1								Nutrients	H	Confined Animal Feeding Operations	H
2002	14.2	0	13.2	0	0	1	0	Other habitat alterations	M	Nonirrigated crop production	H
										Hydromodification - Development	M
Stillwater River (Brush Creek to Great Miami R.) EWH											
OH57 1								Other habitat alterations	M	Dam construction - Development	M
1992	14.2	0	3.6	0	10.6	0	14.2	Organic enrichment/DO	H	Hydromodification - Development	M
										Combined Sewer Overflow	H
										Municipal Point Sources	H

† Magnitude of causes and sources are given as follows: H - High, M - Moderate, S - Slight, T - Threat

Table 1.1. Continued

AQUATIC LIFE USE STATUS

Segment	URM	LRM	FULLY	THREAT	PARTIAL	NON	Unassessed	**Causes†**		**Sources†**	
Pigeye Creek WWH											
OH57 2								Organic enrichment/DO	H	Onsite wastewater systems	H
2002	1.9	0	0	0	1.9	0	0			(septic tanks)	
Mill Creek WWH											
OH57 3Other habitat alterations HChannelization - Development H											
2002	5.7	0	0.5	0	0	5.2	0	Organic enrichment/DO	H	Hydromodification - Development	H
								Unionized Ammonia	H	Major Industrial Point Source	H
Mill Creek WWH											
OH57 3								Other habitat alterations	S	Spills	H
1998	5.7	0	0.6	0	0	3.8	5.7	Organic enrichment/DO	H	Other	H
								Unionized Ammonia	H	Channelization - Development	S
										Wastewater	H
Mill Creek WWH											
OH57 3								Organic enrichment/DO	H	Channelization - Development	S
1996	5.7	0	0	0.6	0	3.8	5.7	Unionized Ammonia	T	Industrial Permitted	T
								Unionized Ammonia	H	Industrial Permitted	H
										Urban Runoff/Storm Sewers (NPS)	T
										Urban Runoff/Storm Sewers (NPS)	H

† Magnitude of causes and sources are given as follows: H - High, M - Moderate, S - Slight, T - Threat

Table 1.1. Continued.

AQUATIC LIFE USE STATUS

Segment	URM	LRM	FULLY	THREAT	PARTIAL	NON	Unassessed	**Causes†**		**Sources†**	
Jones Run WWH											
OH57 6								Organic enrichment/DO	H		
2002	0.6	0	0	0	0.6	0	0				
Painter Creek MWH/WWH											
OH57 18								Organic enrichment/DO	H	Combined Sewer Overflow	M
2002	19.7	0	3.25			16.5		Nutrients	M	Combined Sewer Overflow	H
`								Unionized Ammonia	M	Minor Municipal Point Source	H
Painter Creek MWH/WWH											
OH57 18								Other habitat alterations	H	Natural	M
1998	19.7	0	4.75	0	0	15	19.7	Organic enrichment/DO	M	Other	M
								Nutrients	M	Channelization - Agriculture	H
										Hydromodification - Agriculture	H
										Nonirrigated crop production	M
										Minor Municipal Point Source	H
Painter Creek MWH/WWH											
OH57 18								Organic enrichment/DO	H	Hazardous waste	H
1992	19.7	0	11.9	0	0.2	7.65	19.7	Unionized Ammonia	H	Combined Sewer Overflow	M
										Municipal Point Sources	H

† Magnitude of causes and sources are given as follows: H - High, M - Moderate, S - Slight, T - Threat

Table 1.1. Continued.

			AQUATIC LIFE USE STATUS								
Segment	URM	LRM	FULLY	THREAT	PARTIAL	NON	Unassessed	**Causes†**		**Sources†**	
Little Painter Creek MWH											
OH57 19								Organic enrichment/DO	H	Animal holding/management areas	H
2002	5.2	0	4.2	0	1	0	0				
Brush Creek WWH											
OH57 8								Organic enrichment/DO	H	Channelization - Development	M
2002	8	0	6	0	0	2	0	Unionized Ammonia	M	Hydromodification - Development	M
										Septage disposal	H
Brush Creek WWH											
OH57 8								Other habitat alterations	H	Channelization - Agriculture	H
1998	8	0	0	0	0	8	8	Nutrients	H	Hydromodification - Agriculture	H
										Nonirrigated crop production	H
Harris Creek MWH/WWH											
OH57 38								Organic enrichment/DO	H	Channelization - Agriculture	H
2002	9.1	0	6.1	0	3	0	0	Siltation	H	Hydromodification - Agriculture	H
										Minor Municipal Point Source	M
Harris Creek MWH/WWH											
OH57 38								Nutrients	H	Range Grazing - Riparian	S
1998	9.1	0	0	0	1.3	0	9.1			Nonirrigated crop production	H

† Magnitude of causes and sources are given as follows: H - High, M - Moderate, S - Slight, T - Threat

Table 1.1. Continued.

Segment	URM	LRM	FULLY	THREAT	PARTIAL	NON	Unassessed	Causes†		Sources†	
					AQUATIC LIFE USE STATUS						
Ballinger Run MWH/WWH											
OH57 39								Other habitat alterations	H	Channelization - Agriculture	H
2002	4.6	0	0	0	0	4.6	0	Organic enrichment/DO	H	Hydromodification - Agriculture	H
										Combined Sewer Overflow	H
Ballinger Run MWH/WWH											
OH57 39								Other habitat alterations	H	Channelization - Agriculture	H
1998	4.6	0	0	0	0	4.6	4.6	Siltation	H	Hydromodification - Agriculture	H
								Nutrients	H	Nonirrigated crop production	H
										Minor Municipal Point Source	M
Greenville Creek (Headwaters to West Branch) EWH											
OH57 32								Organic enrichment/DO	H	Feedlots (Confined Animal Feeding)	H
1992	40.5	24.3	6.5	0	4.7	0	16.2			Nonirrigated crop production	H
Greenville Creek (West Br. To Dividing Br.) WWH											
OH57 26								Other habitat alterations	M	Channelization - Development	H
2002	24.3	15.2	2.6	0	6	0.5	0	Organic enrichment/DO	H	Hydromodification - Development	H
										Major Municipal Point Source	H

† Magnitude of causes and sources are given as follows: H - High, M - Moderate, S - Slight, T - Threat

Table 1.1. Continued.

AQUATIC LIFE USE STATUS

Segment	URM	LRM	FULLY	THREAT	PARTIAL	NON	Unassessed	**Causes†**		**Sources†**	
Greenville Creek (West Br. To Dividing Br.) WWH											
OH57 26								Other habitat alterations	H	Dam construction - Development	H
1992	24.3	15.2	0	0	9.1	0	9.1	Flow alteration	H	Hydromodification - Development	H
								Organic enrichment/DO	H	Nonirrigated crop production	S
								Siltation	S	Municipal Point Sources	H
										Industrial Point Sources	S
Greenville Creek (Dividing Br. To Stillwater R.) EWH											
OH57 21								Organic enrichment/DO	H	Onsite wastewater systems (septic tanks)	H
2002	15.2	0	9.5	0	2.7	3	0	Nutrients	M	Major Municipal Point Source	H
Greenville Creek (Dividing Br. To Stillwater R.) EWH											
OH57 21								Other habitat alterations	M	Dam construction - Development	M
1992	15.2	0	0	0.3	7.3	7.6	15.2	Organic enrichment/DO	T	Hydromodification - Development	M
								Organic enrichment/DO	H	Nonirrigated crop production	T
										Nonirrigated crop production	M
										Municipal Point Sources	T
										Municipal Point Sources	H
										Industrial Point Sources	S

† Magnitude of causes and sources are given as follows: H - High, M - Moderate, S - Slight, T - Threat

Table 1.1. Continued.

AQUATIC LIFE USE STATUS

Segment	URM	LRM	FULLY	THREAT	PARTIAL	NON	Unassessed	**Causes†**		**Sources†**	
Bolton Run WWH											
OH57 24								Organic enrichment/DO	H	Onsite wastewater systems	H
2002	3.5	0	0	0	3.5	0	0			(septic tanks)	
Dividing Branch WWH											
OH57 25								Organic enrichment/DO	H	Channelization - Agriculture	M
2002	7	0	2.5	2.5				Nutrients	M	Hydromodification - Agriculture	M
										Onsite wastewater systems	H
										(septic tanks)	
Mud Creek WWH											
OH57 28								Other habitat alterations	H	Channelization - Agriculture	H
1992	8	0	7.8	0	0.2	0	8	Siltation	H	Hydromodification - Agriculture	H
Prairie Outlet WWH											
OH57 29								Organic enrichment/DO	H	Onsite wastewater systems	H
2002	2	0	0	0	2	0	0			(septic tanks)	
Prairie Outlet WWH											
OH57 29								Organic enrichment/DO	H	Onsite wastewater systems	H
1992	2	0	0	0	1	0	2	Nutrients	H	(septic tanks)	
										Feedlots (Confined Animal Feeding)	H

† Magnitude of causes and sources are given as follows: H - High, M - Moderate, S - Slight, T - Threat

Table 1.1. Continued.

Segment	URM	LRM	FULLY	THREAT	PARTIAL	NON	Unassessed	Causes†		Sources†	
					AQUATIC LIFE USE STATUS						
Dismal Creek WWH											
OH57 35								Other habitat alterations	H	Channelization - Agriculture	H
2002	9.5	0	2	0	2	1	0	Organic enrichment/DO	H	Hydromodification - Agriculture	H
										Wastewater	H
Swamp Creek WWH/MWH											
OH57 41								Other habitat alterations	M	Channelization - Agriculture	M
2002	13.8	0	4.8	0	6.5	2.5	0	Organic enrichment/DO	H	Hydromodification - Agriculture	M
								Nutrients	M	Confined Animal Feeding Operations	H
Swamp Creek WWH/MWH											
OH57 41								Other habitat alterations	H	Channelization - Agriculture	H
1992	13.8	0	7.3	0	1.6	4.9	13.8	Organic enrichment/DO	H	Hydromodification - Agriculture	H
								Nutrients	H	Feedlots (Confined Animal Feeding)	M
										Nonirrigated crop production	M
										Municipal Point Sources	M
Indian Creek WWH/MWH											
OH57 42								Other habitat alterations	H	Channelization - Agriculture	H
2002	5.2	0	0	0	0.5	6.1	0	Organic enrichment/DO	H	Hydromodification - Agriculture	H
								Nutrients	M	Septage disposal	H
										Confined Animal Feeding Operations	H

† Magnitude of causes and sources are given as follows: H - High, M - Moderate, S - Slight, T - Threat

Table 1.1. Continued.

AQUATIC LIFE USE STATUS

Segment	URM	LRM	FULLY	THREAT	PARTIAL	NON	Unassessed	**Causes†**		**Sources†**	
Indian Creek WWH/MWH											
OH57 42								Other inorganics	H	Spills	H
1998	5.2	0	0	0	0	4.85	5.2	Other	H		
Indian Creek WWH/MWH											
OH57 42								Other habitat alterations	H	Streambank destabilization - Ag	H
1992	5.2	0	0	0	1	0	5.2			Channelization - Agriculture	H
										Hydromodification - Agriculture	H
Boyd Creek MWH											
OH57 44								Other habitat alterations	M	Channelization - Agriculture	M
2002	3.3	0	3	0	1	0	0	Organic enrichment/DO	H	Hydromodification - Agriculture	M
										Onsite wastewater systems (septic tanks)	H
North Fork Stillwater River MWH											
OH57 46								Other habitat alterations	M	Channelization - Agriculture	M
2002	7.7	0				11		Organic enrichment/DO	H	Hydromodification - Agriculture	M
										Confined Animal Feeding Operations	H
South Fork Stillwater River WWH											
OH57 48								Other habitat alterations	H	Channelization - Agriculture	H
2002	7	0	1		6					Hydromodification - Agriculture	H

† Magnitude of causes and sources are given as follows: H - High, M - Moderate, S - Slight, T - Threat

Table 1.1. Continued.

			AQUATIC LIFE USE STATUS								
Segment	URM	LRM	FULLY	THREAT	PARTIAL	NON	Unassessed	**Causes†**		**Sources†**	
Trib. To Stillwater R. (Rm 60.22) MWH											
OH57 45.							1	Other habitat alterations	H	Channelization - Agriculture	H
2002	4.06	0	2	0	0.5	0	0			Hydromodification - Agriculture	H

† Magnitude of causes and sources are given as follows: H - High, M - Moderate, S - Slight, T - Threat

Table 1.2. Status of 2002 303(d) listed segments included in this TMDL report.

WBID	URM	LRM	Segment Name	Causes	TMDL Component
OH57 1	14.2	0	Stillwater River	Nutrients Hydromodification	NPDES included in WLA Dam Removal
OH57 2	1.9	0	Pigeye Creek	Organic enrichment/DO	Septic & livestock implementation plans
OH57 3	5.7	0	Mill Creek	Unionized Ammonia Organic enrichment/DO Other habitat alterations	No, covered separately through NPDES permit
OH57 6	0.6	0	Jones Run	Organic enrichment/DO	Sewer line repaired
OH57 8	8	0	Brush Creek	Unionized Ammonia Organic enrichment/DO	Septic implementation plan
OH57 18	19.75	0	Painter Creek	Unionized Ammonia Nutrients Organic enrichment/DO	NPDES included in WLA, Major treatment plan upgrade underway to include CSO control
OH57 19	5.2	0	Little Painter Creek	Organic enrichment/DO	Livestock implementation plan
OH57 21	15.2	0	Greenville Creek	Organic enrichment/DO Nutrients	Septic implementation plan
OH57 24	3.5	0	Bolton Run	Organic enrichment/DO	Erroneously listed in 303(d) report, Bolton Run is in full attainment of its aquatic life use
OH57 25	7	0	Dividing Branch	Organic enrichment/DO Nutrients	Erroneously listed in 303(d) report, Dividing Branch is in full attainment of its aquatic life use
OH57 26	24.3	15.2	Greenville Creek	Other habitat alterations Organic enrichment/DO	NPDES included in WLA
OH57 29	2	0	Prairie Outlet	Organic enrichment/DO	Septic implementation plan
OH57 35	9.5	0	Dismal Creek	Organic enrichment/DO Other habitat alterations	NPDES included in WLA

Table 1.2. Continued.

WBID	URM	LRM	Segment Name	Causes	TMDL Component
OH57 37	45.88	32.4	Stillwater River	Nutrients	NPDES included in WLA; Livestock implementation plan
OH57 38	9.1	0	Harris Creek	Organic enrichment/DO	NPDES included in WLA, Major treatment plan upgrade underway to include CSO control
OH57 39	4.6	0	Ballinger Run	Other habitat alterations Organic enrichment/DO	NPDES included in WLA, Major treatment plan upgrade underway to include CSO control
OH57 41	13.8	0	Swamp Creek	Organic enrichment/DO Other habitat alterations Nutrients	Livestock and drainage and channelization implementation plans
OH57 42	5.2	0	Indian Creek	Nutrients Organic enrichment/DO Other habitat alterations	Livestock drainage and channelization, and septic implementation plans
OH57 43	57.97	45.88	Stillwater River	Nutrients	Livestock and drainage and channelization implementation plans
OH57 44	3.3	0	Boyd Creek	Organic enrichment/DO Other habitat alterations	Livestock and drainage and channelization implementation plans
OH57 45	67.64	57.97	Stillwater River	Other habitat alterations Organic enrichment/DO Nutrients	Livestock and drainage and channelization implementation plans
OH57	4.06	0	UNT to Stillwater	Other habitat alterations	Drainage and channelization implementation plan
OH57 46	7.7	0	North Fork	Organic enrichment/DO Other habitat alterations	Livestock and drainage and channelization implementation plans
OH57 48	7	0	South Fork	Other habitat alterations	Drainage and channelization implementation plan

Appendix B: 2008 Assessment of Englewood Dam Area

In 2008, Ohio EPA returned to the Stillwater River to assess the current situation around the Englewood dam prior to its removal. Portions of this information is excerpted from the an 2009 Ohio EPA report entitled *Biological and Habitat Studies: 11 River and Stream Projects. Year 2008 Section 319(h) Clean Water Act Grants*, available at http://www.epa.ohio.gov/portals/35/documents/319MonitoringReport2008.pdf

Biological Survey

At the two free-flowing stations sampled in the Stillwater River, excellent physical habitat conditions were present and very good to exceptional biological communities were documented. These two sites (RMs 11.1 and 8.5) fully attained the Exceptional Warmwater Habitat (EWH) biological criteria listed in the Ohio Water Quality Standards. The site located in the project area (RM 9.5 - impounded section of the Stillwater River) had fair instream habitat conditions due to the lack of riffle areas, sparse instream cover, and predominantly sand substrates extensively embedded with silts and muck. Biological results from RM 9.5 did not attain the EWH biocriteria. During the biological sampling activities (July and September), the low head dam was completely intact, and river dredging had commenced.

AQUATIC LIFE USE ATTAINMENT - STILLWATER RIVER 2008.

The Index of Biotic Integrity (IBI), Modified Index of Well-being (MIwb), and Invertebrate Community Index (ICI) scores are based on the performance of the biological community. The Qualitative Habitat Evaluation Index (QHEI) is a measure of the ability of the physical habitat to support a biological community. Stream sites are located in the Eastern Corn Belt Plains (ECBP) ecoregion. In the Ohio Water Quality Standards, this section of the Stillwater River is designated Exceptional Warmwater Habitat (EWH).

Sample Site River Mile	Attainment Status	IBI	MIwb	ICI	QHEI	Biological Assessment
11.1	**FULL**	58	10.5	44[ns]	83.0	Very Good to Exceptional
9.5	**NON**	40*	8.5*	34*	53.0 (Fair)	Marginally Good to Good
8.5	**FULL**	56	10.6	50	87.0	Exceptional

[ns] Nonsignificant departure from biocriterion (≤4 IBI or ICI units; ≤0.5 MIwb units).

* Significant departure from biocriterion (>4 IBI or ICI units, >0.5 MIwb units).

Ecoregion Biocriteria: Eastern Corn Belt Plains (ECBP)		
INDEX – SITE TYPE	WWH	EWH
IBI: Boat	42	48
MIwb: Boat	8.5	9.6
ICI	36	46

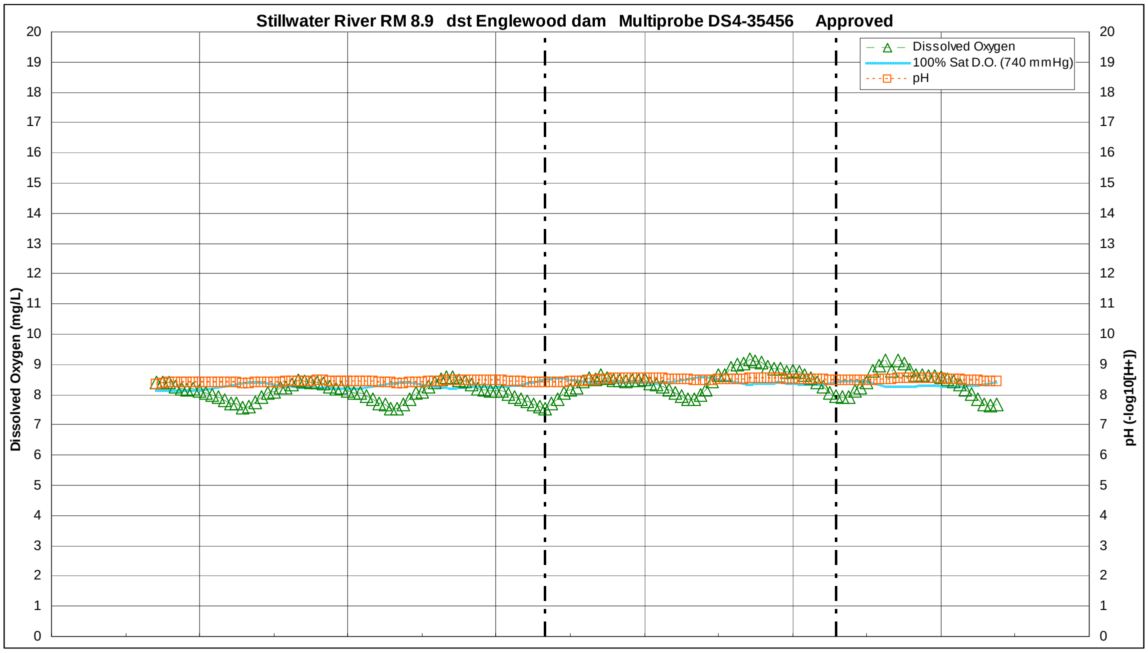
Sampling locations in the Stillwater River, 2008.

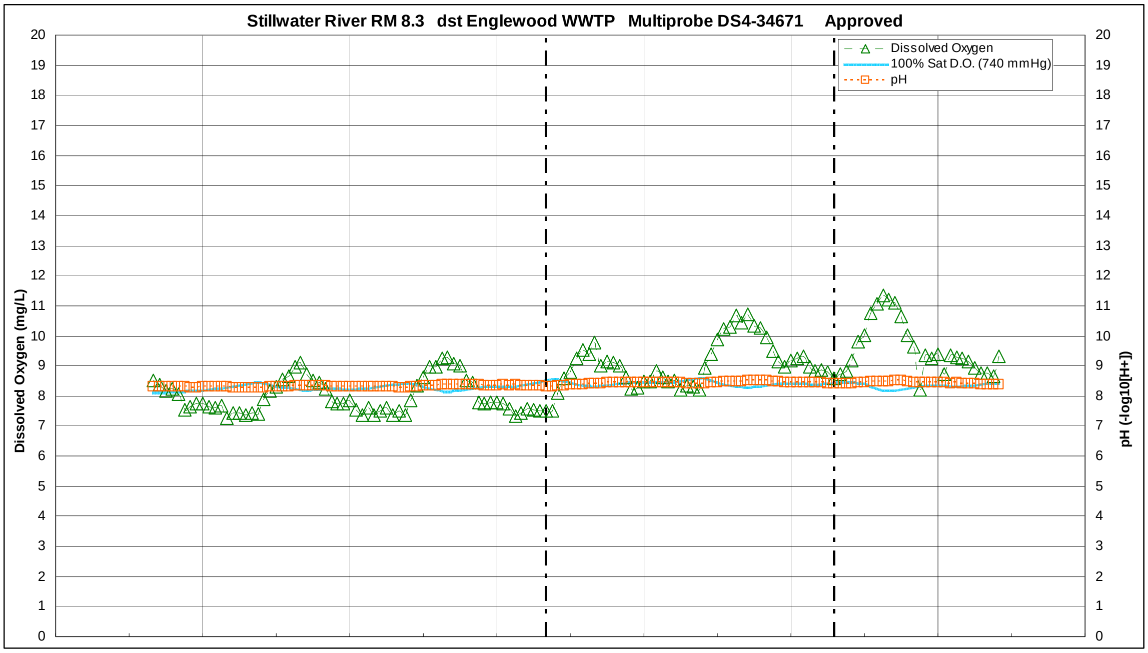
River Mile	Latitude	Longitude	Landmark
11.1	39.89569	84.29022	Upstream Englewood impoundment, near
9.5	39.87405	84.29150	Englewood dam impoundment
8.5	39.86744	84.27564	Downstream Englewood dam and Englewood

Dissolved Oxygen (DO) Monitoring

Two locations, upstream (RM 8.9) and downstream (RM 8.3) of the Englewood WWTP outfall were sampled with multi-parameter continuous datasonde monitors. The upstream location was just downstream of the Englewood dam. The sampling date was a critical low-flow period during a warm, August time period (08/08 to 08/14/2008). Time series traces are portrayed below.

For the authenticated period of 08/11 to 08/13/2008, the minimum DO for RM 8.9 was 7.54 mg/L and for RM 8.3 was 7.49 mg/L. The DO range during this period was 1.64 and 3.23 mg/L, respectively, for the upstream and downstream locations. Both parameters – minimum and range – demonstrate non-enrichment conditions.





Benthic Algae Survey

Benthic samples (3 total) were taken just downstrean of the I-70 bridge (about RM 7.9). This is 0.8 mi DST of the Englewood pipe and is sufficient distance for a full DO effect.

Sample#	Chl_a	Pheo	%Pheo
1	181.83	48.38	26.61
2	213.09	54.90	25.76
3	188.29	50.98	27.08

The mean periphyton chlorophyll was 197.5 mg/m^2 and the mean pheophytin was 51.4 mg/m^2.

Ohio EPA research on nutrients shows that, for streams < 500 mi^2, sites with Chl a values exceeding 194 mg/m^2 are more likely to have wide DO swings. The Stillwater River watershed downstream from Englewood is approximately 600 mi^2.

The statewide dataset is for 109 sites, mostly < 500 mi^2 in drainage area (19 sites had drainage areas > 500 mi^2) compiled to support development of nutrient water quality standards in streams and small rivers. The median value from this dataset is approximately 194 mg/ m^2.

Appendix C: Details of Load Development

C.1 Hydrology calibration
C.2 Chemistry calibration
C.3 Agricultural management scenarios
C.4 WWTP inputs derived from STORET

Appendix C.1 Hydrology Calibration

Appendix C.1.a. Calibration of SWAT for hydrology: documentation of model evolution through parameter selection and modification.

Model Run	Description	Parameter Note	Comments
`HydroStart`	1st run using new DEM and new slope data set; ALPHA_BF corresponding to Arnold baseflow program set for each of three sub-drainages (set in .gw for each subbasin)	ALPHA_BF: engle 0.0768 plhill 0.0858 brad 0.0600	
`Priestley_ESCOvar1`	Same as `HydroStart`, except changed ET model from Penman-Monteith to Priestley-Taylor; ESCO = 0.99 for all AGRR HRUs in Bradford gage drainage area (.hru); ESCO = 0.96 (.bsn) for remaining HRUs (part of Pleasant Hill and Englewood drainage not in Bradford	Priestley-Taylor ESCO = 0.99 (.hru); ESCO = 0.96 (.bsn)	
`Priestley_ESCOvar2`	Same as `Priestley_ESCOvar1`, except set ESCO = 0.96 for all HRUs in Bradford gage drainage area. Thus, all drainages have ESCO = 0.96 and will set once in .bsn file.	ESCO = 0.96 (.bsn)	
`CNred1_Priestley`	Same as `Priestley_ESCOvar2`, except reduced ESCO back to default values (0.95) and reduced CN2 by 4 units (relative to `HydroStart`) but only for AGRR land use in Bradford drainage: AGRR B 78 --> 74 AGRR C 85 --> 81	CN2 (.mgt) -4 ESCO = 0.95 (.bsn)	calibration folder not created
`CNred2_Penman`	Same as `Priestley_ESCOvar2`, except ET model set to Penman-Monteith, reduced ESCO to 0.94, and <u>reduced</u> CN2 by 2 units (relative to `CNred1_Priestley`) but only for AGRR land use in Bradford drainage: AGRR B 74 --> 72 AGRR C 81 --> 79	Penman-Monteith CN2 (.mgt) -2 ESCO = 0.94 (.bsn)	calibration folder not created
`CNred2_Priestley`	Same as `CNred1_Priestley`.	ESCO = 0.95 (.bsn)	
`CNred3_Priest`	Same as `CNred2_Priestley`, except increased ESCO to 0.95, and <u>reduced</u> CN2 by an additional 2 units (relative to CNred1_Priestley) but only for AGRR land use in Bradford drainage: AGRR B 74 --> 72 AGRR C 81 --> 79	CN2 (.mgt) ESCO = 0.96 (.bsn)	

Model Run	Description	Parameter Note	Comments
CNred4_Priest	Same as CNred3_Priest, except reduced CN2 by an additional unit but only for AGRR land use in Bradford drainage: AGRR B 72 --> 71 AGRR C 79 --> 78	CN2 (.mgt) -1	
CNinc1AWC	Same CN as CNred3_Priest, except increased SOL_AWC by 0.02 but only for AGRR land use in Bradford drainage: AGRR B 72 AGRR C 79	CN2 (.mgt) SOL_AWC (.sol) +0.02	slightly prefer this model run over ESCOinc2AWC
ESCOinc2AWC	Same as CNinc1AWC, except decreased ESCO to 0.95 in order to reduce TWYLD, and increased SOL_AWC by 0.02 but only for AGRR land use in Bradford drainage.	ESCO = 0.95 (.bsn) SOL_AWC (.sol) +0.02	end of Bradford calibration
CNred1_incAWC34	Same CN as CNinc1AWC, except reduced CN2 by 4 units (relative to HydroStart) and increased SOL_AWC by 0.02 but only for AGRR land use in Pleasant Hill (interim) drainage: AGRR B 78 --> 74 AGRR C 85 --> 81	CN2 (.mgt) -4 SOL_AWC (.sol) +0.02	xls for sub 34 only
MultiAdjust34	Same CN as CNred1_incAWC34, except increased CN2 by 1 unit, decreased SOL_AWC by 0.01, decrease REVAPMN to 0.7, and decrease ESCO to 0.94 but only for AGRR land use in Pleasant Hill (interim) drainage: AGRR B 74 --> 75 AGRR C 81 --> 82	CN2 (.mgt) +1 SOL_AWC (.sol) -0.01 ESCO = 0.94 (.hru) ESCO = 0.95 (.bsn) REVAPMN = 0.5 mm (.gw)	xls for sub 34 only
2MultiAdjust34	Same CN as MultiAdjust34, except increased CN2 by 1 unit and decreased REVAPMN to 0.15 but only for AGRR land use in Pleasant Hill (interim) drainage: AGRR B 75 --> 76 AGRR C 82 --> 83	CN2 (.mgt) +1 REVAPMN = 0.15 mm (.gw)	
3MultiAdjust34	Same CN as 2MultiAdjust34, except decreased ESCO to 0.93 but only for AGRR land use in Pleasant Hill (interim) drainage: AGRR B 76 AGRR C 83	ESCO = 0.93 (.hru) ESCO = 0.95 (.bsn)	overall change in SOL_AWC from HydroStart is +0.03

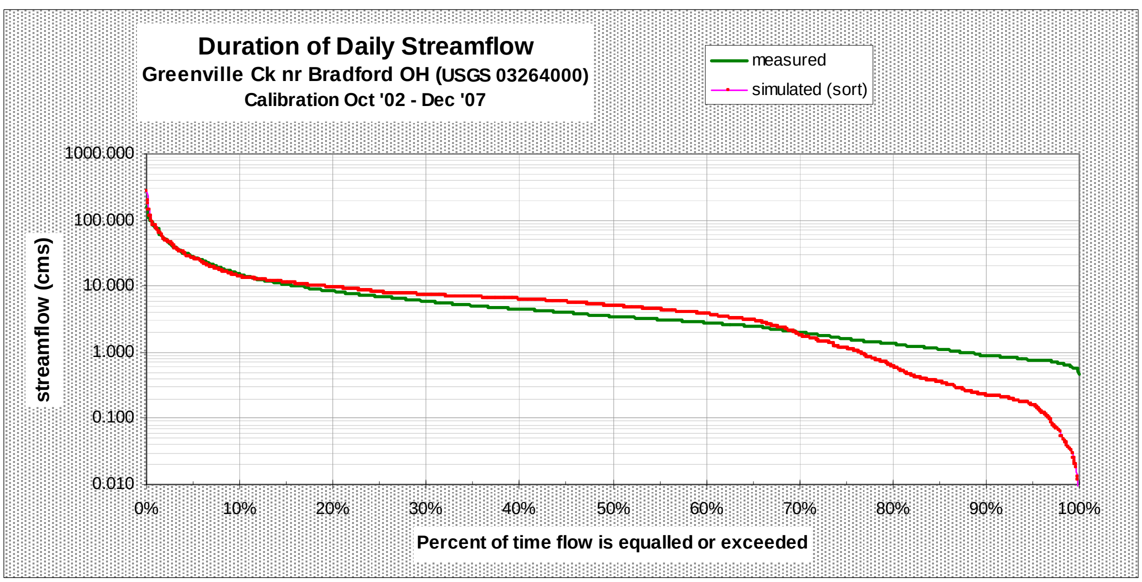
Model Run	Description	Parameter Note	Comments
4MultiAdjust34	Same CN as 3MultiAdjust34, except decreased ESCO to 0.91, but only for AGRR land use in Pleasant Hill (interim) drainage.	ESCO = 0.91 (.hru) ESCO = 0.95 (.bsn)	
5MultiAdjust34	Increased CN2 by 1 unit, increased SOL_AWC by 0.02, and decreased ESCO to 0.90 but only for AGRR land use in Pleasant Hill (interim) drainage: AGRR B 76 --> 77 AGRR C 83 --> 84	CN2 (.mgt) +1 SOL_AWC (.sol) +0.02 ESCO = 0.90 (.hru) ESCO = 0.95 (.bsn)	overall change in SOL_AWC from HydroStart is **+0.05** (max recommended is +/- 0.04)
6MultiAdjust34	Changes apply only for AGRR land use in Pleasant Hill (interim) drainage.	GWQMN = 20 mm (.hru) GWREVAP = 0.20 (.bsn) REVAPMN no change	
7MultiAdjust34	Changes apply only for AGRR land use in Pleasant Hill (interim) drainage.	GWQMN = 25 mm (.hru) SOL_AWC (.sol) -0.01	overall change in SOL_AWC from HydroStart is **+0.04** (max recommended is +/- 0.04)
8MultiAdjust34	Changes apply only for AGRR land use in Pleasant Hill (interim) drainage.	GWQMN = 45 mm (.hru) ESCO = 0.89 (.hru) ESCO = 0.95 (.bsn)	end of Pleasant Hill calibration
MultiAdjust34_39	Same as 8MultiAdjust34, except increased GWQMN to 35 mm for AGRR land use in Bradford drainage and reduced CN2 by 1 for AGRR land use in Pleasant Hill (interim) drainage. AGRR B 77 --> 76 AGRR C 84	GWQMN = 35 mm (Bradford .hru) CN2 -1 (Pleasant Hill .mgt)	not used - 8MultiAdjust34 is better fit
Sim6	Same as 8MultiAdjust34, except reduced CN2 by 2 units and increased SOL_AWC by 0.02 for AGRR land use in Englewood (interim) drainage: AGRR B 78 --> 76 AGRR C 85 --> 83	CN2 (.mgt) -2 SOL_AWC (.sol) +0.02	
2Sim6	Same as Sim6, except reduced CN2 by additional 2 units and increased SOL_AWC by additional 0.02 for AGRR land use in Englewood (interim) drainage: AGRR B 78 --> 74 AGRR C 85 --> 81	CN2 (.mgt) -2 SOL_AWC (.sol) +0.02	overall change in SOL_AWC from HydroStart is **+0.04** (max recommended is +/- 0.04); end of Englewood calibration

Appendix C.1.b Calibration of SWAT for hydrology for <u>Greenville Creek near Bradford OH</u>: total streamflow, surface runoff, baseflow, and baseflow ratio.

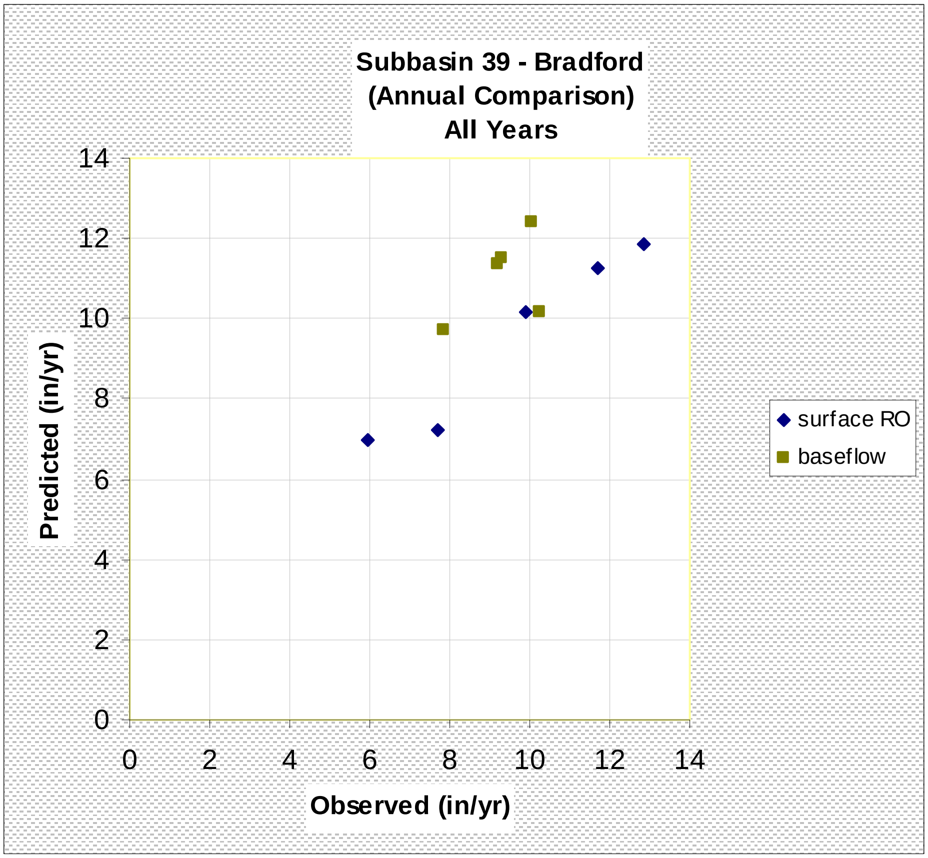
I. Daily total streamflow

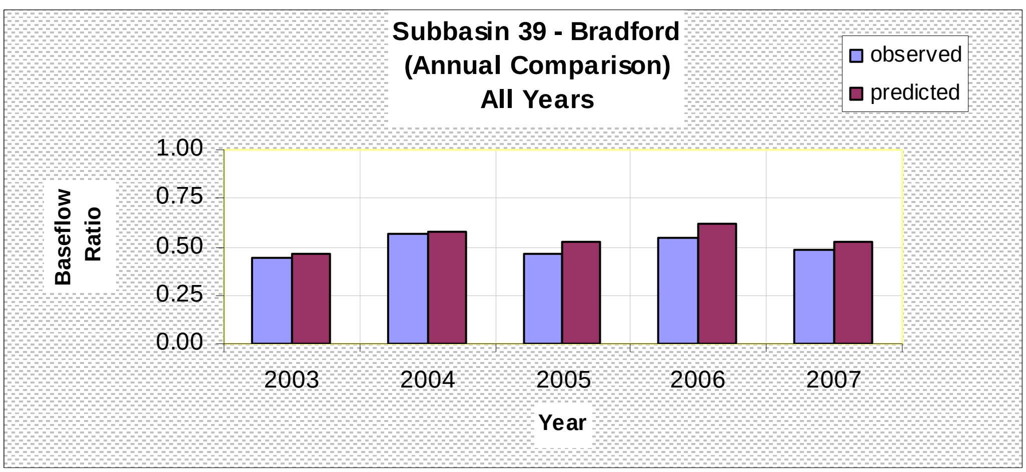
Calibration Period (2001-2007)		
Oavg	7.37	
E_{NS}	0.09	*1: optimal, range (-∞, 1)*
PBIAS	-8.25	*0 optimal*
		>0 underestimate
		<0 overestimate

Validation Period (2000 & 2008 only)		
Oavg	8.81	
E_{NS}	-0.27	*1: optimal, range (-∞, 1)*
PBIAS	-20.44	*0 optimal*
		>0 underestimate
		<0 overestimate



II. Annual comparison of total streamflow, surface runoff, baseflow, and baseflow ratio





	observed (in/yr)	predicted (in/yr)

NOTE: insufficient N years to split sample for calibration/validation.

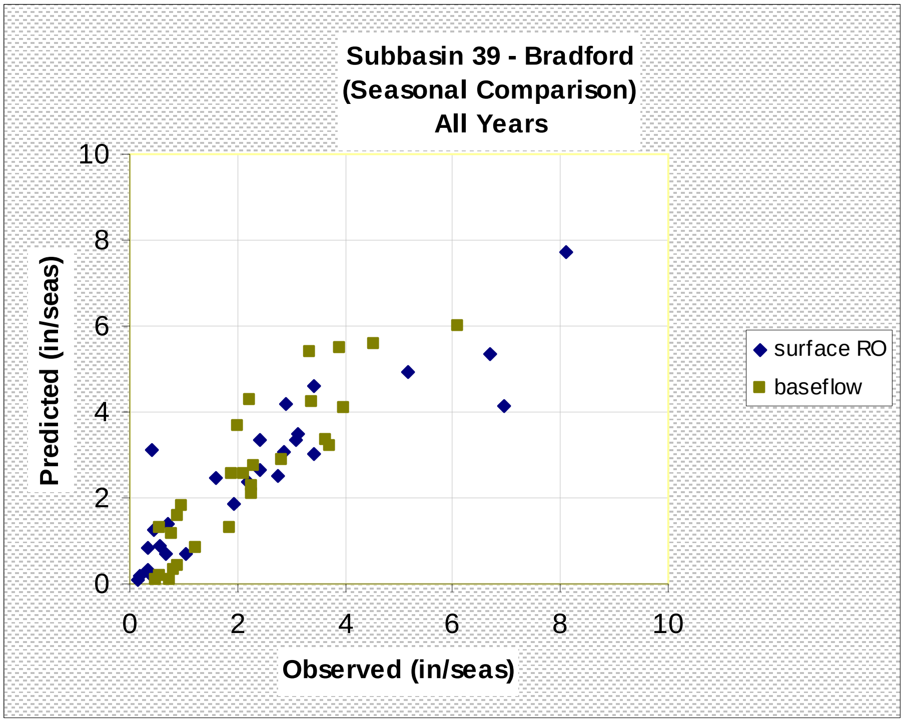
Surface Runoff (all years)			observed (in/yr)	predicted (in/yr)
N			5	5
mean (in/yr)			9.62	9.49
s.d. (in/yr)			2.83	2.27
rel_diff_avg	0.08	(< 0.15)		
E_{NS}	0.92	(> 0.5)		
R^2	0.95	(> 0.6)		

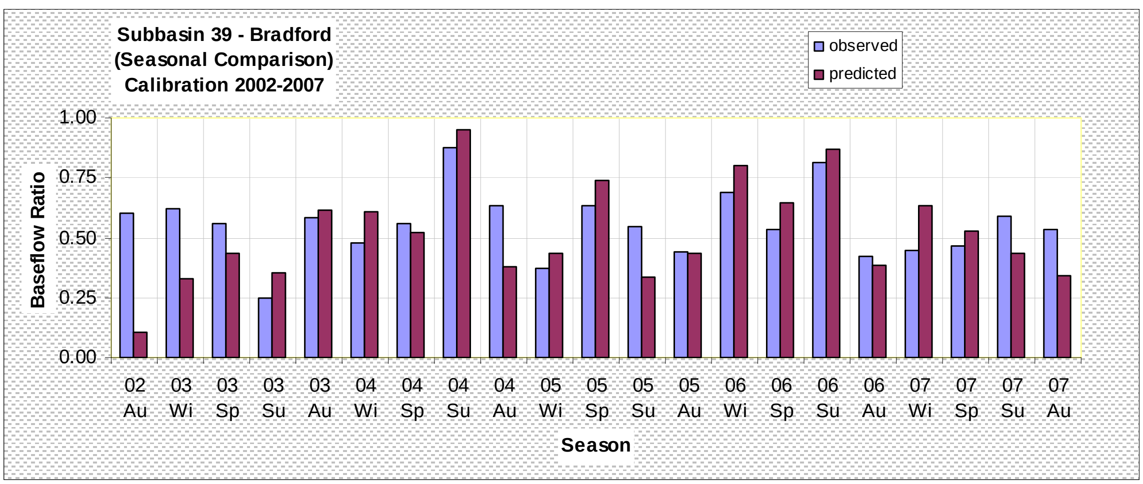
Baseflow (all years)			observed (in/yr)	predicted (in/yr)
mean (in/yr)			9.34	11.02
s.d. (in/yr)			0.94	1.10
rel_diff_avg	0.19	(< 0.15)		
E_{NS}	-0.11	(> 0.5)		
R^2	0.25	(> 0.6)		

Baseflow Ratio (all years)	observed (in/yr)	predicted (in/yr)
mean (in/yr)	0.50	0.54
s.d. (in/yr)	0.05	0.06

Streamflow (total WYLD) (all years)	observed (in/yr)		predicted (in/yr)
N	5		5
mean (in/yr)	18.95		20.51
s.d. (in/yr)	3.72		2.79
R^2	0.86	(> 0.6)	

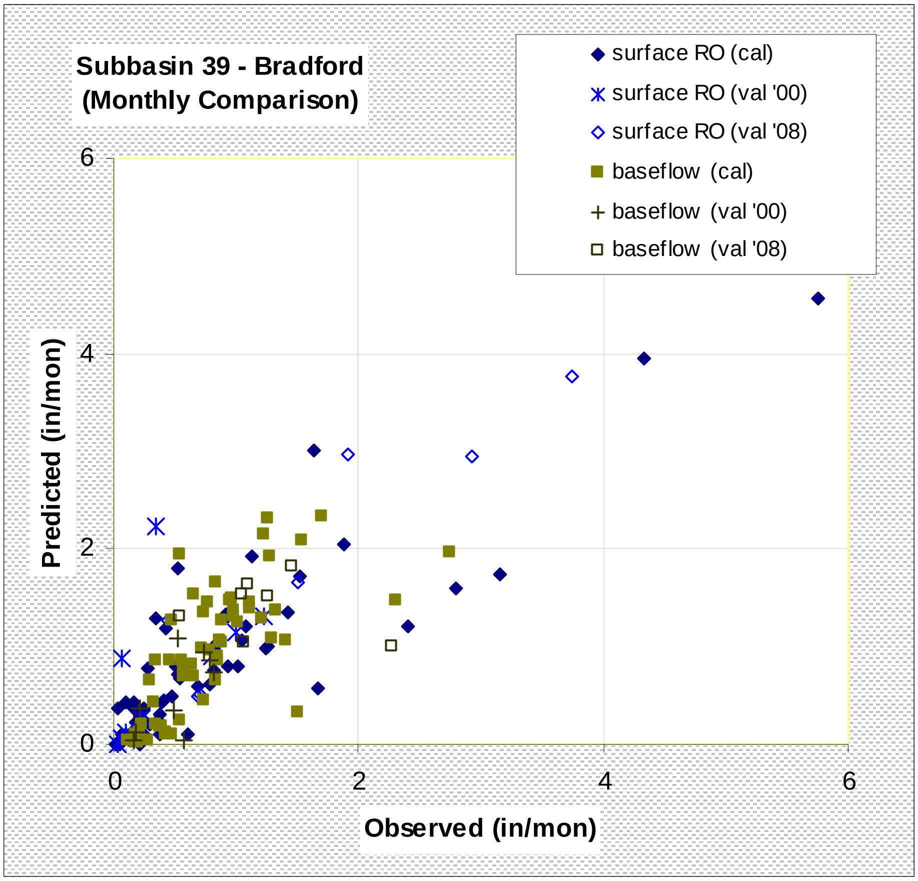
III. Seasonal comparison of total streamflow, surface runoff, baseflow, and baseflow ratio





			observed (in/yr)	predicted (in/yr)
Surface Runoff (2002-2007)				
N			21	21
mean (in/seas)			2.31	2.30
s.d. (in/seas)			1.99	1.59
rel_diff_avg	0.32	(< 0.15)		
E_{NS}	0.82	(> 0.5)		
Baseflow (2002-2007)				
mean (in/seas)			2.25	2.63
s.d. (in/seas)			1.28	1.80
rel_diff_avg	0.41	(< 0.15)		
E_{NS}	0.71	(> 0.5)		
Baseflow Ratio (2002-2007)				
mean (in/seas)			0.56	0.52
s.d. (in/seas)			0.14	0.21
Streamflow (total WYLD) (2002-2007)				
N			21	21
mean (in/seas)			4.55	4.93
s.d. (in/seas)			3.04	3.07
Surface Runoff (2000 & 2008 only)				
N			6	6
mean (in/seas)			2.64	3.42
s.d. (in/seas)			3.02	2.61
rel_diff_avg	1.47	(< 0.15)		
E_{NS}	0.79	(> 0.5)		
Baseflow (2000 & 2008 only)				
mean (in/seas)			2.21	2.41
s.d. (in/seas)			2.10	2.01
rel_diff_avg	0.56	(< 0.15)		
E_{NS}	0.91	(> 0.5)		
Baseflow Ratio (2000 & 2008 only)				
mean (in/seas)			0.54	0.44
s.d. (in/seas)			0.14	0.26

IV. Monthly comparison of total streamflow, surface runoff, baseflow, and baseflow ratio



			observed (in/mon)	predicted (in/mon)
Surface Runoff (2001-2007)				
N			63	63
mean (in/mon)			0.77	0.77
s.d. (in/mon)			1.04	0.90
rel_diff_avg	0.73	(< 0.15)		
E_{NS}	0.78	(> 0.5)		
R^2	0.78	(> 0.6)		
Baseflow (2001-2007)				
mean (in/mon)			0.75	0.88
s.d. (in/mon)			0.52	0.68
rel_diff_avg	0.57	(< 0.15)		
E_{NS}	0.51	(> 0.5)		
R^2	0.55	(> 0.6)		
Baseflow Ratio (2001-2007)				
mean (in/mon)			0.61	0.57
s.d. (in/mon)			0.19	0.27
Surface Runoff (2000 & 2008 only)				
N			16	16
mean (in/mon)			0.99	1.28
s.d. (in/mon)			1.08	1.15
rel_diff_avg	1.35	(< 0.15)		
E_{NS}	0.66	(> 0.5)		
Baseflow (2000 & 2008 only)				
mean (in/mon)			0.83	0.90
s.d. (in/mon)			0.55	0.58
rel_diff_avg	0.50	(< 0.15)		
E_{NS}	0.28	(> 0.5)		
Baseflow Ratio (2000 & 2008 only)				
mean (in/mon)			0.57	0.49
s.d. (in/mon)			0.18	0.28

Appendix C.1.c Calibration of SWAT for hydrology for <u>Stillwater River at Pleasant Hill OH</u>: total streamflow, surface runoff, baseflow, and baseflow ratio.

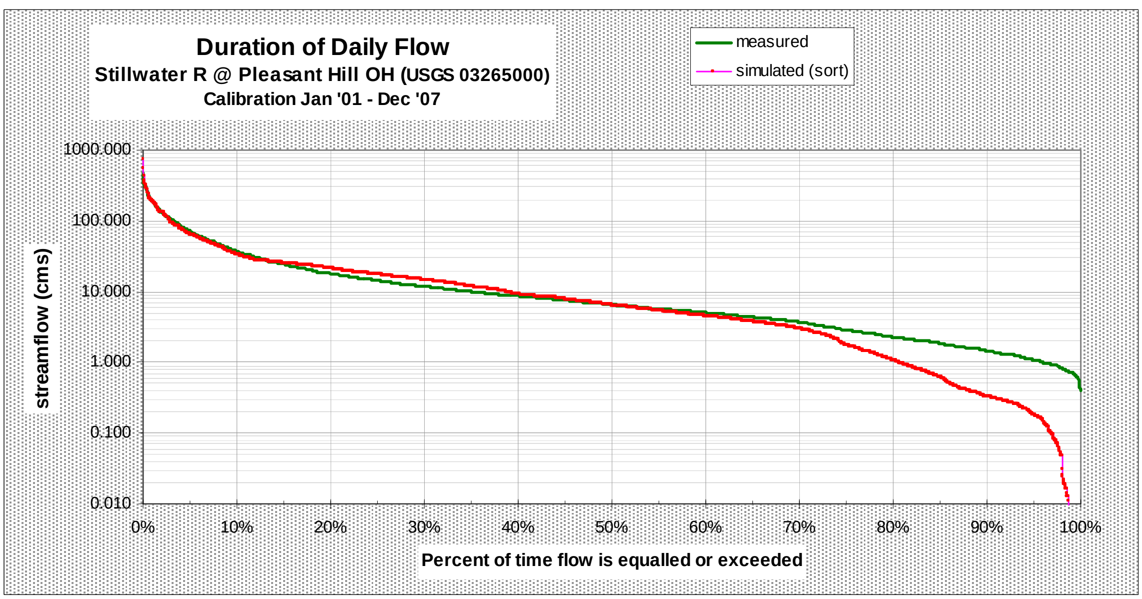
I. Daily total streamflow

Calibration Period (2001-2007)

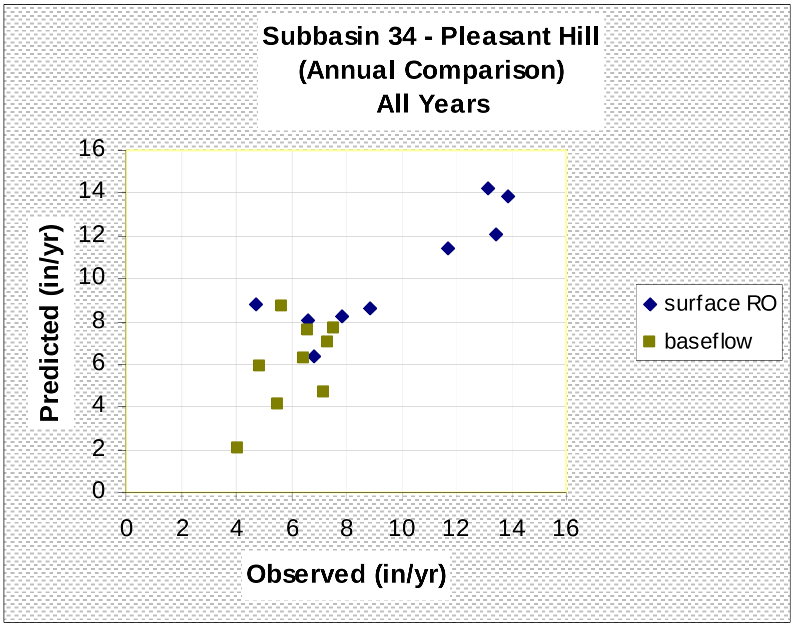
Oavg	17.00	
E_{NS}	0.29	*1: optimal, range (-∞, 1)*
PBIAS	-1.15	*0 optimal*
		>0 underestimate
		<0 overestimate

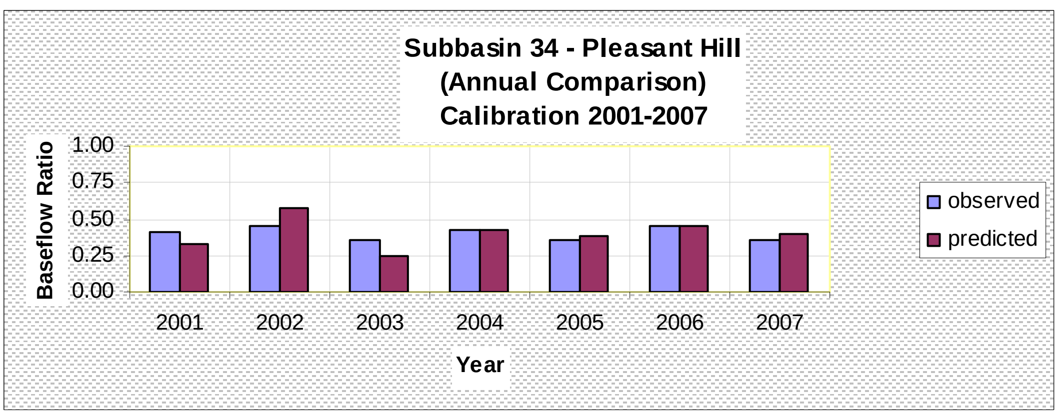
Validation Period (2000 & 2008 only)

Oavg	19.30	
E_{NS}	0.24	*1: optimal, range (-∞, 1)*
PBIAS	-6.44	*0 optimal*
		>0 underestimate
		<0 overestimate



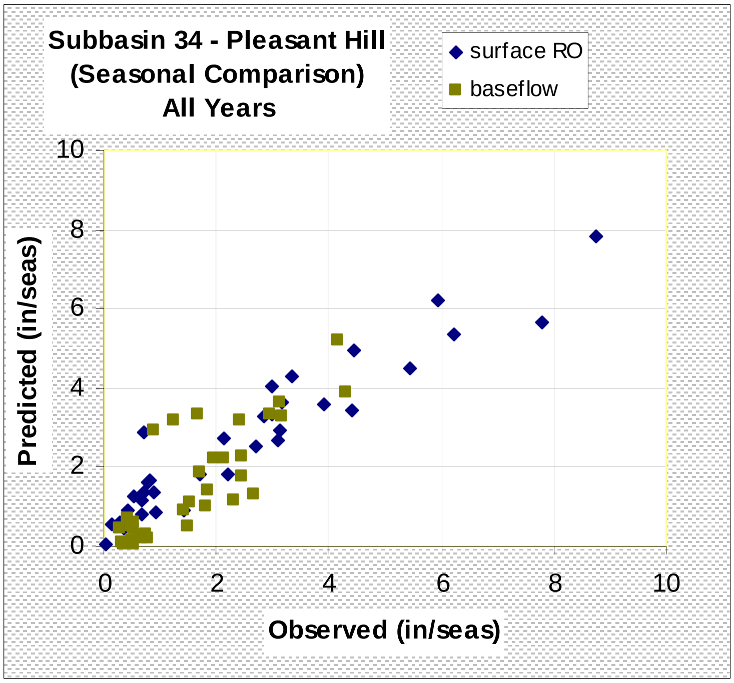
II. Annual comparison of total streamflow, surface runoff, baseflow, and baseflow ratio

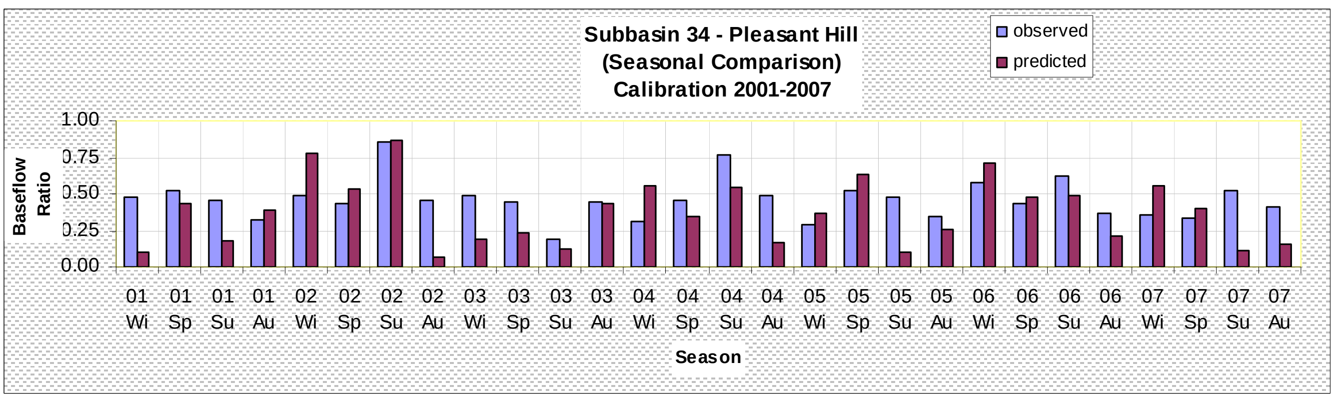




			observed (in/yr)	predicted (in/yr)
Surface Runoff (2001-2007)				
N			7	7
mean (in/yr)			9.78	9.85
s.d. (in/yr)			2.93	2.77
rel_diff_avg	0.08	(< 0.15)		
E_{NS}	0.89	(> 0.5)		
Baseflow (2001-2007)				
mean (in/yr)			6.41	6.53
s.d. (in/yr)			1.04	1.67
rel_diff_avg	0.22	(< 0.15)		
E_{NS}	0.83	(> 0.5)		
Baseflow Ratio (2001-2007)				
mean (in/yr)			0.40	0.40
s.d. (in/yr)			0.04	0.10
Streamflow (total WYLD) (2001-2007)				
N			7	7
mean (in/yr)			16.19	16.38
s.d. (in/yr)			3.84	2.85
R^2	0.83	(> 0.6)		
E_{NS}	0.80	(> 0.5)		
Surface Runoff (2000 & 2008 only)				
N			2	2
mean (in/yr)			9.32	11.36
s.d. (in/yr)			6.46	3.58
rel_diff_avg	0.43	(< 0.15)		
E_{NS}	0.60	(> 0.5)		
Baseflow (2000 & 2008 only)				
mean (in/yr)			5.27	4.16
s.d. (in/yr)			1.73	2.97
rel_diff_avg	0.26	(< 0.15)		
E_{NS}	0.95	(> 0.5)		
Baseflow Ratio (2000 & 2008 only)				
mean (in/yr)			0.39	0.25
s.d. (in/yr)			0.10	0.09

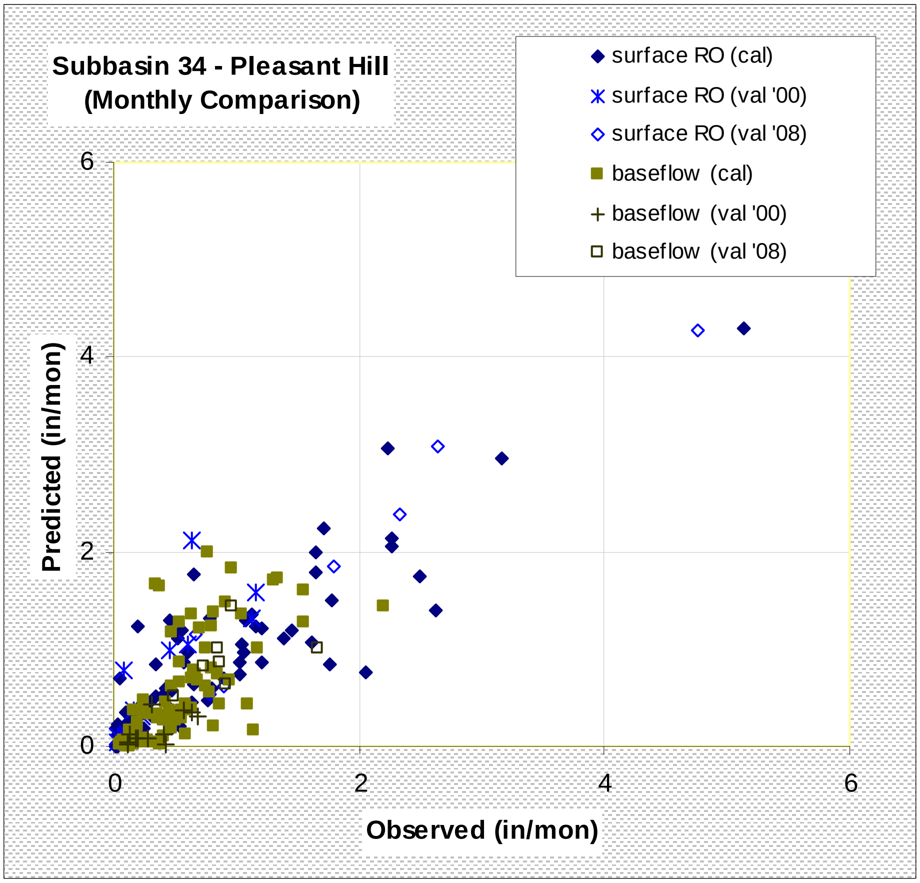
III. Seasonal comparison of total streamflow, surface runoff, baseflow, and baseflow ratio





			observed (in/yr)	predicted (in/yr)
Surface Runoff (2001-2007)				
N			28	28
mean (in/seas)			2.44	2.46
s.d. (in/seas)			2.07	1.69
rel_diff_avg	0.48	(< 0.15)		
E_{NS}	0.89	(> 0.5)		
Baseflow (2001-2007)				
mean (in/seas)			1.60	1.63
s.d. (in/seas)			1.04	1.41
rel_diff_avg	0.54	(< 0.15)		
E_{NS}	0.77	(> 0.5)		
Baseflow Ratio (2001-2007)				
mean (in/seas)			0.46	0.37
s.d. (in/seas)			0.14	0.22
Streamflow (total WYLD) (2001-2007)				
N			28	28
mean (in/seas)			4.05	4.09
s.d. (in/seas)			2.99	2.70
rel_diff_avg	0.22	(< 0.15)		
E_{NS}	0.93	(> 0.5)		
Surface Runoff (2000 & 2008 only)				
N			7	7
mean (in/seas)			2.66	3.25
s.d. (in/seas)			3.10	2.58
rel_diff_avg	0.83	(< 0.15)		
E_{NS}	0.87	(> 0.5)		
Baseflow (2000 & 2008 only)				
mean (in/seas)			1.50	1.19
s.d. (in/seas)			1.42	1.33
rel_diff_avg	0.34	(< 0.15)		
E_{NS}	0.92	(> 0.5)		
Baseflow Ratio (2000 & 2008 only)				
mean (in/seas)			0.43	0.27
s.d. (in/seas)			0.11	0.17

IV. Monthly comparison of total streamflow, surface runoff, baseflow, and baseflow ratio



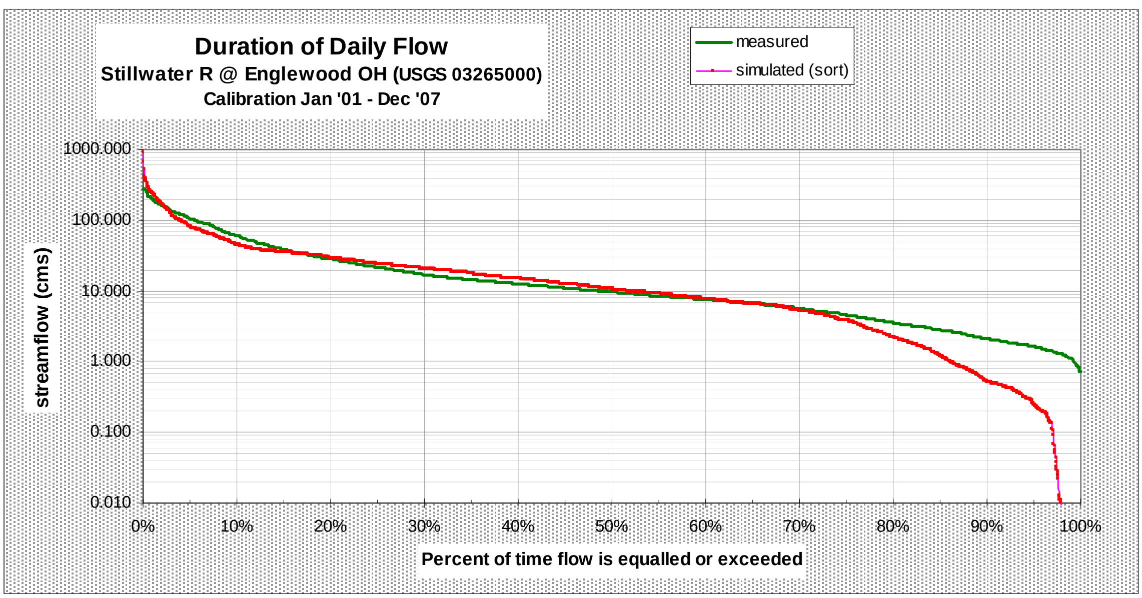
			observed (in/yr)	predicted (in/yr)
Surface Runoff (2001-2007)				
N			84	84
mean (in/mon)			0.81	0.82
s.d. (in/mon)			1.08	0.89
rel_diff_avg	0.92	(< 0.15)		
E_{NS}	0.83	(> 0.5)		
R^2	0.84	(> 0.6)		
Baseflow (2001-2007)				
mean (in/mon)			0.53	0.54
s.d. (in/mon)			0.40	0.55
rel_diff_avg	0.60	(< 0.15)		
E_{NS}	0.62	(> 0.5)		
R^2	0.47	(> 0.6)		
Baseflow Ratio (2001-2007)				
mean (in/mon)			0.53	0.43
s.d. (in/mon)			0.20	0.28
Surface Runoff (2000 & 2008 only)				
N			19	19
mean (in/mon)			0.98	1.20
s.d. (in/mon)			1.19	1.14
rel_diff_avg	1.01	(< 0.15)		
E_{NS}	0.84	(> 0.5)		
Baseflow (2000 & 2008 only)				
mean (in/mon)			0.55	0.44
s.d. (in/mon)			0.39	0.41
rel_diff_avg	0.42	(< 0.15)		
E_{NS}	0.81	(> 0.5)		
Baseflow Ratio (2000 & 2008 only)				
mean (in/mon)			0.48	0.32
s.d. (in/mon)			0.18	0.22

Appendix C.1.c Calibration of SWAT for hydrology for <u>Stillwater River at Englewood OH</u>: total streamflow, surface runoff, baseflow, and baseflow ratio.

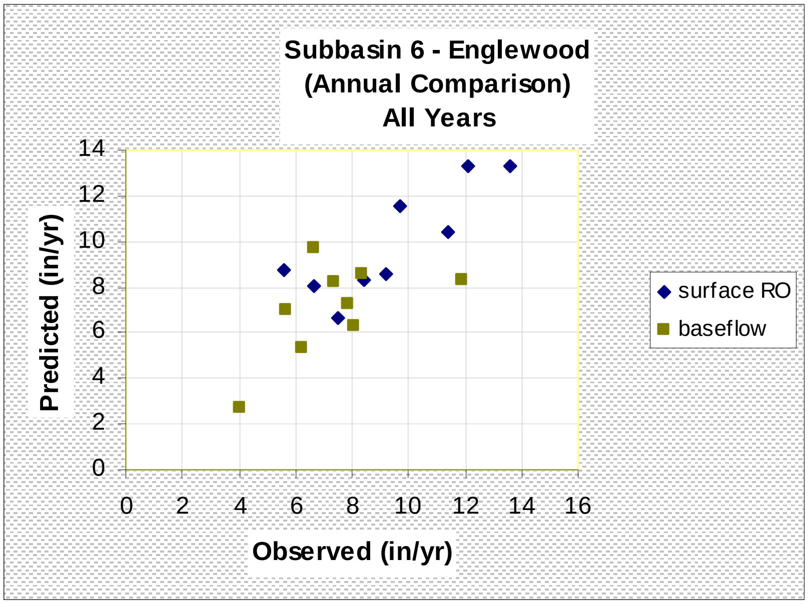
I. Daily total streamflow

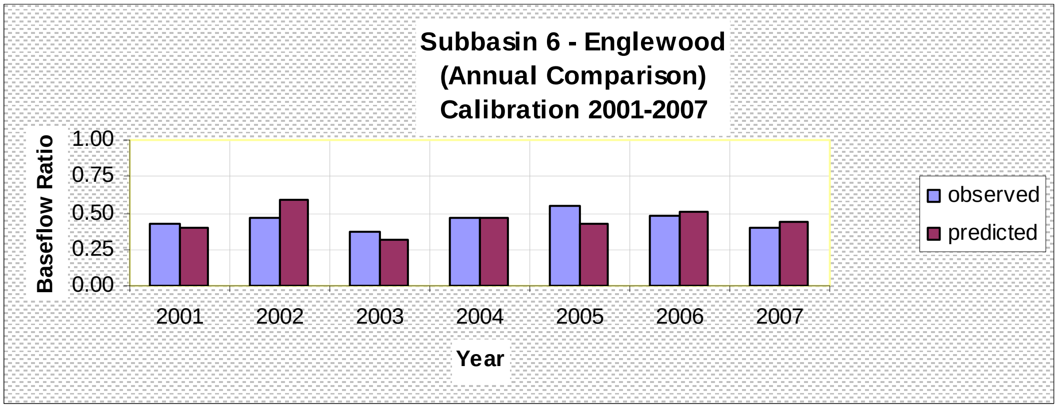
Calibration Period (2001-2007)		
Oavg	23.41	
E_{NS}	-0.25	*1: optimal, range (-∞, 1)*
PBIAS	0.34	*0 optimal*
		>0 underestimate
		<0 overestimate

Validation Period (2000 & 2008 only)		
Oavg	25.32	
E_{NS}	-0.90	*1: optimal, range (-∞, 1)*
PBIAS	-8.44	*0 optimal*
		>0 underestimate
		<0 overestimate



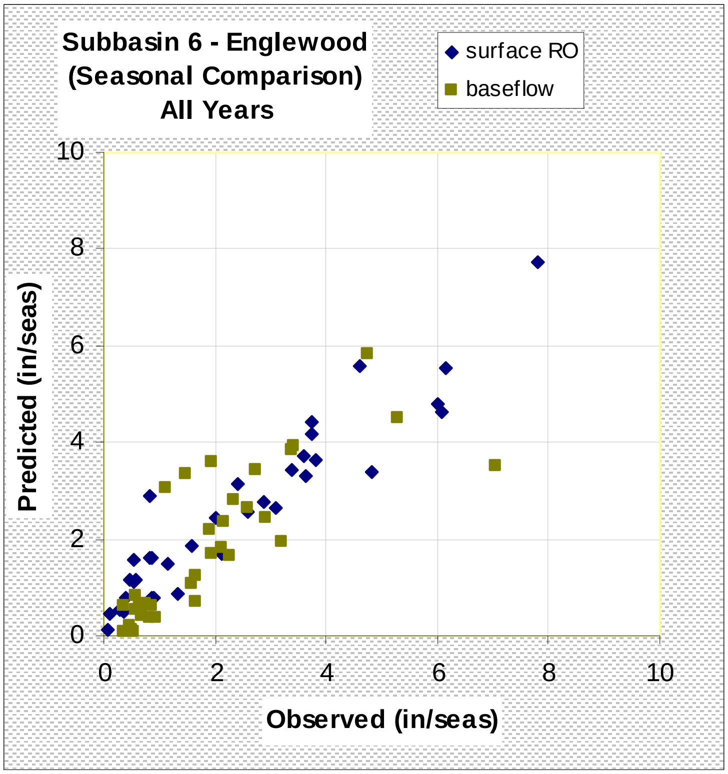
II. Annual comparison of total streamflow, surface runoff, baseflow, and baseflow ratio

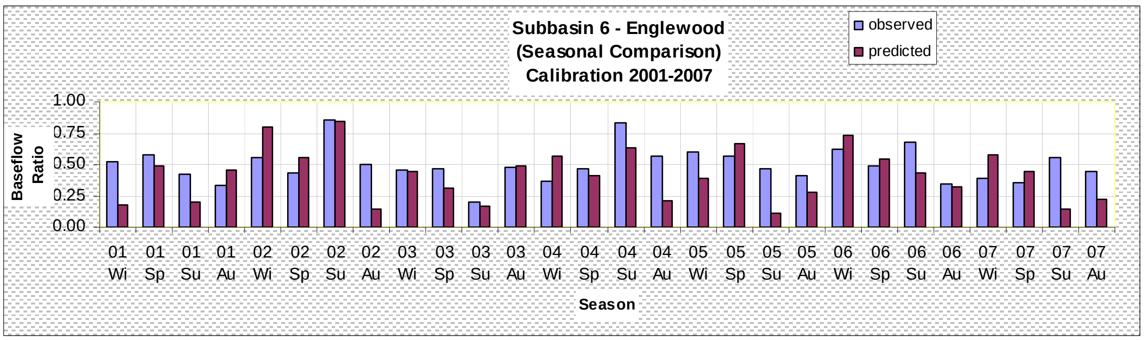




			observed (in/yr)	predicted (in/yr)
Surface Runoff (2001-2007)				
N			7	7
mean (in/yr)			9.49	9.55
s.d. (in/yr)			2.38	2.29
rel_diff_avg	0.10	(< 0.15)		
E_{NS}	0.78	(> 0.5)		
Baseflow (2001-2007)				
mean (in/yr)			7.76	7.65
s.d. (in/yr)			2.07	1.50
rel_diff_avg	0.22	(< 0.15)		
E_{NS}	0.40	(> 0.5)		
Baseflow Ratio (2001-2007)				
mean (in/yr)			0.45	0.45
s.d. (in/yr)			0.06	0.09
Streamflow (total WYLD) (2001-2007)				
N			7	7
mean (in/yr)			17.26	17.20
s.d. (in/yr)			3.69	2.33
R^2	0.82	(> 0.6)		
E_{NS}	0.74	(> 0.5)		
Surface Runoff (2000 & 2008 only)				
N			2	2
mean (in/yr)			8.86	11.03
s.d. (in/yr)			4.61	3.20
rel_diff_avg	0.33	(< 0.15)		
E_{NS}	0.48	(> 0.5)		
Baseflow (2000 & 2008 only)				
mean (in/yr)			5.94	5.02
s.d. (in/yr)			2.69	3.20
rel_diff_avg	0.20	(< 0.15)		
E_{NS}	0.97	(> 0.5)		
Baseflow Ratio (2000 & 2008 only)				
mean (in/yr)			0.41	0.30
s.d. (in/yr)			0.02	0.08

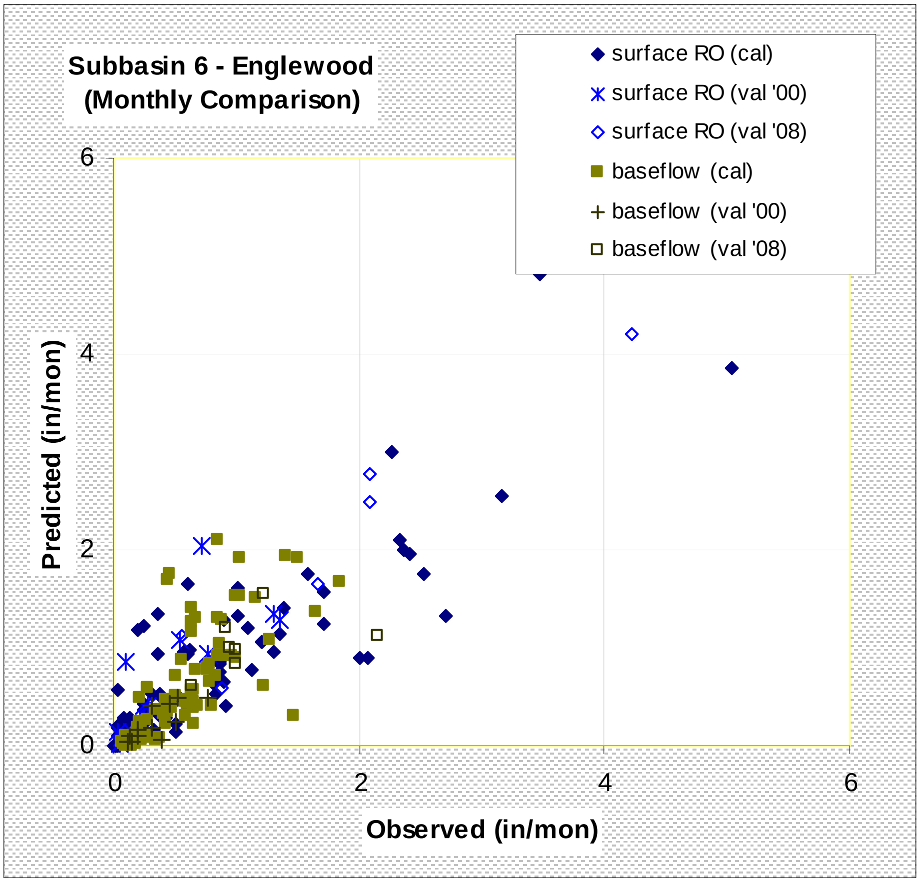
III. Seasonal comparison of total streamflow, surface runoff, baseflow, and baseflow ratio





			observed (in/yr)	predicted (in/yr)
Surface Runoff (2001-2007)				
N			28	28
mean (in/seas)			2.37	2.39
s.d. (in/seas)			1.91	1.58
rel_diff_avg	0.52	(< 0.15)		
E_{NS}	0.88	(> 0.5)		
Baseflow (2001-2007)				
mean (in/seas)			1.94	1.91
s.d. (in/seas)			1.50	1.51
rel_diff_avg	0.45	(< 0.15)		
E_{NS}	0.59	(> 0.5)		
Baseflow Ratio (2001-2007)				
mean (in/seas)			0.50	0.42
s.d. (in/seas)			0.14	0.21
Streamflow (total WYLD) (2001-2007)				
N			28	28
mean (in/seas)			4.32	4.30
s.d. (in/seas)			3.18	2.73
rel_diff_avg	0.23	(< 0.15)		
E_{NS}	0.93	(> 0.5)		
Surface Runoff (2000 & 2008 only)				
N			7	7
mean (in/seas)			2.53	3.15
s.d. (in/seas)			2.74	2.46
rel_diff_avg	0.75	(< 0.15)		
E_{NS}	0.87	(> 0.5)		
Baseflow (2000 & 2008 only)				
mean (in/seas)			1.70	1.43
s.d. (in/seas)			1.74	1.54
rel_diff_avg	0.26	(< 0.15)		
E_{NS}	0.94	(> 0.5)		
Baseflow Ratio (2000 & 2008 only)				
mean (in/seas)			0.45	0.30
s.d. (in/seas)			0.10	0.15

IV. Monthly comparison of total streamflow, surface runoff, baseflow, and baseflow ratio



			observed (in/yr)	predicted (in/yr)
Surface Runoff (2001-2007)				
N			84	84
mean (in/mon)			0.79	0.80
s.d. (in/mon)			0.93	0.85
rel_diff_avg	0.98	(< 0.15)		
E_{NS}	0.76	(> 0.5)		
R^2	0.76	(> 0.6)		
Baseflow (2001-2007)				
mean (in/mon)			0.65	0.64
s.d. (in/mon)			0.71	0.57
rel_diff_avg	0.50	(< 0.15)		
E_{NS}	-0.01	(> 0.5)		
R^2	0.30	(> 0.6)		
Baseflow Ratio (2001-2007)				
mean (in/mon)			0.55	0.47
s.d. (in/mon)			0.19	0.27
Surface Runoff (2000 & 2008 only)				
N			19	19
mean (in/mon)			0.93	1.16
s.d. (in/mon)			1.04	1.09
rel_diff_avg	0.96	(< 0.15)		
E_{NS}	0.80	(> 0.5)		
Baseflow (2000 & 2008 only)				
mean (in/mon)			0.63	0.53
s.d. (in/mon)			0.50	0.46
rel_diff_avg	0.32	(< 0.15)		
E_{NS}	0.73	(> 0.5)		
Baseflow Ratio (2000 & 2008 only)				
mean (in/mon)			0.49	0.37
s.d. (in/mon)			0.17	0.22

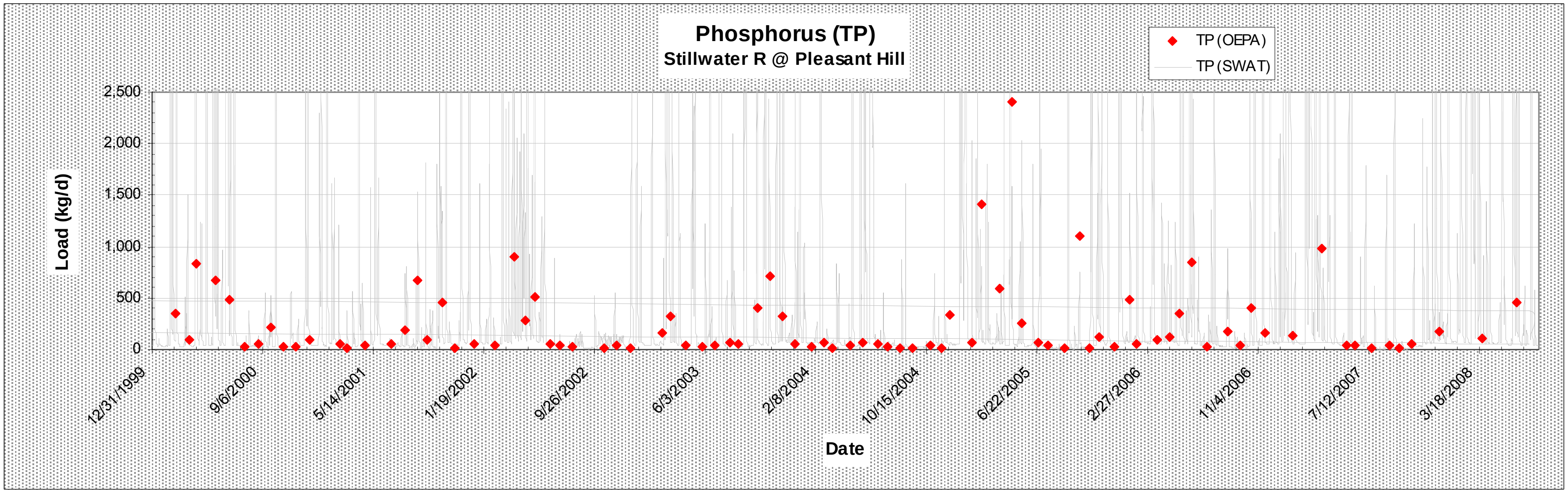
Appendix C.2 Chemistry Calibration

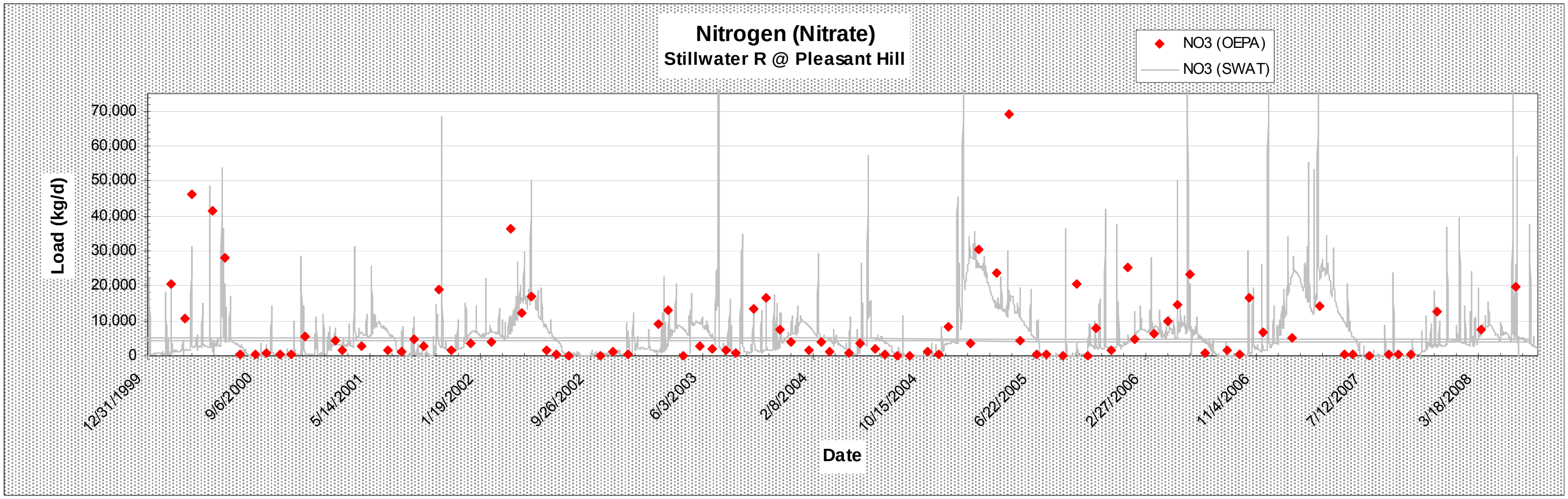
Appendix C.2.a. Calibration of SWAT for nutrients (total phosphorus and nitrate-nitrite): documentation of model evolution through parameter selection and modification.

Model Run	Description	Parameter Note	Comments
oldChemStart	Represents base model using rch output from best calibrated (hydrology) model = CNvar4b_gw5ESCO6a		
ChemDryManure	Same as ChemStart. Then reduced manure fertilizer application by 22% to reflect application of dry mass basis. Nutrient content is based on total solids and not on total mass.	FERT_KG	
ChemNoPsyn	Same as ChemDryManure. Then eliminated all Jan/Feb applications of high P fraction synthetic fertilizer.	FERT_ID	
ChemLowWinManure	Same as ChemNoPsyn. Then, where exists, swapped out high Jan/Feb winter manure application rates with lower rates in Nov for the same rotation year.	FERT_KG	
ChemPparms	Same as ChemLowWinManure. Then modified several general nutrient parameters. For .mgt-based parameters, changed only for AGRR land use.	FRT_SURFACE (.mgt) 0.2 → 0.1 RSDCO (.bsn) 0.05 → 0.03 BIOMIX (.mgt) 0.2 → 0.3 PPERCO (.bsn) 10 → 14 PHOSKD (.bsn) 175 → 195	phosphorus loads increased surprisingly!
ChemSOLPinitial	Same as ChemPparms. Then set SOL_LABn for all layers in chm to 5 mg/kg. Previously this value was set to 0.0 (default) which implies that SOL_LABP is 5 mg/kg.	SOL_LABP (.chm)	
ChemStart	Represents base model using rch output from best calibrated (hydrology) model = 2Sim6		

Model Run	Description	Parameter Note	Comments
ChemLowSynP	Same as `ChemStart`, except reduced application rate of high P fraction synthetic fertilizer (i.e., 00/46/00, 10/34/00, and 18/46/00) to a maximum of 44 kg/ha.	FRT_SURFACE (.mgt) 0.2 → 0.1 Note, general nutrient parameters set to default values (as before `ChemPparms` scenario).	
ChemPparms2	Same as `ChemLowSynP`, except adjusted general and sub-basin nutrient parameters for phosphorus.	FRT_SURFACE (.mgt) 0.1 → 0.01 BIOMIX (.mgt) 0.2 → 0.4 PPERCO (.bsn) 10 → 20 PHOSKD (.bsn) 175 → 200 RSDCO (.bsn) 0.05 → 0.01	
ChemNoSWQ	Same as `ChemPparms2`, except made the in-stream water quality module (i.e., QUAL2E) inactive.	.bsn	
ChemWQparms	Same as `ChemPparms2`, except modified three in-stream water quality module (i.e., QUAL2E) parameters.	AI2 (.wwq) 0.015 --> 0.01 RS5 (.swq) 0.05 --> 0.1 BC4 (.swq) 0.35 --> 0.01	AI2≡fraction of algal biomass that is P RS5≡orgP settling rate BC4≡rate of mineralization of orgP to minP
ChemLowSynP2	Same as `ChemWQparms`, except reduced application rate of high P fraction synthetic fertilizer (i.e., 00/46/00, 10/34/00, and 18/46/00) to a maximum of 25 kg/ha.		
ChemWQparms2	Same as `ChemLowSynP2`, except modified three in-stream water quality module (i.e., QUAL2E) parameters by changing two parameters back to their original values.	AI2 (.wwq) 0.01 --> 0.015 RS5 (.swq) 0.1 --> 0.05	*model chosen*

Appendix C.2.b. Time trace of observed vs. model predicted total phosphorus and nitrate loads at Stillwater River at Pleasant Hill location.




Nitrogen (Nitrate)
Stillwater R @ Pleasant Hill
NO3 (OEPA)
NO3 (SWAT)
Load (kg/d)
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
12/31/1999
9/6/2000
5/14/2001
1/19/2002
9/26/2002
6/3/2003
2/8/2004
10/15/2004
6/22/2005
2/27/2006
11/4/2006
7/12/2007
3/18/2008
Date

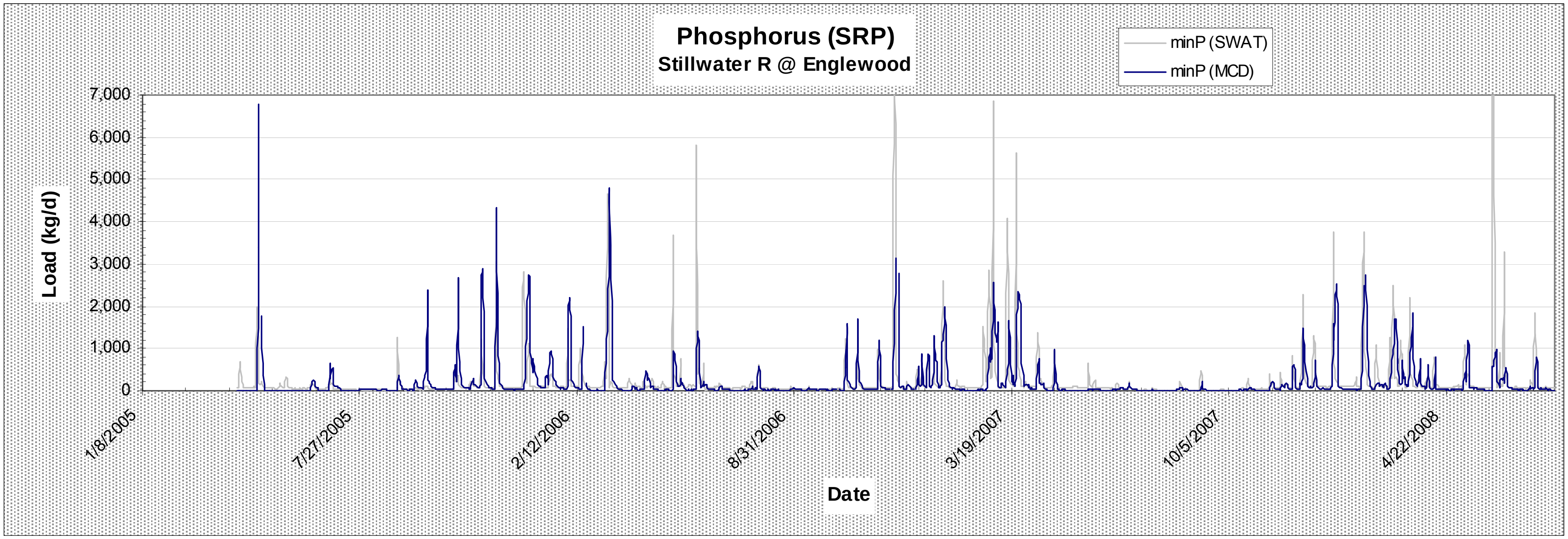
Appendix C.2.c. Comparison of observed and model predicted total phosphorus and nitrate loads at Stillwater River at Pleasant Hill location. The upper box includes all of the 88 specific sample dates whereas the lower box excludes 7 (total phosphorus) and 12 (nitrate) high magnitude events.

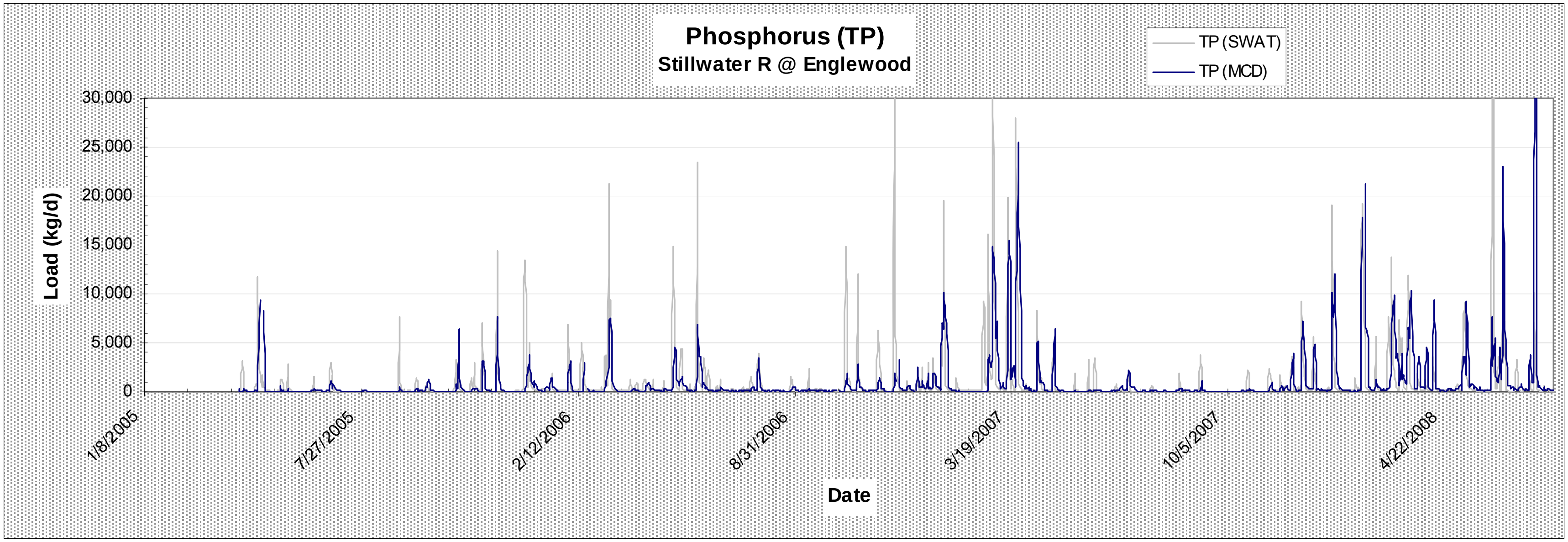
Variable	Count	Mean (kg/d)		Total (kg/d)		Standard Deviation (kg/d)		Avg Abs Rel Diff
		Obs	SWAT	Obs	SWAT	Obs	SWAT	
NO3	88	7,938	5,798	698,576	510,183	11,877	7,716	11.79
TP	88	231	680	20,309	59,866	369	2,372	2.18

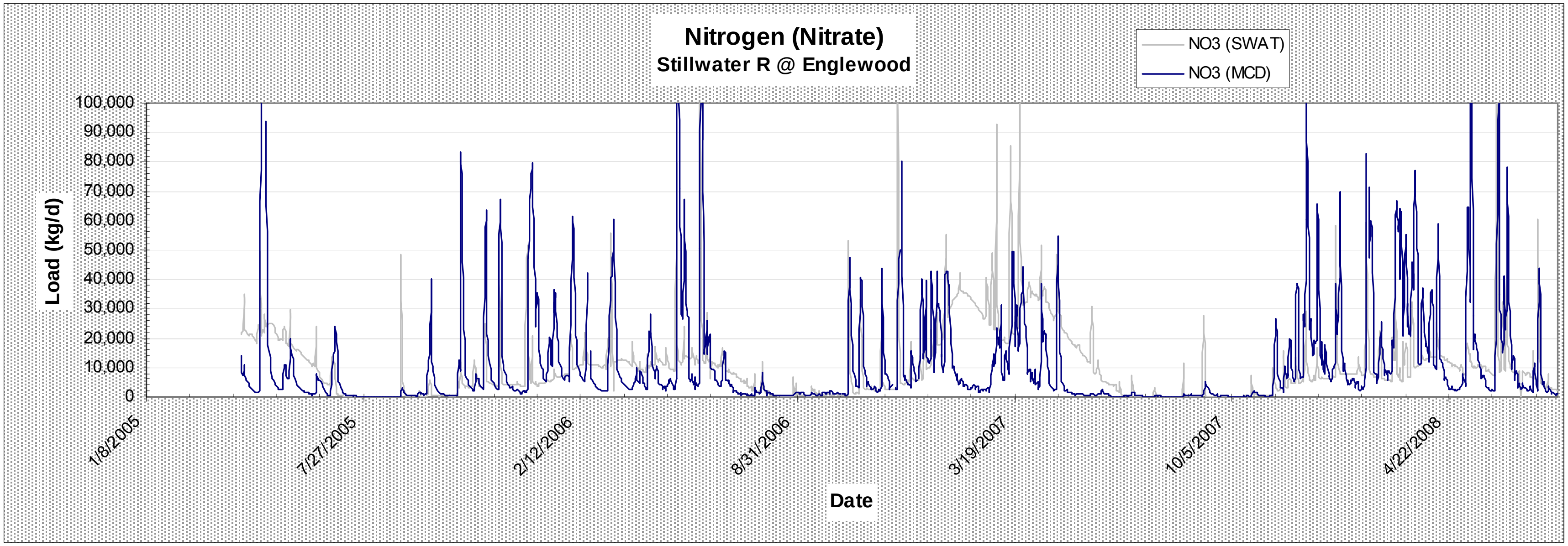
adjusted - high deviation dates eliminated

Variable	Count	Mean (kg/d)		Total (kg/d)		Standard Deviation (kg/d)		Avg Abs Rel Diff
		Obs	SWAT	Obs	SWAT	Obs	SWAT	
NO3	76	9,090	5,642	690,811	428,823	12,396	7,800	0.89
TP	81	229	280	18,797	22,966	377	585	0.87

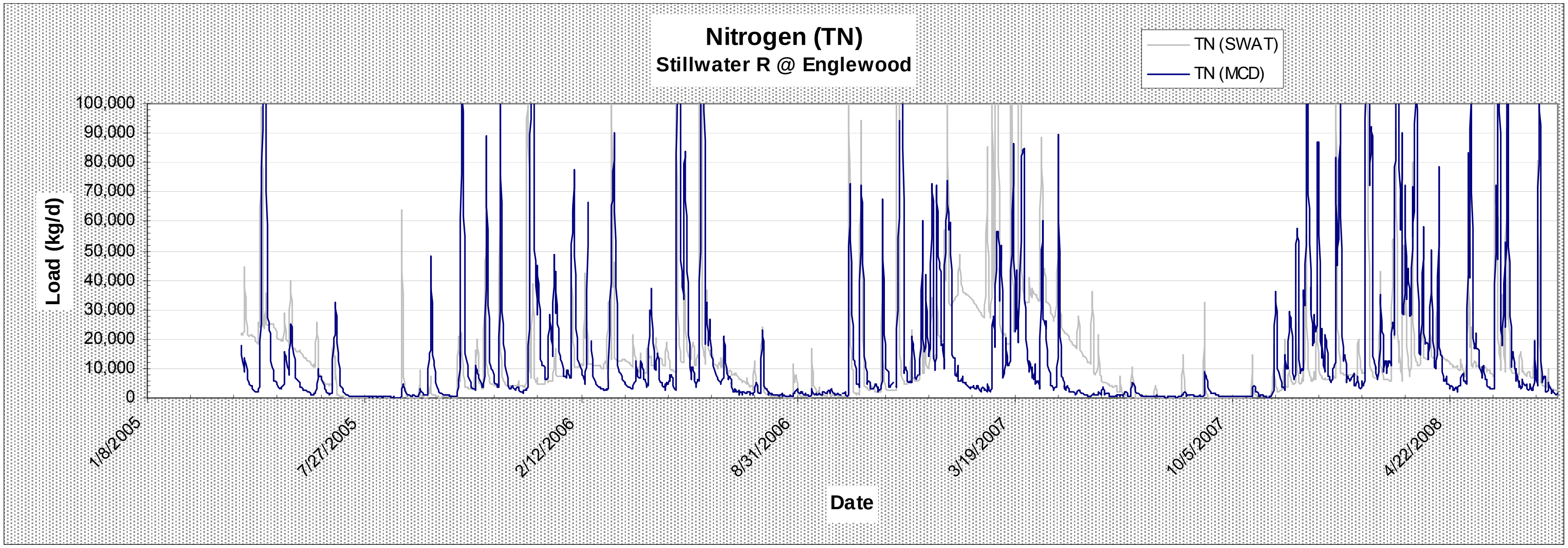
Appendix C.2.d. Time trace of observed vs. model predicted total phosphorus, ortho-phosphorus (soluble reactive phosphorus or SRP), nitrate, and total nitrogen loads at Stillwater River at Englewood location. Observed data obtained from Miami Conservancy District (MCD).




Phosphorus (TP)
Stillwater R @ Englewood
TP (SWAT)
TP (MCD)
Load (kg/d)
30,000
25,000
20,000
15,000
10,000
5,000
0
1/8/2005
7/27/2005
2/12/2006
8/31/2006
3/19/2007
10/5/2007
4/22/2008
Date

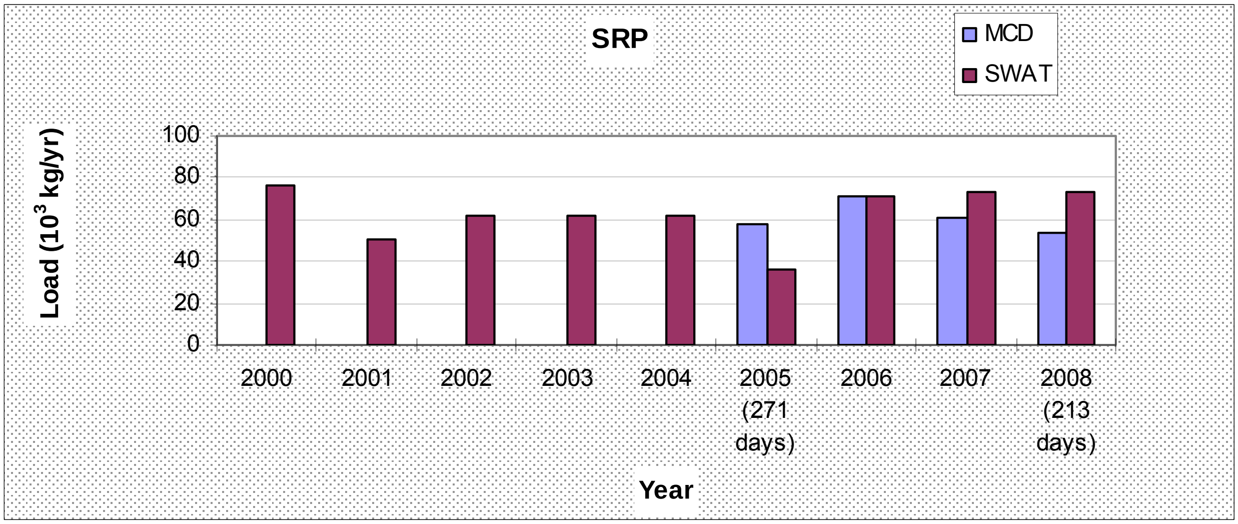


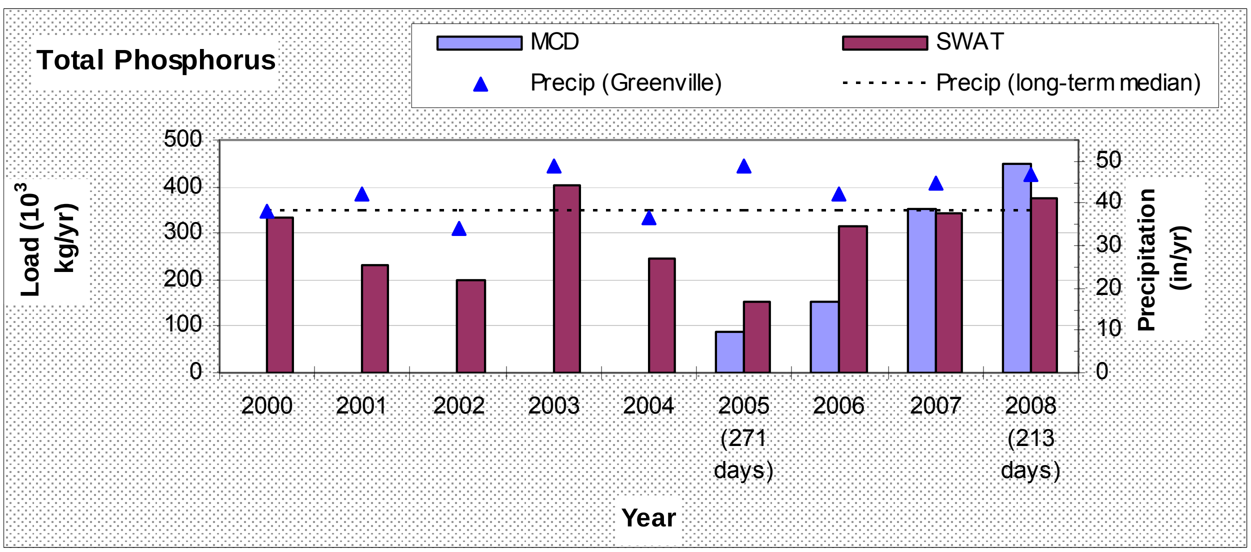
Nitrogen (Nitrate)
Stillwater R @ Englewood
NO3 (SWAT)
NO3 (MCD)
Load (kg/d)
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
1/8/2005
7/27/2005
2/12/2006
8/31/2006
3/19/2007
10/5/2007
4/22/2008
Date

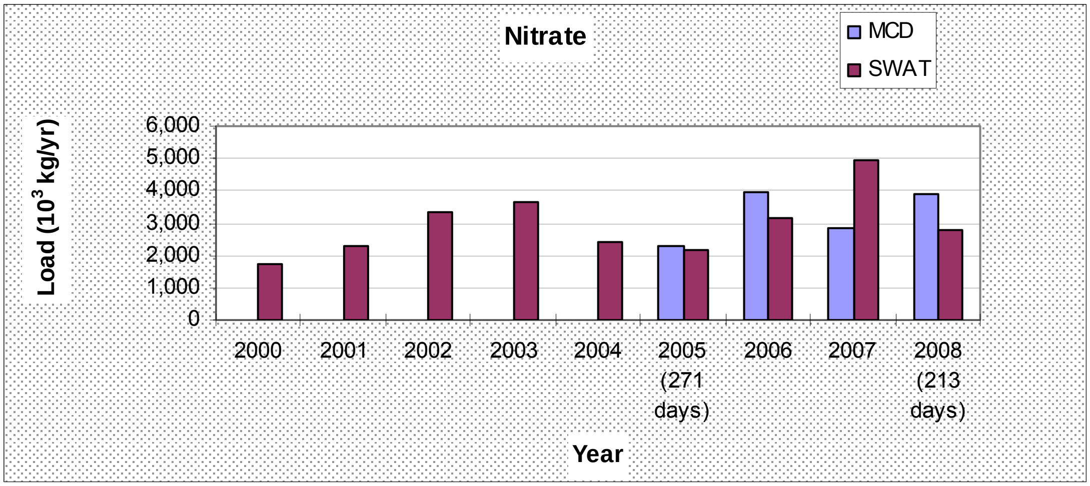


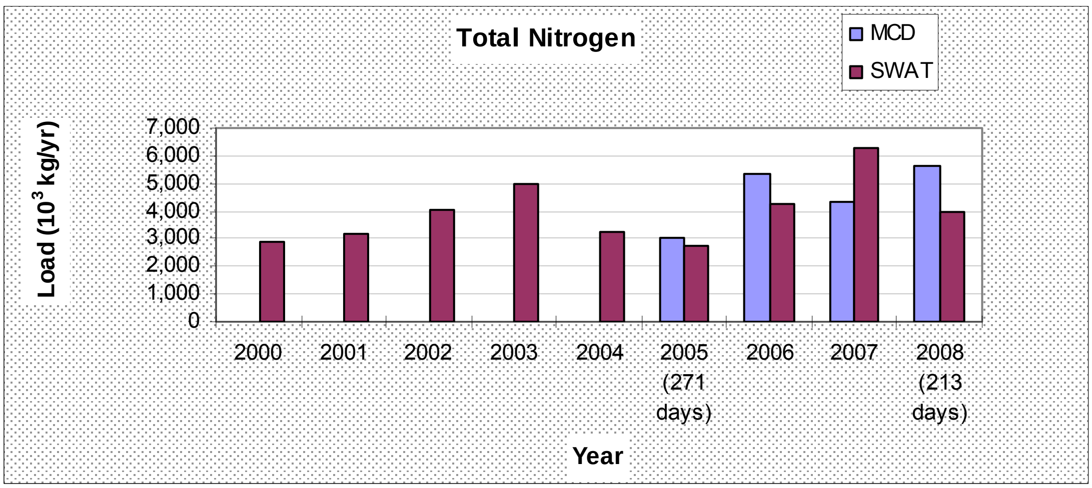
Nitrogen (TN)
Stillwater R @ Englewood
TN (SWAT)
TN (MCD)
Load (kg/d)
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
1/8/2005
7/27/2005
2/12/2006
8/31/2006
3/19/2007
10/5/2007
4/22/2008
Date

Appendix C.2.e. Annual comparison (using histograms) of observed vs. model predicted total phosphorus, orthophosphorus (soluble reactive phosphorus or SRP), nitrate, and total nitrogen loads at Stillwater River at Englewood location. Observed data obtained from Miami Conservancy District (MCD).






Nitrate
MCD
SWAT
Load (10^3 kg/yr)
6,000
5,000
4,000
3,000
2,000
1,000
0
2000
2001
2002
2003
2004
2005 (271 days)
2006
2007
2008 (213 days)
Year


Total Nitrogen
MCD
SWAT
Load (10^3 kg/yr)
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
2000
2001
2002
2003
2004
2005 (271 days)
2006
2007
2008 (213 days)
Year

Appendix C.2.f. Magnitudes used in histograms in **Appendix C.2.e** of observed vs. model predicted loads for several species of nitrogen and phosphorus at Stillwater River at Englewood location. Observed data obtained from Miami Conservancy District (MCD).

Ratio Predicted/Observed

	NO3(x)	TN(x)	SRP(x)	TP(x)
2005 (271 days)	0.96	0.89	0.62	1.73
2006	0.80	0.79	1.00	2.09
2007	1.73	1.45	1.20	0.97
2008 (213 days)	0.72	0.71	1.36	0.83

MCD

YEAR	#days for sum	totNH3(kg/yr)	totOrgN(kg/yr)	totNO2(kg/yr)	totNO3(kg/yr)	totTN(kg/yr)	totSRP(kg/yr)	totTP(kg/yr)
2005 (269 days)	269	24,892	710,356	21,427	2,278,031	3,034,716	57,538	89,272
2006	359	52,956	1,305,506	49,423	3,941,819	5,349,679	71,310	151,980
2007	365	160,875	1,252,074	59,114	2,853,641	4,325,719	61,205	350,061
2008 (212 days)	212	80,229	1,540,081	82,845	3,893,214	5,596,365	53,675	449,499

SWAT

YEAR	#days for sum	totNH4(kg/yr)	totorgN(kg/yr)	totNO2(kg/yr)	totNO3(kg/yr)	totTN(kg/yr)	totminP(kg/yr)	totTP(kg/yr)
2000	366	437,219	486,496	198,554	1,738,304	2,860,560	76,489	335,279
2001	365	300,350	409,656	145,615	2,301,644	3,157,275	50,464	230,435
2002	365	256,447	323,674	107,894	3,334,284	4,022,282	61,491	201,220
2003	365	525,621	557,716	286,080	3,644,134	5,013,552	61,479	404,632
2004	366	280,016	380,065	130,464	2,427,079	3,217,616	62,350	243,438
2005 (271 days)	271	210,606	219,715	90,692	2,186,885	2,707,897	35,679	154,642
2006	365	417,347	473,156	206,849	3,137,407	4,234,778	71,512	317,019
2007	365	539,982	580,165	208,296	4,928,310	6,256,761	73,305	340,771
2008 (213 days)	213	463,841	501,135	241,472	2,785,096	3,991,557	72,907	374,520

C.3 Agricultural Management Scenarios

Management Scenarios – Corn/Soybean and No Tillage

SUBBASIN: *43* **HRU:** 1 **AGRR** *OH037Br*

NROT	CN2	USLE_P
2	72	1.00

YR	MON	DAY	OPERATION	CROP	FERTILIZER	FRT_KG	FRT(lbs/Ac	TILLAGE
1	2	15	Fertilizer		00-00-60	30	27	
1	3	15	Fertilizer		18-46-00	20	18	
1	3	20	Tillage			0	0	Generic No-till Mixing
1	3	25	Fertilizer		Anhydrous Ammonia	35	31	
1	4	5	Fertilizer		Anhydrous Ammonia	75	67	
1	4	5	Plant	CORN		0	0	
1	4	15	Tillage			0	0	Generic No-till Mixing
1	4	15	Fertilizer		10-34-00	25	22	
1	4	15	Fertilizer		00-00-60	10	9	
1	6	1	Fertilizer		Anhydrous Ammonia	75	67	
1	10	20	Harvest & Kill			0	0	
1	11	5	Fertilizer		00-00-60	175	156	
2	2	1	Fertilizer		00-00-60	30	27	
2	4	15	Fertilizer		00-00-60	10	9	
2	4	15	Tillage			0	0	Generic No-till Mixing
2	5	15	Plant	SOYB		0	0	
2	10	15	Fertilizer		18-46-00	25	22	
2	10	15	Harvest & Kill			0	0	
2	11	5	Fertilizer		00-00-60	175	156	
2	11	15	Tillage			0	0	Generic No-till Mixing

Management Scenarios – Corn/Soybean with Tillage

SUBBASIN: 32 **HRU:** 1 **AGRR** OH109CrA

NROT	CN2	USLE_P
2	84	1.00

YR	MON	DAY	OPERATION	CROP	FERTILIZER	FRT_KG	FRT(lbs/Ac	TILLAGE
1	2	15	Fertilizer		00-00-60	30	27	
1	3	15	Fertilizer		18-46-00	20	18	
1	3	20	Tillage			0	0	Field Cultivator Ge15ft
1	3	25	Fertilizer		Anhydrous Ammonia	35	31	
1	4	5	Plant	CORN		0	0	
1	4	5	Fertilizer		Anhydrous Ammonia	75	67	
1	4	15	Fertilizer		00-00-60	10	9	
1	4	15	Fertilizer		10-34-00	25	22	
1	6	1	Fertilizer		Anhydrous Ammonia	75	67	
1	10	20	Harvest & Kill			0	0	
1	11	5	Fertilizer		00-00-60	175	156	
1	11	15	Tillage			0	0	Generic No-till Mixing
2	2	1	Fertilizer		00-00-60	30	27	
2	4	15	Fertilizer		00-00-60	10	9	
2	4	15	Tillage			0	0	Generic No-till Mixing
2	5	15	Plant	SOYB		0	0	
2	10	15	Fertilizer		18-46-00	25	22	
2	10	15	Harvest & Kill			0	0	
2	11	5	Fertilizer		00-00-60	175	156	
2	11	15	Tillage			0	0	Chisel Plow Gt21ft

Management Scenarios – Corn/Soybean and No Tillage with Manure

SUBBASIN:	*13*	**HRU:**	1	**AGRR**	*OH037Br*

NROT	***CN2***	***USLE_P***
2	72	1.00

YR	***MON***	***DAY***	***OPERATION***	***CROP***	***FERTILIZER***	***FRT_KG***	***FRT(lbs/Ac***	***TILLAGE***
1	1	30	Fertilizer		Generic-Fresh Manure	10	9	
1	3	20	Tillage			0	0	Generic No-till Mixing
1	4	5	Plant	CORN		0	0	
1	6	1	Fertilizer		Anhydrous Ammonia	100	89	
1	10	20	Harvest & Kill			0	0	
1	11	1	Fertilizer		Generic-Fresh Manure	45	40	
1	11	5	Fertilizer		00-00-60	175	156	
1	11	15	Tillage			0	0	Generic No-till Mixing
2	1	30	Fertilizer		Generic-Fresh Manure	6	5	
2	2	1	Fertilizer		00-00-60	30	27	
2	4	15	Fertilizer		00-00-60	10	9	
2	4	15	Tillage			0	0	Generic No-till Mixing
2	5	15	Plant	SOYB		0	0	
2	10	15	Harvest & Kill			0	0	
2	10	30	Tillage			0	0	Generic No-till Mixing
2	10	30	Fertilizer		Generic-Fresh Manure	51	46	

Management Scenarios - Corn/Soybean and Tillage with Manure

SUBBASIN: 6 **HRU:** 1 **AGRR** OH113Bs

NROT	CN2	USLE_P
2	74	1.00

YR	MON	DAY	OPERATION	CROP	FERTILIZER	FRT_KG	FRT(lbs/Ac	TILLAGE
1	1	30	Fertilizer		Generic-Fresh Manure	1	1	
1	3	20	Tillage			0	0	Field Cultivator Ge15ft
1	4	5	Plant	CORN		0	0	
1	6	1	Fertilizer		Anhydrous Ammonia	100	89	
1	10	20	Harvest & Kill			0	0	
1	11	1	Fertilizer		Generic-Fresh Manure	1	1	
1	11	5	Fertilizer		00-00-60	175	156	
1	11	15	Tillage			0	0	Generic No-till Mixing
2	1	30	Fertilizer		Generic-Fresh Manure	1	1	
2	2	1	Fertilizer		00-00-60	30	27	
2	4	15	Tillage			0	0	Generic No-till Mixing
2	4	15	Fertilizer		00-00-60	10	9	
2	5	15	Plant	SOYB		0	0	
2	10	15	Harvest & Kill			0	0	
2	10	30	Fertilizer		Generic-Fresh Manure	1	1	
2	10	30	Tillage			0	0	Chisel Plow Gt21ft

Management Scenarios - Corn/Soybean/Winter Wheat and Tillage with Manure

SUBBASIN: 24 **HRU:** 1 **AGRR** IN135FcA

NROT	CN2	USLE_P
5	79	1.00

YR	MON	DAY	OPERATION	CROP	FERTILIZER	FRT_KG	FRT(lbs/Ac	TILLAGE
1	1	30	Fertilizer		Generic-Fresh Manure	11	10	
1	3	20	Tillage			0	0	Field Cultivator Ge15ft
1	4	5	Plant	CORN		0	0	
1	6	1	Fertilizer		Anhydrous Ammonia	100	89	
1	10	20	Harvest & Kill			0	0	
1	11	1	Fertilizer		Generic-Fresh Manure	55	49	
1	11	5	Fertilizer		00-00-60	175	156	
1	11	15	Tillage			0	0	Generic No-till Mixing
2	1	30	Fertilizer		Generic-Fresh Manure	1	1	
2	2	1	Fertilizer		00-00-60	30	27	
2	4	15	Tillage			0	0	Generic No-till Mixing
2	4	15	Fertilizer		00-00-60	10	9	
2	5	15	Plant	SOYB		0	0	
2	10	15	Harvest & Kill			0	0	
2	10	30	Fertilizer		Generic-Fresh Manure	65	58	
2	11	15	Tillage			0	0	Chisel Plow Gt21ft
3	1	30	Fertilizer		Generic-Fresh Manure	11	10	
3	3	20	Tillage			0	0	Field Cultivator Ge15ft
3	4	5	Plant	CORN		0	0	
3	6	1	Fertilizer		Anhydrous Ammonia	100	89	
3	10	20	Harvest & Kill			0	0	
3	11	1	Fertilizer		Generic-Fresh Manure	55	49	
3	11	5	Fertilizer		00-00-60	175	156	
3	11	15	Tillage			0	0	Generic No-till Mixing
4	1	30	Fertilizer		Generic-Fresh Manure	1	1	
4	2	1	Fertilizer		00-00-60	30	27	
4	4	15	Tillage			0	0	Generic No-till Mixing
4	4	15	Fertilizer		00-00-60	10	9	
4	5	15	Plant	SOYB		0	0	
4	10	5	Harvest & Kill			0	0	

4	10	5	Fertilizer		Generic-Fresh Manure	65	58	
4	10	15	Plant	WWHT		0	0	
5	3	1	Fertilizer		28-00-00	50	45	
5	5	1	Fertilizer		28-00-00	190	170	
5	6	10	Fertilizer		28-00-00	50	45	
5	6	10	Tillage			0	0	Generic No-till Mixing
5	7	20	Harvest & Kill			0	0	
5	10	30	Fertilizer		Generic-Fresh Manure	66	59	
5	11	15	Tillage			0	0	Chisel Plow Gt21ft

Management Scenarios - Corn/Soybean/Winter Wheat/Perennial Grassand and No Tillage with Manure

SUBBASIN: *27* **HRU:** 1 **AGRR** *OH037BnA*

NROT	***CN2***	***USLE_P***
7	84	1.00

YR	***MON***	***DAY***	***OPERATION***	***CROP***	***FERTILIZER***	***FRT_KG***	***FRT(lbs/Ac***	***TILLAGE***
1	1	30	Fertilizer		Generic-Fresh Manure	11	10	
1	3	20	Tillage			0	0	Generic No-till Mixing
1	4	5	Plant	CORN		0	0	
1	6	1	Fertilizer		Anhydrous Ammonia	100	89	
1	10	20	Harvest & Kill			0	0	
1	11	1	Fertilizer		Generic-Fresh Manure	275	245	
1	11	5	Fertilizer		00-00-60	175	156	
1	11	15	Tillage			0	0	Generic No-till Mixing
2	1	30	Fertilizer		Generic-Fresh Manure	1	1	
2	2	1	Fertilizer		00-00-60	30	27	
2	4	15	Fertilizer		00-00-60	10	9	
2	4	15	Tillage			0	0	Generic No-till Mixing
2	5	15	Plant	SOYB		0	0	
2	10	5	Fertilizer		Generic-Fresh Manure	285	254	
2	10	5	Harvest & Kill			0	0	
2	10	15	Plant	WWHT		0	0	
3	3	1	Fertilizer		28-00-00	50	45	
3	5	1	Fertilizer		28-00-00	190	170	
3	6	10	Tillage			0	0	Generic No-till Mixing
3	6	10	Fertilizer		28-00-00	50	45	
3	7	20	Harvest & Kill			0	0	
3	7	20	Fertilizer		Generic-Fresh Manure	286	255	
3	8	5	Tillage			0	0	Chisel Plow Gt21ft
3	8	10	Tillage			0	0	Field Cultivator Ge15ft
3	8	30	Plant	HAY		0	0	
3	11	15	Fertilizer		00-00-60	165	147	
3	11	15	Fertilizer		00-46-00	25	22	
4	2	15	Fertilizer		00-00-60	165	147	
4	5	30	Fertilizer		00-46-00	5	4	
4	5	30	Harvest only			0	0	

4	5	30	Fertilizer	00-00-60	10	9	
4	7	10	Harvest only		0	0	
4	8	20	Harvest only		0	0	
4	9	30	Harvest only		0	0	
4	9	30	Fertilizer	Generic-Fresh Manure	286	255	
4	11	15	Fertilizer	00-00-60	175	156	
4	11	15	Fertilizer	00-46-00	25	22	
5	2	15	Fertilizer	00-00-60	30	27	
5	5	30	Fertilizer	00-00-60	10	9	
5	5	30	Fertilizer	00-46-00	5	4	
5	5	30	Harvest only		0	0	
5	7	10	Harvest only		0	0	
5	8	20	Harvest only		0	0	
5	9	30	Fertilizer	Generic-Fresh Manure	286	255	
5	9	30	Harvest only		0	0	
5	11	15	Fertilizer	00-00-60	165	147	
5	11	15	Fertilizer	00-46-00	25	22	
6	2	15	Fertilizer	00-00-60	30	27	
6	5	30	Fertilizer	00-46-00	5	4	
6	5	30	Fertilizer	00-00-60	10	9	
6	5	30	Harvest only		0	0	
6	7	10	Harvest only		0	0	
6	8	20	Harvest only		0	0	
6	9	30	Harvest only		0	0	
6	9	30	Fertilizer	Generic-Fresh Manure	286	255	
6	11	15	Fertilizer	00-00-60	165	147	
6	11	15	Fertilizer	00-46-00	25	22	
7	2	15	Fertilizer	00-00-60	30	27	
7	5	30	Harvest only		0	0	
7	5	30	Fertilizer	00-00-60	10	9	
7	5	30	Fertilizer	00-46-00	5	4	
7	7	10	Harvest only		0	0	
7	8	20	Harvest only		0	0	
7	9	30	Harvest & Kill		0	0	
7	10	30	Fertilizer	Generic-Fresh Manure	286	255	
7	11	15	Tillage		0	0	Generic No-till Mixing

Management Scenarios - Corn/Soybean/Winter Wheat/Perennial Grass and Tillage with Manure

SUBBASIN: *16* **HRU:** 1 **AGRR** *OH037Br*

NROT	*CN2*	*USLE_P*
7	77	1.00

YR	*MON*	*DAY*	*OPERATION*	*CROP*	*FERTILIZER*	*FRT_KG*	*FRT(lbs/Ac*	*TILLAGE*
1	1	30	Fertilizer		Generic-Fresh Manure	11	10	
1	3	20	Tillage			0	0	Field Cultivator Ge15ft
1	4	5	Plant	CORN		0	0	
1	6	1	Fertilizer		Anhydrous Ammonia	100	89	
1	10	20	Harvest & Kill			0	0	
1	11	1	Fertilizer		Generic-Fresh Manure	99	88	
1	11	5	Fertilizer		00-00-60	175	156	
1	11	15	Tillage			0	0	Generic No-till Mixing
2	1	30	Fertilizer		Generic-Fresh Manure	11	10	
2	2	1	Fertilizer		00-00-60	30	27	
2	4	15	Fertilizer		00-00-60	10	9	
2	4	15	Tillage			0	0	Generic No-till Mixing
2	5	15	Plant	SOYB		0	0	
2	10	5	Fertilizer		Generic-Fresh Manure	99	88	
2	10	5	Tillage			0	0	Generic No-till Mixing
2	10	5	Harvest & Kill			0	0	
2	10	15	Plant	WWHT		0	0	
3	3	1	Fertilizer		28-00-00	50	45	
3	5	1	Fertilizer		28-00-00	190	170	
3	6	10	Fertilizer		28-00-00	50	45	
3	6	10	Tillage			0	0	Generic No-till Mixing
3	7	20	Harvest & Kill			0	0	
3	7	20	Fertilizer		Generic-Fresh Manure	109	98	
3	8	5	Tillage			0	0	Chisel Plow Gt21ft
3	8	10	Tillage			0	0	Field Cultivator Ge15ft
3	8	30	Plant	HAY		0	0	
3	11	15	Fertilizer		00-46-00	25	22	
3	11	15	Fertilizer		00-00-60	165	147	
4	2	15	Fertilizer		00-00-60	165	147	
4	5	30	Fertilizer		00-46-00	5	4	
4	5	30	Harvest only			0	0	

4	5	30	Fertilizer	00-00-60	10	9	
4	7	10	Harvest only		0	0	
4	8	20	Harvest only		0	0	
4	9	30	Harvest only		0	0	
4	9	30	Fertilizer	Generic-Fresh Manure	109	98	
4	11	15	Fertilizer	00-00-60	175	156	
4	11	15	Fertilizer	00-46-00	25	22	
5	2	15	Fertilizer	00-00-60	30	27	
5	5	30	Fertilizer	00-00-60	10	9	
5	5	30	Fertilizer	00-46-00	5	4	
5	5	30	Harvest only		0	0	
5	7	10	Harvest only		0	0	
5	8	20	Harvest only		0	0	
5	9	30	Harvest only		0	0	
5	9	30	Fertilizer	Generic-Fresh Manure	109	98	
5	11	15	Fertilizer	00-46-00	25	22	
5	11	15	Fertilizer	00-00-60	165	147	
6	2	15	Fertilizer	00-00-60	30	27	
6	5	30	Fertilizer	00-46-00	5	4	
6	5	30	Harvest only		0	0	
6	5	30	Fertilizer	00-00-60	10	9	
6	7	10	Harvest only		0	0	
6	8	20	Harvest only		0	0	
6	9	30	Harvest only		0	0	
6	9	30	Fertilizer	Generic-Fresh Manure	109	98	
6	11	15	Fertilizer	00-00-60	165	147	
6	11	15	Fertilizer	00-46-00	25	22	
7	2	15	Fertilizer	00-00-60	30	27	
7	5	30	Fertilizer	00-00-60	10	9	
7	5	30	Harvest only		0	0	
7	5	30	Fertilizer	00-46-00	5	4	
7	7	10	Harvest only		0	0	
7	8	20	Harvest only		0	0	
7	9	30	Harvest & Kill		0	0	
7	10	30	Fertilizer	Generic-Fresh Manure	109	98	
7	11	15	Tillage		0	0	Chisel Plow Gt21ft

Appendix C.4. WWTP Inputs Derived from STORET

To simulate the loading of water and pollutants from sources not associated with a land area (e.g. sewage treatment plants), SWAT allows point source information to be read in at any point along the channel network. The point source loadings may be summarized on a daily, monthly, yearly, or average annual basis. For the revised Stillwater River TMDL, point source loadings were generated on a *daily basis* using information provided in the facilities Discharge Monitoring Report (DMR). All WWTP facilities within the study area submit flow on a daily basis, or when discharge occurs. Because of permit requirements imposed in the 2001 TMDL, most public facilities (those with ADF > 0.02 MGD) have monitored for total phosphorus on a weekly basis. This monitoring was very valuable in accurately representing discharge effluent in terms of phosphorus. Nearly all public facilities required nitrogen specie monitoring.

The following general assumptions were made in applying Ohio EPA DMR information for SWAT input:

1) For 00610, any value noted as below detection limit (comment = AA) was set to 0.01 mg-N/L. See Permit Guidance 9 “Limits Below Quantification” – Attachment: Conventional Parameters (p 6, 1998).

2) In determining the partition of total phosphorus (00665) into MINP and ORGP, 85% of 00665 was assumed to be MINP (i.e., SRP). Assumed ORGP = 0 for WWTP effluent. The remaining 15% of 00665 was assumed to lie within the particulate P pool (i.e., either organic or inorganic). If 00665 was not measured, then effluent concentration for POTW was assumed to be 2.5 mg-P/L.

3) When large gaps in the serial record existed for a given parameter, the long-term (1999-2008 or a 9.5 year record) average daily concentration stratified by month for that particular day (matching the month) was substituted in the gap.

4) For short gaps in the serial record (less than 30 days) exist, the last value measured until the next value was measured and substituted in the gap. This rule applied to 00665 and 00630. It did not apply to 00625 (TKN) because would create negative ORGN estimates.

5) 00625 was used to calculate ORGN because TKN – ammonia = ORGN. For 00625, the long-term (1999-2008 or a 9.5 year record) average daily concentration was substituted. If this average assigned to a given day was less than the measured 00610, then ORGN was assumed to be zero.

6) When 00630 (NO2+NO3) was measured, NO2 was assumed to be approximately zero. That is, all inorganic nitrogen existed as NO3.

Tables C.4.1 and ***C.4.2*** describe the comparison between the point-source based input data needs for SWAT (defined as measured input) and information available for these same entities through STORET[1] and Ohio DMRs.

Table C.4.1. **Comparison of STORET parameters to SWAT input data needs.**

Parameter (generic)	SWAT Parameter (specific)		STORET Parameter Name	STORET Parameter Code[1]
Water	Contribution to streamflow.	FLO	Flow rate (GPD) Flow rate (MGD)	***00056*** ***50050***
Nutrients – Nitrogen species	Organic nitrogen (kg N) Ammonia (kg N) Nitrite (kg N) Nitrate (kg N)	ORGN NH3___ NO2___ NO3___	Total organic nitrogen (mg/l) Ammonia [NH_3] nitrogen (mg/l) Nitrite [NO_2^-] nitrogen (mg/l) Nitrate [NO_3^-] nitrogen (mg/l) Total Kjeldahl nitrogen (mg/l) Nitrite plus nitrate [NO_2^-+NO_3^-] nitrogen (mg/l)	00605 **00610** 00615 00620 **00625** **00630**
Nutrients – Phosphorus species	Organic phosphorus (kg P) Mineralized phosphorus (kg P)	ORGP MINP___	Total phosphate (mg/l) Total orthophosphate [PO_4^-] (mg/l) Total phosphorus (mg/l) Dissolved phosphorus (mg/l)	00650 00660 **00665** 00666

Notes:

(1) STORET code in ***bold-italics*** indicates DMR data likely available for major POTW in Stillwater River watershed.

[1] STORET (short for STOrage and RETrieval) is a repository for water quality, biological, and physical data and is used by state environmental agencies, EPA and other federal agencies, universities, private citizens, and many others.

***Table C.4.2.* Transforming monthly operating report data to SWAT measured input.**					
Parameter (generic)	**SWAT Parameter (specific)**		**STORET Parameter Name**	**STORET Parameter Code**	**Solution**
Water	Contribution to streamflow (m^3/d).	FLO	Flow rate (GPD) Flow rate (MGD)	00056 **50050**	Convert either to m^3/d.
Nutrients – Nitrogen species	Organic nitrogen (kg N/d) Ammonia (kg N/d) Nitrite (kg N/d) Nitrate (kg N/d)	ORGN NH3___ NO2___ NO3___	Total organic nitrogen (mg/l) Ammonia [NH_3] nitrogen (mg/l) Nitrite [NO_2^-] nitrogen (mg/l) Nitrate [NO_3^-] nitrogen (mg/l) Total Kjeldahl nitrogen (mg/l) Nitrite plus nitrate [NO_2^-+NO_3^-] nitrogen (mg/l)	00605 **00610** 00615 00620 **00625** **00630**	See note (4). See note (3). See note (1). See note (2). See note (4).
Nutrients – Phosphorus species	Organic phosphorus (kg P/d) Mineralized phosphorus (kg P/d)	ORGP MINP___	Total phosphate (mg/l) Total orthophosphate [PO_4^-] (mg/l) Total phosphorus (mg/l) Dissolved phosphorus (mg/l)	00650 00660 **00665** 00666	 See note (5). See note (5).

Notes (referenced in tables above):

1) Determine **NO_2^-** as kg-N per day: Assume approaches zero for wastewater effluent (K. Kroeger and J. Van Dommelen, Ohio EPA Division of Surface Water Technical Assistance Unit; 2002, personal communication). In nitrogen species kinetics, $NH_4^+ \rightarrow NO_2^- \rightarrow NO_3^-$, NO_2^- is short-lived and often exits (denitrifies) system as N_2 (g).

2) Determine **NO_3^-** as kg-N per day: Given (1) above, apply parameter code 00630 (nitrate plus nitrite). Because 00630 are reported as mg-N per liter (Standard Methods for the Examination of Water and Wastewater, 1992), a ratio of molecular weight does not need to apply.

3) Determine **NH_4^+ (NH_3)** as kg-N per day: Apply parameter code 00610. Note that 00610 is reported as NH_3 but NH_4^+ is the parameter that is actually measured. During the analysis of an effluent sample, the pH is shifted toward the higher end of the scale (14.0) where NH_4^+ dominates (K. Kroeger and J. Van Dommelen, Ohio EPA Division of Surface Water Technical Assistance Unit; 2002, personal communication). In a wastewater stream, ammonium ions exist in equilibrium with ammonia. In normal ranges of pH (6.0-8.0) and at 20 ÉC, the composition of effluent is 96–99.96% NH_4^+ and 0.04–4% NH_3 (USEPA 1985, p 264). Because 00610 is reported as mg-N per liter (Standard Methods for the Examination of Water and Wastewater, 1992), a ratio of molecular weight does not need to apply.

4) Determine **organic nitrogen** as kg-N per day: The following approximation can be made:

Total Organic Nitrogen = Total Kjeldahl Nitrogen – Ammonia Nitrogen

Subtract parameter code 00610 from parameter code 00625 (in loading units) to generate the load for total organic nitrogen. Because 00625 is reported as mg-N per liter (Standard Methods for the Examination of Water and Wastewater, 1992), a ratio of molecular weight does not need to apply.

5) Parameter code 00665 **(total phosphorus**) is the total amount of phosphorus in the sample after all forms (of phosphorus) have been converted to PO_4^{3-} (phosphate). Organic phosphate is produced mostly from industrial process sources; only a very small amount occurs in most municipal wastewaters (Hauser 1996, p 74). All forms of phosphate can occur in solution, in particles or detritus, or in bodies of aquatic organisms.

Biological processes are mainly responsible for forming organic phosphates. Organic phosphates are contributed to sewage by body wastes and food residues, and may also be formed from orthophosphates in biological treatment processes or by receiving water biota.

Fractionalization of the total phosphorus load to **mineralized**[2] **P** (total inorganic form) and **organic P** is required for input to the SWAT model. This fractionalization will be based on results of the Little Miami River Preliminary Assessment of USE Attainability or PAUSE (Buchburger et al. 1997) where 85 percent (by load) of all phosphorus discharged by the 14 WWTPs in that basin was soluble reactive phosphorus (SRP) [3].

References Cited

Buchburger, S.G. and others (1997) *Little Miami River Preliminary Assessment of USE Attainability (PAUSE)*, University of Cincinnati, 53 pp.

Greenberg, A.E. and others (1992) *Standard methods for the examination of water and wastewater*. 18th Edition, Published by APHA, AWWA, and WEF.

Hauser, B. (1996) *Practical manual of wastewater chemistry*. Ann Arbor Press, Chelsea MI, 135 pp.

[2] Mineralization (or sometimes re-mineralization) is the process in which organic compounds are broken down into simple inorganic components. Complete mineralization typically involves oxidation (using oxygen), but it can also occur under anoxic conditions.

[3] From April 1996 to March 1997 (12 months), WWTP effluent yielded 168.3 metric tons. Of that total, 142.3 metric tons were in the form of SRP (or 84.6 percent).

Appendix D: Responses to Public Comments

The draft Stillwater River Watershed Total Maximum Daily Load Report was available for public review from June 9 through July 10, 2009. One comment letter was submitted, on July 10 by Steven N. Haughey on behalf of the Cities of Englewood and Union. The letter is presented in its entirety; the response follows on page D-6.

Comment

I. INTRODUCTION.

The Cities of Englewood, Ohio and Union, Ohio (hereinafter "the Cities") are small, primarily residential communities with current populations of approximately 12,500 and 6,400, respectively. Union has no existing industrial tax base and Englewood has a minimal industrial tax base.

Both Cities are undergoing wastewater treatment plant upgrades and related projects as part of their voluntary nutrient reduction programs. Englewood spent approximately $1 million on capital upgrades to its clarifier and influent solids removal processes, and approximately $250,000 to install new instrumentation and automated control systems for its WWTP as part of its commitment to reduce nutrient loadings using innovative operational techniques rather than conventional capital improvements. And Union is evaluating a proposal to (1) add a septage receiving station to help reduce nutrient loadings and stream impairments caused by poorly designed or operated private home sewage disposal systems, and (2) convert its WWTP to a controlled discharge facility, at an estimated total cost of over $3 million.

In 2005 both Cities signed as founding members an agreement with the Water Conservation Subdistrict of the Miami Conservancy District, pursuant to which the Cities have paid significant funds to the Subdistrict for the development, implementation and oversight of the Great Miami River Watershed Water Quality Credit Trading Program. The primary purpose of the program is to promote the improvement of stream quality and riparian habitat in the Great Miami River basin, including the Stillwater River. The Cities also contributed funds separately to promote voluntary agricultural best management practices by crop and livestock farmers in the upper reaches of the Stillwater River, as a means to reduce nutrient loadings in the upper reaches. The Cities are particularly proud of the fact that more than 50 tons per year of nutrient loadings have already been eliminated with this program in just the first four years of its existence, and that the trading program is touted by both Ohio EPA and U.S. EPA as a model for other basins to follow.

Finally, Englewood is nearing completion of a project with the Fiver Rivers MetroParks to remove the last part of the low-head dam near the discharge point for its WWTP. The low-head dam is no longer needed for flood control. Its pooling effect increases the temperature of the water during the low-flow summer period, causing a slight dip in DO and slight impairment in the downstream biocriteria scores. Englewood committed to removing this dam in the interest of further improving water quality in the lower reaches of the Stillwater River. Nearby bank restoration is also a part of the project.

The Cities remain strongly committed to the nutrient trading program, and to other riparian corridor improvement programs. Broadly speaking, the Cities view the high quality water and riparian habitat along the lower reaches of the Stillwater as a critically important resource for tourism, recreation, and economic development for both Cities.

II. SUMMARY OF THE CITIES' COMMENTS.

Obviously the Cities are pleased to see that Ohio EPA proposes, as part of the revised TMDL, to remove the new phosphorus effluent limitations and loading reduction programs that were placed in their respective renewal permits. When the original TMDL was issued, the Cities' comments opposed the recommendation to impose limits and loading reductions because chemical and biological data for the lower reaches of the Stillwater River did not support a finding that nutrient discharges from the Cities were causing nutrient-induced impairments downstream, and because the Cities' nutrient loadings were less than 0.5% of the estimated loadings entering the basin. The Cities' comments also opposed the recommendation because chemical and biological survey data demonstrated that the lower reaches were achieving water quality criteria consistent with an exceptional habitat and, just as importantly, because the lower reaches had excellent physical habitats and riparian corridors, a critically important parameter that positively affects the capacity of a flowing stream to assimilate nutrient loadings.

Data collected by Ohio EPA and the Conservancy District since the original TMDL was issued continues to support this fundamental premise. The stream data continues to demonstrate unequivocally that the two Cities are not causing downstream impairment of chemical or biological criteria, and that both Cities' nutrient loadings have actually decreased during this time as part of their voluntary nutrient reduction programs summarized above.

In addition, in-stream nutrient chemical data collected by the Conservation District in the Stillwater River over the last four years demonstrates that the original estimated annual nutrient loadings were inflated by a significant margin. During this same interval, the trading program was implemented aggressively by the Conservancy District, resulting in additional significant reductions in upstream nutrient loadings.

The Cities would like to think that the impetus behind the revised TMDL was the continued demonstration of a successful trading program, and the collection of stream nutrient data showing much smaller nutrient loadings than originally estimated, and not the Cities' administrative appeal of their respective renewal permits.

During the course of the administrative appeals, the Cities reached some conclusions with respect to the Agency's TMDL process:

1. The biological impairments found in the Stillwater River basin are caused almost exclusively by non-point source discharges, and habitat and stream alterations, not by point source discharges from POTWs, a characteristic that exists in all, or nearly all, of the TMDLs that Ohio EPA has issued across the State of Ohio;

2. Despite this characteristic, most, if not all, of the TMDLs in Ohio recommend imposition of stringent numeric phosphorus effluent limitations on the POTWs located in the basin, *notwithstanding a separate finding that the POTWs are almost always an insignificant source of nutrient loadings in the basin;*

3. Despite Ohio EPA's acknowledgement that excellent canopy and riparian corridor is a significant factor in the assimilative capacity of a stream to carry nutrient loadings and still achieve biocriteria, many of the TMDLs across the State impose stringent numeric phosphorus limits on POTWs even when, like Union and Englewood, their outfalls are located along stream reaches that have excellent canopies and riparian corridors and, in some cases, are in full attainment of applicable biocriteria; and

4. Despite serious flaws in the Agency's 1999 Association Report, from which target instream phosphorus values are derived for rivers in Ohio, Ohio EPA continues to support the report and its findings, even in the face of the revised TMDL for the Stillwater River.

While the Cities are very pleased with the revisions to the TMDL, they believe that the circumstances that led Ohio EPA to decide to revise the TMDL warrant a much broader consideration, and perhaps complete reassessment, of the underpinnings and basic assumptions of the entire TMDL process. The Cities hope that information obtained following the issuance of the original TMDL for the Stillwater River will lead Ohio EPA to re-examine other TMDLs and, in particular, their recommendations for affected POTWs, so that other POTWs can avoid significant capital expenditures for nutrient reductions that will not alleviate downstream biological impairments.

III. THE CITIES SUPPORT THE REVISED TMDL BECAUSE IT AVOIDS A SIGNIFICANT CAPITAL EXPENDITURE THAT WOULD NOT HAVE LED TO A MEASURABLE IMPROVEMENT IN DOWNSTREAM WATER QUALITY.

The long-term phosphorous reduction requirements imposed in the City's permits would have required that each City spend well in excess of $1,000,000 in capital expenditures to consistently achieve the mandated reductions. Such capital expenditures would have required that each City substantially increase rates and charges for their respective customers at a time when the local economy can least afford it.

Based on the biological and chemical data collected in the downstream reaches of the Stillwater River, imposing significant additional phosphorous loading reductions on the Cities would not have led to a measureable improvement in downstream ambient water quality. Consistent with this fact is that statement in the Fact Sheet for the revised draft TMDL, stating that the impoundment of water behind the lowhead dam in the lower reaches of the River is the only reason the lower segments fail to fully attain all applicable water quality goals. The soon-to-be completed removal of the last part of the dam is the only step necessary to allow full attainment of all criteria.

Both Cities appreciate Ohio EPA's willingness to recognize that additional phosphorous reductions in their respective discharges is unnecessary to achieving downstream water quality goals in the River.

IV. THE CITIES SUPPORT THE REVISED TMDL BECAUSE IT ACKNOWLEDGES THE SUCCESS OF THE TRADING PROGRAM, AFFORDS THE PROGRAM MORE

CREDIBILITY, AND RECOGNIZES, CONSISTENT WITH APPLICABLE TMDL RULES, THAT CORRECTING DECADES OF NON-POINT SOURCE IMPAIRMENTS IS BEST ACHIEVED THROUGH PROMOTING LOCAL TRADING PROGRAMS.

The revised TMDL is particularly important because it acknowledges the success of the Conservancy District's trading program. The collection of regular in-stream nutrient data by the Conservancy District over the last four years or so is arguably the single most important reason why the TMDL is being revised today. Proving that in-stream nutrient target values are being achieved, and that original, estimated annual nutrient loadings were substantially inflated, was possible only as a result of the District's trading program. Both Ohio EPA and U.S. EPA have regularly touted the Conservancy District's trading program as a model program. The revised TMDL effectively acknowledges the success and the importance of the trading program, and affords it even greater credibility so that it can continue to be successful for the foreseeable future.

Just as important, Ohio EPA's TMDL rules, as well as those promulgated by U.S. EPA, state that the process of eliminating water quality impairments is not required to be completed within a fixed period of time, such as, for example, a five-year permit cycle. All that is required is that a TMDL implementation plan provide "reasonable assurances" that progress will be made toward eventual elimination of the impairments. In basins like the Stillwater River, where non-point source impairments from historical agricultural, livestock and dairy practices, stream and habitat alterations, and outdated septic systems are the predominant source of impairment, it is imperative that trading programs like that implemented by the Conservancy District be afforded considerable flexibility and time with which to alleviate decades of past practices that created the current impairments. In some respects, the revised TMDL is a direct acknowledgement that the Conservancy District's trading program is on the right track, and should be afforded additional flexibility and time with which to accomplish its important goals and objectives.

V. THE CITIES SUPPORT THE REVISED TMDL, BUT RECOMMEND THAT OHIO EPA RE-EXAMINE THE TMDL PROCESS AND OTHER EXISTING TMDLS BASED ON INFORMATION OBTAINED IN THE AFTERMATH OF THE ORIGINAL STILLWATER RIVER TMDL.

The stream nutrient data collected by the Conservancy District over the last four years or so demonstrated that the model used by Ohio EPA to estimate annual non-point source nutrient loads in the original TMDL overestimated the loadings by a wide margin. In response to that data, to the Agency's credit, it didn't ignore the data, but rather collected additional data of its own, and then employed a newer, more elaborate model to estimate annual non-point source loadings in the basin. Presumably, and hopefully, the newer, more elaborate model will be used in all future TMDLs that Ohio EPA performs on other streams in the State. The Cities ask that Ohio EPA confirm that to be the case.

But what about the dozens of existing TMDLs across the State where the previous model was used and presumably overestimated loadings by a wide margin for the applicable basin, yet those TMDLs are presently being implemented through costly, mandated point source nutrient reductions from POTWs that, as it turns out, may be based upon faulty data? While the Cities *strongly support the revised TMDL for obvious reasons, in some respects the Cities' good fortune is sheer happenstance to be located in a basin where an elaborate trading program was in place with an aggressive stream data collection effort to coincide with the program. Will other TMDLs be re-evaluated in light of the data that the Conservancy District collected on the Stillwater River?*

During the course of the administrative appeals of their respective permits, the Cities' representatives reviewed numerous TMDLs from around the State and compared the processes, data collection, conclusions, and recommendations therein to those contained in the original TMDL for the Stillwater River. That effort resulted in the following observations with respect to the Agency's TMDL process as a whole:

1. The fact that the biological impairments found in the Stillwater River basin are caused almost exclusively by non-point source discharges, septic systems, and habitat and stream alterations, and not by point source discharges from POTWs, is far from unique, but rather this characteristic permeates nearly all of the TMDLs that Ohio EPA has issued in Ohio;

2. Despite this characteristic, most, if not all, of the TMDLs issued in Ohio recommend imposition of stringent numeric phosphorus effluent limitations on the POTWs located in the basin, notwithstanding the fact that the nutrient loading data collected for the applicable basin shows that the POTWs are almost always an insignificant source of nutrient loadings;

3. Although Ohio EPA acknowledges that excellent canopy and riparian corridor is a significant positive factor in the assimilative capacity of a stream to carry higher nutrient loadings and still achieve biocriteria, many TMDLs impose the same stringent numeric phosphorus limits on all POTWs even when, like Union and Englewood, outfalls are located along stream reaches that have excellent canopies and riparian corridors, and correspondingly excellent biocriteria scores; and

4. All, or at least nearly all, TMDLs in Ohio establish instream phosphorus nutrient target values taken directly from the Agency's 1999 Association Report, a report that (a) was never peer reviewed, (b) fails to factor a host of habitat and stream morphological characteristics as reasons why biological scores may be lower than at reference sites with low nutrient loadings, and (c) employs a reference stream approach that (i) U.S. EPA intended only to be a starting point from which states would develop refined, "effects-based" criteria using scientifically defensible approaches, and (ii) was replaced by U.S. EPA in December 2007 with a "weight of evidence" approach after ASIWPCA, of which Ohio EPA is member, sent U.S. EPA a letter highlighting problems implementing the reference stream approach.[1]

These findings form the basis for the Cities' recommendation to Ohio EPA that the Agency

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[1] See http://www.asiwpca.org/home/docs/Ltr2EPANutrients.pdf (copy of the ASIWPCA letter). Even the "weight of evidence" approach has been widely criticized, causing U.S. EPA to recently agree to subject it to a full peer review by the Science Advisory Board. See 74 Fed. Reg. 19085, April 27, 2009. See generally "Critical Evaluation of EPA Stream Nutrient Standard Initiatives," John C. Hall and William T. Hall, Hall & Associates, published at Vol. 40, No. 27, Bureau of National Affairs Analysis & Perspective, pp. 1593-1609, July 3, 2009.

not treat the revised TMDL for the Stillwater River as an isolated situation, to be shelved and forgotten in the grand scheme of the TMDL program. Instead, the Cities recommend that Ohio EPA re-examine the TMDL process in light of these findings. Specifically, the Cities recommend at least the following steps:

1. Review existing TMDLs where recommended nutrient effluent limits and loading reductions for POTWs have not yet been implemented or, if implemented, are not yet at the design or construction stage, to determine whether replacement of the limits with an aggressive, mandatory non-point source trading program will lead to far greater nutrient reductions, improved biological scores, at considerable cost savings to the affected communities; and

2. Discard the 1999 Association Report, or at least recognize its limitations and view it for what it really is – a starting point that may still have limited future utility depending on the outcome of U.S. EPA's nutrient stream initiatives.

If the Agency's goal is real relief for biologically impaired streams in Ohio, less ratcheting down on POTWs in terms of nutrient effluent limits, and aggressive examination of ways to encourage and promote trading programs like the successful Conservancy District program, are the keys. The Cities would welcome an opportunity be part of testimonials to encourage other basins in Ohio to develop and implement their own trading programs modeled on the Conservancy District's successful program.

VI. CONCLUSION.

The Cities expended considerable sums in legal and consulting costs over the last six years to protect their rights thru (1) filing comments and attending meetings on the original draft TMDL, (2) filing appeals when their respective renewal permits were issued with stringent phosphorus limits and loading reductions, (3) evaluating other TMDLs issued for streams across the State, and (4) funding the collection of stream nutrient data for the Stillwater River over the course of several years in order to compare actual versus estimated nutrient loadings. During this period, in order to demonstrate their commitment to improving water quality in the River despite opposing the TMDL's recommendations, each City spent millions to implement voluntary capital and operational nutrient reduction programs. And they each signed on, as founding members, to arguably the State's most aggressive and highly successful nutrient trading program, thereby each committing yet additional expenditure of substantial funds to help implement the program's goals and objectives.

The issuance of the revised TMDL for the Stillwater River is the culmination of a long process. The Cities support the revised TMDL and hope that Ohio EPA will accept these comments in the positive, and most importantly constructive, manner in which they are offered. For all of the foregoing reasons, the Cities request that the Agency finalize the draft, revised TMDL without delay.

Response

Ohio EPA appreciates the efforts of the communities of Englewood and Union to reduce nutrient loadings. The evolution of this TMDL demonstrates the value of follow-up monitoring, which has proven to be a good investment by the Miami Conservancy District (MCD) and the communities. We continue to encourage the collection of dependable water quality data as we all seek to restore Ohio's water quality resources.

While we acknowledge that Englewood has completed plant upgrades, we are seeing no sustained reductions in the discharge of phosphorus, based on annual and seasonal concentration and loading data. Englewood data for 2002 (when they began reporting) through July 2009 are attached. Similar data for Union (now contemplating upgrades; reporting since 2007) show their summer concentrations are lower in 2009 than 2007, a good sign but of limited duration.

Throughout the comment letter, mention is made repeatedly that the original TMDL overestimated loadings by a wide margin. We must point out that we never attempted to hide this fact; the issue is discussed in the original TMDL document and was discussed openly and at length with all parties, including Englewood and Union, during the development of the original TMDL. The revised analysis uses the same model with improved inputs, seeking to eliminate sources of error and uncertainty to arrive at a better loading estimate.

Although the comments submitted by the communities ultimately endorse the revised TMDL and seek its adoption, the letter also makes a number of requests that Ohio EPA alter its approach to nutrients and TMDLs. A number of statements are made that Ohio EPA believes require a response. The following discussion is organized by general topic.

<u>Revise Ohio's TMDL Approach</u>

Ohio EPA is taking a reasonable approach to addressing water quality problems caused by excessive phosphorus. Typically, we seek a phased phosphorus reduction: to reduce point source effluent concentrations down to the achievable limit of 1.0 mg/l while efforts are made to improve the capacity of the stream to assimilate nutrients.

We have used various tools to bring about the changes needed, such as compliance schedules and reopener language in permits to adjust limits as a situation improves and writing permits in terms of a plant's current flow, with provisions that as flows increase towards design, phosphorus concentrations must be reduced. This "adaptive management" approach is consistent with findings of newer research on nutrient criteria.

<u>Focus on Nonpoint Sources Rather than Point Sources</u>

It is true that nonpoint sources of nutrients are a significant, sometimes overwhelming, factor in impairment of Ohio's waters by nutrients. But point sources are also significant in many cases, especially at times of low stream flow. In the Stillwater River watershed in particular, despite the presence of substantial nonpoint sources in the form of animal feeding operations, four point sources contribute significantly to impairment in the upper watershed: Greenville, Bradford, Versailles, and Arcanum POTWs.

While assessment results and modeling might show that nonpoint sources of pollution are a major cause of nonattainment, POTWs can have local impacts. Where nonattainment downstream of a POTW is related to high phosphorus concentrations in its discharge during low flow periods, the nonattainment will be addressed only by reductions at the POTW. Many of our TMDLs for nutrients are seasonal, with point source control recommended during the summer months.

The comments made by Englewood and Union reflect a general misunderstanding of the nutrient cycle and the relative loads from point sources and nonpoint sources with regard to sensitive times of year and other factors. POTW effluent generally has a high proportion of dissolved phosphorus, the most bioavailable form. Nonpoint source runoff is generally particulate (but tile drains deliver dissolved phosphorus). So, just looking at the relative loads of total phosphorus between point sources and nonpoint sources is not directly indicative of their impact. Another consideration is that nutrient cycling is a long distance process that persists for many miles downstream. The outfall may be a good canopy section of a river, but the nutrients are still being exported downstream where there will be a break in the canopy and sunlight will spark algal production and other impacts. Also, there is no guarantee that a canopy or good habitat will remain into the future.

<u>Eliminate Point Source Permit Phosphorus Limits Below 1.0 mg/l</u>

We write permits for phased, adaptive implementation with allowances for options such as water quality trading and reopener language. We have rarely included a total phosphorus effluent limit below 1 mg/l without such allowances. Also, point source phosphorus limits are generally only required of significant POTWs in phosphorus-impaired watersheds.

An effluent of 1 mg/l is not a stringent phosphorus limit. Major dischargers in the Lake Erie basin have been complying with this level for decades. Two recent U.S. EPA publications[2][3] discuss alternatives for nutrient removal. The *Nutrient Control Design Manual, State of Technology Review Report* states:

> "Direct addition of metal salts to activated sludge processes followed by conventional clarification can typically remove TP to effluent levels between 0.5 and 1.0 mg/l (Bott et al., 2007)." (EPA/600/R-09/012, page 31)
>
> "The technologies described in this section *(various biological phosphorus removal technologies)* are generally capable of phosphorus removal to effluent levels of 0.5 to 1.0

[2] Municipal Nutrient Removal Technologies Reference Document (EPA 832-R-08-006, September 2008) at http://www.epa.gov/OWM/mtb/mnrt-volume1.pdf.
[3] The *Nutrient Control Design Manual, State of Technology Review Report* (EPA/600/R-09/012, January 2009, http://www.epa.gov/nrmrl/pubs/600r09012/600r09012.pdf)

mg/l . . . Biological phosphorus removal can be combined with other technologies to achieve very low effluent concentrations (< 0.2 mg/l)." (EPA/600/R-09/012, page 48)

<u>Discard the "Associations" Document</u>

We believe the "Associations" report is still relevant. Recognizing its limitations, we have always used the document as a starting point for analysis. We have employed its recommendations with flexibility both in selecting targets and in applying results in TMDL recommendations. Because the study is based on a substantial data set, the values derived from the report are not substantially different from U.S. EPA's nutrient values or recent Ohio EPA research numbers. Until Ohio adopts nutrient criteria (through the standard public rule-making process), we plan to continue to consider the Associations document in TMDL analyses.

<u>Revisit All Ohio TMDLs</u>

We respectfully decline the request to revisit all Ohio TMDLs in light of the Stillwater revision. The TMDL process is dynamic, incorporating lessons learned both in Ohio and across the nation and reacting to new decisions and guidelines from U.S. EPA. The lessons of the original Stillwater TMDL have been a part of Ohio's TMDL program for several years. However, the primary reason for not revisiting other Ohio TMDLs is that in many ways the original Stillwater TMDL was unique, perhaps owing to its timing at the beginning of Ohio's TMDL program.

First, as an early Ohio TMDL, the original TMDL analysis was completed on the larger "HUC11" scale (units that average about 130 square miles) which meant that the allocations were at a coarser scale. The new analysis is at the "HUC12" scale (units average about 20 square miles). Thus, the old analysis had 6 allocation pieces while the new project has 44 pieces, resulting in better resolution. Most Ohio TMDL projects have been completed at the finer scale.

Second, in the original Stillwater TMDL, we were trying to anticipate reductions that would be needed for the Gulf of Mexico hypoxia situation. The Great Miami River watershed had been targeted as a major source. The urgency of the Gulf hypoxia situation appears to have receded so it was not considered in the revised Stillwater TMDL. The original Stillwater TMDL is the only Ohio TMDL that attempted to consider Gulf hypoxia.

Finally, in the original analysis a sophisticated model (SWAT) was used that arguably was not supported by the data available (e.g., crop data). Understanding more about the privacy protections of the Farm Bill (crop practice data are likely to be shielded), Ohio EPA does not typically pursue such a model now, instead using simpler models and more straightforward analysis techniques such as load duration curves. Ultimately, model selection is project specific; the same model would not be appropriate for all projects. The SWAT model has actually been used on only a few Ohio TMDL projects, and these did not attempt the intense detail of the original Stillwater model.

The availability of new data was the major factor in Ohio EPA's decision to revisit the 2004 Stillwater TMDL. When data are presented that call into question TMDL results in other areas, similar to the Stillwater situation, we will consider the need for a reevaluation.

Consider Mandating Water Quality Trading

Ohio EPA supports MCD's trading program and we look forward to future developments. However, the only measure of success at this point is administrative – five POTWs in the trading area are engaged as partners, the agriculture community is involved, four rounds for nonpoint source load reduction projects have been funded, and estimates of loading reductions have been calculated. Success in terms of water quality improvements in the upper Stillwater watershed where the nonpoint source reduction projects are underway is unknown and success won't be measured for some time to come. Success in financial terms – more water quality improvement per dollar – is similar. Thus, while the MCD program is promising, judging its success in terms of water quality improvement or financial savings is premature.

MCD provides a good example, but expanding trading to other areas may be a challenge due to three major issues: authority, infrastructure, and money. With regard to authority, Ohio does not plan to mandate water quality trading – it will continue to be a voluntary program, an option. In its initial trading efforts, the State of Michigan tried to set up a program where the state would do everything, but there were many difficulties – too much work, too complicated, no money.

Infrastructure is a major challenge. In both cases where trading is happening in Ohio, some infrastructure was already in place. The Sugar Creek trading project (Alpine Cheese) benefits from Ohio State University's long-standing research programs in the watershed. MCD was already a well established watershed-based authority in the Great Miami River area due to its status as a conservancy district. Even as a conservancy organization, MCD did a lot of work to build the foundation for its trading program. Having done that work, MCD is starting to look at having its partners be able to sell other credits besides phosphorus – carbon credits, for instance or nitrogen credits to the power plants in the Ohio River basin if the Electric Power Research Institute (EPRI) regional trading program becomes a reality. Similarly, the group working to establish a trading program in the Cuyahoga basin is forming a conservancy district first to provide the infrastructure for a trading program. They are using the MCD model – political subdivision of state working in a large watershed.

Trading programs can require considerable amounts of money. In general, sources of funding to establish a trading program could be private investment, government grants, or other sources. For MCD, the initial pilot (years 1 through 3) was funded with $1,200,000 from POTWs and a $937,000 grant from USDA/NRCS. Years 4 and 5 are funded with $251,000 in non-federal funds and a $753,900 U.S. EPA grant (anticipated, not yet awarded). The Sugar Creek trading program has been funded by a $100,000 OSU/OARDC matching grant and $250,000 from Alpine Cheese Company. Pulling together and maintaining adequate funding would seem to require a stable infrastructure.

Ohio EPA has not received any trading plans since we adopted our rules but we have been assured by people involved in trading nationally and in other states that our rules are not the problem (our rules are being used as a model by other states). Rather, when people decide they want to pursue trading, they find out that there really is a lot of work involved to set up a program – regardless of whether they have to operate under rules.

The elimination of phosphorus limits for the communities of Englewood and Union could present a new challenge to the MCD trading program. Without a permit requirement to reduce phosphorus, a POTW may have little reason to participate in a trading program. MCD has been successful in selling its trading program to its POTW partners by focusing on future phosphorus regulation. In its comments, Englewood and Union argue that the nutrient targets should be eliminated (and thus, presumably nutrient TMDLs and permit requirements). Would trading continue in Ohio without permit limits? How MCD handles this challenge could be instructive for future Ohio trading efforts.

In closing, we note that many TMDLs in Ohio are being implemented, and water quality problems are being reduced or eliminated. We recognize that there are many ways besides TMDLs to accomplish this goal. We look forward to the continued efforts of the communities of Englewood and Union in promoting voluntary pollutant loading reductions, water quality trading, high-quality stream monitoring, and the value of restoring and preserving riparian habitat.

Monthly Operating Report (MOR) Statistics for: Englewood WWTP; 1PD00001 (permit #)

Season	Year	# of Obs.	# Below Detection	Minimum	Percentiles						Maximum	Mean
					5th	25th	50th	75th	95th	99th		
Monitoring Station 001;		**Reporting Code:**		**00665;**			**Parameter Name:**	**Phosphorus, Total (P) (mg/l)**				
Summer	2002	17	0	0.27	0.406	0.5	0.82	2.3	3.208	3.5536	3.64	1.3847
Summer	2003	17	0	0.36	0.368	0.55	0.8	1.32	2.44	2.568	2.6	1.0529
Summer	2004	18	0	0.31	0.803	1.09	1.215	1.3375	1.483	1.4966	1.5	1.1833
Summer	2005	18	0	0.17	0.17	0.34	1.22	2.2625	4.793	4.8066	4.81	1.6372
Summer	2006	17	0	0.55	0.614	1.16	1.63	2.25	6.536	7.0032	7.12	2.1259
Summer	2007	17	0	0.32	0.776	1.5	1.71	1.88	3.272	3.3424	3.36	1.8412
Summer	2008	17	0	0.35	0.574	0.87	1.34	1.81	2.592	3.6544	3.92	1.4918
Summer	2009	4	0	0.384	0.6054	1.491	2.045	2.2375	2.2555	2.2591	2.26	1.6835
Summer Overall	2002-2009	125	0	0.17	0.312	0.8	1.3	1.88	3.584	6.0108	7.12	1.534
Winter	2003	13	0	0.26	0.29	0.34	0.44	0.66	1.02	1.164	1.2	0.53769
Winter	2004	13	0	0.23	0.236	0.31	0.43	0.85	1.234	1.5268	1.6	0.59615
Winter	2005	13	0	0.19	0.202	0.22	0.61	1.96	2.914	3.0628	3.1	1.1915
Winter	2006	12	0	0.05	0.1215	0.58	1.215	1.8125	4.5815	5.4923	5.72	1.6017
Winter	2007	13	0	0.2	0.2	0.37	0.46	0.68	0.888	0.9456	0.96	0.51615
Winter	2008	13	0	0.15	0.222	0.36	0.57	0.74	2.514	3.3588	3.57	0.90538
Winter	2009	13	0	0.26	0.296	0.4	0.57	0.83	1.026	1.0932	1.11	0.61308
Winter Overall	2002-2009	90	0	0.05	0.2	0.345	0.55	0.895	2.7045	3.8777	5.72	0.84333
Annual	2002	36	0	0.27	0.3175	0.495	0.835	1.5525	2.8	3.451	3.64	1.1447
Annual	2003	52	0	0.26	0.351	0.55	0.89	1.34	2.49	2.8778	2.99	1.0469
Annual	2004	52	0	0.18	0.24	0.4825	1.19	1.3425	2.6855	2.947	3.1	1.1077
Annual	2005	52	0	0.17	0.1855	0.355	0.795	1.715	4.2645	4.7998	4.81	1.2427
Annual	2006	52	1	0	0.173	0.5475	0.875	1.64	3.9765	6.7477	7.12	1.3258
Annual	2007	52	1	0	0.1665	0.3925	0.805	1.7025	3.074	3.9627	4.59	1.1458
Annual	2008	53	0	0.1	0.162	0.54	0.93	1.81	3.842	4.3752	4.63	1.3358
Annual	2009	25	0	0.234	0.256	0.57	1.11	1.86	2.596	3.3792	3.6	1.2489
Annual Overall	2002-2009	374	2	0	0.21	0.48	0.905	1.6	3.2045	4.7954	7.12	1.199
Monitoring Station 001;		**Reporting Code:**		**00665;**			**Parameter Name:**	**Phosphorus, Total (P) (kg/day)**				
Summer	2002	17	0	1.271306	1.5287	2.0384	4.0471	8.9076	12.038	14.664	15.32047	5.9412
Summer	2003	17	0	1.586445	1.796	2.9545	5.0942	8.4935	14.206	21.623	23.47714	6.771
Summer	2004	18	0	3.28538	4.6032	4.9794	5.7697	6.4062	8.7582	10.113	10.45114	6.0421
Summer	2005	18	0	0.815895	0.82738	1.6152	6.2089	9.0217	18.877	19.773	19.99756	7.1257
Summer	2006	17	0	2.7833	2.9495	5.9859	8.2054	12.175	40.796	72.862	80.87849	13.809

Monthly Operating Report (MOR) Statistics for: Englewood WWTP; 1PD00001 (permit #)

Season	Year	# of Obs.	# Below Detection	Minimum	Percentiles						Maximum	Mean
					5th	25th	50th	75th	95th	99th		
Summer	2007	17	0	1.535802	3.3686	6.5723	7.9337	9.3071	14.337	14.391	14.40476	8.1384
Summer	2008	17	0	2.048328	2.3687	4.0378	6.0999	7.6079	16.211	28.487	31.55607	7.4696
Summer	2009	4	0	1.77029	3.1139	8.4885	10.757	12.707	17.314	18.236	18.46618	10.438
Summer Overall	2002-2009	125	0	0.815895	1.5459	3.8268	6.4158	9.0945	18.366	31.369	80.87849	7.9597
Winter	2003	13	0	1.751698	1.8394	2.7148	3.7588	4.5409	5.7304	6.4729	6.658572	3.6787
Winter	2004	13	0	1.50431	1.668	2.8421	4.1491	7.048	10.258	13.151	13.8743	5.0921
Winter	2005	13	0	1.435575	1.539	2.6475	8.4033	18.816	20.54	21.224	21.39524	10.101
Winter	2006	12	0	0.39629	0.79511	4.1851	10.339	16.029	60.17	75.305	79.08818	17.174
Winter	2007	13	0	1.631335	1.8698	2.7654	4.0666	4.6376	6.631	6.7744	6.810275	3.987
Winter	2008	13	0	1.256431	1.5705	2.5661	3.6313	5.1565	25.279	35.886	38.53751	7.1664
Winter	2009	13	0	1.073653	1.5435	2.1829	3.0958	4.062	5.5726	6.2199	6.381737	3.3446
Winter Overall	2002-2009	90	0	0.39629	1.4665	2.5178	4.0445	6.7168	20.754	48.476	79.08818	7.1099
Annual	2002	36	0	1.271306	1.7169	3.5732	5.3041	8.223	11.434	14.187	15.32047	5.926
Annual	2003	52	0	1.586445	1.8577	3.7477	6.3077	8.7627	15.577	20.705	23.47714	7.2054
Annual	2004	52	0	1.222934	1.7543	3.4472	5.386	7.4548	20.313	23.497	24.14906	7.0078
Annual	2005	52	0	0.815895	1.0964	2.622	5.6435	9.7064	20.811	38.722	44.69233	7.9854
Annual	2006	52	1	0	1.3877	3.2949	5.9502	10.553	25.712	79.965	80.87849	10.104
Annual	2007	52	1	0	1.1862	2.7645	5.5593	7.3906	13.046	25.479	37.00481	6.145
Annual	2008	53	0	0.989021	1.3746	2.9476	5.5286	7.4722	22.487	43.702	49.29656	7.4702
Annual	2009	25	0	1.131026	1.6033	3.3525	5.8052	10.549	18.013	18.47	18.47186	7.2759
Annual Overall	2002-2009	374	2	0	1.4301	3.1037	5.5712	8.7037	19.468	40.199	80.87849	7.4611

Monthly Operating Report (MOR) Statistics for: Union STP; 1PB00030 (permit #)

Monitoring Station 001; Reporting Code: 00665; Parameter Name: Phosphorus, Total (P) (mg/l)

Season	Year	# of Obs.	# Below Detection	Minimum	Percentiles 5th	25th	50th	75th	95th	99th	Maximum	Mean
Summer	2007	51	0	1.45	1.54	1.865	2	2.37	2.975	3.14	3.17	2.1202
Summer	2008	52	0	0.782	1.1985	1.5325	1.815	2.18	3.106	4.1366	4.31	1.9052
Summer	2009	13	0	0.84	0.96	1.19	1.34	1.45	1.714	1.7188	1.72	1.3369
Summer Overall	2006-2009	116	0	0.782	1.1825	1.615	1.91	2.18	2.9625	3.8965	4.31	1.9361
Winter	2007	12	0	0.855	0.91275	1.185	1.29	1.4875	1.731	1.8982	1.94	1.3238
Winter	2008	38	0	0.667	0.7295	0.95775	1.205	1.445	1.942	2.0226	2.03	1.2339
Winter	2009	38	0	0.675	0.8277	1.0325	1.2	1.42	2.313	3.1676	3.36	1.3391
Winter Overall	2006-2009	88	0	0.667	0.78095	1.0063	1.21	1.435	2.023	2.9076	3.36	1.2916
Annual	2006	9	0	1.22	1.228	1.36	1.47	1.47	1.874	2.0308	2.07	1.4756
Annual	2007	111	0	0.855	1.19	1.54	1.9	2.085	2.775	3.099	3.17	1.8721
Annual	2008	158	0	0.643	0.81005	1.095	1.63	1.93	2.282	3.6907	4.31	1.5745
Annual	2009	74	0	0.675	0.8379	1.09	1.325	1.4475	2.004	2.9804	3.36	1.357
Annual Overall	2006-2009	352	0	0.643	0.86755	1.21	1.6	1.9425	2.547	3.2631	4.31	1.6201

Monitoring Station 001; Reporting Code: 00665; Parameter Name: Phosphorus, Total (P) (kg/day)

Season	Year	# of Obs.	# Below Detection	Minimum	Percentiles 5th	25th	50th	75th	95th	99th	Maximum	Mean
Summer	2007	51	0	2.071341	3.057	3.3644	4.0727	4.853	5.9217	6.5291	7.074089	4.1602
Summer	2008	52	0	2.836328	3.2288	3.9964	4.7662	6.1664	9.9436	12.14	12.53319	5.4287
Summer	2009	13	0	3.003473	3.1985	3.5222	3.5864	4.1941	4.6278	5.0163	5.113384	3.7692
Summer Overall	2006-2009	116	0	2.071341	3.0558	3.5272	4.3169	5.1351	7.7797	11.538	12.53319	4.685
Winter	2007	12	0	3.255706	3.3149	3.9619	4.1216	4.7001	6.0292	6.0639	6.072578	4.3818
Winter	2008	38	0	2.188824	2.461	3.5773	4.4904	5.4972	6.7519	7.8383	8.303722	4.5577
Winter	2009	38	0	2.285444	2.6217	3.1902	3.5381	4.3114	6.1601	7.9215	8.520792	3.9101
Winter Overall	2006-2009	88	0	2.188824	2.5624	3.2583	4.0663	4.8383	6.5704	8.3319	8.520792	4.2541
Annual	2006	9	0	3.588748	3.6963	3.9727	4.0975	4.3537	5.6898	5.933	5.993775	4.3627
Annual	2007	111	0	2.031425	3.105	3.5183	4.3692	4.9706	6.5643	7.2334	7.623747	4.4298
Annual	2008	158	0	2.147458	2.7239	3.7323	4.3532	5.2742	7.8221	10.911	12.53319	4.7134
Annual	2009	74	0	2.285444	2.7015	3.3032	3.6057	4.2993	5.4961	7.3384	8.520792	3.92
Annual Overall	2006-2009	352	0	2.031425	2.8193	3.5214	4.1857	4.9697	7.0585	9.2582	12.53319	4.4482

Good # samples

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