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

Draft Report for Public Review
June 8, 2009

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Acknowledgments

This project is an update to the modeling analysis of the 2004 Stillwater River TMDL. The following Ohio EPA staff provided technical services for this report:

Biological Assessment - Bob Miltner
NPDES Permit Issues - Gary Stuhlfauth, Joseph Miller, Joseph Reynolds
Non-point Pollution Assessment - Hugh Trimble
Water Quality Modeling Support - Dale White

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.

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 will be 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 will be completed after the public comment period and included in an appendix to the final report.

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.

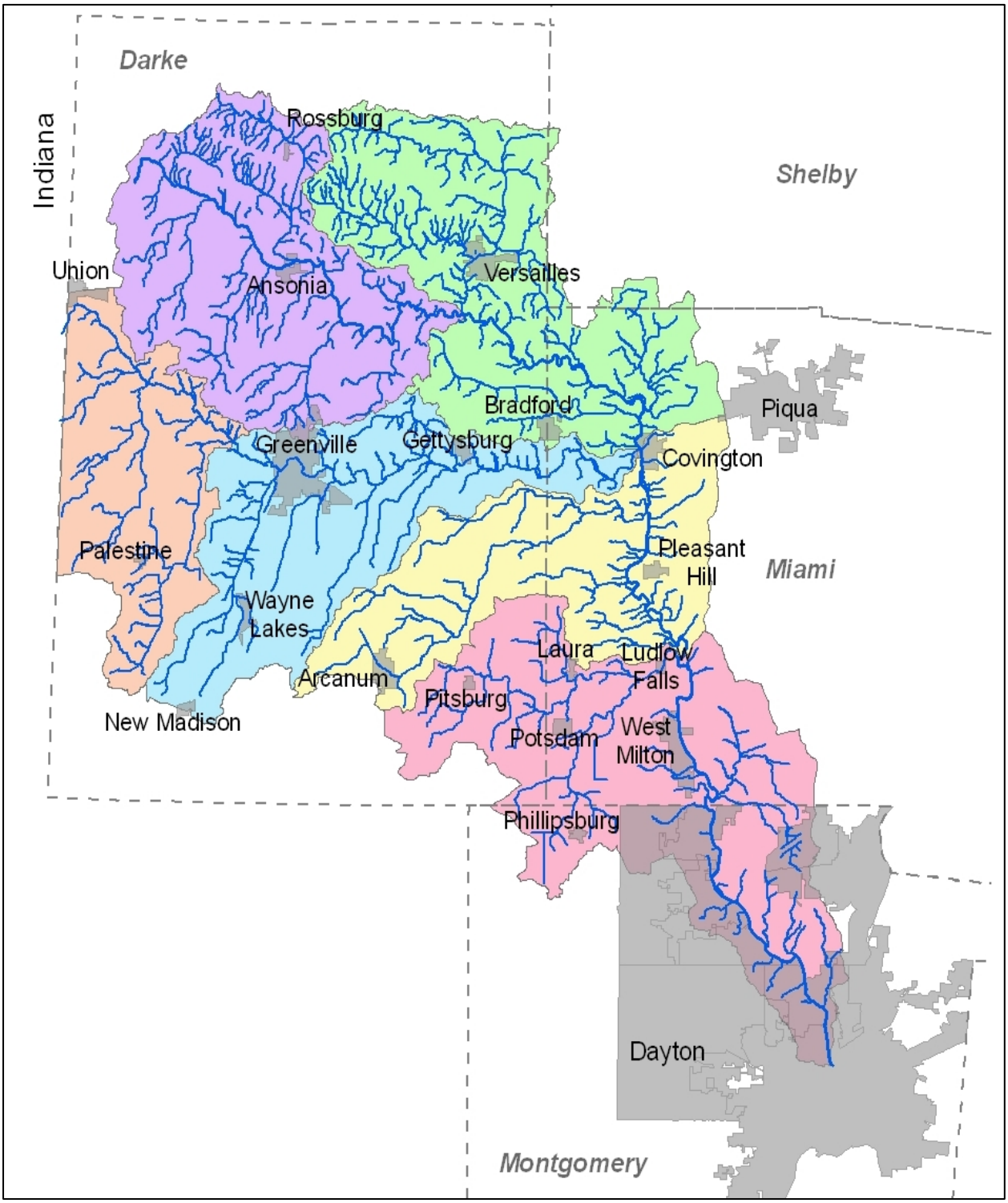


Figure 1.1. Stillwater River watershed in western Ohio.

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 Greenville 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.

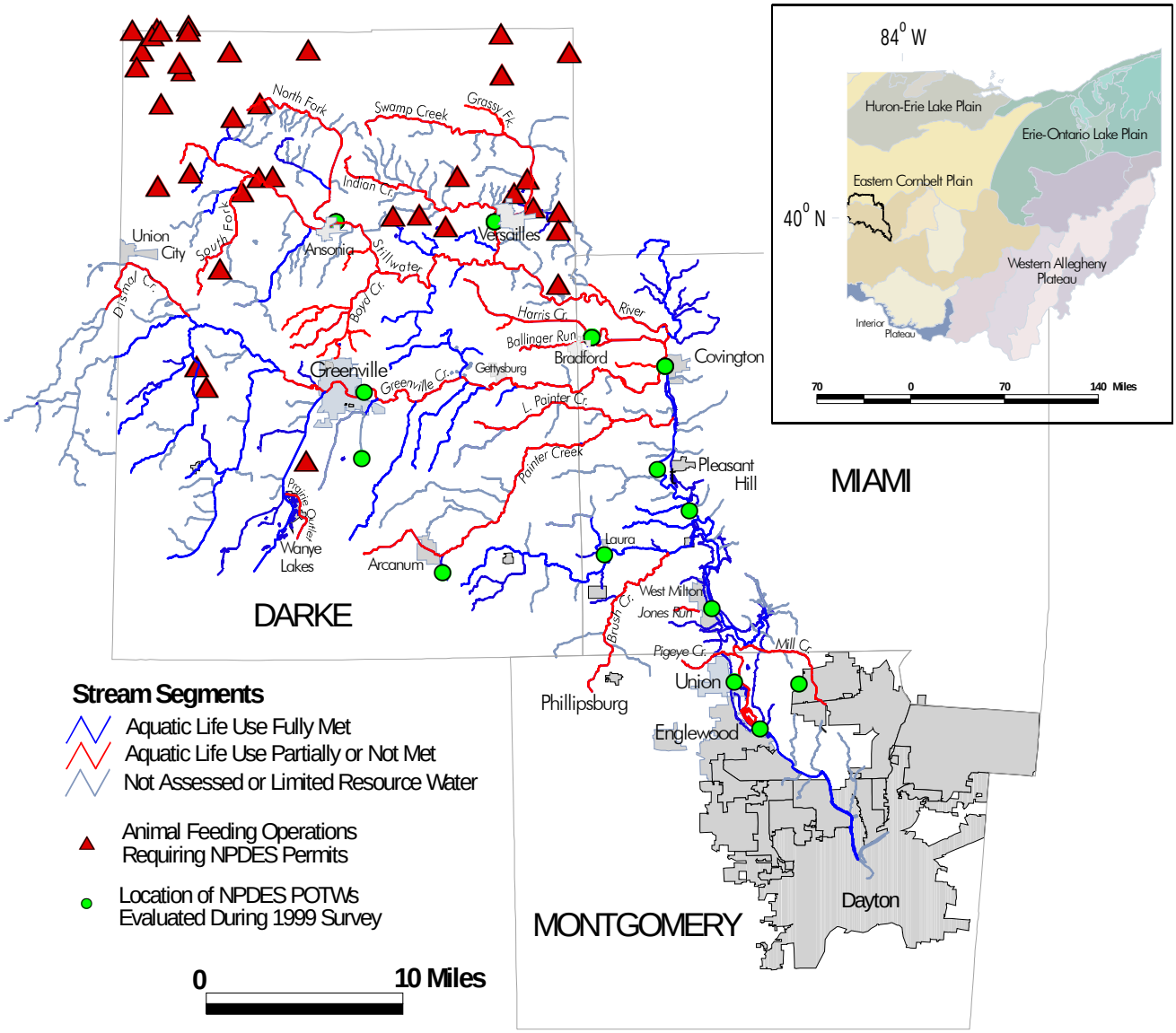


Figure 2.1 - Geographic location of the Stillwater River watershed in Ohio, principal cities within the watershed, and waterbody segments with impaired aquatic life uses in relation to NPDES permitted facilities

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*	7.8ns	32ns	43	Partial	Organic enrichment - CSOs			
58.1	38	9.0	-	47	Full				
57.9	37ns	8.3	MGns	48	Full				
57.0	-	-	34ns	-	(Full)				
			EWH /WWH Proposed						
54.4	43	7.8ns	-	44	NON/Full				
				EWH					
52.0/51.2	46ns	9.0ns	44ns	73	Full				
47.8	48	9.6	38*	74	Partial	Sedimentation and nutrient enrichment			
44.1	47	10.2	42ns	73	Full				
41.4	50	9.2ns	36*	75	Partial	Sedimentation and nutrient enrichment			
37.7	51	9.3ns	44ns	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	44ns	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	22[*]	NA	F[*]	47	NON	Toxics (deicers) - Dayton Airport
1.2	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	16[*]	NA	10[*]	32	NON	Organic enrichment - CSOs.
14.7	12[*]	NA	4[*]	28	NON	Toxics (NH_4) - CSOs & sewage lagoon
9.7/8.9	24	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	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	27	NA	28	33	Full	
6.5	17[*]	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	36ns	NA	F*	30	Partial	Hydromod, enrichment
1.3	-	-	F*	-	(NON)	Hydromod, enrichment
0.4	38ns	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	26	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 (≤4 IBI or ICI units, or ≤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.

Biocriteria

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.

Organic Enrichment

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.*, 90th 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 90th 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 90th 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[‡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 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 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 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.

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. 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.

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.

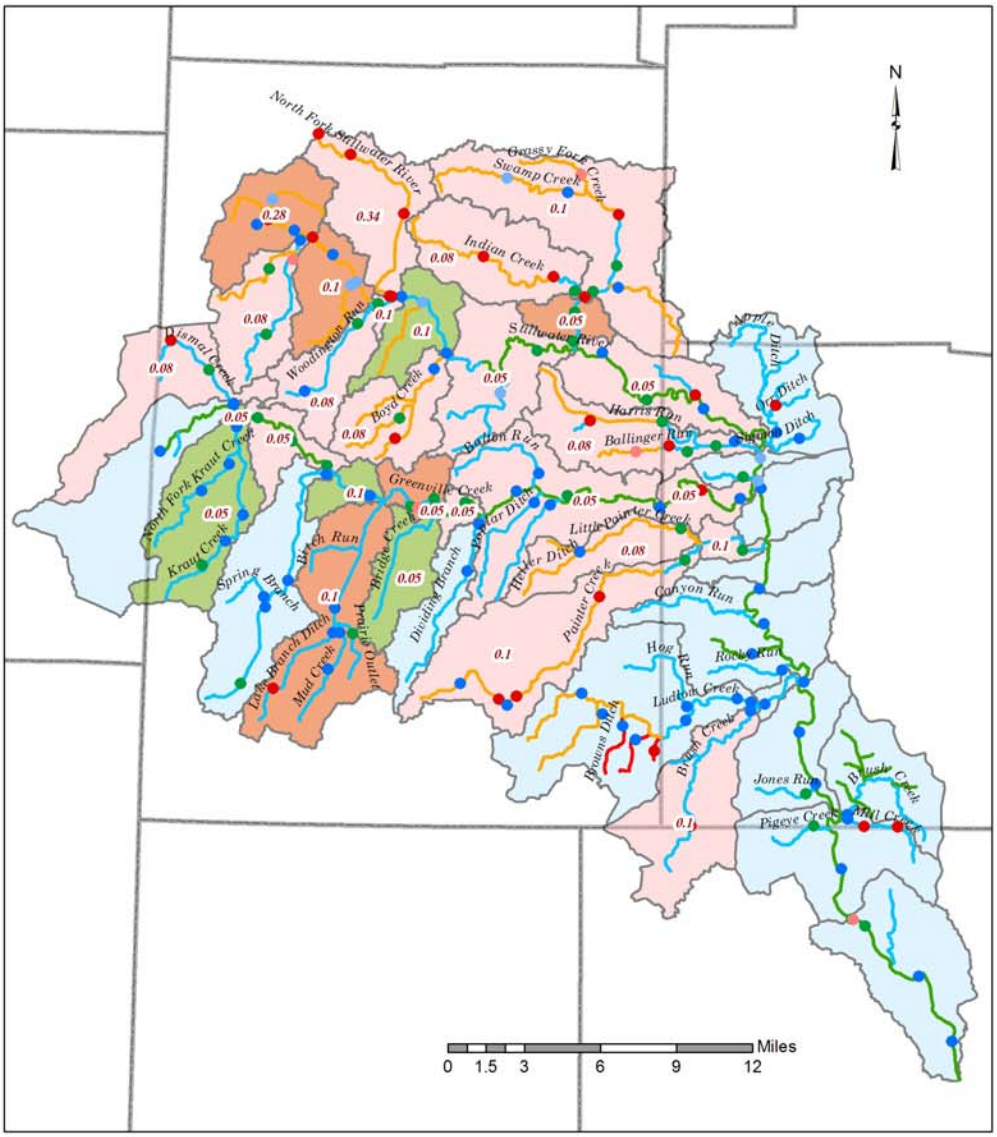
Figure 4.2 Map of Stillwater River watershed showing aquatic life use designation (by reach), aquatic life use attainment (by point location), and assignment of aquatic life use impairment (by 12-digit HUC). The numerical label for each HUC is the total phosphorus target (in mg-P/L) obtained from the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



ALU Designation	ALU Attainment	Impairment Assigned
EWH	full	not impaired
WWH	(full)	not impaired, but protecting DST use
MWH	partial	impaired, but protecting DST use
LRW	non	impaired
	(non)	Label (red): indicates total P target (mg/L)

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 4.10. 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 total phosphorus limit recommendations between 2004 and 2009 TMDLs. 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 total phosphorus limit recommendations between 2004 and 2009 TMDLs.
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.

References

Arnold, J.G. and Allen, P.M. 1999. Validation of automated methods for estimating baseflow and groundwater recharge from stream flow records. *Journal of the American Water Resources Association* 35:411–424.

Arnold, J.G., Srinivasan, R., Muttiah, R.S., and Williams, J.R. 1998. Large area hydrologic modeling and assessment. Part I: Model development. *Journal of the American Water Resources Association* 34(1):73-89.

Baydack, R.K., H. Campa, and J.B. Haufler. Eds. 1999. *Practical approaches to the conservation of biological diversity*. Island Press, Washington D.C.

Brown, L.C. 1994. Ohio's Hydrologic Cycle. Department of Agricultural Engineering, Ohio State University Extension. *AEX 461*.

DeShon J. E. 1995. Development and application of the Invertebrate Community Index (ICI). Biological Assessment and Criteria, Tools for Water Resource Planning. (Eds. W. S. Davis and T. P. Simon), 217-243. Lewis Publishers, Boca Raton, FL.

Fausch, D.O., J.R. Karr and P.R. Yant. 1984. Regional application of an index of biotic integrity based on stream fish communities. Trans. Amer. Fish. Soc. 113:39-55.

Karr, J.R. 1981. Assessment of biotic integrity using fish communities. Fisheries 6 (6): 21-27.

Leonard , P.M. and D.J. Orth. 1986. Application and testing of an Index of Biotic Integrity in small, cool water streams. Trans. Am. Fish. Soc. 115: 401-414.

MVRPC. 2003a. Livestock and Poultry Operation Inventory and Assessment for Darke County, Ohio. Miami River Valley Planning Commission.

___ 2003b. Livestock and Poultry Operation Inventory and Assessment for Miami County, Ohio. Miami River Valley Planning Commission.

Monteith, J.L. 1965. Evaporation and the environment. p. 205-234. *In* The state and movement of water in living organisms, XIXth Symposium. Society for Experimental Biology, Swansea, Cambridge University Press.

Moriasi, D.N., Arnold, J.G., Van Liew, M.W., Bingner, R.L., Harmel, R.D., and Veith, T.L. 2007. Model evaluation guidelines for systematic quantification of accuracy in watershed simulations. *Transactions of the ASABE* 50(3):885-900.

Newbold, J. D., Elwood, J. W., O'Neill, R. V., and A. L. Sheldon. 1983. Phosphorus dynamics in a woodland stream ecosystem: a study of nutrient spiraling. Ecology 64: 1249-1265.

Ohio EPA 1987a. Biological criteria for the protection of aquatic life: Volume I. The role of biological data in water quality assessment. Division of Water Quality Monitoring and Assessment, Surface Water Section, Columbus, Ohio.

___1987b. Biological criteria for the protection of aquatic life: Volume II. Users manual for biological field assessment of Ohio surface waters. Division of Water Quality Monitoring and Assessment, Surface Water Section, Columbus, Ohio.

___1988a. Ohio nonpoint source assessment. Division of Water Quality Monitoring and Assessment, Nonpoint Source Management Section Columbus, Ohio.

___1988b. Biological and Water Quality Study of the Little Scioto River Watershed - Marion County , Ohio. Division of Water Quality Monitoring and Assessment, Columbus, Ohio.

___1989a. Addendum to biological criteria for the protection of aquatic life: Users manual for biological field assessment of Ohio surface waters. Division of Water Quality Planning and Assessment, Surface Water Section, Columbus, Ohio.

___1989b. Biological criteria for the protection of aquatic life: Volume III. Standardized biological field sampling and laboratory methods for assessing fish and macroinvertebrate communities. Division of Water Quality Planning and Assessment, Columbus, Ohio.

___1989c. Ohio EPA manual of surveillance methods and quality assurance practices, updated edition. Division of Environmental Services, Columbus, Ohio.

___1990a. The use of biological criteria in the Ohio EPA surface water monitoring and assessment program. Division of Water Quality Planning & Assessment, Ecological Assessment Section, Columbus, Ohio.

___1993. State of Ohio Water Quality Standards. Chapter 3745-1 of the Ohio Administrative Code.

___1995. Justification and rationale for revisions to the dissolved oxygen criteria in the Ohio Water Quality Standards. Ohio EPA Technical Bulletin MAS/1995-12-5. Columbus, Ohio.

___1999. Associations between nutrients, habitat, and the aquatic biota in Ohio rivers and streams. Ohio EPA Technical Bulletin MAS/1999-1-1. Columbus, Ohio.

___2001. Biological and water quality study of the Stillwater River basin, 1999. Ohio EPA Biological and Water Quality Reports MAS/2001-12-8. Columbus, Ohio.

___2004. Total Maximum Daily Loads for the Stillwater River Watershed. Division of Surface Water, Columbus, Ohio. Available at http://www.epa.state.oh.us/dsw/tmdl/index.html

___2008. Ohio 2008 Integrated Water Quality Monitoring and Assessment Report. Ohio EPA. Columbus, Ohio. Available at http://www.epa.state.oh.us/dsw/tmdl/2008IntReport/2008OhioIntegratedReport.html

Priestley, C.H.B. and Taylor, R.J. 1972. On the assessment of surface heat flux and evaporation using large-scale parameters. *Monthly Weather Review* 100:81-92.

Rankin, E.T. 1989. The qualitative habitat evaluation index (QHEI): rationale, methods, and application. Division of Water Quality Planning and Assessment, Columbus, Ohio.

Rutledge, A.T. 1998. Computer programs for describing the recession of ground-water discharge and for estimating mean ground-water recharge and discharge from streamflow data. *US Geological Survey Water-Resources Investigations Report 98-4148*, 43 p.
Srinivasan, R., Ramanarayanan, T.S., Arnold, J.G., and Bednarz, S.T. 1998. Large area hydrologic modeling and assessment. Part II: Model application. *Journal of the American Water Resources Association* 34(1):91-101.

Thurston, R. V., R. C. Russo, and K. Emerson. 1979. Aqueous ammonia equilibrium - Tabulation of percent un-ionized ammonia. U.S. EPA Environmental Research Laboratory, Duluth, MN. EPA-600/3-79-091.

U.S. EPA. 2002. *Onsite Wastewater Treatment Systems Manual.* EPA/625/R-00/008. Office of Water and Office of Research and Development.

___ 1999. *Protocol for Developing Nutrient TMDLs*, EPA 841-B-99-007, p.5-8, Washington, D.C.

Van Liew, M.W., Veith, T.L., Bosch, D.D., and Arnold, J.G. 2007. Suitability of SWAT for the Conservation Effects Assessment Project: A comparison on USDA ARS watersheds. *Journal Hydrologic Engineering* 12(2):173-189.

Yoder, C. O. and M. A. Smith. 1999. Using fish assemblages in a state biological assessment and criteria program: Essential concepts and considerations. Assessing the Sustainability and Biological Integrity of Water Resources Using Fish Communities. (Ed. T. P. Simon), 17-56. CRC Press, NY.

Yoder, C.O. and E.T. Rankin. 1998. The role of biological indicators in a state water quality management process. Journal of Environmental Monitoring and Assessment, 51(1-2): 61-88.

Yoder C. O. and E.T. Rankin. 1995. Biological criteria program development and implementation in Ohio. Biological Assessment and Criteria, Tools for Water Resource Planning. (Eds. W. S. Davis and T. P. Simon), pp. 109-144. Lewis Publishers, Boca Raton, FL.