Woolper Creek Watershed Plan

Prepared for

Woolper Creek Watershed Initiative

October 2016

Table of Contents

Appendices

Chapter 2 Appendix:

Chapter 3 Appendices:

Chapter 4 Appendices:

Chapter 5 Appendices:

Chapter 6 Appendices:

CHAPTER 1

Getting Started

Woolper Creek Watershed Plan

Prepared by the

Woolper Creek Watershed Initiative

October 2016

Chapter 1: Getting Started

The Woolper Creek Watershed Initiative (WCWI) was developed to spearhead the development of this Plan and begin to work towards conservation efforts and improved stream conditions throughout the Woolper Creek Watershed. This chapter provides a brief overview of the Woolper Creek Watershed, the issues it faces, and the community-led initiative that has been formed to address its future.

1.1 The Watershed

Threats to the streams throughout the Woolper Creek Watershed are growing at a rapid pace.

The 33-square mile Woolper Creek Watershed is located in Boone County, which is Kentucky's second fastest growing county and one of the top 100 in the nation (U.S. Census, 2009). This watershed is a priority within Boone County because threats to the Woolper Creek are growing at a rapid pace. With continued growth and urbanization comes additional impervious surfaces, and such increases in impervious surfaces, if not properly managed, have an unmistakable effect on the quality of streams. By decreasing infiltration and increasing direct runoff, impervious cover can create larger peak flows, less groundwater recharge, and increased flashiness, especially if stormwater is routed directly to streams (Sauer *et al.*, 1983; Konrad and Booth, 2002; Poff *et al.*, 2006). Such changes in flow, referred to as hydromodification, broadly associated with urbanization, can have profound effects on biologic and geomorphic processes, including channel instability (Booth, 1990; Simon and Downs, 1995; Trimble, 1997; Bledsoe and Watson, 2001; Chin and Gregory, 2001; Chin, 2006). Hydromodification is evident throughout the Northern Kentucky region, as streams have become unstable due to inadequately managed stormwater runoff causing an erosive flow regime. Northern Kentucky streams in developed watersheds are becoming larger and their bed material is becoming coarser (Hawley *et al.*, 2013). Such alterations in flow and sediment mobility can affect aquatic life cycles, habitats, and food webs, and facilitate colonization by invasive species, among other types of degradation (Waters, 1995; Paul and Meyer, 2001; Booth *et al.*, 2004; Poff *et al.*, 2006).

Figure 1-1: The impacts of hydromodification in the Allen Fork Subwatershed are illustrated by the eroding streambank

The impacts of hydromodification are clearly evident in the Woolper Creek Watershed (**Figure 1-1**). The two most impaired stream segments according to the 303(d) nonsupport list lie in the most developed portions of the watershed (i.e., Woolper Creek miles 11.9 to 14.0 and Allen Fork miles 2.0 to 4.6). These stream segments are listed as impaired for several types of pollutants, such as bacteria, nutrients, and sediment, and the primary source is suspected to be unspecified urban runoff. A third stream segment (Woolper Creek miles 2.8 to 7.2) is listed for only one pollutant (fecal coliform) with a suspected source of agriculture (KDOW, 2008).

Despite the challenges facing the Woolper Creek Watershed, we find ourselves at a critical juncture with reason to hope. Favorable factors in the watershed include that the dominant land use is currently forest and that much of the forest is projected to remain undisturbed through 2030 as future development is anticipated to target predominantly pasture land (LimnoTech, 2009). Additionally, KDOW has identified one of the least developed subwatersheds in the basin, Double Lick Creek (**Figure 1-2**), as a reference reach stream (401 KAR 10:030) and as an outstanding state resource water (401 KAR 10:026).

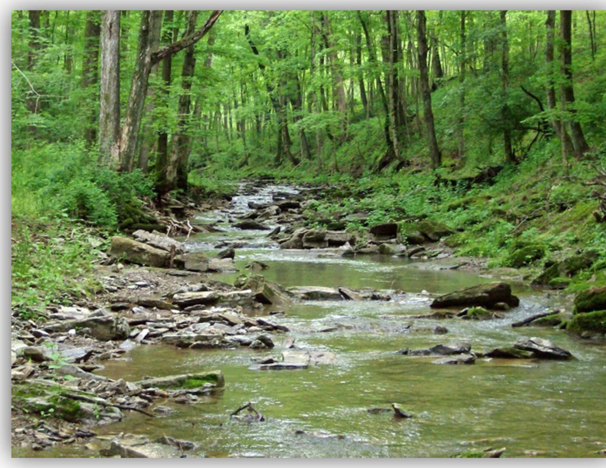


Figure 1-2: Double Lick Subwatershed is considered an outstanding state resource water

The scale of the problems, despite seeming quite large, pale in comparison to the amount of energy, stewardship and capital that has been and continues to be invested by our expansive array of stakeholders. Project partners understand the problem and want solutions. Given the results of this Plan, regional agencies will have the necessary tools to reduce the risks of hydromodification on future development, as well as guidance on how best to arrest existing instabilities, putting the Woolper Creek Watershed on a clear path toward restored stream health. The Woolper Creek Watershed is at a critical crossroads - effective planning and implementation of strategies and best management practices (BMPs) are needed in the immediate future to both protect and restore this area.

1.2 Partners and Stakeholders

Collaboration among partners who are committed to developing a comprehensive watershed plan and dedicated to making a difference in the Woolper Creek Watershed is imperative for successful watershed planning. The WCWI is a collaborative effort guided by a steering committee of local agencies which has a responsibility to the community to protect natural resources. Additionally, the WCWI has engaged the local community to educate and learn from the public, and garner support for implementing this watershed plan and working towards restored and protected streams throughout the Woolper Creek Watershed. Concerned citizens have showed interest in this watershed plan and have been invaluable in identifying issues throughout the watershed.

Collaboration with vested partners and stakeholders as well as the local community builds the foundation for a successful watershed plan.

The key project partners that are involved with the implementation of the 319(h) grant, along with their contact information, are as follows:

Agency Name: Boone County Conservation District
Agency Address: 6028 Camp Ernst Rd., Burlington, KY 41005
Role/Contribution to Project: Project Steering Committee, Project Management
Contact Person: Mark Jacobs
Phone No. 859-586-7903
E-mail address: markjacobs@nkcd.org

Agency Name: Northern Kentucky Health Department
Agency Address: 610 Medical Village Dr., Edgewood, KY 41017
Role/Contribution to Project: Project Steering Committee
Contact Person: Steve Divine
Phone No. 859-363-2023
E-mail address: steve.divine@nkyhealth.org

Agency Name: Sanitation District No. 1
Agency Address: 1045 Eaton Dr., Fort Wright, KY 41017
Role/Contribution to Project: Monitoring, Data, Education, Project Steering Committee
Contact Person: Matt Wooten
Phone No. 859-578-6882
E-mail address: mwooten@sd1.org

Agency Name: Northern Kentucky University Center for Environmental Restoration
Agency Address: Northern Kentucky University, 510 Johns Hill Rd., Highland Heights, KY 41076
Role/Contribution to Project: Project Steering Committee, Project Match
Contact Person: Scott Fennell
Phone No. 859-448-8953
E-mail address: fennells@nku.edu

Agency Name: Boone County Fiscal Court
Agency Address: 2950 Washington St., Burlington, KY 41005
Role/Contribution to Project: Project Steering Committee
Contact Person: Scott Pennington
Phone No. 859-334-2242
E-mail address: spennington@boonecountyky.org

Agency Name: Kentucky Transportation Cabinet
Agency Address: 421 Buttermilk Pike, Covington, KY 41017
Agency Mailing Address: PO Box 17130, Covington, KY 41017
Role/Contribution to Project: Project Steering Committee, Public Outreach
Contact Person: Stacee Hans
Phone No. 859-341-2700
E-mail address: stacee.hans@ky.gov

Agency Name: Kenton County Airport Board
Agency Address: PO Box 752000, Cincinnati, OH 45275
Role/Contribution to Project: Project Steering Committee
Contact Person: Donald Chapman
Phone No. 859-767-7884
E-mail address: DChapman@cvgairport.com

Agency Name: Boone County Planning Commission
Agency Address: 2950 Washington St., Room 317, Burlington, KY 41005
Agency Mailing Address: PO Box 958, Burlington, KY 41005
Role/Contribution to Project: Project Steering Committee, Mapping and Plan Development
Contact Person: Kevin Costello, Executive Director
Phone No. 859-334-2196
E-mail address: kcostello@boonecountyky.org

Agency Name: Northern Kentucky Area Development District
Agency Address: 22 Spiral Dr., Florence, KY 41042
Role/Contribution to Project: Project Steering Committee & Reporting
Contact Person: Sara Jo Shipley
Phone No. 859-283-1885
E-mail address: sarajo.shipley@nkadd.org

Agency Name: Kentucky Division of Water
Agency Address: 200 Fair Oaks Ln., Frankfort, KY 40601
Role/Contribution to Project: Project Steering Committee
Contact Person: Alyson Jinks
Phone No. 502-782-6988
E-mail address: alyson.jinks@ky.gov

Agency Name: Kentucky Division of Water
Agency Address: 200 Fair Oaks Ln., Frankfort, KY 40601
Role/Contribution to Project: Project Steering Committee
Contact Person: Chad Von Gruenigen
Phone No. 502-564-3410
E-mail address: Chad.VonGruenigen@ky.gov

References

Bledsoe, B.P. and Watson, C.C., 2001. Effects of urbanization on channel instability. Journal of the American Water Resources Association, 37(2): 255-270.

Booth, D.B., 1990. Stream-channel incision following drainage-basin urbanization. Water Resources Bulletin, 26(3): 407-417.

Booth, D.B., Karr, J.R., Schauman, S., Konrad, C.P., Morley, S.A., Larson, M.G., Burges, S.J., 2004. Reviving urban streams: land use, hydrology, biology, and human behavior. Journal of the American Water Resources Association 40 (5), 1351–1364

Chin, A., 2006. Urban transformation of river landscapes in a global context. Geomorphology 79 (3–4), 460–487.

Chin, A. and Gregory, K.J., 2001. Urbanization and adjustment of ephemeral stream channels. Annals of the Association of American Geographers, 91(4): 595-608.

Hawley, R.J., MacMannis, K.R. and Wooten, M.S., 2013. Bed coarsening, riffle shortening, and channel enlargement in urbanizing watersheds, northern Kentucky, U.S.A. Geomorphology, 201: 111-126.

KDOW, 2008. Final 2008 Integrated Report to Congress on the Condition of Water Resources in Kentucky. Volume II. 303(d) List of Surfaces Waters, Kentucky Energy and Environment Cabinet, Department for Environmental Protection, Division of Water, Frankfort, KY.

Konrad, C.P. and Booth, D.B., 2002. Hydrologic trends associated with urban development for selected streams in the Puget Sound Basin, Western Washington. Water-Resources Investigations Report 02-4040. U.S. Geological Survey, Tacoma, Washington.

LimnoTech, 2009. Woolper Creek Watershed Characterization Report. Prepared for Sanitation District No. 1 of Northern Kentucky, Fort Wright, KY.

Paul, M.J., and Meyer, J.L., 2001. Streams in the urban landscape. Annual Review of Ecology and Systematics 32:333–365.

Poff, N.L., Bledsoe, B.P., and Cuhaciyan, C.O., 2006. Hydrologic variation with land use across the contiguous United States: geomorphic and ecological consequences for stream ecosystems. Geomorphology 79 (3–4), 264–285.

Sauer V.B., Thomas Jr W.O., Stricker V.A., Wilson K.V., 1983. Flood characteristics of urban watersheds in the United States. U. S. Geological Survey Water-Supply Paper 2207.

Simon, A. and Downs, P.W., 1995. An interdisciplinary approach to evaluation of potential instability in alluvial channels. Geomorphology 12, 215–232.

Trimble, S.W., 1997. Contribution of stream channel erosion to sediment yield from an urbanizing watershed. Science 278, 1442–1444.

U.S. Census, 2009. Housing Unit Estimates for the 100 Fastest Growing Counties with 5,000 or More Housing Units in 2008: April 1, 2000 to July 1, 2008. U.S. Census Bureau, Population Division. http://www.census.gov/popest/housing/HU-EST2008-top100.html.

Waters, T.F., 1995. Sediment in streams – sources, biological effects, and control. American Fisheries Society. Monograph 7, 251.

CHAPTER 2

Exploring the Woolper Creek Watershed

Woolper Creek Watershed Plan

Prepared by the

Woolper Creek Watershed Initiative

October 2016

Chapter 2: Exploring the Woolper Creek Watershed

This chapter will discuss background information on the Woolper Creek Watershed, including water resources, natural features, vegetation, animal abundance, human influences, and demographics. The Woolper Creek and its tributaries (i.e., Allen Fork, Double Lick, and Ashby's Fork), drain 33 square miles to the Ohio River, are located within Boone County, Kentucky, and are the waterways of concern for this Watershed Plan. Much of the information presented is from the *Woolper Creek Watershed Characterization Report* (LimnoTech, 2009). GIS data was provided by Boone County Planning Commission and the Kentucky Geography Network.

Overall the watershed can be characterized as largely forested with substantial amounts of development occurring in the headwaters. Impairments in the watershed include fecal coliform, organic enrichment, nutrients/eutrophication, and total suspended solids. Much of these impairments can be explained by the development in the watershed, which adds unfiltered stormwater runoff to waterways and increases rates of stream erosion.

Interesting geology found within the watershed dates back to when glaciers receded from the area, leaving deposits of limestone and granite. Native Americans occupied the Woolper Creek Watershed prior to European settlement, which began in the mid-1700s. From there, Boone County's population remained fairly consistent until about 1950, when development began to accelerate. Many of the findings presented below including land use, water use, and plants and vegetation have been, and will continue to be, impacted by the development of the watershed unless development practices are better designed to be protective of natural resources.

2.1 Watershed Inventory and Water Resources

2.1.1 Watershed Boundary

The Woolper Creek Watershed (HUC 050902030801) is located entirely within Boone County, Kentucky, totals 33 square miles, and is comprised of six subwatersheds (**Figure 2-1**). The watershed is in the western part of the county, which is less developed than other parts of the county, such as the Interstate 75/71 corridor. Although there are no city boundaries within the watershed, there are two census-designated places located there: Burlington, which is the county seat, and Hebron. The headwaters of Woolper Creek start west of the Cincinnati/Northern Kentucky International Airport (CVG) near Hebron, and proceed west approximately 13.9 miles until its confluence with the Ohio River. Approximate bounds of the watershed include Interstate 275 to the north and North Bend Road (KY-237) to the east. To the south, no one road serves as the boundary, but Burlington Pike (KY-18), East Bend Road (KY-338), Rogers Lane, and Botts Lane approximate the bounds. The western edge of the watershed is the Ohio River.

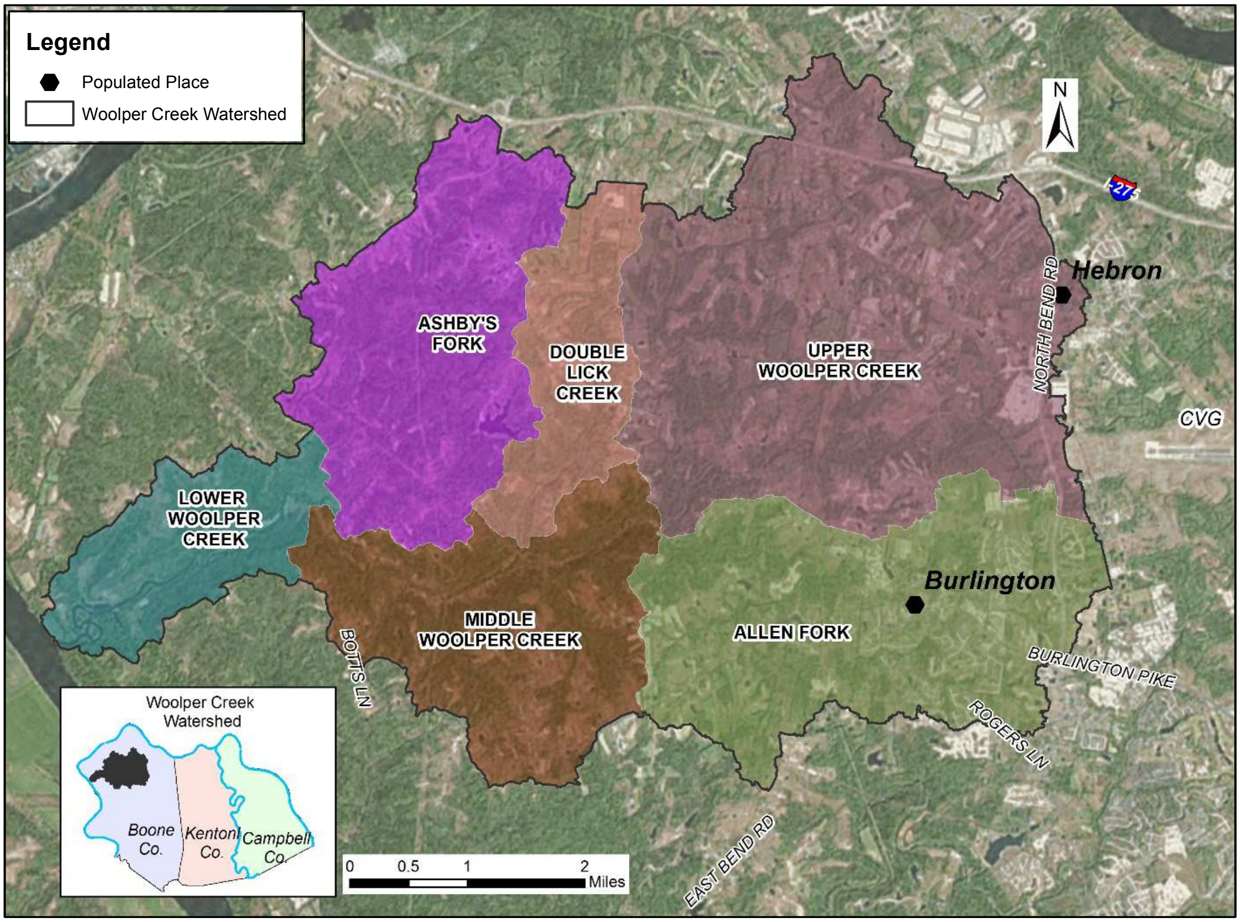


Figure 2-1: Woolper Creek Watershed with census-designated places, unincorporated communities, and boundary roads

2.1.2 Hydrology

Aside from the Upper, Middle, and Lower Woolper Creek Subwatersheds, there are three named tributaries: Allen Fork, Ashby's Fork, and Double Lick Creek. The Allen Fork Subwatershed is in the southeast portion of the watershed and is highly developed. Ashby's Fork and Double Lick Creek Subwatersheds are in the middle of the watershed, are comprised of mostly undeveloped and rural lands, and drain from the north. There is a total of 144.7 miles of blue line streams in the Woolper Creek Watershed.

There is one USGS gage within Woolper Creek, titled USGS 03262001 Woolper Creek at Woolper Road near Burlington, KY. The gage is actually located in the Middle Woolper Creek Subwatershed at river mile 4.8. Data collection began in December 2000 at this gage, which monitors the flow from 24.2 square miles, or 77%, of the watershed. Based on the Water Data Report by USGS (2013), the annual mean flow between Water Years 2002 and 2013 was 36.6 cubic feet per second (cfs), or 16,430 gallons per minute (gpm). Ten percent of the recorded flows at this site have been less than 0.21 cfs (about 95 gpm), whereas ten percent of the recorded flows have been greater than 67 cfs (30,100 gpm). The maximum peak flow recorded was 6,640 cfs on July 18, 2001, which is nearly three million gallons per minute. On average, March has the highest average flows (59.3 cfs), with May closely following (54.2 cfs). November and October, with 2.05 cfs and 2.97 cfs respectively, have the lowest average flows.

Kentucky's Bluegrass Region is trending upward for both rainfall and temperatures, with July as the hottest month.

Based on data from Burlington, Kentucky, July is the hottest month, with an average high of 86°F; January is the coldest month with an average high of 39°F. May is the wettest month, with nearly 5 inches of average rainfall, and approximately 42.6 inches of rain is averaged per year (TWC, 2014). According to the Kentucky Climate Center, both rainfall and temperatures have been trending upward in the Bluegrass Region since the 1960s.

Based on data provided by the National Wetlands Inventory, there is a total of 245 acres of wetland within Woolper Creek (**Figure 2-2**). The majority of this wetland area, or 175 acres, is considered freshwater pond. The remaining 70 acres is comprised of freshwater forested/shrub wetlands, freshwater emergent wetlands, and riverine areas; see **Table 2-1** for details. The largest lake in the watershed is Schneider Lake, which is in the Ashby's Fork Subwatershed. Additionally, the Northern Kentucky Stream and Wetland Restoration Program (NKSWRP) created 0.2 acres of stormwater wetlands as part of a stream restoration project in the headwaters of the Allen Fork Subwatershed.

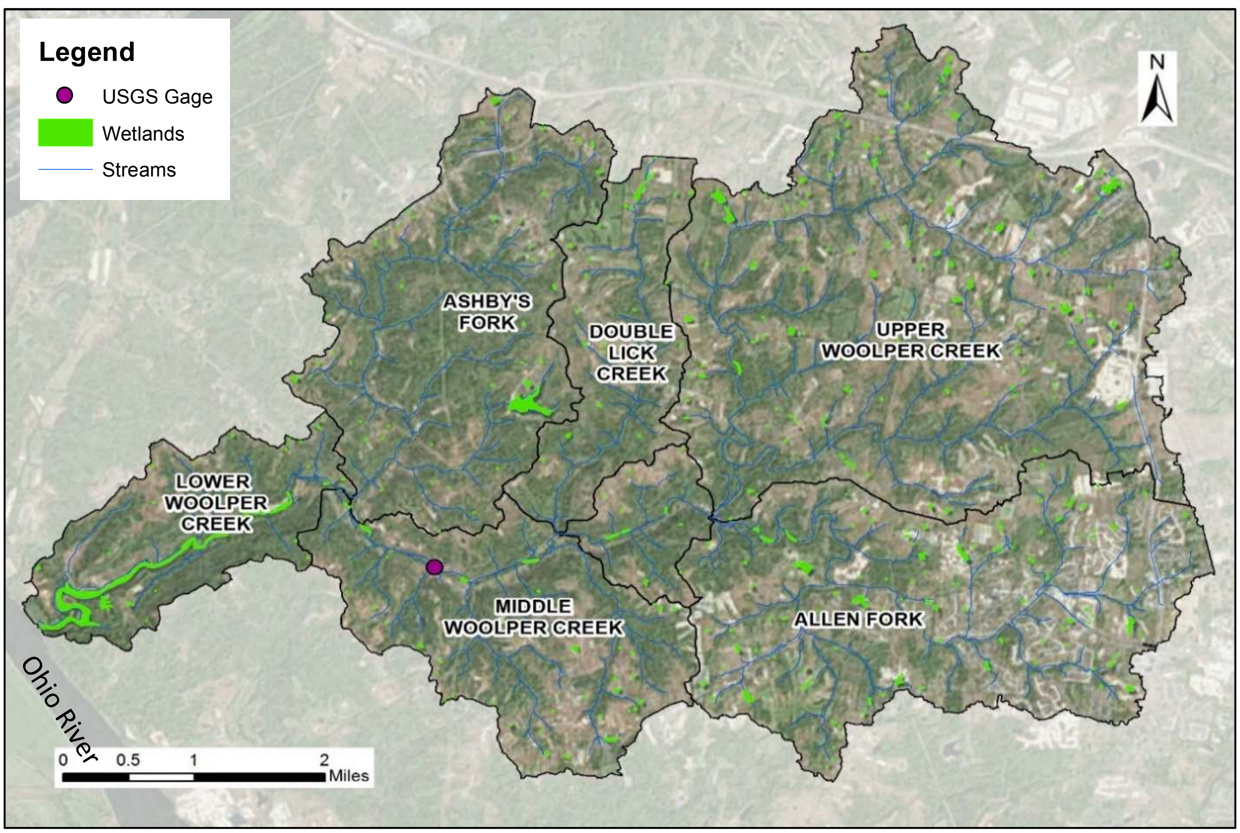


Figure 2-2: Woolper Creek Watershed hydrology

Table 2-1: Summary of wetlands by subwatershed

Subwatershed	Freshwater Emergent Wetland	Freshwater Forested/Shrub Wetland	Freshwater Pond	Riverine	Total
Allen Fork	1.3	3.3	48.6	0.0	53.3
Ashby's Fork	0.6	0.0	28.7	0.0	29.3
Double Lick Creek	0.0	0.0	9.7	0.0	9.7
Lower Woolper Creek	0.0	8.1	7.1	47.9	63.2
Middle Woolper Creek	0.2	5.5	14.0	0.4	20.0
Upper Woolper Creek	0.9	1.7	67.4	0.0	70.0
TOTAL (acres)	3.0	18.6	175.5	48.3	245.4

2.1.3 Groundwater – Surface Water Interaction

Groundwater yields in Woolper Creek can be estimated by the Bull Fork, Grant Lake Limestone/Fairview, and Kope Formations that are found within it. All three formations can yield between 100 and 500 gallons per day (gpd) to wells in valleys or on broad ridges and valley bottoms. The Grant Lake Limestone/Fairview Formation may yield greater than 500 gpd, dependent on the location (Carey and Stickney, 2004). Within Boone County, the boundary between fresh and saline water ranges from less than 400 feet above sea level along the Ohio River to 700 feet in the highlands of the county. Generally, salt water is found at depths greater than 100 feet below the level of the principal valley bottoms. High shale percentages, resulting in few karst features, in the Outer Bluegrass rocks indicate a low to moderate sensitivity to groundwater contamination in the Woolper Creek Watershed (Ray *et al*., 1994).

There is potential within the Woolper Creek Watershed for karst geology, although the presence of shale makes that unlikely.

There are no Kentucky Division of Water (KDOW) wellhead protection areas in the watershed; a total of six sinkhole areas are located within the watershed, along with one spring. The hydrogeologic sensitivity in the watershed ranges from low to moderate (**Figure 2-3**). This rating accounts for three primary hydrologic components: recharge, flow, and dispersion. Areas with lower sensitivity are less likely to have sinkholes and other depressions, use diffuse flow, and have only localized dispersion.

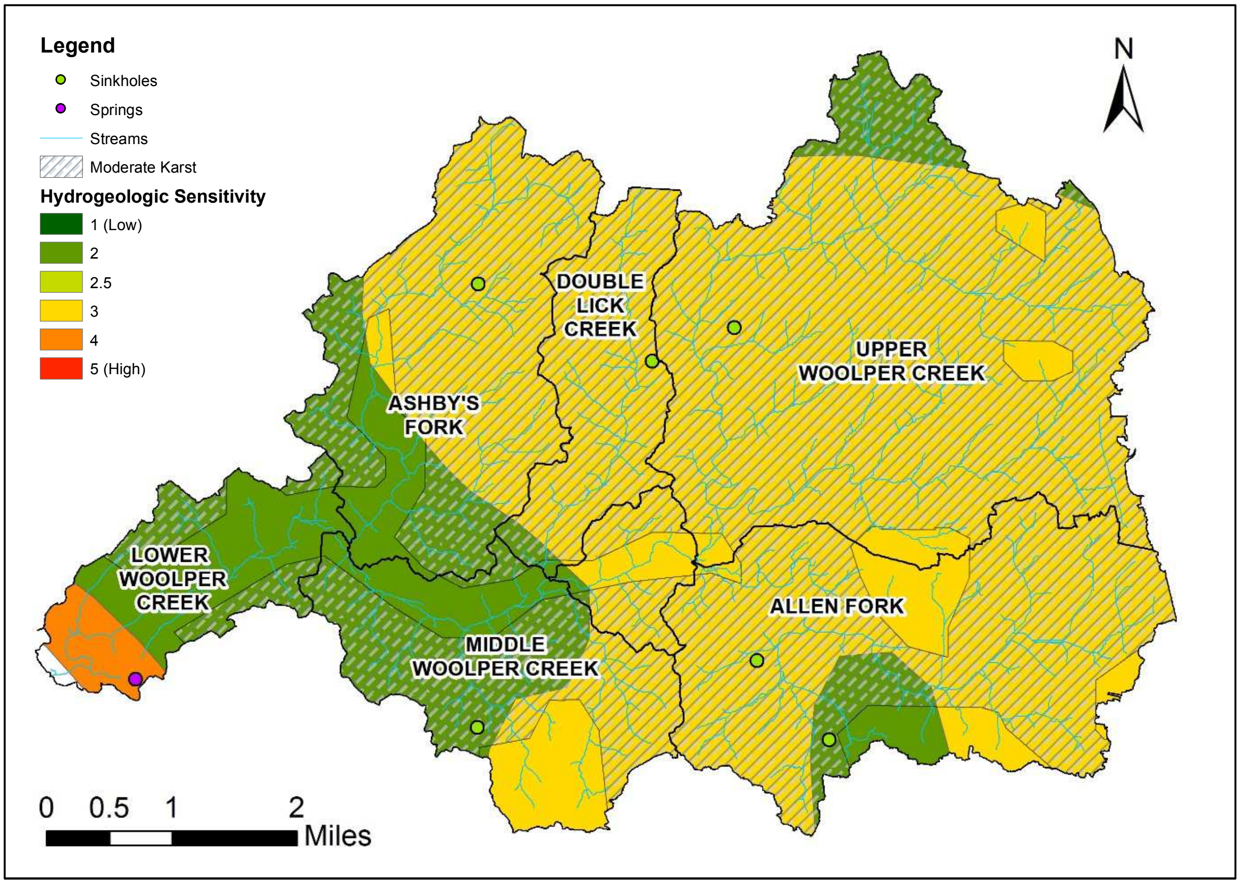


Figure 2-3: Woolper Creek Watershed karst areas and sink holes

2.1.4 Flooding

Based on Federal Emergency Management Agency (FEMA) mapping, the 100-year floodplain extends mainly through Lower and Middle Woolper Creek, and then continues through the Allen Fork Subwatershed (**Figure 2-4**). This area encompasses nearly 565 acres. The 500-year floodplain increases in size only in the Lower Woolper Creek Subwatershed, adding approximately 28 acres to the 100-year flood zone. **Table 2-2** provides a summary by subwatershed.

Table 2-2: Woolper Creek Watershed flood zones by subwatershed

Subwatershed	100-year floodplain		500-year floodplain	
	Total Acres	Percentage	Total Acres	Percentage
Allen Fork	109.4	2%	109.4	2%
Ashby's Fork	7.3	0.2%	7.3	0.2%
Double Lick Creek	0.0	0.0%	0.0	0.0%
Lower Woolper Creek	313.6	20%	341.6	22%
Middle Woolper Creek	132.7	4%	132.7	4%
Upper Woolper Creek	2.4	0.03%	2.4	0.03%
TOTAL	565.4	3%	593.4	3%

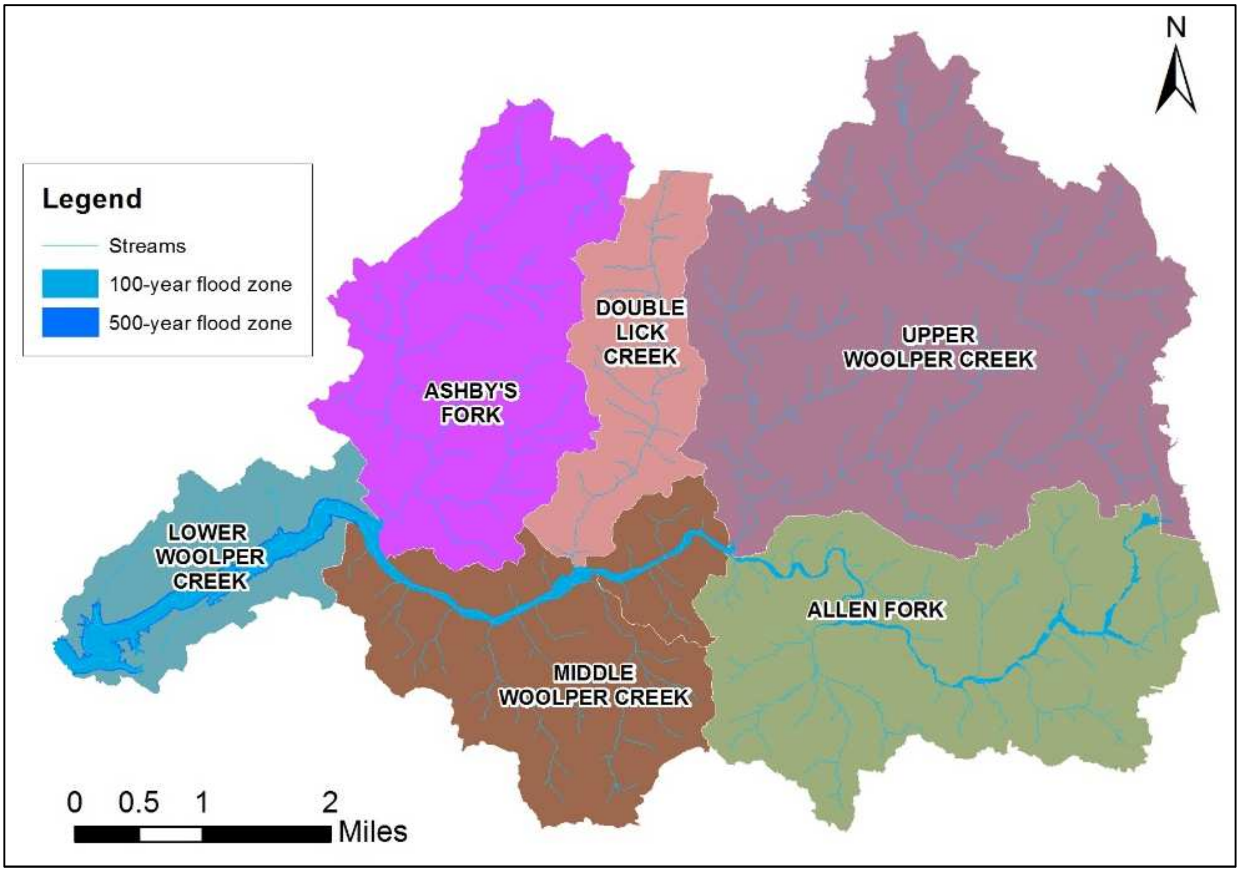


Figure 2-4: Woolper Creek Watershed flood zones

Known flooding issues exist in the Allen Fork and Upper Woolper Creek Subwatersheds (**Figure 2-5**). Recent projects to mitigate this flooding have been discussed by regional agencies, such as the Sanitation District of Northern Kentucky (SD1). This information is discussed in further detail in Chapters 5 and 6.

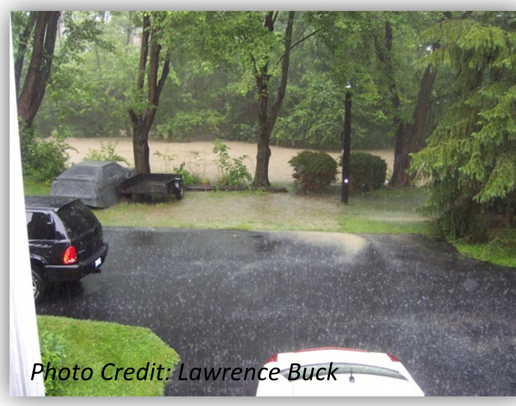


Figure 2-5: Flooding in the Allen Fork Subwatershed after a 2-year storm event

2.1.5 Regulatory Status of Waterways

Every two years, the Clean Water Act requires KDOW to submit a document to Congress regarding the condition of the waterways. This report includes details about the designated uses of waterways throughout Kentucky, information on what designated uses are impaired, potential pollutants of concern, possible sources of pollutants, and details relating to Total Maximum Daily Loads (TMDLs), which is one of the regulatory tools used to mitigate impaired waters. Woolper Creek, along with its tributaries, has been designated by KDOW for warm water aquatic habitat (WAH), primary contact recreation (PCR), secondary contact recreation (SCR), domestic water supply (DWS), and fish consumption (FC) at applicable points of withdrawal (401 KAR 10:026). These uses are defined below.

- **Warm water aquatic habitat** means any surface water and associated substrate capable of supporting indigenous warm water aquatic life.
- **Primary contact recreation** waters means those waters suitable for full body contact recreation during the recreation season of May 1 through October 31.
- **Secondary contact recreation** waters means those waters that are suitable for partial body contact recreation, with minimal threat to public health due to water quality.
- **Domestic water supply** means surface waters that with conventional domestic water supply treatment are suitable for human consumption through a public water system as defined in 401 KAR 8:010, culinary purposes, or for use in any food or beverage processing industry; and meet state and federal regulations under the Safe Drinking Water Act, as amended, 42 U.S.C. 300f – 300j. There are no wellhead protection zones identified in the watershed.
- **Fish consumption** means protecting human health regarding fish consumption. This is not a designated use in Kentucky water quality standards but the use is implied in 401 KAR 10:031 Section 2 and through the human health criteria in Section 6.

In addition to the designations above, KDOW has also listed Double Lick Creek as an outstanding state resource water (401 KAR 10:026) and reference reach stream (401 KAR 10:030). These designations are defined below.

- **Outstanding state resource waters** means a surface water categorized by the cabinet as an outstanding state resource water pursuant to 401 KAR 10:001.
- **Reference reach waters** are a representative subpopulation of the least-impacted streams within a bioregion. These streams serve as chemical, physical and biological models from which to determine the degree of impairment (physical, chemical or biological) to similar stream systems in each representative bioregion. These are not necessarily pristine streams, but represent those least-disturbed conditions that are attainable in each bioregion.

Sediment, bacteria, and nutrients have been identified as impairments to sections of Woolper Creek and its tributaries.

Specific sections of Woolper Creek, along with the Allen Fork tributary, have been classified on the Kentucky 303(d) List of Impaired Waters for biological indicators of nutrients/eutrophication, meaning that fair biology was identified in these reaches and is a result of high nutrient levels and excessive algae, which violates the narrative water quality criteria in Kentucky. Additionally, reaches are listed as impaired for high levels of fecal coliform (i.e. bacteria) and total suspended solids. **Table 2-2** lists each impaired section, the pollutants of concern, and suspected sources, as specified in the Kentucky 303(d) List of Impaired Waters (KDOW, 2012). These areas can be found in **Figure 2-5** as well.

Table 2-3: Stream Sections in the Woolper Creek Watershed on the 2012 Kentucky 303(d) List of Impaired Waters

STREAM NAME	RIVER MILES	POLLUTANT	CATEGORY	USE	SUSPECTED SOURCE(S)
Woolper Creek into Ohio River	2.8 to 7.45	Fecal Coliform	Non - Supporting	PCR	Agriculture
Woolper Creek into Ohio River	11.9 to 14.0	Fecal Coliform	Non - Supporting	PCR	Illegal Dumps or Other Inappropriate Waste Disposal; Urban Runoff/Storm Sewers
Woolper Creek into Ohio River	11.9 to 14.0	Cause Unknown	Non - Supporting	WAH	Illegal Dumps or Other Inappropriate Waste Disposal; Urban Runoff/Storm Sewers
Woolper Creek into Ohio River	11.9 to 14.0	Nutrient/Eutrophication Biological Indicators	Non - Supporting	WAH	Illegal Dumps or Other Inappropriate Waste Disposal
Woolper Creek into Ohio River	11.9 to 14.0	Organic Enrichment (Sewage) Biological Indicators	Non - Supporting	WAH	Illegal Dumps or Other Inappropriate Waste Disposal; Urban Runoff/Storm Sewers
`Woolper Creek into Ohio River	11.9 to 14.0	Total Suspended Solids	Non - Supporting	WAH	Illegal Dumps or Other Inappropriate Waste Disposal; Impacts from Hydrostructure Flow Regulation/modification; Urban Runoff/Storm Sewers
Allen Fork into Woolper Creek	2.0 to 4.6	Nutrient/Eutrophication Biological Indicators	Partially Supporting	WAH	Animal Feeding Operations
Allen Fork into Woolper Creek	2.0 to 4.6	Sedimentation/ Siltation	Partially Supporting	WAH	Habitat Modification – other than Hydromodification; Unspecified Urban Stormwater

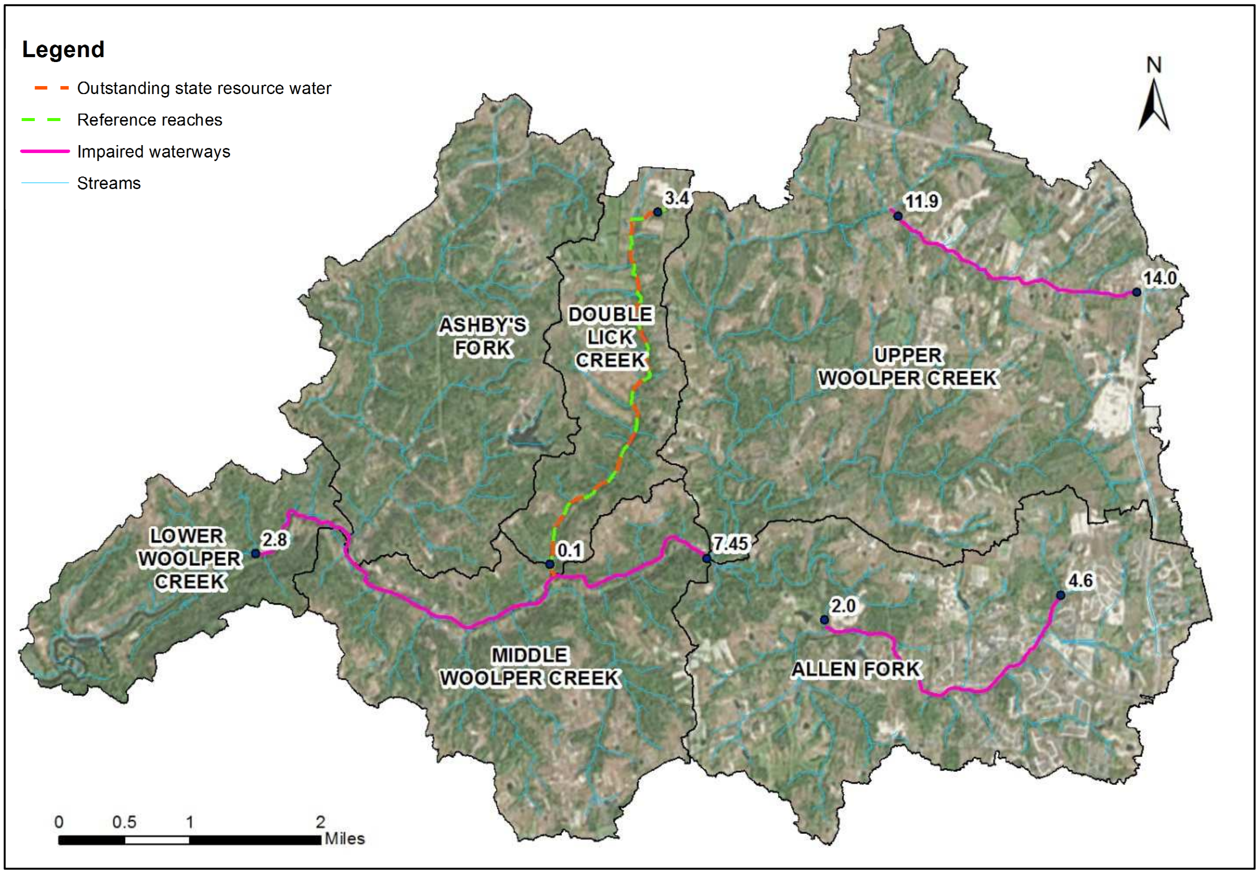


Figure 2-5: Woolper Creek Special Uses and Impaired Waters - Reference Table 2-3 for additional details regarding the impaired reaches

2.1.6 Water Quality and Biology

Prior to the development of this watershed plan, data relating to water quality have been collected within the watershed by many different agencies, including KDOW, Northern Kentucky University (NKU), Licking River Watershed Watch (LRWW), United States Geological Society (USGS), and Sanitation District No. 1 (SD1). These data extend to as early as 1995. The following discussion summarizes the findings reported in the *Woolper Creek Watershed Characterization Report*.

Reviewing historical bacteria exceedances, *E.coli* and fecal coliform were common at nearly all monitored locations, although the number of samples was limited. No instances of 5 samples over a 30-day period were conducted, which prohibited a comparison of the geometric mean. Dissolved oxygen historically was found to not be in violation (i.e., less than 4 mg/L) the majority of the time, although violations were reported in Water Years 2002, 2004, and 2005. Water Years 2002 and 2005 also documented pH violations (i.e., measurement in exceedance of 9 su), although these were also infrequent. More recent data showed only one dissolved oxygen measurement to be in violation, which occurred in August of 2007. Upon reviewing past climatological data provided by the

Historical water quality samples show infrequent violations of pH, dissolved oxygen and common violations of E.coli and fecal coliform.

National Oceanic and Atmospheric Administration (NOAA), March through August 2007 had a combined 13 inches less precipitation than normal, and the mean temperature for August 2007 was seven degrees above normal. These drought and low flow conditions may explain the single measurement in violation.

Between 2002 and 2004, KDOW sampled macroinvertebrates at a total of 12 sites within the watershed to better understand stream biology. The measurements were ranked using Kentucky's Macroinvertebrate Biotic Index (MBI) ratings, which presented mostly "Poor" ratings. Two locations established better results, Ashby's Fork received "Excellent" while Double Lick Creek received "Fair". Other biological indices included measurements of diatoms, or benthic algae sensitive to water quality changes, and the Kentucky Index of Biotic Integrity (KIBI-fish). Sites ranked using these parameters ranged from "Poor" to "Good".

2.1.7 Geomorphology

Fluvial geomorphology is the study of how flowing water shapes the land, in particular, the form, composition, and stability of stream channels. Streams are complex systems and their shape and stability is driven by the flow regime, vegetative and bed material resistance, slope, valley confinement, floodplain connectivity, and so forth. An understanding of geomorphic conditions is important for assessing stream stability, identifying sediment sources, classifying the physical habitat conditions, and determining the overall health of the stream.

Northern Kentucky's geomorphic setting includes shallow bedrock, fast-growing vegetation, and cohesive stream banks.

In general, Northern Kentucky's geomorphic setting is relatively homogenous and can be characterized by fast-growing vegetation with relatively dense root networks, clay soils creating cohesive stream banks, and shallow limestone bedrock. This setting is disrupted when factors such as urbanization and/or channelization become a primary driver of the geomorphic conditions. As explained in Chapter 1, increased imperviousness is directly associated with urbanization, and inadequate management of the stormwater runoff from impervious surfaces has serious implications on biologic and geomorphic processes. Many studies have illustrated that urbanization causes stream channel instability (Booth, 1990; Simon and Downs, 1995; Trimble, 1997; Bledsoe and Watson, 2001; Chin and Gregory, 2001; Chin, 2006; Hawley *et al.*, 2013). Hydromodification, a term coined by the USEPA, is becoming more and more prevalent across the United States. This includes channelization/channel modification, dams, and streambank/shoreline erosion. Throughout the Northern Kentucky region, urban induced hydromodification has caused substantial streambank erosion and channel instability (Hawley *et al.*, 2013).

More specifically, urbanization can explain differences in shape and stability between two streams in an otherwise similar setting. For example, the forested reference stream in the Double Lick Creek Subwatershed has a similar climatic, geologic, and topographic setting as the Allen Fork Subwatershed, which is highly developed. Despite the relatively similar natural settings, the impacts of urbanization have resulted in a stark contrast in stream form, stability, and habitat condition. This is a topic that will be discussed in greater detail in subsequent chapters of this Watershed Plan.

2.2 Natural Features

2.2.1 Geology and Topography

The Woolper Creek Watershed is located within the Outer Bluegrass Physiographic Region (Ray *et al.*, 1994) and is underlain mainly by Ordovician-age interbedded limestone and shale of between 425 and 500 million years old. The Woolper Creek Watershed has rolling upland areas that are underlain by the Grant Lake Limestone/Fairview and Bull Fork Formations. These formations produce broad stream valleys and form valley sides, and groundwater yields vary. In areas where the shale content increases, rates of natural erosion are higher and create steep topography. The Kope Formation is found along the main stem of Woolper Creek, which has erodible shale. According to the Kentucky Geological Survey, this formation has poor drainage and soft shale which typically results in hillside slippage when exposed to the weather. (Carey and Stickney, 2004). At the confluence with the Ohio River, it is likely that glaciers existed some 132,000 to 300,000 years ago, which is evidenced by conglomerate rock, such as the Split Rock Formation (LimnoTech, 2009). Other minor geologic formations can also be found is select locations (**Figure 2-6**).

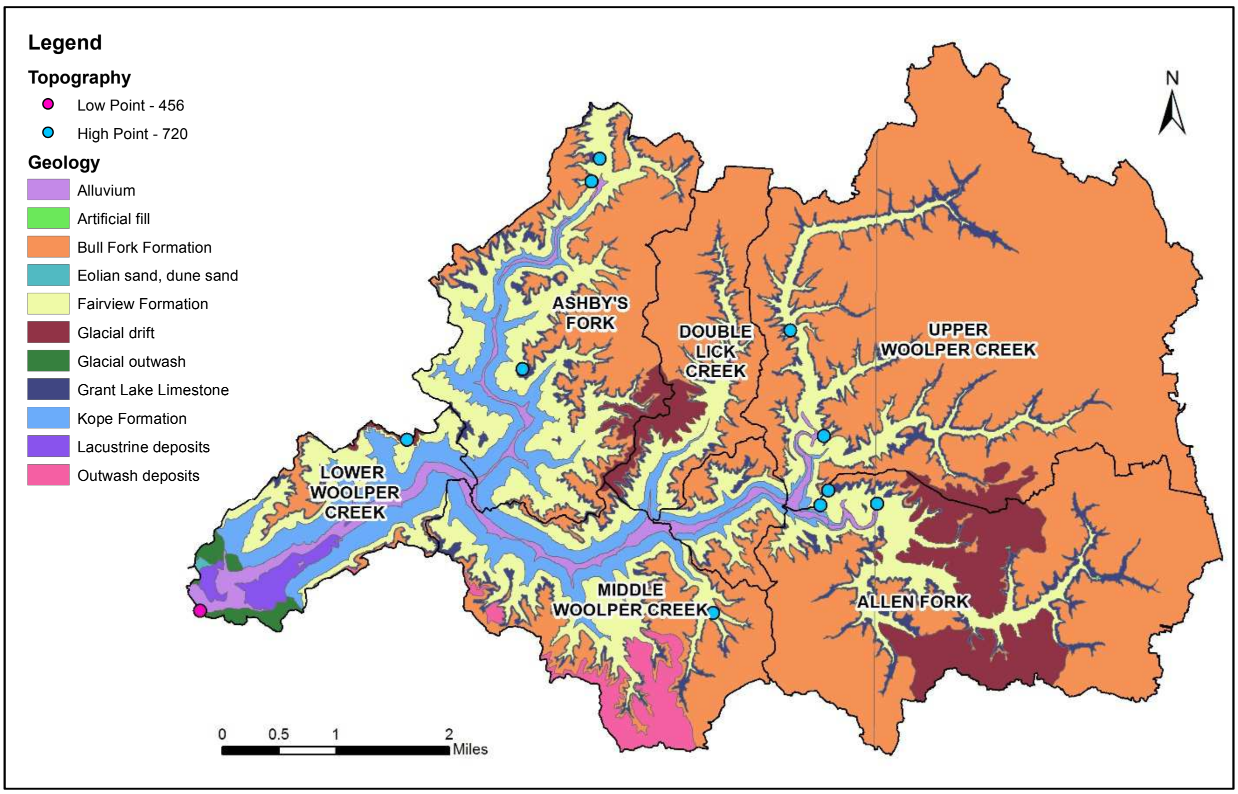


Figure 2-6: Woolper Creek Watershed Geology and Topography

The glacial deposits that can be found in Boone County are the same as can be found along Lakes Superior and Huron, along with inland lakes in Michigan and Northern Indiana. Near the mouth of

Woolper Creek is "Split Rock", which is part of these glacial deposits, shown in **Figure 2-7**. This formation is composed mostly of conglomerated limestone pebbles, with granitic pebbles sparingly intermixed. It is believed that "Split Rock" could be the terminal point of a glacier. At the confluence with the Ohio River, there are cliffs of similar composition that rise nearly 100 feet (Wright, 1884).

Figure 2-7: "Split Rock"

The topography of the Woolper Creek Watershed is influenced by the Ohio River (Carey and Stickney, 2004), which serves as the base level for the watershed. At the confluence with the Ohio River, the elevation is 456 and increases as high as 720 feet. The highest elevations are scattered throughout the watershed. The upstream end of the Ashby's Fork Subwatershed and near the confluence of the Upper Woolper Creek and Allen Fork Subwatersheds are two of the highest points (**Figure 2-6**). The normal pool level of the Ohio River at the confluence is 453.6 (LimnoTech, 2009).

2.2.2 Soils

There are a multitude of soil types within the Woolper Creek Watershed; however, three dominant types make up 75% of the watershed. The Rossmoyne soil loam classification accounts for nearly 38% of the watershed. These soils are silt loams that comprise uplands and stream terraces that have a moderate to high productivity potential. The Jessup silt loam classification comprises 20% of the watershed and is an upland and stream terrace soil with a moderate productivity potential. The other major classification of soil within Woolper Creek Watershed is the Eden silty clay loam classification. At 17% of the watershed, these upland, moderate productivity potential soils have a residuum that is clayey, weathered from shale and/or limestone (NRCS, 2006).

Soils are predominately hydrologic soil group C and D, which allow minimal to no infiltration.

Soil type affects drainage, flooding, permeability, slope stability, and siltation, all of which interact dynamically in the Woolper Creek Watershed. With the exception of streamside alluvial soils, all of the soils in the watershed (93%) are considered "highly erodible" as indicated by an index for erodibility (NRCS, 2006). The NRCS uses a formula to determine soil erodibility, and for example, "highly erodible" soils have eight times the tolerable erosion rate. The hydrologic soil group (HSG) is another soil classification, which is determined by the NRCS, classifies the soil's potential for stormwater runoff. Soil groups "C" and "D" indicate relatively low infiltration rates (i.e., ~0.10 inches per hour and < 0.05 inches per hour, respectively) and create higher rates of stormwater runoff than HSG "B" or "A" (i.e., ~0.2 inches per hour and > 0.3 inches per hour, respectively). 97% of the watershed is classified as HSG "C" or "D," meaning that nearly the entire watershed has soils with naturally low infiltration rates. This is important not only for natural hydrology, but also for what types of BMPs make sense (i.e., infiltration BMPs will not work without amended soils). Another parameter shared by virtually all areas of the watershed is a "very limited" septic suitability; only about 1% of the watershed is rated for septic suitability. The hydrologic group mapping can be seen in **Figure 2-8**, with a summary by subwatershed presented in **Table 2-4**.

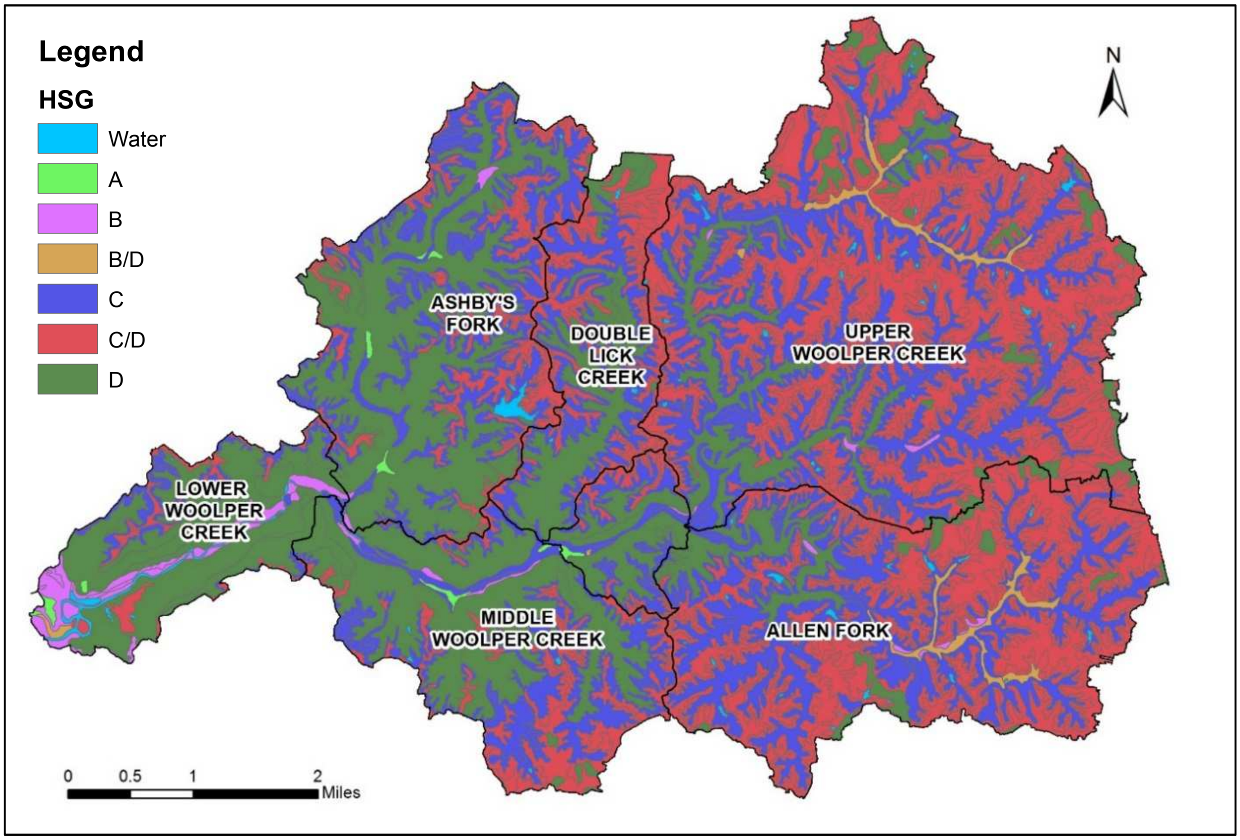


Figure 2-8: Woolper Creek Watershed hydrologic soil groups and septic suitability

Table 2-4: Woolper Creek Watershed soil groups

	HSG	Water	A	B	B/D	C	C/D	D	Total
			Decreasing rates of natural infiltration →						
Allen Fork	**Acres**	24.9	0.0	17.3	101.5	1,536.6	2,369.5	395.5	4,445.1
	%	1%	0%	0%	2%	35%	53%	9%	100%
Ashby's Fork	**Acres**	27.7	17.3	14.7	0.0	1,104.1	587.0	1,697.0	3,447.9
	%	1%	1%	0%	0%	32%	17%	49%	100%
Double Lick Creek	**Acres**	4.0	0.0	0.0	0.0	475.3	511.0	540.0	1,530.3
	%	0%	0%	0%	0%	31%	33%	35%	100%
Lower Woolper Creek	**Acres**	55.3	14.7	207.9	10.3	165.7	129.2	1,003.7	1,586.9
	%	3%	1%	13%	1%	10%	8%	63%	100%
Middle Woolper Creek	**Acres**	8.7	19.2	21.4	1.0	971.2	617.7	1,498.0	3,137.3
	%	0%	1%	1%	0%	31%	20%	48%	100%
Upper Woolper Creek	**Acres**	39.3	0.0	14.2	87.3	2,266.1	3,762.4	837.7	7,007.0
	%	1%	0%	0%	1%	32%	54%	12%	100%
Total	**Acres**	159.8	51.3	275.6	200.1	6,518.9	7,976.8	5,971.9	21,154.4
	%	1%	0%	1%	1%	**31%**	**38%**	**28%**	100%

2.2.3 Ecoregions

Ecoregions represent areas with similar ecosystems and environmental resources. The Woolper Creek Watershed lies within the Outer Bluegrass sub-region (71d) of the Interior Plateau Ecoregion. This ecoregion has dissected uplands, knobs, a few deeply incised master streams, and large areas of karst. Specific to the Outer Bluegrass, sinkholes, springs, entrenched rivers, and intermittent and perennial streams are present. Suspended sediment and nutrient concentrations can be high here. Glacial deposits are present here, unlike in any other area of Kentucky, and the natural soil fertility is relatively high. Open savanna woodlands, white oak stands, and cane were present during pre-settlement (Woods *et al*., 2002).

2.2.4 Riparian/Streamside Vegetation

Vegetated areas directly adjacent to the stream, which are commonly called riparian buffers, provide several benefits to the system. This buffer assists in capturing pollutants transported by stormwater runoff during wet weather conditions, enhances stream bank stability, provides valuable habitat for wildlife, and improves the overall aesthetics of the stream. Riparian buffers

Figure 2-9: Riparian vegetation is dense throughout many areas in the Double Lick Creek Subwatershed

are most prevalent throughout the undeveloped, forested regions of the watershed (**Figure 2-9**). Using a 50-foot stream offset on both sides of each stream segment and land cover data provided by Boone County, 66% of the watershed has a forested buffer around the stream (**Figure 2-10**). 17% of the watershed's buffer area is classified as developed; to be conservative, it can be assumed that these areas do not have a vegetated buffer.

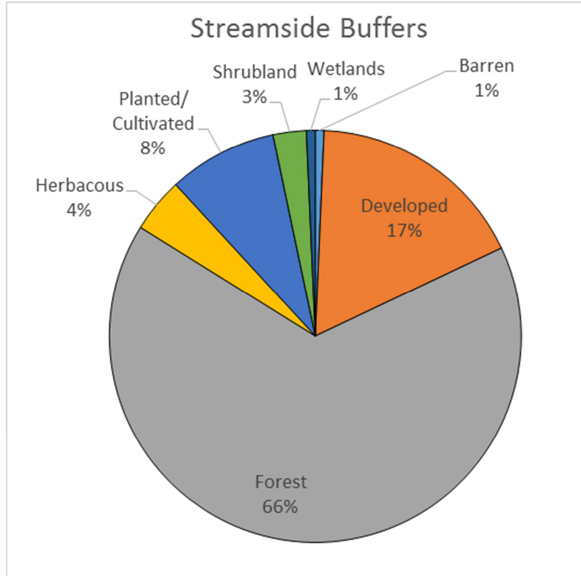


Figure 2-10: Streamside buffer estimation based on Boone County land cover and a 50-foot buffer area

These estimations were validated by the windshield surveys at the 17 sites used for hydromodification surveys. The majority of these sites, including some in developed subwatersheds, had a well-established vegetated buffer zone with multiple rows of trees.

The types of vegetation that are found in the riparian buffer zones throughout the Woolper Creek Watershed are abundant, including white oak, northern red oak, chinquapin oak, white ash, blue ash, sugar maple, red maple, yellow-poplar, and eastern red cedar that are commonly found along river drainages and in gorges (Jones, 2005). Furthermore, sycamore, walnut, boxelder, willow, and American elm are also common species found in the riparian zones.

While the native vegetation detailed above provides great riparian buffer zones and habitat, invasive species can threaten the environment. For example, streamside bush honeysuckle threatens frog tadpoles by reducing drainage into wetland spawning areas and by providing a food source that is significantly less nutritious than the native vegetation it replaces (Wallace and Durtsche, 2010).

2.2.5 Rare and Exotic/Invasive Plants and Animals

Northern Kentucky is naturally rich in plant and animal abundance. Over 400 species of wildlife have been observed in Boone County, including 203 species of birds, 107 species of fish, 25 species of amphibians, 27 species of mammals, and 19 species of reptiles, according to the Kentucky Department of Fish and Wildlife (KDFWR) (2014). As of April 2013, Boone County has between 6 to 10 rare plant species located there, which is higher than all the surrounding counties (White and Littlefield, 2014). **Figure 2-11** presents an example of a Cope's Gray Treefrog living in the Woolper Creek Watershed.

Figure 2-11: Cope's Gray Treefrog

The following table, **Table 2-5**, summarizes the endangered, threatened, and "special concern" species that are currently found within Boone County. The table has taken both national and state-level rankings into account. While not all these species can be found in streams or along their banks, preservation of the undeveloped lands that serve as their habitats (e.g., wetlands, grasslands, and woodlands) have clear benefits for the downstream water resources. The bald eagle has been delisted from the Endangered Species List, but is still protected under the Bald and Golden Eagle Protection Act and the Migratory Bird Treaty Act, and is known to reside in Boone County (USFWS, 2014). More specifically, there is a nesting pair of bald eagles near the mouth of Woolper Creek. Additional information on all endangered, threatened, and "special concern" species can be found in **Appendix 2-A**.

Table 2-5: Species of Concern in the Woolper Creek Watershed (KSNPC, 2014; USFWS, 2014)

Taxonomic Group	*Scientific Name*	Common Name	Federal Status	State Status
Vascular Plants	*Prenanthes crepidinea*	Nodding Rattlesnake-root	None	Special concern
Vascular Plants	*Trifolium stoloniferum*	Running buffalo clover	Endangered	Threatened
Aquatic Snails	*Lioplax sulculosa*	Furrowed Lioplax	None	Special concern
Insects	*Dryobius sexnotatus*	Six-banded Longhorn Beetle	Species of Management Concern	Threatened
Fish	*Ictiobus niger*	Black Buffalo	None	Special concern
Amphibians	*Cryptobranchus alleganiensis alleganiensis*	Eastern Hellbender	Species of Management Concern	Endangered
Amphibians	*Plethodon cinereus*	Redback salamander	None	Special concern
Breeding Birds	*Ammodramus henslowii*	Henslow's Sparrow	Species of Management Concern	Special concern
Breeding Birds	*Haliaeetus leucocephalus*	Bald Eagle	Delisted	Threatened
Breeding Birds	*Passerculus sandwichensis*	Savannah Sparrow	None	Special concern
Breeding Birds	*Riparia riparia*	Bank Swallow	None	Special concern
Breeding Birds	*Tyto alba*	Barn Owl	None	Special concern
Mammals	*Myotis sodalist*	Indiana Bat	Endangered	Endangered

Invasive species, which are also known as invasive exotics, include any species that is not native to the region and adversely impacts the natural environment through habitat destruction, soil degradation, decreased groundwater levels, and ultimately loss of native species. Some common invasive species that can be found throughout Boone County include bush honeysuckle, Dutch elm disease, multi-flora rose, Callery pear, poison hemlock, and garlic mustard. These invasive exotics, along with more recent invasions from others (e.g., the emerald ash borer, Asian long-horned beetle, Zebra mussel, Asian carp, and many others) pose threats to stream ecosystems, local ecology and economy.

2.3 Human Influences and Impacts

By reviewing **Figure 2-1** and noting the presence of population areas and roads, it is clear that there have been human influences within the Woolper Creek Watershed, especially in the headwaters. These influences have impacted both the land and water.

Figure 2-12: White bass caught in Woolper Creek

2.3.1 Water Use

Woolper Creek itself is utilized as a recreational waterway for fishing (**Figure 2-12**), canoeing, and kayaking. Protecting this resource is important for the local community. Additional information on the headings below can be found in Chapter 5.

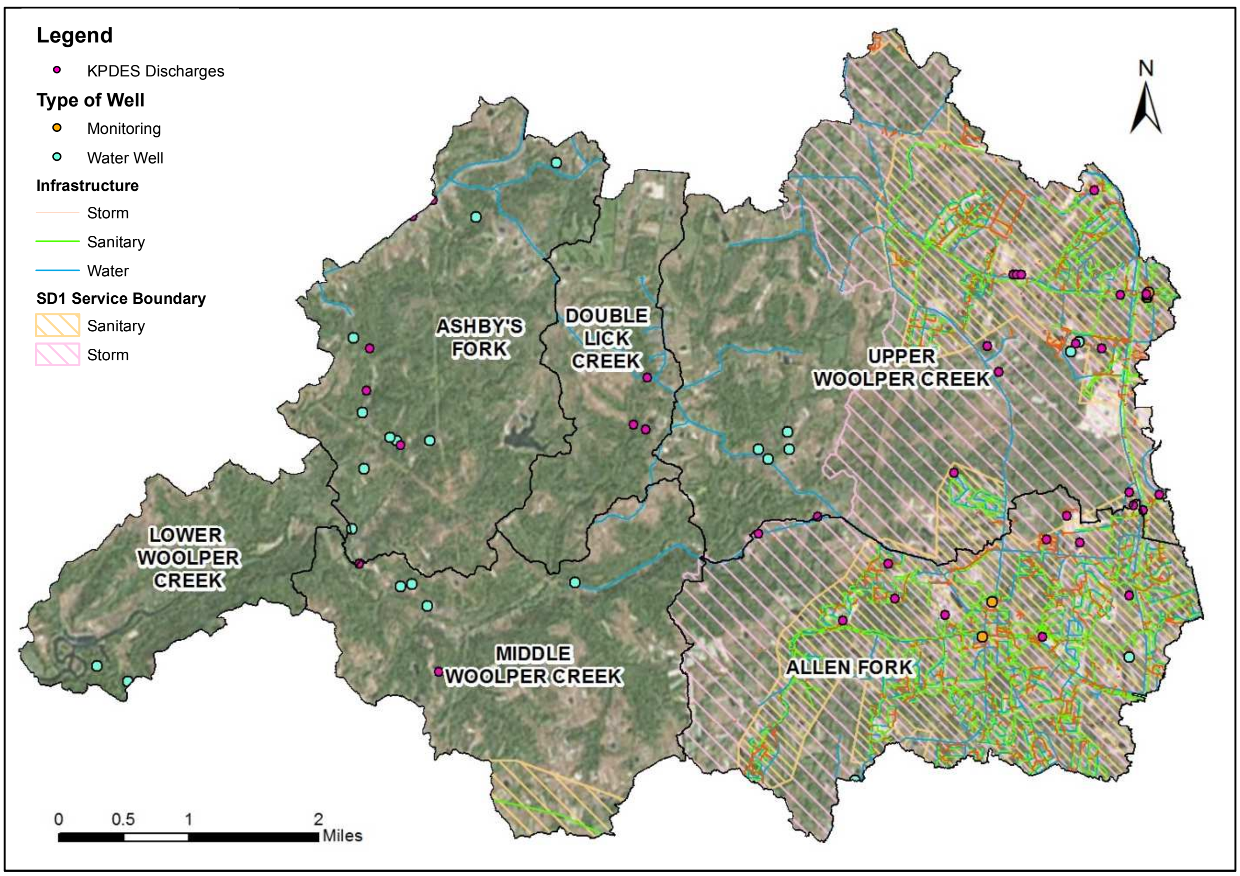


Figure 2-13: Woolper Creek Watershed water use information

Water Withdrawals

The Woolper Creek Watershed has a total of 44 known water wells within its boundaries (**Figure 2-13**). Of these, 21 are monitoring wells that are primarily used for ambient monitoring. The remaining 23 wells are water wells used for a combination of domestic and unknown uses. There has been no data to suggest any wells are for agricultural usage.

Public Water Supply

As mentioned in Section 2.1.3, there are no wellhead protection areas within the Woolper Creek Watershed. Between 20 and 25% of the watershed area is served by a public water supply, as shown in **Figure 2-13**. The entire Woolper Creek Watershed is located within its source water protection area.

Discharges

There are a total of 51 Kentucky Pollutant Discharge Elimination System (KPDES) permits within the Woolper Creek Watershed. All discharges have an EPA rating of "minor". Of the 51, 24 are effective permits, of which six permits have expired and will remain effective until they are reissued or terminated. The remaining 27 permits have been terminated. Most of the expired permits were issued to operators of dwellings other than apartment buildings, and many of the terminated permits include highway and street construction and general contractors of single-family houses. The locations of these KPDES discharges are presented in **Figure 2-13**.

Unsewered Areas

Per a shapefile from SD1, approximately 27% of the watershed is within the separate sanitary system operated by SD1, which encompasses about 74.9 miles of sewer. SD1's storm sewer service area incorporates slightly more of the watershed at 44%, with 175.9 miles of channels and swales and 34.5 miles of sewer. There are no combined sewers in this area. Historically, there were a total of six sanitary sewer overflows throughout the Woolper Creek Watershed, which included the Bullittsville Pump Station, the Allen Fork Pump Station, and four manholes located in the Allen Fork Subwatershed. SD1's Pump Station Overflow Elimination Plan and subsequent annual reports indicate that measures have been taken to mitigate the overflows at the Allen Fork Pump Station and the Taylorsport Pump Station, which is downstream of the Bullittsville Pump Station. Infrastructure and service boundaries are also presented in **Figure 2-13**.

A vast majority of the Woolper Creek Watershed is undeveloped, and therefore, it is considered to be unsewered. Analysis of the watershed indicates that up to 20% of the parcels (or 1,155 of the total 5,703 parcels that have a building in the watershed) could be served by septic systems. This number was calculated by combining two numbers: 1) the number of parcels with a building outside the SD1 service area, and 2) the number of parcels without an active sanitary account or nearby sewer within the SD1 service area, as it was assumed these must be served by septic. Although every building type does not require sewerage (e.g., storage units, barns, etc.), this rough analysis provided a maximum amount of parcels that could be served by septic systems. **Figure 2-14** presents the parcels that are unsewered and potentially served by septic systems. White regions of this graphic illustrate the parcel is undeveloped (i.e., does not have a building on it) and/or there is not an active SD1 sanitary account on this parcel.

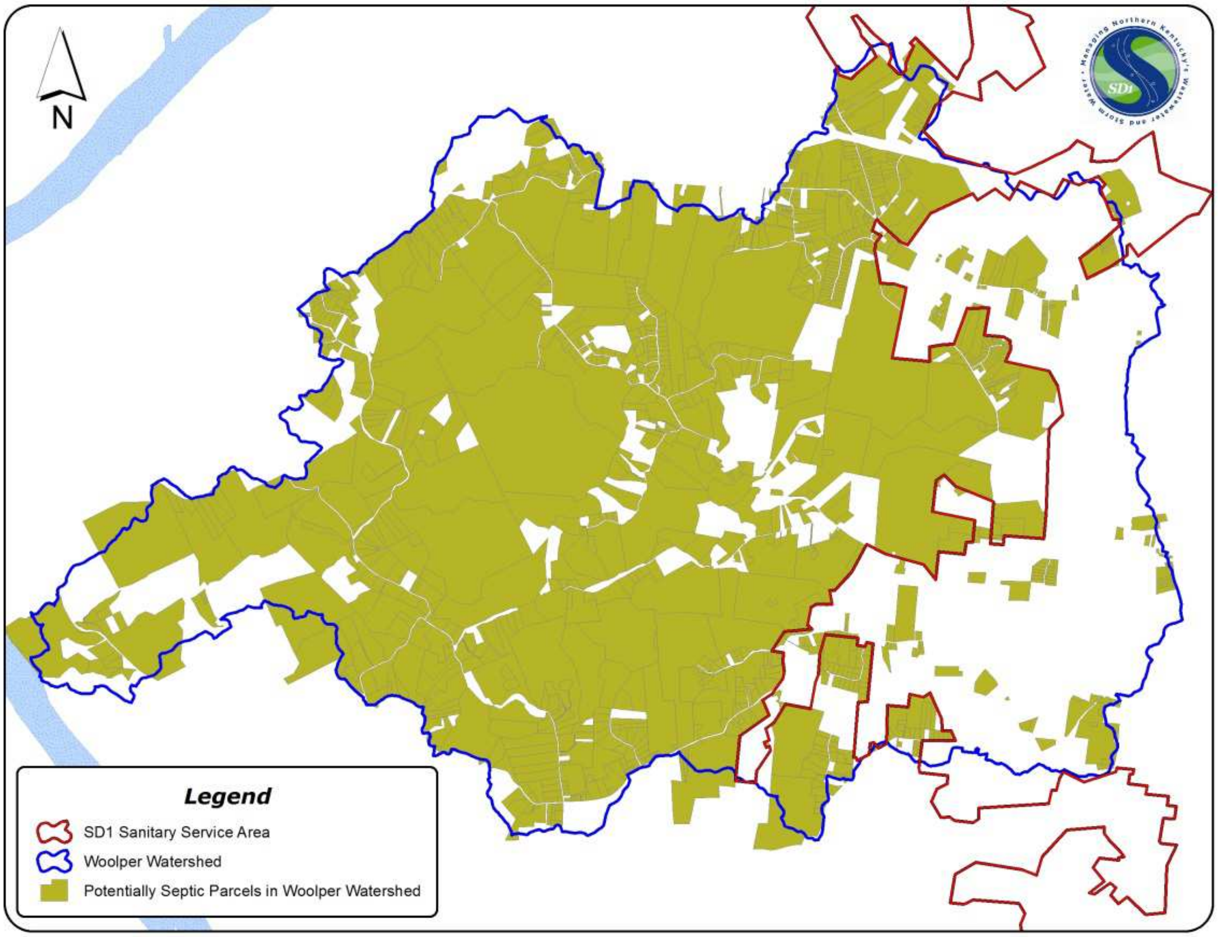


Figure 2-14: Unsewered areas within the Woolper Creek Watershed (Kaeff, 2014, Pers.Comm.)

2.3.2 General Land Use

The Woolper Creek Watershed was utilized by humans even before Europeans came to America. Native Americans occupied Northern Kentucky since at least 9,500 B.C. (Pollack, 2008). Their lifestyle was a semi-nomadic existence, moving based on the seasons for hunting, fishing, and gathering. Around 1,000 B.C., ceremonialism arose, farming became more prominent, and trading was more extensive. Semi-permanent villages developed, as did burial mounds. Permanent villages followed, around A.D. 1,000, where there was great dependence on the Ohio River and other local streams. These villages depended heavily on freshwater fish and mussels, determined from archaeological finds at these sites. It is believed that these villages were present until the time that the first Europeans came, around the mid-1700s, as these Europeans did not find any villages on their explorations.

Europeans began settling in the area around the late 1780s (Warminski, 2002), and again depended heavily on the Ohio River and other streams. Travel along the Ohio River and its tributaries was extremely popular. Tanners Station, where present-day Petersburg is, was arguably the first settlement in the area. Boone County was established in 1799, which is when development expanded, including resource extraction and land clearing and planting. Additional information on the population growth of Boone County can be found in Section 2.4.

> ***The developed portions of the watershed correspond to impaired stream segment locations.***

Today's land uses in the Woolper Creek Watershed are residential and commercial in the headwaters of Upper Woolper Creek and Allen Fork, with primarily forested, open space areas throughout the remaining areas of the watershed (**Figure 2-15**). Land cover follows suit, with mostly forests in the downstream areas and developments in the headwaters (**Figure 2-16**). Forested land and open space areas account for 43% of the land cover. These findings are also summarized in **Tables 2-6 and 2-7**. Notice that the most developed portions of the watershed correspond to stream segments listed as impaired on the 303(d) List (**Table 2-3**).

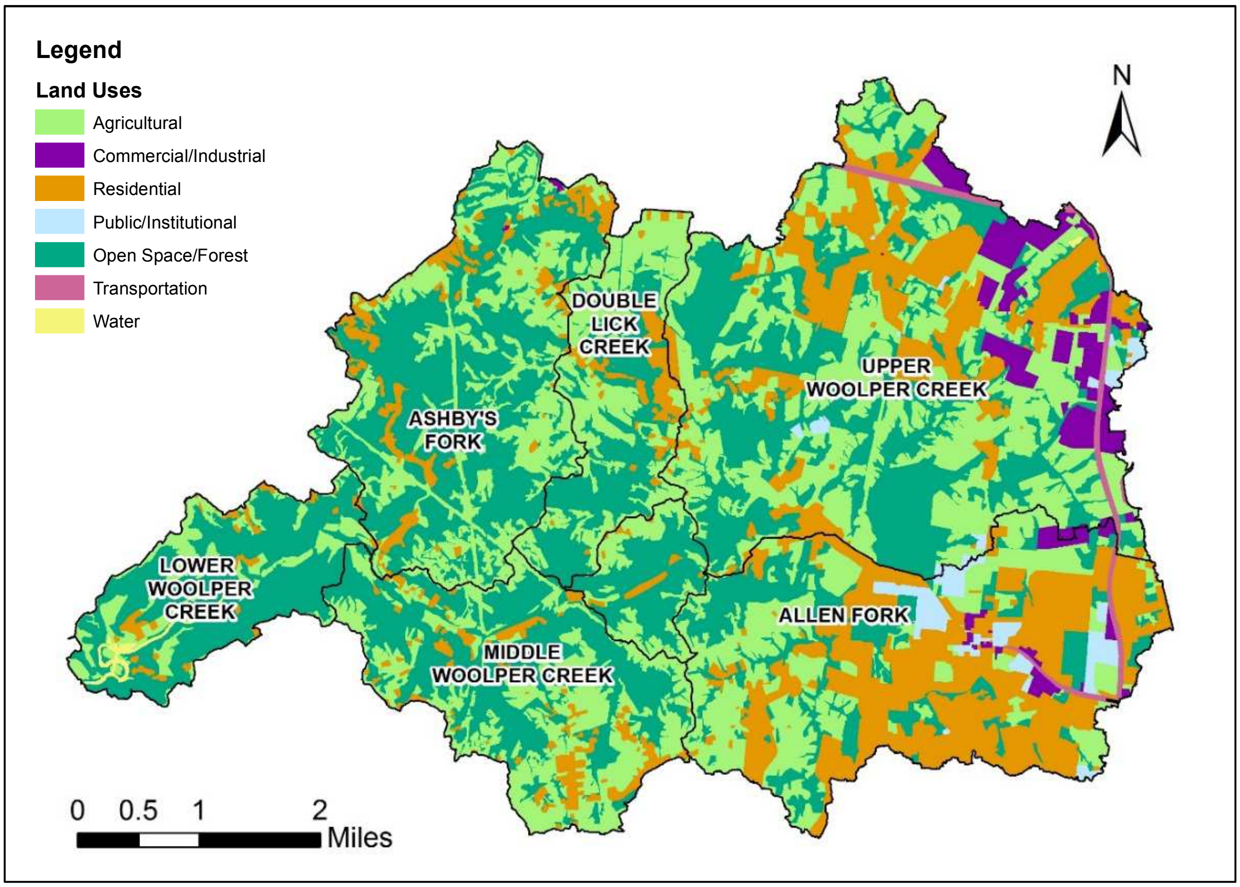


Figure 2-15: Woolper Creek Watershed land use

Table 2-6: Land use by subwatershed

		Agricultural	Commercial / Industrial	Residential	Public/ Institutional	Open Space/ Forest	Transpor-tation	Water	Total
Allen Fork	**Acres**	1,168	113	1,930	248	933	54	0	4,445
	%	26%	3%	43%	6%	21%	1%	0%	100%
Ashby's Fork	**Acres**	1,050	6	310	0	2,080	1	0	3,448
	%	30%	0%	9%	0%	60%	0%	0%	100%
Double Lick Creek	**Acres**	655	0	181	0	694	0	0	1,530
	%	43%	0%	12%	0%	45%	0%	0%	100%
Lower Woolper Creek	**Acres**	342	0	74	0	1,132	0	39	1,587
	%	22%	0%	5%	0%	71%	0%	2%	100%
Middle Woolper Creek	**Acres**	1,085	0	297	0	1,755	0	0	3,137
	%	35%	0%	9%	0%	56%	0%	0%	100%
Upper Woolper Creek	**Acres**	2,413	528	1,361	79	2,502	120	4	7,007
	%	34%	8%	19%	1%	36%	2%	0%	100%
Total	**Acres**	6,712	648	4,154	327	9,096	174	43	21,154
	%	32%	3%	20%	2%	43%	1%	0%	100%

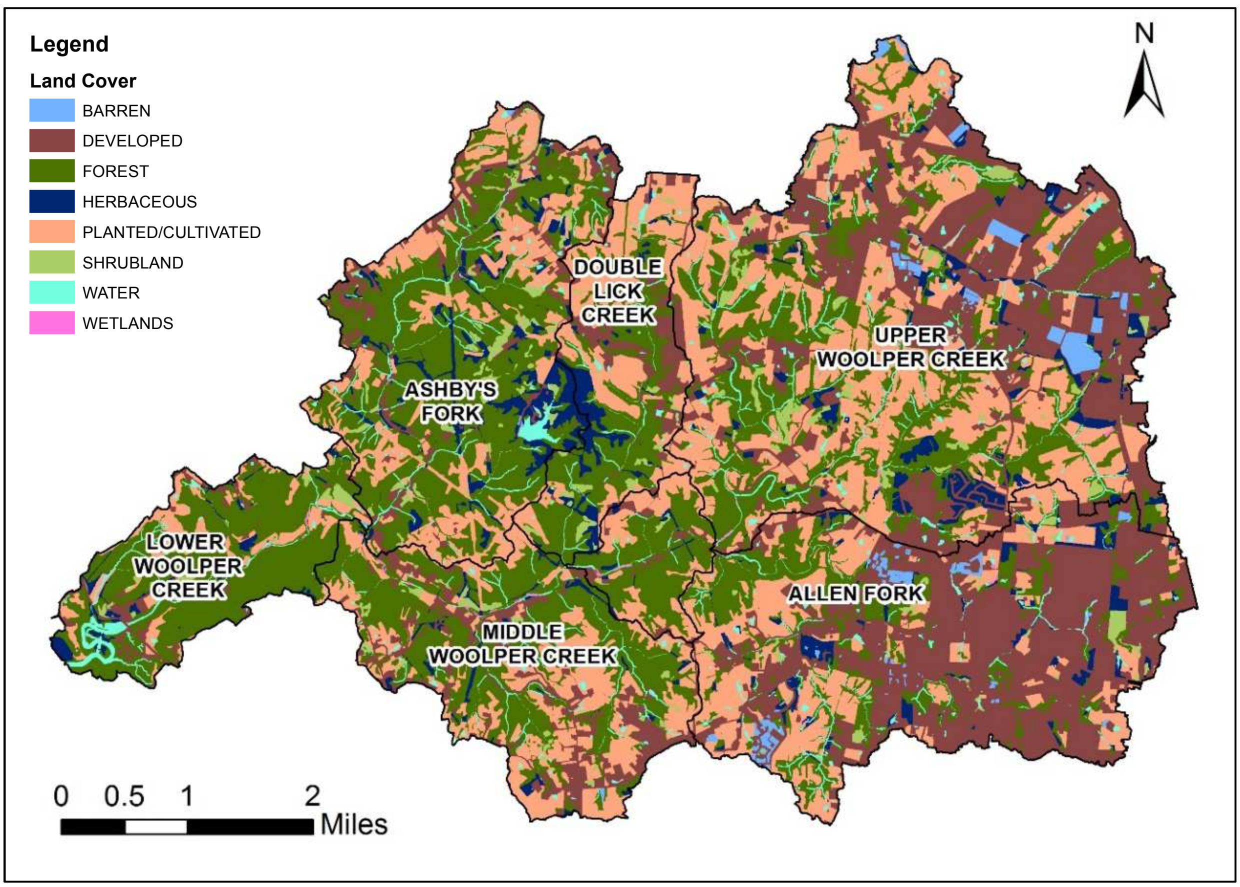


Figure 2-16: Woolper Creek Watershed land cover

Table 2-7: Land cover by subwatershed

		Barren	Developed	Forest	Herbaceous	Planted/ Cultivated	Shrubland	Water	Wetlands	Total
Allen Fork	**Acres**	83	2,160	846	171	999	73	112	2	4,445
	%	2%	49%	19%	4%	22%	2%	3%	0%	100%
Ashby's Fork	**Acres**	3	396	1,820	302	707	124	95	1	3,448
	%	0%	11%	53%	9%	20%	4%	3%	0%	100%
Double Lick Creek	**Acres**	0	203	603	105	545	42	33	0	1,530
	%	0%	13%	39%	7%	36%	3%	2%	0%	100%
Lower Woolper Creek	**Acres**	1	99	1,007	70	281	39	89	1	1,587
	%	0%	6%	63%	4%	18%	2%	6%	0%	100%
Middle Woolper Creek	**Acres**	2	398	1,561	81	956	54	75	8	3,136
	%	0%	13%	50%	3%	30%	2%	2%	0%	100%
Upper Woolper Creek	**Acres**	136	2,131	1,859	305	2,250	159	162	4	7,007
	%	2%	30%	27%	4%	32%	2%	2%	0%	100%
Total	**Acres**	224	5,387	7,696	1034	5,738	491	566	17	21,153
	%	1%	25%	36%	5%	27%	2%	3%	0%	100%

The Upper Woolper Creek and Allen Fork Subwatersheds have the highest amounts of residential land, and are the only subwatersheds with commercial and industrial land use. They also have the lowest percentages of open space/forest lands.

Over 40% of the watershed is open space, and preservation of this land could substantially benefit water quality.

It is promising that over 40% of the watershed is still open space and forested lands. Preserving these areas would likely be one of the most cost-effective strategies to protecting Woolper Creek (CWP, 2013). As for agricultural lands, local sources explain that this land is utilized for hay production, row crops, tobacco farms, and fruit/vegetable farms, as well as small cattle farms and equine farms. The National Land Cover Database (NLCD) classifies agricultural lands as either pasture/hay or cultivated crops. The large majority of this land use is classified as hay/pasture (87%), leaving only 11% of the land to be classified as cultivated crops (NLCD, 2011). There are no permitted concentrated animal feeding operations (CAFOs) or animal feeding operations (AFOs) in the watershed, although livestock are present. Hebron, in the headwaters, has a large number of horses (LimnoTech, 2009).

There are two major parks within the Woolper Creek Watershed, including Boone Woods Park and England-Idlewild Park. The Boone County Fairgrounds are also within the watershed's borders. Nearly all of the main property owners within the watershed own large tracts of agricultural land and/or forested land.

Impervious Surfaces

The headwaters of the watershed (i.e., Allen Fork and Upper Woolper Creek), where there is a high concentration of commercial, industrial, and residential areas, create more runoff due to impervious surfaces, which tends to create worse water quality than undeveloped areas of forest and pasture land (i.e., Double Lick Creek and Lower Woolper Creek). The Woolper Creek Watershed has 2.35 square miles of impervious surface, which is equivalent to only seven percent of the watershed. However, much of this impervious area is concentrated in the Allen Fork Subwatershed and the headwaters of the Upper Woolper Creek Subwatershed (**Figure 2-17** and **Table 2-8**).

Table 2-8: Imperviousness by subwatershed

Subwatershed	Area (ac)	Percent
Lower Woolper Creek	21.7	1.4%
Middle Woolper Creek	71.5	2.3%
Upper Woolper Creek	683.5	9.8%
Double Lick Creek	33.4	2.2%
Ashby's Fork	76.4	2.2%
Allen Fork	615.7	13.9%
Total	1502.2	7.1%

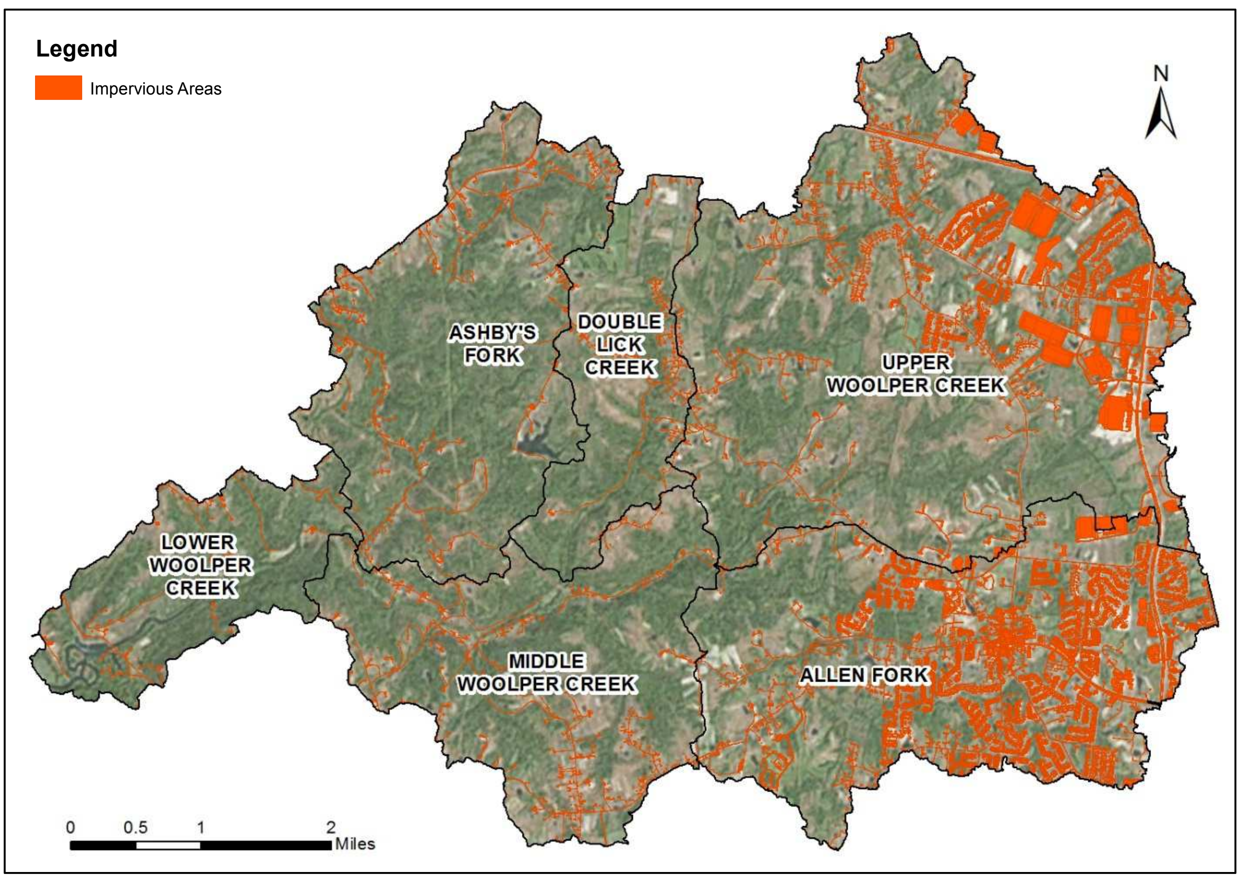


Figure 2-17: Woolper Creek Watershed impervious areas

2.3.3 Other Water Disturbances

In-stream Construction or Disturbance (Hydromodification)

Development has had an impact on the Woolper Creek Watershed. Some impacts have been beneficial, such as the old Split Rock Conservation Park that was located near the mouth of Woolper Creek, which restored habitat and promoted conservation practices and biodiversity. Others have negatively impacted the stream, such as the retaining wall that has straightened part of the channel (**Figure 2-18**) and an abandoned marina project that was started near the mouth of Woolper Creek, with channelization efforts that created large areas of unstable banks and channel erosion and destroyed the oxbow (Jonas, 2015, Pers.Comm.).

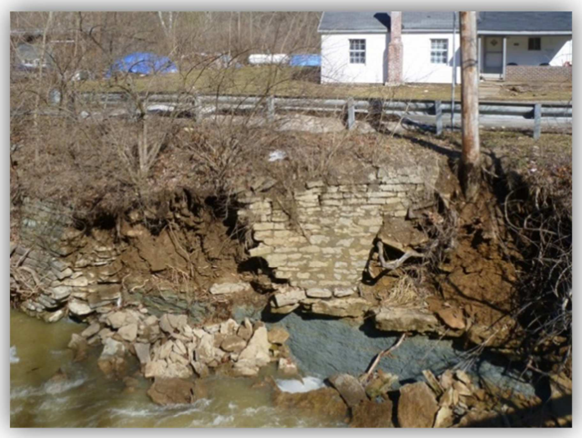


Figure 2-18: Stream disturbances - Collapsing wall on Allen Fork near the confluence with the main branch of Woolper Creek

There are no dams within the Woolper Creek Watershed included in the National Inventory of Dams, which is managed by the US Army Corps of Engineers (USACE). This database only accounts for high hazard dams and those that have a potential for loss of human life and significant property or environmental destruction. These dams are equal to or exceed 25 feet in height and 15 acre-feet of storage, or 50 acre-feet of storage with a height over six feet. There is one smaller, KDOW-regulated dam within the watershed, which is located in the Ashby's Fork Subwatershed. It is the Schneider Lake Dam, located at the discharge of the lake into a tributary of Ashby's Fork.

2.3.4 Land Disturbances That Can Impact Waterways

Mining and Quarries

Based on available data and input from watershed stakeholders, there are no quarries or active mines within the watershed. Other land disturbances that can negatively impact the waterways, such as development and construction activities, are discussed in Chapter 5.

2.3.5 Hazardous Materials

Hazardous materials are substances that pose a potential risk to health, property or the environment due to their properties. Boone County Code of Ordinances Chapter 95 addresses hazardous material enforcement in Boone County and designates the Emergency Management Office as the primary enforcement agency. Companies that manufacture, use, transport, or store hazardous materials in Boone County are required by law to report the quantity and location of these materials to Boone County Emergency Management (BCEM) and have contingency plans in place in case of unexpected release.

There are two main areas of concern related to hazardous materials within the Woolper Creek Watershed, the first being transportation of materials by truck along Interstate 275. One recent analysis showed that United States Department of Transportation recognized classes of hazardous materials are regularly trucked along Interstate 275, with Flammable Liquids, Combustible Liquids, and Non-Flammable Gases being the most common. Included in the observed commodities were motor fuels, nitrogen, oxygen, and other gases, and asphalt (NKEPC, 2011).

The second area of concern is the Mid-Valley Pipeline, which transports approximately 200,000 barrels per day of sweet crude oil from Longview, Texas to Lima, Ohio (BCEM, 2014). Completed in the 1950s, this pipeline runs through Boone County, along the northeast edge of the Woolper Creek Watershed. The Mid-Valley Oil Storage Facility, which is a crude oil compressor station, is just outside the watershed boundary. While a pipeline emergency response plan does exist for the pipeline, the age of the infrastructure and human error both make crude oil spills a possibility. In 2005, a break in this pipeline spilled 260,000 gallons into the Kentucky River. In Boone County in 2008, an SD1 construction crew inadvertently ruptured the line near Camp Ernst Road, which created an 115,000 gallon spill. There are also commercial and industrial HazMat storage facilities in the watershed (e.g., gas stations) but their exact number is unknown.

2.4 Demographics and Social Issues

Boone County's population has been substantially increasing since 1950.

Boone County was established in 1799, and until the mid-1950s, the population seldom rose above 15,000 people (**Figure 2-19**). Starting in 1960, the population rose from 21,940 people to 118,811 in 2010 (BCPC, 2010). The last decade during that period, from 2000 to 2010, had the most rapid increase in population in the county's history (32,830 people in 10 years or 38.2%). The population increase during that decade was one of the two fastest in all of Kentucky. Correspondingly, housing units increased by 35% to 45,043 units from 2000 to 2008 (US Census, 2009). Furthermore, as the economy recovers, it is anticipated that many of the 11,671 planned and approved housing units that have not yet been built will begin to move forward (Jonas, 2010, Pers. Comm.), and these development numbers do not include commercial development. Overall development within the Woolper Creek Watershed is predicted to increase between now and 2030. A portion of the land in the Upper Woolper Creek subwatershed is not planned for development because of its proximity to the CVG airport and the

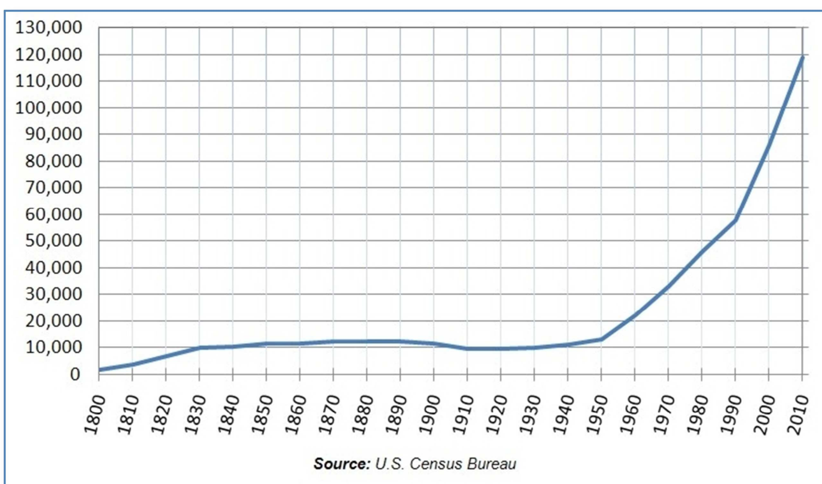


Figure 2-19: Boone County Population 1800 to 2010

area is affected by high jet noise levels during takeoff. The east and northeast portions of this subwatershed will experience continued growth. The Allen Fork subwatershed will also experience continued growth during the long-range planning horizon through the year 2035 (Jonas, 2015, Pers. Comm.).

As evident in **Figures 2-15** through **2-17**, some of this steep increase in development occurred in Woolper Creek's headwaters. Based on Boone County's Comprehensive Plan (2010), development is expected to continue over the next 25 years, with even more development occurring in Allen Fork and Upper Woolper Creek. Population growth is expected to be lower in the western portion of the watershed (**Figure 2-19**, BCPC, 2010).

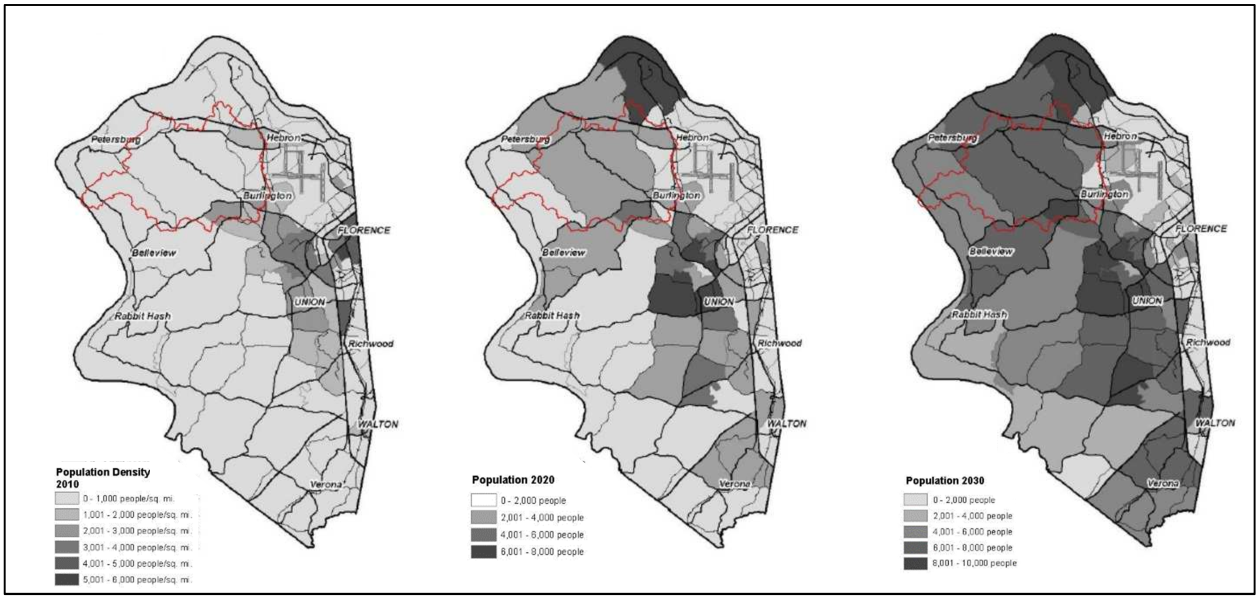


Figure 2-20: Boone County anticipated population density in 2010 (left), 2020 (middle), and 2030 (right) (BCPC, 2010)

According to the Boone County Comprehensive Plan (2010), Hebron and Burlington are two high growth areas, both within the watershed. While the county is expected to continue its growth, the demographics are anticipated to shift, with a decreasing proportion of young and middle-aged persons and married couple households. This will raise the median age. Diversity, for both race and ethnicity, is anticipated to increase.

Over 90% of the county's population is white, although recent trends show that diversity is increasing. In 2010, over 90% of the county had graduated high school, and over 30% of the county had a bachelor's degree or higher. These trends, which show increases in diversity and percentage of both high school and bachelor's degrees, are expected to continue.

Future growth is anticipated to threaten stream health.

Boone County's median household income was $64,008, nearly 60% higher than the state average and six percent higher than the national average. While recent unemployment numbers are high, 9.9% in 2010, these are again better than both the state and national averages, as is the percent of the population below the poverty level. Overall, these above-average income trends are expected to continue (BCPC, 2010).

2.5 Team Observations

The Woolper Creek Watershed is primarily characterized by forested cover throughout much of the western portion of the watershed and development in the eastern headwaters. The team understands that the Double Lick and Lower Woolper Subwatersheds (i.e., down by Split Rock) are beautiful and they would like to work to conserve these regions. Furthermore, the team understands the issues facing the streams in the developed subwatersheds - the Allen Fork and Upper Woolper Creek Subwatersheds (e.g., flooding and degraded physical conditions). The unique nature of the Woolper Creek Watershed provides a great opportunity to protect the streams and implement storm water best management practices (BMPs) in some of the degraded portions of the watershed that would transfer benefits to stream reaches for many miles downstream. The WCWI believes with the right combination of tools and implementation efforts, we can all work together to improve the condition of the streams throughout the Woolper Watershed and potentially de-list segments from the 303(d) list.

2.6 Interim Conclusions

Overall conclusions from exploring the Woolper Creek Watershed show that there are significant areas of development within the headwaters, but that the development significantly decreases when moving downstream. Locating the developments in the headwaters can result in decreases to water quality, habitat, and stream stability due to increased flows that can impact downstream reaches as well. In addition, the small amount of residential area and imperviousness within the Double Lick Creek Subwatershed are consistent with the relatively healthy condition of its stream, and explain why the state would designate it as an Outstanding State Resource Water.

Moving forward, we will need to use data collection and analysis to better understand the specific pollutants in the Woolper Creek Watershed and to tailor implementation efforts to protect and restore these valuable resources.

References

Bledsoe, B.P. and Watson, C.C., 2001. Effects of urbanization on channel instability. Journal of the American Water Resources Association, 37(2): 255-270.

Boone County Emergency Management (BCEM), 2014. Boone County Emergency Operations Plan, 2014 Edition. Boone County Emergency Management office, Burlington, KY.

Boone County Planning Commission (BCPC), 2010. 2010 Boone County Comprehensive Plan: Planning for the year 2035. Adopted June 6, 2012. Boone County Planning Commission, Burlington, KY.

Booth, D.B., 1990. Stream-channel incision following drainage-basin urbanization. Water Resources Bulletin, 26(3): 407-417.

Carey, D.I. and Stickney, J.F., 2004. Groundwater Resources of Boone County, Kentucky. County Report 8, Series XII, Kentucky Geological Survey.

Chin, A., 2006. Urban transformation of river landscapes in a global context. Geomorphology 79 (3–4), 460–487.

Chin, A. and Gregory, K.J., 2001. Urbanization and adjustment of ephemeral stream channels. Annals of the Association of American Geographers, 91(4): 595-608.

CWP, 2013. Cost-Effectiveness Study of Urban Stormwater BMPs in the James River Basin. Center for Watershed Protection, Eliot City, MD. June.

Hawley, R.J., MacMannis, K.R. and Wooten, M.S., 2013. Bed coarsening, riffle shortening, and channel enlargement in urbanizing watersheds, northern Kentucky, U.S.A. Geomorphology, 201: 111-126.

Jonas, R., 2010, Approved Housing Units. Boone County Planning Commission, Pers.Comm.

Jonas, R.A., 2015. Woolper Creek Watershed Study Comments. Pers.Comm.

Jones, R.L., 2005. Plant Life of Kentucky: An Illustrated Guide to the Vascular Flora. University Press of Kentucky.

KDFWR, 2014. Species Information: Boone County. Website: http://app.fw.ky.gov/speciesinfo/countyListSpecies.asp Accessed August 25, 2014.

KDOW, 2013. Final 2012 Integrated Report to Congress on the Condition of Water Resources in Kentucky Volume II. 303(d) List of Surface Waters.

KSNPC (Kentucky State Nature Preserves Commission), 2014. Report of Endangered, Threatened, and Special Concern Plants, Animals, and Natural Communities for Boone County, Kentucky. Kentucky State Nature Preserves Commission

LimnoTech, 2009. Woolper Creek Watershed Characterization Report. Prepared for Sanitation District No. 1 of Northern Kentucky, Fort Wright, KY.

Natural Resources Conservation Service (NRCS), 2006. gSSURGO/GIS format. http://datagateway.nrcs.usda.gov/.

NKEPC (Northern Kentucky Emergency Planning Committee), 2011. Hazardous Commodity Flow Study.

Paylor, R.L, and Currens, J.C., 2002. Karst Occurrence in Kentucky. Kentucky Geological Survey, University of Kentucky.

Pollack, David, 2008. "Archaeological Overviews," in The Archaeology of Kentucky: An Update. State Historic Preservation Plan Report No. 3, Kentucky Heritage Council, Frankfort.

Ray, Joseph A., James S. Webb, and Phillip W. O'Dell, 1994. Groundwater Sensitivity Regions of Kentucky. Kentucky Department for Environmental Protection, Division of Water, Groundwater Branch.

Simon, A. and Downs, P.W., 1995. An interdisciplinary approach to evaluation of potential instability in alluvial channels. Geomorphology 12, 215–232.

The Weather Channel (TWC), 2014. Monthly Averages for Burlington, KY. Website: http://www.weather.com/weather/wxclimatology/monthly/graph/USKY0742 Accessed August 14, 2014

Trimble, S.W., 1997. Contribution of stream channel erosion to sediment yield from an urbanizing watershed. Science 278, 1442–1444.

United States Fish and Wildlife Service (USFWS), 2014. Endangered, Threatened, Proposed, and Candidate Species in Boone County, Kentucky. US Fish and Wildlife Service Kentucky Ecological Services Field Office. Available: http://www.fws.gov/frankfort/pdf/KY_te_list_by_county.pdf Accessed August 25, 2014.

US Census, 2009. Annual Estimates of the Resident Population for Counties of Kentucky: April 1, 2000 to July 1, 2009. U.S. Census Bureau, Population Division. http://ksdc.louisville.edu/kpr/popest/coest2009.xls.

USGS, 2013. Water Data Report 2013 for 03262001 Woolper Creek at Woolper Creek Road Near Burlington, KY. Available: http://wdr.water.usgs.gov/wy2013/pdfs/03262001.2013.pdf

Wallace, Andrew, and Richard Durtsche, 2010. "The Effects of the Invasive Amur Honeysuckle Leaf Consumption on Green Frog Tadpoles," in Proceedings Kentucky Water Resources Annual Symposium. Kentucky Water Resources Research Institute, Lexington, Kentucky, p 85-86.

Warminski, Margaret, 2002. "Historic Overview of Boone County", in Historic Structures of Boone County, Kentucky. Boone County Historic Preservation Review Board, Burlington.

White, D.L. and Littlefield, T., 2014. Report on Kentucky's Native Flora: Status and Trends of Rare Plants 2014. Kentucky State Nature Preserves Commission.

Woods, A.J., J.M. Omernik, W.H. Martin, G.J. Pond, W.M. Andrews, S.M. Call, J.A. Comstock, and D.D. Taylor, 2002. Ecoregions of Kentucky. Color poster with map, descriptive text, summary tables, and photographs, U.S. Geological Survey (map scale 1:1,000,000), Reston, VA.

Wright, G.F., 1884. The Glacial Boundary in Ohio, Indiana, and Kentucky. The Western Reserve Historical Society, Leader Print Co., Cleveland, OH.

CHAPTER 3

Learning More and Monitoring

Woolper Creek Watershed Plan

Prepared by the

Woolper Creek Watershed Initiative

October 2016

Chapter 3: Learning More and Monitoring

With a solid understanding of the watershed characteristics and existing data available, the Woolper Creek Watershed Initiative (WCWI) embarked on a monitoring program to learn more about the extent and likely causes of impairments in the streams. A comprehensive monitoring program is an important foundation to watershed plans because it provides an understanding of existing stream conditions in order to achieve the two major goals of watershed planning – to protect good water quality and improve poor water quality (KDOW, 2010). Monitoring provides data to identify the pollutants of concern, which then assists in determining potential pollutant sources and developing strategic solutions to improve the impaired reaches of the stream network. The WCWI monitoring program was designed to be multi-faceted to understand several elements of stream health, including water quality and stream flow sampling, hydrogeomorphic surveys, and habitat and biological assessments. Such a comprehensive monitoring program allowed the WCWI to better understand the watershed conditions because the complexity of stream systems is interdependent on multiple components. The stream function pyramid (**Figure 3-1**) illustrates the connectivity of the interdependent network of dynamic parts and how each component is built upon others. Stream health is dependent upon an equilibrium of all pieces of the pyramid. The types of land use (e.g., agricultural, rural, developed, open space, etc.) and the ways we use the land and manage the stormwater that runs off the land impacts the flow regime of the streams (e.g., more erosive flows) and the types of nonpoint source pollutants being washed off the land (water quality). The way people manage the land and change the stream flow impacts the geomorphic shape/habitat conditions (e.g., bank erosion and channel instability) and the quality of the water (e.g., pollutant loads and contamination). For example, the more erosive flow regime associated with urban development causes stream channel instability, resulting in increased sediment loads. In another example, improperly managed agricultural lands could result in increased nutrient loads. The nature of these combined elements (land use, stream flow, physical/habitat, and water quality) creates impacts and feedbacks within aquatic ecosystems (biological). This chapter, titled "Learning More and Monitoring," presents a summary of the WCWI multi-faceted Phase 1 and Phase 2 monitoring programs. The

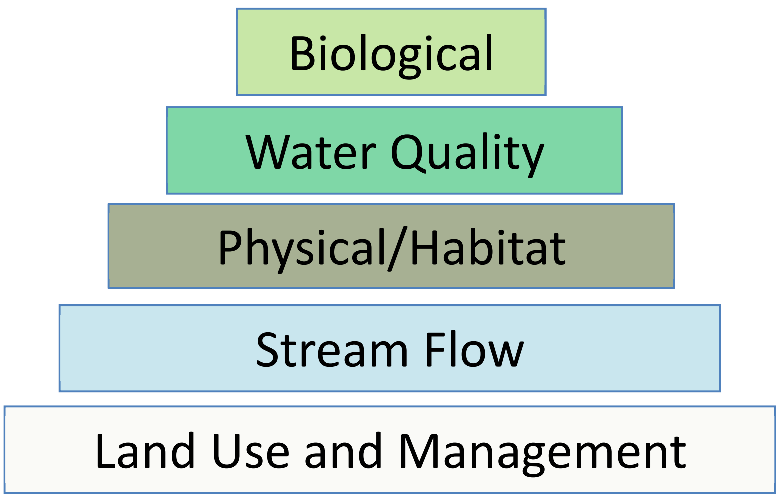


Figure 3-1: Stream function pyramid adapted from Harmon *et al.* (2012)

WCWI monitoring program was designed to be multi-faceted to understand several elements of stream health, including hydrologic, geomorphic, habitat, water chemistry, and biological monitoring.

2011 Quality Assurance Project Plan for the Woolper Creek Watershed Plan (QAPP, **Appendix 3-A**) provides more detailed information regarding sampling parameters, methods, and frequencies.

3.1 Determining Monitoring Needs

The first step to developing a monitoring program includes a data inventory to understand the data that already exists throughout the watershed, identify gaps, and then determine additional monitoring needs. The Sanitation District No. 1 of Northern Kentucky (SD1), which is a vested stakeholder and an active member of the WCWI Steering Committee, had been collecting water chemistry, biological, and geomorphic data at several locations between 2006 and 2011. In the Woolper Creek Watershed, this includes a total of six locations - two of the locations having geomorphic surveys, five having water chemistry data, and all six having biological assessments (macroinvertebrate and/or fish sampling). The SD1 monitoring program included water quality monitoring in order to establish a baseline condition and all data were collected using standard procedures and quality assurance measures that are consistent with those outlined in the QAPP. These monitoring sites are located near the mouths of the HUC 14 watersheds; and therefore, in the fall of 2011, SD1's existing data was approved by KDOW to serve as Phase 1 sampling.

Several years of existing SD1 monitoring data provided sufficient information for the Phase 1 monitoring program.

The data sharing by SD1 and collaboration with KDOW allowed WCWI to more effectively use their limited resources by immediately moving to Phase 2 of the required monitoring for watershed plans. The Phase 2 effort resampled SD1's monitoring sites and added several additional monitoring sites further upstream, providing a total of 10 Phase 2 water quality monitoring locations throughout the watershed. Site WPC 1.4 was excluded from the Phase 2 monitoring program because it is likely influenced by the backwater of the Ohio River. Instead, the WCWI included the SD1 reference site DLC 1.0 as part of the water chemistry sampling program for Phase 2 sampling. Furthermore, the WCWI monitoring program included extensive geomorphic monitoring because hydromodification due to the erosive, urban flow regime is prevalent in Northern Kentucky streams. This included hydrogeomorphic surveys at 18 locations throughout the watershed. **Table 3-1** summarizes SD1's existing (pre-2011) monitoring locations used for Phase 1 monitoring and the Phase 2 monitoring locations (2012-2013) where the WCWI collected data, including the 18 hydrogeomorphic monitoring locations.

The WCWI Phase 2 monitoring program included extensive geomorphic monitoring because hydromodification due to the erosive, urban flow regime is prevalent in Northern Kentucky Streams.

Table 3-1: Summary of existing and proposed Woolper Creek sampling

Site ID[1]	Water Chemistry Sampling		Habitat & Biological Assessments		Physical - Hydrogeomorphic	
	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2
WPC 1.4[2]	SD1		SD1			
ASF 0.0	SD1	WCWI	SD1	WCWI		WCWI
WPC 5.0	SD1	WCWI	SD1	WCWI	SD1	WCWI
DLC 1.0[3]		WCWI	SD1	WCWI	SD1	WCWI
WPC 8.8	SD1	WCWI	SD1	WCWI		WCWI
ALF 0.1	SD1	WCWI	SD1	WCWI		WCWI
ASF 1.8		WCWI		WCWI		WCWI
WPC 8.1 – UNT 0.9		WCWI		WCWI		WCWI
WPC 12.3		WCWI		WCWI		WCWI
UT ALF 0.2		WCWI		WCWI		WCWI
ALF 2.7		WCWI		WCWI		WCWI
ASF 3.6						WCWI
WPC 5.3 – UNT 0.1						WCWI
WPC 11.0						WCWI
WPC 13.3 – UNT 0.1						WCWI
WPC 8.1 – UNT 2.7						WCWI
ALF 4.0						WCWI
ALF 4.8						WCWI
ALF 4.7 – UNT 0.1						WCWI

[1] Monitoring sites were selected along the main stem of Woolper Creek as well as targeted locations throughout the subwatersheds. The naming convention of each site is based on its location. The first three letters represent the stream and the numbers indicate the actual location on the stream (i.e., the number of stream miles upstream of the mouth). Therefore, site WPC 1.4 is located on Woolper Creek, 1.4 stream miles upstream of its confluence with the Ohio River. WPC - Woolper Creek; ASF – Ashby's Fork; DLC – Double Lick Creek; ALF – Allen Fork; UT or UNT – Unnamed tributary

[2] WPC 1.4 is likely influenced by backwater from the Ohio River and was not included for Phase 2 sampling.

[3] As an alternative to WPC 1.4, we monitored DLC 1.0 to fill in the water quality data gaps on Double Lick Creek—a reference reach stream (401 KAR 10:030) that is also an Outstanding State Resource Water (401 KAR 10:026). The Double Lick data can influence watershed-specific benchmarks for the project, given the exceptional quality of its biological communities.

3.2 Obtaining Additional Data through Monitoring

Understanding the available data from Phase 1 monitoring, it was determined that Phase 2 monitoring would require more hydrogeomorphic sites to better understand hydromodification throughout the watershed. Additional sites for water chemistry, habitat and biological monitoring were also established during Phase 2 monitoring for a more accurate determination of impairment locations and targeting appropriate implementation strategies.

3.2.1 Monitoring and Data Analysis for the Woolper Creek Watershed

The WCWI's phased monitoring model included Phase 1 monitoring, which occurred between 2006 and 2011 at several SD1 monitoring locations, followed by Phase 2 monitoring at the all but one of the same sampling locations as well as several additional locations in 2012 and 2013. The monitoring program includes a total of six Phase 1 sites near the mouths of the HUC 14 watersheds (five with water quality data, two with geomorphic data, five with habitat data, and six with biological data). The Phase 2 program includes additional Phase 2 sites located farther upstream in select subwatersheds for a total of ten sites that were monitored for water chemistry, geomorphology, habitat, and biology. There are also an additional eight hydromodification sites that were monitored for geomorphic sampling only, for a combined total of 18 geomorphic sampling sites (**Table 3-1, Figure 3-2**). The following sections provide a brief summary of the multi-faceted elements of WCWI monitoring efforts. As previously mentioned, additional information regarding sampling parameters, methods, and frequencies is included in the 2011 QAPP for the Woolper Creek Watershed Plan (**Appendix 3-A**).

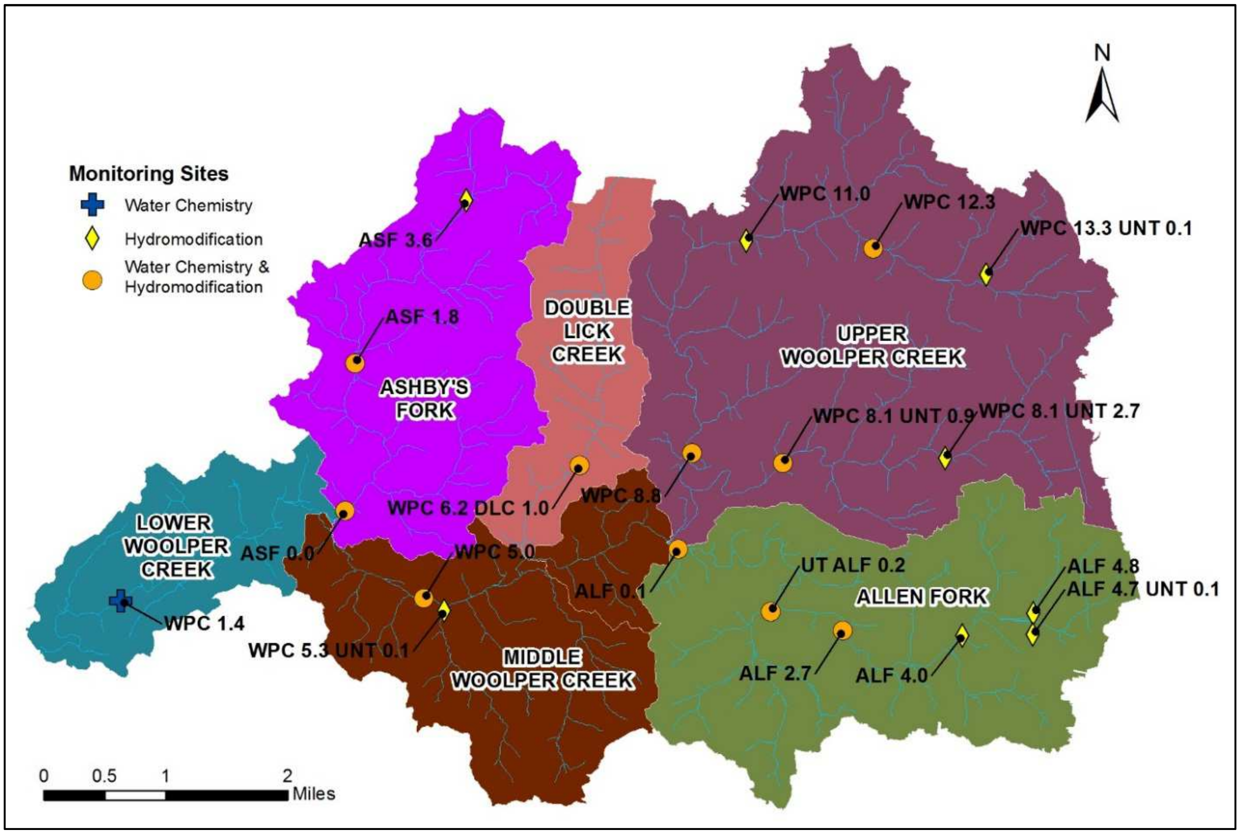


Figure 3-2: Woolper Creek monitoring locations

Water Chemistry Sampling

Water quality monitoring (**Figure 3-3**) is important to understanding the condition of the stream in terms of identifying specific pollutants of concern and estimating the degree of impairment based on the pollutant concentration and the frequency of exceedance. For Phase 2 monitoring, sampling frequencies and parameters were collected according to the Watershed Planning Guidebook for

Kentucky Communities (KDOW Guidebook) (2010) and included measurements of water chemistry parameters as well as hydrologic (flow) monitoring for each sample. Sampling occurred during both dry and wet weather events. Several field measurements were taken at the site, and additional samples were sent to the laboratory. **Table 3-2** presents the water quality monitoring data collected in the field and measured in the laboratory. Please refer to the Woolper QAPP (**Appendix 3-A**) for additional information regarding sampling methods.

Figure 3-3: Collecting a water quality sample at a monitoring site on Ashby's Fork

Table 3-2: Water quality monitoring data measured in the field versus the laboratory

Field Measurements	Parameters Measured in the Laboratory
Temperature	Bacteria (*E.coli*)
pH	Sediment (Total Suspended Solids (TSS))
Dissolved Oxygen	Nutrients (Total Phosphorus (TP), Total Kjeldahl Nitrogen (TKN), Phosphate (P), Nitrate-Nitrite (NN), Ammonia as Nitrogen
Specific Conductance	
Turbidity	
Stream Discharge	Carbonaceous Biochemical Oxygen Demand (CBOD)
Percent Saturation	

Physical Monitoring – Hydrogeomorphic Surveys

Several Northern Kentucky streams have been negatively impacted by urbanization and inadequately managed stormwater runoff from impervious surfaces, resulting in channel instability, degraded habitat conditions, and increased sediment pollution. Therefore, the WCWI hydrogeomorphic monitoring effort was designed to measure the physical changes in stream channels (e.g., bank and bed erosion) in response to the changes in the flow regime due to watershed urbanization (i.e., 'hydromodification').

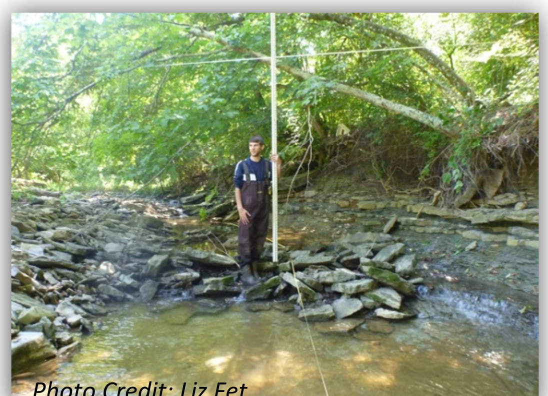


Figure 3-4: Hydrogeomorphic surveying at site ALF 0.1 - collecting cross section data

Boone County Conservation District (BCCD) and SD1 collected detailed hydrogeomorphic survey data (**Figure 3-4**) at a total of 18 sites, including cross sections, profiles, and pebble counts, according to the industry standard methods outlined in the QAPP. Data collection methods were based on industry standard techniques (Harrelson *et al.*, 1994; Bunte and Abt, 2001a; Bunte and Abt, 2001b; Potyondy and Bunte, 2002) and were conducted according to standard SD1 operating procedures (SD1, 2009). Two of the 18 hydrogeomorphic survey sites were part of SD1's hydromodification monitoring program (WPC 5.0 and DLC 1.0). Beginning in 2008, SD1 has collected several years of hydrogeomorphic survey data at these two sites. The hydrogeomorphic data from SD1 served as both Phase 1 and Phase 2 monitoring data. The other 16 hydrogeomorphic monitoring sites have two rounds of hydrogeomorphic survey data collected in 2012 and again in 2013, with each survey round separated by approximately one year. All survey data have been systematically processed and are presented in **Appendix 4-C**.

Physical Monitoring – Habitat Assessments

In addition to detailed hydrogeomorphic surveys, physical monitoring of the Woolper Creek stream network included habitat assessments during both Phase 1 and Phase 2 monitoring, which centered around the quality of in-stream and riparian habitat. The following parameters were included in the assessments:

- Epifaunal substrate/available cover;
- Embeddedness;
- Velocity/depth regime;
- Sediment deposition;
- Channel flow status;
- Channel alteration;
- Frequency of riffles or bends;
- Left/right bank stability;
- Left/right vegetative protection, and;
- Riparian vegetative zones.

An overall score for the habitat condition was established based on the parameters listed above and was used in conjunction with the other assessments listed in this section. In particular, the previous section collected quantitative physical monitoring whereas these habitat condition scores provide monitoring in a more qualitative manner. These assessments were conducted according to standard KDOW methods as specified in the QAPP (e.g., Barbour *et al.*, 1999; KDOW, 2001).

Biological Assessments

Lastly, Phase 1 and Phase 2 monitoring included biological monitoring of benthic macroinvertebrates as well as some fish sampling. Benthic macroinvertebrates are small organisms that live in the bed material of streams such as on the surfaces of cobbles and gravels. They are key indicators of stream health due to their sensitivity to change. In order to capture the diversity of the biological community, the WCWI conducted biological sampling in the spring (Phase 2 monitoring) and utilized SD1's data from early summer months for Phase 1 monitoring. Benthic macroinvertebrate samples were collected, classified, and counted to determine standard metrics such as:

- Genus Taxa Richness;
- Modified HBI;
- Modified %EPT abundance
- %Ephemeroptera;
- Genus Ephemeroptera;
- %Chironomidae+%Oligochaeta, and;
- %Primary Clingers.

These metrics were used to calculate an average Macroinvertebrate Biotic Index (MBI) score, according to KDOW's regionally-specific index (Pond *et al.*, 2003) for the overall site biological condition. The biological assessments were based on the EPA's Rapid Bioassessment Protocols for high gradient streams (Barbour *et al.*, 1999), as adapted for Kentucky, and were collected and analyzed according to industry standard procedures as specified in the QAPP.

3.2.2 Phase 1 Monitoring

As previously mentioned, Phase 1 monitoring included a total of six SD1 monitoring locations - two of the locations having geomorphic surveys, five having water chemistry data, five sites having habitat assessments, and all six having biological assessments. This monitoring data was collected between 2006 and 2011.

Scale

Phase 1 monitoring locations include broad-scale monitoring at the mouth of all subwatersheds as well as a couple additional sites on the main branch of Woolper Creek. With the exceptions of site WPC 1.4, which had a drainage area of 32 mi^2, and site WPC 5.0, which had a drainage area of 24 mi^2, all other monitoring locations were less than 10 mi^2. The average drainage area to the other four monitoring locations was 5.1 mi^2 and ranged from 1.8 to 6.7 mi^2. The Phase 1 SD1 monitoring locations included one site near the mouth of the Woolper Creek at river mile 1.4 (WPC 1.4); sites at the mouths of the three major subwatersheds, Ashby's Fork (ASF 0.0), Allen Fork (ALF 0.1), and Double Lick Creek (DLC 1.0); and two sites further upstream on the Woolper Creek at river miles 5.0 and 8.8 (WPC 5.0 and WPC 8.8). See **Figure 3-5**.

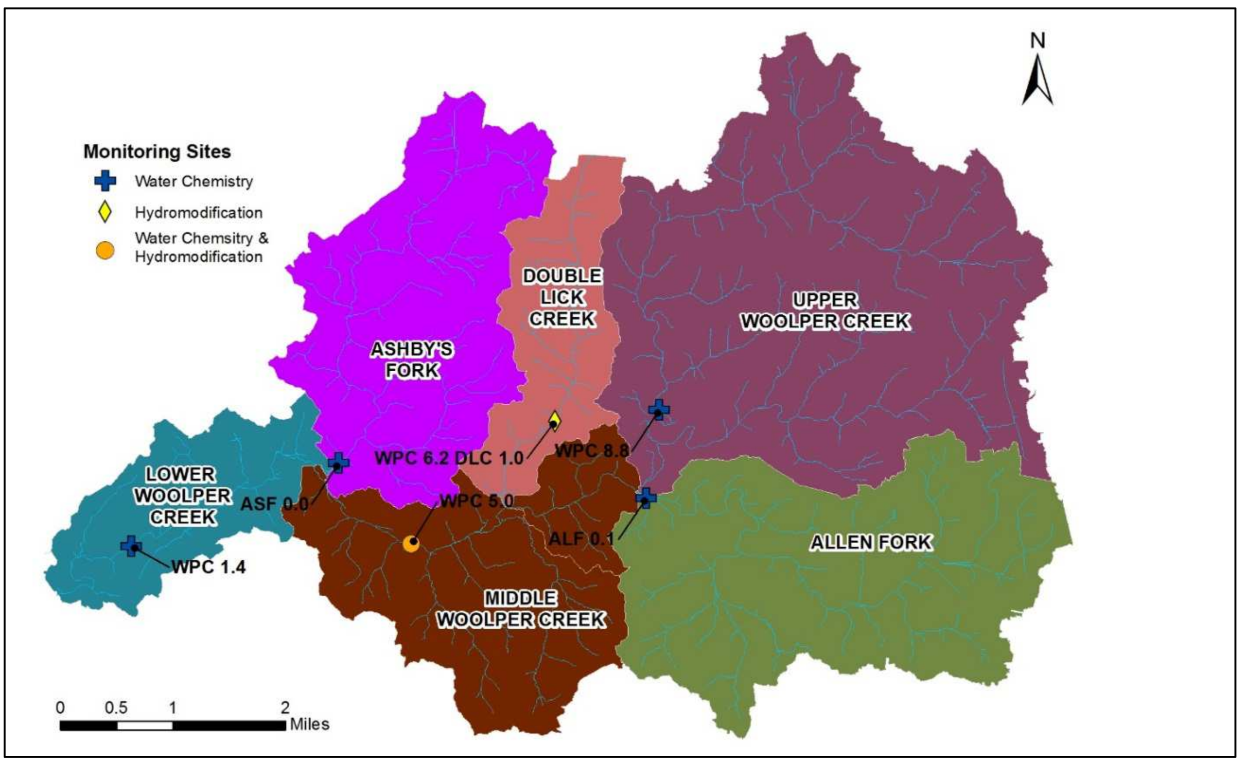


Figure 3-5: Phase 1 monitoring sites

Parameters

To begin to understand stream health, the Phase 1 WCWI monitoring program performed measurements including water chemistry sampling, geomorphic surveys, habitat assessments, and biological (macroinvertebrate/fish) assessments. The water chemistry monitoring data was collected prior to the development of the Woolper QAPP (**Appendix 3-A**); and therefore, not all parameters collected during Phase 2 monitoring were collected during Phase 1 monitoring. However, all samples included as part of the Phase 1 water chemistry monitoring program included measurements of *E.coli*, Fecal Coliform, NN, TP, TKN, TSS, and CBOD. Phase 1 sampling did not include measurements of flow or field measurements such as temperature, pH, specific conductance, turbidity, etc. The parameters measured during the geomorphic surveys, habitat assessments, and biological assessments match those measured during Phase 2 sampling. Section 3.2.1 above presents a summary of each of these monitoring efforts and the Woolper QAPP (**Appendix 3-A**) provides detailed information regarding types of parameters measured as well as procedures and methodology followed for data collection.

Methods

The methods for all water quality sampling were based on KDOW Standard Operating Procedures (SOPs). Hydrogeomorphic surveys were conducted according to SD1 SOPs (SD1, 2009), which are based on industry standard methods used to design the SD1 Hydromodification Monitoring Program. Habitat and biological assessments followed standard SD1 procedures, which follow the *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers* (Barbour *et al*., 1999) while the biological assessments also followed the *Methods for Sampling Benthic Macroinvertebrate Communities in Wadeable Waters* (KDOW, 2009). Reference the QAPP (**Appendix 3-A**) for detailed information regarding the monitoring methods and procedures.

Frequency

SD1 water chemistry monitoring involved sampling in August of 2007 and 2008, as well as several sample events throughout the months of June, September, and October of 2009, amounting to a total of ten sampling events. Hydrogeomorphic surveys were completed in 2008, 2010, and 2011. SD1 habitat assessments were completed in June of 2009 at all Phase 1 sites except site WPC 1.4. SD1 also conducted biological assessments at all Phase 1 sites in 2009. This included both macroinvertebrate and/or fish sampling. Additionally, every spring from 2008 through 2013, SD1 conducted annual habitat and biological (macroinvertebrate) assessments at site DLC 1.0.

3.2.3 Phase 2 Monitoring

While the Phase 1 monitoring data provided a general assessment of the health of the Woolper Creek, the bulk of the WCWI monitoring program included Phase 2 monitoring, which involved a total of ten sampling locations where WCWI conducted water chemistry sampling, hydrogeomorphic surveys, habitat assessments, and biological assessments. Phase 2 monitoring also involved hydrogeomorphic surveys at eight additional monitoring locations, providing a total of 18 sites where WCWI conducted hydrogeomorphic monitoring. Phase 2 monitoring was completed in 2012 and 2013. This provided a more detailed examination of the watershed.

Scale

With the exception of site WPC 1.4, Phase 2 monitoring involved repeat monitoring at all Phase 1 monitoring locations as well as several additional monitoring locations further upstream. Instead of collecting additional water chemistry data at WPC 1.4, which is likely impacted by the backwater of the Ohio River, the WCWI included the SD1 reference site DLC 1.0 as part of the water quality sampling program for Phase 2 sampling. Each subwatershed was divided into smaller catchments to allow a better understanding of the condition of the stream networks, contributing pollutants, and potential sources. Monitoring at a smaller scale provided more detailed data for targeted implementation, which is further discussed in Chapters 5 and 6 of this Watershed Plan. Aside from site WPC 5.0, which has a drainage area of 24.2 mi^2, Phase 2 sampling locations were relatively small, having an average drainage area of 3.8 mi^2 and ranging from 1.8 to 6.7 mi^2. When including the additional eight hydrogeomorphic sampling locations, the average drainage area decreases to 2.6 mi^2 and ranges from 0.31 to 6.7 mi^2. See **Figure 3-6**.

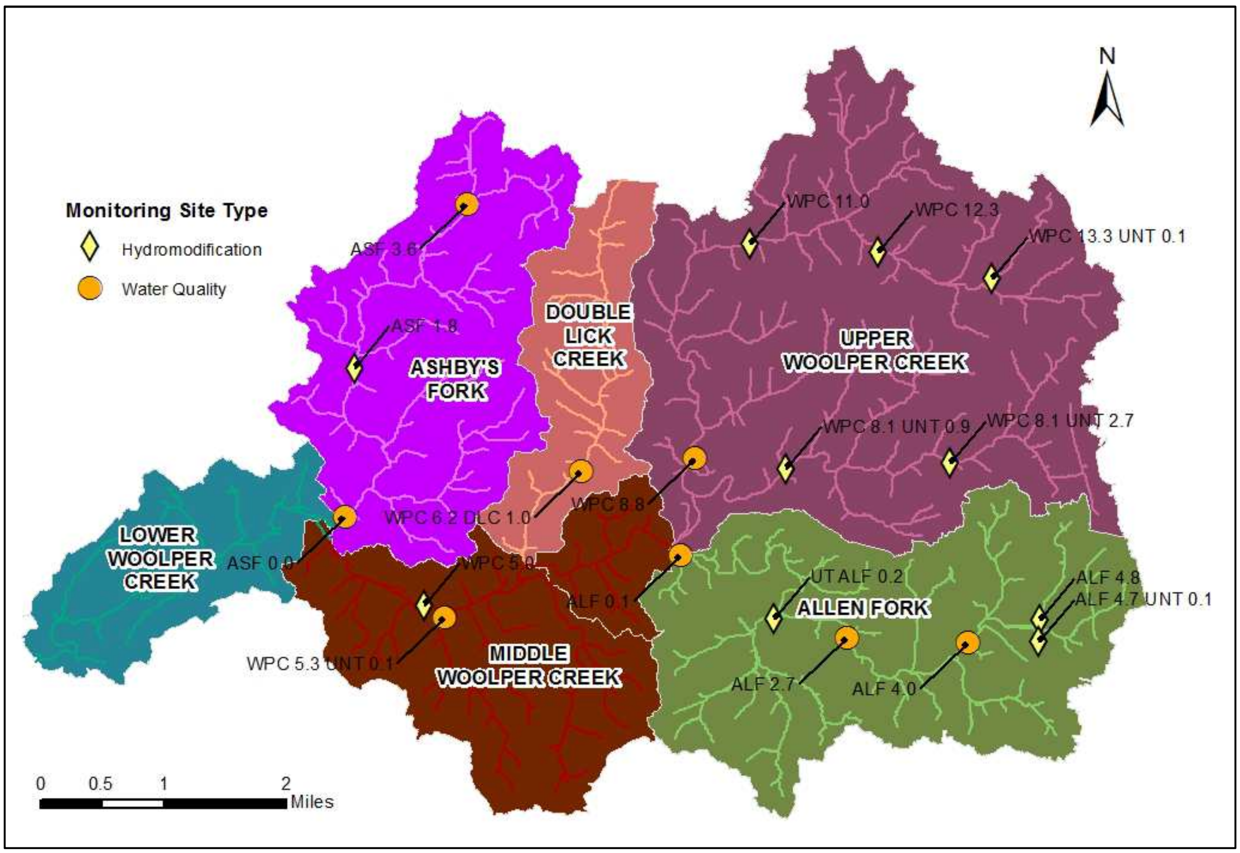


Figure 3-6: Phase 2 monitoring sites

Parameters

As previously mentioned, the WCWI monitoring program measured several aspects of stream health including water chemistry sampling, geomorphic surveys, habitat assessments, and biological assessments. Section 3.2.1 above presents a summary of the parameters measured for each of these monitoring efforts. Additionally, the Woolper QAPP (**Appendix 3-A**) provides detailed information regarding types of parameters measured as well as procedures and methodology followed for data collection.

Methods

The methods for all water quality sampling were based on KDOW SOPs. Hydrogeomorphic surveys were conducted according to SD1 SOPs (SD1, 2009), which are based on industry standard methods used to design the SD1 Hydromodification Monitoring Program. Habitat and biological assessments followed standard SD1 procedures, which follow the *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers* (Barbour *et al*., 1999) while the biological assessments also followed the *Methods for Sampling Benthic Macroinvertebrate Communities in Wadeable Waters* (KDOW, 2009). Reference the QAPP (**Appendix 3-A**) for detailed information regarding the monitoring methods and procedures.

Frequency

In accordance with the Guidebook (KDOW, 2010), the WCWI collected Phase 2 water chemistry samples monthly for 12 consecutive months, and *E.coli* was measured during several additional sampling events to provide an adequate number of samples during the Primary Contact Recreation (PCR) season, which occurs from May 1st to October 31st. The WCWI planned to collect the five additional *E.coli* samples in July of 2012 but could not sample because of low flow conditions. Therefore, in October of 2012 the WCWI collected five *E.coli* samples within ~30 days. This water chemistry monitoring program began in June of 2012 and included a total of 21 sampling events, with seven of the 21 events being for *E.coli* only. **Table 3-3** presents a summary of all the water chemistry sample dates.

Table 3-3: Summary of water chemistry sample dates

Date	Comment
06/29/12	Low flow conditions at some sites
7/12/2012 Ecoli	Low flow conditions at some sites
7/19/2012 Ecoli	Low flow conditions at some sites
07/25/12 Ecoli	Low flow conditions at some sites
08/08/12	Low flow conditions - No Sample
09/06/12	Low flow conditions at some sites
10/2/2012 Ecoli	Did not sample ASF 0.0 or ASF 1.8
10/4/2012 Ecoli	
10/10/2012 Ecoli	
10/11/12	
10/16/2012 Ecoli	
10/18/2012 Ecoli	Sampled only ASF 0.0 and ASF 1.8
11/08/12	
12/05/12	
01/10/13	
02/07/13	
03/28/13	
04/18/13	
05/23/13	
06/20/13	
07/16/13	

Ecoli Only *E.coli* and field data were sampled on these dates.

WCWI conducted two rounds of hydrogeomorphic surveys at 16 of the 18 hydrogeomorphic monitoring sites. Each round of surveys was separated by approximately one year. The other two hydrogeomorphic monitoring sites, which include sites DLC 1.0 and WPC 5.0, were part of SD1's Hydromodification Monitoring Program. Since 2008, SD1 has completed a total of five rounds of surveys at DLC 1.0 and four rounds of surveys at WPC 5.0. For the Phase 2 data analysis the WCWI utilized data collected at DLC 1.0 in both 2012 and 2013. SD1 did not collect hydrogeomorphic survey data at WPC 5.0 in 2012; and therefore, the Phase 2 data analysis utilized data collected in 2011 and 2013.

Habitat and biological assessments were completed in the spring of 2012. In May 2012, the WCWI conducted the assessments at all of the monitoring locations except site DLC 1.0. SD1 completes routine monitoring at this site on an annual basis because it is a reference site in outstanding condition. Therefore, the results of SD1's 2012 assessment, which was conducted in April 2012, were utilized in the data analysis presented in Chapter 4. Overall, biological assessments included data collection at six headwater streams and four wadeable streams. Reference the QAPP for detailed information regarding the monitoring frequency.

Drainage Area: 6.73 square miles

Total Stream Length: 15.94 miles

Main Channel Length (MCL): 5.93 miles

305(b) Overall Use Streams: 0.33 miles per square mile of drainage area

Stream Density: 2.37 miles per square mile of drainage area

Total Road Length: 48.81 miles

Road Density: 7.25 miles per square mile of drainage area

Road/Stream Intersections: 1.9 per mile of stream

Developed Area: 50.1 %

Agriculture: 22.27%

Forest Cover: 17.66%

Tree Canopy Cover: 16.95%

Barren Land Cover: 1.92 %

Land Cover Change (1999-2009) : 19.16%

Wetland Density: 0.01 square miles per square mile of drainage area

Karst Area: 82.57%

Impervious Cover: 14.37%

Average Slope: 10.51%

Average Channel Slope: 38.04 %

Elevation at 10% of MCL: 641.12 feet

Elevation at 85% MCL: 810.23 feet

Elevation Standard Deviation: 38.83 standard deviation

Riparian Area: 0.09 square miles per square mile of drainage area

Riparian Roads: 5.77 miles

Riparian Agriculture: 7.18 %

Riparian Forest Cover: 40.87 %

Riparian Impervious Cover: 5.59 %

Riparian Zone Average Slope : 16.18 %

Riparian Zone Slope Standard Deviation: 14.83 standard deviation

KPDES Permits: 0.25 per mile of stream

Wastewater Outfalls: 0.06 per mile of stream

Package Treatment Plants: 0.06 per mile of stream

Regulated Dams: 0 per mile of stream

Population Density: 1452 persons per square mile of drainage area

Local Parks: 0.01 square miles per square mile of drainage area

* The Woolper Creek watershed has no Animal Feeding Operations, Oil and Gas Wells, or Stewardship Lands

* The mean annual precipitation is 42.5 inches throughout the Woolper Creek watershed basin.

Soil Hydrologic Grouping:

Type A: 0 %	Type B: 0.4 %
Type BD: 2.36 %	Type C: 34.39%
Type CD: 54.64 %	Type D: 7.64 %

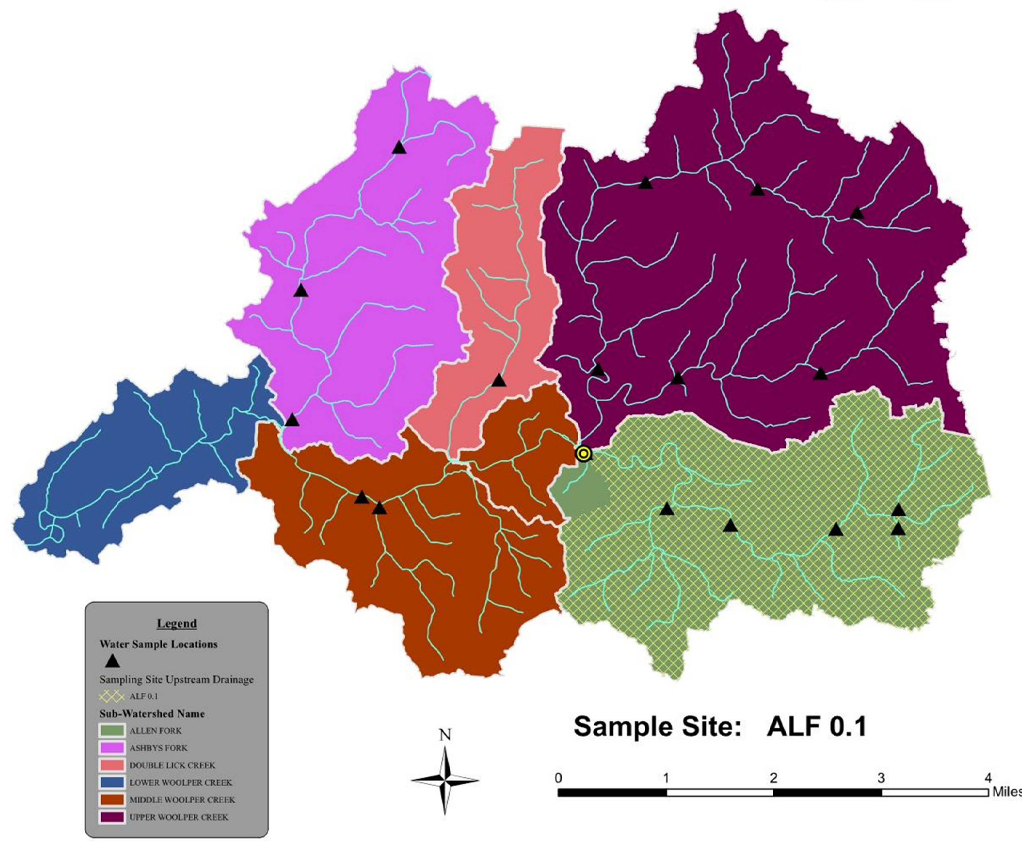


Figure 3-7: Watershed characteristics of the Allen Fork Subwatershed

3.2.4 Other Monitoring Options & Data Used in the Analysis

The water quality analysis utilized several other monitoring data in addition to the aforementioned monitoring information described in the above sections. In particular, the water quality analysis utilized land use data, rainfall data, flow gage data, SD1 Stream Condition Indices, and SD1 Stability Indices.

Land Use Data

As presented in Chapter 2, the WCWI completed a comprehensive inventory of watershed land use characteristics utilizing Geographic Information System (GIS) data provided by the Boone County Planning Commission (BCPC). In addition to the detailed information presented in Chapter 2, the BCPC used its GIS database to compile and summarize pertinent information on a catchment basis - upstream of each monitoring location so it could be analyzed in relation to the water quality sampling results. **Figure 3-7** presents an example of the summarized GIS characteristics and accompanying map for monitoring site ALF 0.1. Maps and GIS characteristics for all other monitoring locations are included in **Appendix 3-B**. Land use is an important element that was analyzed as part of the watershed inventory and applied to the water quality data analysis. The data provided a better understanding of the geospatial characteristics of individual subwatersheds and quantitatively described the geologic, hydrologic, and human impact to the watershed. Reference Section 2.3.2 General Land Use for a breakdown of the land use characteristics by subwatershed. A few key items to remember from Chapter 2 include that although forest is the primary land cover, the Woolper Creek Watershed is 25% developed and both the headwaters of Woolper Creek and the Allen Fork Subwatershed, which are currently the most developed regions of the watershed, are expected to become more and more developed in the future.

Rainfall Data

Rainfall data, collected at the Cincinnati/Northern Kentucky International Airport (CVG) and reported by the National Climate Data Center (NCDC, 2013), was analyzed to classify water quality sampling events as wet weather versus dry weather. As mentioned in Chapter 2, the CVG airport is located directly east of the Woolper Creek Watershed (**Figure 3-8**), within the northeastern portion of the Gunpowder Creek Watershed. Classifications of wet weather versus dry weather sampling events allowed WCWI to analyze variations in pollutant concentrations and understand what might be causing such variations. Concentrations typically fluctuate throughout the sampling period and can sometimes be correlated to precipitation-driven changes and the associated changes in stream flow. Analysis of the rainfall data served as the basis for evaluating the relationship between rainfall, stream discharge, and associated spikes in pollutant concentrations (i.e., wet weather and the "first flush" of pollutants will likely correlate with an increase in pollutant concentration). Classification of wet versus dry weather samples also helps to decipher if water quality issues are related to point or nonpoint sources of pollution because nonpoint source pollution is strongly related to stormwater runoff during wet weather events. This evaluation is discussed in further detail in **Appendix 4-B**.

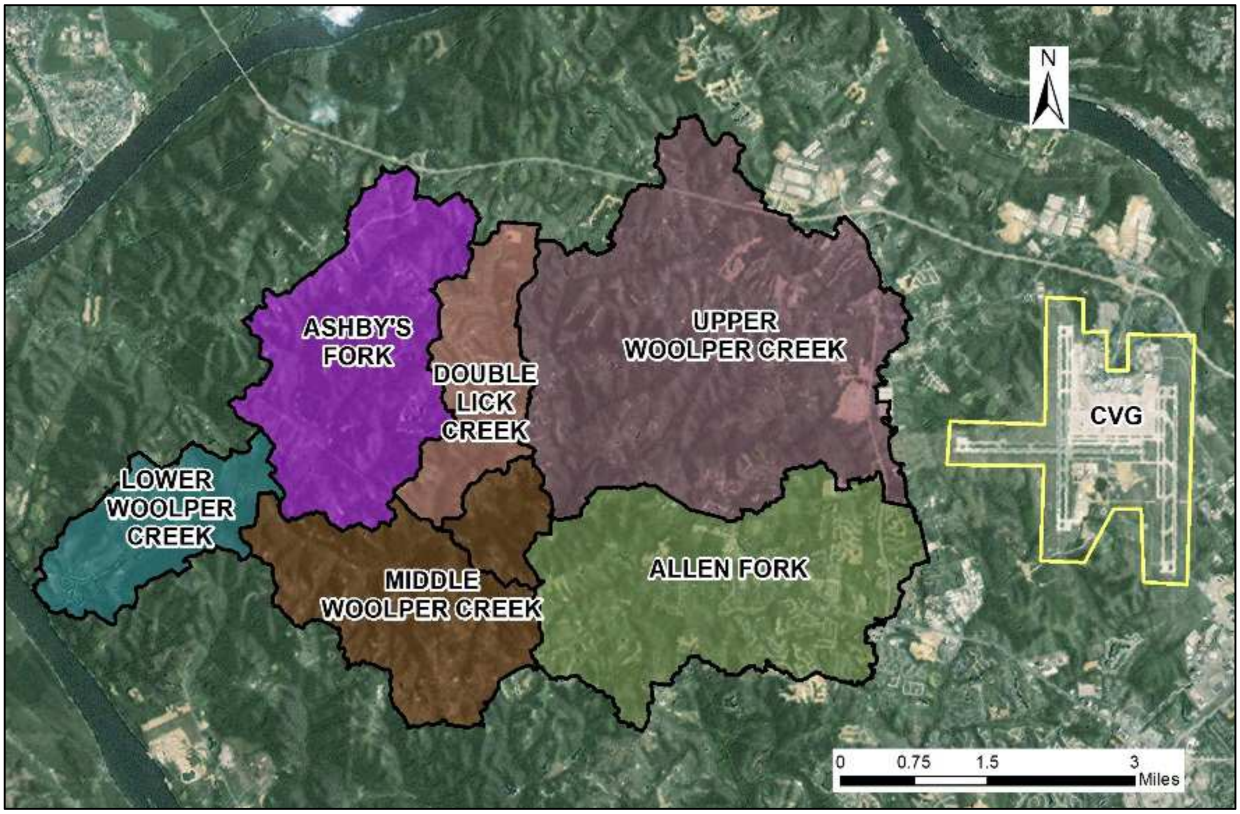


Figure 3-8: Woolper Creek proximity to airport

Flow Monitoring

Stream discharge data are important for calculating pollutant loadings at each sampling site. The WCWI monitoring program involved flow measurements taken during water chemistry sampling events in 2012 and 2013 in order to calculate flow after Rantz *et al*. (1982). This involves depth and velocity measurements at constant interval distances across the stream from a reference point on the shore. The data analysis also utilized flow data from the U.S. Geological Survey (USGS) Gage No. 03262001 for Woolper Creek at Woolper Road near Burlington, Kentucky (**Figure 3-9**) which records flow at 15-minute intervals year round. The gage is sponsored by SD1 and was an invaluable contribution to WCWI because it provided the foundation to create the flow duration and pollutant loading curves presented in Chapter 4.

The WCWI installed pressure transducer data loggers to record water depth information along three tributaries throughout the Woolper Creek Watershed. These data were then processed, analyzed, and summarized to understand trends across varying degrees of urbanization – undeveloped, developing, and developed. The data loggers were installed at the following sampling sites: DLC 1.0 (3% impervious, undeveloped), ALF 0.1 (14% impervious, developing), and ALF 2.7 (21% impervious, developed). Depth information for the three sites was systematically processed and summarized. **Figure 3-9** highlights the flow monitoring locations.

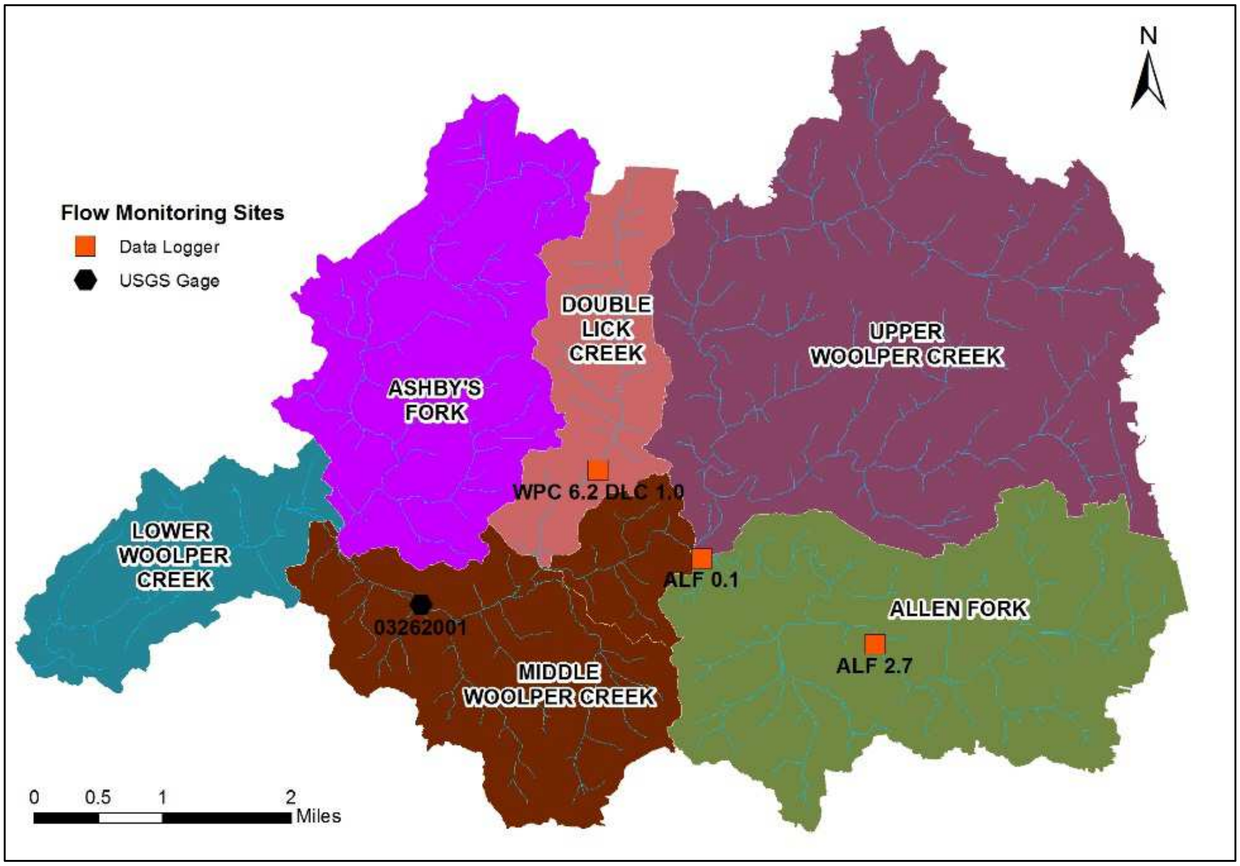


Figure 3-9: Flow monitoring locations

Sanitation District No. 1 of Northern Kentucky Stream Stability Index

Each site had a Stream Stability Index score calculated. The Stream Stability Index (Sustainable Streams, 2012) developed for SD1 utilizes seven physical parameters to evaluate the multi-dimensional effects of hydromodification on stream channels. The parameters are left/right bank stability, cross-sectional shape, bedrock exposure, embeddedness, pool depth, and riffle frequency. During development of the tool, regional stream data was collected and used to calibrate the index, and field testing was performed for verification. The index is on a 0 to 10 scale, with 0 implying the site is very unstable and 10 implying it is very stable.

Please note that a synthesis of the data and results is provided in Chapter 4 with supplemental information provided in the Appendices. Reference **Appendix 3-C** for all of the raw data used in the analysis.

References

Barbour, M.T., Gerritsen, J., Snyder, B.D. and Stribling, J.B., 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: Periphyton, benthic macroinvertebrates and fish. EPA 841-B-99-002, U. S. Environmental Protection Agency, Office of Water, Washington, DC.

Bunte, K. and Abt, S.R., 2001a. Sampling frame for improving pebble count accuracy in coarse gravel-bed streams. Journal of the American Water Resources Association, 37(4): 1001-1014.

Bunte, K. and Abt, S.R., 2001b. Sampling surface and subsurface particle-size distributions in wadable gravel-and cobble-bed streams for analyses in sediment transport, hydraulics, and streambed monitoring. In: F.S. U.S. Department of Agriculture (Editor). Gen. Tech. Rep. RMRS-GTR-74. Rocky Mountain Research Station Fort Collins, CO, pp. 428.

Harmon, W., Starr, R., Carter, M., Tweedy, K., Clemmons, M., Suggs, K., Miller, C., 2012. A Function-Based Framework for Stream Assessment and Restoration Projects. US Environmental Protection Agency, Office of Wetlands, Oceans, and Watersheds, Washington, DC EPA 843-K-12-006.

Harrelson, C.C., Rawlins, C.L. and Potyondy, J.P., 1994. Stream channel reference sites: an illustrated guide to field technique. In: F.S. U. S. Department of Agriculture, Rocky Mountain Forest and Range Experiment Station (Editor). Gen. Tech. Rep. RM-245, Fort Collins, CO, pp. 61.

KDOW, 2001. Methods for Assessing Biological Integrity of Surface Waters, Kentucky Division of Water (KDOW): Draft, Kentucky Department for Environmental Protection, Division of Water, Water Quality Branch, Ecological Support Section, Frankfort, KY.

KDOW, 2009. Methods for Sampling Benthic Macroinvertebrate Communities in Wadeable Waters, Commonwealth of Kentucky, Energy and Environment Cabinet, Department for Environmental Protection, Division of Water, Frankfort, KY.

KDOW, 2010. Watershed Planning Guidebook for Kentucky Communities. Prepared by the Kentucky Division of Water and the Kentucky Waterways Alliance. Frankfort, KY.

LimnoTech, 2009. Woolper Creek Watershed Characterization Report, Prepared for Sanitation District No. 1 of Northern Kentucky, Fort Wright, KY.

LimnoTech, 2013. A Stream Condition Index for Water Utility Resource Management in Northern Kentucky, Prepared for Sanitation District No. 1, Fort Wright, KY.

NCDC, 2013. Local climatological data publications monthly summary of daily temperature extremes, degree days, precipitation and winds: 1947-2012: Covington [CVG]. National Oceanic and Atmospheric Administration, National Climatic Data Center, Asheville, NC.

Pond, G.J., Call, S.M., Brumley, J.F. and Compton, M.C., 2003. The Kentucky macroinvertebrate bioassessment index: derivation of regional narrative ratings for wadeable and headwater streams, Kentucky Department of Environmental Protection, Division of Water, Frankfort, KY.

Potyondy, J. and Bunte, K., 2002. Sampling with the US SAH-97 hand-held particle size analyzer. In: W.E.S. Federal Interagency Sedimentation Project (Editor). Federal Interagency Sedimentation Project, Waterways Experiment Station, Vicksburg, MS, pp. 6.

Rantz, S.E. *et al*., 1982. Measurement and Computation of Streamflow: Volume 1. Measurement of Stage and Discharge, U.S. Geological Survey Water-Supply Paper 2175.

SD1, 2009. Standard Operating Procedures for Hydromodification Field Surveys. Revision No. 1, Sanitation District No. 1, Fort Wright, KY.

Sustainable Streams, 2012. Regionally-Calibrated Channel Stability Index for Northern Kentucky Streams--Preliminary, SD1 of Northern Kentucky, Fort Wright, KY

CHAPTER 4

Analyzing Results

Woolper Creek Watershed Plan

Prepared by the

Woolper Creek Watershed Initiative

October 2016

Chapter 4: Analyzing Results

Understanding existing stream conditions and identifying pollutants of concern as well as potential sources of pollutants has been a critical step in developing the Woolper Creek Watershed Plan. This chapter presents data summarized from SD1's historic water quality sampling locations (Phase 1 sampling) as well as a detailed analysis of the data collected during the WCWI 12-month water quality monitoring program conducted from June 2012 through July 2013, habitat and biological assessments completed in the spring of 2012, and two rounds of hydromodification monitoring (Phase 2 sampling). This information is important for developing strategies to improve the degraded areas of the watershed and protect the areas that are in good condition.

Just as the Phase 2 monitoring program was designed to assess multiple measures of stream health, the Phase 2 analysis is also centered around the stream function pyramid and based upon an integrated approach to watershed planning. As presented in Chapter 3, the stream function pyramid includes land use and land use management, stream flow, physical/habitat conditions, water quality, and finally, biological components – each dependent upon the others, with ecological integrity being dependent upon all components of the pyramid. Rather than analyzing each component in isolation, the data analysis process quantitatively evaluated how each component is interconnected. Analysis of the stream function pyramid components served as the foundation for identifying pollutants of concern, their potential sources, and possible solutions and best management practices (BMPs).

Quantitative analysis of each component of the stream function pyramid and how the elements are dependent on one another served as the basis for this data analysis.

4.1 Understanding the Goal of the Analysis

As one of the leading causes of impairment to stream health across the state of Kentucky, nonpoint source runoff (i.e., stormwater) has greatly influenced water quality and is the primary focus of this Watershed Plan. Urbanization, as well as inadequately managed impervious surfaces (i.e., roads, parking lots, rooftops, etc.), is a a major threat to water quality in the Woolper Creek Watershed because increased development and changes to the land use disrupts the hydrology of the watershed resulting in larger volumes of unfiltered stormwater runoff, which creates a more erosive flow regime that degrades the health of the stream system. Although a large portion of the watershed is forested, increased development throughout the sensitive headwater streams has impacted the water quality of the streams (i.e., erosion/instability, excess sedimentation, degraded biological communities, loss of ecological function, etc.). Furthermore, as mentioned in Chapter 2, the Woolper Creek Watershed is located in Boone County, which is one of the fastest developing counties in the state and one of the top 100 in the nation (US Census, 2009). In addition to the threats of urbanization, agricultural land use, including areas used for cultivated crops and pasture/hay, and areas with onsite wastewater practices are potential sources of pollution in the rural regions of the watershed. The ultimate goal of this analysis was to understand the existing conditions in a way that points to the locations throughout the watershed where implementation of BMPs will be the most practicable, reasonable, efficient, and effective (KDOW, 2010).

4.2 Data Analysis Requirements for 319-Funded Watershed Plans

Streams and rivers are among the most complex of physical systems with multiple interdependent components that impact overall stream health. Streams are systems—their hydrology affects their stability, which in turn affects their water quality and biotic integrity. As explained, in *Chapter 3 – Learning More*, the WCWI designed the monitoring program to assess multiple measures of stream health using flow monitoring, geomorphic surveys, habitat assessments, water quality samples, macroinvertebrate assessments, and land use analysis.

4.2.1 Phase 1 - Analysis

The following section presents summary data from SD1's routine monitoring of sites throughout the Woolper Creek Watershed. These data provided an understanding of the general conditions of the watershed to inform the development of the WCWI Phase 2 monitoring program.

Comparisons of Parameter Concentrations

Parameter concentrations were compared to water quality standards and benchmarks for healthy streams in the Northern Kentucky region, as provided by KDOW. Water quality standards, which provide criteria to protect surface waters, promote aquatic habitat, and safeguard human health, were obtained from Kentucky Administrative Regulations defined in *401 KAR 10:031 - Surface water standards*. The only water quality criteria incorporated in this analysis was the criteria for bacteria, as measured by *E.coli*. KDOW provided benchmark information specific to the Woolper Creek Watershed to be used for many other parameters included in this analysis. These benchmarks are documented in the following reports: *Woolper Creek Watershed Plan Benchmark Recommendations for Nutrient Parameters* (February 2012) and the *Woolper Creek Watershed Plan Benchmark Recommendations for Non-Nutrient Parameters* (February 2012). These reports, which are included in **Appendix 4-A**, provide guidance regarding the benchmarks, which are based on typical values in comparable reference and healthy streams. The WCWI would like to emphasize that the benchmark concentrations are simply estimates for water quality goals to achieve a healthy stream system. These values serve to provide context for the data collected, but are not equivalent to water quality criteria.

To understand the quality of the water in the Phase 1 samples, *E.coli,* total suspended solids (TSS), and total phosphorus (TP) concentrations were compared to allowable concentrations (**Figure 4-1**). The allowable concentration for *E.coli* is the numeric water quality standard of 240 cfu/100mL and the benchmark concentrations for TSS, and TP are 7.25 mg/L, and 0.08 mg/L, respectively. WPC 1.4 was the only site where the mean *E.coli* concentration was at or below the water quality standard however, all TSS sample concentrations were above the benchmark for the same site. As mentioned in Chapter 3, the results from WPC 1.4 have been influenced by backwater from the Ohio River. All mean concentrations for the remaining four sites for both *E.coli* and TSS were measured above the allowable values. The mean TP concentration at each site was measured above the benchmark. From these Phase

1 data, some preliminary conclusions were that *E. coli* concentrations were slightly elevated; TSS ranged mostly above the water quality benchmark and was a slightly greater concern during the Phase 1 review; and nearly every sample of TP was above the benchmark, indicating there may be an issue in the watershed, and would be further evaluated in Phase 2 monitoring.

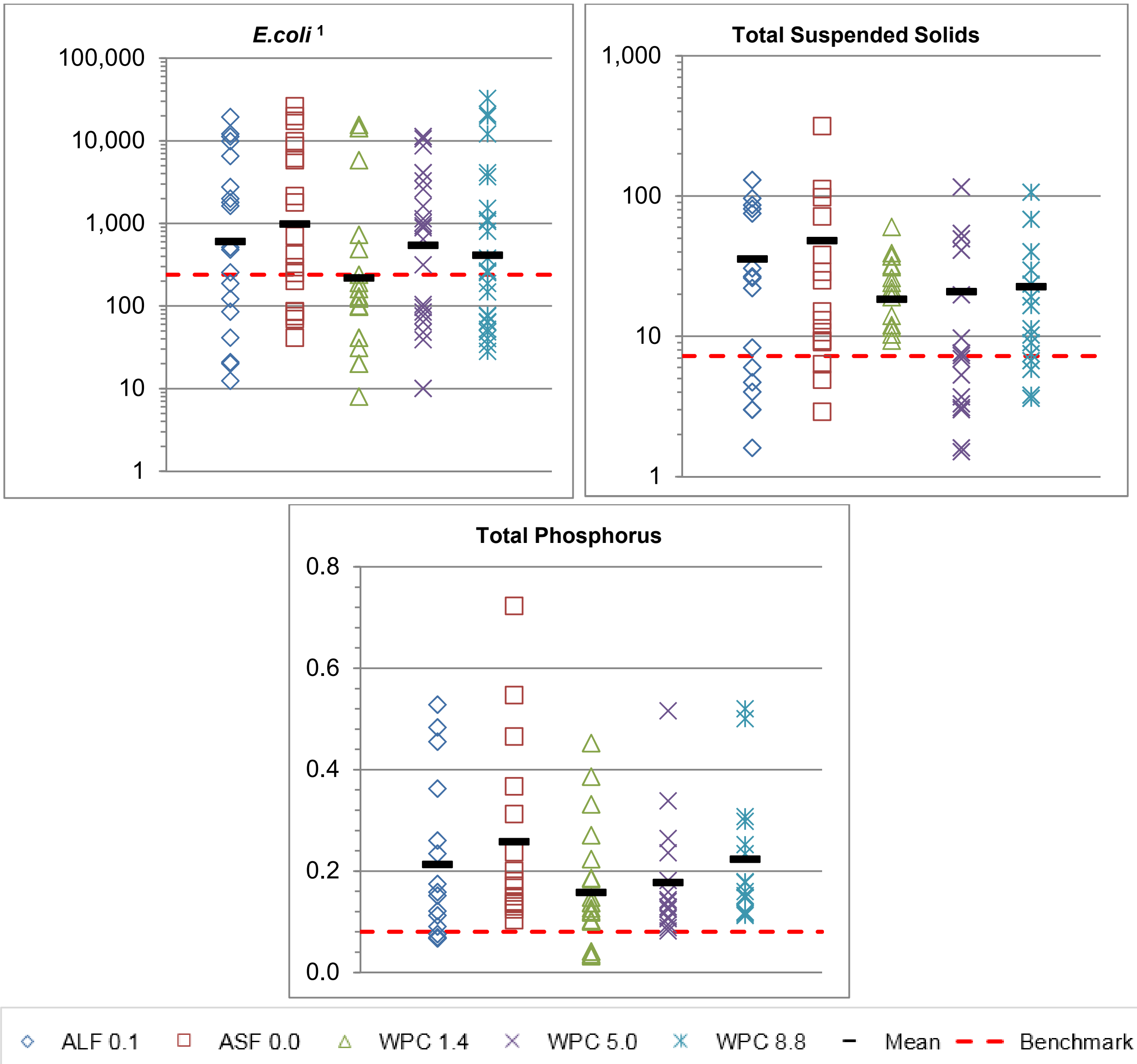


Figure 4-1: Phase 1 water quality sample concentrations collected between 2006 and 2010 by SD1 in the Woolper Creek Watershed.

[1] Mean sample concentrations for *E.coli* were calculated as the geometric mean of the sample concentrations.

Nitrate+Nitrite (NN) and Total Kjehdahl Nitrogen (TKN) were not collected as part of Phase 1 data. Pollutant loads and yields were not calculated for Phase 1 data because this monitoring data did not include flow information.

4.2.2 Phase 1 - Prioritization

Following analysis of the monitoring data, subwatersheds could be evaluated to inform the development of the Phase 2 monitoring program and determine where Phase 2 monitoring should be conducted. All the sites in Phase 1 monitoring, with the exception of WPC 1.4, were selected for Phase 2 monitoring, along with the addition of 13 new sites. Details on why these sites were prioritized, including a comparison of Phase 1 data and site feasibility factors, are discussed below.

Organizing Analytical Data

The analytical data presented in Section 4.2.1 has been organized to assist in categorizing the subwatersheds. Parameter concentrations will be presented in such a way as to work toward the goal of understanding where in the watershed restoration and protection efforts are needed.

Comparisons of parameter concentrations

The following rankings, **Table 4-1**, have been determined based on the analysis of Phase 1 monitoring data (Section 4.2.1). For the period that Phase 1 monitoring was conducted, WPC 5.0 had the most exceedances of the benchmark for *E.coli,* WPC 1.4 for TSS, and ASF 0.0 for TP. The site with the fewest exceedances of the benchmark concentration for both TSS and TP was WPC 5.0, while WPC 1.4 had the fewest exceedances for *E.coli*.

Table 4-1: Phase 1 subwatersheds ranked from the highest to the lowest number of samples exceeding the benchmark.

Ranking	*E.coli*	Total Suspended Solids	Total Phosphorus
1 (highest)	WPC 5.0	WPC 1.4	ASF 0.0[1]
2	WPC 8.8	ASF 0.0	WPC 1.4[1]
3	ASF 0.0	WPC 8.8	WPC 5.0[1]
4	ALF 0.1	ALF 0.1	WPC 8.8[1]
5 (lowest)	WPC 1.4	WPC 5.0	ALF 0.1

[1] Sites have 16 exceedances, creating a tie in the rankings for the most.

Alternatively, the subwatersheds were also ranked based on highest maximum concentration, and the rankings differed from those presented above. The highest maximum *E.coli* concentration was measured at WPC 8.8. In comparison, WPC 5.0 had the lowest maximum concentration. ASF 0.0 had the highest maximum concentration of both TSS and TP, and WPC 1.4 had the lowest (**Table 4-2**).

Table 4-2: Phase 1 subwatersheds ranked from the highest to the lowest maximum concentration.

Ranking	*E.coli*	Total Suspended Solids	Total Phosphorus
1 (highest)	WPC 8.8	ASF 0.0	ASF 0.0
2	ASF 0.0	ALF 0.1	ALF 0.1
3	ALF 0.1	WPC 5.0	WPC 8.8
4	WPC 1.4	WPC 8.8	WPC 5.0
5 (lowest)	WPC 5.0	WPC 1.4	WPC 1.4

Regulatory Status of the Waterway

Chapter 2 presented the stream segments within the Woolper Creek Watershed that are on KDOW's 303(d) List of Impaired Waters, which was based on the *Final 2012 Integrated Report to Congress* on the Condition of Water Resources in Kentucky Volume II 303(d) List of Surface Waters. Portions of the watershed along the Woolper Creek main stem and throughout Allen Fork are impaired for warm water aquatic habitat (not supporting/ partially supporting) and primary contact recreation (not supporting). The primary suspected sources listed by KDOW included unspecified urban stormwater and habitat modification – other than hydromodification. **Figure 4-2** displays the locations of impaired waterways within the watershed; refer to Chapter 2 for a detailed table (**Table 2-3**) on each impaired section and the pollutants of concern, as listed in the Kentucky 303(d) List of Impaired Waters (KDOW, 2012). This table highlights several suspected sources of pollution, including agriculture, illegal dumps/inappropriate waste disposal, urban runoff/storm sewers, impacts from hydrostructure flow regulation/modification, animal feeding operations, habitat modification-other than hydromodification, and unspecified urban stormwater. **Figure 4-2** also highlights Double Lick Creek as an outstanding state resource water and reference reach.

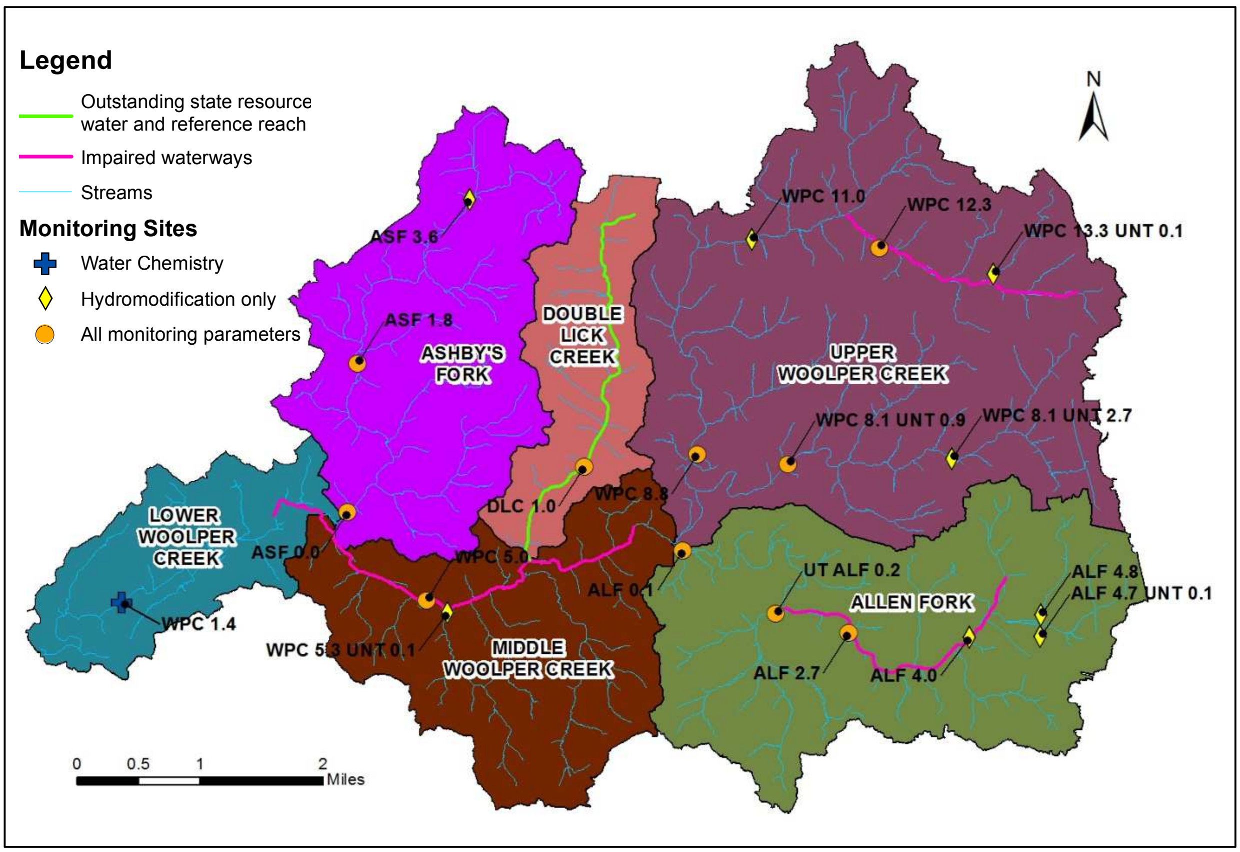


Figure 4-2: Kentucky 303(d) List of Impaired Waters classifications for streams in the Woolper Creek.

Feasibility Factors

It is important to the WCWI that efforts in this watershed make a substantial and long-lasting impact. To identify priority subwatersheds for further monitoring, it was important to review the following factors to identify the feasibility of making an impact on water quality and overall stream health.

Regulatory matters

The WCWI is not aware of any regulatory matters that may hinder the ability of the group to make an impact in any of the subwatersheds. The stream reaches that are listed on KDOW's 303(d) list do not currently have TMDLs in place, however focusing on these subwatersheds may provide a greater benefit if the stream can be delisted prior to TMDL development. As presented in **Figure 4-2**, the reaches include sections of Middle and Upper Woolper Creek as well as the Allen Fork Subwatershed (i.e., Phase 1 monitoring locations WPC 5.0, WPC 8.8, and ALF 0.1). Obtaining additional monitoring data in these areas would be useful. Further information on regulatory matters is discussed in Chapter 5.

Stakeholder cooperation

As listed in Chapter 1, the stakeholders that comprise the WCWI are active and dedicated to improving stream conditions. Focusing efforts in the subwatersheds that are more developed (i.e., Allen Fork and Upper Woolper Creek) may provide stakeholders with projects that would benefit the largest number of people.

SD1, a very involved stakeholder in the WCWI, uses Double Lick Creek as a reference site for the entire Northern Kentucky region. Protecting this site for their continued use would be beneficial, and monitoring data in the subwatershed should be collected during Phase 2 monitoring.

Political will

The Boone County Fiscal Court is a stakeholder for this Plan, which demonstrates their support for improving Woolper Creek. Directing efforts to the most developed portions of the watershed (i.e., Allen Fork and Upper Woolper Creek) and where there are flooding problems (i.e., Upper Woolper Creek and Allen Fork) could garner additional political support, but the WCWI anticipates support regardless of which subwatersheds receive priority.

Available funding

Many of the project partners have already or are willing to donate, whether monetary or otherwise, for the success of the Plan. For example, the Northern Kentucky Stream and Wetland Restoration Program (NKSWRP) has available funding, and selecting subwatersheds that will improve overall water quality and stream health in Woolper Creek will provide the opportunity to use these funds. This program is an in-lieu-fee program established through the Louisville

Figure 4-3: Flooding in the Upper Woolper Creek Subwatershed, downstream of Hebron.

District of the U.S. Army Corps of Engineers, the Northern Kentucky University Center for Environmental Restoration, and the Northern Kentucky University Research Foundation. The program has provided over $10 million of restoration projects throughout the Northern Kentucky region, with more than $2 million spent on restoring the Woolper Creek streams (NKSWRP, 2013).

In addition, implementation funding through BCCD must focus on overall stream health to optimize its own funds. To do this, upstream subwatersheds should be selected for monitoring to better understand the contribution of loads from the developed upstream portions of the watershed.

Areas of local concern

Flooding has been documented in the headwaters of Woolper Creek (e.g., downstream of Hebron, **Figure 4-3**) and in Allen Fork (e.g., the Darlington Farms Subdivision). Residents have concerns about this flooding, and directing efforts to these locations may garner additional support.

Existing priority status

While not evaluated during Phase 1 monitoring, the subwatershed of Double Lick Creek is considered an outstanding state water resource and reference reach by KDOW and is used as a reference site by SD1. It is important to protect this reach as development continues, and Phase 2 monitoring was recommended.

Watershed management activities

NKSWRP has restored the severely degraded mouth of Woolper Creek and the adjacent tributaries via a $1.6 million restoration project covering ca. 15,000 feet of stream and riparian buffers at the Split Rock Conservation Park. Through Wildlife Habitat Incentive Program, Conservation Reserve Program, and Farm Build Incentive Program grant monies, BCCD collaborated with NKSWRP to restore the wetland areas adjacent to the restoration efforts completed by NKSWRP (**Figure 4-4**). NKSWRP has also invested ~$470,000 in Allen Fork to restore 4,400 feet of stream and 0.2 acres of stormwater wetlands. As mentioned, this area of the Woolper Creek Watershed is listed as impaired, and the restoration of stream in this subwatershed aids in working to remove this reach from the 303(d) list. Looking ahead toward additional restoration investments by the Northern Kentucky Stream and Wetland Restoration Fund, several other priority projects have been identified in the Woolper Creek Watershed.

Figure 4-4: Restored wetland area around Stone Creek at the Split Rock Conservation Park.

The Toyota North American Parts Center in Hebron, Kentucky (Upper Woolper Creek Subwatershed) is currently part of a pilot study involving the USEPA, SD1, BCCD and private partners involving an onsite, existing detention basin. The detention basin's outlet control structure has been retrofitted to throttle back small storm events that would normally pass through the basin with minimal detention (**Figure 4-5**). The goal is to minimize the erosion in the receiving stream caused by discharge rates that are higher than pre-development, due to the impervious surfaces in the drainage area. This is accomplished for small storm events while allowing larger storm events to pass through the basin as originally designed. Results have been extremely favorable, showing that the device has the potential to cost-effectively reduce the erosive power of the post-developed flow regime to better match the rates of erosion in undeveloped watersheds. Additional data is being collected on potential water quality benefits.

Figure 4-5: Detention basin retrofit at Toyota site during storm event on June 4, 2014.

Another project completed in the watershed is a detention basin at the YMCA, done in conjunction with SD1 and NKSWRP with an explicit focus on mitigating hydromodification. Additional funding may become available for stormwater management efforts in the subwatershed, specifically within the Darlington Farms Subdivision.

Lastly, NKSWRP constructed a stormwater wetland at Burlington Elementary in the Allen Fork Subwatershed in 2008 (**Figure 4-6**). The projects listed above illustrate that there is vested interest in protecting the Woolper Creek Watershed.

Figure 4-6: Constructed wetland at Burlington Elementary in the Allen Fork Subwatershed.

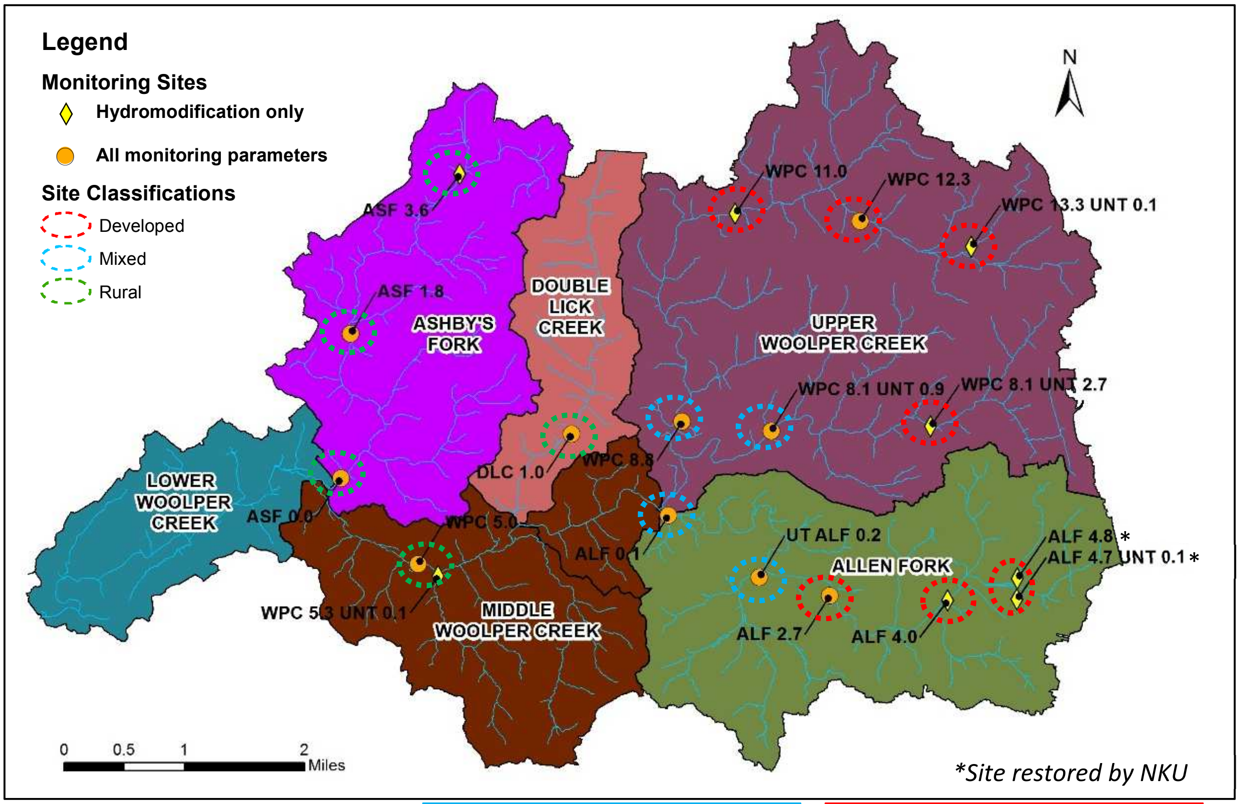
Monitoring considerations

The only site that presented consideration for omission in Phase 2 monitoring was WPC 1.4. This site is in close proximity to the Ohio River and is likely influenced by backwater; for this reason, it was excluded from Phase 2 monitoring. No other site presented any issues during Phase 1 monitoring that would hinder or prohibit the successful completion of Phase 2 monitoring. Additional sites along Ashby's Fork, Allen Fork, and Middle and Upper Woolper Creek were recommended to better understand variability within these subwatersheds. In particular, throughout Northern Kentucky the effects of hydromodification had been documented in streams with developed watersheds, such as coarsened beds, enlarged channels, longer pools, and shorter riffles (Hawley et al., 2013). In coordination with KDOW and other technical subcommittee members, additional "hydromodification" sites were included in the Phase 2 monitoring plan to better understand its extent and severity.

4.2.3 Phase 2 - Analysis

The Phase 2 monitoring data analysis is centered on the elements of the stream function pyramid presented in *Chapter 3 – Learning More.* Before completing the analysis, all of the monitoring data was systematically summarized and processed. **Appendix 4-B** provides details regarding the methodology used to process the rainfall data, flow data, hydrogeomorphic survey data, and water chemistry data. Rainfall data was analyzed to classify water quality sampling events as wet weather versus dry weather. Flow monitoring was processed to generate relationships between the flow at the USGS gage site and the flow at the monitoring sites to ultimately create flow duration curves that were utilized in calculating the pollutant loads. Geomorphic survey data documented the physical changes in the channel, and water chemistry data was processed to generate box and whisker plots as well as pollutant load duration curves.

Data analysis involved an evaluation of the watershed inventory data to relate the results of the monitoring program with land use, and ultimately to identify potential sources of pollutants. The watershed monitoring locations were divided into three categories based on the percent impervious area in each subwatershed. Classifications included developed subwatersheds with percent impervious values ranging from 16 to 42%; rural subwatersheds with percent impervious values ranging from 2 to 5%; and mixed subwatersheds with percent impervious values ranging from 6 to 15% (**Figure 4-7**).



Rural Monitoring Sites
(2-5% Impervious)
ASF 0.0 DLC 1.0
ASF 1.8 WPC 6.2
ASF 3.6 WPC 5.3 UNT 0.1

Mixed Monitoring Sites
(6-15% Impervious)
ALF 0.1 WPC 8.8
WPC 8.1 UNT 0.9 UT ALF 0.2

Developed Monitoring Sites
(16-42% Impervious)
ALF 2.7 WPC 8.1 UNT 2.7
ALF 4.0 WPC 11.0
ALF 4.7 UNT 0.1 WPC 12.3
ALF 4.8 WPC 13.3 UNT 0.1

Figure 4-7: Percent impervious values were utilized to classify each catchment upstream of the monitoring locations as developed, rural, or mixed.

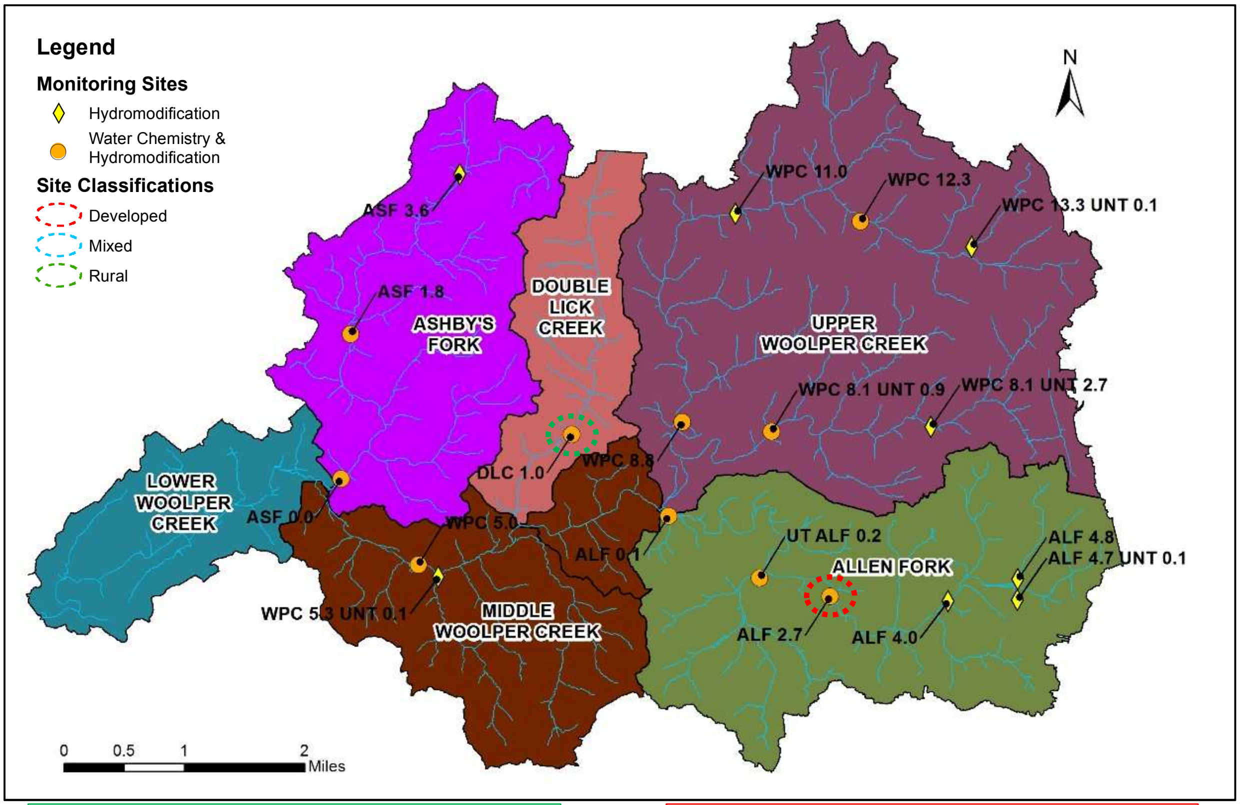
Stream Flow

Alteration to the pre-developed landscape and insufficient management of the stormwater runoff leaving developed lands impacts the natural flow regime. This altered flow regime can cause downstream flooding as well as detrimental impacts to the receiving stream quality. The urban flow regime associated with increased development and inadequately managed impervious area has greatly impacted Northern Kentucky streams (Hawley *et al.*, 2013). For example, extremely erosive flows have been observed during relatively small storm events in Northern Kentucky watersheds. **Figure 4-8** illustrates fast, erosive flows occurring in the

Figure 4-8: Erosive flows during 0.45-inch storm.

Pleasant Run basin, which is about 100 acres in size, after a rainfall event on 11/16/10 that was less than the 2-month storm (magnitude: 0.45 inches; duration: 2 hours; (2-hour, 2-month = 0.81 inches)).

The WCWI evaluated level logger data from three sites throughout the Woolper Creek Watershed – an undeveloped site, a developing site, and a developed site. In **Figure 4-9**, comparison of level logger information from the two sites with the most varying levels of development (i.e., undeveloped against developed) illustrates that the urban flow regime leads to flashier, larger, and deeper flows at the developed site (ALF 2.7, 21% impervious).



Rural Monitoring Site DLC 1.0: 3.0% Impervious

Developed Monitoring Site ALF 2.7: 21% Impervious

Figure 4-9: Level logger data locations for an undeveloped site (DLC 1.0) and a developed site (ALF 2.7).

The WCWI analyzed the water depths relative to the average depth at each site. **Figure 4-10** presents probability distribution function of the standardized water level (calculated by the measured water depth divided by the average water depth) for the two subwatersheds. This exemplifies that the standardized water level at the developed site is greater than the undeveloped site during storms and has lower dry-weather flows, whereas the undeveloped gage shows very little fluctuation in water depth for all but the rarest of flows. Deeper water levels at the developed site increase shear stress, create more erosive power, and increase the possibility for bed material mobility and stream erosion. Evaluation of the 1% exceedance line illustrates the following:

- 1% of the time, the undeveloped site exceeds about 1.5 times the average depth, and
- 1% of the time, the developed site exceeds about 3 times the average depth.

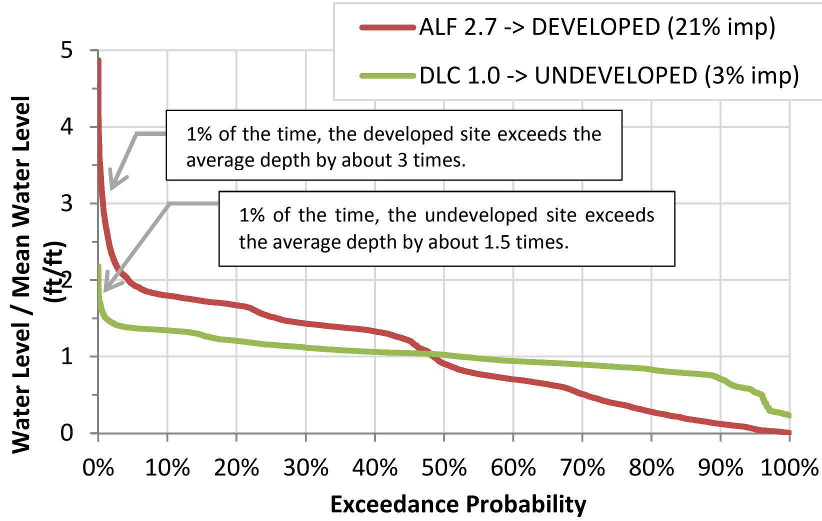


Figure 4-10: Probability distribution function of the standardized water level measured by level loggers at undeveloped and developed monitoring locations.

Further evaluation of the level logger information involved the calculation of the absolute value of relative change in the water level to understand flow variability. As measured in 15-minute increments, the developed site illustrated a much more variable water level than the undeveloped site (**Figure 4-11**). Again, when evaluating the 1% exceedance probability:

- 1% of the time, the undeveloped site has a water level that differs from the previously recorded depth by more than ~2%, and
- 1% of the time, the developed site has a water level that differs from the previously recorded depth by more than ~34%.

Water depths in developed watersheds change much quicker than in undeveloped watersheds.

In summary, the water levels at the developed site changed at rates that were more than 10-fold higher than the water surface in the undeveloped watershed. The larger and flashier flows associated with unmanaged urban development can lead to increased flooding potential, excessive stream erosion, overall channel enlargement/instability that can cause water quality impairments (e.g., high TSS and sedimentation/siltation), and adverse effects on aquatic biota such as fish and macroinvertebrates.

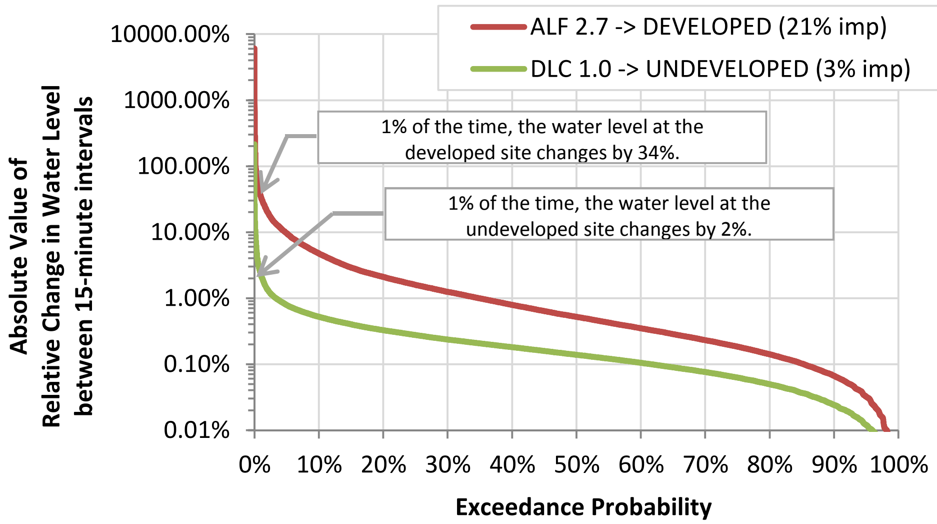


Figure 4-11: Probability distribution function of the water level variability measured by level loggers at undeveloped and developed monitoring locations.

Physical:

Flooding During Small Rain Events Causes Property Damage

The larger and flashier flows discussed in the previous section can cause potential for flooding issues because inadequate management of stormwater runoff from developed areas causes increased peak discharges, volume, and frequency of floods. Such flooding can be hazardous and cause substantial damage to adjacent properties.

The urban flow regime causes flooding as well as streambed erosion and unstable channel conditions.

Flooding is a common occurrence along some of the headwater streams in the Woolper Creek Watershed. A property owner near the hydrogeomorphic monitoring site WPC 13.3-UNT 0.1 frequently expresses concerns about flooding issues during both large and relatively small rain events. For example, the photos in **Figure 4-12** illustrate flooding conditions after a 6-month storm (1.88 inches over 12 hours) on April 19, 2011.

Figure 4-12: Flooding in the developed headwaters of the Woolper Creek near Site WPC 13.3-UNT 0.1 taken ~24 hours after 1.88-inch rain event on 4/20/11.

Erosive Flows Cause Unstable Channel Conditions

Streams are complex systems, and when the flow regime is altered, the stream will respond in an attempt to obtain a new equilibrium with the altered flows. In addition to flooding, the larger and flashier flows discussed in the previous section cause an increase in the erosive power of the stream. Because the flows have increased power to erode the existing streambed material, this causes an imbalance (**Figure 4-13**; Lane, 1955); and therefore, the channel begins to degrade, adjust its geometry, and become unstable. This response, termed hydromodification, is one of the leading sources of impairment in streams across the United States and was a focus of the Woolper Creek Phase 2 monitoring program. First, the bed material composition is altered, as the stones making up the streambed gradually become coarser (Hawley *et al.*, 2013). Transport of streambed material is a natural process, but developed watersheds tend to erode the particles at much higher rates than undeveloped watersheds. As the stream continues to evolve and respond to the increased erosive power of the urban flow regime, the channel then begins to incise and the streambanks start to collapse and widen (**Figure 4-14**).

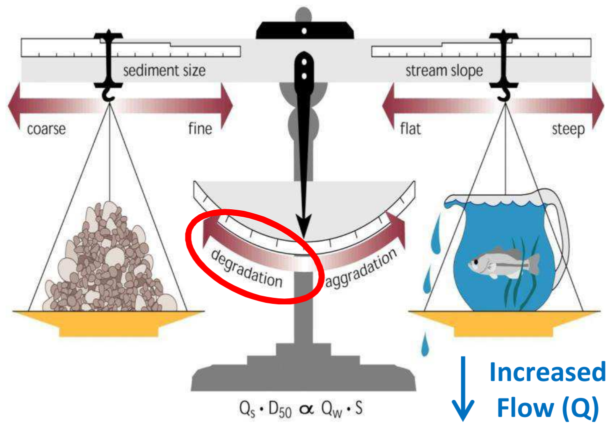


Figure 4-13: The increased flow of the urban flow regime causes an imbalance to the stream system resulting in degradation (Lane, 1955).

Figure 4-14: Channel Evolution Sequence in response to increased flows from urbanization, Adapted from Schumm *et al.* (1984) and Hawley *et al.* (2012).

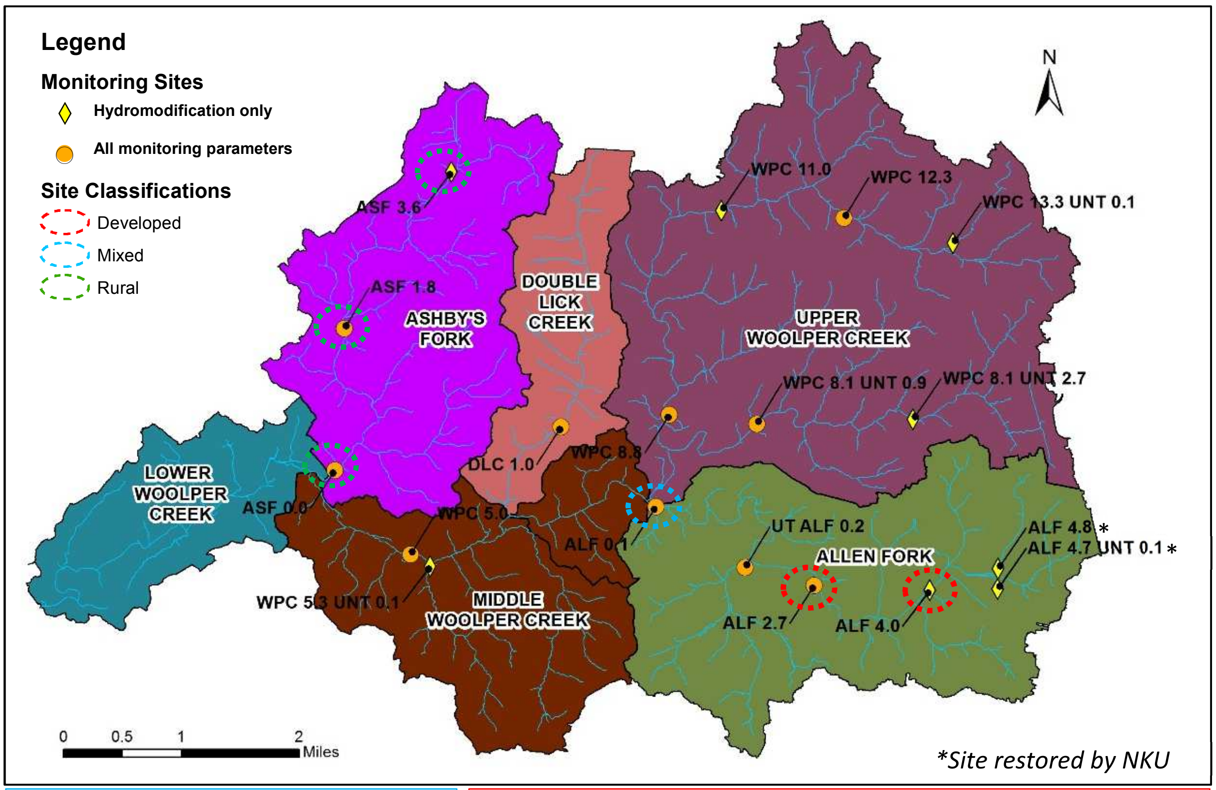
These responses were widely documented in the Gunpowder Creek Watershed monitoring program; a watershed located directly south of the Woolper Creek Watershed that has experienced a greater extent and density of headwater development over longer periods of time than the Woolper Creek Watershed. Stream monitoring in Gunpowder Creek confirmed that bank erosion was a dominant source of sediment, and that sediment (TSS) was the most concerning water quality pollutant, particularly in the developed headwater streams.

In contrast to the Gunpowder Creek Watershed, headwater development of the Woolper Creek Watershed has occurred relatively recently, and the hydromodification and water chemistry monitoring data illustrated that the receiving streams are still in the initial response stages to urban development. Bank erosion and sediment pollution (TSS) were not as prevalent as in Gunpowder Creek; however, hydrogeomorphic surveys documented high bed material instability in the developed headwaters of

Upper Woolper Creek as well as the Allen Fork Subwatershed. Reference **Appendix 4-C** for the Woolper Creek processed hydrogeomorphic monitoring data.

Unstable Conditions were Most Prominent in Developed Watersheds

Again, since the Woolper Creek Watershed is in the earlier stages of development when compared to the Gunpowder Creek Watershed, streambed instability (between Stage 1 and Stage 2 of the Channel Evolution Sequence, **Figure 4-14**) was the most prominent form of unstable conditions observed at nearly all of the developed hydrogeomorphic monitoring sites throughout the watershed (**Figure 4-15**). Sites not circled in the figure had measured changes in the bed material composition that were similar to the minor changes observed at Double Lick Creek (the reference site) and were not considered to be a concern. Sites circled in the figure had substantially greater changes in the bed material composition between sample years than what was observed at Double Lick Creek and were considered unstable.



Mixed Monitoring Site	Developed Monitoring Sites	
ALF 0.1: 14% Impervious	**ALF 2.7:** 21% Impervious	**WPC 11.0:** 17% Impervious
	ALF 4.0: 27% Impervious	**WPC 12.3:** 27% Impervious

Figure 4-15: Bed material instability was observed at many of the developed hydrogeomorphic monitoring locations throughout the Woolper Creek (circled sites).

The bed material composition was extremely active throughout the hydrogeomorphic monitoring locations in the Allen Fork Subwatershed. Beginning with an unstable site in the headwaters of this subwatershed, ALF 4.0 (drainage area: 1.73 mi^2, 23% impervious), the median particle increased nearly 200% from 36 mm to 107 mm (**Figure 4-16**) in just one year. Moving downstream to the next site, ALF 2.7 (drainage area: 3.59 mi^2, 21% impervious), the smaller sediment particles eroded from ALF 4.0 have been transported downstream to site ALF 2.7, temporarily making the bed material at ALF 2.7 slightly finer (**Figure 4-17**). Bed material instability was also observed at the most downstream site in the Allen Fork Subwatershed, ALF 0.1 (drainage area: 6.73 mi^2, 14% impervious), where the 84^{th} percentile particle (d84) increased by 222% in one year.

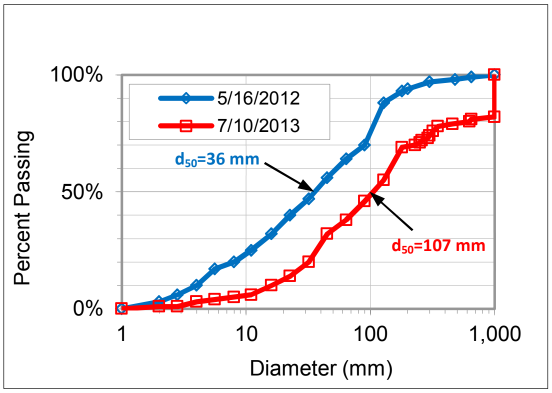


Figure 4-16: Bed material is very active and unstable at developed site ALF 4.0 (1.73 mi^2, 23% impervious).

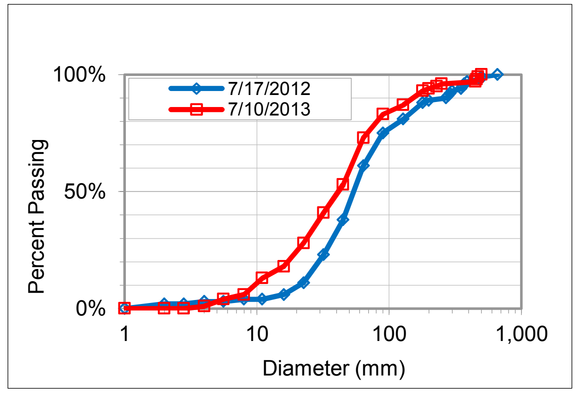


Figure 4-17: Fining of bed material at ALF 2.7 (3.59 mi^2, 21% impervious) is explained by the degrading nature of the reach further upstream (ALF 4.0).

In addition to some of the geomorphic monitoring locations in the Allen Fork Subwatershed, a couple of the sites in the headwaters of Woolper Creek also demonstrated bed material instability. The median particle at WPC 12.3 (drainage area: 1.83 mi^2, 27% impervious), one of the most developed subwatersheds in the upper reaches of Woolper Creek, increased by nearly 100% in one year from 61 mm to 120 mm (**Figure 4-18**). The erosive flow regime has clearly had the power to move even the largest particles (See ~300 mm particles that was mobilized and lodged in a vertical alignment between surveys (**Figure 4-19**)). In contrast, five years of monitoring in the undeveloped watershed of Double Lick (DLC 1.0, drainage area: 1.82 mi^2, 3% impervious) has documented very little change in the bed material composition; for example, the median particle has ranged between 46 mm and 60 mm, and has never changed by more than 20% in any given year (**Figure 4-20**).

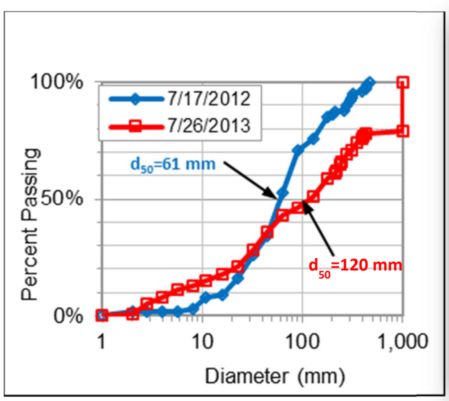


Figure 4-18: Bed material is very active and unstable at developed site WPC 12.3 (1.8 mi^2, 27% impervious).

Figure 4-19: Large particle moved by erosive flows (WPC 12.3).

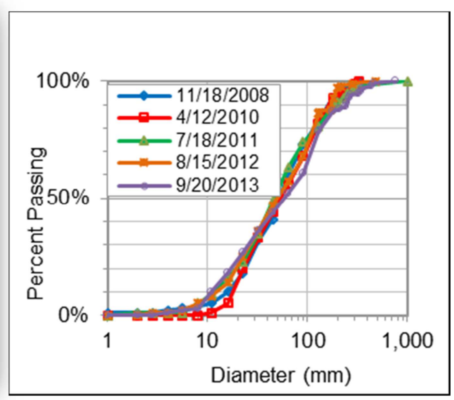


Figure 4-20: Five years of monitoring in the undeveloped watershed of Double Lick illustrate stable conditions.

In addition to bed material instability, hydrogeomorphic monitoring data in the developed headwaters of the watershed also illustrated signs of unstable profile conditions. Particularly at site WPC 11.0 (drainage area: 3.92 mi^2, 17.1% impervious), the pool located just upstream of the cross section location deepened by 44% from 0.41 to 0.59 feet (**Figure 4-21**).

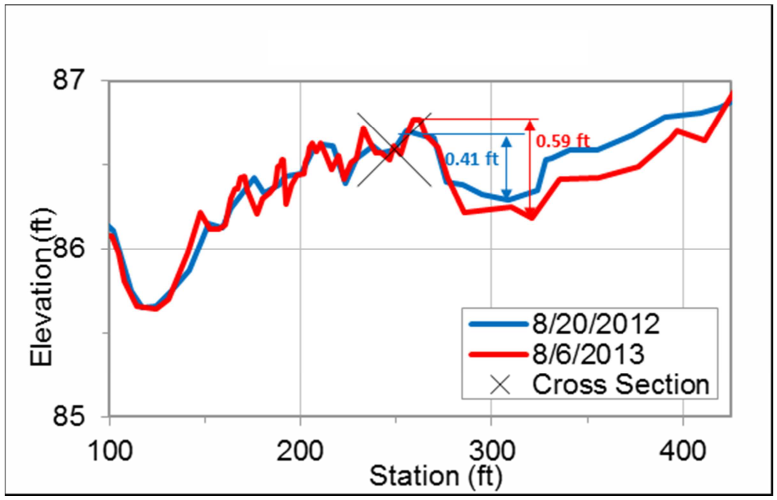


Figure 4-21: Unstable profile conditions were documented in the developed headwaters of Woolper Creek with the deepening of pools.

The Woolper Creek hydrogeomorphic monitoring data illustrates that stream stability tends to decrease substantially in developed watersheds. Moreover, this relationship has also been documented throughout Northern Kentucky. Impervious area has been strongly correlated to channel enlargement, bed coarsening, shorter riffles, and deeper, longer pools in Northern Kentucky streams, as documented in a peer-reviewed study of 40 stream sites (Hawley *et al.*, 2013).

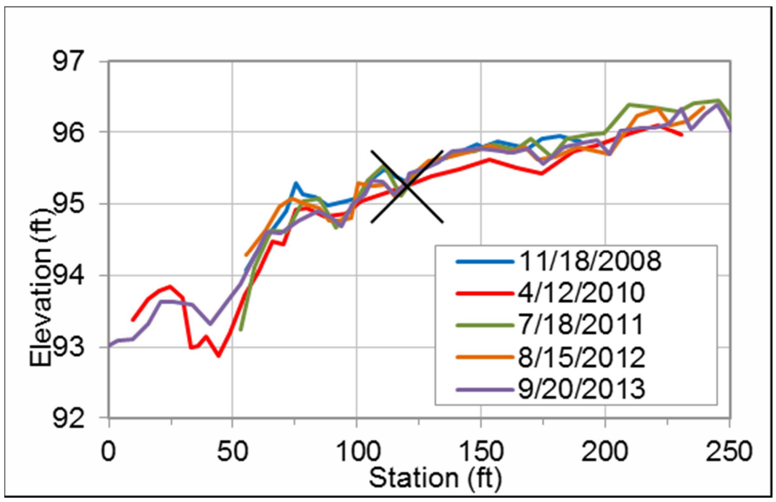


Figure 4-22: DLC 1.0 profile highlights the stability at this reference site.

Many Sites throughout the Watershed Illustrate Stable Conditions

Stable conditions were observed at hydrogeomorphic monitoring locations in the rural subwatersheds (Double Lick Creek and Ashby's Fork) and two reaches in the headwaters of the Allen Fork Subwatershed (ALF 4.8 and ALF 4.7-UNT 0.1) that were restored by the NKSWRP. The flow regime in the rural subwatersheds is more natural and stable than the developed subwatersheds; and therefore, the channel geometry remained consistent between the monitoring years. As previously mentioned, very little change in the bed material composition was observed over five years of monitoring in the undeveloped subwatershed of Double Lick (**Figure 4-20**). The profile geometry at site DLC 1.0 also indicates extremely stable conditions (**Figure 4-22**). Furthermore, stable conditions were observed at the monitoring locations throughout the rural watershed of Ashby's Fork (**Figure 4-23**).

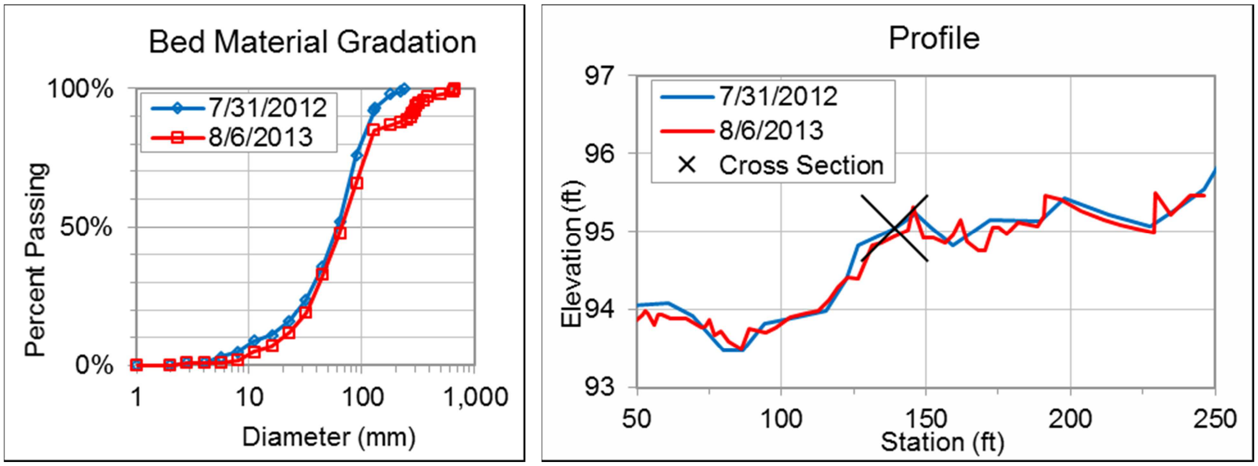


Figure 4-23: Bed material composition and profile for ASF 1.8, located in the rural subwatershed of Ashby's Fork.

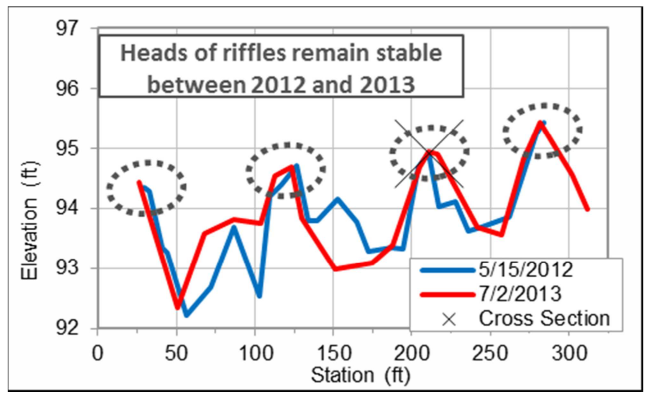


Figure 4-24: Profile of ALF 4.8 highlighting stable heads of riffles between monitoring years.

As discussed above, in 2011 NKSWRP completed two stream restoration projects in the headwaters of the Allen Fork Subwatershed near hydrogeomorphic monitoring sites ALF 4.8 and ALF 4.7-UNT 0.1. Although these sites are located downstream of very impervious catchments (ALF 4.8: 24.8% impervious and ALF 4.7-UNT 0.1: 41.4% impervious), the restoration projects were successful in that the results of WCWI's monitoring efforts illustrate effectively stable conditions. The heads of riffles at these monitoring locations remained stable between each round of hydrogeomorphic survey, allowing the pools to fill in and bed material became slightly finer (**Figure 4-24**). This implies that the NKSWRP projects, at a cost of ~$107 per foot were able to stabilize the stream reach, prevent further downcutting, and serve as a sink for some of the fine sediment that is being transported from unstable reaches. The NKU effort is a clear example of a successful stream restoration project, with direct benefits to the WCWI. The project was also able to count as a local matching investment for the project such that WCWI did not need to raise ~$470,000 in cash resources to make up the required 40% match.

Habitat

Developed, Unstable Monitoring Sites Scored Low on Habitat Assessments

The physical integrity of the stream system strongly impacts habitat conditions.

The physical conditions of the stream, such as bank stability, embeddedness, and frequency of riffles and bends, provide aquatic habitat that is important for microorganisms to thrive. In addition to the geomorphic elements discussed in the previous section, the habitat assessments provided information regarding the physical condition of the streams. Hydromodification monitoring and habitat assessments on sites throughout Woolper Creek have documented that unstable streams degrade aquatic habitat and ultimately, biological activity. This is illustrated through evaluation of the habitat scores (KDOW, 2008) in relation to the unstable conditions observed throughout the developed headwaters, which indicate that the sites with the most degraded habitat conditions (as represented by a low habitat score) also had the most unstable geomorphic conditions. **Figure 4-25** relates the habitat assessment scores to the cross section conditions, as measured by the average change (weighted by point spacing) in bed elevation between the 2012 and 2013 hydrogeomorphic surveys. **Figure 4-26** relates the habitat assessment scores to the bed material conditions, as measured by the average change between the pebble counts performed during 2012 and again in 2013. The dashed green circle in these figures illustrates that the most stable sites that experienced the least amount of change between hydrogeomorphic surveys also scored the highest on the habitat assessments.

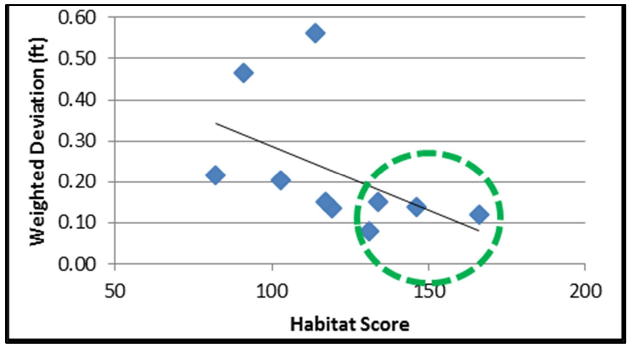


Figure 4-25: Comparison of habitat scores to change in cross section weighted deviation measurements. Green circle identifies sites with the best habitat were the most stable.

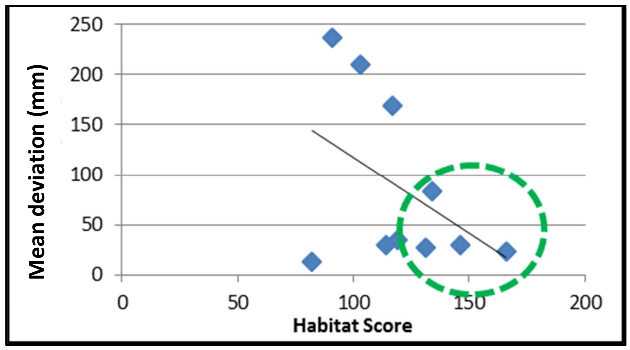


Figure 4-26: Comparison of habitat scores to change in mean deviation of all 100 particles measured at each site. Green circle identifies sites with the best habitat were the most stable.

As previously discussed, the hydrogeomorphic surveys documented unstable conditions in the most developed regions of the watershed. Particularly, bed material instability was observed throughout the Allen Fork Subwatershed as well as much of the headwaters of Upper Woolper Creek, which are the most urbanized regions of the watershed. Unstable bed material conditions substantially impact aquatic life as the erosive urban flow regime transports greater amounts of bed material downstream, leaving fewer particles to form important habitat, such as riffles and pools, for aquatic life. **Figure 4-27** illustrates that the habitat scores tended to be much lower in the developed and mixed-use subwatersheds, with only one rural site exhibiting below average habitat (ASF 0.0). This also indicates that urbanization is the leading cause of water quality impairment in the Woolper Creek watershed. In sum, existing habitat conditions provide valuable information regarding the health of the aquatic community and biological integrity of the stream. Degraded habitat characteristics provide poor conditions for macroinvertebrate communities and therefore also degrade the biological conditions at the sites.

	Site	Habitat Score
Rural	DLC 1.0*	156
	ASF 1.8	119
	ASF 0.0	82
Mixed	WPC 8.1-UNT 0.9	146
	WPC 8.8	134
	UT ALF 0.2	117
	WPC 5.0	114
	ALF 0.1	91
Developed	ALF 2.7	131
	WPC 12.3	103
AVERAGE HABITAT SCORE:		119

*Habitat score provided by SD1

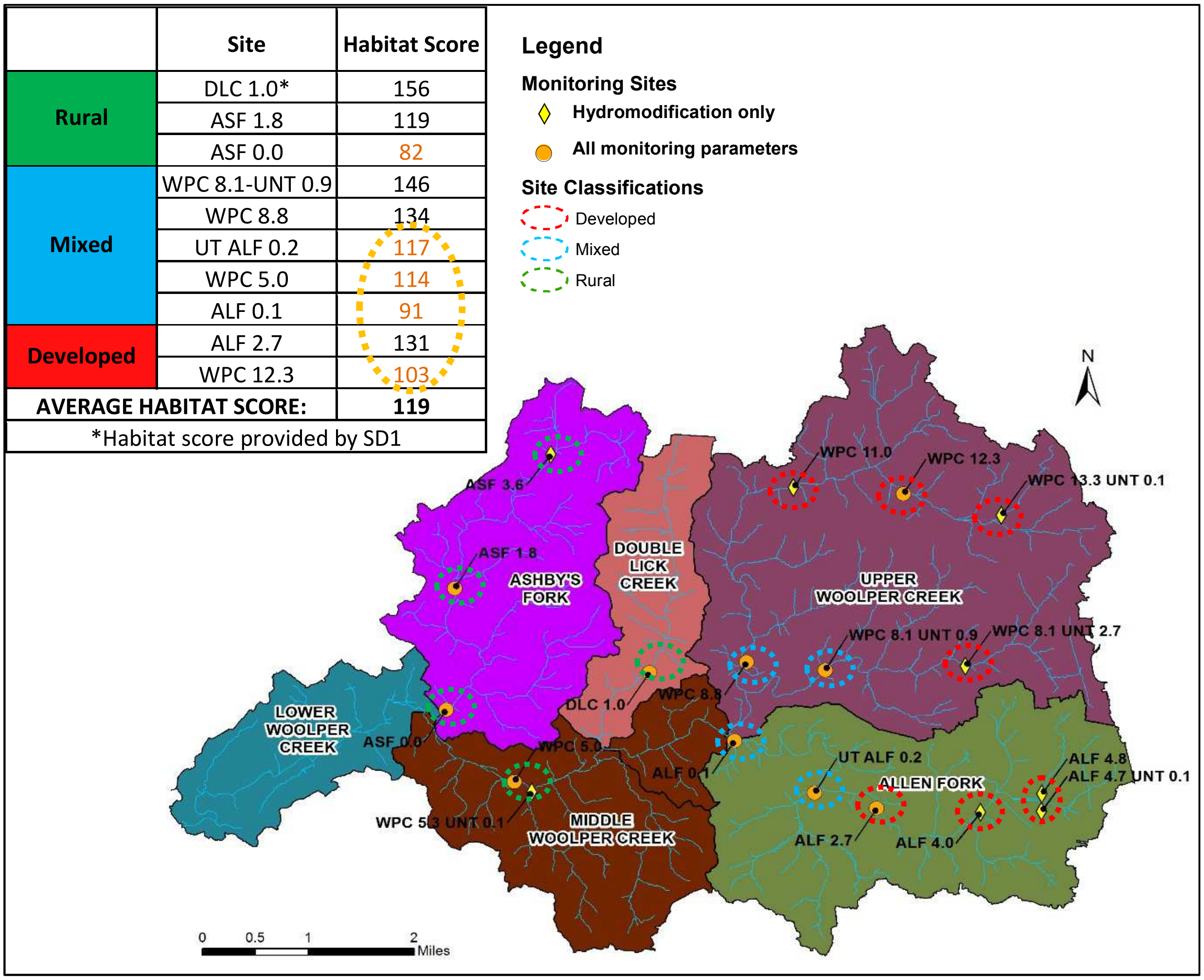


Figure 4-27: Comparison of habitat scores and development at Phase 2 monitoring sites. Many of the developed and mixed sites had below average habitat scores (circled in yellow).

Inadequate Riparian Buffer Zones Negatively Impact the Streams Habitat Conditions

In addition to geomorphic elements, such as bank stability, slope, and a balance of both pool and riffle habitat, elements such as riparian vegetation, floodplain connectivity, natural flow cycles, woody debris, and in-stream aquatic vegetation are all important factors in supporting habitat structure and biological integrity. The WCWI has documented several stream reaches throughout the watershed that are lacking adequate riparian buffer zones (**Figure 4-28**), which partially explains why ASF 0.0 had such a low habitat score even though it was in a rural watershed.

Riparian vegetation is important because it provides numerous health benefits to stream systems. These vegetated areas adjacent to the stream provide valuable habitat for wildlife, aid in capturing nonpoint source pollutants transported by stormwater runoff during wet weather conditions, enhance streambank stability, and improve the aesthetics of the stream. Riparian vegetation is also a source of woody debris, shade, and leaves that provide organic material to the system.

Figure 4-28: Lack of riparian buffer zones along Woolper Creek near site WPC 12.3 (left) and Ashby's Fork near site ASF 0.0 (right).

Water Chemistry

Monitoring results indicate the water quality is near benchmark levels.

In order to further understand the condition of the stream network throughout the Woolper Creek Watershed, the WCWI analyzed Phase 2 water chemistry monitoring data to obtain insight about potential pollutants of concern and possible sources of the pollutants. The data were processed and compared to important factors such as rainfall and stream discharge, and indicated that much of the water quality throughout the Woolper Creek stream networks is near benchmark levels. The following section, as well as supplemental appendices (**Appendix 4-D**: Water Quality Box and Whisker Plots and **Appendix 4-E**: Pollutant Loadings), presents the results of the water chemistry analysis.

<u>*Comparisons of Parameter Concentrations*</u>

The WCWI collated all sample concentrations by water quality parameter, sampling site, and type of sample (wet versus dry and dry7) to evaluate the samples exceeding the water quality benchmark concentrations for healthy stream systems and generate water quality box and whisker plots (**Appendix 4-D**).

a) Water Quality Standards and Benchmarks

As discussed in Section 4.2.1, water quality benchmarks were obtained from various sources. In addition to the established criteria for bacteria, as measured by *E.coli*, criteria for dissolved oxygen and unionized ammonia were used from *401 KAR 10:031 - Surface water standards*. Again, KDOW provided benchmark criteria specific to the Woolper Creek Watershed to be used for all other parameters. For the nutrient benchmark values, KDOW tailored the benchmarks to the watershed by using regional and watershed-specific data, including typical literature values and water samples from 12 ecoregional reference reaches within the Ohio Bluegrass bioregion (ecoregion 71d). Benchmarks and criteria are included in **Table 4-4**.

Considering that the benchmark values used in analysis are likely more stringent than numeric regulatory criteria (if they existed), the load reduction targets could be larger than necessary to restore the streams to levels that would facilitate compliance with their designated uses. However, the dataset is relatively small to be used to determine estimates of more appropriate benchmarks for the Woolper Creek Watershed, especially given the small amount of reference site data. It should be stated that although BCCD and KDOW could discuss more appropriate benchmarks, the small dataset makes this an unlikely option. Considering the level of analysis and guidance nature of benchmark values (i.e., frame of reference and not requirement), the provided benchmarks seem appropriate at this time to help target initial estimates of load reductions related to desired water quality improvements. If additional monitoring data is collected in the future, particularly in the Double Lick Subwatershed during flow conditions, the benchmark values should be reevaluated.

Water quality benchmarks provided approximate goals to uphold a healthy stream system.

Summary of All Sample Concentration Exceedances

First, the WCWI evaluated the sample concentrations of each water chemistry parameter measured at the sampling locations. This initial evaluation did not consider statistical outliers in the dataset as determined in the water quality box plot figures nor did it look at the concentrations in relation to the stream discharge, or pollutant loads. WCWI evaluated the sample concentration datasets as a whole and also analyzed the samples based on their characterizations regarding rainfall data (wet, dry, or dry7 sampling events). Dry7 is defined as an event with less than 0.01 inches of rain occurring within the 7-day period before the sampling event, however when reviewing these data, the dry7 information should not be considered as a definite representation of dry conditions because in several cases this is based on only one sampling event. Reference **Appendix 4-B** for additional information regarding the methodology for processing the raw data used in this analysis. **Table 4-3** presents the percent of water quality samples that exceeded the benchmark or criteria set for each individual parameter. Sample exceedances that were greater than 80% are identified in red (most concerning) and all sample categories with less than 30% exceedance are identified in green (least concerning).

These results indicate that TSS, Nitrate-Nitrite as N (NN), Unionized Ammonia (Union Amm), and Dissolved Oxygen (DO) were the least concerning pollutants measured. TP and Total Kjeldahl Nitrogen (TKN) were typically always above the water quality benchmarks; however, this may be more of a reflection of the benchmark levels being too low for the region as opposed to nutrients being a true cause for concern. As evident throughout this section, the degree of TP and TKN benchmark exceedances is relatively low (typically ~1-2 times the benchmark levels), and measurements at most sites were within the same range of those observed at DLC 1.0, which is ranked by KDOW as an outstanding state resource water and supports some of the most diverse biological communities in the region. Specific conductivity was also typically above the benchmark, and although pollutant loads are not calculated for this parameter, any future monitoring should continue to collect this data.

Table 4-3: Percent exceedances above water quality benchmark concentrations.

Parameter:		TSS	Turbid[4]	TP[3]	TKN[3]	NN	Union Amm	DO	SpCon[4]	*E.coli*
Benchmark:		7.25 mg/L	8.3 NTU	0.08 mg/L	0.3 mg/L	0.3 mg/L	0.05 mg/L	**4** mg/L	522.5 µS/cm	**240** colonies/100mL
ALF 0.1	**All**	25%	25%	42%	83%	17%	8%	0%	60%	32%
	Dry7[2]	100%	50%	100%	100%	0%	0%	0%	50%	0%
	Wet	33%	40%	67%	67%	33%	0%	0%	40%	80%
	Dry	13%	9%	25%	88%	13%	13%	0%	73%	18%
ALF 2.7	**All**	8%	21%	58%	100%	25%	17%	5%	61%	53%
	Dry7[2]	100%	33%	100%	100%	0%	100%	33%	100%	67%
	Wet	0%	60%	100%	100%	67%	0%	0%	20%	80%
	Dry	0%	0%	38%	100%	13%	13%	0%	70%	36%
ASF 0.0	**All**	42%	32%	100%	58%	8%	8%	26%	79%	50%
	Dry7[2]	0%	33%	100%	100%	0%	100%	100%	100%	50%
	Wet	33%	25%	100%	33%	33%	0%	50%	100%	75%
	Dry	50%	33%	100%	63%	0%	0%	0%	67%	42%
ASF 1.8	**All**	50%	58%	100%	50%	25%	8%	0%	84%	28%
	Dry7[2]	100%	100%	100%	100%	0%	0%	0%	100%	50%
	Wet	67%	50%	100%	67%	67%	0%	0%	100%	50%
	Dry	38%	50%	100%	38%	13%	13%	0%	75%	17%
UT ALF 0.2	**All**	50%	61%	83%	92%	58%	17%	22%	59%	56%
	Dry7[2]	100%	50%	100%	100%	0%	100%	100%	100%	0%
	Wet	0%	100%	67%	100%	33%	0%	20%	60%	100%
	Dry	63%	45%	88%	88%	75%	13%	9%	50%	45%
WPC 12.3	**All**	17%	15%	58%	100%	33%	33%	10%	100%	74%
	Dry7[2]	100%	25%	100%	100%	0%	100%	25%	100%	100%
	Wet	0%	20%	33%	100%	33%	0%	0%	100%	80%
	Dry	13%	9%	63%	100%	38%	38%	9%	100%	64%
WPC 5.0	**All**	17%	25%	67%	75%	17%	8%	10%	74%	47%
	Dry7[2]	0%	0%	100%	100%	0%	100%	50%	100%	100%
	Wet	0%	50%	67%	67%	33%	0%	0%	75%	75%
	Dry	25%	25%	63%	75%	13%	0%	0%	64%	25%
DLC 1.0[1]	**All**	17%	32%	100%	67%	25%	17%	21%	74%	39%
	Dry7[2]	0%	0%	100%	100%	0%	100%	100%	100%	50%
	Wet	0%	40%	100%	100%	33%	0%	20%	100%	80%
	Dry	25%	36%	100%	50%	25%	13%	0%	55%	18%
WPC 8.1-UNT 0.9	**All**	33%	70%	0%	0%	0%	0%	25%	60%	61%
	Dry7[2]	100%	75%	100%	100%	0%	100%	100%	50%	0%
	Wet	0%	80%	100%	100%	67%	0%	20%	40%	80%
	Dry	38%	64%	75%	88%	50%	25%	0%	73%	64%
WPC 8.8	**All**	33%	47%	83%	92%	50%	17%	11%	68%	50%
	Dry7[2]	100%	100%	100%	100%	0%	100%	67%	100%	50%
	Wet	0%	60%	100%	67%	67%	0%	0%	40%	100%
	Dry	38%	27%	75%	100%	50%	13%	0%	73%	27%

[1]DLC 1.0 is considered an outstanding state resource water and reference reach by KDOW, is used as a Reference Site for SD1's routine monitoring, and supports some of the most diverse biological communities in the region.
[2]Dry[7] defined as an event with less than 0.01 inches of rain occurring within the 7-day period before the sampling event
[3]TP and TKN exceedances is relatively low (typically ~1-2 times the benchmark levels), and measurements at most sites were within the same range of those observed at DLC 1.0.
[4]Turbidity has been abbreviated to Turbid and specific conductance has been shortened to SpCon.

b) Water Quality Box and Whisker Plots

The WCWI created water quality box and whisker plots (**Appendix 4-D**) to evaluate the range of concentrations, statistical outliers, and the relation to the water quality benchmarks. These figures provide a visual observation of the range of concentrations for all samples as well as samples in the wet, dry, and dry7 categories. In addition to displaying a range of sample concentrations, each box and whisker plot depicts statistical outliers, the mean concentration for each category, and the overall relation to the water quality benchmark or criteria set for that parameter. **Figure 4-29** and **Figure 4-30** present examples of the box and whisker plots included in **Appendix 4-D**. Occasionally high samples were observed at most sites, but these tended to be statistical outliers, as represented by the circles on the water quality box and whisker plots. These values should not be dismissed but we understand the potential that they could be anomalies. For example, **Figure 4-29** illustrates how overall, the average *E.coli* concentrations were near benchmark values, except at site WPC 12.3 in the headwaters of Woolper Creek. Two sites in the Allen Fork Subwatershed, sites UT ALF 0.2 and ALF 4.7 also had mean concentrations that were slightly above the *E.coli* benchmark, and review of **Figure 4-30** (sample ranges by wet, dry, and dry7) suggests that *E.coli* concentrations within Allen Fork are most concerning during the wet weather events, but are still generally within one order of magnitude of the benchmark.

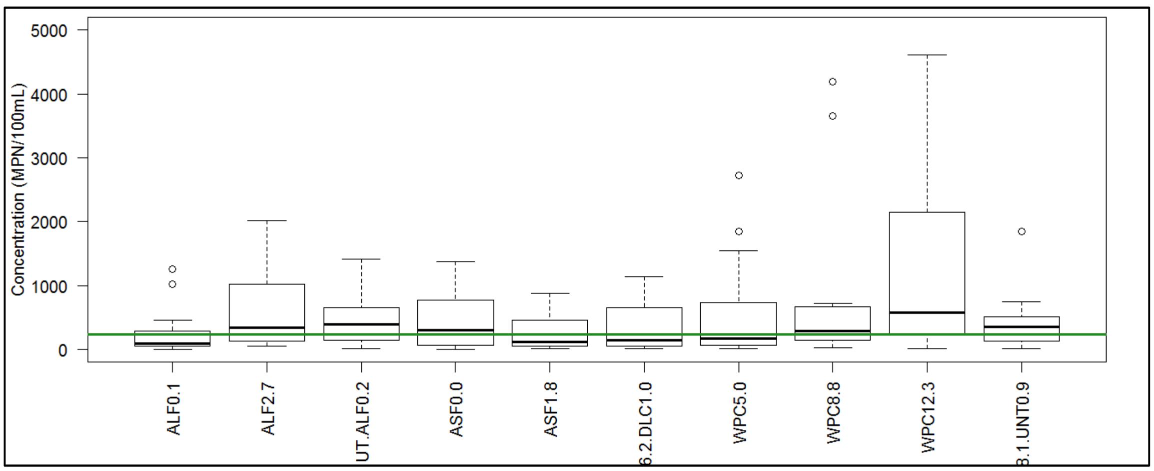


Figure 4-29: *E.coli* sample concentrations at all sites (green line represents water quality standard: LN(240 colonies/100mL)).

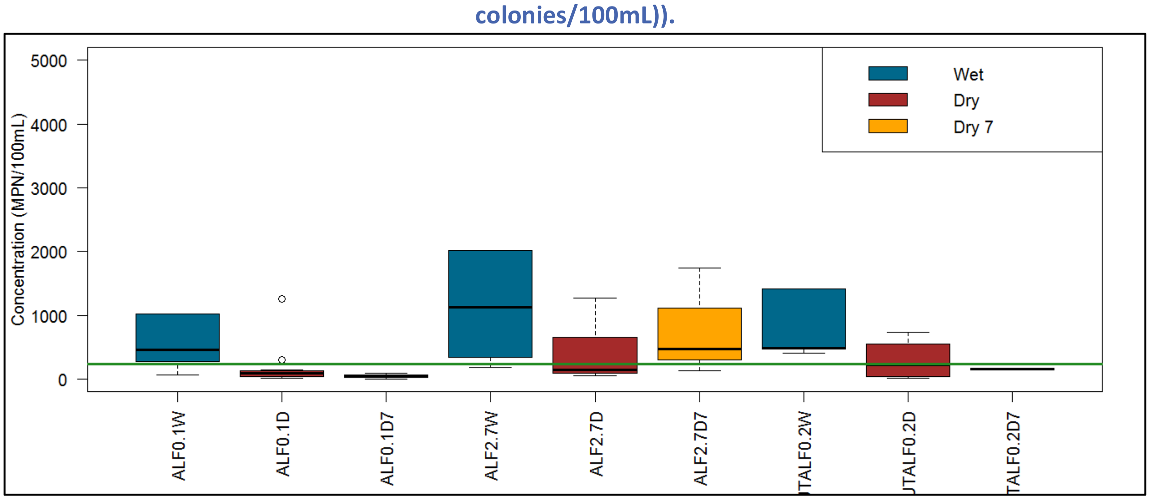


Figure 4-30: *E.coli* sample concentrations at Allen Fork sites during wet and dry weather conditions (green line represents water quality standard: LN(240 colonies/100mL)).

Comparisons of Pollutant Loads

The water chemistry analysis also involved calculation of pollutant loads as well as the creation of pollutant load duration curves. A pollutant load converts a concentration to a value that is comparable independently of the flow, providing the amount of a specific pollutant being transported by the stream with units of weight per period of time (i.e., lbs/day). As a value independent from flow, pollutant loads can be compared across watersheds (KDOW, 2010). Using these data, the relationship between stream flow, pollutant loading capacity, and the frequency and magnitude of exceedances in water quality benchmarks can be determined.

The water quality analysis used the pollutant loads to develop pollutant load duration curves for bacteria (*E.coli*), TSS, and nutrients (TP, TKN, NN) at all water quality monitoring sites. These curves highlight the relationship between exceedances in water quality benchmarks and flow conditions (e.g., high flow vs. low flow conditions, wet weather vs. dry weather conditions), as well as estimate of overall pollutant loads and yields. **Figure 4-31** presents the *E.coli* load durations at WPC 12.3; the remaining pollutant load duration curves are located in **Appendix 4-E**. As mentioned previously, benchmarks serve as guidance for achieving water quality levels that should be supportive of aquatic life but they are not necessarily representative of an exact threshold between supportive and non-supportive conditions. The threshold between supportive and non-supportive conditions is represented by the numeric criteria whereas the benchmarks included in the analysis are just estimates. Therefore, these graphs are meant to provide a sense of scale for the pollutants in each subwatershed, not to set load reductions to achieve water quality targets.

Pollutant load duration curves also serve in estimating the total annual pollutant loads. In **Appendix 4-E**, projected annual pollutant loads, annual benchmark pollutant loads, and the percent difference for each parameter has been included. Determining the ratio of the projected load to the benchmark load provides information on the degree of exceedance for each pollutant, where a value greater than one indicates an exceedance of the benchmark. The ratios of total annual load to annual benchmark are presented in **Figure 4-32** for each parameter at each water quality monitoring site. This figure illustrates that generally, with the exception of two sites (WPC 12.3 and UT ALF 0.2); the pollutant loads for *E.coli* and TSS are near or below benchmark values. The figure also illustrates that nutrient loads were slightly above benchmark levels at all sites, even DLC 1.0, which is considered an outstanding state resource water and reference reach by KDOW and used as a reference site for SD1's ongoing monitoring program in Northern Kentucky.

Pollutant loads are at or near benchmark values for all but two sites, WPC 12.3 and UT ALF 0.2.

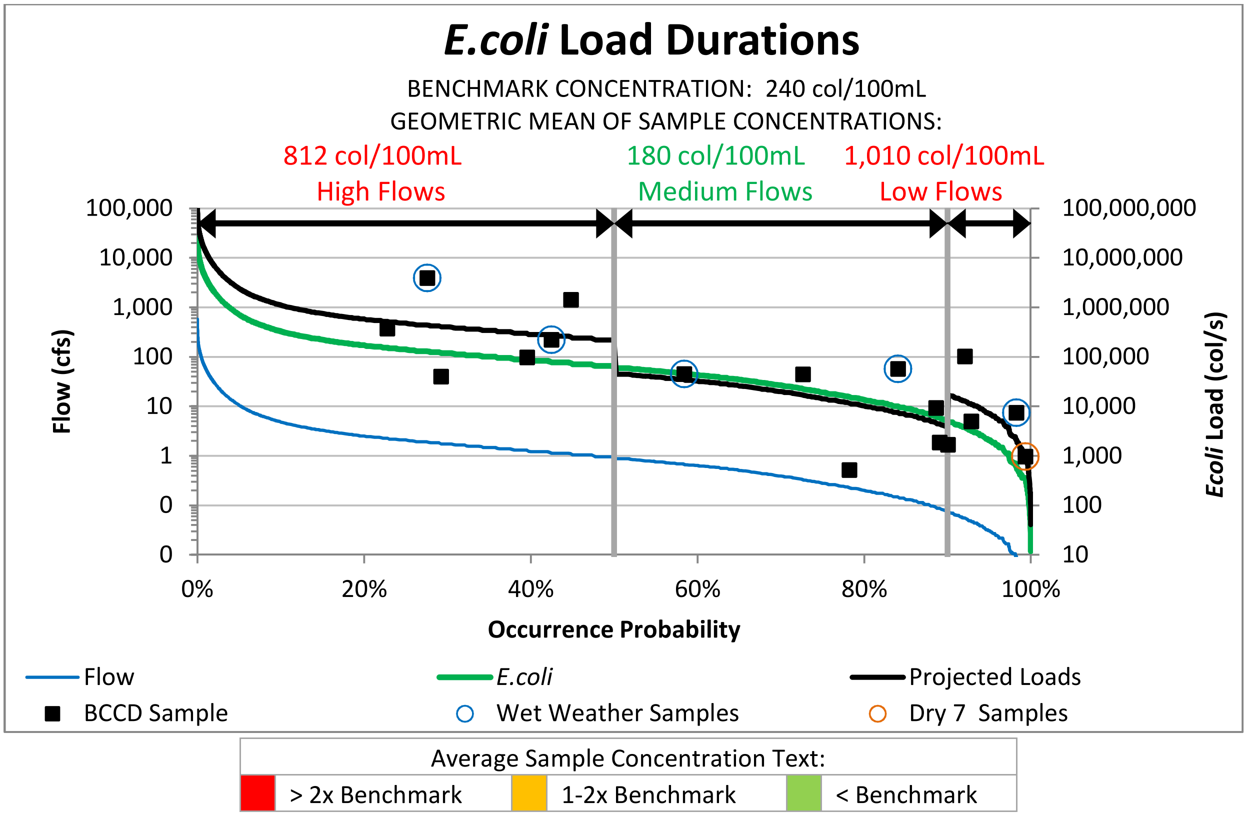


Figure 4-31: *E.coli* load durations at developed site WPC 12.3 (27.3% impervious).

Note: This load duration approach is meant to provide estimates of the scale of the problem, or lack thereof, in each subwatershed and is not intended to represent precise loads. Values listed above each flow category represent the geometric mean of the concentrations sampled within that flow category.

The next four figures illustrate the pollutant load ratios at each monitoring location for the pollutants of bacteria (*E.coli*), sediment (TSS), phosphorus (TP), and nitrogen (NN and TKN). First, **Figure 4-33** illustrates that the annual pollutant loads for *E.coli* are generally near benchmark levels at many of the sites, except WPC 12.3. **Figure 4-34** illustrates that sediment loads are below the benchmark. As previously discussed, although phosphorus levels are slightly above benchmark levels at all sites (**Figure 4-35**), the only site that departs from the range of the reference site levels at DLC 1.0 is UT ALF 0.2. Lastly, **Figure 4-36** illustrates that nitrogen levels tend to be near or slightly above the benchmark levels at all of the sites including DLC 1.0, indicating that the established nutrient benchmarks may be more conservative than background conditions in this region.

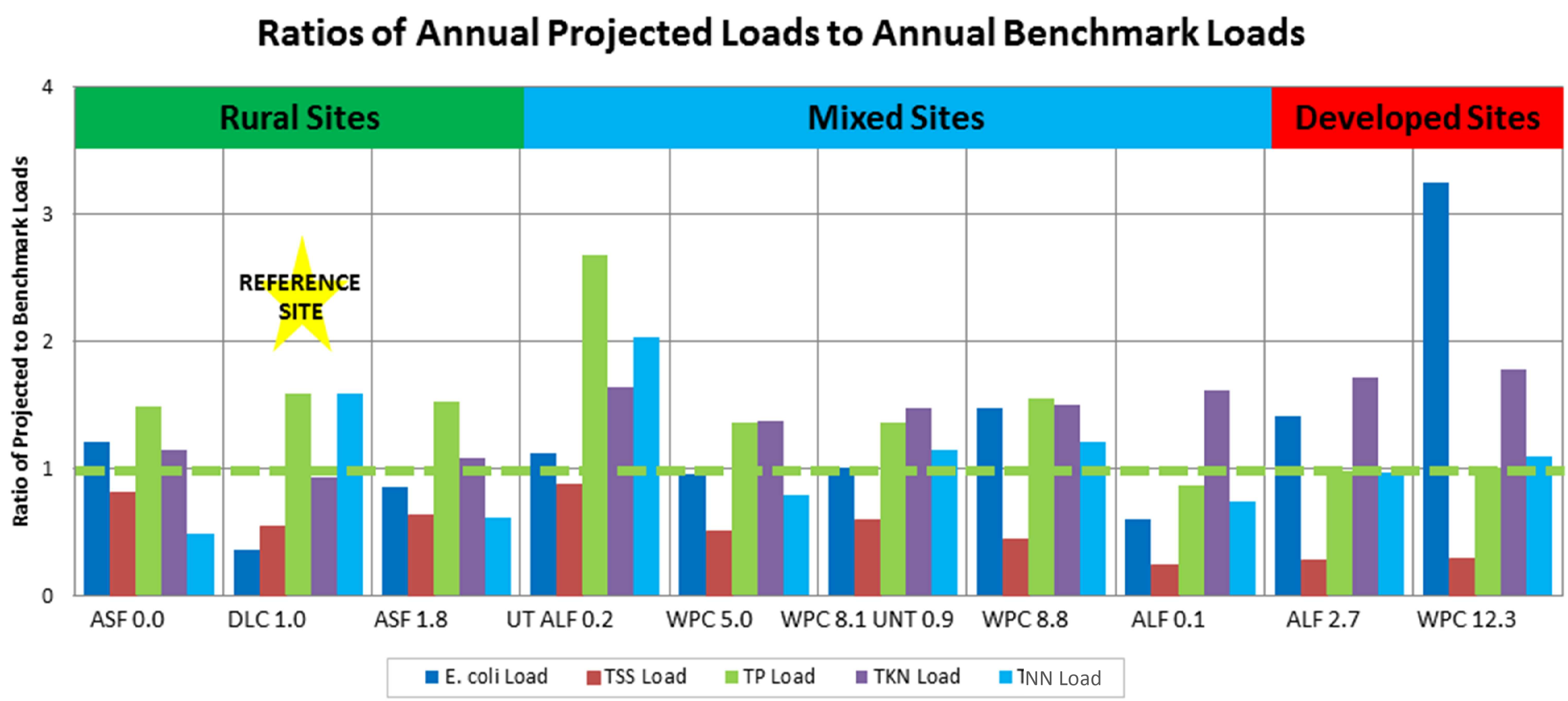


Figure 4-32: Ratios of projected loads to benchmark pollutant loads illustrate that generally the pollutants throughout the Woolper Creek Watershed are near benchmark levels at all sites except UT ALF 0.2 and WPC 12.3.

(ratios = projected load divided by the water quality benchmark or standard; the green line represents the water quality benchmark or standard = 1).

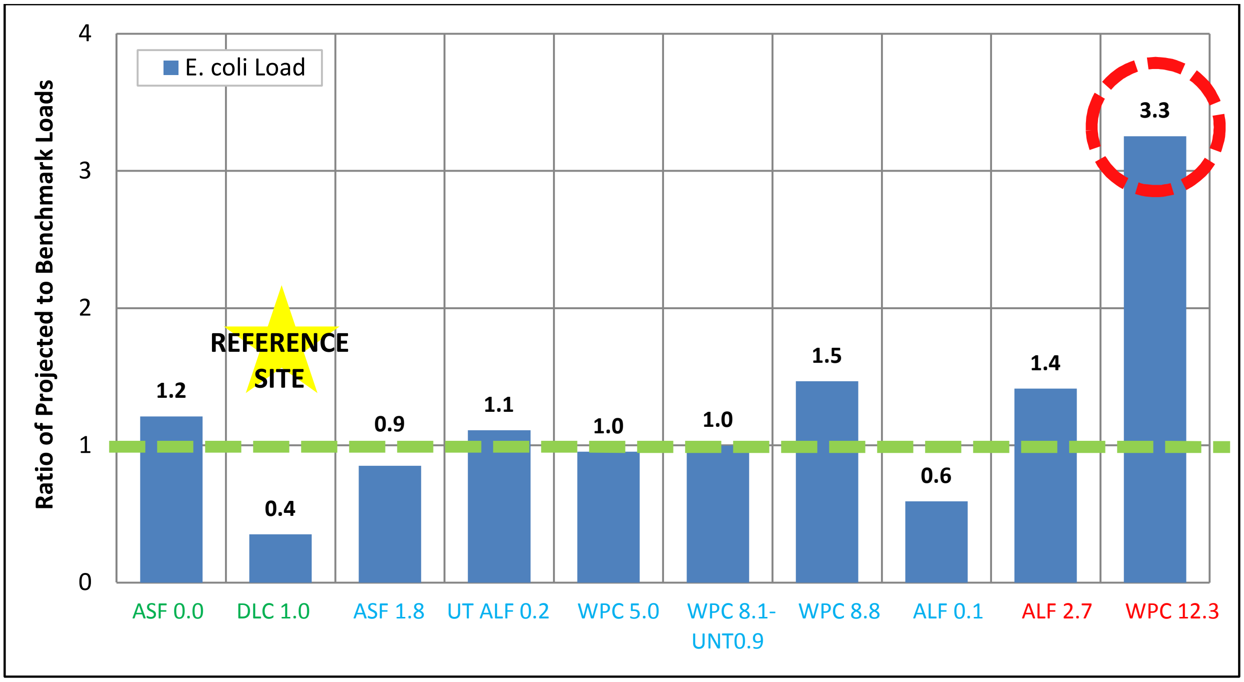


Figure 4-33: *E.coli* ratios of annual projected loads to annual benchmark loads for each site in the Woolper Creek Watershed.

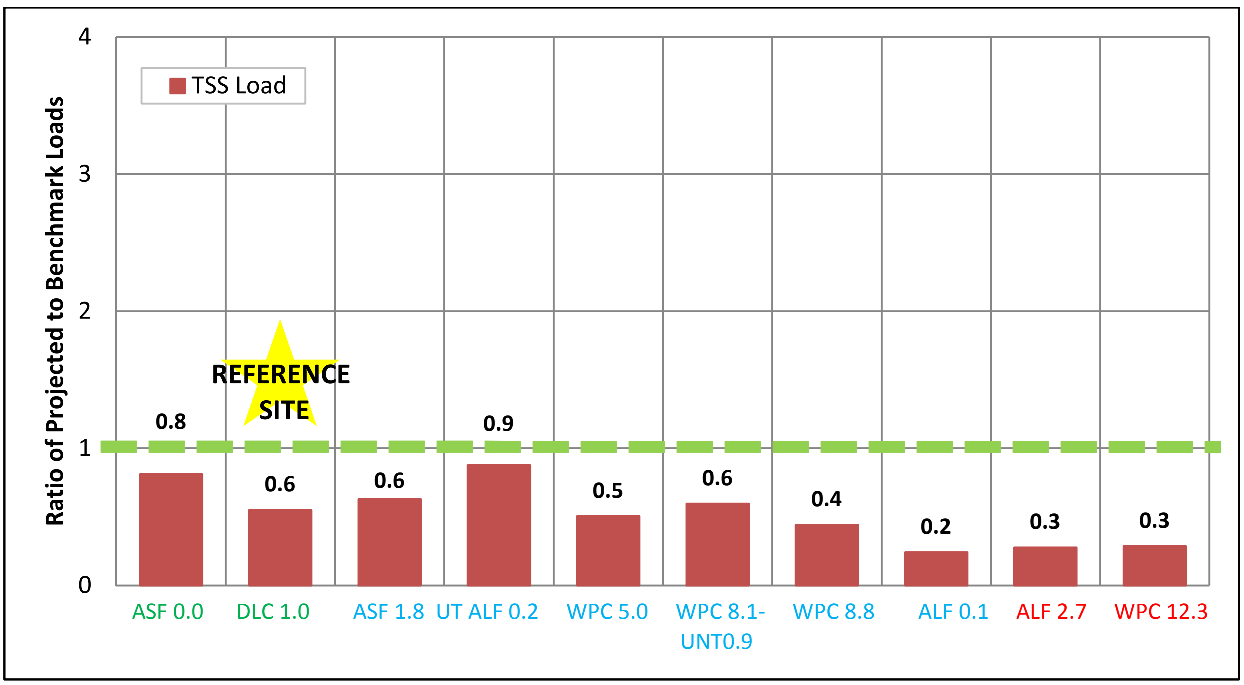


Figure 4-34: TSS ratios of annual projected loads to annual benchmark loads for each site in the Woolper Creek Watershed.

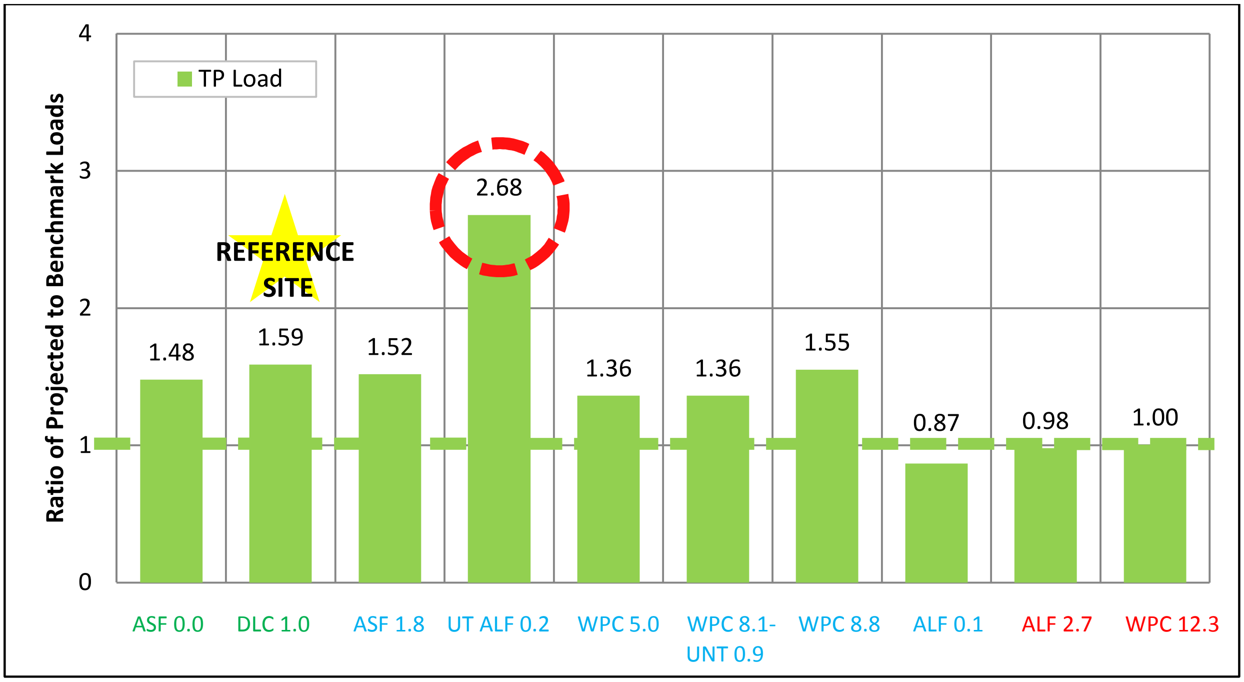


Figure 4-35: Total phosphorus ratios of annual projected loads to annual benchmark loads for each site in the Woolper Creek Watershed.

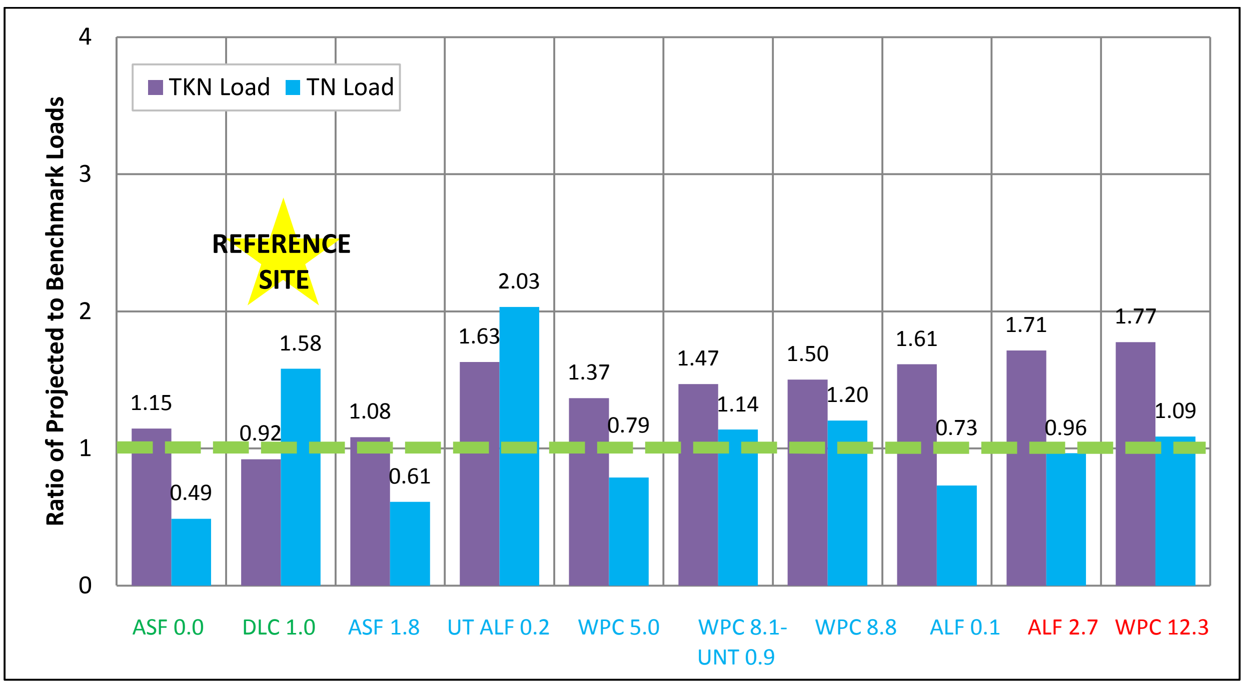


Figure 4-36: Total Nitrate-Nitrite as N and Total Kjeldahl Nitrogen ratios of annual projected loads to annual benchmark loads for each site in the Woolper Creek Watershed.

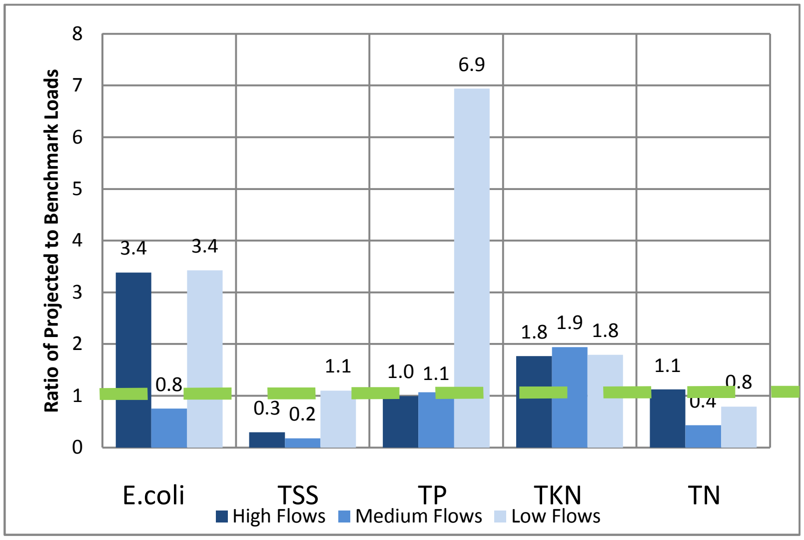


Figure 4-37: WPC 12.3 ratios of project to benchmark annual loads.

WCWI also evaluated the ratios of the projected loads relative to benchmark loads across low, medium, and high flow conditions (**Figure 4-37**, **Appendix 4-E**). This comparison presented information related to when specific parameters may be most concerning at each of the monitoring locations.

Additionally, WCWI calculated estimates offload reductions that would be necessary to reach watershed-wide benchmark levels for each parameter at each water quality monitoring site (**Table 4-4**). The red text in **Table 4-4** illustrates the highest pollutant load reductions needed throughout the watershed (greater than 100%) and the gray text (negative values) illustrates the annual pollutant loads that were below the benchmark loads. This table further underscores the findings that 1) many of the pollutant loads throughout the Woolper Creek Watershed are below the benchmarks; 2) bacteria (*E.coli*) appears to be a potential concern at WPC 12.3; and 3) the nutrient levels stand out at UT ALF 0.2, compared to all other sites that were within the same order of the reference site (DLC 1.0). Furthermore, this table supports that sediment pollution is not concerning throughout the watershed. In addition to the values below, **Appendix 4-E** presents a breakdown of the percent load reductions necessary for each flow category (high, medium, and low flows).

Table 4-4: Estimates of percent load reductions necessary to meet water quality benchmarks at each monitoring location.

Site	*E.coli*	TSS	TP	TKN	NN
ASF 0.0	21%	-19%	48%	15%	-51%
DLC 1.0	-65%	-45%	59%	-8%	58%
ASF 1.8	-15%	-37%	52%	8%	-39%
UT ALF 0.2	11%	-12%	168%	63%	103%
WPC 5.0	-5%	-49%	36%	37%	-21%
WPC 8.1 – UNT 0.9	0%	-40%	36%	47%	14%
WPC 8.8	47%	-56%	55%	50%	20%
ALF 0.1	-41%	-76%	-13%	61%	-27%
ALF 2.7	41%	-72%	-2%	71%	-4%
WPC 12.3	225%	-71%	0%	77%	9%

Comparison of Pollutant Yields

To standardize the annual loads based on the area of the watershed, pollutant yields were calculated. The total load was divided by the size of the subwatershed to develop the pollutant yield. **Table 4-5** presents not only the total pollutant yield for each parameter and subwatershed, but also provides the pollutant yields based on the classification of flows.

Table 4-5: Pollutant yields at each monitoring location (green represents the rural sites, blue represents the mixed sites, and red represents the developed sites).

Site		Pollutant Yield				
		E.coli Yield	TSS Yield	TP Yield	TKN Yield	NN Yield
		(col/yr/ac)	(lb/yr/ac)	(lb/yr/ac)	(lb/yr/ac)	(lb/yr/ac)
ASF 0.0	High Flows	5.01E+09	22.4	0.5	1.4	0.6
	Medium Flows	4.11E+08	1.8	0.025	0.0	0.0
	Low Flows	1.31E+06	0.0	0.001	0.0	0.0
	TOTAL	5.43E+09	24.2	0.5	1.4	0.6
ASF 1.8	High Flows	4.79E+09	22.1	0.6	1.6	0.9
	Medium Flows	3.49E+07	1.6	0.033	0.1	0.1
	Low Flows	3.69E+06	0.1	0.001	0.0	0.0
	TOTAL	4.83E+09	23.8	0.6	1.7	1.0
DLC 1.0	High Flows	1.74E+09	19.8	0.6	1.3	2.4
	Medium Flows	2.86E+08	1.3	0.049	0.1	0.1
	Low Flows	2.64E+06	0.1	0.001	0.0	0.0
	TOTAL	2.02E+09	21.1	0.7	1.5	2.5
ALF 0.1	High Flows	2.99E+09	7.1	0.3	2.2	1.0
	Medium Flows	1.56E+08	1.4	0.029	0.1	0.0
	Low Flows	1.65E+06	0.1	0.000	0.0	0.0
	TOTAL	3.15E+09	8.6	0.3	2.4	1.1
ALF 2.7	High Flows	8.12E+09	10.7	0.4	2.7	1.6
	Medium Flows	4.14E+08	0.5	0.032	0.2	0.1
	Low Flows	9.34E+06	0.0	0.000	0.0	0.0
	TOTAL	8.54E+09	11.1	0.4	2.9	1.6
UT ALF 0.2	High Flows	4.01E+09	20.5	0.8	1.7	2.2
	Medium Flows	4.19E+08	2.9	0.028	0.1	0.1
	Low Flows	2.47E+06	0.0	0.001	0.0	0.0
	TOTAL	4.44E+09	23.3	0.8	1.8	2.2
WPC 5.0	High Flows	4.86E+09	16.4	0.4	1.9	1.1
	Medium Flows	2.42E+08	1.6	0.119	0.1	0.0
	Low Flows	3.27E+06	0.0	0.000	0.0	0.0
	TOTAL	5.11E+09	18.1	0.5	2.0	1.2
WPC 8.8	High Flows	8.97E+09	17.3	0.7	2.5	2.0
	Medium Flows	3.13E+08	1.3	0.044	0.2	0.1
	Low Flows	6.67E+06	0.1	0.001	0.0	0.0
	TOTAL	9.29E+09	18.6	0.7	2.6	2.1
WPC 12.3	High Flows	1.98E+10	11.4	0.4	2.8	1.8
	Medium Flows	2.32E+08	0.4	0.024	0.2	0.0
	Low Flows	2.04E+07	0.0	0.003	0.0	0.0
	TOTAL	2.01E+10	11.8	0.5	3.0	1.8
WPC 8.1 – UNT 0.9	High Flows	4.84E+09	19.7	0.5	2.0	1.6
	Medium Flows	3.26E+08	0.9	0.044	0.1	0.1
	Low Flows	6.32E+06	0.1	0.001	0.0	0.0
	TOTAL	5.17E+09	20.6	0.5	2.1	1.6

Comparison of Watershed Inventory Data to Pollutant Concentrations and Loads/Yields

A better understanding of pollutants of concern and possible causes of pollution is obtained by comparing the watershed inventory data to the pollutant concentrations and loads/yields. As previously mentioned, the monitoring locations were categorized into three types of land use based on their percentage of impervious area, including developed watersheds, rural watersheds, and mixed watersheds. Differing land use can be related to certain pollutants of concern during both wet and dry weather and provide inferences regarding potential sources of pollution.

In Allen Fork, the water quality is worst at the most upstream site, which drains the subwatershed with the greatest development intensity. This points to stormwater runoff as the primary source of *E.coli*, TSS, and nutrients, especially in the developed headwaters upstream of site ALF 2.7. In the downstream areas, loads become more diluted and some natural assimilation may be occurring. Although it is possible that a point source is contributing to the occasionally high dry weather loads in the downstream reach, it could also be residual loads from wet weather sources upstream that are working through the system.

UT ALF 0.2 is partially developed and partially rural. This site has high *E.coli*, TSS, TP, and NN concentrations during wet weather. Possible sources of these constituents could be stormwater runoff from development as well as rural sources, such as livestock, row crops, and fruit/vegetable farms. Review of the National Land Cover Database indicates a small concentration of land used for cultivated crops upstream of this monitoring location, which could explain the excessively high nutrient loads measured at this site.

Ashby's Fork is a rural subwatershed with agriculture and/or cattle operations. *E.coli*, TSS, TP, and TKN are only slightly concerning and could be explained by a small number of cows having direct access to the creek or a lack of riparian buffers allowing waste into the stream. Because dry weather pollution is not a concern, this seems to indicate that septic system failures are not a concern in this subwatershed.

Despite having loads that are slightly above the benchmark levels, Double Lick Creek supports a diverse biological community and serves as a regional reference stream.

The Double Lick Creek Subwatershed is mostly forested and serves as the best reference site for Woolper Creek, as well as one of the most diverse biological communities in all of Northern Kentucky. As stated previously, measured TP and TKN concentrations above the benchmarks may indicate that the nutrient benchmarks are not necessarily reflective of distinct thresholds between high and low water quality in Woolper Creek. Indeed, excess algae and eutrophication were not observed at any of the sites, which would suggest that nutrient loads are in compliance with Kentucky's narrative standards for nutrients. Characteristics of the natural setting, such as the region's shallow limestone/shale bedrock, may serve as a natural source for dissolved constituents such as Phosphorus. Further supporting this concept is the fact that several sites, including DLC 1.0, have TP and TKN loads that are higher than the benchmarks; however, *E.coli* loads are lower. Particularly in Double Lick, application of artificial fertilizers is not anticipated, and most other anthropogenic nutrient sources would also likely have a bacteria signature. Phosphorous loads could also be reflective of historic loads that are still latched onto sediment that is stored in the system as well. In any case, the diverse biological community observed at Double Lick is indicative of system with water quality levels that are supportive of aquatic life.

For the Woolper Creek Subwatersheds, similar to the Allen Fork Subwatershed, there seemed to be few causes for concern related to water quality, but conditions do worsen moving upstream toward the developed headwaters. In the downstream reaches (i.e., WPC 5.0), mid-range flows show high TP concentrations which may indicate a local source such as exposed shale/limestone and/or other source. However, because other constituents do not stand out at this site, the elevated phosphorus levels at WPC 5.0 may be reflective of lower assimilation rates in this system. Phosphorus generally is adsorbed to sediment, which then takes a long time to move through the system, and it is possible that the slightly elevated concentrations are a function of historic loads from when cattle and agriculture were more prevalent or may be coming from the upstream developed areas.

Moving upstream, WPC 8.8 drains a slightly developed area. The phosphorus and TKN loads here could be from rural sources, especially during low flows, and/or from the upstream development. The upstream development could even lead to residual dry weather loads as the pollutants from upstream slowly work through the system.

Still farther upstream is WPC 12.3. Although it is not completely built out, it is one of the more developed subwatersheds in Woolper Creek. The high *E.coli* and TKN loads during wet weather are likely attributable to stormwater runoff from the more developed areas. The low flow constituents could be emblematic of residual wet weather loads. SD1 is currently investigating the high E.coli loads in this region of the watershed.

WPC 8.1-UNT 0.9 is a mostly undeveloped tributary that receives flow from heavily developed headwaters, including Toyota, Prologis, and many other industrial sites. While there may be dry weather sources for the constituents measured, wet weather residual flows during dry weather may be the source. With the exception of nutrients, the pollutant loads at this site were at or below benchmark levels.

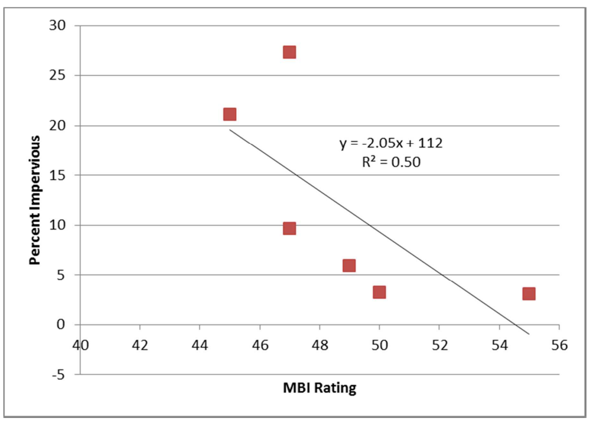
Conditions improve in Woolper Creek from upstream to downstream, moving from developed to undeveloped.

In sum, the data collected at the monitoring sites along Woolper Creek show that conditions improve moving upstream to downstream. This suggests that the highest loads are coming from the headwaters. It is suspected that this is also occurring in the Allen Fork Subwatershed, which would impact site WPC 5.0. These findings generally support the conclusion that rural loads are not as concerning as developed, which are worse in the headwaters. Moving downstream, loads, yields, and concentrations decrease, which indicate that dilution and assimilation dominate due to the higher proportion of rural land in the watershed. Finally, the fact that nutrient loads were above benchmark concentrations at the forested reference site (i.e., Double Lick), where a relatively healthy macroinvertebrate community exists and there were no signs of excess algae or eutrophication, reinforces the treatment of nutrient benchmarks as order-of-magnitude guides for water quality in the Woolper Creek Watershed as opposed to prescriptive targets for precise load reduction efforts. Lastly, it should be noted that the downstream reach on Woolper Creek from river mile 2.8 to 7.45 was listed as impaired on the 303(d) list due to agricultural sources.

All of these findings seem to support a best management practices (BMP) strategy that attempts to better mitigate excess stormwater from the developed areas of the watershed, with a focus on the more dominant concern of hydromodification.

Biological Assessment

At the stream function pyramid's apex, stream biology is dependent on all the factors that have already been discussed in the previous sections: land use and management, stream flow, physical/habitat conditions, and overall water quality. Healthy aquatic life requires good water quality, stable physical conditions, natural flow regimes, and a watershed with a focus on sustainable management. These parameters have negative correlations with conventional development practices, such that the biological assessments in Woolper Creek show a negative correlation to development for both headwater streams and wadeable streams (**Figure 4-38**). In summary, MBI scores across the Woolper Creek Watershed range from fair to good, with all headwater and wadeable streams within either developed or mixed having fair biology, and all rural subwatersheds having good biology (**Figure 4-39**).



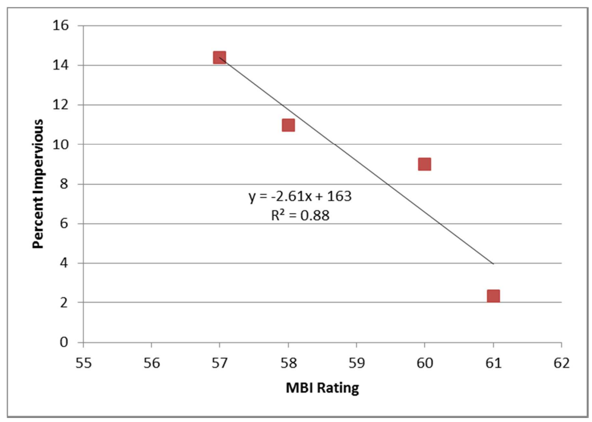
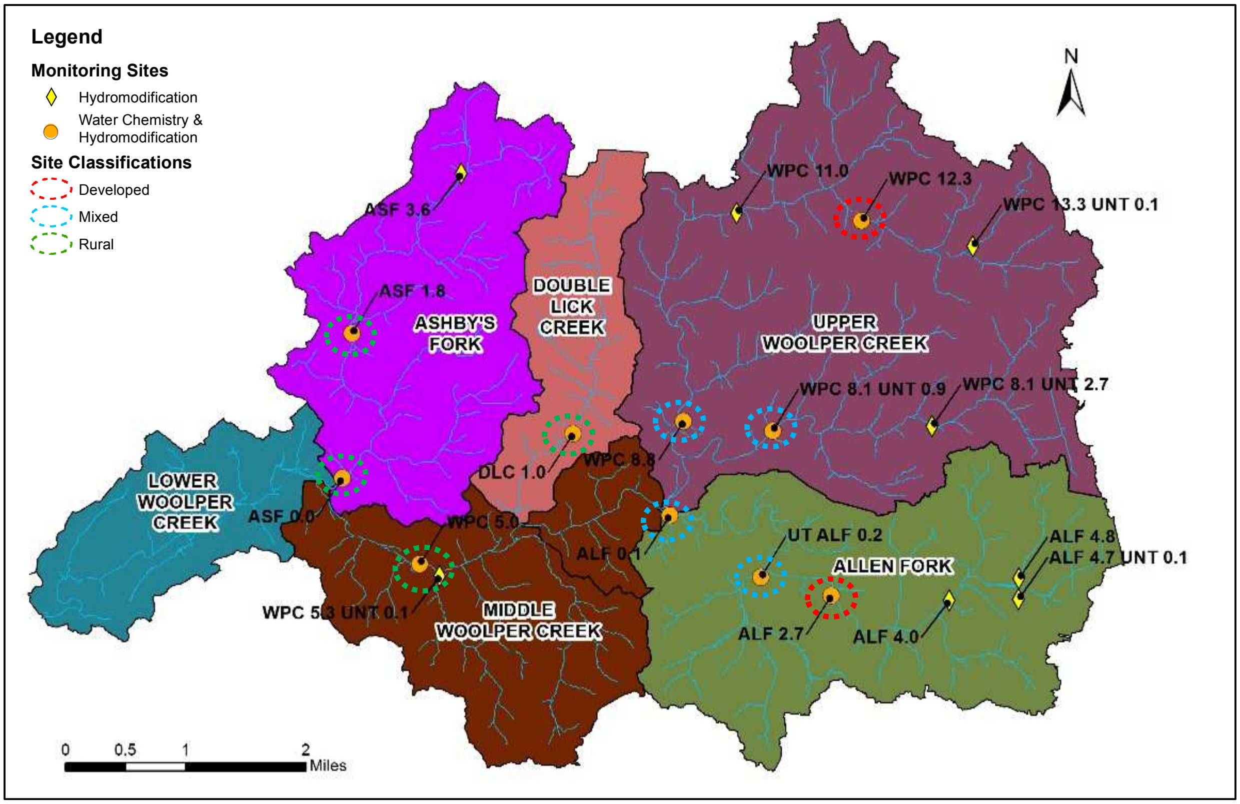


Figure 4-38: Decrease in MBI scores as percent impervious increases for headwater (left) and wadeable (right) stream reaches.

Reductions in both biological integrity and habitat quality were best explained by unnaturally high rates of streambed instability, underscoring hydromodification as a first-priority concern.

Beyond simply "development," the multifaceted data collection program was able to provide insights regarding the relative importance of the various factors that could be affecting the biological communities (**Figure 4-40**). For example, as discussed previously, most of the sampling locations showed water quality conditions that were generally comparable to those observed at our reference site in Double Lick Creek (**Figure 4-41**), even when considering limitations in the collected data (i.e., few flowing water samples, one single year considered dry). By contrast, interannual bed material sampling indicated that only the least developed subwatersheds exhibited bed stability conditions that were similar to those of Double Lick (**Figure 4-42**). As further underscored by the hydrological sampling discussed above (Section 4.2.3 Phase 2 – Analysis_*Stream Flow*), this can be explained by the erosive nature of the urban flow regime being released from conventionally designed stormwater management facilities in the developed headwaters of Woolper Creek. Looking ahead to prioritization, the association between bed instability and reduced biological integrity suggests that implementation efforts should focus on reducing the erosivity of the urban flow regime as a first priority BMP strategy.



HEADWATER STREAMS			
	Site	MBI	Rating
Rural	DLC 1.0*	55	Good
	ASF 1.8	50	Fair
Mixed	ALF 0.2	49	Fair
	WPC 8.1	47	Fair
Developed	WPC 12.3	47	Fair
	ALF 2.7	45	Fair
*MBI score provided by SD1			

WADEABLE STREAMS			
	Site	MBI	Rating
Rural	ASF 0.0	61	Good
Mixed	ALF 0.1	57	Fair
	WPC 8.8	58	Fair
	WPC 5.0	60	Fair

Figure 4-39: MBI scores across the Woolper Creek Watershed highlight fair to good ratings for all sites. Notice the Fair ratings span across the mixed and developed subwatersheds (yellow circles in table).

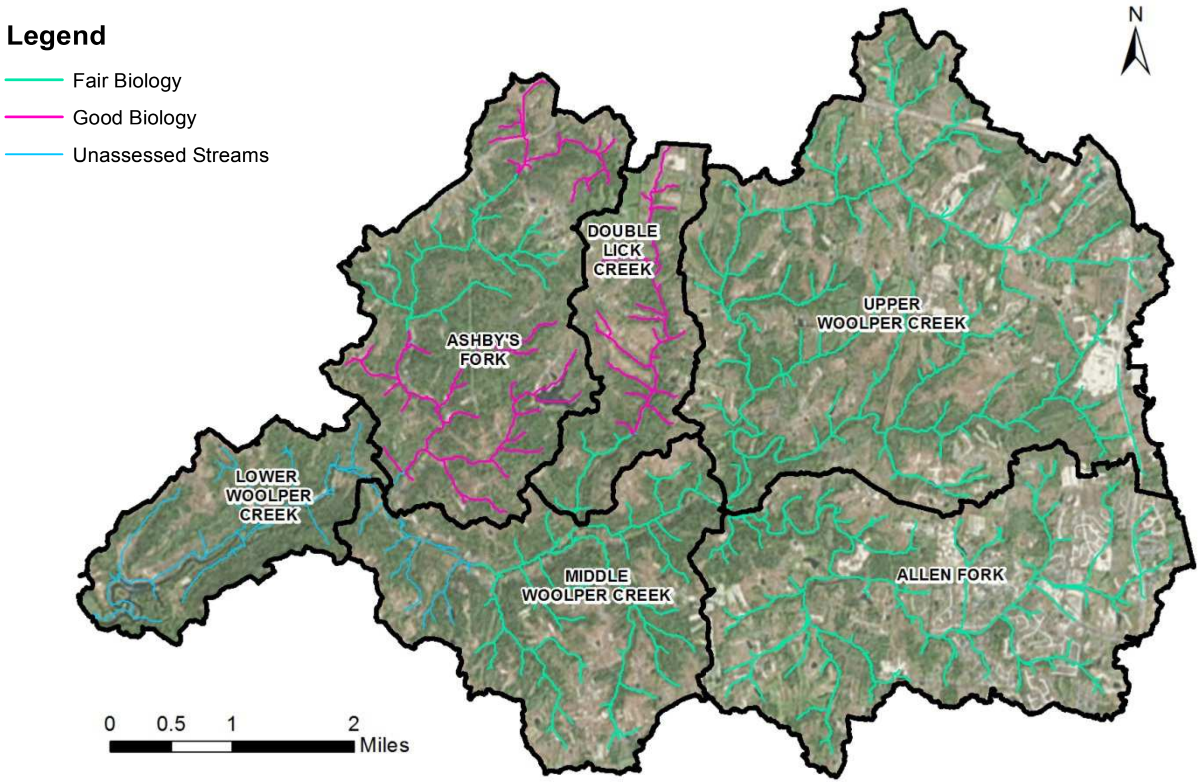


Figure 4-40: Color-coded stream segments immediately upstream of monitoring sites with Fair and Good biology scores show that sites with Fair biology drain subwatersheds with developed headwaters.

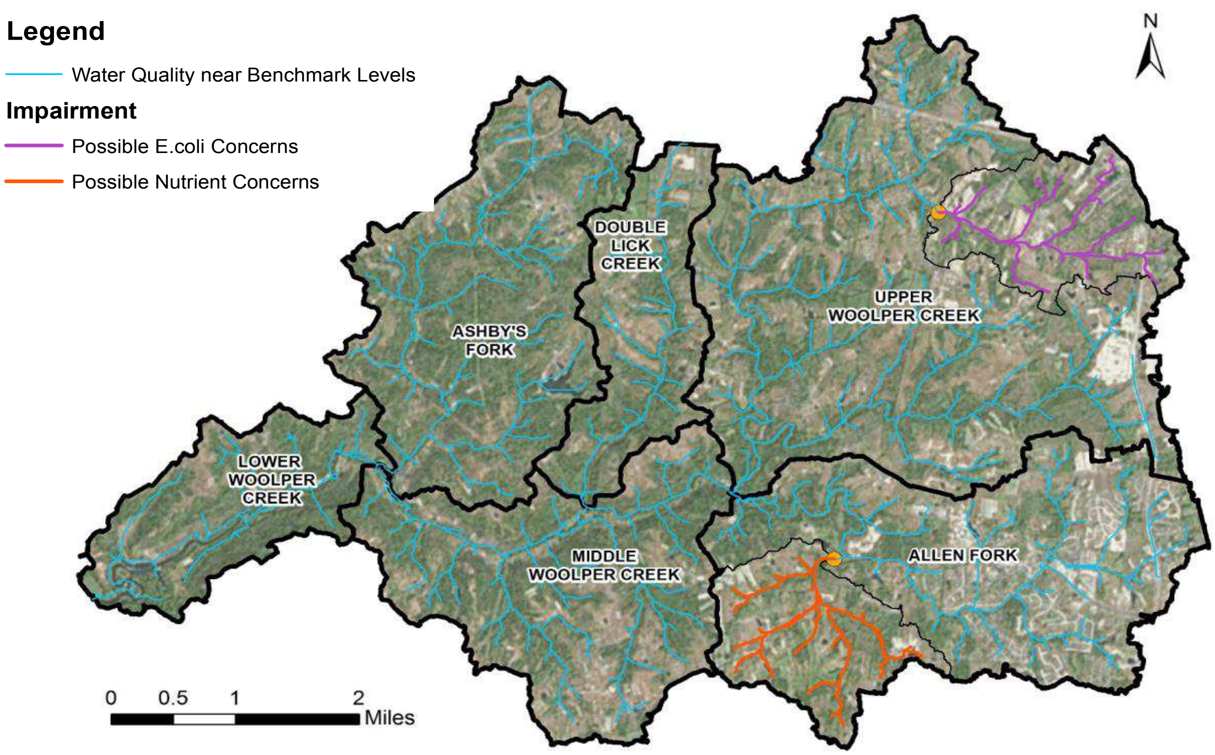


Figure 4-41: Color-coded stream segments immediately upstream of the two monitoring sites with possible E.coli and Nutrient concerns help to prioritize the subwatersheds with the greatest water quality concerns.

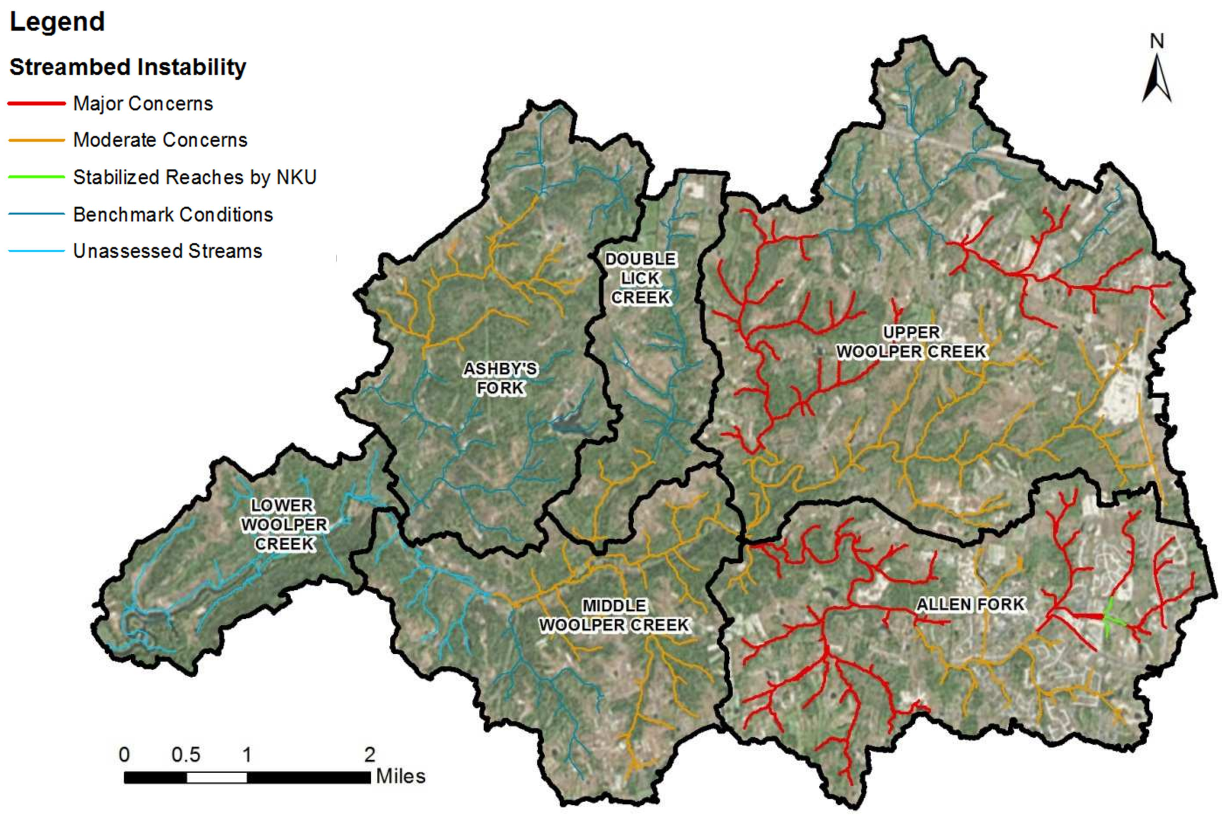


Figure 4-42: Color-coded stream segments immediately upstream of monitoring sites with streambed instability ranging from benchmark conditions (Double Lick and Lower Ashby's) to moderate and major instability show that sites with the greatest streambed instability drain subwatersheds with developed headwaters. Because the biological impacts (Figure 4-40) best align with sites that also have elevated rates of streambed instability, this further underscores hydromodification as one of the root causes of biological impacts in the Woolper Creek Watershed.

4.2.4 Phase 2 - Prioritization

The additional detail provided in Phase 2 monitoring provides an even better understanding of pollutant sources and which subwatersheds should be targeted for future implementation efforts. The following will discuss analytical data organization, regulatory status of the waterway, and feasibility factors.

> ***Because water quality monitoring indicated relatively few concerns throughout the watershed, prioritization focused on addressing hydromodification and the associated streambed instability caused by erosive stormwater runoff.***

The sites have been prioritized based on hydromodification and stream stability, indicating that Allen Fork (UT ALF 0.2, ALF 0.1, ALF 2.7, and ALF 4.0), which is developed, is the most unstable subwatershed. Upper Woolper Creek is also considered a priority as a developed watershed, due to major streambed instability and *E.coli* concerns. Double Lick Creek (DLC 1.0) represents one of the most pristine stream reaches in the county and should be preserved, making it another priority watershed. The following sections present a summary of the water quality parameters along with feasibility constraints for the prioritized sites.

Organizing Analytical Data

Parameter concentrations, pollutant loads, and pollutant yields have been organized to assist in prioritization of the subwatersheds. Several sites saw concentrations higher than the benchmark, showing that nutrients, sediment, and bacteria are concerns, as listed in the 303(d) list. The fact that there were no sites with consistently poor water quality and/or extremely elevated pollutant concentrations relative to our reference site DLC 1.0, reinforces the prioritization that was driven by hydromodification concerns as opposed to water quality.

<u>*Comparisons of parameter concentrations*</u>

To begin, the concentrations of parameters in each subwatershed have been ranked in two ways. **Table 4-6** ranks the subwatersheds from that with the highest number of samples exceeding the benchmark to the lowest, and **Table 4-7** ranks the subwatersheds by highest to lowest average parameter concentration. The red text highlights our most developed subwatershed of Allen Fork; the orange text represents our second most developed subwatershed of Upper Woolper; the green text highlights our pristine, undeveloped subwatershed, Double Lick; and the black text represents all other sampling sites (Middle Woolper (WPC 5.0) and Ashby's Fork).

Table 4-6: Subwatersheds ranked from the highest to the lowest number of samples exceeding the benchmark.

E.coli		**TSS**		**TP**		**TKN**		**NN**	
WPC 12.3	**74%**	ASF 1.8	50%	ASF 0.0	100%	**ALF 2.7**	**100%**	**UT ALF 0.2**	**58%**
WPC 8.1 - UNT 0.9	**61%**	**UT ALF 0.2**	**50%**	ASF 1.8	100%	**WPC 12.3**	**100%**	**WPC 8.8**	**50%**
UT ALF 0.2	**56%**	ASF 0.0	42%	**DLC 1.0**	**100%**	**UT ALF 0.2**	**92%**	**WPC 12.3**	**33%**
ALF 2.7	**53%**	**WPC 8.1 - UNT 0.9**	**33%**	**UT ALF 0.2**	**83%**	**WPC 8.8**	**92%**	**ALF 2.7**	**25%**
ASF 0.0	50%	**WPC 8.8**	**33%**	**WPC 8.8**	**83%**	**ALF 0.1**	**83%**	ASF 1.8	25%
WPC 8.8	**50%**	**ALF 0.1**	**25%**	WPC 5.0	67%	WPC 5.0	75%	**DLC 1.0**	**25%**
E.coli	**TSS**	**TP**	**TKN**	**NN**	***E.coli***	**TSS**	**TP**	**TKN**	**NN**
WPC 5.0	47%	**WPC 12.3**	**17%**	**ALF 2.7**	**58%**	**DLC 1.0**	**67%**	**ALF 0.1**	**17%**
DLC 1.0	**39%**	WPC 5.0	17%	**WPC 12.3**	**58%**	ASF 0.0	58%	WPC 5.0	17%
ALF 0.1	**32%**	**DLC 1.0**	**17%**	**ALF 0.1**	**42%**	ASF 1.8	50%	ASF 0.0	8%
ASF 1.8	28%	**ALF 2.7**	**8%**	**WPC 8.1 - UNT 0.9**	**0%**	**WPC 8.1 - UNT 0.9**	**0%**	**WPC 8.1 - UNT 0.9**	**0%**

Table 4-7: Subwatersheds ranked from the highest to the lowest average sample concentrations.

E.coli[1]		TSS		TP		TKN		NN	
WPC 12.3	532	UT ALF 0.2	11.61	WPC 12.3	0.21	WPC 8.1 - UNT 0.9	0.60	UT ALF 0.2	0.44
ALF 2.7	371	ASF 1.8	8.82	UT ALF 0.2	0.20	WPC 12.3	0.58	DLC 1.0	0.31
UT ALF 0.2	309	WPC 8.8	7.78	DLC 1.0	0.19	ALF 2.7	0.55	WPC 8.8	0.31
WPC 8.8	282	WPC 8.1 - UNT 0.9	7.75	WPC 5.0	0.19	UT ALF 0.2	0.51	WPC 8.1 - UNT 0.9	0.30
WPC 8.1 - UNT 0.9	267	ASF 0.0	6.30	ASF 1.8	0.18	WPC 8.8	0.49	WPC 12.3	0.25
WPC 5.0	225	ALF 0.1	5.74	WPC 8.1 - UNT 0.9	0.15	ALF 0.1	0.48	ASF 1.8	0.24
ASF 0.0	211	DLC 1.0	5.56	WPC 8.8	0.14	WPC 5.0	0.39	ALF 2.7	0.22
DLC 1.0	159	WPC 12.3	4.93	ASF 0.0	0.13	DLC 1.0	0.37	WPC 5.0	0.18
ASF 1.8	128	WPC 5.0	4.28	ALF 0.1	0.09	ASF 0.0	0.35	ASF 0.0	0.18
ALF 0.1	103	ALF 2.7	2.34	ALF 2.7	0.09	ASF 1.8	0.35	ALF 0.1	0.17

[1] Average sample concentrations for *E.coli* were calculated as the geometric mean of the sample concentrations.

Comparisons of pollutant loads and yields

Summarizing the pollutant loads and yields for each monitoring site presents a useful comparison in understanding the priority subwatersheds. These two parameters standardize the data analysis across all flows and subwatershed size. **Table 4-8** has rankings for the subwatersheds based on projected annual loads. **Table 4-9** presents the rankings for projected annual yields.

Table 4-8: Subwatersheds ranked from the highest to the lowest projected annual loads.

E.coli (col/yr)		TSS (lb/yr)		TP (lb/yr)		TKN (lb/yr)		NN (lb/yr)	
WPC 5.0	7.90E+13	WPC 5.0	279,351	WPC 5.0	8,287	WPC 5.0	31,226	WPC 5.0	18,010
WPC 8.8	3.85E+13	ASF 0.0	82,193	WPC 8.8	2,991	WPC 8.8	10,861	WPC 8.8	8,707
WPC 12.3	2.35E+13	WPC 8.8	77,161	ASF 0.0	1,653	ALF 0.1	10,158	ALF 0.1	4,601
ALF 2.7	1.96E+13	WPC 8.1 UNT 0.9	48,704	ALF 0.1	1,456	ALF 2.7	6,553	WPC 8.1 UNT 0.9	3,839
ASF 0.0	1.84E+13	ASF 1.8	42,030	WPC 8.1 UNT 0.9	1,226	WPC 8.1 UNT 0.9	4,958	ALF 2.7	3,688
ALF 0.1	1.36E+13	ALF 0.1	36,874	ASF 1.8	1,120	ASF 0.0	4,799	DLC 1.0	2,909
WPC 8.1 UNT 0.9	1.22E+13	UT ALF 0.2	26,927	ALF 2.7	998	WPC 12.3	3,533	UT ALF 0.2	2,578
ASF 1.8	8.54E+12	ALF 2.7	25,567	UT ALF 0.2	907	ASF 1.8	2,996	WPC 12.3	2,166
UT ALF 0.2	5.12E+12	DLC 1.0	24,487	DLC 1.0	780	UT ALF 0.2	2,071	ASF 0.0	2,044
DLC 1.0	2.35E+12	WPC 12.3	13,788	WPC 12.3	533	DLC 1.0	1,696	ASF 1.8	1,689

Table 4-9: Subwatersheds ranked from the highest to the lowest yields.

E.coli (col/yr/ac)		TSS (lb/yr/ac)		TP (lb/yr/ac)		TKN (lb/yr/ac)		NN (lb/yr/ac)	
WPC 12.3	**2.01E+10**	ASF 0.0	24.2	**UT ALF 0.2**	**0.8**	**WPC 12.3**	**3.0**	**DLC 1.0**	**2.4**
WPC 8.8	**9.29E+09**	ASF 1.8	23.8	**DLC 1.0**	**0.7**	**ALF 2.7**	**2.9**	**UT ALF 0.2**	**2.2**
ALF 2.7	**8.54E+09**	**UT ALF 0.2**	**23.3**	**WPC 8.8**	**0.7**	**WPC 8.8**	**2.6**	**WPC 8.8**	**2.0**
ASF 0.0	5.43E+09	**DLC 1.0**	**21.1**	ASF 1.8	0.6	**ALF 0.1**	**2.4**	**WPC 12.3**	**1.8**
WPC 8.1 - UNT 0.9	**5.17E+09**	**WPC 8.1 - UNT 0.9**	**20.6**	ASF 0.0	0.5	**WPC 8.1 UNT 0.9**	**2.1**	**ALF 2.7**	**1.6**
WPC 5.0	5.11E+09	**WPC 8.8**	**18.6**	WPC 5.0	0.5	WPC 5.0	2.0	**WPC 8.1 UNT 0.9**	**1.6**
ASF 1.8	4.83E+09	WPC 5.0	18.1	**WPC 12.3**	**0.5**	**UT ALF 0.2**	**1.8**	WPC 5.0	1.1
UT ALF 0.2	**4.44E+09**	**WPC 12.3**	**11.8**	**WPC 8.1 UNT 0.9**	**0.5**	ASF 1.8	1.7	**ALF 0.1**	**1**
ALF 0.1	**3.15E+09**	**ALF 2.7**	**11.1**	**ALF 2.7**	0.4	**DLC 1.0**	**1.5**	ASF 1.8	0.9
DLC 1.0	**2.02E+09**	**ALF 0.1**	**8.6**	**ALF 0.1**	0.3	ASF 0.0	1.4	ASF 0.0	0.6

Feasibility Factors

The lack of a pattern in subwatersheds' pollutant loads and yields reinforced the prioritization of hydromodification as a driving factor in the reduced biological integrity in many of the developed watersheds in the Woolper Creek Watershed. The next step was to understand the feasibility factors that may affect the implementation of focused efforts in any of the areas. The information provided below is an expansion of the Phase 1 feasibility factors discussed in Section 4.2.2 and is specifically tailored to Upper Woolper Creek, Allen Fork, and Double Lick Creek Subwatersheds.

Regulatory matters

As stated in Section 4.2.2, there are areas of the Woolper Creek Watershed that are listed on KDOW's 303(d) list. Relating these reaches to the Phase 2 monitoring data, monitoring stations in Allen Fork that are along the segments listed include UT ALF 0.2, ALF 2.7, and ALF 4.0 and monitoring stations in Upper Woolper that are along the segments listed include WPC 11.0 and WPC 12.3. Focusing efforts in these subwatersheds would not only improve stream health but may also be able to facilitate the removal of these stream reaches from the 303(d) list and preclude the need of a more regulatory-driven TMDL. If successful, the effort would demonstrate that locally-driven efforts to remove streams from the 303(d) list might be just as effective but less costly and/or contentious as TMDL-driven approaches.

Double Lick Creek and Ashby's Fork are listed as outstanding state water resources and reference reaches by KDOW. Focusing efforts here can protect these resources.

Stakeholder cooperation

The WCWI anticipates good stakeholder cooperation regardless of the selected priority areas. As mentioned under Phase 1's feasibility factors (Section 4.2.2), preserving the quality of Double Lick Creek as a reference stream will be important to all stakeholders in this Plan.

Political will

The WCWI is not aware of any area favored by local politicians and anticipates political support regardless of the selected priority areas.

Available funding

The WCWI plans to apply for additional grant funding for implementation throughout the watershed. Funding from private sources will be dependent on the types of projects for implementation, but may be more likely by targeting areas of local concern.

Areas of local concern

As mentioned in Section 4.2.3, there is flooding in the watershed in the headwaters, near site WPC 13.3-UNT 0.1 as well as in Allen Fork downstream of the Darlington Farms Subdivision (ALF 4.0). The inline pond at Darlington Farms has sedimentation issues and may present on opportunity for outside funding.

Existing priority status

It is clear why Double Lick Creek is classified as an outstanding state water resource by KDOW and used by SD1 as a reference site. Protecting this subwatershed would be beneficial to keeping these designations, as well as serving as the benchmark for other regional streams. Ashby's Fork is also listed as an outstanding state water resource and reference reach.

Watershed management activities

The WCWI is not aware of any additional watershed management activities within the subwatersheds that were not previously discussed in Section 4.2.2.

Monitoring considerations

Monitoring has provided the necessary insight to understand the conditions in the Woolper Creek stream network, as well as the key drivers of impairments. If additional funding becomes available, supplementary sampling in the watershed, specifically Double Lick Creek, could provide enough information to evaluate the potential for determining new benchmarks for the watershed with better confidence. Continued monitoring, especially flow monitoring and hydromodification surveys would be efficient ways to track the success of implementation efforts.

4.3 Other Analysis Options for Non-319-Funded Watershed Plans

The holistic stream system assessments have provided the foundation for understanding and prioritizing pollutants and suspected sources. The monitoring results have also helped to educate the public and other stakeholders through public meetings and corresponding media coverage. Therefore, the monitoring program has not only played a role in understanding existing conditions, but also in promoting public stewardship.

4.4 Prioritized Subwatersheds

After completing the monitoring programs and analyzing all of the data, the WCWI has decided to prioritize the Allen Fork Subwatershed as the most impaired, developed subwatershed and the Double Lick Subwatershed as the subwatershed slated for conservation efforts. The Upper Woolper Creek Subwatershed will also be prioritized due to complaints of hydromodification and flooding concerns connected to development occurring in the headwaters in recent years. While the developed regions of the watershed have been selected as a priority area for initial implementation efforts, the rural regions dispersed throughout the watershed are also potential contributors to the nonpoint source pollution measured at a couple of the monitoring sites. Therefore, rural areas where agricultural and onsite wastewater practices can lead to degraded water quality will also be considered for implementation efforts, as discussed further in Chapters 5 and 6.

In every case, developed and mixed use watersheds did not have levels of biological integrity that were measured in rural streams. Although their water quality was not extremely degraded, their flows were flashier and more erosive, their habitat tended to be poorer, and their streambeds tended to be less stable (**Figure 4-43**). The common trend connecting all of these concerns is hydromodification (i.e., too much stormwater runoff that accelerates stream erosion and habitat destruction). Therefore, as discussed in Chapter 5, stormwater BMPs that attempt to better manage the volume and rate of stormwater runoff from developed areas and have direct benefits for nutrient, sediment, and pathogen loading reductions, will be a priority moving forward.

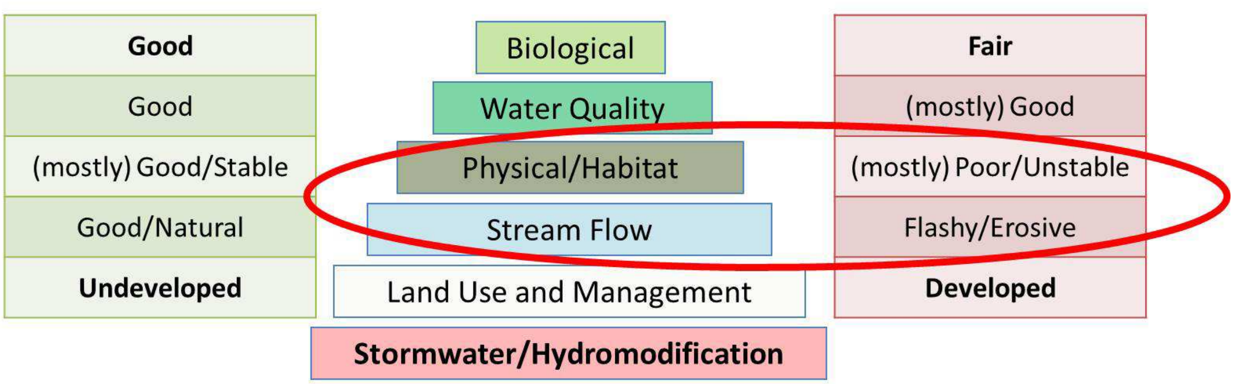


Figure 4-43: Developed sites in Woolper Creek have worse stream health than undeveloped streams.

References

Hawley, R.J., Bledsoe, B.P., Stein, E.D., Haines, B.E., 2012. Channel evolution model of semiarid stream response to urban-induced hydromodification. J. Am. Water Resour. Assoc. 48 (4), 722–744.

Hawley, R.J., MacMannis, K.R. and Wooten, M.S., 2013a. Bed coarsening, riffle shortening, and channel enlargement in urbanizing watersheds, northern Kentucky, U.S.A. Geomorphology. http://dx.doi.org/10.1016/j.geomorph.2013.06.013.

KDOW, 2008. Methods for assessing biological integrity of surface waters. Kentucky Department of Environmental Protection, Division of Water, Frankfort, KY.

KDOW, 2010. Watershed Planning Guidebook for Kentucky Communities. Prepared by the Kentucky Division of Water and the Kentucky Waterways Alliance. Frankfort, KY

KDOW, 2012. Final 2012 Integrated Report to Congress on the Condition of Water Resources in Kentucky Volume II. 303(d) List of Surface Waters.

Lane, E.W. 1955. The Importance of Fluvial Morphology in Hydraulic Engineering, American Society of Civil Engineering, Proceedings, 81, paper 745: 1-17.

LimnoTech, 2009. Woolper Creek Watershed Characterization Report. Prepared for Sanitation District No. 1 of Northern Kentucky, Fort Wright, KY.

NKSWRP, 2013. Northern Kentucky Stream and Wetland Restoration Program Annual Report 2013. Northern Kentucky Center for Environmental Restoration. http://environmentalrestoration.nku.edu/program.html.

Salminen, R. (ed). P-Phosphorus. Geochemical Atlas of Europe. Part 1 Background Information, Methodology and Maps.

Schumm, S.A., Harvey, M.D. and Watson, C.C., 1984. Incised channels: Morphology, Dynamics, and Control. Water Resources Publications, Littleton, Colorado.

US Census, 2009. Annual Estimates of the Resident Population for Counties of Kentucky: April 1, 2000 to July 1, 2009. U.S. Census Bureau, Population Division. http://ksdc.louisville.edu/kpr/popest/coest2009.xls.

CHAPTER 5

Finding Solutions

Woolper Creek Watershed Plan

Prepared by the

Woolper Creek Watershed Initiative

October 2016

Chapter 5: Finding Solutions

5.1 Overview of Best Management Practices

Best management practices reduce pollution in watersheds.

Best management practices (BMPs) are items, methods or actions that are employed to reduce both point and nonpoint source pollution within a watershed. BMPs are vital to the success of the Watershed Plan, and there are many different BMPs that can be appropriate.

Structural and Non-structural Best Management Practices

The two types of BMPs that have been included in the Woolper Creek Watershed Plan include structural and non-structural BMPs. A structural BMP is a built system, something that requires design, installation, and maintenance. A few examples include rain gardens, detention basin retrofits, and bankfull wetlands. A non-structural BMP is less tangible, but equally as important, and can be a method or activity. Examples of non-structural BMPs include education, management plans, and training.

5.1.1 Best Management Practices for Specific Land Uses

The *Watershed Planning Guidebook for Kentucky Communities* (KDOW, 2010) provides an extensive list of BMPs for specific land uses. This list has been reviewed as part of the effort to select appropriate BMPs for the Woolper Creek Watershed.

General

Before providing details on the appropriate BMPs from Woolper Creek, the WCWI would like to present their philosophy on BMP selection and implementation. To gain the most benefit from implementation projects, the WCWI plans to evaluate, and implement if appropriate, not only projects within the priority subwatersheds, but all subwatersheds. If presented with a cost-effective project, with potential for water quality recovery and project success, the WCWI would like to implement it regardless of its location in the watershed. By using this approach, it is anticipated that the 319(h) grant funding could serve as a catalyst for expanding local projects to provide the most benefit for the watershed.

As a reminder, the priority subwatersheds are the Allen Fork and Upper Woolper Creek Subwatersheds due to development and impaired conditions and Double Lick Creek Subwatershed for its status as outstanding state resource water.

Stormwater

As stated in Chapter 4, stormwater is an important focus of the Watershed Plan because controlling the erosive flows of stormwater will maintain or improve the water quality in the watershed. As such, the majority of this chapter will focus on stormwater BMPs, which are most impactful in areas with substantial amounts of runoff (i.e., high impervious areas). There is a lot of existing storage already within the watershed, however it was conventionally designed for water quantity control (i.e., flood control). Traditional flood control designs focus on the flows from only large events, typically controlling the 2-year storm and larger. The International Stormwater BMP Database shows that a traditional detention basin can reduce *E.coli* by 67% and a retention basin can reduce *E.coli* by 95% (Leisenring *et al.*, 2012). Without these basins, peak flows entering the downstream creeks would be larger for these events, with worse water quality.

Conventional detention basin design can cause more erosion than pre-developed conditions.

However, greater benefits can be achieved using these existing basins by retrofitting them for channel protection. Retrofitting existing basins allows for control of smaller, more frequent storms (e.g., 6-month, 1-year) through the basin while also allowing larger events (e.g., 10-year, 50-year) to pass through as originally designed. The conventional method of designing detention basins, which focuses on the 2-year event and larger, allows the flows from smaller, more frequent events to send excess stormwater runoff downstream, causing more streambank and streambed erosion than under pre-developed conditions. Additionally, retrofits are able to double the residence time of water within the basin, which could potentially double the pollutant reductions that are dependent upon residence time (Goodrich *et al.*, 2014).

New storage, including green infrastructure and bankfull wetlands, is another viable alternative to manage stormwater flows, although these tend to be more expensive than optimizing existing basins within the watershed. These features would be sized for flood control and water quality, as local regulations require. In addition, meeting channel protection goals would be important to achieving stable stream reaches. The Northern Kentucky Stormwater BMP Manual by SD1 and the City of Florence is a great local reference for details on appropriate types of green infrastructure and design parameters. Channel protection design guidance has been developed specifically for Woolper Creek to assist local engineers and developers on these guidelines and is included in **Appendix 5-A**. **Figure 5-1** presents some images of stormwater BMPs.

Figure 5-1: Stormwater BMPs: bioretention (left), detention basin (middle), and bioswale (right)

Agriculture

Agricultural BMPs can encompass activities for lands that are used for livestock or crop farming. These BMPs should be designed to mitigate the effects of pesticides, fertilizers, animal waste, and other potential pollutants to improve water quality and stream health (KDOW, 2010). Useful resources for agricultural BMP implementation include the National Resources Conservation Service (NRCS) National Handbook of Conservation Practices and Kentucky Department of Agriculture’s website.

Farmers in the watershed have incentive programs at their disposal for manure management and riparian buffer strips. For example, the Ohio River Basin Water Quality Trading Pilot Project encourages nutrient trading in collaboration with the Electric Power Research Institute and the American Farmland Trust. The Environmental Quality Incentives Program (EQIP), under the U.S. Department of Agriculture (USDA), offers financial and technical assistance to farmers that embrace environmental stewardship through conservation practices that address natural resource concerns, such as conservation tillage, conservation coverage, nutrient management, field buffers, and riparian buffer strips (**Figure 5-2**). In the event that funding from programs such as EQIP is not available, 319(h) funding could be utilized to provide similar assistance through a similar cost-share program.

Figure 5-2: Agricultural BMPs: livestock exclusion fencing (left), buffer strip between agriculture and stream (middle), and alternative water source for cattle (right)

Focusing more on livestock, exclusion fencing (**Figure 5-2, left**) is a very popular way to reduce the impacts of livestock on streams. Preventing livestock (e.g., cows, horses, sheep, etc.) from accessing the stream minimizes direct sources of *E.coli* and provides more stable streambanks, as the livestock are no longer disrupting the riparian zone. An alternative water source is nearly always needed for the livestock, and these sources tend to keep the livestock healthier and more productive (Zeckoski *et al.*, 2012).

Construction

Construction BMPs prevent stream degradation during construction by detaining sediment and other pollutants onsite (KDOW, 2010). BMPs for construction sites include silt fencing, inlet inserts, straw wattles, check dams, and Stormwater Pollution Prevention Plans (SWPPPs) (**Figure 5-3**).

Figure 5-3: Construction BMPs: silt fence (left), inlet protection (middle), and straw wattles (right)

Kentucky's guidance on construction BMPs is available through the *Kentucky Erosion Prevention and Sediment Control Field Guide* and the *Best Management Practices (BMPs) for Controlling Erosion, Sediment, and Pollutant Runoff from Construction Sites*. SD1 requires BMPs on all active construction sites that are larger than one acre or part of a larger development (SD1, 2011). Plansets undergo review and construction sites are inspected to confirm compliance, per their Kentucky Pollutant Discharge Elimination Program (KPDES) Storm Water Management Plan (SWMP) (SD1, 2010).

Forestry

Despite the fact that over 40% of the Woolper Creek Watershed is covered by forests/open space, the WCWI is not currently aware of any active forestry sites. The BMPs listed below will be much more important if forestry activities begin to occur, although the groundwork can be laid now for a successful future. Implementing BMPs that protect the surrounding streams from the pollutants associated with the forestry industry is important. Some of these BMPs include establishment of culverts, riparian buffer zones, diversion ditches, chemical management, and preharvest planting. A useful reference for forestry BMPs is *The Kentucky Forest Landowner's Handbook*.

Figure 5-4: Forestry BMPs: Use of a culvert for stream crossing (left) and erosion protection using straw and bales (right)

Onsite Wastewater Treatment

Onsite wastewater treatment BMPs are those BMPs that provide proper installation and function of onsite wastewater treatment facilities, such as septic systems and/or sanitary sewer systems. Maintenance is also very important to prevent malfunctions in the systems (KDOW, 2010). Both the *Kentucky Onsite Wastewater Association Homeowner's Guide* (KOWA, 2001) and the *EPA Handbook for Managing Onsite and Clustered (Decentralized) Wastewater Treatment Systems* (EPA, 2005) can be found online and are valuable resources for onsite wastewater treatment installation and maintenance.

Approximately 20% of Woolper Creek Watershed's parcels are assumed to have septic.

Both sanitary sewers and septic systems are present within the Woolper Creek Watershed. About 20% of the watershed's parcels, or 1,155 of the total 5,703 parcels, have a building on them, are unsewered and could have a septic system (see **Figure 2-13** in Chapter 2). This was determined by evaluating the number of parcels with a building that are not served by SD1 (Kaeff, 2014, Pers.Comm.). Areas not served by SD1 are in the rural areas of the watershed, including Lower Woolper Creek, Ashby's Fork, and Double Lick Creek. Faulty septic systems are regulated by the Northern Kentucky Health Department, and detailed information regarding their conditions is unavailable. Proper functionality of septic systems requires knowledgeable installers and proper maintenance (**Figure 5-5**). Maintenance of the sanitary sewer system is performed by SD1 and is not part of this watershed plan.

Figure 5-5: Onsite Wastewater Treatment BMPs: Maintenance/septic pumping are routine procedures (left); Placement of the septic system can impact the maintenance (right)

Chapter 4 states that the largest source of bacteria is expected to be stormwater runoff, as every sampling site had at least 50% of the wet weather samples exceeding the allowable limit. However, it is possible that failing septic systems could be a contributor to bacteria issues in some rural subwatersheds where *E.coli* concentrations were elevated during dry, base-flow conditions. In these areas, like Middle Woolper Creek, onsite wastewater treatment BMPs and septic system improvement programs could have an impact.

Future development is a possibility within the Woolper Creek Watershed, which would bring sanitary sewers to currently unsewered areas. As described in Section 2.4, it is anticipated that the watershed will become more populated in future years, particularly in Hebron and Burlington. One example lies just outside Woolper's boundary, where SD1 is currently evaluating system capacity for a development. The current configuration would require expansion of SD1's service area farther into the Woolper Creek Watershed to achieve capacity for the development (Kaeff, 2014, Pers.comm.). Onsite wastewater BMPs should not be implemented in these areas that are experiencing or anticipating fast growth in the near future. Decisions regarding the location and extent of onsite wastewater BMP implementation will be deferred to the judgement of the Northern Kentucky Health Department.

5.1.2 Regulatory Programs

The following section describes the existing regulatory programs that are applicable within the Woolper Creek Watershed. It is anticipated that a thorough understanding of these programs will help to shape selected BMPs and their implementation.

Source Water Protection Plans, Wellhead Protection Program, and Groundwater Protection Plans

As determined in Chapter 2, there are no wellhead protection zones, or groundwater protection areas within the Woolper Creek Watershed, and as such, there are no available protection plans that are applicable. Looking farther downstream in Boone County however, there are four areas along the Ohio River that are wellhead protection areas (**Figure 5-6**). While outside these zones, improving the quality of Woolper Creek's water shows goodwill and may indirectly benefit these areas.

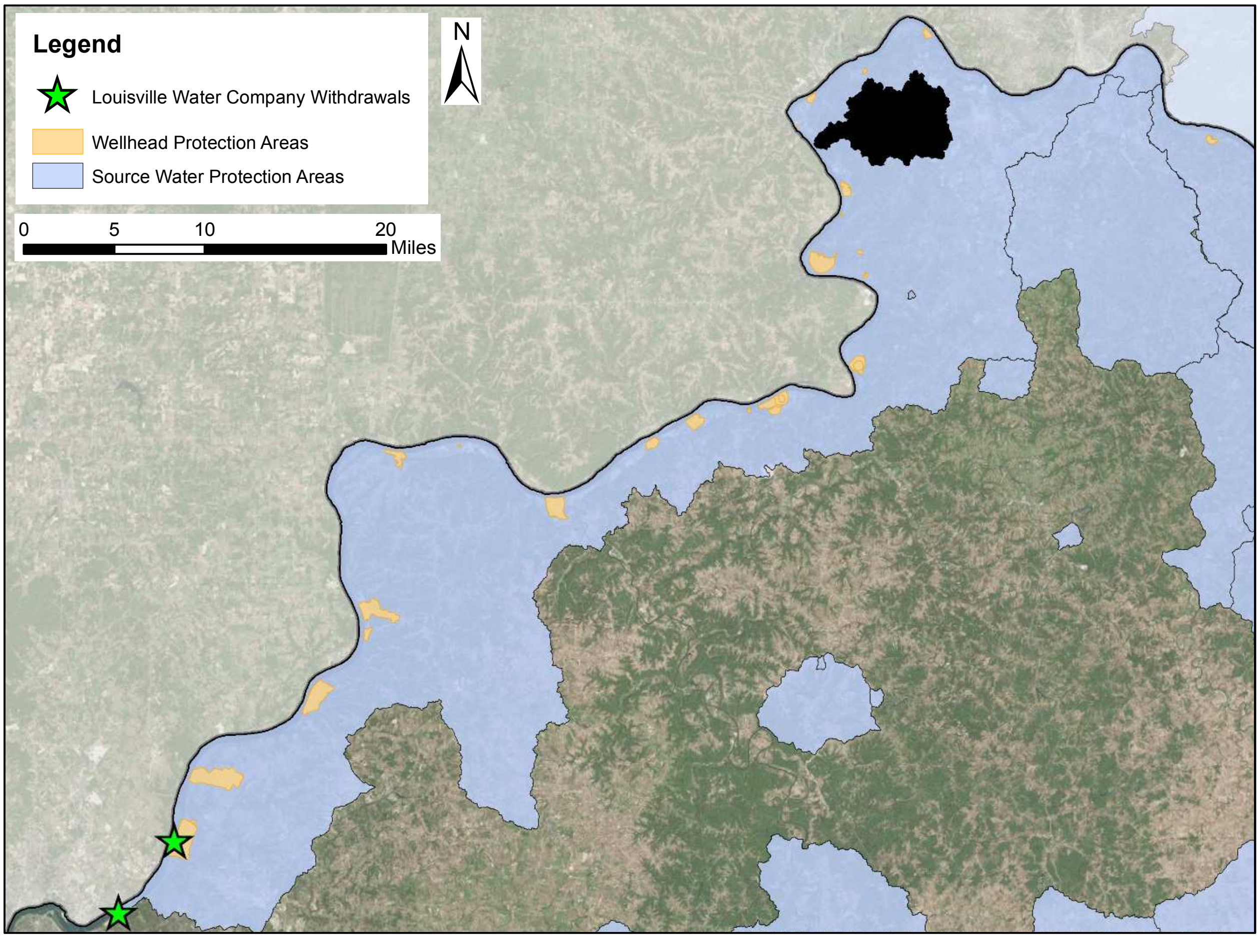


Figure 5-6: Source water protection area encompassing the Woolper Creek Watershed, with withdrawal locations near Louisville, KY

The Woolper Creek Watershed is situated in a source water protection area for the Louisville Water Company, along with nearly all of Boone County (**Figure 5-6**). The Louisville Water Company uses water from the Ohio River to supply water to Louisville Metro and parts of Bullitt and Oldham counties. Their Source Water Protection Plan was approved by KDOW in October 2003. Open communications with the Louisville Water Company may be beneficial to the WCWI's efforts.

Agriculture Water Quality Plans

To comply with the Kentucky Agriculture Water Quality Act, water quality plans for agriculture are required for any farm operations on ten or more contiguous acres that are used for agriculture or silviculture (KDOW, 2010). These plans should address farming practices that could negatively impact water quality. Assistance to farmers is available through agricultural agencies, extension offices, and conservation districts. Boone County has a rich history of farming, and BCCD reports that there are 102 water quality plans, along with 553 certifications, on file at their offices for the county. BCCD will continue to put forth efforts to coordinate with farmers on reviews and revisions to these plans as necessary.

Regulations and Programs for Wetlands and In-stream Construction or Disturbance

As previously discussed in Chapter 2, there are 245 acres of wetlands and nearly 145 miles of blue line streams within the Woolper Creek Watershed. These areas are protected by Section 404 of the Clean Water Act, which regulates the discharge of dredged or fill materials into the waters of the United States and their surrounding wetlands (KDOW, 2010). Since the beginning of 2014, one individual permit has been issued in the Woolper Creek Watershed. The Gateway International Business Park Development, along Conrad Lane between Bullittsville Road and KY-237, was issued a standard individual permit on February 26, 2015. Additionally, there are no pending individual permits through the USACE Louisville District (USACE, 2015).

Regulations for Floodplain Construction

Nearly every subwatershed, with the exception of Double Lick Creek, has some area within the 100-year floodplain, with Lower Woolper Creek's flood zone expanding for the 500-year event. Refer to Section 2.1.4 in Chapter 2 for further details. Protecting these areas is important for overall stream health, as these areas serve as buffers, filtering particles in stormwater as it flows to the stream. Construction of permanent structures within any floodplain area is not recommended and typically requires a permit from the KDOW Floodplain Office.

The Woolper Creek Watershed has 10 floodplain permits located within its boundaries (March 2016 GIS review). The uses for these permits are varied, but include structures/buildings, stream restorations, and utilities. The permit locations are included in **Figure 5-7**. Ashby's Fork and Lower Woolper Creek do not have any permits, while Double Lick has one permit, Middle Woolper Creek has two permits, Upper Woolper Creek has five permits, and Allen Fork both has two permits.

The majority of the floodplain permits are in the two most developed subwatersheds.

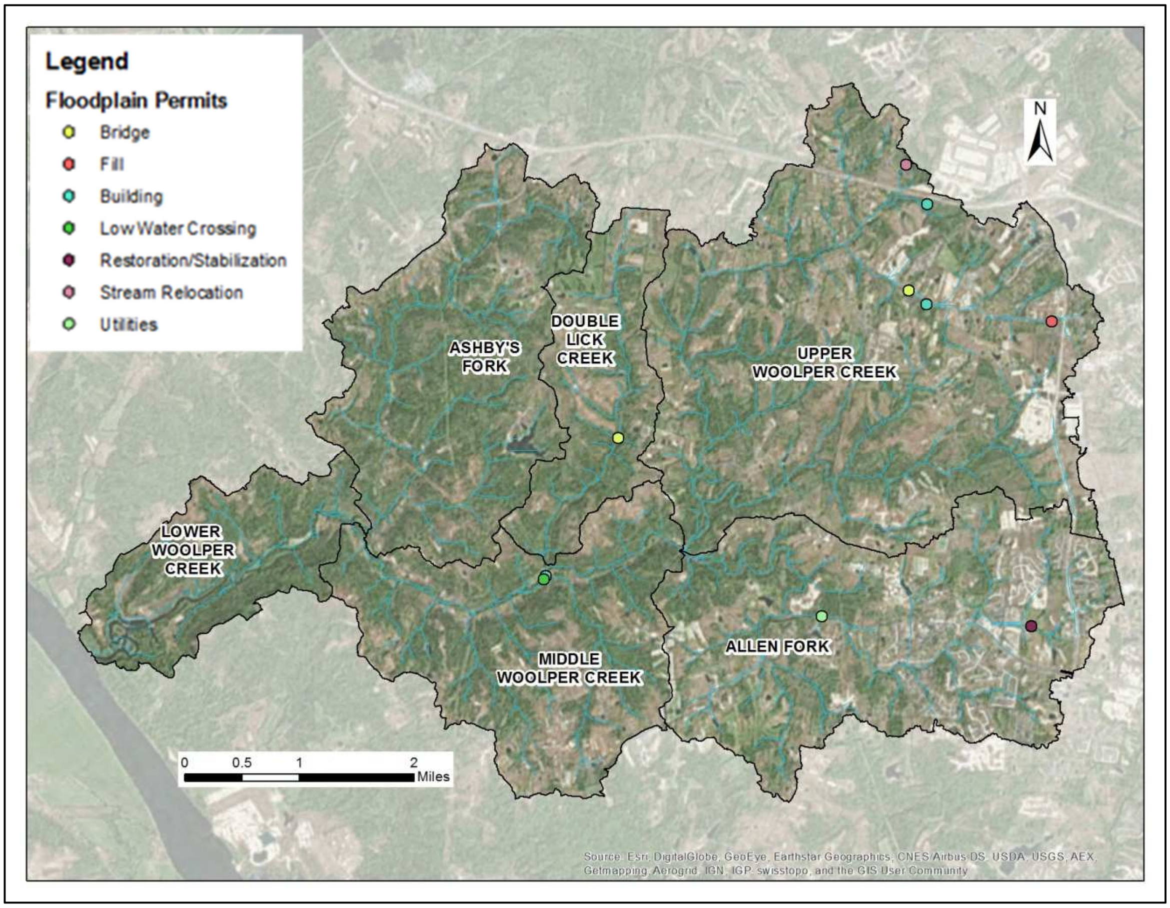


Figure 5-7: Floodplain permit locations with the Woolper Creek Watershed

Facility Plans for Wastewater

There are no wastewater treatment plants within the Woolper Creek Watershed; SD1 operates the regional plants that serve the sewered residents in the watershed, as identified in **Figure 2-12**. The areas outside the SD1 service boundary are serviced by septic systems, which do not require facility plans.

Programs and Permits for Managing Wastewater Discharges

A Kentucky Pollutant Discharge Elimination System (KPDES) permit is required for all activities that discharge to a waterway. Individual permits issued by KDOW are required for concentrated animal feeding operations (CAFOs), CSOs, industrial facilities, mining operations, municipalities, the oil and gas industry, pretreatment programs, sanitary wastewater treatment facilities, and stormwater point source discharges. As discussed in Chapter 2, there are 51 KPDES permits in the watershed, of which 24 are effective permits (six of these permits have expired and will remain effective until they are reissued or terminated). The remaining 27 permits have been terminated.

Programs and Permits for Managing Stormwater Discharges

Municipal Separate Storm Sewer Systems (MS4) are for public entities that discharge to waters of the United States, and permits are held by SD1 and the Kentucky Transportation Cabinet (KYTC) within the Woolper Creek Watershed. MS4 stormwater permits require six minimum controls, including:

- Public education/outreach
- Public involvement/participation
- Illicit discharge detection and elimination
- Construction site runoff control
- Post-construction stormwater management for new and redevelopment
- Pollution prevention/good housekeeping

Both SD1 and KYTC are on the WCWI Steering Committee and are working towards a healthy watershed. It is important to note that none of the activities funded by the 319(h) program have been reported by the project partners on their MS4 permit reporting.

Programs and Permits for Managing Combined Sewer Overflows (CSOs) and Sanitary Sewer Overflows (SSOs)

There are no CSOs within Woolper Creek, as there are no combined sewers within the watershed so the programs and permits applicable within other Northern Kentucky areas do not apply.

As discussed, there are sanitary sewers within the watershed, and they are operated and maintained by SD1. There are six historical SSOs within the watershed (LimnoTech, 2009). Five of the SSOs are within Allen Fork, with one tributary to the Woolper Creek. **Table 5-1** summarizes these points.

Table 5-1: Summary of SSO locations in the Woolper Creek Watershed (LimnoTech, 2009)

Manhole ID	Direct Discharge to:	Typical Year Spill Frequency[1]	Typical Year Volume (MG)[1]
2390002	Allen Fork	0	0
2390006	Allen Fork	0	0
2390762	Allen Fork	3	0
2390008	Allen Fork	0	0
2390PS1 (Allen Fork PS)	Allen Fork	0	0
2370PS1 (Bullittsville PS)	Woolper Creek tributary	0	0

[1] Based on modeling information and subject to change.

From increasing pump station pumping capacity to upsizing sewers to provide additional capacity during wet weather conditions and addressing inflow and infiltration concerns, SD1 has expended a substantial effort to eradicate SSOs throughout their service area. SD1 authored the *Pump Station Overflow Elimination Plan* (2008) to eliminate SSOs caused by inadequate pump stations, including both the Allen Fork and Bullittsville pump stations. The Phase II Improvement projects alone cost over $30 million in infrastructure improvements to abate SSO's (LimnoTech, 2009). As of May 2014, the Allen Fork Pump Station improvements have been completed as well as the Taylorsport Pump Station improvements, which encompassed the Bullittsville Pump Station (SD1, 2014).

Special Land Use Planning or Existing Watershed Plans

The Boone County Planning Commission (BCPC) leads the county's development of comprehensive plans, zoning regulations, and subdivision regulations. Refer to their website for these documents and other applicable studies and projects. The BCPC is also an active member of the WCWI Steering Committee.

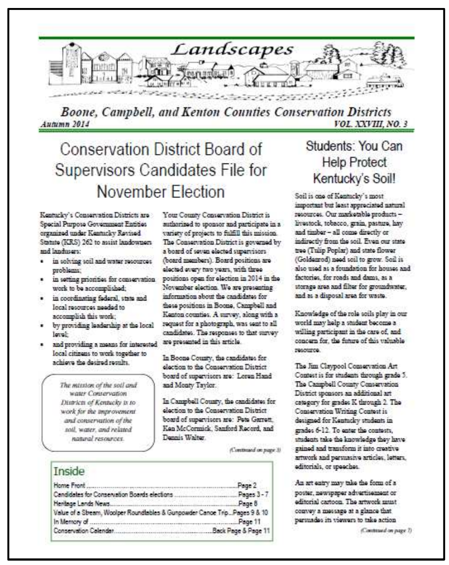
As discussed in Chapter 2, there are large areas of open and forested land throughout the western portions of the watershed. Over 40% of the land use is considered open space/forest. The Center for Watershed Protection (2013) considers preservation of large, undeveloped land to be one of the most cost-effective strategies to protect water quality. A better understanding of any special land use planning areas within the watershed will be helpful to preserving the open land.

Preserving any of the large, open, forested land in the watershed would protect water quality.

The Boone Conservancy, a non-profit organization dedicated to park creation and land protection is a useful resource for preservation of special land uses, and BCCD coordinates with them when possible. Wildlife Conservation Kentucky is another non-profit that leases the Split Rock Park at the confluence of the Woolper Creek with the Ohio River.

LimnoTech authored a watershed characterization report for the Woolper Creek Watershed in 2009, and the document has been a valuable resource while writing this Watershed Plan. The document is not a watershed plan itself, as it does not propose implementation efforts in the watershed, but focuses solely on the existing conditions.

Both the Allen Fork and Upper Woolper Creek Subwatersheds have received a lot of attention due to flooding and stream stabilization issues. For example, In September 2005 an Allen Fork Headwater Feasibility Study was completed to evaluate this subwatershed. This study, which was sponsored by Boone County Public Works Department and SD1, can be found in **Appendix 5-B**. Furthermore, as part of this Watershed Planning effort, WCWI is studying these two subwatersheds and the opportunity to retrofit existing detention basins. For example, the Allen Fork Watershed Analysis technical memorandum dated September 2014 and prepared by Strand Associates, Inc. identifies candidates for detention basin retrofits. The follow-up technical memorandum also prepared by Strand, titled Allen Fork Watershed Storm Water Basin Retrofit Analysis and dated June 2015, summarizes the optimization of 11 basins within the subwatershed that provide peak flow attenuation to reduce the


Landscapes

Boone, Campbell, and Kenton Counties Conservation Districts

Autumn 2014 VOL. XXVIII, NO. 3

Conservation District Board of Supervisors Candidates File for November Election

Kentucky's Conservation Districts are Special Purpose Government Entities organized under Kentucky Revised Statute (KRS) 262 to assist landowners and landusers:

- in solving soil and water resources problems;
- in setting priorities for conservation work to be accomplished;
- in coordinating federal, state and local resources needed to accomplish this work;
- by providing leadership at the local level;
- and providing a means for interested local citizens to work together to achieve the desired results.

The mission of the soil and water Conservation Districts of Kentucky is to work for the improvement and conservation of the soil, water, and related natural resources.

Your County Conservation District is authorized to sponsor and participate in a variety of projects to fulfill this mission. The Conservation District is governed by a board of seven elected supervisors (board members). Board positions are elected every two years, with three positions open for election in 2014 in the November election. We are presenting information about the candidates for these positions in Boone, Campbell and Kenton counties. A survey, along with a request for a photograph, was sent to all candidates. The responses to that survey are presented in this article.

In Boone County, the candidates for election to the Conservation District board of supervisors are: Loren Hand and Monty Taylor.

In Campbell County, the candidates for election to the Conservation District board of supervisors are: Pete Garrett, Ken McCormick, Sanford Record, and Dennis Walter.

(Continued on page 3)

Inside

Students: You Can Help Protect Kentucky's Soil!

Soil is one of Kentucky's most important but least appreciated natural resources. Our marketable products – livestock, tobacco, grain, pasture, hay and timber – all come directly or indirectly from the soil. Even our state tree (Tulip Poplar) and state flower (Goldenrod) need soil to grow. Soil is also used as a foundation for houses and factories, for roads and dams, as a storage area and filter for groundwater, and as a disposal area for waste.

Knowledge of the role soils play in our world may help a student become a willing participant in the care of, and concern for, the future of this valuable resource.

The Jim Claypool Conservation Art Contest is for students through grade 5. The Campbell County Conservation District sponsors an additional art category for grades K through 2. The Conservation Writing Contest is designed for Kentucky students in grades 6-12. To enter the contests, students take the knowledge they have gained and transform it into creative artwork and persuasive articles, letters, editorials, or speeches.

An art entry may take the form of a poster, newspaper advertisement or editorial cartoon. The artwork must convey a message at a glance that persuades its viewers to take action

(Continued on page 7)

Figure 5-8: *Landscapes* newsletter from Fall 2014 includes details on the benefits of streams

amount of flows in the receiving streams that exceed the critical flow for streambed erosion. Furthermore, Strand Associates is completing an evaluation of the detention basins in the Upper Woolper Creek Subwatershed, which includes detailed study and modeling of 17 basins as retrofit opportunities. The full technical memorandums and presentations can be found in **Appendix 5-B**.

5.1.3 Education as a Best Management Practice

The WCWI already uses education as a BMP for improvements in the watershed. This non-structural BMP has engaged the public through educating the community about pollutants of concern, potential sources of pollutants, and solutions to improve the condition of the streams within the watershed. Articles have been published in the *Landscapes* newsletter (**Figure 5-8**), a Boone Conservancy publication. Fact sheets and cut sheets, which are discussed in more detail throughout Chapter 6, have been developed to assist residents, developers, and engineers on appropriate BMPs and how to appropriately design them. Public meetings have been held for residents to voice opinions and concerns. These activities, which are educating the community, will continue throughout the implementation phase of the Woolper Creek Watershed Plan.

The WCWI feels that it is important to present and provide information in an accommodating manner for larger public appeal, so the WCWI has developed a Watershed Plan summary document that succinctly covers the most important aspects of this Plan. The document, entitled the Woolper Creek Watershed Plan - Public Outreach Document, provides an overview of the Plan for residents of the watershed to easily understand the Plan's contents.

Continuing educational efforts using signage, training, and media will increase the impact of the structural BMPs.

Furthermore, as the WCWI implements the Plan and begins to install BMPs throughout the watershed, it will be important to provide signage for the structural BMPs that are constructed within the watershed, so residents can understand the progress being made and appreciate the benefits. Signage may also be useful along waterways with public access, with topics covering pollutants and overall watershed health.

Signage in parks and other places will also be used as part of a pet waste program (**Figure 5-9**). Along with explaining the importance of a pet waste program, this signage can provide dog owners with information on the impacts of left-behind dog waste on stream systems. Ample trash receptacles and bags are also important

Figure 5-9: Example sign for pet waste program

structural components to complement the pet waste program.

Additional educational opportunities include training engineers, developers, and staff about the numerous structural BMPs and providing the right resources for their installations to be successful. One example of this is the fact sheets that have been developed regarding channel protection design (**Appendix 5-A**). Outreach on the BCCD Facebook page, which may include posts and/or videos, could also be a great way to use social media to spread educational information about Woolper Creek.

5.2 Selecting Best Management Practices for the Prioritized Subwatersheds in the Woolper Creek Watershed

The following sections provide details regarding the BMP strategy that has been tailored to the Woolper Creek Watershed after exploring the watershed and collecting and analyzing stream data. The WCWI would again like to stress that as projects arise, it could be beneficial to adjust the priority subwatersheds or implement projects in the lesser priority subwatersheds. The potential for water quality recovery will also be considered as opportunities for implementation projects arise throughout the Woolper Creek Watershed. In order to utilize the implementation funds in the most economical way, each project will be evaluated regardless of the subwatershed. Currently, the priority subwatersheds where the WCWI efforts will begin are outlined below:

- Developed Subwatershed: Allen Fork
    - High imperviousness
    - Most impaired developed subwatershed
- Developed Subwatershed (second priority): Upper Woolper Creek
    - High imperviousness
    - Flooding concerns
    - Second-most impaired developed subwatershed
- Undeveloped Subwatershed: Double Lick Creek
    - Outstanding state resource water
    - Good water quality to protect

5.2.1 Selecting BMPs for Allen Fork and Upper Woolper Creek (Developed Subwatersheds)

The stream function pyramid, as presented in chapters 3 and 4, provides an understanding of how improperly managed land use (i.e., increased impervious area) leads to flashy flow regimes that degrade habitat, water quality, and biology of stream networks. Stormwater is reaching streams faster, warmer (in summer months), and dirtier than during pre-developed conditions. To mitigate the impacts in these developed areas, best management practices (BMPs) must be selected that will control the volume while improving the quality of the water.

Stormwater Volume-Based BMPs

Volume-based BMPs can reduce stormwater peak flows and remove pollutants, creating multiple levels of benefits related to the stream function pyramid. By restoring a more natural flow regime, the habitat and biology of the stream system can also be restored. Many aquatic species have evolved to and require the natural streambed disturbance frequencies that occur in undeveloped watersheds; however, flashy flow regimes, caused by development, create disturbance events that erode the streambed material at frequencies that can cause aquatic communities to shift in composition and diversity. The importance of the natural streambed disturbance regime to the region's aquatic communities has been documented in greater detail in Chapter 4, as well as a recent peer-reviewed journal article by several of the partners who have helped to collect data and write this watershed plan (Hawley *et al*., 2016).

The WCWI has estimated the approximate storage volumes needed throughout the Woolper Creek Watershed in order to restore a more natural streambed disturbance regime that would reduce stream channel erosion and benefit biological communities. Through desktop analysis, an estimated 228 basins exist within the watershed, and although many of these are likely small farm ponds, there are substantial amounts of existing stormwater storage in what are likely traditional detention basins. This desktop analysis, which is further discussed in **Appendix 5-C**, determined there could be enough existing storage throughout much of the watershed to potentially restore a more natural streambed disturbance regime; however, this storage would need to be retrofitted to be better optimized to provide adequate water quality and channel protection benefits.

Figure 5-10: Detention basin retrofit technology cost-effectively optimizes excess capacity for downstream channel stability

One cost-effective way to achieve reductions in stormwater peak flows is to modify, or retrofit, the outlet of the existing detention and retention basins, without conducting any extensive earthmoving activities. Because many of these basins were likely designed for conventional peak flow/flood control, frequent storm events typically pass through them with little attenuation and can cause or exacerbate downstream channel erosion (Hawley, 2012). By modifying the basins, peak flows for smaller events can be reduced to be released at rates that minimize streambed erosion, while allowing larger flood-control events to pass through the basin as originally designed. Modifications can be simple, such as an orifice plate or other minor change to the outlet control structure (e.g., the DetainH2O device, **Figure 5-10**, Hawley *et al.*, In Revision), or they can be more in-depth with changes to basin grading and/or installation of amended soil.

In fact, SD1 has recently implemented additional requirements for developers to design to the critical flow threshold for smaller storms, such that new basins on future developments should be designed to meet flood control, water quality and channel protection criteria. In addition to flood control starting at the 2-year event and water quality for the 0.8-inch event, developers are required to further reduce the 2-year peak flow leaving their sites. For SD1, the basin's outflow must be less than 0.4 cfs per acre of area draining to the basin for the 2-year event to achieve channel protection.

There are numerous opportunities within the Woolper Creek Watershed to implement stormwater volume-based controls, including detention basin retrofits.

In regards to areas with existing developments that have conventionally designed detention basins, retrofits could also help to alleviate flooding. Beyond adjusting the peak flows for the 2-year storm event as discussed above, peak flows from larger storm events (e.g., 10-year, 25-year) may also be able to be managed through modifications to the outlet control structure, depending on the original design and excess freeboard in the basin.

The Allen Fork Subwatershed currently has 102 identified detention and retention basins, none of which are likely optimized for channel protection. The desktop analysis of these basins, described in **Appendix 5-C**, provided an estimated storage of ~93 acre-feet that is not optimized. Based on an evaluation of existing projects in the Northern Kentucky region, it was estimated that the Allen Fork Subwatershed requires only ~84 acre-feet of optimized storage, provided that the storage could capture and mitigate all of the existing impervious area. This means that the Allen Fork Watershed might not necessarily require the construction of new storage basins, provided there are enough opportunities to retrofit the existing basins that are already in the watershed. That is, if the existing storage that already exists within the watershed was optimized, it could be enough to protect the streams from excess bank erosion induced by erosive flows.

With this information, the WCWI decided to pursue a more detailed evaluation of the basins throughout the Allen Fork Subwatershed to understand which basins could be easily retrofitted to cost-effectively provide optimized controls, as it is unrealistic to retrofit all ~102 basins in the subwatershed. Therefore, Strand Associates and Sustainable Streams completed detailed storm water and sediment transport modeling of prioritized detention basins throughout Allen Fork, providing specific recommendations for retrofitting the basins to provide channel protection. Of the 16 basins evaluated, 11 provide viable opportunities for potential implementation efforts. This study illustrated that simple adjustments to outlet control structures can have a cost-effective impact on the stream integrity by reducing the magnitude and frequency of exceedances of $Q_{critical}$. Excess sediment transport capacity is anticipated to be reduced by approximately 25% at ALF 0.1 and 60% at ALF 4.0 simply by implementing these 11 retrofit opportunities. **Appendix 5-B** includes the technical memorandum provided by Strand Associates.

Furthermore, in the Upper Woolper Creek Subwatershed increased development has occurred within the past 20 years and is generating a substantial amount of stormwater runoff. Approximately 90 detention/retention basins exist in the Upper Woolper Creek Subwatershed. Based on interpolation using existing projects, and further discussed in **Appendix 5-C**, the Upper Woolper Creek Subwatershed needs approximately 92 ac-ft of optimized storage. Evaluation of existing storage throughout the watershed indicates approximately 105 ac-ft of storage, which would need to be optimized to provide water quality and channel protection. However, it should be noted that only a portion of the ~105 ac-ft of storage will present viable opportunities for retrofits; and therefore, new storage opportunities (e.g., bankfull wetlands, detention, etc.) will also need to be implemented in this subwatershed.

Furthermore, flooding that occurs in this subwatershed is likely a result of the increased development, which is creating flows greater than those that can pass through the existing culverts. By retrofitting detention basins in this subwatershed, decreasing peak flows exiting the basins for the 2-year storm (i.e., channel protection) and larger, flows may be able to pass through the existing stormwater drainage infrastructure that currently do not provide the capacity to pass the flood flows.

More specifically, flooding concerns have been expressed in the headwaters of the Upper Woolper Creek Subwatershed, upstream of the Lauren Meadows Drive and Benjamin Lane culverts (**Figure 5-11)**. This portion of the subwatershed has been stressed with substantial commercial and industrial developments over the last 20 years and the existing detention/retention basins present potentially viable opportunities for providing channel protection. An evaluation effort is currently underway by Strand Associates; and their detention analysis presentation for the Upper Woolper Creek Subwatershed has been included in **Appendix 5-B**. As illustrated in this Upper Woolper Creek Subwatershed Detention Analysis presentation, 25 retention/detention basins exist in the headwaters of the subwatershed, upstream of the primary flooding locations at Lauren Meadows Drive and Benjamin Lane. After an initial screening, Strand is currently analyzing 17 of these basins in more detail.

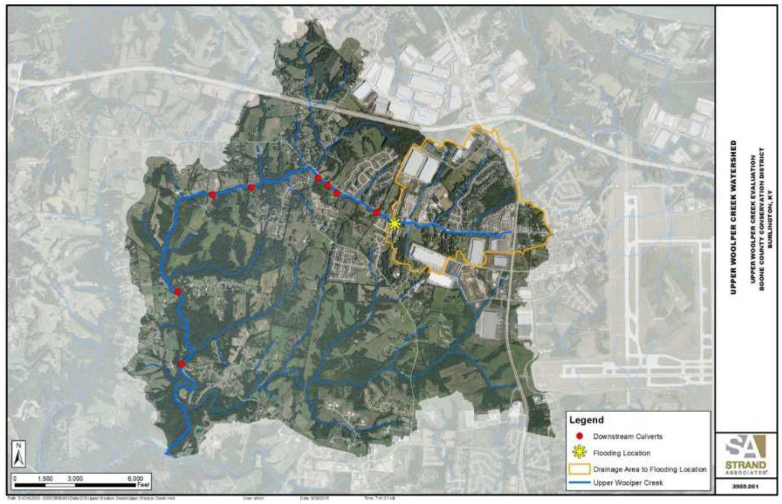


Figure 5-11: Flooding location in the headwaters of the Upper Woolper Creek Subwatershed provides focus for detention basin retrofit study upstream

To optimize existing storage for channel protection, it is necessary to understand the design goals. The critical flow, also known as $Q_{critical}$, is the flow in a stream at which erosion of the bed material is estimated to begin. Flows higher than the critical flow mobilize bed and bank material. $Q_{critical}$ values were calculated using data from the hydrogeomorphic surveys and are represented as a percentage of the two-year peak flow (i.e., Q_2). **Figure 5-12** presents the findings of the analysis performed to determine appropriate $Q_{critical}$ values specific to the Woolper Creek Subwatersheds. Guidance for designing BMPs utilizing the $Q_{critical}$ values is included in **Appendix 5-A**.

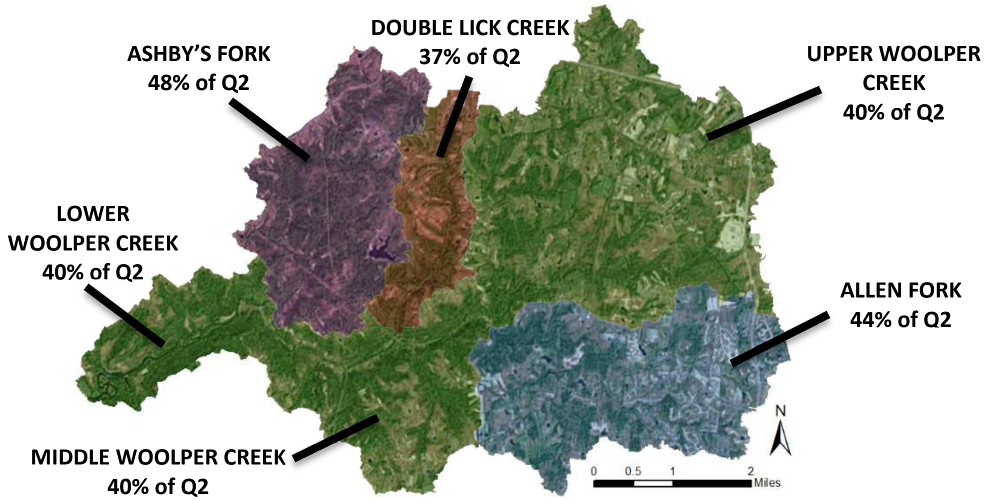


Figure 5-12: $Q_{critical}$ values for the Woolper Creek Subwatersheds represented as a percentage of the 2-year peak flow

Detention basin retrofits may represent the most cost-effective opportunities to restore more natural rates of streambed erosion and biological disturbance in Woolper Creek; however, other BMPs may ultimately be necessary in areas, for example, where large amounts of impervious area are currently undetained retrofits. Beneficial BMPs to evaluate include extended detention basins, bioretention basins, bankfull wetlands, and enhanced swales. Enhanced swales are specifically tailored to linear locations, such as roadway right-of-way. Additional information on these BMPs can be found in Chapter 6. Volume-based BMPs like those mentioned above help to reduce erosive flows and also tend to improve water quality. Indeed, filtration-type BMPs that cleanse stormwater but do little to mitigate the large peak flows (e.g. green roofs, porous pavement, and hydrodynamic separators) typically have lower pollutant reduction rates than volume-based BMPs (**Figure 5-13**). The figures, developed using data from the International BMP Database (Leisenring *et al.,* 2012), show that two pollutants, *E.coli* and phosphorus, tend to have better removal rates in volume based BMPs as opposed to other BMPs.

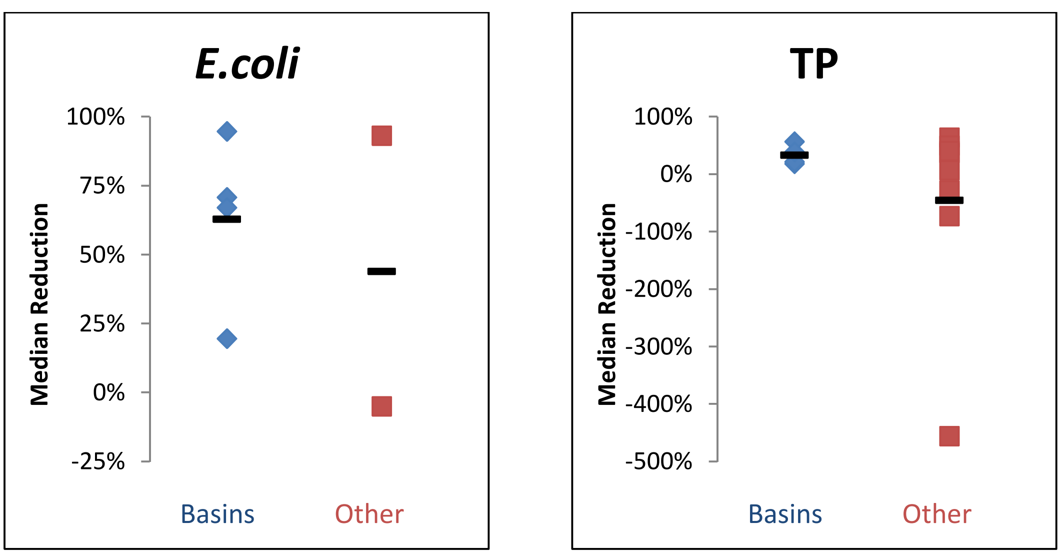


Figure 5-13: Median reduction of *E.coli* and total phosphorous by stormwater quantity BMPs versus reduction by other BMPs. 'Basins' includes detention, retention, bioretention, and wetlands. 'Other' includes all other BMPs listed in the International BMP Database (Leisenring *et al.*, 2012)

Additional BMPs

It is anticipated that the majority of the impairments in Allen Fork and Upper Woolper Creek could be resolved by focusing on the stormwater volume-based BMPs; however, many additional BMPs can benefit the subwatershed. Construction BMPs using the requirements from the *Kentucky Best Management Practices for Construction Activities* and SD1's Stormwater Quality Management Plan will help reduce erosion and sediment loading, especially since these watersheds are continuing to develop. Although Allen Fork is highly developed, ~26% is still classified as agricultural, mostly on the western side, and ~34% of Upper Woolper Creek is classified as agricultural. Identifying the type of agriculture in these subwatersheds and utilizing appropriate BMPs could help to reduce nutrient loading. Education will also be very important to informing residents about implementation efforts and better management practices.

Agricultural, construction, and education BMPs will be beneficial to the developed subwatersheds in addition to volume-based stormwater controls.

The WCWI does not plan to implement on-site wastewater BMPs in the Allen Fork or Upper Woolper Creek Subwatersheds but will utilize as appropriate. Allen Fork's *E.coli* levels did not tend to be above the allowable concentration. Upper Woolper Creek did have *E.coli* levels higher than the allowable; however, it is expected that much of the anticipated population growth over the next 15 years will occur in the Allen Fork and Upper Woolper Creek Subwatersheds, which will replace remaining septic systems with sanitary sewer service. Again, any decisions regarding onsite wastewater BMP implementation will be deferred to the judgement of the Northern Kentucky Health Department, as appropriate.

A pet waste program could be beneficial for these subwatersheds, given that the high percentage of residential landuse (Allen Fork: 43%; Upper Woolper Creek: 19%) could imply a high prevalence of dogs. By educating dog owners through signage and waste receptacles in the public setting, it would be the goal to have pet waste picked up and disposed of both in parks and in backyards.

5.2.2 Selecting BMPs for Double Lick Creek (Undeveloped Subwatershed)

BMPs that protect the Double Lick Creek are the most important in this subwatershed in order to preserve the high quality nature of the stream. The majority of the subwatershed is forested (45%), with a similar percentage being classified as agricultural land (43%).

Forestry BMPs and Preservation of Land

For the forested areas of the watershed, WCWI may conduct informational sessions with the Kentucky Division of Forestry, the Northern Kentucky Urban Forestry Council, and the Boone County Urban Forest Commission to continue to educate and inform the industry on their impacts to local streams.

Conservation easements and property acquisition in the Double Lick Creek Subwatershed are other viable options for preservation. There is currently no public land in the subwatershed however, acquiring land for a park or natural conservation, specifically along the creek, could allow residents to enjoy and understand the pristine quality of this stream.

Agricultural BMPs

For the agricultural areas, additional research is needed to determine if the agricultural lands are primarily livestock or crops. Livestock fencing could be beneficial for reducing *E.coli* loads, although the analysis presented in Chapter 4 illustrates that *E.coli* loads are not a substantial issue, as dry weather *E.coli* concentrations only exceeded the water quality standard in less than 20% of the samples. Nutrient loadings exceeded the water quality standard in many of the samples, which could be lessened with filter strips (i.e., riparian planting areas) or a reduction in fertilizer application, if crops are found in the subwatershed.

Review and Revision of Existing Rules and Regulations

Changes to stormwater management guidance in 2012 brought about requirements to provide treatment of the first 0.80 inches of rain from every event (i.e., 80th percentile event). SD1 and the City of Florence developed the Northern Kentucky Storm Water Best Management Practices Manual (**Figure 5-14**) to assist developers and designers on how best to achieve these new regulations.

The recent improvements made to local regulations regarding water quality treatment made great strides in improving the health of receiving streams in the watershed, however through data collection for this watershed plan and other data collected across the region by SD1, the importance of the $Q_{critical}$ for stream erosion has now been documented in the region and SD1 has required stormwater designs on new developments to meet the channel protection criteria discussed above.

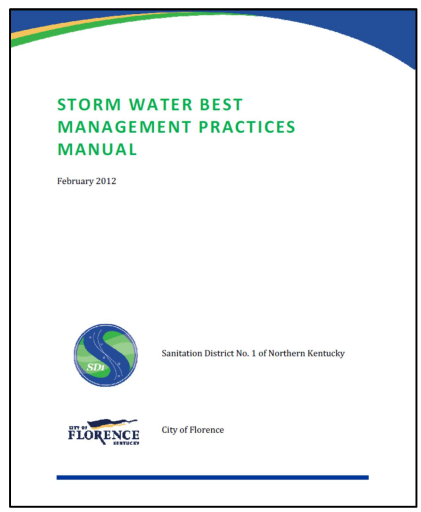


Figure 5-14: The Northern Kentucky Storm Water BMP Manual

Another member of the WCWI Steering Committee is the Boone County Planning Commission (BCPC), responsible for the planning and zoning requirements and subdivision regulations in the county, which includes stormwater guidance for areas outside of SD1's jurisdiction. As such, a review of these regulations could be as beneficial as a review of SD1's. The review would be most beneficial in the least developed areas, including Double Lick Creek. Current requirements include stream buffer zones based on Kentucky's General Permit for stormwater discharges associated with construction activities, or KYR10 (Boone County, 2010) and embraces the Northern Kentucky Storm Water Best Management Practices Manual's guidance.

Agency Planning and Coordination

BCPC and SD1 already work well together to manage stormwater in the Woolper Creek Watershed, but continued planning and coordination between these and other local agencies is key to the successful implementation of this Plan. One such example is the review and revision of stormwater rules and regulations. Identifying revisions to all the above-mentioned documents that are mutually agreeable by all stakeholders will assist in gaining support for these revisions and reducing inconveniences as they are first implemented. Preserving natural drainage features and floodplains, conserving large tracts of public land, and protecting water resources on flood control projects are all additional examples of actions in the watershed that will require coordination of multiple agencies.

The WCWI brings many of these agencies together during Steering Committee meetings, where good discussion and helpful ideas are nurtured. Continuing these relationships and discussions is important, as no one agency is the cause of all the problems or keeper of all the solutions. The effort of the entire team is necessary to improve Woolper Creek.

Additional BMPs

As the Double Lick Subwatershed is much less developed than Allen Fork or Upper Woolper Creek, septic is anticipated to be the primary source of wastewater treatment. Although *E.coli* levels were not generally over the allowable concentration, assisting homeowners with the maintenance of septic systems will be evaluated as issues arise. The WCWI will coordinate closely with the Northern Kentucky Health Department regarding potential opportunities to implement onsite wastewater BMPs throughout the Double Lick Subwatershed.

If development occurs in the watershed, construction BMPs will be used on all sites, as outlined in the *Kentucky Best Management Practices for Construction Activities* and SD1's Stormwater Quality Management Plan. Education will play a role in this subwatershed also. Lastly, if development occurs in the Double Lick subwatershed, it should attempt to preserve the Outstanding Water Resource of Double Lick Creek.

5.2.3 Selecting BMPs for Additional Areas of the Woolper Creek Watershed

As mentioned multiple times throughout this Plan, the goal of the WCWI is to make the biggest impact possible on the Woolper Creek Watershed. To achieve this goal, it is important to look at beneficial projects as they arise, regardless of the specific location. While the Double Lick Creek, Allen Fork, and Upper Woolper Creek Subwatersheds are currently the three priority subwatersheds, the WCWI may choose to implement projects in other subwatersheds, if it will have a greater impact on overall watershed health. Items that will be considered include additional funding, location, project partners, willing property owners, project size, and visibility. While project ranking criteria has not been specifically developed, the Steering Committee will discuss and evaluate projects as necessary during implementation.

Table 5-2 summarizes BMP strategies appropriate to employ within the Woolper Creek Watershed.

Table 5-2: List of BMPs tailored to the Woolper Creek Watershed

	Structural Practices	Non-Structural Practices
Agriculture	Contour buffer strips Field buffers Grassed waterways Herbaceous wind barriers Live fascines Livestock exclusion fence (prevents livestock from wading into streams) Terraces Waste treatment lagoons Filter strips Alternative water sources Cover crops	Brush management Conservation coverage Conservation tillage Fertilizer management Nutrient management plans Operation of planting machines along the contour to avoid ditch formation Pesticide management Preharvest planning Prescribed/rotational grazing Residue management Workshops/training for developing nutrient management plans
Forestry	Culverts Revegetation of firelines with adapted herbaceous species Temporary cover crops Tree planting/reforestation Windrows	Education campaign on forestry-related nonpoint source controls Fire management Forest chemical management Training loggers and landowners about forest management practices, forest ecology and silviculture Review of local forestry practices with Kentucky Division of Foresty
Unde-veloped		Preservation of open/undeveloped space
Developed	Bioretention cells Bioinfiltration basins Onsite/clustered wastewater treatment systems Daylighting Detention basin retrofits Green roofs Enhanced swales Infiltration basins Permeable pavements Rain barrels Rain gardens Stormwater ponds Sand filters Sediment basins Tree revetments Water quality swales	Development of greenways in critical areas Flood control master planning with channel erosion and water quality components Management programs for onsite and clustered/onsite (decentralized) wastewater treatment systems, including homeowner education programs and pump-out/repair programs Pet waste programs/signage Planning for reduction of impervious surfaces (e.g., eliminating or reducing curb and gutter) Setbacks Storm drain stenciling
Overall Watershed	Conversion of turf areas to native vegetation Establishment of riparian buffers Live staking Mulch Revetments Riparian establishment/restoration Stream Restoration Stream Stabilization Wetland creation/restoration	Educational materials Erosion and sediment control plans Fee-In-Lieu-Of plans to fund BMP projects Fund a watershed coordinator Illicit discharge detection/elimination program Interagency planning and coordination Monitoring program Planning and proper road layout and design Pollution prevention plans Review and revision of planning and zoning Review and revision of stormwater rules/regs. Stewardship incentives programs Workshops on proper installation and maintenance of structural BMPs Workshop/training on stormwater design for stream erosion protection Onsite wastewater programs - homeowner education & pump-out/repair programs

*Note that practices listed under one land use category can be applied in other land use settings as well.

5.3 Finding Solutions - Summary

Utilizing the watershed information collected in Chapter 2 and the water quality data monitored and analyzed in Chapters 3 and 4, numerous BMPs for specific land uses and constituents of concern have been evaluated. Overall, stormwater volume-based BMPs are the most important structural BMP with educational efforts and conservation of land being the most important non-structural BMPs. It is the plan of the WCWI to focus implementation efforts to these BMPs, as practical, in the Allen Fork, Upper Woolper Creek, and Double Lick Creek Subwatersheds to improve the health of the watershed. Agricultural, forestry, on-site wastewater, and construction BMPs will also be utilized, as appropriate in these and other subwatersheds, to fully restore the habitat, water quality, and biology of Woolper Creek.

References

Boone County, 2010. Boone County Subdivision Regulations. Boone County Planning Commission. Burlington, KY. November. 174 pp.

Center for Watershed Protection, 2013. Cost-Effectiveness Study of Urban Stormwater BMPs in the James River Basin. Center for Watershed Protection, Eliot City, MD. June.

Emerson, C.H., Welty, C. and Traver, R., 2003. Application of HEC-HMS to model the additive effects of multiple detention basins over a range of measured storm volumes, World Water and Environmental Resources Congress. ASCE.

EPA, 2005. Handbook for Managing Onsite and Clustered (Decentralized) Wastewater Treatment Systems. US Environmental Protection Agency, Washington, D.C. 66 pp. Available: http://www.epa.gov/owm/septic/pubs/onsite_handbook.pdf.

Goodrich, J.A., Hawley, R.J., Wooten, M.S., Frye, C., Jacobs, M., Beaulieu, J.J., and Korth, N.L., 2014. Change the Game with Green Infrastructure - Retrofits of Existing Detention Basin may be Orders of Magnitude More Cost-Effective than New BMP Construction, Stormwater Congress. Water Environment Federation, WEFTEC, New Orleans, LA, Sept 29-Oct 1.

Hawley, R.J, 2012. A Regionally-calibrated Approach to 'Channel Protection Controls'—How Meeting New Stormwater Regulations Can Improve Stream Stability and Protect Urban Infrastructure. In Proceedings of the Water Environment Federation Stormwater Symposium, Baltimore, MD, July 18-20.

Hawley R.J., Wooten, M.S., MacMannis, K.R., and Fet, E.V., 2016. When do macroinvertebrate communities of reference streams resemble urban streams? The biological relevance of $Q_{critical}$. *Freshwater Science*, 35(3): XXX-XXX. DOI: 10.1086/687808

Hawley R.J., Goodrich, J.A., Korth, N.L., Rust, C.J., Fet, E.V., Frye, C., MacMannis, K.R., Wooten, M.S., Jacobs, M., Sinha, R., In Revision. Detention outlet retrofit device improves the functionality of existing detention basins by reducing erosive flows in receiving channels. *Journal of the American Water Resources Association*

Kaeff, C., 2014, Pers. Comm. Woolper Septic Count. SD1, Regulatory Reporting & Wet Weather Coordinator (859-578-7450 x7332).

KDOW, 2010. Watershed Planning Guidebook for Kentucky Communities. Prepared by the Kentucky Division of Water and the Kentucky Waterways Alliance. Frankfort, KY.

KOWA, 2001. A Kentucky Homeowner's Guide to Septic Systems. Kentucky Onsite Wastewater

Association, Inc. 23 pp. Available: http://www.kentuckyonsite.org/documents/1%20KentuckyHomeownerGuide7-06.pdf.

Leisenring, M., Clary, J., and Hobson, P. 2012. International Stormwater Best Management Practices (BMP) Database Pollutant Category Summary Statistical Addendum: TSS, Bacteria, Nutrients, and Metals. Prepared by Geosyntec Consultants and Wright Water Engineers for the Water Environment Research Foundation. July, 2012.

LimnoTech, 2009. Woolper Creek Watershed Characterization Report, Prepared for Sanitation District No. 1 of Northern Kentucky, Fort Wright, KY.

SD1, 2010. Storm Water Management Plan for Second Permit Cycle (2010-2015). Sanitation District No. 1 of Northern Kentucky, Kentucky. October. pp.36.

SD1, 2011. Storm Water Rules and Regulations. Sanitation District No. 1, Fort Wright, KY.

SD1, 2014. Pump Station Overflow Elimination 2014 Annual Report. Sanitation District No. 1 of Northern Kentucky, Kentucky. May.

Strand Associates, Inc., 2015. Allen Fork Watershed Storm Water Basin Retrofit Analysis Technical Memorandum (Draft), Prepared for Boone County Conservation District, Burlington, KY.

USACE, 2015. ORM Permit Decisions. United States Army Corps of Engineers. Available: http://geo.usace.army.mil/egis/f?p=340:1:0::NO Accessed: July 1, 2015.

Zeckoski, R., Benham, B., and Lunsford, C., 2012. Streamside Livestock Exclusion: A tool for increasing farm income and improving water quality. Virginia Cooperative Extension. VCE Publication 442-766.

CHAPTER 6

Strategy for Success

Woolper Creek Watershed Plan

Prepared by the

Woolper Creek Watershed Initiative

October 2016

Chapter 6: Strategy for Success

Chapter 6 documents the feasibility of BMPs within the Woolper Creek Watershed with an emphasis on achieving water quality improvements. This chapter culminates with a detailed plan of action for improvements to the watershed, including timeframes for implementation, projected pollutant load reductions, and costs.

6.1 BMP Feasibility

6.1.1 Feasibility Factors

Chapter 5 presented numerous BMPs that may be applicable to the Woolper Creek Watershed. However, selecting the appropriate BMPs for the watershed includes understanding the feasibility factors for implementation in this setting. Regulatory matters, stakeholder cooperation, political will, available funding, cost-effectiveness, priority areas, existing priority efforts within the watershed, and watershed management activities will be evaluated further.

Regulatory Matters

Many of the entities that develop regulations in the watershed are part of the WCWI Steering Committee, including Sanitation District No. 1 of Northern Kentucky (SD1), the City of Florence, Boone County Fiscal Court, the Kentucky Transportation Cabinet (KYTC), the Boone County Planning Commission (BCPC), and the Kentucky Division of Water (KDOW). The members of these organizations that are part of the committee provide valuable insight into the regulatory matters being undertaken at each organization that may result in duplicate efforts and/or help achieve WCWI's goals.

There are currently regulations in the watershed that SD1 and the BCPC enforce to manage stormwater quality.

SD1 and KYTC have permits through KDOW for their stormwater systems that drain to the Woolper Creek Watershed. As an MS4, SD1 has numerous regulations that must be met by implementing measures as detailed in Section 5.1.2. These five-year permits cover construction site BMPs and illicit discharges, which are not central elements of the Woolper Creek Watershed Plan.

Combined sewer overflows (CSOs) and sanitary sewer overflows (SSOs) fall under SD1's jurisdiction, although there are no CSOs or active SSOs within Woolper Creek. Kentucky Pollutant Discharge Elimination System (KPDES) permits fall under KDOW jurisdiction and are not a concern of this Plan. Furthermore, the Woolper Creek Watershed does not have any TMDLs.

The Boone County Planning Commission (BCPC) sets development regulations for the Woolper Creek Watershed and is a part of the WCWI Steering Committee.

Stakeholder Cooperation

The contributions of the members of the WCWI Steering Committee have been noteworthy, and this Plan would not be nearly as comprehensive without these entities. **Table 6-1** presents the stakeholder agencies and the contributions to date.

Table 6-1: Summary by stakeholder of contributions of time, personnel, supplies, equipment, access, project planning, and implementation to date

Stakeholder Agency	Steering Committee Meetings	Public Meetings/ Roundtables	Data Collection	Implementation/ Project Planning
Boone County Conservation District	X	X	X	X
Boone County Fiscal Court	X			
Boone County Planning Commission	X	X		
Kenton County Airport Board	X			
Kentucky Division of Water	X	X	X	X
Kentucky Transportation Cabinet	X	X		
Northern Kentucky Area Development District	X			
Northern Kentucky Health Department	X			
Northern Kentucky University Center for Environmental Restoration	X			X
Sanitation District No. 1	X	X	X	X

Additionally, the WCWI Steering Committee has and will continue to work with private companies on watershed efforts. For example, the Toyota North American Parts Center in Hebron, Kentucky has worked with the USEPA and WCWI members, such as the Boone County Conservation District (BCCD), SD1, and Sustainable Streams, LLC, to install a detention basin retrofit on their property. Finding additional private project partners in the watershed to donate time, talents, or funding will be beneficial to the Plan's successful implementation. Additionally, Boone County Public Schools has been a valuable partner as well, with the installation of a second detention basin retrofit at Stephens Elementary.

The WCWI understands that it is necessary and beneficial to include the public in the planning efforts as well as the future implementation of projects. In addition to the educational initiatives discussed in Chapter 5, two public meetings were held. A question and response period during these meetings was conducted to better understand the local concerns of the community. **Table 6-2** shows some of the more common responses from the two meetings.

Table 6-2: Questions and responses from participants

Question	Responses
1. Why is a clean healthy stream important to you?	Recreation, Safety, Quality of Life, Aquatic Habitat/Wildlife, Drinking Water Resource
2. What land uses in the watershed are you most concerned about?	Development, Impervious Surfaces
3. What do you think are the most common problems?	Erosion and Runoff, Flooding, Development, Pesticide Use
4. What BMPs do you consider feasible in Woolper Creek?	Detention/Retention, Education, Responsible Development/Ordinances/Planning
5. What issues in Woolper Creek do you consider a priority?	Stormwater Runoff, Flooding, Conservation of Undeveloped Regions (i.e., Double Lick)

Additionally, the conversations covered the damaging impacts from flooding within the watershed (**Figure 6-1**). One resident, who lives in the headwaters of the Upper Woolper Creek Subwatershed, estimated over $75,000 in property damage since 2009. The stream has drastically changed since he was a child, with the loss of riffles, wider banks, and deeper pools. The following quotes from residents indicate the severity of their experiences and support the hydrogeomorphic impairments documented throughout Chapter 4.


Phone credit: Harvey Richardson

Figure 6-1: Flooding at 2377 Petersburg Road in the Upper Woolper Creek Subwatershed

"The creek looks like it's carrying a 100-year rain event after just 0.5-inches of rain."

"I am not against development; I just want the stormwater from urbanized areas to be properly managed so it does not erode the stream systems and cause flooding."

"The number one issue we need to correct is flooding concerns and the increased amount of impervious surfaces in the headwaters is the reason we are having these flooding issues."

"The stream in my backyard has dramatically changed since I was a child. It used to be a small creek with riffles where we would play, and now the banks have widened and the rocks have been flushed downstream, leaving long deep pools that frequently flood my yard after small rain events."

"The amount the creek has changed in the last 2 years is mind blowing – especially in the springtime. A few years ago we had an 8-foot deep pool in the stream on our property and the next year it filled and it is now only 4-feet deep."

"The creek has changed dramatically – it used to be deep, but now it is shallow and filled in. My fields are frequently flooded and trees washed up onto my land."

"Water quantity seems to be a bigger issue than water quality."

Political Will

The Boone County Fiscal Court is a member of the Steering Committee and understands the goals that the WCWI are trying to achieve; however, the Court must also weigh numerous other factors when making decisions for the county. Development brings jobs and housing to the county, which increases the population and collected taxes. Determining how to regulate this industry without driving it away or degrading the environment is important to the continued prosperity of the region. This Plan has demonstrated that the current degradation is a result of the increase in impervious surfaces associated with development and stormwater regulations that are inadequately managing changes to the flow regime.

The monies that must be spent in the region on an annual basis to mitigate infrastructure degradation from stream impacts are very costly. In 2011, Boone County's state-funded roads required $3.1 million in repairs to stream corridors due to stream erosion (Hawley *et al.*, 2013a). Other entities, such as SD1 and Duke Energy, must also fix infrastructure that is damaged from stream degradation, which can increase customers' bills. Regulatory burdens associated with fixing impaired streams is typically more expensive than if the stream was properly protected at the onset of development.

As evident by the responses at the public meetings, the Northern Kentucky residents are aware of and familiar with the local degradation. Flooding issues are common and numerous residents have attempted to protect their banks from erosion with concrete or retaining walls. Yet, until recently, there have not been many political actions taken to update stormwater regulations, as the development community has largely opposed these regulations.

"I am not against development; I just want the stormwater from urbanized areas to be properly managed so it does not erode the stream systems and cause flooding." – Woolper Creek Resident

Additional education is needed for the development community to better understand the exact detriments that non-optimized detention is creating in the receiving streams. Analysis has shown that BMPs can be designed for channel protection with minor additional engineering efforts and the BMPs do not need to increase appreciably in size, if at all (Sustainable Streams, 2012). These educational efforts should help to ease the pushback of the development community on political figures, which should make the recent changes to the regional stormwater design criteria related to $Q_{critical}$ more sustainable.

The Steering Committee and other technical staff and leaders have embraced the WCWI. SD1 has been aware of hydromodification and $Q_{critical}$ for years, and as previously mentioned has recently implemented channel protection requirements. Additionally, SD1 has developed a decision tree to assist all SD1 designers with implementing hydromodification/channel protection controls on new projects.

The main message of the Plan, to control erosive flows in the watershed, has been embraced by the Steering Committee and many of their organizations.

Available Funding

The WCWI plans to use the following key rationale to make funding the implementation phase of this Plan a success. These items include:

1) Identify cost-effective BMPs,
2) Develop and expand partnerships among regional agencies,
3) Allocate public monies to achieve greater benefits for less cost, and
4) Leverage funding from partner agencies and private entities in the watershed.

This Plan's development is in large part due to a grant from the USEPA under §319(h) of the Clean Water Act through KDOW. The funding has allowed for the creation of the watershed plan, with remaining dollars to be used for implementation efforts. Another grant application will be submitted for additional funding to be used solely for implementation efforts. The second grant, should it be approved, would provide the necessary funding to begin implementation efforts and start to restore and protect the watershed, as outlined in the following sections.

Whether used as match for the 319(h) grant, or just as funding if the second grant is not awarded, the WCWI is hopeful to expand partnerships with private entities and Steering Committee organizations. Leveraging funds between organizations should provide more cost- and time-effective projects in the watershed than entities such as SD1 or Boone County may be able to provide alone. One enticement that may bring private entities to the table is earned media, whereby funding stream network improvements gains the entity unsolicited, positive publicity.

Local entities have already been generous with their resources to protect channel stability, and this generosity is expected to continue.

Both private and public entities have proven this is feasible. For example, SD1 has demonstrated their commitment to Northern Kentucky stream integrity on two inflow and infiltration (I/I) projects, which removed stormwater from the sanitary sewer system. To mitigate the impacts of this additional stormwater now routed to the streams, SD1 included channel protection controls in the designs of both projects (Hawley *et al.*, 2012). Toyota and Boone County Public Schools have been an extremely valuable in the Woolper Creek Watershed by allowing a detention basin retrofits to be installed on their property. Project members include BCCD, SD1, USEPA, and others that have pooled resources to achieve the project goals. Furthermore, private entities such as Prologis, who is building at 529,000-square foot facility, have incorporated channel protection goals into retention basin designs.

Additional information on funding can be found in Section 6.3.

Cost-benefit Analysis

As stated in the section above, identifying cost-effective BMPs is one goal to expanding the impact of available funding. To achieve this goal, a cost-benefit analysis will be necessary when evaluating projects. Planning-level costs and benefits for common stormwater volume-based BMPs have been included in **Table 6-3**, and will be used for apples-to-apples comparisons of projects. **Appendix 6-A** provides additional insight into how the pollutant removal rates were developed.

Table 6-3: Unit costs and typical pollutant removal rates for volume-based BMPs

Volume-based BMP	Approximate Cost per Storage Volume[a] ($/ft^3)	Approximate Removal Rates of Watershed-sourced Pollutants[d]			
		E.coli	TSS[e]	TP	TN
Detention Basin Retrofits	$1.50[b]	67%	64%	21%	TBD
Wetland Creation/Restoration	$2	19%	29%	7%	16%
Extended Detention Basins	$2	67%	64%	21%	TBD
Bioinfiltration/Bioretention Basins	$4	71%	78%	18%	28%
Retention Basins	$2	95%	81%	57%	30%
Enhanced Swales	$2.25[c]	TBD	56%	TBD	16%

[a] Cost estimates include construction costs and an estimate for design and permitting. Not included are costs associated with land acquisition. Costs for new detention/retention/wetlands are based on regional excavation costs after Hawley *et al.* (2012), with ~10-15% added for design. Costs for bioinfiltration/bioretention basins are based on typical regional pricing of ~$15-20/ft^2 compiled by Strand Associates (Rust, 2014, Pers.Comm.), and assume a 5-foot storage depth, resulting in ~$3-4/ft^3. Detention basin retrofits assume relatively simple retrofits with restricted pipe and bypass installation after Hawley *et al.* (2013b), limited material and installation costs, and targeted efforts by a design engineer for design optimization and permitting, for an estimated total of ~$10,000/basin. Costs/time not included are associated with: engaging property owners and determining basin access and existing capacity/appropriateness of the basin for retrofitting.

[b] Detention basin retrofit cost per storage volume refers to added volume, based on an estimated 10% overdesign of existing basins, with an estimated average volume of 1.4 ac-ft. The extra 10% would result in 0.14 ac-ft of new storage per ~$10,000 retrofit, yielding a cost of ~$1.50/ft^3. Additionally, the existing 1.4 ac-ft of flood control storage would be converted to optimized storage, resulting in 1.54 ac-ft/retrofit. Using this volume, the cost per optimized storage volume is ~$0.15/ft^3.

[c] Enhanced swale cost per storage volume assumes the subsurface storage volume plus the water quality volume above the surface. The cost per storage volume may decrease if enhanced swales are used as the primary source of conveyance with additional surface depth.

[d] Estimated pollutant removal rates are dependent upon numerous site-specific parameters and cannot be predicted with high accuracy. These removal rates are intended to provide a relative context for the various types of volume-based BMPs, such that their relative benefits can be compared to their relative costs. With the exception of basin retrofits, approximate removal rates were obtained from the International Stormwater BMP Database (Leisenring, 2012). Data is still being collected regarding the effectiveness of detention basin retrofits and water quality improvements. Refer to **Appendix 6-A** for more details on removal rates.

[e] This TSS removal rate refers to the settling out of sediment within each BMP. It is important to note that for the Woolper Creek Watershed, the primary source of TSS in streams is not likely from upland erosion, but from stream bank erosion, caused by an excessively erosive flow regime. This means that the cost per optimized storage volume is a more relevant metric for determining cost-effectiveness associated with TSS removal.

Many of the stormwater volume-based controls presented in **Table 6-3** have similar costs, although detention basin retrofits are the most economical and are expected to provide relatively high removal efficiencies. Recall that stormwater volume, as it relates to excess stream erosion, is the largest concern in the watershed, and each type of volume-based BMP has the potential to contribute to a less erosive flow regime. Experience in the neighboring Gunpowder Creek Watershed suggests that detention basin retrofits and bankfull wetlands are great opportunities to cost-effectively reduce erosive flows in stream networks. Understanding the costs and benefits of implementing the Woolper Creek Watershed Plan is extremely important, and therefore, the WCWI has prioritized detention basin retrofits as the focus of initial implementation efforts.

Recall that stormwater volume, as it relates to excess stream erosion, is the largest concern in the watershed, and each type of volume-based BMP (e.g., detention basin retrofits and bankfull wetlands) has the potential to contribute to a less erosive flow regime.

In addition to stormwater volume-based BMPs, there are several cost-effective agricultural and onsite wastewater BMPs that might be employed throughout the Woolper Creek Watershed. The WCWI recognizes that BMP selection and implementation will be strategic for mitigation of pollutant loads from land management areas. In regards to agricultural regions, the WCWI understands that nutrient pollutant loads were elevated at monitoring site UT ALF 0.2, one of its rural monitoring sites with upstream land use of cultivated crops. While the USDA supports implementation of various types of agricultural BMPs, both nutrient management plans and conservation tillage practices rank high in terms of cost-effectiveness for cultivated crop regions, as these BMPs have minimal costs and nutrient reduction efficiencies ranging up to 20 percent for phosphorus (USDA, 2013). Furthermore, cover crops can be a very cost-effective agricultural BMP, especially in areas with high nitrogen pollutant loads. The USDA reports a 34 percent nitrogen reduction efficiency for cover crops with average cost/acre/year at approximately $73 (USDA, 2013). While cultivated crops are the primary land use upstream of UT ALF 0.2, some of the rural regions of the Woolper Creek Watershed include land used for livestock grazing; and therefore livestock exclusion fencing with an alternative water source can be an effective BMP for keeping animals out of the stream. Furthermore, the Northern Kentucky Health Department works to assist homeowners with failing onsite wastewater systems. The most cost-effective onsite wastewater BMP includes coordination with Northern Kentucky Health Department to identify cost-share programs for repair of failing onsite wastewater systems. However, STEPL reports that the Septic Failure Rate for the Woolper Creek Watershed is only 0.34% and several of the rural areas that utilize onsite wastewater will need to connect to SD1's sewer system as it is expanded into these areas. Therefore, onsite wastewater improvements are not currently a priority BMP for the WCWI.

Areas of Local Concern

A common theme throughout this plan has been that developed areas have more erosive flow regimes, which can degrade all aspects of stream health. Understanding that notion makes the developed areas of the watershed *areas of local concern*. This is evident from the Allen Fork Subwatershed being listed as a priority subwatershed. The Upper Woolper Creek Subwatershed is another heavily developed subwatershed that is also considered a priority subwatershed.

Going hand-in-hand with development are areas of flooding. Specifically in the Darlington Farms subdivision in Allen Fork and the headwaters of Upper Woolper Creek, where flooding issues have been widely documented. Areas with flooding are of great concern to the residents. Both of these considerations highlight the importance of implementing stormwater volume-based BMPs throughout the watershed but specifically in the developed subwatersheds.

Another area of concern, which is also a priority subwatershed, is the Double Lick Creek Subwatershed. As mentioned numerous times throughout the Plan, this is an outstanding state resource water that should be protected. Failure to protect this resource could result in a loss of one of the most diverse aquatic communities in Northern Kentucky.

Existing Priority Status

As discussed in the previous paragraph, the Double Lick Creek has priority status as an outstanding state resource water and it is also used by SD1 as a reference stream. There are no areas of the watershed that have federal priority status.

Work has already been conducted in parts of the Allen Fork Subwatershed in Boone Woods, upstream of site ALF 4.0. SD1 has also worked to better understand the Allen Fork Subwatershed through a stream restoration project near Darlington Farms and additional analysis on detention basin assets. Focusing WCWI efforts in Allen Fork will help to protect the stream restoration in Boone Woods, completed with Northern Kentucky Stream Corridor Restoration Fund monies and make use of the information already gathered for SD1.

Small-scale BMP controls such as rain gardens and cisterns can provide great community based opportunities to educate homeowners about stormwater.

Furthermore, master planning efforts are sure to occur throughout the watershed, as development expands and flooding concerns continue. It will be important for the WCWI to capitalize on these activities and collaborate with master planning efforts to ensure conservation of natural resources and protection of the stream integrity. Research by the USEPA found that solutions to large-scale problems, such as neighborhood flooding, cannot improve water quality or stream habitat by only implementing lot-level controls, regardless of public and financial support (Roy *et al.*, 2012). Master planning efforts that collaborate with several entities, are critical to properly solving large-scale problems. However, these smaller scale BMP controls (e.g., rain barrel/rain garden initiatives) can provide great community-based opportunities to improve water quality while also educating homeowners about stormwater runoff.

Watershed Management Activities

Chapter 5 discussed ongoing activities within the watershed, such as source water protection plans, past and current watershed studies, wastewater authorities, agricultural water quality plans, and special land use planning. As all of the Woolper Creek Watershed is part of Louisville Water Company's source water protection area and it is unknown where agricultural water quality plans apply and if special land use planning areas exist, these activities do not highlight any specific areas of the watershed for implementation efforts.

SD1 has a stormwater inspection and maintenance program, which includes inspection of existing detention basins. Capitalizing on this program could lead to efficiencies in identifying prime candidates for detention basin retrofits. As discussed in Chapter 5, the WCWI has already evaluated several detention basin retrofit opportunities in the Allen Fork and Upper Woolper Creek Subwatersheds. Master planning for flood control projects is another area that may provide benefits to the Woolper Creek Watershed, although no projects are known at this time. BCCD will be useful in the rural subwatersheds, as they provide agricultural outreach and assistance programs.

6.2 Developing a Plan of Action

The Plan of Action for the Woolper Creek Watershed was developed through a collaboration of the Technical Sub-committee, which included individuals from Boone County, BCCD, KDOW, SD1, and Sustainable Streams. Using **Table 5-2**, which includes all appropriate BMPs for Woolper Creek, the group identified the optimal BMPs with consideration for pollutants of concern, likely sources, cost effectiveness, and feasibility.

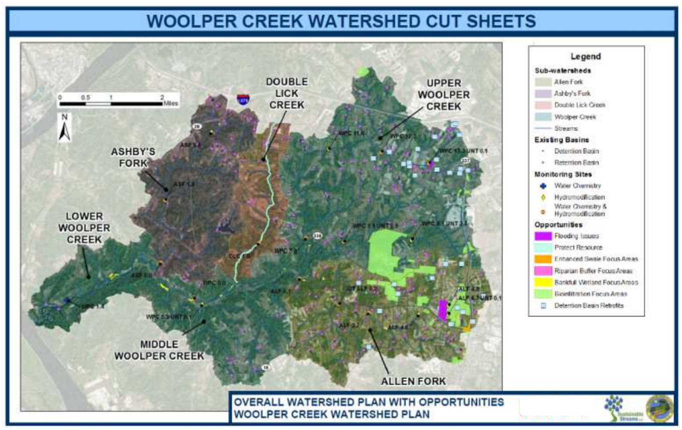


Figure 6-2: Watershed map illustrating potential opportunities throughout the Woolper Creek Watershed.

Restoring a natural flow regime to the watershed through optimizing and implementing stormwater volume BMPs is an important focus of the Watershed Plan.

As a reminder, the stream function pyramid shows that an unnatural flow regime can impact the habitat, water quality, and biology of a stream system. To improve the headwater conditions and protect the conditions in the main stream corridor, it will be important to restore a natural flow regime to the watershed. Through optimizing and implementing BMPs that control stormwater volume, it is anticipated that the monitored parameters will have decreased yields. Monitoring efforts will also be important, to know where and how to supplement these BMPs with other management efforts.

6.2.1 Developing Action Items

The Technical Sub-Committee developed action items for the overall Woolper Creek Watershed and land uses found within the priority subwatersheds of Allen Fork, Upper Woolper Creek, and Double Lick Creek. Action items were selected with consideration for their cost, pollutant removal, available funding mechanisms, and feasibility of implementation. At this time, the exact locations of BMPs are not listed, with the exception of detention basin retrofits, to allow the flexibility to implement BMPs in the most cost-effective locations as projects arise. The watershed map (**Figure 6-2**) provided in **Appendix 6-B** does provide some insight into possible locations for BMPs. Technical assistance will be provided as needed by the Technical Sub-committee and supplemented as necessary.

The provided list is only one combination of BMPs that could be feasible in Woolper Creek at this time, based on discussions by the Technical Sub-Committee. Logical changes may be made as awareness of this Plan grows and private entities wish to assist in implementation or projects through SD1 and/or KYTC become known. The provided costs are planning-level.

Subwatershed Prioritization

The action items have been selected based on their applicability and the current needs of the priority subwatersheds. These priority subwatersheds and specific action items have been chosen with current data available; and as such, the action items were developed for specific land uses in order to apply these BMPs to anywhere in Woolper Creek that the land uses are found. Based on the extent of impairment, known opportunities, feasibility, and stream status, the following prioritization of all subwatersheds will be used.

1. Allen Fork (developed headwaters)
2. Upper Woolper Creek (developed headwaters)
3. Double Lick Creek (undeveloped headwaters)
4. Ashby's Fork (mixed rural/developed headwaters)
5. Middle Woolper Creek (developed headwaters)
6. Lower Woolper Creek (undeveloped bottomlands)

> ***WCWI proposes for their subwatershed prioritization to be responsive to the opportunities that arise in the watershed by other stakeholders***

Action Items for the Overall Woolper Creek Watershed

1. **Coordination with NKU FILO Program** – Fee-In-Lieu-Of (FILO) funds are collected as part of the Stream and Wetland Restoration Program of Northern Kentucky when developments or other land-disturbance projects physically alter streams. The Northern Kentucky University (NKU) Center for Environmental Restoration (CER) runs the program, is part of the WCWI Steering Committee, and is continually looking for worthwhile projects. Components of FILO-funded projects have included riparian buffers, livestock management and stream exclusion, stream restorations, sediment removal, bank re-vegetation and protection, stormwater wetlands, detention basin retrofits, and floodplain reconnection. There are projects within the Woolper Creek Watershed that would benefit from these funds, and funds have been allocated to develop proposals for consideration. *Estimated Total Cost: $1,000.*
2. **Education and Outreach** – This action item includes publishing project updates on the BCCD website and county newsletters and incorporating signage on projects, where feasible, including educational signage with implemented projects, and conducting workshops. These actions will educate the community on the progress of the Plan and behavioral changes that will impact the watershed. *Estimated Total Cost: $6,000 for items such as educational signage and workshops.*

3. **On-site Wastewater Treatment** – On-site wastewater treatment is not currently a priority BMP, as percent exceedances of the water quality standard for *E.coli* were not as elevated as nutrients or TSS. However, select implementation of improvements may be beneficial. These improvements will be led by the Northern Kentucky Health Department with supplemental assistance from the WCWI and may include replacing or repairing faulty septic systems and straight pipes. The WCWI may provide assistance in identifying the highest priority areas, identifying funding opportunities, and locating the faulty systems. *Estimated Total Cost: To Be Determined.*
4. **Revise Rules and Regulations** – Discussed in Section 5.2.2, the current Rules and Regulations account for water quality treatment, which helps to reduce the peak flows of small storm events; however, additional steps can be taken to reduce these flows below the $Q_{critical}$ threshold. SD1 is currently implementing channel protection requirements; however, SD1 should continue to ensure that channel protection controls are adequately implemented on all projects, where feasible, moving forward. These revisions are not anticipated to increase costs for developers, property owners, or maintenance staff. *Estimated Total Cost: $15,000 (technical support to coordinate with SD1).*

Adding channel protection into the Rules and Regulations would have beneficial results for streams.

5. **Riparian Plantings** – Riparian planting zones, or buffer strips, are required between developments and stream systems, but these BMPs provide benefits in areas where development is not located directly on the streambank as well. These areas, planted with native grasses, forbs, and woody vegetation, have been found to be very effective at removing pollutants from overland runoff (Wenger, 1999). Moreover, these areas provide food sources (e.g., leaf litter), habitat (e.g., large woody debris), and protection from degradation (i.e., stabilization to reduce bank erosion). Assuming a 15-foot wide buffer strip and seeding costs that range from $100 and $700 per acre, the average cost is ~$0.15 per foot. Adding live stakes, which are a woody cutting from a tree or shrub that stabilizes the soil, brings the riparian plantings cost to ~$15 per foot of buffer, with a rate of one live stake per square yard. *Estimated Total Cost: $15,000 (1,000-linear feet goal).*
6. **Stewardship Programs** – Good stewards of the Woolper Creek Watershed are important so the WCWI plans to develop programs for these stewards. It will be important to identify entities that are willing to contribute resources, either financial or otherwise. Involvement in the implementation of this Plan will make it successful, as the community will feel a sense of ownership. These programs are not anticipated to be costly, but should have substantial results, if done appropriately (Galvin, 2005). It is expected that coordination with KDOW's Licking River Basin Coordinator on this task will be beneficial. The WCWI will partner with Boone County schools, Boone County Parks, and private organizations to implement projects through community stewards. For example WCWI may work with these entities to convert a mowed lot to native grasses, reforest a hill slope, or plant a bioswale. Additionally, the WCWI plans to continue to work closely with community educational programs by visiting classrooms to educate students about the importance of water quality and aquatic life and participate in

summer educational programs hosted by Boone County Parks, such as the Family Nature Day at Boone Woods. *Estimated Total Cost: $9,000 ($3,000/year for 3 years).*

7. **Success Monitoring and Analysis** – The work in Woolper Creek must be evaluated to ensure improvements are occurring within the streams. Efforts will begin with water quality monitoring, as it is the quickest indicator of an effective plan. Stream stability, monitored through hydromodification field surveys (**Figure 6-3**), can take longer as it relies on vegetative recovery over multiple growing seasons. Biology can take the longest time to recover. Through annual monitoring, the Steering Committee will be able to modify the implementation strategies once certain water quality benchmarks are achieved or BMP benefits are monitored. *Estimated Total Cost: $99,000 ($33,000/year for 3 years).*


Phone credit: Liz Fet

Figure 6-3: Conducting a pebble count as part of a hydromodification survey

8. **Structural and Non-Structural BMPs** – BMPs will be applied throughout the watershed as appropriate and cost-effective. Further detail on the types and locations of BMPs are found within this section. *Estimated Total Cost: Provided in specific BMP sections per priority area outlined below.*
9. **Training and/or Technical Support Programs** – Training and technical support programs will be focused on educating designers, contractors, and local staff on channel protection controls. The WCWI has developed resources to provide guidance incorporating channel protection controls into BMP design (**Appendix 5-A**). Items included in these programs may be workshops, fact sheets such as those included in **Appendix 5-A**, or tours of existing BMPs. Local staff may include employees at SD1 or Boone County. The goal will be to help these individuals understand the ease with which channel protection can be achieved. *Estimated Total Cost: $45,000 ($15,000/year for 3 years).*
10. **Watershed Coordinator** –This person, a watershed coordinator, should not be a volunteer because of the importance of continuity and devotion to making things happen. It is anticipated that the installation, implementation, and maintenance of BMPs, as well as monitoring and strategic adjustment of the watershed plan would fall to this position. Additionally, one of the most important roles of the Watershed Coordinator is to reach out to the local community to provide water quality-related education. *Estimated Total Cost: $90,000 (20 hours/week for 3 years)*

Action Items for Developed Areas

1. **Detention Basin Retrofits** – Two retrofits have already been installed within the Woolper Creek Watershed and are providing a reduction in the discharge peak flow. It is the goal of the WCWI to greatly expand the number of retrofits in the subwatershed because of their cost-

effectiveness. Allen Fork has had 16 detention and retention basins identified through field visits and detailed analysis as initial opportunities, with 11 of these basins prioritized as viable opportunities (**Figure 6-4**). Upper Woolper Creek has an additional 17 basins that are currently being evaluated for retrofit opportunities. Depending on willing property owners and potential partnerships, these will be the prime candidates to target for implementation and would reduce channel erosion and increase water quality treatment potential (Hawley *et al.*, 2013b). Refer to Chapter 5 and **Appendix 5-B** for additional information on these. *Estimated Total Cost: $200,000 (design and installation of 20 retrofits.)*

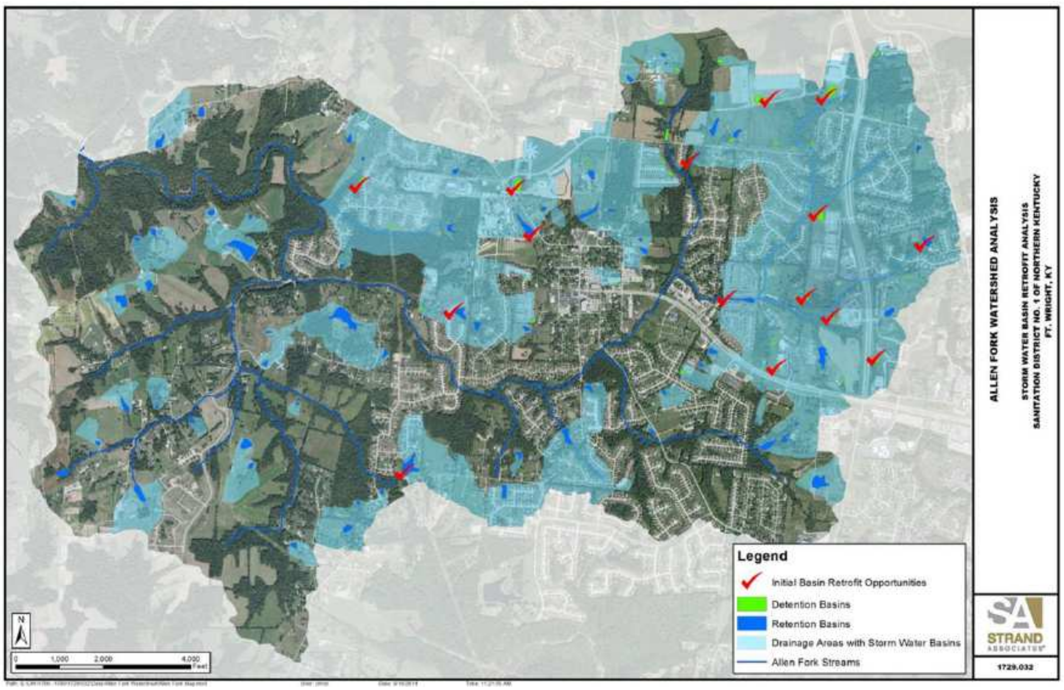


Figure 6-4: Allen Fork Prioritized Detention Basin Retrofit Locations (Strand Associates, Inc., 2015)

2. **New Detention Basins and Bioinfiltration/Bioretention Basins** – Although there are several benefits of implementing detention basin retrofits, not every existing basin will be conducive to retrofitting. Additionally, new storage is still needed throughout areas with unmanaged impervious surfaces lacking any type of existing stormwater control (See **Appendix 5-C**). Land acquisition could be a large cost, so public lands will be prioritized, as well as private land owners with a willingness to donate property to install facilities to control downstream flooding, erosion, and poor water quality. It will be important to design these basins for channel protection as well as flood control and water quality treatment. *Estimated Total Cost: $218,000 (design and installation of 2.25 ac-ft of additional storage)*
3. **Enhanced Swale Pilot Study** – Coordination between WCWI, SD1, and KYTC could provide a viable opportunity to design, install, and monitor an innovative BMP, incorporating flood control, water quality, and channel protection to roadway projects. This linear BMP would provide control to roads and interstates, which are commonly discharged directly to the streams without any treatment. If the pilot project proves to be as successful as preliminary estimates suggest, the WCWI may pursue this opportunity throughout several regions of the watershed.

Estimated Total Cost: $97,000 (design and installation of enhanced swales to treat a 4,000 lane-ft stretch of roadway).

4. **Pet Waste Program/Educational Outreach** – These programs have been found to be one of the most cost-effective stormwater management practices (CWP, 2013). To implement a worthwhile program, stations should be appropriately labeled and well stocked in areas frequently trafficked by dog walkers. Load reductions vary based on the concentration of bacteria in dog waste, anticipated fraction of daily waste captured per dog, stream delivery ratio, and an estimated fraction of dog walkers who clean up after their dogs (Caraco, 2002; CWP, 2013). *Estimated Total Cost: $15,000 (materials, installation, and maintenance of 8 stations).*
5. **Wetland Creation/Restoration –** Restoration of wetlands has already occurred in the Allen Fork Subwatershed, in Boone Woods. Additional restoration of wetlands in the subwatershed, or the creation of bankfull wetlands, will be extremely beneficial. Bankfull wetlands should be located where there are large, low-lying areas next to the channel, ideally on publicly-owned land and/or on willing private properties. These BMPs are less common than detention basins, as they are relatively new, but can serve as a great offline treatment system that also provides additional storage for the watershed and habitat to the stream. See **Appendix 6-B** for additional details on this BMP. *Estimated Total Cost: $187,000 (design and installation of 2.15 ac-ft of wetland storage).*

Bankfull wetlands serve as a great offline treatment system that also provides additional storage for the watershed.

Action Items for Agricultural Land

1. **Livestock Exclusion Fencing –** Exclusion fencing for livestock will help to remove farm animals from the streams. Livestock can easily degrade the stream by trampling bank vegetation and depositing waste directly into the stream. The exclusion fencing may prohibit livestock from entering the stream completely. When livestock are completely prohibited from entering the stream, an alternative water source must be provided. The first step in this action item is to locate farms that could use exclusion fencing, including horse farms. Protection of the banks will also create buffer strips. *Estimated Total Cost: $3,000 has been included as a placeholder for a demonstration project but this amount is subject to expand as opportunities arise (installation of 1,500 linear-ft of fencing and possible alternative water sources has been included as a demonstration project).*
2. **Other Agriculture-Related BMPs** – In addition to livestock exclusion fencing, the WCWI anticipates implementation of relevant structural and non-structural BMPs such as filter strips, cover crops, conservation tillage practices, agricultural water quality plans, and nutrient management plans. While funding for these BMPs could be obtained from other sources, it should be noted that 319(h) funding may be utilized to provide similar assistance through a cost-share program. *Estimated Total Cost: To be determined as opportunities arise.*

Action Items for Undeveloped Areas

1. **Conservation of Open Areas –** Preserving and protecting open spaces is considered to be one of the most cost-effective methods to protecting water quality, according to the CWP (2013). The WCWI may be able to find methods of preserving public lands that would be cost-effective; some of which may include revising the Rules and Regulations and installing buffer strips. Other opportunities may be to purchase land or obtain conservation easements within the subwatershed. There are two conservation groups within the watershed that could be useful for this task. This action item does not currently have funds allocated, as no properties have currently been identified, although this may change during implementation. *Estimated Total Cost: $0 at this time.*

The above-mentioned action items have been summarized with details relating to potential funding mechanisms, responsible parties, and estimated costs in **Table 6-4**. A list of implementation goals and potential load reductions is included in **Table 6-5**. Furthermore, **Figures 6-5** through **6-8** present focus areas related to many of the action items, potential load reductions, and implementation goals. **Figure 6-9** presents a larger version of the stormwater volume-based controls illustrated in **Figure 6-5**, providing additional details on actual projects that could be implemented. This figure illustrates the primary focus of WCWI's initial implementation efforts, especially in the developed regions of the watershed. Additionally, many of the action items have cut sheets provided in **Appendix 6-B**.

Table 6-4 - Prioritized BMP list including action items, potential funding mechanisms, responsible parties, and budgetary costs

BMP	Action Items	Potential Funding Mechanism	Responsible Parties	Unit Cost	Implementation Amount	Total Cost
Overall Watershed						
Coordination with NKU FILO Program	1. Coordinate projects with NKU. 2. Provide guidance on best project locations.	319(h) grant[a] NKU FILO funds	WCWI; NKU	$333 /year	3	$1,000
Education and Outreach	1. Publish project updates on the BCCD website and in the *Landscapes* and *What's Happening* newsletters. 2. Incorporate educational signage into any projects, whenever feasible.	319(h) grant[a]	WCWI	$2,000 /year	3	$6,000
On-site Wastewater Treatment	1. Work with the N. KY Health Department to determine feasibility and areas of greatest concern. 2. Identify potential faulty septic system and/or straight pipes. 3. Pursue funding sources in coordination with the N. KY Health Department or other entity to address identified issues.	319(h) grant[a]	N. KY Health Department	$ - EA	To Be Determined	To Be Determined
Revise Rules and Regulations	1. Continue coordination with SD1 regarding channel protection controls. 2. Coordinate with BCPC to incorporate more LID strategies into Planning/Zoning Requirements and Subdivision Regulations.	319(h) grant[a]	WCWI; SD1; BCPC	$15,000 EA	1	$15,000
Riparian Plantings[e]	1. Identify areas along the stream corridor that are lacking vegetation. 2. Facilitate partnerships to promote reforestation, especially along stream riparian zones and on steep slopes. 3. Plant vegetation along the stream banks.	319(h) grant[a]	WCWI	$15 / LF	1,000	$15,000
Stewardship Programs (public/private/ individual)	1. Identify entities willing to contribute to project funding and/or implementation efforts. 2. Continue to engage and educate the local community to garner support for project implementation and future success monitoring efforts.	319(h) grant[a]	WCWI; Private companies; Individual landowners	$3,000 /year	3	$9,000

BMP	Action Items	Potential Funding Mechanism	Responsible Parties	Unit Cost		Implementation Amount	Total Cost
Structural and Non-structural BMPs	1. Design and construct any BMP's listed in Table 5-3.	-	-	See specific categories below.			
Success Monitoring and Analysis	1. Complete water quality and hydromodification monitoring at strategic locations downstream of constructed projects. 2. Evaluate monitoring data for future implementation guidance.	319(h) grant[a]	WCWI	$33,000	/year	3	$99,000
Training/Technical Support Program	1. Develop training material and conduct training sessions to educate local designers and contractors on the importance of water quality and channel protection controls.	319(h) grant[a]	WCWI; SD1	$15,000	/year	3	$45,000
Watershed Coordinator (Half time)	1. Administer, manage, and implement the Watershed Plan.	319(h) grant[a]	WCWI	$30,000	/year	3	$90,000
Developed Headwaters [b]							
Bioinfiltration/ Bioretention Basins	1. Locate opportunities for basins. 2. Coordinate with landowners. 3. Design and construct basins.	319(h) grant[a] Landowners	WCWI; SD1; Landowners	$174,000	/ac-ft	0.25	$44,000
Detention Basin Retrofits	1. Locate existing basins with potential based on capacity, impact, and potential owner cooperation. 2. Work with owners to secure grant money where possible. 3. Design and install the retrofits, overcompensating locally if necessary to reach the design target for the entire subwatershed, considering impact of BMPs.	319(h) grant[a] Landowners	WCWI; SD1; Landowners	$10,000	EA	20	$200,000
Detention Basins	1. Locate opportunities for new detention basins in heavily developed areas without detention. 2. Coordinate with landowners to allow construction of a new basin or obtain property to construct one. Design and construct the detention basins that provide channel protection controls.	319(h) grant[a] Landowners	WCWI; SD1; Landowners	$87,000	/ac-ft	2	$174,000

BMP	Action Items	Potential Funding Mechanism	Responsible Parties	Unit Cost		Implementation Amount	Total Cost
Enhanced Swale Pilot Study	1. Locate opportunities for enhanced swales in transportation corridors that do not have detention. 2. Coordinate with KYTC to incorporate design on roadway project. 3. Design and construct the enhanced swales for flood control, water quality, and channel protection.	319(h) grant[a] KYTC	WCWI; KYTC	$24	/lane-foot	4,000	$97,000
Pet Waste Program/ Educational Outreach	1. Identify locations with frequent dog walkers. 2. Identify roles and responsibilities for supplying bags and maintaining receptacles. 3. Install educational signage as well as pet waste bags and trash receptacles at pet waste stations.	319(h) grant[a]	WCWI	$1,845	/Sta[f]	8	$15,000
Wetland Creation/ Restoration	1. Evaluate feasibility of obtaining a single, generic permit from KDOW to perform this type of work in the floodplain. 2. Continue coordination and cost-sharing with NKU FILO. 3. Design and construct/restore wetlands.	319(h) grant[a] NKU FILO funds	WCWI; KDOW; NKU	$87,000	/ac-ft	2.15	$187,000
Agricultural Areas [c]							
Livestock Exclusion Fencing	1. Map horse farms in GIS if possible 2. Targeted outreach to horse farms 3. Targeted outreach to livestock farms that lack adequate exclusion fencing 4. Continue to promote incentive programs for manure management, fencing, and riparian buffer strips.	319(h) grant[a] USDA (EQUIP)	WCWI; USDA; Landowners	$2	/ LF[g]	~1,500	$3,000[h]
Other Agriculture-Related BMPs	1. Collaborate with landowners to implement non-structural BMPs (e.g., agricultural water quality plans, nutrient management plans, conservation tillage practices, etc.) 4. Identify locations for structural BMPs (e.g., filter strips, cover crops, etc.)	319(h) grant[a] USDA	WCWI; USDA; Landowners	TBD		TBD	TBD

BMP	Action Items	Potential Funding Mechanism	Responsible Parties	Unit Cost	Implementation Amount	Total Cost
Undeveloped Areas/Forestry[d]						
Conservation of Open Areas	1. Continue to promote conservation of forested lands, particularly those that currently serve as riparian buffer zones. 2. Conduct meeting with local conservation groups regarding efforts to identify potential properties for conservation.	-	WCWI; N. KY Urban Forestry Council; Heritage Land Trust	$ - /year	3	$0
					TOTAL	**$1,000,000**

(a) 319(h) grant monies include a 40% non-federal match.

(b) BMP strategies for developed areas will be evaluated first in the priority subwatershed of Allen Fork. However, WCWI plans to implement these strategies in any subwatershed in which opportunities are optimal and cost-effective.

(c) BMP strategies for agricultural areas will be evaluated first in the priority subwatershed of Double Lick Creek. However, WCWI plans to implement these strategies in any subwatershed in which opportunities are optimal and cost-effective.

(d) BMP strategies for undeveloped and forestry areas will be evaluated first in the priority subwatershed of Double Lick Creek. However, WCWI plans to implement these strategies in any subwatershed in which opportunities are optimal and cost-effective.

(e) Cost per linear foot assumes a ~15-foot wide riparian buffer strip along the top of the stream bank using average seeding cost estimates from EQIP ranging from ~$100 to ~$700 per acre. Buffer will be sewn with native riparian vegetation seeds, with one live stake per square yard, averaging ~1.5 live stakes per linear foot of riparian buffer strip. Live staking is estimated to cost $10 per stake for material and installation.

(f) Costs for the installation and maintenance of pet waste stations include $200 per station for materials, an estimated 4 hours per station at $70 per hour (2 workers) for installation, and an estimated 15 minutes per week for 3 years at $35 per hour for maintenance. These are consistent with national references and local pricing experience.

(g) Livestock exclusion fencing cost estimates are based on EQIP standards for fence installation ($1.53 per foot) and access control ($19.98 per acre). Access control was converted to a cost per foot by assuming square lots (660'x660' per acre), resulting in an estimated $0.03 per foot. The costs provided by EQIP represent 75% of total estimated cost, so these numbers were multiplied by 1.33 to approximate the total (~$2.08 per foot).

(h) The $3,000 allocated for livestock exclusion fencing has been included as a placeholder for a demonstration project, but this amount is subject to expand as opportunities arise.

Table 6-5: Prioritized BMP list including implementation goals and estimated load reductions

BMP	Goals for Implementation[a]				Estimated Load Reductions[b]			
	Short-term	Intermediate	Long-term	Total	TSS	Bacteria	TP	TN
Overall Watershed								
Coordination with NKU FILO Program	1	2	As needed	3 years				
Education and Outreach	1	2	As needed	3 years				
On-site Wastewater Treatment	As needed	As needed	As needed	As needed	NA	13.8 billion CFU/system/year[q]	3.8 lbs/system/year[q]	12.8 lbs/system/year[q
Revise Rules & Regulations[d]	1	0	As needed	1 revision				
Riparian Plantings	1,000	3,000	As needed	4,000 LF	74 %[c]	TBD	48 %[c]	35 %[c]
Stewardship Programs (public/ private/ individual)	1	2	As needed	3 years				
Structural and Non-structural BMPs	See details on specific BMPs below.				See details on specific BMPs below.			
Success Monitoring and Analysis	0	3	As needed	3 years				
Training/ Technical Support Program	1	2	As needed	3 years				

BMP	Goals for Implementation[a]					Estimated Load Reductions[b]							
	Short-term	Intermediate	Long-term	Total		TSS		Bacteria		TP		TN	
Watershed Coordinator (half time)	1	2	As needed	3	years								
Developed Headwaters [e] [f]													
Bioinfiltration/ Bioretention[i]	0.1	0.15	As needed	0.25	ac-ft	34	lbs/yr	17	billion colonies/yr	0.3	lbs/yr	1.3	lbs/yr
DB Retrofits [g][h][i]	10	10	As needed	20	retrofits	3,860	lbs/yr	2.2	trillion colonies/yr	43	lbs/yr	TBD	
Detention Basins [g] [j]	1	1	As needed	2	ac-ft	125	lbs/yr	76	billion colonies/yr	1.5	lbs/yr	TBD	
Enhanced Swales Pilot Study[i]	0	4,000	As needed	4,000	ln-ft	98	lbs/yr	TBD	trillion colonies/yr	TBD	lbs/yr	3.1	lbs/yr
Pet Waste Program/ Educational Outreach [k]	0	8	As needed	8	stations	-		82	billion colonies/ dog in the program area/yr [l]	1,000	lbs/yr	11,000	lbs/yr
Wetland Creation/ Restoration [m] [i]	0	2	As needed	2	ac-ft	6,805	lbs/yr	2.4	trillion colonies/yr	224	lbs/yr	TBD	lbs/yr
Agricultural Areas													
Livestock Exclusion Fencing [n]	0	~1,500[p]	As needed	1,500	lf	TBD		157	billion colonies/ livestock animal excluded/yr [o]	9	lbs/head of cattle excluded /yr [n]	60	lbs/head of cattle excluded /yr [n]
Other Agricultural BMPs	TBD	TBD	TBD	TBD		TBD		TBD		TBD		TBD	

BMP	Goals for Implementation[a]				Estimated Load Reductions[b]			
	Short-term	Intermediate	Long-term	Total	TSS	Bacteria	TP	TN
Undeveloped Areas/Forestry								
Conservation/ Preservation of open areas	1	2	As needed	3 meetings	-	-	-	-

[a] Implementation is dependent on receiving 319(h) grant money that takes us through three years of grant funding and goals following this three year timeframe (i.e., long-term goals) should be determined based on the project implementation and success monitoring. All quantities are subject to change as opportunities arise and the WCWI begins to implement this Watershed Plan.

[b] See **Appendix 6-A** for methodology used to determine estimated load reductions.

[c] Reported values for TSS, phosphorous and nitrogen removal refer to pollutants flowing from upstream and filtered by the riparian zone adjacent to the channel (Wenger, 1999). Absolute reductions will depend on drainage areas for restored riparian segments and pollutant levels coming from those drainage areas, and would need to be calculated per case. Reduction in TSS due to stream bank stabilization by vegetation is not included in the estimated reductions, but could have a larger impact than filtration where existing banks are bare and unstable.

[d] Load reductions for revised rules and regulations can have a substantial impact on improving the health of the steams.

[e] Allen Fork is the highest priority subwatershed and Upper Woolper Creek is the second highest priority watershed, with detailed analysis already conducted on existing storage volumes available and necessary. For these reasons, efforts in the developed headwaters will begin here. Estimated load reductions are calculated using the average pollutant yield from the Allen Fork and Upper Woolper Creek monitoring sites and pollutant removal percentages reported in the International Stormwater BMP Database, see Appendix 6-A for additional information regarding these calculations.

[f] Flooding concerns as well as stream impairments in the Allen Fork and Upper Woolper Creek Subwatersheds give reason to also prioritize this area for implementation efforts.

[g] Detention basin retrofits are assumed to have optimized storage. Reduction rates were calculated under the assumptions that storage time is approximately doubled when release rates are optimized, and that an approximate doubling of treatment time will result in an approximate doubling of pollutant load removal over that of standard detention basins as reported in the International Stormwater BMP Database (Leisenring *et al.*, 2012). See **Appendix 5-C** and **Appendix 6-A**.

[h] Assumes 20 of the recommended basins from Strand Associates, Inc.'s analyses of the Allen Fork and Upper Woolper Creek Sub-watersheds (2015, included in **Appendix 5-B**) are retrofitted. Per the analyses completed in the Allen Fork and Upper Woolper Creek Sub-watersheds, each retrofit installed in Allen Fork could treat an average drainage area of 23.4 acres and each retrofit in the Upper Woolper Creek Sub-watershed could treat an average area of 23.4 acres.

[i] Stormwater controls should be designed for water quality and channel protection (i.e., to control the release of stormwater to minimize excess rates of bed material and bank erosion in receiving streams).

[j] The calculated TSS load reduction from detention basins is based on 100% reduction of TSS that would be attributable to bank erosion induced by excess stormwater from the land area that is drained by the detention basin.

(k) Phosphorous and nitrogen cost-effectiveness rates are taken directly from CWP (2013), with nitrogen removal as $0.44 per lb removed and phosphorous removal as $3.36 per lb. These are approximate rates based on assumptions and should be revised as more appropriate, regional data become available.

(l) Bacteria reduction by a pet waste program is not calculated as a function of number of stations. Instead, stations are expected to be installed at a proper density to adequately serve the population of pet owners who will use them. The reduction was calculated as a function of daily waste production per dog (Caraco, 2002), fecal concentration in dog waste (Caraco, 2002), anticipated fraction of daily waste captured (CWP, 2013), percentage of dog owners who are expected to clean up after their dogs (Caraco, 2002), and stream delivery ratio (Caraco, 2002).

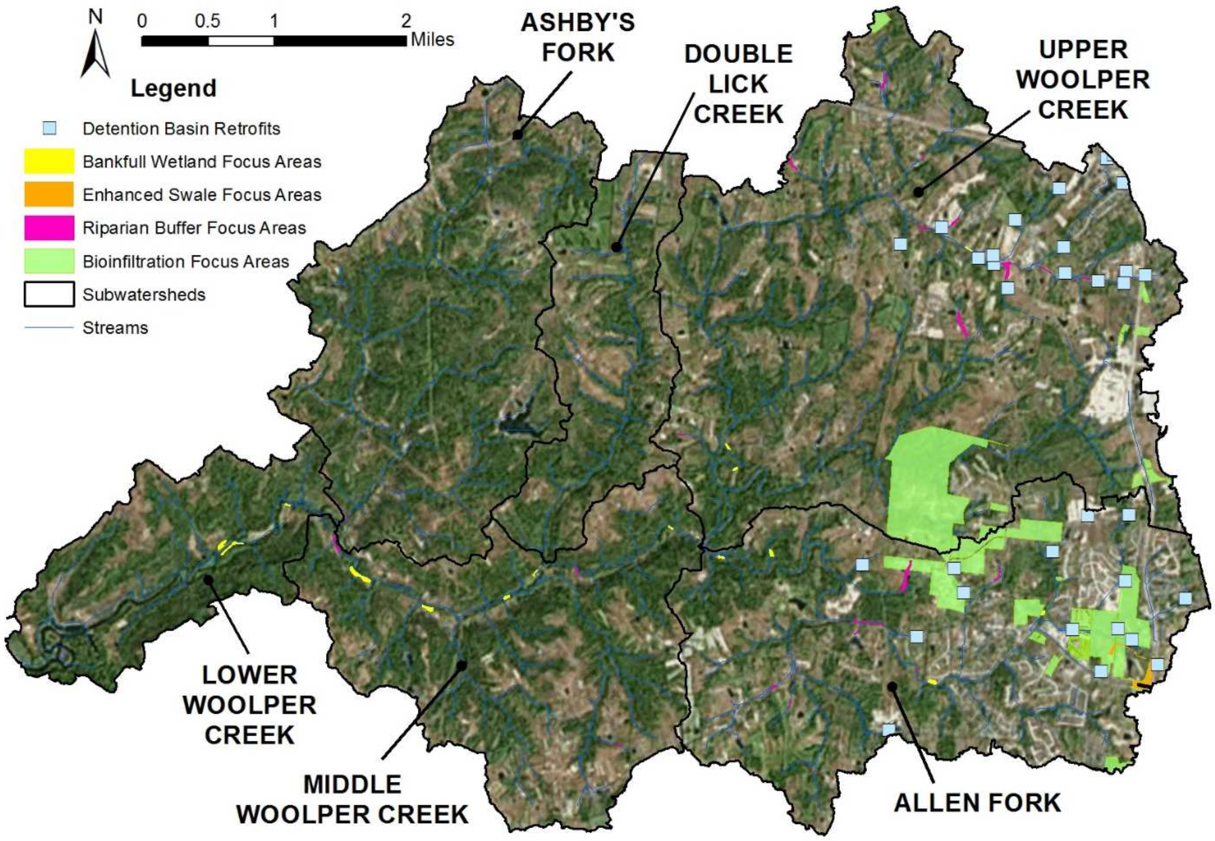
(m) Removal rates by wetland channels as reported in the International Stormwater BMP Database (Leisenring *et al.*, 2012) were used to calculate those for wetlands here, under the anticipation that bankfull/benchfull wetlands would be utilized in the Allen Fork or Upper Woolper Creek Sub-watersheds.

(n) Based on 300 lbs of nitrogen and 45 lbs of phosphorous produced per cow per year (Hart *et. al*., 1997). Similar to the bacteria calculation, an estimated 20% of manure is assumed to be deposited directly into streams when available, resulting in a 20% reduction by exclusion fencing.

(o) Bacteria production by livestock estimates were taken from BWC (2009), which reports 2.5 million cfu per gram of raw manure. This falls within the range of values reported in literature (e.g., Wright *et al.,* 2001). The Banklick Watershed Plan also reports 4,160 tons of manure produced annually by 3,000 livestock, for an average of 1.38 tons per livestock per year. Assuming 20% of livestock waste is deposited directly into streams when available, exclusion fencing and/or riparian buffers will reduce bacteria from manure by 20% per livestock excluded.

(p) The livestock exclusion fencing quantity listed is for a small demonstration project and this is subject to expand as opportunities arise.

(q) Onsite wastewater load reductions provided by KDOW and Northern Kentucky Health Department through the spreadsheet model developed as part of a 319(h) grant for the Eagle Creek of the Kentucky River Watershed. The numbers included in the table present the average reduction provided per system, as the amount of mitigation is dependent upon whether the onsite wastewater system was repaired or fully replaced and the degree of failure.



Detention Basin Retrofit Goal: 20 retrofits
Estimated TSS reduction: 3,860 lbs/yr
Estimated bacteria reduction: 2.2trillion colonies per year
Estimated TP reduction: 43 lbs/yr
Estimated TN reduction: TBD lbs/yr

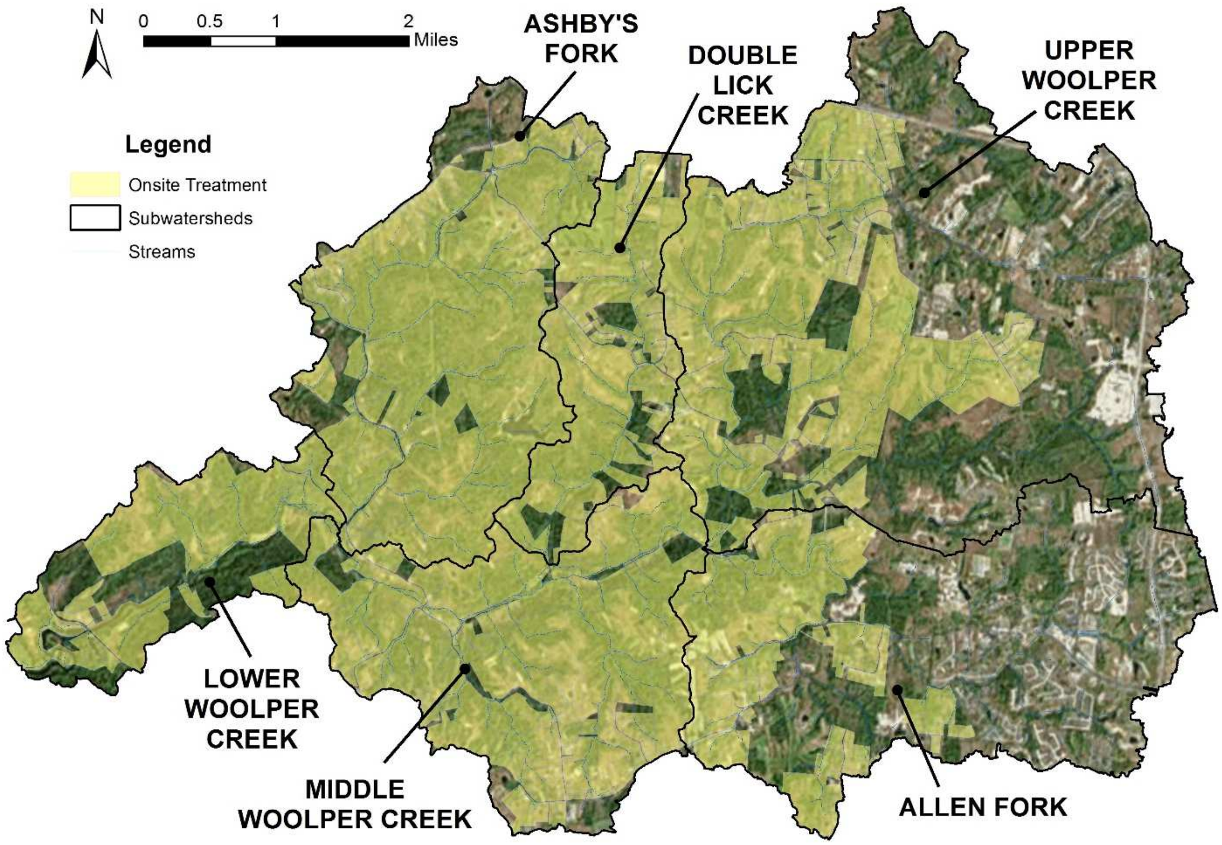
Bankfull Wetland BMP Goal: 2 acre-feet
Estimated TSS reduction: 6,805 lbs/yr
Estimated bacteria reduction: 2.4 trillion colonies per year
Estimated TP reduction: 223 lbs/yr
Estimated TN reduction: TBD lbs/yr

Enhanced Swale BMP Goal: 4,000 linear feet
Estimated TSS reduction: 98 lbs/yr
Estimated bacteria reduction: TBD colonies per year
Estimated TP reduction: TBD lbs/yr
Estimated TN reduction: 3.1 lbs/yr

Bioinfiltration BMP Goal: 0.25 acre-feet
Estimated TSS reduction: 34 lbs/yr
Estimated bacteria reduction: 2 trillion colonies per year
Estimated TP reduction: 0.3 lbs/yr
Estimated TN reduction: 1.3 lbs/yr

Riparian Buffer BMP Goal: 1,000 linear feet
Estimated TSS reduction: 74%
Estimated bacteria reduction: TBD
Estimated TP reduction: 48%
Estimated TN reduction: 35%

Figure 6-5: Volume-Based Stormwater Controls and Riparian Buffer Strip Focus Areas (See Tables 6-4 and 6-5 for further details)



Onsite Treatment BMP Goal: No definitive goal

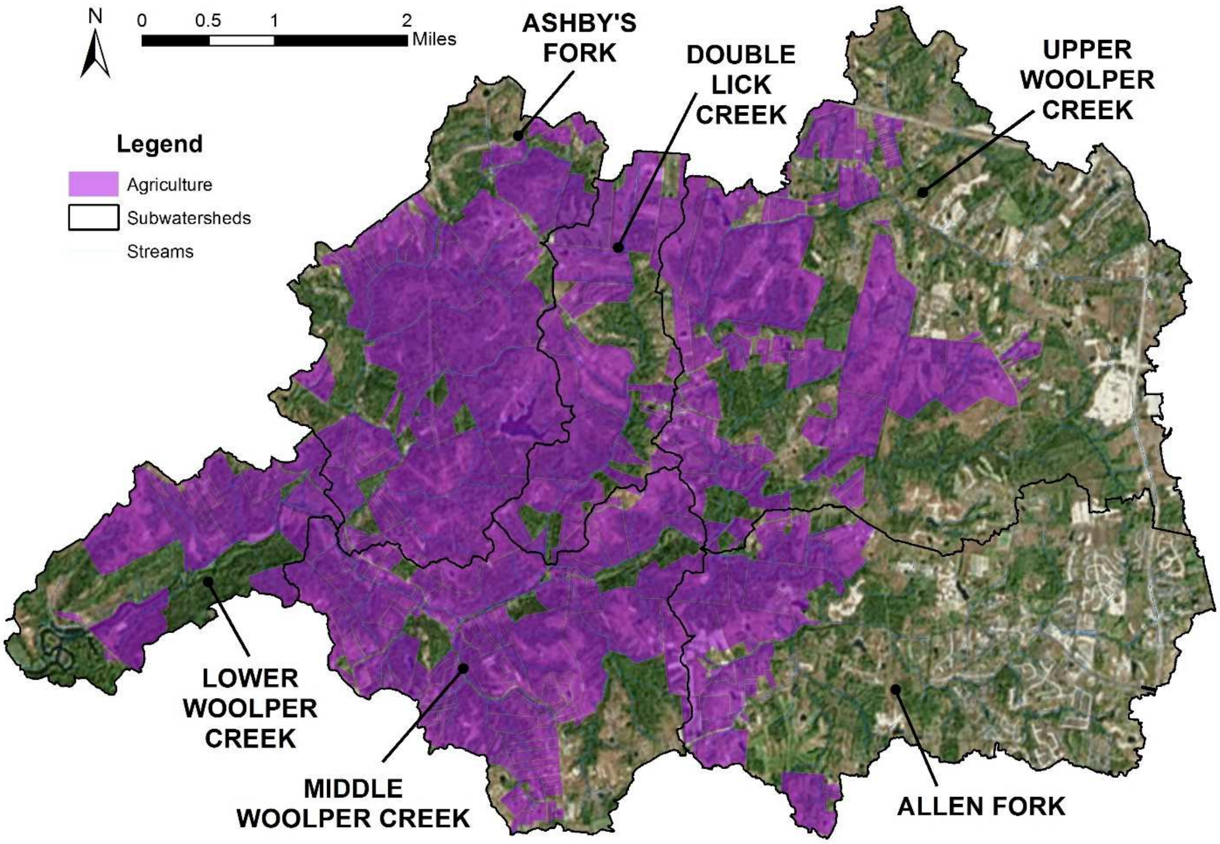
Estimated TSS reduction: NA

Estimated bacteria reduction: 13.8 billion CFU/system/year (average value dependent upon degree of repair and replacement)

Estimated TP reduction: 3.8 lbs/system/year (average value dependent upon degree of repair and replacement)

Estimated TN reduction: 12.8 lbs/system/year (average value dependent upon degree of repair and replacement)

Figure 6-6: Onsite Wastewater Treatment Focus Areas (See Tables 6-4 and 6-5 for further details)



Agricultural BMP Goal: 1,500 linear feet of livestock exclusion fencing for a small demonstration project. Other agricultural BMPs may be implemented as opportunities arise.

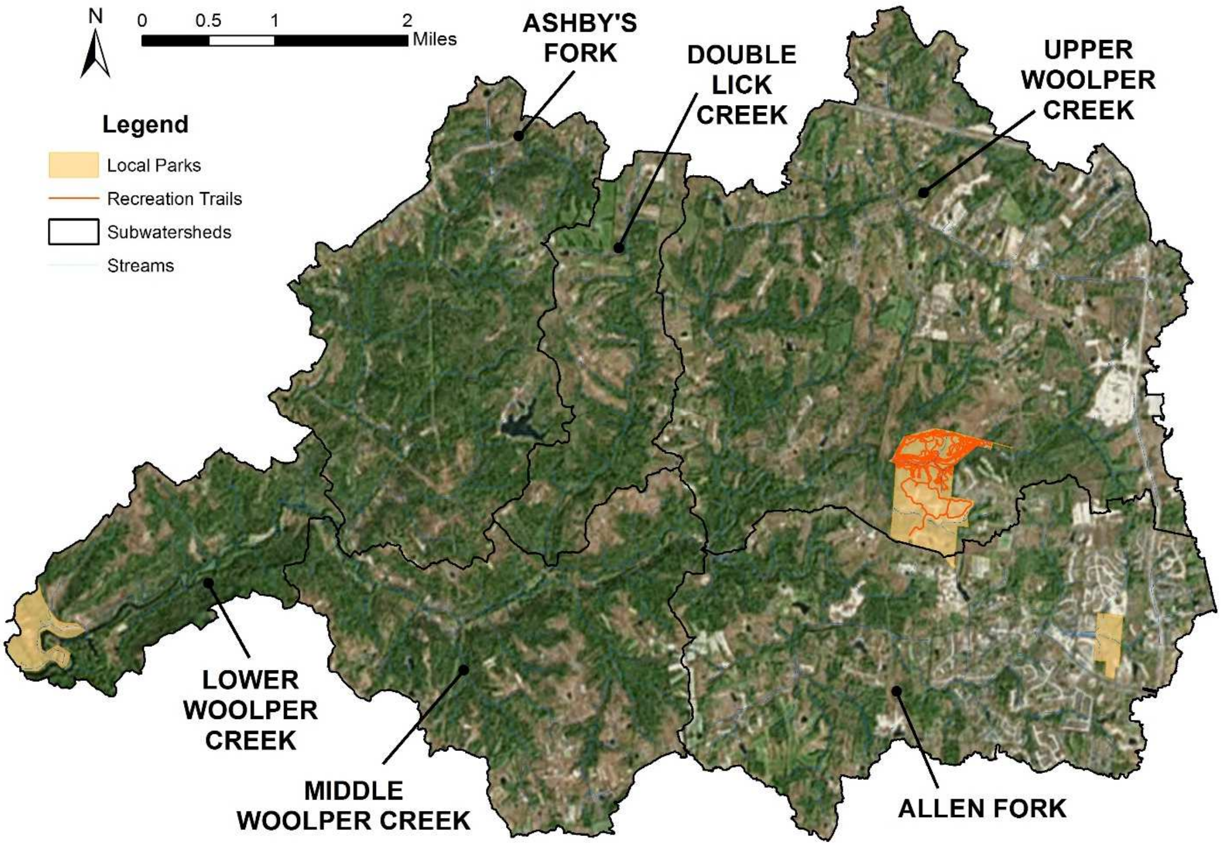
Estimated TSS reduction: TBD

Estimated bacteria reduction: 157 billion colonies per livestock animal excluded per year

Estimated TP reduction: 9 pounds per head of cattle excluded per year

Estimated TN reduction: 60 pounds per head of cattle excluded per year

Figure 6-7: Agricultural Focus Areas (See Tables 6-4 and 6-5 for further details)



Pet Waste Program BMP Goal: 8 stations

Estimated TSS reduction: None anticipated

Estimated bacteria reduction: 82 billion colonies per dog in the program area per year

Estimated TP reduction: 1,000 pounds per year

Estimated TN reduction: 11,000 pounds per year

Figure 6-8: Pet Waste Program Focus Areas (See Tables 6-4 and 6-5 for further details)

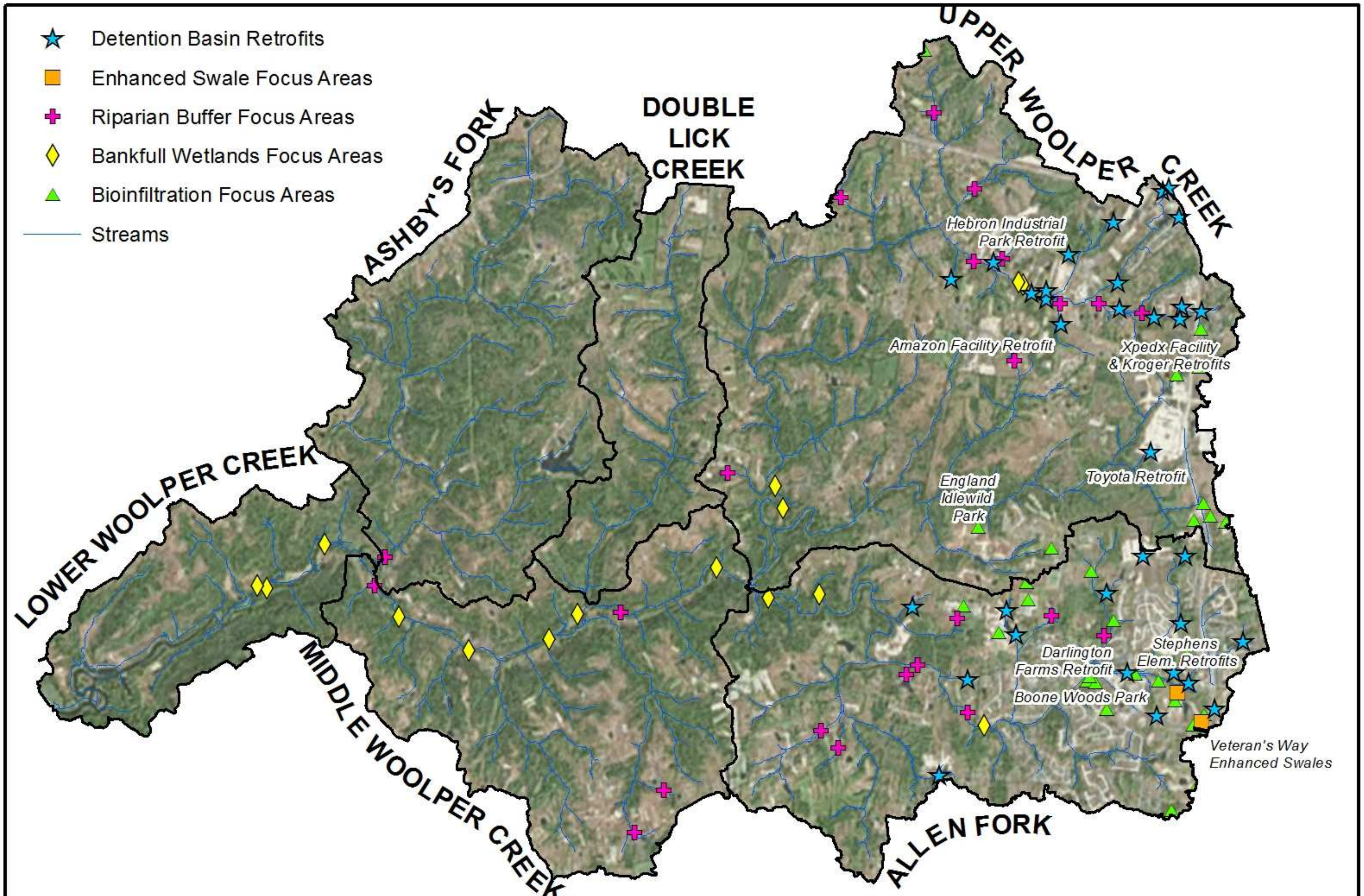


FIGURE 6-9: WOOLPER CREEK WATERSHED PLAN IMPLEMENTATION
STORMWATER VOLUME-BASED CONTROLS
Woolper Creek Watershed Plan
Boone County Conservation District

6.2.2 Plan Examples

After close review, the WCWI has used two plan examples and one set of guidance in the development of the action items and overall Watershed Plan. The guidance document that was used is the *Watershed Planning Guidebook for Kentucky Communities*, published by KDOW. This guidance document served as the basis for the plan development and was integral in developing the framework for the action items. The Gunpowder Creek Watershed Plan, which was recently approved by KDOW was also used, as it is a neighboring watershed that is experiencing many of the same issues and has many of the same members on its Steering Committee. The references section of each chapter is quite extensive, documenting the technical reports and peer reviewed papers on stream integrity and hydromodification that were also used (e.g., Hawley *et al.,* 2012).

6.3 Finding the Resources

The WCWI has been able to recruit extensive resources for the watershed plan already and will continue to identify new sources. The combination of individuals and organizations that are part of the Steering Committee and Technical Sub-committee bring unique ideas and viewpoints to discussions.

Similar to the efforts to date, the WCWI intends to use a variety of resources to fund implementation efforts

6.3.1 Potential Resources

The following potential resources will be further examined as exact needs are identified. The list is not all-inclusive, but does highlight some potentially promising partnership opportunities.

NRCS Resources

The National Resources Conservation Service (NRCS) will be useful for farming- and conservation-related needs. Specifically, the Conservation of Private Grazing Land (CPGL) program, the Conservation Reserve Program (CRP), and the Environmental Quality Incentives Program (EQIP) are three potential options. These programs provide technical assistance for land management and improved water quality, and sometimes provide financial assistance as well.

319(h) Nonpoint Source Funds

The WCWI plans to apply for additional funding, to be used for implementation, as mentioned in Section 6.1.1. After the Plan has been finalized, any remaining funds from the current grant will be used for implementation. Refer to Chapter 7 for additional details.

Kentucky EXCEL

The Excellence in Environmental Leadership (EXCEL) program, run by Kentucky's Energy and Environment Cabinet, offers incentives for businesses that are environmentally regulated when they assist in watershed activities. Although not a useful resource now, companies in the Woolper Creek Watershed may join EXCEL in future years.

In-Lieu Fee Program for Stream and Wetland Mitigation

The WCWI has partnered with the FILO program in the past and anticipates using it as a resource, as shown in **Table 6-4** and **Table 6-5** and discussed in Section 6.2.1.

Kentucky Transportation Cabinet

KYTC uses a third-party source for mitigating wetlands and stream activities. Members of the Steering Committee and Technical Sub-committee have good relationships with employees of the third-party, the United States Fish and Wildlife Service (USFWS). Additional discussions will be needed to determine if there is any funding for projects within the watershed.

Another method of using KYTC as a resource would be for the implementation of enhanced swales on roadway projects within the watershed. The Cabinet currently is not required to treat their stormwater runoff, and WCWI is not aware of any pilot installations in the state at this time. It will be important to test this BMP to better understand removal efficiencies, design shortcomings, and costs.

Additional Resources

Several other additional resources exist and will be utilized as necessary by the WCWI. Some examples of other resources include the Federal Emergency Management Agency (FEMA), the United States Army Corps of Engineers (USACE), and the Northern Kentucky Health Department. Furthermore, it is expected that continued resources will be allocated from both SD1 and NKU as implementation begins. These resources will include assistance with identifying projects, constructing BMPs, and monitoring. Flooding master planning that may occur through SD1 for parts of the watershed is one example of an investment that will be a resource to the WCWI. Retrofitting detention basins will make great use of the available funding and assets already in the ground within the watershed.

References

BWC, 2009. The Banklick Watershed Based Plan: Kenton and Boone Counties: A Holistic Approach to Watershed Improvement. Banklick Watershed Council, Strand Associates. October

Caraco, D. 2002. *The Watershed Treatment Model: Version 3.1*. U.S. Environmental Protection Agency, Region V. Center for Watershed Protection. Ellicott City, MD.

CWP, 2013. Cost-Effectiveness Study of Urban Stormwater BMPs in the James River Basin. Center for Watershed Protection, Eliot City, MD. June.

Galvin, D. 2005. Measuring results from outreach and education programs --- Can we see improvements downstream? Proceedings of the 4th National Conference on Nonpoint Source Pollution and Stormwater Education Programs (Kirschner, R.J., eds.), Chicago, IL: Chicago Botanic Garden, US EPA.

Hart, J., Gangwer, M., Graham, M., and Marx, E.S., 1997. Dairy manure as a fertilizer source. Oregon State University. Corvallis, OR. http://extension.oregonstate.edu/catalog/html/em/em8586/

Hawley, R.J., Wooten, M.S., Vatter, B.C., Onderak, E., Lachniet, M .J., Schade, T., Grant, G., Groh, B., and J. DelVerne. 2012. Integrating stormwater controls designed for channel protection, water quality, and inflow/infiltration mitigation in two pilot watersheds to restore a more natural flow regime in urban streams. *Watershed Science Bulletin*. 3(1), 25-37.

Hawley, R.J., MacMannis, K.R. and Wooten, M.S., 2013a. How Poor Stormwater Practices Are Shortening the Life of Our Nation's Infrastructure--Recalibrating Stormwater Management for Stream Channel Stability and Infrastructure Sustainability, World Environmental and Water Resources Congress. American Society of Civil Engineers, Environmental and Water Resources Institute, Cincinnati, OH, May 19-23.

Hawley, R.J., Goodrich, J.A., Beaulieu, J.J., and K.R. MacMannis. 2013b. Green Retrofit Technology for Detention Basin Outlet Control Structures. A poster presentation to the Mississippi River Gulf of Mexico Watershed Nutrient Task Force, Hypoxia Task Force Meeting. Louisville, KY, April 18.

King County, 2013. Development of a Stormwater Retrofit Plan for Water Resources Inventory Area 9: SUSTAIN Model Pilot Study. Prepared by Curtis DeGasperi, Water and Land Resources Division. Seattle, Washington

Leisenring, M., Clary, J., and Hobson, P. 2012. International Stormwater BMP Database. Prepared by Geosyntec Consultants and Wright Water Engineers for the Water Environment Research Foundation. July, 2012.

Miller, M., 2013. Preliminary TSS removal performance of bankfull wetlands in the Mill Creek, Cincinnati, OH. Pers. Comm.

Roy, A.H., Rhea, L.K., Shuster, W.D., and St. Amand, A., 2012. Managing Stormwater for Freshwater Ecosystems: Go Big Or Go Home. In Proceedings of the 60th Annual Meeting of Society for Freshwater Science. Louisville, KY, May 20-24.

Rust, C. 2014. Typical regional pricing of bioinfiltration basins based on an inventory of past construction projects. Pers.Comm.

Strand Associates, Inc., 2014. Allen Fork Watershed Analysis technical memorandum. Prepared for Sanitation District No. 1.

Sustainable Streams, 2012. Development of a regionally-calibrated critical flow for stormwater management, SD1 of Northern Kentucky.

USDA, 2013. Building Capacity to Analyze the Economic Impacts of Nutrient Trading and Other Policy Approaches for Reducing Agriculture's Nutrient Discharge into the Chesapeake Bay Watershed.

Wenger, S. 1999. A Review of the Scientific Literature on Riparian Buffer Width, Extent, and Vegetation. Prepared for the Office of Public Service & Outreach, Institute of Ecology, University of Georgia. March.

Wright, R.J., Coots, R., and Cusimano, R.F., 2001. Lower Snohomish River Tributaries Fecal Coliform Total Maximum Daily Load Evaluation Publication 00-10-087. Washington Department of Ecology Water Quality Program, P.O. Box 47600, Olympia, WA, 98504-7600. 24 pps plus appendices.

CHAPTER 7

Making It Happen

Woolper Creek Watershed Plan

Prepared by the

Woolper Creek Watershed Initiative

October 2016

Chapter 7: Making It Happen

This chapter contains some detail regarding the implementation of the Woolper Creek Watershed Initiative (WCWI), including advocates of the Plan, financial details, the roles and functions for implementation, adaptability of the WCWI to future changes and challenges, as well as measures for tracking progress and success of the WCWI. Implementation is critical to restoring the degraded portions of the watershed and conserving the beautiful resource of Woolper Creek (**Figure 7-1**).

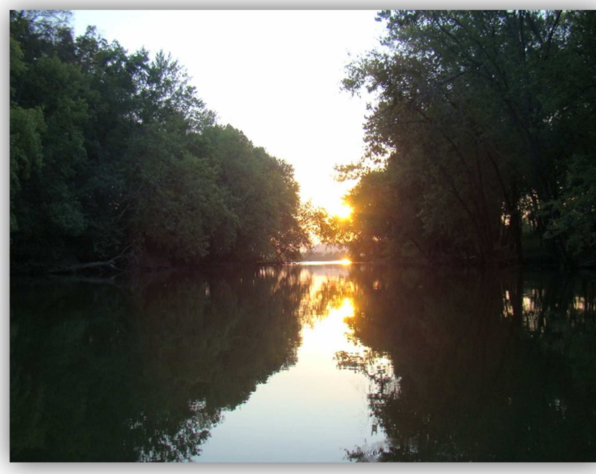


Figure 7-1: Sun setting over Woolper Creek

7.1 Advocating for the Woolper Creek Watershed Plan

Throughout the development of this Plan, the WCWI Steering Committee has met regularly and anticipates meeting at least every other month following the Plan's completion to guide its implementation. The Steering Committee includes representatives of the following agencies (see Chapter 1 for a list of personnel and their roles):

- Boone County Conservation District
- Kentucky Division of Water
- Sanitation District No. 1 of Northern Kentucky
- Northern Kentucky University Center for Environmental Restoration
- Northern Kentucky Health Department
- Boone County Fiscal Court/Public Works
- Kentucky Transportation Cabinet
- Kenton County Airport Board
- Boone County Planning Commission
- Northern Kentucky Area Development District

7.1.1 Reach Out

WCWI understands that reaching out to the community does not stop once the Plan is complete. This task will be led by the Watershed Coordinator. Outreach events will be important for educating the local community members on the next steps and engaging those who have not been involved to date. The WCWI has developed a report for the public that summarizes this Plan, the *Public Outreach Summary Document – Woolper Creek Watershed Plan*. The report closely follows this Plan but provides a more concise, shorter read for the community to understand the elements of the Plan without reading this entire document.

Additionally, as described in Chapter 5, the WCWI already uses education as a BMP and will continue to reach out to the community through a variety of media outlets such as the *Landscapes* newsletter - a Boone Conservancy publication mailed to over 45,000 households quarterly, the Conservations District's Facebook page, and public meetings/presentations regarding the implementation projects. Furthermore, the WCWI plans to install signage at several projects that are located in heavily populated areas, explaining the purpose of the BMP and the importance of water quality. Lastly, the WCWI plans to visit classrooms of local schools to educate the youth, work with community groups to conduct clean ups throughout the watershed, and engage in local events such as Family Nature Day at Boone Woods.

7.1.2 Communication Alternatives

Communication is important to the continued success of the Plan, as communication during implementation will spread the word about volunteer opportunities, funding needs, and project progress. It could also present opportunities for partnerships and cost-shares to implement cost-effective projects throughout the watershed.

As mentioned above, WCWI has developed a summary document to concisely provide a general overview of the Watershed Plan. This document will serve as an educational piece as well as a marketing tool. This document will be available on BCCD's website, www.boonecountyky.org/bccd/.

Additional outreach will continue through various forms of media, presentations to stakeholder groups and agencies, surveys, and public meetings. WCWI held several public meetings to gather input and educate the community about the development of this Plan. There was good attendance at these meetings, and the WCWI anticipates this to continue throughout the implementation phases of the project. It is the intent that these meetings will not only cover implementation efforts but can serve as a reminder of the aquatic life and habitat these efforts are trying to protect, like the sunfish in **Figure 7-2**.

Figure 7-2: Longear sunfish caught in creek

The WCWI anticipates the continuation of their media campaign through email, postal mail, press releases, and articles. BCCD's quarterly newsletter, *Landscapes*, and Boone County's publication of *What's Happening in Boone County* reach over 43,000 households, and these media outlets will continue to be used during the implementation phase. *The Boone County Recorder*, the local weekly newspaper, has also been used to publish articles. BCCD's website and Facebook are additional means for the WCWI to continue to disseminate information.

7.2 Securing and Managing Financial Resources

The WCWI has been fortunate enough to receive grant funding through a Kentucky Nonpoint Source Pollution Control Program grant, or 319(h) grant, supported by matching funds from a variety of non-Federal sources. WCWI plans to submit another grant request for additional funding for BMP implementation. The request is expected to total $1,000,000, consisting of 60% in Federal funds and 40% match.

Funding outside of the Federal 319(h) grant could be generated from local and regional private organizations as well as local, State, and Federal grant sources that may be identified. Private individuals, local non-profit organizations, and county agencies will also be encouraged to participate in plan implementation and funding. Specifically for county agencies, it will be important that funding be included in future budgets, requiring early communication. The WCWI understands that not all additional funding sources can be used as match for the 319(h) grant.

In addition to the above-mentioned funding that may be used to meet the 40% match, the following non-monetary items are a few examples that may be utilized:

- BCCD: personnel time, operating expenses, supplies, publication(s), travel, outreach, etc.
- SD1: Personnel time, installation of BMPs to restore the natural flow regime
- Boone County: Installation of BMPs to restore the natural flow regime
- Volunteers: time to increase public awareness of the projects
- Contractual support for the development and implementation of a success monitoring program
- Contractual support related to technical aspects of the project

The Northern Kentucky Area Development District is providing financial administration of the grant. Effectively, however, BCCD acts as the overall managers of the Plan and approves invoices and budgets.

7.3 Implementation Functions and Roles

The **Watershed Coordinator** for Woolper Creek will continue to be Mark Jacobs of the Boone County Conservation District. The roles of the Watershed Coordinator include plan implementation, public outreach, and education efforts. Mr. Jacobs is highly qualified to implement this Plan and is also the Watershed Coordinator for the Gunpowder Creek Watershed.

The **Technical Sub-committee** has the role of assisting in plan implementation and providing expertise when needed. The Technical Sub-committee is composed of representatives from the Conservation District, Boone County Public Works, Kentucky Transportation Cabinet, SD1, and Sustainable Streams, LLC. It is anticipated that this group will help to identify projects, assess and compare opportunities, and possibly identify additional funding sources.

Volunteers and **Partner Agencies** will be utilized for continued donations of time and resources for tasks such as Steering Committee and public meetings, data collection, and implementation. Students from

Thomas More College that volunteered during the data collection phase are anticipated to be used again to collect monitoring data, a two-fold benefit where cost can be reduced and awareness can be expanded. As mentioned above, volunteer time may be used to meet the local match for the 319(h) grant funding.

7.4 Adapting to Changes and Challenges

Flexibility will be important for this Plan's implementation. As mentioned in previous chapters, the WCWI anticipates to implement projects in not only the priority sub-watersheds, but any sub-watershed with a beneficial, cost-effective project. WCWI's approach of implementation, monitoring, and reassessing (**Figure 7-3**) is an important aspect of the implementation efforts. After implementing projects, monitoring can be conducted to understand improvements to the in-stream conditions. These results can then be used to reassess future implementation projects. This process will also help the WCWI to partner on appropriate projects with stakeholders and partner agencies.

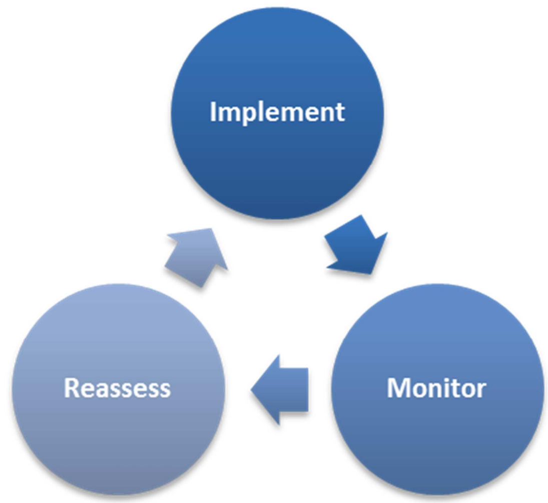


Figure 7-3: WCWI Watershed Plan Approach

Other unforeseen changes may be necessary as well during implementation. These will be addressed as they arise through the Steering Committee meetings and advice from the Technical Sub-committee.

7.5 Measuring Progress and Success

7.5.1 Tracking Progress

Numerous methods will be employed to track progress during the implementation phase. As in **Figure 7-4**, monitoring of the stream during implementation will be completed to understand pollutant loads as they relate to the benchmark loads. The WCWI will work with KDOW to develop and implement an in-stream success monitoring program to measure improvements. The sampling program will be comparable to the sampling that was performed during the planning phase and will be conducted under a KDOW-approved Quality Assurance Project Plan (QAPP). Depending on available funding and input from KDOW, success monitoring of individual BMPs may also be conducted, for example, via grab sampling and flow monitoring. Surveys may also be used to track the progress of non-structural BMPs such as training seminars and education. Records will be kept by the Watershed Coordinator.

7.5.2 Improvements in Watershed Health or Practices

Evaluation of monitoring efforts discussed in Section 7.5.1 will be conducted by the Watershed Coordinator, with assistance from the Technical Sub-committee as necessary. Additionally, the success of various implementation projects will be measured differently. One example of a simple measurement will be the implementation rate of the proposed activities (e.g., two detention basin retrofits installed during the first year of implementation with an overall goal of 20 retrofits throughout the entire implementation phase). For measuring the success of non-structural BMPs, such as public outreach activities, surveys and feedback at public meetings will mostly be used. In addition, plan reviews by SD1 and Boone County should be useful to note implementation of volume-based stormwater controls.

7.5.3 Improvements in Water Quality

The samples collected from in-stream monitoring will be compared to the benchmark loads, and the ratios presented in Chapter 4 will be reevaluated. The goal will be to reduce the ratio of projected loads to benchmark loads from those presented in Chapter 4. As mentioned in that chapter, it may not be necessary to lower the ratios to a value of 1.0, as Double Lick Creek had ratios higher than 1.0 for both TP and TN, and it is used as a reference stream by SD1. A reduction in the ratio will represent an improvement in water quality. Other in-stream monitoring at the established stations may include biological, hydrological, habitat, and geomorphic surveys (**Figure 7-4**). This action item will also guide future adjustments to the BMP implementation strategy and document BMP effectiveness in the local setting.

Figure 7-4: Sampling efforts during Plan development

7.5.4 Group Vitality

The group vitality of the WCWI is high; both the Steering Committee and Technical Sub-committee want to see their hard work pay off through the successful implementation of the *Woolper Creek Watershed Plan.* By implementing, monitoring, and reassessing over this phase of the Plan, continued interest and excitement is anticipated from the ever-improving health of the creek because the results will be tangible.