Final Report

Gunpowder Creek Watershed Plan

Prepared by the

Gunpowder Creek Watershed Initiative

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Executive Summary

The Gunpowder Creek Watershed is located in Boone County, Kentucky, is the largest watershed in the county, and is rapidly developing with continued growth expected in future years. Gunpowder Creek has been listed on the Kentucky Division of Water's (KDOW) 303(d) List for Impaired Waters for sediment, bacteria, and nutrients as a result of the streambank erosion/instability, excess sedimentation, degraded biological communities, and loss of ecological function that exist today. In order to combat these impairments and preserve this great resource for future generations (**Figure 1**), the Gunpowder Creek Watershed Initiative (GCWI) was developed by the Boone County Conservation District (BCCD). This initiative, which is funded through federal 319(h) grant funding, has met the goals and objectives of its FY 2009 grant application and continues to improve and protect the resources throughout the Gunpowder Creek Watershed today through several implementation projects that are already underway. The GCWI FFY 2009 Project Application outlines objectives that can be grouped into four main categories: (1) develop a KDOW-approved watershed plan, (2) promote long-term community stewardship, (3) develop a Watershed Data Analysis Report (DAR), and (4) set goals and select Best Management Practices (BMPs) for a management strategy to reduce nonpoint source pollutant loads and improve or protect streams throughout the Gunpowder Creek Watershed. With that, the GCWI completed a robust monitoring effort to inform the Watershed DAR and development of a comprehensive watershed plan for Gunpowder Creek, presenting a detailed understanding of in-stream conditions, including pollutants of concern, probable sources of these pollutants, and a plan of action to address the impacts to and protect the resources of the watershed. The plan of action includes appropriate, cost-effective BMPs to be implemented throughout the watershed to begin to reduce the amount of nonpoint source pollution in the streams. In addition to BCCD, numerous other stakeholders have been active participants in the GCWI and the development of this plan. The GCWI has truly created an environment for ongoing stewardship for the watershed, as many stakeholders continue to contribute to the success of this watershed plan and its implementation efforts.

Figure 1: GCWI formed to preserve the Gunpowder Creek for future generations

In order to inform the development of the watershed plan, the GCWI conducted a watershed characterization evaluation, in-stream monitoring, and several public meetings to engage the public in developing an appropriate plan of action. The purpose of the watershed characterization exercise was to understand its history, development, and resources. For example, some topics covered include hydrology, history of flooding, natural features of the watershed, human influences, and demographics. After gathering existing data and watershed characteristics, the next step in understanding the health of the watershed was to conduct in-stream monitoring. The GCWI monitoring program was multi-faceted and provided a comprehensive understanding of several dimensions of stream health, including: flow monitoring, hydrogeomorphic surveys, habitat assessments, water quality samples, and macroinvertebrate assessments. The analysis of the monitoring data was completed using an integrated approach, which focuses on the concept that there are many interdependencies for overall stream health, highlighted by the stream function pyramid in **Figure 2**. Stream flow results confirmed the urban flow regime is flashier and larger, causing increased erosion, more water quality impairments, degraded habitat conditions, and increased potential for flooding concerns. Hydrogeomorphic (physical) results illustrated that streams in the urban/suburban subwatersheds were unstable, with development being linked to stream channel enlargement, bed coarsening, shorter riffles, and longer and deeper pools (Hawley *et al.,* 2013a). In fact, the streams throughout Gunpowder Creek were so degraded that over 100 percent of the sediment measured in the water column could be explained through bank failure, meaning the sediment loads in the stream are coming from the stream itself. This is evident at an extremely dynamic site in South Fork Gunpowder experiencing tension crack bank failure (**Figure 17**). Habitat assessment scores were negatively correlated with geomorphic measures of habitat, such as changes in the top width of the bankfull channel, meaning the most unstable sites exhibited the most degraded habitat conditions. Water quality data were analyzed to evaluate variations in pollutant concentrations. Results of this analysis indicate that bacteria (as measured by *E.coli*) and sediment (as measured by TSS) are the most concerning pollutants in the Gunpowder Creek Watershed, particularly in the most developed regions of the watershed. The biological health of Gunpowder Creek is dependent on all other factors presented above, as biological integrity suffered the most in the more impervious, developed portions of the watershed. This is consistent with the rest of the data analysis and supports the prioritization of the most developed areas of the watershed. Details regarding watershed characterization, in-stream monitoring, and data analysis results are included in the Watershed DAR as well as chapters 2, 3, and 4 of the watershed plan. Results from the data analysis are included in the Results section of this report.

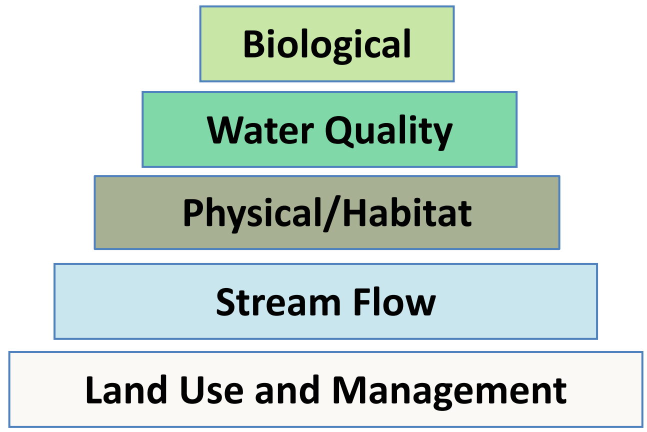


Figure 2: Stream Function Pyramid adapted from Harmon *et al*. 2012

The data analysis portion of the project informed development of strategic solutions to be implemented. BMPs presented throughout chapter 5 of the watershed plan include BMPs focused on stormwater, agriculture, construction, forestry, and onsite wastewater treatment, as all of these are applicable to specific regions of the watershed. While it has been established that TSS is the most concerning pollutant in the Gunpowder Creek Watershed, with the major source of TSS suspected to be bank erosion caused by the erosive flows in the creek from stormwater runoff, volume-based stormwater controls were designated as a cost-effective, priority BMP to provide improved water quality and stream channel protection.

Chapter 6 of the watershed plan presents a combination of BMPs to address the impacts to and protect the resources of the Gunpowder Creek Watershed and culminates with a BMP Action Plan. This BMP Action Plan categorizes including overall watershed BMPs, developed headwater BMPs, agricultural BMPs, and undeveloped/forestry BMPs. Although this plan includes initial strategies to begin to achieve the goals of the watershed plan, the GCWI plans to make smart investments as opportunities arise, monitor the progress, then reassess through continued monitoring – with the goal to continually improve the effectiveness of the implementation efforts.

Furthermore, a key consideration in the development of the selected BMPs was the stakeholder cooperation and input from several roundtable discussions. Tailoring the BMPs to the gathered responses provides the supportive foundation for successful implementation of the plan. In addition to the GCWI Steering Committee and regional partners, the public has been actively involved. One open house and three roundtable meetings (**Figure 3**) were held to gain feedback on issues and considerations in the watershed. These efforts are important for developing long-term community stewardship in the Gunpowder Creek Watershed. Public outreach has been integral to the plan's success so far and will continue. The media campaign, presentations, and public meetings have been invaluable. The strategic solutions and long-term community stewardship efforts included in the final chapters of the watershed plan are summarized in the Discussion section of this report.

Figure 3: One of several well-attended public meetings on the Gunpowder Creek Watershed Initiative

Introduction and Background

1.0 Background:

The Gunpowder Creek Watershed is located in Boone County, which is Kentucky's second fastest growing county and one of the top 100 in the nation (Census, 2009). From 2000 to 2009, county population was estimated to increase by 38% to 118,576 (Census, 2010). Correspondingly, housing units increased by 35% to 45,043 units from 2000 to 2008 (Census, 2010). This does not take into account commercial development during the same period. Concerned and interested groups and agencies, led by the Boone County Conservation District formed the Gunpowder Creek Watershed Initiative (GCWI) to develop strategies to improve and/or protect the water quality of Gunpowder Creek.

2.0 Purpose / Problem:

Gunpowder Creek has been listed on the Kentucky Division of Water's (KDOW) 303(d) List for Impaired Waters for sediment, bacteria, and nutrients as a result of the streambank erosion/instability, excess sedimentation, degraded biological communities, and loss of ecological function that exist today. Threats to the water quality of Gunpowder Creek are growing at a rapid pace as Boone County continues to develop. Nonpoint source pollution, due to hydromodification, habitat alteration, and sedimentation, is the leading cause of impairments in the watershed. While most of the upper reaches of the watershed have been developed, historic land uses such as agriculture also impact the lower portions of the watershed. Development in the county continues to push south and west across the watershed, negatively impacting streams.

3.0 Goals and Objectives:

The goal of the GCWI is to improve and/or maintain water quality in the Gunpowder Creek watershed through development of a KDOW-approved watershed plan. The objectives of this project were grouped into four main categories, with objectives 2, 3, and 4 informing the development of the KDOW-approved watershed plan (objective 1):

Objective 1: Plan - The development of a KDOW-approved watershed plan that meets the USEPA a – i criteria that will result in improvement, maintenance, and protection of the overall natural resource health of the watershed by identifying more clearly the threats to the watershed, opportunities for mitigation or protection from future impairment and efforts that need to be taken to reduce current impairments. *The Gunpowder Creek Watershed Plan is included as Appendix D of this Final Report.*

Objective 2: Stewardship - Develop long-term community stewardship for the Gunpowder Creek Watershed so that water quality management can continue beyond the time horizon of this grant. This information is included throughout several chapters of the watershed plan, specifically chapters 5 through 7. *GCWI Public Meeting Survey Results and Roundtable Discussion Summary Reports are included as Appendix E of this Final Report.*

<u>Objective 3</u>: <u>Watershed Data Analysis Report</u> - Compile existing data, identify gaps, develop a KDOW-approved phased monitoring component that will allow the GCWI, through the plan, to accurately identify the pollutants and sources and estimate pollutant loads. Identify subwatersheds most in need of water quality management activities. Generate a KDOW-approved watershed data analysis report. The information presented in this report informs the development of chapters 3 and 4 of the watershed plan. *The Watershed Data Analysis Report is included as Appendix C of this Final Report.*

<u>Objective 4:</u> <u>Management Strategy</u> – Develop a management strategy by setting goals, identifying load reductions, and selecting Best Management Practices (BMPs) that would most effectively reduce NPS pollutant loads and improve or protect the water quality of the watershed. This information is presented in chapters 5, 6, and 7 of the watershed plan.

4.0 The Opportunity:

This project provides the opportunity to create lasting partnerships dedicated to improving and protecting the water quality of Gunpowder Creek. The timing for the development of the watershed plan and the implementation of BMPs is very appropriate, as the watershed becomes more urbanized and such measures become primarily corrective instead of protective, and thus much more costly to implement. Let it be reiterated that future implementation will be based on the approved watershed plan and the information contained in it from the phased monitoring.

5.0 Other Pertinent Work:

The GCWI is supported by stakeholders and stewards throughout the watershed; and therefore, several other entities are also working in collaboration to improve and protect Gunpowder Creek. For example, the Sanitation District No. 1 of Northern Kentucky (SD1) continues to collect in-stream monitoring data throughout many of the sampling sites in Gunpowder Creek and is genuinely committed to promoting improved stormwater regulations that encourage developers to install stormwater BMPs that provide water quality, channel protection, and flood control. The City of Florence, along with SD1, has been a strategic partner on a more detailed study of potential detention basin retrofit projects in the priority subwatershed of South Fork Gunpowder. Furthermore, Boone County Public Schools has partnered with BCCD for the implementation of a basin retrofit project at Ockerman Middle School, and it is collaborating with BCCD to potentially install additional retrofits at other public school facilities within the watershed. The Northern Kentucky Urban Forestry Council completed an Urban Tree Canopy Assessment of northern Kentucky and designated the Gunpowder Creek Watershed as an area to receive a priority planting plan. While these entities present just a handful of examples, the GCWI is truly a collaborative effort with several key organizations and personnel involved, as evident by the extensive list of acknowledgements included in this Final Report.

Materials and Methods

1.0 Description of the Project Area

The Gunpowder Creek Watershed, located in Boone County, Kentucky, is the largest watershed in the county (58.2 square miles) and is comprised of four smaller subwatersheds, along with the main Gunpowder Creek Watershed (**Figure 4**): South Fork Gunpowder, Fowler Fork, Long Branch, and Riddles Run. The headwaters originate near the Greater Cincinnati/Northern Kentucky International Airport (CVG) in the northern region of the watershed and flow approximately 36 miles southwest to the Ohio River. There is a total of 143.1 miles of blue line streams in the watershed. Many sections throughout the headwaters of Gunpowder Creek, along with sections of South Fork Gunpowder Creek, are listed on KDOW's 303(d) List of Impaired Waters for sedimentation/siltation, nutrient/eutrophication, biological indicators, organic enrichment (sewage), warm water aquatic habitat (nonsupport), and primary contact recreation water (nonsupport). Suspected sources include urban stormwater, agriculture, site clearance, and streambank modifications (**Table 1**).

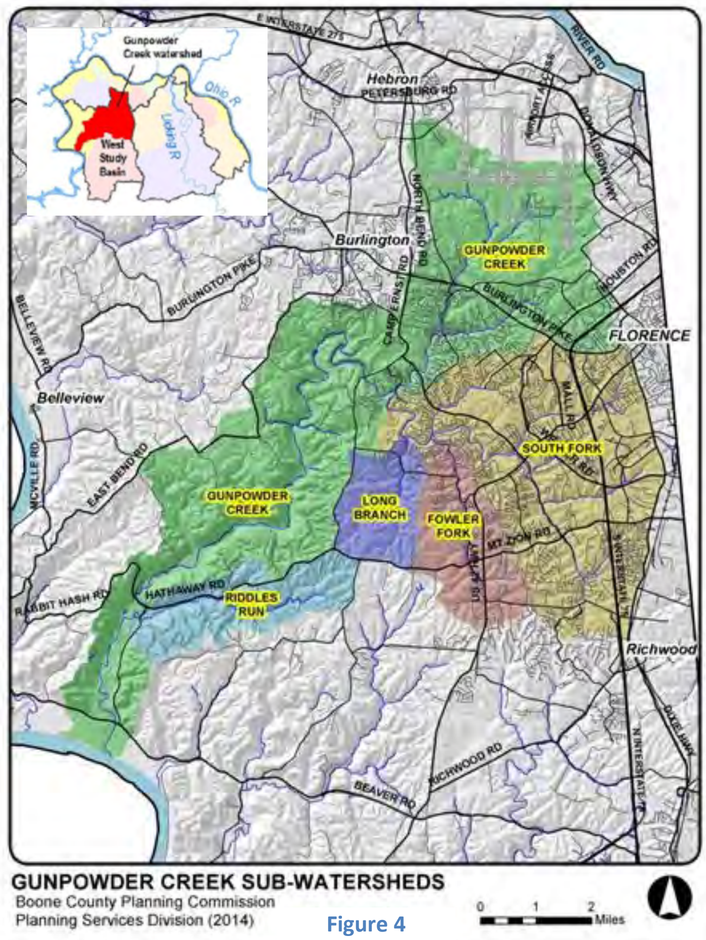


Figure 4

Table 1: Stream sections in the watershed on the Kentucky 303(d) List of Impaired Waters (KDOW, 2012)

STREAM NAME	RIVER MILES	POLLUTANT	SUSPECTED SOURCE(S)
Gunpowder Creek into Ohio River	0.0 to 15.0	Sedimentation/Siltation	Site Clearance (Land Development or Redevelopment)
Gunpowder Creek	15.4 to 17.1	Nutrient/Eutrophication Biological Indicators	Agriculture; Site Clearance; Unspecified Urban Stormwater
Gunpowder Creek	15.4 to 17.1	Organic Enrichment (Sewage) Biological Indicators	Agriculture; Unspecified Urban Stormwater
Gunpowder Creek	15.4 to 17.1	Sedimentation/Siltation	Agriculture; Highway/Road/Bridge Runoff; Loss of Riparian Habitat; Site Clearance; Streambank Modifications/ Destabilization; Unspecified Urban Stormwater
Gunpowder Creek	18.9 to 21.6	Cause Unknown	Unspecified Urban Stormwater

South Fork Gunpowder Creek	0.0 to 2.0	Nutrient/Eutrophication Biological Indicators, Organic Enrichment (Sewage) Biological Indicators, Sedimentation/Siltation, and Turbidity	Agriculture; Package Plant or Other Permitted Small Flow Discharges; Site Clearance; Post-development Erosion and Sedimentation
South Fork Gunpowder Creek	4.1 to 6.8	Fecal Coliform	Source Unknown

Being located in one of the most rapidly developing counties in the Commonwealth of Kentucky, Gunpowder Creek has become more and more degraded due to anthropogenic influences, particularly in the developed headwaters of Gunpowder Creek and South Fork Gunpowder Creek. Future expansion of development into the western portions of the watershed is anticipated to coincide with a continued increase in population for at least the next 25 years. Despite these development pressures, much of the land in the watershed is undeveloped (57 percent), which includes woodlands, recreation, and agricultural uses. Residential land comprises nearly 30 percent of the area, with dense development covering nearly 20 percent. Today, the creek is used for many recreational activities, including fishing and kayaking.

The GCWI developed a comprehensive monitoring program to help understand stream health and inform the development of the Water Quality Data Analysis Report (DAR) and ultimately the watershed plan. This included flow monitoring, hydrogeomorphic surveys, habitat assessments, water quality samples, and macroinvertebrate assessments. The monitoring completed as part of the GCWI monitoring program was conducted at the mouth of the subwatersheds, within the main branch, and on some unnamed tributaries. As part of this effort, flow, hydrogeomorphic, water chemistry, habitat, and biological data were collected at six sites in the watershed. Additionally, as part of SD1's ongoing Hydromodifiction Monitoring Program, hydrogeomorphic data were collected at three more sites, for a total of 9 sites with hydrogeomorphic data (**Figure 5, Table 2**).

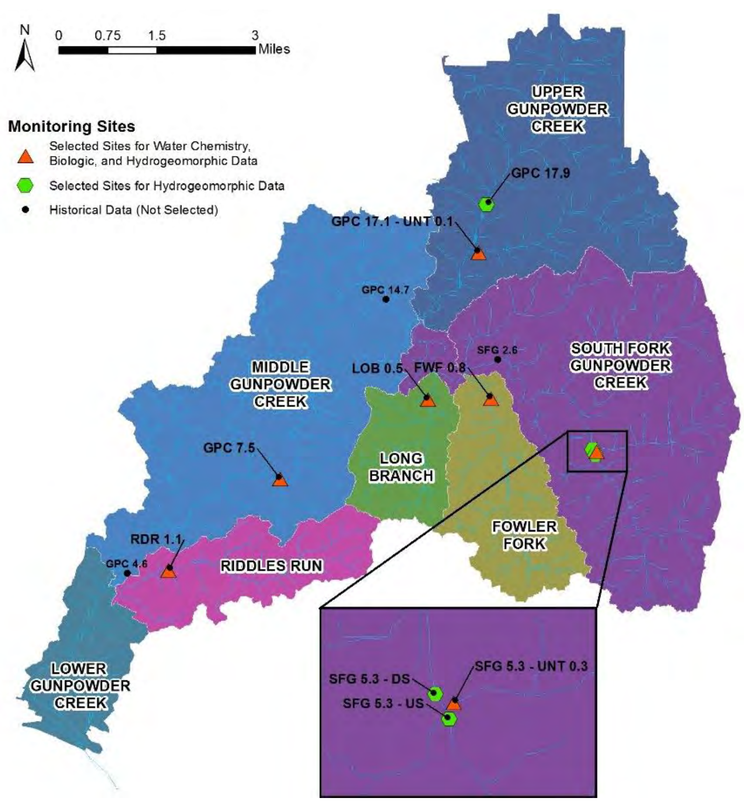


Figure 5: GCWI monitoring sites

Table 2: Summary of existing and selected monitoring sites for Gunpowder Creek sampling

SITE NAME (Stream & River Mile)	STREAM NAME	SITE LOCATION (Decimal Degrees)	
		Latitude	Longitude
GPC 4.6	Gunpowder Creek	38.933752	-84.789426
GPC 7.5	Gunpowder Creek	38.954653	-84.745833
GPC 14.7	Gunpowder Creek	38.994638	-84.716271
GPC 17.9	Gunpowder Creek	39.015753	-84.687930
GPC 17.1 - UNT 0.1	Unnamed Tributary to Gunpowder Creek	39.005020	-84.689940
SFG 2.6	South Fork of Gunpowder Creek	38.981674	-84.684500
SFG 5.3 - DS	South Fork of Gunpowder Creek	38.961638	-84.657351
SFG 5.3 - US	South Fork of Gunpowder Creek	38.960377	-84.656824
SFG 5.3 - UNT 0.3	Unnamed Tributary to South Fork of Gunpowder Creek	38.961213	-84.656198
FWF 0.8	Fowlers Fork	38.972779	-84.686212
LDB 0.5	Long Branch	38.972507	-84.703982
RDR 1.1	Riddles Run	38.934208	-84.778223

The goal of analyzing the monitoring data was to better understand existing stream health, inform the development of the Water Quality DAR as well as chapters 3 and 4 of the watershed plan, and ultimately provide data for creating an integrated implementation plan for the watershed that will be feasible, efficient, and effective.

2.0 Description of the Methods used to obtain the Results for the Project

All monitoring data were collected and analyzed according to industry standard procedures as specified in the *2011 Quality Assurance Project Plan for Gunpowder Creek Watershed Plan* (QAPP). This QAPP is included in **Appendix B**. Flow monitoring utilized USGS gauge 03277075 (Gunpowder Creek at Camp Ernst Road near Union, KY) in addition to measurements taken in the field. Hydrogeomorphic surveys were conducted to measure channel instability. Hydrogeomorphic data collected in the field included cross section and profile measurements as well as pebble counts of the bed material. Habitat assessments focused on the quality of in-stream and riparian habitat and were conducted according to KDOW methods (e.g., Barbour *et al.*, 1999; KDOW, 2001). All water quality sampling methods were in accordance with the KDOW Standard Operating Procedures (SOPs). Water quality sampling included both field measurements (e.g., temperature, pH, dissolved oxygen, specific conductance, etc.) as well as parameters measured in the laboratory (e.g., bacteria, sediment, nutrients, etc.). For the biological assessments, benthic macroinvertebrate samples were based on the EPA's Rapid Bioassessment Protocols for high gradient streams (Barbour *et al.*, 1999), as adapted for Kentucky. **Table 3** summarizes the sampling categories as well as references for the established methods used to collect this data. Furthermore, the QAPP outlines quality objectives and appropriate SOP criteria for field and lab personnel to follow for sampling and laboratory analysis, while considering quality indicators such as precision, bias, accuracy, representativeness, comparability, completeness, and sensitivity. Reference the QAPP for additional detail regarding these quality indicators for each sampling category as well as any special training/certification necessary, appropriate documentation and records, and sampling methodology.

Table 3: Summary of Gunpowder Creek sampling efforts and referenced methodologies

Category	Sub-Category	Parameter	References
Water quality (Chemical)	Bacteria	*E. coli* (*Escherichia coli*)	SM9223 B
	Nutrients	NO_3/NO_2 (Nitrate-Nitrite)	EPA 353.2
		NH_3-N (Ammonia-Nitrogen)	SM4500NH3 D
		TKN (Total Kjeldahl Nitrogen)	EPA 351.2
		TP (Total Phosphorus)	EPA 365.1
		OP (Orthophosphate)	EPA 365.3
		CBOD5 (5-day Carbonaceous Biochemical Oxygen Demand)	HACH 10230
	Sediment	TSS (Total Suspended Sediment)	SM2540 D
	Field Data	Turbidity (actual or estimated)	
		pH (Hydronium Ions/Acidity)	
		DO (Dissolved Oxygen)	
		Conductivity (Ionic Content/ TSS)	
		% Saturation (Percentage of DO)	
		Temperature	
Hydrologic	Flow	Volumetric Stream Discharge Rate	(KDOW, 2010b)
Biological	Macroinvertebrates	Taxonomic Identification (lab)	(KDOW, 2009)
	Fish	Taxonomic Identification (field)	(SD1, 2007)
	Habitat	Rapid Bioassessment Protocol	(Barbour et al., 1999)
Geomorphic	Geometric	Cross-section and profile surveys	(Harrelson et al., 1994)
	Bed material	Pebble counts	(Bunte and Abt, 2001a; 2001b)

Once the monitoring data were collected, data analysis involved several different methodologies such as processing the hydromodification survey data, generating water quality box plots and pollutant load duration curves, and evaluating statistical trends with the other data such as habitat assessment scores, MBI values, and watershed characterization GIS data. Chapter 4 of the watershed plan includes detailed information regarding the methodologies used to systematically process and evaluate the monitoring data. The following paragraphs present a brief summary of the analysis completed in this chapter of the watershed plan.

The hydrogeomorphic data were processed to understand measurements of the cross section, profile, and bed material data to provide consistency across all sites and evaluate measures of channel change using the methodologies outlined by Hawley *et al.,* 2013. Examples of summary metrics include bankfull area, depth, and top width; riffle length, pool length, pool depth, slope, and the pool/riffle ratio; and the 16th, 59th, and 84th percentile bed material particles. With this data, measured rates of change and weighted deviation calculations between the 2011 and 2012 rounds of surveys were completed to understand the geomorphic modifications during the monitoring period.

Water quality data were processed to evaluate variations in pollutant concentrations and understand what might be causing such variations. The analysis included an evaluation of relationships with rainfall (wet and dry weather events) and stream discharge data to examine changes in the pollutants of concern related to precipitation-driven changes and the associated changes in stream flow. Sample concentrations, summarized by water quality parameter, sampling site, and type of sample (wet versus dry), were plotted on standard box and whisker plots to provide a visual observation of the range of sample concentrations, the mean concentration for each parameter evaluated (excluding statistical outliers), and the overall relation to the water quality benchmark or standard set for that parameter. In addition to the water quality box and whisker plots, the analysis included flow duration curves that served as the foundation for developing pollutant load duration curves for several pollutants of concern at all water chemistry monitoring sites. Such pollutant load duration curves were used to analyze the relationship between exceedances in water quality benchmarks/standards and flow conditions (e.g., high flow vs. low flow conditions, wet weather vs. dry weather conditions), as well as estimate overall pollutant loads and yields.

Statistical analysis, using the R program (R Development Core Team, 2012), was used to evaluate the strength of various relationships between water quality monitoring data and watershed characteristics such as land use data. Because hydromodification is a known water quality concern in Gunpowder Creek and can be a source of impairments such as high TSS, this analysis also incorporated the results of the hydromodification monitoring in order to identify statistically-significant relationships between every aspect of the stream function pyramid (**Figure 1**). This included correlations among and between land use, flow, water quality, habitat, and macroinvertebrate communities.

Additional analysis was completed to estimate the pollutant load reductions for applicable BMPs outlined in chapters 5 and 6 of the watershed plan. More specifically, Appendix 5-B of the watershed plan presents detailed information regarding the TSS loads coming from the streambanks, Appendix 5-C of the watershed plan outlines the methodology used to determine stormwater storage needs and potential pollutant load reductions from additional storage and detention basin retrofits, and the BMP action item summary table (**Table 11**) includes footnotes outlining assumptions and methods for estimated load reductions presented in the table (this table is also included in chapter 6 of the plan). Additionally, data from the International Stormwater BMP Database was utilized to inform the effectiveness of stormwater volume-based BMPs presented in the watershed plan (Leisenring *et al*., 2012).

In an effort to quantify the effect of bank erosion on TSS levels in the water column, erosion was calculated via discretization of the cross sections that were generated from the hydrogeomorphic monitoring data. These erosional areas were then converted to annual volumes for each reach using simple calculus, operating under the conservative assumptions that no bank erosion occurred at the upstream boundary of each stream, and bank erosion area was linearly distributed along the profile of the main channel. Again, this information is presented in Appendix 5-B of the watershed plan.

Furthermore, three local case studies were utilized to estimate the stormwater storage volumes needed in the Gunpowder Creek Watershed and understand how much storage volume needs to be optimized to better match the natural rates of erosion in receiving streams. These case studies present detailed evaluations of the volume requirements necessary for in-stream channel protection. Under the assumption that the relationship between impervious area and required storage is linear between case studies, volume requirements upstream of each catchment area were interpolated using the unique imperviousness upstream of that catchment. Applying this scaling approach to all of the headwater streams with relatively small drainage areas provides an idea of the amount of optimized stormwater storage that is needed in each headwater area to prevent excess erosion in the receiving streams. An estimate of the total storage needed for the developed portion of the Gunpowder Creek Watershed can then be developed by summing all of the headwater estimates and accounting for any gaps that were not otherwise considered. Again, this information is presented in Appendix 5-C of the watershed plan.

Lastly, the BMP action item table (**Table 11**) presents several assumptions and references utilized to estimate pollutant load reductions. For example, estimated load reductions for riparian plantings include reported values for TSS, phosphorus and nitrogen removal by Wenger, 1999; bacteria production by livestock estimates reference BWC, 2009; removal rates for stormwater BMPs such as bioinfiltration, detention basin retrofits, and new detention basins utilized BMP efficiencies documented in the International Stormwater BMP database (Leisenring *et al*., 2012); nutrient removal rates for livestock exclusion fencing were taken from Hart *et al*., 1997; etc. Please reference the table included in the watershed plan for additional detail regarding the estimates for pollutant load reductions.

3.0 Description of any Specialized Materials that were used in the Collection of Data for the Project

A detailed description of all sampling methods and equipment/materials used is included in the QAPP. This section highlights some specialized materials used for the data collection aspect of this grant project. Water quality data were generated via grab samples and using auto-samplers. Grab samples were collected by the GCWI and sent to Cardinal Laboratory where water quality parameters, such as bacteria (*E.coli*), nutrients (NO_3/NO_2, NH3-N, TKN, TP, OP, CBOD5) and sediment (TSS) were tested. The GCWI utilized an automatic sampler to measure parameters such as water temperature, pH, dissolved oxygen (DO), specific conductivity, turbidity, and velocity. For hydrologic sampling, a minimum of ten depth measurements were taken with a survey rod and velocity was measured with a velocity probe at 60 percent of the depth below the water's surface. This hydrologic sampling follows procedures defined by Rantz *et al.* (1982).

Macroinvertebrate sampling involved a 600-micron net and mesh wash bucket. Multi-habitat sweep samples utilized an 800 micron D-frame net. All samples were properly sieved in the field to remove small debris and excess sediment, immediately preserved in a 70 percent alcohol solution and transported to the taxonomic laboratory for processing. Fish sampling involved materials such as a backpack-type shocking device at the wadeable sites. Lastly, geomorphic monitoring involved survey equipment to capture channel and profile geometry and a standard US SAH-97 phi template (i.e., gravelometer) to measure the bed material gradation.

Results and Discussion

1.0 Analyzing Results

Introduction

As previously mentioned, this analysis was based upon an integrated approach to watershed planning through the stream function pyramid (**Figure 1**). The approach to this data analysis is unique in that rather than analyzing each component in isolation, we look at the system as it is—an interconnected network of dynamic parts. Quantitative analysis of the stream function pyramid components served as the foundation for identifying pollutants of concern, their potential sources, and possible solutions and BMPs that could be implemented to mitigate such pollutants. As previously explained, the GCWI monitoring program was designed to assess multiple measures of stream health using flow monitoring, geomorphic surveys, habitat assessments, water quality samples, macroinvertebrate assessments, and land use analysis. While collecting this comprehensive monitoring data, the GCWI followed all procedures outlined in the QAPP, including checks performed on the data to promote accuracy and precision. Please reference the QAPP, included as **Appendix B**, for more details on the actual checks performed on the data. The overall results of both Phase I (2011 data) and Phase 2 (2012 data) monitoring are consistent with the preliminary assessment that was made during the QAPP development. Pollutants associated with hydromodification (e.g., TSS) seem to be the most concerning impairments, particularly in the heavily developed headwaters of the Gunpowder Creek Watershed (e.g., TSS loads ~30 to 60 times higher than benchmark levels). Indeed, the worst sites for macroinvertebrates were found along headwater tributaries to the main branch and South Fork Gunpowder Creek, which are the two most developed subwatersheds. The erosive urban flow regime has caused active bank erosion and flushed nearly all of the habitat-forming bed material at these sites, leaving featureless bedrock streams void of aquatic habitat or refugia (i.e., isolated refuges where species can survive in an otherwise broken ecosystem). The bank erosion and unstable bed material has resulted in high sediment loads throughout the Gunpowder Creek Watershed. These apparent relationships observed in the Gunpowder Creek Watershed are consistent with the statistically-significant relationships from SD1's Hydromodification Monitoring Program, which includes of a robust dataset of 40 unique sites from Northern Kentucky . This dataset is separate from the GCWI monitoring program, but both illustrated similar outcomes – urbanization, as measured by impervious area, has been correlated to channel enlargement, bed coarsening, shorter riffles, and deeper, longer pools (Hawley *et al*., 2013a).

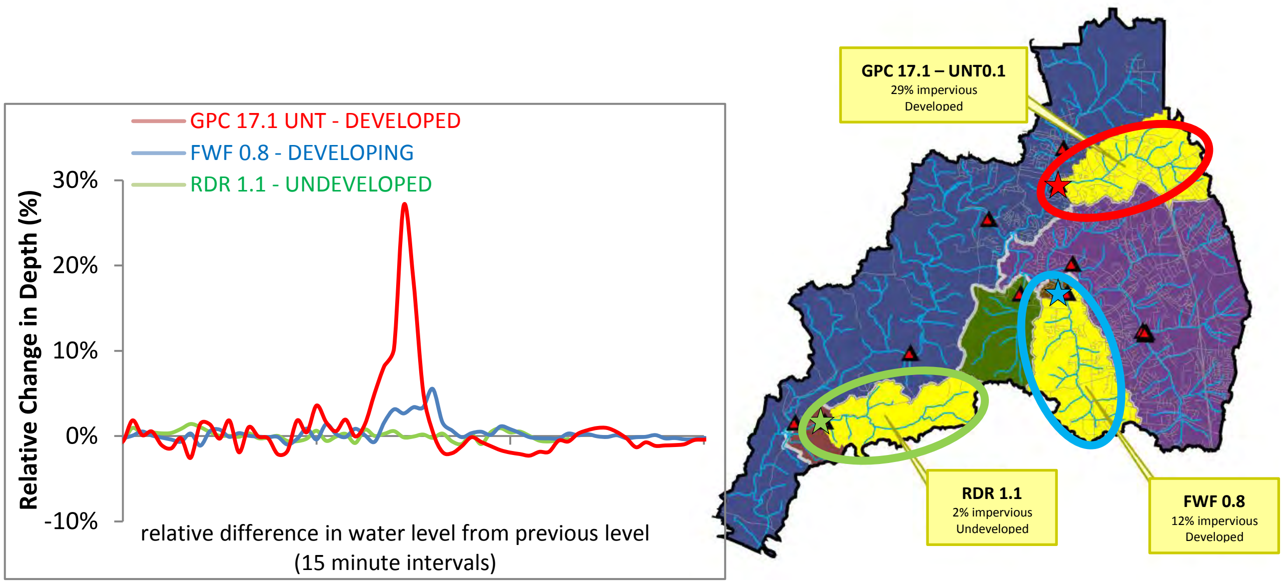
In comparing the 2011 Phase 1 monitoring results with the 2012 Phase 2 monitoring results, many water quality indicators drastically changed due to the substantial difference in rainfall that occurred during each monitoring effort. Samples collected during 2011, a record rainfall year with over 70 inches of rain (NCDC, 2012), provided insight regarding the types of pollutants washed off the land during runoff events. In contrast, samples collected in 2012, a much drier year, indicated the types of pollutants released directly into the stream without the influence of rainfall. Some examples of large differences in wet and dry monitoring (2011 versus 2012) in the Gunpowder Creek Watershed include high levels of bacteria strongly linked to wet weather (a relationship across all sites), whereas higher levels of specific conductivity and nutrients were linked to dry weather at a few monitoring locations, which could be indicative of possible direct sources in select areas such as livestock access or septic systems. Analysis of the monitoring data and how it relates to watershed conditions serves as the foundation for determining BMP implementation that will likely be the most feasible, efficient, and effective (chapters 5 and 6 of the watershed plan).

Stream Flow Monitoring Results

The urban flow regime associated with increased development and unmitigated impervious area has greatly impacted Northern Kentucky streams (Hawley *et al.*, 2013a). **Figure 6** presents an example of a Northern Kentucky stream, Pleasant Run (~100 acre basin), that experiences erosive flows even on relatively small storm events. The photo illustrates a 0.45-inch rainfall event (11/16/10) with a duration of 2 hours, which is less than the 2-month storm (2-month, 2-hour = 0.81”). This example illustrates that very fast, erosive flows occur during many storms. Comparison of data logger information from three sites within the Gunpowder Creek Watershed of similar drainage area but varying levels of development, **Figure 7(b)**, illustrated that the altered flow regime associated with conventional urban development leads to flashier and larger flows. This is evidenced by the comparison of the measured flows at all three data logger locations, **Figure 7(a)**, which shows that the most developed site experienced much higher changes in water levels during the same rain event. The flashier and larger flows associated with unmanaged urban development lead to 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 6: Erosive flows during 0.45-inch storm

Stormwater runoff in the developed headwaters makes stream flow rise and fall very rapidly and can cause flooding and streambank erosion.



(a) Percent Relative Change in Water Depth Over Time [(a)] ***(b) Data Logger Locations***

Figure 7: Water levels rise and fall more rapidly in developed watersheds

[(a)] GPC 17.1-UNT 0.1 has been shortened to GPC 17.1 UNT in the graph above.

Physical – Hydrogeomorphic Data Monitoring Results

Analyses of physical data indicate that streams in urban/suburban watersheds tend to be getting larger. An in-depth study of Northern Kentucky streams has demonstrated their overall shape is deepening and widening, their riffles are shrinking, their pools tend to be getting both longer and deeper, and watersheds in early stages of development (i.e., less than 15% total impervious area) were correlated with bed material coarsening as finer bed material is stripped away and moved downstream (Hawley *et al.,* 2013a). Unstable streams degrade water quality, aquatic habitat, and ultimately biological activity. Additionally, the unstable nature of many streams throughout Northern Kentucky has destroyed public and private infrastructure and adjacent property (Hawley *et al*., 2013b; **Figure 8**). Stability and habitat quality tend to decrease in developed watersheds and increased impervious area has been strongly correlated to channel enlargement, bed coarsening, shorter riffles, longer and deeper pools, and stream instability in Northern Kentucky streams (Hawley *et al.,* 2013a). In general, the processed hydrogeomorphic survey data along Gunpowder Creek illustrated similar relationships to other Northern Kentucky streams; however, the relationships were not as significant, perhaps due to the presence of vertical grade control (bedrock) at many of the sites. In relation to percent impervious surfaces, both bankfull area and bankfull top width linear regressions were the most clear. The average

Figure 8: Streams widen and destroy public infrastructure

> ***Erosive flows can degrade habitat, cause bank erosion, and create high sediment loads.***

annual change in bankfull area and bankfull top width appears to have a positive relationship to percent impervious, but were not statistically significant with *p* values of 0.23 and 0.13, respectively.

When evaluating cross-sectional enlargement (i.e., annual increase in bankfull area per year) against land use, some examples of GIS parameters that illustrated significant ($p < 0.05$) relationships include percent barren land (**Figure 9**) and percent riparian roads (**Figure 10**). In a watershed comprised of predominantly clay soils (93.5% Hydrologic Soil Group Types C and D), barren land cover can behave similarly to impervious land area because it lacks the vegetation to slow down and transpire stormwater runoff. Additionally, the presence of roadways within the riparian corridor was strongly correlated to channel enlargement, indicating that the presence of riparian roads seemed to explain a greater portion of channel enlargement than watershed imperviousness. Roads often route their stormwater directly and efficiently to streams, whereas large developments tend to include some level of stormwater detention. Therefore, the case can be made that roadway imperviousness causes more hydrological effects than other types of impervious area. Riparian roads may also be indicative of potential channelization that may have occurred to create more optimal roadway alignments. Channelization is widely documented to increase the erosive energy of streams, which also makes them more prone to channel erosion and enlargement.

Overall physical/habitat relationships illustrate concerns with channel enlargement and habitat.

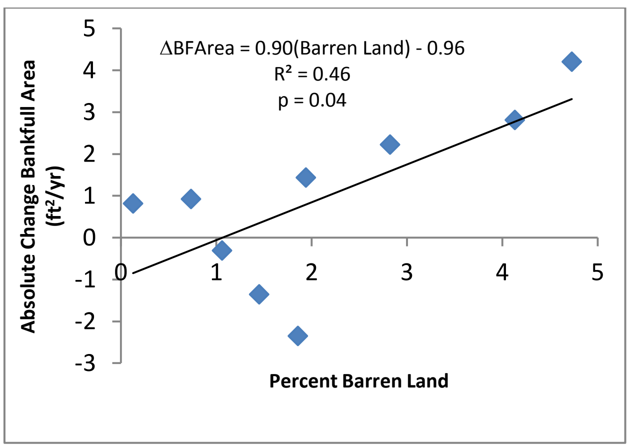


Figure 9: Channel enlargement is positively correlated to percent barren land

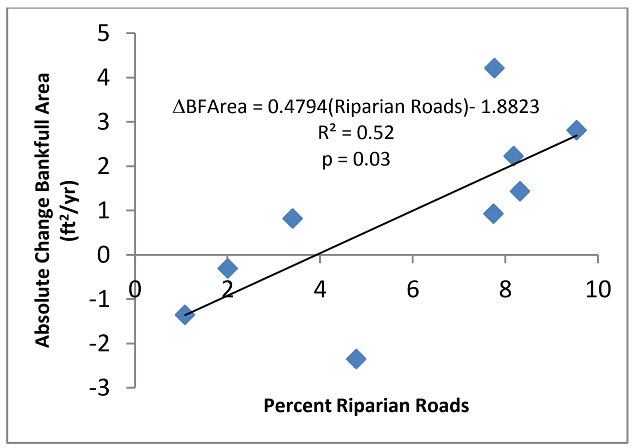


Figure 10: Channel enlargement is positively correlated to percent riparian roads

In addition to land cover metrics, linear regression relationships relating enlargement and water quality were evaluated. Across both high and low flows, TSS was positively associated with channel enlargement and widening. Specifically, the correlation between mean TSS concentration at low flow and channel widening was nearly statistically significant ($p = 0.05$), and the correlation with the mean high flow concentration was highly significant ($p = 0.003$) when withholding site GPC 17.1-UNT 0.1 (**Figure 11**), which was a physically-based outlier due to the fact that bank erosion from previous years have caused an over-widened channel with a mid-channel tree, which led to a log jam that temporarily induced deposition during the survey period (*i.e.*, see **Figure 18**). These finding are supported by other researchers that have documented channel erosion, enlargement, and bank failure as the dominant source of suspended sediment in many streams (Trimble, 1997; Simon and Klimetz, 2008; Wilson et al., 2007).

Further analyses illustrate that degraded habitat is also correlated to channel instability. For example, the Habitat Score was negatively correlated to both the change in bankfull area per year and the change in bankfull top width per year, with significant *p* values of 0.05 and 0.02 (**Figure 12**), respectively.

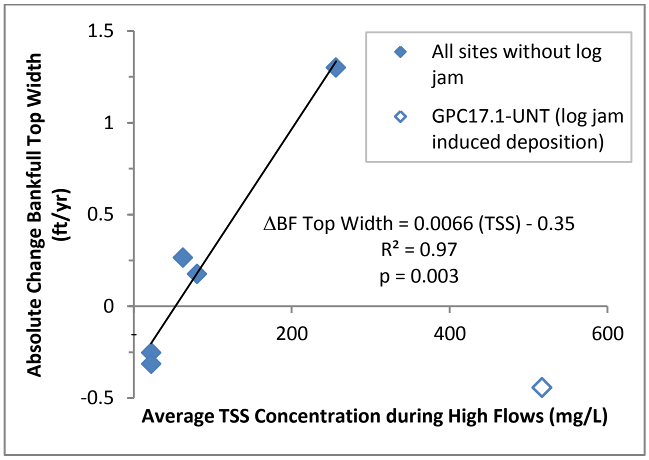


Figure 11: Channel widening is positively correlated to TSS

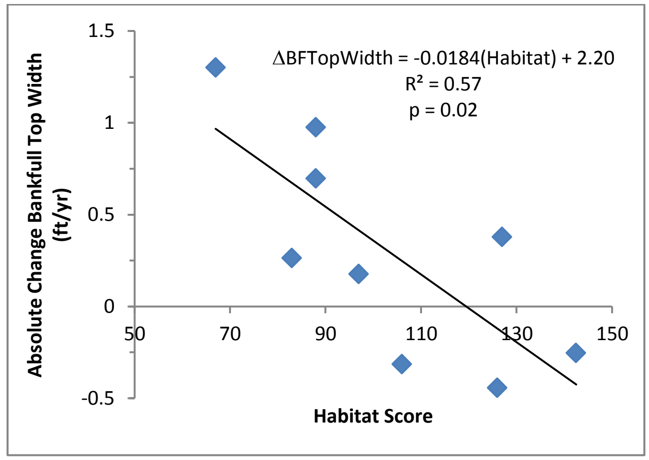


Figure 12: Channel enlargement is negatively correlated to habitat score

Hydromodification Monitoring Sites Case Studies

Hydromodification monitoring at sites along Gunpowder Creek document the physical changes that have occurred through both quantitative data captured by hydrogeomorphic surveys and observations of visual changes documented in annual photographs. Of the nine hydromodification monitoring sites assessed for this analysis, three case studies present representative examples of the problems throughout much of the Gunpowder Creek Watershed. These three locations are described below, with locations illustrated in **Figure 13**.

1. South Fork Gunpowder Creek (SFG 5.3-DS, 28% impervious): An extremely dynamic site that experienced bank failure and bed incision;
2. Unnamed Tributary of South Fork Gunpowder Creek (SFG 5.3-UNT 0.3, 41% impervious): A site with relatively shallow bedrock and a well-connected floodplain experiencing geotechnical mass wasting and bank widening , and;
3. Unnamed Tributary of Gunpowder Creek (GPC 17.1-UNT 0.1, 29% impervious): A site with erosive flows that transported large amounts of woody debris.

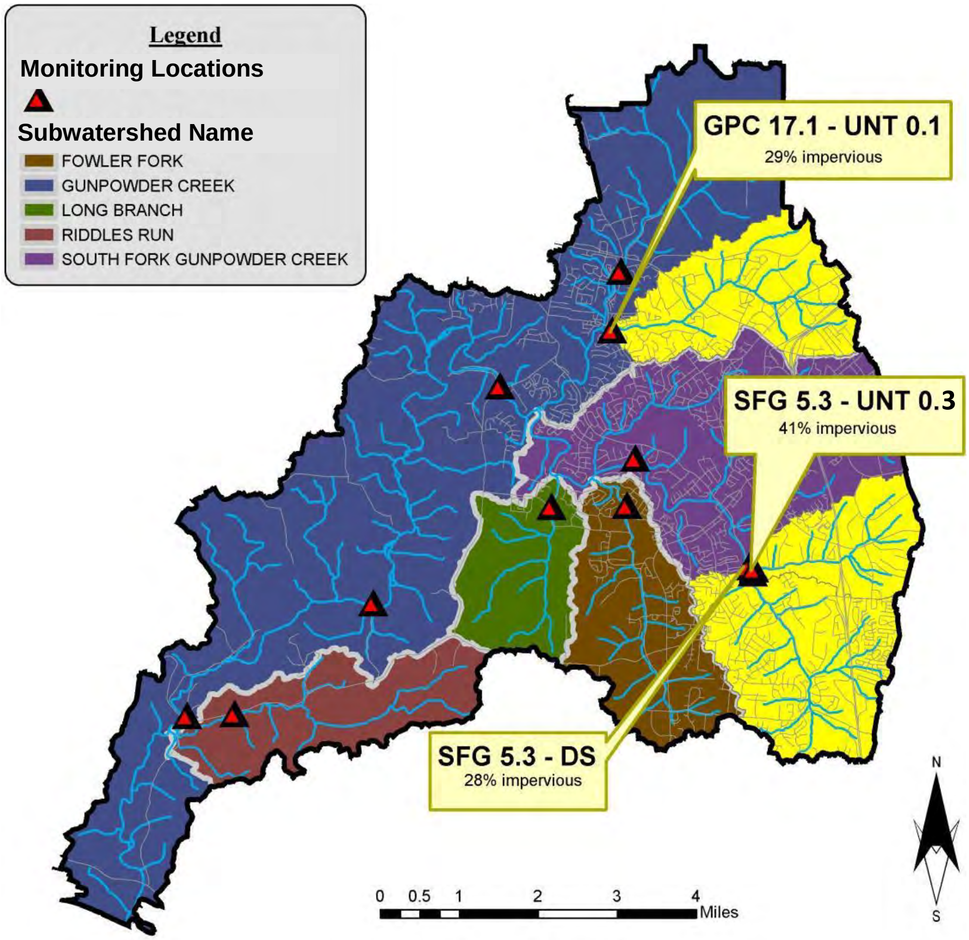


Figure 13: Physical/habitat case studies throughout the Gunpowder Creek Watershed

Case Study 1: South Fork Gunpowder Creek (SFG 5.3-DS)

Stream channel dynamics exhibit bank failure, tree loss, and bedrock incision.

The South Fork Gunpowder Creek is located in the southeastern portion of the watershed and includes three monitoring sites within close proximity to each other, all approximately 5.3 miles upstream of the confluence with the Gunpowder Creek main stem. While the monitoring data at all three of these survey sites has illustrated that the sites are all extremely dynamic, the downstream site (SFG 5.3-DS) was the most dynamic, with lost trees, bedrock incision, and compromised storm sewer infrastructure. This site has an upstream drainage area of 6.91 square miles, and the watershed is fairly developed with approximately 29% impervious area.

Over the four rounds of surveys conducted by SD1 as part of its hydromodification monitoring program, collected between 2008 and 2012, both physical observations and quantitative data supports that the channel is enlarging, the longitudinal slope is responding to headcut migration (i.e., becoming flatter), bedrock is being fractured and mobilized, and the bed material gradation is coarsening. Storm sewer infrastructure at the site has been compromised by the eroding bank, causing a pipe outfall to become dislodged from its concrete headwall (**Figure 14**).

The following list presents a summary of key metrics and the corresponding percent change over this time period (2008 to 2012).

- Bankfull area increased by 5%; benchfull area increased by 18%
- Profile slope decreased by 60%.
- Bed material gradation became substantially coarser (d16 increasing by 467%; d50 increasing by 1760%, and d84 increasing by 278%).

Figure 14: Storm sewer infrastructure at Site SFG 5.3-DS compromised by erosive, urban flow regime

Additional details regarding the changes in cross-sectional, profile, and bed material gradation can be found in Appendix 4-A of the watershed plan.

The erosive flow regime has caused the banks to erode, particularly the left bank, which has expanded more than three feet between 2008 and 2012, resulting in the loss of two trees (**Figure 15**-red). If this erosive flow regime is left unmitigated, the banks along this reach may continue to fail, impacting costly infrastructure and continuing to degrade stream habitat and water quality. Similar to most unstable Northern Kentucky streams, the South Fork Gunpowder Creek is responding to the erosive urban flow regime through headcut migrations along the longitudinal profile. The 60% decrease in slope over the four rounds of surveys can be attributed to the presence of this headcut migration (**Figure 15**-yellow). This type of channel response is seen as a primary cause of longitudinal slope adjustment and tends to change the nature of the stream with a decrease in riffle lengths and increase in pool lengths, which has been documented at this site and numerous other study sites across Northern Kentucky (Hawley *et al.*, 2013a).

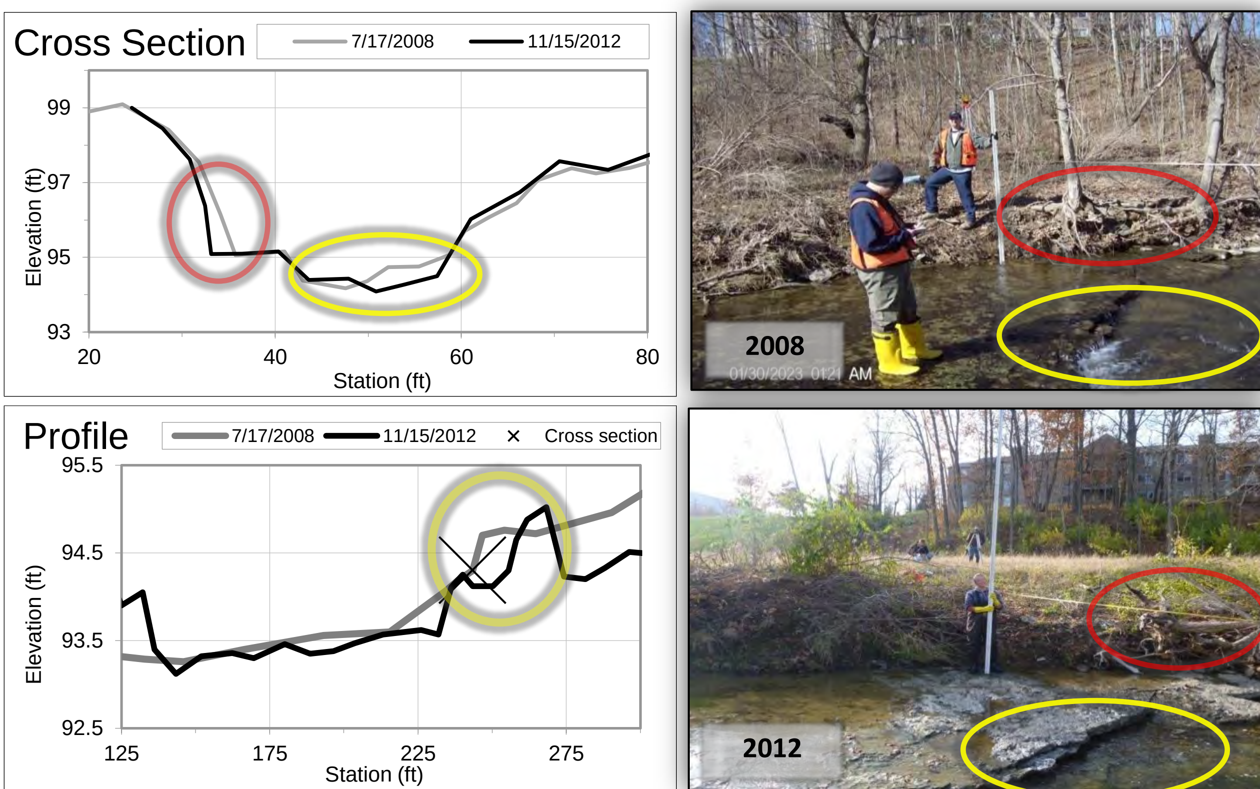


Figure 15: Erosive flows incise bedrock (yellow) and cause tree loss from bank failure (red)

This site is also experiencing bedrock incision as well as coarsening of the stream bed material. Conventional wisdom suggests that shallow bedrock tends to minimize or prolong channel incision by serving as a form of grade control, which makes the dominant source of channel instability bank failure and channel widening through both fluvial erosion and mass wasting mechanisms (Hawley *et al.*, 2013a). The survey data at SFG 5.3-DS confirms this response but also indicates that at times even sites with exposed bedrock can be extremely unstable and the stream bed can still degrade and incise as the exposed bedrock weathers and begins to fracture (**Figure 15**-yellow).

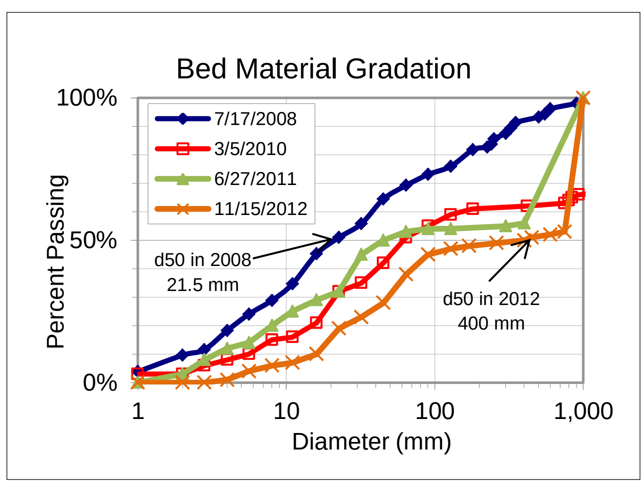


Figure 16: SFG 5.3-DS coarsening bed material

The active break-up of the channel bedrock and additional bed incision is concerning because bedrock in Northern Kentucky tends to be thin (approximately 6 inches to 1 foot) seams of limestone, which is a relatively strong rock, between thick (approximately 3 to 5 feet) layers of very weak shale. As the limestone layer gradually fractures and is mobilized, the underpinning shale layer quickly becomes eroded. This threshold condition of limestone surface weathering can result in very large increases in bank height (approximately 5 feet) on relatively shortened timescales. The energy of the urban flow regime has also resulted in sediment transport and substantial coarsening of the bed material at this site (**Figure 16**). Note that the corresponding photos of this site and the following case study (SFG 5.3-UNT 0.3) are nearly completely void of any habitat-forming particles and are comprised of featureless bedrock bottoms.

Case Study 2: Unnamed Tributary of South Fork Gunpowder Creek (SFG 5.3-UNT 0.3)

Another site located in the South Fork Gunpowder Creek Subwatershed (SFG 5.3-UNT 0.3) also experienced bank failure over several rounds of hydrogeomorphic monitoring. This site has an upstream drainage area of 2.2 square miles, and the watershed is very developed with approximately 41% impervious area coverage. A photo taken during 2012 monitoring captures a continuous tension crack (bank failure) along the entire length of the bank (**Figure 17**). This is a good example of geotechnical mass wasting and bank widening even on a bank with a relatively short height and at a site with shallow bedrock and a relatively well-connected floodplain. Such failure emphasizes the importance of a riparian buffer strip with thick vegetation to aid in stabilizing the bank.

Figure 17: SFG 5.3-UNT 0.3 tension crack bank failure

Case Study 3: Unnamed Tributary of Gunpowder Creek (GPC 17.1-UNT 0.1)

This site, GPC 17.1-UNT 0.1 (29% impervious), located in the headwaters of Gunpowder Creek, experienced powerful erosive flows over the rounds of hydrogeomorphic monitoring. A series of photos taken in 2010, 2011, and again in 2012 (**Figure 18**) illustrates a tree becoming more damaged as time progresses. Additionally, the location of large woody debris is altered from year to year, indicating flows strong enough to transport heavy logs. The location of the tree (well over 10 feet into the channel) is indicative of historic widening as it is unlikely for a tree sprout to be able to take root in the middle of an active channel.

2010 *2011* *2012*

Figure 18: Erosive flows at GPC 17.1-UNT 0.1 transport large woody debris and damage tree

These three case studies, as mentioned above, provide a glimpse into the types of hydromodification impacts observed in the stream. They also pair nicely with the data analysis, which supports these findings.

Habitat Assessment Results

Wetlands, vegetated riparian areas, native plant communities, and healthy stream channel conditions are important elements to support habitat structure and biological integrity. As previously mentioned in the section titled *Physical-Hydrogeomorphic Data*, the physical condition of a stream system strongly influences the habitat conditions, as the SD1 Habitat Score was negatively correlated to both the change in bankfull area per year and the change in bankfull top width per year, with significant *p* values of 0.05 and 0.02, respectively (**Figure 12**). Hydrogeomorphic data supports that the erosive urban flow regime has destroyed the nature of the Gunpowder Creek streams, leaving homogenous, featureless stream beds composed of exposed bedrock, long pools, and short riffles (**Figure 19**). **Table 4** presents the average habitat scores from the 2011 and 2012 Habitat Assessments.

Such degraded habitat characteristics provide poor conditions for macroinvertebrate communities, and therefore also degrade the biological conditions at the sites. Even some of the less developed watersheds such as Long Branch had relatively poor habitat, which could have been attributable to historic channelization, or other factors. Notice that the most unstable monitoring site, SFG 5.3-UNT 0.3, also scored the lowest on the Habitat Assessments.

(a) Pristine stream example in Northern Kentucky

(b) Homogeneous, featureless bedrock streambed

Figure 19: Physical characteristics of the streambed strongly influence habitat conditions

Table 4: Average habitat scores from the 2011 and 2012 habitat assessments illustrate the lowest habitat score at the most unstable site – SFG 5.3 – UNT 0.3

Monitoring Site	Habitat Score
SFG 5.3-UNT 0.3	67
LOB 0.5	83
FWF 0.8	97
RDR 1.1	106
GPC 17.1-UNT 0.1	129.5
GPC 7.5	142.5

Water Quality Monitoring Results

Land use management, erosive flows, and bank erosion are all driving factors that impact water quality

Analysis of water chemistry data in the Gunpowder Creek Watershed provides insight about potential pollutants of concern and possible sources of the pollutants, such as land use, land use management, erosive flows, and bank erosion. All water chemistry data were processed to evaluate variations in pollutant concentrations and understand what might be causing such variations, such as changes in wet and dry weather conditions and the associated fluxes in stream discharge data. The following section presents the results of the water chemistry analysis.

Comparisons of Parameter Concentrations

Sample concentrations, summarized by water quality parameter, sampling site, and type of sample (wet versus dry and dry7) were initially analyzed using water quality box and whisker plots (Appendix 4-B of the watershed plan) that provided a visual observation of the range of sample concentrations for all samples as well as samples in the wet, dry, and dry7 categories. Each box and whisker plot depicted the range of sample concentrations with excluded statistical outliers, the mean concentration for each category, and the overall relation to the water quality benchmark or standard for that parameter. In addition to the box and whisker plots analyzed for each individual water quality parameter, this analysis involved evaluation of the ratios of sample concentrations to the water quality benchmark or standard at each monitoring location.

a) Water Quality Standards and Benchmarks

Water quality standards utilized throughout the analysis were obtained from Kentucky Administrative Regulations defined in *401 KAR 10:031 - Surface water standards*. The standards provide water quality criteria applicable to all surface waters to protect their indicated use, promote aquatic habitat, and safeguard human health. The water quality standards incorporated in this analysis include set criteria for bacteria, as measured by *E.coli,* as well as set criteria for dissolved oxygen and unionized ammonia.

All other parameters included in this analysis are compared to water quality benchmarks provided by KDOW in the *Gunpowder Creek Watershed Plan Benchmark Recommendations for Nutrient Parameters* (February 2012) and the *Gunpowder Creek Watershed Plan Benchmark Recommendations for Non-Nutrient Parameters* (February 2012) documents. These guidance documents set initial benchmarks based on typical values in comparable healthy, reference streams and are included in Appendix 4-E of the watershed plan. In making the nutrient benchmark recommendations, KDOW considered regional and watershed-specific nutrient expectations, regional-scale patterns in biological effects, and the specific indicators of nutrient enrichment observed in the watershed. The final benchmark recommendations provided by KDOW are primarily based on review of water quality samples at 12 ecoregional reference reaches within the Outer Bluegrass bioregion (ecoregion 71d) as well as typical literature values often cited for healthy streams.

Benchmark values provided by KDOW give a broad frame of reference to understand the general level of concern and approximate orders of load reduction that may be necessary to come within reasonable targets for water quality. While the benchmark values provide reasonable targets for water quality, desired attainment goals may be achieved without meeting benchmark concentrations. Designations such as Primary Contact Recreation (PCR) and Warm Water Aquatic Habitat (WAH) may be achieved even if the benchmarks are not met. Again, the benchmark values provided information to understand the scale of the problems and the GCWI would like to emphasize that the precise load is not the focus since the benchmark values are simply interim target values. As discussed in chapters 5 and 6, the GCWI's approach for this watershed plan is to implement a reasonable level of BMPs and continue to monitor. GCWI plans to make smart investments as opportunities arise, monitor the progress, then reassess through continued monitoring.

b) Summary of All Sample Concentration Exceedances

Water chemistry parameters were evaluated to determine which pollutants were most concerning during wet versus dry weather sampling. **Table 5** presents the percent of water quality samples that exceeded the benchmark or standard set for each individual parameter. This represents the number of times the samples exceeded the benchmark level. Therefore, if the GCWI collected 11 samples and 9 were above the benchmark level, a percentage of 82 was included in the table. All sample exceedances greater than 80% are identified in red (most concerning) and all sample categories with less than 20% exceedance are identified in blue (least concerning). These results indicate that Total Phosphorus (TP) and Total Kjeldahl Nitrogen (TKN) are typically always above the water quality benchmark, while pollutants such as Dissolved Oxygen (DO), Nitrate-Nitrite as N (NN), and Unionized Ammonia (Union Amm) are the least concerning. Additional analysis of the nutrient concentrations and their pollutant loading indicates these pollutants are not as large of an issue as bacteria and sediment because the degree of exceedance is much lower. For example, 100% of all wet-weather samples from all sites exceeded the water quality standard for *E.coli*, and concentrations tended to be 1 to 2 orders of magnitude higher than the standard. The sampling results for *E.coli*, along with Total Suspended Solids (TSS)/Turbidity (Turbid) and Specific Conductance (SpCon) present interesting statistical relationships related to exceedances during wet versus dry weather sampling and are presented in additional detail in the following sections.

Table 5: Percent exceedances above water quality benchmark/standard concentration

(This represents the number of times the samples exceeded the benchmark level)

Water Quality Sampling Sites		Parameter:	TSS	Turbid	TP	TKN	NN	Union	DO	SpCon	*E.coli*
		No. Samples:	11	11	11	11	11	11	11	11	16
		No. Wet Samples:	3	3	3	3	3	3	3	3	3
		No. Dry Samples:	5	5	5	5	5	5	5	5	8
		No. Dry7 Samples:	3	3	3	3	3	3	3	3	5
		Benchmark[1] Standard[1]:	7.25	8.3	0.08	0.3	0.3	0.05	**4**	522.5	**240**
			mg/L	NTU	mg/L	mg/L	mg/L	mg/L	mg/L	µS/cm	colonies/100mL
	GPC 7.5	**All**	91%	64%	100%	100%	45%	0%	0%	36%	38%
		Wet	100%	100%	100%	100%	100%	0%	0%	0%	100%
		Dry	80%	40%	100%	100%	40%	0%	0%	60%	25%
		Dry7[3]	100%	67%	100%	100%	0%	0%	0%	33%	20%
	GPC 17.1-UNT 0.1	**All**	45%	55%	91%	100%	18%	0%	0%	82%	40%
		Wet	67%	67%	100%	100%	33%	0%	0%	67%	100%
		Dry	60%	80%	80%	100%	20%	0%	0%	80%	38%
		Dry7[3]	0%	0%	100%	100%	0%	0%	0%	100%	0%
	SFG 5.3-UNT 0.3	**All**	55%	27%	64%	100%	9%	0%	9%	91%	50%
		Wet	100%	67%	100%	100%	33%	0%	33%	67%	100%
		Dry	20%	20%	40%	100%	0%	0%	0%	100%	50%
		Dry7[3]	67%	0%	67%	100%	0%	0%	0%	100%	20%
	FWF 0.8	**All**	55%	36%	91%	100%	18%	0%	10%	73%	75%
		Wet	100%	67%	100%	100%	67%	0%	33%	33%	100%
		Dry	20%	20%	80%	100%	0%	0%	0%	80%	88%
		Dry7[3]	67%	33%	100%	100%	0%	0%	33%	100%	40%
	RDR 1.1[2]	**All**	40%	20%	90%	80%	10%	0%	50%	80%	67%
		Wet	67%	67%	100%	100%	33%	0%	33%	33%	100%
		Dry	20%	0%	80%	60%	0%	0%	40%	100%	63%
		Dry7[3]	50%	0%	100%	100%	0%	0%	100%	100%	50%
	LOB 0.5	**All**	91%	64%	100%	100%	18%	0%	9%	27%	88%
		Wet	100%	67%	100%	100%	67%	0%	33%	33%	100%
		Dry	80%	40%	100%	100%	0%	0%	0%	40%	75%
		Dry7[3]	100%	100%	100%	100%	0%	0%	0%	0%	100%

[1]Water quality standards are presented in bold and represent parameters regulated by KDOW. All other parameters are compared to a water quality benchmark, which are pollutant levels that tend to be found in the region's healthier streams according to data and analysis by KDOW. The water quality standards included in this analysis include only dissolved oxygen and E.coli

[2]Due to dry conditions sampling did not occur at RDR 1.1 on 8/7/12; therefore, this site has only two Dry7 samples and a total of 15 samples for E.coli and 10 for the remaining parameters.

[3]Dry7 defined as event with less than 0.01 inches of rain occurring within the 7-day period before the sampling event. Reference Chapter 3 for additional information regarding the classification of sampling events as wet, dry, and dry7.

c) *E.coli* Concentrations

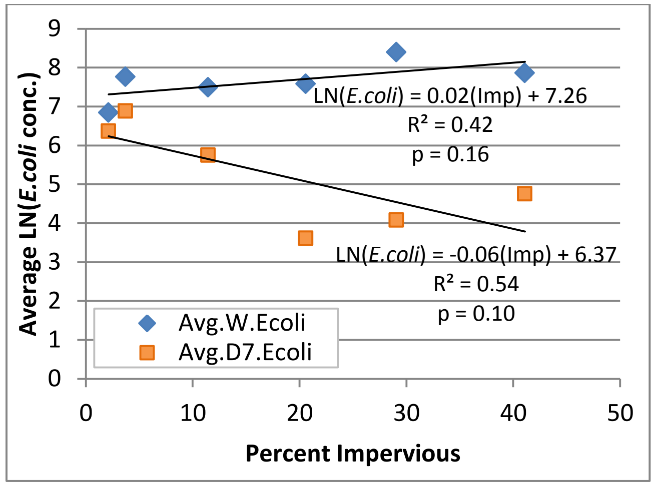


Figure 20: *E.coli* as a function of percent impervious

E.coli is used as an indicator of bacteria within the stream system, where an increase in concentration increases the possibility of the presence of potentially harmful pathogens. As illustrated in **Table 5** and the *E.coli* Sample Box Plot below (**Figure 20**), 100% of wet weather *E.coli* samples at all sites exceeded the water quality standard (i.e., green line in **Figure 21**). Additionally, there is a positive association between the geometric mean of sample concentrations at each site and watershed imperviousness, illustrating that the most developed watersheds appear to have a larger concern with bacteria during wet weather (**Figure 20**). The opposite relationship is evident during dry weather sampling, as the geometric mean of the *E.coli* sample concentrations decreased with an increase in watershed imperviousness, indicating that bacteria levels during dry weather is a larger problem for rural watersheds (**Figure 20**). Both of these associations provide important insights relative to suspected sources of pollution; however, neither was statistically significant to the $p < 0.05$ level. Stormwater runoff and animal waste are suspected sources of bacteria in the developed subwatersheds, while septic systems and animals grazing in the streams are suspected sources of bacteria in the rural subwatersheds. Potential sources of bacteria in the watershed are further discussed later in this chapter. It is also important to note that the wet weather samples are based on three sampling events that occurred during 2011 prior to SD1's completion of system improvements aimed at mitigating several sanitary overflows in the Gunpowder Creek Watershed (historic overflow locations have been documented along the South Fork and tributary, Fowler Fork, and the main branch). Although there are many potential sources of bacteria throughout the Gunpowder Creek Watershed, it is possible that the high bacteria concentrations during wet weather in 2011 may have been partially attributable to sewer overflows.

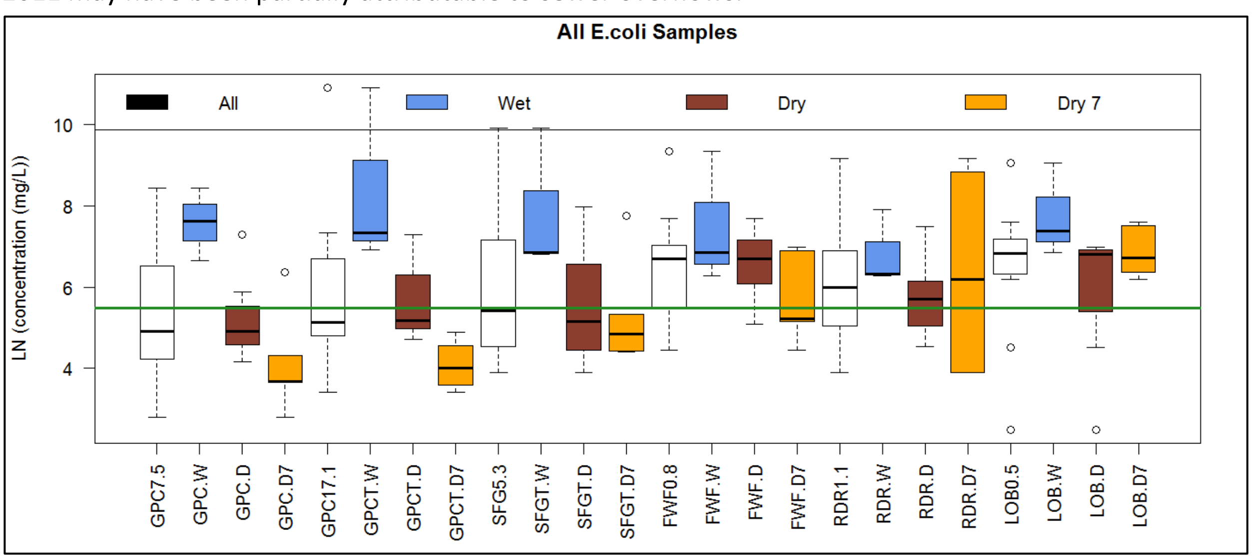


Figure 21: *E.coli* sample concentrations during wet and dry weather conditions (green line represents water quality standard: LN(240 colonies/100mL)) [(a)]

[(a)] In this figure, GPC 17.1-UNT 0.1 was shortened to GPC17.1. SFG 5.3-UNT 0.3 was shortened to SFG5.3.

d) TSS Concentrations

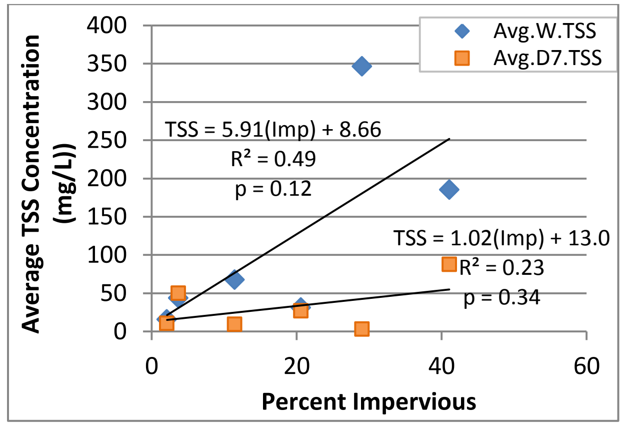


Figure 22: TSS as a function of percent impervious

Sediment, as measured by TSS sample concentrations, is a pollutant of concern during both wet and dry weather conditions (**Figures 22 and 23**). It appears to be a larger issue during wet weather when bank erosion is caused by the urban-induced erosive flow regime as well as when sediment is washed off unvegetated, barren surfaces and transported to the stream. As presented in the section of this chapter titled *Physical-Hydrogeomorphic Data*, TSS was strongly associated with channel enlargement, which was also associated with percent impervious, indicating that bank erosion and channel enlargement are likely sources of the fine sediment found in the streams, as has been well-documented in other systems (Trimble, 1997; Simon and Klimetz, 2008; Wilson *et al.*, 2007). Such high rates of bank erosion and channel enlargement have likely been caused by the erosive urban flow regime, which is also degrading the habitat conditions and is a probable cause of biological impairments. While TSS in an indicator of erosive flows degrading habitat conditions, it also contributes to biological impairment through direct pathways (e.g., clogging gills) and indirect pathways (e.g., causing embeddedness of the bed material habitat). Bank erosion and channel enlargement are also potential sources of TSS during dry weather for several reasons. First, bank failure by mass wasting can occur during both periods of wet and dry weather. Second, once the fine sediment loads from bank failure are slumped into the stream, it can take long periods of time to flush the sediment load. Silt, and in particular clay, can remain suspended in the water column for hours and days, respectively, such that these loads can be sources even during prolonged periods of dry weather. Finally, even low flows at site GPC 7.5 would have sufficient capacity to transport silt and clay given the relatively large drainage area and reasonably high base flow, even during periods of dry weather.

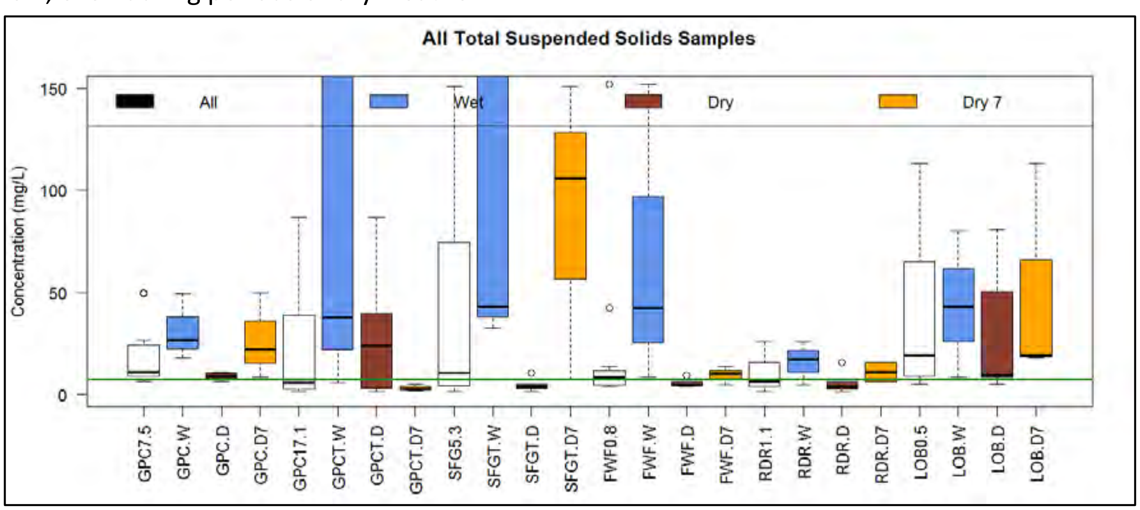


Figure 23: TSS sample concentrations during wet and dry weather conditions (green line represents water quality benchmark: 7.25 mg/L) [(a)]

[(a)] In this figure, GPC 17.1-UNT 0.1 was shortened to GPC17.1. SFG 5.3-UNT 0.3 was shortened to SFG5.3.

e) Specific Conductivity Measurements

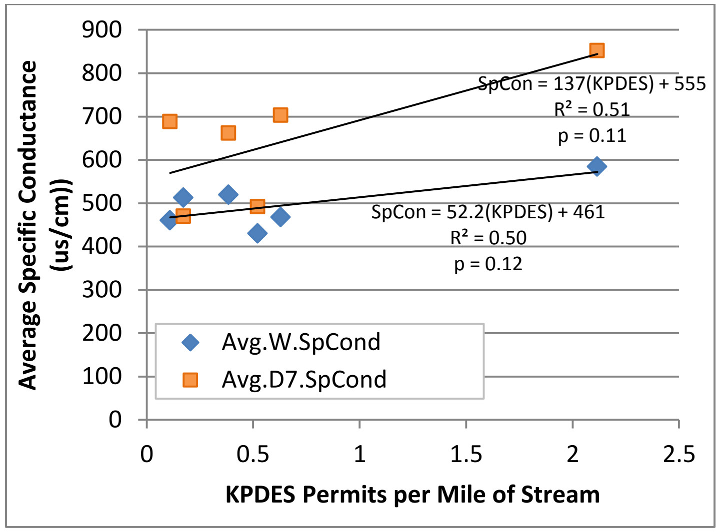


Figure 24: Average specific conductance concentrations are correlated to the number of KPDES permits per mile in each subwatershed

Specific conductance, which measures the water's ability to conduct electricity, can be used as a surrogate to determine if total dissolved solids are a potential pollutant of concern; however, it should be noted that specific conductivity can be naturally high in Northern Kentucky streams because of natural sources such as groundwater seeps which tend to increase conductivity from the amount of dissolved solids in the water. Sampling results indicate conductivity is worse during dry weather conditions, particularly at SFG 5.3-UNT 0.3, the subwatershed which contains the most number of KPDES permit sites per mile of stream. This observation, as well as the positive relationships presented in **Figure 24**, could indicate that total dissolved solids are possibly polluting the stream via KPDES discharges during dry weather conditions. In addition, specific conductivity was negatively correlated to sample flow at each site with significant *p* values less than 0.05 at four sites (GPC 17.1-UNT 0.1, SFG 5.3-UNT 0.3, FWF 0.8, and RDR 1.1). This also supports that specific conductance is more problematic during low flow conditions and that concentrations tend to become diluted during wet weather (note that the brown and orange boxes in **Figure 25** tend to be higher than the blue boxes at most sites).

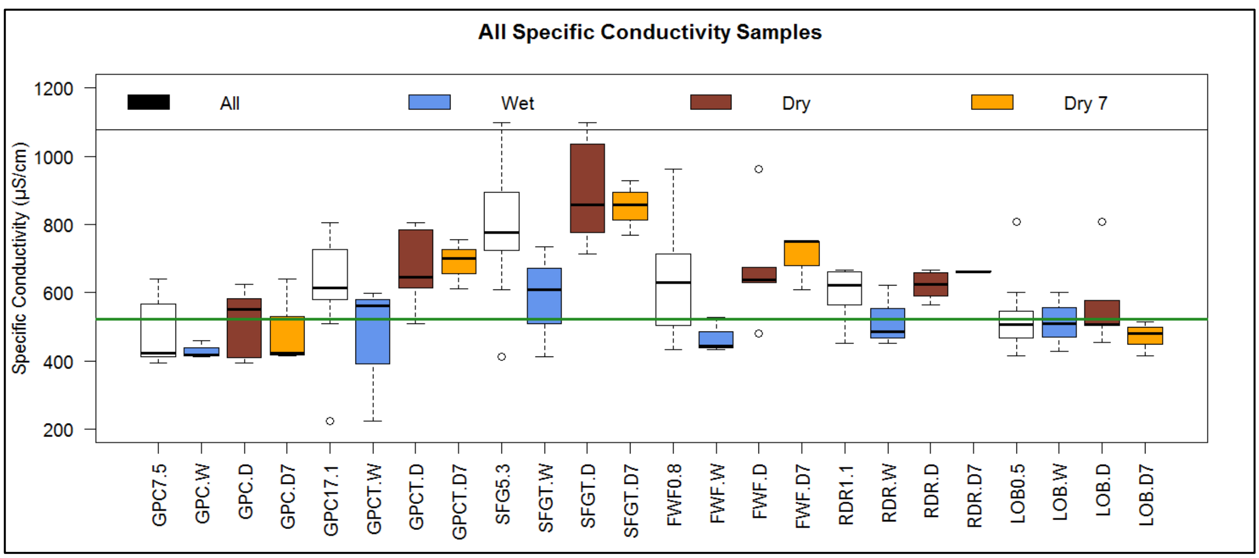


Figure 25: Specific conductance sample measurements during wet and dry weather conditions (green line represents water quality benchmark: 522.5 µS/cm) [(a)]

[(a)] In this figure, GPC 17.1-UNT 0.1 was shortened to GPC17.1. SFG 5.3-UNT 0.3 was shortened to SFG5.3.

Comparisons of Pollutant Loads

Pollutant load duration curves add another level of insight to the water quality analysis and allow for pollutant concentrations to be characterized at varying flow regimes, providing a visual figure of the relationship between stream flows, pollutant loading capacity, and the frequency and magnitude of exceedances in water quality benchmarks based on flow conditions. Pollutant loads, which are defined by both the concentration of the pollutant and the stream flow, determine the amount of a specific pollutant being transported by the stream in terms of weight per period of time (e.g., lbs/day). Loadings are important to evaluate because they provide a more balanced comparison between subwatersheds, as a subwatershed with a low concentration and large flows could have a higher total load than a watershed that has a high pollutant concentration but only a little flow (KDOW, 2010a). The Gunpowder Creek water quality analysis included development of pollutant load duration curves to analyze bacteria (*E.coli*), total suspended sediment (TSS), and nutrients (TP, TKN, NN) at all six water quality monitoring sites. **Figure 26** presents the *E.coli* Load Durations at GPC 17.1-UNT 0.1 and is an example of the pollutant load duration curves developed at all sites (Appendix 4-C of the watershed plan). This load duration approach, with the limited amount of water quality data provided for this analysis, is meant to provide estimates of the scale of the problem in each subwatershed and not indicate exact loads necessary to achieve interim water quality targets.

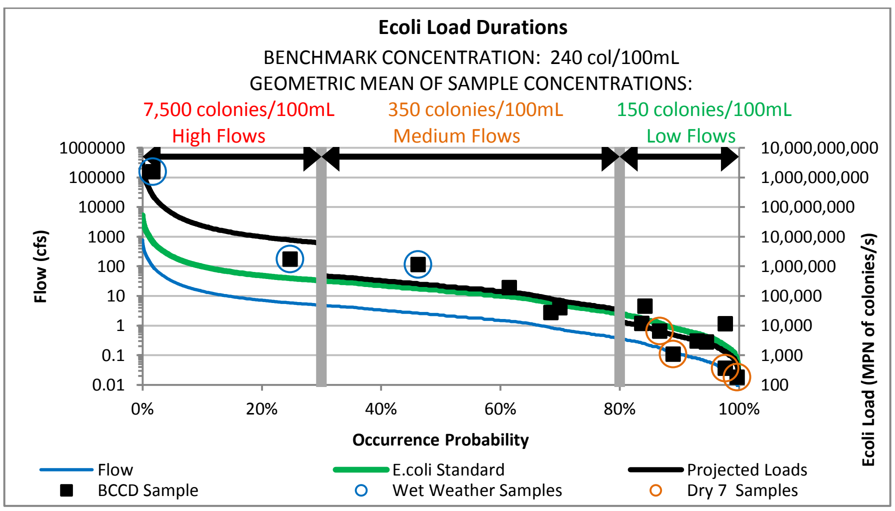


Figure 26: *E.coli* load durations at developed site, GPC 17.1-UNT 0.1 (29% impervious)

Note: This load duration approach with the limited amount of water quality data provided for this analysis is meant to provide estimates of the scale of the problem in each watershed 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

In addition to providing a visual representation of the relationship between stream flows, pollutant loading capacity, and the frequency and magnitude of exceedances in water quality benchmarks, the pollutant load duration curves provide means of estimating the total annual pollutant loads occurring at a particular site over the course of an entire year. Projected annual pollutant loads, benchmark annual pollutant loads, and the percent difference for each parameter is presented in a summary table for each water quality monitoring site (Appendix 4-C of the watershed plan).

With further evaluation of the annual pollutant loads, the ratio of the projected load to the benchmark load (defined by the projected load divided by the water quality benchmark) was calculated to analyze the degree of exceedance for each pollutant on the same scale, with any ratio above one being an exceedance of the water quality benchmark. **Figure 27** presents this ratio for total loads of each parameter analyzed at the water quality monitoring locations. This figure illustrates that both sediment (TSS) and bacteria (*E.coli*) are of greater concern than nutrient loads (TP, TKN, and NN) throughout the Gunpowder Creek Watershed. Additionally, this figure illustrates that generally two subwatersheds appear to be contributing the most pollution by weight within the watershed - the headwaters of Gunpowder Creek (GPC 17.1-UNT 0.1) and South Fork Gunpowder (SFG 5.3-UNT 0.1).

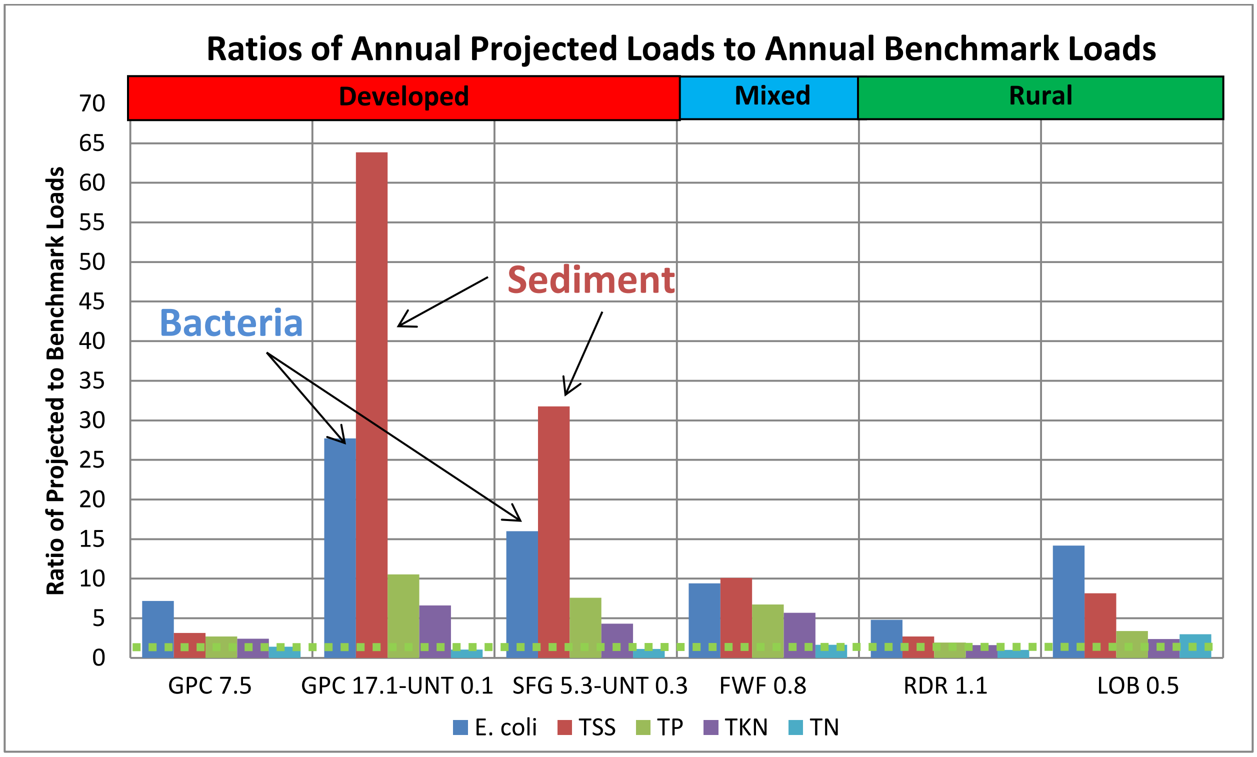


Figure 27: Ratios of projected loads to benchmark pollutant loads illustrate that bacteria and sediment are the greatest pollutants of concern in the Gunpowder Creek Watershed

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

Ratios of projected loads to benchmark loads were also evaluated during the various flow conditions (high, medium, and low). This analysis confirmed the results presented in previous sections – bacteria and sediment are of greater concern during wet weather conditions when the stream flows are high. **Figure 28** presents an example of this analysis. The evaluations of projected to benchmark load ratios at all monitoring sites are included in Appendix 4-C of the watershed plan. **Table 6** presents the projected percent load reductions necessary for each parameter at the water quality monitoring sites. The red text illustrates the highest pollutant load reductions needed throughout the watershed (greater than 80%). It further underscores the findings that 1) sediment (TSS) and bacteria (*E.coli*) are the pollutants in need of the greatest reductions and 2) the most developed sites of SFG 5.3-UNT 0.3 and GPC 17.1-UNT 0.1 tend to have higher reductions than the less developed sites. Additionally, the percent load reductions for each flow category are included in Appendix 4-C of the watershed plan.

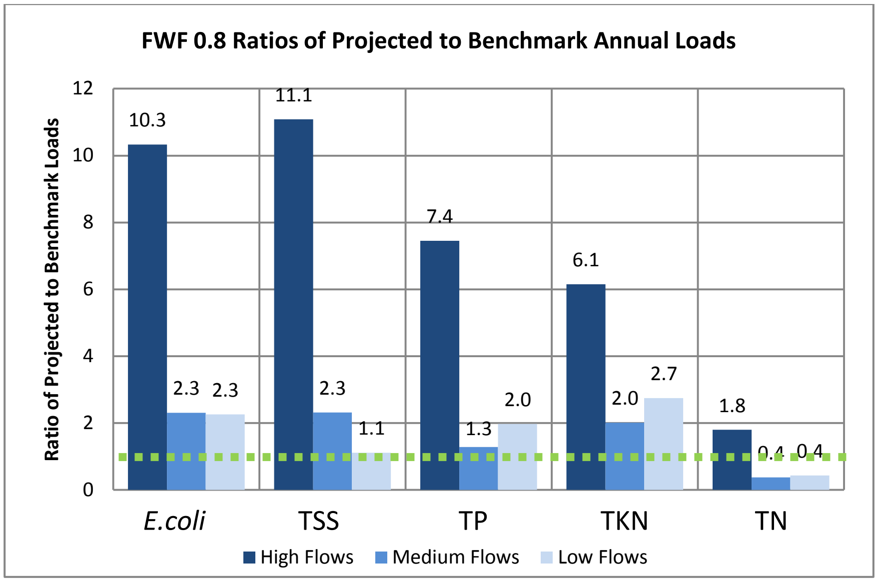


Figure 28: Evaluation of projected to benchmark load ratios at individual monitoring sites illustrates greater exceedances during high flows (wet weather conditions)

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

Table 6: Estimates of percent load reductions necessary to meet water quality benchmarks at each monitoring location

Site	*E. coli*	TSS	TP	TKN	TN
GPC 7.5	86%	68%	63%	59%	28%
GPC 17.1-UNT 0.1	96%	98%	91%	85%	4%
SFG 5.3-UNT 0.3	94%	97%	87%	77%	10%
FWF 0.8	89%	90%	85%	82%	39%
RDR 1.1	79%	63%	48%	38%	83%
LOB 0.5	93%	88%	71%	58%	67%

Comparison of Pollutant Yields

The annual loads estimated from the load duration curves were standardized by determining the pollutant yield for each subwatershed. This accounts for the geographic size differences between the subwatersheds. The pollutant yield was determined by dividing each load by the total area of the sub-watershed. **Table 7** presents the standardized pollutant yields, which also supports the findings above that bacteria and sediment tend to be the pollutants of greatest concern and that they become worse in the developed headwaters of the watershed (SFG 5.3-UNT 0.3 and GPC 17.1-UNT 0.1).

Table 7: Pollutant yields at each monitoring location

SITE	FLOW	POLLUTANT YIELD				
		E. coli (col/yr/ac)	TSS (lb/yr/ac)	TP (lb/yr/ac)	TKN (lb/yr/ac)	TN (lb/yr/ac)
SFG 5.3-UNT 0.3	High Flows	8.20E+10	1,084.3	2.8	5.8	1.5
	Medium Flows	1.15E+09	14.3	0.1	0.4	0.1
	Low Flows	1.32E+07	0.6	0.0	0.0	0.0
	Total	8.31E+10	1,099.1	2.9	6.2	1.6
RDR 1.1	High Flows	2.86E+10	112.3	0.8	2.6	1.7
	Medium Flows	2.02E+09	2.6	0.1	0.2	0.1
	Low Flows	2.64E+07	0.1	0.0	0.0	0.0
	Total	3.07E+10	115.1	0.9	2.8	1.8
LOB 0.5	High Flows	7.61E+10	277.8	1.3	3.2	4.4
	Medium Flows	2.55E+09	22.5	0.1	0.4	0.1
	Low Flows	3.62E+07	0.5	0.0	0.0	0.0
	Total	7.87E+10	300.8	1.4	3.6	4.6
GPC 17.1-UNT 0.1	High Flows	2.23E+11	3,404.9	6.1	14.4	2.0
	Medium Flows	1.31E+09	38.4	0.2	0.4	0.3
	Low Flows	1.52E+07	0.2	0.0	0.0	0.0
	Total	2.24E+11	3,443.5	6.3	14.8	2.3
FWF 0.8	High Flows	6.11E+10	436.7	3.2	10.0	2.9
	Medium Flows	1.72E+09	11.5	0.1	0.4	0.1
	Low Flows	4.53E+07	0.1	0.0	0.0	0.0
	Total	6.29E+10	448.4	3.3	10.5	3.0
GPC 7.5	High Flows	5.54E+10	143.3	1.4	4.8	2.8
	Medium Flows	1.33E+09	22.5	0.2	0.5	0.2
	Low Flows	1.02E+07	0.4	0.0	0.0	0.0
	Total	5.67E+10	166.2	1.6	5.3	3.0

Biological Assessment Results

Biological health in rural watersheds tended to be more impacted by habitat and dry weather pollution.

The biological health of a stream system is dependent on all other supporting factors, and it is presented at the top of the stream function pyramid (**Figure 1**). The core of this pyramid is built on land use and management, stream flow, physical/habitat conditions, and overall water quality. Macroinvertebrate communities particularly rely on their natural flow and disturbance regimes, healthy habitat conditions, and excellent water quality, all of which show negative correlations with development and were discussed earlier in this report. Statistical analysis of the Gunpowder Creek Biological Assessments in relation to percent impervious also supports that biological health suffers in the most developed watersheds, as the MBI Score and the Percent Clinger Score were both negatively associated with watershed imperviousness (**Figure 29 and Figure 30**). **Figure 31** presents the aquatic macroinvertebrate scores (MBI) for each monitoring location and the influencing factors that largely impacted the aquatic macroinvertebrate health, including flow, habitat, and water quality, which are all affected by land use and land use management.

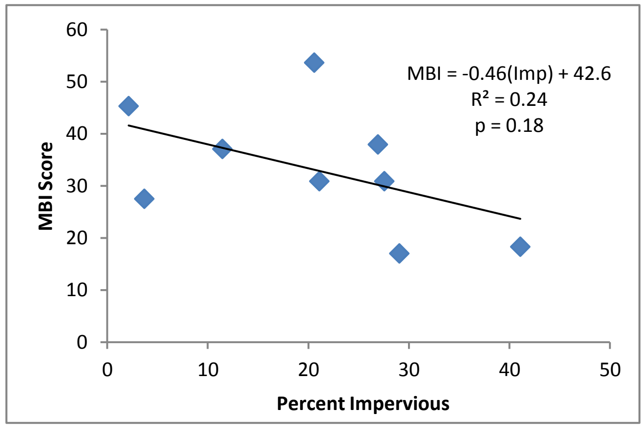


Figure 29: -Increased development, as measured by percent impervious, results in degraded MBI scores

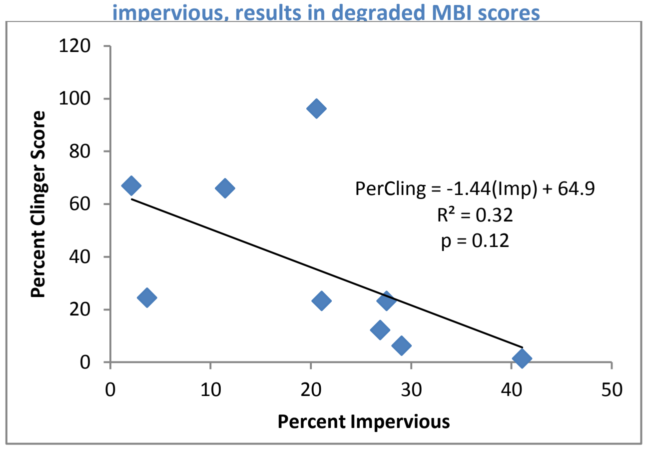


Figure 30: The percent clinger population is negatively associated with percent impervious

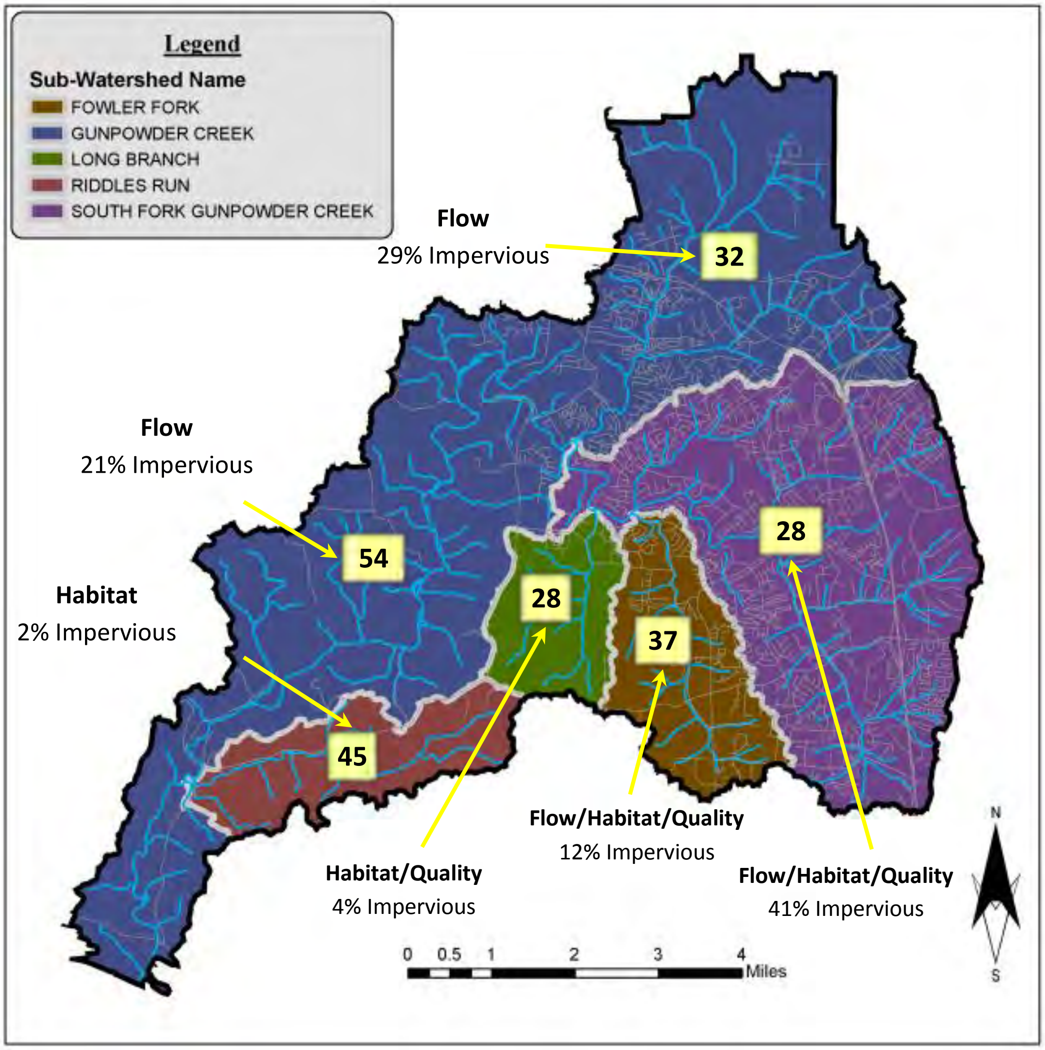


Figure 31: Biological health is dependent upon all pieces of the pyramid

Building Stewardship through Stakeholder Cooperation

The GCWI Steering Committee includes a broad range of public agencies that have taken an active role in guiding the project. A technical committee and KDOW representatives have provided technical expertise throughout the project as well. Regional partners have donated their time and talents to help make this project the success that it is. Some of the contributions are summarized in Table 8.

Table 8: Summary of primary contributions of time, personnel, supplies, equipment, access, project planning, and implementation by regional stakeholders

Stakeholder Agency	Steering Committee Meetings	Public Meetings/ Roundtables	Data Collection	Implementation/ Project Planning
Boone County Conservation District	√	√	√	√
Boone County Planning Commission	√	√		
Cincinnati/Northern Kentucky Airport	√			√
City of Florence	√	√		√
City of Union	√			

Kentucky Division of Water	√	√	√	√
Kentucky Transportation Cabinet	√	√		
Licking River Watershed Watch	√		√	
Northern Kentucky Health Department	√			√
Northern Kentucky University Center for Environmental Restoration				√
Sanitation District No. 1	√	√	√	√
Thomas More College/Dr. Chris Lorentz			√	

Beyond the list of these more active stakeholders, the Steering Committee has a goal of increasing stewardship of private companies. For example, in the adjacent watershed of Woolper Creek, Toyota has been very supportive of the pilot installation of the detention basin retrofit technology developed and monitored by the USEPA and other regional partners including BCCD, SD1, and Sustainable Streams. Finding corporations from within the Gunpowder Creek Watershed to contribute to project funding and/or implementation, including structural and non-structural practices, is a goal for GCWI as we implement BMPs in the watershed.

And most importantly, the public has been actively involved throughout the project. News of the project has been distributed through local media along with the *Landscapes* newsletter of Boone, Campbell, and Kenton Counties Conservation Districts. A total of four well-attended public meetings have been held at numerous locations throughout the watershed. GCWI has also presented at meetings of local organizations, such as the Northern Kentucky Fly Fishers, who are very active in the watershed.

The public has been eager to learn about the project, hear the results of the monitoring efforts, and offer their input regarding prioritizing problems and solutions. In January of 2011, 83 people participated in the GCWI's Open House and Presentation, an effort to introduce the public to the project and encourage community support and participation. Approximately 70 participants engaged in a series of three roundtable meetings in September of 2013. Divided into 11 total groups, they provided facilitated feedback to five questions. The questions and the dominant answers are provided in **Table 9**.

Table 9: Questions and dominant responses from 11 roundtable groups with approximately 70 participants

Question	Dominant Responses[(1)]
1. Why is a clean healthy stream important to you?	Recreation (73%), Aesthetics (66%), Quality of Life/Health (54%)
2. What land uses in the watershed are you most concerned about?	Development (100%)
3. What do you think are the most common problems?	Runoff (73%), Flooding/Safety (66%)
4. What BPMs do you consider feasible in Gunpowder Creek?	Detention/Retention (82%), Education (66%), Responsible Development/Ordinances (55%)
5. What issues in Gunpowder Creek do you consider a priority?	Stormwater Runoff (66%), Flooding (55%)

[(1)]Responses that were listed by more than half of the groups. For a summary of all responses, see supporting handout in Appendix 6-A of the watershed plan.

In summary, 100% of the groups felt that development was a land use that they were most concerned about. Stormwater runoff and flooding were problems that were typically associated with development and considered priorities among a majority of the groups. BMPs such as improved stormwater detention, education, and ordinances that promote responsible development were considered feasible by 82%, 66%, and 55% of the groups, respectively. A commonly shared sentiment was that folks did not necessarily want new ordinances; they simply wanted the existing rules and regulations to be revised to work better to actually protect stream health and keep downstream properties from flooding and eroding.

Summary documents illustrating the outcomes of the open house and roundtable discussions are included as **Appendix E** of this Final Report.

2.0 Discussion

Introduction

The results of the data analysis provided detailed information to understand pollutants of concern as well as potential sources of these pollutants. Furthermore, as explained throughout the Results section, these data, when compared to watershed characteristics, provide insight on potential causes of the pollutants of concern. This information, coupled with valuable insights from the public and stakeholder groups involved with the Steering Committee, provided a foundation for determining appropriate BMPs that can be implemented throughout the watershed. These BMPs as well as a strategy for initial implementation efforts are included in chapters 5 through 7 of the watershed plan.

Comparison of Watershed Inventory Data to In-stream Monitoring Results

A better understanding of pollutants of concern and possible drivers of the pollutants is obtained by comparing the watershed inventory data to the pollutant concentrations and loads/yields. Generally, the monitoring locations can be categorized into developed watersheds, rural watersheds, and mixed based on their percentage of impervious area. 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.

The monitoring locations were organized into three types of land use based on watershed imperviousness, including developed watersheds (20-40% impervious) on the eastern side of the Gunpowder Creek Watershed, rural watersheds (2-4% impervious) on the southern portion of the Gunpowder Creek Watershed, and mixed (developed/rural, 12% impervious). These types of land uses also come with different types of stakeholder groups which affect project implementation feasibility.

Differing land use can be related to certain pollutants of concern during both wet and dry weather and can provide inferences regarding potential sources of pollution. South Fork Gunpowder Creek and the headwaters of Gunpowder Creek are classified as developed; Riddles Run and Long Branch are classified as rural; and Fowlers Fork is considered mixed. Sampling locations, and their related development category, are illustrated in **Figure 32**. The most impervious areas of the watershed, which are located in the headwaters, have been extremely detrimental on the health of these stream systems. In many watersheds the headwaters are typically the most healthy stream reaches, but due to the increased development in the Gunpowder Creek Watershed headwaters, these stream reaches have been degraded.

Therefore, these subwatersheds have been prioritized as the areas of the watershed in most need of stormwater mitigation including both structural and nonstructural BMPs. The sections below summarize the most concerning and least concerning pollutants for the three watershed types, along with likely sources and possible causes.

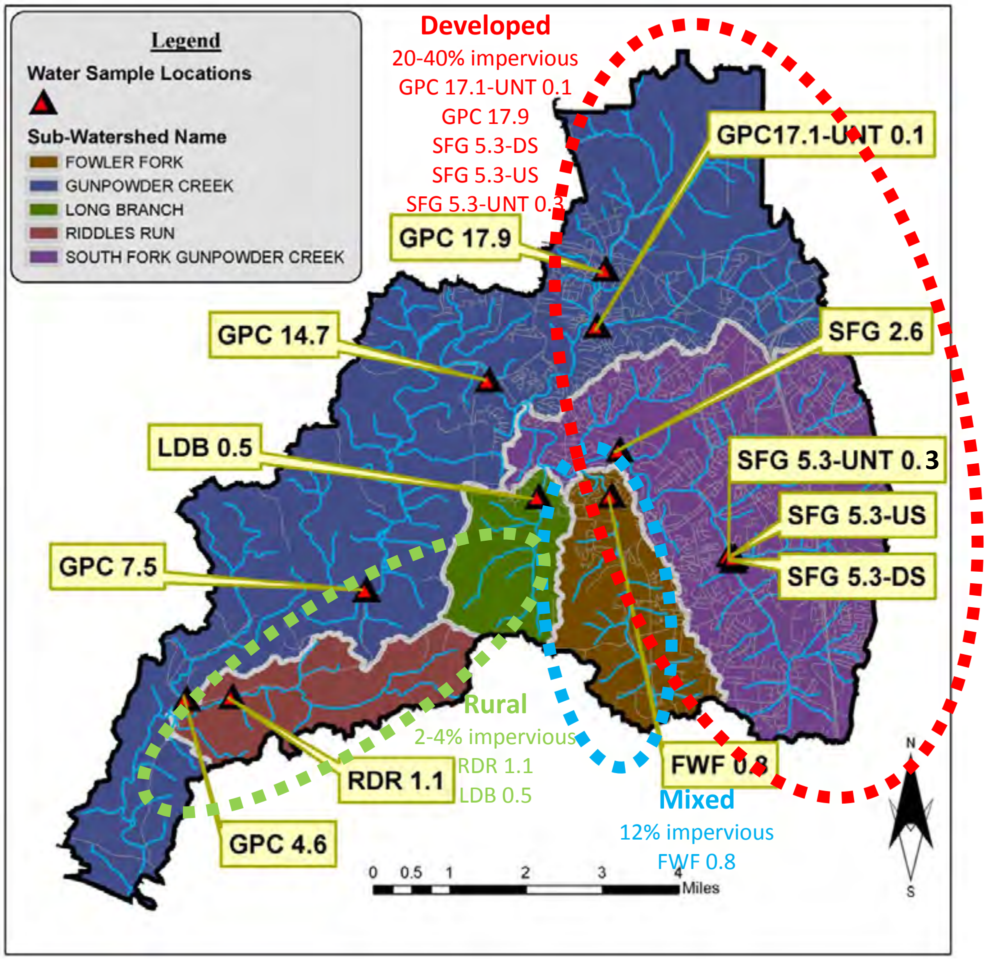


Figure 32: Sampling sites classified by primary land use (developed, mixed, and rural)

1. Developed Watersheds

First, the streams in developed subwatersheds (20-40% impervious), located within the headwaters of Gunpowder Creek and South Fork Gunpowder Creek on the eastern side of the watershed, had high loadings of bacteria and suspended sediment during wet weather (Figure 33). The predominant cause of high bacteria and TSS loadings is likely excess stormwater runoff because these same developed sites have fewer issues with dry weather bacteria. This tends to indicate that the developed sites are primarily impacted by stormwater runoff and nonpoint source pollution. Nonpoint source pollution results from everyday activities such as littering, pet waste, fertilizing the lawn, land clearing for development, and agricultural activities, all allowing pollutants generated by these activities to be washed into the stormwater collection system and eventually flowing into our waterways. As discussed in *Comparisons of Parameter Concentrations* in the Results section of this Final Report, some of the developed sites had high loadings of specific conductance during dry weather, especially the SFG 5.3- UNT 0.1 sampling location. This may be attributable to natural sources; however, this subwatershed also had a high density of KPDES dischargers and may be indicative of a direct dry weather discharge with potentially-high dissolved solids.

Most Concerning	Likely Sources	Possible Causes
Bacteria (Wet Weather)	Stormwater runoff	Animal Waste
Suspended Sediment (Wet Weather)	Bank Erosion	Erosive Flows Unvegetated Banks
Specific Conductance (Dry Weather)	Point Sources?	Point Source Treatment

Least Concerning	Likely Reason	Prevented Pollutant
Bacteria (Dry Weather)	Sanitary Sewers	Human Waste

Figure 33: Water quality results in developed watersheds

2. Rural Watersheds

Next, the streams within rural subwatersheds (2-4% impervious) tended to be impacted more during dry weather, suggesting that direct sources of pollutants (e.g., septic systems and/or animals grazing in the stream) may be the predominant issue in these subwatersheds (Long Branch [LOB 0.5] and

Most Concerning	Likely Sources	Possible Causes
Bacteria & Nutrients (Dry Weather)	Septic Systems Animal (direct)	Septic maintenance Cattle/Horse Fencing
Specific Conductance (Dry Weather)	Septic Systems Point Sources?	Septic maintenance Point Source Treatment

Least Concerning	Likely Reason	Prevented Pollution
Nutrients (Wet Weather)	Fertilizer Management	Excess Algae

Figure 34: Water quality results in rural watersheds

Riddles Run [RDR 1.1]). The most concerning pollutants identified in the rural watersheds included high levels of bacteria, nutrients, and specific conductance, all during periods of dry weather (**Figure 34**). This suggests potential pollution from sources, such as septic systems, livestock in the stream, and/or point sources such as KPDES permitted discharges.

3. Mixed Watersheds

Finally, streams in mixed subwatersheds (rural/developed, 12% impervious – Fowlers Fork) showed signs of both dry-weather and wet-weather pollution. The most concerning pollutants, as summarized in **Figure 35**, include bacteria during wet weather as well as specific conductance and nutrients during dry weather. The least concerning pollutant was bacteria during dry weather. These results provide insights on some potential sources, such as stormwater runoff, septic systems, and/or animal waste.

Most Concerning	Likely Sources	Possible Causes
Bacteria (Wet Weather)	Stormwater runoff	Animal Waste
Specific Conductance (Dry Weather)	Septic Systems Point Sources?	Septic maintenance Point Source Treatment
Nutrients (Dry Weather)	Septic Systems Animal (direct)	Septic maintenance Cattle/Horse Fencing

Least Concerning	Likely Reason	Prevented Pollutant
Bacteria (Dry Weather)	Sanitary Sewers	Human Waste

Figure 35: Water quality results in mixed watersheds

Finding Solutions

As outlined in the *Watershed Planning Guidebook for Kentucky Communities* (KDOW, 2010c), there are two major categories of BMPs: structural and non-structural. Structural practices refer to those which are built on the ground and require construction, installation and maintenance, such as detention basin retrofits, livestock fencing, retention ponds, etc., while non-structural BMPs include less tangible practices, such as public education on water quality, stormwater ordinances, etc. The Gunpowder Creek Watershed Plan is comprehensive and includes provisions for the implementation of both structural and non-structural BMPs. These BMPs have been evaluated based on the impairments in the Gunpowder stream network, results of monitoring and data analysis, and existing land uses. Specifically, BMPs focused on stormwater, agriculture, construction, forestry, and onsite wastewater treatment are applicable to the watershed. Education is another valuable BMP that is cost-effective and applicable.

The biggest problem within the watershed, which was discussed in the Results section of this report, is inadequately managed stormwater runoff creating erosive flows that in turn lead to hydromodification concerns, including channel erosion, high concentrations of TSS, and other pollutant issues within the stream. The hydromodification problem is nearly watershed-wide but is most prominent in the developed watersheds. Due to the existing stream conditions and volume of stormwater generated from development in South Fork Gunpowder, it has been identified as the highest priority subwatershed.

As the Gunpowder Creek Watershed is an unconventional, large watershed that incorporates many land uses and anticipated continued growth, the priority subwatersheds may change as opportunities arise. To utilize spending as efficiently and effectively as possible, other subwatersheds may become higher priority during the implementation phase. The Riddles Run Subwatershed currently has a lot of agricultural activities; the Lower Gunpowder Creek Subwatershed is currently undeveloped; and as previously mentioned the South Fork Gunpowder is highly developed. Any of these subwatersheds, with the right combination of identified projects and additional funding sources may become the "low-hanging fruit;" and therefore, these three subwatersheds have been identified as GCWI's priority subwatersheds. We anticipate 319(h) grant funding to serve as a catalyst throughout the watershed, with the goal of combining the GCWI efforts with others' to improve stream benefits more than would be accomplished by GCWI alone. **Table 10** on the next page is tailored to the Gunpowder Creek Watershed and includes an all-encompassing list of BMPs that are applicable to the Gunpowder Creek.

Table 10: BMP list tailored to the water quality issues observed in the Gunpowder Creek Watershed

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

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

Strategies for Implementation Success

As previously mentioned, the Gunpowder Creek Watershed Plan is comprehensive in that it includes several types of BMPs, both structural and non-structural, for a variety of land uses. Chapter 6 of the watershed plan includes a strategy for success by outlining an initial plan of action for the watershed.

The Gunpowder Creek Watershed Plan has been tailored to focus on the highest priority problems using the most cost-effective BMPs, stakeholder input and the most feasible opportunities. For example, rather than prescribing the precise location of all of the estimated 170 acre-feet of new stormwater storage that may be necessary to mitigate stream erosion, the plan calls for locating bankfull wetlands, extended detention, and detention basin retrofits based on access, opportunity, and overall cost-effectiveness in achieving the total optimized storage goal. For the purposes of increasing the potential impact of BMP implementation, Action Items have been targeted to priority watersheds, for example South Fork for developed areas and Riddles Run for rural areas; however, locations of BMPs within those priority areas remains flexible in order to capitalize on those that are the most cost-effective and feasible.

Items requiring technical assistance, such as engineering design, hydromodification training, etc., are evident throughout the Action Item list, and estimates of corresponding fees have been included. Responsible parties include the GCWI, its Steering Committee, and specific partners for specific projects. Funding mechanisms include 319(h) funding, as well as local and state sources, for example, Boone County Parks may be a partner on the installation and maintenance of the pet waste program. Even the BMPs included on the Action Item List may be flexible as new opportunities arise, for example, a septic system program via the Northern Kentucky Health Department or a steep slope reforestation program via the either one of the local urban forestry organizations. More specifically, the Northern Kentucky Urban Forestry Council recently prioritized the Gunpowder Creek Watershed as a “Priority Planting Zone” to plant ~$8,000 worth of riparian trees. BCCD plans to partner with the Urban Forestry Council’s Urban Tree Committee to develop planting plans and plant trees within the riparian zone of Gunpowder Creek.

In sum, the Action Item list represents one combination of logical, high-priority BMPs that seem to be feasible based upon known opportunities at the time of the writing of the plan; however, they are subject to change based on the changing nature of the watershed and its opportunities. The Action Items are organized by categories of overall watershed, developed areas, agricultural lands, and undeveloped areas. Cost estimates are informed by a combination of unit costs from literature and local projects. Because the costs are for planning purposes, they err on being conservative such that if implementation costs are less than what is budgeted, additional BMPs can be implemented from the cost savings. Conceptual locations and cut sheets for several of these BMPs are included as Appendix 6-B of the watershed plan. The following action items are summarized in **Tables 11 and 12**. Additionally, a series of maps are included at the end of this chapter to illustrate potential focus areas for implementation efforts related to some of the action items.

Overall Watershed BMPs

The following BMPs have been considered appropriate measures to implement across the watershed, based on the considerations above.

- Training and technical support program
- Coordination with NKU's Stream and Wetland Restoration Program
- Watershed coordinator position
- Review/Revision of Rules and Regulations
- Success monitoring and analysis
- Stewardship programs
- Education and outreach
- Riparian plantings
- Onsite wastewater BMPs
- Structural and non-structural BMPs

Training and technical support for local designers and contractors can provide education to key individuals on the various BMPs and implementation strategies within the watershed. The education component pairs nicely with the NKU Stream and Wetland Restoration Program, which stabilizes degraded stream reaches and restores habitat after developments or other projects physically alter streams. Training and technical support could also lead to a better understanding of how to cost-effectively design for channel protection on future development projects. By hiring a watershed coordinator, the GCWI would have someone to manage and coordinate implementation efforts in a way that also considers stream channel protection and water quality. This particularly relates to coordination between regional agencies on local projects, such as flood control in Florence or the Whispering Trails subdivision.

Partnered with this is a review and revision of regional rules and regulations related to development practices and stormwater management. Recently, SD1 and the City of Florence developed a BMP Manual which requires water quality treatment of the first 0.8 inches of rain. Adapting this document to include channel protection controls designed for $Q_{critical}$ could drastically improve the effectiveness of stormwater management controls at protecting stream channels from excess erosion. Designing for $Q_{critical}$ would require the capture and release of all storms up to and including the 2-year storm below the critical flow for stream erosion.

Success monitoring and analysis calls on both GCWI and SD1 to continue water quality and hydromodification monitoring within the watershed. It is paramount to the GCWI's implementation efforts to continue to monitor the streams to understand the positive impacts of each project and reassess the implementation plan moving forward.

Stewardship programs could be led by the watershed coordinator and would educate and provide outreach programs for homeowners and large corporate and institutional properties. Furthermore, education and outreach efforts will be directed to those that live and work in the watershed, and these activities will focus on educating the community to understand necessary behavioral change that will make a difference in the integrity of the watershed. Riparian plantings could do a lot to buffer overland stormwater runoff prior to entering the creek and protect streambanks from excess erosion. Onsite wastewater treatment is not a priority BMP at this time, although it may become more beneficial as implementation progresses. Lastly, both structural and non-structural BMPs can be implemented wherever there is a cost-effective opportunity.

Developed Headwaters BMPs

As discovered throughout monitoring and data analysis, the developed subwatersheds have the greatest pollutant load ratios for TSS and bacteria in addition to the worst biological indicators. For these reasons, these subwatersheds have been identified as the highest priority for focused efforts to mitigate erosive flows that have altered the habitat, impaired the water quality, and lowered the biologic integrity. The following BMPs have been considered appropriate measures to implement in the developed headwater subwatersheds, based on the considerations above.

- Bioretention
- Detention basin retrofits
- Detention basins
- Wetland creation/restoration
- Pet waste program

Many of the BMPs identified for the developed subwatersheds are stormwater controls, which will be implemented to mitigate erosive flows. While the implementation methods may differ, all stormwater controls will serve as volume-based BMPs to detain stormwater runoff and filter TSS, bacteria, and nutrients from the runoff.

Implementation costs and siting restraints will impact which BMPs are selected. Detention basin retrofits are 10 to 100 times more cost-effective and there are many existing basins within the watershed that are potential candidates. New detention basins will be focused in areas with large amounts of impervious area that are currently not detained; coordination with private property owners is anticipated. Bioretention basins could also be installed in these situations and will be evaluated on an individual basis. Wetland creation and restoration may be utilized in low-lying areas adjacent to the channel.

Implementation of a pet waste program, specifically in areas with high dog-walking traffic, could have a significant impact on bacteria in the stream.

Agricultural BMPs

Livestock exclusion fencing has been considered an appropriate measure to implement in agricultural areas. In addition to removing cattle and horses from the stream, this effort will also create riparian buffer zones, which will help in filtering waste in overland runoff. As an initial step, an improved inventory of horse properties in the watershed may help to target BMP outreach and implementation.

Undeveloped Areas/Forestry BMPs

Conservation of open areas has been considered an appropriate measure to implement in undeveloped and forested areas, based on the considerations above. As Boone County continues to develop, preserving and improving existing green space will be vital to protecting the county's water resources. The GCWI has already identified publicly owned undeveloped lands that can be targeted for conservation practices.

BMP Feasibility/Priority List

There are any number of combinations of volume-based stormwater BMPs, rural dry-weather BMPs, and education/outreach BMPs that will result in load reductions to meet the water quality benchmarks in the Gunpowder Creek and its tributaries. **Table 11** includes the Action Items listed above, with potential funding mechanisms, responsible parties, and goals for implementation. **Table 12** includes a prioritized list based on Steering Committee and Technical Committee input, load reduction effectiveness, feasibility, and a preliminary cost target of $1,000,000 for the initial implementation phase. For the focus areas related to the Action Items and implementation goals, refer to **Figure 36** to **Figure 40**.

Table 11: Prioritized BMP list including Action Items, potential funding mechanisms, responsible parties, and goals for implementation

BMP	Action Items	Potential Funding Mechanism	Responsible Parties	Goals for Implementation[e] Short-term	Intermediate	Long-term	Total	
Overall Watershed								
Coordination with NKU FILO Program	1. Coordinate projects with NKU. 2. Provide guidance on best project locations.	319(h) grant[d] NKU FILO funds	GCWI NKU	0	1	2	3	years
Revise Rules and Regulations	1. Review participation rate in the SD1 Qcritical credit program for new developments. 2. Continue coordination with SD1 and Florence regarding channel protection controls. 3. Coordinate with BCPC to incorporate more LID strategies into Planning/Zoning Requirements and Subdivision Regulations.	319(h) grant[d]	GCWI SD1 & Florence BCPC	1	0	0	1	revision
Riparian Plantings	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[d]	GCWI	500	2,500	1,500	4,500	linear feet
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[d]	GCWI	0	1	2	3	years
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[d]	GCWI Private Companies Individual Landowners	1	1	1	3	years
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[d]	GCWI SD1 & Florence	1	1	1	3	years

BMP	Action Items	Potential Funding Mechanism	Responsible Parties	Goals for Implementation[e] Short-term	Intermediate	Long-term	Total	
Watershed Coordinator (half time)	1. Administer, manage, and implement the Watershed Plan.	319(h) grant[d]	GCWI	1	1	1	3	years
Structural and non-structural BMPs	1. Design and construct any BMPs listed in Table 5-3 of the watershed plan.	-	-	As needed	As needed	As needed	-	
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 entities to address identified issues.	-	N. KY Health Department	0	As needed	As needed	-	
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[d]	GCWI	1	1	1	3	years
Developed Headwaters [a]								
Bioinfiltration	1. Locate opportunities for bioinfiltration. 2. Coordinate with landowners. 3. Design and construct bioinfiltration.	319(h) grant[d] Landowners	GCWI SD1 & Florence Landowners	0.35	0	0	0	acre-feet
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[d] Landowners	GCWI SD1 & Florence Landowners	2	4	4	10	retrofits

BMP	Action Items	Potential Funding Mechanism	Responsible Parties	Goals for Implementation[e]				
				Short-term	Intermediate	Long-term	Total	
Detention Basins	1. Locate opportunities for new detention basins in heavily developed areas that do not currently have detention. 2. Coordinate with landowners to allow construction of a new basin or obtain property to construct new detention basins. 3. Design and construct the detention basins that provide channel protection controls.	319(h) grant[d] Landowners	GCWI SD1 & Florence Landowners	1	1	1	3	acre-feet
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.	319(h) grant[d]	GCWI	2	8	6	16	stations
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[d] NKU FILO funds	GCWI KDOW NKU	0	2	1	3	acre-feet
Agricultural Areas [b]								
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[d] USDA (EQUIP)	GCWI USDA Landowners	2,000	4,500	3,500	10,000	linear feet

BMP	Action Items	Potential Funding Mechanism	Responsible Parties	Goals for Implementation[e]				
				Short-term	Intermediate	Long-term	Total	
Undeveloped Areas/Forestry[c]								
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.	-	GCWI N. KY Urban Forestry Council	1	1	1	3	meetings

[a] Developed BMP strategies will be evaluated first in the priority subwatershed of South Fork Gunpowder. However, GCWI plans to implement these strategies in any subwatershed in which opportunities are optimal and cost-effective.

[b] Agricultural BMP strategies will be evaluated first in the priority subwatershed of Riddles Run. However, GCWI plans to implement these strategies in any subwatershed in which opportunities are optimal and cost-effective.

[c] Undeveloped Areas/Forestry BMP strategies will be evaluated first in the priority subwatershed of Lower Gunpowder. However, GCWI plans to implement these strategies in any subwatershed in which opportunities are optimal and cost-effective.

[d] 319(h) grant monies include a 40 percent non-federal match. Reference Table 6-7 for additional information regarding the cost of each BMP.

[e] Implementation is dependent on receiving 319(h) grant money and takes us through 2018 and goals following 2018 should be determined based on the project implementation and success monitoring.

BMP	Unit Cost		#	Total Cost	Estimated Load Reductions in Priority Watershed: TSS	Bacteria	TP	TN
Overall Watershed								
Coordination with NKU FILO Program	$ 333	per year	3	$ 1,000	-	-	-	-
Revise Rules and Regulations	$ 15,000	ea	1	$ 15,000	100 %[(a)]	100 %[(a)]	100 %[(a)]	100 %[(a)]
Riparian Plantings [(b)]	$ 20	per lf	4500	$ 90,000	74 %[(c)]	629 billion colonies per livestock animal excluded per yr [(d)]	48 %[(c)]	35 %[(c)]
Success Monitoring and Analysis	$ 20,000	per year	3	$ 60,000	-	-	-	-
Stewardship Programs (public/private/ individual)	$ 3,000	per year	3	$ 9,000	-	-	-	-
Training/ Technical Support Program	$ 15,000	per year	3	$ 45,000	-	-	-	-
Watershed Coordinator (half time)	$ 30,000	per year	3	$ 90,000	-	-	-	-
Developed Headwaters [(e)]								
Bioinfiltration [(f)]	$ 174,000	per ac-ft	0.35	$ 61,000	11,000 lbs	2,000 billion colonies/yr	20 lbs/yr	TBD
DB Retrofits [(f)(g)(h)]	$ 10,000	ea	10	$ 100,000	1,520,000 lbs	240,000 billion colonies/yr	2,000 lbs/yr	TBD
Detention Basins [(f)(i)]	$ 87,000	per ac-ft	3	$ 261,000	100,000 lbs	20,000 billion colonies/yr	100 lbs/yr	TBD
Pet Waste Program [(j)]	$ 1,845	per station	16	$ 30,000	-	82 billion colonies per dog in the program area per year [(k)]	3,000 lbs/yr	23,000 lbs/yr
Wetland Creation/ Restoration [(l)]	$ 87,000	per ac-ft	2.5	$ 218,000	63,000 lbs	4,000 billion colonies per year	60 lbs/yr	70 lbs/yr

BMP	Unit Cost		#	Total Cost	TSS	Estimated Load Reductions in Priority Watershed Bacteria	TP	TN
Agricultural Areas								
Livestock Exclusion Fencing [m]	$	2 per lf	10,000	$ 20,000	TBD	629 billion colonies per livestock animal excluded per yr [d]	9 lbs per head of cattle excluded per yr [n]	60 lbs per head of cattle excluded per yr [n]
Undeveloped Areas/Forestry								
Conservation of open areas	$	- -	-		-	-	-	-
			TOTAL	$ 1,000,000				

[a] Load reductions for revised rules and regulations assume that rules can be revised to reduce 100% of the excess future loads from future development relative to the current rules and regulations.

[b] Cost per linear foot assumes a ~15 ft 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 1 live stake per square yard, averaging ~1.5 live stakes per lineal foot of riparian buffer strip. Live staking is estimated to cost $10 per stake for material and installation.

[c] Reported values for TSS, phosphorous and nitrogen removal refer to pollutants flowing from upland 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] 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 3000 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.

[e] The South Fork of Gunpowder Creek has the highest impervious cover, highest TSS levels, and most excessive bank erosion. It is also likely that this subwatershed has the largest shortage of detention volume. SD1 reports that there are 139 detention basins in the subwatershed. Assuming the 1.4 ac-ft per basin estimate, there is an estimated 200 ac-ft of detention storage. Based on interpolation from case studies, the South Fork subwatershed could need approximately 550 ac-ft of optimized storage for channel protection. This means the South Fork could be up to 350 ac-ft short of the target volume. Comparing this to the estimated 185 ac-ft shortage for the entire watershed upstream of the gage shows the limitations of using average detention basin sizes from a limited sample size to develop watershed-scale estimates. Even so, the anlaysis underscores the likelihood that the South Fork of Gunpowder Creek is the watersehd with the largest stormwater storage deficit. Therefore, early efforts for mitigating the erosive flow regime should be focused here, including all new detention volume and retrofits.

[f] Bioinfiltration, detention basin retrofits, and detention basins 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 Internation Storm Water BMP Database (Leisenring et al., 2012). See Tables 5-5 and 5-6.

[f] Bioinfiltration, detention basin retrofits, and detention basins 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 Internation Storm Water BMP Database (Leisenring, 2012). See Tables 5-5 and 5-6.

[g] Assume that the larger basins within the watershed are targeted for retrofits, with an average existing volume of 5 ac-ft. This yields an estimated 5.5 ac-ft of optimized storage per basin.

[h] Detention basin retrofits should be designed to control the release of stormwater to minimize excess rates of bed material and bank erosion in receiving streams. Local case studies to date suggest load reductions of 80-120% of corresponding TSS loads from future bank failure that would be attributable to the local catchment area draining to the respective detention basin. Assuming an average TSS reduction rate of 100%, installing 10 in the South Fork subwatershed, targeting the largest available ponds (estimated at an average of 5 ac-ft), the retrofits may remove up to 1.5 million pounds of TSS from the stream they drain to.

[i]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. By installing these new detention basins in the South Fork subwatershed, where there is an estimated ~600,000 lb/mi2yr - or 9.8 million lbs total - generated by bank erosion, 3 ac-ft of new storage in this subwatershed results in an estimated 100,000 lbs of TSS removal in the South Fork subwatershed.

[j] Costs for the installation and maintenance of pet waste stations include $200 per station for materials, an estimated 4 hrs per station at $70 per hr (2 workers) for installation, and an estimated 15 minutes per week for 3 years at $35 per hr for maintenance. These are consistent with national references and local pricing experience. 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 very approximate rates based on several assumptions, and should be revised as more appropriate, regional data become available.

[k] Bacteria reduction by a pet waste program is not calculated as a function of # 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 wast 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).

[l] Removal rates by wetland channels as reported in the International Storm Water BMP Database (Leisenring, 2012) were used to calculate those for wetlands here, under the anticipation that bankfull/benchfull wetlands would be utilized in the SFG 5.3 UT watershed. It was assumed that enough wetlands would be constructed so that approximately 20% of the flow in the stream would be routed through these wetlands, removing ~29% of TSS, ~19% of bacteria, ~7% of phosphorous, and ~16% of nitrogen from that ~20%.

[m] Livestock exclusion fencing cost estimates are based on EQIP standards for fence installation ($1.53 per ft) 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 mulitplied by 1.33 to approximate the total (~$2.08 per ft).

The following figures present initial focus areas for implementation efforts.

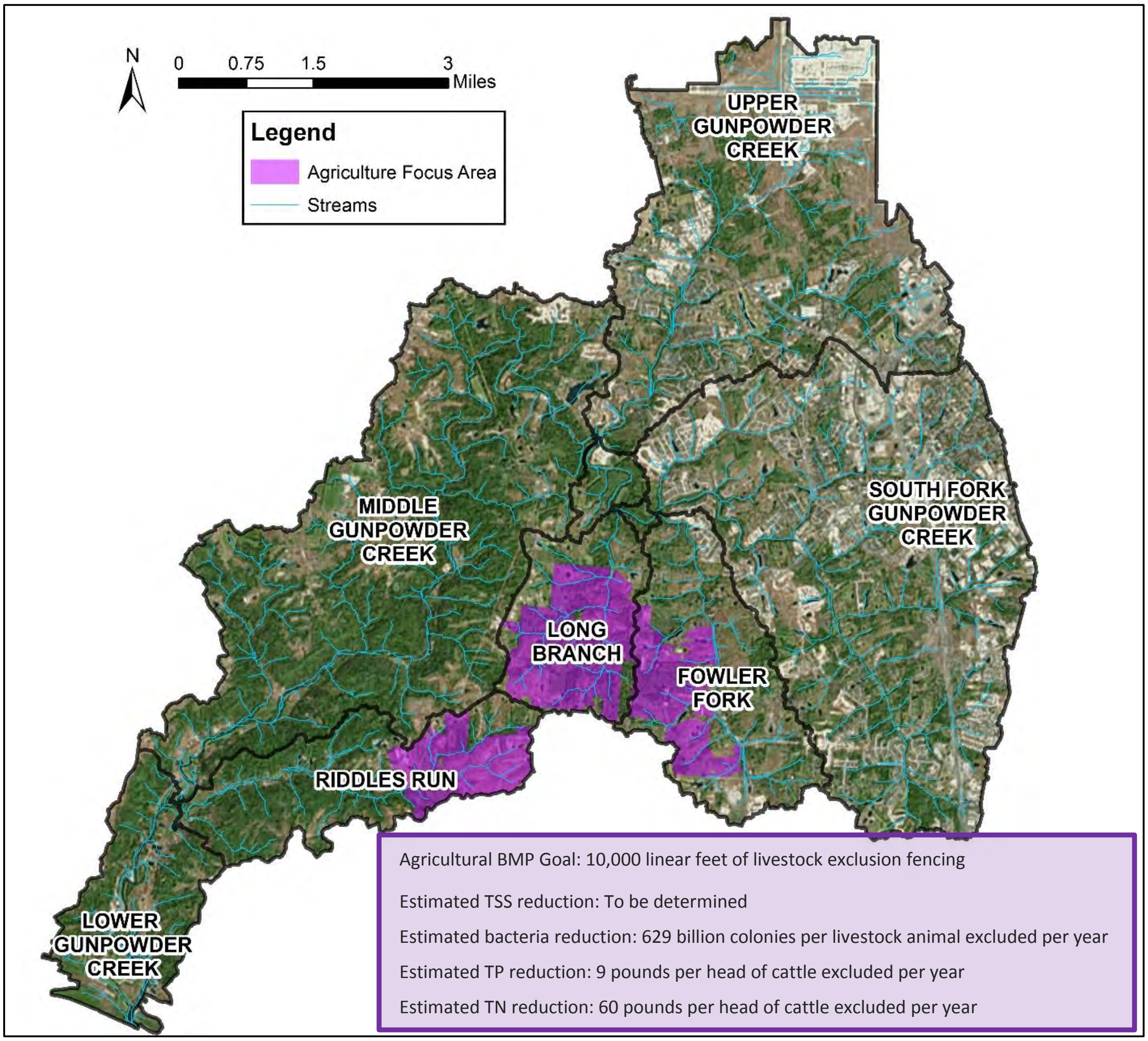
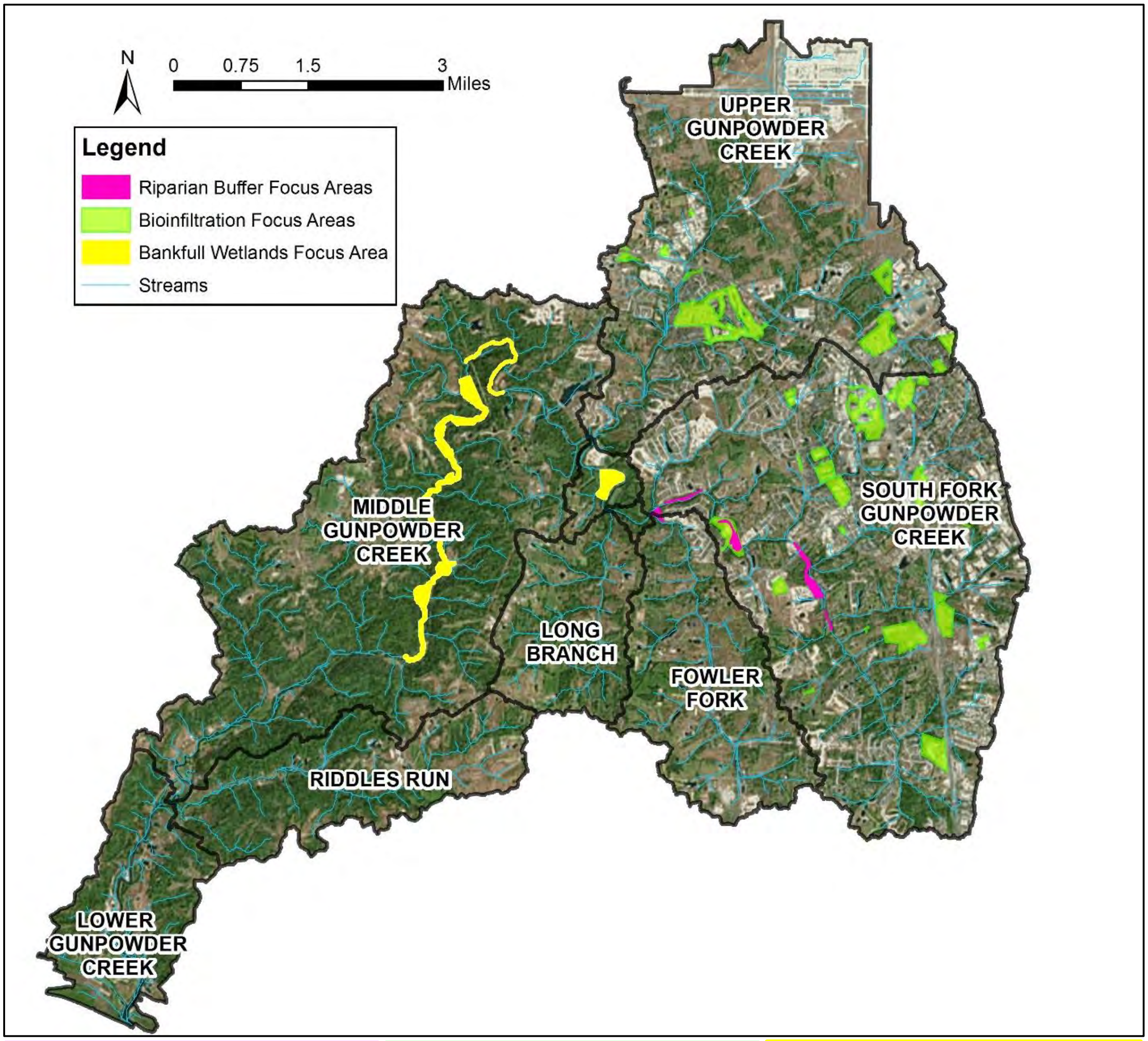


Figure 36: Potential focus areas for agricultural BMP implementation (See Tables 11 and 12 for further details)

Note: The depicted agricultural BMP focus areas were identified by Boone County Conservation District.



Riparian Buffer BMP Goal: 4,500 linear feet

Estimated TSS reduction: 74%

Estimated bacteria reduction: 629 billion colonies per year

Estimated TP reduction: 48%

Estimated TN reduction: 35%

Bioinfiltration BMP Goal: 0.35 acre-feet of storage

Estimated TSS reduction: 11,000 pounds

Estimated bacteria reduction: 2,000 billion colonies per year

Estimated TP reduction: 20 pounds per year

Estimated TN reduction: To be determined

Bankfull Wetlands BMP Goal: 2.5 acre-feet of storage

Estimated TSS reduction: 63,000 pounds

Estimated bacteria reduction: 4,000 billion colonies per year

Estimated TP reduction: 60 pounds per year

Estimated TN reduction: 70 pounds per year

Figure 37: Potential focus areas for riparian buffer and stormwater BMP implementation (See Tables 11 and 12 for further details)

Note: Initial bioretention focus areas were determined by highlighting large parcels of land with high levels of impervious surface. Nearly all of the parcels identified above are public properties. Riparian buffer focus areas were identified by Boone County Conservation District. Bankfull wetlands were determined by evaluating low-lying areas near the streams.

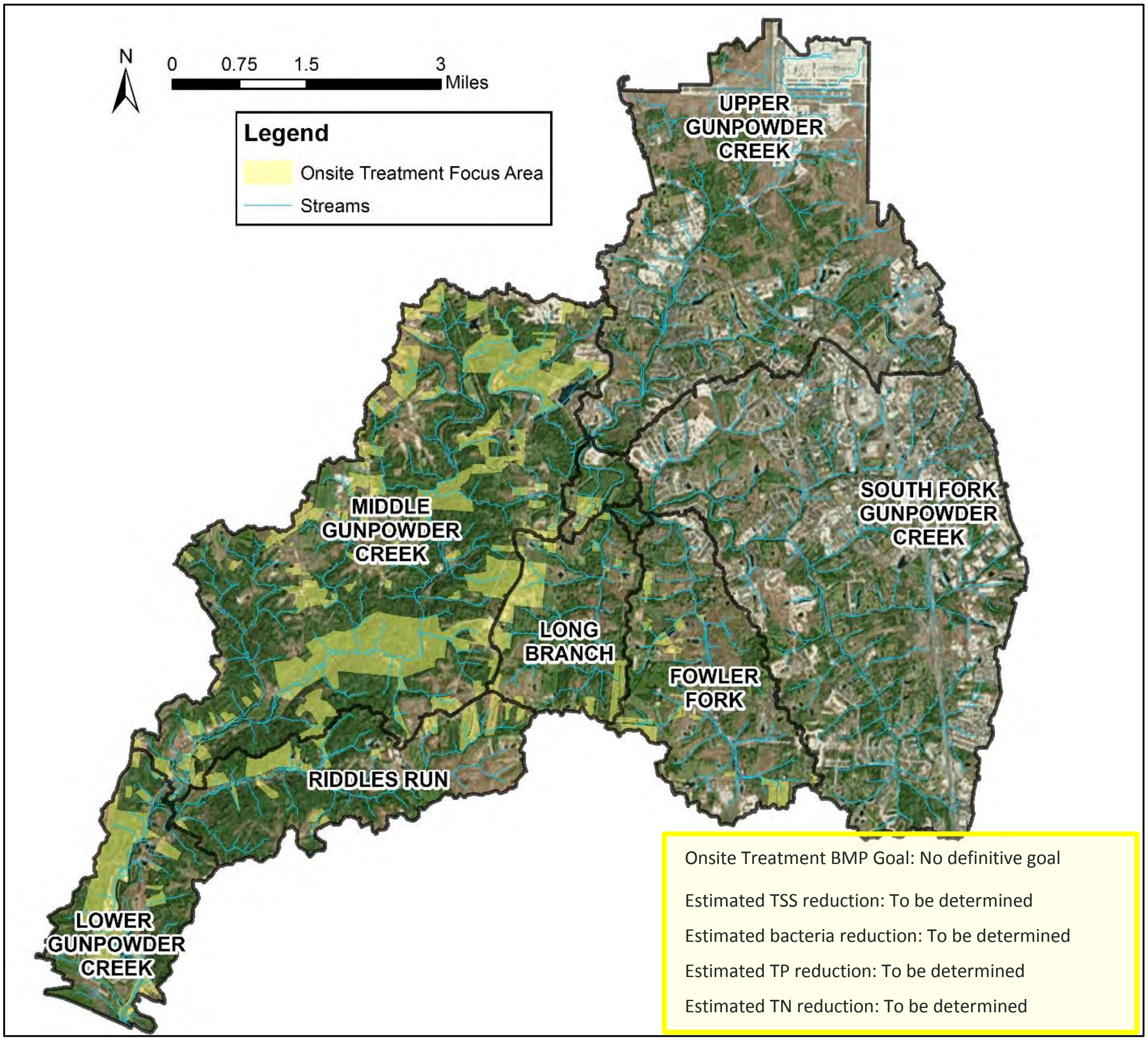


Figure 38: Potential focus areas for onsite wastewater treatment implementation (See Tables 11 and 12 for further details)

Note: Initial onsite wastewater treatment focus areas were determined by parcels that have a building on them but are not served by SD1's sanitary sewer system, as presented in chapter 5 of the watershed plan.

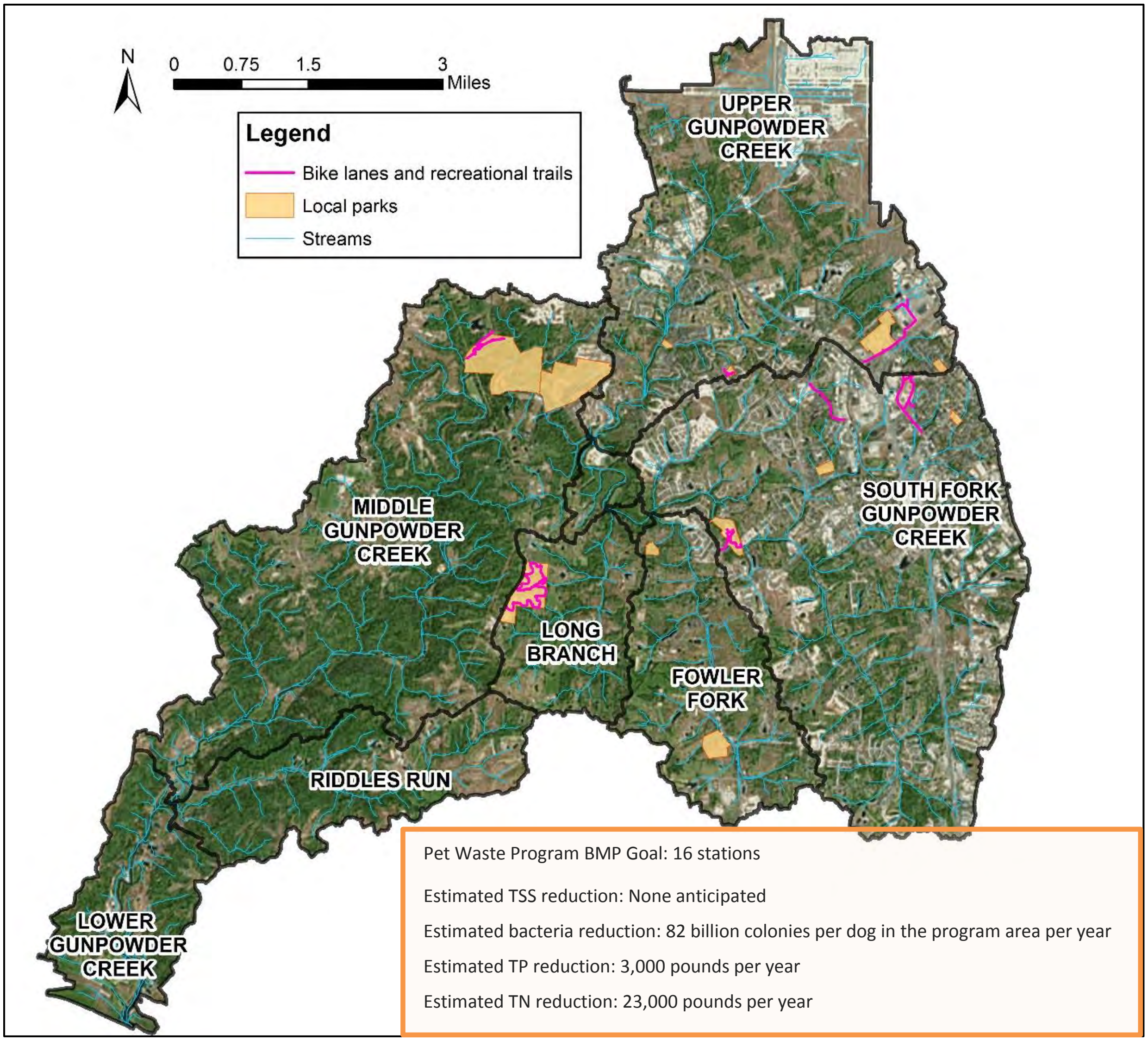


Figure 39: Potential focus areas for pet waste program implementation (See Tables 11 and 12 for further details)

Note: Initial pet waste program focus areas were determined by highlighting the locations of local parks and recreational trails and bike lanes to determine where dog walkers may be most prevalent. There are no dog parks within the watershed.

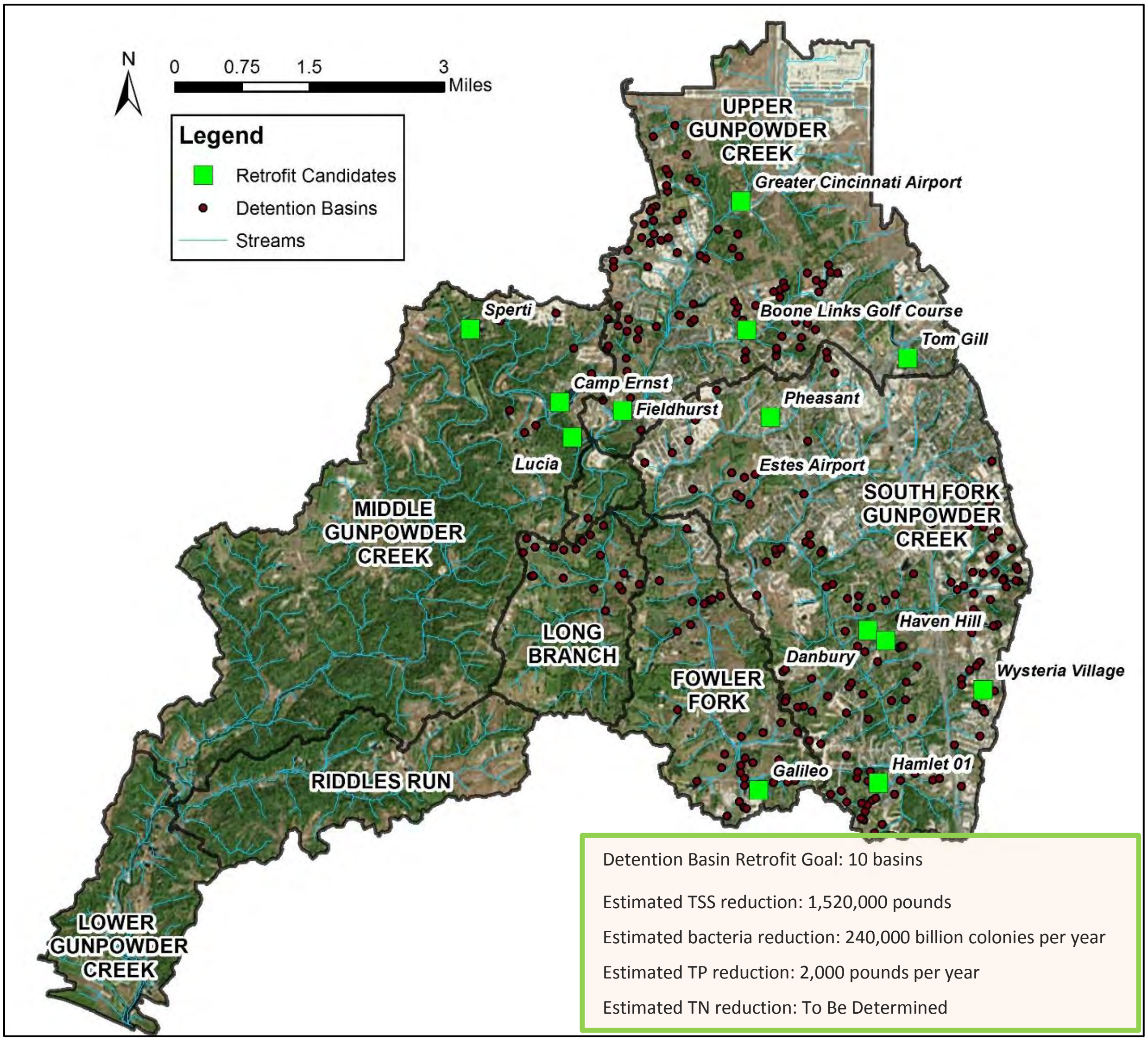


Figure 40: Potential focus areas for detention basin retrofit implementation (See Tables 11 and 12 for further details)

Note: The initial detention basin retrofit focus areas were determined using field data from approximately 20 basins within the watershed and engineering judgment identify the most optimal configurations for retrofitting.

Conclusions

1.0 Conclusion, Recommendations, and Lessons Learned

Over the duration of this 319(h) grant project, the GCWI has made great strides in building stewardship among the community and forming a solid foundation for improving and protecting the resources of the Gunpowder Creek Watershed. From establishing Steering, stakeholder, and other committees to guide the process of developing and implementing a comprehensive watershed plan to completing a robust in-stream monitoring program, identifying pollutants of concern and writing the watershed plan, the GCWI has achieved the goals and objectives outlined in the 319(h) Project Application.

The Gunpowder Creek Watershed Plan presents an all-inclusive approach to watershed planning. The multi-faceted monitoring program served as the basis for determining pollutant loads and potential sources of pollutants. This monitoring program, coupled with the GCWI's public outreach efforts and collaboration with stakeholder and Steering Committees, led to the development of appropriate BMPs to be implemented to reduce pollutant loads and protect the resources of the watershed - all leading to the development of a comprehensive watershed plan that has been approved by KDOW and USEPA. The key recommendation and primary focus for management strategies presented in the watershed plan centers around flow regime restoration through implementation of optimized stormwater BMPs. The GCWI anticipates that these BMPs will also yield meaningful reductions in bacteria, phosphorous, and nitrogen levels. These practices will be supplemented by targeted mitigation and restoration efforts aimed at pollutant sources throughout the watershed, particularly in the developed, priority subwatershed of South Fork Gunpowder.

Moving forward, a monitoring plan should be implemented to measure the effects of the watershed management efforts, along with regular reassessment of the effectiveness of installed BMPs, which will potentially highlight the need for adjustments to the overall strategy. It should be noted that water quality is the quickest indicator of an effective plan, while stream stability can take longer, as it relies on vegetative recovery that may take multiple growing seasons. Biological recovery can take an even longer amount of time, as it relies on water quality and stream stability as prerequisites.

Lastly, facilitating community and corporate stewardship is a critical part of the plan's success. The GCWI understands that education and outreach programs for home owners and large corporate or institutional properties can have relatively low cost, but can deliver measurable results if done effectively (Galvin, 2005), and it will continue to conduct public outreach activities during the implementation phases of this project.

2.0 Project Measures of Success

As outlined in the Project Application, the GCWI determined several measures of success during the application phase of the project. This section presents each measure of success as well as a brief description of the outcomes achieved by GCWI to complete the goals and objectives.

1. The development of a KDOW-approved watershed plan that meets the USEPA a-i criteria.
    - Relates to Objective 1: Plan – The development of a KDOW approved watershed plan that meets the USEPA a-i criteria that will result in improvement, maintenance, and protection of the overall natural resource health of the watershed by identifying more clearly the threats to the watershed, opportunities for mitigation or protection from future impairment and efforts that need to be taken to reduce current impairments.
    The GCWI developed the Gunpowder Creek Watershed Plan, which was finalized in December of 2014 and approved by KDOW and USEPA in April of 2015. The Gunpowder Creek Watershed Plan document is included as Appendix D of this Final Report.
    - Relates to Objective 2: Stewardship – Develop long-term community stewardship for the Gunpowder Creek Watershed so that water quality management can continue beyond the time horizon of this grant.
    As evident throughout this Final Report, the GCWI has certainly built a great foundation for building long-term community stewardship. By engaging the public, the GCWI has cultivated an informed community regarding the current conditions of the Gunpowder Creek Watershed as well as appropriate implementation strategies by involving government officials, local citizens and landowners, stakeholders, and the general public. The GCWI conducted 4 public meetings to solicit public input and participation in the watershed planning process. This includes an open house and presentation on the GCWI in January of 2011 as well as a series of roundtable meetings in September of 2013. A summary of the outcomes of the roundtable discussions that occurred at these public meetings is included in the Results and Discussion sections of this Final Report, with details provided in the supporting documents included in Appendix E. Furthermore, the GCWI-established Steering, stakeholder, and other technical sub-committees helped guide the process of developing and implementing the watershed plan. Key organizations involved in these committees are included in the Acknowledgements section of this Final Report.
    - Relates to Objective 3: Watershed Data Analysis Report – Compile existing data, identify gaps, and develop a KDOW-approved phased monitoring component that will allow the GCWI, through the plan, to accurately identify the pollutants and sources and estimate pollutant loads. Identify subwatersheds most in need of water quality management activities. Generate a KDOW-approved watershed data analysis report.
    After compiling existing data and identifying gaps, the GCWI completed a phased monitoring program in 2011 and 2012. The Watershed Data Analysis Report was finalized and approved by KDOW in August of 2013. Much of the analysis presented in this report is included throughout chapters 3 and 4 of the Gunpowder Creek Watershed Plan and the Results and Discussion sections of this Final Report. The subwatershed in most need of water quality management activities include South Fork Gunpowder, the priority developed subwatershed. The Watershed Data Analysis Report is included as Appendix C.

- Relates to Objective 4: Management Strategy – Develop a management strategy by setting goals, identifying load reductions, and selecting BMPs that would most effectively reduce NPS pollutant loads and improve or protect the water quality of the watershed.
  The management strategy developed by the GCWI, which includes identifying appropriate BMPs as well as estimated load reductions, is included in chapters 5 through 7 of the Gunpowder Creek Watershed Plan and summarized throughout the Results and Discussion sections of this Final Report. While stormwater volume-based controls are a primary focus of the watershed plan, the GCWI's management strategy is comprehensive and includes a multitude of both structural and nonstructural BMPs from agricultural and forestry/undeveloped BMPs to those that can be implemented in more urbanized, developed regions of the watershed.

2. Development and implementation of an educational outreach program for watershed stakeholders to encourage involvement in the watershed planning process and long-term stewardship of the watershed.
   - Relates to Objective 2
     The GCWI understands that educational outreach programs are an effective nonstructural BMP to engage and educate the public within the watershed community. With its multi-pronged educational strategy, the GCWI has engaged the public to teach them and gather feedback about pollutants of concern, potential sources of pollutants, and practical solutions to improve the conditions of the streams. The GCWI conducted a series of community roundtable meetings, asking anyone who lives, works, or recreates in the watershed to attend and share their experiences. The information gathered at these meetings is an important part of the watershed planning process, as the interest, attitudes and opinions of the community can be a driving force behind implementing a successful long-term management plan for the Gunpowder Creek. Furthermore, another important aspect of the GCWI's educational outreach program is its media campaign, which includes updates and links on their website, articles published frequently in the Landscapes *and* What's Happening *newsletters, which are distributed by the Boone County Conservancy. Lastly, the GCWI has distributed several summary documents to the public, such as the KDOW Report Cards, Community Roundtables Summary Report, a Hydromodification Report, and the Public Outreach Summary Document (all of which can be found on the GCWI's website http://www.boonecountyky.org/agencies/boone_county_conservation_district/gunpowder_creel_watershed_initiative.aspx).*
3. Generation of a KDOW-approved watershed data analysis report.
   - Relates to Objective 3
     As previously mentioned, the GCWI conducted a multifaceted, phased monitoring program to inform the development of the Watershed Data Analysis Report, which was finalized and approved by KDOW in August of 2013.
4. Development of a management strategy that includes goals, targeted load reductions and a prioritized list of BMPs that would most effectively reduce NPS pollutant loads and improve or protect the water quality of Gunpowder Creek.

- Relates to Objective 4

  Again, as previously mentioned, the management strategy developed by the GCWI is included in chapters 5 through 7 of the Gunpowder Creek Watershed Plan and summarized throughout the Results and Discussion sections of this Final Report. More specifically, chapter 6 of the watershed plan presents an Action Plan, which highlights the prioritized list of BMPs as well as goals for implementation, estimated costs, potential funding mechanisms, responsible parties, and targeted pollutant load reductions.

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Appendices

Appendix A – Financial and Administrative Closeout
Appendix B – KDOW-approved Quality Assurance Project Plan
Appendix C – Watershed Data Analysis Report
Appendix D – KDOW-approved Watershed Plan
Appendix E – GCWI Public Meeting Survey Results and Roundtable Discussion Summary Reports

APPENDIX A FINANCIAL CLOSEOUT

Grant No: C9994861-09 **State:** Kentucky

Project Name: The Gunpowder Creek Watershed Initiative

Contractor: Boone County Conservation District

Budget Period Start Date: 01/01/2010 **End Date:** 5/31/2016
Total Project Cost: $835,093.00

Water body/Watershed Identification: Gunpowder Creek (HUC$_{11}$ 05090203190)
Licking and Ohio Tributary
NPS Category: Watershed-based plan

Purpose Statement: The goal of the Gunpowder Creek Watershed Initiative (GCWI) is to develop a watershed based plan (WBP) that will identify more clearly the threats to the watershed, identify opportunities for mitigation or protection from future impairment and identify efforts that need to be taken to reduce current impairments.

Boone County Conservation District's Milestones

Milestone	Expected Begin Date	Expected End Date	Actual Begin Date	Actual End Date
1. Submit all draft materials to the Cabinet for review and approval.	Duration		4/10	Complete
2. Submit advanced written notice on all workshops, demonstrations, and/or field days to the Cabinet.	Duration			Complete
3. Form Initial Watershed Steering Committee.		11/08*	11/08	11/08
4. Collect water quality related studies from partners.	11/08*	5/10	11/08	01/10
5. Review and assess existing water quality data; identify gaps & develop plan to fill data gaps.	01/10	7/10	3/10	5/11
6. Submit and obtain QAPP approval from KDOW.	5/10	11/10	6/10	5/11
7. Develop and submit to NPS staff outreach/educational program materials for approval.	3/10	11/13	5/10	Complete
8. Submit schedule of outreach/education programs to KDOW.	3/10	12/13	Duration	Complete
9. Submit advance written notice to KDOW NPS program staff for community meetings and outreach/education events.	7/10	12/13	Duration	Complete
10. Hold annual community meetings.	7/10	12/13	1/11	Complete

11. Identify and select needed technical assistance for WBP development.	11/10	12/11	9/11	Complete
12. Collect water quality data and physical data to fill data gaps.	2/10	12/11	4/11	Complete
13. Submit raw data and laboratory data package to KDOW.	3/10	1/12	9/11	Complete
14. Select tools/models for data analysis.	1/10	12/11	10/11	Complete
15. Analyze data using approved tools/models.	6/10	5/12	10/11	Complete
16. Calculate current pollutant loads.	6/10	10/12		Complete
17. Submit watershed data analysis report including source information, and load calculations to KDOW for review and approval.	10/12	2/13	Phase I DAR - approved	Phase II DAR- Approved
18. Estimate load reductions needed and identify, estimate costs of and prioritize needed management measures.	2/13	5/13		Complete
19. Identify criteria to determine if load reductions are being achieved and develop a monitoring strategy to evaluate the effectiveness of recommended BMPs, and submit to KDOW for review and approval.	2/13	5/13		Complete
20. Develop management measures implementation schedule.	7/13	8/13	**in plan**	Complete
21. Submit WBP to NPS Staff for review and acceptance; incorporate changes suggested.	9/13	11/13	3/2014	**Complete**
22. Submit WBP to KDOW for final acceptance.	11/13	12/13	Submitted 10/7/2014	Complete
23. Upon request of the Division of Water, submit Annual Report and/or participate in the Cabinet sponsored biennial NPS Conference.	Duration	11/11		
24. Submit three copies of the Final Report and submit three copies of all products produced by this project.	10/13	12/13	Submitted	Complete

* Completed and in operation

Status of Boone County Conservation District's Milestones

Provide a brief sentence or two explaining the progress of each milestone.

1.) Milestone #1 – Submit all draft materials to the cabinet for review and approval
- Draft of a press release announcing that the Boone County Conservation District was awarded a 319(h) grant to develop a watershed Based Plan for Gunpowder Creek was submitted to KDOW and approved.
- A draft of the QAPP for Gunpowder Creek was emailed to KDOW for review.
- Bill inserts, flyers, a newspaper article and a press release were developed to promote the Gunpowder Creek Open house and Presentation set for January 13th, 2011. All materials were approved by KDOW.
- An article on stream restoration and project updates were sent to KDOW for review and approval. The articles were approved.
- January 2013 – An article on the" Biology of a Stream" was submitted for review and approval. The article appeared in the Winter/Spring 2013 What's Happening publication.
- March 2013 – A flyer, a survey and a news release were submitted for review and approval. These materials were for a public presentation held on March 21, 2013.
- An article on the updated Health Report Card including the Phase II data was approved by KDOW. The article appeared in the Summer 2013 What's Happening publication.
- October 2013 - A Summary Report of three community roundtable meetings was developed and submitted to KDOW for review.
- November 2013 – Gunpowder Roundtable Summary Report was completed.
- An article for the publication *What's Happening* was sent to KDOW for review.
- Complete

2.) Milestone #3 - Gunpowder Creek Watershed Steering committee formed – met on Wednesday, January 27th 2010 and Wednesday March 31st, 2010.

- Gunpowder Creek Watershed Steering committee did not meet on Wednesday, May 26th 2010 but communication was made through email. Steering committee members were:
  - ➢ updated on progress of the monitoring plan and QAPP
  - ➢ sent a draft of the press release for review and comments
  - ➢ updated on community education efforts.

- The Gunpowder Creek Watershed Steering Committee met on Wednesday, September 29th. The Committee discussed the following topics:
  - o New Uri Stream Project –The City of Florence has been working on this project to stabilize this section of stream in a highly urbanized residential area in Florence. The purpose of the project is to prevent further erosion and degradation of the stream channel and prevent flooding to residents. Josh Hunt and Peter Glenn from the City of Florence confirmed that no federal funds were used in the project and this project will not be submitted in a Phase II report. Josh will provide a letter stating this. The steering committee will seek to use this project as a match for 319 funds.
  - o The steering committee reviewed a power point presentation designed to educate agencies and public officials and garner support for the project.

Many suggestions were made and will be incorporated into the presentation.
    - The committee discussed plans for the development of our first public meeting. The meeting will be educational and informational and gather support for the project. An outreach committee will form to set a date and arrange a place for this meeting. The committee will also discuss content and educational displays and materials as well as advertising for the meeting.
    - Matt Wooten from SD 1 gave a brief report on findings from macro invertebrate surveys. Four sites were evaluated, 2 in South Fork and 2 on the main stem of Gunpowder. The two South Fork sites were poor. One main stem site was poor and the other was fair.
- The Gunpowder Creek Watershed Steering Committee met on 12/15/2010. The following topics were discussed.
    - Project match – New Uri and Allen Fork projects
    - Testing Sites
    - Presentation to Fiscal Court.
    - Public meeting

- 1/26/2011 – A Steering Committee was held at the Boone County cooperative Extension Building in the Kells Room. The Steering Committee reviewed the Open House and Presentation and the status of the QAPP.

- 2/18/2011 - Mark Jacobs attended the LRWW Watershed Planning Meeting.

- 2/19/2011 - Mark Jacobs and Tome Comte attended the LRWW Annual Conference at Blue Licks Park.

- 3/30/2011 – GCWI Steering Committee met at the Boone County Cooperative Extension Building. The agenda included:
    - Project Update
    - Status of the QAPP
    - Public Information Plan
    - Presentation from Matt Wooten - Biological Response and Stream Channel Dynamics: A Northern Kentucky Case Study.

- 5/25/2011 – The GCWI Steering Committee met at the Boone County Cooperative Extension Building. The agenda included:
    - Project update – QAPP approved, LRWW student training, Sampling schedule.
    - 2011 First Quarter Report
    - Potential stream restoration projects
    - Discussion of the next public meeting
    - Review of survey results from January 2011 public meeting
- 7/27/2011 – A GCWI steering committee was held at the Boone County Cooperative Extension Building. The steering committee discussed the following items.
    - Project update – update on sampling efforts including a short power point presentation given by Mark Jacobs

- Update on possible stream restoration projects in the area. NKUCAE is investigating several projects that may be relevant to the Gunpowder project.
- Public outreach – The committee discussed the next public meeting about the GCWI. A subcommittee will meet to begin to plan the event.

- 9/28/2011 – The GCWI steering committee was held at the Boone County Cooperative Extension Building. The following issues were discussed.
  - Project update - Phase 1 data analysis and another fish survey of the Camp Michaels site.
  - Progress on possible stream restoration projects. The Central Park project is supposed to be on the Fiscal Court agenda soon. Central park is in the Gunpowder Creek watershed.
  - The committee was updated of the public outreach committee meeting held in July. The public meeting will likely be scheduled early in 2012 pending the Phase 1 data analysis report.
- Scott Fennell from NKU Center for Applied Ecology has joined the Gunpowder Creek Watershed Initiative Steering Committee.
- 11/30/2011 – The GCWI Steering Committee met to tour the stream restoration site at Boone Woods.
- The January Steering Committee was postponed.
- 2/2012 – The steering committee attended a meeting and tour of the EPA Experimental Stream Facility in Ohio. The Gunpowder Steering committee met with EPA staff to discuss possible areas of collaboration.
- 3/28/2012 – A Steering Committee meeting was held at the Boone County Cooperative Extension Building. The Agenda included:
  - Update of GCWI Project
  - Discussion of the next public Meeting
  - Discussion of the Draft DAR from Malcolm Pirnie
  - TMC environmental Academy – Student Involvement
- 5/30/2012 – A Steering Committee meeting was held at the Boone County Cooperative Extension Building. The Agenda included:
  - Update Phase I Data Analysis Report
  - Short power point presentation
  - Data Management
  - Phase II Monitoring
  - Student training
  - Biology, Bacteria, Chemistry, Hydromod Data Collection
- Planning for Public meeting 9/26/2012 – A Steering Committee meeting was held at the Boone County Cooperative Extension Building. The agenda included:
  - Project update
  - Schedule of Technical and Outreach Committee meetings.
  - Other Grant opportunities.
  - Writing the Watershed Plan – assistance from Boone County Planning and Zoning.
- November 2012 – The Technical Committee and the Outreach Committee met this month.
- A Steering Committee Meeting was held on 11/28/2012 at the Boone County Cooperative Extension Building. The agenda included:
  - Monitoring update
  - Public Outreach

- Technical review
- Watershed Plan Update
- Other Grant Opportunities

- The Outreach committee met on 1/11/2013, 2/1/2013, 2/27/2013 and 3/20 2013 to plan for the public presentation on March 21.
- The steering committee met on 2/27/2013. The committee met for a preview of the public presentation scheduled March 21.
- The Steering Committee met on April 24, 2013. The agenda included:
  - Project update
  - What's Happening Article and plan for round table meetings
  - Review of Phase II DAR by the Technical Committee
  - The development of the watershed plan
  - Update on other grant opportunities
- The Technical Committee met April 10 to submit comments on the Phase II DAR.
- The Outreach Committee met on June 17 to plan for the upcoming roundtable meetings.
- The Technical Committee met on June 24 to begin to develop a list of possible BMPs tom use for the upcoming round table meetings.
- The Steering Committee met on June 26, 2013. The agenda included:
  - Project update
  - Plan for roundtable meetings
  - Technical committee update
  - Writing the watershed Plan
  - Update on other projects
- The outreach committee met on July 18 to plan for upcoming round table meetings.
- The steering committee met on August 28, 2013. The agenda included:
  - Project Update
  - Report on Outreach meetings/Roundtable Meetings
  - Update on the Watershed Plan
  - Fall Fieldtrip Planning.
- December 2013 - The Steering Committee met on December 13 and toured the Airport's water treatment facility in the headwaters of Gunpowder Creek. 12 people toured the facility.
- January 2014 – Steering committee met on January 22. The agenda included items on watershed plan development and BMP review. The meeting also included activities in Fowler Fork and other grant opportunities. Draft chapters 1 – 6 were sent to the steering committee for review and comments.
- The GCWI Steering Committee met on Wednesday, July 30.
- The GCWI Steering Committee met on Wednesday, September 24.
- October 2014 – December 2014 – The Watershed Steering Committee did not meet this quarter. Meetings will resume February 2015.
- February 25, 2015 – The GCWI Steering Committee met. Representatives from KDOW attended the meeting to discuss the development of a TMDL for e.coli in Gunpowder. KDOW reps and the steering committee agreed to an alternative approach to E. coli issues.
- April 2015 – The GCWI Steering Committee met to review the status of the project. The Watershed Plan received conditional acceptance from KDOW.
- June 24, 2015 – The GCWI Steering Committee met. The committee discussed the status of EPA review of the Watershed Plan, The status if the Implementation

Project Application and potential implementation projects. The Implementation Application was APPROVED by KDOC.

3.) Milestone # 4 – Collect Water Quality Related Studies – All known water quality information related to Gunpowder Creek have been collected. Sources include SD #1, Licking River Watershed Watch, Kentucky Division of Water, City of Florence and Boone County.
   - Mark Jacobs acquired all known monitoring reports for KPDES permitted sites in Gunpowder Creek Watershed. **Complete**

4.) Milestone # 5 – Review and assess existing water quality data; identify gaps & develop plan to fill gaps – A technical committee has been formed to review water quality data, develop a monitoring plan and develop a QAPP. Members include: Mary Kathryn Dickerson, Mark Jacobs and Tom Comte (Boone County Conservation District) and Matt Wooten and Mindy Scott (SD #1). This committee met for the first time on March 15th 2010.
   - The technical committee that includes Mary Kathryn Dickerson, Mark Jacobs and Tom Comte (Boone County Conservation District) and Matt Wooten and Mindy Scott (SD #1) Met April 21, 2010 from 2:30 to 3:30. The committee discussed the development of a monitoring plan and potential new sites to consider. KDOW TMDL person will be consulted when sites are identified.
   - Matt indicated that he would begin sampling in mid May at SD 1 sites.
   - Mark Jacobs, Tom Comte and Matt Wooten met with Chris Lorenz (LRWW) to discuss collaboration on water monitoring in Gunpowder Creek. SD 1 is funding a LRWW project in Gunpowder Creek. Every effort is being made to coordinate all activity between organizations, avoid duplication and ensure quality of data collected. Data will be collected under an approved QAPP.
   - The GCWI Technical Committee has been working with SD1 and LRWW to coordinate testing efforts in Gunpowder Creek. LRWW will focus testing efforts at locations not tested by SD 1. LRWW and the GCWI Technical Committee have located six additional test sites in the Gunpowder Creek Watershed in addition to five SD 1 sites. These sites were chosen to fill gaps and obtain important information at the mouth of subwatersheds that have not been tested. Sites were located, mapped and permission was obtained to access sites where needed. The GCFWI will review these sites with KDOW and TMDL branch to assure adequate coverage.
   - Matt Wooten from SD 1 gave a brief report on findings from macro invertebrate surveys. Four site were evaluated, 2 in South Fork and 2 on the main stem of Gunpowder. The two South Fork sites were poor. One main stem site was poor and the other was fair.
   - The technical committee had a meeting on 10/12/2010 to discuss the development of a QAPP for GCWI. Tom Comte, Matt Wooten, Bob Hawley and Mark Jacobs attended the meeting. Bob Hawley from Sustainable Streams will assist with the development of the QAPP.

- The new Uri project in Florence was submitted to KDOW for review to use as a match project for the GCWI 319(h) grant.
- 11/4/2010 – The New Uri Project was not accepted as an appropriate match for the GCWI grant.
- A stream restoration project in Allen Fork of Woolper Creek implemented by NKU Center for Applied Ecology was submitted as project match to KDOW. This project was accepted by KDOW as acceptable project match.
- 1/21/2011 – Members of the GCWI Technical committee met with representatives from SD 1 to coordinate planning efforts. SD 1 will begin a master planning effort that includes hydraulic and water quality modeling. GCWI and SD 1 will work together to fill data gaps and avoid duplication of efforts.
- 10/17/2011 – Members of the technical committee met with representatives from SD1 for an update on the effort to conduct water quantity modeling in portions of the Gunpowder watershed.
- 3/2012 – The technical committee including KDOW staff met to review the draft of the Phase I DAR.
- The technical committee has begun to developing a phase II monitoring plan based on the draft phase I DAR.
- The technical committee has been reviewing the draft of the Phase I Data Analysis Report
- We have been working with Boone County GIS to improve mapping and data management.
- **Complete**

5.) Milestone #7 – Develop and submit to NPS staff outreach/educational program materials for approval

- Tom Comte and Mark Jacobs met with Peggy Casey from SD 1 to discuss community outreach and meetings. Watershed tours, photo journals and web site development were discussed as possible ways to engage and encourage the public to participate.
- Tom Comte and Mark Jacobs met with Barry Couch from Boone County Information Systems Department. Barry develops and maintains websites for the county. Barry will consider assisting with the development of a watershed web site.
- The steering committee reviewed a power point presentation designed to educate agencies and public officials and garner support for the project. Many suggestions were made and will be incorporated into the presentation. The presentation will be sent to KDOW for review when complete.
- 11/19/2010 – Bill inserts, flyers, a newspaper article and a press release were developed to promote the event and sent to KDOW for approval.
- 11/22/2010 – All materials were approved by KDOW.
- An article on stream restoration and project updates were sent to KDOW for review and approval. The articles were approved. The articles were in *What's Happening* publication and the Boone County Conservation District's newsletter *Landscapes.*
- The slide presentation was added to the Boone County Conservation web site.

- An article and photos for What's Happening and Landscapes was prepared to announce a Gunpowder Public Meeting on June 13, 2012. The article was sent to KDOW for approval.
- The presentation and all flyers and materials were approved by KDOW.
- An article on the 'Biology of a Stream" and announcing the next public meeting was submitted to KDOW. The article was approved and will be in the next *What's Happening*.
- January 2013 – An article on the" Biology of a Stream" was submitted for review and approval. The article appeared in the Winter/Spring 2013 What's Happening publication.
- March 2013 – A flyer, a survey and a news released were submitted for review and approval. These materials were for a public presentation held on March 21, 2013.
- A report card for the Gunpowder Creek watershed was updated with 2012 dated with the assistance of KDOW.
- April 2013 – An article about the updated Health Report Card was submitted for approval. The article appeared in the *What's Happening* publication.
- KDOW is assisting with and reviewing all materials for the Watershed Round Table Meetings.
- An article announcing the round table meetings was sent to KDOW and approved. The article appeared in the Fall issue of *What's Happening* and the Conservation District newsletter *Landscapes.*
- An article announcing a June Open House and completion of the Gunpowder Watershed Plan that will go to *What's Happening* publication was sent to KDOW for review.
- Complete

6.) Milestone #10 – Hold annual community meetings

- The committee discussed plans for the development of our first public meeting. The meeting will be educational and informational and gather support for the project. An outreach committee will form to set a date and arrange a place for this meeting. The committee will also discuss content and educational displays and materials as well as advertising for the meeting. KDOW will be contacted and informed about the meeting when more information is gathered. All materials will be approved by KDOW before the meeting.
- An Outreach Committee was formed to plan for the first public meeting regarding the Gunpowder Creek Watershed Initiative. The Gunpowder Creek Open House and presentation is planned for Thursday, January 13th from 6-8 p.m. at Randall K. Cooper High School Library.
- 1/13/2011 – GCWI held its first public meeting. The meeting was an Open House and Presentation held at the Randall K. Cooper High School Library. The purpose of the meeting was to inform people about the Gunpowder Creek Watershed Initiative and what we as a community can do to protect and restore Gunpowder Creek.
- Mark Jacobs and Tom Comte gave presentations on the Gunpowder Creek Watershed Initiative to City of Florence Council and Boone County Planning and Zoning Commission.

- The GCWI Steering Committee discussed planning the next public meeting. An Outreach subcommittee will meet to begin planning the event.
- July 13th 2011 – A public Outreach committee meeting was held to begin planning the next public meeting. The committee discussed possible dates, location, subject matter, advertising etc. The committee decided to have the meeting after the first of the year and base the meeting on results from this summer sampling. We will meet again after the Phase 1 data analysis is complete. The development of a watershed group was discussed and the committee agreed to begin to encourage the development of a citizen watershed group at this meeting.
- August 2011 – The Boone County Public Library was contacted regarding use of the facilities for a public meeting. The library will be available and they will assist with advertising. The date will be set later when the phase 1 analysis report is complete.
- Mark Jacobs gave presentation on the Gunpowder Creek Watershed Initiative at the NKU Campus Community Partnership for Sustainability
- The steering committee discussed scheduling the next annual meeting. The meeting/presentation will be based on the Phase I Data Analysis Report and a tentative date of Wednesday, June 13, 2012 has been set. The event will be held at the Boone County Public Library in Burlington. An education committee will meet to plan the event.
- A public meeting about the Gunpowder Creek Watershed Initiative was held on June 13, 2012. Approximately 40 people attended.
- The GCWI worked with KDOW to develop a presentation and Watershed Report Card for the event.
- TMCEA students assisted with the public meeting and developed displays on sampling techniques for the public.
- Mark Jacobs and Tom Comte provided and educational tour of lower Gunpowder Creek to the local chapter of the Sierra Club.
- November 2012 – The Outreach committee met on two occasions and scheduled a public meeting at Ryle High School. The meeting is scheduled for Thursday, March 21 at 7:00 pm. Representatives from KDOW are on the Outreach Committee.
- A presentation on the status of Gunpowder Creek was given to the Steering committee and other invited guests. The presentation included 2012 data. Approximately 50 people attended.
- A public presentation was given on the updated status of Gunpowder Creek based on the 2012 data. The presentation was held at the Larry A. Ryle High School Commons on Thursday, March 21. Approximately 56 people attended.
- Mark Jacobs gave a presentation on the status of Gunpowder Creek to the Northern Kentucky Fly Fishers organization. Approximately 50 people attended.
- Three roundtable meetings are being planned for September. The Outreach Committee is working on dates and locations for the meetings.
- Three Watershed Roundtable Meetings are being planned for September 2013. The first will be on September 12 at the Good Shepherd Lutheran Church in Florence, the second will be on September 18 at the Fire station In Union and the third will be at the YMCA Camp Ernst in Burlington.
- Three round table meeting were held in September 2013. Approximately 70 people attended the meetings.
- A summary report for the Gunpowder Creek Roundtable Meetings was developed and review by KDOW

- Presentations of the Roundtable summary Report were given to the SD1 Board of Directors and the Stormwater Action Committee (SWAC)
- Nov.14 2013 – A TMDL presentation was organized by GCWI and given to community members.
- GCWI is planning an Open House in June to introduce a draft watershed plan to the public. Notice has been sent to KDOW.
- GCWI held an Open House event at South Fork Park in Florence on June 12. A draft summary of the watershed plan was distributed to attendees for comments. Approximately 20 people attended.
- **Complete**

7.) Milestone # 11 – Identify and select needed technical assistance for WBP development

- The Boone County Conservation District has hired Sustainable Streams, LLC. To assist with QAPP development and to assist with load reduction calculation for stream restoration projects that may be submitted for project match.
- Cardinal Labs was selected to assist with water quality samples.
- Environmental Laboratories Inc. was selected to assist with macroinertebrate assessment.
- Sustainable Streams, LLC was selected to assist with hydromodification surveys of selected sites in Gunpowder Creek.
- July 2011 – Mark Jacobs has been meeting with Steve Gay from Boone County GIS to discuss GIS equipment and software to be used for the project. Long term maintenance issues were also discussed. Boone GIS will assist with these issues.
- A request for quotes to conduct Phase 1 data analysis is being developed.
- Dr. Hawley and Mark Jacobs met with representatives from Boone County GIS to discuss services need to delineate watersheds above hydromod sampling sites and other services. A scope of services will be developed for review. September 2011 – Requests for quotes to develop a Phase 1 Data Analysis report was sent to 4 firms, two submitted quotes. The Boone County Conservation District Board of Supervisors was sent the information to review.
- Craig Frye form SD1 agreed to assist with training and set up of data loggers.
- Boone County GIS has been chosen to provide GIS services
- Malcolm Pirnie was chosen to work with the Boone County Conservation District and the Gunpowder Creek Watershed Initiative to review all data from Phase 1 monitoring and other data collected and develop a Data Analysis Report. A draft of this report will be submitted to KDOW for review when complete.
- 1/2012 – GCWI has contracted with Boone County GIS for GIS services.
- We have developed a draft Request for Proposals for Phase II Data Analysis. This will be sent out and posted on the BCCD website after review form the technical committee.
- Sustainable Streams LLC. Was chosen to develop the Phase II Data Analysis Report.
- The technical committee met on January 14 to discuss watershed metrics being developed by Boone County GIS, Phase II data analysis by Sustainable Streams, LLC. And working with Boone County Planning to write the watershed plan.
- A draft of the Phase II DAR is currently under review.
- Oct. 2013 – The Phase II DAR was approved by KDOW
- **Complete**

8.) Milestone #6 – Submit and obtain QAPP approval from KDOW

- 10/27/2010 – A draft of the QAPP for Gunpowder Creek was emailed to KDOW for review.
- 2/3/2011 – Members of the Technical Committee met to review data for QAPP development and a monitoring plan.
- 2/10/2011 – Members of the technical committee met with Bob Hawley from Sustainable Streams to review elements of the QAPP in preparation of a meeting with KDOW.
- 2/25/2011 – Members of the GCWI Technical Committee met with KDOW staff to review the draft QAPP and Monitoring Plan.
- 3/25/2011 The QAPP with suggested corrections was sent to KDOW for approval.
- July 2011 – We have been working with Environmental Labs Inc. to update and make minor changes in the QAPP. Changes will be sent to KDOW for review.
- Changes to the Gunpowder QAPP were submitted to KDOW for approval. The changes were approved.
- **Complete**

9.) Milestone #9 – Submit advance written notice to KDOW NPS program Staff for community meetings and outreach/education events.

- KDOW NPS Staff was informed of the Gunpowder Creek open House and Presentation scheduled for Thursday January 13th from 6-8p.m
- 11/17/2011 – Notice of a stream restoration site tour in Boone Woods was sent to KDOW and the steering committee.
- November 2012 – The Outreach committee met on two occasions and scheduled a public meeting at Ryle High School. The meeting is scheduled for Thursday, March 21 at 7:00 pm. Representatives from KDOW are on the Outreach Committee.
- A presentation on the status of Gunpowder Creek was given to the Steering committee and other invited guests. The presentation included 2012 data. Approximately 50 people attended.
- A public presentation was given on the updated status of Gunpowder Creek based on the 2012 data. The presentation was held at the Larry A. Ryle High School Commons on Thursday, March 21. Approximately 56 people attended.
- Three Watershed Roundtable Meetings are being planned for September 2013. The first will be on September 12 at the Good Shepherd Lutheran Church in Florence, the second will be on September 18 at the Fire station In Union and the third will be at the YMCA Camp Ernst in Burlington. KDOW is assisting with the planning and review of the presentation materials.
- All three Watershed Roundtable Meetings were completed and a summary of the meetings was developed and distributed.
- GCWI is planning an Open House in June to introduce a draft watershed plan to the public. Notice has been sent to KDOW.
- The announcements and advertisements for June 12, 2014 Open House was sent to KDOW for review and approval.
- **Complete**

10.) Milestone #12 – Collect water quality data and physical data to fill data gaps.

- Data collection at 6 selected sites has begun. Data collection is in collaboration with Licking River Watershed Watch, SD 1 and Thomas More College. Macroinvertebrate collection and habitat assessment was completed in May and water chemistry data collection began in June.
- July 2011 – Water chemistry and flow sampling is ongoing. Two rounds have been completed to date with the assistance of TMC Environmental Academy students. Equipment was provided through LRWW.
- July 2011 – E. Coli sampling (5 samples in 30 days) was completed on July 17th. Sampling has been going well with much help form SD1 and students from Thomas More College Environmental Academy.
- July 2011 – A fish survey of the Camp Michaels site was conducted with the assistance of staff from SD1, ORSANCO and TMC Environmental Academy Students. Matt Wooten from SD1 will evaluate the results.
- August 2011 – We received the macro analysis report from Environmental Labs Inc. The technical committee will review and discuss the results.
- August 2011 – all sampling scheduled for 2011 has been completed.
- August 2011 – Dr. Bob Hawley completed a report on the hydromodification surveys.
- October 6 – Conducted a fish survey at the Camp Michaels monitoring site with assistance from SD1 and ORSANCO.
- Data loggers to record depth and temperature were placed in various locations in Gunpowder Creek. Locations are GPC 17.1 UNT1.1 (Oakbrook), FWF 0.8 (Fowler Fork) ad RDR 1.1 (Riddles Run)
- 2/2012 - We met with Dr. Chris Lorentz from Thomas More College to discuss a partnership with The Environmental Academy. Five Students from the Academy will assist with data collection in Phase II monitoring.
- Two additional data loggers were placed in locations in Fowler Fork to assist SD1 with a study.
- TMC Environmental Academy students have been trained to assist with data collection for Phase II.
- 5/2012 – Biology samples for Gunpowder were collected and taken to Environmental Labs Inc. in Madison Indiana
- Water quality sampling began in June 2012.
- July 2012 – Phase II sampling update:
    - Two rounds of water quality sampling for July have been completed.
    - E. coli mean sample has been completed.
    - We continue to collect data from dataloggers at three sites in Gunpowder Creek.
- August 2012 – Phase II sampling update:
    - Water quality monitoring is complete.
    - We continue to collect depth data from data loggers at three sites in Gunpowder Creek.
- September 2012 – Monitoring data loggers continues.
- October 2012 – Phase II Update
    - We continue to monitor depth at three sites in Gunpowder Watershed with dataloggers.
    - Two hydromod resurveys have been completed this month.
- November 2012 –Phase II update
    - We continue to monitor depth dataloggers

- We worked with SD1 to resurvey hydromod sites at South Fork Gunpowder and Camp Michaels.
- Met with Dr. Bob Hawley and Steve Gay (Dir GIS Services, Boone County) to discuss GIS paramaters for Gunpowder watershed.

- December 2012 – Phase II update
- Data Loggers have been removed from three sites in Gunpowder Creek. All sampling described in the monitoring plan is complete.

11.) Milestone #13 – Submit raw data and laboratory data package to KDOW.

- September 2011 – Copies of all raw data collected during 2011 was sent to the technical committee for review. The raw data was also delivered to KDOW for review.
- Raw data collected in the field as part of the Phase II sampling is sent to representatives of KDOW as it is received from the lab.
- All raw laboratory data is sent to KDOW as soon as it is received.
- A draft of the Phase II DAR has been sent to all members of the technical committee for review.
- All data has been sent to KDOW.

12.) Milestone #23. Upon request of the Division of Water, submit Annual Report and/or participate in the Cabinet sponsored biennial NPS Conference.

- An annual report was submitted to KDOW including load reduction calculations for the Boone Woods Stream Restoration Project
- GCWI submitted an annual report and representatives from KDOW visited the Boone County Conservation District in July to review progress on the project.
- August 20, 2013 – KDOW site visit and review of the Gunpowder watershed project.

13.) Milestone # 14 – Select tools/models for data analysis

- 1/2012 – KDOW provided bench marks for Gunpowder Creek to be used in the Data Analysis Report.
- Methods for calculating pollutant loads is described in the Draft Phase I DAR.
- All tools, models and methods for data analysis are described in the Draft Phase II DAR
- **Complete**

14.)Milestone # 15 – Analyze data using approved tools and models.

- 2/2012 – Malcolm Pirnie provided a draft DAR for review. Members of the technical review committee and KDOW reviewed the document and provided comments.
- The final updates for the Phase I DAR are in progress. Gunpowder Technical committee and KDOW reviewed the document and submitted comments for the final report.
- The Final Phase I DAR has been submitted, reviewed and approved by KDOW.
- November 2012 –We have been developing a RFP for Phase II data analysis.
- The Draft Phase II DAR is currently under review.
- **Complete**

15.) Milestone #17 – Submit watershed data analysis report including source information, and load calculations to KDOW for review and approval.

- The Draft Phase II DAR is currently under review
- KDOW has submitted comments on the Phase II DAR. Dr. Hawley from Sustainable Streams LLC and the technical committee are working on addressing those comments.
- The Phase II DAR is complete and has been approved.
- **Complete**

16.) Milestone # 21. Submit WBP to NPS Staff for review and acceptance; incorporate changes suggested.

- Brian Shorkey from the Boone Copunty Planning commission has been assisting with the Watershed plan. Brian is working on drafting the first three chapters. The outreach committee has been reviewing the drafts.
- September 2013- We sent a letter of request to have the project deadline extended for six months from December 2013 to June 2014. The new deadline was approved and the new deadline is June 2014.
- Chapters 1 through 3 of the watershed plan has been drafted and is being reviewed by the steering committee.
- Charters 4, 5, 6 and 7 are currently being drafted and will be ready for review by the steering committee soon.
- Matt Becher from the Boone County Planning commission is now assisting with the development of the watershed plan.
- January 2014 – Chapters 4,5 and 6 has been drafted have been sent to the steering committee for review and comments.
- We have been meeting regularly with KDOW staff to review draft chapters of the watershed plan.
- Chapter review with KDOW staff continues.
- Draft chapters 1 – 6 have been sent to KDOW NPS staff for initial review.
- We have requested and received a project extension from KDOW. The new completion date for the watershed plan in December 31, 2014.
- The WBP was submitted to KDOW for full review on October 7, 2014.
- The Gunpowder Creek Watershed Initiative has received comments from the non-point source staff and has addressed all comments. The plan was sent back for final review.
- April 2015 – GCWI Watershed Plan has been sent to KDOW and received conditional acceptance. The document has been sent to EPA for review.
- 10/19/2015 – The Gunpowder Creek Watershed Plan has been approved by the EPA.

17.) Milestone # 18 – Estimate load reductions needed and identify estimate costs and prioritize management measures needed.

- Load reductions and estimated costs have been discussed with the technical committee and the steering committee and are incorporated into the draft WSP.
- **Complete**

18.) Milestone #19 - Identify criteria to determine if load reductions are being achieved and develop a monitoring strategy to evaluate the effectiveness of recommended BMPs, and submit to KDOW for review and approval.

- This is being incorporated into the watershed plan
- **Complete**

19.) Milestone #20 – Develop management measures implementation schedule.

- This has been developed and is being incorporated into the watershed plan.
- We have requested and received a project extension from KDOW. The new completion date for the watershed plan in December 31, 2014.
- Due to on-going watershed plan review from KDOW we requested a project extension on December 23, 2014.
- The extension was granted on January 7, 2015. The completion date has been extended to June 2015.
- Complete
- The GCWI steering committee is working on several potential implementation projects. Any remaining funds from this project will be used for any of these projects that are approved.

✓ A contract for the 2014 Implementation Grant began August 1, 2015.

A BMP Plan was developed and submitted to KDOW and was approved in August 2015. The remainder of the funds for the 2009 319(h) Grant will be used to implement some of the practices outlined in the Gunpowder Creek Watershed Plan. The following is a narritave explaining those projects being considered.

1) YMCA Camp Ernst Bankfull Wetland – This project will add 5 -7 acre feet of storage as well as reduce the number of event that exceed Q critical. The project will also improve riparian habitat and be used for outdoor education in YMCA programs
    a. All permitting has been received and the project has begun.
2) Purchase of Water Monitoring Equipment –This includes the purchase of a YSI multi parameter water quality meter and a Hach Velocity meter for on-going sampling of established sites and post BMP monitoring.
    a. This equipment has been purchased
3) Microbial Source Tracking Project in South Fork of Gunpowder Creek – This project is in partnership with SD1 and Purdue University and will help detect dominate sources of fecal contamination at selected sites in Gunpowder Creek.
    a. This project is underway.
4) South Fork Gunpowder Detention Basin Modeling Project- This project is model and prioritizing detention basins in South Fork of Gunpowder for potential retrofit.
    a. This project has been completed
5) Ockerman Middle School Detention Basin – This project is on the grounds of Ockerman Middle School includes retrofitting the outlet for stream channel protection, using natural vegetation to improve water quality and provide an outdoor learning area for teachers and students.
    a. This project has begun. We are developing a bioswale to lead to the basin and incorporating biosoils, underdrain, native plants and an improved outlet design. We will include educational signage and the basin will be used by science teachers as a learning lab.

6) Boone County High School Detention Basin – This project includes renovating an existing, poorly functioning detention basin. BCCD was contacted by Boone County Schools to participate. BCCD provided technical assistance and grant funds provided native seed and plants to improve water quality. Grant funds will also provide educational signage. The basin will be used by the science teacher as an outdoor learning lab. The project will be complete by the end of May.

Budget Summary

Original Detailed Budget as submitted January 2009

Detailed Budget			
Budget Categories (Itemize all Categories)	§319(h)	Non-Federal Match	TOTAL
Personnel	$234,972	$78,800	$313,772
Supplies	$14,000		$14,000
Equipment	$5,000		$5,000
Travel	$6,084		$6,084
Contractual	$239,000	$249,237	$488,237
Operating Cost		$6,000	$6,000
Other	$2,000		$2,000
Total	**$501,056**	**$334,037**	**$835,093**
	60 %	**40%**	**100**

Original Budget Narrative as submitted January 2009

The proposed budget includes cost estimates based on the best available information and those costs that can be reasonably surmised at this time. As with any budget, as future costs, additional information, and the results of the WBP becomes available, the budget will be updated to reflect the needed changes within the amount granted. This four year project requests funds for the development of a WBP for Gunpowder Creek including phased monitoring. A total of $100,000 has been budgeted for technical assistance to aid with the development of a WBP, with an additional $138,028 budgeted for monitoring. Until the review of existing data is completed as a part of the WBP, the amount budgeted for monitoring is a best guess based on the professional expertise brought to bear by various steering committee members. Phased monitoring is the key to the development a comprehensive WBP and for determining the most effective and efficient use of BMPs. These costs are in addition to the amounts budgeted for a dedicated project manager.

Non-Federal match fund dollars: A significant part of this project is being supported by matching funds as required by the grant guidelines. A total of $334,037 is being contributed by the various project partners to this effort. The bulk of this is $239,000 from NKUCAE in the form of FILO “Fees in Lieu of” for potential stream restoration and other storm water retrofit projects by other community partners such as the City of Florence that are anticipated to occur in Boone County. A total of $78,800 will be provided by various volunteers through serving on the steering committee, conducting education and outreach activities to the public, and in volunteering staff time to aid with project management and monitoring activities. The Northern Kentucky Area Development District will provide $2,600 in pro bono administrative support in terms of staff time (60 hours over four years) for various aspects of the project such as, but not limited to, preparation of committee materials, staff assistance at roundtable meetings or assistance in presenting the educational/outreach programs. The Boone County Conservation District will provide $6,000 in overhead match in the forms of rent, utilities, and various shared office supplies. The GCWI is aware that federal funds available to project partners cannot be used as match.

Personnel: Personnel costs in the budget include $234,972 from 319(h) funds for the Boone County Conservation District to fund a Project Coordinator position with benefits ($172,405 over 4 years) to oversee the project and partially fund the existing District Coordinator position with benefits ($62,567 over four years) to provide technical assistance and education outreach activities. The remaining personnel costs are matching funds explained above.

Supplies: A total of $14,000 in 319(h) funds are being requested for supplies, the bulk of these funds ($11,000 over 4 years) going to produce the approved educational and outreach materials. The remainder is for monitoring supplies, project management and technical assistance ($1,000 each over 4 years).

Equipment: A total of $5,000 in 319(h) funds is being requested to purchase various computer and presentation equipment to aid in the development and presentation of the educational materials. After the project ends, the Boone County Conservation District plans to continue to use the equipment to further promote public outreach and education efforts developed as a part of the WBP.

Travel: A total of $6,084 in 319(h) grant money is being requested to cover travel costs associated with monitoring, education/outreach efforts, and transportation to various meetings. It is estimated that this will cover 10,400 miles at 58.5 cents per mile.

Contractual: A total of $239,000 in 319(h) grant money is requested to cover contractual expenses. A total of $135,000 (over 4 years) has been budgeted for monitoring contracts. A total of $100,000 for Technical Assistance contracts to aid with the development of the WBP. The Northern Kentucky Area Development District has been budgeted $4,000 (over 4 years) for grant administration services.

Operating costs: No 319(h) funds are requested to cover operating expenses (overhead) as these will be provided by the Boone County Conservation District as a match.

Other expenses: A total of $2,000 in 319(h) funds are being requested for training for Project Coordinator and other assisting staff.

No part of the funding awarded or matching funds applied as a part of this grant will be used to meet any regulatory requirements such as KPDES permitting requirements, any Phase II requirements (MS4), or any consent decrees previously entered into with the EPA or KDOW. As previously stated, it is the intent of the GCWI to move forward with the development and implementation of a WBP to the best of the group's ability regardless of the level of grant funding.

Budget Summary

Revised Detailed Budget as submitted November 2011

Detailed Budget			
Budget Categories (Itemize all Categories)	§319(h)	Non-Federal Match	TOTAL
Personnel	$234,972	$78,800	$313,772
Supplies	$14,000		$14,000
Equipment	$5,000		$5,000
Travel	$6,084		$6,084
Contractual	$239,000	$231,237	$476,237
Operating Cost		$18,000	$18,000
Other	$2,000		$2,000
Total	**$501,056**	**$334,037**	**$835,093**
	60 %	**40 %**	**100 %**

Revised Budget Narrative as submitted November 2011

The proposed budget includes cost estimates based on the best available information and those costs that can be reasonably surmised at this time. As with any budget, as future costs, additional information, and the results of the WBP becomes available, the budget will be updated to reflect the needed changes within the amount granted. This four year project requests funds for the development of a WBP for Gunpowder Creek including phased monitoring. A total of $100,000 has been budgeted for technical assistance to aid with the development of a WBP, with an additional $138,028 budgeted for monitoring. Until the review of existing data is completed as a part of the WBP, the amount budgeted for monitoring is a best guess based on the professional expertise brought to bear by various steering committee members. Phased monitoring is the key to the development a comprehensive WBP and for determining the most effective and efficient use of BMPs. These costs are in addition to the amounts budgeted for a dedicated project manager.

Non-Federal match fund dollars: A significant part of this project is being supported by matching funds as required by the grant guidelines. A total of $334,037 is being contributed by the various project partners to this effort. The bulk of this is $239,000 from NKUCAE in the form of FILO "Fees in Lieu of" for potential stream restoration and other storm water retrofit projects by other community partners such as the City of Florence that are anticipated to occur in Boone County. A total of $78,800 will be provided by various volunteers through serving on the steering committee, conducting education and outreach activities to the public, and in volunteering staff time to aid with project management and monitoring activities. The Northern Kentucky Area Development District will provide $2,600 in pro bono administrative support in terms of staff time (60 hours over four years) for various aspects of the project such as, but not limited to, preparation of committee materials, staff assistance at roundtable meetings or assistance in presenting the educational/outreach programs. The Boone County Conservation District will provide $18,000 in overhead match in the forms of rent, utilities, and various shared office supplies. The GCWI is aware that federal funds available to project partners cannot be used as match.

Personnel: Personnel costs in the budget include $234,972 from 319(h) funds for the Boone County Conservation District to fund a Project Coordinator position with benefits ($172,405 over 4 years) to oversee the project and partially fund the existing District Coordinator position with benefits ($62,567 over four years) to provide technical assistance and education outreach activities. The remaining personnel costs are matching funds explained above.

Supplies: A total of $14,000 in 319(h) funds are being requested for supplies, the bulk of these funds ($11,000 over 4 years) going to produce the approved educational and outreach materials. The remainder is for monitoring supplies, project management and technical assistance ($1,000 each over 4 years).

Equipment: A total of $5,000 in 319(h) funds is being requested to purchase various computer and presentation equipment to aid in the development and presentation of the educational materials. After the project ends, the Boone County Conservation District plans to continue to use the equipment to further promote public outreach and education efforts developed as a part of the WBP.

Travel: A total of $6,084 in 319(h) grant money is being requested to cover travel costs associated with monitoring, education/outreach efforts, and transportation to various meetings. It is estimated that this will cover 10,400 miles at 58.5 cents per mile.

Contractual: A total of $239,000 in 319(h) grant money is requested to cover contractual expenses. A total of $135,000 (over 4 years) has been budgeted for monitoring contracts. A total of $100,000 for Technical Assistance contracts to aid with the development of the WBP. The Northern Kentucky Area Development District has been budgeted $4,000 (over 4 years) for grant administration services.

Operating costs: No 319(h) funds are requested to cover operating expenses (overhead) as these will be provided by the Boone County Conservation District as a match.

Other expenses: A total of $2,000 in 319(h) funds are being requested for training for Project Coordinator and other assisting staff.

No part of the funding awarded or matching funds applied as a part of this grant will be used to meet any regulatory requirements such as KPDES permitting requirements, any Phase II requirements (MS4), or any consent decrees previously entered into with the EPA or KDOW. As previously stated, it is the intent of the GCWI to move forward with the development and implementation of a WBP to the best of the group's ability regardless of the level of grant funding.

Revised Detailed Budget as submitted April 2015

Budget Categories	319(h) Dollars	Match	TOTAL
Personnel	$145,000	$15,375	$160,375
Supplies	$25,000		$25,000
Equipment	$5,000		$5,000
Travel	$6,084		$6,084
Contractual	$317,972	$305,520	$623,492
Operating Cost		$13,142	$13,142
Other	$2,000		$2,000
TOTAL	$501,056	$334,037	$835,093

Revised Budget Narrative as submitted April 2015

The proposed budget includes cost estimates based on the best available information and a trend analysis. As with any budget, additional information and actual costs differed from the initial estimates and as such the Gunpowder Creek Watershed Initiative is requesting that this budget amendment be granted. The basis for this grant, preparing a watershed plan, is complete and is awaiting approval from KDOW and the EPA. This project has just finished its 5th year and will need 6 to 12 more months to implement some of the proposed BMPs.

Non-Federal match fund dollars: A significant part of this project is being supported by matching funds as required by the grant guidelines. A total of $334,037 is being contributed by the various project partners to this effort. The majority of the budgeted $277,163 will come from NKUCAE in the form of FILO "Fees in Lieu of" for potential stream restoration and other storm water retrofit projects, by other community partners such as the City of Florence, that are anticipated to occur in Boone County. A total of $32,874 will be provided by various volunteers through serving on the steering committee, conducting education and outreach activities to the public, and in volunteering staff time to aid with project management and monitoring activities. The Northern Kentucky Area Development District has exceeded its estimate of $2,600 in pro bono administrative support in terms of staff time (60 hours over four years) for various aspects of the project such as, but not limited to, preparation of committee materials, staff assistance at roundtable meetings or assistance in presenting the educational/outreach programs. The Gunpowder Creek Watershed Initiative is aware that federal funds available to project partners cannot be used as match.

Reasons for the request:

1) The GCWI project management has been very efficient with its funds and has been able to meet the match before the close of the project.
2) The final watershed plan has been written and is awaiting approval from KDOW. The BMPs that were created for this project are unique. KDOW has approved GCWI to use remaining funds on BMP implementation.
3) Money spent on BMP projects will further the outcomes of the project and will provide measurable results.

No part of the funding awarded or matching funds applied as a part of this grant will be used to meet any regulatory requirements such as KPDES permitting requirements, any Phase II requirements (MS4), or any consent decrees previously entered into with the EPA or KDOW. As previously stated, it is the intent of the GCWI to move forward with the development and implementation of a WBP to the best of the group's ability regardless of the level of grant funding.

Equipment Summary

ITEM	QTY	PRICE	VENDOR
HP 8540w Notebook w/ArcView SU	2	$9,200.00	ESRI
Advanced Docking Station	2	$630.00	ESRI
LA1905wg 19" Wide-Screen Monitor	2	$630.00	ESRI

Boone County Conservation District was reimbursed $501,056. All dollars were spent; there were no excess project funds to reallocate. This project did generate overmatch provided by the Boone County Conservation District. This overmatch was not posted to the Grant. Remaining equipment will be used for future projects pertaining to the Gunpowder Creek Watershed. Grant # C9994861-09 does not have any special conditions placed on it by the USEPA.

APPENDIX B

Quality Assurance Project Plan

Gunpowder Creek Watershed Plan
Final Report

Prepared by the
Gunpowder Creek Watershed Initiative

QUALITY ASSURANCE PROJECT PLAN

FOR

Gunpowder Creek Watershed Based Plan

DRAFT

Effective Date: April 15, 2011

Revision Date: April 12, 2011

Revision No: Original QAPP

Prepared by:

Sustainable Streams, LLC
2038 Eastern Parkway, Suite 1
Louisville, KY 40204

On behalf of:

Gunpowder Creek Watershed Initiative
Boone County Conservation District
6028 Camp Ernst Road
Burlington, KY 41005

Submitted to:

The Kentucky Energy and Environment Cabinet
Department for Environmental Protection
Division of Water, Nonpoint Source Section
200 Fair Oaks Lane, Fourth Floor
Frankfort, KY 40601

GROUP A ELEMENTS: PROJECT MANAGEMENT

A1: TITLE AND APPROVAL SHEETS

QUALITY ASSURANCE PROJECT PLAN FOR GUNPOWDER CREEK WATERSHED BASED PLAN

April 12, 2011

Boone County Conservation District

APPROVAL SIGNATURES

Boone County Conservation District:

Title	Name	Signature	Date
Project Manager	Mark Jacobs	Mark Jacobs	4/12/2011
QA Officer	Mary Kathryn Dickerson	Mary Kathryn Dickerson	12 April 2011

Kentucky Division of Water:

Title	Name	Signature	Date
Nonpoint Section Supervisor	Jim Roe	James L. Roe	5/3/2011
QA Officer	Lisa Hicks	Lisa A. Hicks	5/4/11

REVISION HISTORY

Revision No.	Date of Revision	Page(s) Revised	Revision Explanation
Original QAPP	April 12, 2011	All	Addressing KDOW comments from Pre-approved (reviewable) copy of QAPP

A2: Table of Contents

List of Tables

List of Figures

A3: Distribution List

The purpose of a distribution list is to identify all individuals who should receive a signed copy of the approved Quality Assurance Project Plan (QAPP), either in print or electronic format. The personnel listed in Table 1 should also receive any subsequent revisions to the approved QAPP.

Table 1: QAPP Distribution List

Title	Name	Affiliation	Tel. No.	No. of copies
Project Manager	Mark Jacobs markjacobs@nkcd.org	BCCD[a]	859-586-7903	1
Project QA Officer	Mary Kathryn Dickerson mkdickerson@nkcd.org	BCCD[a]	859-586-7903	1
KDOW Nonpoint Section Supervisor	Jim Roe james.roe@ky.gov	KDOW[b]	502-564-3410	1
KDOW QA Officer	Lisa Hicks lisa.hicks@ky.gov	KDOW[b]	502-564-3410	1
Steering Committee Chair	Tom Comte tecomte@fuse.net	BCCD[a]	859-586-9043	1
Project Technical Adviser	Matt Wooten mwooten@sd1.org	SD1[c]	859-578-6887	1
Project Technical Adviser	Mindy Scott mscott@sd1.org	SD1[c]	859-578-6743	1
Project Technical Adviser	Bob Hawley bob.hawley@sustainablestreams.com	Sustainable Streams[d]	502-718-2912	1
Water Chemistry Lab Manager	Antoinette Rucshman Antoinette@cardinallabs.com	Cardinal Labs[e]	859-341-9989	1
Water Chemistry QA Officer	Krista Line krista@cardinallabs.com	Cardinal Labs[e]	859-341-9989	1
Biological Lab Manager	Marcia Wooton mwooton@thirdrockconsultants.com	Third Rock[f]	859-977-2000	1
Biological Lab QA Officer	Bert Remley bremley@thirdrockconsultants.com	Third Rock[f]	859-977-2000	1

[a] Boone County Conservation District, 6028 Camp Ernst Rd., Burlington, KY 41005
[b] Kentucky Division of Water, Nonpoint Source Section, 200 Fair Oaks Lane, Fourth Floor, Frankfort, KY 40601

[c] Sanitation District No. 1, 1045 Eaton Dr., Fort Wright, KY 41017
[d] Sustainable Streams, LLC, 2038 Eastern Parkway #1, Louisville, KY 40204
[e] Cardinal Laboratories, Inc., 104 North Street, Wilder, KY 41071
[f] Third Rock Consultants, LLC., 2526 Regency Rd. #180, Lexington, KY 40503

A4: PROJECT/TASK ORGANIZATION

A project organizational chart allows one to easily identify the roles and responsibilities of key individuals and hierarchically depicts communication lines between individuals/organizations.

The organizational chart for the Gunpowder Watershed Based Plan QAPP is provided below (Figure 1). Although staff/roles may change during a project, it is important to highlight the responsibilities of the most central positions:

- **Project Manager** (Mark Jacobs): A Project Manager (PM) is responsible for all aspects of the project including quality. They must ensure that all data collection/analysis/ management personnel are properly trained in approved QAPP procedures. A PM also serves as the communication hub, keeping the Kentucky Division of Water (KDOW), steering committee, QA Officer, etc. updated on the project. EPA Guidance notes that a PM may play several other roles in a project (e.g. Chemical Data Collection Manager); however, the PM may NOT serve as the QA Officer. Should the QAPP need to be revised during the project, the PM is responsible for updating and distributing the revised QAPP.

- **Project QA Officer** (Mary Kathryn Dickerson): The purpose of a Project Quality Assurance (QA) Officer is to ensure that the QA procedures outlined in the QAPP are being followed throughout the project. Although the QA officer may have other roles in the broader project (e.g. assisting with Watershed Based Plan), it is essential that the QA officer remain independent of data generation, laboratory analysis, and data management. The QA officer may work with QA officers of other organizations such as subcontracted laboratories to ensure QAPP procedures are being followed by other organizations. The QA Officer has the authority to perform any number of field/lab assessments to ensure QAPP compliance. If at any time the QA Officer discovers significant deviations from required procedures or evidence of systematic failure, the QA Officer has the authority to stop all actions, including those conducted by subcontractors. All findings and recommendations for corrective action will be reported to the Project Manager.

- **KDOW Nonpoint Section Supervisor** (Jim Roe): The nonpoint and basin supervisor is the delegated contact for all project activities related to the 319 program. Responsibilities include:

- Reviewing the QAPP for 319 program elements, or designating appropriate representative (technical advisor)
- Approving the QAPP for use in 319 programs
- Approving and/or reviewing submitted data for completeness and applicability

- **KDOW QA Officer** (Lisa Hicks): The Division QA officer is the delegated manager of the routine QA/QC activities that are implemented as part of normal data collection activities. The Division QA officer provides technical support and reviews and approves QA products. Responsibilities include:
  - Reviewing all externally generated QAPPs and coordinating on any planning related to QAPP elements
  - Communicating with EPA Project Officers and EPA QA personnel on issues related to routine sampling and QA activities
  - Understanding EPA monitoring and QA regulations and guidance, and ensuring staff understand and follow these regulations and guidance
  - Understanding Division QA policy and ensuring staff understand and follow the policy
  - Understanding and ensuring adherence to the QAPP
  - Ensuring that all personnel involved in environmental data collection have access to any training or QA information needed to be knowledgeable in QA requirements, protocols, and technology
  - Recommending required management-level corrective actions

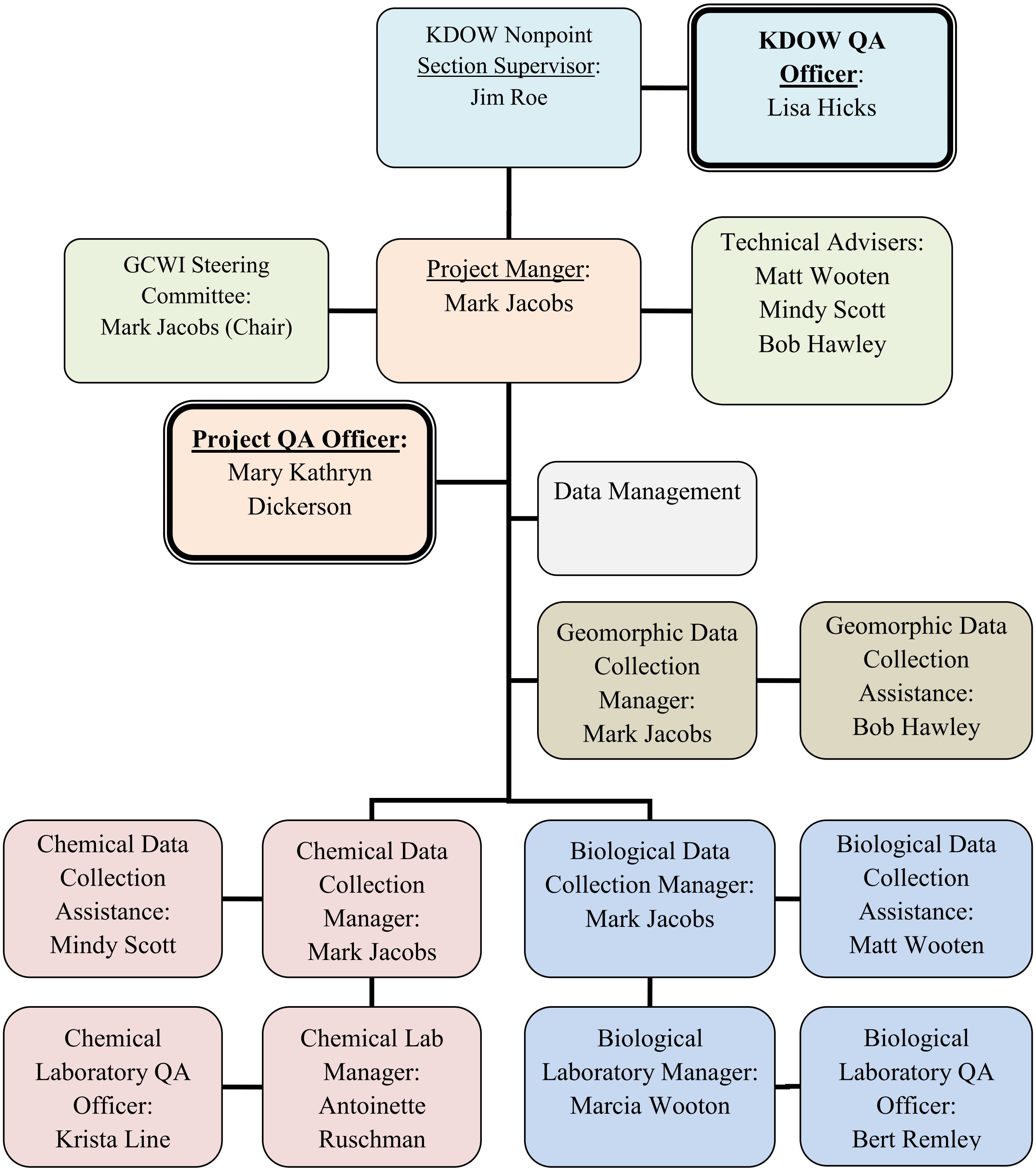

Figure 1: Project Organizational Chart

Central to the success of the overall project is the Gunpowder Creek Watershed Initiative Project Steering Committee (Table 2). The committee is currently chaired by Tom Comte who continues to play an active role in project activities (including the development of this QAPP). The Project Manager and Steering Committee Chair maintain regular communication. The steering committee is regularly updated and asked for feedback during bi-monthly meetings.

Table 2: Gunpowder Creek Watershed Initiative Steering Committee

Name	Affiliation	Tel. No.	Email
Mark Jacobs[a]	Boone Co. Consv. District[b]	859-586-7903	markjacobs@nkcd.org
Steve Divine	N. KY Health Dept. [c]	859-341-4151	Steve.divine@ky.gov
Josh Hunt	City of Florence[d]	859-647-5416	Joshua.hunt@florence-ky.gov
Lajuanda Haight-Maybriar	KY Division of Water[e]	502-564-3410 ext. 4937	Lajuanda.haight-maybriar@ky.gov
Kevin Costello	Boone Co. Planning & Zoning[f]	859-334-9156	kcostello@boonecountyky.org
Greg Sketch	Boone Co. Engineer[g]	(859) 334-3600	gsketch@boonecountyky.org
Yvonne Meichtry	Licking River WW[h]	859-441-9653	ymeichtry@fuse.net
Matt Wooten	Sanitation District No. 1[i]	859-578-6887	mwooten@sd1.org
Donald Chapman	Kenton Co. Airport Board[j]	859-767-7884	dchapman@cvgairport.com
Rick Soper	Boone Co. Consv. District[b]	859-586-7903	N/A
Stacee Hans	KY Dept. Transportation[k]	859-341-2700	Mike.bezold@ky.gov
Mary Kathryn Dickerson	Boone Co. Consv. District[b]	859-586-7903	mkdickerson@nkcd.org

[a] Steering Committee Chairperson
[b] Boone County Conservation District, 6028 Camp Ernst Rd., Burlington, KY 41005
[c] Northern Kentucky District Health Department, 610 Medical Village Dr., Edgewood, KY 41017
[d] City of Florence, 8100 Ewing Blvd., Florence, KY 41042-7588
[e] Kentucky Division of Water, Nonpoint Source Section, 200 Fair Oaks Lane, Fourth Floor, Frankfort, KY 40601
[f] Boone County Planning and Zoning, P.E. Box 958, Burlington, KY 41005
[g] Boone County Engineer, 5645 Idlewild Rd., Burlington, KY 41005-9798
[h] Yvonne Meichtry, Licking River Watershed Watch, 4349 Winters Lane, Cold Springs, KY 41076-9033
[i] Sanitation District No. 1, 1045 Eaton Dr., Fort Wright, KY 41017
[j] Kenton County Airport Board, P.O. Box 752000, Cincinnati, OH 45275
[k] Kentucky Department of Transportation, 421 Buttermilk Pike, Covington, KY 41017

The Boone County Conservation District has contracted with Sustainable Streams, LLC for technical support in developing this QAPP. We have also coordinated with the Licking River Watershed Watch (LRWW), Sanitation District No. 1 (SD1), Thomas More College, Morehead State University, and Kentucky Division of Water (KDOW). This document was informed by EPA (2002a) and KDOW (2010a) guidance, along with QAPPs being used in regional watersheds such as the KDOW-approved QAPP of the neighboring Banklick Creek Watershed

(BWC, 2005) and the draft QAPP of SD1 (2010). A list of potential technical and outreach advisers is provided below (Table 3), along with potential project stakeholders who are also critical for overall project success.

Table 3: Potential Technical Advisers and Stakeholders in the Gunpowder Creek Watershed

Potential Technical Advisers	Potential Stakeholders
1. Kentucky Division of Forestry	1. City of Union
2. Kentucky Department of Fish and Wildlife Resources	2. Northern Kentucky Flyfishers
3. Kentucky Division of Water	3. Hunting and Fishing Clubs
4. Boone County Water District	4. Sierra Club Water Sentinels
5. Natural Resources Conservation Service	5. Northern Kentucky Home Builders Association
6. NKU – Center for Applied Ecology	6. Northern Kentucky Cattle Association
7. Northern Kentucky University	7. Northern Kentucky Horse Network
8. Thomas More College	8. Boone County Farm Bureau
9. University of Kentucky Cooperative Extension Service	9. Boone Conservancy
10. SD1	10. Northern Kentucky Chamber of Commerce
11. Sustainable Streams, LLC	11. Boone County Businessmen's Association
	12. Boone County Public Schools
	13. Boone County Public Library
	14. Boone County Emergency Management – Hazmat Team
	15. Boone County Local Emergency Planning Committee
	16. Citizens of the watershed

Finally, field data collection, laboratory analysis, and data management will be carried out in accordance with the QA procedures outlined herein, regardless of the individual(s) filling those roles. Specific individuals for these roles are unknown at this time.

A5: Problem Definition and Background

The Gunpowder Creek Watershed is located in Boone County (Figure 2), which is Kentucky's second fastest growing county and one of the top 100 in the nation (Census, 2009). From 2000 to 2009, county population was estimated to increase by 38% to 118,576 (Census, 2010). Correspondingly, housing units increased by 35% to 45,043 units from 2000 to 2008 (Census, 2010). This does not take into account commercial development during the same period.

According to Mr. Steve Gay, Director of Boone County GIS Services, approximately 23,680 of these housing units (53% of total) reside in the actual watershed with an estimated population of 59,484 (Pers. Comm., 2009). Mr. Robert Jonas, Boone County GIS Specialist, notes that an additional 12,129 housing units have been approved but not yet built (Pers. Comm., 2009) and municipal plans include commercial development in the watershed, such as the City of Union's ―Union Town Plan."

Threats to the water quality of Gunpowder Creek are growing at a rapid pace as Boone County continues to develop. Nonpoint source pollution, due to hydromodification, habitat alteration, and sedimentation, is thought to be the leading cause of impairments in the watershed. Historic land uses such as agriculture also impact the lower portions of the watershed. The Greater Cincinnati/ Northern Kentucky International Airport has a separate TMDL for ethylene glycol. Most of the upper reaches of the watershed have been developed. Development in the county continues to push south and west across the watershed.

Significant impairments have already been identified in the Upper Gunpowder Creek Watershed. The Northern Kentucky/Greater Cincinnati International Airport was identified as a major source of pollution from de-icing operations and has taken mitigating steps in accordance with the approved TMDL developed to address ethylene glycol (KDOW, 1998). Additional TMDLs are under development by KDOW for other pollutants they have assessed and listed as causes of impairments in the creek and its tributaries (Table 4). These are sedimentation/siltation, nutrient/ eutrophication biological indicators, organic enrichment (sewage) biological indicators, and fecal coliform (KDOW, 2008).

These impairments are related to Boone County's rapid growth over the past decade and an increase in storm water runoff. The county will likely continue to grow for the foreseeable future. As a result, the threat to the Gunpowder Creek watershed from nonpoint source pollution will continue to grow. Based on the evidence of this growing threat, it is important that a more clear understanding of the situation facing the watershed be obtained. We intend to do this through the data collection and analysis outlined in this QAPP, which includes a phased approach to monitoring of water chemistry and biological parameters as specified in the KDOW (2010) Guidebook. Because hydromodification (via urban development) is a great concern in this watershed, we also include geomorphic monitoring that is tailored to capture this impairment. All of the data collection and analysis will be in support of developing a Watershed Based Plan (WBP) that will be funded in part through this grant project. .

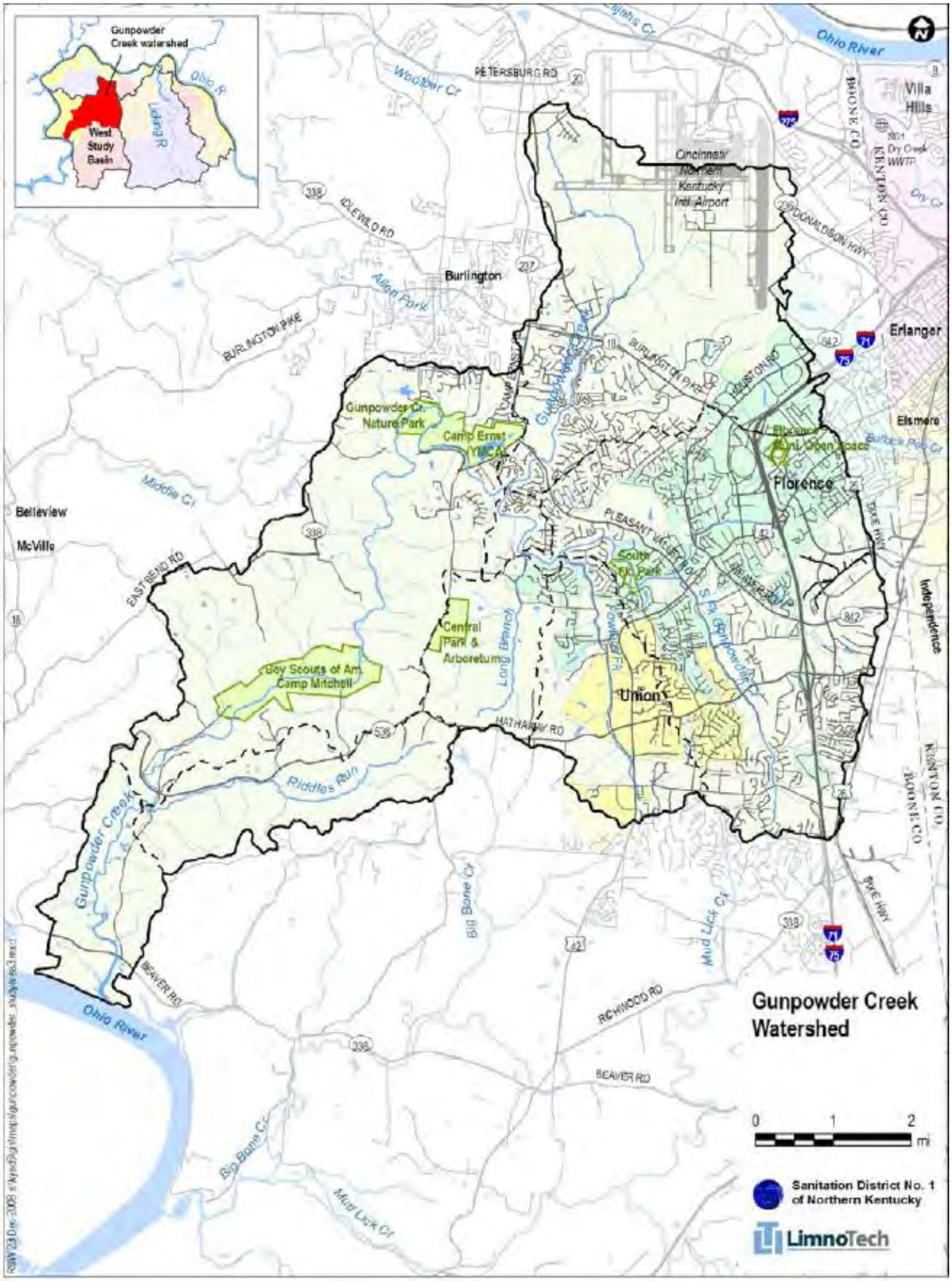

Figure 2: Gunpowder Creek Watershed (LimnoTech, 2009)

Table 4: 303(d)-listed Waterbodies (KDOW, 2008)

Waterbody Segment	Designated uses (Use Support)	Pollutants	Suspected Sources
Gunpowder Ck. RM 0.0 – 15.0	Warm -water Aquatic Habitat (Not supporting)	Sedimentation/siltation	Site Clearance (Land development or redevelopment)
Gunpowder Ck. RM 15.4 – 17.1	Warm -water Aquatic Habitat (Not Supporting)	Sedimentation/siltation; Nutrient/Eutrophication biological indicators Organic enrichment (sewage) biological indicators	Agriculture, Unspecified urban storm water, Streambank modifications/ destabilization, Site clearance (land development or redevelopment), Loss of riparian habitat, Highway/road/bridge runoff (non-construction related)
Gunpowder Ck. RM 18.9 – 21.6	Warm -water Aquatic Habitat (Partially Supporting)	Unknown	Unspecified urban storm water
South Fork Gunpowder Ck. RM 0.0 – 2.0	Warm -water Aquatic Habitat (Not Supporting)	Sedimentation/siltation Turbidity Nutrient/Eutrophication biological indicators Organic enrichment (sewage) biological indicators	Agriculture, Package plant or other permitted small flows discharges, Post-development erosion and sedimentation, Site clearance (land development or redevelopment)
South Fork Gunpowder Ck. RM 4.1 – 6.8	Primary Contact Recreation (Not Supporting)	Fecal coliform	Source unknown

A6: Project/Task Description

The goal of the Gunpowder Creek Watershed Initiative (GCWI) is to improve and/or maintain water quality in the Gunpowder Creek watershed through development of a KDOW-approved WBP. Once the plan is complete and a clearer understanding of the issues facing the watershed is known, appropriate management strategies to mitigate nonpoint source pollution can be identified and selected based on available future funding. Implementation of best management practices (BMPs) will be dictated by the WBP with the goal of making measurable improvements toward water quality standards, such as meeting the designated uses in the watershed of primary contact recreation and warm water aquatic habitat.

Project activities will revolve around meeting EPA's nine criteria (*a – i*) of a WBP (EPA, 2008). Overall project milestones are provided for reference (Table 5); however, the remainder of this document focuses on *criterion a*: *identification of causes of impairments and pollutant sources*.

Table 5: Grant Milestones for the Gunpowder Watershed Initiative

	Milestones	Expected Begin Date		Expected Completion Date	
		Original	Revised	Original	Revised
1	Form Initial Watershed Steering Committee			11/08	
2	Collect water quality related studies from partners	11/08		5/10	
3	Review and assess existing water quality data; identify gaps & develop plan to fill data gaps	11/09		7/10	
4	Submit and obtain QAPP approval from KDOW	5/10		11/10	4/11
5	Develop and submit to NPS staff outreach /educational program materials for approval	3/10		11/13	
6	Submit schedule of outreach/education programs to KDOW	3/10		12/13	
7	Submit advance written notice to KDOW NPS program staff for community meetings and outreach/education events	7/10		12/13	
8	Hold annual community meetings	7/10		12/13	
9	Identify and select needed technical assistance for WBP development	11/10		12/11	
10	Collect water quality data and physical data to fill data gaps	2/10	4/11	12/11	12/12
11	Select tools/models for data analysis	11/09		12/11	12/12
12	Analyze data using approved tools/models	6/10	10/11	5/12	3/13
13	Calculate current pollutant loads	6/10	1/13	10/12	3/13
14	Submit watershed data analysis report including source information, and load calculations to KDOW for review and approval	10/12	1/13	2/13	4/13
15	Estimate load reductions needed and identify, estimate costs of and prioritize needed management measures	2/13		5/13	
16	Identify criteria to determine if load reductions are being achieved and develop a monitoring strategy to evaluate the effectiveness of recommended BMPs, and submit to KDOW for review and approval	2/13		5/13	
17	Develop management measures implementation schedule	7/13		8/13	

Milestones		Expected Begin Date		Expected Completion Date	
		Original	Revised	Original	Revised
18	Submit WBP to NPS Staff for review and approval; incorporate changes suggested	9/13		11/13	
19	Submit WBP to KDOW for final approval	11/13		12/13	
20	Submit 1st Annual Report	10/10		12/10	
21	Submit 2nd Annual Report	10/11		12/11	
22	Submit 3rd Annual Report	10/12		12/12	
23	Submit 4th Annual Report	10/13		12/13	

As seen in Table 5 (Milestones 2 and 3) one of our first tasks was to acquire water quality data that already exists in the Gunpowder Watershed, and subsequently determine what additional data are needed. SD1 has an abundance of data at numerous locations throughout the watershed—all of which have been collected using standard procedures and quality assurance measures that are consistent with those outlined in this QAPP. Five SD1sites that are frequently sampled and spatially distributed in locations that are most consistent with the Phase 1 monitoring guidelines highlighted in KDOW‘s (2010) Guidebook are indicated by the blue circles in Figure 3. Given that hydromodification due to urban development is a major concern in the watershed, SD1 has also undertaken over three years of fluvial geomorphic monitoring at seven sites in the watershed. LRWW has performed historical monitoring at several sites throughout the watershed and, through a grant from SD1, is planning on conducting water chemistry and biological sampling at six key sites, which is intended to fill the remaining gaps at the HUC14 (Phase 1) level. The monitoring locations are summarized in Figure 3 and Table 6, with a breakdown of the Phase 1 monitoring provided in Table 7.

Table 6: Phase 1 Sampling Locations and Site Names

Site Name (Stream & River Mile)	**Stream Name**	**Site Location** (Decimal Degrees)	
		Latitude	**Longitude**
GPC 4.6	Gunpowder Creek	38.933752	-84.789426
GPC 7.5	Gunpowder Creek	38.954653	-84.745833
GPC 14.7	Gunpowder Creek	38.994638	-84.716271
GPC 17.9	Gunpowder Creek	39.015753	-84.687930
GPC 17.1 - UNT 0.1	Unnamed Tributary to Gunpowder Creek	39.005020	-84.689940
SFG 2.6	South Fork of Gunpowder Creek	38.981674	-84.684500
SFG 5.3 - DS	South Fork of Gunpowder Creek	38.961638	-84.657351
SFG 5.3 - US	South Fork of Gunpowder Creek	38.960377	-84.656824
SFG 5.3 - UNT 0.3	Unnamed Tributary to South Fork of Gunpowder Creek	38.961213	-84.656198
FWF 0.8	Fowlers Fork	38.972779	-84.686212
LDB 0.5	Long Branch	38.972507	-84.703982
RDR 1.1	Riddles Run	38.934208	-84.778223

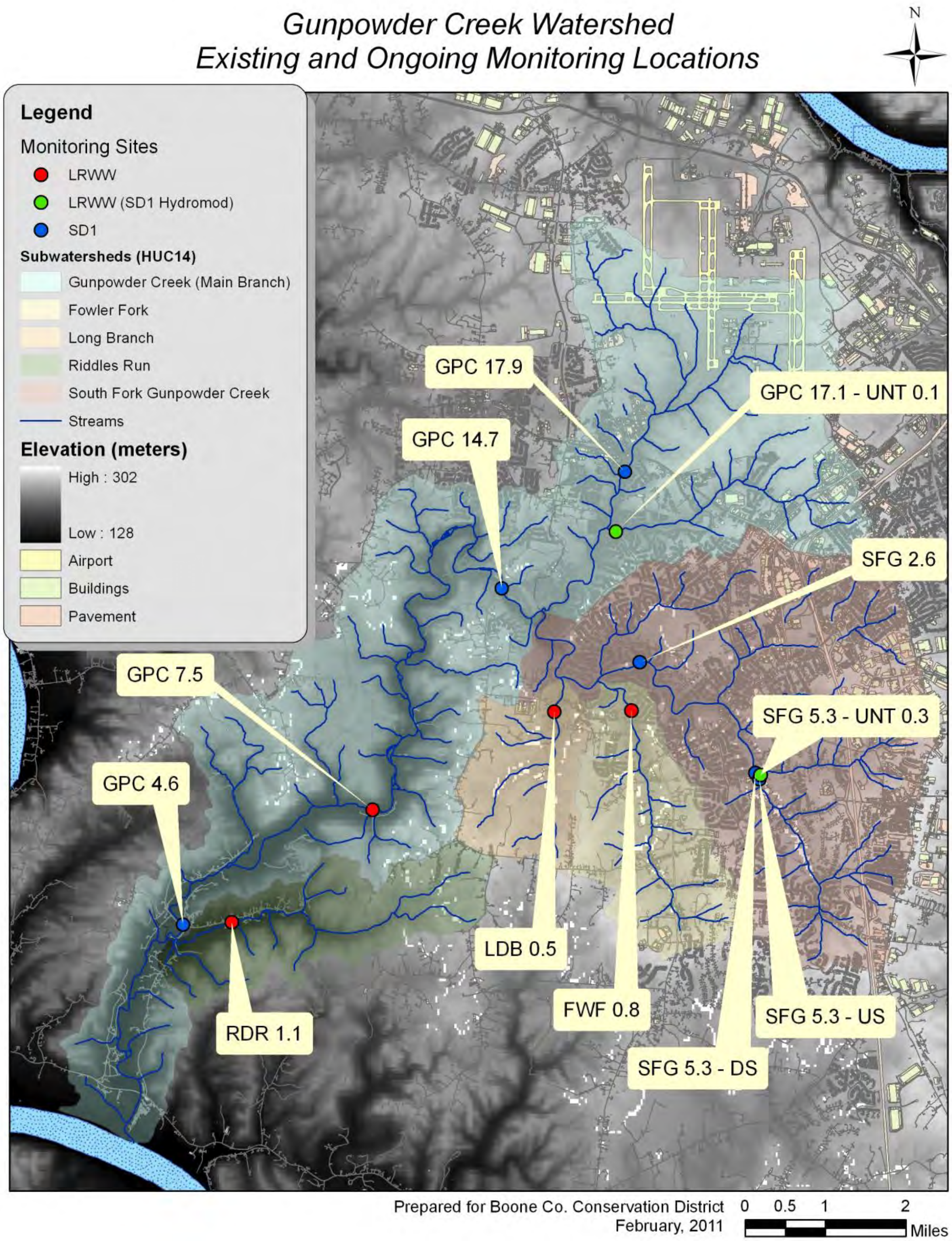

Figure 3: Existing and Ongoing Monitoring Locations in the Gunpowder Creek Watershed

Table 7: Summary of Existing and Proposed Monitoring for Phase 1 Sampling

	Water Chemistry		Biological		Geomorphic	
Phase I Sites[(a)]	Existing	Proposed[(b)]	Existing	Proposed[(c)]	Existing	Proposed[(d)]
GPC 4.6	SD1	SD1	SD1		SD1	
GPC 7.5	LRWW	LRWW		LRWW		BCCD
GPC 14.7	SD1	SD1	SD1		SD1	
GPC 17.9	SD1	SD1	SD1		SD1	
GPC 17.1 - UNT 0.1		LRWW		LRWW	SD1	
SFG 2.6	SD1	SD1	SD1		SD1	
SFG 5.3 - DS	SD1	SD1			SD1	
SFG 5.3 - US			SD1		SD1	
SFG 5.3 - UNT 0.3		LRWW		LRWW	SD1	
FWF 0.8	LRWW	LRWW		LRWW		BCCD
LDB 0.5	LRWW	LRWW		LRWW		BCCD
RDR 1.1	LRWW	LRWW		LRWW		BCCD

[(a)]Phase I monitoring locations are distributed in accordance with the KDOW (2010) Guidebook for WBPs, capturing the downstream reach of all HUC 14 watersheds. After completion of the Phase I monitoring and analysis, Phase II sites will be selected to target upstream reaches in priority subwatersheds

[(b)]Proposed water chemistry sampling includes ongoing dry and wet-weather sampling during the recreational contact season by SD1 with frequencies and parameters designed to inform SD1's ongoing watershed based planning process. LRWW sampling will be performed by students under the supervision of Dr. Chris Lorentz of Thomas More College, with field management by Mark Jacobs of BCCD. They will follow procedures outlined in this QAPP and their sampling frequencies and parameters will be guided by their grant budget.

[(c)]Proposed biological sampling will be conducted by LRWW for fish and macroinvertebrates, performed by students under the supervision of Dr. Chris Lorentz of Thomas More College, with field management by Mark Jacobs (BCCD) and field assistance from Matt Wooten of SD1. They will follow procedures outlined in this QAPP and their sampling frequencies and parameters will be guided by their grant budget.

[(d)]Proposed geomorphic monitoring is designed to monitor channel instabilities (e.g. bank and bed erosion) in response to watershed urbanization (i.e. 'hydromodification'). It will be performed by Mark Jacobs (BCCD) and Dr. Bob Hawley (Sustainable Streams) according to the frequency and procedures outlined in this QAPP (which are identical to SD1's geomorphic data collection SOP for regional comparability). In summary, it includes geometric surveys of channel cross sections and profiles as well as bed material pebble counts collected at each proposed location in this year and then repeated at each site during the following year to capture changes in the channel form and bed material. Among other things, the monitoring will be used to develop loads of fine sediment from channel banks as well as directly inform BMP recommendations in the WBP

.It is important to note that although this grant was awarded prior to the release of the KDOW (2010c) Guidelines, the GCWI will make every effort to meet the KDOW sampling goals to the extent possible within confines of the GCWI scope and budget. All agencies and partners recognize the same broad goal of improved water quality of the Gunpowder Creek Watershed.

With additional sampling planned by both SD1 and LRWW, the GCWI plans to continue to collaborate with their regional partners to realize the best usage of monitoring funds for this grant project. After completion of the 2011 sampling season by SD1 and LRWW, we will perform a thorough analysis of the Phase 1 data to identify priority subwatersheds to target in the Phase 2 sampling year (expected to take place 1/2012 – 12/2012). We understand that this depends on coordination with TMDL Staff at KDOW and their subsequent approval of the Phase 2 locations. Therefore, we will plan to meet with KDOW in November/December 2011 to share Phase 1 results from our project partners and arrive at agreed upon Phase 2 sampling locations.

In general, we anticipate sampling in four categories: water quality (chemical), hydrologic (flow), biologic, and geomorphic sampling (Table 8), all of which will be collected in accordance with the QA procedures presented herein.

Table 8: Proposed GCWI Sampling Categories

Category	Sub-Category	Parameter	Reference
Water quality (Chemical)	Bacteria	E. coli (Escherichia coli)	SM9223 B
	Nutrients	NO_3/NO_2 (Nitrate-Nitrite)	EPA 353.2
		NH_3-N (Ammonia-Nitrogen)	SM4500NH3 D
		TKN (Total Kjeldahl Nitrogen)	EPA 351.2
		TP (Total Phosphorus)	EPA 365.1
		OP (Orthophosphate)	EPA 365.3
		CBOD5 (5-day Carbonaceous Biochemical Oxygen Demand)	HACH 10230
	Sediment	TSS (Total Suspended Sediment)	SM2540 D
	Field Data	Turbidity (actual or estimated)	
		pH (Hydronium Ions/Acidity)	
		DO (Dissolved Oxygen)	
		Conductivity (Ionic Content/ TSS)	
		% Saturation (Percentage of DO)	
		Temperature	
Hydrologic	Flow	Volumetric Stream Discharge Rate	(KDOW, 2010b)
Biological	Macroinvertebrates	Taxonomic Identification (lab)	(KDOW, 2009)
	Fish	Taxonomic Identification (field)	(SD1, 2007)
	Habitat	Rapid Bioassessment Protocol	(Barbour et al., 1999)
Geomorphic	Geometric	cross-section and profile surveys	(Harrelson et al., 1994)
	Bed material	pebble counts	(Bunte and Abt, 2001a; 2001b)

A7: Quality Objectives and Criteria

The primary goal of the QAPP is to ensure that the data generated for this project using 319(h) grant funds meet the standards required by KDOW and be usable for this project. Field and lab personnel will follow standard operating procedures (SOP) for sampling and laboratory analyses. Quality objectives and criteria (Table 9) will include a range of Data Quality Indicators (DQIs) for the various sample types.

Table 9: Data Quality Indicators by Sample Type

Sample Type	Precision	Bias	Accuracy	Representativeness	Comparability	Completeness	Sensitivity
Water quality (Chemical)	✓	✓	✓	✓	✓	✓	✓
Hydrologic	✓				✓		✓
Biological	✓			✓	✓	✓	
Geomorphic	✓	✓		✓	✓	✓	

A7.1 – Precision:

Precision is the measure of agreement among repeated measurements (or split samples) under the same/similar conditions (EPA, 2002a). It can be expressed as an absolute measure or the Relative Percent Difference (RPD) between the measurements or replicate/duplicate samples. Precision objectives (Table 10) are summarized below.

Table 10: Precision Objectives by Sample Sub-Category

Category	Sub-Category	Parameter	Field Precision (RPD)		Analytical Precision (RPD)	
			Objective	Method	Objective	Method
Water quality (Chemical)	Bacteria	E. coli	50%	Field Duplicate	40%	Lab Replicate
	Nutrients	NO_3/NO_2	30%	Field Duplicate	20%	Lab Replicate
		NH_3-N	30%	Field Duplicate	20%	Lab Replicate
		TKN	30%	Field Duplicate	20%	Lab Replicate
		TP	30%	Field Duplicate	20%	Lab Replicate
		OP	30%	Field Duplicate	20%	Lab Replicate
		CBOD5	40%	Field Duplicate	20%	Lab Replicate
	Sediment	TSS	30%	Field Duplicate	20%	Lab Replicate
	Field Data	Turbidity pH DO Conductivity % Saturation Temperature	10%	Repeat Reading	N/A	
Hydrologic	Flow	Discharge	10%	Repeat Reading	N/A	
Biological	Macros	Taxa. ID (lab)	N/A		95%	Repeat ID
	Fish	Taxa. ID (field)	95%	Repeat ID	N/A	
Geomorphic	Geometric	cross-section survey	0.5 ft (vert.) 2.0 ft (horz.)	Absolute Diff. Rebar to Rebar[(a)]	N/A	
	Bed material	pebble count	± ½ phi size	Repeat Measurement	N/A	

[(a)]Absolute difference at rebar monuments during annually repeated level-tape survey

Water Quality (Chemical)

Precision of water chemistry samples will be estimated via a combination of laboratory replicates and repeated field measurements. Precision of split samples (lab replicates) and field duplicates will be estimated by RPD using the following equation:

$$RPD = \frac{(C_a - C_b)}{\frac{(C_a + C_b)}{2}} \times 100\%$$

Where: C_a = Measured concentration of sample

C_b = Measured concentration of replicate sample

Precision of field data measurements (pH, temp, etc.) will be checked via repeated measurements by independent samplers and estimated using RPD. Water chemistry precision procedures (lab replicates, field duplicates, and repeat field readings) will be performed a minimum of once per event for each parameter. Specifically regarding field duplicates, they will be collected once per event for each parameter at a minimum of 10% of the sampling locations (i.e. one (1) out of every ten (10) locations). For grab samples, field duplicates are defined as two samples of equal volume that are collected simultaneously from the same location at the same time. For bucket and/or churn splitter samples, field duplicates are equal volumes filled from the same bucket/churn splitter sample.

For E. coli samples, KDOW requires field blanks to evaluate contamination levels from ambient conditions, sample containers, or sample storage containers. For grab samples, this means filling an E. coli sample bottle with deionized water and keeping the lid open an equal length of time as the actual sample is exposed to the atmosphere. If using buckets and/or churn splitters, rinsate blanks are required to determine potential contamination from the buckets/churns. A rinsate blank is an E. coli sample bottle that is filled with deionized water that was first passed through the bucket and/or churn splitter. Field blanks (and rinsate blanks if using buckets/churns) will be collected once per event for E. coli samples at 10% of the sampling locations.

Hydrologic

Precision of flow measurements will be estimated by repeat field measurements by a second observer at least once per sampling event.

Biological

Taxonomic precision will be estimated using repeated taxonomic identification by an independent taxonomist. The precision objective is for 95% agreement among all repeated identifications. If taxonomic precision falls below 95% agreement, all samples in the sample group will be re-identified. A third taxonomist will reconcile identification differences.

Geomorphic

Geometric survey precision will be estimated at each cross section (i.e. site) by comparing horizontal and vertical differences observed at the rebar monuments between sample years (i.e. annually repeated surveys). Absolute errors will be kept to ±0.5 ft and ±2.0 ft in the vertical and lateral dimensions, respectively. Standardized errors (by dividing by the length of the cross section) shall be kept ≤ 0.01 ft/ft (vertical) and ≤ 0.025 ft/ft (horizontal). If errors are observed greater than this range, an independent survey between rebar monuments will be performed to estimate which survey year was most accurate.

Bed material precision will be tested through repeated measurements of individual pebbles by a second observer. The objective is for size estimates not to vary by more than ½ phi size on the US SAH-97 (or equivalent) aluminum half-phi template. If a repeated sample varies by greater than ½ phi size, the entire pebble count will be repeated.

A7.2 – Bias:

Bias is the systematic deviation of measured values in one direction (EPA, 2002a). Bias can be tested by comparing replicate data and/or repeated measurements. If regular deviation occurs between replicate/repeat data, skewness will be estimated to determine if the bias is statistically significant. Statistically significant biased data will either be corrected or discarded.

A7.3 – Accuracy:

Accuracy describes how close a measurement is to a known value (EPA, 2002a). Quality objectives for biological and geomorphic metrics are more appropriately classified as precision objectives; however, accuracy in water chemistry laboratory analysis can be estimated using matrix spikes. A matrix spike is when a reference sample of known concentration is added to a field sample and reanalyzed. Accuracy is assessed by estimating the Percent Recovery using the equation below:

$$\%R = \frac{(C_S - C_U)}{C_A} \times 100\%$$

Where: C_S = Measured concentration of spiked sample

C_U = Measured concentration of unspiked sample

C_A = Actual concentration of added spike

For water chemistry samples, the accuracy objective for matrix spikes is a percent recovery of 80 – 120%.

Control samples and laboratory blanks are other methods of assessing accuracy. Laboratory blanks are particularly employed for bacteria (E. coli) analyses and assessed via a presence/absence criteria. Control samples for non-bacteria parameters are assessed via Percent Recovery using the following equation:

$$\%R = \frac{C_M}{C_C} \times 100\%$$

Where: C_M = Measured concentration of control sample

C_C = Actual concentration of control sample

For E. coli samples, the accuracy objective for laboratory control samples is to correctly classify the presence/absence of E. coli in the control sample. Regarding Percent Recovery of non-bacteria control samples that will be used for other water chemistry suites, the accuracy objective is 80 – 120% recovery. The accuracy objectives are summarized below (Table 11).

Table 11: Accuracy Objectives for Water Quality (Chemistry) Laboratory Analyses

Sub-Category	Parameter	Objective	Method
Bacteria	E. coli	Presence/Absence	Laboratory Control Sample
Nutrients	NO_3/NO_2	80-120% Recovery	Laboratory Control Sample/ Matrix Spike
	NH_3-N	80-120% Recovery	Laboratory Control Sample/ Matrix Spike
	TKN	80-120% Recovery	Laboratory Control Sample/ Matrix Spike
	TP	80-120% Recovery	Laboratory Control Sample/ Matrix Spike
	OP	80-120% Recovery	Laboratory Control Sample/ Matrix Spike
	CBOD5	80-120% Recovery	Laboratory Control Sample
Sediment	TSS	80-120% Recovery	Laboratory Control Sample

A7.4 – Representativeness:

Representativeness is the degree to which data accurately and precisely represent a characteristic of a population, variability at a sampling location, and conditions of the environment/process being measured (EPA, 2002a). Sample sites are representative if they encompass a range of conditions that is characteristic of the region being studied. In the case of the Gunpowder Watershed, the key gradient to capturing nonpoint source pollution is representing the range of landuse conditions that result in nonpoint source runoff (e.g. agricultural, urban, suburban) versus more of a reference watershed such as forest or prairie. By locating sample sites near the mouths of all major tributaries (Figure 3), we capture the full range of sub-watershed landuse conditions from undeveloped to fully developed (Figure 2).

Additionally, water chemistry sampling is representative if it is collected across a gradient of runoff conditions. We achieve this by targeting a mix of dry and wet-weather sampling events.

A7.5 – Comparability:

Comparability is the degree to which data collected in this study can be compared with other data across the region (EPA, 2002a). This is ensured by following standard sampling procedures, handling methods, etc. Standard procedures for water chemistry, biological, and hydrologic sampling are well established (Table 8). As geomorphic sampling has been less common in water quality projects, the employed procedures have been more variable.

Particularly in regards to the nonpoint source issue of hydromodification, geomorphic monitoring is designed to capture the physical responses of streams to the altered (developed) flow regime relative to the natural variability observed in undeveloped basins. For example, what types of bed degradation and bank erosion rates are evident in urban basins versus forested basins? Methods used to characterize such change have included quantifiable measurements using bank pins (Rosgen, 2001) and repeated cross-section surveys (Dunne and Leopold, 1978; Henshaw and Booth, 2000) and more qualitative assessments via ‗expert' judgment (e.g. Johnson et al., 1999; Pfankuch, 1978; Rosgen, 2007; Simon and Downs, 1995).

Recognizing that quantifiable methods tend to transfer better across different users and agencies, a recent literature review determined that spatially-integrated cross sections and profiles with accompanying pebble counts provided optimum value and precision for capturing the multidimensional effects of hydromodification (Bledsoe et al., 2008; Hawley, 2009). In this light, the Standard Operating Procedure (SOP) of SD1 (2009) entails 100-particle pebble counts after Bunte and Abt (2001a; 2001b) and cross-section and profile surveys after Harrelson *et al.* (1994). For comparability with prior and ongoing SD1 data, we will collect geomorphic data using comparable methods.

A7.6 – Completeness:

Completeness is the amount of usable data acquired compared to the amount of data that was expected from a monitoring plan (EPA, 2002a). Events which may contribute to data being unusable include access/safety issues, sampling container problems, equipment failures, holding time exceedances, sample sorting/damage, noncompliant QA/QC, etc. This project does not have statistical criteria that require a specific degree of completeness; however, our completeness objective is to have 90% of all collected data to be usable.

A7.7 – Sensitivity:

Sensitivity refers to the capacity of a method or instrument to discern different levels of the variable of interest (EPA, 2002a). This is typically referred to as a method/instrument detection limit or a laboratory quantification limit. That is, at what concentration is a pollutant so trace that it becomes undetectable by an instrument and/or differences between sample concentrations indiscernible. Pollutant levels of concern for this project are well above detection limits of industry standard equipment and methods. Depending on what equipment is available to GCWI, detection limits of industry standard equipment is provided below (Table 12).

Table 12: Specification Limits of Industry Standard Equipment and Detection Limits

(a) Field

Parameter	Instrument	Range	Accuracy	Resolution
Temperature	Hydrolab	-5 to 50°C	±0.10°C	0.01°C
	YSI	-5 to 45°C	±0.15°C	0.01°C
pH	Hydrolab	0 to 14 units	±0.2 units	0.01 units
	YSI	0 to 14 units	±0.2 units	0.01 units
Dissolved Oxygen	Hydrolab	0 to 20 mg/L	±0.2 mg/L	0.01 mg/L
	YSI	0 to 20 mg/L	±0.2 mg/L	0.01 mg/L
Conductivity	Hydrolab	0 to 1,000 µS/cm	±0.5% of range	4 digits
	YSI	0 to 1,000 µS/cm	±1% of range	4 digits
Flow	Marsh-McBirney	-0.5 to +20 ft/sec	±2% of reading	±0.05 ft/sec

(b) Laboratory

Sub-Category	Parameter	Reference Method	Reporting Limit	Standard Analytical Procedure (SAP)
Bacteria	E. coli[(a)]	SM9223 B	4-10 MPN/100 mL	Micro 013
Nutrients	NO_3/NO_2	EPA 353.2	0.013 mg/L	Inorg 045
	NH_3-N	SM4500NH3 D	0.03 mg/L	Inorg 018
	TKN	EPA 351.2	0.144 mg/L	Inorg 040
	TP	EPA 365.1	0.01 mg/L	Inorg 041
	OP[(b)]	EPA 365.3	0.007 mg/L	Inorg 013
	CBOD5[(c)]	HACH 10230	2 mg/L	Inorg 014
Sediment	TSS	SM2540 D	1 mg/L	Inorg 007

[(a)]E. coli depends on dilution range (ND on 25 mL max = <4 MPN/100 mL; ND on 10 mL max = < 10 MPN/100 mL)

[(b)]Orthophosphate should be field filtered with 0.45 µm membrane filter

[(c)]5-day Biochemical Oxygen Demand values below current MDL (4.6 mg/L) will be reported as an estimate with J Qualifier

A8: Special Training/Certifications

The GCWI includes steering committee members and project partners that cover a broad range of expertise across all sampling categories with both professional and academic training. This includes:

- Water quality (chemical): Mary Kathryn Dickerson, Mark Jacobs, and Tom Comte (BCCD); Dr. Yvonne Meichtry (LRWW); Lajuanda Haight-Maybriar (KDOW); Mindy Scott and Matt Wooten (SD1); Chris Lorentz (Thomas More); and Bob Hawley (Sustainable Streams)
- Hydrologic: Mindy Scott, Matt Wooten; Scott Fennell (NKU), and Bob Hawley
- Biological: Mary Kathryn Dickerson, Dr. Yvonne Meichtry, Matt Wooten; Scott Fennell, and Chris Lorentz
- Geomorphic: Matt Wooten; Scott Fennell, and Bob Hawley

Sampling technicians and managers will be trained in their respective water quality, hydrologic, biological, and geomorphic sampling procedures described herein (Section B2). Experienced sampling personnel will direct the training and training records will be stored by BCCD and/or their contracted consultants and/or partner agencies where applicable. Laboratories conducting analytical work should have appropriate certifications including:

- Water quality (chemical) laboratory: <u>recommended to have at least one of the following</u>
    - **KY Micro**: Commonwealth of Kentucky Energy and Environment Cabinet Drinking Water Laboratory Certification Program
    - **NELAC**: National Environmental Laboratory Accreditation Conference (Non-profit institute that manages the National Environmental Laboratory Accreditation Program, NELAP)
    - **A2LA**: American Association for Laboratory Accreditation
- Taxonomic Identification (biological) laboratory:
    - **NABS**: North American Benthological Society Taxonomic Certification

A9: Documentation and Records

Data management is discussed in detail in Section B10. Documents and records are described in the subsections below.

A9.1 – Field Documentation and Records

Field data will be collected on paper forms, sample labels, and/or field books. Chain of Custody (COC) sheets will accompany samples to receiving laboratories and returned to BCCD following analysis. Information on sample labels will be entered into electronic databases by the receiving laboratories. Data from field books and forms will be entered into electronic databases at the office. Original paper copies of COC sheets, field forms and field books will be kept by BCCD for no less than five years. At a minimum, field sampling technicians will record the following for each sample:

- Site name/location
- Initials of field technicians
- Date and time of sample

Field books for geomorphic data collection will be used for site sketches, level-tape surveys, and bed material pebble counts (Figure 11).

A9.2 – Laboratory Documentation and Records

Samples requiring laboratory analysis will be delivered to receiving laboratories accompanied by COC sheets. Laboratories will retain COC sheets during their analyses and return them to BCCD upon analytical completion for storage. Information on sample labels will be entered into electronic databases by the receiving laboratories. Analytical results will be summarized via an electronic database and reported to BCCD. The analytical database will include a minimum of the following:

- Sample collection date and time
- Date and time sample was received
- Date and time of sample analysis
- Sample name and location
- Analysis name and method
- Analysis result
- Analysis reporting limit
- Analyst initials performing analysis
- Laboratory QA/QC results/summary

Turnaround times for water chemistry and macroinvertebrate laboratory analysis are expected to be approximately 3 weeks and 30 days, respectively.

A9.3 – QA Reports

Should revisions to this QAPP be determined necessary, the QA Officer and Project Manager will work with the KDOW Project Manager and QA Officer to revise the QAPP. After revisions are approved by KDOW, the Project Manager (Mark Jacobs) will distribute revised copies according to the distribution list (Table 1) and ensure that all project personnel are made aware of the necessary changes (Figure 1). Upon receiving revised QAPP documents, recipients will be instructed to discard older versions (both electronic and hard copies).

A9.4 – Final Reports

Sampling results will be stored in electronic databases (i.e. M.S. Excel) and stored throughout the project at a minimum of two locations. One of the locations will be BCCD and the other location will be a project stakeholder (e.g. SD1). Final results will be summarized in the project‘s technical report (i.e. Data Analysis Report). Selected results and summaries will also be included in the project‘s final report (i.e. Watershed Based Plan). The final QA‘d version of the database will be stored at a minimum of two locations for a period of no less than ten years. The final project database will also be available to the public and partner agencies upon request (e.g. SD1). It will also be submitted to KDOW in an Excel format that is agreeable to both BCCD and KDOW. All original electronic sampling results will be retained by BCCD and at least one project stakeholder (e.g. SD1) for no less than ten (10) years.

A9.5 – Reports and Deliverables to KDOW

We call out a separate sub-section of specific deliverables for KDOW. They include:

- Quality Assurance Evaluation Report (QER): due at the end of the first data collection for each sampling type (e.g. water chemistry, biological, etc.), or whenever requested by KDOW. KDOW will provide template/example for this report.
- Raw data (in the form of field sheets and calibration records): requested randomly by KDOW and/or at the end of data collection
- Progress reports: due at time of invoicing or an otherwise agreed upon schedule
- Final data in Excel format: specific spreadsheet format to be agreeable to both BCCD and KDOW

GROUP B ELEMENTS: DATA GENERATION AND ACQUISITION

B1: SAMPLING PROCESS DESIGN (EXPERIMENTAL DESIGN)

The first step in developing a Watershed Based Plan that will protect and enhance the water quality of the Gunpowder Creek Watershed is to gather an understanding of the baseline condition of the watershed. Based on data from previous efforts and the current plans of SD1 and LRWW, some additional data collection is expected under the umbrella of this project. GCWI will solicit technical assistance from experienced experts where needed, for example, the Center for Applied Ecology at Northern Kentucky University. If it is determined that additional data are needed, the sampling design will be informed by KDOW (2010c) guidelines and collaboration with project partners to best optimize the sampling that could be collected under this project.

Existing monitoring locations (Figure 3) have been placed near the mouth of all HUC14 watersheds, which is consistent with the placement of ―Phase 1" monitoring locations specified in the KDOW (2010c) WBP Guidebook. The GCWI intends to make every effort to meet the KDOW sampling goals to the extent possible within confines of the GCWI scope and budget, despite being planned and awarded prior to the Guidebook release. Following the 2010/2011 sample collection by SD1 and LRWW, GCWI will perform a Phase 1 assessment to identify prioritized sub-watersheds for ―Phase 2" monitoring. We intend to meet with KDOW at this time to develop a ―Phase 2" Monitoring Plan, which will be approved prior to the collection of ―Phase 2" data with this 319(h) grant funding.

Regarding a ―Phase 1" Monitoring Plan, a technical subcommittee of the GCWI has convened and identified hydromodification monitoring as a priority for this year‘s sampling season. SD1 currently collects hydromodification data at seven (7) locations in the Gunpowder Creek watershed (GPC 14.7, GPC 17.9, GPC17.1-UNT0.1, SFG2.6, SFG5.3-DS, SFG5.3-US, SFG5.3-UNT0.3)[1]. The technical subcommittee has arrived at a consensus to pursue hydromodification monitoring at the four (4) LRWW sites (Figure 3) that do not have hydromodification data collected by SD1. This includes: FWF 0.8, GPC 7.5, LDB 0.5, and RDR 1.1. We discussed this and the rest of our Phase 1 sampling plans (Table 7) with KDOW at February 25, 2011 meeting, in which we received positive feedback (pending the approval of this QAPP).

Regardless of what specific sampling is planned/approved for Gunpowder Creek, any additional data that are collected by the GCWI under this 319(h) grant project will use the sampling methods listed below.

[1] SD1 collects hydromodification data at all of their wadeable sites listed above. GPC4.6 is in the backwater of the Ohio River and not a wadeable site, therefore, hydromodification data is not collected at GPC 4.6.

B2: SAMPLING METHODS

B2.1 – Water Quality (Chemical) Sampling

Water quality data may be generated via grab samples from stream banks or bridges, or with auto-samplers. The following methods for water chemistry sampling are primarily informed by and adapted from the KDOW-approved BWC (2005) QAPP for neighboring Banklick Creek Watershed. Table 13 indicates preservation methods and sample holding times for possible sample suites that may be analyzed for this project.

Table 13: Preservation and Holding Time of Potential Water Quality Parameters

Sub-Category	Parameter	Reference Method	Preservation	Holding Time
Bacteria	E. coli[a]	SM9223 B	$Na_2S_2O_3$	12 hours[a]
Nutrients	NO_3/NO_2	EPA 353.2	H_2SO_4	28 days
	NH_3-N	SM4500NH3 D	H_2SO_4	28 days
	TKN	EPA 351.2	H_2SO_4	28 days
	TP	EPA 365.1	H_2SO_4	28 days
	OP[b]	EPA 365.3	Unpreserved	48 hours
	CBOD5	HACH 10230	Unpreserved	48 hours
Sediment	TSS	SM2540 D	Unpreserved	7 days

[a]we will make every effort to meet a 6-hour holding time for E.coli samples; however, a 12-hour goal for this project will be needed for watershed size, the number and specifications of field parameters, etc.

[b]Orthophosphate should be field filtered with 0.45 µm membrane filter

Sampling from Stream Banks or Bridges/Overpasses

Samples will be collected from stream banks or bridges to minimize safety concerns. The procedures described below assume that a two-person sampling team with some basic knowledge of the accepted procedures used to collect environmental samples will take the samples. The two-person team will have decided before beginning work who will be the ―Clean hands" and who will be the ―Dirty hands". The designation will determine the division of labor between them. In general, ―Clean Hands" will be in charge of any activities that might involve direct contact with the sample, while ―Dirty Hands" will handle equipment, take notes, and any other activities that do not involve direct contact with the sample. The specific duties of each individual are described below.

1. Before arriving on site both team members should have thoroughly washed and dried their hands and forearms. Soap and water should be kept on hand at all times in case a team member‘s hands become excessively dirty.

2. Immediately upon arriving on site both team members should set-up any necessary safety equipment such as lights or cones. In cases where the bank slope is steep or slippery, or whenever there is a risk of a team member falling, especially if falling could results in being swept away in a fast moving stream, it may be necessary to ‗tie-off' to a static object. It is highly recommended that a self-retracting lifeline, with a built in winch, be used to decrease the risk of falling and, if necessary, pull a team member out of the stream and/or up the bank without exposing other team members to the same hazards. It may be necessary to have a third team member available to act as a safety supervisor and lifeline operator.

3. Once all of the necessary equipment is set-up and it is safe to begin work, ―Clean Hands" should put on a fresh pair of non-talc latex gloves and begin triple rinsing the pre-cleaned sampling bucket. If metals are among the analtyes to be tested, then the bucket should be made from a non-reactive plastic such as Nalgene; otherwise the bucket should be made from stainless steel.

4. While ―Clean Hands" rinses the sampling bucket, ―Dirty Hands" should be filling out the necessary field paper work, including preparing the label for the sample bottle(s), and begin taking any environmental readings (temperature, DO, pH, etc.)

5. After the bucket has been properly rinsed and the paperwork completed, ―Dirty Hands" should put on a pair of non-talc latex gloves to assist ―Clean Hands" in the sample collection.

6. ―Dirty Hands" should throw the bucket into the water body, while only holding onto the rope and being careful to not touch the bank, tree branches, or anything else. Once the bucket is filled, ―Dirty Hands" may pull in the bucket, being extremely careful not to let the bucket touch the bank, to ―Clean Hands" who will empty the bucket back into the water body. This process needs to be repeated twice more to ―river rinse" the bucket. This can be a tedious and time-consuming task, so in cases where it is possible to fill and empty the bucket without pulling it back to the bank or having the bucket touch anything, it is recommended to do so.

7. Now that the bucket has been ‗river rinsed', the sample can be collected. ―Dirty Hands" should follow the same procedure to lower and raise the bucket in Step 6, so that ―Clean Hands" can submerge the sample bottle into the bucket to collect the sample while minimizing, to the greatest extent possible, the amount of exposure the sample has to the

open air. Whenever possible, it is preferable that the bucket be submerged and the sample pulled up from beneath the surface.

8. Now that the sample has been collected, ―Dirty Hands" should label and store the sample on ice in a clean cooler while ―Clean Hands" changes gloves.

9. For analyses that require more than one bottle for sampling to be completed Steps 7 and 8 should be repeated (including the replacement of gloves) until enough volume has been collected.

10. When the sample needs to be composited over time, or if the sample site is not in a good mixing zone and the sample needs to be composited across the stream, it will be necessary to use a churn splitter. In that case, ―Clean Hands" will need to have triple washed the churn splitter using deionized water and, if possible, a river rinse from the water body, making sure that all surfaces (including the lid) that may come in contact with the sample are rinsed and purged. The spigot should be purged with each washing.

11. The general process will remain the same when collecting time composited samples except that when ―Clean Hands" has control of the sampling bucket, ―Clean Hands" will pour the sample into the churn splitter and immediately close the lid. This process will repeat until enough samples have been collected over the specified period of time.

12. In cases where the samples must be composited from aliquots from the left bank, right bank, and middle of the stream, the bucket should be thrown to one section of the stream by ―Dirty Hands", pulled across to ―Clean Hands", who will pour it directly into the churn splitter and immediately close the lid. This will need to be repeated at the next section until a cross-section of the stream has been collected into the churn splitter.

13. Now that the sample is ready to be collected, ―Dirty Hands" should ‗churn' the sample using at least ten slow strokes of the churn. It is very important that the churn never breaks the surface of the sample as this can introduce additional oxygen into the sample.

14. ―Clean Hands" should purge excess samples before filling the sample bottles. The following guidelines will help reduce the opportunity for contamination to enter the sample:

a. Be sure to position the churn splitter so that it is fairly level and the spigot is not touching anything.

b. Avoid resting the churn splitter under trees, wires, poles etc.

c. Minimize the amount of time the lid of the churn splitter is not secured over the churn splitter.

d. When rinsing the churn splitter, use copious amounts of de-ionized water.

e. Before arriving on site, the churn splitter should have been thoroughly washed and dried. The churn splitter still needs to be triple rinsed once the team has arrived on site. If a bucket will be used to transport sample from the water body, it should also be washed and dried before arriving on site, in addition to being triple rinsed before sampling.

f. If multiple sites are going to be sampled using the same equipment, sample in the order of the site with the lowest expected concentrations to the one with the highest. For example, if samples are going to be taken near a discharge point, the upstream sample should be taken first, then the downstream sample, and finally the sample nearest the discharge point.

g. The churn splitter must be triple rinsed between every sample. It is preferred that it be cleaned as close in time as possible to the collection of the sample.

Collecting Samples Using a Flow Triggered Automatic Sampler

The procedures described below assume that a two-person sampling team with some basic knowledge of the accepted procedures used to collect environmental samples will take the samples. The two-person team will have decided before beginning work who will be the ―Clean Hands” and who will be the ―Dirty Hands”. The designation will determine the division of labor between them. In general, ―Clean Hands” will be in charge of any activities that might involve direct contact with the sample, while ―Dirty Hands” will handle equipment, take notes, and any other activities that do not involve direct contact with the sample. The specific duties of each individual are described below. The procedure described in this protocol assumes that the automatic sampler will be left in place at the sampling site and that a sampling team will collect the samples some time after an event is completed.

Please refer to the user manual for information on setting-up and programming specific pieces of equipment.

1. Before arriving on site both team members should have thoroughly washed and dried their hands and forearms. Soap and water should be kept on hand at all times in case a team member‘s hands become excessively dirty.

2. Immediately upon arriving on site both team members should set-up any necessary safety equipment such as lights, cones, or traffic barricades.

3. Once all of the necessary equipment is set-up and it is safe to begin work, ―Clean Hands” should put on a fresh pair of non-talc latex gloves.

4. ―Dirty Hands” should fill out the necessary field paper work, including preparing the label for the sample bottle(s), and begin taking any environmental readings (temperature, DO, pH, etc.) Once that is completed, ―Dirty Hands” should put on a fresh pair of non-talc latex gloves to assist in the sample collection.

5. ―Dirty Hands” should unlock the sample bottle compartment and open up the automatic sampler so that ―Clean Hands” has free and easy access to the sample bottles.

6. ―Dirty Hands” should then open the bags containing the automatic sampler bottle caps but should not actually touch the caps. ―Clean Hands” should reach into the bags and bring out each cap for the bottles.

7. After all of the sample bottles have been sealed, they can be removed from the automatic sampler, labeled, and stored on ice in a clean cooler.

8. In cases where the sample must be transferred to a ―traditional” sample bottle, the sample should be carefully poured from the automatic sampler bottle into the ―traditional” sample bottle. At no time should the automatic sampler bottle touch the ―traditional” bottle. The use of a funnel is strongly discouraged; however, if it is necessary the funnel should be pre-cleaned thoroughly and stored in at least two airtight bags made of non-reactive plastic.

9. If several bottles are going to be composited for analysis the use of a churn splitter will be necessary. In that case, ―Clean Hands” will need to have triple washed the churn splitter using deionized water, paying close attention to be sure that all surfaces, including the lid, that may come in contact with the sample are rinsed and purged the spigot with each washing.

10. The appropriate automatic sampler bottles should be poured into the churn splitter and the lid closed immediately.

11. Now that the sample is ready to be collected, ―Dirty Hands” should ‗churn‘ the sample using at least ten slow strokes of the churn. It is very important that the churn never breaks the surface of the sample as this can introduce additional oxygen into the sample.

12. ―Clean Hands” should purge with excess sample before filling the sample bottles.

The following guidelines will help reduce the opportunity for contamination to enter the sample:

a. Be sure to position the churn splitter so that it is fairly level and the spigot is not touching anything.

b. Avoid resting the churn splitter under trees, wires, poles etc.

c. Minimize the amount of time the lid of the churn splitter is not secured over the churn splitter.

d. When rinsing the churn splitter, use copious amounts of de-ionized water.

e. Before arriving on site, the churn splitter should have been thoroughly washed and dried. The churn splitter still needs to be triple rinsed once the team has arrived on site. If a bucket will be used to transport sample from the water body, it should also be washed and dried before arriving on site, in addition to being triple rinsed before sampling.

f. If multiple sites are going to be sampled using the same equipment, sample in the order of the site with the lowest expected concentrations to the one with the highest. For example, if samples are going to be taken near a discharge point, the upstream sample should be taken first, then the downstream sample, and finally the sample nearest the discharge point.

g. The churn splitter must be triple rinsed between every sample. It is preferred that it be cleaned as close in time as possible to the collection of the sample.

The following general guidelines should be followed to insure the highest quality results are achieved when using automatic samplers:

a. Automatic samplers should be cleaned and maintained regularly according to their manufacturer‘s recommendation. Careful attention should be paid to the tubing running to and from the sampler and the pump when being cleaned as they come in direct contact with the sample. In cases where ultra-low detection levels are called for it may be necessary to install pre-cleaned tubing and pump right before sampling is set to begin.

b. The bottles in the automatic sampler should be pre-cleaned before being set-up.

c. The bottle storage compartment should be closed tight enough so that no possible contaminant such as rain, leaves, or other debris could enter the sample bottle.

d. Automatic samplers should be placed to the greatest extent possible in a flat, dry location with the smallest chance of the sampler being submerged.

e. Caps to the automatic sampler bottles can be left in the automatic sampler, or carried with the sampling team. In either case they should be pre-cleaned and stored in at least two airtight bags made from a non-reactive plastic.

f. When opening and closing the sample bottle compartment, be careful not to accidentally knock any dirt or debris that may be attached to the automatic sampler into a sample bottle. Additionally, the top of the automatic sampler should not be placed down so that the bottom rim is in the dirt or mud.

The automatic samplers may be triggered by flow meters that might be used to simultaneously collect stream flow data during sample collection. If collecting flow data with an auto device, data will be downloaded via a laptop computer connection or other device and downloaded using the appropriate software. Flow data should be reviewed in the field to verify that the flow meter is working correctly. Field crews should attempt to correct any malfunctions in the field as soon as possible to return the meter to a calibrated state before leaving the site. If time does not allow for adjustments to be made then the field team should return as soon as possible to address the flow meter.

B2.2 – Hydrologic Sampling

Hydrologic (flow) data will be collected according to the KDOW (2010b) *"Standard Operating Procedure for Measuring Stream Discharge."* As stated in the KDOW (2010c) Guidebook for WBPs, flow data is required for every sample collected. SD1 collects flow data with every dry weather sample[2]. There are also 14 USGS gages across northern KY that record flow at 15-minute intervals. One of those gages is located in Gunpowder Creek (GPC14.7). Continuous gage records can be used to augment flow records at nearby locations using a variety of scaling procedures (e.g. Emmett, 1975; Hawley and Bledsoe, In review; Hey, 1975; Leopold, 1994; Watson et al., 1997). This makes flow measurements by GCWI during high/dangerous flow conditions unnecessary.

The GCWI will collect stream discharge measurements using the following procedures during every water quality (chemical) sampling event where unsafe/hazardous conditions do not exist. The step-by-step procedures below are modeled after the KDOW (2010b) SOP.

Flow Sampling Using a Portable Flow Meter

1. Arrive at site visually inspect the stream current for unsafe conditions. Hazardous flow conditions vary from stream to stream depending on channel slope, confinement, water quality, water depth etc. (e.g. a 2-foot depth in a steep boulder canyon can be very dangerous, whereas a 2-foot depth in a wide flat sand bed channel may not pose as great of a hazard risk). Good judgment should be used to determine if unsafe conditions exist—this includes the sense to abort flow measurements when determined unsafe in the middle of a sample collection.

[2] SD1 does not collect flow data during wet weather sampling events due to the inherent danger of streams during high flow.

2. If unsafe conditions do not exist, string a measuring tape taught across the channel. Rebar/pins may be useful in pulling the tape taught. Determine the width of the active stream flow by measuring from the edge of water on the left bank to the edge of water on the right bank and subtracting any slack water areas.

3. Divide the width of active stream flow by 10 (using a calculator) to determine the width of sample increments[3]. Alternatively, one can select an even/easy increment width (e.g. 2 feet), provided it results in 10 or more total increments across the channel and ends at the edge of water on the right bank.

4. Add the incremental width calculated above to the edge of water on the left bank (see Figure 4). Repeat 9 more times until arriving at the edge of water on the right bank. Record those values on the field sheet—these locations are where flow depth and velocity will be measured.

5. At each incremental location measure the depth of water to the nearest 0.10 feet (or better).

6. Position the velocity probe at 60% of the depth below the water's surface. For example, if the depth is 1.0 feet, the velocity should be measured at 0.6 feet down from the surface (40% or 0.4 feet up from the bottom). Most portable flow meters can be set up to do this somewhat automatically using their setting position.

7. Once the flow probe is in the setting position at 60% of the depth and is facing directly upstream into the flow, observe the velocity over a 10-20 second period. Record a velocity value that best approximates the mean of the observations.

8. Record all width increments, depths, and velocities on the field sheet so that the total volumetric flow can be calculated by a simple spreadsheet program.

[3] If the increment is less than 0.2 ft, divide the total width by a smaller number of increments (e.g. 5) to achieve an increment width that is greater than 0.2 ft.

$$q_4 = v_4 \left[\frac{b_5 - b_3}{2}\right] d_4$$

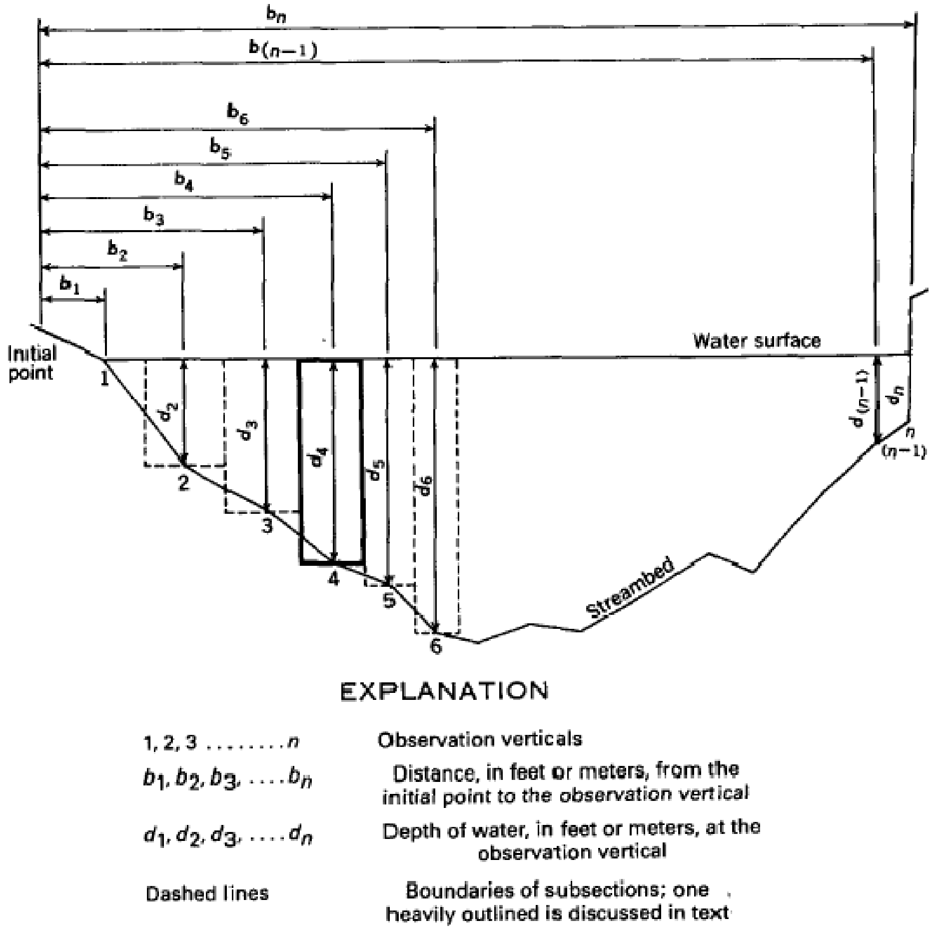

Figure 4: Depth and Velocity Measured at Incremental Locations to Integrate Total Volumetric Flow with Example Calculation after Rantz et al. (1982)

B2.3 – Biological Sampling

Biological sampling will be conducted according to EPA's Rapid Bioassessment Protocols for high gradient streams (Barbour et al. 1999) and *"Methods for Sampling Benthic Macroinvertebrate Communities in Wadeable Waters"* (KDOW 2009). The goal will be to detect ecological differences between sites if such differences exist. The potential types of biological sampling that may be employed on this project include: macroinvertebrates, fish, and habitat (described in detail below). The following methods are primarily informed by and adapted from SD1 (2007) QAPP for Biological and Habitat Surveys to maintain regional consistency/comparability.

Macroinvertebrate Sampling

The macroinvertebrate community will be sampled at all sites using the rapid bioassessment multi-habitat approach (Barbour *et al.* 1999) and modified to reflect KDOW protocol requirements (KDOW 2009). At each site, a riffle sample will be collected, where four (4) 0.25 m^2 samples are taken from mid-riffle or thalweg (path of the deepest thread of water), dislodging benthos by vigorously disturbing 0.25m^2 (20 x 20 in) in front of the 600 micron net. Large rocks should be hand washed into the net. The contents of the net are washed and all four samples are composited into a 600-micron mesh wash bucket and kept separate from all other sub-habitat collections. Additionally, a qualitative multi-habitat sweep sample (using an 800 micron D-frame net) is collected that targets a variety of non-riffle habitats. Each habitat type should be swept three times, whenever possible.

At non-wadeable sites (e.g. backwater of Ohio River), macroinvertebrates will be sampled following the large river approach developed by ORSANCO and refined by SD1 (2007). Typically, a stream reach for this method is 500m in length. Hester-Dendy (HD) multi-plate artificial substrates are deployed at the upstream end of the reach in both shallow (< 1m) water and deep (approximately 3m) water. Additionally, a multi-habitat qualitative sample using a D-frame net is collected in 100m intervals throughout the 500m reach. These six (6) multi-habitat sub-samples are composited to create one sample. The shallow and deep HD samples are preserved independently, for a total of 3 samples per stream reach.

Samples will be sieved in the field using a standard 600-micron sieve to remove small debris and excess sediment. Extremely large debris will be thoroughly washed into the sieve and discarded. Immediately following collection, samples are placed in pre-labeled containers, keeping riffle and multi-habitat samples separate. Additional labels are placed inside all containers to identify the sample in the event the outer label is removed or obliterated. Samples will be immediately preserved in a 70% alcohol solution and shipped to the taxonomic laboratory for processing.

Initially, collected samples will be sieved in the field using a standard 500-micron sieve to remove small debris and excess sediment. Extremely large debris will be thoroughly washed into the sieve and discarded. Immediately following collection, samples will be placed in prelabeled containers. Additional labels will be placed inside all biological samples to identify the sample in the event the outer label is accidentally removed or obliterated. Samples will be immediately preserved in a 70% alcohol solution and shipped to a taxonomic laboratory for processing. All samples collected will be accompanied by chain-of-custody documents.

Biological community sampling and fish shocking will not occur at the same site on the same day in order to avoid sampling disturbed areas.

Fish Sampling

Measurements of the structure and function of the fish community also provide insight to stream health and water quality. At all wadeable sites, fish community structure will be sampled with a backpack type shocking device utilizing the rapid bioassessment multihabitat electrofishing approach (Barbour et al., 1999) and modified to reflect KDOW (2001) protocol requirements at all wadeable sites. The 100-meters of stream identified in the habitat assessment will be the focus of the fish collections. Areas outside of the habitat assessment may be sampled if portions of the habitat assessment area are not accessible with the backpack electrofishing unit. Sampling will occur for one hour over the 100-meter area. A minimum of two riffle areas will be sampled for site segments containing riffles.

At sites that are non-wadeable (e.g. backwater of Ohio River), fish communities will be sampled via night-time boat electrofishing (where applicable) after a protocol developed by ORSANCO and refined by SD1 (2007). Where boat electrofishing is required, a zone will consist of a 500m reach of shoreline, in which a minimum of 1800 shocking seconds will be applied.

Fish will be identified in the field by a trained taxonomist. Fish will be separated in the field by species and counted. The numbers of each species will be recorded and the presence of disease or external anomalies will be noted. Total length will be measured for larger predatory fish species. Following identification and measurement, fish will be immediately released. Any species not identified in the field with certainty will be retained and identified in the laboratory. In the event that a threatened or endangered species is collected, it will be noted and released immediately. A reference fish collection will be created for each stream sampled. The reference collection will be housed at Thomas More College Ohio River Field Station.

Field data from the first sampling event will be evaluated to determine the level of acceptable variability for the number of fish collected. Based on the sampling variability, future collection methods may be altered.

Habitat Sampling

A habitat is defined as —. . the quality of the instream and riparian habitat that influences the structure and function of the aquatic community in a stream,"(Barbour et al., 1999). Habitat and biodiversity are closely linked, and a biological community is limited by the quality of the habitat. A habitat assessment evaluates physical and chemical components of the stream along with biotic interactions. Altered habitat can be a major stressor to aquatic systems, and these assessments will help determine if chemical or non-chemical stressors are present. The measurement of physical characteristics and parameters will provide insight to the condition of the biological community.

An initial habitat assessment will be performed at each site by a team of at least two personnel who have been trained in the habitat assessment procedures. Habitat assessments will follow EPA's Rapid Bioassessment Protocols for high gradient streams (Barbour et al., 1999) and *"Methods for Assessing Biological Integrity of Surface Waters"* (KDOW, 2001). Physical Characterization / Water Quality field sheets will be completed for each site. Physical Characterization / Water Quality metrics consist of watershed features (predominant surrounding land use, local watershed non-point source pollution, and erosion), riparian vegetation, in-stream features, large woody debris, aquatic vegetation, water quality, sediment/substrate quality, inorganic substrate components, and organic substrate components (Barbour et al., 1999).

Detailed sketches or photographs of the assessed stream reach for each site will be drawn to scale and include approximate areas of habitat types such as aquatic vegetation (submerged, emergent), inorganic substrate (gravel, cobble, boulder), fallen trees/snags, and undercut banks. This will provide the proportions of each habitat type to be sampled during the benthic macroinvertebrate sampling events.

Habitat Assessment field sheets for high gradient streams will be completed for each station (Barbour et al., 1999). The habitat assessment information will be used to qualitatively characterize the aquatic bottomland communities along the reaches of Northern Kentucky Streams. Habitat parameters include epifaunal substrate/available cover, embeddedness, water velocity and depth regime, sediment deposition, channel flow status, channel alteration, frequency of riffles, bank stability, vegetative protection, and riparian vegetative zone. Habitat observations will include notations of other factors potentially influencing the character and quality of the aquatic communities. A record of the habitat assessment site will be maintained with photographs taken of the 100-meter reach.

Field-measurable parameters of dissolved oxygen (DO), specific conductance (SpCond), water temperature, and pH will be analyzed during each sampling event utilizing a multi-probe water quality meter, or comparable unit.

B2.4 – Geomorphic Sampling

Geomorphic data will be collected using industry standard methods by trained personnel. Geometric data will be informed by Harrelson *et al.* (1994) and pebble counts will be modeled after Bunte and Abt (2001a; 2001b). The procedures are designed to measure the multidimensional effects of hydromodification from the conversion of land from undeveloped to developed and are a result of a recent literature review (Bledsoe et al., 2008; Hawley, 2009). Specifically, the methods are intended to directly quantify how stream channels adjust their cross-sectional and longitudinal (profile) forms, along with their bed material composition, in response to the altered runoff conditions from watershed urbanization. The monitoring and quantification of channel bed and bank erosion directly informs estimates of fine sediment loads from channel sources. The data are also critical for developing tailored recommendations for BMPs to arrest channel instability, mitigate hydromodification, and promote the natural flow and sediment regimes that are necessary for meeting the warm-water aquatic habitat designated use.

The following methods are primarily informed by and adapted from the Water Quality Control Board-Approved QAPP for Hydromodification Assessment and Management in Southern California (Stein, 2007), as well as the Standard Operating Procedures of SD1 (2009) to ensure regional comparability with previously collected hydromodification data in Northern Kentucky.

Channel Geometry Data

Geometric data collection is designed to capture changes in channel form via annually repeated cross-section surveys (Dunne and Leopold, 1978; Henshaw and Booth, 2000) with spatially integrated longitudinal thalweg profiles (Bledsoe et al., 2008; Hawley, 2009; SD1, 2009).

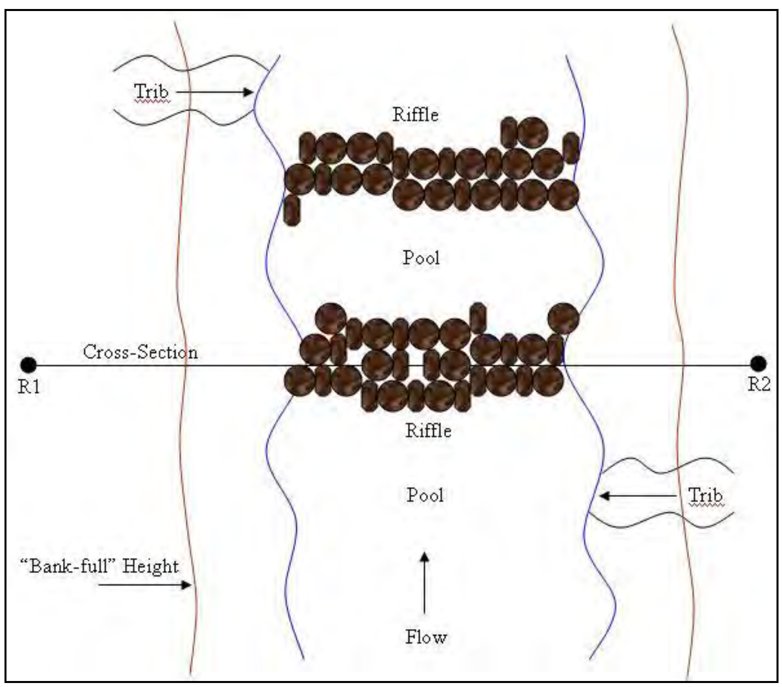

Figure 5: Cross section layout adapted from SD1 (2009) SOP

Cross sections will be located at representative riffle sections and oriented perpendicularly to flow direction at flood stage and extend well into the adjacent floodplain (Figure 5). Semi-permanent (rebar) monuments will be placed at the cross-section bounds and serve as reference points for the annually repeated surveys (SD1, 2009). Each rebar monument will be referenced to three permanent landmarks (e.g. well-established trees, boulders, utility poles, edge of curb or pavement, manholes, etc.). Sketches and measurements to each landmark will be used to triangulate the rebar monuments for future surveys. Approximate GPS coordinates (ca. ±10 feet) will be recorded for each rebar; however, triangulation and a metal detector will be the primary methods for relocating rebar monuments during future surveys.

Surveys will be performed with a level and tape (or equivalent) to ensure regional comparability (SD1, 2009). The tape will be pulled tight between the two rebar pins, ensuring minimal sag. The ‗0' end of the tape is placed at the rebar on the left side of the channel when looking downstream (i.e. ‗R1'). Shots will be taken at a maximum of every 5 meters across the cross section; however, they will normally be spaced much closer to capture all major grade breaks (i.e. changes in slope), depositional surfaces, toes of slopes, channel thalweg, etc. (Harrelson et al., 1994). Spacing will be particularly close at each bank to ensure an accurate representation of bank height and angle.

The longitudinal profile along the channel thalweg will be surveyed over a minimum of three riffle-pool sequences over the site reach or for a distance of up to 100 meters. The tape is laid out from downstream to upstream and should trace the thalweg of the stream. The thalweg is defined as the deepest point in the stream at any given cross section and typically meanders from one side of the channel to the other as one moves up or downstream. It typically parallels the flow direction at flood stage. Survey measurements should be collected at every vertical break in slope (e.g. head of riffle, toe of riffle, knickpoint/headcut, etc.) and at every key horizontal change or feature (e.g. meander bends, thalweg crossings, etc.) (Harrelson et al., 1994). The maximum spacing of profile shots shall be 20 meters. The profile is spatially referenced to the cross section (and thereby the rebar monuments) by noting at what station the profile tape intersects the cross-section tape.

Each survey is documented with a photo of the cross section location (typically looking upstream). A photo of each bank will also be recorded. Either a survey rod or a field technician should be included in each photo for scale.

Throughout the channel geometry surveys, the level bubble of the instrument shall be periodically checked to ensure levelness. If the instrument is found to be out of level or is bumped at any point during the survey, the instrument shall be re-leveled and backsight reshot. If the elevation is off by greater than 2 cm, the data logged since the time of the previous level check will be discarded.

Bed Material Data

Samples of the channel bed material are based on the methodology developed by Bunte and Abt (2001a; 2001b). As employed by SD1, a 100-particle pebble count is sufficient to capture the key size classes and gradations of Northern Kentucky streams (SD1, 2009). A square sampling frame (e.g. 0.25 or 0.5 meter square) is placed at regular intervals (e.g. 0.5 or 1 meter spacing) along complete cross-section transects from the toe of the left bank to the toe of the right bank. If the 100th particle is reached in the middle of a transect, a full transect should be completed before stopping the pebble count to eliminate bias from oversampling one side of the cross section.

At each sample location, the field technician will sample the four pebbles in contact with the sampling frame at each corner. Use of a sampling frame eliminates the bias of Wolman (toe) pebble counts toward larger particles (Bunte and Abt, 2001a). Each pebble will be measured using a US SAH-97 (or equivalent) phi template (Figure 6). Employing phi templates eliminates measurement error that can occur when measuring along the b-axis of a curved particle in a traditional pebble count (Potyondy and Bunte, 2002).

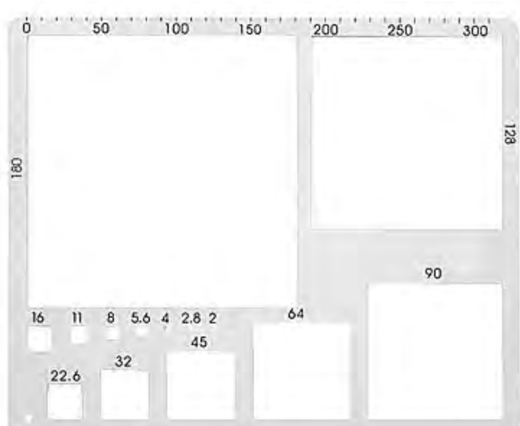

Figure 6: Standard US SAH-97 phi template (i.e. 'gravelometer')–NOT TO SCALE

For cases when the corner of the sampling frame is in contact with fine particles (d < 2 mm), the field technician shall do one of two procedures. If the layer of fine particles is greater than ca. ½ inch thick (approximately one finger width), the measurement shall be recorded as < 2 mm. If the fine particles are in a relatively thin layer (less than ca. ½ inch thick) and are only hiding a larger particle, the buried substrate should be sampled. A breadth of regional experience indicates that fine particles (d < 2 mm) generally do not constitute a substantial fraction of volumetric pebble counts, and sieve sampling is consequently not necessary.

For particles larger than 180 mm, the length of the b-axis should be estimated using the scale on the side of the phi template. Care should be taken to avoid sampling the same particle more than once. For sites where exposed, intact bedrock occupies substantial portions of the channel bed, this may be understandably unavoidable but should be minimized to the extent practicable.

Bed material samples will be collected with a trained, two-person team. One technician will collect and measure the samples and a second observer will record the samples. The second observer will perform repeat measurements of randomly selected particles. The repeat measurements shall not vary by more than ½ phi size. If such an error is observed the sampler(s) will be retrained on bed material sampling procedures and the pebble count shall be repeated.

B3: Sample Handling and Custody

B3.1 – Water Quality (Chemical) Sampling

Water quality samples will be handled via standard chain of custody protocols. All samples will be labeled with standard information (Figure 7). Samples will be kept on ice in coolers during transport. Chain-of-custody sheets will accompany samples to the laboratory where they will be signed by the relinquishing and receiving parties (Figure 8).

Client:	Boone County Conservation District
Sample ID:	
Location:	
Collection Time:	
Collection Date:	
Analysis:	
Preservation:	

Figure 7: Example Sample Label

CHAIN OF CUSTODY RECORD

Boone County Conservation District
6028 Camp Ernst Road
Burlington, KY 41005

Project Location or Number:

Results to: Mark Jacobs

Phone #: 859-586-7903

Fax #:

Address:

Sampler (print):

Cardinal Labs Log In Test Results

Residual Chlorine Check + / - / N/A

pH check >10 / <2 / N (Neutral)

Purchase Order #:

Preservative codes: 1. HNO_3 2. NaOH 3. HCl 4. H_2SO_4 5. $Na_2S_2O_3$ 6. None 7. H_3PO_4 — Enter #

Cardinal Laboratories
104 North Street
Wilder, KY 41071
859-341-9989
859-341-5081 fax
info@cardinallabs.com

Cardinal Project #

Analytes / Method Number

Sample Location or ID	Date	Time	Matrix	Grab/Comp	# Bottles	E coli	TSS	BOD	TP,NN,TKN,NH3	OP(filtered)	Cardinal Sample ID #
(Preservative code)						5	6	6	4	6	
Site 1 Hr 0 - Location 1					5	1	1	1	1	1	
Site 2 Hr 0 - Location 2					5	1	1	1	1	1	
Site 3 Hr 0 - Location 3					5	1	1	1	1	1	
Site 4 Hr 0 - Location 4					5	1	1	1	1	1	
Site 5 Hr 0 - Location 5					5	1	1	1	1	1	
Blank Hr 0					5	1	1	1	1	1	
Duplicate Hr 0					5	1	1	1	1	1	

Field Comments:

Turn-Around-Time (TAT): 24 Hr 48 Hr Normal

Shipment Method: **Dropped off - Cooler**

Cooling/Packing Material: **Wet Ice**

Tracking Number: **N/A**

Cooler Temp:

Checked By:

Samples checked by:

Samples distributed/storage time:

Relinquished by Sampler: Date Time — Received by Lab Runner: Date Time

Samples logged into LIMS by:

Relinquished by Lab Runner: Date Time — Received by Laboratory: Date Time

Special Instructions:

Hazards:

Chain Complete? Yes No N/A — Sample Amount Correct? Yes No — Custody Seal Intact? Yes No — Additional Comments: — Problems and/or Corrective Action?

Headspace? Yes No N/A — Correct Bottles? Yes No — Condition of Samples? — Yes (record on back of form) No

Figure 8: Example Chain of Custody Sheet from Cardinal Labs of Northern KY

B3.2 – Hydrologic Sampling

Flow measurements will accompany all samples where/when hazardous conditions do not exist. For comparability, flow will be collected after Rantz et al. (1982), and recorded on SD1's field form (Figure 9). Width, depth, and velocity will be recorded at each incremental location (Figure 4), such that volumetric flow rate can be automatically integrated using a simple spreadsheet model back at the office.

Sanitation District No.1 Flow Data Sheet **Version 2007.1**

Project Name ____ **Date** ____
Study Basin ____ **Start Time** ____
Samplers ____ **End Time** ____
Equipment ID ____
Project Descriptor ____
Stream Conditions ____
Weather Conditions ____ **Air Temp (°F)** ____
Field Observations ____

	Distance From Shore Reference (feet)	Panel Number	Panel Width (feet)	Water Depth (feet)	Velocity Readings 20% Depth (fps)	60% Depth (fps)	80% Depth (fps)	Mean Velocity (fps)	Panel Discharge (cfs)	Time (hh:mm)
1		1						0.0	0.0	
2		2						0.0	0.0	
3		3						0.0	0.0	
4		4						0.0	0.0	
5		5						0.0	0.0	
6		6						0.0	0.0	
7		7						0.0	0.0	
8		8						0.0	0.0	
9		9						0.0	0.0	
10		10						0.0	0.0	
11		11						0.0	0.0	
12		12						0.0	0.0	
13		13						0.0	0.0	
14		14						0.0	0.0	
15		15						0.0	0.0	
16		16						0.0	0.0	
17		17						0.0	0.0	
18		18						0.0	0.0	
19		19						0.0	0.0	
#		20						0.0	0.0	
21										
#						Total Panel Discharge			0.0	cfs

Figure 9: Example Field Form for Measuring Flow (provided by SD1)

B3.3 – Biological Sampling

Biological samples will be handled via standard chain of custody protocols. Field observations will be recorded on standard forms such as Barbour *et al.* (1999) or equivalent, (Figure 10). All samples collected for laboratory analysis will be preserved immediately after collection and transported to the receiving laboratory, accompanied by chain-of-custody documents. When received by the laboratory, chain-of custody documents will be completed and samples will be logged into the laboratory logbook and/or laboratory database. Any further preservation will be conducted at this time. Maximum holding times before analysis, as stated in applicable laboratory method SOPs, will be followed.

BENTHIC MACROINVERTEBRATE FIELD DATA SHEET

STREAM NAME	LOCATION	
STATION #________ RIVERMILE________	STREAM CLASS	
LAT __________ LONG __________	RIVER BASIN	
STORET #	AGENCY	
INVESTIGATORS		LOT NUMBER
FORM COMPLETED BY	DATE ______ TIME ______ AM PM	REASON FOR SURVEY

HABITAT TYPES	**Indicate the percentage of each habitat type present** ❑ Cobble____% ❑ Snags____% ❑ Vegetated Banks____% ❑ Sand____% ❑ Submerged Macrophytes____% ❑ Other ( )____%
SAMPLE COLLECTION	**Gear used** ❑ D-frame ❑ kick-net ❑ Other ____________ **How were the samples collected?** ❑ wading ❑ from bank ❑ from boat **Indicate the number of jabs/kicks taken in each habitat type.** ❑ Cobble____ ❑ Snags____ ❑ Vegetated Banks____ ❑ Sand____ ❑ Submerged Macrophytes____ ❑ Other ( )____
GENERAL COMMENTS	

QUALITATIVE LISTING OF AQUATIC BIOTA
Indicate estimated abundance: 0 = Absent/Not Observed, 1 = Rare, 2 = Common, 3= Abundant, 4 = Dominant

Periphyton	0 1 2 3 4	Slimes	0 1 2 3 4
Filamentous Algae	0 1 2 3 4	Macroinvertebrates	0 1 2 3 4
Macrophytes	0 1 2 3 4	Fish	0 1 2 3 4

FIELD OBSERVATIONS OF MACROBENTHOS
Indicate estimated abundance: 0 = Absent/Not Observed, 1 = Rare (1-3 organisms), 2 = Common (3-9 organisms), 3= Abundant (>10 organisms), 4 = Dominant (>50 organisms)

Porifera	0 1 2 3 4	Anisoptera	0 1 2 3 4	Chironomidae	0 1 2 3 4
Hydrozoa	0 1 2 3 4	Zygoptera	0 1 2 3 4	Ephemeroptera	0 1 2 3 4
Platyhelminthes	0 1 2 3 4	Hemiptera	0 1 2 3 4	Trichoptera	0 1 2 3 4
Turbellaria	0 1 2 3 4	Coleoptera	0 1 2 3 4	Other	0 1 2 3 4
Hirudinea	0 1 2 3 4	Lepidoptera	0 1 2 3 4		
Oligochaeta	0 1 2 3 4	Sialidae	0 1 2 3 4		
Isopoda	0 1 2 3 4	Corydalidae	0 1 2 3 4		
Amphipoda	0 1 2 3 4	Tipulidae	0 1 2 3 4		
Decapoda	0 1 2 3 4	Empididae	0 1 2 3 4		
Gastropoda	0 1 2 3 4	Simuliidae	0 1 2 3 4		
Bivalvia	0 1 2 3 4	Tabinidae	0 1 2 3 4		
		Culcidae	0 1 2 3 4		

Figure 10: Example Macroinvertebrate Field Data Sheet after Barbour *et al.* (1999)

B3.4 – Geomorphic Sampling

Geomorphic data, both channel geometry and bed material, will be logged into field books during field data collection (Figure 11). Field book pages will be copied and stored in separate locations upon returning to the office. Data will be logged into electronic databases within one month of data collection. Original copies of field books will be stored at the Boone County Conservation District.

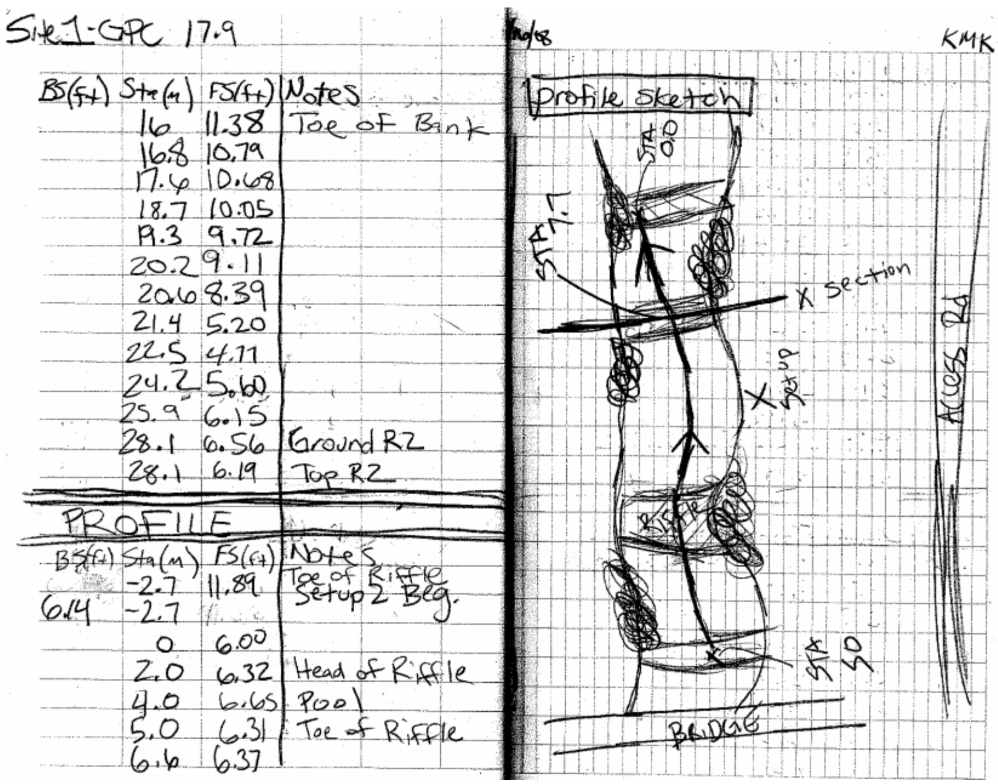

Figure 11: Example Field Book Record of Regional 'Hydromodification' Surveys by SD1

B4: Analytical Methods

All project analytical methods will adhere to industry standard procedures referenced throughout this QAPP. This includes standard EPA methods for water chemistry laboratory analyses (i.e. Table 12), standard EPA methods for biological analyses (Barbour et al., 1999), and industry standard procedures for stream flow (Rantz et al., 1982), channel geometry (Harrelson et al., 1994) and bed material (Bunte and Abt, 2001a; 2001b). As instructed in the KDOW (2010a) QAPP template, analytical methods are subcategorized below into 1) field measurement methods (*water quality field measurements, flow, channel geometry, and bed material*), 2) field analysis methods (*fish taxonomy*), and 3) laboratory analyses methods (*water chemistry and macroinvertebrate taxonomy*).

B4.1 – Field Measurement Methods

In-stream water quality field measurements will be collected with multi-probe sampling instruments with ranges and sensitivities listed in Table 11. Field personnel will be trained in proper multi-probe sampling methods and take measurements according to equipment specifications.

Stream flow will be measured incrementally after Rantz et al. (1982) such that a simple integration of all of the incremental flows will provide an estimate of total stream flow. Personnel will be trained in the use of a portable flow meter and automated spreadsheets will ensure proper integration of the field measurements back at the office.

Channel geometry surveys will be modeled after Harrelson et al. (1994) using a level and tape survey method. Tape shall be 50- to 100-meter fiberglass or equivalent. Level shall be a bubble-level type with 20x magnification or equivalent. Both instrument and rod personnel will be trained in their respective duties and have a comprehensive understanding of basic level-tape survey methodology including instrument setup and leveling, rod sighting, rod reading, rod positioning, rod boots, rod turning, backsighting, foresighting, moving the instrument to a new setup, etc.

Bed material measurements will be taken according to a 100-particle pebble count after Bunte and Abt (2001a; 2001b). Pebble measurements will be made using a US SAH-97 (or equivalent) phi template (Figure 6) after Potyondy and Bunte (2002). The phi template serves as a multi-sized field sieve. Measurements are obtained by recording the smallest phi size a given pebble can pass completely through (i.e. without becoming stuck or lodged).

B4.2 – Field Analysis Methods

Taxonomic identification of fish will be performed in the field using all available and appropriate taxonomic keys and regional distribution records. For the purpose quality assurance/quality control, 10% of the fish specimens from a given site or at least one voucher specimen from each species collected should be re-identified by a qualified fish taxonomist (e.g. Matt Wooten). When needed, independent taxonomic verifications made by recognized experts (based on education and/or experience) are used to confirm suspect identifications. Unknown and voucher fish specimens will be fixed in a 10% formalin solution for at least 2 weeks, rinsed and soaked in tap water for 1-2 days and stored in a 70% ethanol solution.

B4.3 – Laboratory Analyses Methods

Analytical methods for potential water chemistry parameters that may be included in this project will be based on standard EPA methodologies (Table 12). Laboratory taxonomic evaluations for macroinvertebrate samples will be performed according to standard EPA sorting and identification procedures (Barbour et al., 1999). Upon receipt of the benthic samples at laboratory, chain-of-custody forms will be completed and the samples will be inventoried. Samples will be preserved in 70% alcohol solution.

Benthic samples will be sorted and separated into major phylogenetic categories. All organisms will be removed with fine-tipped forceps or a pipette and placed in shell vials containing a 70% isopropyl alcohol solution. All identifications will be performed or verified by experienced taxonomists (e.g. Bert Remley) and verified in accordance with the laboratory QA/QC program. All identifications and enumerations will be recorded on standardized sheets for consistency and ease of data entry. Organisms will be identified to the lowest practical identification level (LPIL). Data will be entered into a database that will be transferred to the Boone County Conservation District upon completion of the analyses.

Subsampling techniques may be necessary in case of large sample volume. This will follow appropriate EPA and KDOW protocols. A comprehensive voucher set will be produced and retained for the duration of all regional projects along with identified specimens.

Turnaround times for water chemistry and macroinvertebrate laboratory analysis are expected to be approximately 3 weeks and 30 days, respectively.

B5: QUALITY CONTROL

Quality objectives and procedures were described in detail in section A7, with specific objectives listed in Tables 9 and 10. As instructed in the KDOW (2010a) QAPP template, quality control requirements are subcategorized below into 1) field sampling quality control (*water quality and macroinvertebrate sampling*), 2) field measurements /analysis quality control (*water quality field measurements, flow, channel geometry, bed material, and fish taxonomy*), and 3) laboratory analysis quality control (*water chemistry and macroinvertebrate taxonomy*).

B5.1 – Field Sampling Quality Control

Quality in field sampling is best achieved by following proven, industry standard procedures. These protocols were described in detail in section B2. All samples will be collected in teams of two or more with ample time to ensure both safety and quality. Each team member will be trained in proper sampling methods and have the authority to request a re-sample if they observe a potential contamination or accidental protocol breach. The QA Officer also has the authority to provide random site visits to verify that the QA procedures outlined herein are being followed at all times. The goal is that by having fully trained personnel working in teams of two with more than adequate time for sample collection, field quality will be achieved through time-tested sampling techniques prescribed by EPA/KDOW.

Field Sampling Precision will be checked via repeat measurements of field parameters and by collecting field duplicates for water chemistry analysis (Table 9). The frequency of the Field

Sampling QC measures shall be once per event (i.e. one set of duplicate samples and repeat field measurements at one site per sampling event).

B5.2 – Field Measurements/Analysis Quality Control

Water quality field measurements will be collected with multi-probe sampling instruments with ranges and sensitivities listed in Table 11. All field personnel will be trained in proper multi-probe sampling techniques and take measurements according to equipment specifications. All personnel will have the authority to perform independent quality checks on field measurements, which should not vary by more than 10%. If such a deviation is observed, it may be a function of natural variability, instrument, or operator error. In either case, the measurement will be re-measured for a minimum of 30 seconds and re-recorded. If this occurs on more than one occasion during the same sampling event, the instrument should be checked and re-calibrated as needed at the first opportunity. If it is determined not to be instrument error, the field technician will be re-trained in proper field measurement procedures and the data noted as possibly suspect.

Stream flow will be measured using a portable flow meter during all water chemistry sampling events where hazardous conditions do not exist. Once per event, a second observer will perform a repeat measurement of incremental flow (i.e. depth and velocity at one location), which should not vary by more than 10%. Similarly to the water chemistry measurements collected with the multi-probe, the second observer should take steps to determine if the discrepancy is from natural variability, instrument error/calibration, or user error, and take actions accordingly.

Channel geometry surveys after Harrelson et al. (1994) using a level and tape survey method will be checked by the variability between rebar monuments during annually repeated surveys. Absolute errors will be kept to ±0.5 ft (vertical) and ±2.0 ft (horizontal), and standardized errors (by dividing by the length of the cross section) shall be kept ≤ 0.01 ft/ft (vertical) and ≤ 0.025 ft/ft (horizontal). If errors are observed greater than this range, an independent survey between rebar monuments will be performed to estimate which survey year was most accurate.

Quality of bed material measurements after Bunte and Abt (2001a; 2001b) will be checked through repeated measurements of individual pebbles by a second observer. The objective is for size estimates not to vary by more than ½ phi size on the US SAH-97 (or equivalent) aluminum phi template (Figure 6). If a repeated sample varies by greater than ½ phi size, personnel will be re-trained in proper use of a phi template after Potyondy and Bunte (2002) and the entire pebble count will be repeated.

Taxonomic identification of fish will be performed in the field using all available and appropriate taxonomic keys and regional distribution records. For quality control, 10% of the fish specimens from a given site or at least one voucher specimen from each species collected should be re-identified by a qualified fish taxonomist. When needed, independent taxonomic verifications made by recognized experts (based on education and/or experience) are used to confirm suspect identifications. Unknown and voucher fish specimens will be fixed in a 10% formalin solution for at least 2 weeks, rinsed and soaked in tap water for 1-2 days and stored in a 70% ethanol solution. In situations where preservation of specimen is impractical (e.g. 8 pound channel catfish), photos will be an acceptable alternative to voucher specimen.

B5.3 – Laboratory Analysis Quality Control

Analytical quality control for potential water chemistry parameters that may be included in this project will be based on standard EPA methodologies (Table 12). Contracted laboratories will maintain and follow internal QA/QC procedures and pass annual quality inspections by the Commonwealth of Kentucky and/or annual audits by NELAC or A2LA. At a minimum, laboratory analyses will achieve the QA/QC criteria outlined in Tables 9 and 10 regarding laboratory replicates, matrix spikes, percent recoveries, etc. The frequency of water chemistry laboratory QC procedures is outlined in Table 14.

Table 14: Frequency of Laboratory QA/QC Procedures for Water Quality Parameters

Sub-Category	Parameter	Method Blank	Positive Control	Negative Control	Lab Replicate	Lab Control Sample (LCS)	LCS Duplicate	Matrix Spike
Bacteria	E. coli	1 per 20	1 per 20	1 per 20	1 per 20			
Nutrients	NO_3/NO_2	1 per 20				1 per 20	1 per 20[(a)]	1 per 10
	NH_3-N	1 per 20				1 per 20	1 per 20[(b)]	1 per 20
	TKN	1 per 20				1 per 20	1 per 20[(a)]	1 per 10
	TP	1 per 20				1 per 20	1 per 20[(a)]	1 per 10
	OP	1 per 20				1 per 20	1 per 20[(b)]	1 per 20
	CBOD5	1 per 20			1 per 20[(c)]	1 per 20		
Sediment	TSS	1 per 20			1 per 10[(d)]	1 per 20		

[(a)]Can be sample duplicate or Matrix Spike Duplicate

[(b)]Can be lab replicate, sample duplicate, LCS Duplicate, or Matrix Spike Duplicate

[(c)]Sample volume dependent—if not enough sample, LCS Duplicate will be run as an alternative

[(d)]Can be lab replicate, sample duplicate, or LCS Duplicate

Laboratory taxonomic evaluations for macroinvertebrate samples will be performed according to standard EPA sorting and identification procedures (Barbour et al., 1999). QA/QC checks will occur on no less than 10% of the samples processed. A minimum of 10% of all sorted samples will be checked for completeness. Completeness checks will be accomplished by re-sorting the residual sample material by a different technician. If the animals removed from the residual material total 10% or more of the total number of animals in the sample, this constitutes a QC failure, and all samples sorted by that technician shall be resorted back until the time of the last acceptable QC check.

For identification tasks, at least 10% of all identified samples will be checked for identification and enumeration accuracy. Taxonomic checks will be performed by the re-identification of the selected samples by a different taxonomist. A discrepancy of 5% or more constitutes a QC failure and all samples identified by the taxonomist on that project will be reworked.

Data entry will be facilitated by the use of standardized sheets to record organism identifications and counts for each sample. A visual check of all data will be performed by experienced personnel to assure completeness and accuracy of the data.

B6: Instrument/Equipment Testing, Inspection, and Maintenance

As instructed in the KDOW (2010a) QAPP template, instrument/equipment testing, inspection, and maintenance procedures are subcategorized below into 1) field measurement instruments (*water quality field measurements, flow, channel geometry, and bed material*), 2) field instruments/equipment (*fish taxonomy*), and 3) laboratory analysis instruments/equipment (*water chemistry and macroinvertebrate taxonomy*).

B6.1 – Field Measurement Instruments/Equipment

In-stream water quality field measurements and stream flow measurements will be collected with multi-probe sampling instruments and portable flow meters, respectively. Their ranges and sensitivities listed in Table 11. The probe(s) and portable flow meter will be inspected and maintained according to the manufacturer‘s specifications. Technicians will periodically (i.e. once per month during the sampling season) test the probe(s) in deionized water to ensure proper operation. Probes that do not operate properly after calibration will be sent for manufacturer‘s inspection/calibration and be either recalibrated or deemed nonrepairable and replaced.

Channel geometry data will be collected using a standard level-tape method using a 20x magnification level (or equivalent). The level will be inspected and maintained according to the manufacturer‘s specifications and periodically tested with established benchmarks at the Boone County Conservation District Office or at their designated consultant‘s office at intervals of once per month during the sampling season. If the survey instrument falls out of level and connot be corrected, it will be sent to a survey vendor for calibration where it will be either recalibrated or deemed nonrepairable and replaced.

Pebble measurements will be made using a US SAH-97 (or equivalent) phi template (Figure 6). The phi template will be periodically inspected for damage and compared with a second template. Irreversibly damaged phi templates will be discarded and replaced.

B6.2 – Field Instruments/Equipment

Taxonomic identification of fish will be performed in the field using all available and appropriate taxonomic keys and regional distribution records. The biological sampling manager will periodically check with appropriate authorities to ensure that the team is using the most up-to-date taxonomic keys and records.

B6.3 – Laboratory Analysis Instruments/Equipment

Laboratory analytical instruments and equipment will be inspected and maintained according to the manufacturer's specifications or testing standards—whichever is more stringent. Prior to the beginning of analysis for a given event, equipment should be tested to ensure proper operation.

Laboratory taxonomic evaluations for macroinvertebrate samples will be performed according to standard EPA sorting and identification procedures (Barbour et al., 1999) using all available and appropriate taxonomic keys and regional distribution records. The laboratory manager will periodically check with appropriate authorities to ensure that the laboratory is using the most up-to-date taxonomic keys and records. Forceps and pipettes shall be periodically inspected. Damaged forceps/pipettes will be discarded to avoid damaging macroinvertebrate specimen.

B7: INSTRUMENT/EQUIPMENT CALIBRATION AND FREQUENCY

As instructed in the KDOW (2010a) QAPP template, instrument/equipment calibration and frequency is subcategorized below into 1) field measurement instruments (*water quality field measurements, flow, channel geometry, and bed material*), 2) field instruments/equipment (*fish taxonomy*), and 3) laboratory analysis instruments/equipment (*water chemistry and macroinvertebrate taxonomy*).

B7.1 – Field Measurement Instruments/Equipment

In-stream water quality field measurements will be collected with multi-probe sampling instruments with ranges and sensitivities listed in Table 11. The probe(s) will be calibrated according to the manufacturer's specifications or whenever testing/inspection warrant calibration. Particular attention will be given to the dissolved oxygen (DO) probe, which will be calibrated at intervals of once per month during the sampling season. Likewise, the portable flow meter that will be used to measure stream flow will be calibrated according to manufacturer specifications or whenever warranted by testing/inspection.

Channel geometry data will be collected using a standard level-tape method using a 20x magnification level (or equivalent). The level will be calibrated according to the manufacturer's specifications or whenever testing/inspection warrant calibration. Levels typically need to be recalibrated by a trained professional whenever the level bubble does not stay centered on standard level setup/levelness techniques.

Pebble measurements will be made using a US SAH-97 (or equivalent) phi template (Figure 6), which are calibrated in the factory. The phi template will be periodically inspected for damage. Irreversibly damaged phi templates cannot be recalibrated and will be discarded.

B7.2 – Field Instruments/Equipment

Taxonomic identification of fish will be performed in the field using all available and appropriate taxonomic keys and regional distribution records. Taxonomic keys do not require calibration.

B7.3 – Laboratory Analysis Instruments/Equipment

Laboratory analytical instruments and equipment will be calibrated according to the manufacturer‛s specifications or whenever testing indicates that the equipment has fallen out of calibration.

Laboratory taxonomic evaluations of macroinvertebrates will be performed according to standard EPA sorting and identification procedures (Barbour et al., 1999) using all available and appropriate taxonomic keys and regional distribution records. Taxonomic keys do not require calibration.

B8: Inspection/Acceptance of Supplies and Consumables

As instructed in the KDOW (2010a) QAPP template, inspection/acceptance of supplies and consumables are subcategorized below into 1) field sampling supplies and consumables (*water quality and macroinvertebrate sampling*), 2) field measurement/analyses supplies and consumables (*water quality field measurements, channel geometry, bed material, and fish taxonomy*), and 3) laboratory analyses supplies and consumables (*water chemistry and macroinvertebrate taxonomy*).

B8.1 – Field Sampling Supplies and Consumables

Water quality and macroinvertebrate sampling requires sample containers that have been certifiably cleaned according to their respective standards. All sample containers will be inspected for defects by the Sampling Manager (Mark Jacobs) or his designated technician, and will only be accepted with a certification of acceptable cleaning. Sample containers will come pre-preserved for the respective parameters with $Na_2S_2O_3$ or H_2SO_4 according to Table 13.

B8.2 – Field Measurement/Analyses Supplies and Consumables

Channel geometry surveys and bed material pebble counts do consume supplies that require QA/QC inspections prior to use. Standard rebar and flagging tape from local hardware stores are generally sufficient.

Water quality field measurements and taxonomic identification of fish also use limited consumables. Supplies requiring special inspection/certification (e.g. non-talc latex gloves) shall be inspected for proper certification.

B8.3 – Laboratory Analyses Supplies and Consumables

Analytical methods for potential water chemistry parameters that may be included in this project will be based on standard EPA methodologies (Table 12). Laboratory taxonomic evaluations for macroinvertebrate samples will be performed according to standard EPA sorting and identification procedures (Barbour et al., 1999). All supplies and consumables for laboratory analyses will be inspected by the Laboratory Manager to verify compliance with laboratory methodologies and standard procedures.

B9: Data Acquisition Requirements for Non-direct Measurements

The purpose of this section is to specify the requirements that the GCWI will use to determine if data collected through non-direct measures may be used for this project. This includes data that were collected by other projects/organizations, data acquired from GIS databases, maps, photographs, scientific literature, historical documents, testimony of residents, etc.

The Gunpowder Creek watershed has an extensive network of active stakeholders, including many agencies that have collected and continue to collect high-quality data. This includes extensive water chemistry, biological, fluvial geomorphic, and GIS databases. The GCWI intends to acquire, inspect, and potentially use as much of the data that are relevant to the project, provided they meet the criteria outlined below (primarily in reference to and adapted from Stein, 2007). Any limitations found regarding a given data set will be recorded and reported to the stakeholder who shared that data.

1. The data should have been collected from streams located in northern Kentucky watersheds.
    a. For water chemistry and biological samples, data should have been collected from within the boundaries of the Gunpowder Creek watershed.
    b. For fluvial geomorphic and hydrologic analyses, data from hydrogeomorphically comparable watersheds in northern Kentucky may be used (with appropriate limitations) to support analytical trends from data within the Gunpowder Creek watershed.
2. The data should have been collected in a way that adequately characterizes the chemical/biological/geomorphic condition of the stream using standard, accepted, and comparable methods to those outlined herein.

3. The data should be relevant to the goals of this study.

4. The data should be readily available.

5. Metadata describing the original purpose and objectives for the data, sampling methods and location, procedures for data collection and analysis, and QA/QC information should accompany the data set or be available through consultation with the data authors.

6. The authors of the data set should be available for consultation about such issues as missing data, filling data gaps, the meaning of zero counts, interpretation of outlier data points, and limitations on interpretation of the data set, including the degree to which the data can be extrapolated from the data-collection sites to other sites for which data do not exist.

7. The data set should be scientifically credible and clear of any controversy about its validity, integrity, and ownership, and it should not be currently withheld from distribution because of legal or proprietary concerns. Consistent data collection and analysis methods and quality assurance procedures should apply to the entire data set.

8. The data should be recent enough to pertain to either existing field conditions or the question at hand.

    a. For the purposes of this study, ―recent enough" means that no data more than 15 years old for water chemistry and biological samples. It is assumed that this period is an acceptable interval within which to expect only negligible changes in condition at the site, IF no major impacts (anthropogenic or natural) have occurred (e.g. major flood, fire, change in land use practices).

    b. Regarding fluvial geomorphic and GIS data, historical changes in channel geometry and landuse can provide insights to the project, including—and sometimes especially if—those data are from preceding years. This may even include qualitative descriptions from residents, historic aerial photography, maps, etc. provided that they are used within their qualitative context and not extrapolated to/mixed with present quantitative data.

B10: Data Management

The purpose of this section is to outline how data generated by this project will be managed, stored, and used. The procedures are consistent with the Boone County Conservation District standard data management procedures. The following is primarily informed by and adapted from Stein (2007).

A systematic naming/numbering system will be developed for unique identification of individual samples, sampling events, and sampling sites. The sample numbering system will contain codes that will allow the computer system to distinguish among several different sample types. This system will be flexible enough to allow changes during the demonstration project, while maintaining a structure that allows easy comprehension of the sample type.

To minimize the errors associated with entry and transcription of data from one medium to another, data will be captured electronically where possible. Clearly stated standard operation procedures will be given to the field crews with respect to the use of the field computer systems and the entry of data in the field. Contingency plans will also be stated explicitly in the event that the field systems fail.

All data collected in the field on paper forms or field books will be entered into an Excel spreadsheet as soon as possible after completion. Data entry will be double checked for data entry or typographical errors. All data will be stored in at least two locations or on a network with regular offsite backups. Original paper copies of field forms and field books will be archived and stored for at least five years.

Data results from analytical testing will be entered into the laboratory‘s database after an initial review of the data against method criteria. A secondary reviewer then reviews the data before it is released to GCWI. Should errors arise in the laboratory, a non-conformance report/corrective action report is generated. This report identifies the problem or error, gives planned corrective action and corrective action follow-up procedures. This form is reviewed and agreed to by the laboratory section manager, project manager, QA manager, and analyst. All completed forms are kept in the QA Manager‘s possession.

Upon receipt of the data, GCWI will perform a review of the quality assurance checks and report any variances back to the laboratory for rectification. Should no variances arise, the data will be accepted and used.

All original electronic data files of sample results (e.g. water chemistry sample results) will be retained for at least ten years at BCCD and stored offsite by at least one project partner (e.g. SD1). The final project database will also be available to the public and partner agencies upon request (e.g. SD1, KDOW, etc.), and will be retained by BCCD and at least one project partner (e.g. SD1) for at least ten years.

GROUP C ELEMENTS: ASSESSMENT AND OVERSIGHT

C1: ASSESSMENTS AND RESPONSE ACTIONS

Mark Jacobs (Project Manager) will be responsible for the day-to-day oversight of the project. Mary Kathryn Dickerson (QA Officer) will meet with the Project Manager on a quarterly basis to discuss the collection process, field analyses, data management, and the overall status of the project.

Furthermore, the QA Officer has the authority to conduct random audits at any number of sampling locations/events, to ensure that procedures described here are being followed. The project team will discuss procedures and assess errors in measurements at least biannually. Data collection will be repeated if necessary, as determined by the QA officer in consultation with the Project Manager.

C2: REPORTS TO MANAGEMENT

The status of data collection will be reported to the KDOW Project Manager on a annual basis beginning with the onset of data collection and continuing until the completion of all project data collection as a part of the annual project reports required by this 319(h) grant. Additionally, a Data Analysis Report (DAR) and a Watershed Based Plan (WBP) will be prepared by GCWI for this project. All reports will be prepared and submitted by the Project Manager (Mark Jacobs), in consultation with the Project QA Officer (Mary Kathryn Dickerson), the project steering committee, technical advisers, etc.

GROUP D ELEMENTS: DATA VALIDATION AND USABILITY

D1: DATA REVIEW, VERIFICATION, AND VALIDATION

Data review, verification, and validation steps and procedures were guided by KDOW's (2010) QAPP template, Stein's (2007) CA-approved QAPP, and EPA's (2002b) guidance on environmental data verification and validation. Data generated by project activities will be reviewed against the data quality objectives cited in Element A7 and the quality assurance/quality control practices cited in Elements B5 – B8. Data quality flags from the water chemistry laboratory are provided in Figure 12.

Common Laboratory Qualifiers

A	Value reported is the average of two or more determinations.
B	Analyte was detected in both the sample and the associated method blank. Result exhibits the potential for high bias.
B'	Analyte was detected in the associated method blank.
C	LCD was analyzed instead of MSD due to limited sample volume.
D	Duplicate or replicate failed to meet acceptance criteria.
E	Result is reported as less than the Total result.
F	High concentration resulted in required dilution and elevated detection limit.
F'	Limited sample volume, turbidity or other matrix effect resulted in elevated quant limit/reporting limit or other interferences.
G	Analysis results exceed your permit or regulatory limitation.
H	Result exhibits the potential for high bias.
H'	Low response for IS; possible high bias for detected compounds.
I	Matrix interference.
J	Result is estimated below current MDL
K	The fecal coliform or E.coli count is an estimate, based on colony counts outside the optimum range of 20-60 CFU.
L	LCS failed to meet acceptance criteria.
L'	LCD failed to meet acceptance criteria.
M	MS recovery outside of acceptance criteria.
M'	MSD recovery outside of acceptance criteria.
N	Analysis is not covered under NELAP accreditation.
O	An appropriate aliquot of your sample was subcontracted to a NELAP accredited laboratory. The report is attached.
P	BOD or CBOD seed depletion was outside acceptance limits. All other QC passed, so no effect.
P'	BOD/CBOD method blank concentration was high. All other QC passed, so no effect.
Q	Sample was received or analyzed outside of method established holding time.
R	Sample was received warm, was submitted in inappropriate container, or was improperly preserved.
S	One or more surrogate recoveries failed to meet acceptance criteria.
T	Laboratory contamination is suspected.
U	Analyte not detected.
V	Compound(s) in CCV or ICV had a high %R but results are <RL, or below regulatory limitations.
W	The pH,Dissolved Oxygen,and Total Residual Cholrine were measured upon arrival to the laboratory.
W'	The Ammonia was preserved upon arrival to the laboratory.
X	Analysis was not performed.
X'	Analysis was performed, but valid data could not be obtained.
Y	Coliform bacteria are used as indicator organisms. This water yielded no coliform bacteria; therefore, it is potable. Kentucky Certification KY 00053
Z	Coliform Bacteria are used as indicators for possible fecal contamination. This water had a high number of total coliform bacteria, therefore, it is not potable. Disinfection with regular chlorine bleach and resampling are recommended. Kentucky Certification KY 00053
Z'	E. coli NEGATIVE.
NE	No effect on data
RR	Sample will be reanalyzed
(#)	Indicates number of items referenced in qualifier. *Example S(2) would indicate that 2 surrogate recoveries were outside acceptance criteria.*
*	*(project specific comment)*

Common Laboratory Abbreviation

%R	Percent Recovery
CCV	Continuing Calibration Verification.
ICV	Initial Calibration Verification.
LCD	Laboratory Control Sample Duplicate
LCS	Laboratory Control Sample
MB	Method Blank
MDL	Method Detection Limit
MS	Matrix Spike
MSD	Matrix Spike Duplicate
QA	Quality Assurance
QC	Quality Control
RL	Reporting Limit
RPD	Relative Percent Difference

Figure 12: Data Quality Flags and Abbreviations Used by Cardinal Laboratories

Data will be separated into three categories: data meeting all data quality objectives, data failing precision or recovery criteria, and data failing to meet accuracy criteria. Data meeting all data quality objectives, but with failures of quality assurance/quality control practices will be set aside until the impact of the failure on data quality is determined. Once determined, the data will be moved into either the first category or the last category.

Data falling in the first category is considered usable by the project. Data falling in the last category is considered not usable. Data falling in the second category will have all aspects assessed. If sufficient evidence is found supporting data quality for use in this project, the data will be moved to the first category, but will be flagged with a ―J” as per EPA specifications.

D2: VERIFICATION AND VALIDATION METHODS

Data collected in the field will be validated and verified by the respective Field Data Collection Manager, including assuring that field QA procedures have been maintained. Field operations personnel will check data sheets for completeness and maintain chain-of-custody forms. The Laboratory Manager shall verify that laboratory data quality assurance procedures have been maintained. Field and laboratory records shall be archived in the project file and retained by GCWI.

Data incorporated in the database will be reviewed and tested by the Project Manager. Results of field data will be uploaded into the project database. The original data sheets will be checked for completeness and correctness. Electronic entries will be compared to the original hardcopy data sheets and any errors in the database will be corrected. The original data field sheets will be retained by the Project Manager. Because errors can arise when manually entering hand-written field book data into electronic databases, the electronic data will not be used until all manually entered data have been checked for completeness and any transcription errors corrected.

The Project Manager and QA officer will conduct a final review of the data to ensure completeness and precision criteria have been met. Any data qualifications or limitations on data use will be noted in the database at this stage.

In addition to quality control measures governing data collection, the electronic database developed to store field data will also incorporate numerous measures to assure accurate data entry and processing. The following measures will be implemented:

1. Each field in the database that requires a value will be checked for null or missing values.
2. Standard codes will be provided in look-up lists for use in populating the data table fields.
3. The entry of duplicate records will be prevented, based on a unique combination of fields that define the primary key.

4. If the record set is related to another table in the database, it will be checked for orphan records (i.e., all parent records have child records and all child records have parent records).

5. All of the sites will be checked for having corresponding records in each data table.

The Project Manager, Mark Jacobs, will be responsible for oversight of data collection and the initial analysis of the raw data obtained from the field and any contracted laboratory. Any data requiring reconciliation and/or corrective action will be done by a committee composed of the Project Manager and the QA Officer. Any corrections require a unanimous agreement that the correction is appropriate. All QA and data verification fields will be included in the final project database. In the case of data verification resulting in a change to data, the Project Manager shall inform all data users and make corrections.

The Project Manager and QA Officer shall be informed if data accuracy, reliability or usability has been reduced as the result of errors in stored data or corrupted data files. All data users shall be notified of data problems and corrections.

D3: Reconciliation with User Requirements

Data collected during this project will provide a means of estimating water quality impairments and sources in the Gunpowder Creek watershed as outlined in Elements A5 and A6 (Problem Definition and Background, and Project/Task Description, respectively). We recognize, however, that even the best QA-approved, validated data may not result in a total understanding of all possible nonpoint source pollutants, their spatial and temporal variability, and their precise/exact sources. As it is the nature of nonpoint source pollution, we recognize that the data collected by and used for this project will have clear limitations.

Furthermore, all project reports will identify limitations of the data and discuss appropriate and inappropriate uses of the data and the resultant WBP that is developed. The goal of the GCWI is to improve and/or maintain water quality in the Gunpowder Creek watershed through development of a KDOW-approved WBP. Once the plan is complete and a clearer understanding of the issues facing the watershed is known, appropriate management strategies to mitigate nonpoint source pollution can be identified and selected based on available future funding. By following the QA procedures and guidance outline herein, any data collected by this project will assist in achieving this goal.

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APPENDIX C

Watershed Data Analysis Report

Gunpowder Creek Watershed Plan
Final Report

Prepared by the
Gunpowder Creek Watershed Initiative

Phase II Water Quality Data Analysis Report for the Gunpowder Creek Watershed Initiative

Sustainable Streams LLC
Science · Service · Solutions

Prepared for
Boone County Conservation District
August 2013

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1.0 Executive Summary:

As one of the most rapidly developing counties in the state of Kentucky, Boone County's watersheds are experiencing the negative impacts associated with development. Specifically, the Gunpowder Creek has been under increasing pressure and is classified on the 303(d) List of Impaired Waters for high levels of sediment, bacteria, and nutrients. In an effort to restore these impaired waters, the Boone County Conservation District (BCCD), funded in part by a federal EPA/KDOW 319(h) grant, is creating a watershed plan to address nonpoint source pollution, and the plan is being developed based on goals set by the Gunpowder Creek Watershed Initiative (GCWI). This *Phase II Water Quality Data Analysis Report* presents the results of two rounds of stream monitoring data and assessments, providing details regarding pollutants of concern, potential sources of pollutants, and various solutions to be considered to improve dominant causes of impairments. The analysis is based upon an integrated approach to watershed planning through the stream function pyramid, an interconnected network of several components built upon one another. The stream function pyramid includes land use and land use management, stream flow, physical/habitat conditions, water quality, and finally, biological components – each dependent on the other as an equilibrium of all elements is necessary for healthy stream systems. Quantitative 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) that could be implemented to mitigate such pollutants.

First, stream flow analysis supported that development tends to make water levels rise and fall more rapidly, leading to flashier and larger flows, excessive stream erosion, overall channel enlargement/instability, and adverse effects on aquatic biota such as fish and macroinvertebrates. The results of the flow analysis were further confirmed through the physical data documented by repeat hydromodification surveys. Measured change in channel enlargement was positively correlated to land use characteristics associated with development, such as impervious surfaces, barren land ($p = 0.04$), and riparian roads ($p = 0.03$). Channel enlargement was also positively correlated to water quality impairments with sediment being the best performing parameter tested ($p = 0.10$).

Water quality impairments were then related to land use, erosive flows, and bank erosion, all driving factors that impact the quality of the water as well as habitat and biological conditions. Water quality samples were evaluated through box and whisker plots as well as pollutant load duration curves and allowable pollutant loadings, each relating the variability in pollutants to the changes in weather conditions and examining exceedances in water quality benchmarks. In evaluating the pollutant load exceedances, generally two of the most developed subwatersheds appeared to be contributing the most pollution by weight within the watershed - the headwaters of Gunpowder Creek and South Fork Gunpowder Creek. Results of the water quality analysis also provided insight regarding pollutants of concern and their potential sources. Developed watersheds illustrated larger concerns with bacteria and suspended sediment during wet weather conditions while the less developed, rural watersheds (Riddles Run and Long Branch) experienced higher concerns with bacteria, nutrients, and specific conductance during dry weather. The Fowlers Fork watershed, which represents a mix of developed and rural land use, experienced a combination of the above listed concerns with bacteria being an issue during wet weather conditions and both specific conductance and nutrient concerns during dry weather. Such conclusions were supported by regression analysis. For example, bacteria (as measured by *E.coli* concentrations) was positively correlated to percent impervious ($p = 0.16$) during wet weather conditions, and it was negatively correlated to percent impervious ($p = 0.10$) during dry weather conditions. Watersheds with the most impervious surfaces had issues with bacteria during wet weather and watersheds with the least impervious surfaces had larger issues with bacteria during dry weather.

The results of the *Phase II Water Quality Data Analysis Report* are concluded with a discussion regarding solutions that consider the dominant causes of impairments: point repairs to address dry weather pollution issues and stormwater-based solutions to address wet weather pollution issues. Some examples of point repair solutions include septic system maintenance and point source treatment. Examples of stormwater-based solutions, which should be the focus of the watershed plan for mitigating nonpoint source pollution, include measures that manage the erosive flow regime to protect the physical nature of the streams and improve aquatic habitat as well as measures that filter pollutants before they reach the stream, such as vegetated riparian buffer strips. In particular, recommended strategies include managing stormwater to the critical flow for stream channel protection, stormwater BMPs, detention basin retrofits, targeted in-stream restoration efforts, and vegetated riparian buffer strips along with livestock fencing.

2.0 Introduction:

Nonpoint source runoff (i.e., stormwater) has been identified as one of the leading causes of impairment to stream water quality throughout the state of Kentucky. The ways we live on our land greatly impact the health of our stream systems. Our actions affect hydrology as well as point and nonpoint pollutant loads and habitat/food availability, which create impacts to and feedbacks within aquatic ecosystems. Increased development, as well as improperly managed impervious surfaces (roads, parking lots, rooftops, etc.), disrupts a watershed's hydrology, altering the natural flow regime which negatively impacts stream quality. Additionally, both stream system assessments and public education play important roles in stream quality as understanding existing conditions and promoting public stewardship are critical for protecting our resources.

Boone County in Northern Kentucky is one of the most rapidly developing counties in the state, and its watersheds are currently experiencing the impacts associated with that development (i.e., stream bank erosion/instability, excess sedimentation, degraded biological communities, loss of ecological function, etc.). Specifically, the Gunpowder Creek has been under increasing pressure as development continues to expand, and it has been classified on the 303(d) List of Impaired Waters for high levels of sediment, bacteria, and nutrients. Therefore, the Boone County Conservation District (BCCD), funded in part by a federal 319(h) grant, is working to improve the water quality in the Gunpowder Creek Watershed through the goals of the Gunpowder Creek Watershed Initiative (GCWI) and development of a watershed plan. This *Phase II Water Quality Data Analysis Report* is an important aspect of the watershed plan, as it presents the results of two rounds of stream quality monitoring, providing details on pollutants of concern, potential sources of pollutants, and various solutions to be considered to improve the dominant causes of impairments.

Figure 1 - Gunpowder Creek Watershed Located in Central Boone County (BCCD)

2.1 Gunpowder Creek Watershed

The Gunpowder Creek Watershed has a total drainage area of approximately 58 square miles and is located in the central portion of Boone County, Kentucky (Figure 1). The headwaters of the creek begin in the northeastern portion of the watershed near the Cincinnati/Northern Kentucky International Airport and flow approximately 36 miles southwest to the Ohio River. Additionally, the creek has four larger tributaries (South Fork Gunpowder, Fowlers Fork, Long Branch, and Riddles Run), all located south of the main stem and totaling approximately 143 miles of streams throughout the entire watershed.

Similar to most watersheds, the land use is diverse including industrial, commercial, urban, suburban, residential, agricultural, rural and recreational land use. The watershed consists of approximately 325 miles of roads and the land is primarily characterized by 43% development, 29% forest cover, and 18% agricultural. Approximately 93% of soils have poor infiltration rates (hydrologic soil groups C, CD, and D). Reference the *Gunpowder Creek Watershed Characterization Report* for additional information regarding the physical and natural features of the watershed, land cover, infrastructure, stream conditions, potential pollutant sources and other features in the watershed (LimnoTech, 2009).

2.2 Kentucky 303(d) List of Impaired Waters for Gunpowder Creek

As previously mentioned, several sections of the Gunpowder Creek have been classified on the Kentucky 303(d) List of Impaired Waters for high levels of sediment, bacteria, and nutrients. The *Final 2010 Integrated Report to Congress on the Condition of Water Resources in Kentucky Volume II. 303(d) List of Surface Waters* lists the impairments for the Gunpowder Creek Watershed. A 1.7 mile reach of the main branch of Gunpowder Creek from mile 15.4 to 17.1 is impaired for warm water aquatic habitat (nonsupport) with suspected sources of agriculture, highway/road/bridge runoff (non-construction related), loss of riparian habitat, site clearance (land development or redevelopment), stream bank modifications/destabilization, and unspecified urban stormwater. Additionally, a 2.7 mile reach further upstream from mile 18.9 to 21.6 is also on the 303(d) List of Impaired Waters. This section is impaired for warm water aquatic habitat (partial support) with suspected sources of unspecified urban stormwater. A total of approximately five miles of the South Fork Gunpowder Creek is also listed as impaired. First, there are two miles listed as impaired for warm water aquatic habitat (nonsupport), from mile 0.0 to 2.0. Suspected sources in this reach of stream include agriculture, package plants or other permitted small flow discharges, post-development erosion and sedimentation, and site clearance (land development or redevelopment). Second, about 2.7 miles of stream further upstream on the South Fork Gunpowder Creek is listed as impaired from mile 4.1 to 6.8. This section of stream is impaired for primary contact recreation water (nonsupport) for unknown sources. The following table presents each impaired section and the pollutants of concern, as listed in the Kentucky 303(d) List of Impaired Waters (KDOW, 2010).

Table 1 – 303(d) List of Impaired Surface Waters for Gunpowder Creek Watershed

Stream Name	County	River Miles	Pollutant
Gunpowder Creek into Ohio River	Boone	15.4 to 17.1	Sedimentation/Siltation
Gunpowder Creek	Boone	15.4 to 17.1	Nutrient/Eutrophication Biological Indicators
Gunpowder Creek	Boone	15.4 to 17.1	Organic Enrichment (Sewage) Biological Indicators
Gunpowder Creek into Ohio River	Boone	18.9 to 21.6	Cause Unknown
South Fork Gunpowder Creek into Gunpowder Creek	Boone	0.0 to 2.0	Nutrient/Eutrophication Biological Indicators
South Fork Gunpowder Creek	Boone	0.0 to 2.0	Organic Enrichment (Sewage) Biological Indicators
South Fork Gunpowder Creek	Boone	0.0 to 2.0	Sedimentation/Siltation
South Fork Gunpowder Creek	Boone	0.0 to 2.0	Turbidity
South Fork Gunpowder Creek into Gunpowder Creek	Boone	4.1 to 6.8	Fecal Coliform

2.3 Water Quality Data Analysis

Streams and rivers are among the most complex of physical systems with multiple interdependent components that impact the overall stream health. Streams are systems—their hydrology affects their stability, which in turn affects their water quality and biotic integrity. The stream function pyramid (Figure 2) illustrates that how we live on the land (land use and management) affects hydrology (stream flow), as well as point and nonpoint pollutant loads. Both hydrology and pollutant loads impact the physical health of the stream, habitat/food availability, and overall water quality, which then creates impacts to and feedbacks within aquatic ecosystems (biological). The approach to this *Phase II Water Quality Data Analysis Report* is unique in that rather than analyzing each component in isolation, we look at the system as it is—an interconnected network of dynamic parts. The GCWI monitoring program was designed to assess multiple measures of stream health using flow monitoring, geomorphic surveys, habitat assessments, water quality samples, macroinvertebrate assessments, and land use analysis.

The overall results of both Phase I and Phase II monitoring, as summarized in the *Gunpowder Creek Watershed Health Report - Phase II* developed by the Kentucky Division of Water (KDOW), are consistent with the preliminary assessment that was made during the Quality Assurance Project Plan (QAPP) development. Pollutants associated with hydromodification (e.g., TSS) seem to be the most concerning impairments (average 2012 grade at all sites C-), particularly in the heavily developed headwaters of the Gunpowder Creek Watershed. Indeed, the worst sites for macroinvertebrates were found along headwater tributaries to the main branch and South Fork of Gunpowder Creek, which are the two most developed subwatersheds. The erosive urban flow regime has caused active bank erosion and flushed nearly all of the habitat-forming bed material at these sites, leaving featureless bedrock streams void of aquatic habitat or refugia. These apparent relationships observed in the Gunpowder Creek Watershed are consistent with the statistically-significant relationships of a dataset of 40 unique sites from Northern Kentucky (Hawley *et al*., 2013).

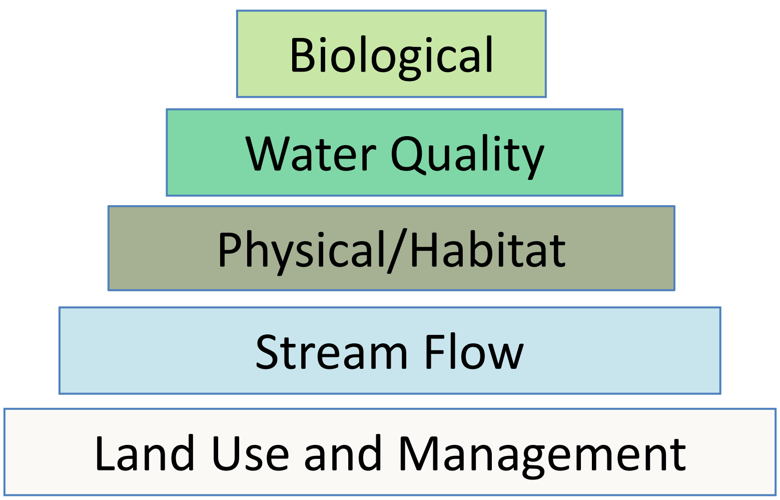


Figure 2 - Stream Function Pyramid
Adapted from Center of Watershed Protection

In comparing the 2011 Phase I monitoring results with the 2012 Phase II monitoring results, many water quality indicators drastically changed due to the substantial difference in rainfall that occurred during each monitoring effort. Samples collected during 2011, a record rainfall year with over 70 inches of rain (NCDC, 2012), provided insight regarding the types of pollutants washed off the land during runoff events. In contrast, samples collected in 2012, a much drier year, indicated the types of pollutants released directly into the stream without the influence of rainfall. Some examples of large differences in wet and dry monitoring (2011 versus 2012) in the Gunpowder Creek Watershed include high levels of bacteria strongly linked to wet weather (a relationship across all sites), whereas higher levels of specific conductivity and nutrients were linked to dry weather at a few monitoring locations, which could be indicative of possible point sources in select areas.

3.0 Data Collection and Methodology:

An understanding of existing conditions through relevant available data served as the foundation on which the entire water quality analysis was based. Several sources of supporting flow gauge and rainfall data as well as sampling data and survey data were collected, reviewed, processed, and summarized to serve as the backbone of the entire analysis. Analysis of these data provided a better understanding of the issues facing each subwatershed and assisted in identifying appropriate management strategies to mitigate nonpoint source pollution in specific subwatersheds.

Figure 3 - Collecting water quality data in Gunpowder Creek (SD1)

As defined in the QAPP, GCWI partnered with the Sanitation District No. 1 of Northern Kentucky (SD1), Thomas More College, and the Licking River Watershed Watch to conduct water quality monitoring in 2011 and 2012 at six sites strategically selected throughout the Gunpowder Creek Watershed. These monitoring sites include one site along the main stem (GPC 7.5 at Camp Michaels), one in the headwater tributaries of the main stem (GPC 17.1-UNT 0.1 at Oakbrook Park), one in the headwaters of the South Fork of Gunpowder Creek (SFG 5.3-UNT 0.1 at Sunnybrook) and one in each of the large tributaries south of the main stem, Riddles Run, Long Branch, and Fowlers Fork (RDR 1.1, LOB 0.5, and FWF 0.8, respectively). Figure 3 presents a photograph of GCWI collecting water quality data in Gunpowder Creek. Additionally, SD1 monitors several sites throughout the watershed. As part of SD1's hydromodification monitoring program, four rounds of hydrogeomorphic survey data, which were collected between 2008 and 2012, were provided for five of its hydromodification monitoring sites (SFG 5.3-DS, SFG 5.3-US, SFG 5.3-UNT 0.1, GPC 17.9 and GPC-UNT 17.1). This SD1 hydromodification data was supplemented with hydromodification survey data collected in 2011 and 2012 by GCWI at the remaining water quality monitoring sites (GPC 7.5, RDR 1.1, LOB 0.5, and FWF 0.8). Water quality sampling sites and sites with 2011 and 2012 hydrogeomorphic survey data are presented in Figure 4.

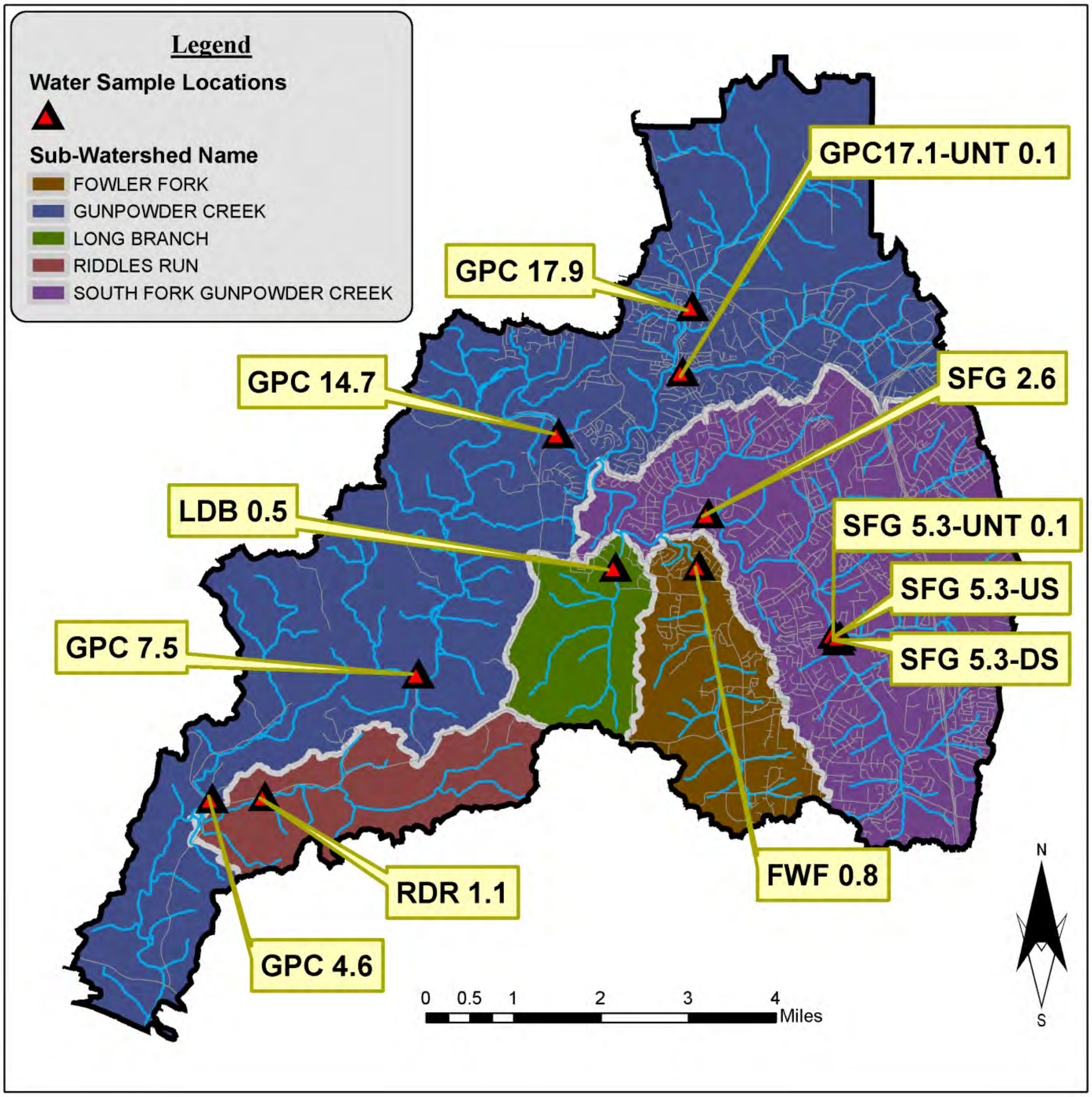


Figure 4 - BCCD and SD1 Gunpowder Creek Monitoring Sites Utilized in Phase II Water Quality Data Analysis

Note: Sites GPC 4.6, GPC 7.5, GPC 14.7, and SFG 2.6 are historic monitoring locations. Data from these locations was not available for this analysis.

3.1 Land Use and Management

In order to assess existing land use information and assist in determining potential sources of pollution, the Boone County Planning Commission utilized its detailed Geographic Information System (GIS) database to analyze, collate, and summarize data on a watershed and subwatershed basis. Such data allowed the geospatial characteristics of individual watersheds to be quantitatively described to better understand their geologic, hydrologic, and human impact. Over 40 parameters were summarized for this analysis. A few examples of pertinent GIS parameters include percent impervious surfaces, forest cover, barren land, riparian area, riparian roads, riparian impervious, Kentucky Pollutant Discharge Elimination System (KPDES) outfalls, and National Resource Conservation Service (NRCS) soil types. Figure 5 on the next page presents a land use map for the watershed. Notice the large portions of commercial/developed land throughout the headwaters on the eastern side of the watershed and the predominantly agricultural/rural land on the western side of the watershed. Such land cover observations assist in explaining the types of pollutant issues in various portions of the watershed.

3.2 Rainfall Data

In addition to land use data, rainfall plays a pertinent role in the hydrology of a watershed, with mean annual precipitation of 42.5 inches across the Gunpowder Creek Watershed. Rainfall data collected at the Cincinnati/Northern Kentucky International Airport (CVG), which is located within the northeastern portion of the Gunpowder Creek Watershed, was analyzed to classify water quality sampling events as wet weather versus dry weather. Daily rainfall totals within seven days prior to each sampling event were evaluated to determine sample classification. Of the 11 sampling dates, three events experienced over 0.7 inches of rainfall within 48 hours of the sample date and were classified as "wet." Review of the United States Geological Survey (USGS) Gauge No. 03277075 for Gunpowder Creek at Camp Ernst Road near Union, Kentucky on these sample dates indicates the Gunpowder Creek experienced high flows within at least 24 to 48 hours of the sampling event. The other eight sampling dates were relatively dry; however, three events were extremely dry with less than 0.01 inches of rain occurring within the 7-day period before the sampling event. Such events were classified as "dry7" for this analysis, with all other sampling classified as "dry." Additional *E.coli* sampling (16 sampling dates total) included two more "dry7" sampling events and three more standard "dry" sampling events.

3.3 Flow Monitoring

Flow data from USGS Gauge No. 03277075 for Gunpowder Creek at Camp Ernst Road near Union, Kentucky, was collected and summarized to use in the water quality data analysis. Flow measurements were also taken during both the 2011 and 2012 water quality monitoring efforts according to procedures outlined in the QAPP. Each 2011 sampling event included documentation of velocities, depths, and reference distances from the shore. The flow was then calculated using the full discharge panel method. Given the extremely dry conditions of 2012, flow monitoring was challenging due to the lack of water in the streams during sampling events, with some sampling events having no flow, some having too low of water depths to obtain a velocity reading, and others having enough depth to obtain only one velocity and one depth reading at the deepest portion of the stream but not enough water to take measurements for the full discharge panel method. For the sampling events with only one velocity and one depth measurement, stream discharge was estimated by assuming a panel width of 0.3 feet, a width calibrated with measurements taken at GPC 7.5.

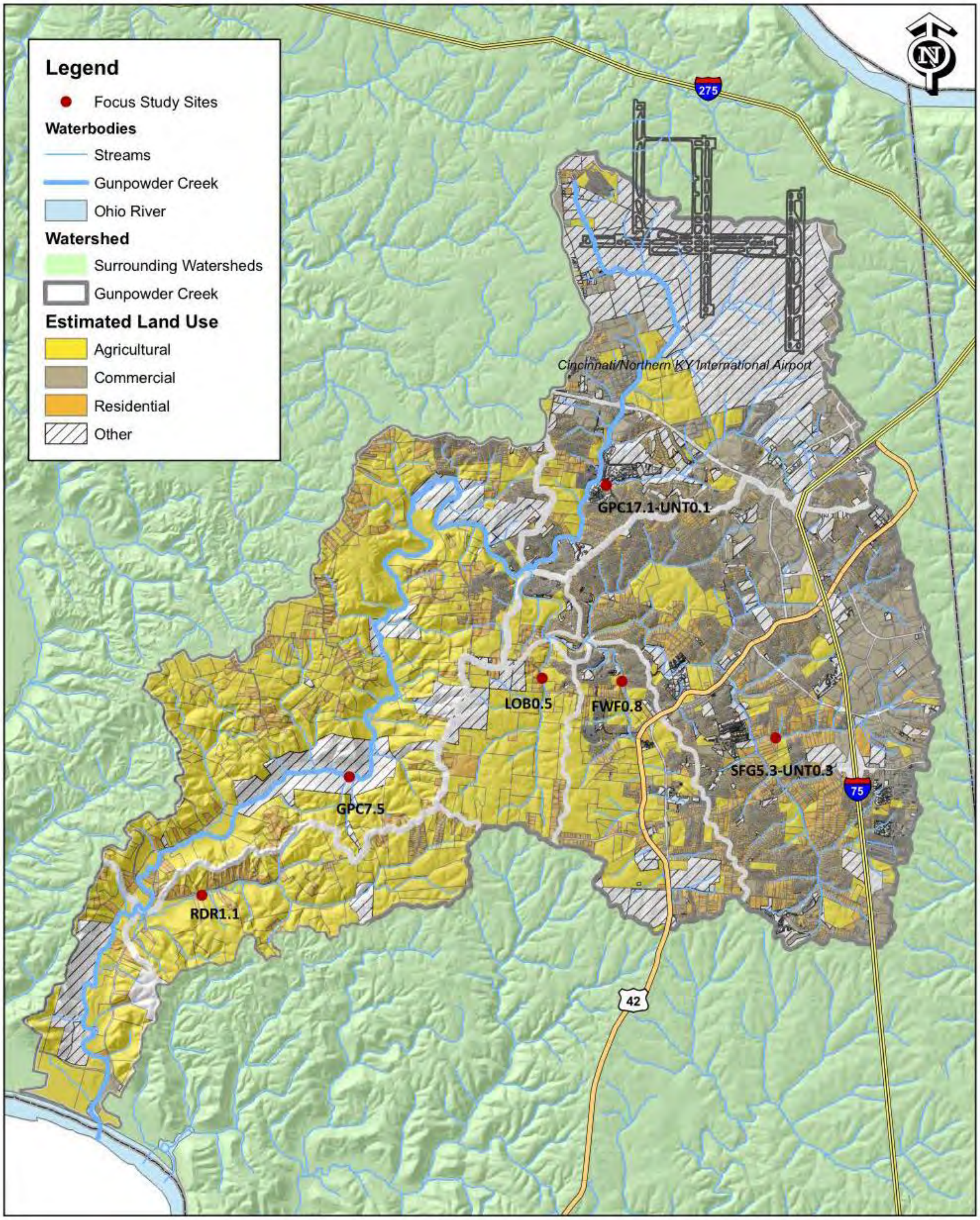


Figure 5 - Gunpowder Creek Estimated Land Use (KDOW)

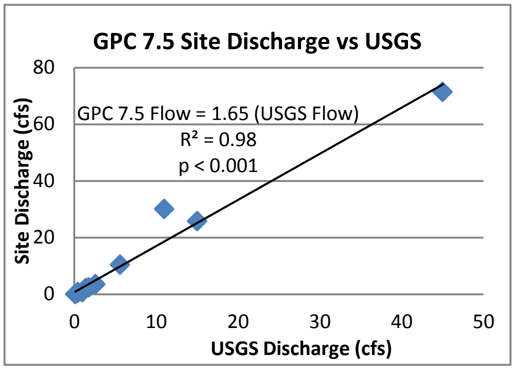


Figure 6-Example Site Discharge vs. USGS Discharge Regression Line

The discharge at sampling events with no flow, too low of water depths to obtain a velocity measurement, or a missed flow reading was calculated using regression equations that correlated the flow measurements at each site to the corresponding flow at the USGS gauge. Figure 6 presents an example of a regression equation developed to estimate site discharge at GPC 7.5. All site discharge versus USGS gauge relationships were significant ($p<0.001$) with R^2 values greater than 0.92.

The USGS gauge data was also used to develop a flow duration curve to be scaled to each monitoring site and serve as the basis for developing pollutant load duration curves. In order to develop a comprehensive curve with typical flow patterns, five years of gauge data (2007-2012) were utilized. However, it should be noted that data from water year 2012 had not been completely finalized by the USGS at the time of analysis and were still considered “provisional and subject to revision.” All data was checked for consistency and any 15-minute intervals without flow records were excluded from the 5 year dataset. The aforementioned regression equations were then used to properly scale the gauge flow duration curve to each monitoring site.

Additionally, water depth information from pressure transducer data loggers, installed by BCCD along three upper tributaries of similar size, was processed and analyzed to document statistical relationships across a gradient of urbanization – undeveloped, developing, and developed. The data loggers were installed near the following sampling sites: RDR 1.1 (2% impervious, 3.2 mi^2), FWF 0.8 (12% impervious, 4.3 mi^2), and GPC 17.1-UNT 0.1 (29% impervious, 3.8 mi^2). Depth information for the three sites was systematically processed and summarized, illustrating higher relative peaks in the developed watershed when compared to the developing and undeveloped watersheds.[1]

3.4 Physical Monitoring - Hydrogeomorphic Data

The hydromodification component of the monitoring effort focused on measuring the physical changes in stream channels, as the altered flow regime associated with conventional urban development leads to flashier and larger flows, excessive stream erosion, and overall channel enlargement/instability that can cause water quality impairments (e.g. high TSS and sedimentation/siltation) and have adverse effects on aquatic biota such as fish and macroinvertebrates. Additionally, accelerated bank erosion, channel widening, and enlargement pose risks to adjacent public infrastructure (e.g., sewers, roads, and bridges) and private property.

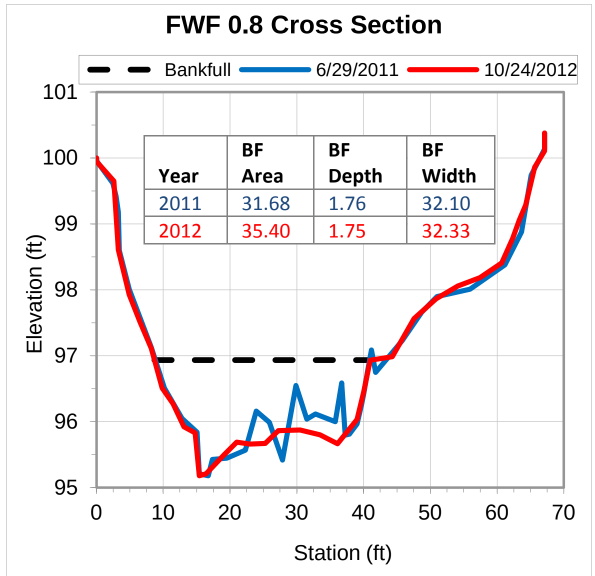
Beginning in 2011, BCCD and SD1 collected detailed hydrogeomorphic survey data according to the industry-standard methods outlined in the QAPP (including cross sections, profiles, and pebble counts) at four sites according to a standard operating procedure (SD1, 2009) based on industry standard techniques (Bunte and Abt, 2001a; Bunte and Abt, 2001b; Harrelson *et al.*, 1994; Potyondy and Bunte,

[1] More involved flow data collection, such as collecting panel-style flow measurements across a range of flows similar to the USGS, could have resulted in a “stage-discharge” rating curve to convert these depth measurements to flow estimates. However, this level of data collection is time intensive and can be dangerous during high flows, and was concluded to be beyond the needs, scope, and budget of this project.

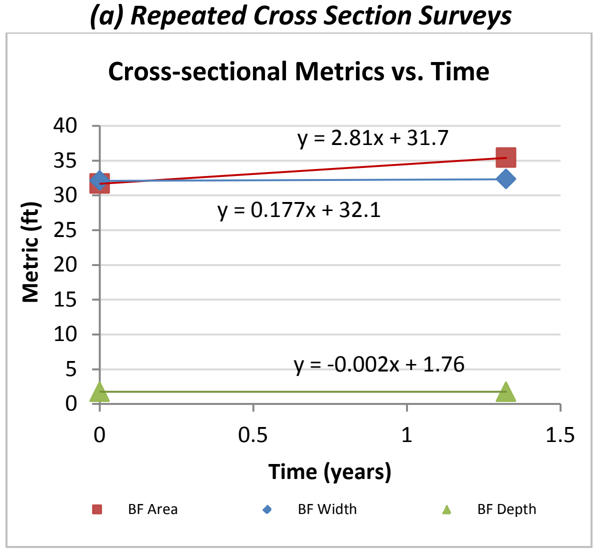
2002). Furthermore, included as part of SD1's hydromodification monitoring program, SD1 has collected several years of hydrogeomorphic survey data at five additional sites for a total of nine unique hydrogeomorphic sites throughout the Gunpowder Creek Watershed. All nine sites have at least two rounds of hydrogeomorphic survey data, with each survey round separated by approximately one year. All survey data have been systematically processed, including adjustments for field errors, and are presented in Appendix A.

In processing the raw survey data, systematic measurements were made for each dimension for consistency across all sites. Cross-sectional measures of channel change included bankfull area, thalweg depths, and top width, all calculated with reference to the lowest top of bank from both survey years, defined as the point at which a defined bank breaks to an angle of less than ~15 degrees for a horizontal distance of at least three feet after Hawley, *et al*. (2013). In addition, the degree of instability was classified using quantitative measures of changes in riffle length, pool length, pool depth, slope, and the pool/riffle ratio, as all profile surveys were broken into several pool-riffle reaches that were measured from the head of one riffle to the head of the next riffle upstream. Regarding bed material composition, key metrics, including the 16th, 50th, and 84th percentile particles (d16, d50, and d84), were determined and compared across each round of survey data.

Average rates of change over the 2011 and 2012 rounds of surveys at each site were completed using linear regression of each important variable verses time between surveys. For example, at Site FWF 0.8 bankfull area increased from 31.68 to 35.40 ft^2 between surveys on June 29, 2011 and October 24, 2012, as shown in Figure 7(a). The absolute change between surveys was an increase of 3.72 ft^2. Corresponding linear regression analysis of cross sectional area versus time revealed an average enlargement rate of 2.81 ft^2 per year, as shown in Figure 7(b). Average rates of measured change of key metrics at each site using linear regression analysis are presented in Appendix A. Such average rates between only two data points can be misleading in that they imply more certainty than actually exists. However, these regression lines are meant to illustrate the variability between the two years of data and provide comparison to regional data (Hawley *et al.,* 2013).



(a) Repeated Cross Section Surveys



(b) Rates of Change Over Time

Figure 7-Measured Change in Cross-sectional Form and Linear Regression at FWF0.8

In addition to measured rates of change of the summary metrics discussed above (e.g. bankfull cross sectional area, profile riffle length, d_{50} of the bed material, etc.), the average weighted deviation between the elevation of each 2011 data point and the 2012 elevation at the same station was calculated *sensu* Baker *et al.* (2012) and Hawley, *et al.* (In prep). Cross section weighted deviation measured change in the ground surface of the active channel bed; profile weighted deviation measured change along the channel thalweg; and bed material weighted deviation measured the change between the bed material gradations of the pebble count on a logarithmic scale.[2]

Lastly, SD1's Stream Stability Index (SustainableStreams, 2012b), a physically-based evaluation tool developed to incorporate the multidimensional effects of hydromodification on stream channels, was calculated for each site and evaluated against statistical relationships during the analysis. Computed using cross-sectional shape, bedrock composition, left bank stability, right bank stability, pool depth, embeddedness, and riffle frequency, this index presents an overall determination of the degree of stability for each monitoring location.

3.5 Habitat Assessments

Monitoring also included habitat assessments during one sample event in 2011 and then another in 2012 according to standard KDOW methods as specified in the QAPP. The assessments focused on the quality of in-stream and riparian habitat and included habitat parameters such as 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, riparian vegetative zones. All the parameters were then assessed to develop a total habitat score for the site's overall habitat condition, which provided a summary for the general habitat condition that is supporting or degrading the structure and function of the aquatic community in the stream. The qualitative habitat assessments served to complement the quantitative physical monitoring described in Section 3.4 by capturing important aspects of the channel habitat that the physical surveys did not, for example riparian vegetation condition, which can play an important role in bank stability.

3.6 Water Quality

Water quality monitoring data included several measurements taken at the site as well as several parameters measured in the laboratory according to industry standard procedures as specified in the QAPP. Field measurements included temperature, pH, dissolved oxygen, specific conductance, turbidity, flow, and percent saturation. Samples sent to the laboratory provided additional measurements of bacteria (*E.coli*), sediment (Total Suspended Solids [TSS]), nutrients (Total Phosphorus [TP], Total Kjeldahl Nitrogen [TKN], Phosphate [P], Nitrate-Nitrite [NN], Ammonia as Nitrogen); and Carbonaceous Biological Oxygen Demand (BOD). In accordance with the KDOW approved QAPP and within project budgets, limited water quality monitoring data was conducted throughout the months of June through August. With the exception of *E.coli,* water quality monitoring included 6 sampling events in 2011 and 5 sampling events in 2012, as KDOW approved for one sampling event in 2012 to be skipped because there was too little flow in the streams to collect samples. The GCWI collected 2 additional *E.coli* samples in both 2011 and 2012. Although the *Watershed Planning Guidebook for Kentucky Communities*, suggests collecting *E.coli*, nutrients, and TSS monthly for a 12 month period, GCWI had a KDOW approved QAPP and budget prior to the completion of the *Watershed Planning Guidebook for Kentucky Communities.* The monitoring plan focused GCWI resources to the primary recreation season

[2] Logarithmic scales are industry standard for bed material gradations, similar to *E.coli* and flow

when pollutant loads could be most relevant to the general public. Such a limited sampling period may not capture potentially high nutrient loadings from agricultural sources usually seen during spring flood events or potential salt loadings during winter storms.

All water chemistry data was systematically processed to evaluate variations in pollutant concentrations and understand what might be causing such variations. The analysis included an evaluation of relationships with rainfall (wet and dry weather events) and stream discharge data to examine changes in the monitoring data, as the concentrations varied throughout the sampling period and were related to precipitation driven changes and the associated changes in stream flow. As previously mentioned, each sampling date was classified as wet, dry, or dry7 depending on the amount of recorded rainfall on the days preceding the sample. Sample concentrations, summarized by water quality parameter, sampling site, and type of sample (wet versus dry and dry7), were then plotted on standard box and whisker plots with the statistical software R (R Core Team, 2012). The box and whisker plots, presented in Appendix B, provide a visual observation of the range of sample concentrations, the mean concentration for each parameter evaluated (excluding statistical outliers), and the overall relation to the water quality benchmark or standard set for that parameter. This graphical representation of sample concentrations provided additional detail regarding pollutants of concern during wet versus dry weather conditions.

In addition to the water quality box and whisker plots, the aforementioned flow duration curves served as the foundation for developing pollutant load duration curves for several pollutants of concern at all water quality monitoring sites. Such pollutant load duration curves were used to analyze 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). In developing the load duration curves, water quality sample pollutant loads were calculated by first multiplying the sample flow data by the measured pollutant concentration. Next, the load duration curve figures were developed to include several important aspects: the flow duration curve (scaled from the USGS gauge), an allowable loading curve determined by the water quality benchmark or standard provided by KDOW, and a projected loading curve calculated with the actual water quality sampling loads. In order to develop the allowable loading curve, the flow data used to develop the flow duration curve was multiplied by the water quality benchmark or standard. The projected pollutant load duration curves involved categorizing the pollutant loads into three bins depending on the sample flow, to illustrate pollutant concerns during high flows, medium flows, and low flows. Ratios of the pollutant concentration to the allowable concentration were then determined and applied to each bin's allowable loading curve to calculate the projected loading curve for each bin. All load duration curve figures, associated annual watershed pollutant loads, and percent load reductions necessary to meet the water quality benchmark or standard are included in Appendix C.

3.7 Biological Assessments

Monitoring also included biological, benthic macroinvertebrate, and some fish sampling assessments during one sample event in 2011 and then another in 2012. 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. Benthic macroinvertebrate samples were sorted, identified, and quantified to determine standard metrics such as Genus Taxa Richness, Genus Ephemeroptera, Modified HBI, Modified %EPT abundance, %Ephemeroptera, %Chironomidae+%Oligochaeta, %Primary Clingers; all assessed to develop an average Macroinvertebrate Biotic Index (MBI) score for the overall site biological condition according to KDOW's regionally-specific index (Pond *et al*., 2003). With the exception of site LOB 0.5, the GCWI conducted a 300 pick macroinvertebrate sample at all sites that was divided up into a grid and only 10 percent of the sample was identified. This methodology was included in the QAPP and BCCD discussed it with KDOW. The GCWI conducted a full pick macroinvertebrate sample at one site (LOB 0.5) because the site did not have many species present to sample. Therefore, GCWI was able to identify all of the species at this location and had to use a different methodology because the site is so impaired. Basically, there was very little aquatic life at site LOB 0.5.

3.8 Sanitation District No. 1 of Northern Kentucky Stream Condition Indices

In addition to the habitat assessments and detailed water quality data collected by BCCD, the evaluation involved review and regression analysis with SD1's Stream Condition Indices (SCI), an evaluation and planning tool that serves as a means of compiling large amounts of data into a simple score to assess the overall health of a monitoring site. This includes complex chemical (water quality), physical (habitat), biological, and channel stability (hydromodification) indices rated on a 0-10 scale, including an overall score that is a composite of the four individual indices. The primary purpose of the SCI score is to summarize the overall health of a monitoring site and present the information in terms easily understood to a non-technical audience. While environmental indices, such as the SCI, are frequently used to summarize complex monitoring data, the SD1 SCI is unique because it is calibrated to local conditions.

The water quality component includes chemistry parameters such as bacteria (fecal coliform), dissolved oxygen, metals, nutrients, ammonia, pH, temperature, CBOD, conductivity, and turbidity. The physical habitat component utilizes the ten measures of habitat condition that are determined as part of the SD1 monitoring and assessment program, including epifaunal substrate/available cover, embeddedness, velocity/depth regime, sediment deposition, channel flow status, channel alteration, frequency of riffles (of bends), bank stability, bank vegetative protection, and riparian vegetative zone width. The biological component uses a combination of the Kentucky Index of Biological Integrity (KIBI) (fish communities) and the Kentucky macroinvertebrate Biotic Index (KMBI), utilizing the KMBI in headwater streams and both indices in wadeable streams with fish populations and larger drainage areas. Lastly, the channel stability component utilizes SD1's Stream Stability Index, which is further explained in *Section 3.4 Physical Monitoring - Hydrogeomorphic Data.* Reference the July 2013 SD1 technical memorandum titled *A Stream Condition Index for Water Utility Resource Management in Northern Kentucky* for additional information regarding each sub-index and determination of the associated scores (Limnotech, 2013).

3.9 Kentucky Division of Water Resources Gunpowder Creek Watershed Health Reports

KDOW evaluated the water quality, habitat, and biological health assessments collected by BCCD to generate *Gunpowder Creek Watershed Health Reports* for both the Phase I and Phase II monitoring efforts. Data was divided into indicators of water quality (dissolved oxygen, specific conductance, nutrients, total suspended solids, and *E.coli*) or indicators of biological health (total habitat, aquatic macroinvertebrates, riparian zone, and available cover). Indicators were graded A through F, by comparing them to KDOW water quality standards or benchmark data. The individual grades were averaged by KDOW to determine an overall biological health score and an overall water quality score for each subwatershed. KDOW then averaged these two scores to calculate a watershed health grade. While the purpose of this report is to present the results of the water quality data analysis, it is important to convey the results to both the general public as well as technical audiences. Therefore, the

KDOW grades were utilized as part of the data analysis because they summarize the overall health of the watershed in a means that is easier for the general public to understand.

3.10 Statistical Relationships & Data Analysis

Statistical analysis involved detailed evaluation of various relationships regarding water quality monitoring results and watershed characteristics represented by GIS land use data. Because hydromodification is a known water quality concern in Gunpowder Creek, and can be a source of impairments such as high TSS, this analysis also incorporated the results of the hydromodification monitoring in order to identify statistically-significant relationships between every aspect of the stream function pyramid. This included correlations among and between land use, flow, water quality, habitat, and macroinvertebrate communities. Such a holistic analysis assisted in identifying sources of all impairments as opposed to simply one or two water quality impairments. In this light, BMPs with greater cost effectiveness for all impairments may be identified and prioritized accordingly. Statistical significance was assessed by means of the R^2, adjusted R^2 and *p* value using the R program (R Development Core Team, 2012). Any *p values* less than the 0.05 threshold were considered to be statistically significant. Please note that the statistical relationships presented throughout this report are based on a limited amount of data collected during 2011 and 2012, and while some relationships are statistically significant, this does not prove that the relationships are real. However, it does imply that there is likely a relationship between the variables tested. The fact that many of the relationships presented are physically based (i.e., cause and effect relationships that could be reproduced in a controlled laboratory setting) and consistent with previously published literature adds to a weight of evidence that the relationships are real and not attributable simply to chance or random occurrence.

3.11 Water Quality Standards and Benchmarks

Water quality standards utilized throughout the analysis were obtained from Kentucky Administrative Regulations defined in *401 KAR 10:031 - Surface water standards*. The standards provide water quality criteria applicable to all surface waters to protect their indicated use, promote aquatic habitat, and safeguard human health. The water quality standards incorporated in this analysis include set criteria for bacteria, as measured by *E.coli,* as well as set criteria for dissolved oxygen and unionized ammonia.

All other parameters included in this analysis are compared to water quality benchmarks provided by KDOW in the *Gunpowder Creek Watershed Plan Benchmark Recommendations for Nutrient Parameters* (February 2012) and the *Gunpowder Creek Watershed Plan Benchmark Recommendations for Non-Nutrient Parameters* (February 2012) documents. These guidance documents set initial benchmarks based on typical values in comparable reference and healthy streams and are included in *Appendix F* of this report. In making the nutrient benchmark recommendations, KDOW considered regional and watershed-specific nutrient expectations, regional-scale patterns in biological effects, and the specific indicators of nutrient enrichment observed in the watershed. The final benchmark recommendations provided by KDOW are primarily based on review of water quality samples at 12 ecoregional reference reaches within the Outer Bluegrass bioregion (ecoregion 71d) as well as typical literature values often cited for healthy streams.

Additionally, the screening benchmark provided by KDOW for TSS and Turbidity is meant for baseflow conditions and is not applicable to periods of high flow. Therefore, KDOW usually recommends that the Watershed Plan define an appropriate TSS benchmark for comparison across all flow regimes by evaluating a monitoring location where suspended sediment issues are minimal. However, as noted throughout this report and evident in the hydromodification changes presented in the cross section, profile, and bed material figures included in *Appendix A-Hydromodification Surveys*, suspended sediment and active bed loads are present at all of the monitoring locations; and this limited dataset does not allow for an opportunity to recommend a different TSS benchmark for high flow conditions.

It must be emphasized that the benchmarks are not definite criteria but provide approximate water quality goals to uphold a healthy stream system. These benchmarks represent the best information available to KDOW at the given time, are likely more stringent than necessary, and can be re-evaluated if BCCD and KDOW are interested in discussing alternative benchmark targets. However, it should be noted that more appropriate benchmarks could only be re-evaluated and determined based on larger datasets. The limited amount of data collected for the GCWI would most likely be insufficient to recommend alternative values. Considering that these screening values are likely more stringent than necessary, the load reduction numbers could be slightly inflated. However, because the benchmark values are only goals and not set criteria, they were considered relatively sufficient for this level of analysis. **Benchmark values provided by KDOW give a broad frame of reference to understand the general level of concern and approximate orders of load reduction that may be necessary to come within reasonable targets for water quality.**

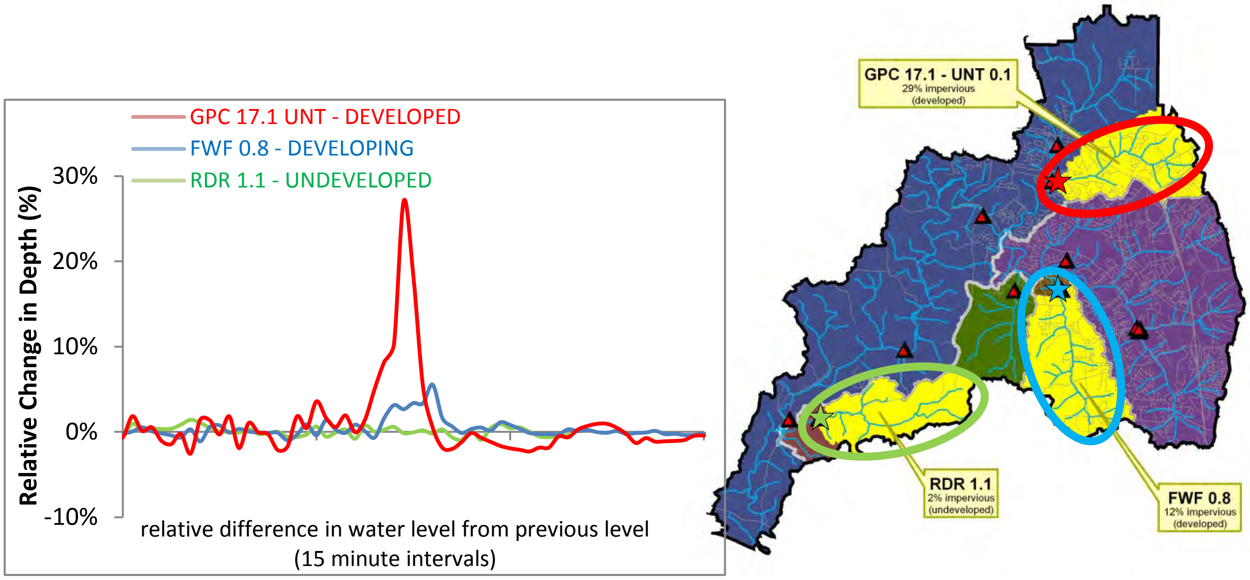
4.0 Results & Related Case Studies:

4.1 Stream Flow: Development Tends to Make Water Levels Rise and Fall More Rapidly

The urban flow regime associated with increased development and unmanaged impervious area has greatly impacted Northern Kentucky streams (Hawley *et al.*, 2013). Figure 8 presents an example of a Northern Kentucky stream, Pleasant Run (~100 acre basin) that experiences erosive flows even on relatively small storm events (photo illustrates 11/16/10 rainfall event: magnitude: 0.45 inches; duration: 2 hours; < 2 month storm (2 hour/2 month = 0.81”). This example illustrates that very fast, erosive flows occur during many storms.

Figure 8-Erosive Flows During 0.45 inch storm

Comparison of data logger information from three sites within the Gunpowder Creek Watershed of similar drainage area but varying levels of development, Figure 9(b), illustrated that the altered flow regime associated with conventional urban development leads to flashier and larger flows. This is evidenced by the comparison of all three data logger locations, Figure 9(a), which shows that the most developed site experienced much higher changes in water levels during the same rain event. The flashier and larger flows associated with unmanaged urban development lead to 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.



(a) Percent Relative Change in Water Depth Over Time ***(b) Data Logger Locations***

Figure 9-Water Levels Rise and Fall More Rapidly in Developed Watersheds

4.2 Physical/Habitat: Erosive Flows Cause Bank Erosion, Channel Enlargement, Destroyed Public Infrastructure, and Degraded Habitat

4.2.1 Overall Physical/Habitat Relationships Illustrate Concerns with Channel Enlargement and Habitat

Analyses of physical data indicate that streams in urban/suburban watersheds tend to be getting larger. An in-depth study of Northern Kentucky streams has demonstrated their overall shape is deepening and widening, their riffles are shrinking, their pools tend to be getting both longer and deeper, and watersheds in early stages of development (i.e., less than 15% total impervious area) were correlated with bed material coarsening (Hawley *et al.,* 2013). Unstable streams degrade water quality, the presence of aquatic habitat, and ultimately biological activity. Additionally, the unstable nature of many streams throughout Northern Kentucky has destroyed infrastructure and adjacent property (Figure 10).

Figure 10-Streams Widen and Destroy Public Infrastructure

Stability and habitat quality tend to decrease in developed watersheds and impervious area has been strongly correlated to channel enlargement, bed coarsening, shorter riffles, longer and deeper pools, and stream instability in Northern Kentucky streams (Hawley *et al.,* 2013). In general, the systemically-processed hydrogeomorphic survey data throughout Gunpowder Creek illustrated similar relationships to Northern Kentucky streams; however, the relationships were not as significant due to the limited number of data points (9 total sites) and the presence of vertical grade control (bedrock) at many of the sites. In relation to percent impervious surfaces, both bankfull area and bankfull top width linear regressions were the most clear. The average annual change in bankfull area and bankfull top width were positively correlated to percent impervious with *p* values of 0.23 and 0.13, respectively. These *p* values mean that there was a 23% and 13% chance, respectively, that these relationships were attributable to chance and chance alone and not representative of actual relationships. In other words, there was about a 77 and 87% chance, respectively, that the measured changes in stream channel area and width were attributable in part to watershed urbanization and not simply a random occurrence. This illustrates the variables are related, however, with *p* values of 0.23 and 0.13, respectively, the correlations are not considered to be statistically significant.

When evaluating cross-sectional enlargement (average annual increase in bankfull area per year) against land use, some examples of GIS parameters that illustrated significant ($p < 0.05$) relationships include percent barren land (Figure 11) and riparian roads (Figure 12). In a watershed comprised of predominantly clay soils (93.5% Hydrologic Soil Group Types C and D), barren land cover can be behave similar to impervious land area because it lacks the vegetation to slow down and transpire stormwater runoff. Additionally, the presence of roadways within the riparian corridor was strongly correlated to channel enlargement, indicating that the presence of riparian roads seemed to explain a greater portion of channel enlargement than watershed imperviousness. Roads often route their stormwater directly, and efficiently, to streams, whereas large developments tend to include some level of stormwater detention. Therefore, the case can be made that roadway imperviousness causes more hydrological effects than other types of impervious area. Riparian roads may also be indicative of potential channelization that may have occurred to create more optimal roadway alignments. Channelization is widely documented to increase the erosive energy of streams, which also makes them more prone to channel erosion and enlargement.

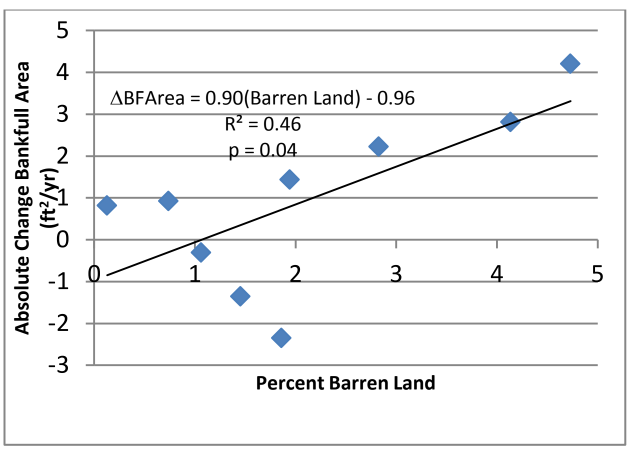


Figure 11-Channel Enlargement is Positively Correlated to Percent Barren Land

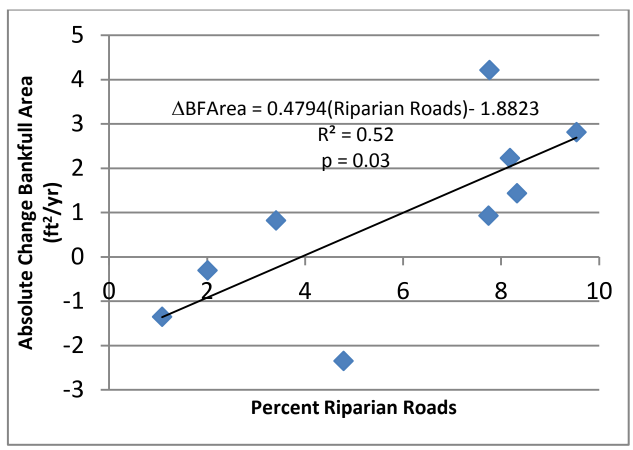


Figure 12-Channel Enlargement is Positively Correlated to Percent Riparian Roads

In addition to GIS metrics, linear regression relationships relating enlargement and water quality were evaluated. Of all the water quality metrics evaluated, TSS correlated the strongest to channel enlargement with a *p* value of 0.10 (Figure 13). That is, there is a 90% chance that channel erosion and enlargement is a dominant source of suspended sediment in the Gunpowder Creek Watershed. Another supporting regression illustrates that degraded habitat correlates to enlarging bankfull area and bankfull width, as the SD1 Habitat Score was negatively correlated to both the change in bankfull area per year and the change in bankfull top width per year, with significant *p* values of 0.05 and 0.02 (Figure 14), respectively.

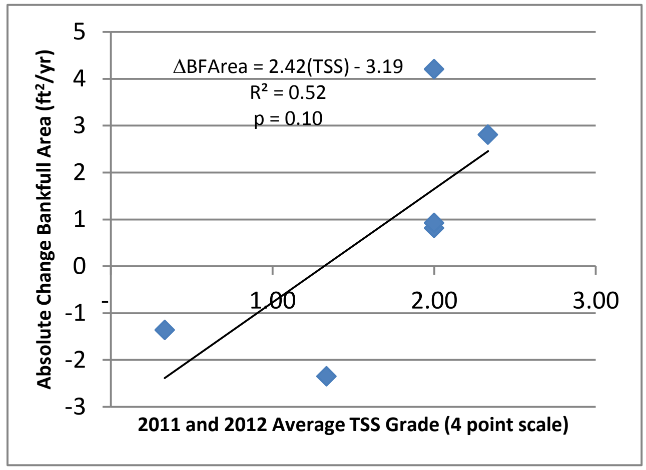


Figure 13-Channel Enlargement is Positively Correlated to KDOW TSS Grade

Hydromodification monitoring on sites throughout Gunpowder Creek document the physical changes that have occurred through both quantitative data captured by hydrogeomorphic surveys and observations of visual changes documented in annual photographs. Of the nine hydromodification monitoring sites assessed for this analysis, three case studies present classic examples of the problems throughout much of the Gunpowder Creek Watershed. This includes an example of an extremely dynamic site that experienced bank failure and bed incision (SFG 5.3-DS, 28% impervious); an example of geotechnical mass wasting and bank widening at a site with relatively shallow bedrock and a well-connected floodplain (GPC 17.1-UNT 0.1, 29% impervious); and an example of a site with erosive flows that transported large amounts of woody debris (SFG 5.3-UNT 0.1, 41% impervious). Locations of these sites are illustrated in Figure 15.

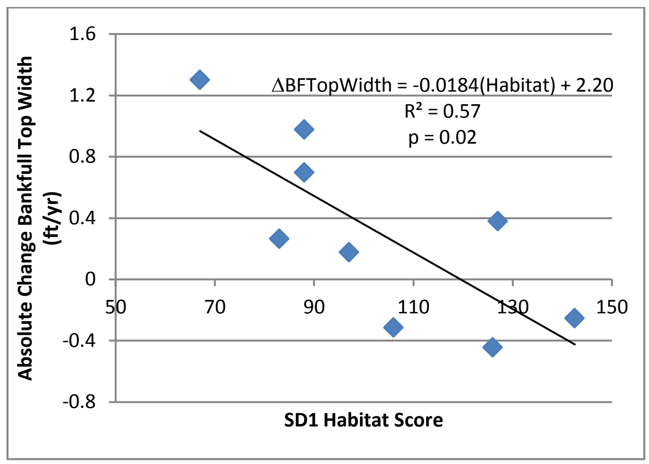


Figure 14-Channel Enlargement is Negatively Correlated to SD1 Habitat Score

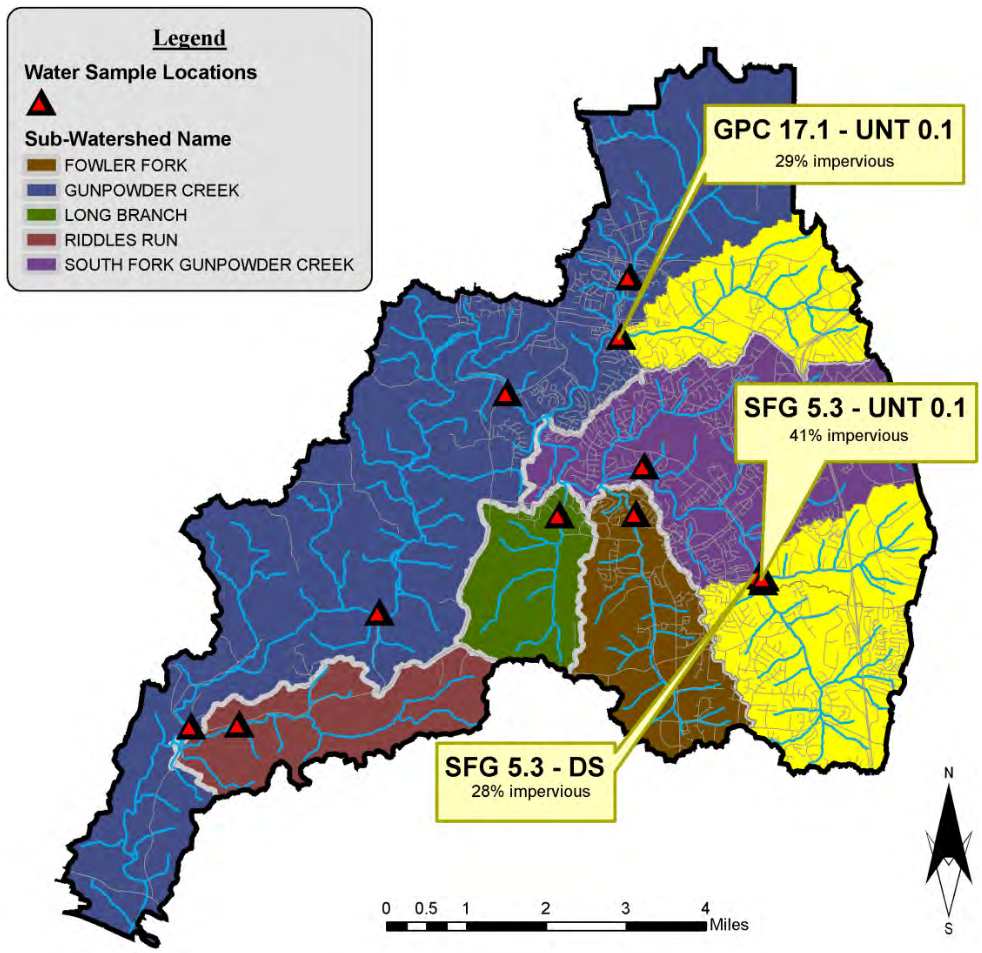


Figure 15-Physical/Habitat Case Studies throughout the Gunpowder Creek Watershed

4.2.2 South Fork Gunpowder Creek Stream Channel Dynamics Exhibit Bank Failure, Tree Loss, and Incision Through Bedrock (SFG 5.3-DS)

The South Fork of Gunpowder Creek is located in the southeastern portion of the watershed and includes three monitoring sites approximately 5.3 miles upstream of the confluence with the Gunpowder Creek main stem. These sites are identified as SFG 5.3-DS, SFG 5.3-US, and SFG 5.3-UNT (i.e., South Fork of Gunpowder, downstream of the confluence with an unnamed tributary, upstream of the confluence, or on the unnamed tributary). While the monitoring data at all three of these survey sites has illustrated that the sites are dynamic, the downstream site (SFG5.3-DS) was the most dynamic with lost trees, bedrock incision, and compromised storm sewer infrastructure. This site has an upstream drainage area of 6.91 square miles, and the watershed is fairly developed with approximately 29% impervious area.

Figure 16-Storm Sewer Infrastructure at Site SFG5.3-DS Compromised by Flow Regime

Over the four rounds of surveys conducted by SD1 as part of its hydromodification monitoring program, collected between 2008 and 2012, both physical observations and quantitative data supports that the channel is enlarging, the longitudinal slope is responding to headcut migration (becoming flatter), bedrock is being fractured and mobilized, and the bed material gradation is coarsening. Storm sewer infrastructure at the site has been compromised by the eroding bank, causing a pipe outfall to become dislodged from its concrete headwall (Figure 16).

The following list presents a summary of key metrics and the corresponding percent change over this time period.

1. Bankfull area increased by 5%; benchfull area increased by 18%.
2. Profile slope decreased by 60%.
3. Bed material gradation became substantially coarser (d16 increasing by 467%; d50 increasing by 1760%, and d84 increasing by 278%.

The erosive flow regime has caused the banks to enlarge, particularly the left bank, which has expanded more than three feet between 2008 and 2012, resulting in the loss of two trees (Figure 17-red). If this erosive flow regime is left unmitigated, the banks may continue to enlarge impacting costly infrastructure and several other trees. Similar to most unstable Northern Kentucky streams, the South Fork of Gunpowder Creek is responding to the erosive urban flow regime through headcut migrations along the longitudinal profile. The 60% decrease in slope over the four rounds of surveys can be attributed to the presence of this headcut migration (Figure 17-yellow). This type of channel response is seen as a primary cause of longitudinal slope adjustment and tends to change the nature of the stream with a decrease in riffle lengths and increase in pool lengths (Hawley *et al*., 2013). In addition to the decrease in slope, consistent with literature, this pool-riffle reach has also experienced an increase in total pool length and decrease in the stream's riffle length.

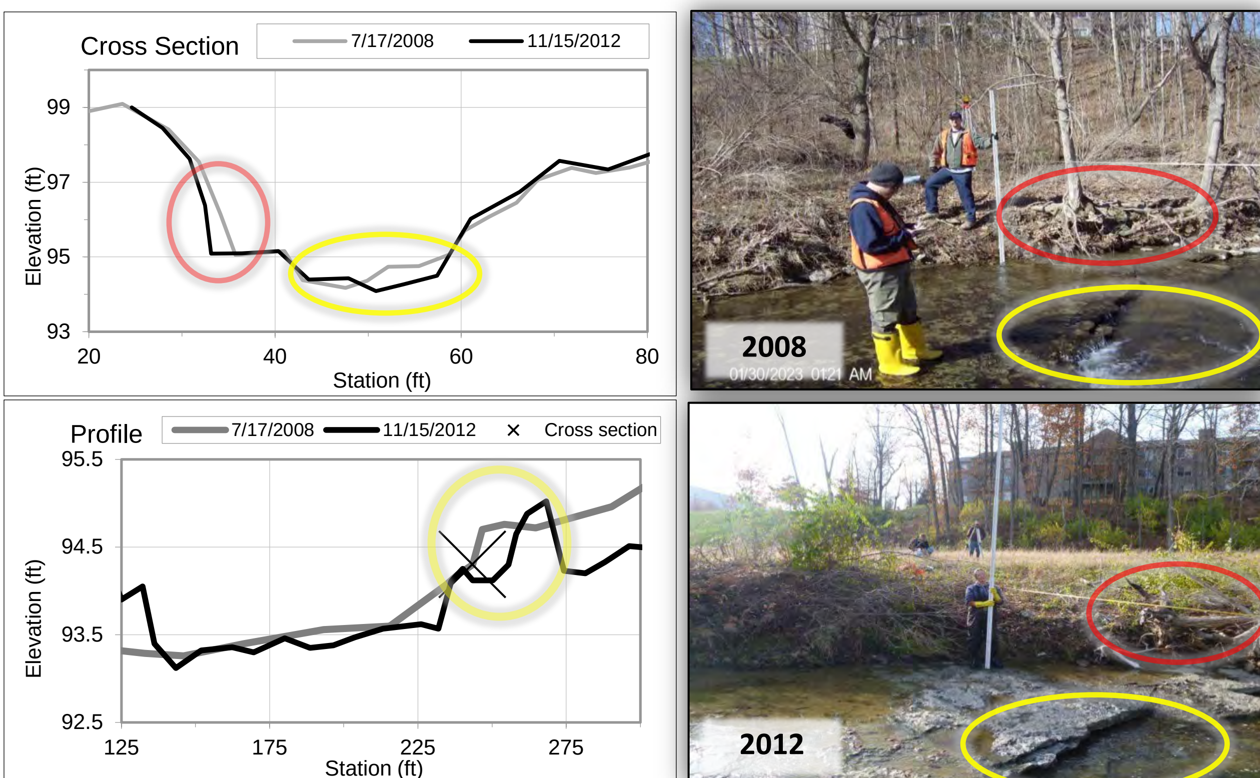


Figure 17-Erosive Flows Incise Bedrock (yellow) and Cause Tree Loss from Bank Failure (red)

This site is also experiencing bedrock incision as well as coarsening bed material gradation. Conventional wisdom suggests that shallow bedrock tends to minimize or prolong channel incision by serving as a form of grade control, which makes the dominate source of channel instability bank failure and channel widening through both fluvial erosion and mass wasting mechanisms (Hawley *et al*., 2013). The survey data at SFG 5.3-DS confirms this response but also indicates that at times even sites with exposed bedrock can be extremely unstable and the stream bed can still degrade and incise as the exposed bedrock weathers and begins to fracture (Figure 17-yellow).

The active break-up of the channel bedrock and additional bed incision is apparent and is concerning because bedrock in Northern Kentucky tends to be thin (less than approximately 6 inches to 1 foot) seams of limestone (relatively strong) between thick (approximately 3 to 5 feet) layers of very weak shale. As the limestone layer gradually fractures and is mobilized, the underpinning shale layer becomes eroded at very fast timescales. This threshold condition of limestone surface weathering can result in very large increases in bank height (approximately 5 feet) on short timescales. The energy of the urban flow regime has also resulted in sediment transport and substantial coarsening of the bed material at this site (Figure 18). Note that the corresponding photos of this site and the following case study (SFG5.3-UNT 0.1) are nearly completely void of any habitat-forming particles and are comprised of featureless bedrock bottoms.

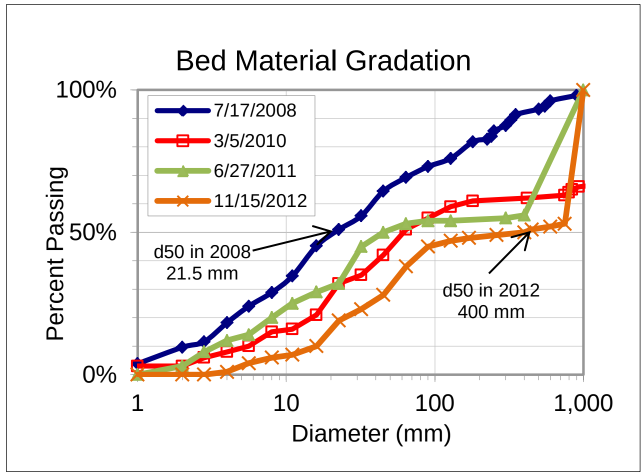


Figure 18-SFG5.3-DS Coarsening Bed Material

4.2.3 Mass Wasting and Bank Widening Can Occur at Sites with Shallow Bedrock and Well-Connected Floodplains (SFG 5.3-UNT 0.1)

Another site located in the South Fork of Gunpowder Creek subwatershed (SFG 5.3-UNT 0.1) also experienced bank failure over the rounds of hydromodification monitoring. This site has an upstream drainage area of 2.2 square miles, and the watershed is very developed with approximately 41% impervious area coverage. A photo taken during 2012 monitoring captures a continuous tension crack (bank failure) along the entire length of the bank (Figure 19). This is a good example of geotechnical mass wasting and bank widening even on a bank with a short height and at a site with shallow bedrock

Figure 19-SFG 5.3-UNT 0.1 Tension Crack Bank Failure

and a well-connected floodplain. Such failure emphasizes the importance of a riparian buffer strip with thick vegetation to aid in stabilizing the bank.

4.2.4 Visual Observations of Large Woody Debris and Damaged Tree Indicate Presence of Erosive Flows at a Site with Little Change to Cross Section Shape (GPC 17.1 – UNT 0.1)

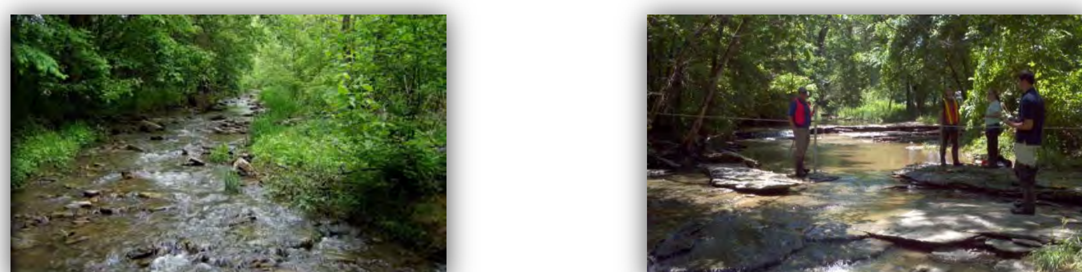
A site located in the headwaters of Gunpowder Creek, GPC 17.1-UNT 0.1 (29% impervious) experienced powerful erosive flows over the rounds of hydromodification monitoring. A series of photos taken in 2010, 2011, and again in 2012 (Figure 20) illustrates a tree becoming more damaged as time progresses. Additionally, the location of large woody debris is altered from year to year, indicating flows strong enough to transport heavy logs. The location of the tree (well over 10 feet into the channel) is indicative of historic widening as it is unlikely for a tree sprout to be able to take root in the middle of an active channel.

2010 2011 2012

Figure 20-Erosive Flows at GPC 17.1-UNT 0.1 Transport Large Woody Debris and Damage Tree

4.3 Habitat: Channel Enlargement and Adverse Physical Conditions are Strongly Correlated to Degraded Habitat Conditions

Wetlands, vegetated riparian areas, native plant communities, and healthy stream channel conditions are important elements to support habitat structure and biology in streams. As previously mentioned, the physical condition of a stream system strongly influences the habitat conditions, as the SD1 Habitat Score was negatively correlated to both the change in bankfull area per year and the change in bankfull top width per year, with significant p values of 0.05 and 0.02, respectively (Figure 14). Hydromodification data supports that the erosive urban flow regime has destroyed the nature of the Gunpowder Creek streams, leaving homogenous, featureless stream beds composed of exposed bedrock, long pools, and short riffles (Figure 21).



(a) Pristine stream example in Northern Kentucky *(b) Homogenous, featureless bedrock streambed*

Figure 21-Physical Characteristics of the Streambed Strongly Influence Habitat Conditions

Such degraded habitat characteristics provide poor conditions for macroinvertebrate communities, and therefore also degrade the biological conditions at the sites. Review of the *Gunpowder Creek Watershed Health Reports* by KDOW indicates that habitat conditions are problematic throughout the Gunpowder Creeks, as the total Habitat grade for both 2011 and 2012 was a D+. Additionally, the KDOW habitat grades at each monitoring location were positively correlated with the SD1 Habitat Score, with a significant p value < 0.01.

4.4 Water Quality: Land Use, Land Use Management, Erosive Flows, and Bank Erosion Are All Driving Factors that Impact Water Quality throughout the Gunpowder Creek

Analysis of water chemistry data in the Gunpowder Creek Watershed provides insight about potential pollutants of concern and possible sources of the pollutants, such as land use, land use management, erosive flows, and bank erosion. All water chemistry data was systematically processed to evaluate variations in pollutant concentrations and understand what might be causing such variations, such as changes in wet and dry weather conditions and the associated fluxes in stream discharge data. The following section, as well as supplementing appendices, presents the results of the water chemistry analysis.

4.4.1 Evaluation of Parameter Concentrations Defines Potential Pollutants of Concern

Sample concentrations, summarized by water quality parameter, sampling site, and type of sample (wet versus dry and dry7) were initially analyzed using water quality box and whisker plots (Appendix B) that provided a visual observation of the range of sample concentrations for all samples as well as samples in the wet, dry, and dry7 categories. Each box and whisker plot depicted the range of sample concentrations with excluded statistical outliers, the mean concentration for each category, and the overall relation to the water quality benchmark or standard set for that parameter. In addition to the box and whisker plots analyzed for each individual water quality parameter, this analysis involved evaluation of the ratios of sample concentrations to the water quality benchmark or standard at each monitoring location.

a) Summary of All Sample Concentration Exceedances

Water chemistry parameters were evaluated to determine which pollutants were most concerning during wet versus dry weather sampling. Table 1 presents the percent of water quality samples that exceeded the benchmark or standard set for each individual parameter. All sample exceedances greater than 80% are identified in red (most concerning) and all sample categories with less than 20% exceedance are identified in blue (least concerning). These results indicate that Total Phosphorus (TP) and Total Kjeldahl Nitrogen (TKN) are typically always above the water quality benchmark, while pollutants such as Dissolved Oxygen (DO), Nitrate-Nitrite as N (NN), and Unionized Ammonia (Union Amm) are the least concerning. Additional analysis of the nutrient concentrations and their pollutant loading indicates this type of pollutant is not as large of an issue as bacteria and sediment because the degree of exceedance is much lower. The sampling results for the remaining pollutants, *E.coli*, Total Suspended Solids (TSS)/Turbidity (Turbid), and Specific Conductance (SpCon) present interesting statistical relationships related to exceedances during wet versus dry weather sampling and are presented in additional detail in the following sections.

Table 2 – Percent Exceedances Above Water Quality Benchmark/Standard Concentration

		Parameter:	TSS	Turbid	TP	TKN	NN	Union Amm	DO	SpCon	*E.coli*
		No. Samples:	11	11	11	11	11	11	11	11	16
		No. Wet Samples:	3	3	3	3	3	3	3	3	3
		No. Dry Samples:	5	5	5	5	5	5	5	5	8
		No. Dry7 Samples:	3	3	3	3	3	3	3	3	5
		Benchmark/ Standard[1]:	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
Water Quality Sampling Sites	GPC 7.5	All	91%	64%	100%	100%	45%	0%	0%	36%	38%
		Wet	100%	100%	100%	100%	100%	0%	0%	0%	100%
		Dry	80%	40%	100%	100%	40%	0%	0%	60%	25%
		Dry7	100%	67%	100%	100%	0%	0%	0%	33%	20%
	GPC 17.1	All	45%	55%	91%	100%	18%	0%	0%	82%	40%
		Wet	67%	67%	100%	100%	33%	0%	0%	67%	100%
		Dry	60%	80%	80%	100%	20%	0%	0%	80%	38%
		Dry7	0%	0%	100%	100%	0%	0%	0%	100%	0%
	SFG 5.3	All	55%	27%	64%	100%	9%	0%	9%	91%	50%
		Wet	100%	67%	100%	100%	33%	0%	33%	67%	100%
		Dry	20%	20%	40%	100%	0%	0%	0%	100%	50%
		Dry7	67%	0%	67%	100%	0%	0%	0%	100%	20%
	FWF 0.8	All	55%	36%	91%	100%	18%	0%	10%	73%	75%
		Wet	100%	67%	100%	100%	67%	0%	33%	33%	100%
		Dry	20%	20%	80%	100%	0%	0%	0%	80%	88%
		Dry7	67%	33%	100%	100%	0%	0%	33%	100%	40%
	RDR 1.1[2]	All	40%	20%	90%	80%	10%	0%	50%	80%	67%
		Wet	67%	67%	100%	100%	33%	0%	33%	33%	100%
		Dry	20%	0%	80%	60%	0%	0%	40%	100%	63%
		Dry7	50%	0%	100%	100%	0%	0%	100%	100%	50%
	LOB 0.5	All	91%	64%	100%	100%	18%	0%	9%	27%	88%
		Wet	100%	67%	100%	100%	67%	0%	33%	33%	100%
		Dry	80%	40%	100%	100%	0%	0%	0%	40%	75%
		Dry7	100%	100%	100%	100%	0%	0%	0%	0%	100%

[1]Water quality standards are presented in bold and represent parameters regulated by KDOW. All other parameters are compared to a water quality benchmark, which are appropriate water quality goals to uphold a healthy stream system. The water quality standards included in this analysis include only dissolved oxygen and *E.coli*

[2]Due to dry conditions sampling did not occur at RDR 1.1 on 8/7/12; therefore, this site has only two Dry7 samples and a total of 15 samples for *E.coli* and 10 for the remaining parameters.

b) E.coli Concentrations

E.coli is an indicator of bacteria present within the stream system and some strands are considered to be potentially harmful to humans if present in large concentrations. As illustrated in Table 2 and the *E.coli* Sample Box Plot below (Figure 23), wet weather *E.coli* sampling at all sites exceeded the water quality standard (i.e., green line in Figure 23). Additionally, there is a positive correlation between the geometric mean of sample concentrations at each site with the associated percent impervious, illustrating that the most developed watersheds appear to have a larger concern with bacteria during wet weather. The opposite correlation is evident during dry weather sampling, as the geometric mean of the *E.coli* sample concentrations decreased with an increase in the total subwatershed percent impervious, indicating that bacteria is a larger problem during dry weather for the less impervious, rural subwatersheds (Figure 22). It is important to note that the wet weather samples are based on three sampling events that occurred during 2011 prior to SD1's completion of system improvements aimed at mitigating several sanitary overflows in the Gunpowder Creek Watershed (historic overflow locations have been documented along the South Fork and tributary, Fowler Fork, and the main branch). Although there are many potential sources of bacteria throughout the Gunpowder Creek Watershed, it is possible that the high bacteria concentrations during wet weather in 2011 may have been partially attributable to sewer overflows. Such results provide insight regarding potential sources and are further discussed in Section 5 of this report.

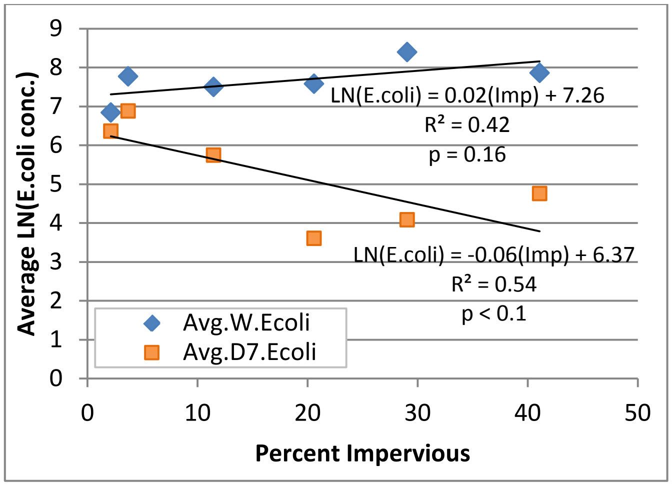


Figure 22-E.coli as a Function of Percent Impervious

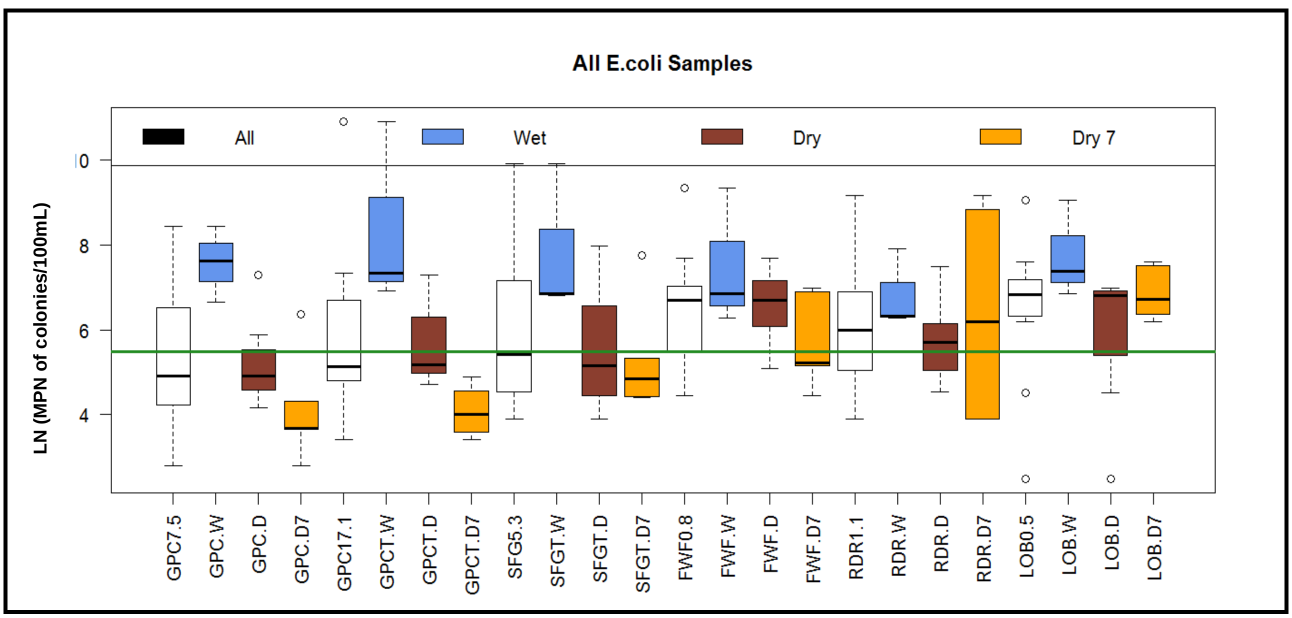


Figure 23-E.coli Sample Concentrations during Wet and Dry Weather Conditions (green line represents water quality standard: LN(240 colonies/100mL))

c) *TSS Concentrations*

Sediment, as measured by TSS sample concentrations, is a pollutant of concern during both wet and dry weather conditions (Figure 25). It appears to be a larger issue during wet weather when bank erosion is caused by the urban induced erosive flow regime as well as when sediment is washed off unvegetated, barren surfaces and transported to the stream (Figure 24). As presented in Section 4.2.1-*Overall Physical/Habitat Relationships Illustrate Concerns with Channel Enlargement and Habitat*, TSS was strongly correlated to channel enlargement, which was also correlated to percent impervious, indicating that bank erosion and channel enlargement are a likely source of the fine sediment found in the streams. Such bank erosion and channel enlargement are caused by the erosive urban flow regime, which is degrading the habitat conditions and likely a partial cause of biological impairments. The geomorphology data, as presented in Section 4.2 as well as Appendix A, highlights the impacts of bank erosion and channel enlargement. While TSS is an indicator of erosive flows degrading habitat conditions, it also contributes to biological impairment of many species for several reasons, but particularly because it can cause embeddedness of the bed material habitat and can clog gills.

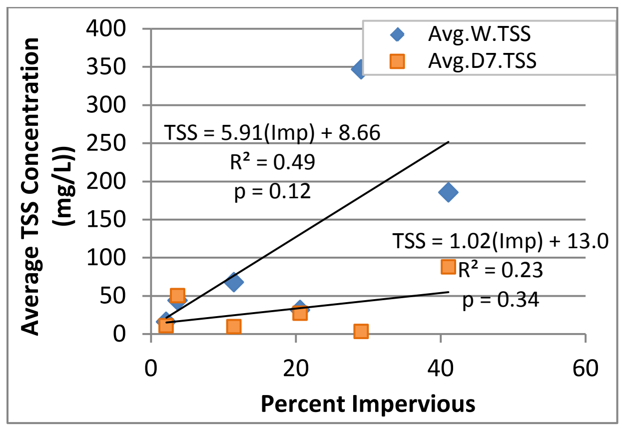


Figure 24-TSS as a Function of Percent Impervious

Bank erosion and channel enlargement could also be a potential source of TSS during dry weather for several reasons. First, bank failure by mass wasting can occur during both periods of wet and dry weather. Second, once the fine sediment loads from bank failure are slumped into the stream, it can take long periods of time to flush the sediment load. Silt, and in particular clay, can take very long periods of time to settle out of the water column, such that these loads can be sources even during prolonged periods of dry weather. Finally, even low flows at site GPC 7.5 would have sufficient capacity to entrain silt and clay given the relatively large drainage area and reasonably high base flow, even during periods of dry weather.

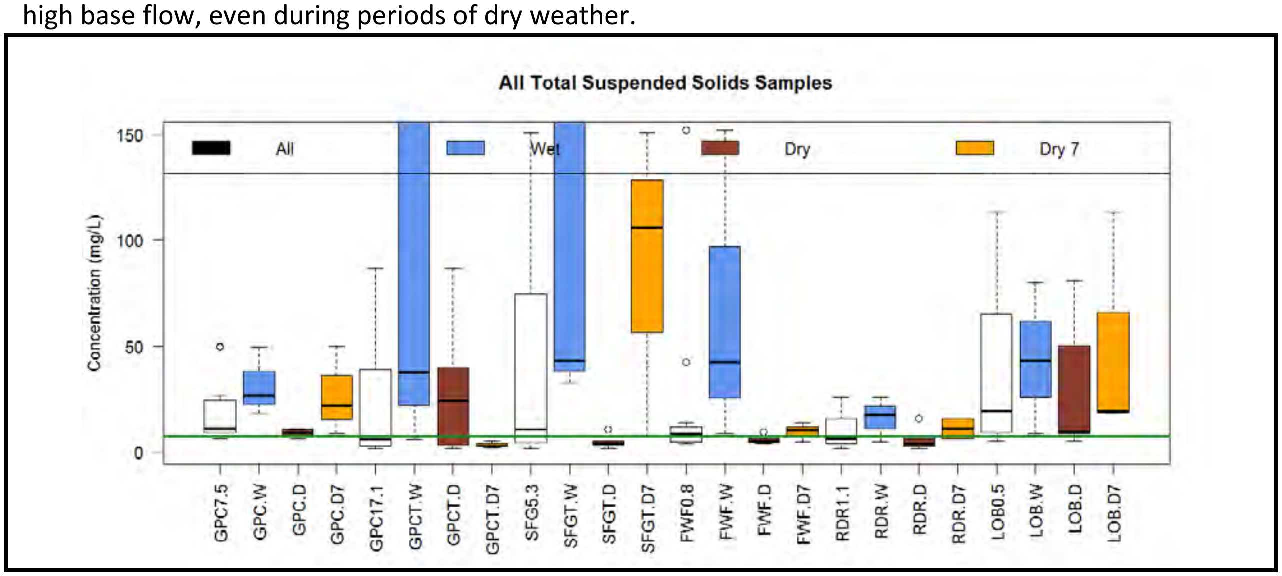


Figure 25-TSS Sample Concentrations during Wet and Dry Weather Conditions (green line represents water quality benchmark: 7.25 mg/L)

d) *Specific Conductivity Concentrations*

Specific conductance, which measures the water's ability to conduct electricity, can be used as a surrogate to determine if total dissolved solids are a pollutant of concern. Specific conductivity is high in Northern Kentucky streams because of natural sources. Sampling results indicate conductivity is worse during dry weather conditions, particularly at SFG 5.3-UNT 0.1, the subwatershed which contains the most number of KPDES permit sites per mile of stream. This observation, as well as the positive relationships presented in Figure 26, could indicate that total dissolved solids are possibly polluting the stream via point source pollution during dry weather conditions. However, it should be emphasized that specific conductivity is naturally high in Northern Kentucky streams and sources such as groundwater seeps could be contributing to these seemingly elevated levels.

In addition, specific conductivity was negatively correlated to sample flow at each site with significant *p* values less than 0.05 at four sites (GPC 17.1-UNT, SFG 5.3-UNT 0.1, FWF 0.8, and RDR 1.1). This also supports that specific conductance is more problematic during low flow conditions (note that the brown and orange boxes in Figure 27 tend to be higher than the blue boxes at most sites).

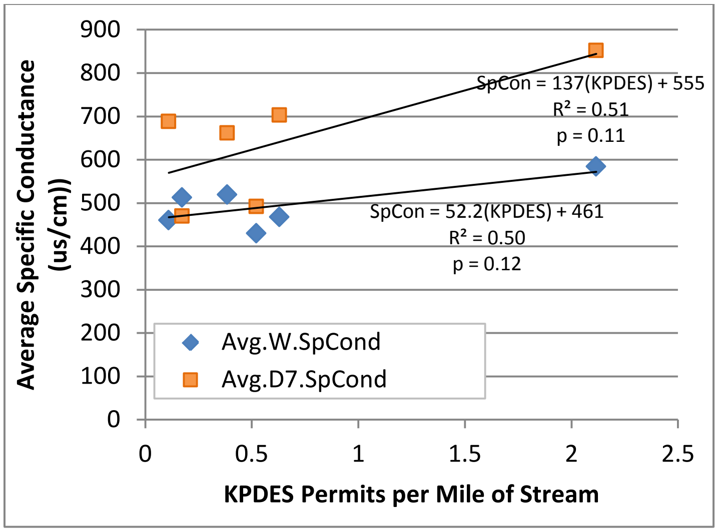


Figure 26-Average Specific Conductance Concentrations are Correlated to the Number of KPDES Permits per Mile in each Subwatershed

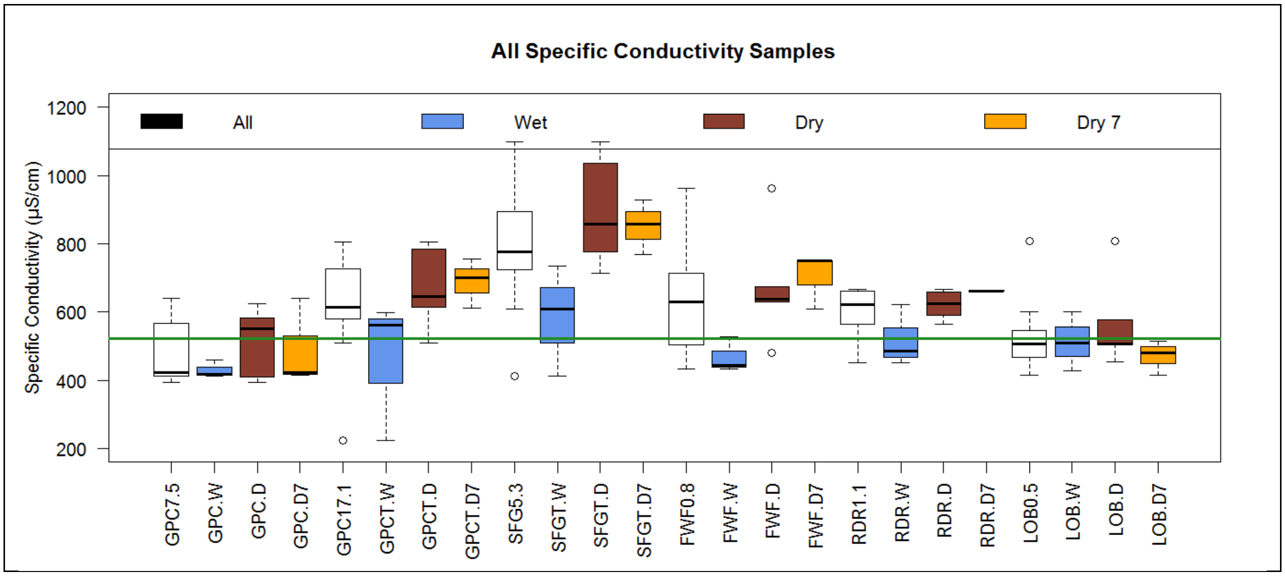


Figure 27-Specific Conductance Sample Concentrations during Wet and Dry Weather Conditions (green line represents water quality benchmark: 522.5 µS/cm)

4.4.2 Evaluation of Pollutant Loads Relate Sample Concentrations to Stream Flow

Pollutant load duration curves add another level of complexity to the water quality analysis and allow for pollutant concentrations to be characterized at varying flow regimes, providing a visual figure of the relationship between stream flows, pollutant loading capacity, and the frequency and magnitude of exceedances in water quality benchmarks based on flow conditions. Pollutant loads, which are defined by both the concentration of the pollutant and the stream flow, determine the amount of a specific pollutant being transported by the stream in terms of weight per period of time (i.e., lbs/day). Loadings are important to evaluate because they provide a more balanced comparison between subwatersheds, as a subwatershed with a low concentration and large flows could have a higher total load than a watershed that has a high pollutant concentration but only a little flow (Kentucky Waterways Alliance, 2010). The Gunpowder Creek water quality analysis included development of pollutant load duration curves to analyze bacteria (*E.coli*), total suspended sediment (TSS), and nutrients (TP, TKN, NN) at all water quality monitoring sites. Figure 28 presents the *E.coli* Load Durations at GPC 17.1-UNT 0.1 and is an example of the pollutant load duration curves developed at all sites (Appendix C). This load duration approach, with the limited amount of water quality data provided for this analysis, is meant to provide estimates of the scale of the problem in each subwatershed and not indicate exact loads necessary to achieve water quality targets.

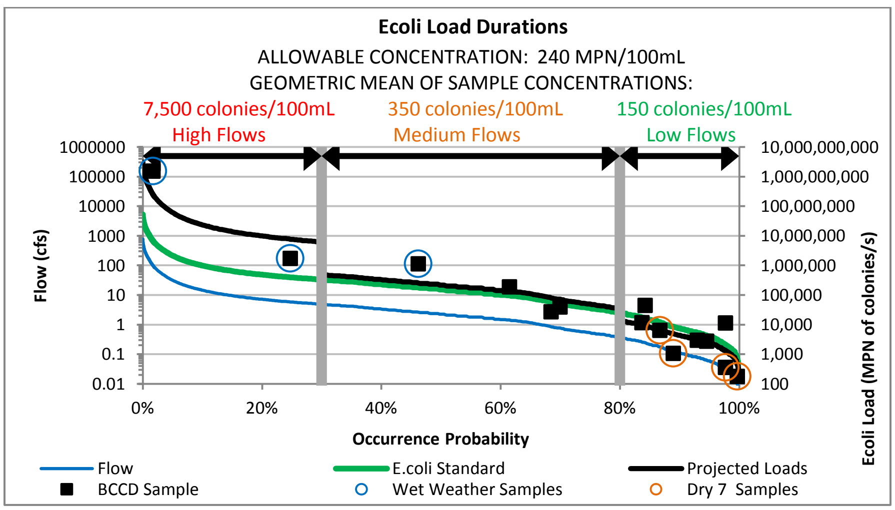


Figure 28-E.coli Load Durations at Developed Site, GPC 17.1-UNT 0.1 (29% impervious) Note: This load duration approach with the limited amount of water quality data provided for this analysis is meant to provide estimates of the scale of the problem in each watershed and not indicate precise numbers. Values listed above each flow category represent the geometric mean of the concentrations sampled within that flow category

In addition to providing a visual representation of the relationship between stream flows, pollutant loading capacity, and the frequency and magnitude of exceedances in water quality benchmarks, the pollutant load duration curves provide means of calculating the total annual pollutant loads occurring at a particular site over the course of an entire year. Projected annual pollutant loads, allowable annual pollutant loads, and the percent difference for each parameter is presented in a summary table for each water quality monitoring site (Appendix C).

With further evaluation of the annual pollutant loads, the ratio of the projected load to the allowable load (defined by the projected load divided by the water quality benchmark/standard) was calculated to analyze the degree of exceedance for each pollutant on the same scale, with any ratio above one being an exceedance of the water quality benchmark. Figure 29 presents this ratio for total loads of each parameter analyzed at the water quality monitoring locations. This figure illustrates that both sediment (TSS) and bacteria (*E.coli*) are of greater concern than nutrient loads (TP, TKN, NN) throughout the Gunpowder Creek Watershed. Additionally, this figure illustrates that generally two subwatersheds appear to be contributing the most pollution by weight within the watershed - the headwaters of Gunpowder Creek (GPC 17.1 UNT) and South Fork Gunpowder (SFG 5.3-UNT 0.1).

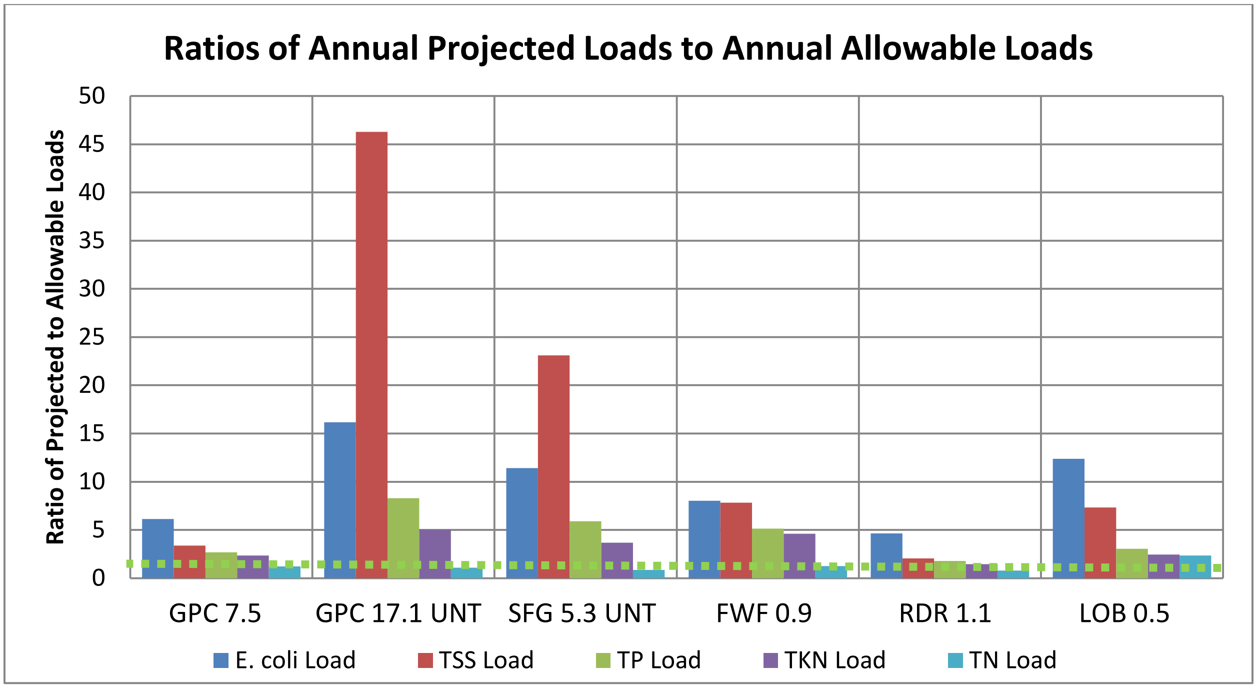


Figure 29-Ratios of Projected Loads to Allowable Pollutant Loads Illustrate that Bacteria and Sediment are the Greatest Pollutants of Concern in the Gunpowder Creek Watershed
(ratios = projected load divided by the water quality benchmark or standard; the green line represents the water quality benchmark or standard = 1)

Ratios of projected loads to allowable loads were also evaluated during the various flow conditions (high, medium, and low). This analysis confirmed the results presented in *Section 4.4.1 Evaluation of Parameter Concentrations Defines Potential Pollutants of Concern* – bacteria and sediment are of greater concern during wet weather conditions when the stream flows are high. Figure 30 presents an example of this analysis. The evaluations of projected to allowable load ratios at all monitoring sites are included in Appendix C. Table 3 presents the percent load reductions necessary for each parameter at the water quality monitoring sites. The red text illustrates the highest pollutant load reductions needed throughout the watershed (greater than 80%). Additionally, the percent load reductions for each flow category are included in Appendix C.

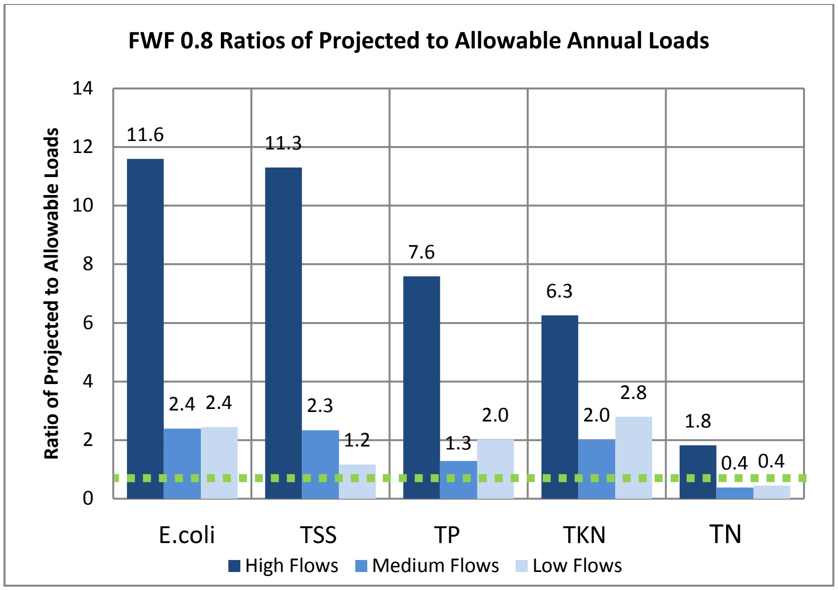


Figure 30-Evaluation of Projected to Allowable Load Rations at Individual Monitoring Sites Illustrates Greater Exceedances during High Flows (Wet Weather Conditions)
(ratios = projected load divided by the water quality benchmark or standard; the green line represents the water quality benchmark or standard = 1)

Table 3 – Percent Load Reductions Necessary at Each Monitoring Location

Site	E. coli	TSS	TP	TKN	TN
GPC 7.5	84%	70%	63%	58%	19%
GPC 17.1	94%	98%	88%	80%	8%
SFG 5.3 UT 0.1	91%	96%	83%	73%	-15%
FWF 0.8	88%	87%	81%	78%	21%
RDR 1.1	78%	51%	44%	31%	-25%
LOB 0.5	92%	86%	67%	59%	57%

4.5 Biological: Biology is Impacted by a Variety of Problems throughout the Watershed and Reflective of Overall Stream Health

The biological health of a stream system is dependent on all other supporting factors, and it is presented at the top of the stream function pyramid included in *Section 2 - Introduction*. The core of this pyramid is built on land use and land use management, stream flow, physical/habitat conditions, and overall water quality. Macroinvertebrate communities particularly rely on their natural flow and disturbance regimes, healthy habitat conditions, and excellent water quality, all of which show negative correlations with development and were discussed earlier in this report. Statistical analysis of the Gunpowder Creek Biological Assessments in relation to percent impervious also supports that biological health suffers in the most developed watersheds, as the MBI Score as well as the Percent Primary Clinger Score both correlated negatively to percent impervious (Figures 31 and 32).

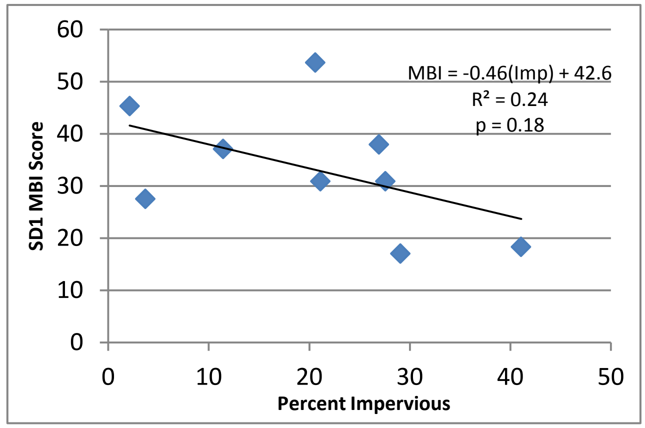


Figure 31-Increased Development, as Measured by Percent Impervious, Results in Degraded MBI Scores

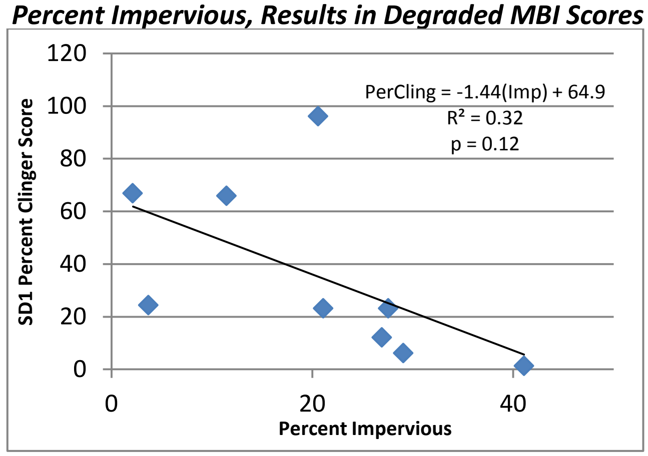
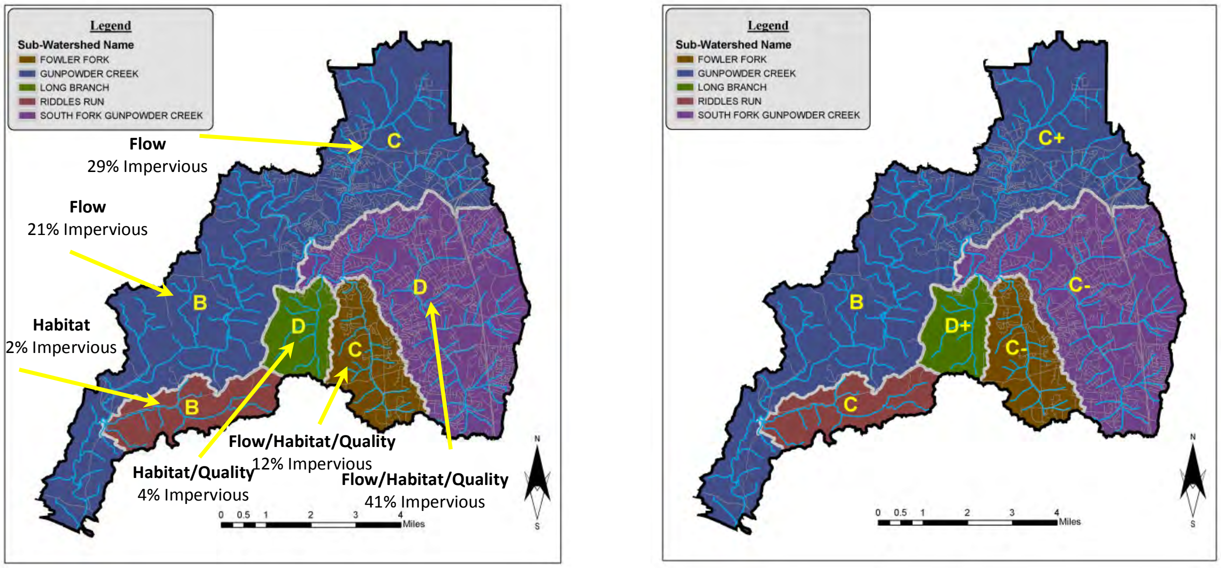


Figure 32-The Percent Clinger Population is Negatively Correlated to Percent Impervious

Furthermore, overall analyses of the KDOW Health Reports illustrate that the results of the biological assessments in 2012 are fairly consistent with the overall KDOW grades for the watershed (Figure 33) as well as the SD1 Stream Condition Index scores (Figure 35). Figure 33 (a) presents the aquatic macroinvertebrate grades for each monitoring location and the influencing factors that largely impacted the aquatic macroinvertebrate grades, including flow, habitat, and water quality, which are all affected by land use and land use management. When comparing the KDOW aquatic macroinvertebrate grades and the overall site grades, the results are very strongly correlated with a significant *p* value of less than 0.01, supporting that indeed the biological health of a watershed is very dependent on the overall health of the watershed. Both of the KDOW Phase I and Phase II *Gunpowder Creek Watershed Health Reports* are included in Appendix D.



(a) KDOW Aquatic Macroinvertebrate 2012 Grades ***(b) KDOW Overall Watershed 2012 Grades***

Figure 33-Biological Health is Related to Overall Health-it Depends on All Pieces of the Pyramid

4.6 KDOW Gunpowder Creek Watershed Health Report Cards and SD1 Stream Condition Indices Summarize the Overall Health of Gunpowder Creek and its Tributaries

In addition, to the biological health and KDOW's overall health report grades, SD1's Stream Condition Indices also provide a concise summary of hydromodification, physical, water quality, and biological conditions at each monitoring location. Such Stream Condition Indices are strongly related to the overall health grades for the watershed (Figure 34). The relationship between Stream Condition Indices and Average 2011 and 2012 KDOW Grades was highly significant ($p = 0.01$). In evaluating the individual grades that influence the overall watershed grade, the relationships between the Stream Condition Indices and parameters such as the total habitat grade and the bacteria grade were particularly strong, with significant p values of 0.02 and 0.05, respectively.

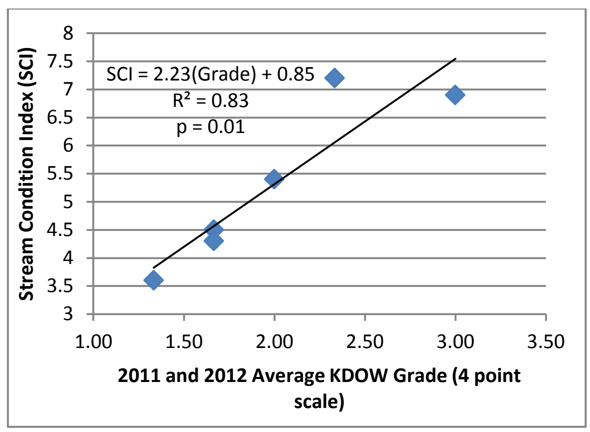


Figure 34-Stream Condition Indices and KDOW Overall Health Grade are Strongly Correlated

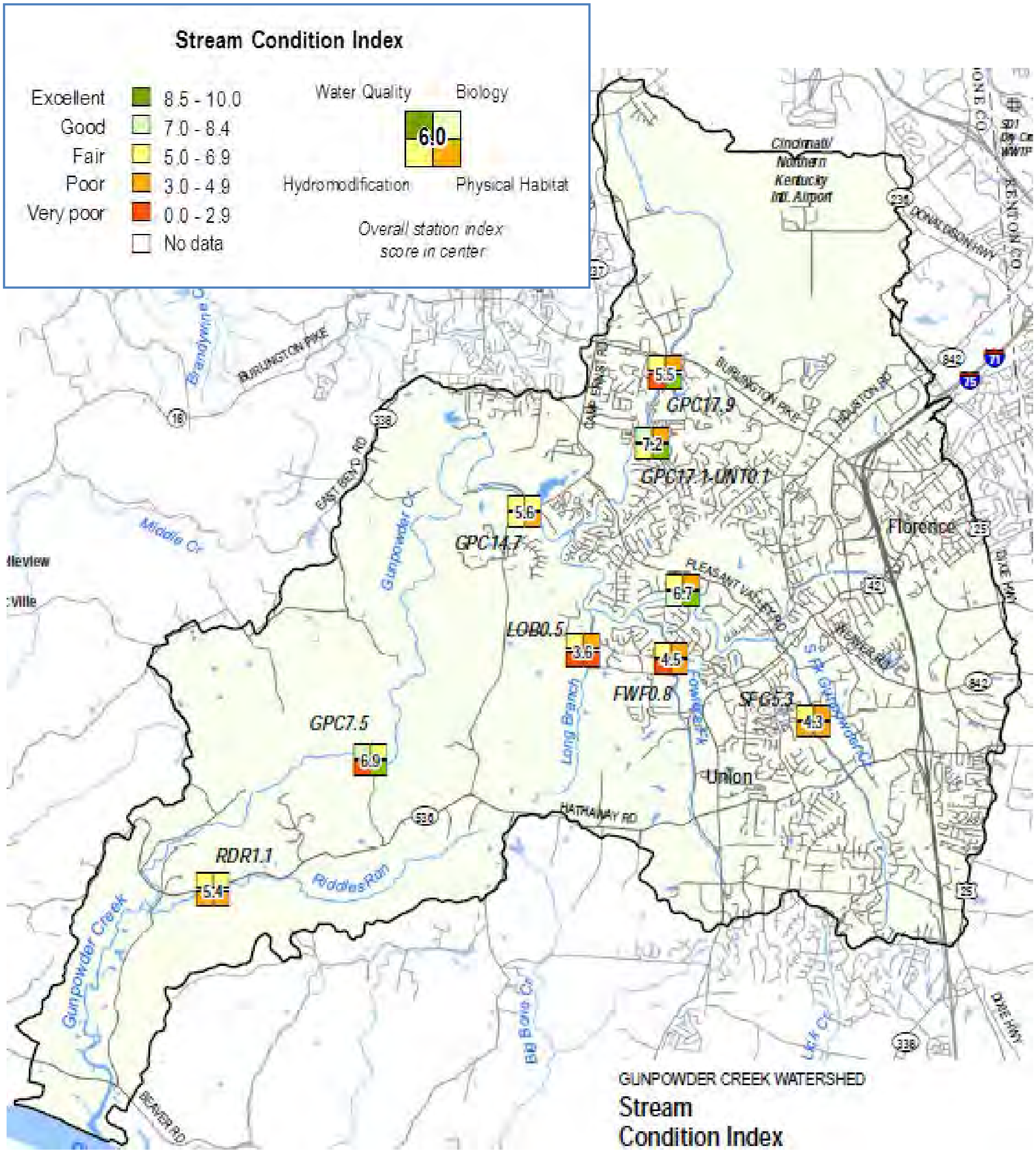


Figure 35-Overall Stream Health Summarized with SD1's Stream Condition Indices

5.0 Discussion & Implications:

5.1 Overall Results of Water Quality Analysis Illustrate that Land Use and Land Use Management Impact Sources of Pollutants during Wet and Dry Weather Conditions

In evaluating the water quality box and whisker plots and load duration curves, several conclusions can be deduced to understand pollutants of concern and possible drivers of the pollutants. Generally, the monitoring locations can be categorized into three types of land use based on percent impervious data, including developed watersheds (20-40% impervious) on the eastern side of the Gunpowder Creek Watershed, rural watersheds (2-4% impervious) on the southern portion of the Gunpowder Creek Watershed, and mixed (developed/rural, 12% impervious). Differing land use can be related to certain pollutants of concern during both wet and dry weather and provided some inference regarding potential sources of pollution. South Fork Gunpowder Creek and the headwaters of Gunpowder Creek have been classified as developed; Riddles Run and Long Branch are classified as rural; and Fowlers Fork is considered mixed. Sampling locations, and their related development category, are illustrated in Figure 36. The most impervious areas of the watershed, which are located in the headwaters, have been extremely detrimental on the health of these stream systems. In many watersheds the headwaters are typically the most pristine and healthy stream reaches, but due to the increased development in the Gunpowder Creek Watershed headwaters, these stream reaches have been degraded.

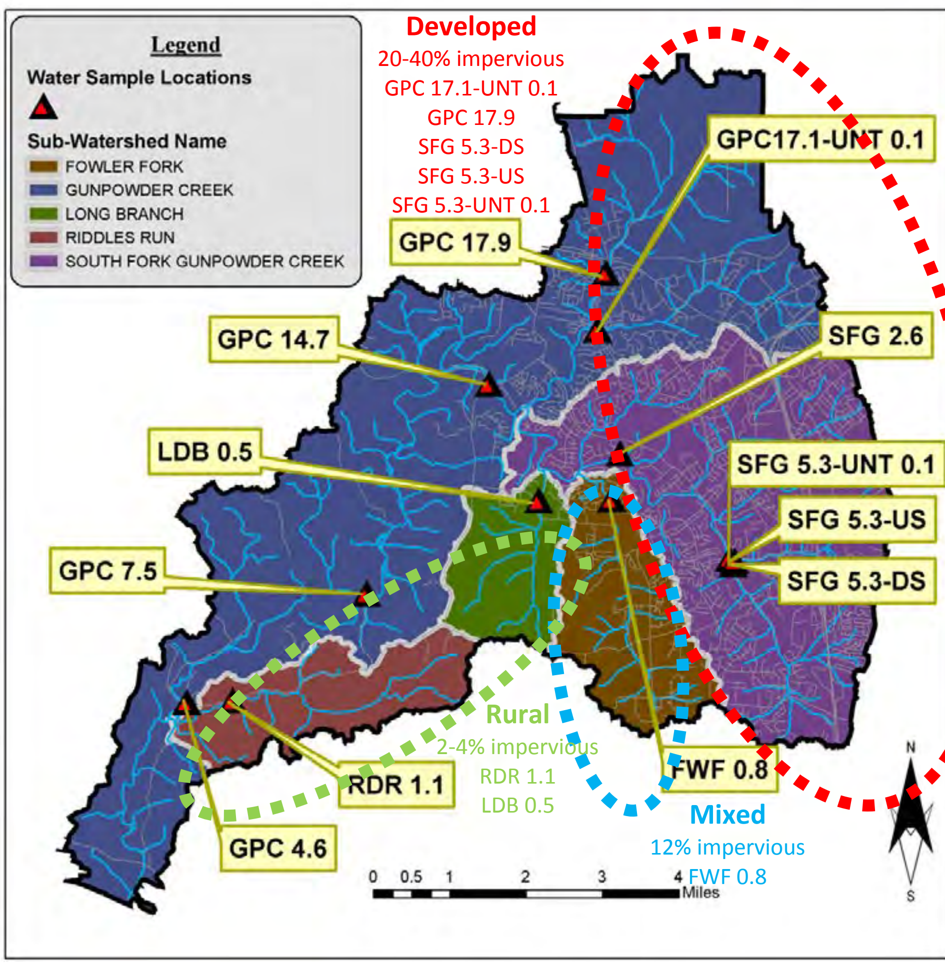


Figure 36-Sampling Sites Classified by Primary Land Use (Developed, Mixed, and Rural)

5.1.1 Developed Watersheds

First, the developed watersheds (20-40% impervious), located within the headwaters of Gunpowder Creek and South Fork Gunpowder Creek on the eastern side of the watershed, had high loadings of bacteria and suspended sediment during wet weather and high loadings of specific conductance during dry weather (Figure 37). The predominant cause of high bacteria and TSS loadings is likely excess stormwater runoff because these same developed sites have fewer issues with dry weather bacteria. This tends to indicate that the developed sites are primarily impacted by stormwater runoff and nonpoint source pollution. Nonpoint source pollution results from everyday activities such as littering, pet waste, fertilizing the lawn, land clearing for development, and agricultural activities, all allowing pollutants generated by these activities to be washed into the stormwater collection system and eventually flowing into our waterways.

Most Concerning Pollutants	Likely Sources	Possible Causes
Bacteria (Wet Weather)	Stormwater runoff	Animal Waste
Suspended Sediment (Wet Weather)	Bank Erosion	Erosive Flows Unvegetated Banks
Specific Conductance (Dry Weather)	Other Point Sources	Point Source Treatment

Least Concerning Pollutants	Likely Reason	Possibly Prevented from Reaching Our Streams
Bacteria (Dry Weather)	Sanitary Sewers	Human Waste

Figure 37-Water Quality Results in Developed Watersheds

5.1.2 Rural Watersheds

Next, rural watersheds (2-4% impervious) tended to be impacted more during dry weather, suggesting that point source pollutants may be the predominant issue in these watersheds (Long Branch [LOB 0.5] and Riddles Run [RDR 1.1]). The most concerning pollutants identified in the rural watersheds included high levels of bacteria, nutrients, and specific conductance all during periods of dry weather (Figure 38). This suggests potential pollutant sources from point sources. There is a relatively high prevalence of septic systems that could be a potential source of pollution, as well as livestock in the stream and KPDES permitted discharges.

Most Concerning Pollutants	Likely Sources	Possible Causes
Bacteria & Nutrients (Dry Weather)	Septic Systems Animal (direct)	Septic maintenance Cattle/Horse Fencing
Specific Conductance (Dry Weather)	Septic Systems Other Point Sources	Septic maintenance Point Source Treatment

Least Concerning Pollutants	Likely Reason	Possibly Prevented from Reaching Our Streams
Nutrients (Wet Weather)	Fertilizer Management	Excess Algae

Figure 38-Water Quality Results in Rural Watersheds

5.1.3 Mixed Watersheds

Finally, mixed watersheds (rural/developed, 12% impervious – Fowlers Fork) showed signs of both point and nonpoint source pollution. The most concerning pollutants, as summarized in Figure 39, include bacteria during wet weather as well as specific conductance and nutrients during dry weather. The least concerning pollutant was bacteria during dry weather. These results provide insight on some potential sources, such as stormwater runoff, septic systems, and animal waste.

Most Concerning Pollutants	Likely Sources	Possible Causes
Bacteria (Wet Weather)	Stormwater runoff	Animal Waste
Specific Conductance (Dry Weather)	Septic Systems Other Point Sources	Septic maintenance Point Source Treatment
Nutrients (Dry Weather)	Septic Systems Animal (direct)	Septic maintenance Cattle/Horse Fencing
Least Concerning Pollutants	**Likely Reason**	**Possibly Prevented from Reaching Our Streams**
Bacteria (Dry Weather)	Sanitary Sewers	Human Waste

Figure 39-Water Quality Results in Mixed Watersheds

5.2 Solutions Should Consider Dominant Causes of Impairments

The purpose of such a holistic analysis of the monitoring efforts was to better identify sources of all impairments affecting the overall health of the stream function pyramid, as opposed to simply one or two water quality impairments. As a result, BMPs with greater cost effectiveness for all impairments can be identified and prioritized accordingly. The results of the water quality analysis have provided insights into identifying appropriate BMP strategies for specific impairments, focusing on two primary types of solutions: (1) stormwater based solutions, which target wet weather, nonpoint source pollution issues, and the related habitat and water quality impairments due to erosive stream flows, and (2) point repair solutions, which address dry weather pollution issues and habitat impairments that are less attributable to the flow regime (Figure 40). Generally, the stormwater based solutions should be primarily implemented in the developed watersheds (headwaters of Gunpowder Creek and South Fork Gunpowder Creek), while the point repair solutions should be considered primarily in the more rural watersheds (Riddles Run and Long Branch).

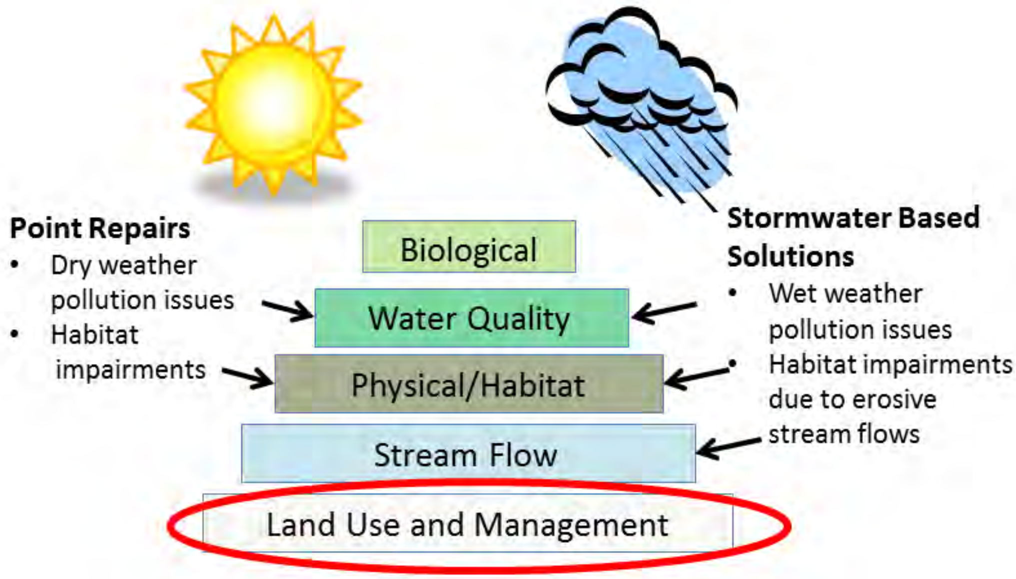


Figure 40-Point Repairs and Stormwater Based Solutions Address Primary Pollutants of Concern

5.2.1 Point Repair Solutions Mitigate Dry Weather Pollution Issues:

Point source pollution typically comes from a single outfall that discharges directly into a stream system. Some examples of point sources include stormwater outfalls, sanitary outfalls, septic system outfalls, combined sewer overflows, and industrial outfalls. KDOW regulates such discharges through the KPDES permit program. Figures 41 presents a demonstrated example of point source pollution. One possible cause of point source pollution throughout the Gunpowder Creek Watershed could be unmaintained septic systems, as bacteria levels were high during dry weather in the rural watersheds. KPDES discharges are also a possible source of point source pollution as specific conductance was high during dry weather in several subwatersheds - particularly SFG 5.3-UNT 0.1. It is important to note that the Northern Kentucky region has several natural sources of relatively high levels of specific conductance and the relationships related to KDPES discharge locations (Figure 26) could be caused by natural groundwater seeps or other natural sources during dry weather. As such, solutions to these issues may include further investigation of KPDES discharges. If further investigation determines a KPDES discharge to be in violation of their permit, BMP strategies may include reaching out to the property owner to inform them of the importance of meeting low pollution levels. If levels remain persistent, possible enforcement of point source treatment may be explored. Furthermore, public education on the importance of septic system maintenance (Figure 42) may also be an important BMP strategy. If the potential problem is verified and proves to be persistent, related BMP strategies may include septic system maintenance cost share programs or extension of sanitary sewer service where possible.

Figure 41-Demonstration Example of Point Source Pollution (using pink die)

Figure 42-Septic System Maintenance

5.2.2 Stormwater Based Solutions Mitigate Wet Weather Pollution Issues:

The stormwater based solutions, should be the primary focus of the watershed plan, as they will help to mitigate nonpoint source pollution issues. Such solutions should mainly target the developed watersheds where impervious area has impacted the erosive urban flow regime (headwaters of Gunpowder Creek and South Fork Gunpowder Creek). Nonpoint source pollution can include daily activities such as fertilizing the lawn, littering, pet waste, land clearing for development, agricultural practices, and runoff from impervious surfaces. Some examples of stormwater based solutions for nonpoint source pollution include addressing the erosive flow regime through proactive management approaches, installing BMPs such as bioinfiltration basins and detention basin retrofits, restoring targeted stream reaches to improve habitat conditions, preserving/restoring vegetated riparian buffer strips along the stream corridor, installing fences to keep livestock out of the streams, and helping the public to understand the impacts of daily actions on the streams (i.e., fertilizing, littering, pet waste, etc.).

a) Addressing the Erosive Flow Regime to Protect the Physical Nature of the Streams and Improve Aquatic Habitat:

1. Critical Flow for Stream Channel Protection

The critical flow for stream channel protection ($Q_{critical}$) is defined as the flow, which when exceeded, increases the likelihood for transport of the controlling bed material and/or bank failure. Storms that are managed and released below $Q_{critical}$ are predicted to result in minimal channel erosion. In contrast, flows that exceed $Q_{critical}$ are more likely to contribute to channel erosion, downcutting, widening, and potentially negative impacts to water quality and adjacent infrastructure (Hawley, 2012). In collaboration with SD1's hydromodification monitoring program, regionally-calibrated thresholds can be incorporated into stormwater management solutions to reduce the risk of further channel enlargement and habitat degradation related to future development. This proactive management approach, which indicates that Northern Kentucky streams generally have a $Q_{critical}$ range of 40-50% of the predeveloped 2-year peak flow (Q_2), is presented in a March 2012 memo by Sustainable Streams entitled, "Development of a Regionally-Calibrated $Q_{critical}$ for Storm Water Management" (Sustainable Streams, 2012(a)). Furthermore, optimizing conventional detention basins to provide water quality and $Q_{critical}$ performance is not expected to substantially increase the size of the BMP footprints relative to what developments are already required to construct to meet current SD1 stormwater management policies.

Generally, evaluation of $Q_{critical}$ estimates at many of the Gunpowder Creek monitoring sites was consistent with the $Q_{critical}$ range for Northern Kentucky streams (40-50% Q_2). However, $Q_{critical}$ estimates are largely skewed by the high prevalence of exposed bedrock. Therefore, a few sites (LOB 0.5, SFG 5.3-DS, and SFG 5.3-US) were excluded from this analysis. $Q_{critical}$ estimates for the hydromodification monitoring sites in Gunpowder Creek indicated an average of approximately 51% of Q_2, with an average range of about 35-75% of Q_2.

2. Best Management Practices Designed for Water Quality as well as Quantity Improvements

Stormwater BMPs are good management techniques because they can be designed to reduce stormwater volume, peak flows, and nonpoint source pollution in both urban and rural settings. This can refer to a wide range of treatment techniques such as evapotranspiration, infiltration, detention, and biological or chemical functions. Some examples of BMPs that could improve the nonpoint source pollution issues in the Gunpowder Creek Watershed include bioinfiltration basins (Figure 43), bioswale conveyance features, porous pavement, reforestation, wetlands, and detention/retention basins.

Figure 43-Example Bioinfiltration Basin

3. Detention Basin Retrofit BMP Provides Economical Alternative to Stream Channel Protection in Developed Watersheds

The Sustainable Streams project team, in collaboration with BCCD, SD1, and US EPA, is currently investigating the efficacy of retrofitting conventional detention basins as an economical alternative to reduce the erosive power of most storms in a typical year and provide extended hold times for water quality benefits. This innovative technology will cost-effectively retrofit conventional detention basin outlet structures to maintain flow rates below the flow that causes erosion of the stream bed material by promoting a hydrograph that more closely matches both the peaks and durations of the pre-developed flow regime (e.g. similar to Hawley *et al*., 2012). Many conventional “peak-matching” flood control detention basins are ubiquitous and many have some level of excess capacity, and the retrofit device utilizes this excess capacity to arrest existing channel instabilities and reduce the risk of channel degradation without adversely affecting flood control capacity. Figure 44 presents a schematic of the detention basin retrofit technology. The success of this BMP will depend on finding detention basin property owners who are willing to install this cost effective technology to reduce the amount of erosive flows that leave their property.

Figure 44-Detention Basin Retrofit Technology

b) Targeted In-stream Restoration Efforts Offer Channel Stability and Improved Habitat Conditions

Stream restoration techniques, although expensive and not always the best solution, may be necessary in some of the most problematic reaches throughout the Gunpowder Creek Watershed. In particular, sites that are dominated by bedrock with little or no aquatic habitat could benefit from the reintroduction of essential habitat elements such as large woody debris and native creek rock at strategic locations. This would be similar to gravel reintroduction projects in western rivers along reaches that are downstream of dams (Kondolf, 1997). Relatively simple and inexpensive log vane structures could provide stability and promote habitat, as wood has been shown to create extremely high levels of macroinvertebrate biomass,

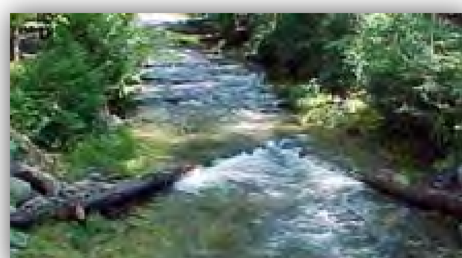


Figure 45-Log Vanes and Woody Debris Provide Stability and Improve Aquatic Habitat Conditions

especially when compared to sand or mud substrates (Benke *et al*., 1981). Log vanes are installed to be angled upstream and tied into the banks to disrupt flow and direct the erosive energy towards the center of the stream, away from the banks. In addition to the log vanes, some rock armoring is likely necessary to support the logging, promote bed stability, and provide additional habitat diversity. Figure 45 on the preceding page presents an example of several log vanes installed in a natural stream setting.

c) Vegetated Riparian Buffer Zones Provide Many Improvements to Stream Health

Riparian buffer zones provide numerous health benefits to stream systems. These vegetated areas adjacent to the stream aid in capturing nonpoint source pollutants transported by stormwater runoff during wet weather conditions, enhance stream bank stability, provide valuable habitat for wildlife, and improve the aesthetics of the stream. The bank failure observed in the headwaters of Gunpowder Creek at site GPC 17.1-UNT 0.1 presents a good example of a location that could use additional stability with a vegetated buffer zone (Figure 46).

Figure 46-Riparian Buffer Zone Could Provide Stability and Water Quality Improvements in the Headwaters of Gunpowder Creek (GPC 17.1-UNT 0.1)

d) Agricultural Fencing Keeps Livestock Out of the Streams

In addition to a healthy vegetated riparian buffer zone, agricultural fencing can be installed to keep livestock out of the streams (Figure 47). Fencing cattle and horses out of streams has many benefits such as protecting the stream banks by lessening the physical disturbance and preventing waste from being deposited directly into the stream system. While fencing can be a large expense to agricultural land owners, several cost-share programs may be used to provide funding assistance to improve the quality of our streams.

Figure 47-Livestock in the Stream Causes Additional Pollution

5.3 Stewardship through Public Involvement and Community Support is Critical for Protecting Public Resources

Community outreach and education efforts are a vital component of all watershed planning projects. Stakeholders and the general public must be informed about their watershed's water quality issues so they can provide input and participate in the planning process. Interested agencies, stakeholders, landowners, neighborhood groups, and the general public can all work toward the common goal of protecting good water quality and improving poor water quality. Such public participation and commitment is critical to ensuring that the improvement and protection of water quality in Gunpowder Creek is feasible, cost effective and continues beyond the grant funding period. In conclusion, all of these efforts have gained synergy as a result of active stakeholders, engaged community partners, a progressive stormwater utility, and a data-driven approach focused on monitoring the root causes of the problems.

6.0 Conclusion:

The objectives of this *Phase II Water Quality Data Analysis Report* were to analyze two rounds of stream monitoring data and health assessments at sites throughout the Gunpowder Creek Watershed, providing details on pollutants of concern, potential sources of pollutants, and various solutions to be considered to improve the dominant causes of impairments. In completing these objectives, quantitative results provided insight regarding the primary pollutants of concern during wet versus dry weather sampling and the relationships to development through subwatershed percent impervious values. The most developed subwatersheds (the headwaters of Gunpowder Creek and South Fork Gunpowder Creek) appeared to be contributing the most pollution by weight, with larger concerns regarding bacteria and suspended sediment during wet weather conditions. Additionally, these more developed watersheds experienced greater dynamics regarding physical changes, as channel enlargement was positively correlated to percent impervious. The less developed, rural watersheds (Riddles Run and Long Branch) experienced higher concerns with bacteria, nutrients, and specific conductance during dry weather and less pollutant concerns during wet weather. The Fowlers Fork watershed, which represents a mix of developed and rural land use, experienced a combination of the above listed concerns, with bacteria being an issue during wet weather conditions and both specific conductance and nutrient concerns during dry weather.

In understanding these results, various solutions can be targeted to improve the overall health of the streams throughout the Gunpowder Creek Watershed. It is recommended that BCCD consider both point repairs to combat dry weather pollution issues and stormwater-based solutions to mitigate wet weather pollution issues. Additionally, community outreach and education efforts are a vital component for the success of all watershed planning projects. In order to build public support and help ensure long-lasting solutions, stakeholders and the general public must be informed about their watershed's water quality issues and how their actions can negatively or positively affect the health of the streams in their watershed, as stewardship is critical for protecting public resources.

7.0 Acknowledgements:

We would like to acknowledge BCCD and the Gunpowder Creek Watershed Technical Committee, and the Gunpowder Watershed Initiative Steering Committee for the opportunity to complete this *Phase II Water Quality Data Analysis Report for GCWI*. We thank BCCD, SD1, Thomas More College, and the Licking River Watershed Watch for collecting detailed monitoring data and assessments utilized to compete this analysis; Boone County Planning Commission GIS Services Division for completing the geospatial analysis, summarizing subwatershed land use and watershed characteristics, and creating many of the maps used throughout this document; KDOW for developing the *Gunpowder Creek Watershed Health Reports - Phase I and Phase II;* the US EPA/KDOW for funding assisting through the 319(h) program; and Northern Kentucky University Center for Applied Ecology (NKU CAE) for funding assistance through the Northern Kentucky Stream and Wetlands Restoration Program. In particular, we are very grateful to Mary Kathryn Dickerson and Mark Jacobs of BCCD, Matt Wooten and Mindy Scott of SD1, Steve Gay and Louis Hill of Boone County Planning Commission, Lajuanda Haight-Maybriar, Katie McKone, and Stefanie Osterman of KDOW, Tom Comte of the Gunpowder Watershed Initiative Steering Committee, and Scott Fennell of NKU CAE among many others.

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APPENDIX D

KDOW-approved Watershed Plan

Gunpowder Creek Watershed Plan
Final Report

Prepared by the
Gunpowder Creek Watershed Initiative

Gunpowder Creek Watershed Plan

Prepared for

Gunpowder Creek Watershed Initiative

December 2014

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Appendices

EXECUTIVE SUMMARY

Gunpowder Creek Watershed Plan

Prepared by the

Gunpowder Creek Watershed Initiative

December 2014

Executive Summary

1.0 Introduction

The Gunpowder Creek Watershed is located in Boone County, Kentucky and flows into the Ohio River. It is the largest watershed in the county (58.2 square miles) and is rapidly developing with continued growth expected in future years. Gunpowder Creek has been listed on the Kentucky Division of Water's (KDOW) 303(d) List for Impaired Waters for sediment, bacteria, and nutrients as a result of the streambank erosion/instability, excess sedimentation, degraded biological communities, and loss of ecological function that exist today. In order to combat these impairments, the Gunpowder Creek Watershed Initiative (GCWI) was developed by the Boone County Conservation District (BCCD). This initiative is funded through federal 319(h) grant funding. The purpose of this document, the *Gunpowder Creek Watershed Plan*, is to better understand the conditions in Gunpowder Creek and develop a plan of action to address the impacts to and protect the resources of the watershed. In addition to BCCD, numerous other stakeholders have been active participants in the GWCI and the development of this plan. The following entities have greatly contributed to the successful development of this document and are valued for their contributions.

- Kentucky Division of Water
- Sanitation District No. 1 of Northern Kentucky (SD1)
- Boone County Planning Commission
- Northern Kentucky University (NKU) Center for Environmental Restoration
- Boone County Fiscal Court
- City of Florence, Kentucky
- City of Union, Kentucky
- Kentucky Transportation Cabinet
- Kenton County Airport Board
- Northern Kentucky Area Development District
- Northern Kentucky Health Department

2.0 Exploring the Gunpowder Creek Watershed

The watershed was explored in great detail to understand its history, development, and resources. Topics covered include a watershed inventory of the location, hydrology, history of flooding, and existing knowledge of stream health; natural features of the watershed (i.e., geology, topography, soils, ecoregions, and climate); the abundance of vegetation and wildlife; human influences (e.g., land use and management); demographics and social issues; and observations by the GCWI.

The watershed is comprised of four smaller watersheds, along with the main Gunpowder Creek Watershed (**Figure ES-1**): South Fork Gunpowder, Fowler Fork, Long Branch, and Riddles Run. The headwaters originate near the Greater Cincinnati/Northern Kentucky International Airport (CVG) on the northern region of the watershed and flow approximately 36 miles southwest to the Ohio River. There is a total of 143.1 miles of blue line streams in the watershed. Many sections throughout the headwaters of Gunpowder Creek, along with sections of South Fork Gunpowder Creek, are listed on KDOW's 303(d) List of Impaired Waters for sedimentation/siltation, nutrient/eutrophication, biological indicators, organic enrichment (sewage), warm water aquatic habitat (nonsupport), and primary contact recreation water (nonsupport). Suspected sources include urban stormwater, agriculture, site clearance, and streambank modifications.

Prior to the development of this *Watershed Plan*, SD1 completed some routine monitoring to characterize the watershed and generally understand stream health. Review of this historic monitoring data indicated high levels of bacteria, degraded biological conditions, as well as severe bank erosion and hydromodification issues. Geomorphically, Gunpowder Creek had noticeable impacts from urbanization to its form, stability, and habitat when compared to local reference streams.

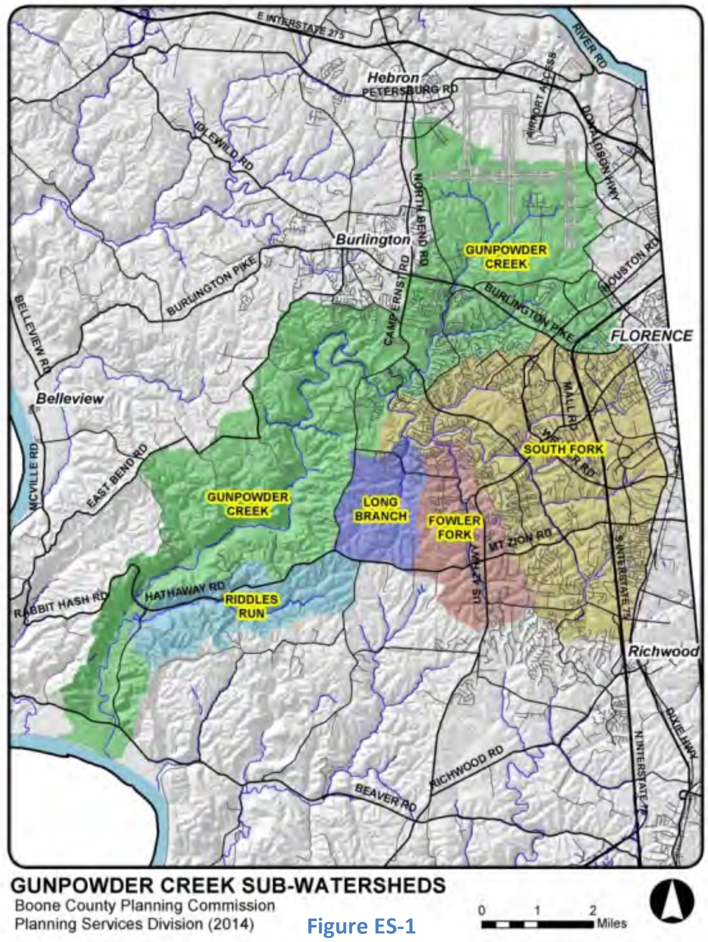

Figure ES-1

In order to understand the changes to the watershed, human influences must be understood. Boone County, which was established in 1799, experienced mild growth until recently when it became one of the fastest growing counties in Kentucky. Dense development includes highly impervious areas such as transportation, industrial, and commercial uses. Nearly all of the development has occurred since 1950, with a 38.2% growth rate from 2000 to 2010 (**Figure ES-2**; BCPC, 2010). Such anthropogenic influences have been particularly extensive in the developed headwaters of the Gunpowder Creek and the South Fork Gunpowder Creek. Future expansion of development into the western portions of the watershed is anticipated to coincide with a continued increase for at least the next 25 years.

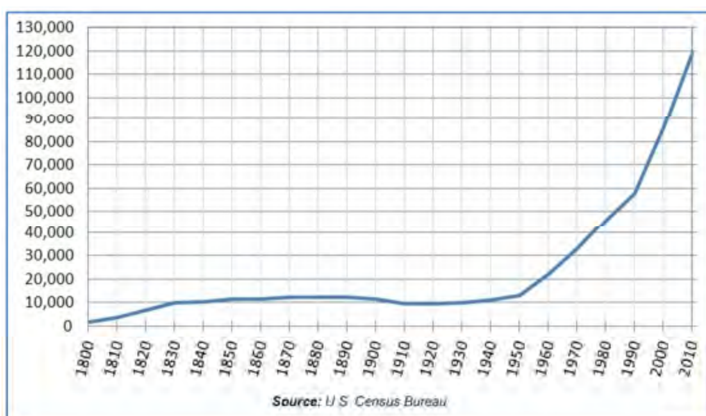

Figure ES-2: Boone County population: 1800 to 2010

Despite these development pressures, much of the land in the watershed is undeveloped (57 percent), which includes woodlands, recreation, and agricultural uses. Residential land comprises nearly 30 percent of the area, with dense development covering nearly 20 percent. Today, the creek is used for many recreational activities, including fishing and kayaking.

3.0 Learning More and Monitoring

After gathering existing data and watershed characteristics, the next step in understanding the health of the watershed was to conduct in-stream monitoring. The GCWI monitoring program involved two phases, with Phase 1 completed in 2011, an extremely wet year with record rainfall, and Phase 2 completed in 2012, a much drier year. This provided insight regarding the types of pollutants washed off the land during rain events versus those released directly to the stream in dry weather. The GCWI monitoring program was multi-faceted and provided a comprehensive understanding of several dimensions of stream health, including: flow monitoring, hydrogeomorphic surveys, habitat assessments, water quality samples, and macroinvertebrate assessments. The variety of these categories provides the breadth and depth to holistically understand the condition of the stream impairments and watershed sources of pollution and degradation.

The monitoring completed as part of the GCWI monitoring program was conducted at the mouth of the subwatersheds, within the main branch, and on some un-named tributaries. As part of this effort, flow, hydrogeomorphic, water chemistry, habitat, and biological data were collected at six sites in the watershed. Additionally, as part of SD1's ongoing Hydromodifiction Monitoring Program, hydrogeomorphic data was collected at three more sites, for a total of 9 sites with hydrogeomorphic data (**Figure ES-3**).

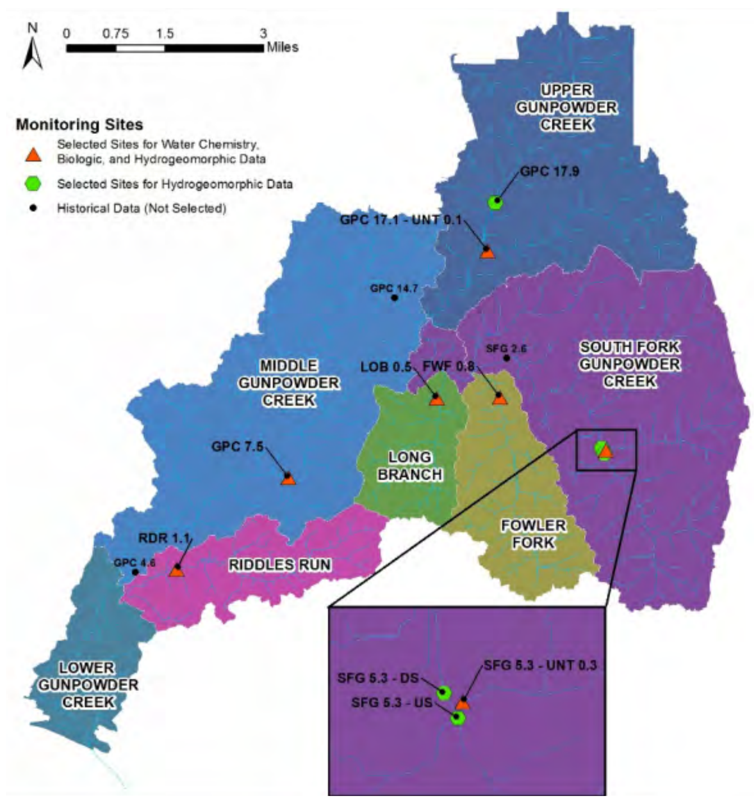

Figure ES-3: GCWI monitoring sites

All monitoring data was collected and analyzed according to industry standard procedures as specified in the *2011 Quality Assurance Project Plan for Gunpowder Creek Watershed Plan* (QAPP). Flow monitoring utilized USGS gauge 03277075 in addition to measurements taken in the field. Hydrogeomorphic surveys were conducted to measure channel instability. Data collected in the field included cross section and profile measurements as well as pebble counts of the bed material. Habitat assessments focused on the quality of in-stream and riparian habitat and were conducted according to KDOW methods (e.g., Barbour *et al.*, 1999; KDOW, 2001). All water quality sampling methods were in accordance with the KDOW Standard Operating Procedures (SOPs). Water quality sampling included both field measurements (e.g., temperature, pH, dissolved oxygen, specific conductance, etc.) as well as parameters measured in the laboratory (e.g., bacteria, sediment, nutrients, etc.). For the biological assessments, benthic macroinvertebrate samples were based on the EPA's Rapid Bioassessment Protocols for high gradient streams (Barbour *et al*., 1999), as adapted for Kentucky.

4.0 Analyzing Results

The analysis of the monitoring data was completed using an integrated approach, which focuses on the concept that there are many interdependencies for overall stream health, highlighted by the stream function pyramid in **Figure ES-4**. Land use and land management alter the flow regime in a stream, which in turn influences the physical characteristics and habitat that are found there. Those changes then impact the quality of the water, which will alter the biotic integrity of the stream. No one component can be evaluated or mitigated on its own; the system must be analyzed holistically.

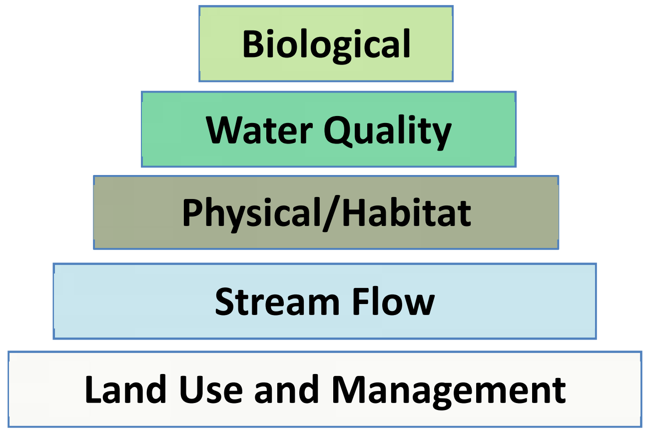

Figure ES-4 - Stream Function Pyramid adapted from Center of Watershed Protection (2011)

The goal of analyzing the monitoring data was to develop an integrated implementation plan for the watershed that will be feasible, efficient, and effective. The overall results from monitoring coincide with preliminary assessments, showing that bacteria and total suspended solids (TSS) are the most concerning pollutants, particularly throughout the developed headwaters and South Fork Gunpowder Creek. In turn, the biology was found to be worst in these most developed subwatersheds, where erosive flows have altered the habitat, impaired the water quality, and lowered the biologic integrity.

Statistical analysis was conducted using the R program in order to identify the strength of the relationship between water quality monitoring data and watershed characteristics. The results of the hydrogeomorphic monitoring were also used to strengthen and tie hydromodification into the analysis. This leads to a better understanding of the sources of all impairments and provides insight into the best management practices (BMPs) that should be employed in the watershed. The following sections present a brief summary of the results of each aspect of GCWI's multi-faceted monitoring program.

Stream Flow Results

Flow from three sites with similar watershed size but varying levels of development demonstrated that the most developed site

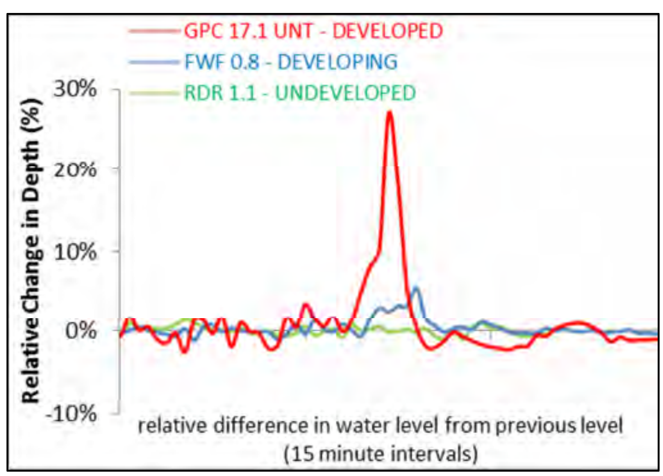

Figure ES-5 - Percent relative change in water depth of time

experienced much higher flows (**Figure ES-5**). This urban flow regime is flashier and larger, causing increased erosion, more water quality impairments, degraded habitat conditions, and increased potential for flooding issues.

Hydrogeomorphic (Physical) Results

Analysis of the hydrogeomorphic survey data supports that streams in urban/suburban watersheds are unstable, as the hydrogeomorphic monitoring sites that exhibited the most instability were located in the most developed areas of the watershed (South Fork Gunpowder and the headwaters of Gunpowder Creek). The analysis completed for Gunpowder Creek was generally consistent with an in depth study of Northern Kentucky streams, which demonstrates that development is linked to stream channel enlargement, bed coarsening, shorter riffles, and longer and deeper pools (Hawley *et al.,* 2013). Overall, GCWI evaluated several different parameters to better understand potential sources of impairments. Both barren land and riparian roads were found to have a positive relationship with cross-sectional enlargement, whereas the subwatersheds with greater amounts of barren land or riparian roads exhibited greater channel instability, as measured by a change in the bankfull area. Using that notion, channel instability was also linked to higher average TSS. Furthermore, this watershed plan presents a few hydrogeomorphic monitoring case studies that provide examples of the types of geomorphic concerns that exist throughout the watershed. This includes an extremely dynamic site experiencing bank failure and bed incision, a site experiencing geotechnical mass wasting and bank widening (**Figure ES-6**), and a site with extremely erosive flows that have transported large amounts of woody debris.

Figure ES-6: SFG 5.3-UNT 0.1 tension crack bank failure

Habitat Results

Furthermore, a stable stream system with adequate riparian buffer areas is critical for supporting habitat structure and biologic integrity. Review of the Habitat Assessment Scores indicates that the most unstable site in the South Fork Gunpowder subwatershed (SFG 5.3-UNT 0.1) scored the lowest of all the sites, having the most degraded habitat. In evaluating all of the sites with geomorphic and habitat data, unstable channel conditions, as measured by channel widening (i.e., a change in bankfull top width), illustrated a negative relationship with the Habitat Assessment Scores, meaning that the most unstable sites exhibited the most degraded habitat conditions (**Figure ES-7**). It

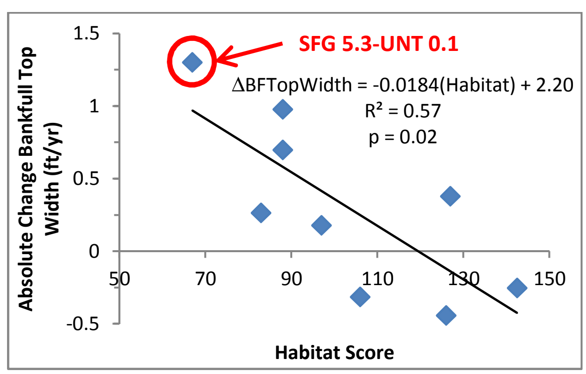

Figure ES-7: Channel widening is negatively correlated to habitat score

Notice the most unstable site, SFG 5.3-UNT 0.1, widened at a rate of more than 1 foot per year and had the lowest habitat score of 67. This site also has the most developed watershed with 41% imperviousness.

can therefore be informed that the erosive, urban flow regime has been a primary cause of the degradation of the Gunpowder Creek in the most developed subwatersheds, leaving homogenous, featureless stream beds composed of exposed bedrocks, short riffles, and long pools.

Water Quality Results

Water quality data were analyzed to evaluate variations in pollutant concentrations and understand the potential causes; parameters were compared to rainfall and stream discharge data. Box and whisker plots were generated using the statistical software R and provided visual observation of the range of sample concentrations in relation to the water quality benchmark for each parameter. While these benchmarks are not definite criteria, they do provide an understanding of the scale of the problems in the watershed as well as interim targets for achieving a healthy stream system. In addition, pollutant load duration curves were developed and then used to analyze 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). The pollutant load determines the specific pollutant amount that is being transported by the stream in terms of weight per period of time (e.g. lbs/day). The load duration curves were also used to estimate overall pollutant loads and calculate pollutant yields.

Figure ES-8 highlights the ratio of annual projected pollutant loads to annual benchmark pollutant loads; it is clear that sediment and bacteria have the highest ratios. Therefore, results of the water quality analysis indicate that bacteria (as measured by *E.coli*) and sediment (as measured by TSS) are the most concerning pollutants in the Gunpowder Creek Watershed, particularly in the most developed regions of the watershed. Other parameters, such as nutrients or dissolved oxygen, were not as concerning.

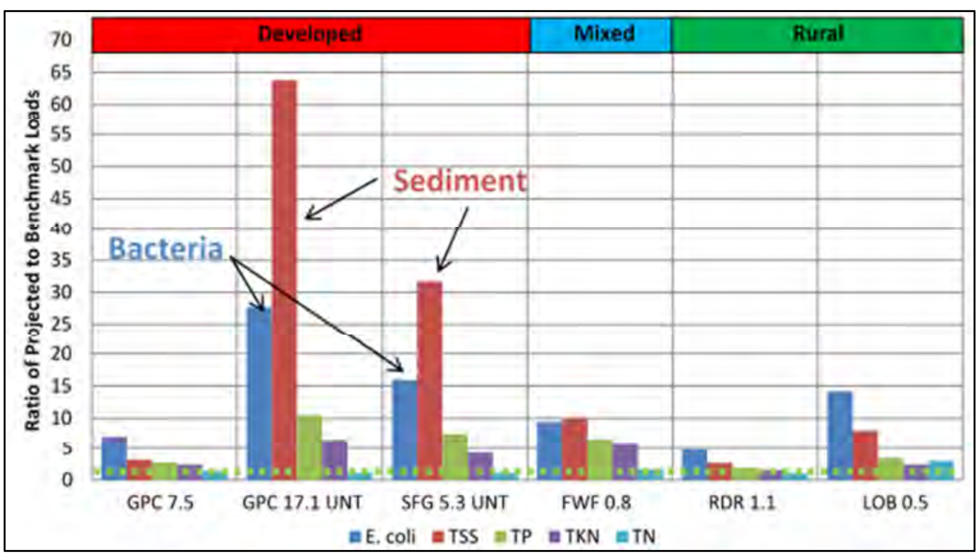

Figure ES-8 – Ratio of annual projected loads to annual benchmark loads

Through further analysis, it was found that under dry conditions, the sites with the most catchment imperviousness had the lowest concentration of *E.coli* in the stream, but that the opposite is true for wet weather conditions. This indicates that the most developed watersheds appear to have a larger concern with bacteria during wet weather whereas the less developed, rural watersheds have higher bacteria concerns during dry weather. Stormwater runoff and animal waste are suspected sources of bacteria in the developed subwatersheds, while septic systems and animals grazing in the streams are suspected sources of bacteria in the rural subwatersheds. As has been noted, TSS is also a pollutant of concern in the watershed and high concentrations of TSS were linked to the most unstable sites in the hydrogeomorphic data analysis. Furthermore, it was found that wet weather causes higher concentrations of TSS in the stream than dry weather does, especially as the percent impervious of the watershed increases. This indicates that bank erosion and channel enlargement are a likely source of the fine sediment found in the stream.

Biological Results

The biological health of the Gunpowder Creek is dependent on all other factors presented above. Statistical analysis between the percent impervious in the watershed and two biologic factors, the MBI Score and the Percent Primary Clinger score, illustrated that the scores decreased with an increase in percent impervious. Therefore, biological integrity suffered the most in the more impervious, developed portions of the watershed. This is consistent with the rest of the data analysis and supports the prioritization of the most developed areas of the watershed.

Potential Sources of Pollutants

These results can be categorized into three types of land use based on watershed imperviousness: developed watersheds (20-40% impervious) on the eastern side of the Gunpowder Creek Watershed, rural watersheds (2-4% impervious) on the southern portion of the Gunpowder Creek Watershed, and mixed use watersheds (developed/rural, 12% impervious). By completing this categorization, the following takeaways can be gleaned.

In developed watersheds, bacteria and suspended sediment are the most concerning parameters during wet weather, most likely caused by animal waste and erosive flows and unvegetated banks, respectively. The likely sources of these include stormwater runoff and bank erosion, respectively. Specific conductance is most concerning during dry weather flow, with a possible cause and likely source being point source treatment. Least concerning in the developed watersheds in Gunpowder is bacteria under dry weather conditions, indicating that one of the primary benefits of watershed development is the expanded sanitary sewer system, which is designed to keep untreated human waste from reaching our streams.

In rural watersheds, dry weather makes bacteria, nutrients, and specific conductance the most concerning pollutants. Bacteria and nutrients likely come from septic systems and/or directly from animals, caused by a lack of septic maintenance and/or inadequate livestock fencing. Specific conductance is possibly from septic systems, point source discharges, and/or natural sources. Nutrients during wet weather events are the least concerning pollutant in rural watersheds.

In mixed use watersheds, bacteria during wet weather events is the most concerning pollutant, which likely comes from stormwater runoff with a possible cause of animal waste. During dry weather, both specific conductance and nutrients are concerning. The likely sources and possible causes are the same as in rural watersheds. Bacteria during dry weather flow is the least concerning pollutant in Gunpowder's mixed use watersheds.

Prioritization

Following the data analysis, the subwatersheds required prioritization to understand which would require stream health improvement actions and which, if any, are in good condition and should be protected from future degradation. The subwatersheds were ranked in numerous ways, including the number of water quality samples exceeding the benchmark concentration, average sample concentrations, projected annual pollutant loads, and pollutant yields. The results of these rankings match the findings in KDOW's 2010 303(d) List of Impaired Waters, showing sediment as a common pollutant and the South Fork Gunpowder and the developed headwaters in the main branch to be the greatest reaches of concern.

5.0 Finding Solutions

Water quality impairments can be mitigated in a variety of ways, using both structural and non-structural BMPs. KDOW provides an extensive list of BMPs in their *Watershed Planning Guidebook for Kentucky Communities* document. These BMPs have been evaluated based on the impairments in the Gunpowder stream network, results of monitoring and data analysis, and existing land uses. Specifically, BMPs focused on stormwater, agriculture, construction, forestry, and onsite wastewater treatment are applicable to the watershed. Education is another valuable BMP that is cost-effective and applicable.

It has been established that TSS is the most concerning pollutant in the Gunpowder Creek Watershed, and more specifically, it was found to be worst in the most developed subwatersheds. The major source of the TSS is suspected to be bank erosion, which is caused by the erosive flows in the creek from stormwater runoff. Therefore, it is clear that stormwater controls must be a key BMP implemented in the watershed. These controls should also help to alleviate bacteria and nutrient impairments in the creek. In order to prioritize BMPs, four implementation categories were developed within Gunpowder Creek Watershed: headwaters/developed areas; undeveloped areas; agricultural areas; and active forestry areas.

Volume-based stormwater controls are the most cost-effective BMP for the developed areas of the watershed. BMPs that are volume-based can control the erosive flows. Filtration-based BMPs would treat the water for TSS, bacteria, and nutrients, but cannot handle the large quantity of water needed to make an impact across the watershed. Examples of volume-based controls include extended detention basins, bioretention basins, constructed wetlands, and retrofits of existing detention/retention basins for improved water quality and channel protection performance.

6.0 Strategy for Success

Using the data analysis and the BMP evaluation, a combination of BMPs have been selected to achieve the goals of the watershed plan, to address the impacts to and protect the resources of the Gunpowder Creek Watershed. Considerations have been taken into account, including regulatory matters, stakeholder cooperation, political will, available funding, cost-effectiveness, priority areas, existing efforts, and watershed management activities. However, a key element of GCWI's approach for this Watershed Plan is to implement a reasonable level of BMPs and continue to monitor. GCWI plans to make smart investments as opportunities arise, monitor the progress, then reassess through continued monitoring – with the goal to continually improve the effectiveness of the implementation efforts (**Figure ES-9**).

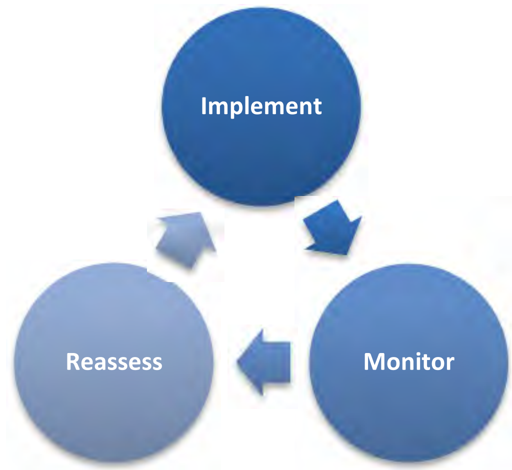

Figure ES-9 – GCWI Watershed Plan approach

A key consideration in the development of the selected BMPs was the stakeholder cooperation and input from several roundtable discussions. Tailoring the BMPs to the gathered responses provides the supportive foundation for successful implementation of the plan. In addition to the GCWI Steering Committee and regional partners, the public has been actively involved. Three roundtable meetings (**Figure ES-10**) were held to gain feedback on issues and considerations in the watershed.

Figure ES-10 - One of several well-attended public meetings on the Gunpowder Creek Watershed Initiative

Development was a concern from every roundtable group, and stormwater runoff and flooding, considered to be linked to development, were priority issues for the majority of the groups. **Table ES-1** highlights the questions and responses from the roundtable groups. As outlined below, the selected BMPs have been identified, where applicable, to address the dominant issues outlined by the public.

Table ES-1. Questions and dominant responses from 11 roundtable groups with approximately 70 participants

Question	Dominant Responses(1)
1. Why is a clean healthy stream important to you?	Recreation (73%), Aesthetics (66%), Quality of Life/Health (54%)
2. What land uses in the watershed are you most concerned about?	Development (100%)
3. What do you think are the most common problems?	Runoff (73%), Flooding/Safety (66%)
4. What BPMs do you consider feasible in Gunpowder Creek?	Detention/Retention (82%), Education (66%), Responsible Development/Ordinances (55%)
5. What issues in Gunpowder Creek do you consider a priority?	Stormwater Runoff (66%), Flooding (55%)

(1)Responses that were listed by more than half of the groups. For a summary of all responses, see supporting handout in ***Appendix 6-A****.*

Overall Watershed BMPs

The following BMPs have been considered appropriate measures to implement across the watershed, based on the considerations above.

- Training and technical support program
- Coordination with NKU's Stream and Wetland Restoration Program
- Watershed coordinator position
- Review/Revision of Rules and Regulations
- Success monitoring and analysis
- Stewardship programs
- Riparian plantings

Training and technical support for local designers and contractors can provide education to key individuals on the various BMPs and implementation strategies within the watershed. The education component pairs nicely with the NKU Stream and Wetland Restoration Program, which stabilizes degraded stream reaches and restores habitat after developments or other projects physically alter streams. Training and technical support could also lead to a better understanding of how to cost-effectively design for channel protection on future development projects. By hiring a watershed coordinator, the GCWI would have someone to manage and coordinate implementation efforts in a way that also considers stream channel protection and water quality. This particularly relates to coordination between regional agencies on local projects, such as flood control in Florence or the Whispering Trails subdivision.

Partnered with this is a review and revision of regional rules and regulations related to development practices and stormwater management. Recently, SD1 and the City of Florence developed a BMP Manual which requires water quality treatment of the first 0.8 inches of rain. Adapting this document to include channel protection controls designed for $Q_{critical}$ could drastically improve the effectiveness of strowmater management controls at protecting stream channels from excess erosion. Designing for $Q_{critical}$ would require the capture and release of all storms up to and including the 2-year storm below the critical flow for stream erosion.

Success monitoring and analysis calls on both the GCWI and SD1 as well, to continue water quality and hydromodification monitoring within the watershed. Stewardship programs could be led by the watershed coordinator, and would educate and provide outreach programs for homeowners and large corporate and institutional properties. Riparian plantings could do a lot to buffer overland stormwater runoff prior to entering the creek and protect streambanks from excess erosion.

Developed Headwaters BMPs

As discovered throughout monitoring and data analysis, the developed subwatersheds have the greatest pollutant load ratios for TSS and bacteria in addition to the worst biological indicators. For these reasons, these subwatersheds have been identified as the highest priority for focused efforts to mitigate erosive flows that have altered the habitat, impaired the water quality, and lowered the biologic integrity. The following BMPs have been considered appropriate measures to implement in the developed headwater subwatersheds, based on the considerations above.

- Bioretention
- Detention basin retrofits
- Detention basins
- Wetland creation/restoration
- Pet waste program

Many of the BMPs identified for the developed subwatersheds are stormwater controls, which will be implemented to mitigate erosive flows. While the implementation methods may differ, all four will serve as volume-based BMPs to detain stormwater runoff and filter TSS, bacteria, and nutrients from the runoff. Infiltration-type BMPs are less feasible in this watershed due to the prevalence of clay soils.

Implementation costs and siting restraints will impact which BMPs are selected. Detention basin retrofits are 10 to 100 times more cost-effective and there are many existing basins within the watershed that are potential candidates. New detention basins will be focused in areas with large amounts of impervious area that are currently not detained; coordination with private property owners is anticipated. Bioretention basins could also be installed in these situations and will be evaluated on an individual basis. Wetland creation and restoration may be utilized in low-lying areas adjacent to the channel.

Implementation of a pet waste program, specifically in areas with high dog-walking traffic, could have a significant impact on bacteria in the stream.

Agricultural BMPs

Livestock exclusion fencing has been considered an appropriate measure to implement in agricultural areas, based on the considerations above. In addition to removing cattle and horses from the stream, this effort will also create riparian buffer zones, which will help in filtering waste in overland runoff. As an initial step, an improved inventory of horse properties in the watershed may help to target BMP outreach and implementation.

Undeveloped Areas/Forestry BMPs

Conservation of open areas has been considered an appropriate measure to implement in undeveloped and forested areas, based on the considerations above. As Boone County continues to develop, preserving and improving existing green space will be vital to protecting the county's water resources. The GCWI has already identified publicly owned undeveloped lands that can be targeted for conservation practices.

Subwatershed Prioritization

Subwatersheds were prioritized for implementation, based on the extent of the impairment and number of identified opportunities within each subwatershed, cost, and feasibility. The prioritization is included in the list below, but is subject to change based on changes to the criteria for prioritization as different partnering opportunities arise to implement large, impactful projects throughout the watershed.

1. South Fork (developed headwaters)
2. Riddles Run (agricultural headwaters)
3. Lower Gunpowder (undeveloped bottomlands)
4. Fowler Fork (mixed rural/developed headwaters)
5. Upper Gunpowder (developed headwaters)
6. Long Branch (agricultural headwaters)

Resources

The amount of effort that has been put forth to date have been astounding. Specifically, SD1 and NKU have been extremely valuable in contributing both financial and human resources to the development of the *Gunpowder Creek Watershed Plan*. Moving forward, capitalizing on the existing resources, including the number of existing, non-retrofitted detention basins, will be a key to success. It will be important to piggyback on existing efforts, including the flood control improvements currently underway by SD1 and the City of Florence, and to capitalize on the available resources, including the 535 existing non-retrofitted detention basins and existing large publicly-owned tracts of land, in order implement the integrated solutions for the Gunpowder Creek Watershed.

7.0 Making It Happen

Finally, we come to most important final step: make implementation happen. The efforts completed to date would mean nothing if the plan was not well executed, and this section will highlight the "who" and "how" for implementing the *Gunpowder Creek Watershed Plan*.

Mark Jacobs from BCCD has done a phenomenal job to date, serving as the Watershed Coordinator, and the GCWI Steering Committee has elected to have him continue in this role. Mr. Jacobs, along with members of the technical sub-committee will be the implementation undertakers. The Steering Committee, outlined in Section 1.0, will continue to meet at least every other month to guide implementation efforts.

Public outreach has been integral to the plan's success so far and will continue. The media campaign, presentations, and public meetings have been invaluable. Continued efforts will include articles in the Conservation District's and County's newsletters, among other efforts. Fundraising will be important to continuing efforts. The funding to date has been primarily through a FFY 2009 Kentucky Nonpoint Source Pollution Control Program grant and many non-Federal sources, this will not cover implementation. A grant request has been submitted for FFY 2014 for $1,000,000. The local match portion of $400,000 would likely come from BCCD, SD1, the City of Florence, Boone County Parks, and volunteer time. Additional funding for the GWCI will be sought through local and regional private foundations as well as local, State, and Federal grant sources that may be identified.

Highlighted in **Figure ES-9**, monitoring and evaluating the in-stream success of the implementation efforts are priorities for the GCWI. GCWI will develop a KDOW-approved monitoring plan and Quality Assurance Project Plan (QAPP) to continue to monitor at the established stations. Success will be measured via implementation rate and water quality results from a KDOW-approved in-stream success monitoring program. The plan will be evaluated and updated as implementation efforts continue to work toward the restoration of a healthy Gunpowder Creek.

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CHAPTER 1

Introduction

Gunpowder Creek Watershed Plan

Prepared by the

Gunpowder Creek Watershed Initiative

December 2014

Chapter 1: Introduction

This chapter provides a brief overview of the Gunpowder Creek Watershed, the issues it faces, and the community led initiative which has formed to address its future.

1.1 The Watershed

The Gunpowder Creek Watershed is the largest watershed in Boone County, Kentucky, and one of the largest in Northern Kentucky. Flowing southwesterly to its confluence with the Ohio River, the Gunpowder Creek main stem is approximately 36 miles long and encompasses a watershed area of 58.2 square miles. Located entirely in Boone County, Kentucky, the stream originates west of the Cincinnati/Northern Kentucky International Airport (CVG), is home to nearly half of the county's residents and comprises 25% of the land area. The headwaters of the watershed are fairly developed and include portions of the cities of Florence and Union. Downstream, the watershed flows westward into more rural areas of unincorporated Boone County.

Boone County has been growing steadily since the 1960s and consistently ranks as one of the most rapidly developing counties in Kentucky and country. In the coming decades, forecasts show that Boone County will experience continued population growth and development, primarily in the form of suburban residential housing and related land uses. Most of the county's watersheds are already experiencing the impacts associated with this development, including streambank erosion/instability, excess sedimentation, degraded biological communities, loss of ecological function, etc.

The Gunpowder Creek Watershed has been under increasing pressure as development continues to expand to the west. As such, it has been classified on the 303(d) List of Impaired Waters for high levels of sediment, bacteria, and nutrients. In an attempt to address these impacts, the Boone County Conservation District (BCCD), funded in part by a federal 319(h) grant, is working to improve the water quality in the Gunpowder Creek Watershed through the goals of the Gunpowder Creek Watershed Initiative (GCWI) and development of this watershed plan.

1.2 Partners and Stakeholders

The Gunpowder Creek Watershed Initiative (GCWI) is a collaborative effort guided by a Steering Committee of local agencies which have a responsibility to the community to protect natural resources. The key project partners are involved with the implementation of the 319(h) grant and their contact information is as follows:

Agency Name: Boone County Conservation District
Agency Address: 6028 Camp Ernst Road, Burlington, Kentucky 41005
Role/Contribution to Project: Project Steering Committee, Project Administration
Contact Person: Mary Katherine Dickerson
Phone No. 859-586-7903
E-mail address: mdickerson@nkcd.org

Agency Name: Boone County Conservation District
Agency Address: 6028 Camp Ernst Road, Burlington, Kentucky 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 Drive
Role/Contribution to Project: Project Steering Committee
Contact Person: Steve Divine
Phone No. 859-363-2049
E-mail address: steve.divine@nkyhealth.org

Agency Name: Sanitation District No. 1
Agency Address: 1045 Eaton Drive
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 Road, Highland Heights, Kentucky 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: City of Florence, Kentucky
Agency Address: City of Covington, Florence Government Center,
8100 Ewing Boulevard, Florence, Kentucky 41042
Role/Contribution to Project: Project Steering Committee
Contact Person: Josh Hunt
Phone No. 859-371-5491
E-mail address: joshua.hunt@florence-ky.gov

Agency Name: City of Union, Kentucky
Agency Address: City of Union, Union City Building,
1843 Mt. Zion Road, Union, Kentucky 41091
Role/Contribution to Project: Project Steering Committee
Contact Person: Deanna Kline
Phone No. 859-384-1511
E-mail address: commissionerKline@insightbb.com

Agency Name: Boone County Fiscal Court
Agency Address: 2950 Washington Street, Burlington, Kentucky 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, PO Box 17130, Covington, Kentucky 41017
Role/Contribution to Project: Project Steering Committee and 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, 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: Lajuanda Haight-Maybrier
Phone No. 502-564-3410
E-mail address: LajuandaHaight-maybrier@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

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

CHAPTER 2

Exploring the Gunpowder Creek Watershed

Gunpowder Creek Watershed Plan

Prepared by the

Gunpowder Creek Watershed Initiative

December 2014

Chapter 2: Exploring the Gunpowder Creek Watershed

This chapter describes key features of the Gunpowder Creek Watershed, including its extent, formation, natural and cultural resources, as well as some of its history relative to human use of the landscape. Much of this descriptive material is taken from the Gunpowder Creek Watershed Characterization Report (LimnoTech 2009).

2.1 Watershed Inventory

2.1.1 Watershed Location and Extent

Located entirely within Boone County, the Gunpowder Creek Watershed has a total drainage area of 58.2 square miles and is one of the largest watersheds in Northern Kentucky (**Figure 2-1**). The watershed is roughly triangular in shape with one leg running approximately 9 miles north/south across eastern Boone County. Its headwaters originate in the southern end of the Cincinnati/Northern Kentucky International Airport (CVG) and flow approximately 36 miles south and west to the Ohio River. South of CVG, the watershed drains nearly three quarters of the City of Florence and nearly all of the City of Union, which lies near the southeast end of the triangle. The balance of the watershed falls within unincorporated Boone County, narrowing as it meanders westward across the county. The lower reaches of the stream and its mouth form a valley that is more than one mile wide.

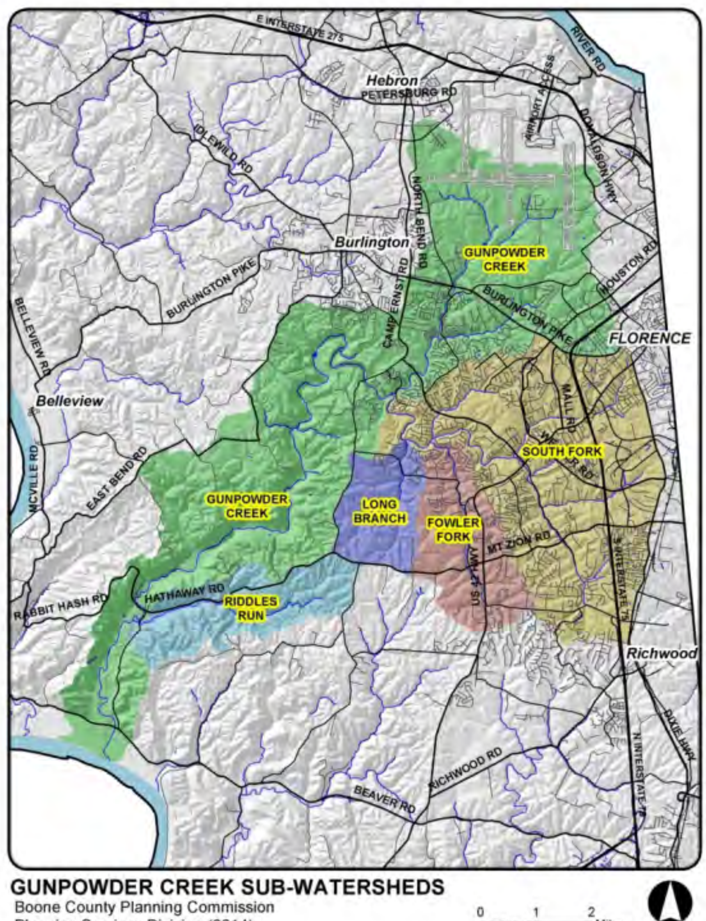

Figure 2-1

2.1.2 Hydrology

The Gunpowder Creek Watershed drains directly into the Ohio River and includes four smaller subwatersheds: South Fork Gunpowder, Fowler Fork, Long Branch, and Riddles Run. South Fork is in the southeast end of the Gunpowder watershed, is the largest of the subwatersheds, and drains much of the City of Florence. Fowlers Fork and Long Branch lie immediately west of South Fork and together, provide much of the drainage for the City of Union. The Riddles Run subwatershed drains much of the southern part of the larger Gunpowder watershed. All of the subwatersheds are located south of the 23.4-mile long main stem. There is a total of 143.1 miles of blue line streams in the Gunpowder Creek Watershed.

One USGS continuous monitoring station is located in the Gunpowder Creek Watershed where the main stem crosses Camp Ernst Road. Approximately 63% of the Gunpowder Creek watershed (36.6 square miles) drains to this station and daily discharge data from April 1999 to present are available. The USGS (2012) reports that between water years 1999 and 2012, the average flow at the station was 59.3 cubic feet per second (cfs), which is more than 26,000 gallons per minute. Ten percent of the recorded flows at this site have been less than 0.94 cfs (about 400 gallons per minute), but flows can increase by up to three orders of magnitude during a storm event. The maximum flow recorded at the USGS station is 6,590 cfs on May 8, 2002, which is nearly 3 million gallons per minute. The periods of high flow tend to be very brief and only last one to two days. In contrast, during extended periods of dry weather, flows at the station can become intermittent. There have been several days with zero flow, including a period during September of 1999 in which there were more than seven days in a row with no flow.

2.1.3 Groundwater – Surface Water Interaction

Groundwater yield in the Gunpowder Creek Watershed varies depending on geological formation. The upper Gunpowder is within the Grant Lake Limestone/Fairview and Bull Fork Formations and the lower Gunpowder is located in Kope Formation. Except near the headwaters, groundwater is generally unavailable on ridgetops. Wells in the valley bottoms can yield 100-500 gallons per day. This water is hard and may contain salt and hydrogen sulfide (Carey and Stickney, 2004). In Boone County, the interface between fresh and saline water ranges from elevations of less than 400 feet ASL 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. The high percentages of shale and minimal development of karst features in the Outer Bluegrass rocks indicate a low to moderate sensitivity to groundwater contamination in the Gunpowder Creek Watershed (Ray et al., 1994).

There are many wells in the Gunpowder Creek Watershed. According to the Kentucky Geological Survey at the University of Kentucky, the groundwater that comes out of Boone County tends to be hard and have a high dissolved mineral content. This is at least partially due to the low amount of interaction between Boone County's ground water and surface water. This low interaction is due to the high clay content in Boone County's soils, which tends to discourage groundwater infiltration. Drilled wells in areas with glacial drift and outwash (near the Gunpowder Creek/Ohio River confluence) are capable of yielding significantly more groundwater than elsewhere in the watershed (Ray et al., 1994).

2.1.4 Flooding

Like most of Boone County's streams, portions of Gunpowder Creek have been known to flood periodically since the county was first settled in the late 1790s. The 100-year floodplain extends almost the entire length of both Gunpowder Creek and South Fork Gunpowder Creek. The larger stream's floodplain is widest, roughly 0.5 miles, between the confluence of Riddles Run and Gunpowder's mouth at the Ohio River. Frequent episodes of flooding have occurred since the early 1990s, which is an ongoing concern of citizens living along the streams in the watershed. More recently, the smaller tributaries in the watershed have been increasingly affected by flooding, as reported by attendees at public roundtable meetings. Portions of the upper Gunpowder Creek watershed frequently experience flooding, though the most extensive flood zone area identified in the Boone County Comprehensive Plan is the lower East Bend Bottom, at the mouth of Gunpowder Creek (BCPC, 2010). Flooding risks will likely increase with amplified runoff events associated with increased population, expanding development, and associated increases of impervious surface and loss of soil stabilizing vegetation to erosion.

2.1.5 Regulatory Status of Waterways

Gunpowder Creek and its tributaries are designated for warm water aquatic habitat, primary contact recreation, secondary contact recreation, and domestic water supply, applicable at existing points of public waters supply 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. Two Wellhead protection zones are identified in the watershed. Both are located in floodplain areas of the lower Gunpowder below Riddles Run (see LimnoTech 2009: Fig 9).

Several sections of Gunpowder Creek have been classified on the Kentucky 303(d) List of Impaired Waters for high levels of sediment, bacteria, and nutrients. **Table 2-1** lists each impaired section and the pollutants of concern, as specified in the Kentucky 303(d) List of Impaired Waters (KDOW, 2011). In addition to the list below, there is a Total Maximum Daily Load (TMDL) for ethylene glycol in Upper Gunpowder Creek near river miles 15.4 to 17.1. This is an approved TMDL, is a point source pollutant, and it is already being addressed. It will not be a focus of this watershed plan.

Table 2-1: Stream sections in the watershed on the Kentucky 303(d) List of Impaired Waters

STREAM NAME	RIVER MILES	POLLUTANT	SUSPECTED SOURCE(S)
Gunpowder Creek into Ohio River	0.0 to 15.0	Sedimentation/Siltation	Site Clearance (Land Development or Redevelopment)
Gunpowder Creek	15.4 to 17.1	Nutrient/Eutrophication Biological Indicators	Agriculture; Site Clearance; Unspecified Urban Stormwater
Gunpowder Creek	15.4 to 17.1	Organic Enrichment (Sewage) Biological Indicators	Agriculture; Unspecified Urban Stormwater
Gunpowder Creek	15.4 to 17.1	Sedimentation/Siltation	Agriculture; Highway/Road/Bridge Runoff; Loss of Riparian Habitat; Site Clearance; Streambank Modifications/ Destabilization; Unspecified Urban Stormwater
Gunpowder Creek	18.9 to 21.6	Cause Unknown	Unspecified Urban Stormwater
South Fork Gunpowder Creek	0.0 to 2.0	Nutrient/Eutrophication Biological Indicators, Organic Enrichment (Sewage) Biological Indicators, Sedimentation/Siltation, and Turbidity	Agriculture; Package Plant or Other Permitted Small Flow Discharges; Site Clearance; Post-development Erosion and Sedimentation
South Fork Gunpowder Creek	4.1 to 6.8	Fecal Coliform	Source Unknown

2.1.6 Water Quality and Biology

The Gunpowder Creek Watershed Characterization Report contains a discussion and analysis of water quality data collected from various points in the watershed from 1985 to 2007 (LimnoTech 2009:35). During that time frame, exceednces of both fecal coliform and *E. coli* were common at many locations within the Gunpowder Creek watershed. Additionally, analysis of data collected at the USGS continuous monitoring revealed violations of dissolved oxygen, temperature and pH criteria. As stated earlier, these and other data have led to portions of Gunpowder Creek to be listed as impaired on Kentucky's 303(d) list of impaired waters (Table 2-1).

Stream biology surveys have been conducted at various locations throughout the Gunpowder watershed. KDOW collected both macroinvertebrate and fish data between 1999 and 2004, producing results that indicate wide variability within the quality of biological communities. This variability is exemplified by both the Macroinvertebrate Biotic Index (MBI) ratings ("very poor" to "fair"), and the Kentucky Index of Biotic Integrity (KIBI-fish) ratings ("very poor to excellent").

As part of their efforts to characterize watershed and stream quality in Northern Kentucky, SD1 also collected both fish and macroinvertebrate samples in 2010. Fish samples were collected at five (5) sites throughout the watershed, producing a total of 35 unique taxa and KIBI ratings of generally "fair" to "good." Macroinvertebrate samples were collected at four (4) locations in the watershed, producing 48 unique taxa and MBI ratings of generally "poor" to "fair."

2.1.7 Geomorphology

Rivers come in many shapes and sizes, and fluvial geomorphology is the study of how flowing water shapes the earth's surface, in particular, the form, composition, and stability of a stream channels. The most dominant drivers of stream form include the climate and corresponding flow regime and vegetation resistance, as well as the geologic setting and the relative resistance of rocks/soils, steepness of the topographic setting, valley confinement, and so forth.

The hydrogeomorphic setting of northern Kentucky is relatively homogenous. The average precipitation of 42.5 inches is the same for the entire region, and supports fast growing vegetation with relatively dense root networks of high strength. Clay soils create low infiltration rates and cohesive streambanks. The somewhat soft and shallow limestone bedrock supplies streams with a relatively limited supply of coarse bed material when compared to steeper and less vegetated settings such as the western U.S. Even so, the hill slopes and valley corridors are relatively steep as the precipitation makes its way from the high ridgetops to the much lower Ohio River over relatively short distances.

Although factors such as climate and geology are the dominant drivers of stream morphology at the regional scale, other factors such as urbanization and/or channelization can become the primary driver within an otherwise homogenous setting. As discussed in subsequent sections of this plan, the amount of impervious area such as rooftops and pavement can explain differences in shape and stability between two streams in an otherwise similar setting. For example, the forested reference stream in the adjacent watershed of Double Lick has a relatively similar climatic, geologic, and topographic setting as the unnamed tributary to the South Fork of Gunpowder along Sunnybrook Dr. which drains the industrial area near the intersection of Weaver Road and Dixie Highway. Despite the relatively similar natural settings, the impacts of urbanization have resulted in a stark contrast in stream form, stability, and habitat condition.

2.2 Natural Features

2.2.1 Geology and Topography

The Gunpowder Creek Watershed is located within the Outer Bluegrass Physiographic Region (Ray et al., 1994). It is underlain primarily by Ordovician-age interbedded limestone and shale of between 425 and 500 million years old. Although most of the watershed is underlain by bedrock with a moderate potential for karst development (Paylor and Currens, 2002), rocks in this region generally contain higher percentages of shale layers and do not develop extensive karst features (Ray et al., 1994).

The rolling upland areas of the Gunpowder Creek Watershed are underlain by the Bull Fork Formation and the Grant Lake Limestone/Fairview. These formations produce broad stream valleys and form valley sides. In areas where the shale content increases, erosion increases and creates steep topography. The lower Gunpowder cuts through the erodible shale found in the Kope Formation.This formation contains a large percentage of shale overlapping with limestone and forms steeper topography than the upper Gunpowder. 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. The floodplains and terraces of Gunpowder Creek and its tributaries include alluvium and glacial sediment deposits of highly erodible material.

The topography of the Gunpowder Creek watershed ranges from broad, gently sloping, uplands in the eastern end of the watershed to deeply dissected valleys in the west. This topographic variation is the result of glacial processes related to the Wisconsin Glaciation of North America, which ended in the Late Pleistocene Era (10,000 - 20,000 years ago). Elevations are higher in the eastern end of the watershed, with upland areas dissected by headwater streams. The highest elevations (965 ft) are found along a ridge that marks the eastern edge of the watershed; U.S. Highway 25 (Dixie Highway) was built along this ridge. The lowest elevation in the watershed (453.6 feet at normal Ohio River pool) is located at the confluence of Gunpowder Creek with the Ohio River.

2.2.2 Soils

Soils in this area formed in semiarid to humid areas, typically under a hardwood forest cover. They have a clay-enriched subsoil and relatively high native fertility. Because of their productivity and abundance, soils in this region represent one of the more important soil orders for food and fiber production. They are widely used both in agriculture and forestry, and are generally easier to keep fertile than other humid-climate soils. These soils are common on limestone plains and support a potential natural vegetation of oak–hickory forest and bluestem prairie.

Three major soil associations occur in the Gunpowder Creek Watershed (see Weisenberger et al., 1973). The Rossmoyne-Jessup association occupies broad, nearly level to sloping ridges and moderately steep side slopes in the glaciated area in the eastern headwaters portion of the watershed. The Eden-Cynthiana association occupies the steep (12-30% slope), highly dissected, portions of the valley, primarily below the South Fork Gunpowder confluence. The Wheeling-Huntington-Alluvial land consists of soils on stream terraces and bottoms and is found along the final 2 miles of the lower Gunpowder to its confluence with the Ohio River.

Soil type affects drainage, flooding, permeability, slope stability, and siltation, all of which interact dynamically in the Gunpowder Creek Watershed. With the exception of streamside alluvial soils, most (83%) of the soils in the watershed are considered either “highly erodible” or “fairly erodible” (14%) 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. Virtually all of the soils in the county have “very limited” Septic Suitability and those within the Gunpowder Creek Watershed are almost all classed either “well drained” or “moderately well drained.”

2.2.3 Ecoregions

The Gunpowder Creek watershed lies within the Outer Bluegrass Ecoregion 71d, which is characterized by sinkholes, springs, entrenched rivers and intermittent and perennial streams (Woods et al. 2002). Wetlands are not common in this ecoregion or the watershed. Streams typically have relatively high levels of suspended sediment and nutrients. Glacial outwash, which tends to be highly erodible, exists in a few areas within the ecoregion. Pre-settlement conditions in the ecoregion consisted of open woodlands with barren openings, and vegetation was mostly oak-hickory, with some white oak, maple-oak-ash and American beech-sugar maple forests (Woods et al. 2002).

The Kentucky State Nature Preserves Commission (KSNPC) monitors the occurrence of exemplary ecological communities, which are relatively undisturbed or have recovered sufficiently from previous disturbances and have the flora and fauna that are believed to represent the ecological communities that existed in Kentucky at the time of European colonization. KSNPC identified calcareous sub-xeric forest and riparian forest as being present in this watershed, with broad areas of each forest type documented along the south-facing hillsides at the entrance of Gunpowder Creek Nature Park. A smaller area of calcareous sub-xeric forest exists further downstream in the vicinity of Camp Michaels. These communities are rare examples of intact communities of this type in Kentucky (KSNPC, 2007).

The Kentucky Division of Water defines Reference Reach Streams as "a representative subpopulation of the least-impacted streams within a bioregion….serving as chemical, physical and biological models from which to determine the degree of impairment…to similar stream systems in each representative bioregion.

Aquatic habitats in the Gunpowder Creek watershed have been altered from their historical state by agricultural, urban and suburban developments. Habitat assessments have been conducted at ten sites in the watershed, beginning as early as 1977 (**Table 2-2**). These assessments were conducted by KDOW using EPA-established protocols and looked at several components of physical habitat within the stream such as faunal substrate, embeddedness, sediment deposition, channel flow status, bank stability, and riparian vegetation zone width. Rankings ranged from "partially supporting" indicating that available habitat can only partially support a diverse and productive ecosystem, to "fully supporting." More recently (2007), portions of Gunpowder Creek were observed to have cobble substrate, variable aquatic habitat types (pools, riffles and runs) and clear water during low flows (LimnoTech 2009:8).

Table 2-2: Aquatic habitat and biological sampling data

STREAM	RIVER MILE	MONITORING					
		HABITAT		MACROINVERTEBRATES		FISH	
		Year(s)	Ranking	Year(s)	Ranking	Year(s)	Ranking
Gunpowder	14.1					1977	Poor
Gunpowder	15.1			1999	Fair		
Gunpowder	16.1	1999, 2004	Partially supporting; Supporting but threatened			1999, 2004	Fair
Gunpowder	18.9	2004	Partially supporting				
Gunpowder	19.5			1995	Poor		
South Fork Gunpowder	1					1977	Very poor
South Fork Gunpowder	1.9	1999, 2004	Partially supporting; Fully supporting			1999, 2004	Poor, Excellent
South Fork Gunpowder	4.3	1999	Partially supporting			1977	Poor
Unnamed Gunpowder trib @ RM 19.4	0.1			1995	Very poor		
Unnamed Gunpowder trib @ RM 18.9	0.1	2004	Partially supporting	1995, 2004	Very poor		

2.2.4 Climate

The United States Department of Energy divides the United States into five climate zones. All of Kentucky, including Boone County, is located in the Mixed-Humid climate zone. The Mixed-Humid zone has moderate weather conditions most of the time but is subject to occasional severe weather events. The temperatures in this area are generally lowest in January and highest in July. Precipitation averages 41.2 inches annually, with the wettest months observed between March and July. The temperature ranges from an average of a high of 86°F in July to a low of 22°F in January. According to the Kentucky Climate Center, both rainfall and temperatures have been trending upward in the Bluegrass Regionsince the 1960s.

2.3 Riparian/Streamside Vegetation

At the time of settlement in the Outer Bluegrass, open savannah woodlands were found on most uplands. Most upland forests have been disturbed repeatedly and current community structure is likely very different from the original forests. Forested areas were mostly oak–hickory. Major species in the oak-hickory cover type includes white, black, and northern red oaks. Other important species include sugar maple, beech, black walnut, and yellow-poplar. Bitternut, pignut, or shagbark hickories may also be present. In the eastern portions of Boone County, cane grew along streams and on bottoms. Distinct vegetation grew in areas underlain by glacial drift. Maple–oak–ash forests grew in the northern portion of the watershed where glacial drift deposits have been removed by erosion. American beech–sugar maple grew on upland glacial till sites on Rossmoyne soils. On well-drained soils over coarse glacial outwash deposits in the north included a few, scattered dry prairie sites. Mixed forests contained white oak, northern red oak, hickory, yellow buckeye, white ash, blue ash, eastern red cedar, black walnut, beech, yellow-poplar, basswood, black cherry, sugar maple, chinquapin oak, bur oak, and black locust. Along river drainages and in gorges: white oak, northern red oak, chinquapin oak, white ash, blue ash, sugar maple, red maple, yellow-poplar, and eastern red cedar (*Plant Life of Kentucky, Ronald Jones, 2005*).

Following European settlement, forests in Boone County were cleared for agriculture, which was the dominant landuse in much of the Gunpowder Creek Watershed until development began to expand in the 1980s and 1990s. In agricultural land that has been abandoned, but has yet to be developed, successional fields of broomsedge and sumac and older successional forests of red cedar and black locust grow. Sycamore, silver maple, boxelder, willow, and American elm are common species along Ohio River bottom lands.

The ever increasing invasion of alien species is recognized as one of the leading threats to biodiversity and imposes enormous costs to agriculture, forestry, fisheries, and other human enterprises, as well as to human health. Bush honeysuckles, Dutch elm disease, multi-flora rose, Callery pear, poison hemlock, and garlic mustard are just a few well known invasive species in Boone County. These exotic species, along with more recent invasions from the emerald ash borer,Asian long-horned beetle, Zebra mussel, Asian carp, and many others pose serious threats to stream ecosystems, local ecology and economy. Invasives can result in loss of native species, habitat destruction, soil degradation, and decreased groundwater levels (Higgins, 2013). In Northern Kentucky, 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).

2.4 Plant and Animal Abundance, Including Rare Species

The Kentucky Department of Fish & Wildlife indicates that over 400 species of wildlife have been observed in Boone County, including 107 species of fish, 25 species of amphibians, 26 species of mammals, and 19 species of reptiles (NatureServe, 2014). According to the Kentucky State Nature Preserve Commission (KSNPC, 2013), of these, several species in the Gunpowder Creek Watershed are of significant concern; **Table 2-3** summarizes these species. Running buffalo clover is a small plant that inhabits streambanks and upland areas; erosion is noted as the biggest threat to this species (KSNPC, 2006). Other factors contributing to population declines are loss of bison populations, nonnative plants, and overall habitat loss (United States Fish and Wildlife Service (USFWS), 2003). The northern leopard frog is an aquatic species that inhabits various habitats including slow flowing areas in creeks and rivers, springs, the nearshore area of lakes, bogs, fens, herbaceous wetlands, riparian areas and grasslands (NatureServe, 2007). Threats to the northern leopard frog include habitat loss, commercial overexploitation, and competition with introduced species. Three of the species identified by KSNPC (Henslow's sparrow, the barn owl, and the redback salamander) are neither aquatic nor dependent on aquatic habitats; however, preservation of the undeveloped lands that serve as their habitats (e.g. grasslands, barns, and woodlands) have clear benefits for the downstream water resources.

Table 2-3: Species of concern in the Gunpowder Creek Watershed

Taxonomic Group	Scientific Name	Common Name	Status	Last	Observed Habitat(s)	Identified Threats
Vascular Plants	Trifolium stoloniferum	Running buffalo clover	Federal - Endangered State - Threatened	2003	Riparian areas, upland areas	Habitat loss, non-native species, bison decline
Breeding Birds	Ammodramus henslowii	Henslow's sparrow	Federal - SOMC State-Special Concern	1950	Grasslands, savannahs	Habitat loss
Breeding Birds	Tyto alba	Barn owl	State - Special Concern	1987	Farms and farm structures	Habitat loss
Amphibians	Plethodon cinereus	Redback salamander	State - Special Concern	1998	Woodlands	Habitat loss, habitat degradation
Amphibians	Rana pipiens	Northern leopard frog	State - Special Concern	1934	Ponds, wetlands, grasslands	Habitat loss, non-native species, commercial overexploitation

2.5 Human Influences and Impacts

Human influences on the Gunpowder Creek Watershed have been significant, especially in the developed headwaters. In order to assess existing land use information and assist in determining potential sources of pollution, the Boone County Planning Commission utilized its detailed Geographic Information System (GIS) database to analyze, collate, and summarize data on a watershed and subwatershed basis. Such data allowed the geospatial characteristics of individual watersheds to be quantitatively described to better understand their geologic, hydrologic, and human impact. Over 40 parameters were summarized for this analysis. A few examples of pertinent GIS parameters include percent impervious surfaces, forest cover, barren land, riparian area, riparian roads, riparian impervious, Kentucky Pollutant Discharge Elimination System (KPDES) outfalls, and National Resource Conservation Service (NRCS) soil types.

2.5.1 History of Human Interaction in the Watershed

Prior to contact with Europeans, Native Americans had occupied Northern Kentucky since at least 9,500 B.C. (see Pollack, 2008). Archaeological evidence suggests that Native Americans began living in and harvesting the natural resources of the Gunpowder Creek Watershed well before the time of Christ. These early inhabitants were semi-nomadic, moving from camp to camp on a seasonal basis, hunting, fishing, and collecting plants from the emerging deciduous forest. They were doubtless attracted to the Gunpowder as a transportation route, but also as a perennial source of water relatively easy to procure dietary protein in the form of fish, fresh water mussels, and other shellfish. Ceremonialism emerged by

1,000 B.C., as did wider trading and more dependence on farming. Camp sites were joined by semi-permanent villages in the lower Gunpowder and burial mounds built by the Adena culture are erected around the county. By A.D. 1,000, permanent villages depended on farming and intensive extraction of natural resources such as freshwater mussels from the larger streams and Ohio River.

The most significant prehistoric sites in the watershed are a series of Fort Ancient villages in the broad bottoms of the lower Gunpowder. This cluster of villages is associated with an even larger grouping of similar sites in the nearby Big Bone and Mud Lick drainages. All are believed to be part of a late prehistoric network of villages scattered along the Ohio River from East Bend to Petersburg. The Fort Ancient people left an impressive archaeological legacy in these villages including house foundations, cemeteries, huge storage and trash pits, tools of bone and stone and perhaps most notably, a range of decorated pottery styles that are hallmarks of the culture (**Figure 2-2**). The Fort Ancient were farmers and favored areas with broad floodplains, such as those in the lower Gunpowder, where they raised corn and other crops. They also heavily exploited freshwater aquatic life. Fort Ancient village sites are rife with bones from virtually every type of freshwater fish (and land animal) in the area, along with vast amounts of mussel shell. Archaeologists believe that the Fort Ancient occupation lasted until about the time of European contact. However, the first Europeans who ventured down the Ohio River in the mid-1700s (most of them in search of Big Bone Lick or other useful natural resources) found no villages and falsely assumed that Kentucky had no aboriginal population.

Figure 2-2: Typical decorated pottery of the Fort Ancient culture

The French lost control of the Ohio Valley following the French & Indian Wars and the first settlers began trickling down the river into the area by the late 1780s (Warminski 2002). Tanners Station (the precursor to Petersburg) was arguably the first, but European footholds were soon established elsewhere, including in North Bend and East Bend Bottoms and at the mouth of Taylors Creek. All of these early settlements had one thing in common: the Ohio River. The river (and its tributaries) was the superhighway of its day and remained the dominant transportation corridor for people and goods until the latter 19th Century. Flatboats, skiffs, and (later) riverboats plied the river and ferries connected it to neighboring towns on the opposite shores.

When Boone County became a county in 1799, less than 200 men owned all of the land and the county's population was just 1,500. Over the next few decades, the population swelled to 10,000. Streams such as Woolper Creek, Big Bone Creek, and Gunpowder Creek were charted to their headwaters and settlement, resource extraction, and land clearing/planting was in full swing. Nineteenth century agricultural activity in Boone County was largely subsistence in nature and most farms were 50-150 acres. Many of the narrow floodplains and terraces along the middle and lower Gunpowder were cleared and cultivated, as were the rolling uplands in the eastern watershed. Farms had diversified production that included row crops, livestock, and tobacco, as well as the occasional mill, distillery, rope walk, or other cottage industry.

Figure 2-3: Stonework and water wheel of "The Grand Water Power"

In 1817, a Virginian named Lewis Crisler settled along Gunpowder Creek about 2 miles south of Burlington (Kreinbrink 2006). Crisler quickly took advantage of the stream's awesome hydraulic power by damming the creek on the upstream side of an oxbow and hewing a channel through the bedrock to create a mill race over to the downstream side of the peninsula – some 1,500 feet away. He used the harvested limestone bedrock to build a huge gristmill and sawmill complex. The mills' massive stonework and ingenious waterworks earned it the local nickname "The Grand Water Power" (**Figure 2-3**). While Crisler's mill was an extreme example of the hydromodifications used in mill construction, other milling operations on the stream also relied on dam construction, stream channel alteration, and excavation of mill ponds and mill races.

The budding agrarian commerce of the 19th Century spawned an extensive network of roads through the Gunpowder Creek Watershed and beyond. The mill became the center of a small farming community and a destination for locals hungry for a way to reduce their grain into meal and harvested timber to lumber. A portion of the 1883 Atlas near the Grand Water Power provides a snapshot of the network (**Figure 2-4**), which provided much greater connectivity through the watershed than today's public road system. The map also shows that homesteads were prevalent, which was the case throughout the watershed. In fact, there are probably fewer people living in the central and lower Gunpowder valley now than in the 1880s. These home sites commonly include stone house foundation and/or chimney remains, wells/cisterns, a root cellar, and perhaps an ice house. While most of the old road beds and mill races are lost to the Gunpowder's maze of meander loops, remnant stone walls that once lined the roads and property lines may yet be found buried in the streamside underbrush. These archaeological ghosts are the most visible evidence of the several thousand years of near-continuous occupation and use of the Gunpowder Creek Watershed.

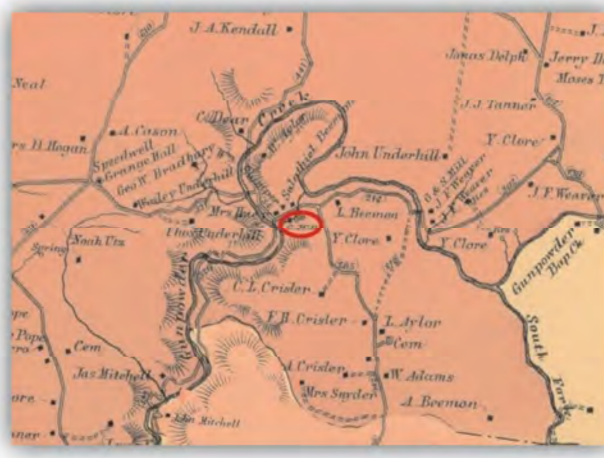

Figure 2-4: Detail of the 1883 Atlas showing a portion of the central Gunpowder valley

2.5.2 Water Use

As previously discussed, humans have been using the water resources in the Gunpowder Creek watershed since prehistoric times. The natural areas of the Lower Gunpowder feature extensive forest resources which foster biological diversity, soil protection, and hillside and stream bank stabilization. This also has positive implications for storm water mitigation and water quality.

Figure 2-5: Kayaking Gunpowder Creek

While some sections of Gunpowder Creek may be impaired for various uses, much of the watershed is already hosting recreation and other uses, including fishing. The stream is identified by the Kentucky Department of Fish and Wildlife Resources as a smallmouth bass stream, based on fish populations (Ross, undated). There are outdoor recreation opportunities throughout the watershed, both on public and private land. The more urbanized Upper Gunpowder includes the Union Pool/park and the City of Florence's South Fork Park, which is the city's most heavily utilized park.

The Lower Gunpowder has several thousand acres of good to high quality forest resources with broad local biological diversity. There are extensive opportunities for outdoor recreation ranging from hiking and nature study to fishing and even whitewater kayaking (**Figures 2-5** and **2-6**). Gunpowder Creek from Camp Ernst Road to Dale Williamson Road has been rated as a class II+ section by American Whitewater and several websites describe this stretch of the river from the viewpoint of boat paddlers. The county's 122-acre Gunpowder Creek Nature Park, located about a mile south of Burlington, has several miles of both gravel and dirt trails and is a popular fishing site. Farther downstream, the county also owns the 125-acre Volpenhein Property, which was acquired with Kentucky Land Heritage Funds due to its excellent quality forest resources along Gunpowder Creek; it is protected by a permanent conservation easement.

The YMCA operates Camp Ernst on 365 acres adjacent to Gunpowder Creek Nature Park. Camp Ernst has served as a summer camp since 1928, offering nature-oriented camps, hiking, and activities for children and families including stream access for fishing and aquatic studies. Camp Ernst's 65-acre lake is used for swimming and is stocked for fishing for campers and the general public. The even larger 675-acre Camp Michaels is owned/operated by the Dan Beard Council and is

Figure 2-6: Fishing on Gunpowder Creek

one of the most actively used Boy Scout camps in the region, with opportunities for nature study, primitive camping, orienteering, and other scout activities.

The Gunpowder Valley south of the Riddles Run confluence and Hathaway Road has broad floodplains and high quality farmland. There is little whitewater potential along this calmer stretch of the creek, which may have Ohio River backwater when the river is up. Trixie's Marina on Beaver Rd. (KY 338) offers access for both motorized and non-motorized boats. Potters Ranch is a 365-acre private retreat facility on the rugged west side of the valley just north of Trixie's. The ranch has a range of accommodations for groups and conferences and offers a range of outdoor activities. The only two active public water supply groundwater wells in the watershed are both located in this downstream portion of the Gunpowder (KDOW, 2007c; KDOW, 2008b).

2.5.3 Land Use

Land cover and land uses have significant implications for runoff and water quality within the watershed, especially relative to the presence of bacteria, nitrogen, and other contaminants. The most recent analysis of current land use in Boone County resides in the Boone County Planning's Commission's Current Land Use GIS data layer, which is based on 2009 aerial photography (see **Figure 2-7 and Table 2-4**). These data segregate uses into classes ranging from Woodlands to Industrial. The following abbreviated descriptions of these classes are taken from the Land Use Element of the 2010 Boone County Comprehensive Plan:

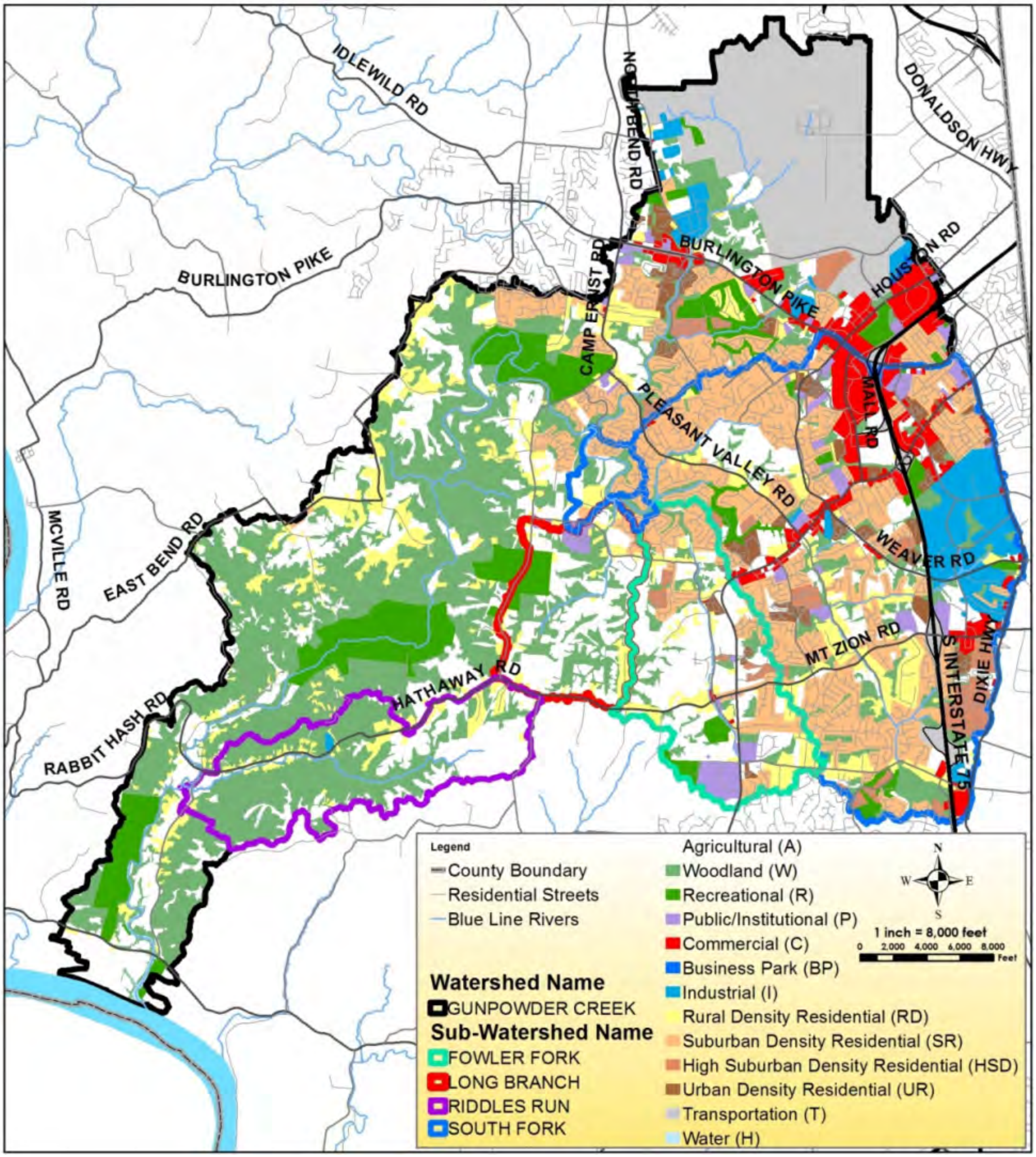

Figure 2-7: Current land use in the Gunpowder Creek Watershed and subwatersheds

Agriculture (A) *Agricultural activity and abandoned, overgrown fields, including vacant/future development areas in urbanized areas;* ***Woodlands (W)*** *Mature wooded areas of greater than one acre;* ***Recreation (R)*** *Outdoor recreation including golf courses, parks, race tracks, private reserves, etc.;* ***Hydrology (H)*** *Water, lakes & rivers;* ***Rural Density Residential (RD)*** *Low density residential up to 1 unit/acre;* ***Suburban Residential (SR)*** *Single family housing of up to 4 units/acre;* ***High Suburban Density Residential (HSD)*** *Single-family and/or attached housing up to 8 units/acre, typified by townhouses and condominiums, but also mobile home parks;* ***Urban Density Residential (UD)*** *Generally condominiums/apartments over 8 units/acre;* ***Transportation (T)*** *Airports, major four lane roads, interstates;* ***Industrial (I)*** *Manufacturing, wholesale, warehousing, distribution, assembly, etc.;* ***Business Park (BP)*** *A mix of office warehouse, research, office, and light industrial uses in a park-*

like, office campus setting.; ***Commercial (C)*** *Retail, corporate and professional office, restaurants, services, etc.;* ***Public/Institutional (P)*** *Government offices, schools, libraries, churches, cemeteries, etc.*

Note that the Agriculture class includes both active and inactive parcels as well as some vacant lots in urban areas. The mapping/analysis methods used by the Planning Commission to create this category makes is impossible to separate the passive from active farmland without conducting a separate analysis. Note also that, despite its definition, the Hydrology land use does not reflect the actual extent of water resources (water, lakes, rivers, wetlands, etc.) in the Gunpowder Creek Watershed. They are expansive, with 143.6 miles of mapped streams and about 570 acres of mapped wetlands throughout the watershed.

Table 2-4: Existing (2009) land use in the Gunpowder Creek Watershed

	Existing Land Use By Subwatershed (acres)						
Land Use Category	**Fowler Fork**	**Long Branch**	**Riddles Run**	**South Fork**	**Rest of Gunpowder**	**LAND USE TOTALS**	**% OF TOTAL**
UNDEVELOPED						**19,257**	**53%**
Agriculture	1,239	839	828	1,144	3,336	7,386	20%
Woodlands	303	540	1,480	998	6,097	9,418	26%
Recreation	98	124	0	245	1,934	2,401	7%
Hydrology	0	0	0	0	52	52	<1%
RESIDENTIAL						**10,192**	**28%**
Rural Density Residential	397	224	279	809	1,462	3,171	9%
Suburban Density Residential	582	53	0	3,639	1,406	5,681	16%
High Suburban Density Residential	80	0	0	440	181	701	2%
Urban Density Residential	40	0	0	413	187	639	2%
DENSE DEVELOPMENT (transportation, industrial, commercial, institutional)						**6,841**	**19%**
Transportation	1	0	0	401	3,244	3,646	10%
Industrial	3	0	11	872	270	1,157	3%
Business Park	0	0	0	0	23	23	<1%
Commercial	12	0	0	834	516	1,362	4%
Public/Institutional	172	58	0	294	130	653	2%
WATERSHED TOTALS	**2,927**	**1,838**	**2,598**	**10,089**	**18,838**	**36,290**	**100%**

The Existing Land Use Map shows that most development is concentrated in the eastern end of the watershed and South Fork Gunpowder subwatershed. The South Fork subwatershed alone has more land devoted to Industrial (872 acres) and Commercial (834 acres) uses than anywhere else in the greater watershed. Well over half of the Suburban Density Residential (3,639 acres) is also found in the South Fork, although Fowler Fork also has an appreciable amount with 582 acres. Rural Density Residential is also prevalent in the South Fork (809 acres), but at a level that is consistent with other parts of the greater watershed. The other land use which has a strong visual presence on the map is the 3,000+ acre area of Transportation at the north end of the map, which represents approximately one third of the total CVG airport acreage in Boone County. The clearance, stormwater, runoff, streambank modification, and sewer activities associated with the development in the eastern watershed appear to correlate strongly with the locations of the segments of the Gunpowder and South Fork Gunpowder on the 303(d) list of impaired streams (see **Table 2-1**).

Other land uses which bear some discussion include the Woodlands, Recreation and Agriculture classes. Woodlands comprise more than one quarter of the land area in the watershed, with the vast majority of total 9,418 acres found in the western end of the valley, including Riddles Run. Fingers of Woodland extend up into Fowlers Fork as well. Most of the other large greenspace areas on the map are Recreation uses (both public & private), which make up about 7% of the total watershed with 2,401 acres. This includes South Fork Park, Gunpowder Creek Nature Park, YMCA Camp Ernst, Central Park, Camp Michaels, and Potters Ranch, among others. One fifth of the watershed is classified as Agriculture land use, with 7,386 acres scattered across much of the watershed and subwatersheds, with the notable exception of the airport property and areas east of I-71/75. Concentrations of Agriculture are found along Richwood Road, Long Branch, Camp Ernst Road and especially East Bend road.

2.5.4 Other Water Disturbances

This section refers to artificial disturbances and stream alteration such as channelization, artificial armoring, or piping/burial. There are certainly examples of this within the watershed (**Figure 2-8**). This is especially true in the eastern portion of the watershed where development has occurred.

2.5.5 Land Disturbances

According to the Watershed Planning Guidebook for Kentucky Communities, this section deals primarily with mining operations. This activity does not affect the Gunpowder Creek Watershed. Activities related to development, such as grading and land clearing, are discussed in other sections.

Figure 2-8: Artificial channel armoring such as concrete (Utterback Creek off Industrial Road) and tractor tires (South Fork of Gunpowder along Gunpowder Road near Sunnybrook Drive) reduce habitat quality and stream integrity

2.5.6 Hazardous Materials

Hazardous Materials are substances which, because of their properties, pose a potential risk to health, property or the environment. 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.

According to BCEM, the top hazardous materials threats within the Gunpowder Creek Watershed are related to: (1) transportation of materials by truck along Interstate 75 and (to a lesser extent) the Norfolk-Southern Railroad, (2) businesses using/storing materials onsite in the Florence Industrial Park, (3) and potential leaks from the Mid-Valley Crude Oil Pipeline. One recent analysis showed that all USDOT recognized classes of hazardous materials are regularly trucked along Interstate 75, with Flammable Liquids, Flammable Gases, and Corrosive Liquids being the most common (NKEPC, 2011). The Norfolk-Southern RR runs along the eastern edge of the Gunpowder Creek Watershed, with spurs extending into the Florence Industrial Park. The top 10 hazardous materials transported along the rail line in 2012 included Molten Sulfer (4,600 cars), Phosphoric Acid (2,300 cars) and Sodium Hydroxide (1,300 cars) (BCEM, 2014). The BCEM considers use and storage of hazardous materials in the Florence Industrial Park to be less of a threat than transport of materials. While on-site storage of fuels (gasoline diesel, etc.) is common, some businesses do maintain inventories of potentially dangerous chemicals such as ammonia, ammonium hydroxide, or corrosive liquids (CAMEO, 2014).

The Mid-Valley Pipeline transports upwards of 200,000 barrels/day of sweet crude oil from Texas to Lima, Ohio, and was completed through Boone County in the 1950s (BCEM, 2014). The pipeline passes north/south through the heart of the Gunpowder Creek Watershed, roughly paralleling Camp Ernst Road on its way past the Mid-Valley Storage Facility on Limaburg Road on the western edge of the CVG airport. The pipeline is an ongoing potential source of crude oil spills, largely due to its age (60+ years). Indeed, in 2005, a break in the line near Carrolton sent 260,000 gallons of crude into the Kentucky River. The last problem in Boone County was in 2008, when an SD1 construction crew ruptured the line in the creek near Camp Ernst Road, resulting in a spill of 115,000 gallons. An early 2014 leak of 10,000 gallons in Colerain Township, Hamilton County, Ohio, reinforces the potential threat posed by the Mid-Valley Pipeline.

2.6 Demographics and Social Issues

From its establishment in 1799 until the mid-1950s, Boone County's population rarely rose above 15,000 (see **Figure 2-9**). From 1960 to 2010, the population increased from 21,940 to 118,811 people (BCPC 2010). The decade from 2000 to 2010 saw the most rapid increase in Boone County's history (32,830 people in 10 years). That 38.2% growth rate was one of the two fastest rates of growth in Kentucky. Much of this population growth occurred in the Gunpowder Creek watershed, especially in the eastern portions of the watershed around Florence and Union, and the Fowlers Fork and South Fork subwatersheds. Over the next 25 years, these areas are expected to experience continued population growth, with the growth spreading west into the Long Branch subwatershed and beyond. In contrast, population density in the western half of the county is not expected to grow substantially in coming years.

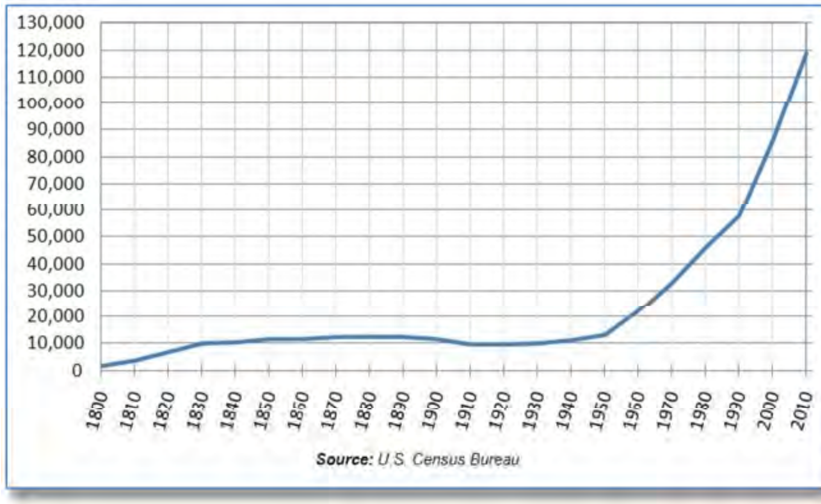

Figure 2-6: Boone County population: 1800 to 2010

The 2010 Boone County Comprehensive Plan further anticipates that in the next 25 years, Boone County will be defined by a decreasing proportion of young and middle aged persons, while the median age will continue to grow older. The percentage of Boone County's married couple households is anticipated to decrease and the county's population will continue to become more diverse in terms of race and ethnicity. At present, the county's level of educational attainment (%'s of both high school and college graduates) is higher than the state average, a trend that is also expected to continue. Boone County's population is predominantly white although the percentage of non-whites has risen from 1% in 1980 to 6.6% in 2010, roughly divided between Asian, African-Americans, and Hispanics (BCPC, 2010: 19). Regarding educational attainment, the percentage of high school graduates in Boone County was 90.5 in 2010, well above the statewide average of 81.9. The percentage of Boone Countians with at least a bachelor's degree (31.9%) was also higher than the Kentucky average of 20.5%.

In summary, Boone County's urbanized and suburbanized areas are expected to grow to the west over the next 25 years. Its population base is maturing and more affluent than that of neighboring counties and the state, trends which are also expected to continue (BCPC, 2010:22). These trends will lead to additional development of land and generation of vehicular traffic in the eastern Gunpowder Creek Watershed and its subwatersheds.

2.7 Team Observations

The Gunpowder Creek Watershed is rich in history as well as cultural and natural resources, including some of the best water resources in Boone County. The demographics and land uses have evolved during the last 50 years, and in particular the last 15 years, as population has increased and land has been rapidly converted from undeveloped to developed. These changes have brought many benefits to the county, such as increased property values; however, they have also resulted in impacts to the quality of our water resources. Sampling by KDOW has shown that several reaches of waterways are impaired and not meeting their designated uses.

It seems clear that if practices do not evolve to become more protective of water resources, Gunpowder Creek will continue to become further degraded as the rapid pace of development continues. This is one of the primary reasons why the GCWI is pursuing a watershed plan. We understood a need to collect more data to better pinpoint the sources of the water pollution. In doing so, we want to identify the most cost-effective ways to prevent future problems as the County continues to grow, as well as reverse the damages of the past. It is our hope that in so doing, Boone County can grow in a more sustainable way and provide high quality natural resources and quality of life to its citizens.

2.8 Interim Conclusions

Gunpowder Creek is impaired; however, there is reason for hope. Point source pollution, such as sewer overflows, may have been a big problem in the past but partners such as SD1 are investing large amounts of money to mitigate those pollutant sources. Impacts from stormwater runoff and nonpoint source pollution have also become more transparent as project partners such as SD1, KDOW, and Licking River Watershed Watch have conducted regional monitoring programs. As we better understand the magnitudes and sources of pollution we are confident that our expansive team of partner agencies, a well-informed and engaged public, and public officials embrace these findings and support the full implementation of this plan.

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CHAPTER 3

Learning More and Monitoring

Gunpowder Creek Watershed Plan

Prepared by the

Gunpowder Creek Watershed Initiative

December 2014

Chapter 3: Learning More and Monitoring

The two major goals of watershed planning are to protect good water quality and improve poor water quality, and therefore, a comprehensive monitoring program is necessary to understand the existing conditions of the stream network throughout the watershed. The monitoring program assists in determining the areas of the watershed to be protected and the areas of the watershed that are most impaired. Monitoring is also important because it provides data to better understand the pollutants of concern in the impaired regions of the watershed, which serves as the foundation to identify pollutant sources and develop implementation projects. The Gunpowder Creek Watershed Initiative (GCWI) monitoring program was designed to assess multiple measures of stream health using flow monitoring, hydrogeomorphic surveys, habitat assessments, water quality samples, macroinvertebrate assessments, and land use analysis. This is one of the many strengths of the dataset. In its breadth and depth, the GCWI Phase 1 and Phase 2 monitoring program includes quite a bit of data across several dimensions for a watershed plan. GCWI collected enough data in enough categories to build a weight of evidence towards the problems in the watershed and the scale of these problems. The data provides good information to understand the pollutants of concern in the watershed. The following section provides some detail regarding the GCWI Phase 1 and Phase 2 monitoring programs. Reference the 2011 Quality Assurance Project Plan for Gunpowder Creek Watershed Plan (QAPP, **Appendix 3-A**) for additional information regarding sampling parameters, methods, and frequencies.

3.1 Determining Monitoring Needs

While some water quality data already existed in the Gunpowder Watershed prior to the GCWI monitoring program, additional data were needed to fill in the gaps and provide more recent information regarding the condition of the Gunpowder stream network. The Sanitation District No. 1 of Northern Kentucky (SD1), a member agency of the GCWI steering committee, had conducted water quality monitoring at five sites in the Gunpowder Creek watershed since 2006 in order to establish a baseline condition. This SD1 data was collected using standard procedures and quality assurance measures that are consistent with those outlined in the QAPP. Given that hydromodification due to urban development is a major concern in the watershed, SD1 had also undertaken over three years of hydrogeomorphic monitoring at several sites in the watershed between 2008 and 2010.

While this existing data provided a good foundation for the monitoring program, additional data was needed to fill in the monitoring data gaps. Therefore, the GCWI monitoring program conducted water chemistry, habitat, and biological sampling (**Figure 3-1**) at six key sites in 2011 and 2012. In addition to SD1's ongoing hydrogeomorphic monitoring, GCWI surveyed four additional sites. **Table 3-1** summarizes the existing (pre-2010) and selected (2011-2012) monitoring sites. Reference **Figure 3-2** for a map illustrating the locations of these monitoring sites.

Table 3-1: Summary of existing and selected monitoring sites for Gunpowder Creek sampling

Monitoring Sites[1]	Water Chemistry		Biological		Hydrogeomorphic	
	Existing	Selected	Existing	Selected	Existing	Selected
GPC 4.6	SD1		SD1		SD1	
GPC 7.5		GCWI		GCWI		GCWI
GPC 14.7	SD1		SD1		SD1	
GPC 17.9	SD1		SD1		SD1	SD1
GPC 17.1-UNT 0.1		GCWI		GCWI	SD1	SD1
SFG 2.6	SD1		SD1		SD1	
SFG 5.3-DS	SD1				SD1	SD1
SFG 5.3-US			SD1		SD1	SD1
SFG 5.3-UNT 0.3		GCWI		GCWI	SD1	SD1
FWF 0.8		GCWI		GCWI		GCWI
LOB 0.5		GCWI		GCWI		GCWI
RDR 1.1		GCWI		GCWI		GCWI

[1]Monitoring sites were selected along the main stem of the Gunpowder Creek as well as targeted locations throughout the subwatersheds. The naming convention of each monitoring 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 GPC 4.6 is located on Gunpowder Creek about 4.6 stream miles upstream of the confluence with the Ohio River. Similarly, site FWF 0.8 is on the Fowlers Fork and is located approximately 0.8 stream miles upstream of the confluence with the Gunpowder Creek main stem. (GPC – Gunpowder Creek, SFG – South Fork Gunpowder, FWF – Fowlers Fork, LOB – Long Branch, and RDR – Riddles Run).

3.2 Obtaining Additional Data Through Monitoring

Proper selection of monitoring locations is important because analysis of these monitoring data provide a better understanding of the issues facing each subwatershed and assist in identifying appropriate management strategies to mitigate nonpoint source pollution in specific subwatersheds. Although SD1's existing data gave an overview of the health of the watershed, per the Guidebook and in consultation with KDOW, the GCWI filled in the data gaps by selecting monitoring locations at the mouth of all major subwatersheds. We located our sampling sites by beginning at the mouth of the Gunpowder Creek, and systematically progressed upstream, with samples being collected just below the mouths of significant tributaries, as well as near the mouth of major subwatersheds, upstream of the confluence with Gunpowder Creek (Table 3-1, Figure 3-2). Analysis of these data served as the basis to the water quality data analysis presented in Chapter 4. GCWI partnered with SD1, Thomas More College, and the LRWW to conduct the water quality monitoring in 2011 and 2012 at six sites strategically selected throughout the Gunpowder Creek Watershed. These monitoring sites include one site along the main stem (GPC 7.5 at Camp Michaels), one in the headwater tributaries of the main stem (GPC 17.1-UNT 0.1 at Oakbrook Park), one in the headwaters of the South Fork Gunpowder Creek (SFG 5.3-UNT 0.3 at Sunnybrook) and one in each of the large tributaries south of the

Figure 3-1- Conducting biological sampling in Gunpowder Creek main stem, Riddles Run, Long Branch, and Fowlers Fork (RDR 1.1, LOB 0.5, and FWF 0.8, respectively). Additionally, as part of SD1's hydromodification monitoring program, four rounds of hydrogeomorphic survey data, which were collected between 2008 and 2012, were provided for five of its hydrogeomorphic monitoring sites (SFG 5.3-DS, SFG 5.3-US, SFG 5.3-UNT 0.3, GPC 17.9 and GPC 17.1-UNT 0.1). This SD1 hydrogeomorphic data was supplemented with hydrogeomorphic survey data collected in 2011 and 2012 by the Boone County Conservation District (BCCD) at the remaining water quality monitoring sites (GPC 7.5, RDR 1.1, LOB 0.5, and FWF 0.8). Water quality sampling sites and sites with 2011 and 2012 hydrogeomorphic survey data are presented in **Figure 3-2**.

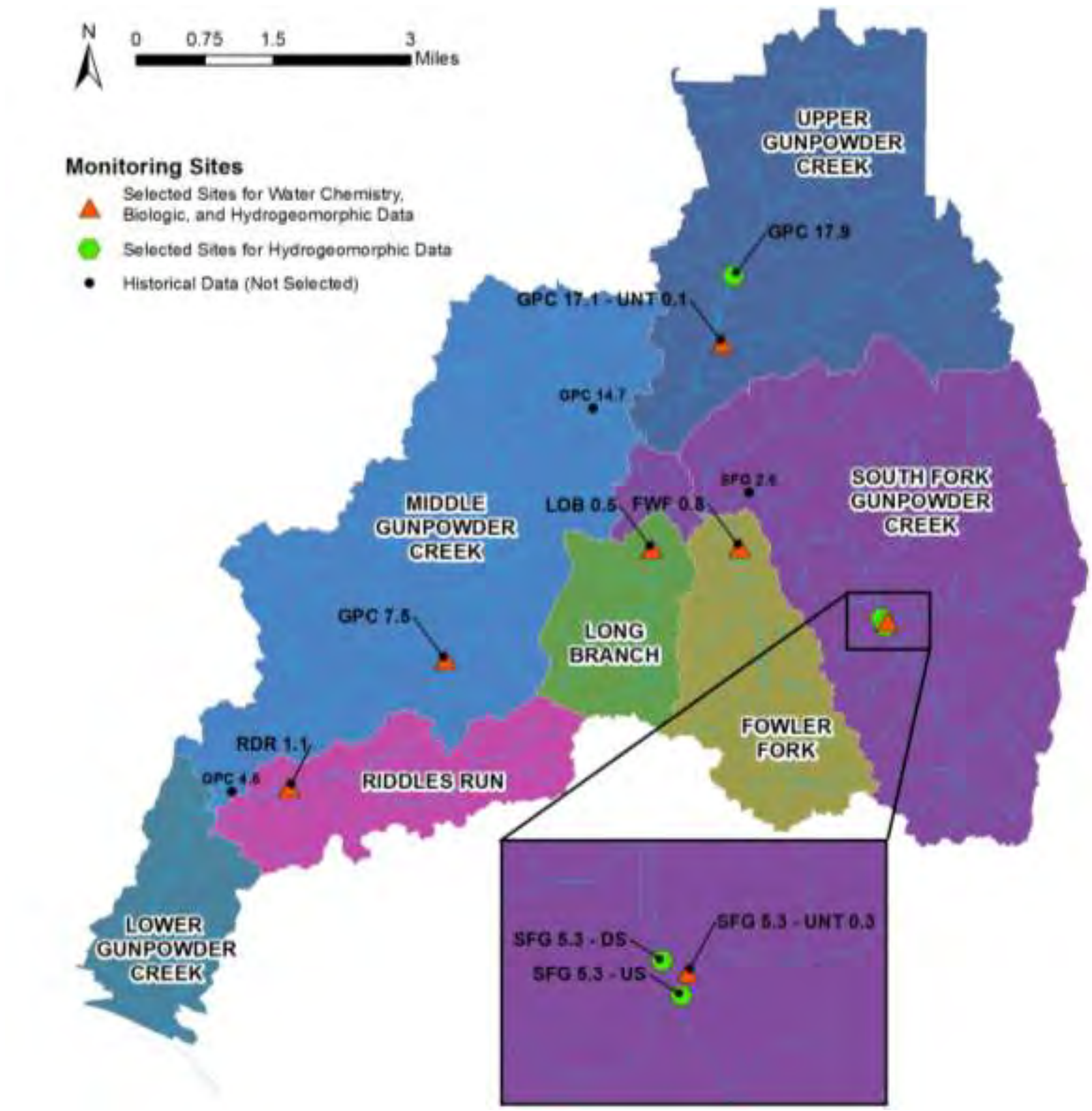

Figure 3-2: BCCD and SD1 Gunpowder Creek monitoring sites utilized in the water quality data analysis
Note: Sites GPC 4.6, GPC 7.5, GPC 14.7, and SFG 2.6 are historic SD1 water quality monitoring locations.

3.2.1 Monitoring and Data Analysis for the Gunpowder Creek Watershed

The GCWI deployed a phased monitoring model to the watershed. Phase 1 monitoring occurred during 2011 followed by Phase 2 monitoring at the same sampling locations in 2012. In accordance with the KDOW approved QAPP and project budget, GCWI did not add additional sampling locations for Phase 2 monitoring in 2012. The GCWI monitoring program and budget was developed prior to the release of the *Watershed Planning Guidebook for Kentucky Communities* (KDOW, 2010). Monitoring sites were strategically selected within each subwatershed to obtain a better understanding of the issues facing each subwatershed and assist in identifying appropriate management strategies to mitigate nonpoint source pollution. The monitoring program included water quality sampling, hydrogeomorphic surveys, habitat assessments, and biological assessments, and the following sections provide a brief summary of the GCWI monitoring efforts. As previously mentioned, please reference the 2011 Quality Assurance Project Plan for Gunpowder Creek Watershed Plan (QAPP) for additional information regarding sampling parameters, methods, and frequencies.

Water Quality

Water chemistry sampling included both dry and wet-weather sampling during the recreational contact season and was performed by students under the supervision of Dr. Chris Lorentz of Thomas More College, with field management by Mark Jacobs of BCCD. They followed procedures outlined in the QAPP and their sampling frequencies and parameters were guided by the grant budget. Monitoring data included several field measurements taken at the site as well as several parameters measured in the laboratory (**Table 3-2**).

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

<table>
<tr><th>Field Measurements</th><th>Parameters Measured in the Laboratory</th></tr>
<tr><td>Temperature</td><td>Bacteria (E.coli)</td></tr>
<tr><td>pH</td><td>Sediment (Total Suspended Solids (TSS))</td></tr>
<tr><td>Dissolved Oxygen</td><td rowspan="3">Nutrients (Total Phosphorus (TP), Total Kjeldahl Nitrogen (TKN), Phosphate (P), Nitrate-Nitrite (NN), Ammonia as Nitrogen)</td></tr>
<tr><td>Specific Conductance</td></tr>
<tr><td>Turbidity</td></tr>
<tr><td>Stream Discharge</td><td>Carbonaceous Biochemical Oxygen Demand (CBOD)</td></tr>
<tr><td>Percent Saturation</td><td></td></tr>
</table>

Physical Monitoring – Hydrogeomorphic Surveys

Hydrogeomorphic monitoring was designed to monitor channel instability (e.g. bank and bed erosion) in response to watershed urbanization (i.e. 'hydromodification'). The hydrogeomorphic component of the monitoring effort focused on measuring the physical changes in stream channels, as the altered flow regime associated with conventional urban development leads to flashier and larger flows, excessive stream erosion, and overall channel enlargement/instability that can cause water quality impairments (e.g. high TSS and sedimentation/siltation) and have adverse effects on aquatic biota such as fish and macroinvertebrates. Accelerated bank erosion, channel widening, and enlargement pose risks to adjacent public infrastructure (e.g., sewers, roads, and bridges) and private property mechanically damaging, undermining and elevating flood risks.

Beginning in 2011, BCCD and SD1 collected detailed hydrogeomorphic survey data according to the industry-standard methods outlined in the QAPP (including cross sections, profiles, and pebble counts) at four sites according to a standard operating procedure (SD1, 2009) based on industry standard techniques (Bunte and Abt, 2001a; Bunte and Abt, 2001b; Harrelson *et al.*, 1994; Potyondy and Bunte, 2002). Included as part of SD1's hydromodification monitoring program, SD1 has collected several years of hydrogeomorphic survey data at five additional sites for a total of nine unique hydrogeomorphic sites throughout the Gunpowder Creek Watershed. All nine sites have at least two rounds of hydrogeomorphic survey data, with each survey round separated by approximately one year. All survey data have been systematically processed and are presented in **Appendix 4-A**.

Physical Monitoring – Habitat Assessments

Monitoring also included habitat assessments during one sample event during Phase 1 monitoring in 2011 and then another during Phase 2 monitoring in 2012 according to standard KDOW methods as specified in the QAPP (e.g. Barbour *et al*., 1999; KDOW, 2001). The assessments focused on the quality of in-stream and riparian habitat and included habitat parameters such as 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, riparian vegetative zones. All the parameters were then assessed to develop a total habitat score for the site's overall habitat condition, which provided a summary for the general habitat condition that is supporting or degrading the structure and function of the aquatic community in the stream. The qualitative habitat assessments served to complement the quantitative physical monitoring described above in Section 3.2.1.b by capturing important aspects of the channel habitat that the physical surveys did not, for example riparian vegetation condition, which can play an important role in bank stability.

Biological Assessments

Biological monitoring included benthic macroinvertebrate sampling and some fish sampling assessments during one sample event during Phase 1 monitoring in 2011 and then another during Phase 2 monitoring in 2012. A seasonal approach was utilized to capture the diversity of the biological community with priority placed on the spring sampling, as the majority of the streams sampled were "headwater" streams, for which the sampling index period is March 1 through May 31. 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. Macroinvertebrate communities are very sensitive to changes in habitat and water quality; and therefore, benthic macroinvertebrate sampling is useful for detecting even small alterations to stream health. Benthic macroinvertebrate samples were sorted, identified, and quantified to determine standard metrics. Standard metrics measured include:

- Genus Taxa Richness
- Genus Ephemeroptera
- Modified HBI
- Modified %EPT abundance
- %Ephemeroptera
- %Chironomidae+%Oligochaeta
- %Primary Clingers

These metrics were all assessed to develop an average Macroinvertebrate Biotic Index (MBI) score for the overall site biological condition according to KDOW's regionally-specific index (Pond *et al*., 2003). The MBI is a simplified index that is based on a multi-metric approach to measure biotic integrity. Some important elements of the MBI include the abundance of macroinvertebrates present as well as the species richness, as measured by the number of distinct taxa found in the sample. The laboratory conducted a 300 pick macroinvertebrate sample at all sites, with the exception of LOB 0.5 (reference **Figure 3.2** for the location of LOB 0.5), which required a full pick due to a sample size of less than 300 organisms due to highly impaired habitat and water quality. This methodology was included in the QAPP and discussed with KDOW.

3.2.2 Phase 1 Monitoring

Scale

According to the *Watershed Planning Guidebook for Kentucky Communities* (KDOW, 2010), Phase 1 monitoring typically involves a broad scale across a watershed that measures approximately 50 mi^2. As discussed above, the GCWI monitoring program took a more detailed approach for Phase 1 monitoring because we already had data at the 50 mi^2 watershed scale. Therefore, Phase 1 monitoring occurred at the mouth of all subwatersheds, throughout the main branch, and on some unnamed tributaries of Gunpowder Creek. With the exception of GPC 7.5 (43.5 mi^2), all other monitoring locations were less than 10 mi^2. The drainage area to all other monitoring locations ranges from 2.2 to 6.9 mi^2, with an average drainage area of 4.2 mi^2. Sampling at the mouth of the subwatersheds was considered to be representative of the pollution sources within the subwatershed and no additional sampling sites were necessary.

Parameters

The GCWI monitoring program measured all required water quality parameters as well as hydrogeomorphic surveys, habitat assessments, and biological assessments. A summary of each of the monitoring efforts is included above in section 3.2.1. Reference the QAPP (**Appendix 3-A**) for detailed information regarding the monitoring procedures.

Methods

All water quality sampling methods were in accordance with the KDOW Standard Operating Procedures (SOPs). Habitat and biological assessments followed the *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers* (Barbour *et al.*, 1999) and the biological assessments also followed the *Methods for Sampling Benthic Macroinvertebrate Communities in Wadeable Waters* (KDOW, 2009). Reference the QAPP for detailed information regarding the monitoring procedures.

Frequency

In accordance with the KDOW-approved QAPP, water quality monitoring data was conducted throughout the months of June through August. Water quality monitoring included 6 sampling events in 2011 as well as 2 additional *E.coli* samples. Although the *Watershed Planning Guidebook for Kentucky Communities* (KDOW, 2010), suggests collecting *E.coli*, nutrients, and TSS monthly for a 12 month period, GCWI preferred to focus its resources on the primary recreation season when pollutant loads could be most relevant to the general public and collect two years of data at the same sites. This turned out to be a valuable decision because the two years had varying rainfall – capturing a gradient of pollutant loads based on variant precipitation. Habitat, biological, and hydrogeomorphic assessments were performed once per year. Reference the QAPP for detailed information regarding the monitoring procedures.

3.2.3 Phase 2 Monitoring

As previously mentioned, GCWI did not add additional sampling locations for Phase 2 monitoring in 2012. This was within project budgets and in agreement with the KDOW-approved QAPP, which again, was developed before the *Watershed Planning Guidebook for Kentucky Communities* (KDOW, 2010) was released. With a set monitoring budget, GCWI did not have the additional funds and resources available to add more sites upstream of the Phase 1 sites. Therefore, the Phase 2 monitoring program involved resampling all Phase 1 monitoring locations. Sampling near the mouth of each subwatershed was considered to be representative of the pollution sources within the subwatershed and no additional sampling sites were necessary. Reference **Appendix 3-B** for all of the raw data collected as part of the Phase 2 monitoring program.

In comparing the 2011 Phase 1 monitoring results with the 2012 Phase 2 monitoring results, many water quality indicators drastically changed due to the substantial difference in rainfall that occurred during each monitoring effort. Samples collected during Phase 1 in 2011, a record rainfall year with over 70 inches of rain (NCDC, 2012), provided insight regarding the types of pollutants washed off the land during runoff events. In contrast, samples collected in 2012, a much drier year, indicated the types of pollutants released directly into the stream without the influence of rainfall.

Due to the nature of this phased monitoring program, the data analysis presented in Chapter 4 discusses Phase 1 and Phase 2 monitoring in an integrated fashion. All data is analyzed and presented in the Phase 1 monitoring section.

Scale

Phase 2 monitoring occurred at the same scale as Phase 1 monitoring because Phase 2 monitoring was performed at the same location as Phase 1 monitoring. Sampling occurred near the mouth of each subwatershed to provide insight on potential pollution sources. With the exception of GPC 7.5 (43.5 mi^2), all monitoring locations were less than 10 mi^2 and ranged 2.2 to 6.9 mi^2, with an average drainage area of 4.2 mi^2.

Parameters

The GCWI monitoring program measured all required water quality parameters as well as hydrogeomorphic surveys, habitat assessments, and biological assessments. A summary of each of the monitoring efforts is included above in section 3.2.1. Reference the QAPP for detailed information regarding the monitoring procedures.

Methods

All water quality sampling methods were in accordance with the KDOW Standard Operating Procedures (SOPs). Habitat and biological assessments followed the *Rapid Bioassessment Prototcols for Use in Streams and Wadeable Rivers* (Barbour *et al*., 1999) and the biological assessments also followed the

Methods for Sampling Benthic Macroinvertebrate Communities in Wadeable Waters (KDOW, 2009). Reference the QAPP for detailed information regarding the monitoring procedures.

Frequency

In accordance with the KDOW approved QAPP and within project budgets, water quality monitoring data was conducted throughout the months of June through August. With the exception of *E.coli,* water quality monitoring involved 5 sampling events in 2012, as KDOW approved for one sampling event in 2012 to be omitted considering there was too little flow in the streams to collect samples. Similar to Phase 1 sampling, the GCWI collected 2 additional *E.coli* samples in 2012. Although the *Watershed Planning Guidebook for Kentucky Communities* (KDOW, 2010), suggests collecting *E.coli*, nutrients, and TSS monthly for a 12 month period, GCWI preferred to focus its resources on the primary recreation season when pollutant loads could be most relevant to the general public and collect two years of data at the same sites. This turned out to be a valuable decision because the two years had varying rainfall – capturing a gradient of pollutant loads based on variant precipitation. Habitat, biological, and hydrogeomorphic assessments were performed once per year. Reference the QAPP for detailed information regarding the monitoring procedures.

3.2.4 Other Monitoring Options & Data Used in the Analysis

In addition to the aforementioned monitoring data, the water quality analysis utilized several sources of supporting information including land use data, rainfall data, flow gauge data, SD1's Stream Condition Indices, SD1's Stability Indices, and KDOW's Gunpowder Creek Watershed Monitoring Reports.

Land Use Data

As previously discussed in Chapter 2, the Boone County Planning Commission utilized its detailed Geographic Information System (GIS) database to analyze, collate, and summarize data on a watershed and subwatershed basis. Maps and landuse characterizations of each subwatershed are provided in **Appendix 3-C**. An example of the maps and land use characteristics for the Fowlers Fork subwatershed is included on the previous page (**Figure 3-3**). **Figure 3-4** on the next page presents a land use map for the watershed. Notice the large portions of commercial/developed land throughout the headwaters on the eastern side of the watershed and the predominantly agricultural/rural land on the western side of the watershed. Such land cover observations assist in explaining the types of pollutant issues in various portions of the watershed.

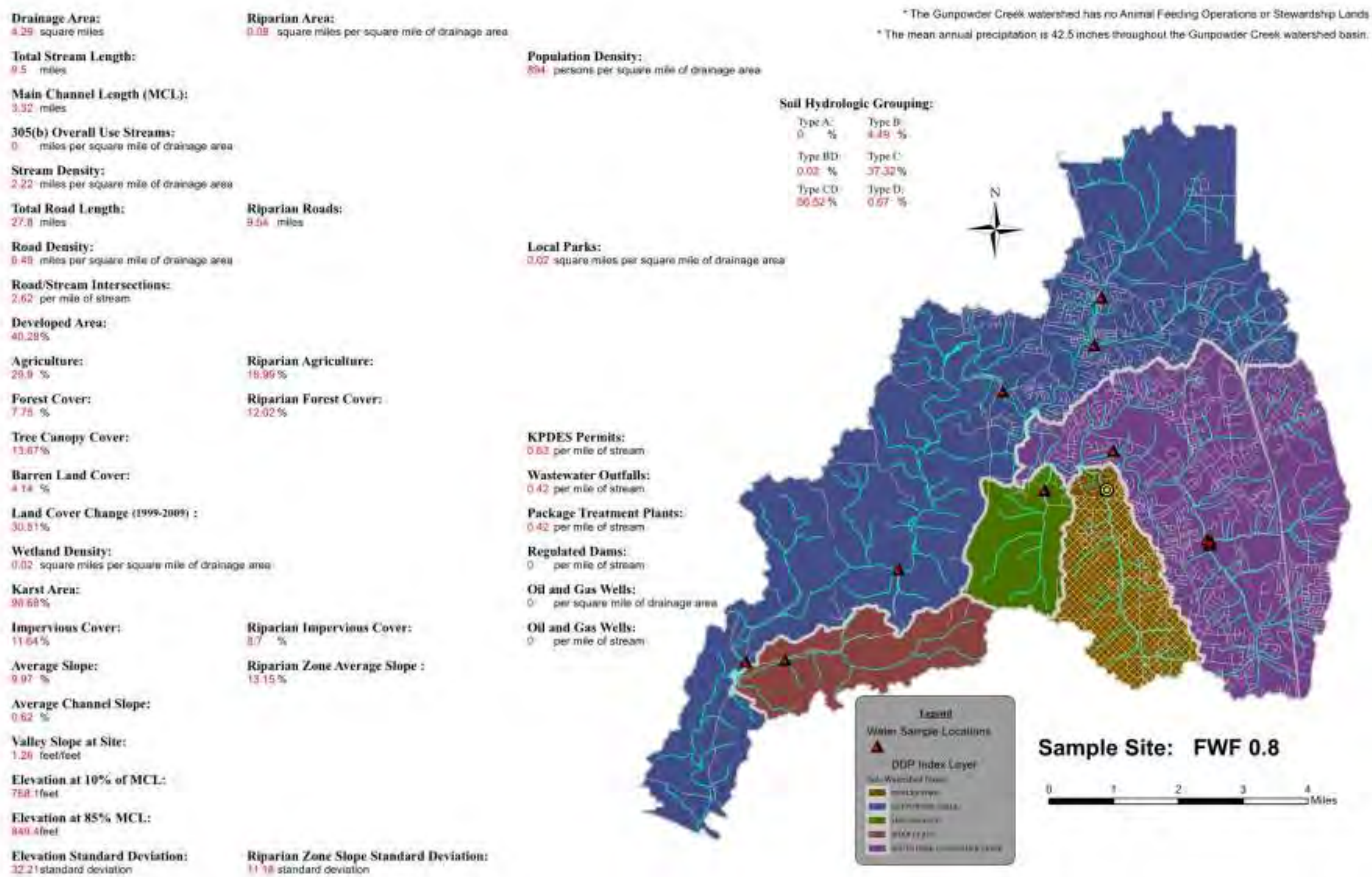

Figure 3-3- Watershed characteristics of the Fowlers Fork Subwatershed

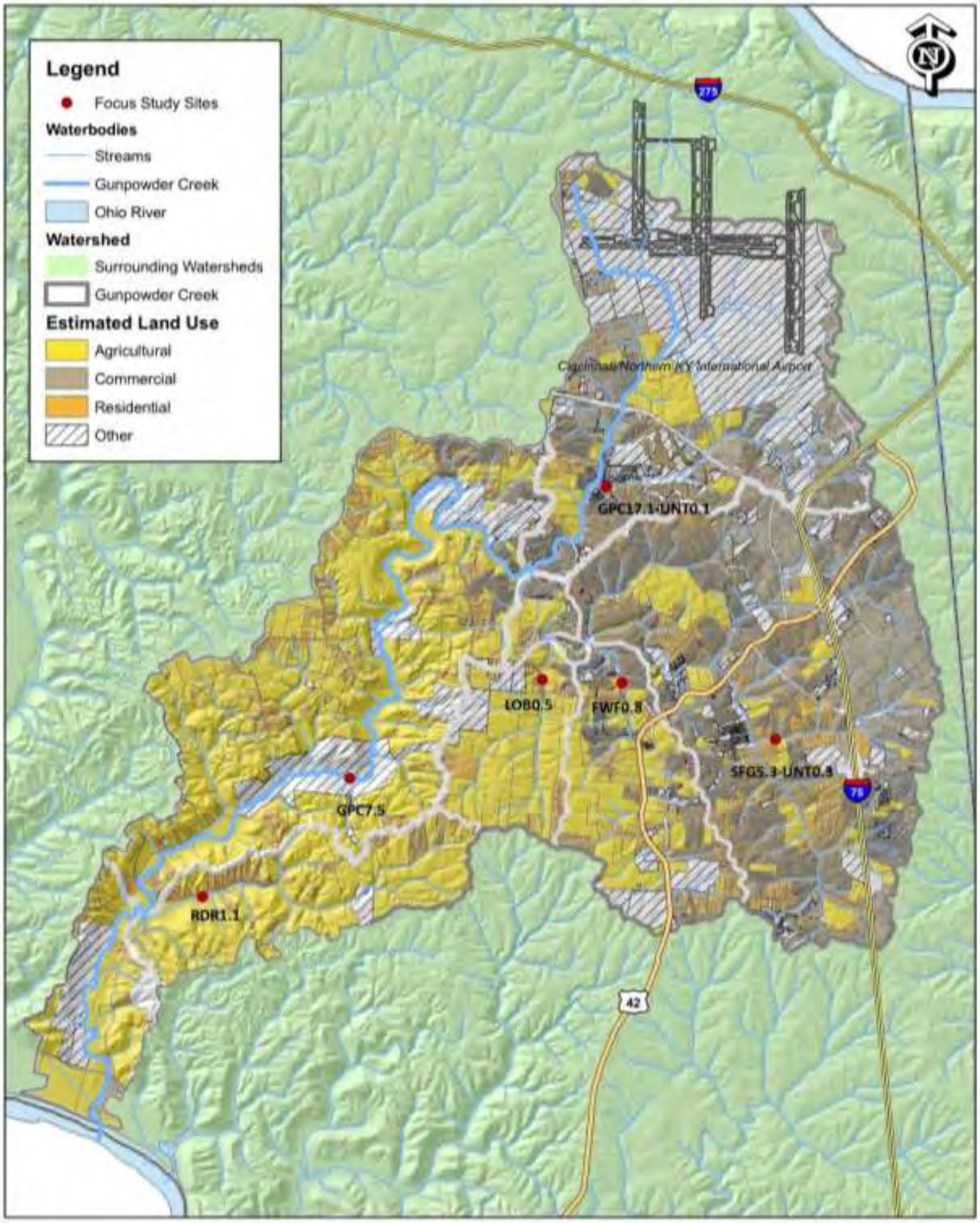

Figure 3-4 – Gunpowder Creek estimated land use (SD1)

Rainfall Data

In addition to land use data, rainfall plays a pertinent role in the hydrology of a watershed. Rainfall data collected at the Cincinnati/Northern Kentucky International Airport (CVG), which is located within the northeastern portion of the Gunpowder Creek Watershed, was analyzed to classify water quality sampling events as wet weather versus dry weather. The data analyzed was collected during the monitoring period. Daily rainfall totals within seven days prior to each sampling event were evaluated to determine sample classification. Of the 11 sampling dates, three events experienced over 0.7 inches of rainfall within 48 hours of the sample date and were classified as "wet." The other eight sampling dates were relatively dry; however, three events were extremely dry with less than 0.01 inches of rain occurring within the 7-day period before the sampling event. Such events were classified as "dry7" for this analysis, with all other sampling classified as "dry." Additional *E.coli* sampling (16 sampling dates total) included two more "dry7" sampling events and three more standard "dry" sampling events. All rainfall data summarized for this analysis is included in **Table 3-3**.

Table 3-3: Rainfall data summarized for each sample date

		TOTAL RAINFALL (in)			
Sample date	Wet vs Dry vs Dry7	On sample date	Day prior to sample date	Two days prior to sample date	Total 7 days prior to sample date
06/20/11	Wet	0.55	0.37	0.33	1.82
06/24/11	Wet	0.0001	0.36	0.56	2.75
07/05/11	Dry	0	0.06	0	0.11
07/07/11	Dry	0	0	0	0.06
07/13/11	Dry	0	0	0	1.17
07/29/11	Dry	0	0	0	0.04
08/04/11	Wet	0	0.73	0	1.66
08/18/11	Dry	0.0001	0	0	0.11
06/22/12	Dry	0	0	0	0.62
06/26/12	Dry7	0	0	0	0.00
06/28/12	Dry7	0	0	0	0.00
07/05/12	Dry	0	0	0	0.30
07/10/12	Dry7	0	0.0001	0.01	0.01
07/11/12	Dry7	0	0	0.0001	0.01
07/23/12	Dry	0	0	0	0.31
08/07/12	Dry7	0	0	0.01	0.01

Flow Monitoring

Flow data from U.S. Geological Survey (USGS) Gauge No. 03277075 for Gunpowder Creek at Camp Ernst Road near Union, Kentucky, was summarized to use in the water quality data analysis. Flow measurements were also taken during both the 2011 and 2012 water quality monitoring efforts according to procedures outlined in the QAPP. Each 2011 sampling event included documentation of velocities, depths, and reference distances from the shore. The flow was then calculated using the full discharge panel method 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 constant interval determines a width of each panel measured. The flow for each panel is then calculated by multiplying the width times the depth and the velocity measurements and then all of the flow measurements are summed to obtain a flow reading for that site.

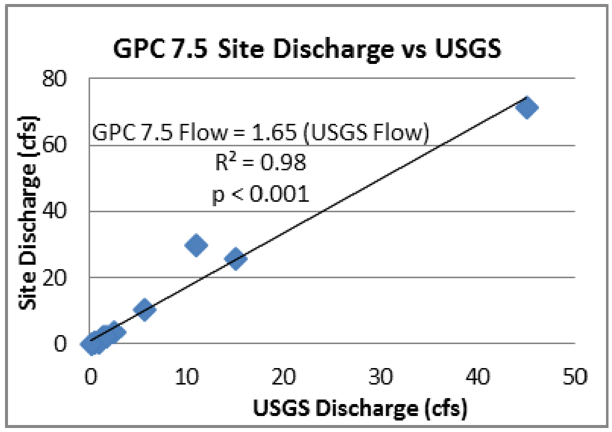

Figure 3-5-Example site discharge vs. USGS discharge regression Line

Given the extremely dry conditions of 2012, flow monitoring was challenging due to limited flow depths in the streams during sampling events, with some sampling events having no measurable flow, some having too low of water depths to obtain a velocity reading, and others having enough depth to obtain only one velocity and one depth reading at the deepest portion of the stream but not enough water to take measurements for the full discharge panel method. For the sampling events with only one velocity and one depth measurement, stream discharge was estimated by assuming a panel width of 0.3 feet, a width determined with measurements taken at GPC 7.5. On 8/7/2012, a "Dry7" sample date, the GCWI completed flow monitoring using the full discharge panel method at GPC 7.5 but also listed one depth and one velocity reading in the field data sheet. The data collected for the full panel discharge method provided an approximate flow and the GCWI used this flow as well as the depth and velocity reading to estimate an appropriate width for calculating the flow during dry conditions. The extremely dry conditions and limited flow data required the GCWI to generate regression equations to estimate the discharge at sampling events with no measurable flow, too low of water depths to obtain a velocity measurement, or a missed flow reading. The regression equations correlated the flow measurements at each site to the corresponding flow at the USGS gauge. Figure 3-5 presents an example of a regression equation developed to estimate site discharge at GPC 7.5. All site discharge versus USGS gauge relationships were significant ($p<0.001$) with R^2 values greater than 0.92.

Furthermore, the USGS gauge data was also used to develop a flow duration curve to be scaled to each monitoring site and serve as the basis for developing pollutant load duration curves. In order to develop a comprehensive curve with typical flow patterns, five years of gauge data (2007-2012) were utilized. Because of the required schedule of the analysis, data from water year 2012 had not been completely finalized by the USGS at the time of analysis and was still considered "provisional and subject to revision." However, this was not anticipated to adversely affect the analysis, because all data was checked for consistency and any 15-minute intervals without flow records were excluded from the 5 year dataset. The aforementioned regression equations were then used to properly scale the gauge flow duration curve to each monitoring site.

Additionally, water depth information from pressure transducer data loggers, installed by BCCD along three upper tributaries of similar size, was processed and analyzed to document trends across a gradient of urbanization – undeveloped, developing, and developed. The data loggers were installed near the following sampling sites: RDR 1.1 (2% impervious, 3.2 mi^2), FWF 0.8 (12% impervious, 4.3 mi^2), and GPC 17.1-UNT 0.1 (29% impervious, 3.8 mi^2). Depth information for the three sites was systematically processed and summarized, illustrating higher relative peak flows in the developed watershed when compared to the developing and undeveloped watersheds.

Sanitation District No. 1 of Northern Kentucky Stream Condition Indices

In addition to the habitat assessments and detailed water quality data collected by BCCD, the evaluation involved review of SD1's Stream Condition Indices (SCI), an evaluation and planning tool that serves as a means of compiling large amounts of data into a simple score to assess the overall health of a monitoring site. This includes complex biological, chemical, physical, and channel stability indices rated on a 0-10 scale, including an overall score that is a composite of the four individual indices. The primary purpose of the SCI score is to summarize the overall health of a monitoring site and present the information in terms easily understood to a non-technical audience. While environmental indices, such as the SCI, are frequently used to summarize complex monitoring data, the SD1 SCI is unique because it is calibrated to local conditions. The GCWI utilized this index as supporting information to illustrate that the outcomes of the data analysis were consistent with the SD1 SCI data.

The water quality component includes chemistry parameters such as bacteria (fecal coliform), dissolved oxygen, metals, nutrients, ammonia, pH, temperature, CBOD, conductivity, and turbidity. The physical habitat component utilizes the ten measures of habitat condition that are determined as part of the SD1 monitoring and assessment program, including epifaunal substrate/available cover, embeddedness, velocity/depth regime, sediment deposition, channel flow status, channel alteration, frequency of riffles (of bends), bank stability, bank vegetative protection, and riparian vegetative zone width. The biological component uses a combination of the Kentucky Index of Biological Integrity (KIBI) (fish communities) and the Kentucky macroinvertebrate Biotic Index (KMBI), utilizing the KMBI in headwater streams and both indices in wadeable streams with fish populations and larger drainage areas. Lastly, the channel stability component utilizes SD1's Stream Stability Index (Sustainable Streams, 2012). Reference the July 2013 SD1 technical memorandum titled *A Stream Condition Index for Water Utility Resource Management in Northern Kentucky* for additional information regarding each sub-index and determination of the associated scores (LimnoTech, 2013). The data collection and calculations for this index was completed around the timeframe of the watershed plan monitoring program.

Kentucky Division of Water Gunpowder Creek Watershed Health Reports

KDOW also evaluated the water quality, habitat, and biological health assessments collected by BCCD to generate Gunpowder Creek Watershed Health Reports for both the Phase 1 and Phase 2 monitoring efforts. Data was divided into indicators of water quality (dissolved oxygen, specific conductance, nutrients, total suspended solids, and *E.coli*) or indicators of biological health (total habitat, aquatic macroinvertebrates, riparian zone, and available cover). Indicators were graded A through F, by comparing them to KDOW water quality standards or benchmark data. The individual grades were averaged by KDOW to determine an overall biological health score and an overall water quality score for each subwatershed. KDOW then averaged these two scores to calculate a watershed health grade. While the purpose of these health reports is to present the results of the water quality data analysis, it is important to convey the results to both the general public as well as technical audiences. The KDOW grades summarize the overall health of the watershed in a means that is easier for the general public to understand. However, at KDOW's request, the Health Report Card Grades were not included in any of the analytical steps presented in Chapter 4 because these reports are for public informational purposes and not for analysis. The KDOW grades were only reviewed as supporting information to illustrate that although KDOW's and the GCWI's efforts to analyze the monitoring data were independent of each other, they both obtained the same conclusions.

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CHAPTER 4

Data Analysis

Gunpowder Creek Watershed Plan

Prepared by the

Gunpowder Creek Watershed Initiative

December 2014

Chapter 4: Analyzing Results

Nonpoint source runoff (i.e., stormwater) has been identified as the leading cause of impairment to stream water quality throughout the state of Kentucky. Boone County, in Northern Kentucky, is one of the most rapidly developing counties in the state, and its watersheds are currently experiencing the impacts associated with that development (i.e., streambank erosion/instability, excess sedimentation, degraded biological communities, loss of ecological function, etc.). Specifically, the Gunpowder Creek has been under increasing pressure as development continues to expand, and it has been classified on the 303(d) List of Impaired Waters for high levels of sediment, bacteria, and nutrients. Therefore, the GCWI monitoring program is important for understanding existing conditions, and analyzing the data collected in the program is an integral step for developing the Gunpowder Creek Watershed Plan. This chapter presents the results of two rounds of stream monitoring data and assessments, providing details regarding pollutants of concern, potential sources of pollutants, and various implications regarding the dominant causes of impairments.

This analysis is based upon an integrated approach to watershed planning through the stream function pyramid (**Figure 4-1**), where each component is dependent on the others, as a harmonious balance of all elements is necessary for healthy stream systems. Streams and rivers are among the most complex of physical systems with multiple interdependent components that impact the overall stream health. Streams are systems—their hydrology affects their stability, which in turn affects their water quality and biotic integrity. The stream function pyramid illustrates that how we live on the land (land use and management) affects hydrology (stream flow), as well as point and nonpoint pollutant loads. Both hydrology and pollutant loads impact the physical health of the stream, habitat/food availability, and overall water quality, which then creates impacts to and reactions within aquatic ecosystems (biological-eg, macroinvertebrate communities). The approach to this data analysis is unique in that rather than analyzing each component in isolation, we look at the system as it is—an interconnected network of dynamic parts. Quantitative 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) that could be implemented to mitigate such pollutants.

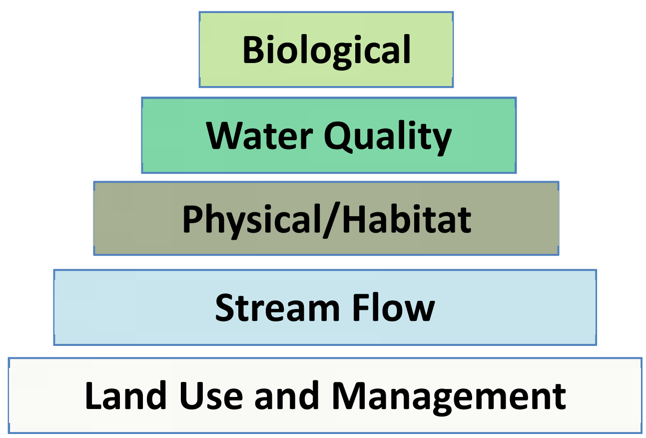


Figure 4-1: Stream Function Pyramid adapted from Center of Watershed Protection (2011)

4.1 Understanding the Goal of the Analysis

As explained, in *Chapter 3 – Learning More*, the GCWI monitoring program was designed to assess multiple measures of stream health using flow monitoring, geomorphic surveys, habitat assessments, water quality samples, macroinvertebrate assessments, and land use analysis. The overall results of both Phase I and Phase 2 monitoring are consistent with the preliminary assessment that was made during the Quality Assurance Project Plan (QAPP) development. Pollutants associated with hydromodification (e.g., TSS) seem to be the most concerning impairments, particularly in the heavily developed headwaters of the Gunpowder Creek Watershed (e.g., TSS loads ~30 to 60 times higher than benchmark levels).

> ***The monitoring program was designed to assess all aspects of stream integrity including biological, chemical, physical, stream flow, and land use.***

Indeed, the worst sites for macroinvertebrates were found along headwater tributaries to the main branch and South Fork Gunpowder Creek, which are the two most developed subwatersheds. The erosive urban flow regime has caused active bank erosion and flushed nearly all of the habitat-forming bed material at these sites, leaving featureless bedrock streams void of aquatic habitat or refugia (isolated refuges where species can survive in an otherwise broken ecosystem). The bank erosion and unstable bed material has resulted in high sediment loads throughout the Gunpowder Creek Watershed These apparent relationships observed in the Gunpowder Creek Watershed are consistent with the statistically-significant relationships from SD1's Hydromodification Monitoring Program, which includes of a robust dataset of 40 unique sites from Northern Kentucky . This dataset is separate from the GCWI monitoring program, but both illustrated similar outcomes – urbanization, as measured by impervious area, has been correlated to channel enlargement, bed coarsening, shorter riffles, and deeper, longer pools (Hawley *et al*., 2013a).

In comparing the 2011 Phase 1 monitoring results with the 2012 Phase 2 monitoring results, many water quality indicators drastically changed due to the substantial difference in rainfall that occurred during each monitoring effort. Samples collected during 2011, a record rainfall year with over 70 inches of rain (NCDC, 2012), provided insight regarding the types of pollutants washed off the land during runoff events. In contrast, samples collected in 2012, a much drier year, indicated the types of pollutants released directly into the stream without the influence of rainfall. Some examples of large differences in wet and dry monitoring (2011 versus 2012) in the Gunpowder Creek Watershed include high levels of bacteria strongly linked to wet weather (a relationship across all sites), whereas higher levels of specific conductivity and nutrients were linked to dry weather at a few monitoring locations, which could be indicative of possible direct sources in select areas such as livestock access or septic systems. Analysis of the monitoring data and how it relates to watershed conditions serves as the foundation for determining BMP implementation that will likely be the most feasible, efficient, and effective (Chapters 5 and 6).

4.2 Data Analysis Requirements for 319-Funded Watershed Plans

As previously explained in *Chapter 3 – Learning More*, the GCWI did not add extra monitoring sites during Phase 2 monitoring in 2012. This was in accordance with its KDOW-approved QAPP and the monitoring plan and budget that was proposed with the initial application. GCWI collected 6 months of data at each site for two years – Phase 1 was collected in 2011 and Phase 2 data was collected in 2012. Both Phase 1 and Phase 2 monitoring data was analyzed simultaneously and is presented in the following sections *4.2.1 Phase 1 and 2 Combined Data Analysis* and *4.2.2 Phase 1 and 2 Combined Prioritization.*

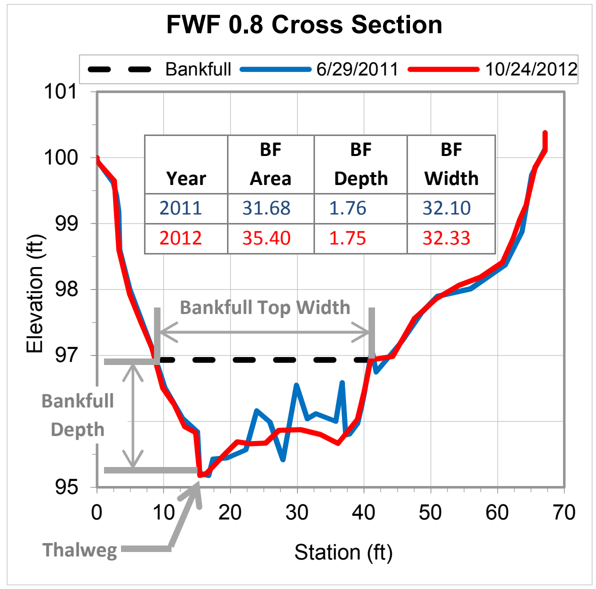
4.2.1 Phase 1 and 2 Combined Data Analysis

Methodology Used for Analysis

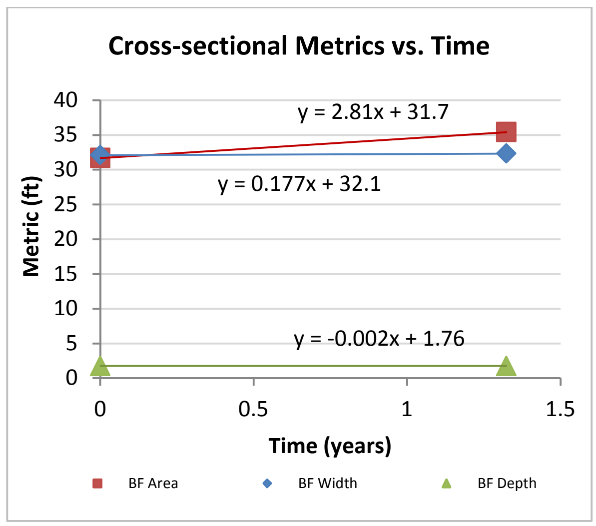
This section provides details regarding the methodology used to systematically process the Phase 1 and Phase 2 monitoring data.

Hydrogeomorphic Data

In processing the raw survey data, measurements were made on the cross section, profile, and bed material data to provide consistency across all sites. Cross-sectional measures of channel change included bankfull area, thalweg depths (i.e., depth to the lowest point of the cross section), and top width, all calculated with reference to the lowest top of bank from both survey years, defined as the point at which a defined bank breaks to an angle of less than ~15 degrees for a horizontal distance of at least three feet after the methodology used in the journal article, *Bed coarsening, riffle shortening, and channel enlargement in urbanizing watersheds* (Hawley *et al.*, 2013a). Reference the cross section (**Figure 4-2(a)**) for an illustration of these measurements. In addition, the degree of instability was classified using quantitative measures of changes in riffle length, pool length, pool depth, slope, and the pool/riffle ratio, as all profile surveys were broken into several pool-riffle reaches that were measured from the head of one riffle to the head of the next riffle upstream. Regarding bed material composition, key metrics, including the 16th, 50th, and 84th percentile particles (d16, d50, and d84), were determined and compared across each round of survey data. Rates of change over the 2011 and 2012 rounds of surveys at each site were completed using linear interpolation (a straight line between two points) of each important variable versus time between surveys. For example, at Site FWF 0.8, bankfull area increased from 31.68 to 35.40 ft^2 between surveys on June 29, 2011 and October 24, 2012, as shown in **Figure 4-2(a)**. The absolute change between surveys was an increase of 3.72 ft^2. Corresponding linear interpolation of cross sectional area versus time revealed an enlargement rate of 2.81 ft^2 per year, as shown in **Figure 4-2(b)**. Rates of measured change of key metrics at each site using linear interpolation are presented in **Appendix 4-A**.



(a) Repeated Cross Section Surveys



(b) Rates of Change Over Time

Figure 4-2: Measured Change in Cross-sectional Form and Linear Interpolation at FWF0.8

In addition to measured rates of change of the summary metrics discussed (e.g. bankfull cross sectional area, profile riffle length, d50 of the bed material, etc.), the weighted deviation between the elevation of each 2011 data point and the 2012 elevation at the same station was calculated based on the methodology used by Baker *et al.* (2012) and Hawley, *et al.* (In prep). Cross section weighted deviation measured change in the ground surface of the active channel bed; profile weighted deviation measured change along the channel thalweg; and bed material weighted deviation measured the change between the bed material gradations of the pebble count on a logarithmic scale. These measurements confirmed the unstable nature of the stream systems throughout the Gunpowder Watershed.

Lastly, SD1's Stream Stability Index (Sustainable Streams, 2012), a physically-based evaluation tool developed to incorporate the multidimensional effects of hydromodification on stream channels, was calculated for each site. This index is computed using cross-sectional shape, bedrock prevalence, left bank stability, right bank stability, pool depth, embeddedness, and riffle frequency. It presents an overall determination of the degree of stability for each monitoring location. This Stream Stability Index was not used as an integral part of the data analysis, but instead, it was incorporated as additional information to support the findings of the data analysis.

Water Quality Data

All water chemistry data was processed to evaluate variations in pollutant concentrations and understand what might be causing such variations. The analysis included an evaluation of relationships with rainfall (wet and dry weather events) and stream discharge data to examine changes in the pollutants of concern related to precipitation-driven changes and the associated changes in stream flow. As previously mentioned in Chapter 3, each sampling date was classified as wet, dry, or dry7 depending on the amount of recorded rainfall on the days preceding the sample. Sample concentrations, summarized by water quality parameter, sampling site, and type of sample (wet versus dry and dry7), were then plotted on standard box and whisker plots with the statistical software R (R Core Team, 2012). The box and whisker plots, presented in **Appendix 4-B**, provide a visual observation of the range of sample concentrations, the mean concentration for each parameter evaluated (excluding statistical outliers), and the overall relation to the water quality benchmark or standard set for that parameter. This graphical representation of sample concentrations provided additional detail regarding pollutants of concern during wet versus dry weather conditions.

In addition to the water quality box and whisker plots, the analysis included flow duration curves that served as the foundation for developing pollutant load duration curves for several pollutants of concern at all water chemistry monitoring sites. Such pollutant load duration curves were used to analyze 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 overall pollutant loads and yields. Instantaneous unit rates of pollutant loads were calculated by multiplying the volumetric flow rate of water at the time of the sample by the measured pollutant concentration (e.g. 10 liters per second x 5 mg per liter = 50 mg per second). The instantaneous pollutant load was calculated by multiplying how long that flow lasted in the sample year by the unit pollutant load (e.g. 1,000 seconds x 50 mg per second = 50,000 mg). The annual load was then the sum of all of the instantaneous pollutant loads from all of the flows that were recorded in a given year. The duration curve, which shows how long a given flow occurred in a given year, is called a flow duration curve. Each site had its own flow duration curve scaled from the USGS gage based on linear regression relationships that were discussed in Section 3.2.4 (e.g., **Figure 3-4**).

Because the resources do not exist to constantly measure pollutant concentrations at every sample location for 24 hours a day, 365 days per year, load duration methodologies typically use an averaging step. In this data analysis, samples were divided into bins, or groups of high flows, medium flows, and low flows. The bins were divided at the 35^{th} and 80^{th} percentile flows to facilitate quasi-equally spaced bins with the goal of having at least a couple of samples in each bin and no bins with zero samples. All concentrations within a given bin were then averaged to calculate the mean concentration for the bin. In the case of *E.coli*, the geometric mean was used for each bin, as is customary. The average instantaneous load for each flow in the bin is calculated by multiplying the average bin concentration by the average volumetric flow rate in the bin. Multiplying the average instantaneous load by the duration of time that occurs in the bin computes the projected load for the given bin. Doing that for all three bins and adding them up provides the annual projected load for a given pollutant at a given site.

Doing the same procedure but using the water quality benchmark concentrations provided by KDOW computes an annual benchmark load for a given pollutant at a given site. Comparing the projected loads to the benchmark loads provides a sense of whether a watershed could have too much of a pollutant of concern or whether the loads are more similar to reference/benchmark conditions and not concerning for water quality. All load duration curve figures, associated annual pollutant loads, and approximate percent load reductions necessary to meet the water quality benchmark are included in **Appendix 4-C**. In addition to pollutant loads, yields were also calculated in order to standardize the data by accounting for differences in geographic size between the subwatersheds. The pollutant yield was determined by dividing each load by the total area of the subwatershed (e.g. 20,000 pounds divided by 1,000 acres = 20 pounds per acre). The pollutant load methodology and step by step calculations are included in **Appendix 4-D**.

Statistical Relationships & Data Analysis

Statistical analysis, using the R program (R Development Core Team, 2012), was used to evaluate the strength of various relationships between water quality monitoring data and watershed characteristics such as land use data. Because hydromodification is a known water quality concern in Gunpowder Creek and can be a source of impairments such as high TSS, this analysis also incorporated the results of the hydromodification monitoring in order to identify statistically-significant relationships between every aspect of the stream function pyramid. This included correlations among and between land use, flow, water quality, habitat, and macroinvertebrate communities. The analysis assisted in identifying a greater understanding of the potential sources of all impairments as opposed to a simpler approach focusing on just one or two water quality impairments. In this light, BMPs with greater cost effectiveness for all impairments could be identified and prioritized accordingly. The strength of the correlations was assessed by the R^2 and adjusted R^2 values, and statistical significance was assessed using the *p* value. R^2 is a measure of how well a regression equation describes the actual data points. This value ranges from 0 to 1, with a value of 1 indicating that the regression equation perfectly describes the data. For example, an R-squared valued of 0.90 indicates there is a 90% chance that the variance in the dependent variable is explained by the independent variable. Adjusted R^2 values are typically less than the R^2 value and attempt to explain the proportion of variance in the data by also accounting for the number of data points as well as additional variables added to the statistical model. It considers original variance as well as residual variance. *p* values represent the probability that a correlation is due to chance and chance alone. For example, a *p* value of 0.10 would imply that there is a 10% chance that a relationship is simply a random occurrence. Any *p values* less than a threshold of 0.05 (i.e. 5%) were considered to be statistically significant. Please note that the statistical relationships presented throughout this chapter are based on a limited amount of data collected during 2011 and 2012, and while some relationships are statistically significant, this does not prove that the relationships are real. However, it does imply that there is likely a relationship between the variables tested. The fact that many of the relationships presented are physically based (i.e., cause and effect relationships that could be reproduced in a controlled laboratory setting) and consistent with previously published literature adds to a weight of evidence that the relationships are real and not attributable simply to chance or random occurrence.

Phase 1 and 2 Combined Monitoring Results

The following sections present the results from the monitoring data collected in both Phase 1 and Phase 2. The analysis is centered on the elements of the Stream Function Pyramid presented in section *4.1 Understanding the Goal of the Analysis.*

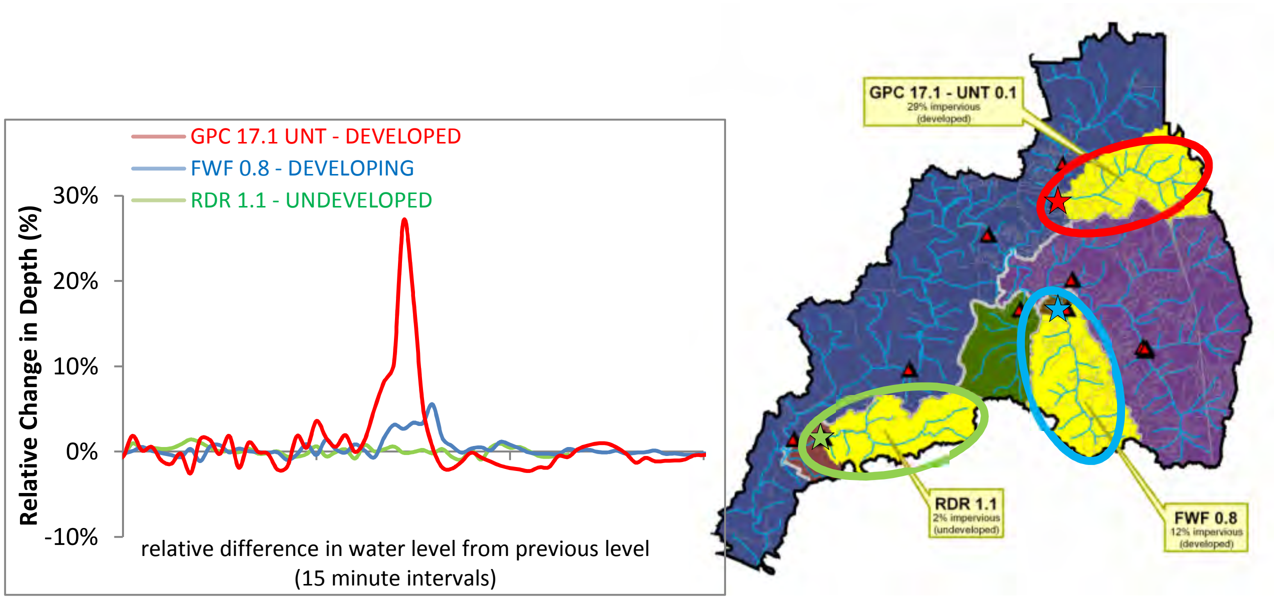
Stream Flow

The urban flow regime associated with increased development and unmitigated impervious area has greatly impacted Northern Kentucky streams (Hawley *et al.*, 2013a). **Figure 4-3** presents an example of a Northern Kentucky stream, Pleasant Run (~100 acre basin), that experiences erosive flows even on relatively small storm events (photo illustrates 11/16/10 rainfall event: magnitude: 0.45 inches; duration: 2 hours; < 2 month storm (2 hour/2 month = 0.81")). This example illustrates that very fast, erosive flows occur during many storms.

Figure 4-3: Erosive flows during 0.45 inch storm

Stormwater runoff in the developed headwaters makes stream flow rise and fall very rapidly and can cause flooding and streambank erosion.

Comparison of data logger information from three sites within the Gunpowder Creek Watershed of similar drainage area but varying levels of development, **Figure 4-4(b)**, illustrated that the altered flow regime associated with conventional urban development leads to flashier and larger flows. This is evidenced by the comparison of the measured flows at all three data logger locations, **Figure 4-4(a)**, which shows that the most developed site experienced much higher changes in water levels during the same rain event. The flashier and larger flows associated with unmanaged urban development lead to 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.



(a) Percent Relative Change in Water Depth Over Time [(a)] ***(b) Data Logger Locations***

Figure 4-4: Water levels rise and fall more rapidly in developed watersheds

[(a)] GPC 17.1-UNT 0.1 has been shortened to GPC 17.1 UNT in the graph above.

Physical – Hydrogeomorphic Data

Figure 4-5: Streams widen and destroy public infrastructure

Analyses of physical data indicate that streams in urban/suburban watersheds tend to be getting larger. An in-depth study of Northern Kentucky streams has demonstrated their overall shape is deepening and widening, their riffles are shrinking, their pools tend to be getting both longer and deeper, and watersheds in early stages of development (i.e., less than 15% total impervious area) were correlated with bed material coarsening as finer bed material is stripped away and moved downstream (Hawley *et al.,* 2013a). Unstable streams degrade water quality, aquatic habitat, and ultimately biological activity. Additionally, the unstable nature of many streams throughout Northern Kentucky has destroyed public and private infrastructure and adjacent property (Hawley *et al*., 2013b; **Figure 4-5**). Stability and habitat quality tend to decrease in developed watersheds and increased impervious area has been strongly correlated to channel enlargement, bed coarsening, shorter riffles, longer and deeper pools, and stream instability in Northern Kentucky streams (Hawley *et al.,* 2013a). In general, the - processed hydrogeomorphic survey data throughout Gunpowder Creek illustrated similar relationships to other Northern Kentucky streams; however, the relationships were not as significant, perhaps due to the presence of vertical grade control (bedrock) at many of the sites. In relation to percent impervious surfaces, both bankfull area and bankfull top width linear regressions were the most clear. The average annual change in bankfull area and bankfull top width

> ***Erosive flows can degrade habitat, cause bank erosion, and create high sediment loads.***

appears to have a positive relationship to percent impervious, but were not statistically significant with *p* values of 0.23 and 0.13, respectively.

Overall physica/habitat relationships illustrate concerns with channel enlargement and habitat.

When evaluating cross-sectional enlargement (annual increase in bankfull area per year) against land use, some examples of GIS parameters that illustrated significant ($p < 0.05$) relationships include percent barren land (**Figure 4-6**) and percent riparian roads (**Figure 4-7**). In a watershed comprised of predominantly clay soils (93.5% Hydrologic Soil Group Types C and D), barren land cover can behave similarly to impervious land area because it lacks the vegetation to slow down and transpire stormwater runoff. Additionally, the presence of roadways within the riparian corridor was strongly correlated to channel enlargement, indicating that the presence of riparian roads seemed to explain a greater portion of channel enlargement than watershed imperviousness. Roads often route their stormwater directly, and efficiently, to streams, whereas large developments tend to include some level of stormwater detention. Therefore, the case can be made that roadway imperviousness causes more hydrological effects than other types of impervious area. Riparian roads may also be indicative of potential channelization that may have occurred to create more optimal roadway alignments. Channelization is widely documented to increase the erosive energy of streams, which also makes them more prone to channel erosion and enlargement.

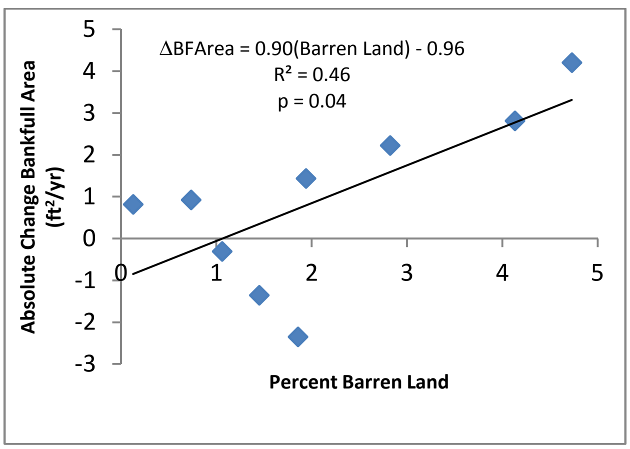


Figure 4-6: Channel enlargement is positively correlated to percent barren land

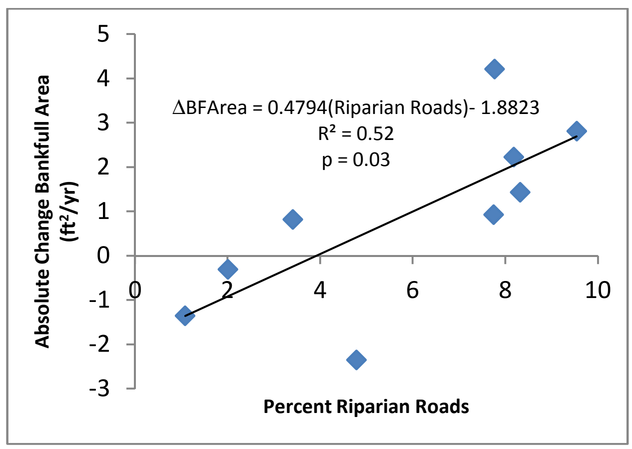


Figure 4-7: Channel enlargement is positively correlated to percent riparian roads

In addition to land cover metrics, linear regression relationships relating enlargement and water quality were evaluated. Across both high and low flows, TSS was positively associated with channel enlargement and widening. Specifically, the correlation between mean TSS concentration at low flow and channel widening was nearly statistically significant ($p = 0.05$), and the correlation with the mean high flow concentration was highly significant ($p = 0.003$) when withholding site GPC 17.1-UNT 0.1 (**Figure 4-8**), which was a physically-based outlier due to the fact that bank erosion from previous years have caused an over-widened channel with a mid-channel tree, which led to a log jam that temporarily induced deposition during the survey period (*i.e.*, see **Figure 4-15**). These finding are supported by other researchers that have documented channel erosion, enlargement, and bank failure as the dominant source of suspended sediment in many streams (Trimble, 1997; Simon and Klimetz, 2008; Wilson et al., 2007).

Further analyses illustrate that degraded habitat is also correlated to channel instability. For example, the Habitat Score (KDOW, 2008) was negatively correlated to both the change in bankfull area per year and the change in bankfull top width per year, with significant *p* values of 0.05 and 0.02 (**Figure 4-9**), respectively.

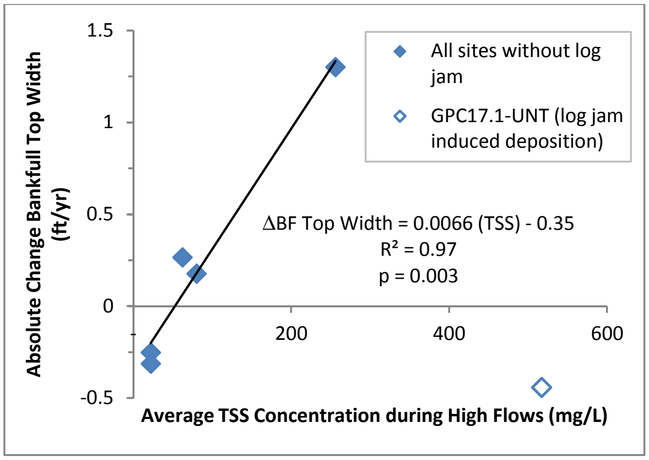


Figure 4-8: Channel widening is positively correlated to TSS

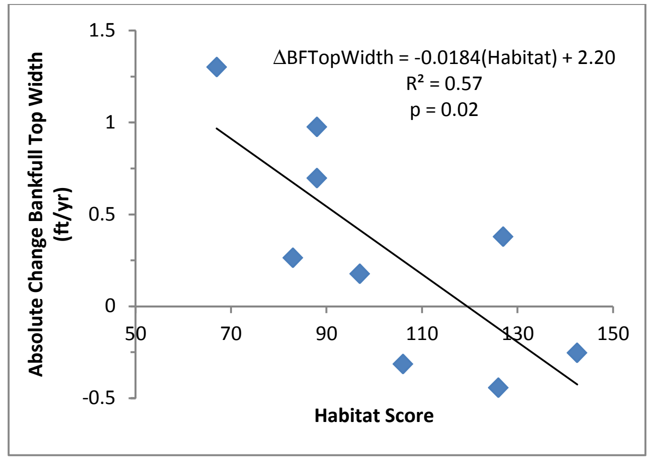


Figure 4-9: Channel enlargement is negatively correlated to habitat score

Hydromodification Monitoring Sites Case Studies

Hydromodification monitoring at sites throughout Gunpowder Creek document the physical changes that have occurred through both quantitative data captured by hydrogeomorphic surveys and observations of visual changes documented in annual photographs. Of the nine hydromodification monitoring sites assessed for this analysis, three case studies present representative examples of the problems throughout much of the Gunpowder Creek Watershed. These three locations are described below, with locations illustrated in **Figure 4-10**.

1. South Fork Gunpowder Creek (SFG 5.3-DS, 28% impervious): An extremely dynamic site that experienced bank failure and bed incision;
2. Unnamed Tributary of South Fork Gunpowder Creek (SFG 5.3-UNT 0.3, 41% impervious): A site with relatively shallow bedrock and a well-connected floodplain experiencing geotechnical mass wasting and bank widening , and;
3. Unnamed Tributary of Gunpowder Creek (GPC 17.1-UNT 0.1, 29% impervious): A site with erosive flows that transported large amounts of woody debris.

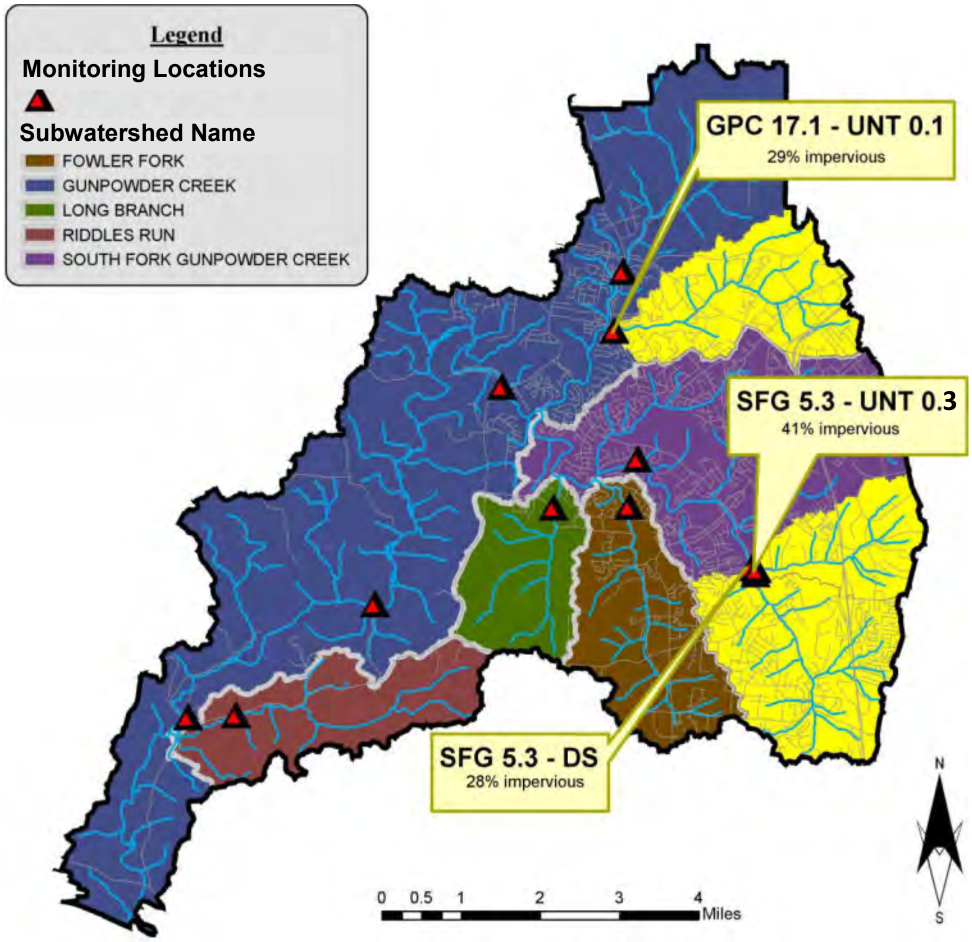


Figure 4-10: Physical/habitat case studies throughout the Gunpowder Creek Watershed

Case Study 1: South Fork Gunpowder Creek (SFG 5.3-DS)

> ***Stream channel dynamics exhibit bank failure, tree loss, and bedrock incision.***

The South Fork Gunpowder Creek is located in the southeastern portion of the watershed and includes three monitoring sites within close proximity to each other, all approximately 5.3 miles upstream of the confluence with the Gunpowder Creek main stem. While the monitoring data at all three of these survey sites has illustrated that the sites are all extremely dynamic, the downstream site (SFG5.3-DS) was the most dynamic, with lost trees, bedrock incision, and compromised storm sewer infrastructure. This site has an upstream drainage area of 6.91 square miles, and the watershed is fairly developed with approximately 29% impervious area.

Over the four rounds of surveys conducted by SD1 as part of its hydromodification monitoring program, collected between 2008 and 2012, both physical observations and quantitative data supports that the channel is enlarging, the longitudinal slope is responding to headcut migration (becoming flatter), bedrock is being fractured and mobilized, and the bed material gradation is coarsening. Storm sewer infrastructure at the site has been compromised by the eroding bank, causing a pipe outfall to become dislodged from its concrete headwall (**Figure 4-11**).

The following list presents a summary of key metrics and the corresponding percent change over this time period (2008 to 2012).

1. Bankfull area increased by 5%; benchfull area increased by 18% (Bankfull is defined in **Figure 4-2(a)**).

2. Profile slope decreased by 60%.

3. Bed material gradation became substantially coarser (d16 increasing by 467%; d50 increasing by 1760%, and d84 increasing by 278%).

Additional details regarding the changes in cross-sectional, profile, and bed material gradation can be found in **Appendix 4-A**.

Figure 4-11: Storm sewer infrastructure at Site SFG 5.3-DS compromised by erosive, urban flow regime

The erosive flow regime has caused the banks to erode, particularly the left bank, which has expanded more than three feet between 2008 and 2012, resulting in the loss of two trees (**Figure 4-12**-red). If this erosive flow regime is left unmitigated, the banks along this reach may continue to fail, impacting costly infrastructure and continuing to degrade stream habitat and water quality. Similar to most unstable Northern Kentucky streams, the South Fork Gunpowder Creek is responding to the erosive urban flow regime through headcut migrations along the longitudinal profile. The 60% decrease in slope over the four rounds of surveys can be attributed to the presence of this headcut migration (**Figure 4-12**-yellow). This type of channel response is seen as a primary cause of longitudinal slope adjustment and tends to change the nature of the stream with a decrease in riffle lengths and increase in pool lengths, which has been documented at this site and numerous other study sites across Northern Kentucky (Hawley *et al.*, 2013a).

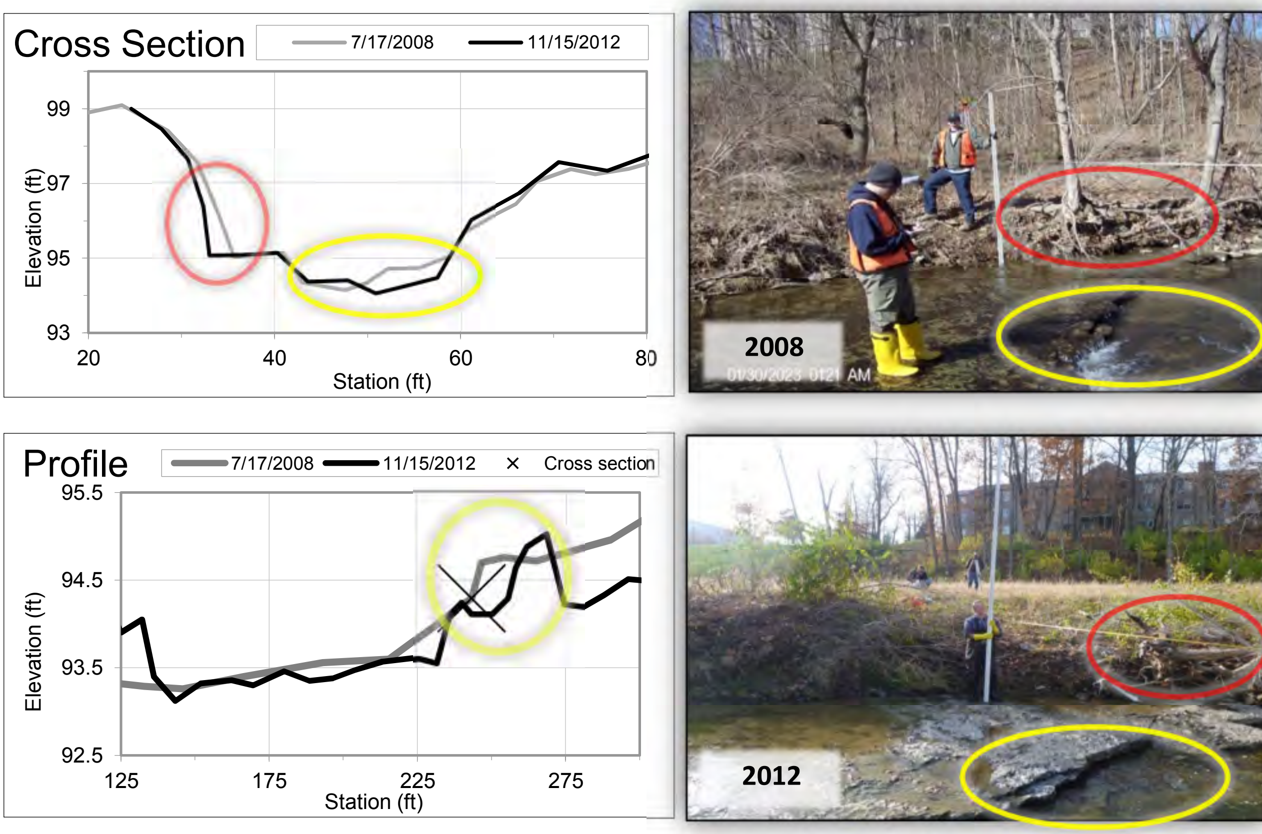


Figure 4-12: Erosive flows incise bedrock (yellow) and cause tree loss from bank failure (red)

This site is also experiencing bedrock incision as well as coarsening of the stream bed material. Conventional wisdom suggests that shallow bedrock tends to minimize or prolong channel incision by serving as a form of grade control, which makes the dominant source of channel instability bank failure and channel widening through both fluvial erosion and mass wasting mechanisms (Hawley *et al.*, 2013a). The survey data at SFG 5.3-DS confirms this response but also indicates that at times even sites with exposed bedrock can be extremely unstable and the stream bed can still degrade and incise as the exposed bedrock weathers and begins to fracture (Figure 4-12-yellow).

The active break-up of the channel bedrock and additional bed incision is concerning because bedrock in Northern Kentucky tends to be thin (approximately 6 inches to 1 foot) seams of limestone, a relatively strong rock, between thick (approximately 3 to 5 feet) layers of very weak shale. As the limestone layer gradually fractures and is mobilized, the underpinning shale layer quickly becomes eroded. This threshold condition of limestone surface weathering can result in very large increases in bank height (approximately 5 feet) on relatively shortened timescales. The energy of the urban flow regime has also resulted in sediment transport and

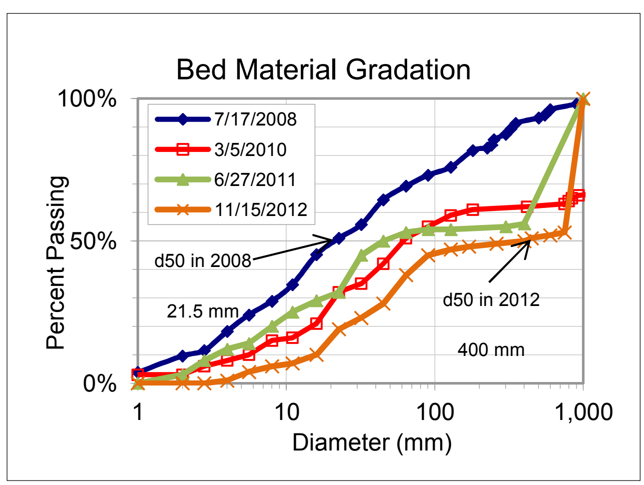


Figure 4-13: SFG 5.3-DS coarsening bed material

substantial coarsening of the bed material at this site (**Figure 4-13**). Note that the corresponding photos of this site and the following case study (SFG5.3-UNT 0.3) are nearly completely void of any habitat-forming particles and are comprised of featureless bedrock bottoms.

Case Study 2: Unnamed Tributary of South Fork Gunpowder Creek (SFG 5.3-UNT 0.3)

Another site located in the South Fork Gunpowder Creek Subwatershed (SFG 5.3-UNT 0.3) also experienced bank failure over several rounds of hydrogeomorphic monitoring. This site has an upstream drainage area of 2.2 square miles, and the watershed is very developed with approximately 41% impervious area coverage. A photo taken during 2012 monitoring captures a continuous tension crack (bank failure) along the entire length of the bank (**Figure 4-14**). This is a good example of geotechnical mass wasting and bank widening even on a bank with a relatively short height and at a site with shallow bedrock and a relatively well-connected floodplain. Such failure emphasizes the importance of a riparian buffer strip with thick vegetation to aid in stabilizing the bank.

Figure 4-14: SFG 5.3-UNT 0.3 tension crack bank failure

Case Study 3: Unnamed Tributary of Gunpowder Creek (GPC 17.1-UNT 0.1)

This site located in the headwaters of Gunpowder Creek, GPC 17.1-UNT 0.1 (29% impervious) experienced powerful erosive flows over the rounds of hydrogeomorphic monitoring. A series of photos taken in 2010, 2011, and again in 2012 (**Figure 4-15**) illustrates a tree becoming more damaged as time progresses. Additionally, the location of large woody debris is altered from year to year, indicating flows strong enough to transport heavy logs. The location of the tree (well over 10 feet into the channel) is indicative of historic widening as it is unlikely for a tree sprout to be able to take root in the middle of an active channel.

2010 2011 2012

Figure 4-15: Erosive flows at GPC 17.1-UNT 0.1 transport large woody debris and damage tree

These three case studies, as mentioned above, provide a glimpse into the types of hydromodification impacts observed in the stream. They also pair nicely with the data analysis, which supports these findings.

Habitat

Wetlands, vegetated riparian areas, native plant communities, and healthy stream channel conditions are important elements to support habitat structure and biological integrity. As previously mentioned in the section titled *Physical-Hydrogeomorphic Data*, the physical condition of a stream system strongly influences the habitat conditions, as the SD1 Habitat Score was negatively correlated to both the change in bankfull area per year and the change in bankfull top width per year, with significant *p* values of 0.05 and 0.02, respectively (**Figure 4-9**). Hydrogeomorphic data supports that the erosive urban flow regime has destroyed the nature of the Gunpowder Creek streams, leaving homogenous, featureless stream beds composed of exposed bedrock, long pools, and short riffles (**Figure 4-16**). **Table 4-1** presents the average habitat scores from the 2011 and 2012 Habitat Assessments.

(a) Pristine stream example in Northern Kentucky

(b) Homogeneous, featureless bedrock streambed

Figure 4-16: Physical characteristics of the streambed strongly influence habitat conditions

Such degraded habitat characteristics provide poor conditions for macroinvertebrate communities, and therefore also degrade the biological conditions at the sites. Even some of the less developed watersheds such as Long Branch had relatively poor habitat, which could have been attributable to historic channelization, or other factors. Notice that the most unstable monitoring site, SFG 5.3-UNT 0.3, also scored the lowest on the Habitat Assessments. Reference the Biological Assessment Section on page 26 for additional information regarding the impacts that poor habitat conditions have had on the biological communities at the sampling locations.

Table 4-1: Average habitat scores from the 2011 and 2012 habitat assessments illustrate the lowest habitat score at the most unstable site – SFG 5.3 – UNT 0.3

Monitoring Site	Habitat Score
SFG 5.3-UNT 0.3	67
LOB 0.5	83
FWF 0.8	97
RDR 1.1	106
GPC 17.1-UNT 0.1	129.5
GPC 7.5	142.5

Water Quality

Land Use Management, Erosive Flows, and Bank Erosion Are All Driving Factors that Impact Water Quality

Analysis of water chemistry data in the Gunpowder Creek Watershed provides insight about potential pollutants of concern and possible sources of the pollutants, such as land use, land use management, erosive flows, and bank erosion. All water chemistry data was processed to evaluate variations in pollutant concentrations and understand what might be causing such variations, such as changes in wet and dry weather conditions and the associated fluxes in stream discharge data. The following section, as well as supplementing appendices, presents the results of the water chemistry analysis.

Comparisons of Parameter Concentrations

Sample concentrations, summarized by water quality parameter, sampling site, and type of sample (wet versus dry and dry7) were initially analyzed using water quality box and whisker plots (**Appendix 4-B**) that provided a visual observation of the range of sample concentrations for all samples as well as samples in the wet, dry, and dry7 categories. Each box and whisker plot depicted the range of sample concentrations with excluded statistical outliers, the mean concentration for each category, and the overall relation to the water quality benchmark or standard set for that parameter. In addition to the box and whisker plots analyzed for each individual water quality parameter, this analysis involved evaluation of the ratios of sample concentrations to the water quality benchmark or standard at each monitoring location.

a) Water Quality Standards and Benchmarks

Water quality standards utilized throughout the analysis were obtained from Kentucky Administrative Regulations defined in *401 KAR 10:031 - Surface water standards*. The standards provide water quality criteria applicable to all surface waters to protect their indicated use, promote aquatic habitat, and safeguard human health. The water quality standards incorporated in this analysis include set criteria for bacteria, as measured by *E.coli,* as well as set criteria for dissolved oxygen and unionized ammonia.

All other parameters included in this analysis are compared to water quality benchmarks provided by KDOW in the *Gunpowder Creek Watershed Plan Benchmark Recommendations for Nutrient Parameters* (February 2012) and the *Gunpowder Creek Watershed Plan Benchmark Recommendations for Non-Nutrient Parameters* (February 2012) documents. These guidance documents set initial benchmarks based on typical values in comparable reference and healthy streams and are included in **Appendix 4-E**. In making the nutrient benchmark recommendations, KDOW considered regional and watershed specific nutrient expectations, regional-scale patterns in biological effects, and the specific indicators of nutrient enrichment observed in the watershed. The final benchmark recommendations provided by KDOW are primarily based on review of water quality samples at 12 ecoregional reference reaches within the Outer Bluegrass bioregion (ecoregion 71d) as well as typical literature values often cited for healthy streams.

Benchmark values provided by KDOW give a broad frame of reference to understand the general level of concern and approximate orders of load reduction that may be necessary to come within reasonable targets for water quality. While the benchmark values provide reasonable targets for water quality, desired attainment goals may be achieved without meeting benchmark concentrations. Designations such as Primary Contact Recreation (PCR) and Warm Water Aquatic Habitat (WAH) may be achieved even if the benchmarks are not met. Again, the benchmark values provided information to understand the scale of the problems and the GCWI would like to emphasize that the precise load is not the focus since the benchmark values are simply interim target values. As discussed in Chapters 5 and 6, the GCWI's approach for this Watershed Plan is to implement a reasonable level of BMPS and continue to monitor. GCWI plans to make smart investments as opportunities arise, monitor the progress, then reassess through continued monitoring.

b) Summary of All Sample Concentration Exceedances

Water chemistry parameters were evaluated to determine which pollutants were most concerning during wet versus dry weather sampling. **Table 4-2** presents the percent of water quality samples that exceeded the benchmark or standard set for each individual parameter. This represents the number of times the samples exceeded the benchmark level. Therefore, if the GCWI collected 11 samples and 9 were above the benchmark level, a percentage of 82 was included in the table. All sample exceedances greater than 80% are identified in red (most concerning) and all sample categories with less than 20% exceedance are identified in blue (least concerning). These results indicate that Total Phosphorus (TP) and Total Kjeldahl Nitrogen (TKN) are typically always above the water quality benchmark, while pollutants such as Dissolved Oxygen (DO), Nitrate-Nitrite as N (NN), and Unionized Ammonia (Union Amm) are the least concerning. Additional analysis of the nutrient concentrations and their pollutant loading indicates this type of pollutant is not as large of an issue as bacteria and sediment because the degree of exceedance is much lower. For example, 100% of all wet-weather samples from all sites exceeded the water quality standard for *E.coli*, and concentrations tended to be 1 to 2 orders of magnitude higher than the standard. The sampling results for *E.coli*, along with Total Suspended Solids (TSS)/Turbidity (Turbid) and Specific Conductance (SpCon) present interesting statistical relationships related to exceedances during wet versus dry weather sampling and are presented in additional detail in the following sections.

Table 4-2: Percent exceedances above water quality benchmark/standard concentration

(This represents the number of times the samples exceeded the benchmark level)

Water Quality Sampling Sites		Parameter:	TSS	Turbid	TP	TKN	NN	Union	DO	SpCon	*E.coli*
		No. Samples:	11	11	11	11	11	11	11	11	16
		No. Wet Samples:	3	3	3	3	3	3	3	3	3
		No. Dry Samples:	5	5	5	5	5	5	5	5	8
		No. Dry7 Samples:	3	3	3	3	3	3	3	3	5
		Benchmark[1]	7.25	8.3	0.08	0.3	0.3	0.05	**4**	522.5	**240**
		Standard[1]:	mg/L	NTU	mg/L	mg/L	mg/L	mg/L	mg/L	µS/cm	colonies/100mL
	GPC 7.5	All	91%	64%	100%	100%	45%	0%	0%	36%	38%
		Wet	100%	100%	100%	100%	100%	0%	0%	0%	100%
		Dry	80%	40%	100%	100%	40%	0%	0%	60%	25%
		Dry7[3]	100%	67%	100%	100%	0%	0%	0%	33%	20%
	GPC 17.1-UNT 0.1	All	45%	55%	91%	100%	18%	0%	0%	82%	40%
		Wet	67%	67%	100%	100%	33%	0%	0%	67%	100%
		Dry	60%	80%	80%	100%	20%	0%	0%	80%	38%
		Dry7[3]	0%	0%	100%	100%	0%	0%	0%	100%	0%
	SFG 5.3-UNT 0.3	All	55%	27%	64%	100%	9%	0%	9%	91%	50%
		Wet	100%	67%	100%	100%	33%	0%	33%	67%	100%
		Dry	20%	20%	40%	100%	0%	0%	0%	100%	50%
		Dry7[3]	67%	0%	67%	100%	0%	0%	0%	100%	20%
	FWF 0.8	All	55%	36%	91%	100%	18%	0%	10%	73%	75%
		Wet	100%	67%	100%	100%	67%	0%	33%	33%	100%
		Dry	20%	20%	80%	100%	0%	0%	0%	80%	88%
		Dry7[3]	67%	33%	100%	100%	0%	0%	33%	100%	40%
	RDR 1.1[2]	All	40%	20%	90%	80%	10%	0%	50%	80%	67%
		Wet	67%	67%	100%	100%	33%	0%	33%	33%	100%
		Dry	20%	0%	80%	60%	0%	0%	40%	100%	63%
		Dry7[3]	50%	0%	100%	100%	0%	0%	100%	100%	50%
	LOB 0.5	All	91%	64%	100%	100%	18%	0%	9%	27%	88%
		Wet	100%	67%	100%	100%	67%	0%	33%	33%	100%
		Dry	80%	40%	100%	100%	0%	0%	0%	40%	75%
		Dry7[3]	100%	100%	100%	100%	0%	0%	0%	0%	100%

[1]Water quality standards are presented in bold and represent parameters regulated by KDOW. All other parameters are compared to a water quality benchmark, which are pollutant levels that tend to be found in the region's healthier streams according to data and analysis by KDOW. The water quality standards included in this analysis include only dissolved oxygen and E.coli

[2]Due to dry conditions sampling did not occur at RDR 1.1 on 8/7/12; therefore, this site has only two Dry7 samples and a total of 15 samples for E.coli and 10 for the remaining parameters.

[3]Dry7 defined as event with less than 0.01 inches of rain occurring within the 7-day period before the sampling event. Reference Chapter 3 for additional information regarding the classification of sampling events as wet, dry, and dry7.

c) *E.coli* Concentrations

E.coli is used as an indicator of bacteria within the stream system, where an increase in concentration increases the possibility of the presence of potentially harmful pathogens. As illustrated in Table 4-2 and the *E.coli* Sample Box Plot below (Figure 4-18), 100% of wet weather *E.coli* samples at all sites exceeded the water quality standard (i.e., green line in Figure 4-18). Additionally, there is a positive association between the geometric mean of sample concentrations at each site and watershed imperviousness, illustrating that the most developed watersheds appear to have a larger concern with bacteria during wet weather (Figure 4-17). The opposite relationship is evident during dry weather sampling, as the geometric mean of the *E.coli* sample concentrations decreased with an increase in watershed imperviousness, indicating that bacteria levels during dry weather is a larger problem for rural watersheds (Figure 4-17). Both of these associations provide important insights relative to suspected sources of pollution; however, neither was statistically significant to the $p < 0.05$ level. Stormwater runoff and animal waste are suspected sources of bacteria in the developed subwatersheds, while septic systems and animals grazing in the streams are suspected sources of bacteria in the rural subwatersheds. Potential sources of bacteria in the watershed are further discussed later in this chapter. It is also important to note that the wet weather samples are based on three sampling events that occurred during 2011 prior to SD1's completion of system improvements aimed at mitigating several sanitary overflows in the Gunpowder Creek Watershed (historic overflow locations have been documented along the South Fork and tributary, Fowler Fork, and the main branch). Although there are many potential sources of bacteria throughout the Gunpowder Creek Watershed, it is possible that the high bacteria concentrations during wet weather in 2011 may have been partially attributable to sewer overflows.

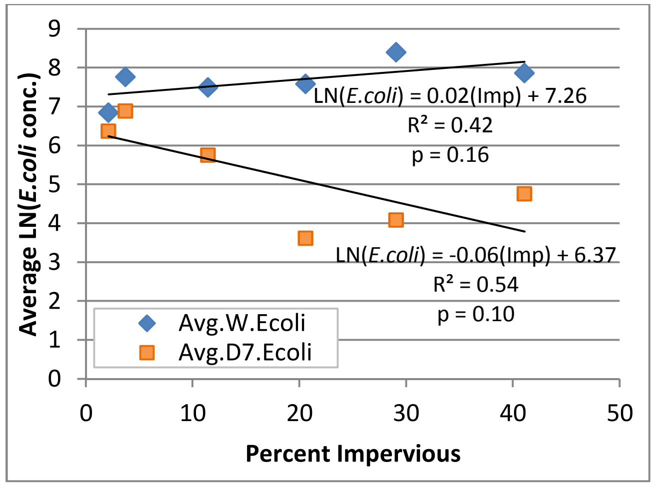


Figure 4-17: *E.coli* as a function of percent impervious

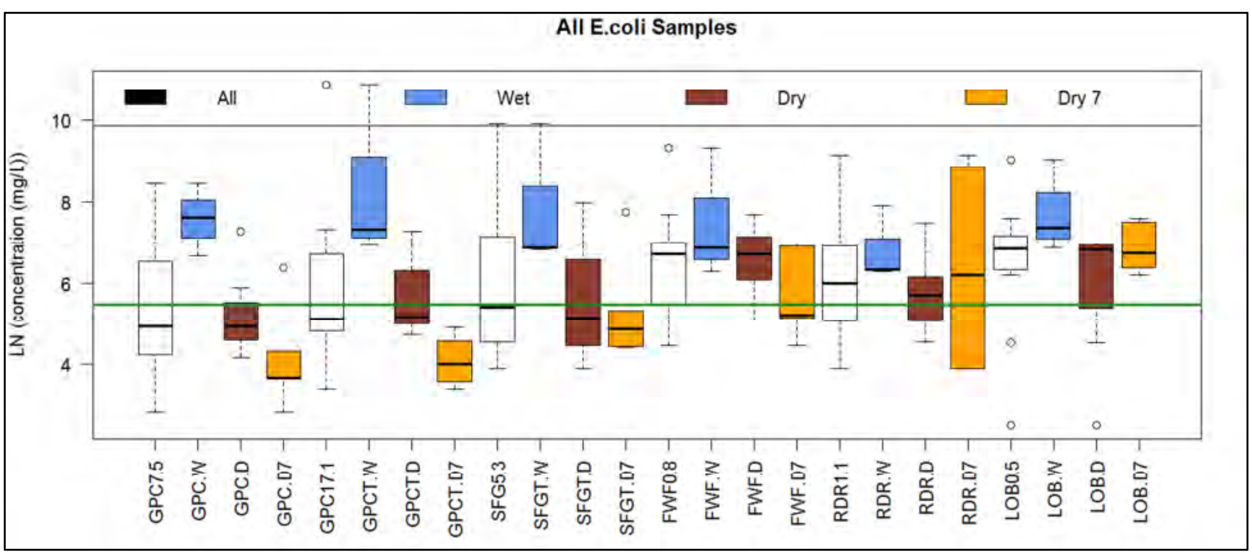


Figure 4-18: *E.coli* sample concentrations during wet and dry weather conditions (green line represents water quality standard: LN(240 colonies/100mL)) [(a)]

[(a)] In this figure, GPC 17.1-UNT 0.1 was shortened to GPC17.1. SFG 5.3-UNT 0.3 was shortened to SFG5.3.

d) TSS Concentrations

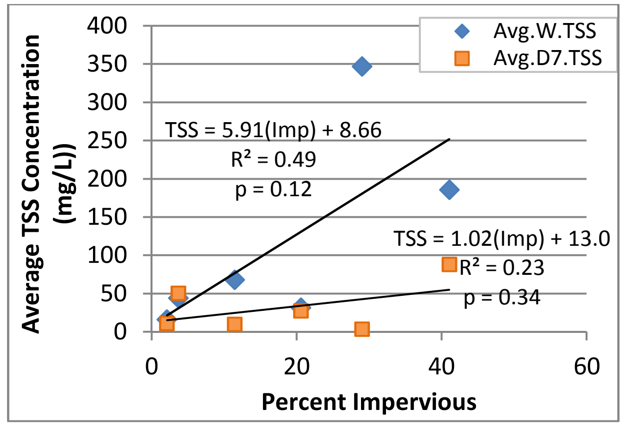


Figure 4-19: TSS as a function of percent impervious

Sediment, as measured by TSS sample concentrations, is a pollutant of concern during both wet and dry weather conditions (Figures 4-19 and 4-20). It appears to be a larger issue during wet weather when bank erosion is caused by the urban induced erosive flow regime as well as when sediment is washed off unvegetated, barren surfaces and transported to the stream. As presented in the section of this chapter titled Physical-Hydrogeomorphic Data, TSS was strongly associated with channel enlargement (Figure 4-8), which was also associated with percent impervious, indicating that bank erosion and channel enlargement are a likely source of the fine sediment found in the streams, as has been well-documented in other systems (Trimble, 1997; Simon and Klimetz, 2008; Wilson et al., 2007). Such high rates of bank erosion and channel enlargement have likely been caused by the erosive urban flow regime, which is also degrading the habitat conditions and is a probable cause of biological impairments. While TSS in an indicator of erosive flows degrading habitat conditions, it also contributes to biological impairment through direct pathways (e.g. clogging gills) and indirect pathways (e.g. causing embeddedness of the bed material habitat). Bank erosion and channel enlargement are also a potential source of TSS during dry weather for several reasons. First, bank failure by mass wasting can occur during both periods of wet and dry weather. Second, once the fine sediment loads from bank failure are slumped into the stream, it can take long periods of time to flush the sediment load. Silt, and in particular clay, can remain suspended in the water column for hours and days, respectively, such that these loads can be sources even during prolonged periods of dry weather. Finally, even low flows at site GPC 7.5 would have sufficient capacity to transport silt and clay given the relatively large drainage area and reasonably high base flow, even during periods of dry weather.

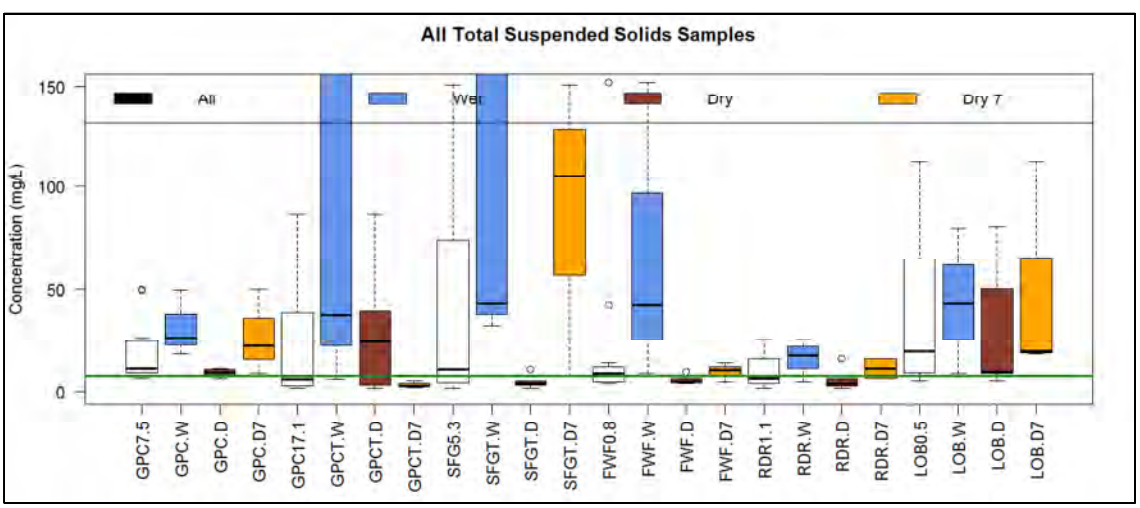


Figure 4-20: TSS sample concentrations during wet and dry weather conditions (green line represents water quality benchmark: 7.25 mg/L) [a]

[a] In this figure, GPC 17.1-UNT 0.1 was shortened to GPC17.1. SFG 5.3-UNT 0.3 was shortened to SFG5.3.

e) Specific Conductivity Measurements

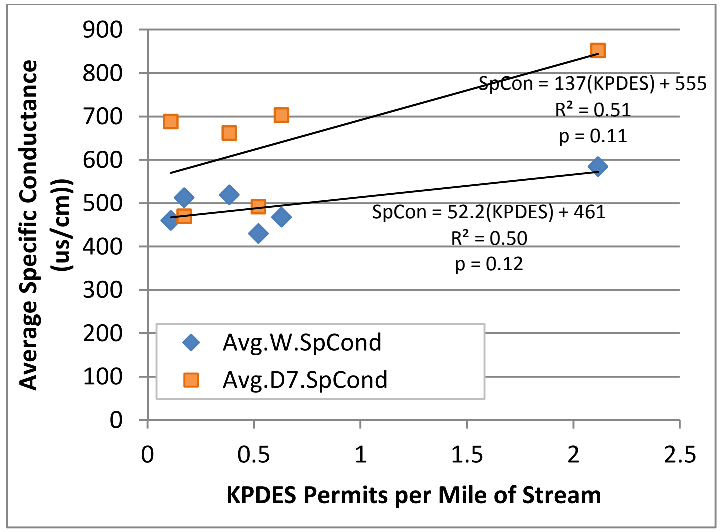


Figure 4-21: Average specific conductance concentrations are correlated to the number of KPDES permits per mile in each subwatershed

Specific conductance, which measures the water's ability to conduct electricity, can be used as a surrogate to determine if total dissolved solids are a potential pollutant of concern; however, it should be noted that specific conductivity can be naturally high in Northern Kentucky streams because of natural sources such as groundwater seeps which tend to increase conductivity from the amount of dissolved solids in the water. Sampling results indicate conductivity is worse during dry weather conditions, particularly at SFG 5.3-UNT 0.3, the subwatershed which contains the most number of KPDES permit sites per mile of stream. This observation, as well as the positive relationships presented in **Figure 4-21**, could indicate that total dissolved solids are possibly polluting the stream via KPDES discharges during dry weather conditions. In addition, specific conductivity was negatively correlated to sample flow at each site with significant *p* values less than 0.05 at four sites (GPC 17.1-UNT 0.1, SFG 5.3-UNT 0.3, FWF 0.8, and RDR 1.1). This also supports that specific conductance is more problematic during low flow conditions and that concentrations tend to become diluted during wet weather (note that the brown and orange boxes in **Figure 4-22** tend to be higher than the blue boxes at most sites).

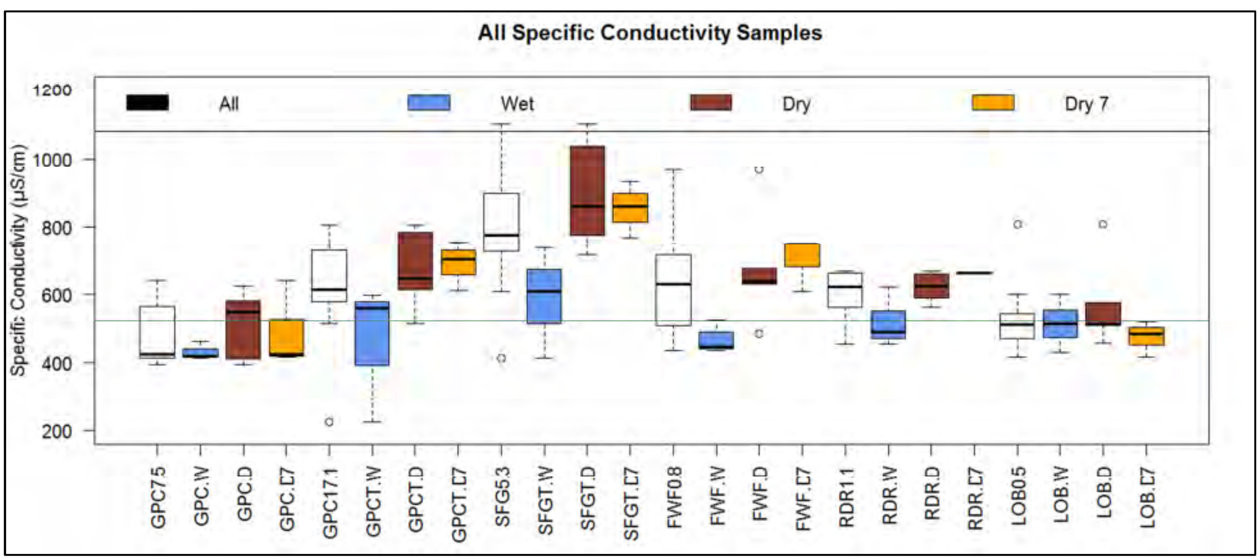


Figure 4-22: Specific conductance sample measurements during wet and dry weather conditions (green line represents water quality benchmark: 522.5 µS/cm) [(a)]

[(a)] In this figure, GPC 17.1-UNT 0.1 was shortened to GPC17.1. SFG 5.3-UNT 0.3 was shortened to SFG5.3.

Comparisons of Pollutant Loads

Pollutant load duration curves add another level of insight to the water quality analysis and allow for pollutant concentrations to be characterized at varying flow regimes, providing a visual figure of the relationship between stream flows, pollutant loading capacity, and the frequency and magnitude of exceedances in water quality benchmarks based on flow conditions. Pollutant loads, which are defined by both the concentration of the pollutant and the stream flow, determine the amount of a specific pollutant being transported by the stream in terms of weight per period of time (i.e., lbs/day). Loadings are important to evaluate because they provide a more balanced comparison between subwatersheds, as a subwatershed with a low concentration and large flows could have a higher total load than a watershed that has a high pollutant concentration but only a little flow (KDOW, 2010a). The Gunpowder Creek water quality analysis included development of pollutant load duration curves to analyze bacteria (*E.coli*), total suspended sediment (TSS), and nutrients (TP, TKN, NN) at all six water quality monitoring sites. **Figure 4-23** presents the *E.coli* Load Durations at GPC 17.1-UNT 0.1 and is an example of the pollutant load duration curves developed at all sites (**Appendix 4-C**). This load duration approach, with the limited amount of water quality data provided for this analysis, is meant to provide estimates of the scale of the problem in each subwatershed and not indicate exact loads necessary to achieve interim water quality targets.

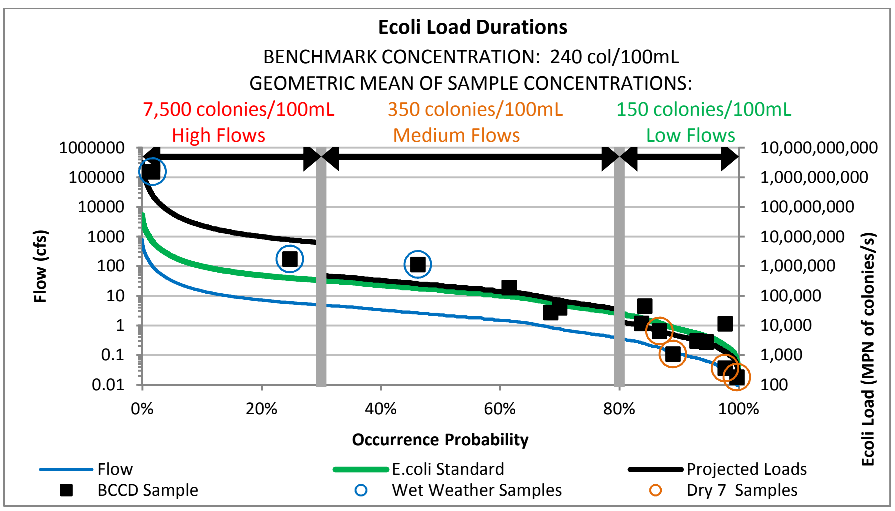


Figure 4-23: *E.coli* load durations at developed site, GPC 17.1-UNT 0.1 (29% impervious)

Note: This load duration approach with the limited amount of water quality data provided for this analysis is meant to provide estimates of the scale of the problem in each watershed 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

In addition to providing a visual representation of the relationship between stream flows, pollutant loading capacity, and the frequency and magnitude of exceedances in water quality benchmarks, the pollutant load duration curves provide means of estimating the total annual pollutant loads occurring at a particular site over the course of an entire year. Projected annual pollutant loads, benchmark annual pollutant loads, and the percent difference for each parameter is presented in a summary table for each water quality monitoring site (**Appendix 4-C**).

Sediment and bacteria during wet weather tended to be the biggest concern, particularly in the most developed watersheds.

With further evaluation of the annual pollutant loads, the ratio of the projected load to the benchmark load (defined by the projected load divided by the water quality benchmark) was calculated to analyze the degree of exceedance for each pollutant on the same scale, with any ratio above one being an exceedance of the water quality benchmark. **Figure 4-24** presents this ratio for total loads of each parameter analyzed at the water quality monitoring locations. This figure illustrates that both sediment (TSS) and bacteria (*E.coli*) are of greater concern than nutrient loads (TP, TKN, and NN) throughout the Gunpowder Creek Watershed. Additionally, this figure illustrates that generally two subwatersheds appear to be contributing the most pollution by weight within the watershed - the headwaters of Gunpowder Creek (GPC 17.1-UNT 0.1) and South Fork Gunpowder (SFG 5.3-UNT 0.1).

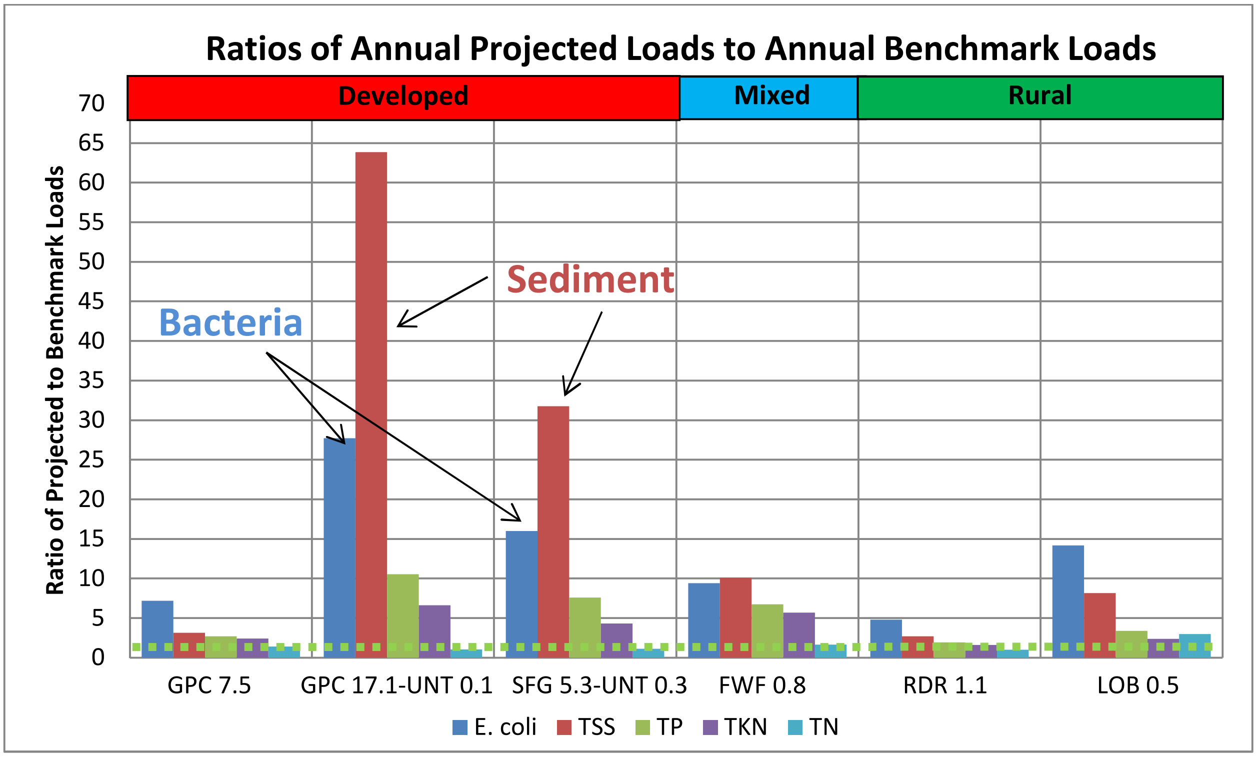


Figure 4-24: Ratios of projected loads to benchmark pollutant loads illustrate that bacteria and sediment are the greatest pollutants of concern in the Gunpowder Creek Watershed

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

Ratios of projected loads to benchmark loads were also evaluated during the various flow conditions (high, medium, and low). This analysis confirmed the results presented in previous sections – bacteria and sediment are of greater concern during wet weather conditions when the stream flows are high.

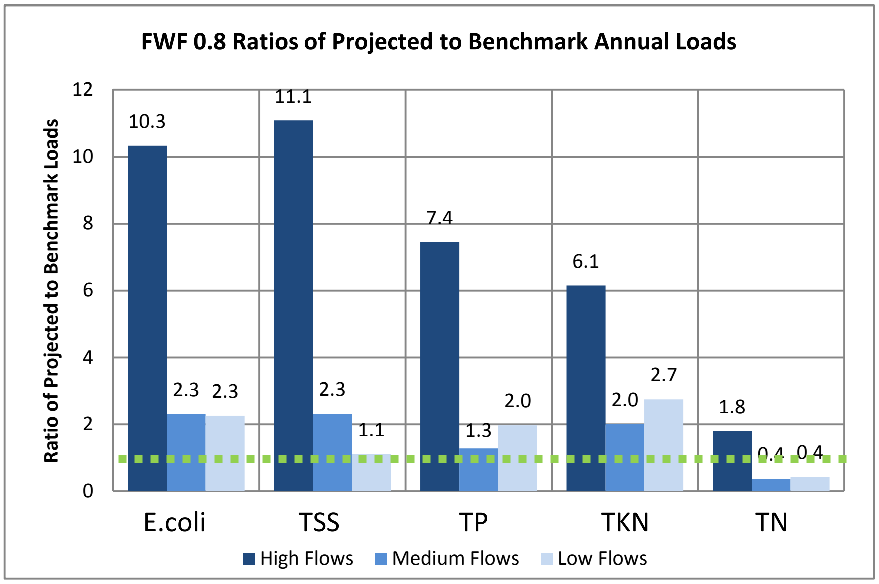


Figure 4-25: Evaluation of projected to benchmark load ratios at individual monitoring sites illustrates greater exceedances during high flows (wet weather conditions)
(ratios = projected load divided by the water quality benchmark or standard; the green line represents the water quality benchmark or standard = 1)

Figure 4-25 presents an example of this analysis. The evaluations of projected to benchmark load ratios at all monitoring sites are included in **Appendix 4-C**. **Table 4-3** presents the projected percent load reductions necessary for each parameter at the water quality monitoring sites. The red text illustrates the highest pollutant load reductions needed throughout the watershed (greater than 80%). It further underscores the findings that 1) sediment (TSS) and bacteria (E.coli) are the pollutants in need of the greatest reductions and 2) the most developed sites of SFG 5.3-UNT 0.3 and GPC 17.1-UNT 0.1 tend to higher reductions than the less developed sites. Additionally, the percent load reductions for each flow category are included in **Appendix 4-C**.

Table 4-3 – Estimates of percent load reductions necessary to meet water quality benchmarks at each monitoring location

Site	*E. coli*	TSS	TP	TKN	TN
GPC 7.5	86%	68%	63%	59%	28%
GPC 17.1-UNT 0.1	96%	98%	91%	85%	4%
SFG 5.3-UNT 0.3	94%	97%	87%	77%	10%
FWF 0.8	89%	90%	85%	82%	39%
RDR 1.1	79%	63%	48%	38%	83%
LOB 0.5	93%	88%	71%	58%	67%

Comparison of Pollutant Yields

The annual loads estimated from the load duration curves were standardized by determining the pollutant yield for each subwatershed. This accounts for the geographic size differences between the subwatersheds. The pollutant yield was determined by dividing each load by the total area of the sub-watershed. **Table 4-4** presents the standardized pollutant yields, which also supports the findings above that bacteria and sediment tend to be the pollutants of greatest concern and that they become worse in the developed headwaters of the watershed (SFG 5.3-UNT 0.3 and GPC 17.1-UNT 0.1).

Table 4-4 – Pollutant yields at each monitoring location

SITE	FLOW	POLLUTANT YIELD				
		E. coli (col/yr/ac)	TSS (lb/yr/ac)	TP (lb/yr/ac)	TKN (lb/yr/ac)	TN (lb/yr/ac)
SFG 5.3-UNT 0.3	High Flows	8.20E+10	1,084.3	2.8	5.8	1.5
	Medium Flows	1.15E+09	14.3	0.1	0.4	0.1
	Low Flows	1.32E+07	0.6	0.0	0.0	0.0
	Total	8.31E+10	1,099.1	2.9	6.2	1.6
RDR 1.1	High Flows	2.86E+10	112.3	0.8	2.6	1.7
	Medium Flows	2.02E+09	2.6	0.1	0.2	0.1
	Low Flows	2.64E+07	0.1	0.0	0.0	0.0
	Total	3.07E+10	115.1	0.9	2.8	1.8
LOB 0.5	High Flows	7.61E+10	277.8	1.3	3.2	4.4
	Medium Flows	2.55E+09	22.5	0.1	0.4	0.1
	Low Flows	3.62E+07	0.5	0.0	0.0	0.0
	Total	7.87E+10	300.8	1.4	3.6	4.6
GPC 17.1-UNT 0.1	High Flows	2.23E+11	3,404.9	6.1	14.4	2.0
	Medium Flows	1.31E+09	38.4	0.2	0.4	0.3
	Low Flows	1.52E+07	0.2	0.0	0.0	0.0
	Total	2.24E+11	3,443.5	6.3	14.8	2.3
FWF 0.8	High Flows	6.11E+10	436.7	3.2	10.0	2.9
	Medium Flows	1.72E+09	11.5	0.1	0.4	0.1
	Low Flows	4.53E+07	0.1	0.0	0.0	0.0
	Total	6.29E+10	448.4	3.3	10.5	3.0
GPC 7.5	High Flows	5.54E+10	143.3	1.4	4.8	2.8
	Medium Flows	1.33E+09	22.5	0.2	0.5	0.2
	Low Flows	1.02E+07	0.4	0.0	0.0	0.0
	Total	5.67E+10	166.2	1.6	5.3	3.0

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

A better understanding of pollutants of concern and possible drivers of the pollutants is obtained by comparing the watershed inventory data to the pollutant concentrations and loads/yields. Generally, the monitoring locations can be categorized into three types of land use based on their percentage of impervious area, including developed watersheds, rural watersheds, and mixed. 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. This is further explained in section *4.2.2 Phase 1 and Phasee 2 Combined - Prioritization.*

Biological Assessment

Biological health in rural watersheds tended to be more impacted by habitat and dry weather pollution.

The biological health of a stream system is dependent on all other supporting factors, and it is presented at the top of the stream function pyramid. The core of this pyramid is built on land use and management, stream flow, physical/habitat conditions, and overall water quality. Macroinvertebrate communities particularly rely on their natural flow and disturbance regimes, healthy habitat conditions, and excellent water quality, all of which show negative correlations with development and were discussed earlier in this report. Statistical analysis of the Gunpowder Creek Biological Assessments in relation to percent impervious also supports that biological health suffers in the most developed watersheds, as the MBI Score and the Percent Clinger Score were both negatively associated with watershed imperviousness (**Figure 4-26 and Figure 4-27**). **Figure 4-28** presents the aquatic macroinvertebrate scores (MBI) for each monitoring location and the influencing factors that largely impacted the aquatic macroinvertebrate health, including flow, habitat, and water quality, which are all affected by land use and land use management.

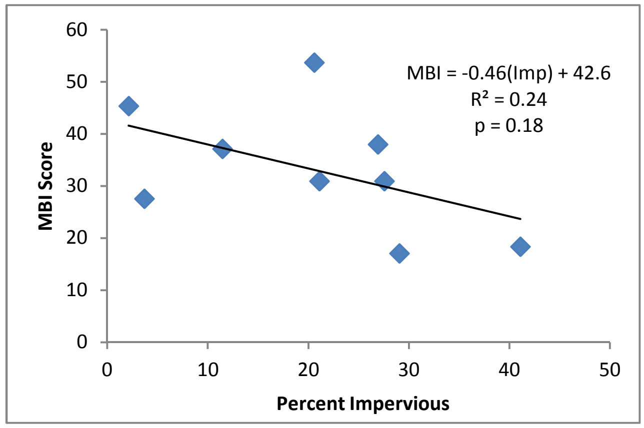


Figure 4-26: -Increased development, as measured by percent impervious, results in degraded MBI scores

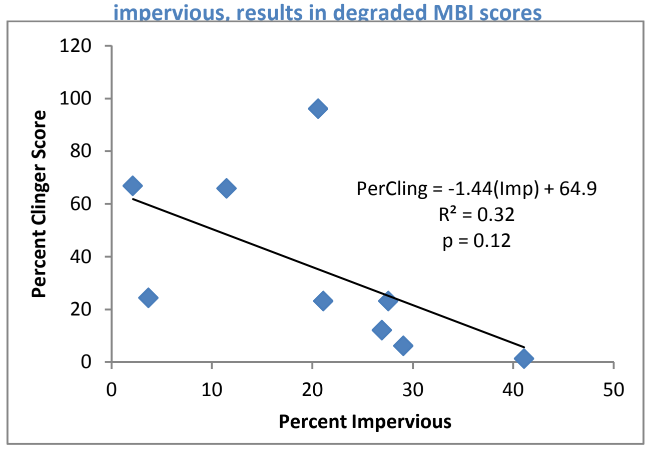


Figure 4-27: The percent clinger population is negatively associated with percent impervious

SD1 Stream Condition Indices Summarize the Overall Health of Gunpowder Creek and its Tributaries

SD1's Stream Condition Indices provide a concise summary of hydromodification, physical, water quality, and biological conditions at each monitoring location. **Figure 4-29** presents a summary of the Stream Condition Indices throughout the Gunpowder Creek Watershed. Overall review of these scores illustrates that the results of the GCWI monitoring program are consistent with SD1 Stream Condition Index scores (**Figure 4-29**). This Stream Condition Index supports the findings of GCWI's data analysis. It was not an integral part of the analysis.

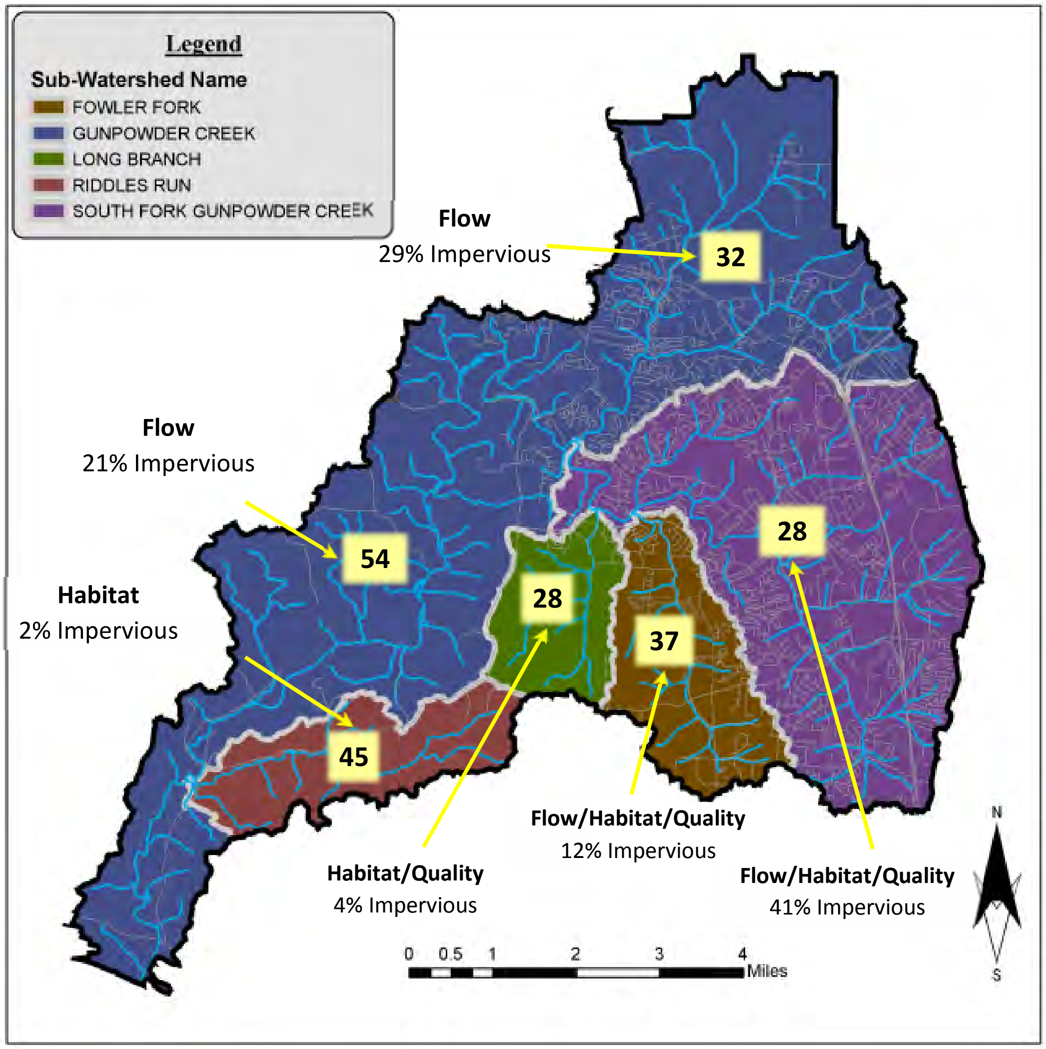


Figure 4-28: Biological health is dependent upon all pieces of the pyramid

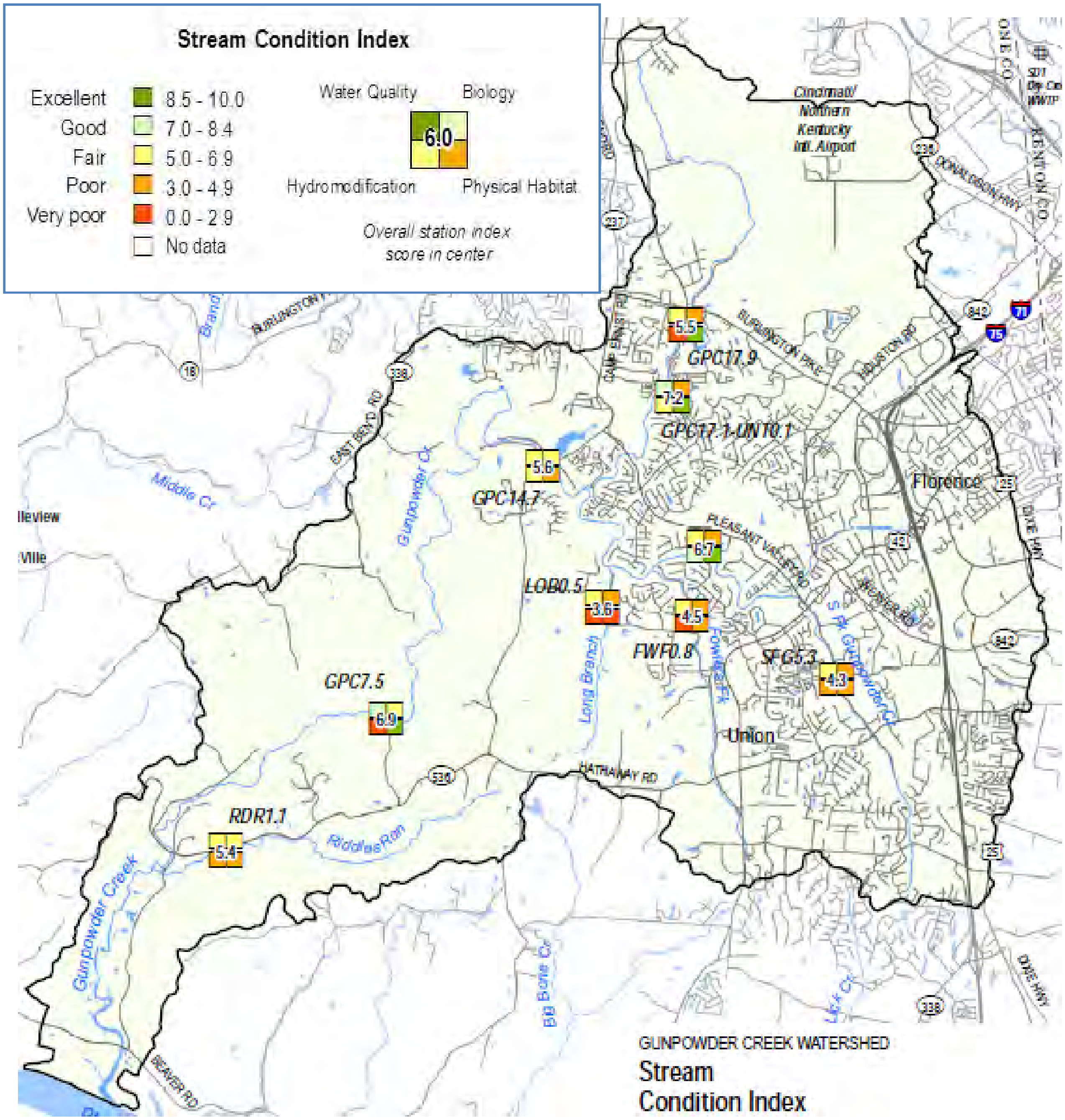


Figure 4-29: Overall stream health summarized with SD1's Stream Condition Indices

4.2.2 Phase 1 and 2 Combined - Prioritization

Further analysis of the data presented above allowed for prioritization of the subwatersheds based on the monitoring data. The analyzed monitoring data provided a better understanding of pollutant sources and which subwatersheds should be targeted for future implementation efforts. Prioritization involved organization and review of the analytical data to rank subwatersheds, evaluation of the regulatory status of the waterways, targeting of pollutants of concern and reviewing feasibility factors.

Organizing Analytical Data

In organizing the water quality data analyzed above, concentrations as well as pollutant loads and yields were all compared in order to rank the subwatersheds and understand which subwatersheds need to be prioritized in terms of lowering the pollutants in the stream and which subwatersheds need to potentially be protected from future degradation.

Comparisons of Parameter Concentrations

Table 4-5 and **Table 4-6** present the subwatersheds ranked based on analysis of the sample concentrations. First, **Table 4-5** presents the subwatersheds ranked by the number of water quality samples exceeding the benchmark concentration. **Table 4-6** presents the subwatersheds ranked by average parameter concentrations.

Table 4-5: Subwatersheds ranked from the greatest to the lowest number of samples exceeding the benchmark [(a)]

PERCENT SAMPLES IN EXCEEDANCE OF BENCHMARK									
E. coli		TSS		TP		TKN		NN	
LOB 0.5	88%	GPC 7.5	91%	GPC 7.5	100%	GPC 7.5	100%	GPC 7.5	50%
FWF 0.8	75%	LOB 0.5	91%	LOB 0.5	100%	GPC 17.1-UNT	100%	GPC 17.1-UNT	17%
RDR 1.1	67%	SFG 5.3-UNT	55%	GPC 17.1-UNT	92%	SFG 5.3-UNT	100%	FWF 0.8	17%
SFG 5.3-UNT	50%	FWF 0.8	55%	FWF 0.8	92%	FWF 0.8	100%	LOB 0.5	17%
GPC 17.1-UNT	40%	GPC 17.1-UNT	45%	RDR 1.1	91%	LOB 0.5	100%	RDR 1.1	9%
GPC 7.5	38%	RDR 1.1	40%	SFG 5.3-UNT	67%	RDR 1.1	82%	SFG 5.3-UNT	8%

[(a)] GPC 17.1-UNT 0.1 has been shortened to GPC 17.1-UNT in this table. SFG 5.3-UNT 0.3 has been shortened to SFG 5.3-UNT in this table.

Table 4-6: Subwatersheds ranked from the greatest to the lowest average sample concentrations [(a)]

AVERAGE SAMPLE CONCENTRATIONS									
E. coli (col/100mL)[(b)]		TSS (mg/L)		TP (mg/L)		TKN (mg/L)		NN (mg/L)	
LOB 0.5	724	GPC 17.1-UNT	109	GPC 17.1-UNT	0.30	FWF 0.8	0.95	GPC 7.5	0.32
FWF 0.8	661	SFG 5.3-UNT	76.7	SFG 5.3-UNT	0.22	GPC 17.1-UNT	0.85	LOB 0.5	0.26
RDR 1.1	454	LOB 0.5	39.6	FWF 0.8	0.22	SFG 5.3-UNT	0.78	FWF 0.8	0.20
SFG 5.3-UNT	368	FWF 0.8	23.6	GPC 7.5	0.19	LOB 0.5	0.77	GPC 17.1-UNT	0.19
GPC 17.1-UNT	317	GPC 7.5	19.9	LOB 0.5	0.18	GPC 7.5	0.74	RDR 1.1	0.16
GPC 7.5	203	RDR 1.1	10.0	RDR 1.1	0.13	RDR 1.1	0.42	SFG 5.3-UNT	0.15

[(a)] GPC 17.1-UNT 0.1 has been shortened to GPC 17.1 UNT in this table. SFG 5.3-UNT 0.3 has been shortened to SFG 5.3 UNT in this table.

[(b)] Average sample concentrations for *E.coli* were calculated as the geomean of the sample concentrations

Comparisons of Pollutant Loads and Yields

Excess stormwater runoff, especially in the developed headwaters, seems to be the common source for many problems throughout the Gunpowder Creek stream network.

Analysis of the pollutant loads and yields provides a better understanding of the subwatersheds in most need of restoration efforts. Pollutant loads consider the flow data and the pollutant yields standardize the data across subwatersheds of different sizes. This allows for an understanding of which subwatersheds are contributing the most pollution by weight within the watershed. **Table 4-7** presents the subwatersheds ranked by projected annual loads. GPC 7.5 is the largest subwatershed (43.5 mi^2) and is downstream of all other sites with the exception of RDR 1.1; therefore, it is no surprise that GPC 7.5 has the highest annual loads for every pollutant, minus TSS. Alternatively, GPC 7.5 drops to a much lower ranking, for all criteria but NN, when calculating pollutant yield. The most developed subwatersheds (GPC 17.1-UNT 0.1 – 29.1% impervious and SFG 5.3-UNT 0.3 – 41.1% impervious) tend to have relatively high pollutant loads, as well as pollutant yields (with the exception of NN), and are illustrated in red text for easy comparison between **Table 4-7** and **Table 4-8**.

Table 4-7: Subwatersheds ranked from the greatest to the lowest projected annual loads [(a)]

PROJECTED ANNUAL LOADS									
E. coli (col/yr)		TSS (lb/yr)		TP (lb/yr)		TKN (lb/yc)		NN (lb/yr)	
GPC 7.5	1.58E+15	GPC 17.1-UNT	8,460,316	GPC 7.5	43,917	GPC 7.5	147,552	GPC 7.5	84,810
GPC 17.1-UNT	5.51E+14	GPC 7.5	4,634,738	GPC 17.1-UNT	15,388	GPC 17.1-UNT	36,328	FWF 0.8	8,269
FWF 0.8	1.72E+14	SFG 5.3-UNT	1,549,534	FWF 0.8	9,093	FWF 0.8	28,711	LOB 0.5	7,938
LOB 0.5	1.36E+14	FWF 0.8	1,231,613	SFG 5.3-UNT	4,088	SFG 5.3-UNT	8,683	GPC 17.1-UNT	5,713
SFG 5.3-UNT	1.17E+14	LOB 0.5	521,995	LOB 0.5	2,398	LOB 0.5	6,302	RDR 1.1	3,628
RDR 1.1	6.26E+13	RDR 1.1	235,259	RDR 1.1	1,845	RDR 1.1	5,800	SFG 5.3-UNT	2,239

[(a)] GPC 17.1-UNT 0.1 has been shortened to GPC-17.1 UNT in this table. SFG 5.3-UNT 0.3 has been shortened to SFG 5.3-UNT in this table.

Table 4-8 presents the subwatersheds ranked by pollutant yields, which confirms that the most developed headwater reaches of Gunpowder Creek (GPC 17.1-UNT 0.1 (3.8 mi^2) and SFG 5.3-UNT 0.3 (2.2 mi^2)) are estimated to contribute much greater amounts of bacteria and sediment per acre of watershed than the less developed portions of the watershed.

Table 4-8: Subwatersheds ranked from the greatest to the lowest yields [(a)]

POLLUTANT YIELD									
E. coli (col/yr/ac)		TSS (lb/yr/ac)		TP (lb/yr/ac)		TKN (lb/yr/ac)		NN (lb/yr/ac)	
GPC 17.1-UNT	2.24E+11	GPC 17.1-UNT	3,443.5	GPC 17.1-UNT	6.3	GPC 17.1-UNT	14.8	LOB 0.5	4.6
SFG 5.3-UNT	8.31E+10	SFG 5.3-UNT	1,099.1	FWF 0.8	3.3	FWF 0.8	10.5	GPC 7.5	3.0
LOB 0.5	7.87E+10	FWF 0.8	448.4	SFG 5.3-UNT	2.9	SFG 5.3-UNT	6.2	FWF 0.8	3.0
FWF 0.8	6.29E+10	LOB 0.5	300.8	GPC 7.5	1.6	GPC 7.5	5.3	GPC 17.1-UNT	2.3
GPC 7.5	5.67E+10	GPC 7.5	166.2	LOB 0.5	1.4	LOB 0.5	3.6	RDR 1.1	1.8
RDR 1.1	3.07E+10	RDR 1.1	115.1	RDR 1.1	0.9	RDR 1.1	2.8	SFG 5.3-UNT	1.6

[(a)] GPC 17.1-UNT 0.1 has been shortened to GPC-17.1 UNT in this table. SFG 5.3-UNT 0.3 has been shortened to SFG 5.3-UNT in this table.

Regulatory Status of the Waterway

A common pollutant of concern between KDOW's 303(d) list and the GCWI analysis is sediment. The developed headwaters in the main branch and the South Fork were also found to be the reaches with the greatest concerns.

As previously presented in Chapter 1, several portions of the Gunpowder Creek and South Fork Gunpowder Creek have been classified on the Kentucky 303(d) List of Impaired Waters for high levels of sediment, bacteria, and nutrients. Several commonalities exist between the KDOW list and the analysis presented throughout this chapter. For example, a common pollutant of concern is sedimentation/siltation, and two common suspected sources were bank destabilization and urban stormwater. The fact that KDOW's list identifies the developed headwaters along the main branch (GPC miles 15.4-21.6) and South Fork Gunpowder Creek (SFG miles 0 to 6.8) as the impaired reaches is consistent with the dominant findings from the GCWI analysis: with the exception of Long Branch, impairments tend to be most problematic in the headwater reaches that drain the portion of the watershed with the most development. This consistency provides supporting information for the GCWI to prioritize the headwaters of Gunpowder Creek and the South Fork Gunpowder Creek as the subwatersheds in most need of immediate action. In addition to the segments of the Gunpowder streams listed as impaired, KDOW has TMDLs created for biological oxygen demand and ammonia for the airport and is in the process of developing a TMDL for *E.coli* for the entire watershed.

Feasibility Factors

Review of the analytical data as well as the regulatory status of the Gunpowder Creek waterways confirms that the most developed subwatersheds should be prioritized for targeted implementation. However, other feasibility factors should also be considered when evaluating the data. Analysis of the monitoring data from the rural and mixed watersheds illustrates that the pollutants of concern and potential sources are different than that of the developed watersheds. The most important feasibility factor included comparison of watershed inventory data to pollutant loads. Other feasibility factors, such as Planning and Zoning regulatory jurisdiction, did not directly impact one subwatershed over another because jurisdictions covered the entire watershed or large parts of several subwatersheds. The cumulative impact of all the factors presented in this section does not change the potential for successfully implementing BMPs in the most impaired subwatersheds. Reference Chapter 6 for more detailed information relating to the feasibility factors.

Comparison of Watershed Inventory Data to Pollutant Loads

The monitoring locations can be organized into three types of land use based on watershed imperviousness, including developed watersheds (20-40% impervious) on the eastern side of the Gunpowder Creek Watershed, rural watersheds (2-4% impervious) on the southern portion of the Gunpowder Creek Watershed, and mixed (developed/rural, 12% impervious). These types of landuses also come with different types of stakeholder groups which affect the feasibility factors addressed in Chapter 5. There are not specific social or cultural factors within the subwatersheds that impact prioritization.

Differing land use can be related to certain pollutants of concern during both wet and dry weather and provided some inference regarding potential sources of pollution. South Fork Gunpowder Creek and the headwaters of Gunpowder Creek have been classified as developed; Riddles Run and Long Branch are classified as rural; and Fowlers Fork is considered mixed. Sampling locations, and their related development category, are illustrated in Figure 4-30. The most impervious areas of the watershed, which are located in the headwaters, have been extremely detrimental on the health of these stream systems. In many watersheds the headwaters are typically the most pristine and healthy stream reaches, but due to the increased development in the Gunpowder Creek Watershed headwaters, these stream reaches have been degraded. Therefore, these subwatersheds have been prioritized as the areas of the watershed in most need of stormwater mitigation including both structural and nonstructural BMPs. The sections below summarize the most concerning and least concerning pollutants for the three watershed types, along with likely sources and possible causes.

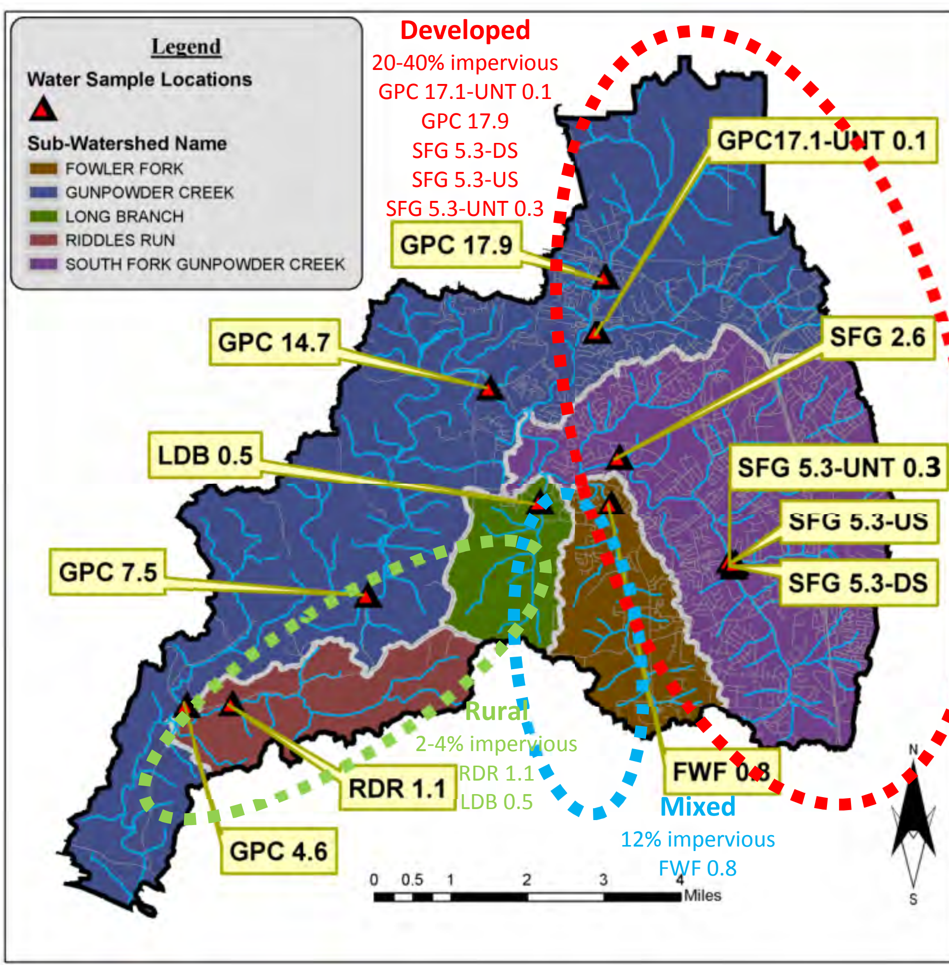


Figure 4-30: Sampling sites classified by primary land use (developed, mixed, and rural)

1. Developed Watersheds

First, the developed watersheds (20-40% impervious), located within the headwaters of Gunpowder Creek and South Fork Gunpowder Creek on the eastern side of the watershed, had high loadings of bacteria and suspended sediment during wet weather (Figure 4-31). The predominant cause of high bacteria and TSS loadings is likely excess stormwater runoff because these same developed sites have fewer issues with dry weather bacteria. This tends to indicate that the developed sites are primarily impacted by stormwater runoff and nonpoint source pollution. Nonpoint source pollution results from everyday activities such as littering, pet waste, fertilizing the lawn, land clearing for development, and agricultural activities, all allowing pollutants generated by these activities to be washed into the stormwater collection system and eventually flowing into our waterways. As discussed in *Comparisons of Parameter Concentrations*, some of the developed sites and high loadings of specific conductance during dry weather, especially the SFG 5.3- UNT 0.1 sampling location. This may be attributable to natural sources; however, this subwatershed also had a high density of KPDES dischargers and may be indicative of a direct dry weather discharge with potentially-high dissolved solids.

Most Concerning	Likely Sources	Possible Causes
Bacteria (Wet Weather)	Stormwater runoff	Animal Waste
Suspended Sediment (Wet Weather)	Bank Erosion	Erosive Flows Unvegetated Banks
Specific Conductance (Dry Weather)	Point Sources?	Point Source Treatment

Least Concerning	Likely Reason	Prevented Pollutant
Bacteria (Dry Weather)	Sanitary Sewers	Human Waste

Figure 4-31: Water quality results in developed watersheds

2. Rural Watersheds

Next, rural watersheds (2-4% impervious) tended to be impacted more during dry weather, suggesting that direct sources of pollutants (e.g., septic systems and/or animals grazing in the stream) may be the predominant issue in these watersheds (Long Branch [LOB 0.5] and Riddles Run [RDR 1.1]). The most concerning pollutants identified in the rural watersheds included high levels of bacteria, nutrients, and specific conductance, all during periods of dry weather (Figure 4-32). This suggests potential pollution from sources, such as septic systems, livestock in the stream, and/or point sources such as KPDES permitted discharges.

Most Concerning	Likely Sources	Possible Causes
Bacteria & Nutrients (Dry Weather)	Septic Systems Animal (direct)	Septic maintenance Cattle/Horse Fencing
Specific Conductance (Dry Weather)	Septic Systems Point Sources?	Septic maintenance Point Source Treatment

Least Concerning	Likely Reason	Prevented Pollution
Nutrients (Wet Weather)	Fertilizer Management	Excess Algae

Figure 4-32: Water quality results in rural watersheds

3. Mixed Watersheds

Most Concerning	Likely Sources	Possible Causes
Bacteria (Wet Weather)	Stormwater runoff	Animal Waste
Specific Conductance (Dry Weather)	Septic Systems Point Sources?	Septic maintenance Point Source Treatment
Nutrients (Dry Weather)	Septic Systems Animal (direct)	Septic maintenance Cattle/Horse Fencing

Least Concerning	Likely Reason	Prevented Pollutant
Bacteria (Dry Weather)	Sanitary Sewers	Human Waste

Figure 4-33: Water quality results in mixed watersheds

Finally, mixed watersheds (rural/developed, 12% impervious – Fowlers Fork) showed signs of both dry-weather and wet-weather pollution. The most concerning pollutants, as summarized in Figure 4-33, include bacteria during wet weather as well as specific conductance and nutrients during dry weather. The least concerning pollutant was bacteria during dry weather. These results provide insights on some potential sources, such as stormwater runoff, septic systems, and/or animal waste.

Regulatory Matters

Regulatory matters should not impact the prioritization of subwatersheds because most of Gunpowder Creek is under the jurisdiction of the same agencies. SD1 and the City of Florence are responsible for the stormwater networks. KDOW, which is guided by the USEPA, governs the KPDES permits and overall condition of the waterways. The city and county ordinances are the same in all of the Gunpowder subwatersheds; and therefore, the ordinances do not impact prioritization. Other than the 303(d) status discussed under the section titled *Regulatory Status of the Waterway*, there is not any spatial prioritization regarding regulatory matters. Reference *Chapter 6.1 BMP Feasibility* for additional information regarding the regulatory matters in the watershed and how they impact successful implementation.

Stakeholder Cooperation

From vested stakeholder agencies who donate their time and resources to the general public, the Gunpowder Creek Watershed has the support of stakeholders who are interested in restoring the Gunpowder Creek. The GCWI Steering Committee involves several different public agencies including KDOW representatives. Throughout the entire project, the public has been actively involved by attending meetings and providing feedback regarding pollutants of concern and prioritizing problems and solutions. The GCWI has hosted 6 public meetings at various locations throughout the watershed, and many of these public meetings had 50 to 100 people in attendance. At these meetings the public has provided valuable insights regarding the most concerning problems and potential solutions. Many local citizens are worried about development and the associated stormwater runoff and flooding issues. Therefore, the developed subwatersheds have been prioritized as part of the Watershed Plan. Stakeholders understand that this is a problem and local landowners seem to be supportive in addressing the issues in all of the subwatersheds. The only exception to this seems to be somewhat of a lack of access in Long Branch, which could limit the ability of GCWI to implement solutions in that rural watershed. Reference Chapter *6.1 BMP Feasibility* for additional information regarding stakeholder involvement and cooperation in the watershed.

Political Will

Support from local officials impacts the entire watershed. Therefore, one particular subwatershed is not more influential than others and cannot be prioritized. Reference *Chapter 6.1 BMP Feasibility* for additional information regarding stakeholder involvement and cooperation in the watershed.

Available Funding

At this time, the GCWI does not have reasons to suspect that there are particular subwatersheds in which they might be able to garner more funds than others. GCWI is working to increase the stewardship of private companies located in the watershed in hopes to build partnerships and garner support for BMP implementation. Flood control master planning by SD1 and Florence typically result in large investments in a particular watershed and is discussed further in *Chapter 6.1 BMP Feasibility*.

Areas of Local Concern

Local citizens have expressed concern about development and the associated stormwater runoff and flooding issues. Flooding issues are commonly discussed at Fiscal Court meetings, and particular problem areas include Whispering Trails in developed headwater reaches of Fowler Fork, Conner Road in the developed headwater reaches of upper Gunpowder, and locations along the developed headwater reaches of the South Fork Gunpowder. As such, the developed headwaters of the Gunpowder Creek have been prioritized because these areas are of concern to the public. Additionally, there are plans for future development throughout several areas of the watershed, particularly in the Fowler Fork subwatershed as well as the South Fork Gunpowder subwatershed. Reference *Chapter 6.1 BMP Feasibility* for additional information regarding areas of local concern throughout the watershed.

Existing Priority Status

Past work has led to resources being spent in the Fowlers Fork subwatershed. With the goal of improving flood control, SD1 recently completed a Fowler Fork Master Plan. Additionally, the City of Florence is currently planning a flood control project behind Kroger/Florence Mall in the headwaters of the Gunpowder Creek called Pheasant Watershed. Lastly, there are several existing and proposed federal, state, and local water quality efforts that exist through entities such as USDA, USEPA, KDOW, USACE, etc. Reference Chapter *6.1 BMP Feasibility* for additional information regarding existing priority status throughout the watershed.

Watershed Management Activities

All of the watershed management activities that exist throughout the Gunpowder Creek Watershed are watershed wide. Therefore, the GCWI cannot prioritize any subwatershed over the others because of watershed management activities. Reference *Chapter 6.1 BMP Feasibility* for additional information regarding watershed management activities in the watershed.

Monitoring Considerations

The holistic monitoring program has not only been a guide in understanding problems and pollutant sources, but if continued, can help to track the success of the implementation efforts proposed in Chapters 5 & 6. It can also help to make BMP implementation more adaptable to conditions in the streams and changing land uses, sources, and the extent of stormwater mitigation throughout the watershed.

4.2.3 Phase 2 - Analysis

As previously mentioned, GCWI did not add sampling locations for Phase 2 monitoring in 2012 due to the project budget and KDOW-approved QAPP, that were developed before the *Watershed Planning Guidebook for Kentucky Communities* was released. Therefore, the Phase 2 monitoring program involved resampling all Phase 1 monitoring locations. Due to the nature of this monitoring program, the Phase 2 data analysis is presented as an integrated approach with Phase 1 data and included in sections *4.2.1 - Phase 1 and 2 Combined Data Analysis* and *4.2.2 - Phase 1 and 2 Combined - Prioritization*.

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

With the exception of additional monitoring locations for Phase 2 monitoring, the GCWI had the budget and resources needed to perform a detailed data analysis. 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.

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CHAPTER 5

Finding Solutions

Gunpowder Creek Watershed Plan

Prepared by the

Gunpowder Creek Watershed Initiative

December 2014

Chapter 5: Finding Solutions

5.1 Overview of Best Management Practices

Methods which aim to mitigate water quality impairments via the efficient and effective use of available resources are referred to as Best Management Practices (BMPs). As outlined in the *Watershed Planning Guidebook for Kentucky Communities* (KDOW, 2010), there are two major categories of BMPs: structural and non-structural. Structural practices refer to those which are built on the ground and require construction, installation and maintenance, such as fencing, retention ponds, etc., while non-structural BMPs include less tangible practices, such as public education on water quality, stormwater ordinances, etc. A watershed management plan should include provisions for the implementation of both structural and non-structural BMPs, as they are equally important and often work best in tandem. Structural BMPs aim to treat targeted impairments in specific locations, while non-structural BMPs help to ensure the sustainability of water quality throughout the watershed and can improve the effectiveness and longevity of installed structural BMPs. This chapter will provide information on a range of BMPs, including the impairments they are designed to treat and the land uses for which they are expected to be most effective. **Figure 5-1** lists some examples of BMPs that may be used within the Gunpowder Creek watershed. In this section several details regarding BMP practices in the watershed are presented, including BMP options for specific land uses, regulatory programs, and education.

Healthy riparian zones help filter sediments and nutrients from runoff, stabilize streamside soils, and provide shade, food, and habitat for the aquatic systems and aquatic life of a waterway.

Rain gardens are shallow, depressed gardens that collect stormwater runoff from rooftops or other hard surfaces. These rain gardens help filter pollutants and act as beautiful landscape features.

Rain barrels collect and store stormwater runoff from rooftops. This water can then be used to irrigate gardens and lawns.

Fencing livestock out of streams and providing alternative water results in pathogen reduction, stream bank protection, and clean water for livestock.


Seeding or covering bare soil with mulch, blankets, mats, and other erosion prevention products as soon as possible is the cheapest way to prevent erosion. Grass seeding alone can reduce erosion by more than 90%.

Figure 5-1: Examples of structural BMPs

5.1.1 Best Management Practice Options for the Gunpowder Creek Watershed for Specific Land Uses

Prior to delving into the applicable BMPs for the Gunpowder Creek Watershed, it is worth discussing the unique circumstances of this watershed. As discussed in Chapter 4, the biggest problem within the watershed is inadequately managed stormwater runoff, which creates erosive flows that in turn lead to hydromodification concerns, including channel erosion, high concentrations of TSS, and other pollutant issues within the stream. The hydromodification problem is nearly watershed-wide but is most prominent in the developed watersheds. Due to the existing stream conditions and volume of stormwater generated from development in South Fork Gunpowder, it has been identified as the highest priority subwatershed.

As the Gunpowder Creek Watershed is an unconventional, large watershed that incorporates many land uses and anticipated continued growth, the priority subwatersheds may change as opportunities arise. To utilize spending as efficiently and effectively as possible, other subwatersheds may become higher priority during the implementation phase. The Riddles Run Subwatershed currently has a lot of agricultural activities; the Lower Gunpowder Creek Subwatershed is currently undeveloped; and as previously mentioned the South Fork Gunpowder is highly developed. Any of these subwatersheds, with the right combination of identified projects and additional funding sources may become the "low-hanging fruit;" and therefore, these three subwatersheds have been identified as GCWI's priority subwatersheds. We anticipate 319(h) grant funding to serve as a catalyst throughout the watershed, with the goal of combining the GCWI efforts with others' to improve stream benefits more than would be accomplished by GCWI alone.

The Watershed Planning Guidebook for Kentucky Communities (KDOW, 2010) provides a list of structural and non-structural BMPs categorized by land use. Categorization is based on the type of practice (structural vs. non-structural) and its associated land use. The data collection efforts and analysis described in Chapters 3 and 4, along with extensive stakeholder involvement and public input has allowed for a more specific and prioritized listing of potential BMPs for each land use, which will be addressed further in this chapter and in Chapter 6.

Many BMPs that help to prevent and mitigate water quality impairments have already been installed/implemented throughout the Gunpowder Creek Watershed, for example, conventional stormwater detention basins. However, the impairments documented in Chapter 4 indicate that the existing BMPs have not adequately protected stream integrity. Continued growth and urbanization, especially near the headwaters of Gunpowder Creek, Fowler's Fork, and South Fork Gunpowder Creek, are anticipated to further impair stream health. A strategic, watershed-scale BMP plan should yield benefits that promote stream stability, water quality, and healthy aquatic habitat. Below is a summary of types of BMPs, with some basic information on their current and potential uses within the watershed.

Stormwater

Stormwater BMPs have conventionally been designed for management of runoff for flood control with a primary focus on water quantity. This is typically achieved through the combination of storage and controlled release. Stormwater quantity-focused BMPs can have a positive impact on pollutant removal as well, through the settling out of particulate matter, extended exposure to sunlight, and nutrient uptake via contact with vegetation. These water quality benefits can be enhanced by creating increased residence time, infiltration, and other treatment processes in the design of BMPs, for example, building bioinfiltration basins (**Figure 5- 2**), wetlands, or extended/optimized detention basins as opposed to conventional detention basins.

Figure 5-2: Bioinfiltration basin with native vegetation designed by Strand Associates to promote a more natural flow regime (Photo by Chris Rust)

Another broad-scale stormwater BMP that is currently being used in the Gunpowder Creek Watershed is flood control master planning. Even with an estimated 535 existing detention basins within the watershed, flooding is perceived to be problematic in several areas. The City of Florence and the Sanitation District No. 1 of Northern Kentucky (SD1) routinely plan and conduct large efforts to improve regional flood management. These efforts typically require extensive hydrologic and hydraulic monitoring and modeling and tend to be expensive in comparison to the Gunpowder Creek Watershed Plan BMP analysis. For example, the costs of two recently performed studies commissioned by SD1 (Fowler Fork Master Plan) and the City of Florence (Pheasant Watershed Study) cost ~$175,000 and ~$85,000, respectively, for the planning alone. These costs do not include the costs to construct the recommendations. Stormwater BMPs will be implemented where opportunities arise. However, the implementation efforts for these types of BMPs will be concentrated in the developed subwatersheds, particularly the priority subwatershed of South Fork Gunpowder.

Agricultural

Agricultural BMPs include practices that are designed to mitigate the effects of pesticides, fertilizers, animal waste and other potential pollutants that can be associated with farming and may be harmful to the streams. They aim to maintain or even enhance the productivity of agricultural land, while benefitting water quality, channel stability, and/or habitat. Some BMPs that are currently in use within the Gunpowder Creek Watershed are livestock exclusion fencing, rotational grazing with pasture renovations, and animal feeding buffers. Currently, farmers within the Gunpowder Creek Watershed have available incentive programs for manure management and riparian buffer strips, as well as the Ohio River Basin Water Quality Trading Pilot Project, which encourages nutrient trading in collaboration with the Electric Power Research Institute and the American Farmland Trust. Additionally, the Environmental Quality Incentives Program (EQIP) run by the U.S. Department of Agriculture (USDA) incentivizes environmental stewardship by offering financial and technical assistance to those farmers that implement conservation practices that address natural resource concerns, such as conservation tillage, nutrient management, conservation coverage, field buffers, and riparian buffer strips. Interested farmers should contact NRCS or BCCD for more information. As the priority agricultural subwatershed, the GCWI will focus implementation of these types of BMPs in the Riddles Run Subwatershed.

Construction

These BMPs are designed to prevent sediment and other pollutants from leaving construction sites. Practices include silt fences, check dams, temporary entrances, erosion control blankets, inlet and outlet protection, etc. The *Kentucky Erosion Prevention and Sediment Control Field Guide* (**Figure 5-3**), produced by KDOW (2004), contains guidance for controlling erosion and sedimentation associated with construction sites. The University of Kentucky has also released a publication entitled *Best Management Practices (BMPs) for Controlling Erosion, Sediment, and Pollutant Runoff from Construction Sites* that provides similar guidance (UK, 2009).

Figure 5-3: Kentucky's Field Guide to Erosion Prevention and Sediment Control (KDOW)

As part of their Storm Water Rules and Regulations (2011), SD1 requires BMPs on all active construction sites that are larger than one acre or part of a larger development. Reviews of submitted plans and site inspections are completed to ensure compliance, per their Kentucky Pollutant Discharge Elimination Program (KPDES) Storm Water Management Plan (SWMP) (SD1, 2010). The City of Florence has an inspection program as well, which conducts site visits to check on erosion protection BMPs. As one of the fastest growing counties in Kentucky prior to the 2007-2011 economic recession, diligence regarding construction BMPs is extremely important for water quality in Gunpowder Creek, and SD1 and the City of Florence's emphasis on proper erosion protection and sediment control at construction sites is anticipated to continue throughout the entire Gunpowder Watershed.

Forestry

Forestry BMPs aim to protect downstream water bodies from runoff polluted by forestry activities and to promote the sustainability of forestry resources. Landowners may look to *The Kentucky Forest Landowner's Handbook* for guidance on good forestry practices that protect the value of the forest and its natural resources such as streams and wildlife (MACED, 1998). Forestry is not considered to be a dominant activity in the watershed; however, numerous local experts have identified the region's tree canopy deficiency as a cause for concern, from stormwater runoff and riparian shade to hillslope stability and the urban heat island effect.

GCWI is working with resources from the Kentucky Division of Forestry, the Northern Kentucky Urban Forestry Council, and the Boone County Urban Forest Commission to:

1) Understand if any improvements can be made on local forestry practices, and
2) Facilitate partnerships to promote reforestation, especially along stream riparian zones and on steep slopes.

As an initial step in the riparian/reforestation prioritization, BCCD's joint agency meeting in March 2014 included a panel discussion on forestry. During this meeting they discussed the local need for forestry conservation and decided to work this issue into BCCD's long range plans. Additionally, riparian reforestation will be a central component of the forestry conservation efforts.

Onsite Wastewater Treatment

Bacteria and specific conductance impairments observed during dry weather periods within the Gunpowder Creek Watershed are an indication of potentially faulty septic and/or sanitary sewer systems. Onsite wastewater treatment BMPs can help to prevent these issues by helping to ensure proper installation and maintenance of these systems. Some available online resources include 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).

Both sanitary sewers and septic systems are present within the Gunpowder Creek Watershed. Less than seven percent of the parcels in the Gunpowder Creek Watershed, or an estimated 1,527 parcels, are assumed to be serviced by septic systems, as determined by those parcels with a building that do not have an active sanitary account with SD1 (Kaeff, 2014a, Pers.Comm.). **Figure 5-4** presents the locations of these septic systems throughout the watershed, and it can be seen that the majority of these parcels are in the undeveloped and rural subwatersheds, which include Lower Gunpowder Creek, Middle Gunpowder Creek, Long Branch, and Riddles Run. Faulty septic systems are regulated by the Northern Kentucky Health Department, which estimates that potentially up to ten percent of the septic systems in Northern Kentucky could be operating improperly. However, the health department does not have a record of failure rates specific to Boone County (LTI, 2009). Therefore, assuming that up to ten percent of the septic systems in the Gunpowder Watershed could be malfunctioning; approximately 153 systems could be working improperly throughout the watershed. Reference Table 5-1 for a breakdown of the approximate number of parcels served by septic systems as well as the number of potentially faulty septic systems. In regards to our priority rural and undeveloped subwatersheds where the septic systems are the most prevalent, 164 of the septic system parcels are located within Riddles Run (up to 16 of the septic systems could be faulty) and 43 of the septic system parcels are located within Lower Gunpowder (up to 4 of the septic systems could be faulty). The Northern Kentucky Health Department issues permits and conducts inspections on septic systems through its on-site sewage program.

Table 5-1: Parcels served by septic systems within the Gunpowder Creek Watershed and the number of potentially faulty septic systems by subwatershed

Subwatershed	Approximate Number of Parcels with Septic Systems	Number of Potentially Faulty Septic Systems[1]
Riddles Run[2]	164	16
Long Branch	98	10
Upper Gunpowder	103	10
Middle Gunpowder	489	49
Lower Gunpowder[3]	43	4
South Fork Gunpowder	494	49
Fowlers Fork	136	14

[1]The number of potentially faulty septic systems is likely an overestimate because the Northern Kentucky Health Department expects that up to ten percent of the septic systems (LTI, 2009) throughout the Northern Kentucky region could be faulty.

[2]Riddles Run is the priority rural subwatershed.

[3]Lower Gunpowder is the priority undeveloped subwatershed.

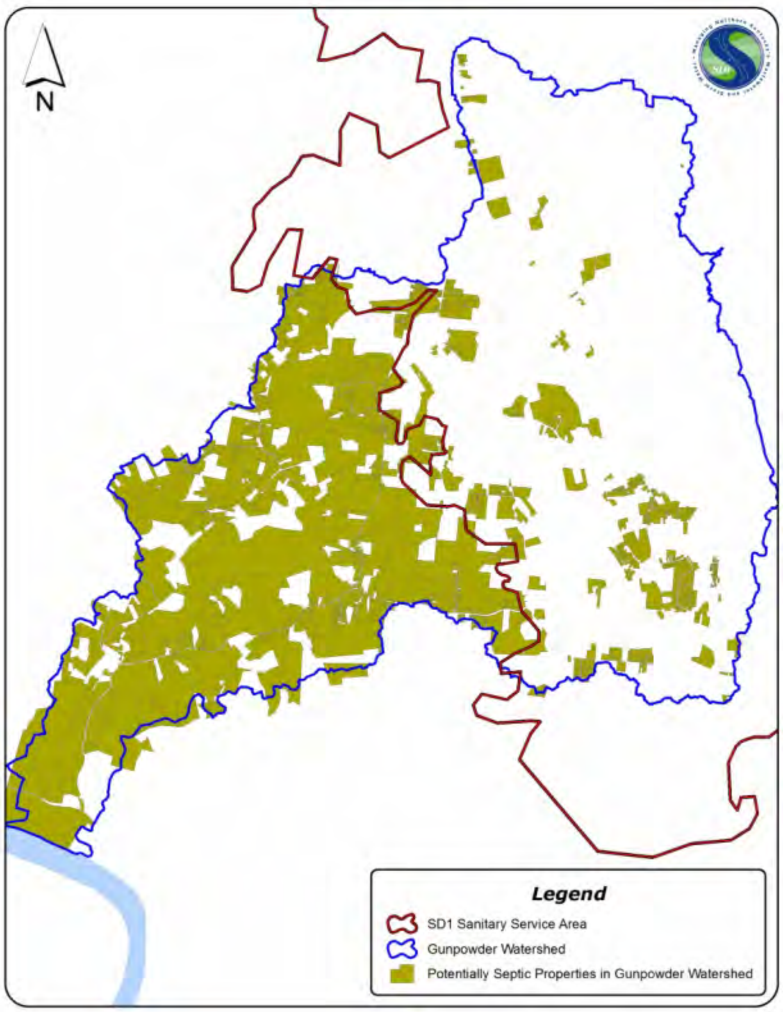

Figure 5-4: Septic systems within the Gunpowder Creek Watershed (Kaeff, 2014, Pers.Comm.)

As mentioned in Chapter 4, the largest source of bacteria is expected to be stormwater runoff. However, failing septic systems could be a contributor to the bacteria issues in the rural subwatersheds, as *E.coli* concentrations were elevated during dry, base-flow conditions. Onsite wastewater treatment BMPs and septic system improvement programs could be implemented in the prioritized undeveloped and rural subwatersheds, Lower Gunpowder and Riddles Run. Furthermore, a benefit to urbanization includes the installation of sanitary sewers. It should be noted that any efforts related to faulty septic systems should only occur in areas where development is not likely to occur in future years. As it is not possible to know exactly where future development will occur, anticipated development, indicated by darker gray shading in **Figure 5-5**, seems more likely in the headwater portions of the watershed. GCWI will coordinate with SD1 to better understand any plans for future expansion of SD1's sanitary sewer service area.

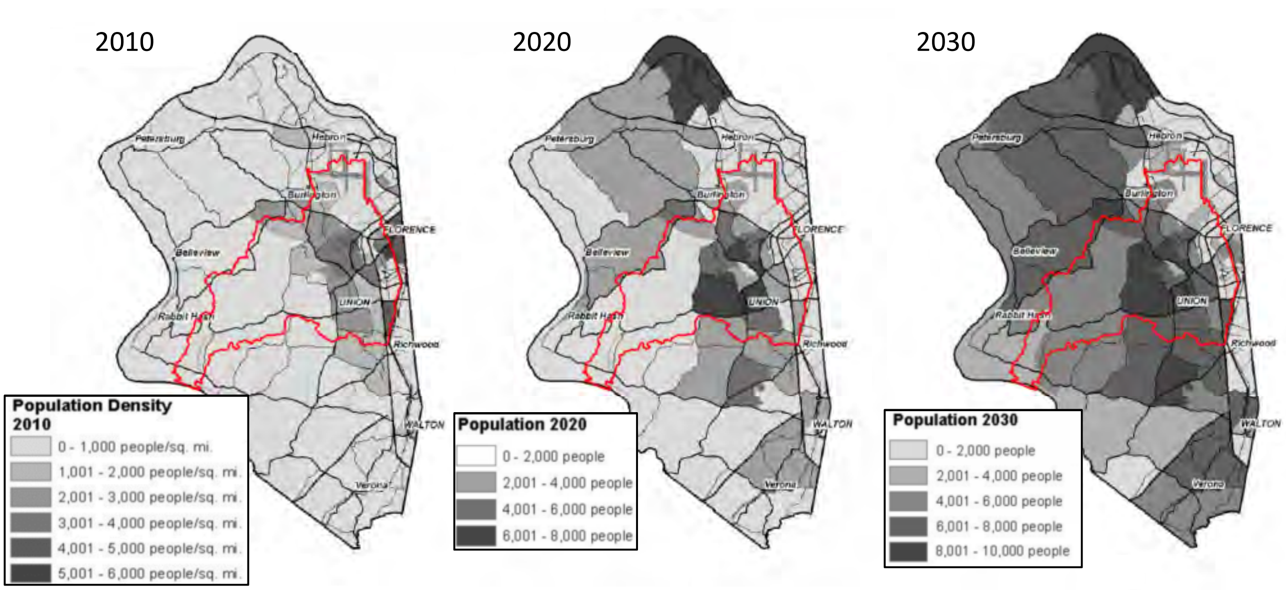

Figure 5-5: Development progression in Boone County from 2010 to 2030 (BCCD, 2012)

5.1.2 Regulatory Programs

Kentucky currently has several regulatory programs that enforce general requirements to promote water quality. It is important to understand the existing regulatory programs and how such programs might impact water quality throughout the Gunpowder Creek Watershed. It is also important to ensure coordination to avoid implementation overlap with regulatory requirements and maximize resources and BMP effectiveness.

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

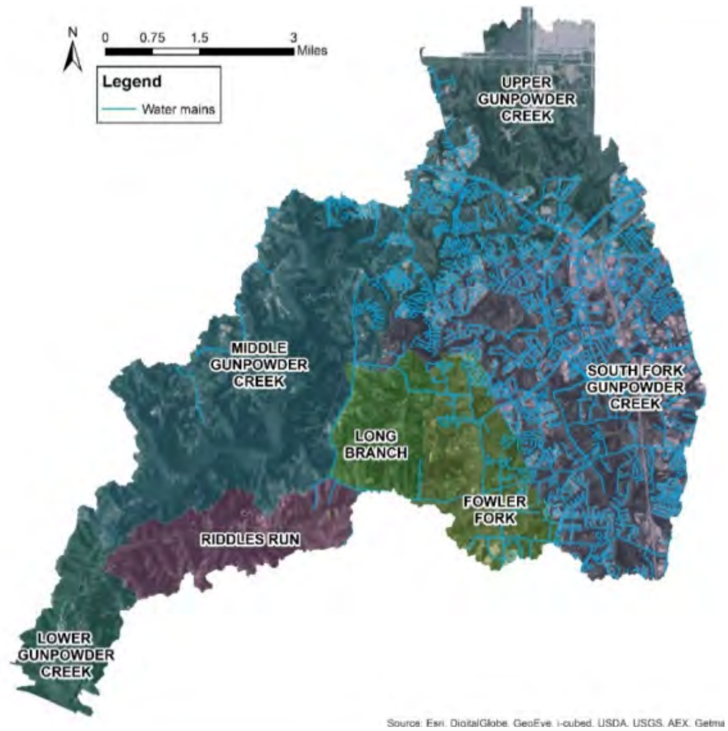

Figure 5-6: Water main locations within Gunpowder Creek

The source of the public water supplies in the Gunpowder Creek Watershed is the Ohio River via the Boone County Water District. Although the confluence of Gunpowder Creek and the Ohio River is downstream of the local water treatment plant intake, the January 2014 spill of 4-methylcyclohexane methanol in the Elk River upstream of Charleston, West Virginia reminds us of the impacts that poor watershed stewardship can have on drinking water supplies. There are countless communities downstream on the Ohio and Mississippi Rivers whose water supplies could be affected by poor watershed stewardship in Gunpowder Creek. More locally, information indicates that several rural areas in the Gunpowder Creek Watershed still rely on rural water sources such as wells, cisterns, or delivery. This includes the rural, undeveloped subwatersheds of Lower Gunpowder Creek, Riddles Run, and the majority of Long Branch and Middle Gunpowder Creek. For anyone on a well, poor watershed stewardship could directly impact their source water **Figure 5-6** highlights the locations within Gunpowder Creek that are serviced by public water supplies.

Agriculture Water Quality Plans

All agriculture and silviculture farms on ten or more contiguous acres are required to develop and implement water quality plans (KDOW, 2010). Agricultural agencies, extension offices, and conservation districts can provide assistance to farmers to help them develop and implement plans that are specific to their farms and comply with the Kentucky Agriculture Water Quality Act. The goal of the plans is to prevent or address any potential water quality impacts that would be created by the farming practices. BCCD reports that there are 102 water quality plans, along with 553 certifications on file at their offices. BCCD plans to coordinate with the farmers and work together to evaluate and review the quality of these plans.

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

Over the last couple centuries, wetland loss and degradation has been a serious issue across the nation. In the contiguous United States over half of the original wetlands have been developed or converted to other uses (EPA, 2013). More specifically, between the 1780s and 1980s the EPA has reported that on average the contiguous United States was losing wetlands at a very rapid rate of approximately 60 acres every hour (Dahl, 1990). In recent decades the USEPA and the US Army Corps of Engineers have implemented programs to protect existing wetlands and encourage wetland restoration. Currently, streams and wetlands are federally protected jurisdictions, and construction activities within their boundaries require both a Federal 404 permit from the US Army Corps of Engineers and a State 401 water quality permit from KDOW. Permanent impacts typically require commensurate restoration of degraded streams or construction of new wetlands and/or fees to be paid in lieu of restoration. The fees fund a stream and wetland restoration program that is directed by the US Army Corps of Engineers and administered locally by the Northern Kentucky Stream and Wetland Restoration Program at Northern Kentucky University's Center for Environmental Restoration (CER). The CER has been very successful in restoring wetlands and stream systems throughout Northern Kentucky. As an active partner in the Gunpowder Creek Watershed Plan, the CER has funded and directed the restoration of several streams and wetlands in the region (**Figure 5-7**). There are currently approximately 0.89 square miles of wetlands throughout the Gunpowder Watershed. The approximate area of wetlands in each of the subwatersheds is summarized in **Table 5-2**, and the number of wetlands that have been disturbed is unknown. However, the GCWI has no reason to suspect that the Gunpowder Creek Watershed has been immune from wetland loss, as experienced throughout the rest of the nation. The GCWI plans to continue to work with the CER to preserve these wetland areas and promote the restoration of wetlands throughout the priority subwatersheds. Furthermore, the GCWI is planning to implement benchfull wetlands as a stormwater BMP to help mitigate the erosive flow regime.

Figure 5-7: Native riparian restoration zone at Boone Woods Park as a part of the stream and wetland mitigation project by NKU CER (Photo by Bob Hawley)

Table 5-2: Wetland areas within the Gunpowder Creek Watershed by subwatershed

Subwatershed	Approximate Wetland Area (square miles)
Riddles Run (upstream of RDR 1.1)	0.02
Long Branch (upstream of LOB 0.5)	0.03
Upper Gunpowder (upstream of GPC 17.1-UNT 0.1)	0.05
Middle Gunpowder (upstream of GPC 4.6)	0.36
Lower Gunpowder	0.17
South Fork Gunpowder (upstream of SFG 2.6)	0.21
Fowlers Fork (upstream of FWF 0.8)	0.05

Regulations for Floodplain Construction

Floodplains are an important part of maintaining overall stream health. These areas serve as a natural filter strip for overland flow that drains to the stream, settling out particles in stormwater runoff. It is beneficial to keep construction activities and development outside the floodplain so that these natural processes can occur unhindered. Construction within Kentucky's floodplain areas typically requires a permit from the KDOW Floodplain Management Section of the Surface Water Permits Branch. The Gunpowder Creek Watershed has 2.9 square miles of area that lies within the 100-year floodplain, with 0.36 square miles being located within South Fork Gunpowder (nearly 54% of the total subwatershed area). Riddles Run has only 0.10 square miles of 100-year floodplain area (2%), whereas Lower Gunpowder Creek has 1.07 square miles (34%). Since March 2003, KDOW has received 48 permit applications for activities within the floodplain in the Gunpowder Creek Watershed. South Fork Gunpowder Subwatershed has had the most with 12 applications, Riddles Run has had two applications, and Lower Gunpowder Creek has had two applications. There are three currently effective floodplain permits: one in the South Fork Gunpowder Subwatershed, one in the Long Branch Subwatershed, and one in the Riddles Run Subwatershed.

Certain BMPs, such as benchfull wetlands, may be useful to implement within a floodplain, yet may require a permit. GCWI plans to evaluate the feasibility of obtaining a single, generic permit for these activities to expedite the process. Whereas most projects completed in a floodplain would exacerbate flooding issues, applicable BMPs would improve the conditions in the floodplain.

Facility Plans for Wastewater

SD1 is the operator of the regional wastewater treatment plants and maintains all of the facility plans. SD1 is an active partner on the GCWI Steering Committee and SD1's plans for sewer line extensions, treatment plant upgrades, etc. are widely discussed in the local media and with other members of the Steering Committee. The area within the Gunpowder Creek Watershed that is serviced by these treatment plants is displayed in orange and yellow in **Figure 5-8**. As discussed in the *Onsite Wastewater Treatment* section above, outside this area is where septic systems are predominately found. Moving forward, GCWI plans to coordinate with residents, developers, SD1, and BCCD to ensure that any septic system outreach activities do not take place in areas where sewer line extensions are planned in the near future. Future outreach will continue to be coordinated as outreach programs are developed to optimize the locations of these activities, but will be directed towards the priority subwatersheds of Riddles Run and Lower Gunpowder Creek. SD1's Sanitary Sewer Rules and Regulations (2013) require the use of sanitary or combined sewers where available in addition to requiring abandonment of a private disposal system if a public system becomes available. Based on Boone County's *2010 Comprehensive Plan*, there is little anticipation that Lower Gunpowder Creek will be developed by 2030. Middle Gunpowder Creek and Riddles Run are also less likely to be developed than in headwater subwatersheds. GCWI hopes to promote conservation practices in the undeveloped portions of the watershed throughout Lower Gunpowder Creek.

As mentioned above, the Northern Kentucky Health Department has not reported any septic system failures specific to Boone County, and it is unknown at the current time where, if anywhere, plans exist to fix faulty septic or sewer systems. However, if onsite wastewater treatment BMPs are implemented in the watershed, GCWI would first evaluate this in the priority rural subwatershed, Riddles Run.

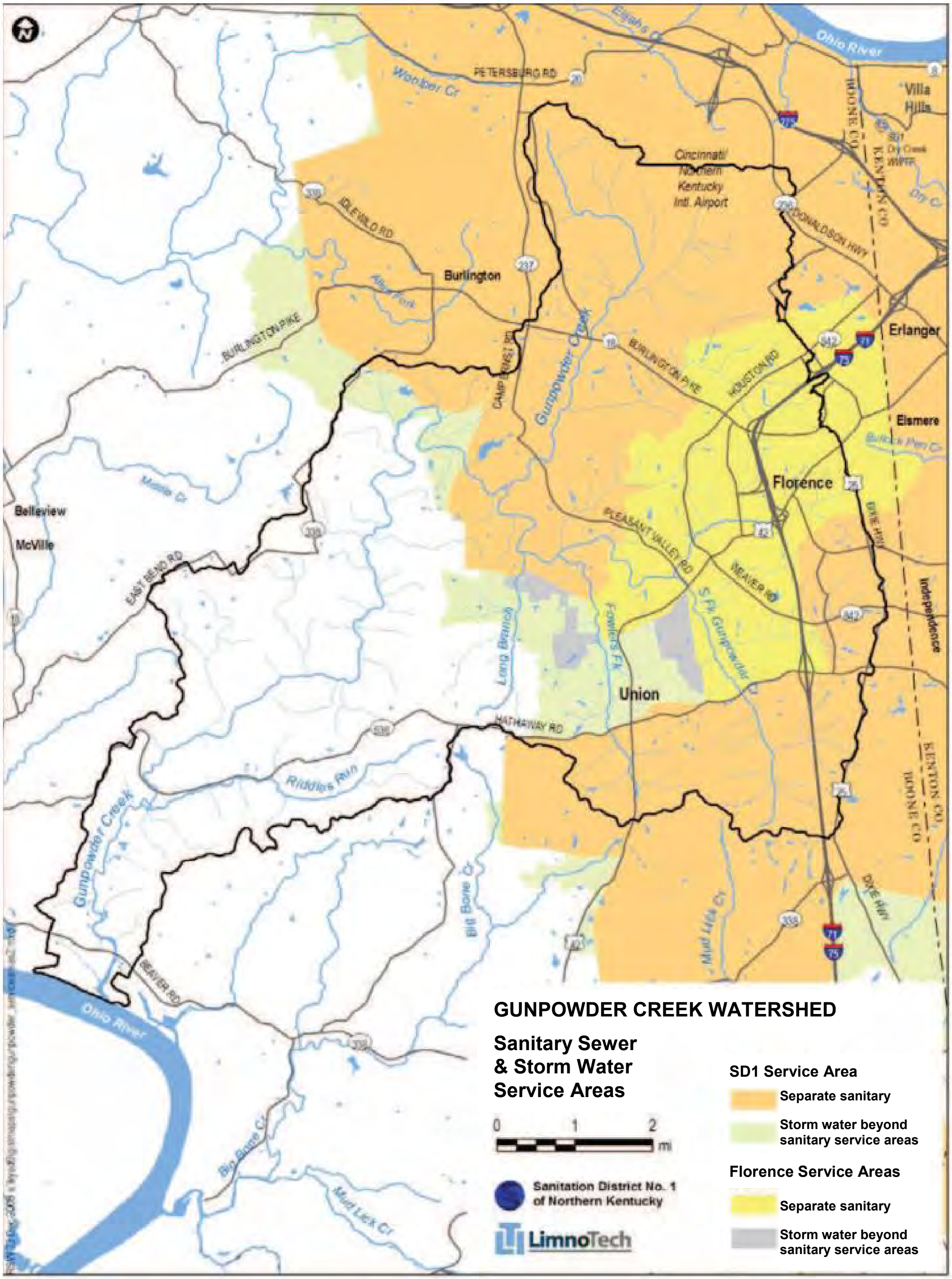

Figure 5-8: Sanitary sewer & stormwater service areas within the Gunpowder Creek Watershed (LTI, 2009)

Programs and Permits for Managing Wastewater Discharges

SD1 also maintains the corresponding permits and programs required to discharge the region's treated wastewater into the Ohio River. Including SD1's permitted discharges, there are 93 KPDES discharge locations along the 143 stream miles in the Gunpowder Creek Watershed. On average, this equates to one KPDES discharge ever 2 ¼ miles of stream; however, the density of KPDES discharges tends to be higher in the developed headwaters. For example, an unnamed tributary to South Fork Gunpowder Creek, located in the headwaters of the watershed, has the highest concentration of impervious surfaces of all study sites in the Gunpowder Creek Watershed (41% imperviousness), draining a stretch of the Interstate 71/75 corridor, along with a highly industrialized area along Weaver Road (KY-842), Empire Drive, Bluegrass Drive, and Dixie Highway (US-25). It also has more than double the density of KPDES permits than all other subwatersheds, with 13 permitted discharges over just 6.1 stream miles, averaging more than two KPDES discharges every mile (**Figure 5-9**).

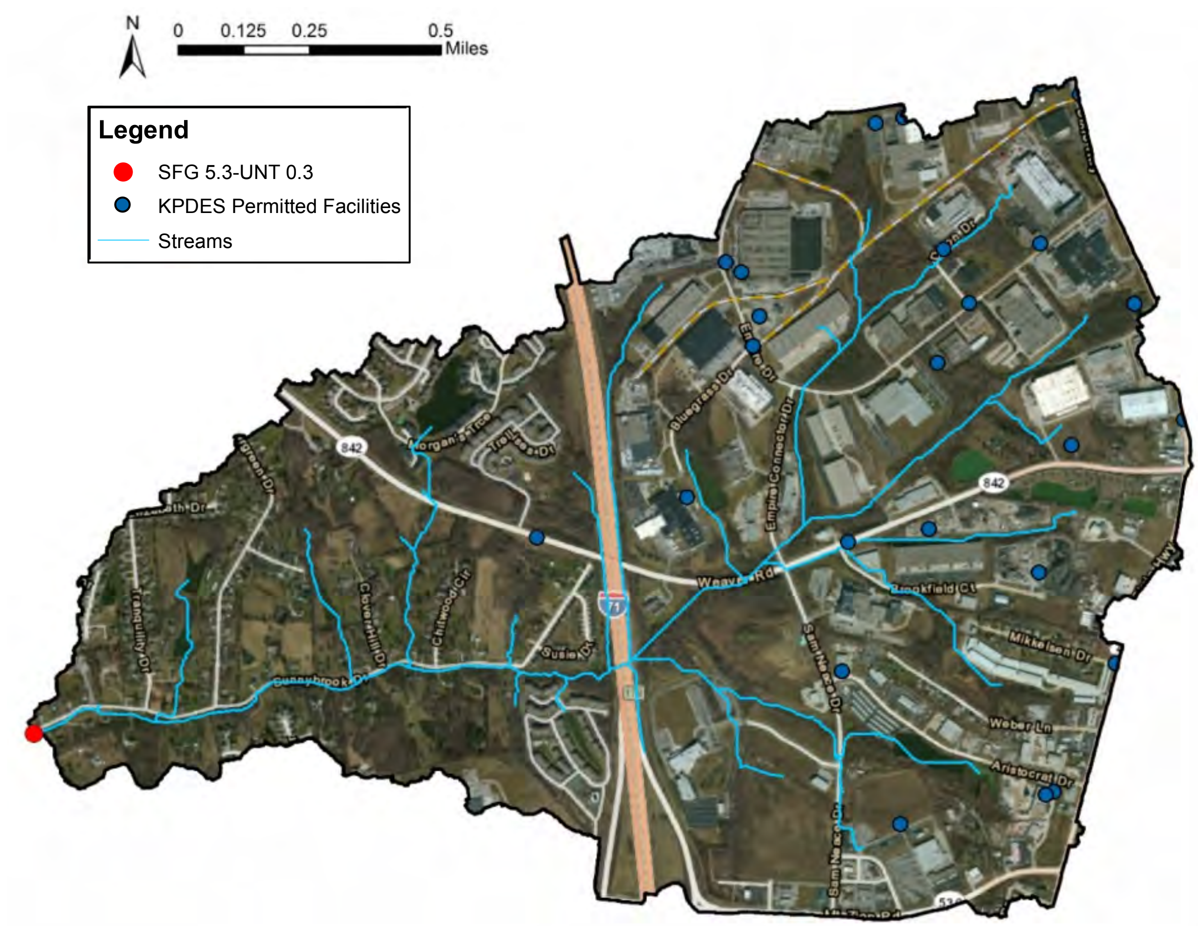

Figure 5-9: Unnamed tributary to South Fork Gunpowder Creek at SFG 5.3-UNT 0.3, highlighting KPDES discharge permits

As discussed in Chapter 4, specific conductance had a positive relationship with the number of KDPES permits per mile of stream. It would be prudent to have KDOW evaluate these permits and their discharges. While conductance is expected to be high in Northern Kentucky, this step should identify any glaring items that should be addressed with the permittees.

Programs and Permits for Managing Stormwater Discharges

SD1, the City of Florence, and the Kentucky Transportation Cabinet (KYTC) are the three major municipal stormwater permittees in the Gunpowder Creek Watershed and maintain the corresponding Municipal Separate Storm Sewer System (MS4) permits and programs required to discharge stormwater into the Gunpowder Creek stream network. Other major stormwater dischargers, such as the Cincinnati/ Northern Kentucky International Airport, are co-permittees with other agencies, such as SD1.

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

All of the major stormwater dischargers are active members of the GCWI Steering Committee and openly share the activities of their stormwater programs. All parties are working toward the goal of improved stream integrity; however, it should be made clear 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 Overflow (CSO) and Sanitary Sewer Overflow (SSO)

SD1 is the operator of the region's combined and sanitary sewers and has a Consent Decree that requires mitigation of the region's overflows. There were several SSOs in the Gunpowder Watershed, including the Kentucky Aire Pump Station, Gunpowder Pump Station, South Hampton Pump Station, Gamon Calmet Pump Station, Union Pump Station, and Manhole #2410387 (near the Oakbrook/Holbrook intersection). Some of the improvements required by the Consent Decree in the Gunpowder Creek Watershed have recently been constructed and the corresponding overflows have been reduced. This may have even been apparent in the water quality data. As mentioned in Chapter 4, the timing of the completion of construction activities indicates that it is possible that the high *E.coli* loads in the headwaters of the main branch, South Fork Gunpowder, and Fowler Fork during the three wet-weather sampling events in 2011 may have been partially attributable to sewer overflows that have since been partially mitigated. One of the largest and most impactful projects has been the tunnel to the Western Regional Wastewater Treatment Plant (WWTP), which cost ~$125 million, but has helped to reduce CSOs and SSOs throughout much of SD1's service area, including within the Gunpowder Creek Watershed. SD1's model indicates that the Western Regional WWTP improvements have had a substantial impact on water quality in the Gunpowder Watershed. Many of the SSOs listed above have been completely eliminated. More specifically, there were four SSOs that were completely eliminated and one that was significantly reduced after the Western Regional WWTP was upgraded. Modeling for

2013, the first full year with improvements, has shown that the four eliminated SSOs reduced 8.43 MG of annual SSO volume, while a reduction of 3.24 MG was achieved at the location of the reduced SSO (Kaeff, 2014b, Pers.Comm.). While the SSO at Manhole #2410387 is still considered to be active, it has been greatly reduced and is a candidate for removal from the SSO list in 2014.

Special Land Use Planning or Existing Watershed Plans

The Boone County Planning Commission works to develop the county's comprehensive plans, zoning regulations and subdivision regulations, perform studies, and evaluate the planning of proposed development projects, many of which are available on their website (BCPC, 2014). Those plans are actively reviewed and commented on by members of the GCWI Technical Committee. The Boone County Planning Commission is an active member of the GCWI Steering Committee. Their office led the writing of several chapters of this document and their GIS Department created nearly all of the mapping that is included in this Watershed Plan.

Boone County has large tracts of publicly-owned land (**Figure 5-10**). It is unknown whether any of these large open areas have associated special land use planning; however, preserving large undeveloped areas is one of the most cost-effective strategies to protect water quality (CWP, 2013). Beyond the existing publicly-owned lands, BCCD coordinates with the Boone Conservancy, an independent nonprofit organization, regarding plans for future land acquisitions. Forested hillslopes and the forested riparian corridor along Lower Gunpowder perform numerous protective services to Gunpowder Creek and are likely a primary reason why the macroinvertebrate communities at GPC 7.5 are not as impaired as the upstream sites. Ensuring that the forested riparian corridor remains intact along Lower Gunpowder is an important goal for maintaining and improving aquatic health. Preserving and acquiring land within the watershed, whether it be publicly-owned land or other available land, is a beneficial strategy for overall watershed health and many options exist to advance these efforts. The GCWI hopes to acquire and preserve some of this land as part of its implementation strategy discussed in Chapter 6. The Watershed Coordinator would lead these efforts.

At least one prior watershed study exists for the Gunpowder Creek Watershed, a Watershed Characterization Report developed by LTI (2009) on behalf of SD1, which was used throughout the data analysis and other sections of this Watershed Plan document. This report presented no action items for the watershed, but was used as the building block for many other sections of this document.

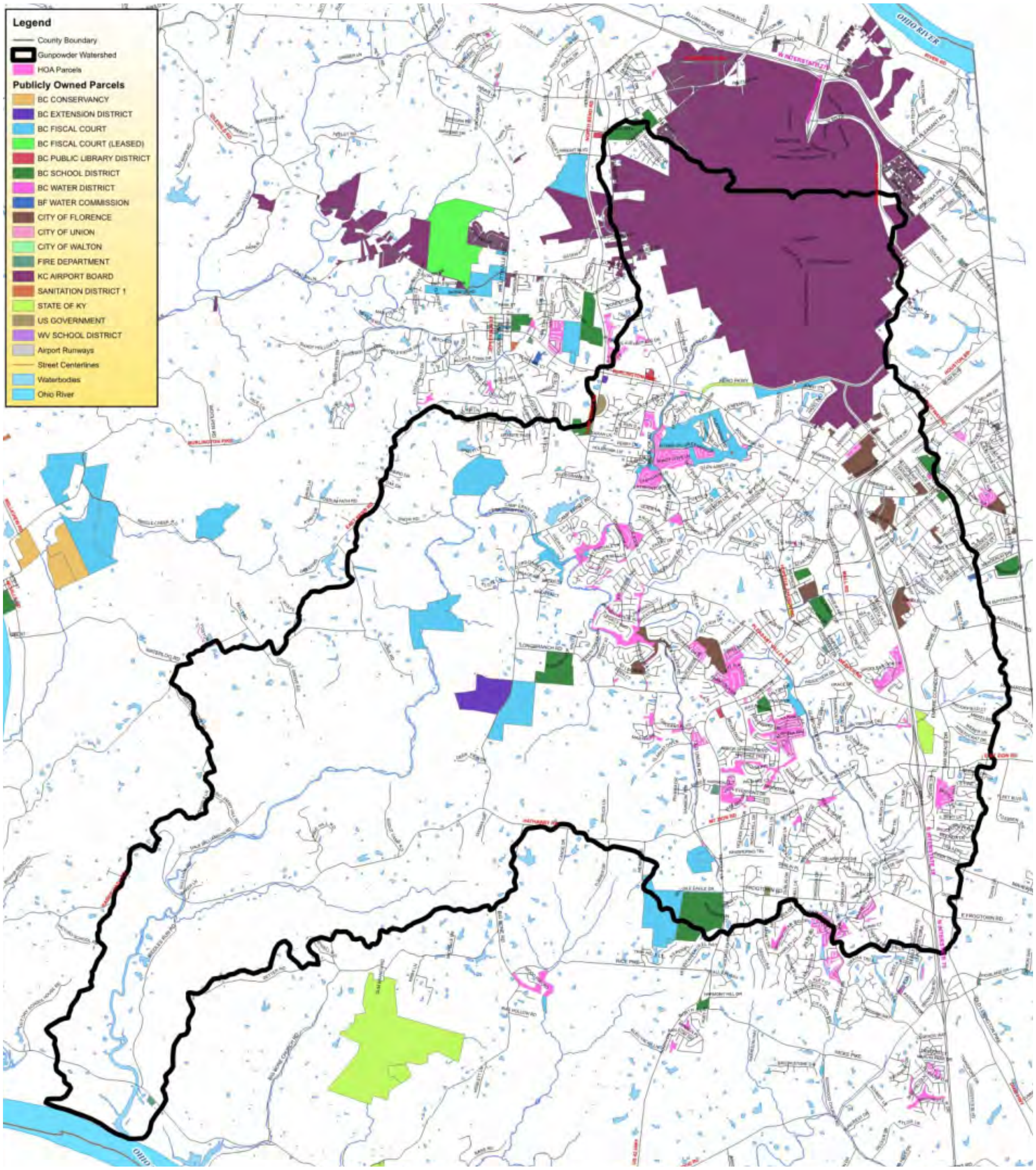

Figure 5-10: The Gunpowder Creek Watershed has large tracts of publicly-owned properties that could be targeted for conservation and/or BMP implementation (see Appendix 5-A for a 24x36 version)

5.1.3 Education as a Best Management Practice

Education and outreach programs can be effective non-structural BMPs to engage and educate the public within the watershed community. The GCWI has a multi-pronged educational strategy to engage the community and teach them about the pollutants of concern, potential sources of pollutants, and solutions to improve the condition of the streams throughout Gunpowder Creek. Education efforts have already begun in the Gunpowder Creek Watershed. Articles have been included in the *Landscapes* and *What's Happening* newsletters, which are publications distributed by the Boone County Conservancy. KDOW's report card of the watershed, along with a hydromodification summary document have been distributed to residents, and dissemination will continue. Displays have been posted, and props have been used at meetings. For example, the concept of detention basin retrofits was presented at a public meeting, and in addition to learning about this BMP strategy, the community was fortunate to see and touch a prototype example of the retrofit device. These methods and documents have already been developed and have received good feedback, and will continue during implementation. For example, the GCWI will include project updates in the widely circulated, *Landscapes* and *What's Happening* newsletters.

Figure 5-11: Effective signage and social marketing campaigns can raise public awareness about pollutants (CWC, 2006)

To educate the community on behavorial changes that will make a difference in the integrity of the watershed, the GCWI has created a Public Summary Outreach document that provides a succinct overview of this Watershed Plan and educates the community on the results of the data analysis as well as future implementation goals. The GCWI plans to distribute this document to the local community throughout the implementation phase of the project.

Furthermore, installation of signage about pollutants (*e.g.*, **Figure 5-11**), watershed health, and watershed stewardship near water bodies and near projects on public land is another way to raise public awareness. The GCWI plans to prioritize BMP implementation toward properties with greater public visibility and include educational signage in order to increase public awareness. For example, ponds located on public lands such as parks or schools will be a priority because of their greater visibility and potential education opportunities. Pet waste programs are an example of education as a BMP. Effectively implemented pet waste programs that provide facilities such as well-stocked bags and convenient trash receptacles at popular dog walking areas are some of the most cost-effective stormwater management programs that have been documented (CWP, 2013). Education and training for designers, managers, and contractors may also be beneficial, given the complexity of some of the dominant impairments in the Gunpowder Creek Watershed such as stormwater-induced bank erosion/TSS. Finally, producing videos on necessary behavioral changes and including them on social media and the BCCD website may also bring change. Such educational videos and project updates will be provided through social media and on the Boone County Conservation District's website.

5.2 Selecting Best Management Practices for the Prioritized Subwatersheds of the Gunpowder Creek Watershed

The following sections synthesize the previous contents of the plan, from land use and geology to water quality pollutant levels and suspected sources, into a tailored BMP strategy for the Gunpowder Creek Watershed prioritized subwatersheds. As the BMPs and subwatersheds are outlined, it is imperative to remember that as projects arise during implementation, the priority watersheds and seemingly most cost-effective BMPs may change. The GCWI plans to work with regional partners to implement sustainable projects as opportunities arise to work together towards more cost-effective and holistic solutions. Again, the GCWI would like to emphasize the following priority subwatersheds:

- Developed: South Fork Gunpowder
    - Selected because of high imperviousness, possibility of future expansion, and TSS as the most concerning pollutant
- Undeveloped: Lower Gunpowder
    - Selected because of high amounts of undeveloped land
- Rural (Agricultural/Forestry): Riddles Run
    - Selected because of agricultural activities and low imperviousness. This subwatershed was selected over the other rural subwatershed, Long Branch, because of feasibility factors, including lack of access along Long Branch.

While these three watersheds have ranked as highest priority, it is critical to underscore that a key component of the GCWI's implementation strategy is to utilize spending as efficiently and effectively as possible; and therefore, the priority watersheds could change with additional information gained as the GCWI moves into the implementation phase of the project. The GCWI plans to use 319(h) grant funding as a catalyst to work with stakeholders and regional partners to incorporate goals of stream channel protection and water quality into projects throughout the watershed.

5.2.1 Selecting BMPs for the South Fork Gunpowder (Predominantly Developed Area of the Gunpowder Creek Watershed)

To begin, the headwaters of the Gunpowder Creek Watershed are heavily developed and some areas are likely to continue to experience growth. South Fork Gunpowder has been identified as the developed priority subwatershed. Water quality monitoring efforts, presented in Chapter 4, have shown that the most concerning pollutant in the streams of the developed subwatersheds is total suspended solids (TSS). The primary source of TSS is suspended sediment that is likely attributable to streambank erosion. Streambank erosion is a natural process; however, developed watersheds tend to erode the streambanks much more than undeveloped watersheds due to the excess runoff that is generated by impervious surfaces and released from stormwater systems at more erosive rates. More details regarding bank erosion as the primary source of TSS in the Gunpowder streams can be found in **Appendix 5-B**.

Stormwater Volume-Based BMPs

Figure 5-12: Detention basin retrofit outlet structure with bypass, located at Toyota pilot project in Burlington, KY (Photo by Rajib Sinha)

In order to mitigate the erosive, urban flow regime, stormwater volume-based BMPs will be implemented in the developed areas of the Gunpowder Creek Watershed. This includes detention basin retrofits (**Figure 5-12**), new detention basins, and bioretention basins. Conventionally-designed detention basins are contributing to the problem of the erosive flow regime in that small events, (e.g., any storm event less than the 2-year storm) are not detained in the basin, as regulations do not require it. These more frequent storms typically allow excess stormwater runoff to cause more erosion downstream than under pre-developed conditions. However, these same BMPs can play a major role in improving the health of Gunpowder Creek. Retrofitting these existing assets to better match natural rates of stream erosion is one of the most important and cost-effective volume-based BMP strategies that can be implemented to reduce the erosive power of stormwater runoff and thereby reduce sediment pollution from bank erosion. These same kinds of BMPs that are optimal for reducing the volume and rate of stormwater runoff are also some of the best BMPs for reducing other pollutants of concern such as bacteria and phosphorus. Preliminary estimates predict that reducing stormwater release rates to the extent that bank erosion is reduced to more natural rates will inherently reduce bacteria and phosphorus loads to more acceptable levels. In addition to optimizing existing detention basin storage, new detention and bioretention basins can assist in providing additional water quality benefits and mitigating erosive flows in the developed subwatersheds. A complete analysis of the existing detention basins, opportunities to optimize existing detention, and additional/new storage needed in Gunpowder Creek has been included in **Appendix 5-C**. This strategy will also have direct benefits for stream habitat and aquatic ecosystems by better matching the pre-developed flow regime of the stream bed and, consequently, improve the conditions for macroinvertebrates that make their homes on the streambed. **Table 5-3** presents a summary of the estimated storage needed for channel protection throughout the Gunpowder Watershed.

Table 5-3: Storage estimates for Gunpowder Creek watershed upstream of gage location, approximately at GPC 14.7

Estimated Storage Needed To Achieve Channel Protection in Gunpowder Creek Watershed based on Gage Location[a]

Drainage Area	Imperviousness	Storage Target[b]	Existing Detention Basins[c]	Estimated Existing Storage[d]	Estimated Storage Shortage	Potential Additional Storage from Retrofits[e]	Potential Additional Storage from New Basins[f]
sq mi	*%*	*acre-ft*	*number*	*acre-ft*	*acre-ft*	*acre-ft*	*acre-ft*
36.6	22.6	935	535	749	186	15	171

[a]gage location is close to the confluence of the three main branches that drain the developed headwaters of Gunpowder Creek. As one moves farther downstream from that location, development intensity decreases

[b]sum of interpolated subwatershed storage targets, based on Pleasant Run, Qcritical Memo, and Toyota Retrofit data

[c]based 285 basins in the SD1 GIS layer and 250 in Florence (J.Hunt, Pers. Comm.). Assumes the 50 basins that were recently transferred from Boone County to SD1 were already included in the SD1 GIS database

[d]applies average detention basin storage volume of 1.4 acre-ft based on a subset of 8 N.Ky detention ponds from the SD1 Rules and Regs Technical Subcommittee (Dec. 2008)

[e]assumes 10% of the 535 existing basins are retrofitted in order to achieve an additional 1' of storage within their existing footprint. The estimated average footprint is based on the assumptions that the average depth is 5' and sideslopes are 3H:1V

[f]estimated remaining storage shortage after retrofitting 10% of the existing detention basins

Specifically in South Fork Gunpowder, it was interpolated that 40.90 ac-ft/mi^2 of optimized storage is necessary to provide adequate channel protection. This is equivalent to ~245 acre-feet of storage within the 6-square mile catchment area. There are nearly 150 existing basins with the South Fork Gunpowder Subwatershed, and although a detailed analysis of these has not been completed at this time, it is more than likely that many of these will be good candidates for detention basin retrofits. Again, additional details regarding this analysis is included in **Appendix 5-C**.

5.2.2 Selecting BMPs for Lower Gunpowder (Predominately Undeveloped Area of the Gunpowder Creek Watershed)

While Boone County has been one of the fastest growing counties in the state of Kentucky, a large portion (~57%) of the overall Gunpowder Creek Watershed remains undeveloped. As the economy continues to recover from the 2007-2011 economic recession, new development is anticipated, some of which will extend into previously undeveloped areas of the watershed (*e.g.,* **Figure 5-13**). Lower Gunpowder Creek is the priority subwatershed for BMPs related to undeveloped areas.

Figure 5-13: Rendering of proposed Union Town Center along the lower reach of Fowler Fork (Union, 2014)

Preserving Open Space Can Protect Water Resources

Protection, preservation, and/or conservation of publicly-owned open spaces should be considered, as this has been documented as one of the most cost-effective strategies to protect water quality (CWP, 2013). This is particularly important in large/old-growth forests, and at strategic areas along stream networks such as the riparian corridor and floodplain along Lower Gunpowder Creek. See **Figure 5-10** and **Appendix 5-A** for a map of current publicly-owned lands. Additionally, publicly-owned open spaces are ideal candidates for installation of BMPs, due to the likelihood of stakeholder cooperation. Special consideration should be given to properties that exist in low-lying areas along stream corridor for the installation of wetlands and riparian restoration, two BMPs that are anticipated to yield excellent results for relatively low installation cost. The primary cost associated with these BMPs is land acquisition, which is not anticipated to be an issue for publicly-owned land by agencies that are members of the project's Steering Committee.

Preservation of open space is one of the most cost-effective ways to protect water quality.

Reviewing Existing Rules and Regulations

Even with strategic conservation efforts of publicly-owned lands, some privately-owned lands will inevitably become developed in the near future. Watershed stewardship practices implemented prior to and/or during the development of this land is anticipated to be more cost-effective than post-development mitigation methods. In 2012, SD1 and the City of Florence released a detailed BMP manual that includes revised guidance and requirements to provide a water quality treatment volume in addition to flood control protection. The requirement of water quality treatment for the 80th percentile event (the first 0.80 inches of rain in any given storm) is an excellent improvement over the conventional design approach that focused exclusively on flood control. However, these revised regulations are not predicted to fully protect stream channels from excess erosion without being optimized by the design engineer to release all storms up to and including the 2-year storm at or below ~40% of the pre-developed 2-year flow rate (Sustainable Streams, 2012). The good news is that optimizing BMP designs to provide channel protection (*e.g.,* stream erosion control) in addition to water quality treatment is not anticipated to result in substantial cost increases relative to what is required under the current Rules and Regulations. In addition to the water quality and flood protection controls, SD1 currently has a credit program for new developments that meets this design parameter, which is referred to as $Q_{critical}$. Reviewing the participation rate of this credit policy may be a first step during implementation phases, in which outreach, training, and review/revision to the Rules and Regulations may be evaluated.

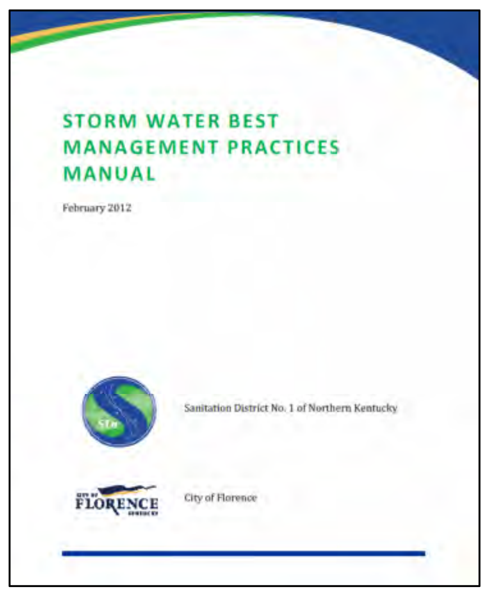

Figure 5-14: The Northern Kentucky Storm Water BMP Manual promotes numerous good practices for minimizing adverse impacts to streams

The Boone County Planning Commission, who is involved with planning and zoning requirements and subdivision regulations, is a member of the GCWI Steering Committee. An internal or external review of the current planning and zoning requirements and subdivision regulations with a focus on promoting lower impact development practices would be beneficial. Although this effort would affect all subwatersheds, Lower Gunpowder would be most benefited because it is nearly completely undeveloped presently. The subdivision regulations currently require stream buffer zones in accordance with what is required by the KDOW Permit KYR10, referred to as the SWPPP (Boone County, 2010). The subdivision regulations also refer to the Northern Kentucky Storm Water Best Management Practices Manual (SD1 & Florence, 2012; **Figure 5-14**), which promotes the following:

- Preservation of natural drainage ways and vegetated swales instead of building storm sewers
- Avoidance of steep slopes
- Fitting the development to the terrain
- Locating the development in less sensitive areas
- Reduced clearing and grading
- Utilization of open spaces
- Reduced impervious cover
- Using buffers and undisturbed areas
- Draining runoff to pervious areas instead of toward driveways and streets

Some communities have more protective rules and regulations such as defined distances for buffer zones and requiring green stormwater infrastructure to be used to the maximum extent feasible (*e.g.,* Seattle, 2013). A review of the local regulations may determine practices that are mutually agreeable by all stakeholders.

The goal of all Steering Committee members is to take reasonable steps to protect the integrity of Gunpowder Creek through locally-appropriate strategies such that future problems can be prevented and existing impairments can be cost-effectively improved. As discussed in the GCWI Steering Committee meetings, no single entity is the cause of all problems, or the source of all solutions. Therefore, working both within and across agencies will be essential for successful implementation toward the goal of improved water quality.

Improving On-Site Wastewater Treatment

It is not anticipated that improvements to septic systems will be a priority implementation activity, however because of the number of septic systems within the Lower Gunpowder Subwatershed (**Figure 5-4**), this strategy cannot be overlooked. The first step to achieving septic system improvements is to work with the Northern Kentucky Health Department to verify the parcels serviced by septic systems and those that could be malfunctioning. Furthermore, visual inspections could help to identify those systems that require maintenance or replacement.

5.2.3 Selecting BMPs for Riddles Run (Predominantly Agricultural Area of Gunpowder Creek Watershed)

Agricultural BMPs

Boone County has approximately 630 farms, ranging from ~5 to ~2,000 acres, within its boundaries. Many of these farms are located within the Gunpowder Creek Watershed, making up approximately 18% of the overall land area. As mentioned in Chapter 4, areas with bacteria concerns during dry weather monitoring highlight potential livestock and septic system issues. Riddles Run has been identified as the priority subwatershed for implementation of agricultural BMPs, as the majority of the E.coli concentrations during dry weather were above the benchmark concentrations, as shown in Chapter 4. In addition, total phosphorus and Total Kjehdahl Nitrogen exceeded the benchmark concentrations for nearly every event, which could indicate fertilizer runoff.

One of the first steps in the implementation of the Gunpowder Creek Watershed Plan will be to evaluate whether any farms in the priority rural watershed of Riddles Run are able to improve their Water Quality Plans and related practices to improve water quality in Riddles Run.

Agriculture can present a specific set of water quality issues, such as livestock disturbance of streambanks and riparian vegetation, bacteria from manure, sediment from bare fields, and nutrients associated with fertilizers and pesticides. Many of these pollutants were observed during monitoring of the streams within the Gunpowder Creek Watershed. Some BMPs that are especially important for livestock farms include fencing (to keep livestock from disturbing streambanks/beds, **Figure 5-15**), rotational grazing with pasture renovations, animal feeding buffers, and proper manure management. Pollution from crop farms can be reduced through the installation of riparian buffer strips, field buffers, conservation cover crops, conservation tillage, and nutrient management. Some incentive programs already exist for the farmers of the Gunpowder Creek Watershed, such as EQIP and a pilot program for nutrient trading.

Figure 5-15: Livestock access can impact stream bank stability, destroy riparian vegetation, and lead to direct deposits of bacteria/waste (Photo by Kelly Kuhbander)

Currently, horse farms in Boone County are not mapped or well monitored, due to horses not being considered livestock, although they present similar problems to streams as livestock farms. An initial mapping effort of horse farms would make targeting outreach efforts more feasible and easier to implement. Some additional BMPs that would be beneficial in agricultural areas with row crops are grassed waterways, contoured buffer strips, and terraces. A useful BMP for agricultural areas with livestock are waste treatment lagoons.

Improving On-Site Wastewater Treatment

Similar to in Lower Gunpowder Subwatershed, improvements to septic systems may be used as an implementation activity in Riddles Run, but will most likely not be a primary focus of implementation dollars due to the possibility of future expansion of the sewer system as development increases.

5.2.4 Selecting BMPs for the Areas of Gunpowder Creek with Active Forestry (Riddles Run & Lower Gunpowder)

Forestry is not considered to be a dominant activity in the watershed and was not anticipated to be a dominant source of any of the water quality pollutants. However, the GCWI knows that the limited forestry activities that do occur in Gunpowder Creek should be encouraged to use good practices. Beyond the BMPs listed by KDOW, one implementation step already completed by BCCD was to host a panel discussion on local forestry practices at their joint agency meeting in March of 2014. During this meeting BCCD and the other participating agencies agreed to seriously promote conservation of forested lands and particularly protect the forested areas that currently serve as riparian buffer zones. GCWI is working to promote reforestation, particularly on barren hillslopes, streambanks, and riparian zones, through partnerships with other community experts and resources such as the Northern Kentucky Urban Forestry Council and the Boone County Urban Forest Commission. These BMPs will be implemented in all priority watersheds but will be particularly focused in the rural and undeveloped priority subwatersheds of Riddles Run and Lower Gunpowder.

5.3 Finding Solutions - Summary

The *Watershed Planning Guidebook for Kentucky Communities* (KDOW, 2010) provides a list of structural and non-structural BMPs categorized by land use. Categorization is based on the type of practice (structural vs. non-structural) and its associated land use. This chapter has presented several BMP options that may be beneficial in the Gunpowder Creek Watershed, specifically tailored to the geologic setting and land uses described in Chapter 2 and the water quality impairments observed during monitoring and outlined in Chapters 3 and 4. The primary pollutant of concern in the Gunpowder streams is suspended sediment (TSS), which was most problematic in the developed headwaters of the watershed. The major source of suspended sediment is suspected to be bank erosion caused by excessively erosive stormwater flows. Therefore, the overall focus of water quality efforts will be on BMPs designed to control stormwater quantities, reducing the potential for erosion in the stream channels. These are anticipated to yield water quality benefits as well, such as bacteria and nutrient reduction. There are also priority areas where monitoring identified bacteria concerns during dry weather, such that mitigation efforts will be targeted to the direct dry-weather sources such as septic systems and cattle/horse access.

The primary pollutant of concern in these streams is suspended sediment, the major source of which is bank erosion caused by excessively erosive stormwater flows.

As previously mentioned, a key strategy of this Watershed Plan includes working together with local stakeholders and regional partners to implement cost-effective, sustainable solutions throughout the Gunpowder Watershed. The GCWI plans to use this Watershed Plan as a catalyst throughout the watershed to improve stream benefits. While South Fork Gunpowder, Lower Gunpowder, and Riddles Run have been listed as the priority subwatersheds , the GCWI emphasizes that opportunities will be evaluated as they arise, and the GCWI plans to consider any BMP that can improve the integrity of the streams. For example, although the first priority subwatersheds include South Fork Gunpowder, Lower Gunpowder, and Riddles Run, GCWI will consider any cost-effective opportunities that arise in the other subwatersheds, including Upper Gunpowder, Middle Gunpowder, Fowlers Fork, and Long Branch. **Table 5-4** on the next page is tailored to the Gunpowder Creek Watershed and includes an all-encompassing list of BMPs that are applicable to the Gunpowder Creek.

Table 5-4: BMP list tailored to the water quality issues observed in the Gunpowder Creek Watershed

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

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

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CHAPTER 6

Strategy for Success

Gunpowder Creek Watershed Plan

Prepared by the

Gunpowder Creek Watershed Initiative

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Chapter 6: Strategy for Success

6.1 BMP Feasibility

Selecting the right combination of BMPs for the Gunpowder Creek Watershed depends on a number of factors, including regulatory matters, stakeholder cooperation, political will, available funding, cost-effectiveness, priority areas, existing priority efforts within the watershed, and watershed management activities. Each of these factors is discussed in Section 6.1.1 below.

6.1.1 Feasibility Factors

Regulatory Matters

The Sanitation District No. 1 of Northern Kentucky (SD1), the City of Florence, and the Kentucky Transportation Cabinet (KYTC) are responsible for the stormwater systems that drain the developed areas of the Gunpowder Creek Watershed and discharge to the stream network. They all hold permits from the Kentucky Division of Water (KDOW) that dictate the conditions that need to be met in order to discharge their stormwater to such waterways. Other entities that discharge stormwater to Gunpowder Creek, such as the Cincinnati/Northern Kentucky International Airport, are co-permittees with other agencies such as SD1.

These permits are revised on a five-year cycle. KDOW is guided by the USEPA regarding the various requirements that should be included in stormwater permits. The national guidance is currently undergoing revisions that are anticipated to include stricter conditions for stormwater discharges, particularly for developed areas. The intent of the revisions is to ensure that the health and quality of waterways is better protected from stormwater runoff as additional land is converted from undeveloped to developed.

SD1 is also regulated by KDOW regarding their combined sewer overflows (CSOs) and sanitary sewer overflows (SSOs), which have been recently reduced via investments and upgrades to the sanitary sewer system in the Gunpowder Creek Watershed, such as the ~$125 million tunnel to the Western Regional Wastewater Treatment Plant. There are also a number of individually-permitted discharges from private sources as a part of the Kentucky Pollutant Discharge Elimination System (KPDES) Program. Approximately 63 total KPDES permits are documented in the watershed.

The Boone County Planning Commission (BCPC) has jurisdiction over the ways that the land in the Gunpowder Creek Watershed can be used and has been an active member of the GCWI Steering Committee.

Total Maximum Daily Loads (TMDLs) are developed by KDOW for waterways that are listed as impaired on the 303(d) list. TMDLs can add special conditions or restrictions to permitted discharges in a waterway depending upon the amount of load reductions that are estimated to be needed to bring a waterway into compliance with water quality standards. There is already a TMDL for ethylene glycol relative to the Airport’s use and treatment of deicing fluid. KDOW recently began the development of a TMDL for *E.coli* in Gunpowder Creek in 2014.

Stakeholder Cooperation

The Gunpowder Creek Watershed Initiative (GCWI) Steering Committee includes a broad range of public agencies that have taken an active role in guiding the project. A technical committee and KDOW representatives have provided technical expertise throughout the project as well. Regional partners have donated their time and talents to help make this project the success that it is. Some of the contributions are summarized in **Table 6-1.**

> ***100% of roundtable participants said development was a land use that they were most concerned about.***

Table 6-1: Incomplete summary of contributions of time, personnel, supplies, equipment, access, project planning, and implementation by regional stakeholders

Stakeholder Agency	Steering Committee Meetings	Public Meetings/ Roundtables	Data Collection	Implementation/ Project Planning
Boone County Conservation District	√	√	√	√
Boone County Planning Commission	√	√		
Cincinnati/Northern Kentucky Airport	√			√
City of Florence	√	√		√
City of Union	√			
Kentucky Division of Water	√	√	√	√
Kentucky Transportation Cabinet	√	√		
Licking River Watershed Watch	√		√	
Northern Kentucky Health Department	√			√
Northern Kentucky University Center for Environmental Restoration				√
Sanitation District No. 1	√	√	√	√
Thomas More College/Dr. Chris Lorentz			√	

Beyond the list of these more active stakeholders, the Steering Committee has a goal of increasing stewardship of private companies. For example, in the adjacent watershed of Woolper Creek, Toyota has been very supportive of the pilot installation of the detention basin retrofit technology developed and monitored by the USEPA and other regional partners including Boone County Conservation District (BCCD), SD1, and Sustainable Streams. Finding corporations from within the Gunpowder Creek Watershed to contribute to project funding and/or implementation, including structural and non-structural practices, is a goal for GCWI as we move to the implementation phase.

And most importantly, the public has been actively involved throughout the project. News of the project has been distributed through local media along with the *Landscapes* newsletter of Boone, Campbell, and Kenton Counties Conservation Districts. A total of 6 well-attended public meetings (**Figure 6-1**) have been held at numerous locations throughout the watershed. GCWI has also presented at meetings of local organizations, such as the Northern Kentucky Fly Fishers, who are very active in the watershed.

The public has been eager to learn about the project, hear the results of the monitoring efforts, and offer their input regarding prioritizing problems and solutions. Approximately 70 participants engaged in a series of three roundtable meetings in September of 2013. Divided into 11 total groups, they provided facilitated feedback to five questions. The questions and the dominant answers are provided in **Table 6-2**.

Table 6-2: Questions and dominant responses from 11 roundtable groups with approximately 70 participants

Question	Dominant Responses[1]
1. Why is a clean healthy stream important to you?	Recreation (73%), Aesthetics (66%), Quality of Life/Health (54%)
2. What land uses in the watershed are you most concerned about?	Development (100%)
3. What do you think are the most common problems?	Runoff (73%), Flooding/Safety (66%)
4. What BPMs do you consider feasible in Gunpowder Creek?	Detention/Retention (82%), Education (66%), Responsible Development/Ordinances (55%)
5. What issues in Gunpowder Creek do you consider a priority?	Stormwater Runoff (66%), Flooding (55%)

[1]Responses that were listed by more than half of the groups. For a summary of all responses, see supporting handout in **Appendix 6-A.**

In summary, 100% of the groups felt that development was a land use that they were most concerned about. Stormwater runoff and flooding were problems that were typically associated with development and considered priorities among a majority of the groups. BMPs such as improved stormwater detention, education, and ordinances that promote responsible development were considered feasible by 82%, 66%, and 55% of the groups, respectively. A commonly shared sentiment was that folks did not necessarily want new ordinances; they simply wanted the existing rules and regulations to be revised to work better to actually protect stream health and keep downstream properties from flooding and eroding.

Political Will

Development is an important industry of Northern Kentucky, providing jobs and housing to promote economic growth. Rules that regulate the industry must balance the costs to the industry with the benefits to the region. What this project has demonstrated is that the status quo is unsustainable: conventional stormwater regulations cost developers money but do not adequately protect stream health. In many ways the impacts to stream health create

> ***An estimated $3.1 million in damages to Boone County's state-funded roads were attributed to stream erosion and flooding in 2011.***

much greater losses to the local economy. For example, stream erosion has impacted dozens of sewers and other infrastructure that are located in stream corridors: damages to Boone County's state-funded roads alone were estimated at $3.1 million in 2011 (Hawley *et al.*, 2013a). Also, the regulatory burden that comes with cleaning up an impaired stream is almost always more expensive than keeping a stream from becoming impaired in the first place.

As previously explained under Stakeholder Cooperation, there is a growing consensus among stakeholders that stormwater rules need to be revised to better protect stream health in Northern Kentucky. In particular, stream erosion is a commonly listed problem by property owners downstream of developments. To date, the development community has generally opposed any new regulation related to stormwater, and there has been a lack of political will to update regulations to better protect against stream erosion. Stakeholders agree that new regulations are not necessarily the solution. Rather, reviewing and revising the existing regulations to better protect stream health was a leading recommendation from the roundtable meetings. Moreover, doing so is not anticipated to be a detriment to the development community. Analysis of stormwater detention basin sizing has demonstrated that optimizing basins to better protect against stream erosion, along with providing water quality treatment and flood control, is not expected to substantially increase the size of the required detention facility relative to current requirements (Sustainable Streams, 2012). Developers would likely be spending essentially the same amount of money on their stormwater controls as they currently do; however, their investments would more fully protect stream health.

Figure 6-1: One of several well-attended public meetings on the Gunpowder Creek Watershed Initiative

Elected leaders have been educated at several phases throughout this project. Numerous public officials attended the public meeting that shared the results of the water quality monitoring, including the Boone County Judge Executive, County Administrator, Director of Parks, Director of Planning, and a County Commissioner. The Watershed Project Coordinator has also presented the results of the Roundtable Meetings to the SD1 Board of Directors, which is appointed by regional elected officials.

Through continued education and public involvement, the will of elected leaders may evolve. Revisited and revised stormwater regulations and/or subdivision regulations to better protect regional streams are a logical starting point.

Beyond the will of elected leaders, technical staff and experts from regional agencies have embraced the goals of the project and have already taken several steps to support improved stream health from within their agencies. For example, both the City of Florence and SD1 have inspection and maintenance programs for existing detention basins and staff at both agencies are actively involved in attempting to find basins that would be good candidates for retrofits.

Available Funding

Solutions need to be both feasible and cost effective.

This work has been funded in part by a grant from the USEPA under §319(h) of the Clean Water Act through KDOW. Effective management and excellent partnerships have allowed the GCWI to efficiently utilize funds and have leftover grant monies at the completion of the plan document, such that some of the current funds can be applied to implementing BMPs. The GCWI has currently applied for additional funds through the 319(h) program for implementation. However, GCWI understands that the scale of the existing problems in Gunpowder Creek is much larger than the available funds through the 319(h) program. Therefore, a core mission of this project has been to:

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.

In regards to developing/expanding partnerships to leverage funds and allocate monies to achieve greater benefits for less cost, SD1 and the City of Florence regularly invest large sums of money in the modeling, design and construction of projects to alleviate flooding problems. Adding goals such as improvements in stream erosion and water quality would be much more cost- and time-effective than trying to fund and implement separate projects to achieve the same goals. Indeed, conventional approaches to flood control projects typically solve flooding problems in one neighborhood, but can potentially make flooding and stream erosion worse along other parts of the network. As demonstrated in Chapters 3 and 4, streams are interdependent systems: flooding affects channel erosion, which affects the water quality. The only way to truly improve stream health is to coordinate project goals.

SD1 has already led by example in this regard by adding channel stability and water quality to two sanitary sewer improvement projects. As detailed by Hawley *et al.* (2012), SD1 was implementing two projects that removed inflow and infiltration (I/I) from the sanitary system. Removing I/I from the sanitary system is beneficial, because it helps to reduce SSOs into the stream networks. However, by taking stormwater out of the sanitary system, SD1 realized that simply discharging it to an already unstable stream could make channel erosion and water quality worse downstream.

Therefore, SD1 had the projects include stormwater BMPs that were designed to reduce the rate at which the stormwater makes its way to the stream network, thereby reducing the amount of potential erosion downstream. Doing so certainly added costs to the project that wouldn't have been incurred on a conventional I/I project; however, the approach was not only better for the stream, but it was better for all stakeholders, particularly the residents. Rather than tearing up yards, streets, and driveways once for the I/I project and then coming back later to address stormwater runoff, the residents could have all of their stormwater and sanitary sewer issues solved through one project.

Finally, solutions must be pragmatic. We must work to identify cost-effective solutions throughout the watershed. Rather than spending $2 million to fully restore a small part of the system to pre-developed conditions, it is much better to spend $200,000 in 10 separate parts of the system to create much greater overall load reductions and benefits to the entire network. The strategy for this Watershed Plan recognizes that funding is finite and keeps in mind the greatest network benefit for the available dollars (**Figure 6-2**).

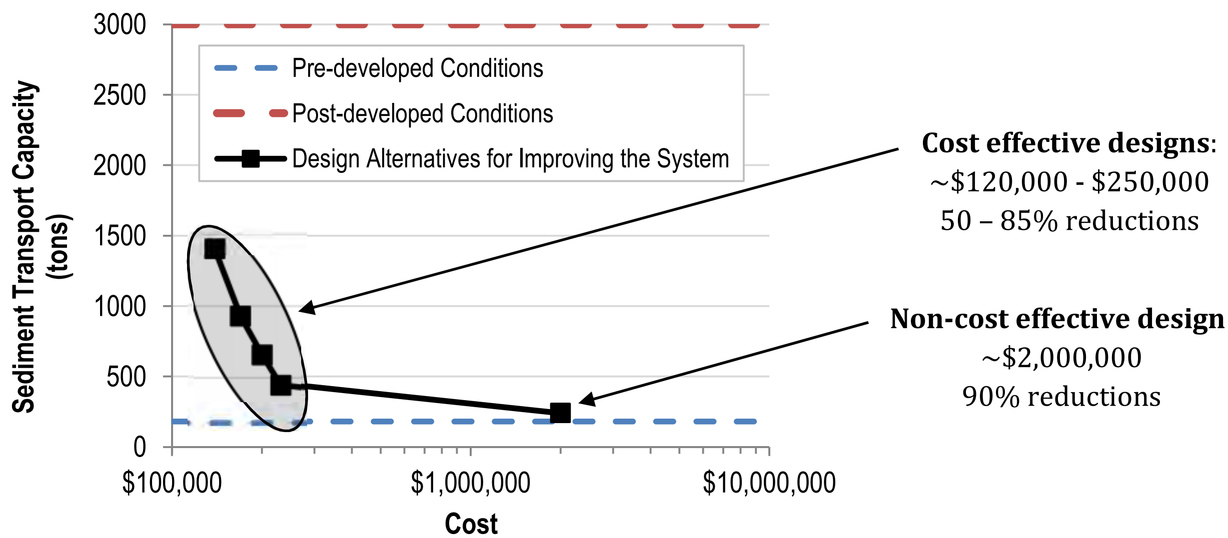


Figure 6-2: Design alternatives for stormwater BMPs to reduce the stream erosion capacity from 3,000 tons by more than half as a part of a sanitary sewer improvement project (adapted from Hawley *et al.*, 2012)

One way to achieve the greatest network benefit is to leverage funds from partner agencies, such that a project can have a greater impact with combined funds, instead of GCWI 319(h) funding alone. Similar to the projects described above, SD1 and the GCWI may pool their resources to either increase the size of a project or include additional features that provide greater benefits to the streams.

Cost-Benefit Analysis

Cost-effectiveness is a major goal of our proposed stormwater-based approach to improved stream conditions. Fortunately, some of the most effective BMPs for the treatment of the Gunpowder Creek Watershed's most concerning impairments (TSS, bacteria, phosphorous) are also relatively inexpensive

(**Table 6-3**). By focusing on solutions that are primarily aimed at restoring a more natural flow regime, such as detention basin retrofits, optimized detention basins, wetland creation/restoration, and other stormwater BMPs, we can significantly reduce TSS levels attributable to bank erosion and anticipate a positive impact on bacteria, phosphorous, and potentially nitrogen levels coming from the watershed.

> ***Stormwater volume-based BMPs tend to be the most cost-effective structural BMPs for removing the primary pollutants in Gunpowder Creek.***

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

Volume-based BMP	Approximate Cost per Storage Volume[(a)]	Typical Removal Rates of Watershed-sourced Pollutants[(c)]			
	($/ft^3)	*E.coli*	TSS[(d)]	TP	TN
Detention Basin Retrofits	$1.50[(b)]	100%	100%	42%	TBD
Wetland Creation/Restoration	$2	19%	29%	7%	16%
Extended Detention Basins	$2	67%	64%	21%	TBD
Bioinfiltration Basins	$4	71%	78%	18%	28%
Retention Basins	$2	N/A	81%	57%	30%

(a) Cost estimates only include construction costs and do not include the costs associated with land acquisition, but do include an estimate for design and permitting. 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 basins are based on typical regional pricing of ~$15-20 per square foot compiled by Strand Associates (Rust, C., 2014, Pers.Comm.), and assuming a 5-foot storage depth resulting in ~$3-4 per cubic foot. 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 per basin. They do not include costs/time associated with engaging property owners, 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 per 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 per retrofit. Using this volume, the cost per optimized storage volume is ~$0.15 per ft^3.

(c) Removal rates listed for wetland creation/restoration, extended detention basins, bioinfiltration basins and retention basins are the average median reduction as reported in the *International Stormwater BMP Database* (Leisenring *et al.*, 2012). Removal rates for detention basin retrofits are based on an estimated doubling of the treatment time associated with flood control detention basins and the assumption that doubled treatment time results in doubling of removal rate. See Appendix 5C for further explanation. Nitrogen removal is anticipated to be improved via detention basin retrofitting due to increased contact time with organic matter (Beaulieu, J., 2013, Pers.Comm); however, their rates are listed as TBD until local monitoring data become available. Reported wetland channel rates were used for wetland creation/restoration, due to anticipated installation of bankfull/benchfull wetlands, which should behave more similarly to wetland channels than standard wetlands. If detention basins, bioinfiltration basins, and retention basins are designed with consideration for channel protection flow rates ($Q_{critical}$), then removal rates are expected to be similar to that of detention basin retrofits.

(d) This TSS removal rate refers to the settling out of sediment within each BMP. It is important to note that for the Gunpowder Creek Watershed, the primary source of TSS in streams is not 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.

From **Table 6-3**, one can see that detention basin retrofits tend to be less expensive than constructing new volume-based BMPs. However, access/feasibility issues may limit the number of detention basins that can be retrofitted, so some level of newly constructed BMPs is also expected to be needed. Construction of new detention basins, retention basins or wetlands are all anticipated to cost ~$2 per cubic foot of storage based on regional excavation costs (Hawley *et al*., 2012), which tend to be less than bioinfiltration basins that range ~$3-4 per cubic foot of storage (*sensu* Rust, C., 2014, Pers.Comm.).

Lot-level controls such as rain gardens and cisterns tend to be much less cost-effective than stormwater volume-based BMPs.

A first-order planning estimate of the total funding that may be required to reduce the stream erosion rates to more natural levels can be determined by combining the unit costs from **Table 6-3** with the estimated storage volumes listed in **Table 5C-4**. Approximately 50 detention basin retrofits at ~$10,000 per basin, plus approximately 170 acre-feet of new storage using a combination of wetlands and/or detention/retention basins at ~$2 per cubic foot would result in an estimate of approximately $15.5 million.

Smaller BMPs such as controls in individual lots (*e.g.,* rain gardens, rain barrels, and green roofs) or conversion of impervious surfaces to porous are not included in **Table 6-3** because they tend to treat much lower stormwater volume for the dollars spent. It does not imply that GCWI is precluding the use of such techniques in the Gunpowder Creek Watershed, but rather, that the focus is on more cost-effective controls for the watershed and problems at hand. To underscore this point, we cite a case study from King County, Washington, where the SUSTAIN stormwater treatment model was used to plan approximately $10.7 million of BMPs including rain gardens, detention, bioretention, etc., in order to meet the load reduction goals in a small pilot watershed of 230 acres (0.40 square miles). Approximately half of the $10.7 million is for installation of lot-level BMPs, such as rain gardens, cisterns, and rain barrels. Extrapolating the King County costs of nearly a half a million dollars per acre to the developed portion of the Gunpowder Creek Watershed would result in over $1 billion spent on BMPs spread over the 36.6-square-mile area (**Table 6-4**). That's nearly 100 times more than the estimates using volume-based BMPs discussed above.

Table 6-4 – King County cost estimates using a mix of lot-level and volume-based BMPs, extrapolated to the Gunpowder Creek Watershed

Range of Cost Estimates to Mitigate Stormwater Runoff in King County Pilot Watershed using SUSTAIN (King County, 2013)

Design Alternative	Costs in King County Pilot Basin	Projected Costs to Gunpowder Watershed at same unit cost as King County[a]
Min	$4,800,000	$489,000,000
"Best"	$10,700,000	$1,090,000,000
Max	$14,700,000	$1,497,000,000

[a] King County costs divided by catchment area (230 acres) multiplied by catchment area at Gunpowder Creek gage location (36.6 mi^2)

Beyond the costs required to solve the problem, it is also important to acknowledge the costs associated with the status quo. We can estimate the annual costs of infrastructure repair due to damages caused by flooding and channel instability in the Gunpowder Creek Watershed based on a summary of regional costs from 2011 (**Table 6-5**). With the total impacts to state roads, sewers, and private utilities estimated at nearly $1 million per year, not including impacts to other property such as local roads and private property, reducing these impacts through more sustainable stormwater management would be beneficial to the region's environment, property owners, tax payers, and rate payers.

In summary, this Watershed Plan focuses on identifying the BMPs that will yield the greatest impact per dollar spent on stream health within the Gunpowder Creek Watershed and the locations in which those BMPs will be most effective. The plan will then be used to aid the decision making process as funds become available. BMP implementation is to be followed by monitoring, reassessing, and adjusting the strategy. For example, continued monitoring may determine that stream health objectives have been met prior to the full implementation of the estimated volumes from **Table 5C-4**.

Table 6-5 – Cost estimate for annual repairs to infrastructure in the Gunpowder Creek Watershed damaged by flooding and channel instability

Projected Repair Costs Due Damages Attributable to Flooding and Channel Instability in Developed Watersheds

Infrastructure Category	Projected Annual Unit Costs[(a)]	Possible Annual Costs in Gunpowder Watershed[(b)]
	$/mi²/y	*$/y*
State Highways[(c)]	$25,000	$915,000
SD1 Sewers[(d)]	$2,500	$91,500
Private Utilities[(e)]	$900	$32,900

[(a)]after Hawley *et al.* (2013)

[(b)]projected using the Gunpowder Creek drainage area to the gage location, which is close to the confluence of the three main branches that drain the developed headwaters of Gunpowder Creek (36.6 mi², 22.6% impervious). As one moves farther downstream from that location, development intensity decreases.

[(c)]based on estimated damages of $3,100,000 in Boone County in 2011. To account for the fact that 2011 was a record rainfall year, the estimated damages from 2011 were reduced by half to approximate more typical precipitation years. Unit rate assumes damages occurred in more developed portions of the county.

[(d)]estimate based on documented impacts to sewer trunk lines in Banklick Creek of more than $500,000 in 2011. Unit rate assumes impacts took 10 years to manifest.

[(e)]estimate based on documented impacts to Duke overhead electric and buried gas lines in the Dry Creek corridor.

Areas of Local Concern

As previously mentioned, the impacts associated with development and future development are a dominate concern for the Gunpowder Creek Watershed. Several areas in the Gunpowder Creek Watershed are approved for, or are in the planning stages for future development. Several on-going residential developments are continuing to move forward in the Gunpowder Creek Watershed that will ultimately tally to over 6,000 additional dwelling units (including single-family as well as multi-family dwellings). Harmony, with over 1,400 units remaining to be built, and Ballyshannon, with 1,200 units to come, are the two largest contributors. Harmony is located in the Fowler Fork Subwatershed and Ballyshannon is located in the Long Branch Subwatershed. Several others will add to the total as they build out including Farmview (located in our priority subwatershed – South Fork Gunpowder), Gunpowder Trails, and others (Bob Jonas, 2014). Throughout the Gunpowder Creek Watershed there are also several plans for commercial developments including the Union Town Plan in Fowler Fork, the Aeroparkway – which is expected to open up approximately 400 acres for development, the Mount Zion Interchange expansion, and Mall

Road – which is expected to open up approximately 60 additional acres of commercial development.

Regarding specific areas of concern and flooding – this was listed as a concern in the Whispering Trails subdivision of Fowler Fork. The South Fork of Gunpowder, which is the most developed subwatershed, was also reported to have flooding concerns.

Existing Priority Status

Detention basin retrofits and stormwater master planning for flood and erosion control may be two of the most cost-effective BMPs for Gunpowder Creek.

Large-scale efforts with the goal of improving flood control within the Gunpowder Creek Watershed are routinely conducted by the City of Florence and SD1, including recent and ongoing projects such as the Fowler Fork Master Plan (SD1) and the Pheasant Watershed Study (City of Florence). As development continues to increase in the coming years, studies for other areas of flooding concern are likely to be performed. Prioritizing GCWI's efforts based on local master planning efforts is important because EPA research has documented that trying to improve such large-scale problems with lot-level controls alone, even with the backing of large public awareness and financial support programs such as reverse auctions, does not appreciably improve water quality or stream habitat (Roy *et al.*, 2012). The GCWI must capitalize on flood control master planning projects because the scale of the problem requires large-scale, coordinated investments focused both on quantity and quality of stream flow. In addition to flood control master planning, SSO reduction within the watershed has also been, and will continue to be, a priority for SD1. The ~$115 million tunnel to the Western Regional Wastewater Treatment Plant has already served to reduce overflows in the Gunpowder Creek Watershed, along with other portions of SD1's service area.

Other existing efforts include agricultural incentive programs for manure management, riparian buffer strips, field buffers, conservation coverage, conservation tillage, nutrient management, nutrient trading, etc., which exist through programs such as the USDA's Environmental Quality Incentives Program (EQIP). Numerous federal (USEPA, USACE, etc.) and state (KDOW) regulations are in place to help control flooding and to protect streams from excessive disturbance and illicit discharges. The GWCI Steering Committee must consider all existing and proposed federal, state, and local water quality efforts, selecting complimentary BMPs and supporting/guiding existing programs in an attempt to maximize the effectiveness of all funding spent in the watershed.

Watershed Management Activities

There are numerous stakeholders and ongoing activities that are intended to improve/protect stream health in the Gunpowder Creek Watershed. The City of Florence and SD1 have stormwater inspection and maintenance programs, including inspection of existing detention basins. Capitalizing on these programs could lead to efficiencies in implementing a detention basin retrofit program.

The BCCD conducts numerous agricultural outreach and assistance programs that can be used to target priority rural watersheds. The City of Florence and SD1 also conduct flood control master plan modeling, design, and implementation, which could be calibrated to also provide water quality and channel protection benefits. Their MS4 stormwater programs are also critical in protecting stream health, including their outreach/education, operations and maintenance, and illicit discharge detection and elimination programs. All of these activities underscore the importance of having a watershed coordinator dedicated to the advocacy and implementation of this Plan as a key component of future success.

6.2 Developing a Plan of Action

The following list of prioritized and targeted action items was developed through a collaborative effort with the Technical Sub-committee of the Gunpowder Creek Steering Committee, including representatives from Boone County, BCCD, KDOW, the City of Florence, SD1, and Sustainable Streams during a meeting held on June 24, 2013. The group began with KDOW's (2010) list of structural and non-structural BMPs from the Guidebook and then systematically tailored the BMPs to align with the pollutants of concern, likely sources, cost effectiveness, and feasibility (**Table 5-3**). Through additional analysis and Steering Committee input, BMPs have been compiled into a preliminary Action Item list.

The primary focus of the Gunpowder Creek Watershed Plan moving forward is on flow regime restoration through implementation of optimized stormwater BMPs, with the anticipation that these BMPs will also yield meaningful reductions in bacteria, phosphorous, and nitrogen levels. These practices will be supplemented by targeted mitigation and restoration efforts aimed at pollutant sources throughout the watershed. A rigorous monitoring plan should be implemented to measure the effects of the watershed management efforts, along with regular reassessment of the effectiveness of installed BMPs, which will potentially highlight the need for adjustments to the overall strategy. It should be noted that water quality is the quickest indicator of an effective plan, while stream stability can take longer, as it relies on vegetative recovery that may take multiple growing seasons. Biological recovery can take an even longer amount of time, as it relies on water quality and stream stability as prerequisites.

6.2.1 Developing Action Items

The Gunpowder Creek Watershed Plan has been tailored to focus on the highest priority problems using the most cost-effective BMPs, stakeholder input and the most feasible opportunities. For example, rather than prescribing the precise location of all of the estimated 170 acre-feet of new stormwater storage that may be necessary to mitigate stream erosion, the plan calls for locating bankfull wetlands, extended detention, and detention basin retrofits based on access, opportunity, and overall cost-effectiveness in achieving the total optimized storage goal. For the purposes of increasing the potential impact of BMP implementation, Action Items have been targeted to priority watersheds, for example South Fork for developed areas and Riddles Run for rural areas; however, locations of BMPs within those priority areas remains flexible in order to capitalize on those that are the most cost-effective and feasible.

Items requiring technical assistance, such as engineering design, hydromodification training, etc., are evident throughout the Action Item list, and estimates of corresponding fees have been included. Responsible parties include the GCWI, its Steering Committee, and specific partners for specific projects, such as the City of Florence for the Pheasant Watershed Study. Funding mechanisms include 319(h) funding, as well as local and state sources, for example, Boone County Parks may be a partner on the installation and maintenance of the pet waste program. Even the BMPs included on the Action Item List may be flexible as new opportunities arise, for example, a septic system program via the Northern Kentucky Health Department or a steep slope reforestation program via the either one of the local urban forestry organizations. More specifically, the Northern Kentucky Urban Forestry Council recently prioritized the Gunpowder Creek Watershed as a "Priority Planting Zone" to plant ~$8,000 worth of riparian trees. BCCD plans to partner with the Urban Forestry Council's Urban Tree Committee to develop planting plans and plant trees within the riparian zone of Gunpowder Creek.

In sum, the Action Item list represents one combination of logical, high-priority BMPs that seem to be feasible based upon known opportunities at the time of the writing of this Plan; however, they are subject to change based on the changing nature of the watershed and its opportunities. The Action Items are organized by categories of overall watershed, developed areas, agricultural lands, and undeveloped areas. Cost estimates are informed by a combination of unit costs from the literature and local projects. Because the costs are for planning purposes, they err on being conservative such that if implementation costs are less than what is budgeted, additional BMPs can be implemented from the cost savings. Conceptual locations and cut sheets for several of these BMPs are included as **Appendix 6-B**. The following action items are summarized in Tables 6-6 and 6-7 (beginning on page 6-20). Additionally, a series of maps are included at the end of this chapter to illustrate potential focus areas for implementation efforts related to some of the action items.

Figure 6-3: Hydromodification surveys measure stream stability and will help to track the impact of stormwater controls on mitigating excess levels of stream erosion

Overall Gunpowder Creek Watershed

1. **Watershed Coordinator** – A watershed coordinator, who would work ~20 hrs a week, is recommended to oversee the installation, implementation, maintenance of BMPs, as well as monitoring and strategic adjustment of the Watershed Plan. The total estimated cost of funding this position is ~$30,000 per year.
2. **Revise Rules and Regulations** – While the BMP Manual developed by SD1 and the City of Florence has added a water quality treatment requirement for the 80th percentile event (0.8 inches), which is an excellent improvement over conventional flood control design, protecting stream channels from excess erosion is still not required. Doing so will allow for the optimization

of BMP designs to provide channel protection control based on local hydromodification data via the use of $Q_{critical}$ controls, which are designed to capture and release all storms up to and including the 2-year storm below the critical flow for stream erosion. The consideration of $Q_{critical}$ in stormwater BMP designs is not anticipated to result in substantial cost impacts to property owners and/or developers. While it is not yet a requirement, SD1 currently has a credit program for new developments that meet the $Q_{critical}$ design target in addition to the water quality and flood protection controls. A proposed budget of ~$15,000 for the technical support that may be needed during the review and revision of the Rules and Regulations is recommended.

3. **Success Monitoring and Analysis** – Continue monitoring water quality at currently established monitoring stations, including yearly hydromodification surveys at the same stations (**Figure 6-3**). This action item is an extremely critical part of the Watershed Plan in that it will guide future adjustments to the strategy, and may document attainment of the water quality benchmarks prior to the implementation levels that were presented in Chapter 5. Therefore, $20,000 per year to fund the monitoring/analysis program is recommended.
4. **Stewardship Programs** – Facilitating community and corporate stewardship is a critical part of the Plan's success. Education and outreach programs for home owners and large corporate or institutional properties can have relatively low cost, but can deliver measurable results if done effectively (Galvin, 2005). Therefore, a $3,000 annual budget is recommended to work with KDOW's education coordinator and other resources to develop outreach materials and programmatic activities to facilitate watershed stewardship.
5. **Coordination with NKU FILO Program** – The Northern Kentucky University (NKU) Center for Environmental Restoration (CER) runs the Stream and Wetland Restoration Program of Northern Kentucky that is funded by the Fee-In-Lieu-Of (FILO) funds that are accrued when developments or other land-disturbance projects physically alter streams. The CER has demonstrated the ability to stabilize degraded stream reaches and restore their habitat, even in urban watersheds. Many of the restoration projects have been constructed in the vicinity of the Gunpowder Creek Watershed, and CER is regularly looking for additional projects. The CER is on the GCWI Steering Committee, and continued coordination with the restoration program is strongly recommended. Up to $1,000 may be budgeted to support the development of restoration proposals for projects that could stabilize stream reaches in the Gunpowder Creek Watershed that are large sources of bank erosion and TSS.
6. **Riparian Plantings** – Buffer zones of native grasses, forbs, and woody vegetation along streams are reported as highly effective at removing pollutants from overland runoff (Wenger, 1999). They also increase habitat in streams via the addition of large woody debris, provide food sources such as leaf litter, and help to reduce bank erosion. Seeding is estimated to range between $100 and $700 per acre, which equates to an average cost of ~$0.15 per foot, if the planted buffer is 15 feet wide. Additionally, installation of one live stake per square yard should cost just over $15 per foot of buffer. Therefore, ~$90,000 is recommended in riparian plantings as a part of this Action Item, which, conservatively, should be enough for ~4,500 linear feet of buffer zones.
7. **Training and/or Technical Support Programs** – Training and/or Technical Support Programs for local designers and contractors are important to provide designers and contractors with an

understanding of the importance of channel protection controls and how they can be relatively easily added to the current design practice for stormwater BMPs. Developing training material and conducting training sessions is expected to cost ~$15,000 per year. The technical support may also be applied to assist BCCD in guiding flood control master planning projects conducted by other project partners (discussed under Item #2 below).

8. **Structural and Non-Structural BMPs** – Implementing BMPs is key to the next stage of the Plan. These BMPs can be implemented wherever in the watershed there is a cost-effective opportunity. Further details specific to the BMPs in the developed headwaters of Gunpowder Creek follow in the next section.
9. **On-site Wastewater Treatment** – On-site wastewater treatment is not a priority BMP at this time, although it may become more beneficial as implementation progresses. The Northern Kentucky Health Department will lead this effort, with possible funding or other assistance provided by the GCWI. The goal will be to identify and repair or replace faulty septic systems and/or straight pipes. Therefore, action items include working with the Northern Kentucky Health Department to determine feasibility and areas of greatest concern, identifying faulty septic systems and/or straight pipes, and pursuing funds in coordination with the Health Department or other entities to address any identified issues.
10. **Education and Outreach** – In addition to the specific education focused on training and technical support for local designers and engineers, other education and outreach efforts will be directed to those that live and work in the Gunpowder Creek Watershed. These activities will focus on educating the community to understand necessary behavioral changes that will make a difference in the integrity of the watershed.

Developed Areas (with an initial focus on the South Fork of Gunpowder Creek Subwatershed)

1. **Detention Basin Retrofits** – BCCD, SD1, USEPA, and Sustainable Streams have been piloting a simple, cost-effective technology to retrofit the outlet control structure of conventional, flood control detention facilities to be optimized to minimize channel erosion and increase water quality treatment potential (Hawley *et al.*, 2013b). Of the estimated 535 existing detention basins in the Gunpowder Creek Watershed, there are approximately 250 in Florence that are annually inspected and maintained. Florence owns approximately 16, but has access to the outlet structures of most. Recently, Boone County transferred ownership of approximately 50 detention basins to SD1. A GIS mapping effort of all major detention ponds in the watershed is already underway. Large detention ponds with large drainage areas should be the primary focus, as they are likely to yield the greatest impact for approximately the same cost. Older ponds may be better candidates as they were likely built under outdated stormwater ordinances, allowing the retrofit to result in a greater change from the current condition. The retrofitted outlet structure will provide greater benefits in basins that have more excess storage capacity than in those basins with limited freeboard storage for the 100-year design storm. Ponds located on public lands such as parks, schools, etc. are of the highest priority, due to the likelihood of stakeholder cooperation. Private landowners should be engaged in order to determine the level of willingness to cooperate in such efforts. If necessary, incentives could be implemented in order to make these watershed stewardship practices more desirable to private stakeholders.

Within the first three years, the target of 10 retrofits installed on larger ponds in the subwatershed should cost ~$100,000 total, and could result in a reduction of ~1.5 million pounds of TSS annually and significant impacts on bacteria, phosphorous, and nitrogen.

2. **New Detention Ponds and Bioinfiltration Basins** – The search for candidate locations should focus on heavily developed areas that do not currently have detention, but have open land between development and receiving streams. As with the retrofits, public lands should be prioritized and private landowners should be engaged to determine the level of potential cooperation. This Action Item could require the purchase of land or incentives for landowners willing to donate land for the installation of optimized detention ponds. BCCD should coordinate with key partners, such as the City of Florence and SD1 to ensure that capital investments for flood control are also designed to maximize channel protection, water quality, and biotic integrity benefits to the extent feasible. This includes providing target flows ($Q_{critical}$) based on hydromodification data collection, geomorphic assessments and analysis efforts of the Watershed Plan. At ~$2 per cubic foot, installation of 3 acre-feet of new detention storage in the South Fork of Gunpowder Creek Subwatershed should cost ~$260,000 and could result in removal of ~100,000 lbs of TSS annually. In the event that a property owner prefers a bioinfiltration basin as opposed to an extended detention basin, 0.4 acre-feet of bioinfiltration for a total of ~$61,000 that is estimated to remove ~11,000 lbs of TSS annually has also been included.
3. **Wetland Creation/Restoration –** A study of aerial photography of the watershed may reveal some optimal locations for wetland creation/restoration. Potential locations that may support wetlands include areas near locations where wetlands currently exist, areas with constructed farm ponds, farm fields that utilize the "lands" method of plowing and dry depressions, among other indicators (Biebighauser, 2011). Ideal candidates for the creation of bankfull or benchfull wetlands include large, low-lying swaths of land adjacent to the channel and publicly-owned lands are again a priority. Bankfull/benchfull wetlands are a relatively new BMP but they have a high potential to treat large volumes of polluted water by routing overbank stream flows through large off-line wetlands. Published performance data is limited; therefore, we have preliminarily used performance data for "wetland channels" from the International BMP Database (Leisenring *et al.*, 2012) until better data become available. These performance data are consistent with preliminary performance data from several bankfull wetlands in the Mill Creek Watershed, an impaired waterbody in Cincinnati with high TSS loads (Miller, M., 2013, Pers. Comm.) as well as an independent analysis for the South Fork of Gunpowder Creek. Therefore, the preliminary TSS removal rates developed for the order of magnitude estimates presented herein are based on an understanding of hydrology, hydraulics and sedimentation (*e.g.,* fall velocities of sand/silt/clay), as well as preliminary performance data from several bankfull wetlands in the Mill Creek Watershed, an impaired waterbody with high TSS loads (Miller, M., 2013, Pers. Comm.). For all flows above benchfull (*e.g.,* ~10 cfs in SFG 5.3-UNT 0.3) we assume that 20% of the flow is routed through the wetland with a ~29% TSS removal rate (Leisenring *et al.*, 2012). This equates to removing ~6% of the TSS load associated with flows above benchfull, or ~63,000 pounds of the estimated 1.1 million pounds annually. A conservative unit cost estimate of ~$2 per acre-feet means the installation of 2.5 acre-feet of

wetlands in the South Fork of Gunpowder Creek Subwatershed should cost approximately $220,000.

4. **Pet Waste Program/Educational Outreach –** Dog doo programs are some of the most cost-effective stormwater management practices documented (CWP, 2013). An adequately implemented pet waste program, including well-stocked and labeled stations in areas high in dog-walking traffic, and regular maintenance, could result in a bacteria reduction of ~80 billion colonies annually per dog in the program area. This estimate is based on values provided in literature for dog waste production, 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). Preliminarily, the installation of 16 stations is recommended. The material, installation and maintenance (3 years) cost of the program is estimated to be ~$30,000.

Agricultural Land (with an initial focus on the Riddle Run Subwatershed)

1. **Livestock Exclusion Fencing –** GCWI should work with local farms to install exclusion fencing to keep livestock out of the streams.

a) **Map horse farms in GIS if possible** - Horse farms may or may not show up in zoning, but BCCD has a list of 30 larger operations that may be used as a starting point.

b) **Targeted outreach to horse farms** - In Riddles Run, there are horse farms in the headwaters and near the monitoring location. Known dry weather *E.coli* issues make this a good candidate.

c) **Targeted outreach to farms that lack adequate exclusion fencing** - Locate farms where fencing may be beneficial and offer assistance to those farmers. Based on the assumption that 20% of cattle waste is deposited directly into streams when available, an estimated ~600 billion colonies per year can be kept out of the streams for each cow excluded by fence installations. Exclusion fencing will not only keep livestock from disrupting and polluting streams directly, it will also result in the creation of riparian buffer zones that help to filter overland runoff. At an approximate cost of $2 per foot, a budget of $20,000 is recommended for the installation of ~10,000 linear feet of fencing.

d) **Offer assistance for other practices** – Continue to provide extension service assistance for rotational grazing, manure management, grassed waterways, cover crops, manure testing for fertilizer application, etc.

Undeveloped Areas (with an initial focus on the Lower Gunpowder Creek Subwatershed)

Boone County has been one of the fastest growing counties in the state of Kentucky. Development slowed during the economic recession; however, new development is anticipated to increase as the economy continues to recover. Beyond the pertinent Action Items listed for the overall watershed above, such as revising rules and regulations (Item #2) and providing training for local designers and contractors (Item #7), the following Action Item is recommended for areas that are currently undeveloped:

1. **Conservation of Open Areas –** BCCD should work with local authorities and stakeholders to pursue cost-effective methods to preserve, conserve, and/or improve green spaces. This includes strategies discussed above for the overall watershed including riparian buffers plantings

(Item #6) and actions pertaining to rules and regulations (Item #2) such as open space requirements, setbacks, reduced use of impervious surfaces, and other strategies to better protect Boone County's water resources. It also includes strategies to preserve/conserve undeveloped lands, especially forested areas along streams and on steep slopes, via conservation easements and other practices to promote the long-term sustainability of the natural condition. GIS mapping of publicly-owned undeveloped lands has already been completed as the first step of the preservation effort (**Figure 5-10** and **Appendix 5-A**). Coordination with private conservation groups, such as The Boone Conservancy, is also being pursued. At the time of the writing of this Plan, no specific properties had been identified as feasible candidates and no line-item funding had been allotted. However, if strategic properties for conservation become available during plan implementation, funds should be re-prioritized to the extent feasible to support the implementation of such efforts.

Subwatershed Prioritization

In order to prioritize subwatersheds for BMP implementation, the extent of impairment, known opportunities within the watershed, cost, and feasibility was all considered. The prioritization was also stratified such that we had a representative sample of the diversity of the watershed land uses and hydrogeomorphic settings. The prioritization includes:

1. South Fork (developed headwaters)
2. Lower Gunpowder (undeveloped bottomlands)
3. Riddles Run (agricultural headwaters)
4. Fowler Fork (mixed rural/developed headwaters)
5. Upper Gunpowder (developed headwaters)
6. Long Branch (agricultural headwaters)

It should be acknowledged that the prioritization could change depending upon the opportunities that arise during the timeframe of implementation funding. For example, flood control master planning projects require large investments for modeling, design, and construction. If a stakeholder agency was planning to develop or implement a master plan in one of the subwatersheds, it should immediately be reconsidered as a possible priority watershed due to the opportunity to leverage large amounts of resources for improvement to both water quantity and quality issues.

Even if smaller opportunities arise such as local flooding concerns, prioritization may be given if there are opportunities to help improve habitat and water quality in addition to flooding. For example, at the Boone County Fiscal Court meeting on February 4, 2014, flooding issues were discussed regarding the property at 1846 Conner Road in Hebron, Kentucky, in the headwaters of Gunpowder Creek (priority area #5 in the list above). From a preliminary inspection of the small upstream catchment area, it seems to be apparent that the lack of adequate stormwater detention at Connor Middle and High Schools is likely a primary cause of the problem (**Figure 6-4**). Increasing the size of the culvert near the property at 1846 Conner Road is certainly one way to improve local flooding; however, it does nothing to improve flooding, channel erosion, or water quality downstream. A larger culvert simply uses public resources to push the flooding problem downstream and allows for stream erosion and water quality pollution to potentially become worse as a consequence.

Figure 6-4 – Aerial photo of the 1846 Connor Road property where flooding issues were discussed at the February 4, 2014 Fiscal Court Meeting. The small upstream catchment area includes Connor Middle School, which appears to have inadequate stormwater controls to protect against downstream flooding and stream erosion. As opposed to strictly focusing on increasing the size of the downstream culvert, public funding could be invested in volume-based stormwater controls to solve the root cause of the problem provide numerous benefits to downstream property owners and the health of Gunpowder Creek.

Alternatively, if partnerships could be established between stakeholders such as Conner Middle and High Schools, Boone County, and others, it could be possible to invest in solutions that address the root cause of the flooding problem. Simple BMPs such as routing downspouts and gutters to open spaces and/or installing new detention could not only help to address flooding at 1846 Conner Road, but also improve flooding, stream erosion, water quality, and habitat throughout the Gunpowder Creek. Implementing such activities in the headwaters of the network can be even more cost-effective than at other locations for this very reason. If such a holistic approach was embraced by the necessary stakeholders, GCWI may reprioritize Upper Gunpowder to be the priority developed watershed as opposed to South Fork (priority area #1 in the list above) in order to more actively support a comprehensive solution.

BMP Feasibility/Priority List

There are any number of combinations of volume-based stormwater BMPs, rural dry-weather BMPs, and education/outreach BMPs that will result in load reductions to meet the water quality benchmarks in the Gunpowder Creek and its tributaries. **Table 6-6** includes the Action Items listed above, with potential funding mechanisms, responsible parties, and goals for implementation. **Table 6-7** includes a prioritized list based on Steering Committee and Technical Committee input, load reduction effectiveness, feasibility, and a preliminary cost target of $1,000,000 for the initial implementation phase. For the focus areas related to the action items and implementation goals, refer to **Figure 6-5** to **Figure 6-7**.

Table 6-6: Prioritized BMP list including action items, potential funding mechanisms, responsible parties, and goals for implementation

BMP	Action Items	Potential Funding Mechanism	Responsible Parties	Goals for Implementation[e] Short-term	Intermediate	Long-term	Total	
Overall Watershed								
Coordination with NKU FILO Program	1. Coordinate projects with NKU. 2. Provide guidance on best project locations.	319(h) grant[d] NKU FILO funds	GCWI NKU	0	1	2	3	years
Revise Rules and Regulations	1. Review participation rate in the SD1 Qcritical credit program for new developments. 2. Continue coordination with SD1 and Florence regarding channel protection controls. 3. Coordinate with BCPC to incorporate more LID strategies into Planning/Zoning Requirements and Subdivision Regulations.	319(h) grant[d]	GCWI SD1 & Florence BCPC	1	0	0	1	revision
Riparian Plantings	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[d]	GCWI	500	2,500	1,500	4,500	linear feet
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[d]	GCWI	0	1	2	3	years
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[d]	GCWI Private Companies Individual Landowners	1	1	1	3	years
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[d]	GWCI SD1 & Florence	1	1	1	3	years

BMP	Action Items	Potential Funding Mechanism	Responsible Parties	Goals for Implementation[e]				
				Short-term	Intermediate	Long-term	Total	
Watershed Coordinator (half time)	1. Administer, manage, and implement the Watershed Plan.	319(h) grant[d]	GCWI	1	1	1	3	years
Structural and non-structural BMPs	1. Design and construct any BMP's listed in Table 5-3.	-	-	As needed	As needed	As needed	-	
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 entities to address identified issues.	-	N. KY Health Department	0	As needed	As needed	-	
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[d]	GCWI	1	1	1	3	years
Developed Headwaters [a]								
Bioinfiltration	1. Locate opportunities for bioinfiltration. 2. Coordinate with landowners. 3. Design and construct bioinfiltration.	319(h) grant[d] Landowners	GCWI SD1 & Florence Landowners	0	0	0	0	acre-feet
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[d] Landowners	GCWI SD1 & Florence Landowners	2	4	4	10	retrofits

BMP	Action Items	Potential Funding Mechanism	Responsible Parties	Goals for Implementation[e]				
				Short-term	Intermediate	Long-term	Total	
Detention Basins	1. Locate opportunities for new detention basins in heavily developed areas that do not currently have detention. 2. Coordinate with landowners to allow construction of a new basin or obtain property to construct new detention basins. 3. Design and construct the detention basins that provide channel protection controls.	319(h) grant[d] Landowners	GCWI SD1 & Florence Landowners	1	1	1	3	acre-feet
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.	319(h) grant[d]	GCWI	2	8	6	16	stations
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[d] NKU FILO funds	GCWI KDOW NKU	0	2	1	3	acre-feet
Agricultural Areas [b]								
Livestock Exclusion Fencing	1. Map hourse 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[d] USDA (EQUIP)	GCWI USDA Landowners	2,000	4,500	3,500	10,000	linear feet

BMP	Action Items	Potential Funding Mechanism	Responsible Parties	Goals for Implementation[e]				
				Short-term	Intermediate	Long-term	Total	
Undeveloped Areas/Forestry[c]								
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.	-	GCWI N. KY Urban Forestry Council	1	1	1	3	meetings

[a] Developed BMP strategies will be evaluated first in the priority subwatershed of South Fork Gunpowder. However, GCWI plans to implement these strategies in any subwatershed in which opportunities are optimal and cost-effective.
[b] Agricultural BMP strategies will be evaluated first in the priority subwatershed of Riddles Run. However, GCWI plans to implement these strategies in any subwatershed in which opportunities are optimal and cost-effective.
[c] Undeveloped Areas/Forestry BMP strategies will be evaluated first in the priority subwatershed of Lower Gunpowder. However, GCWI plans to implement these strategies in any subwatershed in which opportunities are optimal and cost-effective.
[d] 319(h) grant monies include a 40 percent non-federal match. Reference Table 6-7 for additional information regarding the cost of each BMP.
[e] Implementation is dependent on receiving 319(h) grant money and takes us through 2018 and goals following 2018 should be determined based on the project implementation and success monitoring.

Table 6-7: Prioritized BMP list/budget including estimated costs and load reductions

BMP	Unit Cost		#	Total Cost	Estimated Load Reductions in Priority Watershed: TSS	Bacteria	TP	TN
Overall Watershed								
Coordination with NKU FILO Program	$ 333	per year	3	$ 1,000	-	-	-	-
Revise Rules and Regulations	$ 15,000	ea	1	$ 15,000	100 %[a]	100 %[a]	100 %[a]	100 %[a]
Riparian Plantings [b]	$ 20	per lf	4500	$ 90,000	74 %[c]	629 billion colonies per livestock animal excluded per yr [d]	48 %[c]	35 %[c]
Success Monitoring and Analysis	$ 20,000	per year	3	$ 60,000	-	-	-	-
Stewardship Programs (public/private/ individual)	$ 3,000	per year	3	$ 9,000	-	-	-	-
Training/ Technical Support Program	$ 15,000	per year	3	$ 45,000	-	-	-	-
Watershed Coordinator (half time)	$ 30,000	per year	3	$ 90,000	-	-	-	-
Developed Headwaters [e]								
Bioinfiltration [f]	$ 174,000	per ac-ft	0.35	$ 61,000	11,000 lbs	2,000 billion colonies/yr	20 lbs/yr	TBD
DB Retrofits [f][g][h]	$ 10,000	ea	10	$ 100,000	1,520,000 lbs	240,000 billion colonies/yr	2,000 lbs/yr	TBD
Detention Basins [f][i]	$ 87,000	per ac-ft	3	$ 261,000	100,000 lbs	20,000 billion colonies/yr	100 lbs/yr	TBD
Pet Waste Program [j]	$ 1,845	per station	16	$ 30,000	-	82 billion colonies per dog in the program area per year [k]	3,000 lbs/yr	23,000 lbs/yr
Wetland Creation/ Restoration [l]	$ 87,000	per ac-ft	2.5	$ 218,000	63,000 lbs	4,000 billion colonies per year	60 lbs/yr	70 lbs/yr

				Estimated Load Reductions in Priority Watershed			
BMP	**Unit Cost**	**#**	**Total Cost**	**TSS**	**Bacteria**	**TP**	**TN**
Agricultural Areas							
Livestock Exclusion Fencing [m]	$ 2 per lf	10,000	$ 20,000	TBD	629 billion colonies per livestock animal excluded per yr [d]	9 lbs per head of cattle excluded per yr [n]	60 lbs per head of cattle excluded per yr [n]
Undeveloped Areas/Forestry							
Conservation of open areas	$ - -	-		-	-	-	-
		TOTAL	$ 1,000,000				

[a] Load reductions for revised rules and regulations assume that rules can be revised to reduce 100% of the excess future loads from future development relative to the current rules and regulations.

[b] Cost per linear foot assumes a ~15 ft 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 1 live stake per square yard, averaging ~1.5 live stakes per lineal foot of riparian buffer strip. Live staking is estimated to cost $10 per stake for material and installation.

[c] Reported values for TSS, phosphorous and nitrogen removal refer to pollutants flowing from upland 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] 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 3000 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.

[e] The South Fork of Gunpowder Creek has the highest impervious cover, highest TSS levels, and most excessive bank erosion. It is also likely that this subwatershed has the largest shortage of detention volume. SD1 reports that there are 139 detention basins in the subwatershed. Assuming the 1.4 ac-ft per basin estimate, there is an estimated 200 ac-ft of detention storage. Based on interpolation from case studies, the South Fork subwatershed could need approximately 550 ac-ft of optimized storage for channel protection. This means the South Fork could be up to 350 ac-ft short of the target volume. Comparing this to the estimated 185 ac-ft shortage for the entire watershed upstream of the gage shows the limitations of using average detention basin sizes from a limited sample size to develop watershed-scale estimates. Even so, the anlaysis underscores the likelihood that the South Fork of Gunpowder Creek is the watersehd with the largest stormwater storage deficit. Therefore, early efforts for mitigating the erosive flow regime should be focused here, including all new detention volume and retrofits.

[f] [illegible]

[f] Bioinfiltration, detention basin retrofits, and detention basins 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 Internation Storm Water BMP Database (Leisenring, 2012). See Tables 5-5 and 5-6.

[g] Assume that the larger basins within the watershed are targeted for retrofits, with an average existing volume of 5 ac-ft. This yields an estimated 5.5 ac-ft of optimized storage per basin.

[h] Detention basin retrofits should be designed to control the release of stormwater to minimize excess rates of bed material and bank erosion in receiving streams. Local case studies to date suggest load reductions of 80-120% of corresponding TSS loads from future bank failure that would be attributable to the local catchment area draining to the respective detention basin. Assuming an average TSS reduction rate of 100%, installing 10 in the South Fork subwatershed, targeting the largest available ponds (estimated at an average of 5 ac-ft), the retrofits may remove up to 1.5 million pounds of TSS from the stream they drain to.

[i]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. By installing these new detention basins in the South Fork subwatershed, where there is an estimated ~600,000 lb/mi2yr - or 9.8 million lbs total - generated by bank erosion, 3 ac-ft of new storage in this subwatershed results in an estimated 100,000 lbs of TSS removal in the South Fork subwatershed.

[j] Costs for the installation and maintenance of pet waste stations include $200 per station for materials, an estimated 4 hrs per station at $70 per hr (2 workers) for installation, and an estimated 15 minutes per week for 3 years at $35 per hr for maintenance. These are consistent with national references and local pricing experience. 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 very approximate rates based on several assumptions, and should be revised as more appropriate, regional data become available.

[k] Bacteria reduction by a pet waste program is not calculated as a function of # 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 wast 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).

[l] Removal rates by wetland channels as reported in the International Storm Water BMP Database (Leisenring, 2012) were used to calculate those for wetlands here, under the anticipation that bankfull/benchfull wetlands would be utilized in the SFG 5.3 UT watershed. It was assumed that enough wetlands would be constructed so that approximately 20% of the flow in the stream would be routed through these wetlands, removing ~29% of TSS, ~19% of bacteria, ~7% of phosphorous, and ~16% of nitrogen from that ~20%.

[m] Livestock exclusion fencing cost estimates are based on EQIP standards for fence installation ($1.53 per ft) 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 mulitplied by 1.33 to approximate the total (~$2.08 per ft).

The following figures present initial focus areas for implementation efforts.

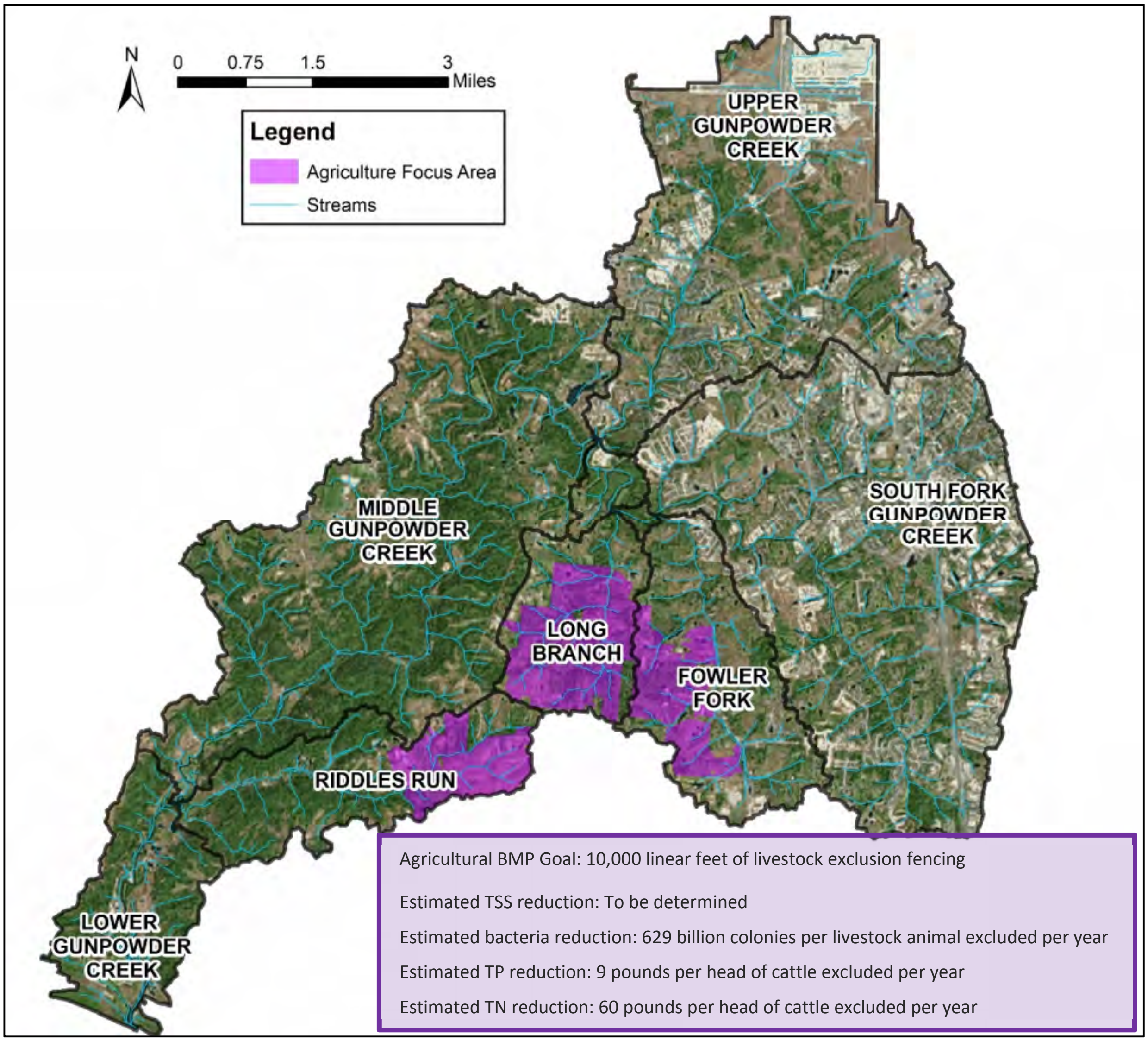
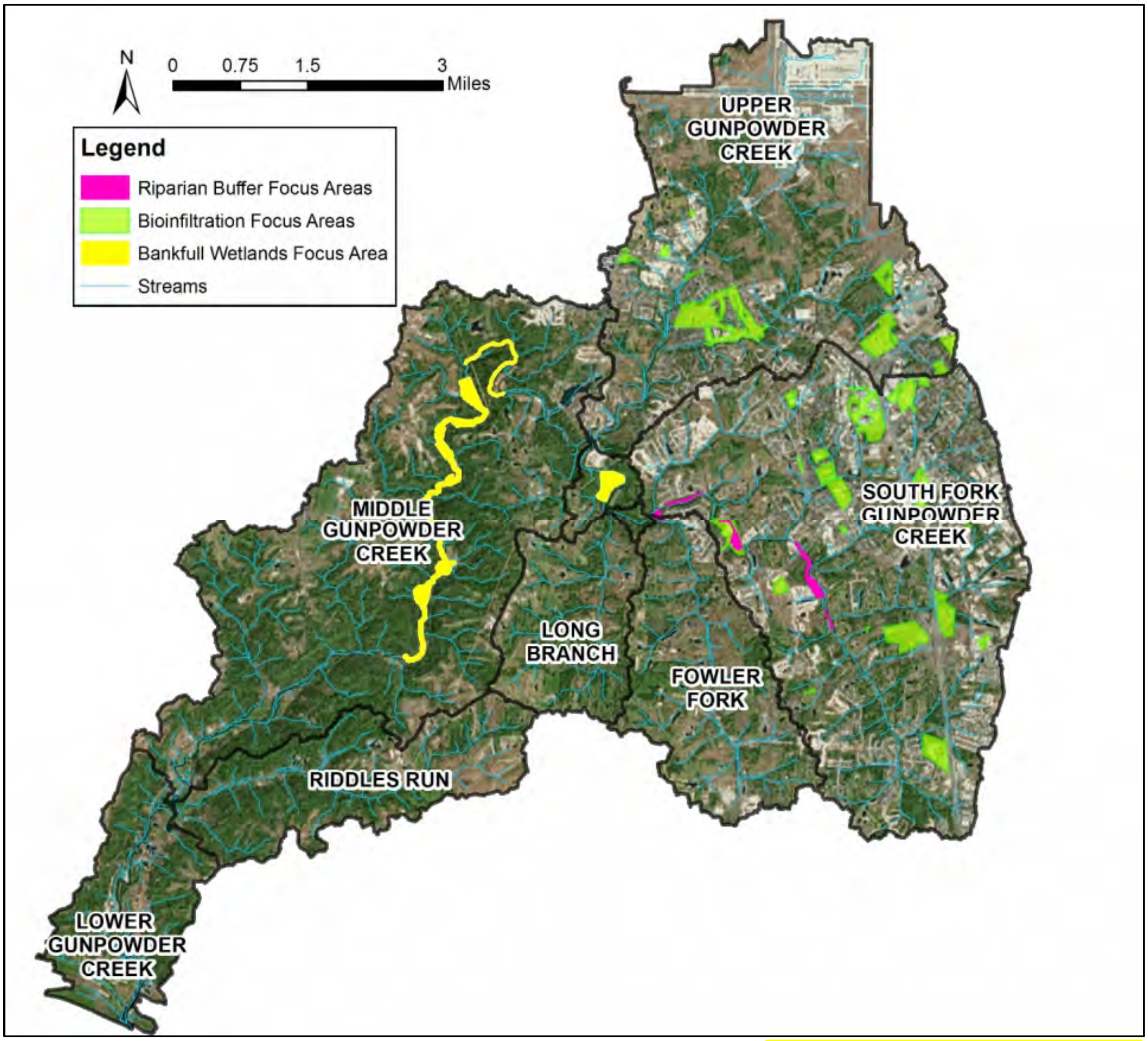


Figure 6-5: Potential Focus Areas for Agricultural BMP Implementation (See Table 6-7 for further details)

Note: The depicted agricultural BMP focus areas were identified by Boone County Conservation District.



Riparian Buffer	Bioinfiltration	Bankfull Wetlands
Riparian Buffer BMP Goal: 4,500 linear feet	Bioinfiltration BMP Goal: 0.35 acre-feet of storage	Bankfull Wetlands BMP Goal: 2.5 acre-feet of storage
Estimated TSS reduction: 74%	Estimated TSS reduction: 11,000 pounds	Estimated TSS reduction: 63,000 pounds
Estimated bacteria reduction: 629 billion colonies per year	Estimated bacteria reduction: 2,000 billion colonies per year	Estimated bacteria reduction: 4,000 billion colonies per year
Estimated TP reduction: 48%	Estimated TP reduction: 20 pounds per year	Estimated TP reduction: 60 pounds per year
Estimated TN reduction: 35%	Estimated TN reduction: To be determined	Estimated TN reduction: 70 pounds per year

Figure 6-6: Potential Focus Areas for Riparian Buffer and Stormwater BMP Implementation (See Table 6-7 for further details)

Note: Initial bioretention focus areas were determined by highlighting large parcels of land with high levels of impervious surface. Nearly all of the parcels identified above are public properties. Riparian buffer focus areas were identified by Boone County Conservation District. Bankfull wetlands were determined by evaluating low-lying areas near the streams.

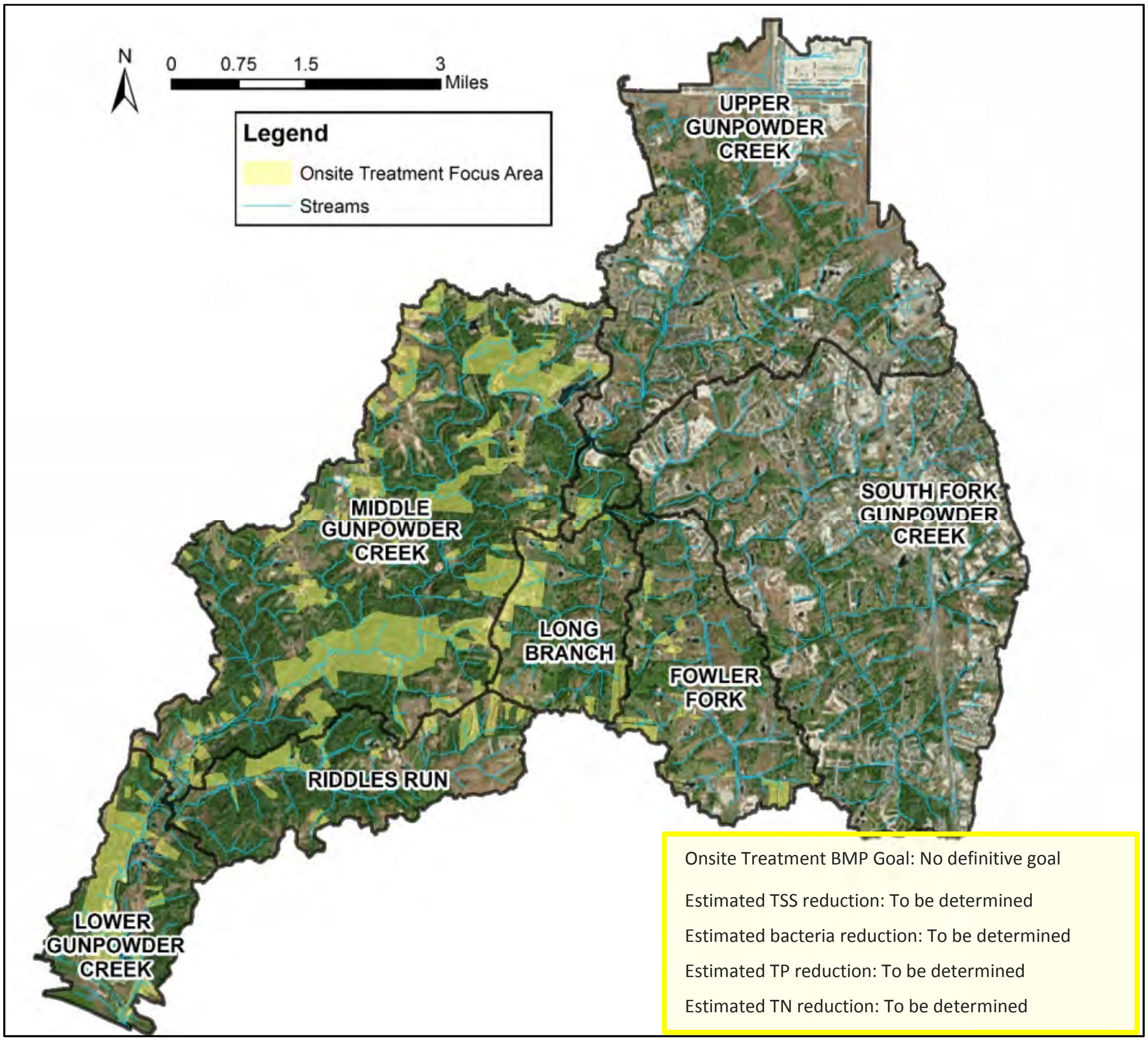


Figure 6-7: Potential Focus Areas for Onsite Wastewater Treatment Implementation (See Table 6-7 for further details)

Note: Initial onsite wastewater treatment focus areas were determined by parcels that have a building on them but are not served by SD1's sanitary sewer system, as presented in Chapter 5 of this Watershed Plan.

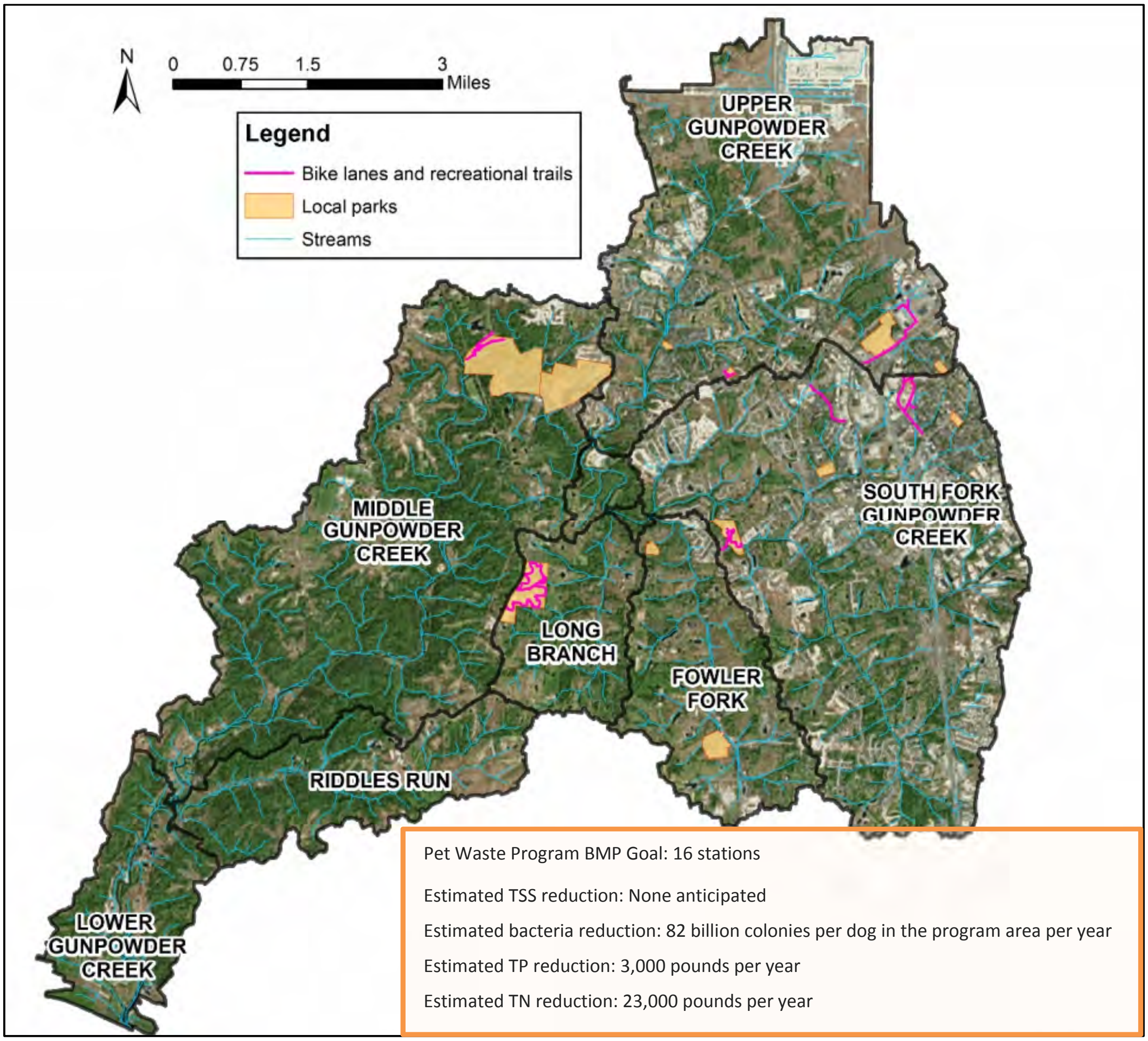


Figure 6-8: Potential Focus Areas for Pet Waste Program Implementation (See Table 6-7 for further details)

Note: Initial pet waste program focus areas were determined by highlighting the locations of local parks and recreational trails and bike lanes to determine where dog walkers may be most prevalent. There are no dog parks within the watershed.

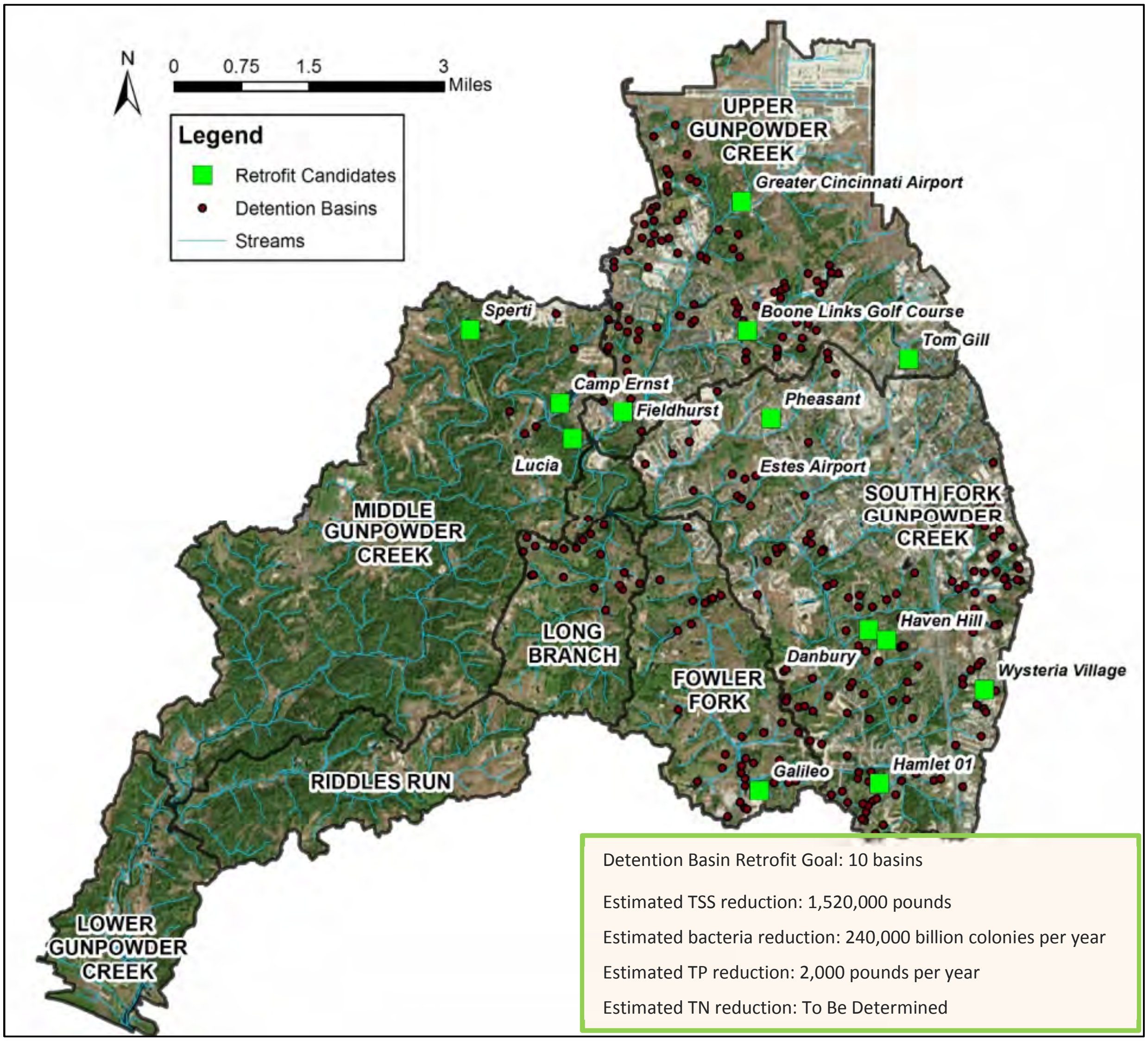


Figure 6-9: Potential Focus Areas for Detention Basin Retrofit Implementation (See Table 6-7 for further details)

Note: The initial detention basin retrofit focus areas were determined using field data from approximately 20 basins within the watershed and engineering judgment identify the most optimal configurations for retrofitting.

6.2.2 Plan Examples

The GCWI has used a wide array of local, regional, and national examples of watershed plans, technical guidance, and critical reviews of planning and guidance. **Table 6-6** regarding the Action Items is a framework that was developed from example guidance. The KDOW-approved Banklick Creek Watershed Plan (BWC, 2009) is from a neighboring watershed and was also referenced in the development of this plan. Technical reports and peer reviewed papers on hydromodification management were also very informative (*e.g.,* Hawley *et al.*, 2012).

6.3 Finding the Resources

The GCWI continues to expand its pool of human and monetary resources to contribute to the success of this project. The Steering Committee, Technical Committee, and BCCD's web of human resources include representatives from local stakeholder agencies and experts across different land management areas (*e.g.,* forestry, agriculture, and development/planning), stream integrity monitoring (*e.g.,* biology, chemistry, habitat, geomorphology, and hydrology), and BMP design/planning (*e.g.,* stormwater, wetlands, stream restoration, wastewater, etc.).

6.3.1 Potential Resources

Numerous partners have contributed and continue to contribute to this project. This provides a list of potential resources and is by no means inclusive of all the possible funding/agency resources that could be available.

NRCS Resources

The National Resources Conservation Service (NRCS) run the Conservation of Private Grazing Land (CPGL) program, which may be using in the Gunpowder Creek Watershed. This program can provide technical assistance to cattle farmers in the watershed on better land management to preserve water quality.

319(h) Nonpoint Source Funds

As mentioned in Section 6.6.1, the GCWI is currently applying for additional 319(h) funding for implementation efforts. The current grant does have remaining funds that will be used for implementation also. Additional details can be found in Chapter 7.

Kentucky EXCEL

Kentucky's Environmental and Public Protection Cabinet runs a program called Excellence in Environmental Leadership (EXCEL). Upon brief evaluation of the list of participating members, it does appear that some businesses that are part of the program are located within the Gunpowder Creek Watershed. Further evaluations and beginning discussions with some of these entities may provide additional resources.

In-Lieu Fee Program for Stream and Wetland Mitigation

This resource has been discussed throughout the chapter and is highlighted in both **Table 6-6** and **Table 6-7**. The GWCI is very aware of the FILO program that is run through NKU and anticipates utilizing this resource.

Additional Resources

NKU and SD1 have been big contributors in terms of project matching sources and monitoring expertise. These partners, along with the City of Florence and others may be able to contribute matching projects on future grant applications. The single largest and underutilized resources in the Gunpowder Creek Watershed are the ~535 existing detention basins valued at ~$60 million. Systematically retrofitting these existing resources will provide much greater benefits to stream health than they are currently providing. The second largest sources of potential resources are the flood control improvement efforts underway by SD1 and the City of Florence. Capitalizing on those large investments to ensure that water quality and stream erosion protection are also improved through those investments would ensure that regional investments of public funds return the greatest cumulative benefit for the least cost. Conservation of any of the large tracts of public or privately owned land could also provide immense benefits regarding the protection of Gunpowder Creek and possibly provide large amounts of potential matching funds to future projects.

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CHAPTER 7

Making It Happen

Gunpowder Creek Watershed Plan

Prepared by the

Gunpowder Creek Watershed Initiative

December 2014

Chapter 7: Making It Happen

This chapter details the implementation of the Gunpowder Creek Watershed Initiative (GCWI), including key personnel, public involvement, fundraising, monitoring, evaluation and future updating of the plan.

7.1 Advocating for the Gunpowder Creek Watershed Plan

The GCWI Steering Committee has met regularly throughout the watershed planning process and will continue to meet 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
- Northern Kentucky Health Department
- Sanitation District No. 1 of Northern Kentucky
- Northern Kentucky University Center for Environmental Restoration
- Boone County Fiscal Court/Public Works
- City of Florence and City of Union
- Kentucky Transportation Cabinet
- Kenton County Airport Board
- Boone County Planning Commission
- Northern Kentucky Area Development District
- Kentucky Division of Water

7.1.1 Reach Out

In addition to keeping the Steering Committee on task, the Watershed Coordinator will be key in reaching out to engage the community in the efforts in the Gunpowder Creek Watershed. The community has been an asset in the development of the Plan, and their continued assistance and interest will be integral to implementation. The GCWI will organize education and outreach events and continue to garner support from the community and work with regional partners to implement the goals of the Watershed Plan.

Figure 7-1: Bluegill caught in Gunpowder Creek

7.1.2 Communication Alternatives

Throughout the planning process, the GCWI's public outreach campaign has included outreach through various forms of media, presentations to stakeholder groups/agencies, surveys, and public meetings including three open houses and three roundtable working sessions. The Watershed Coordinator has also presented and met with groups ranging from City/County officials to fly fishing and kayaking enthusiasts. The Steering Committee fully expects to continue with similar meetings throughout the plan's implemenation.

The ongoing media campaign will continue to utilize email, direct mail, and press releases as well as regular articles in (1) the Conservation District's quarterly *Landscapes* newsletter, which has a distribution of 6,000, and (2) *What's Happening in Boone County*, a unique quarterly publication distributed to over 43,000 households in Boone County. Through press releases, the GCWI has also published periodic articles in *The Boone County Recorder*, the weekly newspaper of record. In addition to *The Recorder's* online presence on www.cincinnati.com and www.nky.com, the GCWI will continue to use the Conservation District's website www.boonecountyky.org/bccd/ and will establish a social media presence via Facebook.

At the time this Plan was written, the finishing touches are being put on a public outreach document that briefly summarizes the Plan. This document will serve as a useful tool for those that do not wish to read the entire plan. The format of the document is similar to the Plan's and the two should be able to be followed congruently.

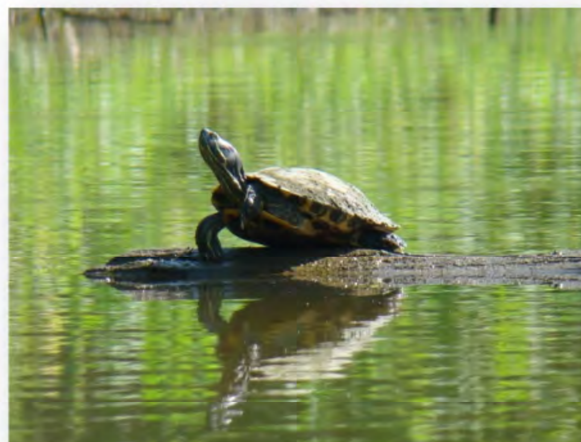

Figure 7-2: Painted turtle sunning itself in Gunpowder Creek

7.2 Securing and Managing Financial Resources

The GCWI has been funded primarily through a FFY 2009 Kentucky Nonpoint Source Pollution Control Program grant, or 319(h) grant, supported by matching funds from a variety of non-Federal sources. The FFY 2014 grant request for the BMP implementation phase of the GWCI is for $1,000,000, including $600,000 in Federal funds with a $400,000 match. Many of the BMP Action Items listed in the Gunpowder Creek Watershed Plan will be fully or partially implemented through this grant. Non-Federal matching funds will likely be associated with project partners in the following forms, among others:

- Boone County Conservation District in the form of personnel time, operating expenses, supplies, publication(s), travel, outreach, etc.
- SD1 and/or City of Florence installing new BMPs or detention basin retrofits that will create additional stormwater storage to better restore the natural flow regime, mitigate streambank erosion, reduce TSS levels, improve habitat, and create a more natural flow regime for benthic macroinvertebrates.

- City of Florence and/or Boone County Parks for installation and maintenance of 16 anticipated dog-doo stations with additional in-kind services from donated time related to the stewardship program.
- Contractual support for the development and implementation of a success monitoring program.
- Contractual support related to technical aspects of the project.
- Volunteer time may be utilized to increase public awareness of the project(s) and provide matching funds, for example, during the riparian planting.

In addition to Federal 319(h) grant funding, additional funding for the GWCI will be sought through local and regaional private foundations as well as local, State, and Federal grant sources that may be identified as potential sources. Private individuals and local non-profit organizations will be encouraged to participate in plan implementation and funding. City and County agencies will be encouraged to include funding for GCWI implementation in their annual budgets, particularly in the form of project-specific BMPs.

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

Mark Jacobs of the Boone County Conservation District will continue to serve as the **Watershed Coordinator** for the GCWI. Plan implementation will primarily be undertaken by Mr. Jacobs, members of the Steering Committee and Technical Sub-committee. Mr. Jacobs will also be in charge of leading the public outreach and education efforts.

Figure 7-3: Little Green Heron along Gunpowder Creek

The **Technical Sub-committee,** consisting of representatives from the Conservation District, City of Florence, City of Union, SD1, and Sustainable Streams, LLC, will be important to the success of the Plan. As projects are identified, the expertise of this group will help to assess the value of each opportunity, comparing multiple opportunities where necessary, and identifying possible additional funding sources or volunteer groups that may be willing to assist with the Plan. GCWI plans to continue monitoring at strategic locations throughout the watershed to track progress and reassess the implementation goals based on the success of installed projects.

Volunteers and Partner Agencies have donated time and resources for tasks such as Steering Committee meetings, public meetings, and data collection, and these resources will continue to be used for implementation. As mentioned above, volunteer time may be used to meet the local match for the 319(h) grant funding. It is also anticipated that students from Thomas More College will again be used in data collection/monitoring efforts to save costs relative to consultant services, as well as expand awareness through greater levels of involvement of younger stakeholders. As occurred during data collection before the Plan was written, specific, trained individuals will be present to ensure the quality of the samples.

7.4 Adapting to Changes and Challenges

A key element of the GCWI's approach for this Watershed Plan includes continued data collection and monitoring to serve as the basis of reassessing the plan (**Figure7-4**). The GCWI is expecting to make changes to the plan over the course of implementation. In order to achieve the most beneficial impact to the stream, the priority sub-watersheds may change as large projects by stakeholder agencies are planned and implemented. The intent of GCWI is to utilize the Plan's funding to partner with other local entities and groups to either include BMPs where they may have otherwise been excluded or expand the effectiveness of the project, for example, by adding channel protection and water quality components to an otherwise conventional flood control project.

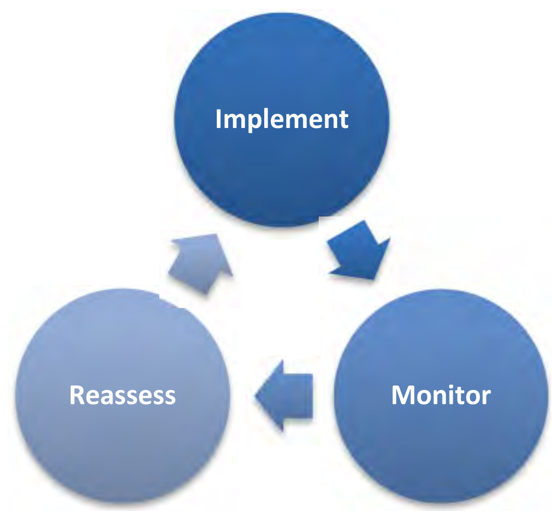

Figure 7-4: GCWI Watershed Plan Approach

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

Monitoring, tracking progress, and adjusting the implementation efforts to improve stream health is central to the GCWI's approach (**Figure 7-4**). Progress will be tracked to measure the improvements in the watershed and Gunpowder Creek's water quality. These records will be kept and monitored by the Watershed Coordinator. Once tracked, the projects and next steps will be reassessed to make sure the implementation is achieving the desired and anticipated results.

7.5.2 Improvements in Watershed Health or Practices

The GCWI will measure success in numerous ways, such as the implementation rate of the proposed activities (e.g. 10,500 feet of exclusion fencing installed out of a goal of 10,000). However, the GCWI will also work with KDOW to develop and implement an in-stream success monitoring program to truly measure water quality results. The sampling program will be comparable to the sampling that was performed during the planning process 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.

For verifying how implementation efforts have affected the conditions of the watershed, SD1 and the cities of Florence and Union will be useful partners. Through plan review with these entities, it will be clear if volume-based stormwater controls are being implemented. For other implementation activities, surveys or feedback at public meetings may be used depending on the activity.

Figure 7-5: Crayfish on the bank of Gunpowder Creek

7.5.3 Improvements in Water Quality

As previously mentioned, documenting in-stream success is a primary goal of the GCWI. Provided with sufficient funding, GCWI will develop a KDOW-approved monitoring plan and QAPP continue to monitor at the established stations, including biological, water quality, hydrological, habitat, and geomorphic surveys. This action item will also guide future adjustments to the BMP implementation strategy and document BMP effectiveness in the local setting.

7.5.4 Group Vitality

Both the Steering Committee and Technical Sub-committee want to see the successful implementation of the *Gunpowder Creek Watershed Plan* and improvements in the water quality and stream stability of the creek. We intend that these groups will continue to be excited and interested in the work that is being done. Through bi-monthly meetings, the Steering Committee will receive progress updates on current efforts. The Technical Sub-committee will receive these updates as their expertise is needed on current efforts.