Chestnut Creek Watershed Based Plan

Marshall County, Kentucky

Revision 2, February 2016

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This watershed management plan is being developed under a Section 319(h) Nonpoint Source Implementation Program Cooperative Agreement (C999486-1-12) awarded by the Commonwealth of Kentucky, Energy and Environment Cabinet, Department for Environmental Protection, Division of Water (KDOW) to the Friends of Clarks River National Wildlife Refuge (FCRNWR) based on an approved work plan. These federal funds were awarded to KDOW from the U.S. Environmental Protection Agency (EPA) under Section 319 of the Clean Water Act.

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CHAPTER I. INTRODUCTION

A. Watershed Background

> *"About five miles from Benton there is a little creek running into East Fork of Clark river (sic), called Chestnut creek (sic). It heads up between two high hills, whose faces form a topographical synclinal. On these hill slopes, facing each other, a few chestnut bushes are found; but they stop absolutely and abruptly at the tops of these two slopes, and on the other sides of these same hills not a chestnut bush is to be found. Nor is there any chestnut in any other part of this section of the country…. How these chestnut bushes came to grow upon the faces of these two hills I cannot imagine; for they could not have come from seeds floated down the stream, inasmuch as the mountain above the head of the stream has no chestnut on it, and never has had any so far as I could find out. The people have recognized the peculiarity of the growth, as indicated by the name of the stream."* - L. H. Defriese, 1877

Such is the story behind the naming of Chestnut Creek, a stream which drains approximately eight square miles and flows into the Clarks River at the Clarks River National Wildlife Refuge near Draffenville, Kentucky in Marshall County. The local land use is primarily agricultural, although development is occurring in Draffenville, including residential subdivisions.

In the *2010 Integrated Report to Congress on the Condition of Water Resources in Kentucky* (KDOW, 2010), Chestnut Creek was categorized as an impaired stream for partial support of both the aquatic life and primary contact recreation uses. Suspected sources of these impairments were not defined.

The *Clarks River Watershed Based Plan (*Strand Associates, Inc., 2009), provisionally accepted by the Kentucky Division of Water (KDOW) in March 2010, identified pollutants of concern within the Clarks River Watershed, potential sources of these pollutants, and best management practices (BMPs). Chestnut Creek Watershed was identified as one of four critical areas where BMP installation should be focused.

The concern about water quality in Chestnut Creek is compounded because of its direct flow into the Clarks River on the Clarks River National Refuge. The refuge was established in July of 1997 to protect the bottomland hardwood forest, an endangered wetland habitat type, bordering the Clarks River. The refuge is composed of approximately 9,500 acres surrounding the Clarks River, and land is still being purchased within its acquisition boundary. The refuge is a seasonal home for over 200 species of migratory birds and encompasses 6% of the remaining wetlands in the state of Kentucky. The Clarks River itself is one of the only rivers in the area that has not been dammed or channelized and provides habitat for several mussel species. While conducting habitat assessments of the Clarks River, refuge biologists have noted large amounts of sediments deposited in the river from Chestnut Creek.

This plan presents the collaborative culmination of an extensive data collection and analysis effort, recruitment of partners and stakeholders in watershed interests, and remediation strategy development. This document is intended to address the nine minimum elements required in the USEPA's *Handbook for Developing Watershed Plans to Restore and Protect Our Waters* (USEPA 2008). These nine elements are as follows:

1. An **identification of the causes and sources** or groups of similar sources that will need to be controlled to achieve the load reductions estimated in this watershed based plan (and to achieve any other watershed goals identified in the watershed based plan), as discussed in item (2) immediately below. Sources that need to be controlled should be identified at the significant subcategory level with estimates of the extent to which they are present in the watershed (*e.g.*, X numbers of dairy cattle feedlots needing upgrading, including a rough estimate of the number

of cattle per facility; Y acres of row crops needing improved nutrient management or sediment control; or Z linear miles of eroded stream bank needing remediation).

2. An **estimate of the load reductions expected for the management measures** described under paragraph (3) below (recognizing the natural variability and the difficulty in precisely predicting the performance of management measures over time). Estimates should be provided at the same level as in item (1) above (e.g., the total load reduction expected for dairy cattle feedlots; row crops; or eroded stream banks).

3. A **description of the nonpoint source management measures that will need to be implemented** to achieve the load reductions estimated under paragraph (2) above (as well as to achieve other watershed goals identified in this watershed based plan), and an identification (using a map or a description) of the critical areas in which those measures will be needed to implement this plan.

4. An **estimate of the amounts of technical and financial assistance needed**, associated costs, and/or the sources and authorities that will be relied upon to implement this plan. As sources of funding, States should consider the use of their Section 319 programs, State Revolving Funds, US Department of Agriculture's (USDA) EQIP and Conservation Reserve Program, and other relevant federal, state, local, and private funds that may be available to assist in implementing this plan.

5. An **information/education component** that will be used to enhance public understanding of the project and encourage their early and continued participation in selecting, designing, and implementing the nonpoint source management measures that will be implemented.

6. A **schedule for implementing the nonpoint source management measures** identified in this plan that is reasonably expeditious.

7. A **description of interim, measurable milestones** for determining whether nonpoint source management measures or other control actions are being implemented.

8. A **set of criteria that can be used to determine whether loading reductions are being achieved over time** and substantial progress is being made towards attaining water quality standards and, if not, the criteria for determining whether this watershed based plan needs to be revised or, if a nonpoint source TMDL has been established, whether the nonpoint source TMDL needs to be revised.

9. A **monitoring component to evaluate the effectiveness of the implementation efforts over time**, measured against the criteria established under item (8) immediately above.

B. Partners and Stakeholders

The Friends of Clarks River National Wildlife Refuge (FCRNWR) started in 1999 as a nonprofit group consisting of private citizens to help the refuge meet its goals and promote the conservation of natural resources. They work to build community awareness regarding the needs of the refuge, as well as general environmental needs in the community. Since their inception, the FCRNWR has assisted the refuge and the community with various environmental projects. The FCRNWR's concern for the water quality of Chestnut Creek has led them to pursue this watershed based plan.

In order to ensure that the watershed based plan is effective in its planning and implementation, the FCRNWR assembled a team of project partners that represent key stakeholders in the project area and have contributed to the development of this plan. These partners include the following key organizations and representatives:

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CHAPTER II. WATERSHED INFORMATION

A. Watershed Location

The Chestnut Creek Watershed, Hydrologic Unit Code (HUC) number 06040006-040-670, is an 8.05 square mile (5,151 acres) watershed located within Marshall County, Kentucky. Chestnut Creek drains into Clarks River. The watershed boundary is shown on Exhibit 1, page 5. The watershed area is generally bounded by US 68 to the northeast, Briensburg Road (KY 58) and Scale Road (KY 795) to the south, and through agricultural fields to the east in the vicinity of Gregg School Road and Tiger Lane. The town of Draffenville is located in the watershed and the Julian M. Carroll Purchase Parkway (I-69) passes through it.

B. Surface Hydrology and Geomorphology

There are 24.36 miles of streams within the Chestnut Creek Watershed. Chestnut Creek is the only named stream in the watershed and has numerous unnamed tributaries.

No USGS sites are located in the vicinity of Chestnut Creek, so the USGS StreamStats for Kentucky program (Hodgkins and Martin 2003) was utilized to generate ungaged estimated instantaneous peak flows with recurrence intervals of 2, 5, 10, 25, 50, 100, 200, and 500 years. The result of this statistics report for the mouth of Chestnut Creek is summarized in Table 1.

Parola *et al.* (2005) performed an evaluation of the geomorphological characteristics of the Mississippi Embayment physiographic region where Chestnut Creek is located. They found streams in this region tend to be characterized by two responses:

> "1. Fine grain sediment eroded from upland hillside slopes has deposited in stream valleys, causing general aggradation of stream valley flats and aggradation of some stream channels.
>
> 2. Channelization - involving channel straightening, relocation, and enlargement - has caused streams to progress through a series of vertical and lateral channel adjustments. Mechanisms of adjustment include (a) channel incision, (b) bank mass failure and erosion, and (c) lateral bank migration and reformation of the channel floodplain and channel planform pattern."

Figure 1 shows an example model of this process.

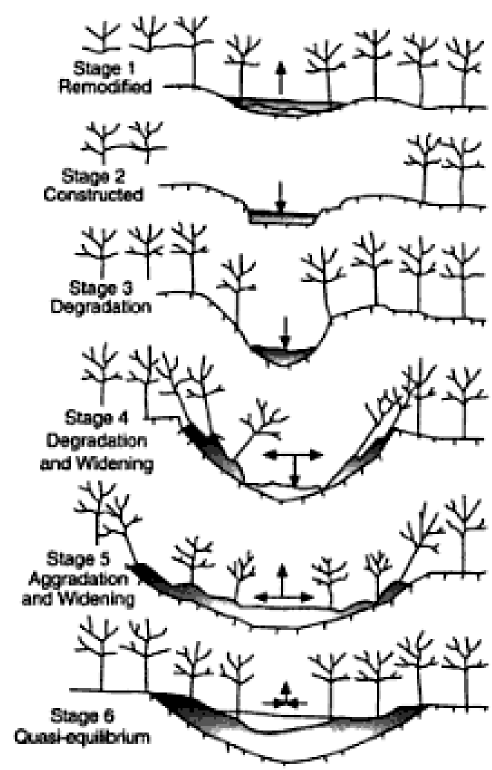
TABLE 1 – STREAMSTATS UNGAGED SITE REPORT FOR CHESTNUT CREEK

Peak Flow Recurrence Interval	Stream Flow (cfs)
2-year	1,070
5-year	1,720
10-year	2,200
25-year	2,870
50-year	3,410
100-year	3,950
200-year	4,560
500-year	5,380

Source: USGS StreamStats drainage mapped from latitude: 36.9051, longitude: -88.3951, NAD83. http://water.usgs.gov/osw/streamstats/kentucky.html

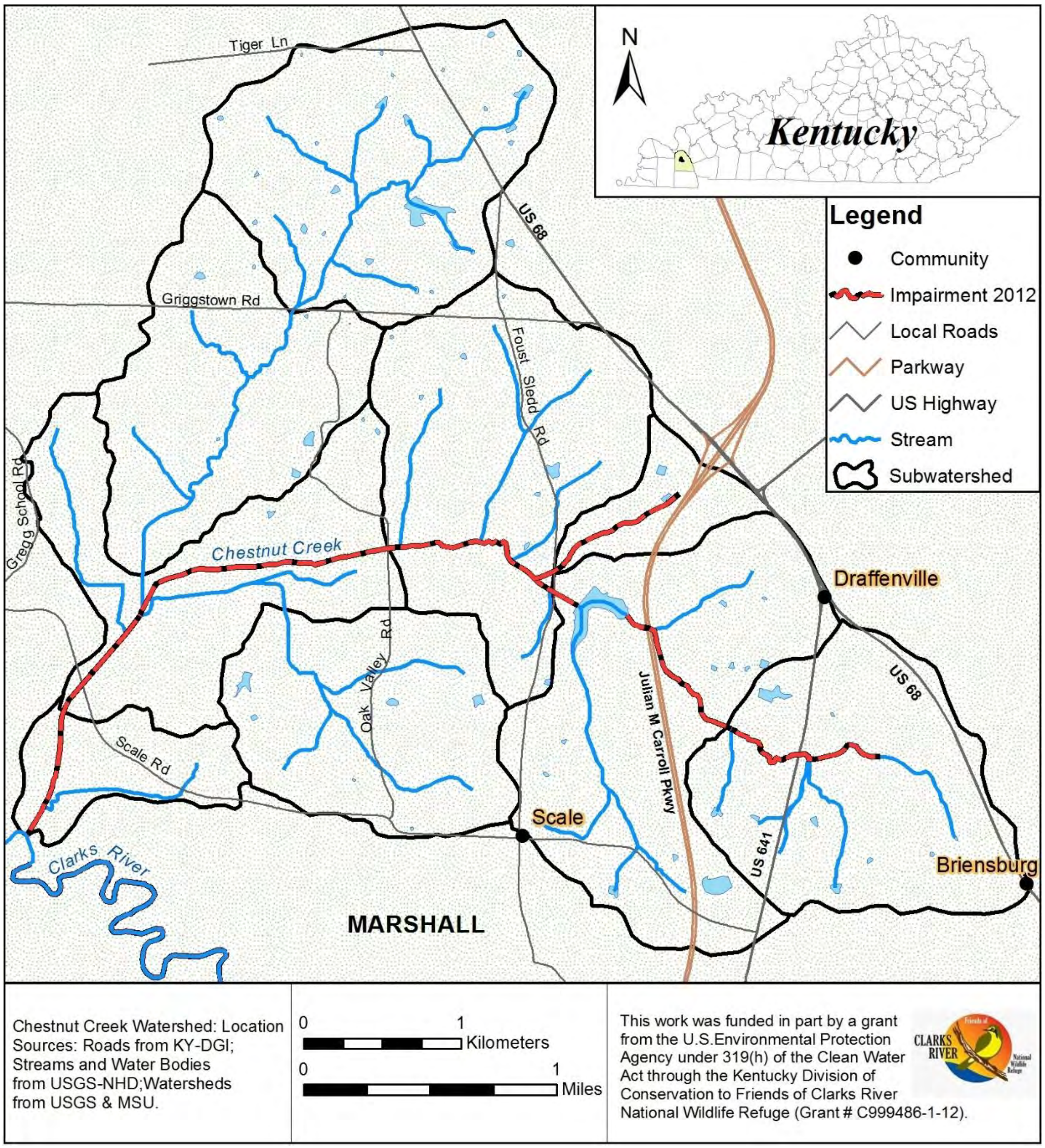
FIGURE 1 – CHANNEL EVOLUTION MODEL

When stream channels become channelized (Stage 2) they change over time to re-stabilze through a process that involves incision (Stage 3), mass erosion and bank failures (Stage 4), and widening and sedimentation (Stage 5) before reaching a new equilibrium (Stage 6). (Image from Simon and Hupp, 1986)



Larger low gradient streams tend to be channelized and in the later stages of channel evolution. In smaller headwater streams, channel incision and widening are prominent. The effects of channelization in headwater streams include headcuts migrating upstream, incising tributaries, decreases in base water levels, decreases in stream length, and degradation of the stream bed. Headcuts travel upstream where they tend to stall at culverts that tend to act as grade control structures. The degradation and widening of the channel due to headcutting is a significant source of sedimentation in the watersheds of the area. (Parola *et al.* 2005)

EXHIBIT 1 – WATERSHED LOCATION

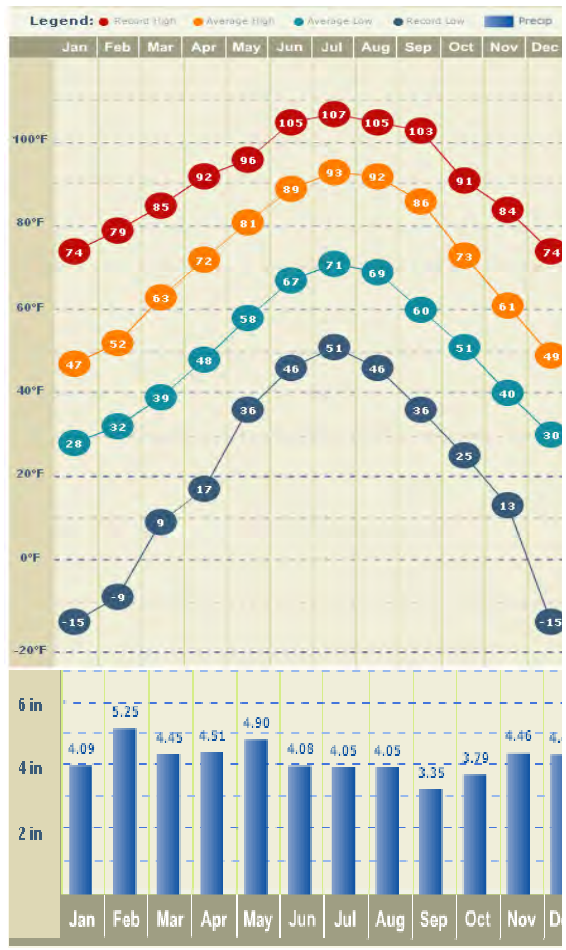


According to Natural Resources Conservation Service (NRCS) records, 3 miles of stream from the Flood Retarding Structure at Foust Sledd Road to East Fork Chestnut Creek were purposely channelized under Public Law-566 in 1966. The channelization was conducted along with the construction of flood retarding structures to minimize flooding concerns. The Soil Conservation Service, now the NRCS, assisted in the design and construction of the flood structures and the channelization, and the operations were overseen by the East Fork Clarks River (EFCR) Watershed Conservancy District. In some reaches excavation was conducted and in other reaches, just vegetation clearing was conducted. Disturbed banks were later stabilized with vegetation. When the EFCR Watershed Conservancy District was disbanded in the 1970s, the maintenance responsibilities were transferred to the Marshall County Conservation District. Because of lack of funding, maintenance of the channels has not occurred at least since the 1980s. These alterations to the stream channels may contribute to the degradation and widening of stream channels in the Chestnut Creek Watershed.

C. Climate and Precipitation

Figure 2 shows the monthly averages for temperature and precipitation based on records from www.weather.com for Benton, Kentucky. On average, the warmest month is July and the coolest in January. The maximum average precipitation occurs in February.

FIGURE 2 – MONTHLY AVERAGES FOR TEMPERATURE AND PRECIPITATION IN BENTON, KY



Source: www.weather.com

D. Groundwater Resources

The Chestnut Creek Watershed is located in a non-karst area. Some groundwater is used for domestic use. As of 1999, over 80% of Marshall County's residents were served by public water, the remainder relying primarily on private domestic wells. It was estimated that by 2020, about 11% of the county will still rely on private water supplies. The groundwater resources that underlie the Chestnut Creek Watershed are typically suitable for household use, although iron may be present at objectionable amounts in some areas. (Carey and Stickney 2004)

In order to evaluate the sensitivity of groundwater resources to water pollution, KDOW developed a hydrologic sensitivity index to quantify the regions of Kentucky (Ray *et al.* 1994). Based on groundwater recharge, flow, and dispersion rates, the index ranges from 1 (low) to 5 (high). The Chestnut Creek Watershed has a sensitivity rating of 2 to 3. This rating is typical for the Jackson Purchase region because "[T]he coarser sediments are prolific aquifers for industrial, municipal, and domestic water supply wells, although they are sensitive to contamination, especially at shallow depth. In general, the relatively low flow velocity within deeper saturation zones provides significant protection from contamination."

E. Flooding

Floodplains are lands adjacent to streams that flood during intense wet weather events. The ability of a stream to access the floodplain is a critical component of a stream's health. When streams have access to natural floodplains, the number and severity of floods is reduced, nonpoint source pollutants are reduced, water slows down and sediments settle out over the large floodplain area, and groundwater can be recharged. A stream that cannot access its floodplain (*e.g.,* by channelization, channel incision, or construction of a flood wall) will carry more energy, causing bank erosion and channel downcutting. It will also carry a higher pollutant load downstream during storm events and may have reduced base flow.

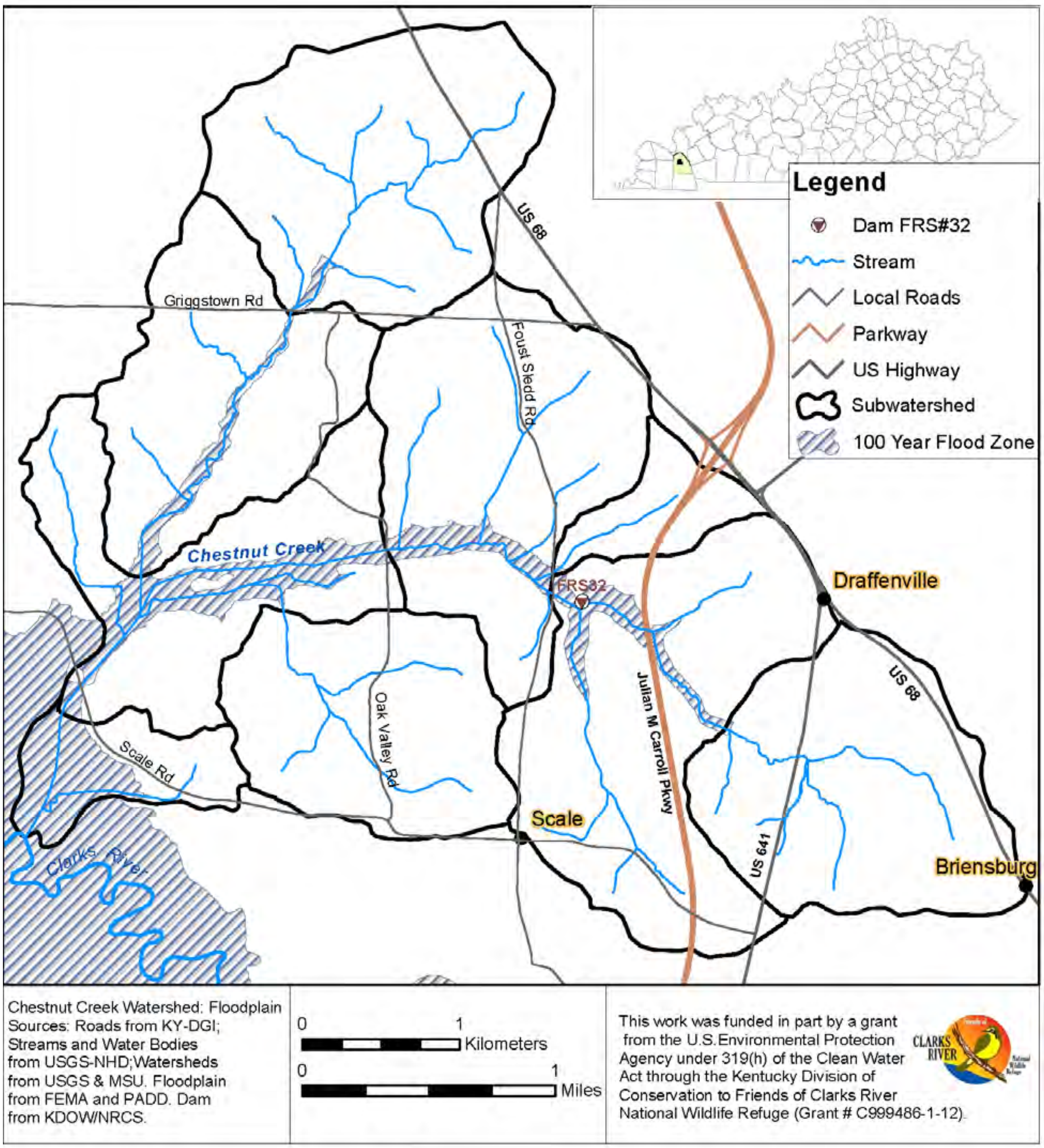
To identify a community's flood risk, the Federal Emergency Management Agency (FEMA) conducts a Flood Insurance Study. The study includes statistical data for river flow, storm tides, hydrologic/hydraulic analyses, and rainfall and topographic surveys. FEMA uses this data to create Flood Insurance Rate Maps (FIRMS) that indicate the risk in a particular area. These digital flood hazard maps provide an official depiction of flood hazards for each community and for properties located within it. Exhibit 2, page 8 shows the 100-year flood zone for the Chestnut Creek Watershed. The 100-year flood is a flood event that has a 1% probability to occur in a given year, and is defined as the Special Flood Hazard Area (SFHA). The 100-year flood has a 26% chance of occurring during a 30-year period. As shown in Table 1, the 100-year flood is predicted to have a flow of 3,410 cfs at the mouth of Chestnut Creek.

The FEMA Hazard Mitigation Grant Program (HMGP) provides grants to states, and states provide subgrants to eligible applicants, to implement long-term hazard mitigation measures after a major disaster declaration. The purpose of the program is to reduce the loss of life and property due to natural disasters and to enable mitigation measures to be implemented during the immediate recovery from a disaster. Acquisition and demolition of substantially damaged buildings located in the Special Flood Hazard Area (SFHA) is the first priority for HMGP project funding in Kentucky. Eligible applicants include state agencies, county and city governments, certain private non-profit organizations and Indian tribes or authorized tribal organizations. Individuals must work through their local government.

In addition to floodplain accessibility, the frequency and magnitude of flooding is affected by the percent of impervious surface in a watershed. Under natural conditions, most rainwater is absorbed into the soil or evapotranspired by trees. With increased impervious surfaces such as rooftops or pavement, water cannot infiltrate into the soil and therefore quickly flows into the stream. This can lead to frequent and/or severe flooding events of higher magnitudes.

One KDOW-regulated dam is located in the watershed and is used as a flood retardant for downstream areas. The structure is called East Fork Clarks River Flood Retarding Structure (FRS) #32 and is located at a latitude / longitude of 36.919294 / -88.355955, at Foust Sledd Road crossing of Chestnut Creek. This structure was constructed in 1962. In 2010, NRCS completed a breach analysis of the structure and reclassified the structure as a high hazard potential (NRCS 2008). A dam is considered high hazard if a failure would result in one or more residences flooding downstream, potentially resulting in loss of life. All high hazard dams are required to have an emergency action plan (EAP) to provide an effective means of communicating imminent dam failure to downstream landowners and a plan has been developed for this dam. The East Fork Clarks River FRS #32 is managed by the Marshall County Conservation District, and they report no structural problems. According to Dianna Angle, NRCS Conservation Planner (personal communication, April 2013), the structure was reclassified due to two mobile homes that have been constructed since the original dam construction in the breach inundation zone. These homes would be inundated with about 1.5 feet of water in the event of a breach. With the reclassification as a high hazard dam, the dam is held to a higher level of structural standards, which would require $2 million to $3 million in construction costs to implement. These improvements are currently unfunded. Discussions with the fiscal court have been underway concerning funding as well as a potential ordinance to prohibit further development downstream of the dam.

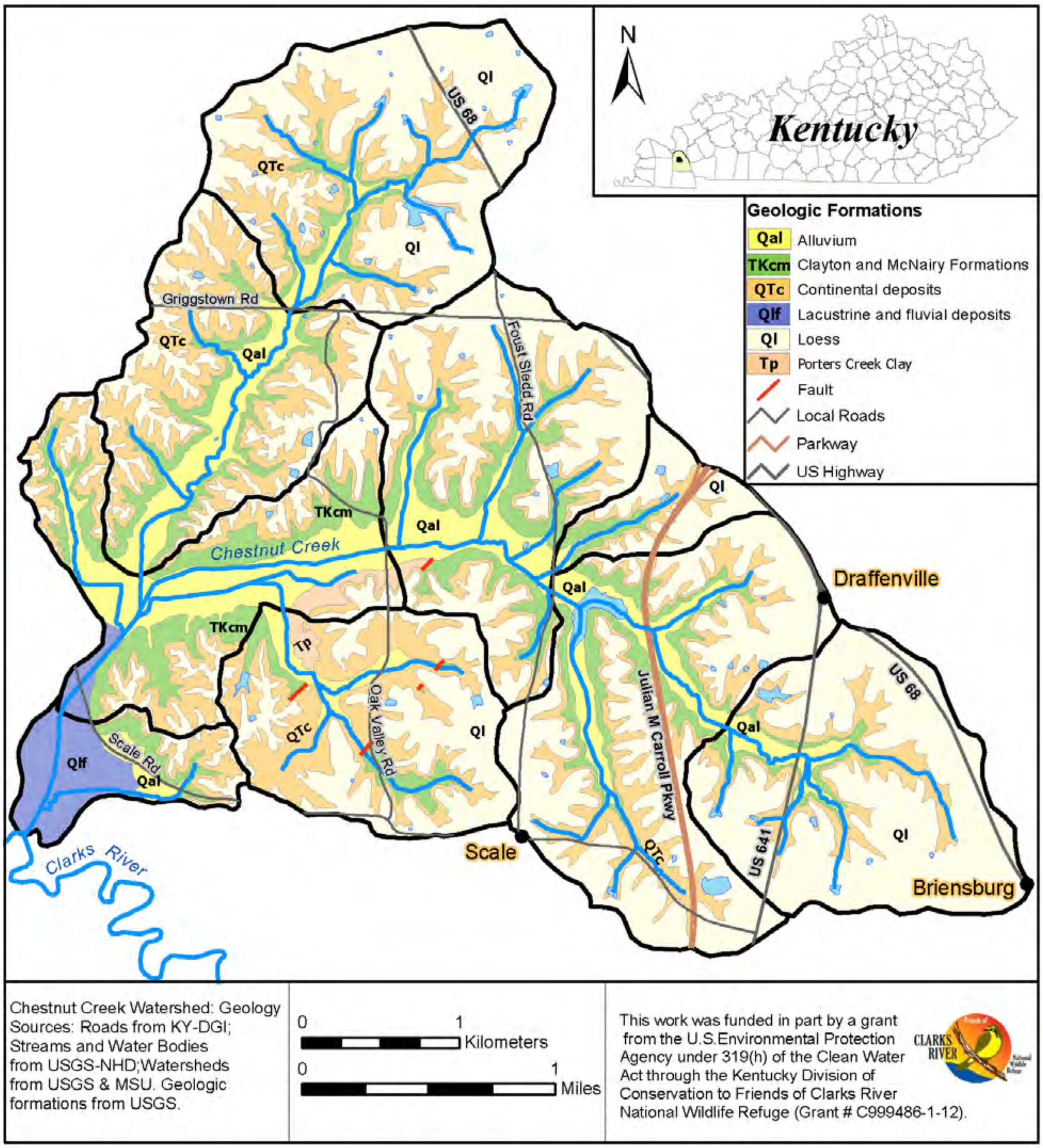
EXHIBIT 2 – FLOODPLAIN



F. Surface Geology

Chestnut Creek Watershed is located in the Elva and Briensburg 7.5-minute geologic quadrangles, as shown in Exhibit 3. The surface geological units in the watershed include alluvium in the stream bottoms progressing uphill to Clayton and McNairy clay and sand, to continental deposits of gravel, sand, and silt, and finally to loess silts at the higher locations. A small portion of Porter's Creek clay and sand are also found near Oak Valley Road.

EXHIBIT 3 – GEOLOGY



G. Ecoregion and Topography

According to Woods *et al.* (2002), the Chestnut Creek Watershed is located in the Loess Plans (74b) and Western Highland Rim (71f) ecoregions.

The Loess Plains ecoregion is described as "a productive agricultural area that is composed of gently rolling uplands, broad bottomlands, and terraces." Its natural vegetation is a mosaic of oak–hickory forest and bluestem prairie, but most of the original vegetation has been replaced by cropland. Agricultural runoff is a noted source of water degradation including high turbidity and siltation as well as channelized streams. (Woods *et al.* 2002)

The Western Highland Rim is described as "a hilly area" that is "much more wooded and rugged than the nearby agricultural plains of [the Loess Plains]." Similar to the Loess Plains the natural vegetation is oak-hickory forest but lacks bluestem prairie. Streams are described as "cool and clear" with "moderate gradients and gravel and sand substrates." (Woods *et al.* 2002)

Exhibit 4, page 11 shows the topography of the area. McGrain and Currens (1978) describe the topography of Marshall County as follows (per Carey and Stickney 2004):

> "Topographically, Marshall County is a gently rolling plain. Highest elevations are found on the flat-topped ridges between the principal drainage lines and range from 550 feet in the southern part of the county to 450 feet in the northern part. Elevations of 550 feet, the highest in the county, occur on a ridge about 4 miles south of Benton and on a ridge just north of the Marshall-Calloway County line about 4 miles west of Hardin. Local differences in elevation rarely exceed 50 feet, except adjacent to drainage lines; here differences between valley bottoms and the upland surface may be 100 to 150 feet. Stream gradients are low. Some swamps are present along the broad, flat valley of the East Fork of the Clarks River.
>
> The elevation of Benton, at the courthouse, is 430 feet. Elevations at other communities are … Briensburg, 495 feet; … Draffenville, 471 feet; …. The elevations at the lodges at Kentucky Dam Village and Kenlake State Parks are 415 and 450 feet, respectively."

H. Soils

According to the data available through the NRCS Web Soil Survey database, the primary soils in the watershed are of Brandon, Grenada, Purchase, and Lax soil series and their complexes. Together these cover about 64% of the soils in the watershed, as shown in Exhibit 5, page 12. According to the county soil survey (Humprey *et al.* 1973), these soils are moderate to severely limited for sewage effluent disposal or sanitary land fill use, thus onsite sewage treatment may be difficult throughout much of the area. Over 70% of the soils in the watershed have a moderate to severe erosional hazard, with the soils found in the watershed being mined for sand and gravel within Marshall County (Humprey *et al.* 1973). This susceptibility to erosion is expected to contribute to sedimentation and siltation in the streams of the watershed.

The *Final Total Maximum Daily Load for Escherichia coli 40 Stream Segments within the Clarks River Watershed Calloway, Graves, Marshall, and McCracken Counties, Kentucky* (MSU 2011) noted that soil type affects the survival and loading of fecal bacteria in the stream system. The following excerpt from that document describes this affect:

> "A review of factors important in the survival of fecal bacteria in soils showed, in general, longer bacteria survival time with greater soil moisture content (survival of days in dry soils versus longer than 1.5 months in wet soils), lower temperatures (with a doubling of the die-off rate for each 10° Celsius increase in

temperature), alkaline soils (survival of days in acidic soils versus weeks in alkaline soils, with neutral soils optimal), decreased sunlight (ultraviolet light is bactericidal), and increased organic material (a nutrient source for the bacteria) (reviewed in Gerba *et al.* 1975). In soils, bacteria can adhere to soil particles, particularly clay particles, and either be retained in the soil or move with water flow via erosion processes (reviewed in *Reddy et al.* 1981). Bacteria that do not adsorb to a soil particle can remain bound to fecal waste particles and move with those particles in runoff or, rarely, be unbound in the soil pore water and move in an unbound state (reviewed in Reddy *et al.* 1981). Soil erosion and water runoff can both move bacteria to a stream or to groundwater." (MSU 2011)

EXHIBIT 4 – TOPOGRAPHY

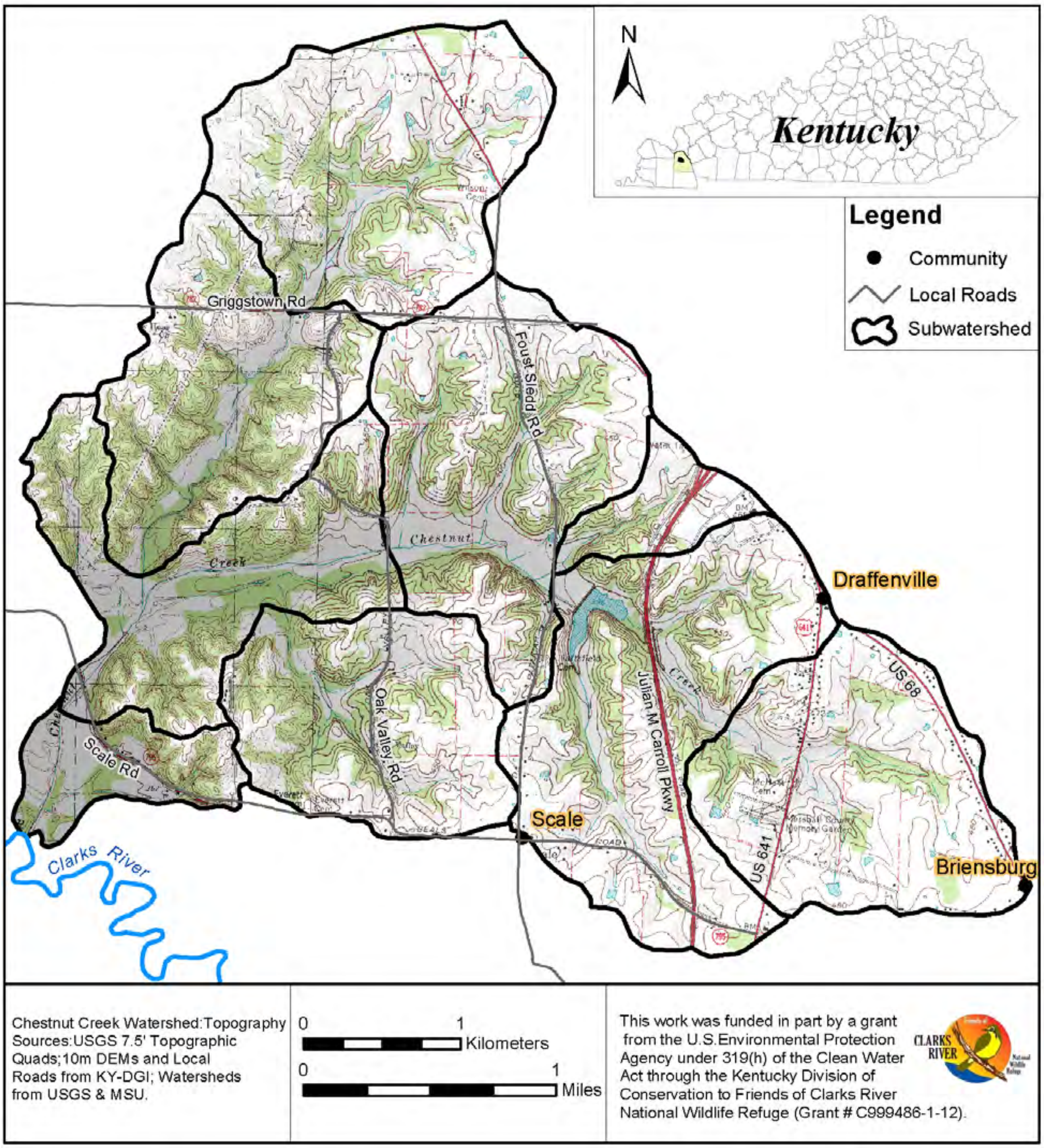
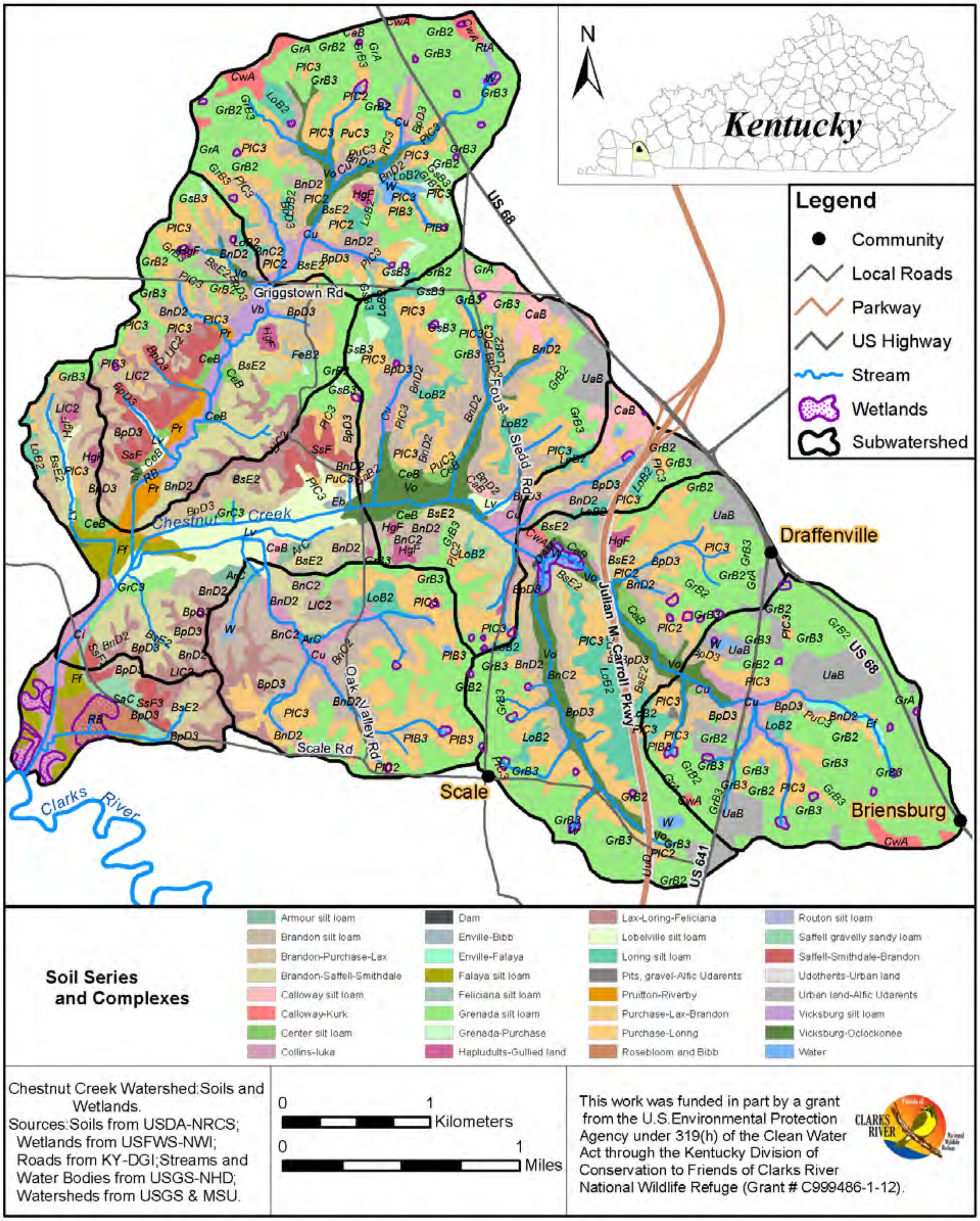


EXHIBIT 5 – SOIL SERIES AND COMPLEXES



Areas of hydric soil are important since wetland restoration or expansion is more likely to be successful in these areas. Only a small percentage (less than 1%) of the soils in the watershed are hydric, including soils in the Bibb series, but a greater percentage are partially hydric (about 3%) including soils in the Falaya, Saffell, and Calloway series. These soils are located near the mouth of Chestnut Creek and near the watershed boundary in the headwaters. The location of wetlands in the watershed, according to National Wetland Inventory (NWI) mapping, is shown in Exhibit 5 above. There are a less than 70 acres of wetland in the area, and most of these are small farm ponds of less than an acre in size. The paucity of streamside wetlands reveals the lowered groundwater levels due to headcutting and channelization.

I. Riparian Ecosystem

The riparian zone or riparian area is the vegetated area adjacent to the stream. Because this area forms a protective buffer for the stream water quality, it is often called a riparian buffer zone.

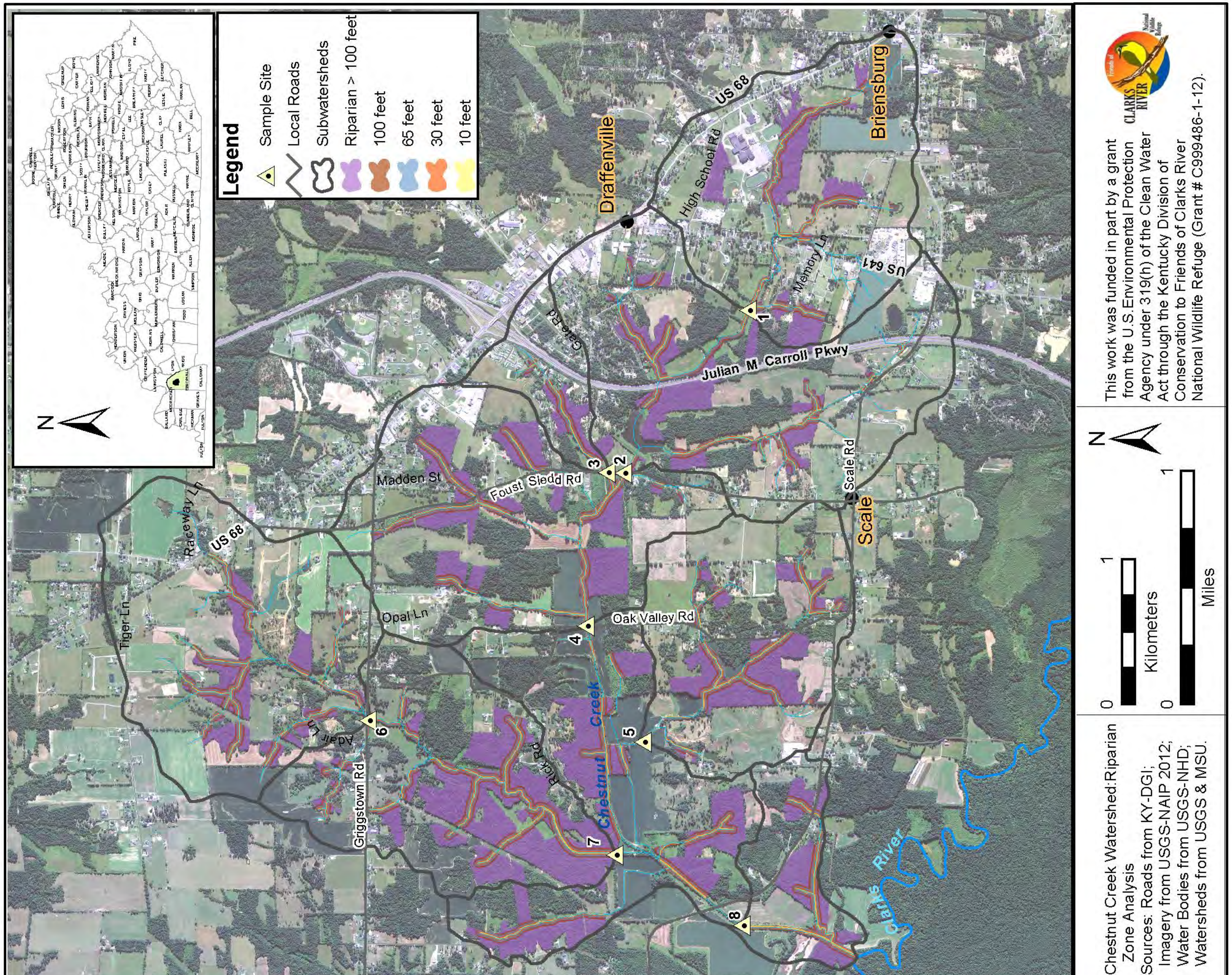
Although riparian zones produce many water quality benefits, these benefits are dependent on the width of the riparian area, the size of the stream that it borders, vegetative composition, and density. The water quality functions provided by the riparian zone vary by stream size. Riparian areas on smaller, headwater streams provide the maximum nutrient removal, shading, and bank stabilization benefits (Palone *et al.* 1997). Fish habitat and aquatic ecosystem benefits are typically greatest for larger, main-stem streams while flood mitigation benefits of riparian buffers increase as the stream size increases. Sediment control benefits remain relatively constant for all stream sizes.

The width of the riparian zone necessary to achieve these benefits varies depending on the function. The US Army Corps of Engineers (Fischer and Fischenich 2000) recommends the following riparian buffer widths for various functions: 5 to 30 meters (16 to 100 feet) for water quality protection, 30 to over 500 meters (100 to over 1,600 feet) for riparian zone habitat, 10 to 20 meters (30 to 65 feet) for stream stabilization, 20 to 150 meters (65 to 500 feet) for flood attenuation, and 3 to 10 meters (10 to 30 feet) for detrital input.

An analysis of the actual riparian widths was compared against the minimum recommended buffer width for each function. Thirty feet was used instead of 16 feet as the minimum width for water quality protection since most filtering occurs within 30 feet for low to moderate slopes found throughout the watershed. The riparian width and edge of water for each bank was delineated from aerial photographs. Areas with forested canopy or overgrown vegetation were included in the riparian buffer zone. Each bank was then divided into segments based on the maximum width of the riparian area and stream order. Exhibit 6, page 14 shows the locations of riparian zones and widths.

Overall, the riparian zones in Chestnut Creek range from well over 100 feet in many forested blocks to no riparian zone at all along some urban and agricultural reaches. In areas where a riparian zone is present, it tends to be greater than 100 feet, providing the full range of benefits to the streams. However, targeted planting efforts and buffer zones along many tributaries as well as the main stem of Chestnut Creek may be necessary for areas where no riparian zone is found.

EXHIBIT 6 – RIPARIAN ZONE



J. Fauna and Flora

The Chestnut Creek Watershed is located in the Briensburg and Elva 7.5-minute quadrangles. According to the Kentucky Department of Fish and Wildlife Resources species information (http://fw.ky.gov/kfwis/speciesInfo/speciesInfo.asp), 273 species have been recorded in these quadrangles including 136 birds, 56 fish, 30 reptiles, 22 amphibians, 20 mammals, 8 mussels, and 1 crustacean. Of these species, 30 have been identified as state or federally listed threatened, endangered, or special concern species. Table 2 lists these species. Best Management Practices that create or improve habitat for these species would be beneficial for the project area.

TABLE 2 – THREATENED, ENDANGERED, AND SPECIAL CONCERN SPECIES OF MARSHALL COUNTY

Common Name	US Status	KY Status	Wildlife Action Plan	Common Name	US Status	KY Status	Wildlife Action Plan
Mammals				**Amphibians**			
Evening Bat	N	S	Yes	Bird-voiced Treefrog	N	S	Yes
Marsh Rice Rat	PS	N	No	Green Treefrog	N	S	Yes
Southeastern Myotis	N	E	Yes	Northern Crawfish Frog	N	S	Yes
Birds				**Reptiles**			
Bald Eagle	N	T	Yes	Eastern Ribbon Snake	N	S	Yes
Barn Owl	N	S	Yes	Northern Water Snake	PS	N	No
Blue-winged Teal	N	T	No	Plainbelly Water Snake	PS	N	No
Brown Creeper	N	E	Yes	Western Mud Snake	N	S	Yes
Dark-eyed Junco	N	S	No	**Mussels**			
Fish Crow	N	S	No	Pocketbook	N	E	Yes
Great Egret	N	E	Yes	Purple Lilliput	N	E	Yes
Henslow's Sparrow	N	S	Yes	Texas Lilliput	N	E	Yes
Loggerhead Shrike	PS	N	Yes	**Crustaceans**			
Northern Bobwhite	PS	N	Yes	Vernal Crayfish	N	T	Yes
Rose-breasted Grosbeak	N	S	Yes	**Fish**			
Yellow-billed Cuckoo	PS	N	No	Central Mudminnow	N	T	Yes
Yellow-crowned Night-heron	N	T	Yes	Cypress Darter	N	T	Yes
				Dollar Sunfish	N	E	Yes

Abbreviations are as follows: PS = Partial Status (status only applies to a portion of the species range), E = Endangered, T = Threatened, S = Special Concern, N = None

Consideration of exotic and invasive species in the watershed are also important. Exotic invasive species of plants can wreak havoc with ecological balance, degrade waterways, and interfere with water uses.

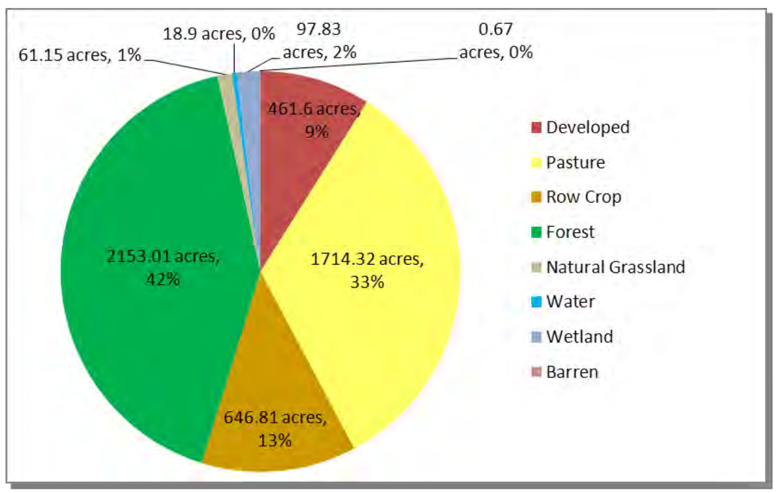
According to Scott Simmons, Refuge Management Specialist at the Clarks River National Wildlife Refuge (personal communication, March 26, 2013), the following exotic, invasive species are the major concerns for the area: autumn and Russian Olive (*Elaeagnus umbellate, E. angustifolia*), bush honeysuckles (*Lonicera maackii, L. morrowi, L. tatarica*), crown vetch (*Coronilla varia*), garlic mustard (*Alliaria petiolata*), Japanese stiltgrass (*Microstegium viminuem*), Japanese honeysuckle (*Lonicera japonica*), kudzu (*Pueraria lobata*), KY 31 tall fescue (*Festuca elatior*), multiflora rose (*Rosa multiflora*), privet (*Ligustrum sinense, L. vulgare*), sericea lespedeza (*Lespedeza cuneata*), tree of heaven (*Ailanthus altissima*), and reed canary grass (*Phalaris arundinacea*). These invasive species can replace diverse native plant communities with just a single species, greatly reducing the quality of wildlife habitat. Particularly in areas where stream restoration is an evaluated BMP, removal of invasive species from the site is important for long-term success.

Wildlife in the area, and its effect on water quality, is also important to consider. The Kentucky Department of Fish and Wildlife Telecheck Harvest Results from 2012 indicate that 28 bobcats, 1,219 deer, and 261 turkeys were harvested in Marshall County (fw.ky.gov). The Clarks River TMDL (MSU 2011) cites Kentucky Department of Fish and Wildlife estimates of the deer population in Marshall County in 2005 and 2006 as 5,149 and 5,611, respectively, or an average of 23 deer per square mile. Using these estimates, the Chestnut Creek watershed could contain an estimated 184 deer. Other estimates on wildlife populations in the area were not available. Wildlife species can contribute to the fecal load of the watershed.

K. Land Use and Nonpoint Source Pollutants

The landcover of the watershed, according to the USGS 2011 Landcover Database (NLCD), is shown in Exhibit 7, page 17 and summarized in Figure 3. The watershed is predominantly agriculture (46%) followed by forest (42%), while urban / suburban development represents about 9% of the land cover. Various land uses have the potential to contribute different pollutants to the watershed.

FIGURE 3 – LAND COVER STATISTICS



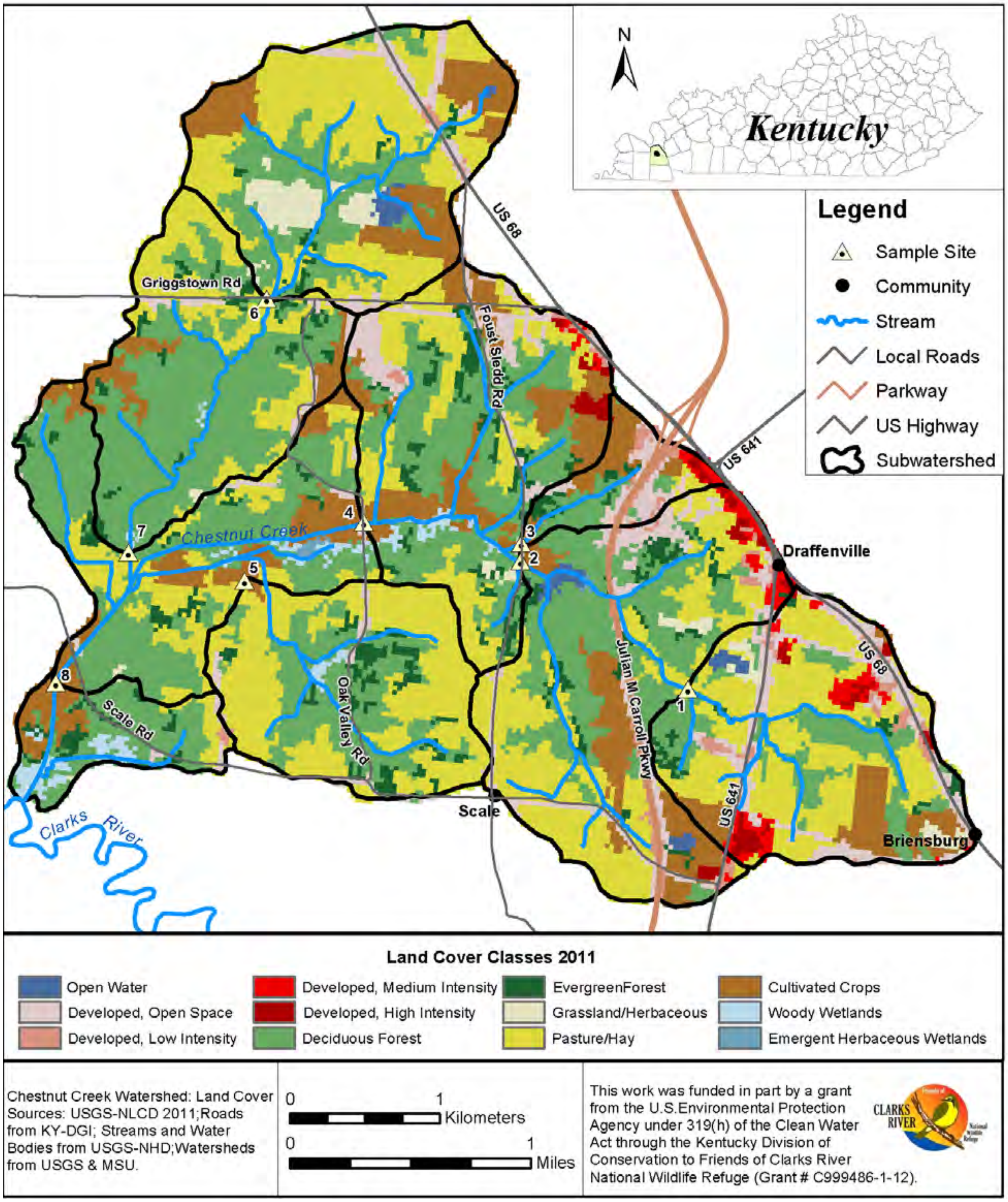
Source: USGS 2001 National Landcover Database (NLCD)

Because forested land cover acts as a natural filter for water, water quality tends to be better in areas surrounded by this use. However, natural erosion and improper timber harvesting methods can impact the watershed quality. Generally, forested land uses contribute a lesser pollutant load than agricultural or urban / suburban development uses.

1. Agriculture

According to the Volume I of the 2010 *Integrated Report to Congress on the Condition of Water Resources in Kentucky* (KDOW 2010a), the leading source of stream impairments in Kentucky is agricultural-related sources. About 55% of the not-supporting streams in Kentucky have agricultural pollution as a source. Agricultural activities that cause NPS pollution include poorly located or managed animal feeding operations; overgrazing; plowing too often or at the wrong time; and improper, excessive, or poorly timed application of pesticides, irrigation water, and fertilizer. Pollutants can include sediment, nutrients, pathogens, pesticides, metals, bank degradation, and habitat loss.

EXHIBIT 7 – LAND USE



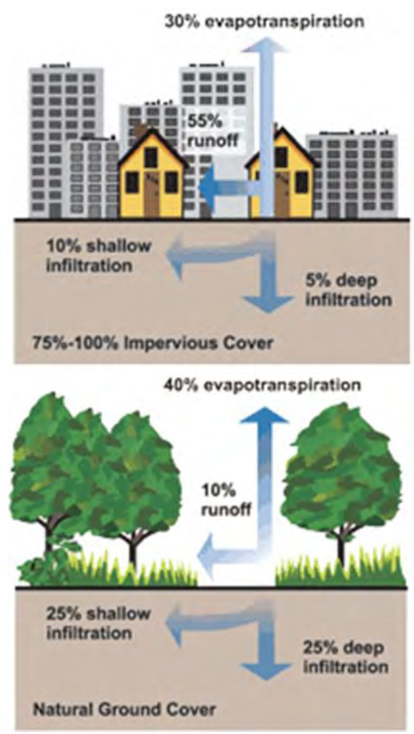
Sedimentation is one of the most prevalent agricultural pollutants due to soil erosion from fields. Nutrients, such as phosphorus, nitrogen, and potassium, are applied in the form of chemical fertilizers, manure, and sludge. When these sources exceed plant needs, or are applied just before it rains, nutrients can wash into aquatic ecosystems. Pathogen sources can include livestock in streams or runoff from pastures as well as runoff from poorly managed animal feeding operations. Grazing livestock can degrade streambanks and destroy habitat. Pesticides, including insecticides, herbicides, and fungicides are used to kill agricultural pests but can run off into the streams. Best Management Practices have been developed to address each of these pollutants, so with proper management the effect of this land use on streams may be minimized.

In the Chestnut Creek Watershed, row cropping accounts for 12.6% (647 acres) and pasture accounts for 33% (1,714 acres) of the land use in the watershed. Row crop fields of corn, wheat, and soybeans are scattered throughout the watershed, but the majority of open fields along Chestnut Creek are being used for pasture. According to Dianna Angle, NRCS Conservation Planner, farmers are experiencing erosion and land loss due to head cutting of drainage ditches and small tributaries on their properties (personal communication, April 2013). Most of the row crop operations are no-till and implement NRCS conservation practice standards including conservation crop rotation (Conservation Practice Code #328), residue and tillage management (#344), mulch till, and grassed waterway (#412). She estimates that approximately 192 acres of row crop fields are enrolled in Conservation Reserve Program, which entails that the entire field is sown in permanent vegetation, including about 49 acres of filter strips (personal communication, May 2013).

Within the pasture areas, there are approximately 10 livestock operations, most of which are cow / calf operations, but a goat operation and several horses are located in the watershed. There are no known confined feedlots, hog farms or poultry operations currently in the watershed. Dianna Angle indicated that most pastures are on a continuous grazing pattern, and although she expects some situations where the cattle have access to the streams for drinking water, this does not occur on the main tributaries in the watershed. Some of the pasture areas are used strictly for hay production and others are just being bush hogged. According to USDA National Agricultural Statistics Service Quick Stats (USDA 2013), Marshall County had a total inventory of 10,300 cattle including calves in 2012, a level that has slowly declined since 2007 (12,500 cattle). Assuming even distribution throughout the county, an estimated 244 cattle would be present in the watershed.

FIGURE 4 – RELATIONSHIP BETWEEN IMPERVIOUS COVER AND SURFACE RUNOFF

Impervious cover in a watershed results in increased surface runoff. As little as 10 percent impervious cover in a watershed can result in stream degradation.



Source: US EPA

2. *Urban / Suburban Development*

The developed areas of the watershed (9%) may also be sources of pollution. One of the greatest sources of pollution in developed areas is runoff from impervious surfaces. Impervious surfaces, such as roadways and rooftops, are surfaces which water cannot penetrate. As these surfaces are unable to infiltrate water, they subject streams to extraordinarily high

flows during storm events, leading to erosion and further pollution. This relationship is illustrated in Figure 4.
On impervious roadways, vehicles introduce numerous pollutants including oils, grease, rubber, and heavy metals (*e.g.,* lead, zinc, copper). Some of these pollutants also accumulate when the vehicles are idle on parking lots, driveways, and other parking areas. Most heavy metals tend to accumulate and remain within vegetated ditches adjacent to the surface. Other roadway pollutants tend to be more mobile. Research indicates that the amount of pollutants in surface waters is proportional to the amount of average daily traffic. Also, in winter months, deicing salt transported through runoff can be a significant pollutant to surface waters. Roof runoff can also be high in certain metals and solids.

In residential areas, lawn fertilization and pesticide applications, carried to streams through the storm sewer system, can also contribute to nonpoint source pollution. Lawn fertilizers (typically high in nitrogen and phosphorus), herbicides, and pesticides are commonly applied in these zones to keep grass green. However, fertilizer that is not absorbed into the soil may be carried into streams in runoff resulting in nutrient pollution problems and algal blooms. Often, household pets are associated with residential areas and can contribute to fecal and nutrient pollution.

L. Human Influences on Watershed

Human influences on the Chestnut Creek Watershed are many and various. In this section, a summary of the different types of human activities in the watershed is given. Demographics of the watershed, point source permitted dischargers, stormwater system, sanitary sewer system, water supply, and watershed management activities are each discussed in their respective sections.

1. Demographics

The Chestnut Creek Watershed is located in two census block groups according to the 2010 census. Data from the U.S. Census Bureau's 2006-2010 American Community Survey 5-year Summary is presented in Table 3, page 20 to provide an overview of the area demographics.

The total population of the watershed area is approximately 1,000 with 126 people per square mile on average for the census block groups in the watershed area. The average per capita income is around $22,500 with around 9% to 17% of the population below the poverty threshold, which varies based on family size. In terms of education, 12 to 17% of adults 25 years and older have not completed a high school, 30 to 35% have a high school diploma, 30 to 39% have some additional education beyond high school, and around 17% have a college degree or additional advanced degree. A little over a quarter of the population is less than 18 years old. Most families (74 to 83%) own their residences, most of which are less than 60 years old. In general, these statistics are similar to demographic data for Marshall County as a whole.

Located within the watershed are multiple schools, churches, and other community centers. Schools in the area include Marshall County High School and Technical Center and Christian Fellowship School. Churches in the area include Oak Valley Church of Christ, Zion's Cause Baptist Church, Draffenville Kingdom Hall of Jehovah's Witnesses, Christian Fellowship Church, World Missions and Evangelism, Briensburg United Methodist, Briensburg Church of Christ, Briensburg Baptist Church, Maple Hill Church, Maple Hill Church of Christ. Three cemeteries include Wilson Cemetery, Hartsfield Cemetery, and Marshall County Memory Gardens. Other places of interest include several mobile home parks and commercial businesses. Some of these key locations are shown in Exhibit 8, page 21.

The Chestnut Creek Watershed is located in Kentucky Senate District 2 (Sen. Danny Carroll), Kentucky House District 6 (Rep. Will Coursey), and 1st Congressional District in Kentucky (Rep. Ed Whitfield).

TABLE 3 – 2010 CENSUS DATA SUMMARY

Census Statistic	Griggstown Road to Purchase Pkwy, Palma Road to Clark River	Purchase Parkway to KY-1463 & Moors Camp Hwy, US-641 & KY-1422 to Clarks River	Marshall County
Population			
Total Population	1,741	1,787	31,386
Population Density (people / sq. mi.)	132	119	104
Income			
Per Capita Income	$26,711	$18,771	$23,056
% Below Poverty	8.8%	16.5%	11.5%
Education (Adults 25 and older)			
% Education < 12th Grade	12.5%	16.7%	16.8%
% High School Diploma Only	30.9%	35.9%	41.2%
% College Degree or Above	17.2%	16.9%	14.8%
Age			
% Age < 18 Years	26.7%	26.8%	21.4%
Housing			
% Built Pre-1950	3.6%	7.3%	7.2%
% Rental Units	16.5%	23.7%	18.1%

Based on data from the U.S. Census Bureau's 2006-2010 American Community Survey 5-year Summary (ACS), Blockgroups 211579502003 and 211579503003.

2. *KPDES Dischargers*

Three permitted Kentucky Pollutant Discharge Elimination System (KPDES) facilities are or have been located in the watershed as shown in Table 4. All dischargers to waters of Kentucky are required to obtain a KPDES permit including concentrated animal feeding operations (CAFOs), combined sewer overflows (CSOs), individual residences, Kentucky Inter-System Operational Permits (KISOPs), mining, municipal, industrial, oil, and gas. These dischargers are shown on Exhibit 9, page 22.

Detailed reports available through the USEPA Enforcement and Compliance History Online (ECHO) Web Site (echo.epa.gov) were reviewed for permit violations and exceedances. Each of these facilities reported routine exceedances of the permitted discharge limits for a number of water quality parameters indicating that these facilities are a source of pollution within the watershed.

TABLE 4 – PERMITTED DISCHARGERS

KPDES Permit No.	Discharger Name	Type of Discharge	Design Capacity (cfs)
KY0028991	Memory Lane Trailer Court	Sanitary Wastewater	0.003
KY0023906	Marshall County High School	Elementary & Secondary Schools	0.046
KY0044181	Marshall County Sanitary District #2	Sanitary Wastewater Treatment Plant	0.23

EXHIBIT 8 – PLACES OF INTEREST

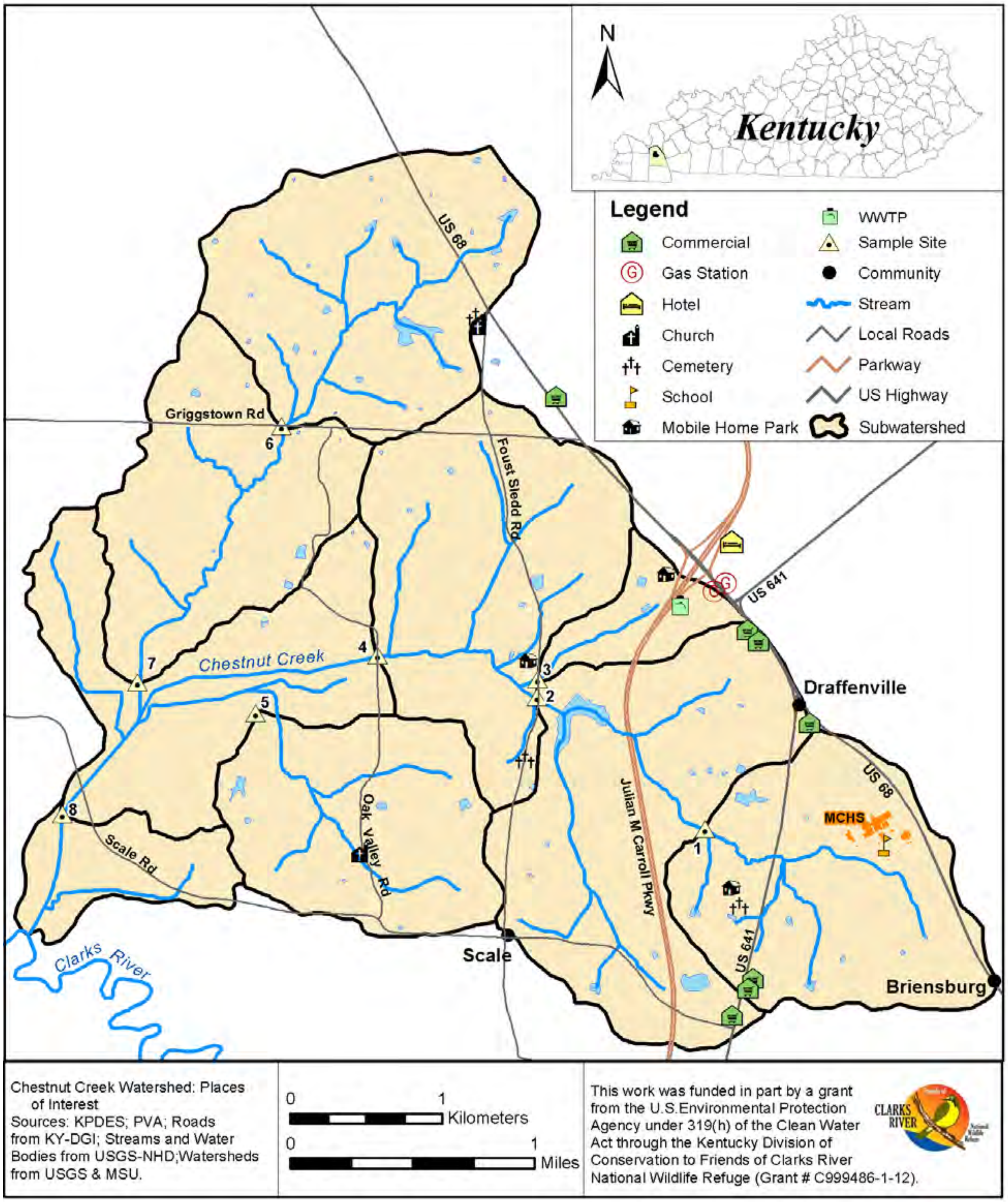
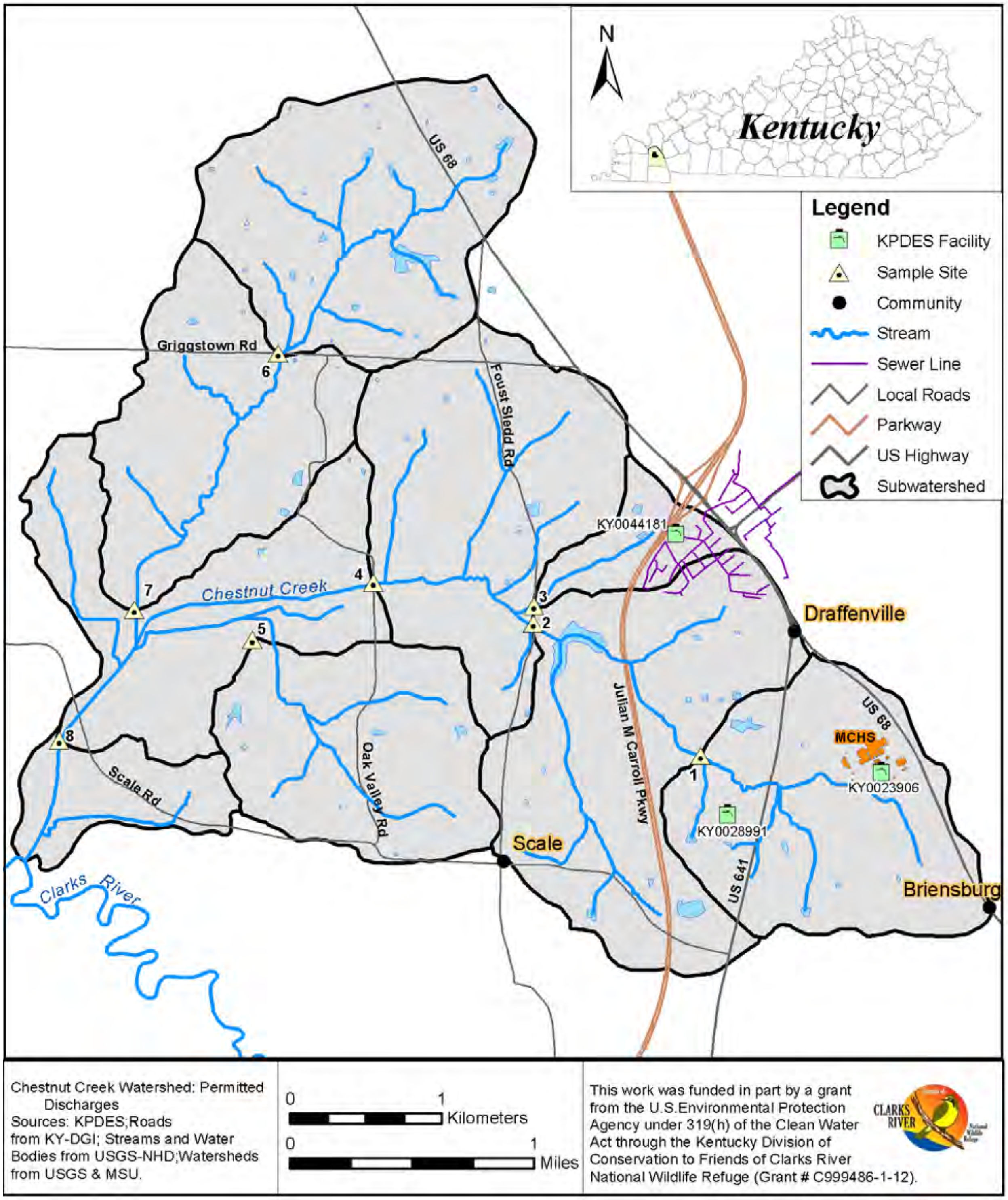


EXHIBIT 9 – KPDES DISCHARGERS AND SANITARY SEWER SYSTEMS



Memory Lane Trailer Court (permit #KY0028991) has a 0.002 MGD (0.003 cfs) treatment system serving over 30 residents. Treatment consists of activated sludge process and aerobic digestion. Its effluent is discharged to an unnamed tributary at RM 4.05 of Chestnut Creek. The unnamed tributary has a 7-day, 10-year low flow of 0.00 cfs. A review of the ECHO reports from January 2012 to March 2015 indicated exceedances of limits for biochemical oxygen demand, total residual chlorine, *E. coli*, ammonia, and total suspended solids. Significant violations occurred for total residual chlorine. Violations occurred in every quarter and significant violations occurred in 4 quarters. Two notices of violation (NOVs) were issued in 2010 as well as one in 2014. In 2010 sludge was observed in the receiving stream and in response septic tanks and field beds were added to decrease load and regular monthly sludge removal was scheduled to achieve compliance. In 2014, multiple issues were cited including floating solids on the clarifier and chlorine contact tank. An additional septic system was installed in 2014 to lessen the load and achieve compliance.

Marshall County High School (permit KY0023906) has a 0.03 MGD (0.046 cfs) treatment system owned by the Marshall County Board of Education. It serves about 1,520 students and effluent is discharged to RM 4.7 of Chestnut Creek. The treatment consists of mixing, sedimentation, chlorine disinfection, activated sludge processes, and aerobic digestion. The 7-day, 10-year low flow condition of Chestnut Creek is 0.00 cfs at the discharge point. A review of the ECHO reports from January 2012 to March 2015 indicated exceedances of limits for biochemical oxygen demand, total residual chlorine, fecal coliform, *E. coli*, ammonia, and total suspended solids. Significant violations occurred for total residual chlorine and ammonia. Violations occurred in every quarter in which reporting occurred and significant violations occurred in six quarters. In 2013, a NOV was issued due to permit limit exceedances and improper operation of the disinfection unit. In 2014, a NOV was issued due to a suspected unauthorized discharge from mobile bathroom units. In each case responses to address the issues were deemed adequate by KDOW.

Marshall County Sanitation District #2 WWTP (permit KY0044181) is a 0.15 MGD (0.23 cfs) facility owned by Marshall County. This facility expanded in 2009 from 0.0495 MGD (0.077 cfs), and the outfall was moved to the opposite side of the creek at RM 0.65 of UT to Chestnut Creek at RM 2.8. The expanded plant treatment consists of comminutor, bar screen, pump station to one of three sequence batch reactor chambers for biological treatment, post aeration, and ultraviolet disinfection. Sludge solids are processed by thickening with digested sludge hauled to an approved landfill on 15-day intervals. A review of the ECHO reports from January 2012 to March 2015 indicated exceedances of limits for biochemical oxygen demand, fecal coliform, *E. coli*, ammonia, and total suspended solids. Significant violations occurred for biochemical oxygen demand, ammonia, and phosphorus. Violations occurred in every quarter, and significant violations occurred in seven quarters. NOVs have been issued in 2012, 2014 (two) and 2015 (two). Each of these NOVS was due to discharges to the stream as well as other maintenance issues including broken valves, improper disinfection unit operation, and other issues. No records of response were obtained from KDOW via open records request.

Other facilities of environmental interest within the Chestnut Creek Watershed were reviewed via open records request of locations listed in the EPA's Facility Registration System. Several sites were listed as current or past Underground Storage Tank Locations including the Hartgroves Citgo (current), Marshall County Board of Education (current), 68 BP (current), Goheen Grocery (closed 2006), and Overnight Transportation (closed 1989). Other environmental issues included stormwater debris stockpiling and burning in 2009, a Marshall County Technical Center mercury spill and cleanup effort in 2005, a meth lab dump in 1999, and miscellaneous burn and odor locations. None of these locations present a threat to water quality.

3. *Stormwater System*

Some stormwater infrastructure is located in the Chestnut Creek Watershed in areas of urban / suburban development. However there are no municipal separate stormwater sewer system (MS4) permitees in the watershed.

4. *Sanitary Sewer System and Waste Management*

According to Michael Carlson of the Marshall County Health Department (personal communication April 11, 2013), the soils in the Chestnut Creek watershed have a fairly shallow fragipan or have tight clay soils, neither of which allow for good percolation. For fragipan soils, they require septic systems to be installed shallower than usual, and for clay soils they increase the size of the bed for more retention. Typically, a separate grey water bed is added for laundry only in order to give more overall volume to the system. Mr. Carlson indicated that few systems have been installed recently due to slow housing development. Existing systems are expected to be undersized according to current standards and poorly maintained. Poorly maintained septic systems can harm water quality by leaking raw sewage into surface water runoff.

The watershed has one small sanitation district serving a limited number of residences and businesses. The local sewer utility, Marshall County Sanitation District #2 (MCSD), currently serves a population of 284 including 130 households mostly within the Chestnut Creek drainage area, as shown in Exhibit 9, page 22. According to the WRIS database (http://kia.ky.gov/wris/portal/), the sewer lines are all PVC including 0.35 mile of 12-inch line, 3.05 miles of 8-inch line, and 2.1 miles of line 6 inches or less. It has 10 wet well lift stations with capacities ranging from 20 to 600 GPM. Currently the sanitation district does not service any customers north of the Purchase Parkway. Most residences and businesses in this northern portion of the watershed should have on-site waste disposal systems.

According to the Kentucky Infrastructure Authority's (KIA) Water Resource Information System (WRIS) FY2013 Project Ranks for Purchase Area Development District (PADD 2013), Marshall County Sanitation District #2 plans to extend sewer service to the Marshall County High School, Christian Fellowship School, commercial businesses along US 68, as shown in Exhibit 9, page 22. This $3.3 million project was evaluated as the highest ranked project in the district. Implementation would allow for the removal of multiple on-site disposal systems, one overburdened septic system at the Christian Fellowship School, and one package WWTP at the Marshall County High School (servicing about 1,500 students). The project includes 8-inch gravity collector and interceptor sewers and a new lift station and force mains. The interceptor sewers will provide a backbone for future expansion in the area. The project also includes rehabilitating portions of the existing collection system known for excessive inflow and infiltration. WRIS Project Rankings are forwarded to state legislatures for potential funding under line item grants from the state budget. The Kentucky state budget is developed on a two-year cycle. Since the project was not funded in 2014, 2016 would be the next year in which the project would be eligible.

A series of local newspaper articles have detailed the struggles the WWTP has had with compliance. The sanitation district chairman believes that either 1) additional lines need to be added to provide additional revenue necessary to enable proper operation of the facility or 2) the system needs to merge with a larger existing system.

5. *Water Supply Planning*

The federal *Safe Drinking Water Act Amendments of 1996* require states to analyze existing and potential threats to each of its public drinking water systems. Source Water Protection Plans assess the quantity of water used in a public water system and formulate protection plans for the source waters used by these systems. There are no permitted water withdrawals in the Chestnut Creek Watershed. The drinking water supply for the Chestnut Creek Watershed is provided by the North Marshall Water District #1. The water treatment plant is located in Tatumsville It is estimated that about 20% of residents in Marshall County receive their drinking water from groundwater wells.

Wellhead Protection Plans are used to assist communities that rely on groundwater as their public water source. According to the Wellhead Protection Program of KDOW, there are no Wellhead Protection Plans in the Chestnut Creek Watershed.

Groundwater Protection Plans (GPPs) are required for anyone engaged in activities that have the potential to pollute groundwater. These activities include anything that could leach into the ground, including septic systems and pesticide storage. The law requires that these facilities have a GPP but does not monitor this requirement. GPPs are required to be recertified every three years and must be updated if activities are changed. KDOW retains the plans indefinitely. The Groundwater Branch of KDOW does not have any groundwater protection plans on file. However, Kentucky Administrative Regulation 401 KAR 5:037 does not require Groundwater Protection Plans (GPPs) to be submitted to the Cabinet for review and approval unless called in by staff. In order to ascertain whether a facility has a GPP, the Groundwater Section highly recommends that a door-to-door survey be conducted within the watershed. Any facilities conducting activities subject to 401 KAR 5:037 that do not have a GPP should contact Susan Mallette of the Kentucky Division of Water.

6. *Watershed Management Activities*

In 2009, Strand Associates, Inc. developed a Watershed Based Plan for Clarks River under a 319(h) funded grant on behalf of the Jackson Purchase RC&D Foundation, Inc. The watershed based plan evaluated all of the Clarks River Watershed of which Chestnut Creek is a part. Chestnut Creek was identified as a focus area in the plan. The Marshall County NRCS identified it as such due to heavy agricultural land use, with greater use by beef cattle operations than row crops, and moderate residential population. The watershed was noted due to the high *E. coli* concentrations, suspected to be due to agricultural activities. The plan recommended multiple areas for installation of filter strips and potential areas for reduced tillage and or contour farming techniques within Chestnut Creek.

Dianna Angle, Conservation Planner at the NRCS, was contacted to determine the current use of agricultural BMPs in the watershed. As of May 6, 2013, she indicated that approximately 192 acres in the Chestnut Creek Watershed were enrolled in the Conservation Reserve Program (CRP). CRP is a land conservation program administered by the Farm Service Agency (FSA) in which farmers agree to remove environmentally sensitive land from agricultural production and plant species that will improve environmental health and quality. Contracts for land enrolled in CRP are 10-15 years in length with a goal of improving water quality, preventing soil erosion, and reducing loss of wildlife habitat. Of these 192 acres, about 49 acres are filters strips. Additionally, on the row crops fields in the Chestnut Creek Watershed, Ms. Angle indicates that most operations are no-till and implement NRCS conservation practice standards including conservation crop rotation (328), residue and tillage management (344), mulch till, and grassed waterway (412).

M. Regulatory Status of Waterways

Kentucky assigns designated uses to each of its waterways, such as recreation, aquatic habitat, and drinking water. For each use, certain chemical, biological, or descriptive ("narrative") criteria apply to protect the stream so that its uses can safely continue. The criteria are used to determine whether a stream is listed as "impaired" in the 303(d) list (KDOW 2010a) and therefore needs TMDL computations and load allocations. Exhibit 1, page 5 shows the impaired reaches in the watershed.

1. Designated Uses

The designated uses of Chestnut Creek and its tributaries include warm water aquatic habitat (WAH), fish consumption, primary contact recreation (PCR), secondary contact recreation (SCR), and domestic water supply. The WAH criteria are in place to protect aquatic life that inhabits streams. PCR criteria are in-place to protect people recreating in a way that likely will result in full body immersion in the water body, such as swimming. Secondary Contact Recreation (SCR) designated use criteria are in place to protect those recreational activities that are likely to result in incidental contact with water, such as boating, fishing, and wading. Fish consumption is not a designated use in Kentucky water quality standards, but the use is implied in 401 KAR 10:031 Section 2 and through human health criteria in Section 6. The fish consumption use is based on waterbody specific monitoring and comparing the fish tissue body burden results for specific pollutants (e.g., mercury, PCB, chlordane) in our water quality standards that apply. Domestic water supply use is applicable to use for drinking water, however no public water intakes are currently located in Chestnut Creek.

2. Designated Uses Impairment Status

Streams are assessed to determine whether they support their designated uses. Each stream receives one of three classifications to denote relative level of designated use support: fully supporting (good to excellent water quality); partially supporting (fair water quality, does not fully meet designated use); and non-supporting (poor water quality). Streams which are either partially supporting or non-supporting their designated uses are listed on the 303(d) list of impaired surface waters of Kentucky.

According to the 2010 303(d) list (KDOW 2010a), Chestnut Creek from 0.0 to 3.0 miles is listed as impaired for WAH (partial support) and PCR (partial support) designated uses due to unknown causes and fecal coliform due to unknown sources.

In 2012, some additional impairments in the Chestnut Creek Watershed were identified. According to the 2012 303(d) list (KDOW 2012), Chestnut Creek from 0.0 to 3.0 miles is listed as impaired for WAH use (non-support) due to unknown causes, dissolved oxygen, and other causes. The unnamed tributary to Chestnut Creek (0.0 to 0.7 miles) near Foust Sledd Road is listed as non-supporting for its WAH designated use due to carbonaceous biochemical oxygen demand, ammonia, total suspended solids, and total residual chlorine from unknown sources and package plant or other permitted discharges. Although these segments are impaired for PCR use (partial support and non-support, respectively) as well, they are not on the 2012 303(d) list for *E. coli* because an approved TMDL has been developed for that pollutant.

In addition, impairments were identified on Chestnut Creek from 3.2 to 3.9 and Chestnut Creek from 3.9 to 4.6 in the 2012 Integrated Report based on self-reported discharge monitoring reports from the KPDES facilities in 2012. Because that data was of insufficient quality to support an official 303(d) listing (Category 5), these segments are listed on 305(b) list of assessed waters as Category 5B. Chestnut Creek from 3.2 to 3.9 is listed as impaired for WAH (non-support) use due to dissolved oxygen saturation and ammonia and PCR (non-support) use due to *E. coli* from package plant or other permitted small flows discharges. Chestnut Creek from 3.9 to 4.6 is listed as impaired for WAH (non-support) use due to carbonaceous biochemical oxygen demand, dissolved oxygen saturation, and ammonia and impaired for PCR (non-support) use due to *E. coli* from package plant or other permitted discharges.

3. Total Maximum Daily Load

An approved TMDL for *E. coli* has been developed for the Clark River Watershed including Chestnut Creek. According to the *Final Total Maximum Daily Load for Escherichia coli 40 Stream Segments within the Clarks River Watershed Calloway, Graves, Marshall, and McCracken Counties, Kentucky* (MSU 2011), Chestnut Creek is non-supporting its PCR designated use as well as an unnamed tributary to Chestnut Creek (0.0 to 0.7 miles). This support status reflects the most recent assessments of the watershed which have not made it into the 303(d) list. The TMDL allocations for Chestnut Creek and the UT of Chestnut Creek are summarized in Table 5.

TABLE 5 – SUMMARY OF TMDL FOR CHESTNUT CREEK

Parameter	Chestnut Creek 0.0 to 3.0	UT Chestnut Creek 0.0 to 0.7
Existing Load (*E. coli* colonies/day)	1.24E+13	2.01E+11
Total TMDL (*E. coli* colonies/day)	6.15E+10	3.12E+09
MOS (*E. coli* colonies/day)	6.15E+09	3.12E+08
TMDL Target (*E. coli* colonies/day) (Total TMDL – MOS)	5.54E+10	2.81E+09
% Reduction	99.6%	98.6%
SWS-WLA (*E. coli* colonies/day)	1.65E+09	1.36E+09
Marshall County High School and Technical Center	2.73E+08	-
Marshall County Sanitation District #2	1.36E+09	1.36E+09
Memory Lane Trailer Court	1.82E+07	-
Future Growth WLA (*E. coli* colonies/day)	5.37E+08	5.80E+07
LA (*E. coli* colonies/day)	5.32E+10	1.39E+09

N. Summary and Conclusions

The streams within the watershed area are impacted for human recreation and warmwater aquatic habitat. The characterization of the watershed has revealed contributing factors to these impairments.

1. Human Recreation Impairment

Chestnut Creek is impaired for human recreational use due to levels of fecal indicator bacteria, such as fecal coliform or *E. coli* exceeding regulatory limits. The characterization of the watershed indicates that the following factors may be contributing to this impairment:

- Sanitary Treatment Systems: Three sanitary treatment systems are permitted to discharge to Chestnut Creek and its tributaries. The Kentucky Division of Water has submitted notices of violation to each of these facilities due to significant violations of the permits, including high *E. coli* concentrations in discharges. Because these facilities are human fecal input sources with higher risk for associated illness, the contribution of these sources to the fecal load is considered to be of greater importance.

- Septic systems installed prior to current standards are expected to be undersized and poorly maintained. They may leak sewage into the surface water due to improper sizing in light of the poor soil conditions. These septic systems may be non-point source contributors to the recreational impairment.

- Row cropping can contribute to fecal inputs due to fertilization of fields, but this is expected to be minimal due high enrollment (30% of row crop acres) in the Conservation Reserve Program and use of conservation practices on most properties.

- Livestock grazing / pasture can contribute fecal inputs to the stream due to direct inputs by livestock with stream access or overland runoff during rain events. Cattle grazing operations may contribute to human recreational use impairment.

2. *Warmwater Aquatic Habitat Impairment*

Chestnut Creek is impaired for warmwater aquatic habitat use due to unknown causes. The characterization of the watershed indicates several contributors to the impairment of habitat for fishes, bugs, and other aquatic organisms including the following:

- Geomorphic stream conditions: Streams in this region of Kentucky tend to be channelized. The effects of this channelization in headwater streams is headcuts migrating upstream, incising tributaries, decreases in base water levels in channels, decreased length of tributary streams, and degradation of the stream bed. The degradation and widening of the channel due to headcutting is a significant source of sedimentation in the watersheds of the area.

- Three miles of stream from Foust Sledd Road to East Fork Chestnut Creek were purposefully channelized in 1966 in conjunction with the construction of flood control dam. These alteration have contributed to further channelization throughout the watershed.

- Wetlands are largely absent from the Chestnut Creek watershed with the exception of small farm ponds indicating that groundwater levels in the area have been lowered due to channelization.

- Farmers in the Chestnut Creek watershed are experiencing erosion and land loss due to head cutting of drainage ditches and small tributaries on their properties.

- Development is 9% of the watershed land use. Impervious surfaces, which are common in developed areas, can cause streams to have abnormally high flows during storm events, leading to erosion and sedimentation. A general rule of thumb is that streams can become impaired where impervious surfaces covers over 10% of the watershed area.

3. *Other Noteworthy Issues*

East Fork Clarks River Flood Retarding Structure (FRS) #32, located at the Foust Sledd Road crossing of Chestnut Creek has been reclassified as a high hazard dam due to the presence of two mobile homes that have been constructed in the breach inundation zone since the original dam construction. While there are no structural problems with the dam, the higher hazard classification structural standards would require $2-3 million in construction costs that are currently unfunded.

CHAPTER III. MONITORING

A. Existing Monitoring

In order to evaluate the water quality within the Chestnut Creek Watershed, data was gathered from all available sources including scientific studies, government, and volunteer sources. The water quality data collected in the watershed has been limited. Only two studies and one volunteer site have been monitored in the Chestnut Creek Watershed. Existing monitoring sites are shown on Exhibit 10, page 30 as well as the monitoring conducted as part of this project.

In 2000, Murray State University conducted watershed based plan monitoring under a 319(h) grant (#C9-994861-99) at 13 sites in the Clarks River Watershed, as well as other basins. One of these monitoring locations (Site 4) was located on Chestnut Creek at Oak Valley Road, near the mouth of the watershed. Six samples were collected on a monthly basis from May to October. Of the six samples, two were above the regulatory limit, as shown in Table 6.

TABLE 6 – 2000 MSU 319(H) SAMPLING – CHESTNUT CREEK AT OAK VALLEY ROAD

Date	Fecal Coliform (CFU/100mL)
5/24/2000	1400
6/20/2000	300
7/24/2000	10
8/21/2000	210
9/25/2000	92,800
10/23/2000	10
Median	**255**

In 2005, KDOW contracted Murray State University's Hancock Biological Station and Center for Reservoir Research to monitor 51 sites in the Clarks River Watershed, of which three were located in the Chestnut Creek Watershed. This sampling was to facilitate TMDL development. Samples were collected during 19 events during the primary contact recreation period. The results of this sampling are summarized in Table 7, page 31. In general, *E. coil* was routinely above regulatory levels at all locations. Dissolved oxygen also dropped below regulatory limits at all sites and turbidity was occasionally high at sites. Water temperature, pH, and conductivity were all within acceptable ranges during the sampling period.

EXHIBIT 10 – MONITORING LOCATIONS

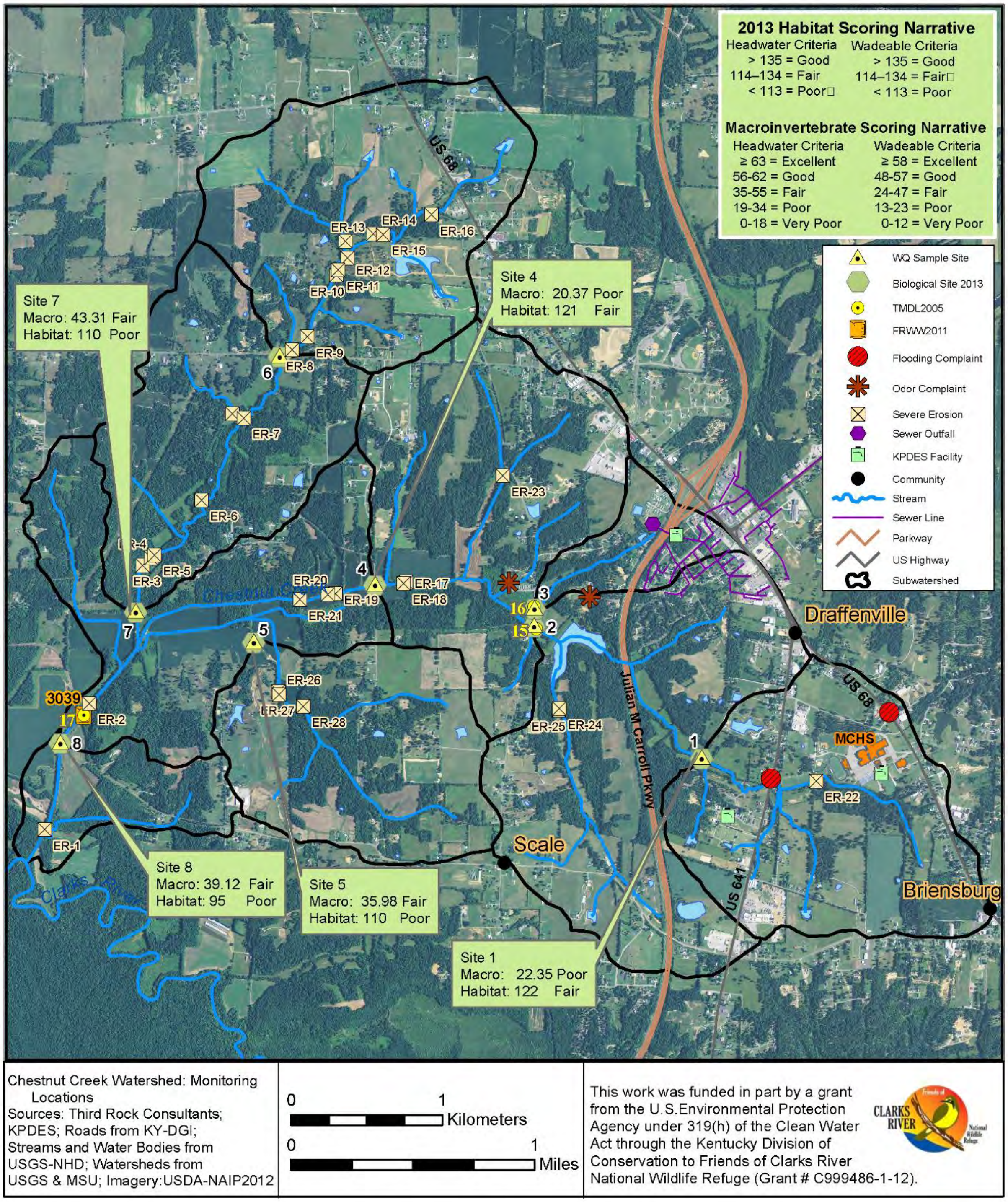


TABLE 7 – SUMMARY OF 2005 MURRAY STATE TMDL SAMPLING SITES IN CHESTNUT CREEK

Site	Statistic	Flow (cfs)	*E. coli* (MPN/100mL)	Turb (NTU)	pH (SU)	Temp ('C)	DO (mg/L)	Cond. (uS/cm)
Site 15 - Chestnut Creek at Foust Sledd Road (RM 2.9) – 14 events	Min	0.0	10	3.4	6.4	16.9	2.1	98
	Average	5.3	1890	16.0	7.1	21.3	4.6	179
	Max	44.1	18416	37.0	7.4	27.2	6.9	255
Site 16 - UNT at Foust Sledd Road (RM 0.1) – 18 events	Min	0.0	20	0.1	6.6	13.4	1.2	25
	Average	0.7	1650	6.9	7.3	19.5	6.9	277
	Max	11.2	15402	40.0	7.6	23.9	10.1	401
Site 17 - Chestnut Creek at Oak Valley Road (RM 0.7) – 14 events	Min	0.0	40	0.4	6.5	13.2	1.1	80
	Average	0.8	6555	12.5	7.1	20.2	5.7	152
	Max	5.0	48392	98.4	7.4	25.4	10.0	294

Only one site in the Chestnut Creek Watershed has been sampled by the Four Rivers Watershed Watch volunteers. Site 3039, located on Chestnut Creek at KY-795 (Scale Road), was sampled on May 5, 2011. Two parameters were measured, *E. coli* at 31 MPN/100mL and triazines at 0.03 ug/L. The triazine level, a type of herbicide which includes atrazine, was below the 3 ug/L maximum contaminant level established by the US EPA for atrazine.

Because the existing dataset was insufficient to determine the water quality or target implementation in the watershed, additional monitoring was planned in order to develop this watershed based plan.

B. Monitoring Needs and Plan

After reviewing the existing monitoring in the Chestnut Creek Watershed, additional monitoring needs were identified in order to support a watershed based plan. In order to address the data gaps, quality assurance project plans (QAPPs) were developed and accepted by KDOW. Two plans were developed for this project. The monitoring under the first QAPP (Morgan 2011) was partially conducted in 2011-2012, but could not be completed due to drought conditions and other factors. Therefore a second QAPP (Evans 2013) was developed in order to guide monitoring efforts in 2013-2014 to complete the dataset initiated in 2011 as well as some subsequently identified gaps. These QAPPs can be reviewed in Appendix A.

The following monitoring activities were conducted under these project plans:

1. Water quality monitoring including nutrients, sediment, bacteria, and field chemistries,
2. *E. coli* geometric mean monitoring,
3. Benthic macroinvertebrate and habitat assessment,
4. Severe erosion visual assessment and bank erosion hazard index, and
5. Bacterial source tracking (BST).

Table 8 describes the sampling locations shown in Exhibit 10, page 30. Table 9, page 33 shows an overview of the dates and locations in which sampling was conducted. Table 10, page 33 provides a comparison of the precipitation that occurred during each month during which sampling was conducted. The following sections provide overviews of the scope and intent of each of these monitoring efforts.

TABLE 8 – DESCRIPTION OF PROJECT MONITORING LOCATIONS

Site ID	Location	Latitude	Longitude	Upstream Area (Sq mi)	Upstream Sites	Previously Sampled
1	Chestnut Creek headwaters with drainage from package treatment plants and mobile home park	36.912251°	-88.345379°	1.1	None	No
2	Chestnut Creek at Foust Sledd Road. just downstream of dam	36.919828°	-88.35808°	2.4	1	Site 15 - TMDL 2005
3	UT to Chestnut Creek at Foust Sledd Road	36.920888°	-88.358062°	0.2	None	Site 16 - TMDL 2005
4	Chestnut Creek at Oak Valley Road	36.922022°	-88.369952°	3.8	1, 2, 3	Site 17 –TMDL 2005, Site 4 – MSU 2000
5	Southern UT to Chestnut Creek with pasture and croplands	36.918401°	-88.378839°	0.9	None	No
6	UT to Chestnut Creek at Griggstown Road	36.935468°	-88.377504°	1.2	None	No
7	Northern UT to Chestnut Creek, near mouth	36.920019°	-88.387638°	2.1	6	No
8	Chestnut Creek at Scale Road, near mouth	36.912072°	-88.392957°	7.7	All	Site 3039 - Watershed Watch 2011

TABLE 9 – SUMMARY OF PROJECT SAMPLING ACTIVITIES

Date	Event	Type	Previous Rainfall Date	Days Since Rain	Previous / Current Rainfall (in)	Site ID - Sampled?								Parameters					
						1	2	3	4	5	6	7	8	E. coli	Nutrients	TSS	In situ	BST	Macro
9/27/11	1	WQ - Dry	9/25/11	2	1.02	Y	Y	Y	Y		Y		Y	X	X	X	X		
10/26/11	2	WQ - Dry	10/19/11	7	0.09	Y		Y	Y					X	X	X	X		
11/8/11	3	WQ - Dry	11/3/11	5	0.52	Y	Y	Y	Y					X	X	X	X		
12/13/11	4	WQ - Wet	12/13/11	0	0.22	Y	Y	Y	Y	Y	Y	Y	Y	X	X	X	X		
1/6/12	5	WQ - Dry	12/27/11	10	0.36	Y	Y	Y	Y	Y	Y	Y	Y	X	X	X	X		
2/23/12	6	WQ - Dry	2/21/12	2	0.07	Y	Y	Y	Y	Y	Y	Y	Y	X	X	X	X		
3/8/12	7	WQ - Wet	3/8/12	0	2.72	Y	Y	Y	Y	Y	Y	Y	Y	X	X	X	X		
4/3/12	8	WQ - Dry	3/25/12	9	0.09	Y	Y	Y	Y	Y	Y	Y	Y	X	X	X	X		
5/29/12	9	WQ - Dry	5/20/12	9	0.01			Y	Y					X	X	X	X		
6/14/12	10	WQ - Dry	6/11/12	3	1.48		Y	Y	Y				Y	X	X	X	X		
7/16/12	11	WQ - Dry	7/14/12	2	0.15			Y						X	X	X	X		
8/13/12	12	WQ - Dry	8/5/12	8	0.20														
9/11/12	13	WQ - Dry	9/8/12	3	0.07			Y						X	X	X	X		
4/17/13	ER	Severe Erosion Assessment				Visual Stream Walk								N/A					
4/18/13	ER	Severe Erosion Assessment				Visual Stream Walk								N/A					
5/1/13	ER	Severe Erosion Assessment				Visual Stream Walk								N/A					
5/1/13	M	Macro Headwater	4/27/13	4	1.01	Y			Y	Y		Y					X		X
6/25/13	M	Macro Wadeable	6/19/13	6	0.01								Y				X		X
9/3/13	E1	Geomean *E coli*	9/2/13	1	0.31	Y	Y	Y	Y	Y	Y	Y	Y	X					
9/5/13	E2	Geomean *E coli*	9/2/13	3	0.31	Y	Y	Y	Y	Y	Y	Y	Y	X					
9/6/13	E3	Geomean *E coli*	9/2/13	4	0.31	Y	Y	Y	Y	Y	Y	Y	Y	X					
9/17/13	E4	Geomean *E coli*	9/16/13	1	0.07			Y						X					
9/30/13	E5	Geomean *E coli*	9/29/13	1	1.64	Y	Y	Y	Y	Y	Y	Y	Y	X					
4/2/14	14	WQ - Wet	4/2/14	0	1.90	Y	Y	Y	Y	Y	Y	Y	Y	X			X	X	
5/9/14	15	WQ - Wet	5/9/14	0	0.05	Y	Y	Y	Y	Y	Y	Y	Y	X	X	X	X	X	
Total WQ Sampling Events						10	10	14	12	7	8	7	9						

TABLE 10 – ANNUAL MARSHALL COUNTY PRECIPITATION (INCHES) BY MONTH

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
2014	1.88	5.98	5.37	9.09	3.00	4.83	1.14	3.80	1.56	5.73	2.26	2.35	46.99
2013	6.78	3.57	3.90	6.03	4.44	10.70	5.26	4.11	5.57	4.49	1.60	5.09	61.55
2012	3.96	1.88	4.25	1.42	2.51	2.49	1.20	1.74	6.52	2.70	2.65	3.74	35.06
2011	1.67	5.89	5.41	16.68	7.49	5.85	2.96	2.30	3.15	1.67	8.77	7.52	69.36
Average*	4.09	5.25	4.45	4.51	4.90	4.08	4.05	4.05	3.35	3.79	4.46	4.43	51.41

NOTE: Blue highlighting indicates monitoring for the project was conducted during the month.
**Averages from www.weather.com for Benton, KY with annual average by summing the months. Monthly numbers from Marshall County Site DRFN at www.kymesonet.org.*

1. *Water Quality Monitoring*

E. coli, nutrients (carbonaceous biochemical oxygen demand, nitrate/nitrite, ammonia, total Kjeldahl nitrogen, orthophosphate, and total phosphorus), sediment (total suspended sediment), field parameters (conductivity, pH, dissolved oxygen, % saturation, and temperature), and stream flow were collected at eight sites within the watershed during dry and wet weather. Initial sampling in 2011-2012 captured both dry and wet conditions. The supplemental sampling in 2013-2014 was intended to capture additional wet weather samples because many of the tributaries did not flow in dry weather conditions.

The purpose of this monitoring activity was to monitor pollutants traditionally related to recreational use and warm water aquatic habitat impairments as well with instream flow in order to allow for comparison with benchmarks and pollutant loads within Chestnut Creek.

2. *E. coli Geometric Mean*

E. coli was collected five times during a 30 day period during the primary contact recreation season. The intention of this sampling was to collect data for comparison to the geometric mean regulatory criteria for *E. coli*.

3. *Benthic Macroinvertebrates and Habitat*

Benthic macroinvertebrates, or "aquatic bugs," are affected by all environmental stream variables including physical, chemical, and biological conditions. Because they cannot escape the pollution, their presence is indicative of both short- and long-term stream health from the cumulative effects of pollution. Samples of the macroinvertebrate community may be collected, species identified, and metrics calculated in order to assess the health of the stream.

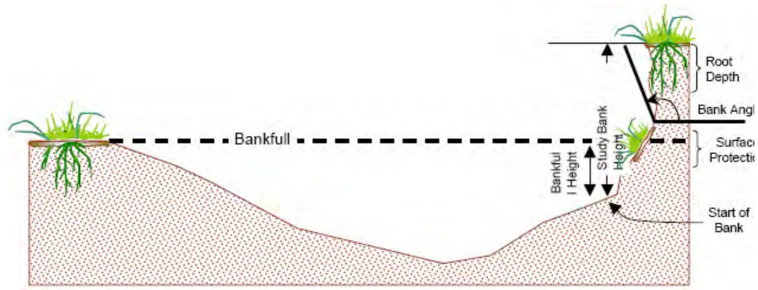
Macroinvertebrate samples were collected at five sites (one wadeable and four headwater) within the Chestnut Creek Watershed. The macroinvertebrate community at each site was sampled using the methods standardized by the KDOW, which involve the collection of two separate samples, riffle and multi-habitat. The riffle sample consists of four 0.25 meters^2 (m^2) samples collected using a kicknet. These samples provide a semi-quantitative sample for use in metric calculations. The qualitative, multi-habitat collections indicates other species present in other habitats in the stream including leaf packs; bedrock; undercut banks/submerged roots; aquatic plant and algae beds; soft sediment; large cobble/small boulder from riffles, runs, and pools; material off rocks, sticks, leaves, and filamentous algae; and large woody debris. High-gradient sampling methods were utilized for the area in error. Samples were preserved and transported to the laboratory for identification of the species and calculation of the community metrics.

At the time of the collection of the macroinvertebrate samples, the habitat was assessed on the reach. Habitat assessments visually assess whether the riffle and pool substrates, stream channelization, riparian conditions, in-stream cover, and other factors provide good quality habitat for fish and aquatic bugs collected at the site.

High-gradient sampling methods were utilized in error for both the macroinvertebrate sampling and habitat assessment.

4. Severe Erosion

FIGURE 5 – DIAGRAM OF BANK EROSION HAZARD INDEX VARIABLES



(*Source: EPA*)

The streams were visually assessed in order to identify severe erosional areas. These areas can be large contributors to sediment pollution and often need to be addressed by best management practices. Not all areas of erosion were documented, only severe areas or areas above normal levels for the region. For each erosion area encountered, the length and height were measured and the bank erosion hazard index (BEHI) and near-bank stress (NBS) ratings were assessed. Figure 5 illustrates the measurements for the BEHI. Together, these measurements indicate a rough approximation of the amount of sediment loading associated with bank erosion.

5. Bacterial Source Tracking

Bacterial source tracking is a method of evaluating the source of fecal inputs into the stream by assessing the DNA of indicator bacteria. The monitoring was intended to collect a dry weather and wet weather sampling event as well as some known sources in order to evaluate whether human or non-human sources were contributing to the pathogen impairment in the watershed.

C. Monitoring Implementation Overview

Technical reports detailing the results of each of the monitoring activities are provided in the following reports:

- Visual Stream Assessments (Appendix B) – includes severe erosion as well as any observed fecal sources
- Habitat and Macroinvertebrate Assessment Report (Appendix C)
- Water Quality Report and QA Evaluation Report (Appendix D)
- Bacterial Source Tracking Report (Appendix E)

Monitoring was conducted primarily as planned. However some changes were made due to weather conditions or unforeseen circumstances.

CHAPTER IV. ANALYSIS

A. Aquatic Community and Habitat

1. Fish

Fish have not been surveyed in Chestnut Creek, but the nearby Clarks River National Wildlife Refuge maintains a list of species that have been found on the refuge as well as within the Lower Tennessee River Watershed, of which Chestnut Creek is a part. Within the Lower Tennessee River Watershed, 157 species have been identified, as listed in Appendix F. Fifty-six species have been identified on the refuge including two bass species, three catfish species, two carp species, one crappie species, twelve darters species, and five sunfish species among others. Of these species, two are considered state threatened including the cypress darter and central mudminnow.

Because many reaches of Chestnut Creek are frequently dry or do not have deep pools, some of the species present at the refuge would not be expected to be present. However, Chestnut Creek is not expected to contain additional species not present in the refuge or the Lower Tennessee River Watershed.

In general, to improve fish habitat in the watershed, the groundwater levels must be raised to support sustained perennial flow.

2. Macroinvertebrates

Macroinvertebrates were sampled at five locations in Chestnut Creek on May 1 and June 25, 2013. As previously mentioned, high-gradient sampling methods were utilized in error instead of the low gradient methods specified for this region. Low-gradient streams have slower velocities than high-gradient streams and naturally lack riffle habitat. Because slightly different sampling methods are used for high-gradient and low-gradient streams, the sampling results collected are qualified as not directly comparable to the KDOW criteria. However, they do illustrate the relative impacts between sites.

Macroinvertebrate biotic indices (MBI) calculated for three of the five sampling stations in the Chestnut Creek watershed resulted in ratings of "fair." The other two sites were rated as "poor." These results are shown in Exhibit 10, page 30.

The "poor" macroinvertebrate communities were located in the headwaters of the watershed with "fair" communities in the lower portion of the watershed. Both poor sites had few species and small populations of pollution intolerant mayflies, stoneflies, and caddisflies. Most sites had an abundance of pollution tolerant taxa such as midges and worms, as well as several tolerant mussel species, but Site 1, in the headwaters of Chestnut Creek upstream of the dam, had the most abundant numbers of these species. Clingers, which are frequently an indicator of unstable substrate or high levels of siltation or embeddedness, were abundant at Site 8, near the mouth of Chestnut Creek, but lower throughout the rest of the watershed. At Site 4, Chestnut Creek at Oak Valley Road, and to a lesser degree at Site 1, pollution from organic enrichment was indicated to present by the macroinvertebrate community.

Based on these qualified scores, the streams of Chestnut Creek are not supporting their warmwater aquatic habitat use in the upper reaches of the watershed and partially supporting this designated use in the lower portion of the watershed. Intermittent flows may be impacting the macroinvertebrate community, as scores are better at larger streams that flowed more often. Unstable substrates are indicated to be impacting the community near the mouth of the watershed while organic enrichment (sewage) is indicated to be impacting the eastern headwater reaches of Chestnut Creek.

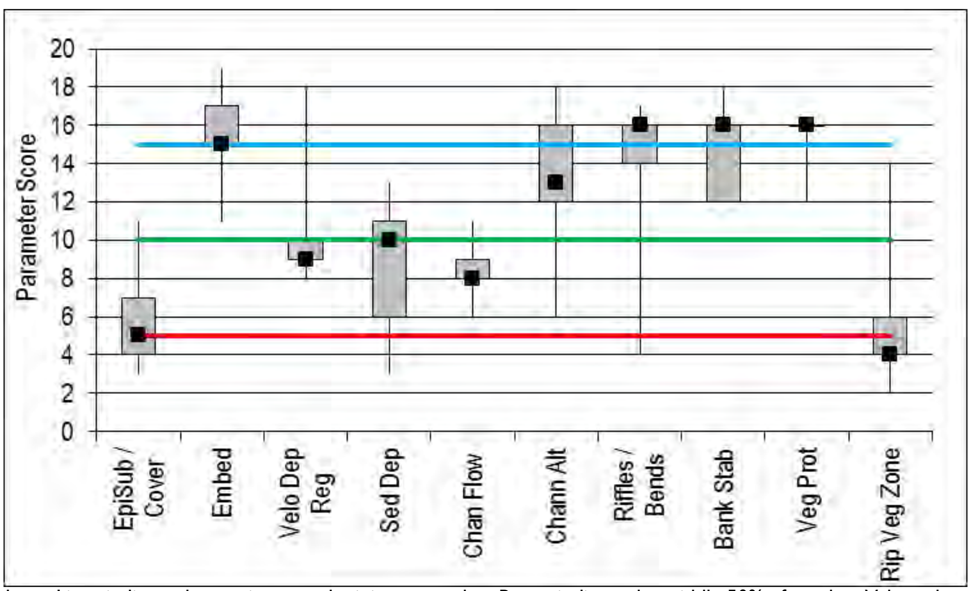
3. *Habitat*

Results from habitat assessments, conducted in conjunction with the macroinvertebrate collections, are summarized on Exhibit 10, page 30. As with the macroinvertebrate scores, because the high-gradient method was utilized rather than the low-gradient method, the results are not directly comparable with KDOW criteria, but are informative for general habitat conditions.

Total habitat scores ranged from "fair" to "poor." Interestingly, the "fair" sites were each associated with "poor" MBI scores, and "poor" habitat sites had "fair" MBI scores. Habitat scores are only representative of the particular reach assessed, while macroinvertebrate communities are impacted by a larger area. However, improvement of habitat will be necessary to aid streams in supporting their designated use for warmwater aquatic habitat.

The range of results for each habitat parameter is shown in the box plot chart in Figure 6. Riparian vegetation zone width was poor on average, as the lowest parameter overall at the sites assessed. Median results for epifaunal substrate / available cover, velocity depth regime, and channel flow status were "Marginal."

FIGURE 6 – CHESTNUT CREEK WATERSHED HABITAT SUMMARY



Note: Lines indicate the maximum and minimum results. Boxes indicate the middle 50% of results. Values above blue line are "Optimal", above the green line are "Suboptimal", above the red line are "Marginal", and below the red line are "Poor".

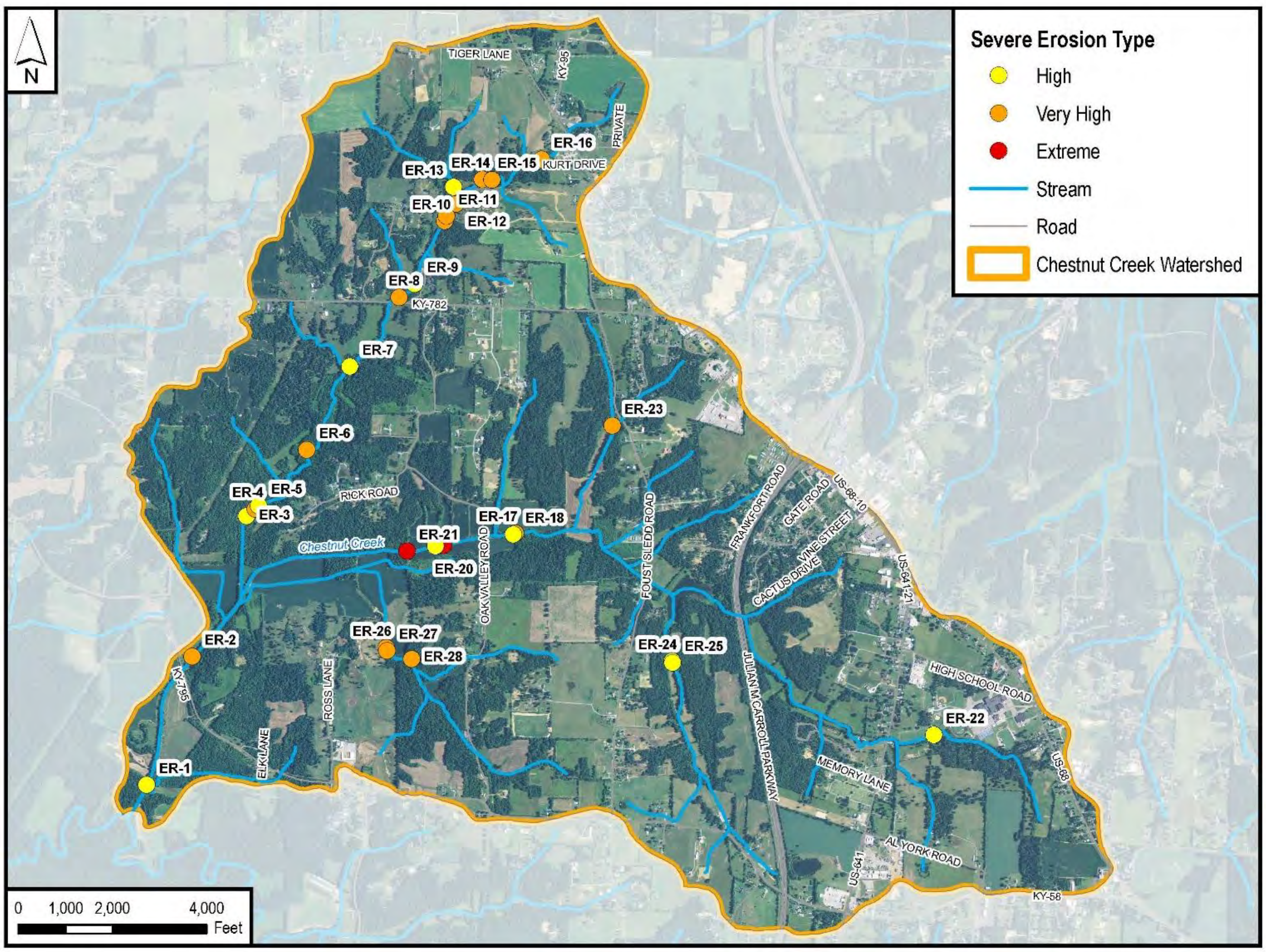
The gravelly, unstable substrate in most streams of the watershed do not provide for good substrate cover for macroinvertebrate species. Restoration efforts to provide increased instream niche habitat should aide in the recovery of macroinvertebrate community. Similarly, narrow riparian corridors are a problem in some areas of the watershed and should be expanded with no-mow zones and native plantings. Some sediment accumulation is occurring, which is linked to the bank erosion noted in other surveys.

This sedimentation covers aquatic habitat and reduces the pool depth, eliminating places for fish and bugs to live.

4. Severe Erosion

The Chestnut Creek Watershed was visually surveyed on April 17, 18, and May 1, 2013. Most of the streams in the watershed had some form of erosion, but only severe erosion areas were measured during this survey. Twenty-eight (28) banks were determined to have severe bank erosion. The locations of these severe erosion areas are shown in Exhibit 11. The amounts of annual erosion occurring at these sites is shown in Table 11, page 39 with examples of the different bank erosion hazard index ratings shown in Figure 7, page 39.

EXHIBIT 11 – SEVERE EROSION SITES



A total of 2,714 linear feet of bank were found to have severe erosion. Eleven banks with a total length of 1,087 feet had a BEHI rating of "High", 15 reaches with a total length of 1,537 feet had a rating of "Very High," and two reaches with a total length of 90 feet were "Extreme."

TABLE 11 – SUMMARY OF SEVERE BANK EROSION REACHES IN CHESTNUT CREEK WATERSHED

ID	Reach Length (ft)	Bank Height (ft)	Bank Erosion Height Index Rating	Erosion from Site (tons/yr)
ER-1	150	4	High	**4.77**
ER-2	108	6	Very High	**5.15**
ER-3	80	5	High	**3.18**
ER-4	100	5.5	Very High	**4.38**
ER-5	100	5.5	High	**4.38**
ER-6	38	4	Very High	**1.21**
ER-7	100	5	High	**20.99**
ER-8	85	6	Very High	**4.06**
ER-9	67	8	High	**4.26**
ER-10	78	8.5	Very High	**5.27**
ER-11	150	8	Very High	**9.55**
ER-12	84	9	Very High	**6.01**
ER-13	135	6.5	High	**6.98**
ER-14	102	9	Very High	**7.30**
ER-15	75	8	Very High	**4.77**
ER-16	102	6.5	Very High	**5.27**
ER-17	50	9	Very High	**3.58**
ER-18	120	7.5	High	**7.16**
ER-19	60	10	Extreme	**4.74**
ER-20	60	10	High	**4.77**
ER-21	30	10	Extreme	**2.37**
ER-22	150	5.5	High	**6.56**
ER-23	90	10	Very High	**7.16**
ER-24	50	6	High	**2.39**
ER-25	75	6	High	**3.58**
ER-26	200	7	Very High	**11.14**
ER-27	200	7	Very High	**11.14**
ER-28	75	9	Very High	**5.37**
			Total Length of Severely Eroding Stream Banks (ft):	**2,714**
			Total Erosion (tons/year):	**167.5**

FIGURE 7 – BANK EROSION HAZARD RATING EXAMPLES

Extreme Rating (ER-19):

Very High Rating (ER-14):

High Rating (ER-05):

Bank erosion hazard index ratings of "extreme", "very high", and "high" in Chestnut Creek Watershed. For scale, the field technician pictured is 6'7" tall.

The banks had average height of seven feet, but the bankfull height was much lower indicating that all streams were deeply channelized and entrenched. On average, only 30% of the banks with severe erosion had root growth to aid in the stabilization of the bank. The bank angle ranged from 60 degrees to 95 degrees, indicating moderate to very high susceptibility to mass erosion. On average, only 22 percent of the banks had protection from sod mats, woody debris, or plant material.

The predicted bank erosion rates indicate that an average of over 2 inches of soil is being lost per year at these sites. At this rate, 167.5 tons of sediment, per year, was predicted to be eroding from just the severely eroding banks in the watershed. With lesser degrees of erosion occurring throughout the watershed, the total sediment contribution of erosion is expected to be much higher. This indicates that bank erosion is a significant contributor to the sediment load in the watershed.

FIGURE 8 – DEBRIS BLOCKAGES OF CHESTNUT CREEK DUE TO CHANNELIZATION AND EROSION

Not only does the channelization and erosion contribute to sedimentation in the watershed, but it also increases the rate of flooding. As stream banks erode, trees located along the banks fall into the stream. As shown in Figure 8, additional debris accumulates behind these trees causing large flooding to occur since water cannot pass these blockages. When the velocity of the water is sufficient to break through the blockage, this debris is released downstream where it causes more erosion and accumulates in a similar location downstream.

The channelization also causes the lowering of the groundwater levels, which are a contributor to the impairment of the macroinvertebrate community in the watershed.

The channelization, erosion, and flooding can be addressed through stream restoration through natural channel design including groundwater berms and floodplain accessibility. While bank stabilization will address some of the immediate erosion concerns on the stream reach, stream restoration will address the erosion on the reach while also restoring the stream to a stable state such that erosion will be less likely to occur in the future.

B. Water Quality

Monitoring was conducted during 15 events from September 2011 to May 2014 at the locations shown in Exhibits 10, page 30. The monitoring included four wet events (occurred during rainfall) and eleven dry events. An additional 5 monitoring events were conducted in September 2013 in order to calculate the *E. coli* geomean. Appendix D contains the full watershed monitoring report.

1. Benchmarks

In order to evaluate the nature and extent of impairments in the Chestnut Creek Watershed, results were compared to applicable water quality benchmarks. Both regulatory and non-regulatory benchmarks are applicable for this analysis. Regulatory criteria are specified for parameters in which a given concentration of the pollutant is directly linked with impairment in the designated use. For other parameters, such as nutrients, specific conductance, suspended solids, or dissolved solids, no regulatory numeric standard has been established due to the variable relationship between biological integrity and concentration levels in different streams. Only narrative criteria have been established due to the difficulty in determining impairment thresholds for these parameters as well as the natural geographic variation of these parameters. The benchmarks used for this analysis are summarized in Table 12.

The regulatory statute for surface waters in Kentucky is found in 401 KAR 10:031. The statute provides minimum water quality standards for all surface waters as well as specific standards that apply to particular designated uses. All streams monitored have designated uses of warmwater aquatic habitat (WAH), primary contact recreation (PCR), and secondary contact recreation (SCR). Standards for PCR are applicable during the recreation season of May 1 through October 31. SCR standards are applicable to the entire year. The non-regulatory benchmarks were provided by KDOW based on reference reaches from the same ecoregion as Chestnut Creek. These recommendations and the data that supports them are provided in Appendix G. No load reduction benchmarks were provided by KDOW for total suspended solids or turbidity. Sediment problems in the watershed are to be addressed by the severe erosion assessments and not by water quality loading calculations.

TABLE 12 – WATER QUALITY BENCHMARKS

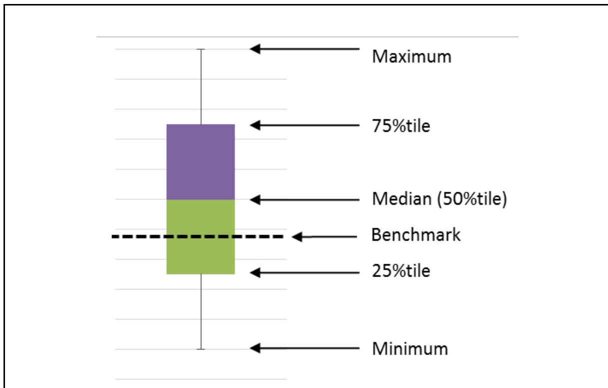
Parameter	Water Quality Standard	Type
pH	6.0 and 9.0 SU, and not to fluctuate more than 1.0 SU over 24 hours	Regulatory WAH
Temperature	< 31.7°C (89°F)	Regulatory WAH
Dissolved oxygen	> 5.0 mg/L as a 24-hour average; or > 4.0 mg/L for instantaneous	Regulatory WAH
*E. coli**	130 CFU/100mLs as 30-day geometric mean, or 240 CFU/100mLs as an instantaneous measurement	Regulatory PCR
Total Phosphorus as P	0.07 mg/L	Non-regulatory WAH
Total Nitrogen as N	1.5 mg/L	Non-regulatory WAH
Ammonia (as N)**	0.5 mg/L	Non-regulatory WAH
Specific Conductance	150 uS/cm	Non-regulatory WAH

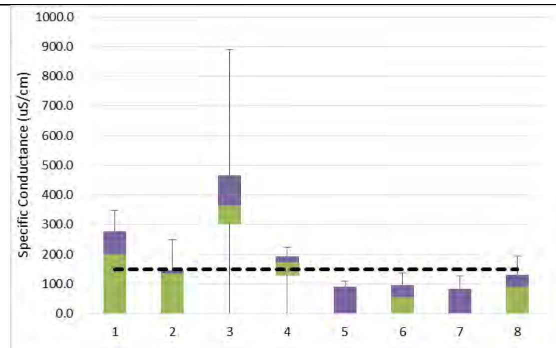
NOTE: Designated uses abbreviated as follows: warmwater aquatic habitat (WAH), primary contact recreation (PCR), secondary contact recreation (SCR).
**Geometric mean based on not less than five samples taken during a 30-day period. Instantaneous standard is not to be exceeded in 20% or more of all samples taken during a 30-day period. If less than five samples are taken in a month, this standard applies.*
***KDOW did not provide a specific benchmark for ammonia. Therefore the benchmark for TKN, in which ammonia is included, was utilized.*

2. *Watershed Concentrations*

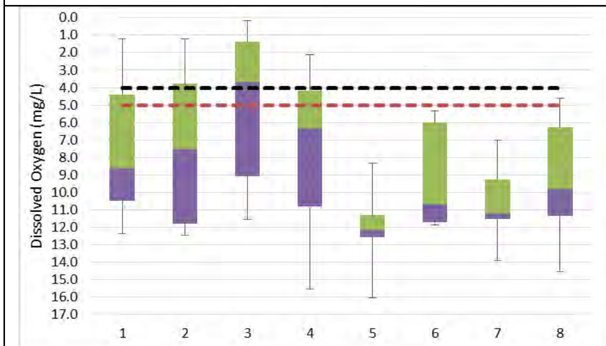
Based on the analysis of all monitoring results, multiple factors are impacting the water quality in the Chestnut Creek Watershed. Concentrations of specific conductance, dissolved oxygen, ammonia, total nitrogen, total phosphorus, and *E. coli* each exceeded benchmark concentrations, as shown in Table 13, page 42. While not shown, temperature was below the regulatory standard during all events. Turbidity and total suspended solids (TSS) were low during dry weather but high during wet weather, as expected.

TABLE 13 – WATER QUALITY CONCENTRATIONS BY SITE

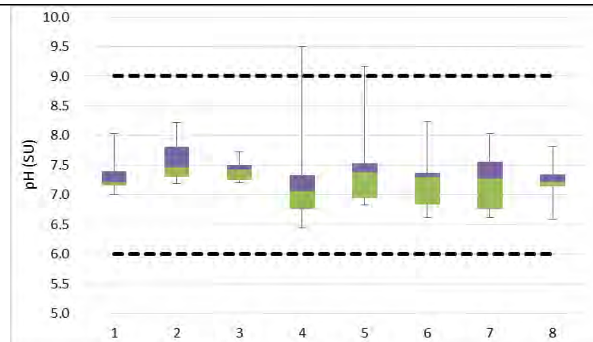




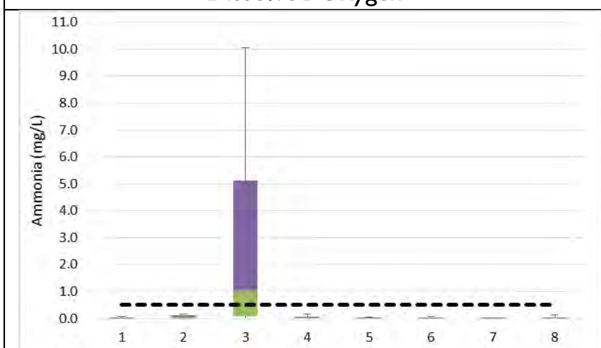
Specific Conductance



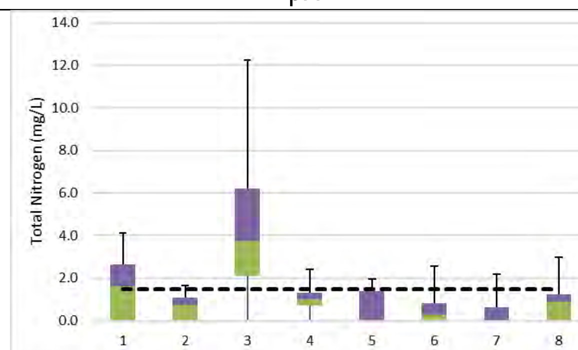
Dissolved Oxygen[1]



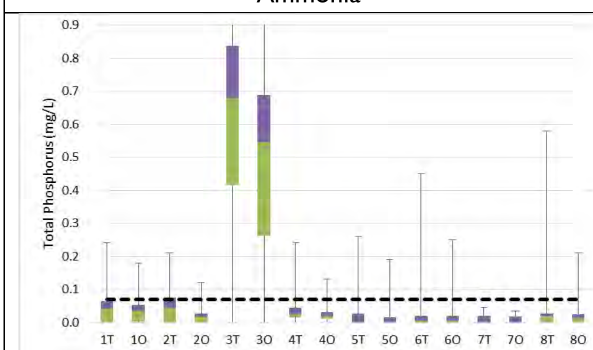
pH



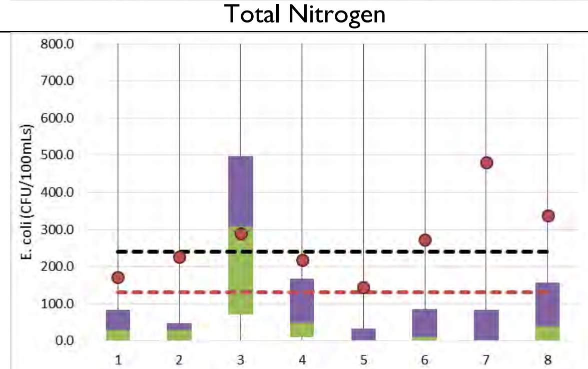
Ammonia



Total Nitrogen



Total (T) and Ortho (O) Phosphorus



E. coli[2]

[1]For dissolved oxygen, the red line indicates the 24-hour average standard, while the black line indicates the instantaneous standard. The axis is flipped since low values are considered exceedances.
[2]For *E.coli*, the red line indicates the geomean standard (130) and black line the instantaneous standard (240). The dots indicate the geomean sampling results. All sites exceeded 1,000 CFU/100mLs during the sampling, with a maximum of 5480 CFU/100mLs at Site 3.

All sites had exceedances of water quality benchmarks for one or more parameters. The percentage of exceedance of each benchmark was calculated for each site and used to generate a water quality health score. These health scores, like report cards, assign letter grades to the frequency of exceedance at each site. *E. coli* was used to develop a human recreation grade, and conductivity, pH, dissolved oxygen, ammonia, nitrogen, and total phosphorus were used to develop water quality health grades. The scores and the percentage of results that exceeded the benchmarks are shown in Table 14. The human recreation grades and water quality health grades are shown in Exhibits 12 and 13, pages 44 and 45, respectively.

TABLE 14 –GRADES AND PERCENTAGE OF RESULTS EXCEEDING WATER QUALITY BENCHMARKS*

Parameter	Conductivity	pH	Oxygen	Ammonia	Nitrogen	Phosphorus	**Overall WQ Health Grade**	E. coli**	**Overall Human Recreation Grade**
Benchmark	150 uS/cm	6 – 9 SU	4 mg/L	0.5 mg/L	1.5 mg/L	0.07 mg/L		240 CFU/100mLs	
1	D - 56%	A - 0%	C - 20%	A - 0%	D - 52%	B - 17%	**C**	22%	**C**
2	B - 20%	A - 0%	D - 38%	A - 0%	B - 8%	C - 35%	**B**	17%	**B**
3	F - 90%	A - 0%	F - 53%	D - 53%	F - 90%	F - 97%	**F**	54%	**F**
4	D - 73%	B - 3%	C - 23%	A - 0%	B - 19%	B - 8%	**B**	20%	**B**
5	A - 0%	B - 2%	A - 0%	A - 0%	B - 16%	B - 8%	**A**	11%	**A**
6	A - 0%	A - 0%	A - 0%	A - 0%	B - 6%	B - 8%	**B**	30%	**B**
7	A - 0%	A - 0%	A - 0%	A - 0%	B - 5%	A - 0%	**B**	32%	**B**
8	B - 9%	A - 0%	A - 0%	A - 0%	B - 14%	B - 10%	**A**	18%	**A**

Note: Shading denotes relative health grade with Red as "F", Orange as "D", Yellow as "C", Green as "B" and Blue as "A." Letter grades for individual parameters are roughly based on KDOW 303(d) listing criteria. The overall score is based on a combination of the parameter grades and the load reductions required to meet benchmarks at each site. Nitrogen refers to total nitrogen, the sum of TKN, nitrate, and nitrite. Phosphorus refers to total phosphorus.
**Percentage of results exceeding benchmarks was calculated in Excel using the "PERCENTRANK" function, which estimates the rank of the benchmark within the dataset as a percentage, and subtracting from 100%.*
***includes geomean E. coli sampling event results*

EXHIBIT 12 – HUMAN RECREATION GRADES

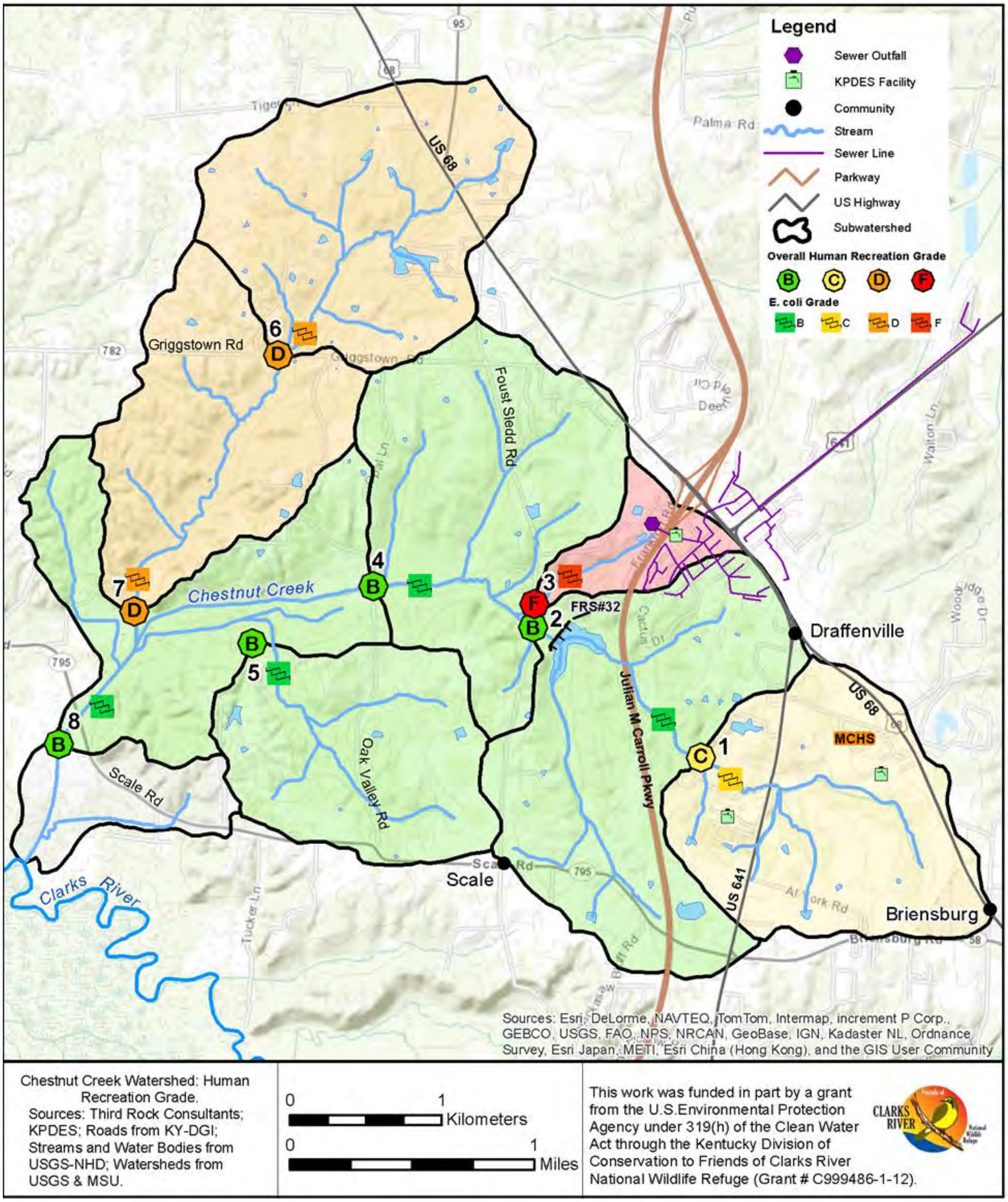


EXHIBIT 13 – WATER QUALITY HEALTH GRADES

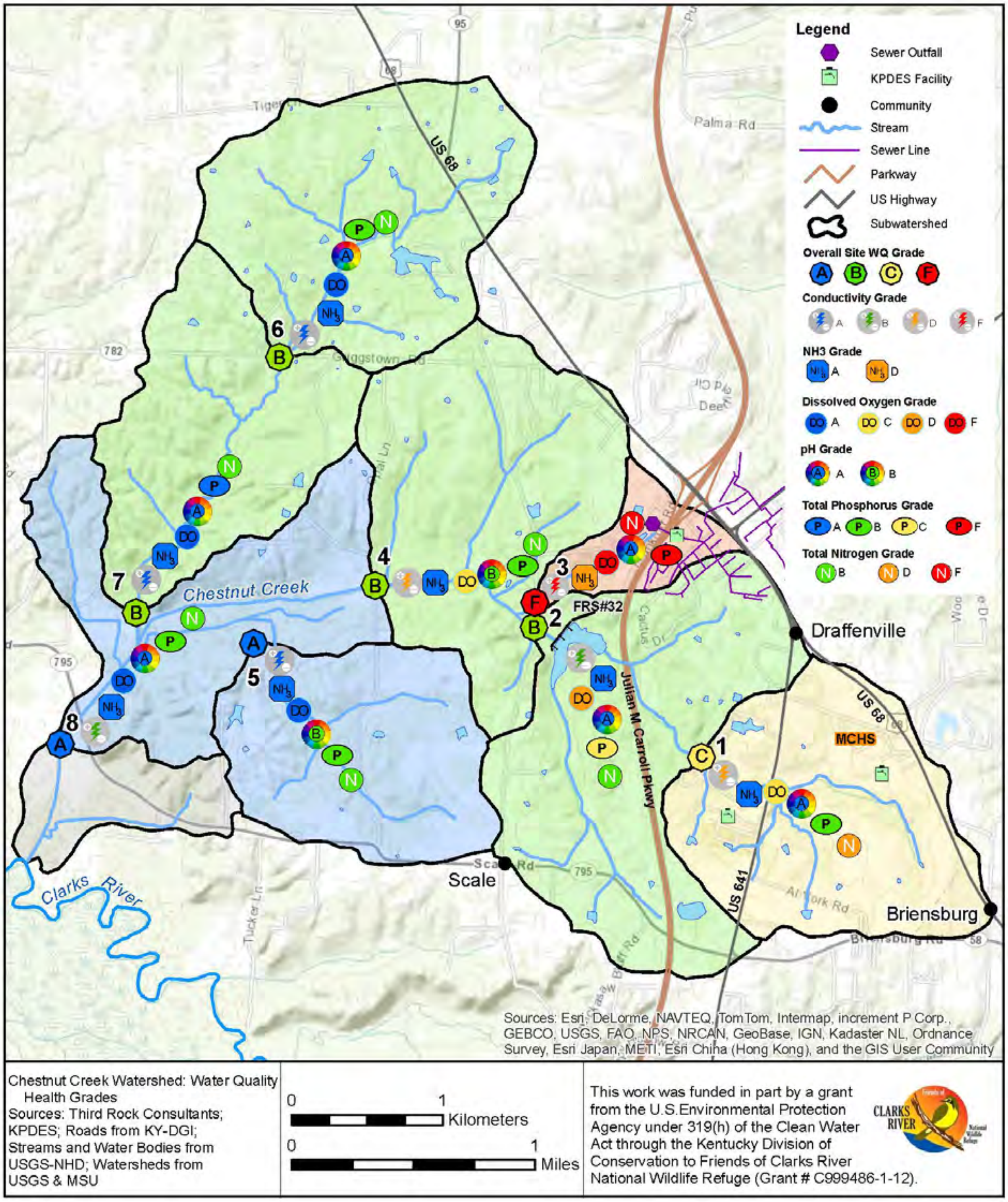
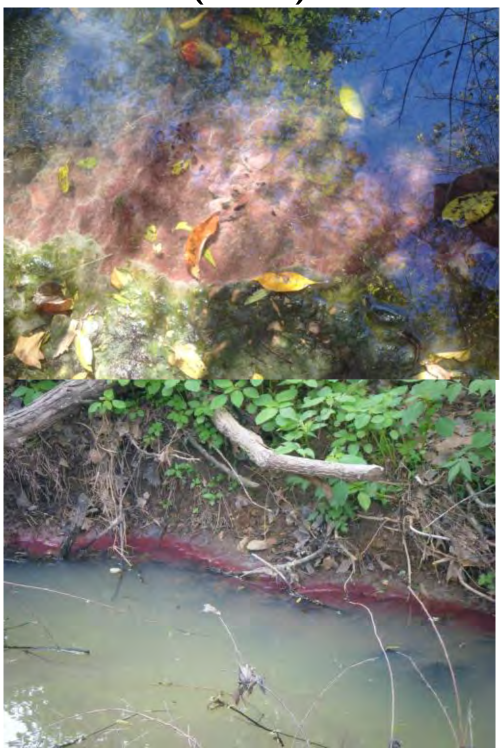


FIGURE 9 – POOR WATER QUALITY AT UNNAMED TRIBUTARY TO CHESTNUT CREEK AT FOUST SLEDD ROAD (SITE 3)



Overall, the worst site for water quality pollutants is Site 3 at the unnamed tributary of Chestnut Creek at Foust Sledd Road with a grade of "F". This site was routinely above benchmarks for specific conductance, dissolved oxygen, ammonia, total nitrogen, total phosphorus, ortho-phosphorus, and *E. coli*. As shown in Figure 9, evidence of impairment could be observed visually in heavy algal growth, biosolids, turbid waters and unknown substances on the surface. Site 1, located in the headwaters upstream of the dam, was also impaired received a "C" grade due to exceedances for total nitrogen, conductivity, dissolved oxygen, and *E.coli*. The best sites, receiving "A" grades, were Sites 5 (southern unnamed tributary to Chestnut Creek) and 8 (Chestnut Creek near the mouth), with few overall exceedances.

Overall, pH and ammonia had the fewest benchmark exceedances. pH only exceeded the 9.0 SU regulatory limit twice during the sampling, both during the 2.72 inches of rainfall that occurred on March 8, 2012. No sites showed statistical difference (at 95% confidence) for pH.

Ammonia was always below 0.5 mg/L at all sites except Site 3, located at the unnamed tributary of Chestnut Creek at Foust Sledd Road, where it exceeded the benchmark during more than half of the events sampled and was significantly higher.

Dissolved oxygen levels were low in the headwaters (Sites 1 – 4) but Sites 5 – 8 met the 4.0 mg/L instantaneous regulatory limit during all events, with some statistically significant differences between the best and worst sites. Low dissolved oxygen levels may be due to algal blooms as a result of high nutrient levels or low flow levels throughout the watershed. At Site 2, the impoundment of Chestnut Creek just upstream is expected to be a contributor to the low levels.

Conductivity was significantly higher at Site 3 than all other sites, exceeding the benchmark in most events. Site 1 was also statistically higher from Sites 5, 6, and 7 but otherwise the differences between sites was not significant. Much of the conductivity at sites where it is high is expected to be due to dissolved phosphorus and nitrogen.

For total nitrogen, all sites exceeded the benchmark at least once, but only Site 1 (due to high nitrate) and Site 3 (due to high ammonia and nitrate) routinely exceed 1.5 mg/L. Likewise all sites, except Site 7, exceeded the total phosphorus benchmark, but only Site 3 was significantly higher than the other sites.

Overall, *E.coli* showed the most exceedances of all parameters, and although Site 3 exceeded the benchmarks at a much higher frequency than other sites, there was no statistically significant differences between the sites. The geomean results for *E. coli* exceed the geomean limit of 130 CF/100mLs at all sites. These results were higher than the instantaneous results because 1) flow was not present except at Site 3 during one of the five sampling events and therefore not sampled at those sites and 2) one of the sampling events was a rain event. All sites exceeded 1,000 CFU/100mLs during at least one event with the highest concentration reaching 5480 CFU/100mLs at Site 3. However, Sites 2, 4, 5, and 8 meet the instantaneous regulatory criteria for *E. coli* because less the 20% of the results exceeded 240 CFU/100mLs at these sites.

Bacterial source tracking samples were collected on April 2 and May 9, 2014 and were tested for Bacteriodetes concentrations using three assays, AllBac for total Bacteroidetes, HuBac for human-associated Bacteroidetes and BoBac for bovine-associated Bacteroidetes. The sampling included a WWTP influent and effluent sample as well as a field blank for quality control. The influent and effluent samples showed high concentrations of the total and human associated Bacteroidetes markers. In the creek water samples the site with the highest positive Bacteroidetes measurements was Site 3 for both events. Water samples from sites 1, 2, and 4 also had low positive concentrations (> 1 mg/L) for one event. However, the HuBac or BoBac Bacteroidetes concentrations were below the detection limit (0. 5mg/L) for all creek water samples so the bacterial source tracking did not aid in identifying the source of the fecal inputs.

In order to facilitate loading calculations, averages were calculated for dry weather and wet weather events. Concentrations below the detection limit were averaged at the detection limit. For dry events, the flow was calculated by averaging the field measured flow. Where flow was present but could not be measured, a value of 0.01 cfs was utilized in the average. Where no flow was present, a zero value was used in the calculations. For wet weather however, measured flows could not be utilized. The travel time between sampling sites during storm events causes the variation in measured flow between sites to be more a factor of when the sampler arrived at the site during the rapid rise and fall of the hydrograph rather than sustained differences between sites. Therefore, a modeled wet weather was utilized in calculations. The results are shown in Table 15.

The modeled flow used for wet weather calculations was intended to simulate a routine rainfall event by using the two-day average precipitation (0.26 inches). One-year flow was calculated manually for each site using TR-55 based on 2.6 inches in 24 hours. Because the two-day rainfall is 10% of the one-year modeled flow, the two-day average was taken as 10% of the one-year flow. The flows were also adjusted to account for the routine discharge flow from the WWTP.

TABLE 15 – DRY AND WET WEATHER AVERAGES FOR WATER QUALITY PARAMETERS

Site	Dry Weather Averages							Wet Weather Averages						
	COND	DO	ECOLI	TP	NH3	TN	FLOW*	COND	DO	ECOLI	TP	NH3	TN	FLOW*
1	127	5.8	34	0.025	0.014	1.2	0.02	191	9.9	723	0.129	0.034	2.4	0.3
2	76	6.2	46	0.037	0.049	0.5	0.11	135	9.3	1060	0.117	0.114	1.4	0.5
3	394	4.1	183	0.583	2.865	3.9	0.02	260	6.0	2232	0.630	2.766	5.4	0.5
4	117	6.2	66	0.021	0.029	0.8	0.27	191	10.3	809	0.115	0.058	1.6	1.1
5	20	12.0	3	0.007	0.003	0.3	0.03	88	12.1	622	0.119	0.026	1.6	0.1
6	28	8.2	100	0.009	0.005	0.3	0.04	108	10.3	1012	0.164	0.034	1.4	0.3
7	21	11.0	13	0.004	0.001	0.2	0.04	93	10.2	656	0.029	0.015	1.3	0.3
8	52	8.3	97	0.014	0.018	0.5	1.84	135	11.2	568	0.211	0.043	1.8	1.4

**For dry weather, flow is the average of the field measured flows. For wet weather, it is the 2-day precipitation flow adjusted for WWTP output.*

3. *Pollutant Loads and Target Reductions*

In order to calculate the annual loads at each site, the average concentrations, flows, and a conversion factor for each event type were multiplied to develop a daily load value for wet events and dry events for each site. Then, an annual load was calculated by weighting the daily load for each event type by the percentage of days annually with that type of condition. NOAA's closest climatological station (Paducah, Kentucky) indicates that precipitation greater than 0.1 inches occurs on 74 days per year on average or 20% of the year (http://w2.weather.gov/climate/index.php?wfo=pah). Therefore dry daily loads were represented for 80% of the year and wet loads for 20% in the annual load calculations. To calculate the target or benchmark load for each site, this same process was utilized, substituting the benchmark concentrations for the measured concentrations. This target load was then subtracted from the actual annual load to determine the load reduction needed to reach the target load.

The load reductions are summarized in Table 16 for total phosphorus, ammonia, total nitrogen, and *E. coli*. Figures 10 to 13, pages 49 and 50, show the annual load contributions by dry and wet weather for each site. These load reductions apply to the entire area upstream of each site and not to the specific subwatershed (incremental loadings). Therefore, at several sites (shown in green in Table 16), efforts to address load reductions at upstream sites will also achieve the necessary reductions at downstream sites. Thus, specific subwatershed locations are in need of BMPs to address pollutant loading exceeding benchmarks, even though the most downstream site (Site 8) is meeting target load levels.

TABLE 16 – PERCENT ANNUAL LOAD REDUCTIONS BY SITE

	% Reduction to Achieve Benchmark Loads			
Site	**Total Phosphorus**	**Ammonia**	**Total Nitrogen**	***E. coli****
1	33% - 5.1 lbs/year	0%	29% - 92.6 lbs/year	57% - 216 billion CFU/year
2	13% - 3.9 lbs /year	0%	0%	60% - 600 billion CFU/year
3	89% - 120 lbs/year	82% - 494 lbs/year	71% - 794 lbs/year	87% - 1,630 billion CFU/year
4	0%	0%	0%	45% - 751 billion CFU/year
5	0%	0%	0%	0%
6	33% - 5.5 lbs/year	0%	0%	64% - 306 billion CFU/year
7	0%	0%	0%	42% - 131 billion CFU/year
8	0%	0%	0%	0%

Note: Yellow denotes areas where load reductions are required, green denotes areas where upstream load reductions will achieve the necessary reductions at downstream sites, and blue denotes areas that are currently meeting benchmark loading.
**E. coli load reductions apply to the 240 CFU/100mLs benchmark*

For ammonia, nitrogen, phosphorus, and *E. coli*, the majority of the annual load is produced during wet weather events during which high concentrations occur in conjunction with high flows. Wet weather loading represents over 75% of the loading on average for these parameters. This is due primarily to the low or no flows that occur throughout the watershed during dry weather. Where Site 3 flowed during almost all events sampled due to the outflow from the wastewater treatment plant, Sites 5, 6, and 7 had no flow during about half of the sampling events. Therefore BMPs which target wet weather sources may have greater impact on load reductions.

FIGURE 10 – ANNUAL TOTAL PHOSPHORUS LOADING CONTRIBUTIONS BY SITE AND EVENT TYPE

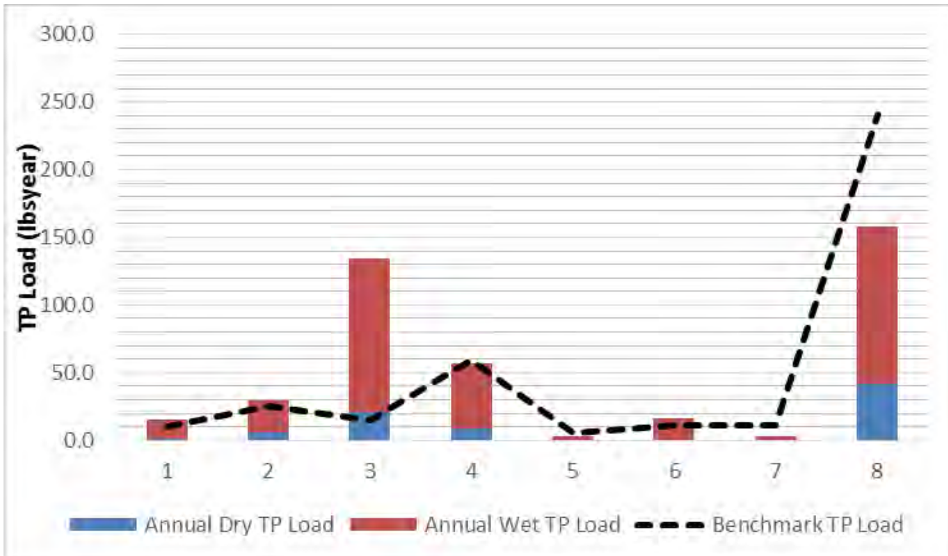
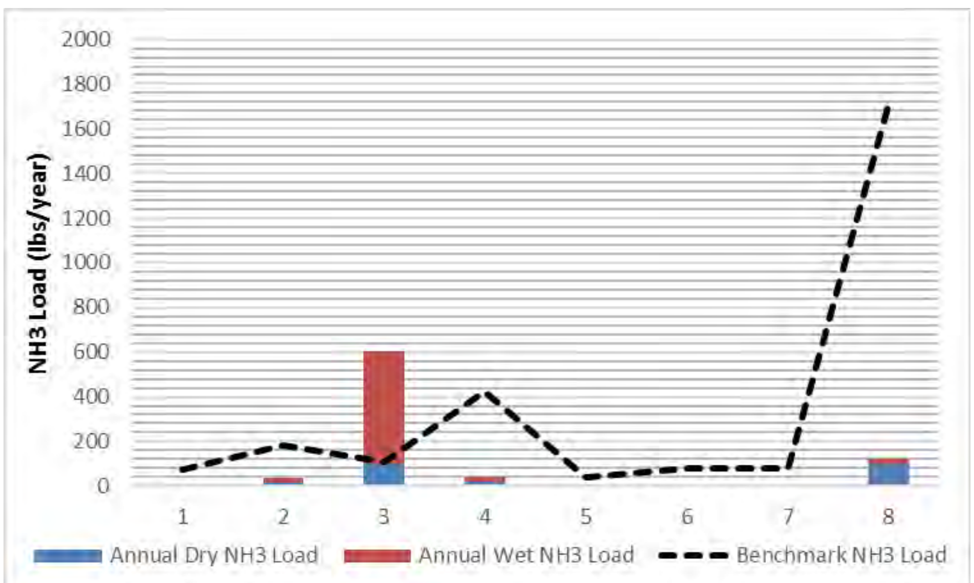


FIGURE 11 – ANNUAL AMMONIA LOADING CONTRIBUTIONS BY SITE AND EVENT TYPE



By far, Site 3 requires the largest load reductions for total phosphorus (120 lbs/year), ammonia (494 lbs/year), total nitrogen (794 lbs/year), and *E. coli* (1,630 billion CFU/year). Sites 4, 5, 7, and 8 either currently meet the benchmark load targets or upstream reduction efforts will meet target loadings for total phosphorus, total nitrogen, and *E. coli*. For phosphorus, load reduction efforts should be targeted towards sources in the drainages of Sites 1, 3, and 6; for nitrogen towards Sites 1 and 3; for ammonia towards Site 3; for *E. coli* towards Sites 1, 2, 3, and 6.

FIGURE 12 – ANNUAL TOTAL NITROGEN LOADING CONTRIBUTIONS BY SITE AND EVENT TYPE

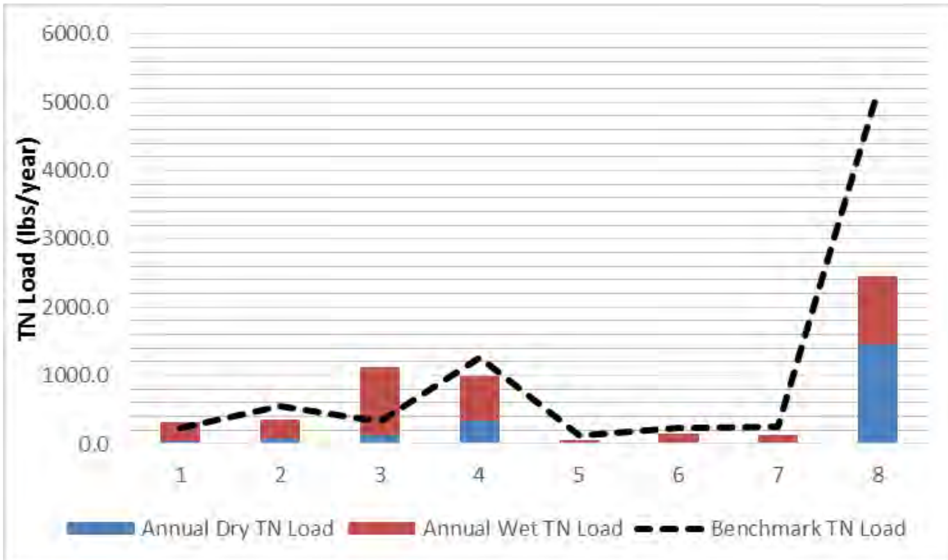
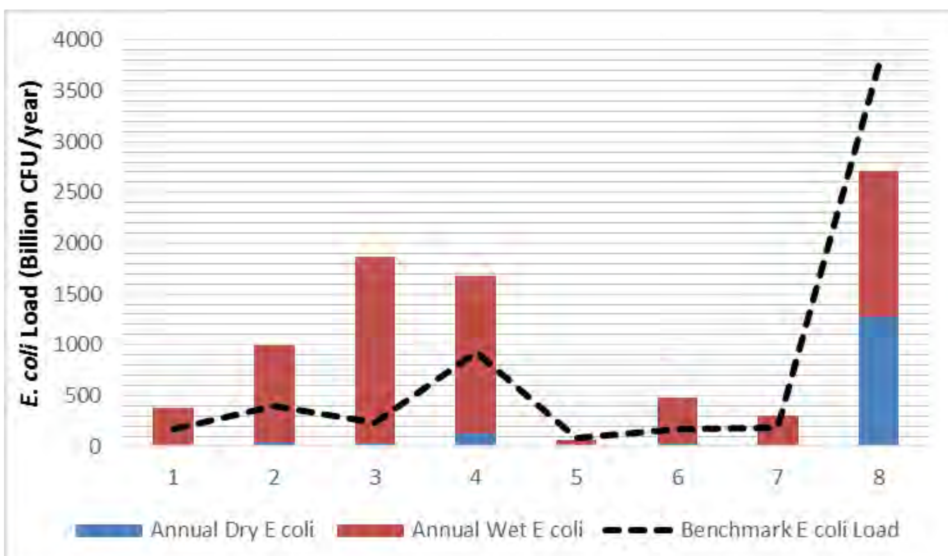


FIGURE 13 – ANNUAL *E. COLI* LOADING CONTRIBUTIONS BY SITE AND EVENT TYPE



4. *Sources of Pollutants*

In order to achieve the reductions in the pollutant loads for phosphorus, nitrogen, and *E. coli*, as well as the number of benchmark exceedances for conductivity, pH, and ammonia, the sources of pollution in the Chestnut Creek must be clearly identified. Based on available data, most of the reductions may be addressing the point sources at the three KPDES facilities located within the watershed. The EPA's Discharge Monitoring Report (DMR) Pollutant Loading Tool (http://cfpub.epa.gov/dmr/facility_detail.cfm) indicates that most of the pollutant loading at Sites 1 and 3 are due to these facilities, as shown in Table 17.

TABLE 17 – AVERAGE ANNUAL POLLUTANT LOADING FROM KPDES PERMITTED FACILITIES, 2011 - 2014

KPDES Permit (Subwatershed)	Ammonia (lbs/yr)	Nitrogen (lbs/yr)	Phosphorus (lbs/yr)
Marshall County Sanitation District #2 (upstream of Site 3)	831	1,108*	268
Memory Lane Trailer Court (upstream of Site 1)	6.5	N/A	N/A
Marshall County High School (upstream of Site 1)	188	N/A	N/A

Source: EPA Discharge Monitoring Report (DMR) Pollutant Loading Tool http://cfpub.epa.gov/dmr/facility_detail.cfm
**excludes potential outlier data*

The average of the annual discharged pollutant load at the Marshall County Sanitation District (MCSD) #2 wastewater treatment plant from 2011 to 2014 accounts for all of the annual loading for total phosphorus (268 lbs/year discharged at MCSD#2 as compared to 135 lbs/year at Site 3), ammonia (831 lbs/year discharged at MCSD#2 as compared to 602.4 lbs/year at Site 3), and total nitrogen (1,108 lbs/year discharged at MCSD#2 as compared to 1,118 lbs/year at Site 3). Because the average daily discharge flow data was not publicly available, the annual load of *E. coli* discharged by this facility could not be calculated, but based on the concentrations of *E.coli* measured at the facility and the known ongoing problems, it is suspected that the excessive *E.coli* load in Site 3 is also due to discharges from MCSD#2. Addressing this point source will also improve the conductivity benchmark exceedances.

At the Memory Lane Trailer Court and the Marshall County High School, both located upstream of Site 1, only annual ammonia loading was available from the EPA's DMR Pollutant Loading Tool. However, the high concentrations of total nitrogen and *E. coli* are regularly reported from these facilities, and high concentrations of total phosphorus are expected. Therefore, addressing these point sources will address the required reductions for total nitrogen, total phosphorus, *E. coli*, and conductivity.

Although much of the *E. coli* loading reductions required to meet benchmark loads at Site 2 may be achieved by addressing the Memory Lane Trailer Court and the Marshall County High School discharges, additional *E.coli* reductions will be necessary in that subwatershed. Sources of *E. coli* in this area may include wildfowl at the impoundment or ponds, failing septic systems, sanitary sewer exfiltration, or agricultural sources.

The excess loading of total phosphorus and *E. coli* upstream of Site 6 may include failing septic systems, stream bank erosion, cattle with access to the stream, overland flow from pastures, and other agricultural nutrient management.

Other sources of impairment that need to be addressed include the severe erosion areas identified throughout the watershed and the associated channel evolution causing low groundwater levels, flooding due to debris blockages, unstable substrate, and other symptoms. Riparian zones should be expanded as well to improve habitat, flood control, and filtration.

CHAPTER V. STRATEGY FOR SUCCESS

A. Goals and Objectives

In order to determine the goals and objectives of the community for this watershed, several methods were employed. Public meetings were held on August 27, 2015 and October 22, 2015 with advertising for the meeting occurring through several articles in the local papers, an announcement at the Marshall County Fiscal Court, and flyers to residents of the watershed. Additionally, an online survey was published online and advertised through email, Facebook, and newspaper articles.

Through these efforts, 27 survey response were obtained. One third (33%) of the responses were from individuals that lived along Chestnut Creek or its tributaries. 59% of the responses were from individuals that lived within the watershed, with the remaining responses from individuals outside the watershed area but interested in its health. 89% of the responses came from individuals who had attended one or more public roundtables.

The survey included three major questions:

1. Why and how is the Chestnut Creek Watershed important to you?
2. What are your greatest concerns with the Chestnut Creek Watershed?
3. What goals or issues would you like to see addressed by the Chestnut Creek Watershed Based Plan?

Figures 14 to 16 represent the results of these survey questions.

FIGURE 14 – WHY AND HOW CHESTNUT CREEK IS IMPORTANT TO STAKEHOLDERS

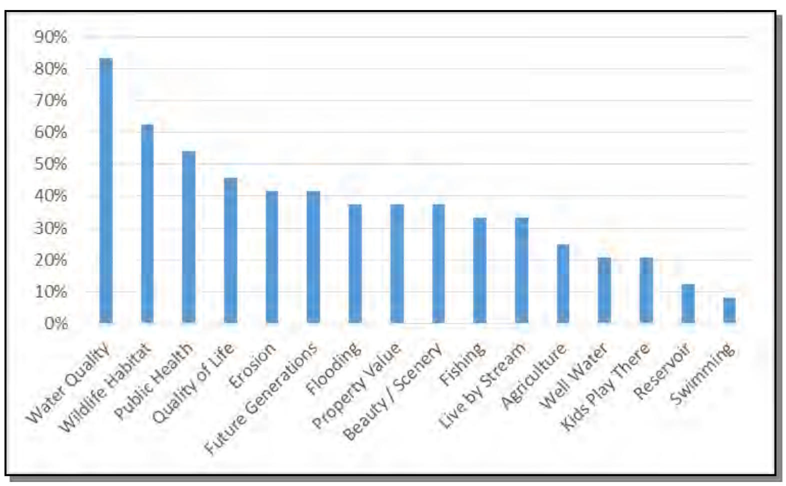


FIGURE 15 – STAKEHOLDERS' GREATEST CONCERNS WITH CHESTNUT CREEK WATERSHED

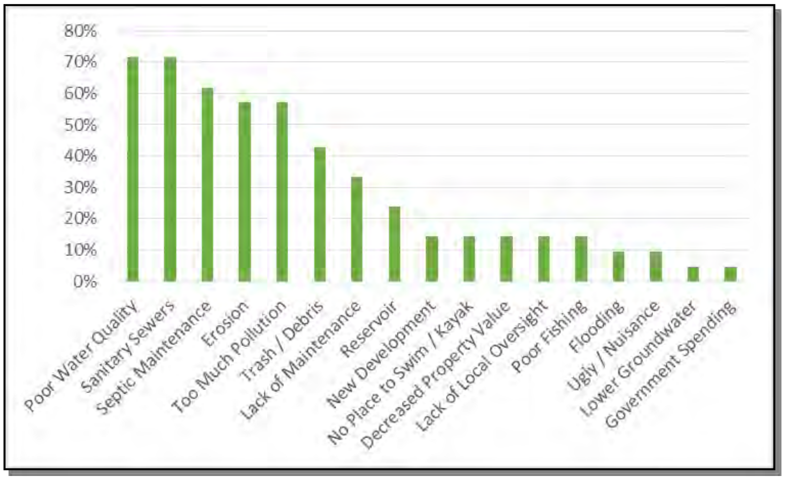
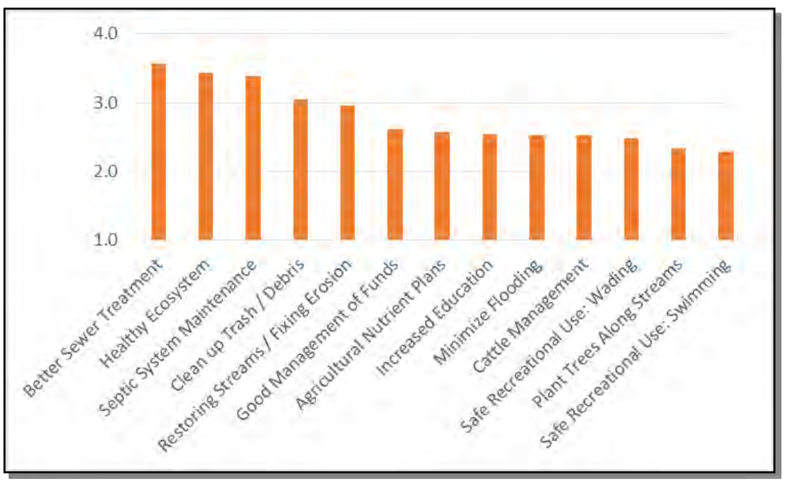


FIGURE 16 – STAKEHOLDER DESIRED GOALS OR ISSUES TO BE ADDRESSED IN WATERSHED BASED PLAN



Based on the survey results and the problems identified in the watershed, the project team drafted a list of goals and objectives and presented it to the community on October 22, 2015. The final goals and objectives were adopted at that roundtable meeting. These goals were also prioritized from greatest to least concern, as follows:

1. Decrease bacteria levels to allow for safe recreational use;
2. Improve the stream habitat to support a healthy aquatic ecosystem;
3. Remove trash and debris clogging waterways;
4. Restore streams to stable, natural channel conditions reducing the rate of flooding, erosion, and sedimentation;
5. Reduce nutrient concentrations (nitrogen and phosphorus) to healthy levels; and
6. Educate the local community about the importance of water resources and how they can help to improve water quality.

For each goal, the pollutant source or cause, measurable indicator of success, and the objectives to be addressed in order to accomplish the goal were identified and summarized in Table 18, page 55. Most of the goals and objectives address impairments and pollutants identified in the watershed. The reduction of bacteria levels in the watershed was considered the greatest priority due to the risk of human illness during recreational use. Measurable indicators of success were selected due to regulatory standards for comparison (such as *E. coli*) or impairments indicated in the watershed monitoring. Other parameters may be utilized, as appropriate, to gage overall success in reducing pollutant loading or linking a loading to a particular source. However, to evaluate overall progress in water quality improvement, the measurable indicators specified should be utilized.

B. BMP Implementation Plan

The watershed goals and objectives were used as a framework to develop a comprehensive BMP Implementation plan with projects and opportunities necessary to restore the designated uses to the watershed and achieve the community goals. The BMP Implementation plan is intended to guide BMP implementation efforts and represent the scope and types of efforts that will be required to meet the watershed goals. As more information is obtained or as individual stakeholders are reached, the approach to obtaining the goals and objectives is expected to change.

The Chestnut Creek Watershed Implementation Plan has been divided into categories based on the BMP type. Within each category, the information necessary for project implementation is summarized, as best as currently possible, including type of BMPs, target audience or area, description of the project including action items, impairment/pollutant addressed, responsible parties including technical assistance, cost estimates, load reductions, funding source(s) or program(s), and milestones.

For the Chestnut Creek Watershed, the implementation plan has been developed primarily at the programmatic level rather than at the site specific level for several reasons. First, much of the pollution loading was attributed to permitted point sources. The amount of reduction which may be achieved by remediation of these sources is difficult to model and cannot be addressed through nonpoint source grant funding. Second, addressing the nonpoint sources of pollution within Chestnut Creek will require outreach to non-traditional customers for BMP implementation through door to door personal visits and other labor intensive efforts to recruit landowners. As such, specification of site specific locations for BMPs at this time is inappropriate.

TABLE 18 – CHESTNUT CREEK WATERSHED PLAN GOALS AND OBJECTIVES

Goal	Source, Cause, Pollutant, or Threat	Measurable Indicator	Objectives
1. Decrease bacteria levels to allow for safe recreational use	• Failing sewer treatment facilities • Septic system failure • Livestock grazing / pasture • Wildlife and other sources • Manuring fields	• *E. coli* • Ammonia	• Exceed *E. coli* instantaneous criteria in less than 20% of samples • Support and petition local efforts to consolidate, remove, or improve sanitary sewer facilities to reduce pollution in facility discharges • Implement a program that encourages landowners to tap on to the improved sanitary sewer facilities where sanitary sewer lines are currently available • Implement a septic system repair program • Implement agricultural best management practices
2. Improve the stream habitat to support a healthy aquatic ecosystem	• Channelization and entrenchment • Low groundwater table, frequently dry streams • Erosion • Unstable gravel bed material • Narrow riparian width	• Macroinvertebrate score • Habitat score • Visual bank measurements	• Restore habitat to the streams including riffles/pools, groundwater berms, and epifaunal substrate • Restore stream attachment with the floodplain and reduce channelization • Stabilize severely eroding stream banks • Improve the quality and width of riparian zones by native plantings and exotic invasive removal
3. Remove trash and debris clogging waterways	• Woody debris / logjams from storm damage and bank failure • Trash and litter	• Number to logjams • Estimated trash / debris removed (in pickup truck loads)	• Document routine locations of trash and debris accumulation • Organize groups to remove trash and debris from watershed on a routine basis • Remove woody debris by chainsaw without disturbing the stream bed material
4. Restore streams to stable, natural channel conditions reducing the rate of flooding, erosion, and sedimentation	• Channelization and entrenchment • Channel alteration including straightening, digging out gravel, riding ATVs in creek, and cattle access. • Increased runoff rate from impervious surfaces	• Length of banks with severe erosion • Impervious acreage removed or infiltrated	• Restore channel dimensions, pattern, and profile • Restore habitat to the streams including riffles/pools, groundwater berms, and epifaunal substrate • Restore stream attachment with the floodplain and reduce channelization • Stabilize severely eroding stream banks • Reduce the runoff rate from impervious surfaces in the watershed through infiltration or storage.
5. Reduce nutrient (nitrogen and phosphorus) to healthy levels	• Failing sewer treatment facilities • Septic system failure • Stream bank erosion • Livestock grazing / pasture • Agricultural nutrient management	• Ammonia • Total nitrogen (TKN, nitrate, nitrite) • Total phosphorus	• Support and petition local efforts to consolidate, remove, or improve sanitary sewer facilities to reduce pollution in facility discharges • Implement a program that encourages landowners to tap on to the improved sanitary sewer facilities where sanitary sewer lines are currently available • Stabilize or restore eroding stream banks • Reduce pollutant levels through stormwater treatment, storage or redirection • Implement a septic system repair program • Implement agricultural best management practices
6. Educate the local community about the importance of water resources and how they can help to improve water quality	• Lack of education • Continuation of practices that cause or facilitate impairment	• Number of interactions • Educational materials distributed	• Increase public knowledge about water quality impairments • Develop targeted educational materials for each problem area • Reach targeted audience about opportunities for implementation on their property • Perform ongoing monitor of stream health conditions

1. General Implementation

Target Audience or Area:	General / Watershed Wide						
Responsible Parties:	FCRNWR with assistance from Basin Coordinator, USFWS, USDA-NRCS, Marshall County Conservation District, Marshall County Health Department, and others.						
Cost Estimate:	$57,000 for part-time coordinator over two years	*Goals Addressed*					
Est. Load Reduction:	N/A	1. Bacteria	2. Habitat	3. Trash / Debris	4. Restore / Stabilize Stream	5. Reduce Nitrogen / Phosphorus	6. Education /
Timeframe:	December 2015 - January 2018						
Description of BMP / Action Items							
1.1. Hire a watershed coordinator. A watershed coordinator is necessary to serve as a central point of contact for the watershed projects. The coordinator will work with local landowners and technical advisors to develop and implement the other BMPs identified in this plan. The coordinator will also be responsible for tracking progress on implementation and scheduling events.		☑	☑	☑	☑	☑	☑
1.2. Develop a local citizen's group. Local residents desired to establish a citizens advocacy group entitled the "Citizens for the Cleanup of Chestnut Creek" (hereafter called "CCC"). This group will coordinate with local residents for events and public action items.		☑	☑	☑	☑	☑	☑

2. *Sanitary Sewer Facilities*

Target Area:	Facilities in Subwatersheds 1 and 3						
Responsible Parties:	FCRNWR, CCC with technical assistance from Basin Coordinator, Marshall County Health Department, and Murray State University and others.						
Cost Estimate:	Activities coordinated through Watershed Coordinator	*Goals Addressed*					
Est. Load Reduction:	Unknown but large portion of *E. coli*, ammonia, nitrogen, and phosphorus	1. Bacteria	2. Habitat	3. Trash / Debris	4. Restore / Stabilize Stream	5. Reduce Nitrogen / Phosphorus	6. Education / Outreach
Timeframe:	Early 2016 for initial efforts to supporting and petition with additional efforts advancing out of feedback.						
Description of BMP / Action Items							
2.1. Reduce pollution in facility discharges - by supporting and petitioning local efforts to consolidate, remove, or improve sanitary sewer facilities		☑				☑	☑
2.2. Commercial Pre-Treatment - NOV reports have indicated that the influent to the MCSD#2 plant is heavily influenced by businesses that may need pre-treatment. Approach businesses to identify potential opportunities for pre-treatment BMPs under future grants.		☑				☑	☑
2.3. Public tour of the wastewater treatment plant facilities - Organized by watershed coordinator with outreach to local community.		☑				☑	☑
2.4. Contact State Representative - MCSD#2 plans to expand to larger area and improve funding of the operation. The project was ranked highest for the Purchase Area Development District for KIA in 2013 but unfunded in 2014. It is eligible again in 2016 but needs legislature support.		☑				☑	☑
2.5. Petition local citizens - Options for the MCSD#2 include expansion or connecting to another local facility for treatment. Public support for these options could be petitioned after getting more detailed information about the options from the district's board.		☑				☑	☑
2.6. Contact Channel 6 - potential story on the creek's current conditions and solutions. Local media attention may aid improvement efforts.		☑				☑	☑

3. *Septic System Repair and Maintenance*

Target Area:	Septic systems within 500 feet of Chestnut Creek or its tributaries within Subwatersheds 1, 2, 3, and 6 primarily; Subwatersheds 4 and 7 secondarily
Responsible Parties:	FCRNWR with technical assistance from Basin Coordinator and Marshall County Health Department.
Cost Estimate:	Program development funded through Watershed Coordinator. Replacement of septic system estimated cost of $4,500 per three bedroom home. Septic system pump-out estimated at $200 per system.
Est. Load Reduction:	Per septic system estimated*1,500 billion CFU/year *E. coli*, 0.088 lbs/year nitrogen
Timeframe:	Initial program development: early 2016. Identify willing participants in 2016-2017. Implementation in 2018-2019.

Description of BMP / Action Items	*Goals Addressed:* 1. Bacteria	2. Habitat	3. Trash / Debris	4. Restore / Stabilize Stream	5. Reduce Nitrogen / Phosphorus	6. Education / Outreach
3.1. Develop Septic System Maintenance Program – The watershed coordinator will work in coordination with the Marshall County Health Department, Basin Coordinator, and FCRNWR project team to develop a program to assist homeowners with failing septic systems in replacing or repairing these systems. To identify issues, homeowners would contact the watershed coordinator or Marshall County Health Department if they suspect their system is failing. The Marshall County Health Department would confirm if there is a system failure and that the home is eligible. A ranking system would be devised to determine the rationale for awarding funding potentially including the severity of the failure based on visual assessment as well as need for financial assistance.	☑				☑	
3.2. Advertise the Program to Landowners – the program is voluntary so requests for participation must be made to local residents in order to identify problems.						☑
3.3. Apply for Subsequent Implementation Grant - Marshall County Health Department to lead in application for funding, most likely through 319(h) grants.	☑				☑	

**Horsely and Whitten's (1996) estimated 1.00E+6 fecal coliform CFU/100mL in septic overcharge was converted to an E. coli concentration using the ratio of the geometric mean standards (200 fecal coliform to 130 E. coli). They also estimated 60 mg/L of total nitrogen in raw sewage with 50% removal in the leach field via denitrification. A septic overcharge of 70 gallons/day/person and average household size of 2.5 were utilized to calculate the rates. These rates are rough estimates since many variables affect the load from a failing system.*

4. Stream and Habitat Improvement

Target Area:	Severe erosion areas throughout watershed.
Responsible Parties:	FCRNWR with technical assistance from the district conservationist for USDA-NRCS, the private lands biologist from the US Fish and Wildlife Service Partners for Fish and Wildlife Program, and the Basin Coordinator.
Cost Estimate:	Dependent on practice. Estimated $53,000 for five projects during initial phase.
Est. Load Reduction:	Dependent upon the severe erosion area and current erosion rates of stream reach. Sediment, phosphorus, nitrogen may be reduced.
Timeframe:	Program development in early 2016. Identify willing participants in 2016-2017. Initial Implementation in 2016-2017.

Description of BMP / Action Items	*Goals Addressed*: 1. Bacteria	2. Habitat	3. Trash / Debris	4. Restore / Stabilize Stream	5. Reduce Nitrogen / Phosphorus	6. Education / Outreach
4.1. Develop Stream Restoration / Stabilization Implementation Program – The watershed coordinator will work in coordination with the district conservationist for USDA-NRCS, the private lands biologist from the US Fish and Wildlife Service Partners for Fish and Wildlife Program, the Basin Coordinator, and FCRNWR project team to develop a ranking system that identifies the types of BMPs that will be funded and the rational for targeting these BMPs. The ranking system will use weight based on the degree of restoration with natural channel stream restoration weighting higher than bank stabilization or headcut stabilization. The ranking system will also address whether the area is a severe erosion area, the area to be addressed, and other factors.		☑		☑	☑	
4.2. Advertise the Program to Landowners – Recruit "non-traditional" and traditional landowners to participate in the stream restoration / stabilization implementation program. Outreach efforts will include mailings, phone communication and door to door visits to reach these landowners.						☑
4.3. Conduct a Field Day on Existing Project – An example project was installed in Subwatershed 8 in 2015. Organizing and conducting a field day to show the results of this project may be used to encourage landowner participation.						☑
4.4. Implement Stream Restoration / Stabilization BMPs - Installation of five stream restoration / stabilization BMPs by 2017 as an initial effort. Additional implementation activities to be pursued based upon the successfulness of these projects.		☑		☑	☑	
4.5. Conservation Easements of Forested Riparian Zones – Work with landowners to put conservation easements in place, where possible, to protect forested riparian zones		☑		☑	☑	
4.6. Riparian Zone Education – Educate landowners on the benefits and function of forested riparian zones.						☑

5. *Trash and Debris BMPs*

<table>
<tr><td colspan="2">Target Area:</td><td colspan="6">Trash and debris blockages on Chestnut Creek and tributaries</td></tr>
<tr><td colspan="2">Responsible Parties:</td><td colspan="6">FCRNWR and CCC with technical assistance from FCRNWR project team</td></tr>
<tr><td colspan="2">Cost Estimate:</td><td>Minimal costs for trash bags and gloves for small trash and debris. Chainsaws or larger equipment may be necessary in some locations</td><td colspan="6">Goals Addressed:</td></tr>
<tr><td colspan="2">Est. Load Reduction:</td><td>N/A, Addressed flooding and erosion</td><td rowspan="3">1. Bacteria</td><td rowspan="3">2. Habitat</td><td rowspan="3">3. Trash / Debris</td><td rowspan="3">4. Restore / Stabilize Stream</td><td rowspan="3">5. Reduce Nitrogen / Phosphorus</td><td rowspan="3">6. Education / Outreach</td></tr>
<tr><td colspan="2">Timeframe:</td><td>Initial program development in early 2016. Identify willing participants in 2016-2017. Implementation in 2016-2017.</td></tr>
<tr><td colspan="3">Description of BMP / Action Items</td></tr>
<tr><td colspan="3">5.1. Develop List of Locations with Blockages and in Need of Cleanup – The watershed coordinator should work with landowners to develop a list of addresses and a map indicating landowners with large trash and debris accumulations in need of removal. The amount of trash and debris at each location should be visually assessed and the number of “pickup trucks” worth of trash and debris listed. The need for chainsaws or heavy equipment should also be evaluated at these sites. Liability waiver forms may be necessary in some instances.</td><td></td><td></td><td>☑</td><td></td><td></td><td>☑</td></tr>
<tr><td colspan="3">5.2. Develop List of Groups Willing to Help and Time Frames – The watershed coordinator should approach church groups, boy scouts, high school student groups, church youth groups, Future Farmers of America, Murray State University Center for Student Involvement, and other volunteer groups in the area about debris removal from streams. Students may have community service requirements that could be fulfilled through debris removal litter cleanup. Neighbors interested in assistance on their property may also be willing to assist on other properties.</td><td></td><td></td><td>☑</td><td></td><td></td><td>☑</td></tr>
<tr><td colspan="3">5.3. Develop a Schedule for Trash and Debris Removal – The watershed coordinator shall work with the list of locations and the groups willing to participate to organize and schedule cleanup events and determine how materials will be disposed. Local businesses may be willing to sponsor cleanup events and pay for supplies / refreshments in return for publication in local media. Each event should be coordinated so that appropriate equipment is available for the site conditions.</td><td></td><td></td><td>☑</td><td></td><td></td><td>☑</td></tr>
<tr><td colspan="3">5.4. Remove Debris and Track Results – Events should be documented by pictures and the amount of “pickups trucks” of material removed. Removal of woody debris from streams shall be supervised by ecologists or water quality professionals to ensure that stream bed material is not disturbed. Large debris may be used for stabilization in other areas if feasible or appropriate.</td><td></td><td></td><td>☑</td><td></td><td></td><td>☑</td></tr>
</table>

6. *Agricultural BMPs*

		1. Bacteria	2. Habitat	3. Trash / Debris	4. Restore / Stabilize Stream	5. Reduce Nitrogen / Phosphorus	6. Education /
Target Area:	Severe erosion areas throughout watershed. Agricultural areas in Subwatersheds 1, 3, and 6 primarily; Subwatersheds 2, 4 and 7 secondarily.						
Responsible Parties:	FCRNWR with technical assistance from district conservationists for USDA-NRCS and the Marshall County Conservation District and the Basin Coordinator.						
Cost Estimate:	Dependent on practice. Estimated $53,000 for five projects during initial phase.	*Goals Addressed:*					
Est. Load Reduction:	Dependent on practice						
Timeframe:	Program development in early 2016. Identify willing participants in 2016-2017. Initial Implementation in 2016-2017.						
Description of BMP / Action Items							
6.1. Identify Cattle Access Areas – Cattle access to streams can affect fecal input, bank erosion, and nutrient pollution. Therefore these areas are considered priority areas for BMP implementation. Areas should be identified by talking to individual land owners and aerial photography.		☑			☑	☑	
6.2. Develop Agricultural BMP Implementation Program – The watershed coordinator will work in coordination with the district conservationists for USDA-NRCS and the Marshall County Conservation District, Basin Coordinator, and FCRNWR project team to develop a ranking system and survey form that identifies the types of BMPs that will be funded and the rational for targeting these BMPs. The ranking system will use potential reductions to pollutants with sediment reduction weighted the highest as well as *E. coli* and nutrients. The survey form would allow for the proper information to be collected in the field for office scoring. Potential BMPs may include streambank stabilization, fencing livestock out of streams and providing alternate watering sources, cover crops, grassed waterways, grade stabilization structures, erosion control practices, pasture renovation practices, timber stand improvement, and other appropriate agricultural BMPs that will address the watershed impairments.		☑			☑	☑	
6.3. Advertise the Program to Landowners – Recruit "non-traditional" and traditional landowners to participate in the agriculture implementation program. Outreach efforts will include mailings, phone communication and door to door visits to reach these landowners.							☑
6.4. Implement Agricultural BMPs - Installation of five agricultural BMPs by 2017 as an initial effort. Additional implementation activities to be pursued based upon the successfulness of these projects.		☑			☑	☑	
6.5. Agricultural Nutrient Management Plans – Assist farmers with development of agricultural nutrient management plans.						☑	

7. *Education & Outreach*

Target Area:	Chestnut Creek Watershed Landowners and Business Owners						
Responsible Parties:	FCRNWR with technical assistance from FCRNWR project team and volunteers						
Cost Estimate:	$90,000 for two years of intensive outreach	*Goals Addressed:*					
Est. Load Reduction:	N/A	1. Bacteria	2. Habitat	3. Trash / Debris	4. Restore / Stabilize Stream	5. Reduce Nitrogen / Phosphorus	6. Education /
Timeframe:	Initial education and outreach efforts in 2016-2017. Re-evaluate after initial period						
Description of BMP / Action Items							
7.1. Develop Education Materials – Develop or compile educational brochures, flyers, and other media on water quality problems and solutions for distribution to public at community roundtables, events, field days, and targeted workshops. Example materials may include summaries of the watershed issues, detailed information about specific land uses and their effect on water systems, environmental tips or factoids that can be published by local papers, and factsheets on the benefits of BMPs such as rain barrels, rainwater cisterns, or rain gardens that can be installed on properties.							☑
7.2. Connect to Nature Program –Conduct the Connect to Nature program with local schools in 2016 and 2017. This program works with local teachers demonstrating how to use the outdoors as an extension of the classroom and help students build a lifelong bond with nature.							☑
7.3. Monitoring Avian Productivity and Survivorship (MAPS) Program – Implement the Monitoring Avian Productivity and Survivorship (MAPS) program in the summer of 2016 and 2017. This program assists in the conservation of birds and their habitats through demographic monitoring.							☑
7.4. Project Learning Tree Green Schools Educator Workshop – Work with Marshall County Schools to host Project Learning Tree Green Schools Educator Workshop. The program inspires students to take personal responsibility for improving the environment at their school, at home, and in their community. Students, teachers, and school staff members receive tools, training, and resources for student-led Green Teams to create healthier schools.							☑
7.5. Marshall County School Green Infrastructure Feasibility Study – Work with the Marshall County School System to start to build capacity for green infrastructure projects on the property. The school property is about 100 acres much of which is paved. A severe erosion area is located on the approximately 1500 feet of stream located on the school property. High velocity runoff in the stream moved a bridge on the property downstream in recent years. A green infrastructure feasibility study should be conducted to evaluate stormwater BMPs that may be implemented on the site. The range of practices to be evaluated includes rainwater cisterns, rain gardens, bio-retention, pervious pavement, riparian plantings, outdoor classrooms,							☑

stream restoration, and other BMPs to infiltrate or store stormwater runoff and improve stream habitat. These options would be presented to the school and project team for the selection of desired BMPs to be implemented.						
7.6. Annual Litter Pick-up Events – Organize annual litter pick up events (2017, 2018) where members of the local community can improve the watershed by removing litter.						☑
7.7. Community Roundtable Meetings – Conduct biannual community roundtable meetings, allowing members of the community to express their concerns and ask questions about water quality issues and environmental issues are discussed in more detail with guest speakers.						☑
7.8. Family Outdoors Night at Clarks River National Wildlife Refuge – Family Outdoors Night at Clarks River National Wildlife Refuge is held every September at the Environmental Education and Recreation Area, which has a handicapped accessible fishing pond. It is an opportunity for the entire community to learn about fish, habitat, and watershed health and to enjoy quality time together in the outdoors. Fishing poles and bait are provided by the refuge, and participants bring their own lawn chairs and coolers.						☑
7.9. Publicity Through Local Media – The project team will work with local media outlets to announce upcoming events, roundtables, and educational sessions. Local media will also be utilized to update the community on the progress of the project. These media outlets will include local newspapers and local radio stations. In addition, flyers promoting events will be placed at locations visible to the community. Events, meetings, and roundtables will also be advertised on the FCRNWR's Facebook page helping the project better reach the younger members of the community who are most likely to see advertisements on the internet and various social networks.						☑
7.10. Technical Advisory Meetings – Local technical advisors will participate on the watershed team that will meet quarterly to discuss the status of the project and offer support to the watershed coordinator.						☑
7.11. Runoff Re-Direction – Contact owners of businesses with large impervious areas to discuss opportunities to infiltrate and capture stormwater through rain gardens or other methods.						☑
7.12. Webpage Development – Develop a webpage for watershed information / plan, upcoming events and dates.						☑
7.13. Recruitment – Develop and implement methods to recruit new members to the FCRNWR and CCC and encourage volunteers. New volunteers should also be enrolled in the Four Rivers Watershed Watch Program, educating these members about the importance of water quality by getting them involved in water quality monitoring activities.						☑

7.14. Volunteer Monitoring – Volunteers should be engaged in the Four Rivers Watershed Watch Program and investigate the sources of *E.coli* in watersheds identified as impaired. Monitoring should be conducted downstream of permitted sewer treatment facilities to evaluate improvements from these sources. Additionally the "hands-on" experience will help local residence become better acquainted with problems in the area.						☑

8. Landowner Sanitary Sewer Facility Tap on Program

<table>
<tr><td>Target Area:</td><td colspan="7">Landowners is subwatershed 3 that have existing sewer lines near their residence that could have septic system decommissioned and lateral lines installed to connect residence to properly functioning sanitary sewer facility</td></tr>
<tr><td>Responsible Parties:</td><td colspan="7">Marshall County Fiscal Court</td></tr>
<tr><td>Cost Estimate:</td><td>Average cost of $3,500 per household to install lateral lines and pay tap on fee to sanitary sewer facility</td><td colspan="6">Goals Addressed:</td></tr>
<tr><td>Est. Load Reduction:</td><td>Per septic system removed from watershed, estimated*1,500 billion CFU/year E. coli, 0.088 lbs/year nitrogen</td><td rowspan="3">1. Bacteria</td><td rowspan="3">2. Habitat</td><td rowspan="3">3. Trash / Debris</td><td rowspan="3">4. Restore / Stabilize Stream</td><td rowspan="3">5. Reduce Nitrogen / Phosphorus</td><td rowspan="3">6. Education / Outreach</td></tr>
<tr><td>Timeframe:</td><td>Initial planning in late 2016, on the ground work in 2017 and 2018</td></tr>
<tr><td colspan="2">Description of BMP / Action Items</td></tr>
<tr><td colspan="2">8.1. Initial Planning – with assistance from Marshall County Sanitation District #2 and Marshall County Health Department, Marshall County Fiscal Court will work to identify the number of houses that currently have a septic system but have sanitary sewer lines available that these residences could tap on to, reducing nonpoint source pollution from these residences when their septic system fails due to poor soil suitability in the watershed for septic systems. The watershed coordinator will work with partners to come up with a plan of action that outlines how many residences have sanitary sewer service available to them that are not utilizing it and an estimate of the approximate cost per residence to tap on to the sanitary sewer system (including tap on fees and lateral line costs). This plan will be presented to the Marshall County Fiscal Court for approval.</td><td>☑</td><td></td><td></td><td></td><td>☑</td><td></td></tr>
<tr><td colspan="2">8.2. Development of Program – upon approval of the initial plan by the Marshall County Fiscal Court, the watershed coordinator will work in coordination with the Marshall County Health Department, Basin Coordinator, Marshall County Sanitation District #2, Marshall County Fiscal Court, and FCRNWR project team to develop a program to connect residences that have sanitary sewer lines available to them to the Marshall County Sanitation District #2, once this facility has been improved and is functioning properly. Details of this program will be incorporated into the existing BMP Implementation Plan. Due to the nature of the soil in this area, even if these septic systems are not currently failing, they are likely to fail at some point in the future, and hooking these residences up to a sanitary sewer facility will prevent nonpoint source pollution in this watershed in the future. Marshall County Fiscal Court will identify specific residences that could tap on to the sanitary sewer system, and make direct contact with these landowners, offering assistance to these landowners with costs associated with tap on to the sanitary sewer system, including tap on fees and lateral line installation costs. Upon completion of this work, staff from Marshall County Sanitation District #2 will inspect work to ensure that it has been completed properly and meets all necessary</td><td>☑</td><td></td><td></td><td></td><td>☑</td><td></td></tr>
</table>

codes. The Marshall County Fiscal Court will work with the Marshall County Health Department to come up with a set of guidelines that must be followed to decommission existing septic systems at these residences. This work will be inspected by the Marshall County Health Department to ensure it is done properly. The Marshall County Fiscal Court will contact all landowners with the potential to tap on to existing sewer lines, but a ranking system will be devised that targets funding first to residences with known failing septic systems.						
8.3. Apply for Implementation Grant - Marshall County Fiscal Court to lead in application for funding, most likely through 319(h) grants.	☑				☑	
8.4. Advertise the Program to Landowners – the Marshall County Fiscal Court will make direct contact with all landowners with the potential to tap on to existing sewer lines.						☑
8.5 Enrollment of Landowners in the Program – Marshall County Fiscal Court will enroll landowners in the program and, with assistance from Marshall County Sanitation District #2 and Marshall County Health Department, conduct activities associated with the program.	☑				☑	☑

C. Funding Sources

Funding for projects listed in the BMP implementation plan may come from a variety of sources to help the property owners or responsible parties to implement the BMPs. Several known funding sources for individual project types are listed in the implementation plan. The grant opportunities are described in more detail in the following sections in order to aid interested applicants.

1. US EPA 319(h) Grants

The US EPA provides funding through Section 319(h) of the Clean Water Act to the Kentucky Nonpoint Source (NPS) Pollution Control Program. These funds can be used to pay for 60 percent of the total cost for qualifying projects, but require a 40 percent nonfederal match. Grants are available for watershed based implementation, and priority consideration will be given to projects for which implement a watershed based plan, such as this one. Project proposal forms may be submitted to the Kentucky NPS Pollution Control Program at any time; however, deadlines apply to specific federal funding cycles. For more information on this grant program, see Kentucky Division of Water website: http://water.ky.gov.

2. FEMA Hazard Mitigation Grant

FEMA's Hazard Mitigation Assistance grant programs provide funding for eligible mitigation activities that reduce disaster losses and protect life and property from future disaster damages including the Hazard Mitigation Grant Program, Pre-Disaster Mitigation, Flood Mitigation Assistance, Repetitive Flood Claims, and Severe Repetitive Loss. If a project will reduce or eliminate the risk of flood damage to the population or structures insured under the National Flood Insurance Program, it may be eligible for funding under one of these programs. For additional details on eligibility requirements and grant details, visit the FEMA website: http://www.fema.gov.

3. Kentucky Department of Fish and Wildlife's Stream Team Program

The Stream Team offers landowners free repairs to eroding and unstable streams and wetlands. Their task is to identify and undertake stream restoration projects statewide. The Stream Team, which includes stream restoration specialists in the Kentucky Department of Fish and Wildlife Resources (KDFWR), works with private landowners and others to identify stream restoration projects. Projects are funded from the Mitigation Fund held in trust solely for repairing streams and wetlands. No state tax general funds or hunting/fishing license dollars are used.

Landowners must meet certain criteria to qualify including a minimum of 1,000 feet of stream with unstable, eroding banks and agreement to a permanent easement typically at least 50 feet wide on each side of the restored stream. In general, both sides of the stream must be available for work, and often several landowners may be involved to provide access to both banks and appropriate protection. Typical projects are on small streams ranging in size from the smallest that may go dry in late summer downstream to those that have permanent flow. Landowner considerations may be and often are included with the projects to meet the needs of property owners. These often include the construction of fords across the stream, fencing, and access to water for livestock. More information about this program is available at http://fw.ky.gov/Fish/Pages/Stream-Team-Program.aspx.

4. Partners for Fish and Wildlife Program

The Partners for Fish & Wildlife program works with private landowners to improve fish and wildlife habitat on their lands. They are leaders in voluntary, community-based stewardship for fish and wildlife conservation. The future of the nation's fish and wildlife depends on private landowners – more than 90% of land in Kentucky is in private ownership. Providing more high quality habitat not only helps wildlife - by contributing to a healthy landscape, you create a conservation legacy to pass on to future generations.

To accomplish this work, the Partners for Fish & Wildlife team up with private conservation organizations, state and federal agencies and tribes. Together, with the landowner, this collective shares funding, materials, equipment, labor and expertise to meet both the landowner's restoration goals and their conservation mission.

5. *USDA-NRCS EQIP Program*

The Environmental Quality Incentive Program (EQIP) provides financial and technical assistance to agricultural producers in order to address natural resource concerns and deliver environmental benefits such as improved water and air quality, conserved ground and surface water, reduced soil erosion and sedimentation or improved or created wildlife habitat. Eligible program participants that rank well can receive financial and technical assistance to implement conservation practices that address natural resource concerns on their land. Visit your local USDA Service Center to apply or visit www.nrcs.usda.gov/getstarted.

6. *State Cost Share*

The Kentucky Soil Erosion and Water Quality Cost Share Program and the Kentucky Soil Stewardship Program were created to help agricultural operations protect the soil and water resources of Kentucky and to implement their agriculture water quality plans. The program helps landowners address existing soil erosion, water quality and other environmental problems associated with their farming or woodland operation.

The 1994 Kentucky General Assembly established this financial and technical assistance program. Kentucky Revised Statute 146.115 establishes that funds be administered by local conservation districts and the Kentucky Soil and Water Conservation Commission with priority given to animal waste-related problems, agricultural district participants and to producers who have their Agriculture Water Quality plans on file with their local conservation districts. Funding comes from the Kentucky General Assembly through direct appropriations to the program from the Tobacco Settlement Funds and from funds provided by the Kentucky Department of Agriculture.

Practices eligible for cost share are agriculture and animal waste control facilities; streambank stabilization; animal waste utilization; vegetative filter strips; integrated crop management; pesticide containment; sinkhole protection; pasture and hay land forage quality; heavy use area protection; rotational grazing system establishment; water well protection; forest land and cropland erosion control systems; closure of agriculture waste impoundment; on-farm fallen animal composting; soil health management; precision nutrient management; strip intercropping system; livestock stream crossing and riparian area protection.

CHAPTER VI. IMPLEMENTATION OVERSIGHT AND SUCCESS MONITORING

The implementation plan for the Chestnut Creek Watershed has numerous best management practices, responsible parties, timelines, objectives, and goals. Key to ensuring that the watershed goals are achieved is monitoring of the implementation activities and their success. This section describes how the plan implementation will be evaluated.

A. Organization

With the completion of this watershed based plan, the focus transitions from planning to implementation. Progress on the plan goals, objectives, and action items will need to be coordinated and monitored in order to ensure that the implementation moves according to schedule and achieves the expected level of success. The transition in focus must also be accompanied by a transition in organization.

1. Watershed Coordinator

The Watershed Coordinator would provide a central contact for the watershed implementation. The responsibilities of this position would include coordination amongst various responsible parties, funding sources, stakeholders, partners, and technical resources, as well as tracking progress of implementation projects and scheduling team meetings. It is recommended that this position be funded, at least in part, through program grants. The Watershed Coordinator would follow the implementation plan to ensure responsible parties remain on schedule and progress on implementation is occurring. The Watershed Coordinator should use adaptive management as the watershed and desires of the stakeholders change.

2. Friends of Clarks River National Wildlife Refuge Implementation Team

The Implementation Team would be comprised of technical advisors, key stakeholders, Friends of Clarks River National Wildlife Refuge representatives, and representatives of the Citizens for the Cleanup of Chestnut Creek. This group is responsible to meet quarterly at a minimum to present and track progress on various BMPs; discuss implementation successes, failures, and additional needs; to address new opportunities, and to delegate work where needed. This group will be similar as the group that helped to develop the plan, but its focus will shift to implementation.

3. Community Roundtables

The community roundtables will be held to present progress on the watershed based plan goals and objectives and to receive feedback from the community about emerging opportunities and issues for adaptive management. All local citizens and stakeholders are invited to participate in such events.

B. Presentation and Outreach

Presentation of this watershed based plan to the general public is a key part of education and outreach. For many of the BMPs, milestones were less concrete because landowner support for implementation had not been evaluated. This plan organizes initial implementation and outreach efforts in order to evaluate the support for participation, and then refocus milestones and priorities based upon the response.

A Fact Sheet has been developed which condenses the findings of the plan for consumption by local leaders and important audiences. Additionally slideshow presentations of the plan findings will allow for outreach to local groups and meetings.

This plan will be made available to the public by making hard copies available at the Marshall County Public Library, the Marshall County Fiscal Court, and with the Watershed Coordinator. Additionally electronic copies of the plan shall be provided upon request to interested parties.

C. Monitoring Success

Success of the Watershed Plan should be monitored in terms of implementation progress, education and behavior change, as well as water quality sampling results. Review of these success indicators will allow the Implementation Team to evaluate whether changes in the implementation strategy or planning are necessary.

1. *Implementation Tracking*

One measures of success is the evaluation of whether the implementation plan is actually being carried out. As such, the Implementation Team should document progress on each of the BMPs over time. Tracking should include responses from responsible parties, funding updates, design and construction updates, impediments, and pending responses. In addition to tracking the status of the individual BMPs, specific measurable indicators of success should be tracked for each BMP. For instance, the number of outreach events should be recorded as well as the number of rain barrels installed and the length of stream stabilized. The latitude and longitude of each of the implemented BMPs should also be documented in order to aid future success monitoring.

2. *Education and Outreach Tracking*

For education and outreach activities, where appropriate pre- and post-educational surveys should be utilized to document changes in perceptions and behaviors as a result of educational activities. These surveys may be used to refine and improve training workshops and outreach events based on the aspects of the programs view as most valuable. These activities should also be evaluated as to whether they are utilizing the most appropriate venues and addressing the desired audiences to accomplish the plan goals.

3. *Water Quality Monitoring*

Water quality monitoring should be performed, using the parameters listed in Table 18 with the goals and objectives, in order to measure the progress made towards the watershed plan goals. The primary source of additional monitoring will be through the Four Rivers Watershed Watch. Monitoring should be conducted to investigate the sources of *E.coli* in watersheds identified as impaired, monitor downstream of permitted sewer treatment facilities to confirm output levels, and at the sites monitored under this plan to review improvements due to implementation. Also when construction projects are funded through a grant, pre- and post-construction sampling should be conducted in order to evaluate the load reduced by the project, where feasible and appropriate.

D. Evaluating and Updating the Plan

The goals, objectives, and recommended BMPs were based upon the best available information and projected needs of the community at the time of this plan development. With time, the watershed changes as well as the people within it and their desires. The impacts to the watershed can also change with time and as new monitoring data is collected. Therefore, the Watershed Plan must have the flexibility to change with time.

As mentioned previously, some development of additional implementation plans will be needed after the first two years of implementation due to the need for focused outreach efforts to landowners for participation. Once these landowners have been contacted to determine their support, the milestones and implementation schedules for individual BMPs should be clarified and this document revised.

It is recommended that the Implementation Team update the plan on a five year basis thereafter, and consider significant changes in approaches on an annual basis. The five year evaluation allows sufficient time for improvements to occur between evaluation periods. Annual evaluations of changes in approach allow for sufficient flexibility to adjust to changes as they occur.

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APPENDICES

APPENDIX A – QUALITY ASSURANCE PROJECT PLANS

APPENDIX B – VISUAL STREAM ASSESSMENTS

APPENDIX C – HABITAT AND MACROINVERTEBRATE ASSESSMENT REPORT

APPENDIX D – WATER QUALITY REPORT AND QA REPORT

APPENDIX E – BACTERIAL SOURCE TRACKING REPORT

APPENDIX F – CLARKS RIVER NATIONAL WILDLIFE REFUGE BIOTA LIST (APPENDIX J FROM COMPREHENSIVE CONSERVATION PLAN REPORT)

APPENDIX G – CHESTNUT CREEK WATERSHED PLAN BENCHMARK RECOMMENDATIONS FROM KENTUCKY DIVISION OF WATER

Quality Assurance Project Plan

Chestnut Creek WBP

Grant Number: C-9994861-09

Prepared By: Third Rock Consultants
2526 Regency Road Suite 180
Lexington, KY 40503

Prepared For: Kentucky Division of Water
200 Fair Oaks Lane Frankfort, KY 40601

Date: June 2013

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SECTION A – PROJECT MANAGEMENT

A1. Title and Approval Sheet

Quality Assurance Project Plan
For Chestnut Creek WBP

June 12, 2013

Steve Evans / QAPP Author and Biological Data Manager	Date
Stacey Hayden / Sampling Manager	Date
Maggie Morgan / Data Manager	Date
Jim Roe / NPS Supervisor, Kentucky Division of Water	Date
Lisa A. Hicks / Quality Assurance Officer, Kentucky Division of Water	Date
Larry Taylor / Quality Assurance Manager, Kentucky Department for Environmental Protection	Date

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Revision History

This page documents the revisions over time to this document. The most recent iteration should be listed in the first space, with consecutive versions following. Signatures may be required for revised documents.

Date of Revision	Page(s)/Section(s) Revised	Revision Explanation
June 12, 2013	Title, 8, 11, 21, 25, 37, 48	Addressing comments from KDOW, grant number, Division of Conservation contact info, adding field filtering for orthophosphate, and adding of Microbac Paducah Office.

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A3. Distribution List

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A4. Project / Task Organization

Figure 1 outlines the relationship between project partners and staff. Roles of specific individuals have been discussed in more detail below:

Jim Roe, Kentucky Division of Water Nonpoint Source Section Supervisor will provide project oversight for the Kentucky Division of Water.

Angie Wingfield, Kentucky Division of Conservation Project Manager will be the responsible official for this project, overseeing overall project operations and budget, as well as tasking contractors with work required to complete this project. She will communicate project needs to the contractor's sampling manager, Stacey Hayden.

Lisa Hicks, Kentucky Division of Water QA Manager will be responsible for reviewing and approving the QA Project Plan. She may provide technical input on proposed sampling design, analytical methodologies, and data review.

Stacey Hayden, Sampling Manager will have overall responsibility for assigning appropriate personnel to complete the water quality sampling tasks included in this plan. She will ensure that the project budget is adhered to. She will communicate with the Division of Conservation Project Manager on work accomplished in this plan and any problems or deviations that need to be resolved. Prior to the first sampling event, the Sampling Manager will coordinate with the Data Manager, and Laboratory Lead to review field and laboratory roles and responsibilities, sampling and field requirements, analytical requirements, sampling schedule, sampling logistics, including delivery to the laboratory, and requirements for field and laboratory documentation.

Steve Evans, Watershed Based Plan and QAPP Author and Biological Data Manager will review data generated for the project, and will assist with preparation of QA reports as required by the project. As the Biological Data Manager, he will have overall responsibility for assigning appropriate personnel to complete the biological monitoring and visual assessments described in this plan. He will ensure that these budgets are adhered to. He will communicate with the Division of Conservation Project Manager on work accomplished in this plan and any problems or deviations that need to be resolved. As watershed based plan author, he will work the project team to develop a watershed plan specific to the Chestnut Creek watershed. He will also be responsible for ensuring that the latest version of the QA Project Plan is distributed to project partners.

Bert Remley, Macroinvertebrate Laboratory Chief Taxonomist will be responsible for overseeing and conducting field biological sampling and data review, proper laboratory identification of macroinvertebrate samples and oversee macroinvertebrate quality assurance.

Jane Benson, MSU Mid America Remote Sensing Center will assist with collection and analysis of GIS data for the project. She will also assist with the development of digital map layers for the project.

Mike Kemp, Load Modeler will perform the load calculations for watershed. He will review all project data and determine whether it is sufficient for calculation purposes.

Maggie Morgan, Data Manager will provide technical support for the project. The Data Manager will also be responsible for obtaining lab documentation, data management, and submission to the sampling manager. The Data Manager will also assist with preparation of QA reports as required by the project.

Karla Johnston, Laboratory Lead will be responsible for assigning appropriate laboratory staff at Hancock Biological Station to perform the analyses specified in this plan, and ensuring that appropriate laboratory QA/QC protocol is followed.

Michael Flournoy and David Lester, Laboratory Lead will be responsible for assigning appropriate laboratory staff at Microbac Laboratories to perform the analyses specified in this plan, and ensuring that appropriate laboratory QA/QC protocol is followed.

Other Project Partners will include USDA-NRCS, Marshall County Fiscal Court, Marshall County Health Department, Marshall County Sanitation District #2, USFWS Clarks River National Wildlife Refuge, FLW Outdoors, and the Four Rivers Basin Team. These partners will provide support during the watershed plan development phase, including education and outreach and promotion of the watershed plan.

A5. Project Definition / Background

The *Clarks River Watershed Based Plan* (Strand Associates, Inc., 2009), provisionally accepted by the Kentucky Division of Water in March of 2010, identified pollutants of concern in the Clarks River watershed, sources of these pollutants, and potential best management practices (BMPs) that could be implemented to address these pollutants of concern. Four pollutants of concern were identified for the Clarks River watershed through analysis of all compiled data, including *E. coli*, nutrients, total suspended solids, and water temperature. Potential sources of these pollutants include agriculture, failing septic systems, eroding stream banks, municipal point source discharges, urban runoff, and construction.

Funding for a subsequent grant, C9994861-07, was used to conduct monitoring in Chestnut Creek, one of the focus areas, for the purpose of developing the watershed based plan. However due to drought conditions, the planned monitoring could not be completed due to dry streams. Only 5 to 11 of the planned monitoring events were collected at each of the eight monitoring sites. Also, the microbial source tracking samples were not collected nor were 5 samples collected within 30 days for the *E. coli* monitoring. Planned habitat and macroinvertebrate monitoring was also not conducted. The purpose of the monitoring project under this grant (C-9994861-09) is to complete the monitoring tasks such that the load determinations can be computed for the watershed based plan.

Chestnut Creek Background Information

Chestnut Creek flows for approximately five miles in Marshall County, Kentucky before dumping into the Clarks River on the Clarks River National Wildlife Refuge. Chestnut Creek is categorized as an impaired stream in the *Integrated Report to Congress on the Condition of Water Resources in Kentucky, 2010* (Kentucky Division of Water, 2010) for partial support of both the aquatic life and primary contact recreation uses. Sources were listed as unknown. The drainage area for Chestnut Creek is approximately eight square miles and includes more urban areas in the eastern portions of the watershed, forested areas in the central portion of the watershed, and agricultural areas throughout the entire watershed (Figure 2). Development is occurring in the more urban portions of the watershed around the Draffenville area, including many new residential subdivisions. Many of the forested areas in the watershed are located along some of the smaller tributaries flowing into Chestnut Creek. Agriculture, including crop fields and pasture for cattle, are distributed throughout the entire drainage area.

The Chestnut Creek watershed has one small sanitation district, Marshall County Sanitation District #2, which serves only portions of the watershed south of the Purchase Parkway. This sanitation district is interested in expanding their sewer lines to accommodate new customers south of the Purchase Parkway along US Highway 641, and is in the process of seeking low interest loans for this expansion. North of the Purchase Parkway, residences in the watershed should have on-site waste disposal systems. Residences along Griggstown Road and Oak Valley Road tend to be older and could have some issues with failing on-site waste disposal systems. There are three mobile home parks in the watershed, two of which have a lagoon system for waste treatment and one with a package treatment plant. There are two package treatment plants associated with the Marshall County Board of Education, one for Marshall County High School (approximately 1,500 students) and one for the board office.

Three sites in the Chestnut Creek watershed were sampled by Murray State University in 2005 as part of a TMDL study funded by the Kentucky Division of Water, but overall data collection in the watershed has been extremely limited. Data collected by Murray State University included *E. coli*, turbidity, pH, dissolved oxygen, and conductivity. *E. coli* concentrations at the downstream site (labeled 17 on Figure 2) exceeded the water quality standard approximately 80% of the time (Hendricks, personal communication). *E. coli* concentrations were also high at site 16, exceeding the water quality standard 50% of the time. Each site, 15, 16 and 17, had at least one event where the turbidity concentration was high and not correlated with a high flow event. Dissolved oxygen concentrations were also low at sites 16 and 17.

A6. Project/Task Description

Environmental monitoring work for this project will be conducted in the Chestnut Creek watershed in Marshall County, Kentucky (Figure 2). The monitoring tasks associated with this task fall under three headings: water quality monitoring, biological monitoring, and visual assessments. Table 2 describes all data to be collected throughout the course of this study, the proposed monitoring schedule, and the collection and analytical methodologies to be used.

Water Quality Monitoring

Data will be collected from a total of eight sites (Table 1, Figure 3). All samples collected will be grab samples from a depth of approximately four inches below the surface, if possible depending on flow levels. The substrate of the stream upstream of the sampling location shall not be disturbed during field collection. Quality assurance samples, including blanks and duplicates, will be also collected through this study.

E. coli, nutrient, and sediment data will be collected during three wet weather events in order to supplement the collected under the previous grant. Initial sampling discussions evaluated whether additional dry weather sampling was necessary; however several tributaries were determined to have only intermittent flow, so wet weather sampling was expected to provide more useful information across the watershed. Samples will be collected under wet weather conditions (with a goal of sampling a 0.4 inch rainfall event) after a 48 hour antecedent dry period. Prior to collecting samples, questionable sites shall be visited to determine whether flow is present such that samples may be collected from all sites. In addition to this sampling, *E. coli* data will also be collected five times during a 30 day period during the primary contact recreation season. It is expected that some sites may be dry during this period, but all flowing sites will be collected during the five collection events in this period. A dry weather and wet weather sampling event will be collected for bacterial source tracking at each site. The dry weather conditions shall be at least 48 hours since the end of a precipitation event. These samples will be sent to an analytical laboratory for analysis. Field data will be collected during each site visit. Monitoring is expected to begin as soon as possible after the approval of this QAPP. All collection methodologies will follow Kentucky Division of Water approved SOPs. Copies of these SOPs have been included in Appendix A.

Each sampling event is expected to take approximately one day to complete. During field sampling events, the Sampling Manager will be in contact with the Data Manager and Laboratory Leads.

Biological Monitoring

Habitat and biological assessments will be performed one time during the respective wadeable and headwater macroinvertebrate index periods in 2013.

Macroinvertebrate samples will be collected at five sites (one wadeable and four headwater) within the Chestnut Creek Watershed, if flow is obtained at all sites. The macroinvertebrate community at each site will be sampled using the recommended methods developed by KDOW (2009, 2011), which involve the collection of two separate samples, riffle and multihabitat. The riffle sample consists of four 0.25 meters^2 (m^2)

samples collected from two separate riffles at each station using a 0.25 m^2 grid and a kicknet (600µm mesh). Riffle collections at each station will be composited to form one semi-quantitative sample. The qualitative, multihabitat sample includes, where habitat is available, samples from leaf packs; sticks/wood; bedrock/slabrock; undercut banks/submerged roots; aquatic macrophyte beds; soft sediment (using a U.S. # 10 sieve); hand-picking of rocks (large cobble/small boulder) from riffles, runs, and pools; *aufwuchs* material off rocks, sticks, leaves, and filamentous algae; and visual searches of large woody debris. All samples collected with the dip net and the rock and wood samples will be processed through a 600µm wash bucket. Results of qualitative sampling from each microhabitat will be combined to form one composite sample for each station. Samples will be preserved in 95 percent ethanol and returned to the laboratory for processing and identification. All organisms will be identified to the lowest possible taxonomic level and recorded on laboratory data sheets. Random 300-specimen subsamples will be removed from the riffle samples using methods described by KDOW (2009).

Habitat assessments will be performed by Third Rock personnel at each of the macroinvertebrate sites. Assessments will be made to document riffle and pool substrates, stream channelization, riparian conditions and in-stream cover. Habitat assessment procedures will follow those outlined in *Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers* (Barbour et al. 1999).

Visual Assessments

Areas of high *E. coli* and total suspended solid locations will be walked and visually assessed in order to identify potential fecal sources and erosional areas. Potential fecal sources will be documented using a GPS and photograph. For severe erosion areas (erosion above normal levels for the region), the length of the erosion area will be measured and the site documented by photographs and GPS. The bank erosion hazard index (BEHI) and near-bank stress (NBS) ratings will be assessed at these sites (Rosgen 2006). These measurements will indicate a rough approximation of the amount of sediment loading associated with bank erosion.

Opportunities for best management practices will also be noted during these assessments.

Data analyses to be performed throughout this study include all the required analyses specified in the *Watershed Planning Guidebook for Kentucky Communities* (KWA, KDOW 2010). This will include a comparison of parameter concentrations to the water quality standards and benchmarks established by the project team, a calculation of pollutant loads and the target load reductions necessary for parameters that exceed the benchmark goals, and a comparison of watershed inventory data to pollutant concentrations and loads to determine potential sources of pollutants. Applicable water quality standards to be used during data analysis include the regulatory criteria identified in 401 KAR 10:031. For parameters without an applicable water quality standard identified in 401 KAR 10:031, a benchmark standard will be developed by the project team based on reference reach data from streams within the greater Clarks River basin, Kentucky ecoregional averages, and other applicable sources.

Reports to be generated throughout this study include a data analysis report that will include the comparison of parameter concentrations to the water quality standards and benchmarks, and a calculation of pollutant loads and the target load reductions necessary for parameters that exceed the benchmark goals, and a watershed plan specific to the Chestnut Creek watershed that will include the comparison of watershed inventory data to pollutant concentrations and loads to determine potential sources of pollutants. This document will also outline potential practices that could achieve the target load reductions necessary to meet the benchmark goals identified.

Project deliverables will include this QA Project Plan, the initial quality evaluation report (QER) after the first sampling event, QERs as requested by the Kentucky Division of Water throughout the monitoring period, the final QER after the last sampling event, a water quality data analysis report, biological monitoring report, and a watershed plan. The initial sampling event is expected to occur as soon as possible after the QAPP approval. The monitoring and reporting of results are expected to be completed by December 31, 2013. The watershed plan is to be completed by October 1, 2014.

A7. Data Quality Objectives (DQOs) and Criteria for Measurement Data

In order to more accurately define threats to water quality in the Chestnut Creek watershed, additional data collection is necessary, including bacterial, nutrient, and sediment data, flow and field data, and habitat and biological assessments. Data collected through this project will then be compared to appropriate water quality standards, established by the Kentucky Division of Water, or benchmark standards, compiled by the project team from available data for reference reach streams in the Mississippi Valley Loess Plains ecoregion 74b, to determine overall water quality in the watershed. Threats to water quality, including potential sources of nonpoint source pollution, in the Chestnut Creek watershed will be identified and best management practices that could be used to address these threats will be compiled. Data quality objectives for this project include collecting reliable data regarding the current water quality conditions in the Chestnut Creek watershed, and performing appropriate analyses of the collected data to correctly identify threats to water quality in this watershed.

This study will be used to estimate pollutant loads for each of the analytical parameters identified in Table 2. Qualitative comparisons of observed values to water quality standards or benchmark standards for the different parameters will be made during the analysis phase of this project. Benchmark standards will be set by the project team, and in the absence of an approved water quality standard, will serve as action levels for this project. Action levels for this project will be sent to Kentucky Division of Water for review as soon as they are drafted by the project team.

Measurement Performance Criteria / Acceptance Criteria

Measurement performance criteria are used in data collection efforts to reduce bias and variability between samples, thus ensuring that data collected will be able to support project decisions. Data quality indicators addressing precision, bias, representativeness, comparability, and completeness have been identified for each of the parameters in this study (Table 3). Precision and bias will be assessed quantitatively using quality control samples and meter and equipment calibration, whereas representativeness and comparability will be assessed qualitatively. Completeness will be assessed quantitatively at the end of the monitoring program through a review the sampling program.

Precision will be assessed quantitatively with duplicate samples and expressed as the relative percent difference (RPD) by the following equation:

$$RPD (\%) = \frac{[X_1 - X_2]}{(X_1 + X_2)/2\backslash} \times 100$$

where,
RPD (%) = relative percent difference
X_1 = original sample concentration
X_2 = duplicate sample concentration
$[X_1 - X_2]$ = absolute value of $X_1 - X_2$

To assess precision, field duplicates will be collected and analyzed for the different parameters. For each sampling event, one duplicate will be submitted for at least two of the analytical parameters (nitrate/nitrite, ammonia-nitrogen, TKN, total phosphorus, orthophosphate, carbonaceous biochemical oxygen demand and total suspended solids).Which parameter that is selected as a duplicate for the different sampling events will be selected at random. For each sampling event, one site from each watershed will be randomly selected to serve as a duplicate bacteriological (*E. coli)* sample. Nutrient and sediment samples with a RPD greater than 20% will be disqualified from this study. Bacterial samples with a RPD greater than 20% will still be accepted in this study due to the great variability that can naturally occur between samples.

For benthic macroinvertebrate identification, ten percent of all sorting pans will be randomly checked by a second sorter to assure that samples have been picked thoroughly. Five percent of all identified samples will randomly be re-identified to insure QA/QC by a second taxonomist. Ninety percent or greater composition comparability (*e.g.*, abundance and richness) is the target success criteria. If there is less than 90 percent comparability between the taxonomists, then taxonomy must be reconciled by both taxonomists and a third taxonomist, if deemed necessary.

Bias will be assessed quantitatively with positive control samples and expressed as % recovery by the following equation:

$$\% \text{ recovery} = X/T \times 100$$

where,
X = Measured concentration
T = True concentration

To assess bias, the frequency of positive control samples and equipment blanks will be at the discretion of laboratory personnel, but at a minimum will be one positive control sample or equipment blank per batch of analytical samples. Samples analyzed as a group with a positive control sample or equipment blank exceeding 20% recovery will be disqualified from this study.

Representativeness will be assessed qualitatively by verifying that appropriate sample collection and analytical methods were followed throughout this process. This will include evaluation of sample handling and chain of custody records, sample preservation, and sample holding times. Representative conditions for sampling events are established via the antecedent conditions for dry and wet events.

Representative conditions for macroinvertebrate sampling are established by the respective index periods for sampling. In addition, macroinvertebrate samples will not be collected during periods of excessively high or low flows or within two weeks of a known scouring flow event.

Comparability will be assessed qualitatively by verifying that field and laboratory data are consistent in terms of methods and units of measure between sampling events.

Completeness will be assessed quantitatively through the following equation:

$$\% \text{ Completeness} = N/T \times 100$$

where,
N = number of usable results
T = total number of samples planned to be collected during study

Unforeseen circumstances can prevent the collection of samples at certain sites during sampling events (sampling site dry, unreachable, etc.). In order to prevent a sampling event occurring when all sites are not flowing, questionable locations shall be visited prior to sampling to evaluate the flow status. Data from collected samples may be deemed unusable due to broken seals or bottles, hold time exceedances, etc. Completeness will be evaluated by comparing the number of samples actually usable to the total number of samples expected to be collected.

For macroinvertebrate sampling, sites may be moved based on flow conditions such that the macroinvertebrate populations of Chestnut Creek and its tributaries are evaluated.

A8. Special Training Requirements / Certification

Field staff will be required to attend the annual Four Rivers Watershed Watch Volunteer training session. Additional training and instruction on the proper collection of environmental samples will be provided by the Data Manager. Training will be provided in the field, and records documenting the date of training will be kept in the Data Manager's project file. Community volunteers wishing to assist with monitoring activities will be trained in proper monitoring methods by project staff, or will perform all activities with field staff partners.

A9. Documentation and Records

Records critical to this project will include this QA Project Plan, all field notes and measurements, chain of custody records, laboratory records, and any progress reports prepared throughout the course of this project. The QAPP author will be responsible for ensuring that all personnel have the most current approved version of the QA Project Plan. After the QA Project Plan has been approved by the Kentucky Division of Water, it will be distributed to all individuals included in section A3. Should any revisions be necessary, all individuals identified in section A3 will be sent the revised plan and required to return the old QA Project Plan, ensuring that there out dated versions of the QA Project Plan do not remain in use. An original copy of all versions of the QA Project Plan will be stored in the project file in Lexington, Kentucky.

Water Quality Monitoring Records

Water quality field measurements and observations will be recorded in a field log, and will be in blue or black ink on waterproof paper. At a minimum, field records will include the sampling location, sampling personnel, summary of field conditions, including qualitative observations and field data collected, and the date and time of sample collection. Duplicate samples will be labeled as such in the field log, but will be assigned a unique sample ID and submitted blind to the laboratory. Any field meter calibration results will also be recorded in the field log. Copies of chain of custody records will also be kept with the field log. Any mistakes in the field log will be crossed out with one line, and will include the initials and date of the person making the correction. The correct information will then be recorded on another line. All additions to the field log will be dated. Field records will be kept with field personnel until completion of the field sampling program, at which time they will be given to the Data Manager and stored in the Data Manager's project file. Biological field measurements will be similarly handled but maintained by the Biological Data Manager's project file.

Digital photographs will be taken at each sampling site during each sampling event. Photographs of any other areas of interest near the sampling sites will also be taken. For each photograph taken, the time, date, subject, and field conditions will be recorded in the field log. Photographs will be archived in a permanent digital file burned to a CD when all sampling events have been completed. This CD will be kept in the respective project files as appropriate.

Water quality laboratory records will be submitted by the laboratory lead to the Data Manager, and will include analytical results for each the analyses performed and QA/QC results as necessary. Copies of chain of custody records indicating the date and time of receipt of samples will also be included in laboratory records. Laboratory reports will be generated upon completion of all analyses for a particular sampling event, and will be sent to the Data Manager in Excel format. After inspection, the Data Manager will forward these records to the Project Manager and Project team. All water quality laboratory reports and records will be stored in the Data Manager's project file. Analytical methods used by the laboratories have been included in Table 2. Laboratory records will be submitted to the Kentucky Division of Water as requested.

Progress reports will be prepared as requested by the Kentucky Division of Water. The first quality assurance report will be sent to the NPS technical advisor with the KDOW after the first sampling event, as soon as results are received from the laboratory. Quality assurance reports will include copies of the field data log, laboratory records, and a discussion of any pertinent issues and their corrective actions, as necessary. A final report will be prepared by the Sampling Manager upon completion of the project. These reports will include analytical results, presented in an Excel spreadsheet, a discussion of project quality assurance, as needed, and narrative discussions of project status in terms of the project milestones. The Data Manager will maintain copies of these reports in the Data Manager's project file.

A copy of all water quality project records will be kept in the Data Manager's project file for a minimum of three years after the project is complete. Management of these project records will be a task of the data manager.

Biological Monitoring and Visual Assessment Records

Field records will include all data recorded in the field including completed field datasheets, field logbooks, monitoring records, and chain of custody sheets. All data will be recorded using black or blue indelible ink, and it is recommended that waterproof paper be used where feasible. Mistakes on field data sheets will be crossed out with one line (so the information is still discernible), with the initials and date of the person making the correction. The correct information should then be recorded legibly on another line, or above or below the original info. If a separate sheet is necessary for new information, the original sheet should be attached to the new sheet, and initialed and dated.

All raw data collected in the field will ultimately be submitted in biological data package. However, all field notes, including the location and frequency of QC sampling, *in situ* measurements, and calibration and maintenance logbooks will be retained for the duration of the grant period in the Biological Data Manager's project file.

Where possible, all field *in situ* measurements will be recorded on the datasheet or chain-of-custody. However, if necessary, results or notes may be maintained in a field notebook. Equipment calibration and maintenance logs will be documented and recorded per procedure specifications.

Third Rock's macroinvertebrate identification laboratory will follow laboratory protocols for benthic macroinvertebrate sample processing, identification and data reporting per KDOW (2009, 2008, 2011) with the following exceptions:

- All samples will be logged into Third Rock's Macroinvertebrate Laboratory Information Management System (MacLIMS) upon receipt.
- Sample identification date will be maintained in MacLIMS.
- Taxonomic QA/QC dates (if applicable) will be noted on individual QA/QC forms and maintained electronically in the project file.
- Initials of the applicable party completing each task associated with sorting, identification, or quality control will be noted electronically in MacLIMS or on associated QA/QC forms.
- QA checks will be documented on applicable forms and maintained in associated project files.

The macroinvertebrate report data package will include a list of the identified species, metric calculations, habitat assessment scores, photographs, completed chain(s)-of-custody, and a data analysis report.

SECTION B - DATA GENERATION AND ACQUISITION

B1. Sampling Process Design

Additional data collection is necessary in order to determine current water quality conditions in the Chestnut Creek watershed and more accurately define threats to water quality in the watershed. Data collection efforts will include collection of field data, including flow and field chemistry, analytical data, including nutrient and bacteriological, and habitat and biological data. Data will be collected monthly for a year, at a minimum, from eight sites in Chestnut Creek (Figure 3, Table 2).

Sampling sites were designed to provide information about impacts from the major land uses in the watersheds and the major tributaries entering Chestnut Creek. Sites were also designed to allow for identification of potential sources of pollutants in the watershed, and capture the water quality impacts of the upper portions of the watershed. Landowner receptiveness to this project was also a consideration during site selection. Rational for individual site selection in each watershed has been included below:

Site 1 Headwaters region of Chestnut Creek. The drainage area for this site includes three package treatment plants, Marshall County High School, Marshall County Board of Education, and one mobile home park. This site will also capture runoff from impervious surfaces in the south end of the watershed.

Site 2 At Foust Sledd Road crossing of Chestnut Creek. The site is located just downstream of a watershed structure managed by NRCS. Much of the fields along Chestnut Creek between sites 1 and 2 have been enrolled in the USDA Conservation Reserve Program. The area includes some pasture and cropland. This site was sampled by Murray State University as part of their TMDL study in 2005.

Site 3 On an unnamed tributary to Chestnut Creek at Foust Sledd Road. This tributary has discharge from Marshall County Sanitation District #2, which has been upgraded in the past few years. The tributary also receives drainage from two mobile home parks with lagoon treatment systems. This site was sampled by Murray State University in 2005 as part of their TMDL study.

Site 4 At Oak Valley Road crossing Chestnut Creek. There are four tributaries that enter Chestnut Creek between sites 2 and 4. The drainage area for this section of Chestnut Creek includes many residential areas on the north end of the watershed, all of which should have on-site waste disposal systems. The area also includes some pasture and cropland.

Site 5 On an unnamed tributary to Chestnut Creek, in a location different than where the stream is mapped to occur, possibly because the direction of the tributary has changed. The drainage area for this tributary includes sections of Oak Valley Road south of Chestnut Creek. The area includes pasture and cropland. There have been cattle in this area in the past.

Site 6 On an unnamed tributary to Chestnut Creek at Griggstown Road. The area includes pasture and cropland, and some cattle. There are some residential developments that drain to this site.

Site 7 At the downstream end of the same tributary as site 6, near where the tributary enters Chestnut Creek. This site is intended to quantify pollutant loads coming from this unnamed tributary. The drainage area between sites 6 and 7 includes many forested areas.

Site 8 At Scale Road crossing of Chestnut Creek. This site is being monitored by Kentucky Division of Water this year, and was monitored by Murray State University as part of their TMDL study in 2005. One tributary enters Chestnut Creek between sites 8 and 9. This site is intended to quantify total pollutant loads from Chestnut Creek into Clarks River, as this site is located near the mouth of Chestnut Creek.

Monitoring parameters were selected based on local knowledge and community concerns with assistance from the *Watershed Planning Guidebook for Kentucky Communities* (KWA, KDOW 2010). These parameters will give a broad view of current water quality conditions in the Chestnut Creek watershed, and also include many of the major pollutants affecting Kentucky streams. Samples will be collected during three events under wet weather conditions after a 48 hour antecedent dry period. A wet weather event shall have a precipitation of at least 0.4 inches as a sampling goal. Effort will be made to obtain all samples during the hydrographic rise. Prior to collecting samples, questionable sites shall be visited to determine whether flow is present such that samples may be collected from all sites. Additional *E. coli* samples will be collected five times during a 30 day period of the primary contact recreation season. It is expected that some sites may be dry during this period, but all flowing sites will be collected during the five collection events in this period. A dry weather and wet weather sampling event will also be collected for bacterial source tracking at each site. The dry weather event shall be at least 48 hours after the end of precipitation. All samples collected will be grab samples. Field data collected will be used to supplement the analytical and bacteriological data collected in terms of defining current water quality conditions in the watershed. Parameters selected, frequency of collection, and collection methods have been included in Table 2.

Duplicate samples and field blanks will be used as a QA/QC method for bacteriological, nutrient and sediment samples. For each sampling event, one duplicate and one field blank will be submitted for at least two of the analytical parameters (nitrate/nitrite, ammonia-nitrogen, TKN, total phosphorus, orthophosphate, carbonaceous biochemical oxygen demand and total suspended solids). The parameter requiring a duplicate sample or field blank will be determined prior to the sampling event, and each parameter will be selected as a duplicate at least one time in this study. Duplicate samples will be used as a QA/QC method for bacteriological samples. For each sampling event, one site from each watershed will be randomly selected to serve as a duplicate sample. All meters that will be used to collect field data will be calibrated before each sampling event. Calibration results will be recorded in the field log.

B2. Sampling Methods

Water Quality Monitoring

Appropriate sample containers for each of the data parameters will be provided by the analytical laboratories, Microbac Labs and Hancock Biological Station (Table 4). These containers will be sterile and contain preservatives as required for each parameter. Nitrate/nitrite, ammonia, and orthophosphate samples will be filtered in the field within 15 minutes of collection by sampling personnel. Nitrate/nitrite and ammonia samples will be analyzed by Hancock Biological Station and orthophosphate by Microbac Laboratories. Nitrate/nitrite and ammonia will be analyzed within 24 hours and orthophosphorus within 48 hours. The remaining nutrient samples to be analyzed by Microbac Laboratories, including total Kjeldahl nitrogen, and total phosphorus samples. All containers will be accompanied by a Chain of Custody Record. Sterile gloves will be used for collection of samples at each of the sites.

Samples from wadeable streams will be collected by dipping sample containers to a depth of four inches with the open end facing upstream. Samples will be collected upstream of sampling personnel, sampling apparatus and any disturbed sediment. Samples from non-wadeable streams will be collected by attaching the sampling container to fishing line and lowering the container from a bridge to the middle of the stream. For parameters that require filtration in wadeable streams, i.e. nitrate/nitrite, ammonia, and orthophosphate samples, sample containers will be filled with the aqueous sample by dipping the container to a depth of four inches with the open end facing upstream. The aqueous sample will then be filtered through a 0.45 µm nylon membrane filter using a 25 mm Millipore Swinnex filter holder attached to a 50cc syringe into the appropriate sterile sample container. A total sample volume of 120 mL will be collected and filtered. For parameters that require filtration in non-wadeable streams, i.e. nitrate/nitrite, ammonia, and orthophosphate samples, sample containers will be attached to fishing line and lowered from a bridge to the middle of the stream. The aqueous sample will then be filtered through a 0.45 µm nylon membrane filter using a 25 mm Millipore Swinnex filter holder attached to a 50cc syringe into the appropriate sterile sample container. A total sample volume of 120 mL will be collected and filtered.

Field blanks will be filled with deionized water and labeled as a sample duplicate. For parameters requiring filtration, i.e. nitrate/nitrite and ammonia samples, field blanks will be collected as rinsate blanks. These rinsate blanks (deionized water filtered through a 0.45 µm nylon membrane filter using a 25 mm Millipore Swinnex filter holder attached to a 50cc syringe) will be labeled as sample duplicates. After collection, samples will be stored in a cooler filled with wet ice until delivery to the analytical laboratory. Collection methodology for each of the data parameters shall follow Kentucky Division of Water approved SOPs (Table 2, Appendix A).

Field data will be collected with the meters identified in Table 5. All meters will be calibrated prior to use in the field with known standard solutions. Probes will be rinsed with sterile DI water in between use at different sites. Waste will be collected and disposed of properly at Hancock Biological Station.

Should any equipment fail during the course of this project, replacement equipment that has been calibrated, if necessary, will be used. Should any sampling containers become compromised, they will not be used. If samples become compromised, they will also not be used.

Biological Monitoring

Sampling for benthic macroinvertebrates will be conducted according to the KDOW's *Methods for Sampling Benthic Macroinvertebrate Communities in Wadeable Waters* (KDOW 2011). Five sites will be sampled including Sites 1, 4, 5, 7, and 8. Of these sites, only Site 8 is a wadeable site; all others are headwater sites.

A collection event consists of a composited semi-quantitative sample and a composited multi-habitat sample. Semi-quantitative samples will be collected from a known area in order to indicate the macroinvertebrate community in the most productive habitat in the stream niche (*i.e.,* riffle). Multi-habitat samples are intended to identify other taxa present in the stream that may not be collected in the semi-quantitative sampling. These two sample types must be kept separate for effective diagnosis of impairment. A summary of the collection techniques used for wadeable and headwater streams is shown in Table 6 and further described in the following sections.

It is important to keep in-stream habitat intended for benthic macroinvertebrate sampling intact and undisturbed until the single and multi-habitat samples have been collected. Therefore, field personnel must avoid walking through areas designated for collection of benthic macroinvertebrates until sampling has been completed. Failure to use caution could result in sample degradation.

After collections are completed, large sticks and leaves will be washed in the field, inspected for organisms and discarded. Rocks will be elutriated and hand washed into a bucket and 600μm sieve. This process will be repeated until a manageable amount of debris and organisms (relative to size of sample container) can be preserved for laboratory sorting. Samples may be partially field picked using a white pan and fine-tipped forceps. The sample container will be preserved with 95% ethanol. While at the sampling location, all macroinvertebrate samples will receive a label. The label may be placed in the sample jar (labels placed in the jar will be written in No. 2 pencil on waterproof paper) and written directly on some portion of the jar. The label will include the site number, if known, stream name, location, county, date sampled and the collector's initials.

After sampling has been completed, all sampling gear will be thoroughly cleaned to remove all benthic macroinvertebrates so that specimens are not carried to the next site. The equipment shall be examined prior to sampling at the next site to ensure that no benthic macroinvertebrates are present.

Macroinvertebrate samples shall be delivered to Third Rock for identification according to *Laboratory Procedures for Macroinvertebrate Processing and Taxonomic Identification and Reporting* (KDOW. 2009). After identification, macroinvertebrate sampling results will be evaluated through calculation of several community metrics prescribed by KDOW 2008. Community metrics include taxa richness, EPT (mayfly, stonefly and caddisfly) richness, total number of individuals, modified percent EPT individuals, modified Hilsenhoff biotic index (mHBI), percent Ephemeroptera, percent primary clingers, and percent Chironomidae plus Oligochaeta (aquatic worms). Results of community metrics at each station will be combined to compute a Macroinvertebrate Bioassessment Index (MBI) score, ranging from 0 (worst) to 100 (best). MBI scores will be compared to scoring criteria developed by KDOW to arrive at water quality ratings of Very Poor, Poor, Fair, Good, or Excellent. For wadeable streams (watersheds greater than 5 mi^2) of the Mississippi Valley-Interior River Lowlands Bioregion, a MBI score below 12 is Very Poor, from 13 to 23 is Poor, from 24 to 47 is Fair, from 48 to 57 is Good, and greater than 58 is Excellent. For headwater streams (watersheds less than 5 mi^2) of the Mississippi Valley-Interior River Lowlands Bioregion, a MBI score below 18 is Very Poor, from 19 to 34 is Poor, from 35 to 55 is Fair, from 56 to 62 is Good, and greater than 63 is Excellent (KDOW 2008).

Results from this project will be compared with Mississippi Valley-Interior River Lowlands Bioregion Criteria. These results and the results of the habitat assessment monitoring will be combined into a final report.

Habitat assessments will include a visual assessment of ten habitat parameters that characterize the stream "micro scale" habitat, the "macro scale" features, and the riparian and bank structure features that are most often influential in affecting the other parameters. The method follows the US EPA's *Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers* (Barbour *et al.* 1999). Each of the parameters will be evaluated on a "Condition Category" scale from 0 to 20. The categories within this scale include “Optimal” for scores from 20 to 16, “Suboptimal” for scores from 15 to 11, “Marginal” for scores from 10 to 6, and “Poor” for scores from 5 to 0. The score for each parameter will be summed to produce a final habitat score (maximum 200).

For parameters 1 to 5, the habitat assessment will evaluate a composite of the entire biological sampling reach. For parameters 6 to 10, an area beginning approximately 100-m upstream of the sampling reach through the sampling reach will be evaluated as a composite. The evaluator will face downstream when determining left and right bank. For parameters 8 to 10, each bank will be scored independently from 10 to 0. At each sampling site, results will be recorded on the Low-Gradient Habitat Assessment Field Data Sheet. Photographs will be taken to document upstream and downstream conditions.

Visual Assessments

Areas of high *E. coli* and total suspended solid locations will be walked and visually assessed in order to identify potential fecal sources and erosional areas.

Potential fecal sources will be documented using a GPS and photograph. These sources may include straight pipes, sewage signs, livestock in the stream, or other similar observations.

For severe erosion areas (erosion above normal levels for the region), the length of the erosion area will be measured and the site documented by photographs and GPS. The bank erosion hazard index (BEHI) and near-bank stress (NBS) ratings will be assessed at these sites (Rosgen 2006). These measurements will indicate a rough approximation of the amount of sediment loading associated with bank erosion. Bank height, bankfull height, root depth ratio, weighted root density, bank angle, surface protection, bank material, and stratification of the bank material will be documented as well as the near-bank stress.

B3. Sample Handling and Custody Requirements

All samples collected will be stored on ice until delivery to the laboratory. Samples delivered to the laboratory will include appropriate labeling and record keeping. Sample security will be documented through the Chain of Custody Record, which will be completed by field personnel. Each time control of the samples is transferred, both parties will complete the appropriate portion of the Chain of Custody Record, including their signature and date and time of transfer. Upon delivery of the samples to the laboratory, the Laboratory Lead will ensure that the Chain of Custody Records have been documented appropriately. Should there be any issues with the Chain of Custody Record, the samples will be flagged and discarded from this study.

Samples will be delivered to the laboratory as soon as possible, ensuring that no hold times are exceeded. Hold times for the different parameters have been included in Table

4. The laboratory shall begin analyses on *E. coli* samples as quickly as possible, preferably within one hour of arrival at the lab, but no more than two hours after arrival. *E. coli* samples exceeding the hold time of eight hours will be flagged as exceeding the hold time and the data will be discarded from this study.

Samples for Microbac Laboratories will be delivered to Microbac's Paducah Office. For samples that must be sent to the main Microbac Lab in Louisville, laboratory personnel will package and ship samples for analysis. This will include ensuring samples are stored on ice for transport to the main lab with all appropriate records, including sample labels and Chain of Custody records, intact and correctly filled out.

B4. Analytical Methods Requirements

Analytical methods for each parameter have been included in Table 2. *E. coli*, total Kjeldahl nitrogen, total phosphorus, orthophosphate, carbonaceous biochemical oxygen demand and total suspended solids will be analyzed by Microbac Labs. Nitrate/nitrite and ammonia samples will be analyzed by Hancock Biological Station. Bacterial source tracking will be performed by the University of Tennessee Center for Environmental Biotechnology. Turnaround time for laboratory analysis and reporting will be one month from the receipt of samples. Contact information for these laboratories has been included in Table 7. Discussions of the methodologies for specific analytes have been included below:

Bacterial Analyses

E. coli Methodology:
Standard Method 9223B (an enzyme substrate test) will be used for *E. coli* analyses. These analyses will be conducted at Microbac's Paducah Office. The laboratory lead for Microbac will be responsible for overseeing the analyses and implementing corrective actions, if necessary. A chromogenic/fluorogenic medium (IDEXX Colilert-18) is added to each sample. The samples are then poured into a 100 mL Quantitray (a plastic tray with countable wells) and incubated at 35±0.5° for 18 hours to enumerate *E. coli* and total coliforms. ONPG in the medium is hydrolyzed by a total coliform enzyme to produce a yellow color. MUG in the medium is hydrolyzed by *E. coli* to produce a fluorescesence upon exposure to ultraviolet light. In the Quantitray, the yellow and fluoresced wells can be counted and calculated as MPN/100mL to determine total coliform and *E. coli* concentrations. Highly contaminated sources may require dilutions to achieve a MPN. Please see Attachment B for a more detailed discussion of Microbac laboratory SOPs.

Bacterial Source Tracking Methodology:
Samples will be processed by centrifugation and direct lysis of the sediment to release environmental DNA. Environmental DNA will be assayed by the method of Layton et al., 2006. In the assay, concentrations of human-specific and total *Bacteroides* fecal

DNA will be measured. If the percentage of human-specific DNA sequences out of the total is high, there is a high likelihood the contamination is from human sources. If the percentage is low, there may be another source of contamination. Process samples for analysis as follows:

1. Centrifuge 250 ml sample at 3000xg for 10 minutes to precipitate fecal *Bacteroides* cells and other sediments.
2. Resuspend sediments in TE buffer and transfer to 50 ml tubes, centrifuge as above, and transfer again to a 1.5 ml microcentrifuge tube. Pellets may be frozen for storage at this point.
3. Resuspend in 100 uL of LyseNGo solution (Pierce Chemical) or add more if necessary to maintain at least a 10:1 ratio to pellet volume. Process according to LyseNGo protocol.
4. Use 5 uL LyseNGo extract in the Layton et al. Real-Time PCR Assay for all *Bacteroides* (AllBac) and human-specific *Bacteroides* (HuBac).

Included are the following controls:
Duplicates
Blanks
Spike (HuBac plasmid)
Positive controls: Standard set (HuBac plasmid), human fecal DNA
Negative controls: DI water, Horse fecal DNA

Results of the assay will determine the concentration of DNA from all *Bacteroides* strains (AllBac) and the subset of Human-specific *Bacteroides* strains (HuBac). As proportions of Human-specific markers increases, so does the likelihood the contamination is due to human sources. This result is reported as the HuBac score. The concentration DNA from of all *Bacteroides* strains is a gauge for the relative extent of contamination from all sources. This result is reported as the AllBac score.

Nutrient Analyses

Nutrient samples analyzed by Hancock Biological Station, including nitrate/nitrite and ammonia samples, will use Inorganic Nonmetals by Flow Injection Analysis (FIA) methods (4130) from the *Standard Methods for the Examination of Water and Wastewater*. These are semi-automated methods that inject a measured volume of sample into a carrier stream, forming a concentration gradient that can be detected by a color reaction or analyte specific detector. These concentration gradients are then passed through a flow-through absorbance detector, creating an absorbance peak, with the area of the peak being proportional to the analyte concentration. The samples will be filtered directly in the field, as described in Section B2, and then kept in a dark, cold storage area until analysis by Hancock Biological Station. According to Hancock Biological Station, this method of preservation nets the most consistent analytical results for these analyses. The laboratory lead for Hancock Biological Station will be responsible for overseeing the analyses and implementing corrective actions, if necessary.

Nitrate/nitrite Methodology:
Standard Method 4500-NO_3^- I (Cadmium Reduction Flow Injection Method) will be used for nitrate & nitrite analyses. This method reduces all nitrates in the sample to nitrite in the presence of copperized cadmium. The nitrite is then diazotized with sulfanilamide and coupled with N-(1-napthyl)-ethylenediamine dihydrochloride to form a highly colored azo dye that is measured colormetrically. Nitrate standards with concentrations of 5.0 ppm, 3.0 ppm, 1.0 ppm, 0.5 ppm, 0.25 ppm, and 0.1 ppm will also be processed by this method. A standard curve is prepared by comparing the absorbance peak areas recorded for standards processed versus the nitrate concentration in the standards. The standard curve will have a correlation coefficient of at least 0.999. A QC sample from an external source (UltraCHECK, Ultra Scientific) will be prepared to check against the standard curve. Sample nitrate concentrations are then calculated by comparing absorbance peak area recorded with the standard curve. Results are expressed as ppm nitrogen as nitrate & nitrite because background nitrite concentrations in the samples are not calculated individually.

Ammonia Methodology:
Standard method 4500 NH_3 H (Flow Injection Method) will be used for ammonia analyses. Ammonia is measured colormetrically with this semi-automated phenate method. In this method, alkaline phenol and hypochlorite react with ammonia in the distillate to form indophenol blue, proportional to the ammonia concentration. The indophenol blue can then be measured colormetrically. Ammonia standards with concentrations of 0.8 ppm, 0.6 ppm, 0.4 ppm, 0.1 ppm, 0.05 ppm, 0.04 ppm, 0.02 ppm, and 0.01 ppm will also be processed with this method. Standard curves are prepared by plotting the ammonia concentration in the standards versus the absorbance peak area recorded. The standard curve will have a correlation coefficient of at least 0.999. A QC sample from an external source (UltraCHECK, Ultra Scientific) will be prepared to check against the standard curve. Ammonia concentrations in the samples are then computed by comparing the sample absorbance response with the standard curve.

The remaining nutrient samples, including total Kjeldahl nitrogen, total phosphorus, orthophosphate, and carbonaceous biochemical oxygen demand will be analyzed by Microbac Laboratories at their main location in Louisville, Kentucky. Sample preservatives for each analyte have been included in Table 4. The laboratory lead for Microbac Laboratories will be responsible for overseeing the analyses and implementing corrective actions, if necessary.

Total Kjeldahl Nitrogen Methodology:
Total Kjeldahl nitrogen is the sum of organic nitrogen and ammonia nitrogen. Standard method 4500-N_{org} C (Semi-Micro-Kjeldahl) will be used for total Kjeldahl nitrogen analyses. Amino nitrogen, free ammonia and ammonia nitrogen are converted to ammonium sulfate in the presence of sulfuric acid, potassium sulfate, and a catalyst. After addition of the base, sodium thiosulfate, ammonia is distilled and absorbed into sulfuric acid. The ammonia concentration is then determined

colormetrically by the SEAL Discrete analyzer. Please see Attachment B for a more detailed discussion of Microbac laboratory SOPs.

Total Phosphorus Methodology:
Standard method 4500-P F (Automated Ascorbic Acid Reduction Method) will be used for total phosphorus analyses. Samples are digested through persulfate digestion (standard method 4500-P B. Sample Preparation), oxidizing total phosphorus to orthophosphate. Orthophosphate in the digested sample reacts with ammonium molybdate and antimony potassium tartrate under acidic conditions to form a complex. This complex is reduced with ascorbic acid to form a blue complex proportional to the amount of total phosphorus in the sample that is measured colormetrically with the SEAL Discrete analyzer. Please see Attachment B for a more detailed discussion of Microbac Laboratory SOPs.

Orthophosphate Methodology:
Standard method 4500-P F (Automated Ascorbic Acid Reduction Method) will be used for orthophosphate analyses. Orthophosphate in the sample reacts with ammonium molybdate and antimony potassium tartrate under acidic conditions to form a complex. This complex is reduced with ascorbic acid to form a blue complex proportional to the amount of orthophosphate in the sample that is measured colormetrically with the SEAL Discrete analyzer. Please see Attachment B for a more detailed discussion of Microbac Laboratory SOPs.

Carbonaceous Biochemical Oxygen Demand Methodology:
Standard method 5210 B (5-Day BOD Test) will be used for carbonaceous BOD analyses. This method measures the amount of molecular oxygen used during a five day incubation period for the biochemical degradation of organic material and the oxidation of inorganic material. The sample container must be filled to overflowing, with no air bubble. That sample is then seeded and incubated for five days. A nitrification inhibitor is added to the seeded sample to eliminate oxidation of nitrogen containing compounds. The dissolved oxygen concentration is measured initially and after incubation, and the carbonaceous biochemical oxygen demand is computed from the difference between the initial and final dissolved oxygen readings. Samples for this project will be run through a low level detection limit process. Please see Attachment B for a more detailed discussion of Microbac laboratory SOPs.

Sediment Analyses

Samples will be analyzed for total suspended solids by Microbac Laboratories at their main location in Louisville, Kentucky. The laboratory lead for Microbac Laboratories will be responsible for overseeing the analyses and implementing corrective actions, if necessary.

Total Suspended Solids Methodology:

USGS Method I-3765-85 will be used for TSS analyses. In this method, a sample is filtered through a 47 mm glass fiber filter and the residue on the filter is then dried overnight at 103° to 105°C. The increase in the weight of the filter before and after drying corresponds to the amount of total suspended solids in the sample. Samples for this project will be run through a low level detection limit process. Please see Attachment B for a more detailed discussion of Microbac laboratory SOPs.

Instrument calibration checks will be performed by lab staff on a regular basis. Appropriate records of these checks will kept by the laboratory. The Laboratory Lead for each analytical laboratory will be responsible corrective actions, should there be any failed calibration checks or contamination of the analytical data. The Laboratory Lead will report any data limitations when turning data over to the data manager.

B5. Quality Control Requirements

Samples will be collected under the supervision of individuals trained in the methods discussed in this QA Project Plan. The supervising sampler will be responsible for ensuring the methods described in this QA Project Plan are followed.

Field QC checks will include field blanks, temperature blanks, and field duplicate samples. Field blanks will be used to evaluate if contaminants have been introduced into the samples during sample collection. Deionized water will be added to sample containers at the sampling location to prepare field blanks. Temperature blanks will be used to ensure that samples are maintained at the appropriate temperature during sample transport. Temperature blanks will consist of a sample container filled with deionized water, and one temperature blank will be added to each cooler during sampling events. Field duplicate samples will be used to evaluate the precision of sample collection. Field duplicates will be collected by filling two sample containers at a sampling location for the same analysis. For each sampling event, one duplicate sample and one field blank will be submitted for at least two of the analytical parameters (nitrate/nitrite, ammonia-nitrogen, TKN, total phosphorus, orthophosphate, carbonaceous biochemical oxygen demand and total suspended solids).Which parameter that is selected as a duplicate or field blank for the different sampling events will be selected at random. For each sampling event, one site from each watershed will be randomly selected to serve as a duplicate bacteriological (*E. coli)* sample.

For field measurements, QC checks will include duplicate measurements, one duplicate measurement per sampling event per parameter. Meters will also be calibrated prior to each sampling event.

Laboratory QC is the responsibility of the laboratory staff. QC checks will include lab blanks and positive control samples for bacteriological samples, and equipment blanks and calibration for all other sampling parameters. The frequency of positive control samples and equipment blanks will be at the discretion of laboratory personnel, but at a minimum will be one positive control sample or equipment blank per batch of analytical samples.

Performance and acceptance criteria for QC checks will follow that outline in Section A A7, Data Quality Objectives (DQOs) and Criteria for Measurement Data. Calculations for precision, bias, represetativness, comparability, and completeness have also been included in Section A7.

For the macroinvertebrate laboratory QC, ten percent of all sorting pans will be checked by a second sorter to assure that samples have been picked thoroughly. These samples will be selected randomly using the MacLIMS database programming. Five percent of all identified samples will be re-identified to insure QA/QC by a second taxonomist. These samples will be selected randomly using the MacLIMS database programming. Ninety percent or greater composition comparability (*e.g.*, abundance and richness) is the target success criteria. If there is less than 90 percent comparability between the taxonomists, then taxonomy must be reconciled by both taxonomists and a third taxonomist, if deemed necessary. This quality control process shall be documented and included in the monitoring report.

B6. Instrument / Equipment Testing, Inspecting and Maintenance Requirements

Field sampling equipment will be inspected and maintained by the sampling manager according to the manufacturer's instructions. Maintenance logs will be kept in the Data Manager's project file. The maintenance log will document any maintenance or service to the equipment.

Laboratory analytical equipment will be inspected and maintained by the laboratory staff according to the manufacturer's instructions. This process will be overseen by the Laboratory Leads for each analytical laboratory, including Hancock Biological Station in Murray, Kentucky and Microbac Laboratories in Louisville, Kentucky. Maintenance and inspection logs will be the responsibility of the Laboratory Lead and will be maintained at the lab location. Should any corrective maintenance of equipment be required, it will be documented in the maintenance and inspection log.

B7. Instrument Calibration and Frequency

Calibration and maintenance of field equipment will be performed according to the manufacturer's instructions and the associated SOP, Standard Operating Procedure: *In situ* Water Quality Measurements and Meter Calibration (DOWSOP03014). Results will be recorded in an instrument/equipment logbook. The frequency of meter calibration has been described in Table 3.

Calibration and maintenance of laboratory equipment will be performed according to the manufacturer's instructions by laboratory staff and overseen by the Laboratory Lead. Some of this information has been included in section B4 and Appendix B.

B8. Inspection / Acceptance Requirements for Supplies and Consumables

Critical supplies and consumables for this project include sample containers and reagents. Sample containers for this project will be provided by the associated analytical laboratory, Microbac Laboratories and Hancock Biological Station. Sample containers provided by the lab will undergo a sterility check by the Laboratory Manager. Laboratory reagents will undergo inspection by the Laboratory Manager prior to sample analyses. Any reagents that are out of date will not be used for this project.

B9. Data Acquisition Requirements for Non-direct Measurements

Data from non-direct measurement sources that could be used for decision making purposes or to direct BMP implementation could include photographs and GIS maps, published literature, and other pertinent background information. Only qualified information can be used for the decision making process. Any analytical data to be used must have been collected under a QA Project Plan, if it is to be used in the decision making process. Other data will serve as supplementary data and cannot be used in the decision making process, including data collected by Four Rivers Watershed Watch volunteers. KPDES monitoring data from the Marshall County Sanitation District #2 will also be incorporated into this study as supplementary data. It can be used to direct data gathering methods for this project, however, should this be needed.

B10. Data Management

Field and laboratory data will be reported to the Data Manger as soon as possible. Turnaround time for lab reports will be one month from the receipt of samples. Laboratory data will be in an electronic spreadsheet, and will include, at a minimum: site ID, sampling location details, field personnel, date of collection, time of collection, flow rate, analytical results, flag if there was an error in the analytical process. Electronic copies of these reports will be stored on a portable storage device that is used for this project only. Hard copies of these reports will also be kept in the Data Manager's project file. Electronic data will be stored in Microsoft Excel format.

A summary of field data will be reported to the Data Manager within two weeks of the sampling event. This will include scanned copies of the field log, including sampling location, sampling personnel, summary of field conditions, and the date and time of sample collection. This will also include scanned copies of the chain of custody record, and digital photographs that are appropriately labeled. These electronic reports will be stored on the portable storage device dedicated to this project. Hard copies of each of these reports will also be kept in the Data Manager's project file. All photographs will be stored digitally as JPEGs, and electronic copies of the field log and chain of custody record will be stored as JPEGs or PDFs. Upon completion of all field work, the original field notebook will be given to the Data Manager for storage in the project file.

The Data Manger will keep backup copies of all data, including electronic copies stored on the portable storage device and hard copies, in the Data Manager's project file for five years.

Macroinvertebrate laboratory results and metric calculations will be the responsibility of the Macroinvertebrate Laboratory Chief Taxonomist.

SECTION C – ASSESSMENT AND OVERSIGHT

C1. Assessments and Response Actions

Assessments will be conducted throughout the project to ensure that this QA Project Plan is being implemented as planned. Project assessments will include field assessments, such as readiness reviews prior to sampling events, field activity audits and a review of field methods after sampling events, and laboratory assessments, including an evaluation of laboratory data generated for sampling events.

Readiness reviews will be completed prior to sampling events by the Sampling Manager. Reviews will include ensuring that sampling personnel are trained in appropriate sampling methods and field equipment use. Equipment maintenance records will be checked by the Sampling Manager to ensure all field equipment is in proper working order. The Sampling Manager will ensure that there are adequate supplies, including sample containers, labels, Chain of Custody records, standards, etc. prior to each event. Field activity audits will be conducted quarterly by the Data Manager, and will assess sample collection methodologies, field procedures, and field records to ensure activities are following those described in this QA Project Plan. If any issues be noted, the Data Manager will work with the Sampling Manager to remedy these issues. Following each sampling event, the Sampling Manager will review field methods to ensure proper procedures described in this QA Project Plan were followed. This will ensure all information and documentation is correct. Results from each of these assessments will be included in a project assessment folder and stored in Reidland, Kentucky. Laboratory packages submitted to the Data Manager will be reviewed for completeness. Should any issues be found, re-testing can be requested.

C2. Reports to Management

The Sampling Manager in combination with the Data Manager will prepare quarterly reports on sampling activities to be given to project partners. These reports will include a summary of field and analytical results, copies of field and laboratory assessments, and a discussion of any problems encountered and recommended solutions.

Quality evaluation reports (QERs) will be prepared for the Kentucky Division of Water, if requested by the Kentucky Division of Water. These reports will include the name of the sampler, equipment calibration results, field parameter measurement results, date and time of sample collection, laboratory analysis results for each sample, including blanks and duplicate samples, laboratory bench sheets (original laboratory data sheets with all calibration information), and laboratory QC reports.

SECTION D – DATA VALIDATION AND USABILITY

D1. Data Review, Validation and Verification

Both field and laboratory data will be reviewed and validated by the Data Manager. Following each sampling event, the Sampling Manager will review all field data collected to ensure it is complete and that any deviations from methodology are properly noted. This reviewed field data will then be given to the Data Manager for a second review. These reviews will be documented with the form found in Figure 4.

Laboratory reports will be verified and validated by the Laboratory Lead prior to submittal to the Data Manager. A list of data quality flags for laboratory reviews has been included in Table 8. Details of this review will be maintained by the laboratory. Any data qualifiers identified by the Laboratory Lead will be included in the final laboratory report submitted to the Data Manager.

Once laboratory data has been submitted to the Data Manager by the Laboratory Lead, the Load Modeler will be responsible for further review, following the form found in Figure 5. This review will include an evaluation of field and laboratory duplicates, field and laboratory blanks, and laboratory control results pertinent to each of the analytical parameters. Any data qualifiers identified by the Laboratory Lead will also be reviewed as necessary. This review will ensure that methodology described in this QA Project Plan was followed, unless specifically noted. Decisions to reject or qualify any date will be made by the Load Modeler, in conjunction with the Sampling Manager, Data Manager, and Laboratory Lead, based on the assessment of failure to follow SOPs and methods described in this QA Project Plan.

Initial data reviews of newly collected data, including field and laboratory data, will follow the forms found in Figures 4 and 5. Once appropriate reviews have been completed, data analyses to be conducted will include a comparison of parameter concentrations to the water quality standards and benchmarks established by the project team, a calculation of pollutant loads and the target load reductions necessary for parameters that exceed the benchmark goals, and a comparison of watershed inventory data to pollutant concentrations and loads to determine potential sources of pollutants. Newly collected data will be compared to past data to determine if there have been changes in water quality conditions in the past six years. If there have been water quality improvements, GIS and land use analyses and landowner interviews at public meetings will be conducted to determine watershed changes that could have resulted in these water quality differences. All data collected will be presented at a public meeting in the watershed.

D2. Validation and Verification Methods

Chain of Custody records must be filled out and signed by the supervising sampler present at the time of sampling. These records will be verified by the Project Manager for precision, missing or illegible information, errors in calculation and values outside the expected range. This review will follow the form found in Figure 4. Laboratory Records will be validated first by the Laboratory Lead, identifying any data quality flags listed in Table 8. These laboratory records will then be verified by the Data Manager for precision, missing or illegible information, errors in calculation, and values outside the expected range. This review will follow the form found in Figure 5. Should any issues with field or laboratory data be identified during the review process, the project team, identified in Section A3 and Figure 1, will be notified via email and/or telephone. The project team will be asked to make suggestions, depending on the particular issue identified, that could prevent the issue from coming up again.

D3. Reconciliation with User Requirements and Data Quality Objectives

The purpose of this project is to collect water quality data that will help to identify sources of potential pollutants so that best management practices can be implemented to improve water quality in the Chestnut Creek watershed. Data must fulfill the requirements established in this QA Project Plan to be useful for this project. Data that does not meet the requirements established in the QA Project Plan, which will be identified during the numerous data reviews described above, will not be used for any decision making processes. The cause of the data failure will also be identified so future failures can be avoided. If the cause of failure is found to be sampler error, samplers will be retraining in field methodology. If the failure is related to equipment failure, calibration and maintenance procedures will be reassessed and improved. If accuracy and precision goals are frequently not met, laboratory analysts will be reviewed individually for analytical technique and to ensure SOPs are being followed. Revisions to this QA Project Plan can be made to revise project specifications, if necessary. All revisions will be submitted to Kentucky Division of Water for approval prior to implementation.

The Sampling Manager, Data Manager, and Laboratory Lead will work together to verify the data collected, and identify any limitations of data collected. All usable data collected will then be compared to the water quality standards and benchmarks established by the project team. In addition, the project team will evaluate the monitoring program at the end of the project to ensure goals were met. If additional data needs collected to meet project goals, revisions to this QA Project Plan can be made.

SECTION E. - REFERENCES AND CITATIONS

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish.* Second Edition. EPA 841-B-99-002. USEPA, Office of Water, Washington, D.C.

Clesceri, L. S., Greenberg, A.E., and Eaton, A.D. 1998. Standard Methods for Examination of Water and Wastewater (20th Edition). American Public Health Association.

Code of Federal Regulations, Title 40, Chapter 1, part 136. Guidelines establishing test procedures for the analysis of pollutants.

Kentucky Division of Water. 2008. *Methods for Assessing Biological Integrity of Surface Waters in Kentucky.* Kentucky Department of Environmental Protection, Division of Water, Frankfort, Kentucky.

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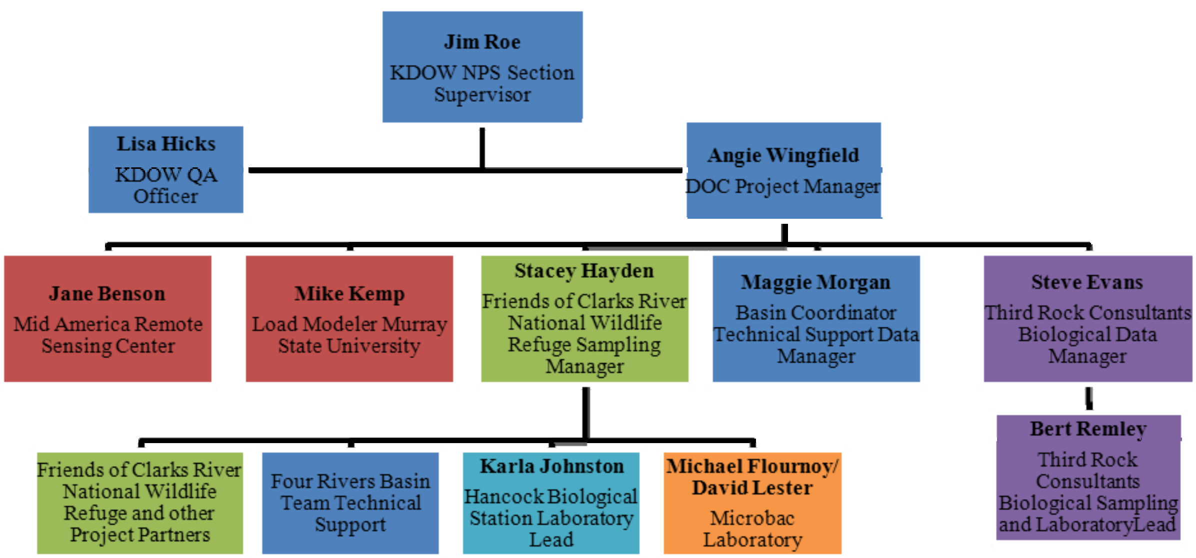
Kentucky Division of Water. 2011. *Methods for Sampling Benthic Macroinvertebrate Communities in Wadeable Waters*. Revision No. 3. DOWSOP03003. Kentucky Department for Environmental Protection, Division of Water, Frankfort, Kentucky.

Kentucky Waterways Alliance and Kentucky Division of Water. 2010. *Watershed Planning Guidebook for Kentucky Communities*.

Rosgen, Dave. 2006. Watershed Assessment of River Stability and Sediment Supply (WARSSS). Wildland Hydrology, Fort Collins, Colorado.

Strand Associates, Inc. 2009. *Clarks River Watershed Based Plan.*

Figures


Jim Roe
KDOW NPS Section Supervisor
Lisa Hicks
KDOW QA Officer
Angie Wingfield
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Jane Benson
Mid America Remote Sensing Center
Mike Kemp
Load Modeler Murray State University
Stacey Hayden
Friends of Clarks River National Wildlife Refuge Sampling Manager
Maggie Morgan
Basin Coordinator Technical Support Data Manager
Steve Evans
Third Rock Consultants Biological Data Manager
Friends of Clarks River National Wildlife Refuge and other Project Partners
Four Rivers Basin Team Technical Support
Karla Johnston
Hancock Biological Station Laboratory Lead
Michael Flournoy/ David Lester
Microbac Laboratory
Bert Remley
Third Rock Consultants Biological Sampling and LaboratoryLead

Figure 1. Project organizational chart showing the relationships between project partners.

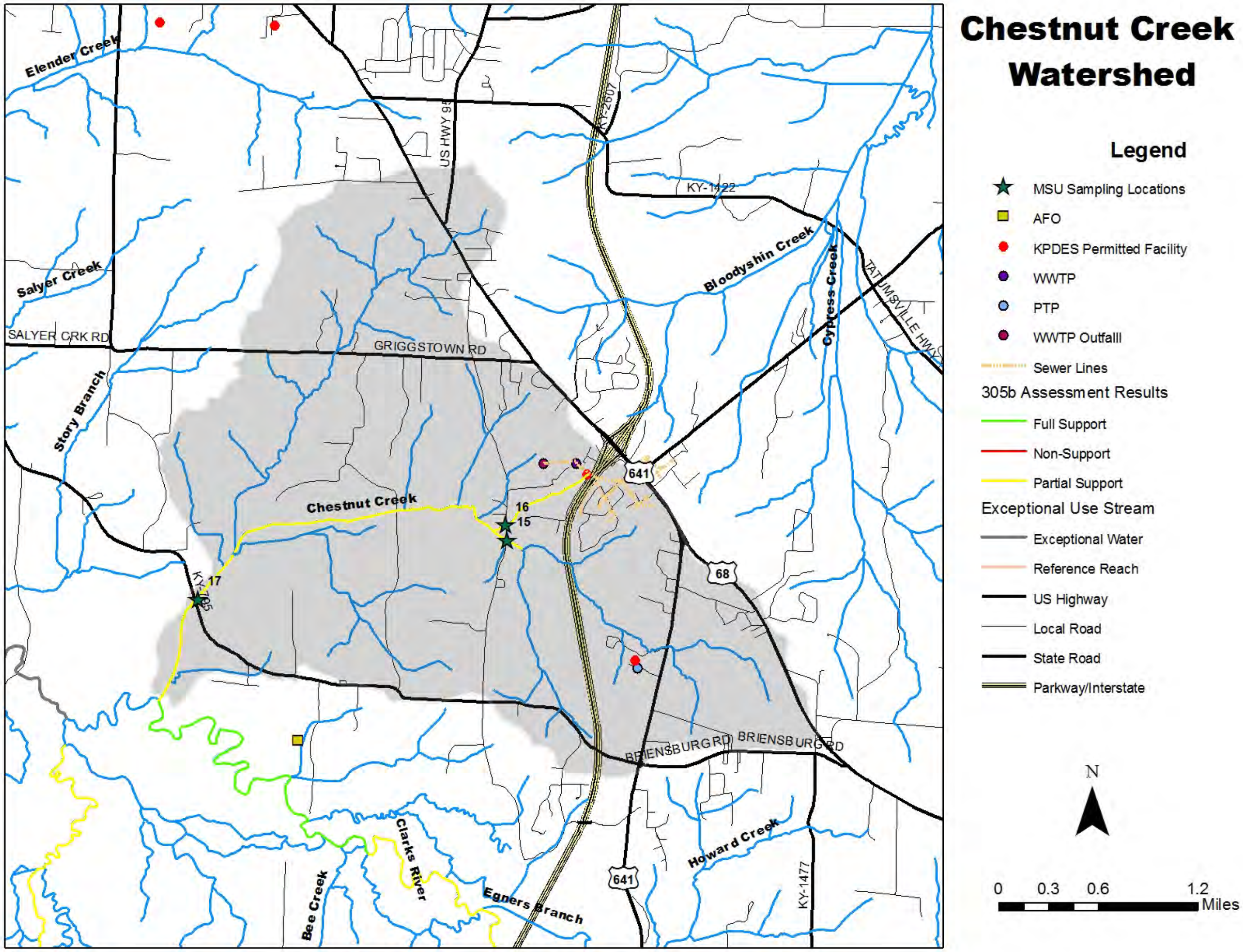

Figure 2. Map showing the Chestnut Creek drainage area.

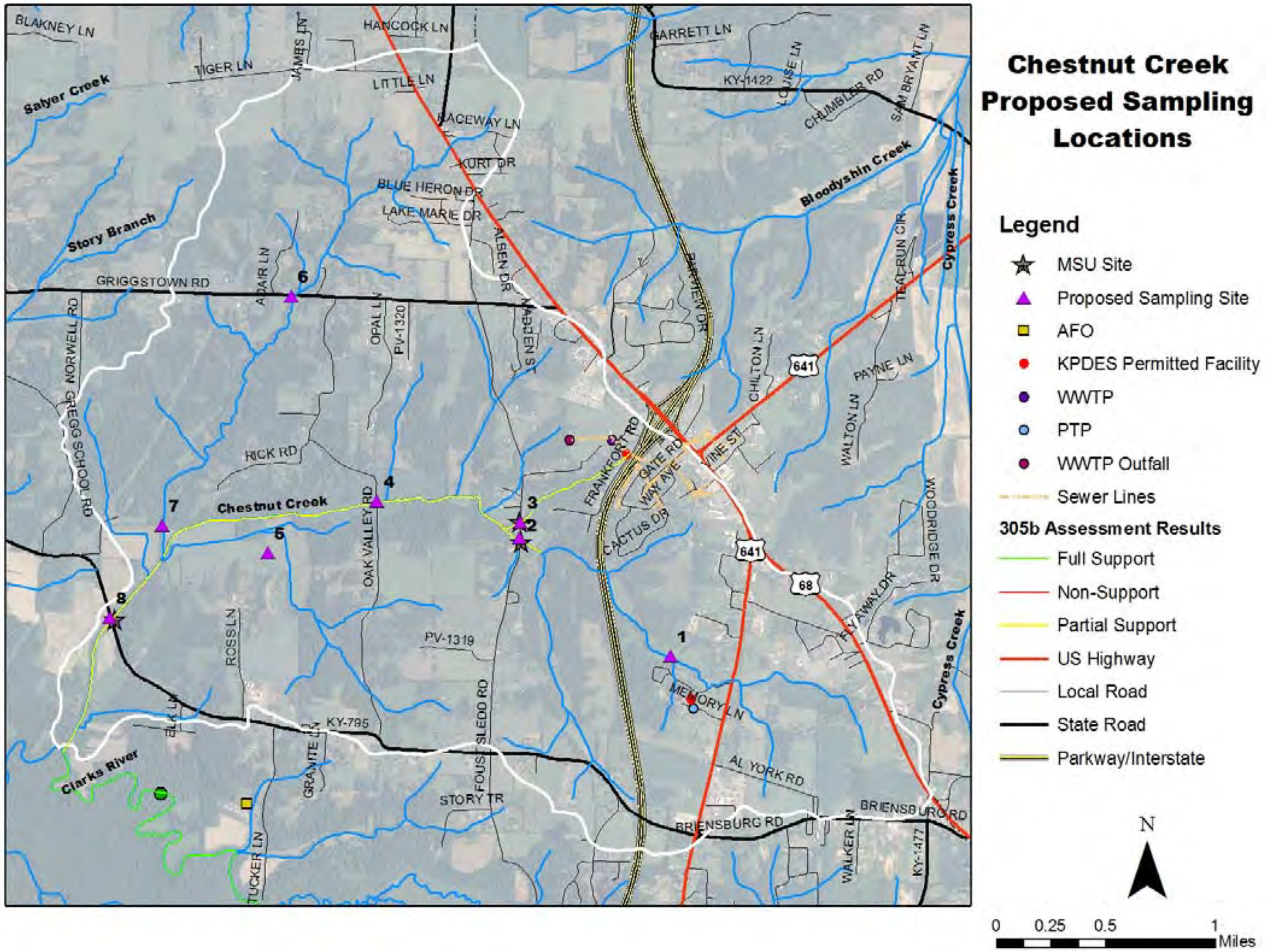

Figure 3. Proposed sampling locations for the Chestnut Creek watershed.

Field Activities Review Form

Sampling Location(s): ____

Sampling Date(s): ____

Mark each topic: Yes, No or N/A and comment as appropriate.

_____ All required information was entered into the field logbook in ink.
Comment:

_____ Deviations from SOPs, along with the date and reasoning, were documented in the field logbook.
Comment:

_____ Samples that could be affected by deviations from SOPs were noted in the logbook.
Comment:

_____ Field measurement data were recorded in the field logbook.
Comment:

_____ Field measurement calibrations were performed and results were within QAPP specified limits.
Comment:

_____ Field measurement QC samples were within the QAPP specified limits.
Comment:

_____ The correct number of samples for each type of analysis were collected from appropriate sites.
Comment:

_____ Field QC samples were collected at the correct frequency.
Comment:

_____ Samples were stored and/or shipped at the proper temperature.
Comment:

_____ Chain of Custody Records were documented properly.
Comment:

_____ Sample hold times were not exceeded during field operations.
Comment:

Reviewers Name: ____

Reviewers Signature: ____

Date: ________________________

Figure 4. Field activities review form.

Laboratory Activities Review Form

Project: ____

Sampling Date(s): ____

Analytical Laboratory: ____

Mark each topic: Yes, No or N/A and comment as appropriate.

_____ Chain of Custody Records were properly completed and signed by everyone involved in transporting the samples.
Comment:

_____ Samples arrived at the laboratory at the proper temperature.
Comment:

_____ Sample hold times were not exceeded.
Comment:

_____ All requested analyses were performed and document in the analytical report.
Comment:

_____ Analyses were performed according to the methods described in the QAPP.
Comment:

_____ A narrative describing any analysis problems was included in the final report.
Comment:

_____ Data qualifiers were flagged and explained.
Comment:

_____ Field blank results were included and were within the acceptance criteria.
Comment:

_____ Field duplicate results were included and were within QAPP defined acceptance criteria.
Comment:

Reviewers Name: ____

Reviewers Signature: _____________________________________

Date: ____________________

Figure 5. Laboratory activities review form.

Tables

Table 1. Sampling locations for Chestnut Creek drainage area.

Site ID	Latitude	Longitude	Upstream Basin (mi^2)	Description
1	36.912251°	-88.345379°	1.1	Headwater of Chestnut Creek with drainage from three package treatment plants and one mobile home park.
2	36.919828°	-88.35808°	2.4	Foust Sledd Road Crossing just downstream of dam on Chestnut Creek.
3	36.920888°	-88.358062°	0.2	Foust Sledd Road Crossing of UT to Chestnut Creek.
4	36.922022°	-88.369952°	3.8	Oak Valley Road Crossing of Chestnut Creek
5	36.918401°	-88.378839°	0.9	Southern UT to Chestnut Creek with pasture and croplands
6	36.935468°	-88.377504°	1.2	UT to Chestnut Creek at Griggstown Road
7	36.920019°	-88.387638°	2.1	Near mount of northern UT to Chestnut Creek
8	36.912072°	-88.392957°	7.7	Scale Road Crossing of Chestnut Creek, near the mouth

Table 2. Summary of environmental monitoring work to be conducted through this study.

Data Category	Parameter	Frequency	Proposed Schedule	Collection Methodology	Analytical Methodology (if applicable)	Detection Limit (if applicable)
Bacteria	*E. coli*	3 times; 5 times during one month of the PCR season	48 hour antecedent dry period and at least 0.4 inches of precipitation; May 1 to October 31, 2013 - 5 times during 30 days	Standard Operating Procedure: Bacteriological Sampling (DOWSOP03017)	IDEXX	1 MPN E. coli / 100 mLs
	Bacterial Source Tracking	Twice	Dry Event (at least 48 hrs after precip.); Wet Event (48 hour antecedent dry period and at least 0.4 inches of precipitation)	Standard Operating Procedure: Bacteriological Sampling (DOWSOP03017)	N/A	N/A
Nutrients	Nitrate/nitrite	3 Events	48 hour antecedent dry period and at least 0.4 inches of precipitation	Standard Operating Procedure: Sampling Surface Water Quality in Lotic Streams (DOWSOP03015) with deviations from the Filtered Sample Hand Pump technique as described in section B2	Standard Methods for Examination of Water and Wastewater Method #4500-NO_3 F	.004 mg/L
	Ammonia	3 Events	48 hour antecedent dry period and at least 0.4 inches of precipitation	Standard Operating Procedure: Sampling Surface Water Quality in Lotic Streams (DOWSOP03015) with deviations from the Filtered Sample Hand Pump technique as described in section B2	Standard Methods for Examination of Water and Wastewater Method #4500-NH_3 G	.006 mg/L
	Total Kjeldahl Nitrogen	3 Events	48 hour antecedent dry period and at least 0.4 inches of precipitation	Standard Operating Procedure: Sampling Surface Water Quality in Lotic Streams (DOWSOP03015)	Standard Methods for Examination of Water and Wastewater Method #4500-N_{org} C	0.2 mg/L
	Total Phosphorus	3 Events	48 hour antecedent dry period and at least 0.4 inches of precipitation	Standard Operating Procedure: Sampling Surface Water Quality in Lotic Streams (DOWSOP03015)	Standard Methods for Examination of Water and Wastewater Method #4500-P F	.01 mg/L
	Orthophosphate	3 Events	48 hour antecedent dry period and at least 0.4 inches of precipitation	Standard Operating Procedure: Sampling Surface Water Quality in Lotic Streams (DOWSOP03015)	Standard Methods for Examination of Water and Wastewater Method #4500-P F	.01 mg/L
	Carbonaceous Biochemical Oxygen Demand	3 Events	48 hour antecedent dry period and at least 0.4 inches of precipitation	Standard Operating Procedure: Sampling Surface Water Quality in Lotic Streams (DOWSOP03015)	Standard Methods for Examination of Water and Wastewater Method #5210B	2 mg/L
Sediment	Total Suspended Solids	3 Events	48 hour antecedent dry period and at least 0.4 inches of precipitation	Standard Operating Procedure: Sampling Surface Water Quality in Lotic Streams (DOWSOP03015)	USGS Method # I3765-85	1 mg/L
Field Data	Flow	Each site Visit	Each site Visit	Standard Operating Procedure: Measuring Stream Discharge (DOWSOP03019)	N/A	N/A
	Turbidity	Each site Visit	Each site Visit	Standard Operating Procedure: *In situ* Water Quality Measurements and Meter Calibration (DOWSOP03014)	N/A	N/A

Table 2. Summary of environmental monitoring work to be conducted through this study, continued.

Data Category	Parameter	Frequency	Proposed Schedule	Collection Methodology	Analytical Methodology (if applicable)	Detection Limit (if applicable)
Field Data	pH	Each site Visit	Each site Visit	Standard Operating Procedure: *In situ* Water Quality Measurements and Meter Calibration (DOWSOP03014)	N/A	N/A
	Dissolved Oxygen	Each site Visit	Each site Visit	Standard Operating Procedure: *In situ* Water Quality Measurements and Meter Calibration (DOWSOP03014)	N/A	N/A
	Conductivity	Each site Visit	Each site Visit	Standard Operating Procedure: *In situ* Water Quality Measurements and Meter Calibration (DOWSOP03014)	N/A	N/A
	% Saturation	Each site Visit	Each site Visit	Standard Operating Procedure: *In situ* Water Quality Measurements and Meter Calibration (DOWSOP03014)	N/A	N/A
	Temperature	Each site Visit	Each site Visit	Standard Operating Procedure: *In situ* Water Quality Measurements and Meter Calibration (DOWSOP03014)	N/A	N/A
Habitat	Habitat Assessment	Once	Coincident with Benthic Macroinvertebrate collection	Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish (EPA 841-B-99-002)	N/A	N/A
Biology	Biological Assessment	Once	Headwater: Mar to May 2013 Wadeable: June to Sept 2013	Benthic Macroinvertebrates Collection Methods in Wadeable Streams SOP (DOWSOP03003)	N/A	N/A

Table 3. Data quality indicators for this project.

Parameter	Data Quality Indicator				
	Precision	**Bias**	**Representativeness**	**Comparability**	**Completeness**
E. coli	Field duplicates; Calculate RPD, but disqualification at the discretion of the project team based on quantitative and qualitative review of data	Lab Blanks, Positive Lab Control Sample with each media batch; Disqualification if %recovery exceeds 75% to 125%	Qualitative Records Review; Disqualification if records review shows inappropriate collection and/or analytical methodology	Qualitative Data Review; Disqualification if review shows inconsistent field and laboratory data	Quantitative Evaluation of Records; Disqualification if review shows incomplete record keeping. Target goal of 90% completeness with regards to the number of usable samples
Bacterial Source Tracking	Field duplicates; Disqualification if data review indicates large differences in results from duplicate samples	Laboratory Control Samples	Qualitative Records Review; Disqualification if records review shows inappropriate collection and/or analytical methodology	Qualitative Data Review; Disqualification if review shows inconsistent field and laboratory data	Quantitative Evaluation of Records; Disqualification if review shows incomplete record keeping. Target goal of 90% completeness with regards to the number of usable samples
Nitrate/nitrite	Field duplicates; Disqualification if RPD>20%	Equipment Blanks, Equipment Calibration, Check Standards every 10 to 20 samples; Disqualification if %recovery exceeds 75% to 125%	Qualitative Records Review; Disqualification if records review shows inappropriate collection and/or analytical methodology	Qualitative Data Review; Disqualification if review shows inconsistent field and laboratory data	Quantitative Evaluation of Records; Disqualification if review shows incomplete record keeping. Target goal of 90% completeness with regards to the number of usable samples
Ammonia	Field duplicates; Disqualification if RPD>20%	Equipment Blanks, Equipment Calibration, Check Standards every 10 to 20 samples; Disqualification if %recovery exceeds 75% to 125%	Qualitative Records Review; Disqualification if records review shows inappropriate collection and/or analytical methodology	Qualitative Data Review; Disqualification if review shows inconsistent field and laboratory data	Quantitative Evaluation of Records; Disqualification if review shows incomplete record keeping. Target goal of 90% completeness with regards to the number of usable samples
Total Kjeldahl Nitrogen	Field duplicates; Disqualification if RPD>20%	Equipment Blanks, Equipment Calibration; Disqualification if %recovery exceeds 75% to 125%	Qualitative Records Review; Disqualification if records review shows inappropriate collection and/or analytical methodology	Qualitative Data Review; Disqualification if review shows inconsistent field and laboratory data	Quantitative Evaluation of Records; Disqualification if review shows incomplete record keeping. Target goal of 90% completeness with regards to the number of usable samples

Table 3. Data quality indicators for this project, continued

Parameter	Data Quality Indicator				
	Precision	**Bias**	**Representativeness**	**Comparability**	**Completeness**
Total Phosphorus	Field duplicates; Disqualification if RPD>20%	Equipment Blanks, Equipment Calibration; Disqualification if %recovery exceeds 75% to 125%	Qualitative Records Review; Disqualification if records review shows inappropriate collection and/or analytical methodology	Qualitative Data Review; Disqualification if review shows inconsistent field and laboratory data	Quantitative Evaluation of Records; Disqualification if review shows incomplete record keeping. Target goal of 90% completeness with regards to the number of usable samples
Orthophosphate	Field duplicates; Disqualification if RPD>20%	Equipment Blanks, Equipment Calibration; Disqualification if %recovery exceeds 75% to 125%	Qualitative Records Review; Disqualification if records review shows inappropriate collection and/or analytical methodology	Qualitative Data Review; Disqualification if review shows inconsistent field and laboratory data	Quantitative Evaluation of Records; Disqualification if review shows incomplete record keeping. Target goal of 90% completeness with regards to the number of usable samples
Carbonaceous Biochemical Oxygen Demand	Field duplicates; Disqualification if RPD>20%	Equipment Blanks, Equipment Calibration; Disqualification if %recovery exceeds 75% to 125%	Qualitative Records Review; Disqualification if records review shows inappropriate collection and/or analytical methodology	Qualitative Data Review; Disqualification if review shows inconsistent field and laboratory data	Quantitative Evaluation of Records; Disqualification if review shows incomplete record keeping. Target goal of 90% completeness with regards to the number of usable samples
Total Suspended Solids	Field duplicates; Disqualification if RPD>20%	Equipment Blanks, Equipment Calibration; Disqualification if %recovery exceeds 75% to 125%	Qualitative Records Review; Disqualification if records review shows inappropriate collection and/or analytical methodology	Qualitative Data Review; Disqualification if review shows inconsistent field and laboratory data	Quantitative Evaluation of Records; Disqualification if review shows incomplete record keeping. Target goal of 90% completeness with regards to the number of usable samples
Field Data	Field duplicates (one per sampling event per parameter); Disqualification if RPD>20%	Meter Calibration; Disqualification if %recovery exceeds 75% to 125%	Qualitative Records Review; Disqualification if records review shows inappropriate collection and/or analytical methodology	Qualitative Data Review; Disqualification if review shows inconsistent field and laboratory data	Quantitative Evaluation of Records; Disqualification if review shows incomplete record keeping. Target goal of 90% completeness with regards to the number of usable samples
Biological Assessment	Taxonomic check; Reconciliation if ≤90% comparability	N/A	Sampling during index period and at least 2 weeks after a scouring flow event	Qualitative Data Review; Disqualification if review shows inconsistent field and laboratory data	Quantitative Evaluation of Records; Disqualification if review shows incomplete record keeping. Target goal of 100% completeness with regards to the number of usable samples

Table 4. Collection methodologies and sample container information to be used during sample collection.

Parameter	Collection Methodology	Sample Container	Preservative	Max Holding Time
E. coli	Standard Operating Procedure: Bacteriological Sampling (DOWSOP03017)	Sterile 120 mL snap top bottle	N/A	6 hours
Bacterial Source Tracking	Standard Operating Procedure: Bacteriological Sampling (DOWSOP03017)	Sterile 500 mL graduated bottle	N/A	8 hours (and then freeze until delivery to the laboratory)
Nitrate/nitrite	Standard Operating Procedure: Sampling Surface Water Quality in Lotic Streams (DOWSOP03015)	Polyethylene plastic sampling bottle	Filter, cool to <= 4^{o}C	28 days
Ammonia	Standard Operating Procedure: Sampling Surface Water Quality in Lotic Streams (DOWSOP03015)	Polyethylene plastic sampling bottle	Filter, cool to <= 4^{o}C	24 hours
Total Kjeldahl Nitrogen	Standard Operating Procedure: Sampling Surface Water Quality in Lotic Streams (DOWSOP03015)	Glass or plastic	Sulfuric acid	28 days
Total Phosphorus	Standard Operating Procedure: Sampling Surface Water Quality in Lotic Streams (DOWSOP03015)	Glass or plastic	Sulfuric acid	28 days
Orthophosphate	Standard Operating Procedure: Sampling Surface Water Quality in Lotic Streams (DOWSOP03015)	Glass or plastic	Filter, cool to <= 4^{o}C	48 hours
Carbonaceous Biochemical Oxygen Demand	Standard Operating Procedure: Sampling Surface Water Quality in Lotic Streams (DOWSOP03015)	Plastic 1 L bottle	N/A	48 hours
Total Suspended Solids	Standard Operating Procedure: Sampling Surface Water Quality in Lotic Streams (DOWSOP03015)	Plastic 1 L bottle	N/A	7 days
Flow	Standard Operating Procedure: Measuring Stream Discharge (DOWSOP03019)	Field parameter	N/A	N/A
Turbidity	Standard Operating Procedure: *In situ* Water Quality Measurements and Meter Calibration (DOWSOP03014)	Field parameter	N/A	N/A
pH	Standard Operating Procedure: *In situ* Water Quality Measurements and Meter Calibration (DOWSOP03014)	Field parameter	N/A	N/A
Dissolved Oxygen	Standard Operating Procedure: *In situ* Water Quality Measurements and Meter Calibration (DOWSOP03014)	Field parameter	N/A	N/A
Conductivity	Standard Operating Procedure: *In situ* Water Quality Measurements and Meter Calibration (DOWSOP03014)	Field parameter	N/A	N/A
% Saturation	Standard Operating Procedure: *In situ* Water Quality Measurements and Meter Calibration (DOWSOP03014)	Field parameter	N/A	N/A
Temperature	Standard Operating Procedure: *In situ* Water Quality Measurements and Meter Calibration (DOWSOP03014)	Field parameter	N/A	N/A
Habitat Assessment	Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish (EPA 841-B-99-002)	Field parameter	N/A	N/A
Biological Assessment	Benthic Macroinvertebrates Collection Methods in Wadeable Streams SOP (DOWSOP03003)	Wide mouthed bottle	95% ethyl alcohol	N/A

Table 5. Meters to be used during collection of field data.

Field Data Parameter	Meter
Flow	Global Water Flow Probe Hand-held Flowmeter
Turbidity	Hach 2100Q Portable Turbidmeter
pH	YSI Multiparameter ProPlus
Dissolved Oxygen	YSI Multiparameter ProPlus
Conductivity	YSI Multiparameter ProPlus
% Saturation	YSI Multiparameter ProPlus
Temperature	YSI Multiparameter ProPlus
Biological Assessment / Habitat Assesment	Hydrolab MS5 Sonde or equivalent (for field *in situ* parameters)

Table 6. Summary of sampling methods for macroinvertebrates.

<table>
<tr><th>Technique</th><th>Sampling Device</th><th>Habitat</th><th>Replicates Composited for Wadeable Sites</th><th>Replicates Composited for Headwater Sites</th></tr>
<tr><td colspan="5">Semi-Quantitaive</td></tr>
<tr><td>1m^2 kicknet / seine</td><td>Kicknet / seine and wash bucket</td><td>Riffle</td><td>4 x 0.25m^2</td><td>4 x 0.25m^2</td></tr>
<tr><td colspan="5">Multi-Habitat Sweep</td></tr>
<tr><td>Undercut banks / roots</td><td rowspan="6">D-frame or triangular dip net and wash bucket</td><td rowspan="5">All applicable</td><td>3</td><td>3</td></tr>
<tr><td>Sticks / Wood</td><td>N/A</td><td>3</td></tr>
<tr><td>Emergent vegetation</td><td>3</td><td>N/A</td></tr>
<tr><td>Bedrock / slabrock</td><td>3</td><td>N/A</td></tr>
<tr><td>J. americana beds</td><td>3</td><td>N/A</td></tr>
<tr><td>Leaf packs</td><td>Riffle – Run – Pool</td><td>3</td><td>3</td></tr>
<tr><td>Silt, sand, fine gravel</td><td>US #10 Sieve</td><td>Margins</td><td>3</td><td>3</td></tr>
<tr><td>Aufwuchs sample</td><td>300 µm nitrex sampler / mesh</td><td rowspan="3">Riffle – Run - Pool</td><td>3</td><td>N/A</td></tr>
<tr><td>Rock pick</td><td rowspan="2">Fine-tipped forceps and wash bucket</td><td>15 total (5 each)</td><td>5 small boulders</td></tr>
<tr><td>Wood sample</td><td>3 to 6 linear meters</td><td>2 linear meters</td></tr>
</table>

Table 7. Contact information for labs to be used in this study.

Lab	Primary Contact	Address	Phone Number
University of Tennessee Center for Environmental Biotechnology	Alice Layton	676 Dabney Hall Knoxville, TN 37996	(865) 974-8080
Hancock Biological Station	Karla Johnston	561 Emma Drive Murray, KY 42071	(270) 474-2272
Microbac Laboratories Main Location	David Lester	3323 Gilmore Industrial Blvd. Louisville, KY 40213	(502) 962-6400
Microbac Laboratories Paducah Satellite Location	Stan Cooke	5309 Reidland Road Paducah, KY 42003	(270) 898-3637
Third Rock Consultants Macroinvertebrate Laboratory	Bert Remley	2526 Regency Road, Suite 180 Lexington, KY 40503	(859) 977-2000

Table 8. Laboratory data quality flags.

AR	Results reported on an as received basis.
B1	Analyte value in the method blank above control limit.
B2	Analyte value in the method blank is between the method detection limit and the reporting detection limit.
C1	Continuing calibration verification (CCV) above upper control limit, analyte(s) not detected.
CE	Conclusion Entry
DI	Surrogate recoveries not calculated due to necessary sample dilution.
DW	Results reported on a dry weight basis.
E1	Elevated reporting or detection limit(s) due to sample matrix interference and sample dilution.
E2	Elevated reporting or detection limit(s) due to high analyte concentration and sample dilution.
E3	Elevated reporting or detection limit(s) due to insufficient sample volume
F1	Test Method EPA 1010 Not Valid For Solid Samples. Samples Analyzed By A Modified 1010 Method.
F2	No Flash Observed; Test Flame Is Being Extinguished By Sample At The Reported Temperature.
H1	Sample received outside of holding time for these analytes.
H2	Analyte was prepared and/or analyzed outside of the analytical method holding time.
J1	The analyte was positively identified; analyte was detected between the reporting limit and method detection limit and the result is an estimated value.
J2	The analyte was positively identified; the result is above the quantitation range and is an estimated value.
L1	Lab control sample (LCS) recovery below lower control limit, all other batch QC acceptable.
L2	Lab control sample (LCS) recovery above upper control limit, all other batch QC acceptable.
L3	Lab control sample (LCS) recovery above upper control limit, analyte not detected.
M1	Matrix Spike Recovery Outside Control Limits Due To Sample Matrix Interference, Biased High.
M2	Matrix Spike Recovery Outside Control Limits Due To Sample Matrix Interference, Biased Low.
M3	Matrix Spike Recovery Outside Control Limits Due To Analyte Concentration. Matrix Spike Evaluation not applicable when sample concentration is >= 4X Spike Concentration.
MC	Miscellaneous (see conclusion statement)
N	The analysis indicates the presence of an analyte for which there is presumptive evidence to make a "tentative identification."Any associated quantitation is an estimate based on industry standard practices.
ND	Not detected at or below the reporting limit (or method detection limit, if listed).
NJ	The analysis indicates the presence of an analyte that has been "tentatively identified" and is an estimated value.
OOC	The above value, over the specification limit, was verified by a second analysis.
P1	Sample received was improperly preserved for these analytes.
P2	Sample pH greater than method limit of 2.
R	The sample results are rejected due to serious deficiencies in the ability to analyze the sample and meet quality control criteria. the presence or absence of the analyte cannot be verified.
R1	Relative percent difference (RPD) of matrix spike duplicates outside of control limit.
R2	Relative percent difference (RPD) of LCS duplicates outside of control limit.
R3	Relative percent difference (RPD) of sample duplicates outside of control limit.
S1	One or more surrogates outside control limits, no target analytes detected.
S2	One or more surrogates outside control limits due to matrix interference.
S3	One or more surrogates outside control limits. The data was accepted based on the valid recovery of remaining surrogate(s).
SUB	Analysis subcontracted.
U	Analyte was analyzed for, but was not detected above the reported sample quantitation limit.
UJ	Analyte was not detected above the reporting limit, however, the reporting limit is approximate & may or may not represent the actual limit of quantitation necessary to accurately & precisely measure the analyte in the sample.
V	Analyte concentration estimated due to sample matrix interference and/or high analyte concentration interference.

Visual Stream Assessments

Chestnut Creek Watershed
Marshall County, Kentucky

Prepared for
Friends of Clarks River
National Wildlife Refuge

May 31, 2013

Prepared by
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Steve Evans

Reviewed by:

Casey Mattingly

THIRD ROCK CONSULTANTS

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Environmental Analysis & Restoration

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APPENDIX

I. INTRODUCTION

This report summarizes results for visual stream assessments in the Chestnut Creek Watershed. The survey was conducted under a Section 319(h) Nonpoint Source Implementation Program Cooperative Agreement (#C9994861-09) awarded by the Commonwealth of Kentucky, Energy and Environment Cabinet, Department for Environmental Protection, Division of Water (KDOW) to Friends of the Clarks River National Wildlife Refuge based on an approved work plan. The survey was conducted according to the preapproved Quality Assurance Project Plan (Third Rock 2013).

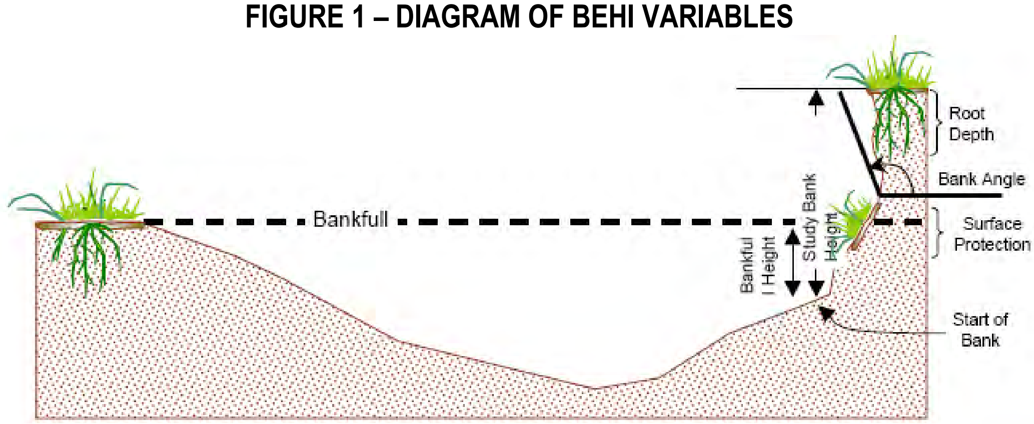
Areas of high *E. coli* and total suspended solids concentrations were visually assessed in order to identify potential fecal sources and erosional areas. Potential fecal sources were documented using a GPS and photograph. For severe erosion areas (erosion above normal levels for the region), the length of the erosion area was measured and the site documented by photographs and GPS. The bank erosion hazard index (BEHI) and near-bank stress (NBS) ratings were assessed at these sites. The measurements were used to provide an approximation of the amount of sediment loading associated with bank erosion in the Chestnut Creek Watershed.

II. METHODS

The prediction of streambank erosion rates was conducted according to "Bank Assessment for Non-point source Consequences of Sediment" (BANCS) method as detailed in *Watershed Assessment of River Stability and Sediment Supply (WARSS)* (Rosgen 2006). This method utilizes two bank erodibility estimation tools: the Bank Erosion Hazard Index (BEHI), and Near Bank Stress (NBS). These tools are used to estimate an erosion rate that is multiplied by the bank height and the length of bank to provide an estimate of cubic yards and/or tons of sediment/year.

All streams in the Chestnut Creek Watershed were visually assessed by field technicians, and stream banks determined to have erosion rates above "normal" levels by field technicians were measured in the field. The BEHI variables and length of eroded bank were recorded in field notebooks, photographs of each bank were taken, and GPS coordinates were measured using Garmin handheld units.

FIGURE 1 – DIAGRAM OF BEHI VARIABLES



(*Source: EPA*)

At each site, the BEHI was determined by measuring seven variables: study bank height, bankfull height, root depth, bank angle, surface protection, bank material, and stratification of bank material. These variables are shown in Figure 1 and described fully in Chapter 5 of

Watershed Assessment of River Stability and Sediment Supply (WARSS) (Rosgen 2006). The study bank height / bankfull height ratio, root depth / bankfull height, weighted root density, bank angle, and surface protection measurements were converted to BEHI ratings using established relationships varying between Very Low and Very High with values between 0 and 10 for each variable. These numeric scores were then summed and adjusted for bank materials and stratification of bank materials to generate an overall BEHI score and risk rating.

The NBS was determined based on aerial photography and field observations using the ratio of radius of curvature to bankfull width. The bankfull width (W_{bkf}) was based on field observations, and the radius of curvature (R_c) was determined based on ArcGIS measurements from aerial photographs. The R_c/ W_{bkf} ratio was converted into a NBS rating based on the conversion table in Table 1.

TABLE 1 – CONVERSION TABLE OF R_C/ W_{BKF} VALUES TO NBS RATINGS

R_c/ W_{bkf} ratio	NBS Rating
>3.00	Very Low
2.21 – 3.00	Low
2.01 – 2.20	Moderate
1.81 – 2.00	High
1.50 – 1.80	Very High
<1.50	Extreme

The BEHI Rating and NBS rating were utilized to determine the erosion rate for each bank based upon the predicted erosion rates based upon Colorado USDA Forest Service (1989) data for streams found in sedimentary and/or metamorphic rock, as shown in Rosgen 2006. While is data is not regionally specific, it is believed to provide an approximation of erosion rates sufficient for the purposes of the watershed based plan. For the watershed based plan, the location of severe erosion reaches and an approximate contribution to the overall sediment loading is important for the direction of remediation activities. Should a more regional curve be developed in the future, the measured BEHI and NBS scores in this report could be recalculated for a more accurate approximation of sediment load from erosion.

To determine potential sources of fecal pollution, field technicians were instructed to note any potential signs of potential fecal sources including livestock access of close proximity, straight pipes, suds, sewage, gray or murky water, toilet paper, smell, and other indicators of fecal pollution. GPS locations are photographs were utilized to record the potential locations.

III. RESULTS

A. Bank Erosion

Third Rock field technicians visually surveyed the Chestnut Creek Watershed on April 17, 18, and May 1, 2013. Tributaries in the watershed were visually surveyed by field technicians while walking each reach until the stream narrowed to the point that no further severe erosion areas were probable upstream. Most of the streams in the watershed had some form of erosion, but only severe erosion areas were measured during this survey. Twenty-eight (28) banks were determined to have severe bank erosion. The locations of these severe erosion areas are shown in Exhibit 1, page 3, and Table 2, page 4 summarizes the measurements recorded at each site. Photos of the reaches are shown in Appendix A.

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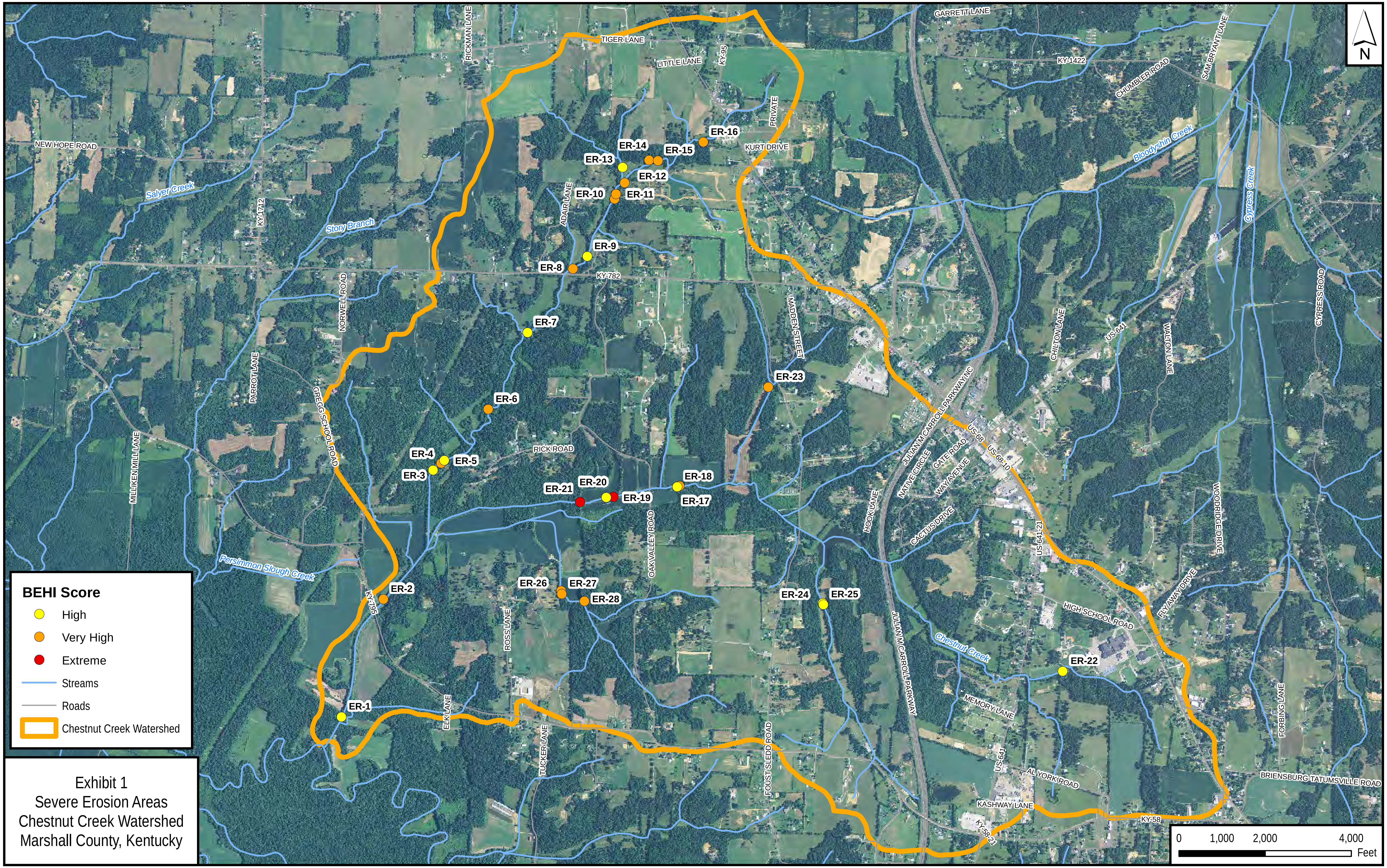

Exhibit 1
Severe Erosion Areas
Chestnut Creek Watershed
Marshall County, Kentucky

TABLE 2 – BANK EROSION HAZARD INDEX MEASUREMENTS FOR SEVERE EROSION REACHES IN CHESTNUT CREEK WATERSHED

ID	Date	Surveyors	Reach Length (ft)	Bank	Study Bank Height (ft)	Bankfull Height (ft)	Ratio A/B	Root Depth (ft)	Ratio D/A	Root Density (%)	Weighted Root Density (%)	Bank Angle (Degrees)	Surface Protection (%)	Bank Material Adjustment	Stratification Adjustment	TOTAL BEHI	BEHI Adjective
ER-1	4/17/2013	EJS, JDW	150	L	4	1.5	2.7	2.5	0.63	40	25%	80	5	3	0	31.5	**High**
ER-2	4/18/2013	EJS, JDW	108	R	6	1.5	4.0	1	0.17	20	3%	80	40	2	0	40	**Very High**
ER-3	4/18/2013	EJS, JDW	80	L	5	2	2.5	2	0.40	40	16%	95	18	0	0	36.7	**High**
ER-4	4/18/2013	EJS, JDW	100	L	5.5	1.5	3.7	1.5	0.27	60	16%	90	0	0	0	42.3	**Very High**
ER-5	4/18/2013	EJS, JDW	100	R	5.5	1.5	3.7	1.5	0.27	60	16%	60	70	0	0	31.3	**High**
ER-6	4/18/2013	EJS, JDW	38	L	4	2.5	1.6	1.5	0.38	35	13%	85	0	2	5	43.3	**Very High**
ER-7	4/18/2013	EJS, JDW	100	L	5	2.25	2.2	1	0.20	20	4%	75	50	0	0	34.1	**High**
ER-8	4/18/2013	EJS, JDW	85	L	6	2	3.0	3	0.50	70	35%	90	20	1	5	40	**Very High**
ER-9	4/18/2013	EJS, JDW	67	L	8	2.5	3.2	3.5	0.44	40	18%	90	5	0	0	39.7	**High**
ER-10	4/18/2013	EJS, JDW	78	L	8.5	2	4.3	2	0.24	30	7%	85	0	0	5	47.5	**Very High**
ER-11	4/18/2013	EJS, JDW	150	L	8	2.5	3.2	2	0.25	40	10%	80	50	2	5	42.5	**Very High**
ER-12	4/18/2013	EJS, JDW	84	L	9	2	4.5	3	0.33	30	10%	85	0	2	5	48	**Very High**
ER-13	4/18/2013	EJS, JDW	135	L	6.5	2.5	2.6	1.5	0.23	40	9%	75	40	2	0	36	**High**
ER-14	4/18/2013	EJS, JDW	102	R	9	2.5	3.6	3	0.33	30	10%	90	10	1	5	47	**Very High**
ER-15	4/18/2013	EJS, JDW	75	R	8	2	4.0	3	0.38	30	11%	90	0	2	5	48.3	**Very High**
ER-16	4/18/2013	EJS, JDW	102	R	6.5	1.5	4.3	2	0.31	30	9%	90	10	1	0	42.3	**Very High**
ER-17	4/18/2013	EJS, JDW	50	R	9	1.5	6.0	2	0.22	25	6%	90	25	0	0	40.3	**Very High**
ER-18	4/18/2013	EJS, JDW	120	L	7.5	2.5	3.0	2.5	0.33	70	23%	90	5	0	0	39.5	**High**
ER-19	4/18/2013	EJS, JDW	60	L	10	2	5.0	0.5	0.05	10	1%	90	0	0	5	52.5	**Extreme**
ER-20	4/18/2013	EJS, JDW	60	L	10	2	5.0	1.25	0.13	20	3%	90	40	0	0	36.3	**High**
ER-21	4/18/2013	EJS, JDW	30	R	10	Soil in stream from agricultural channelization, assumed **Extreme**											**Extreme**
ER-22	5/1/2013	EJS, WCO	150	L	5.5	2.5	2.2	1.5	0.27	15	4%	80	5	0	0	39.9	**High**
ER-23	5/1/2013	EJS, WCO	90	R	10	3	3.3	2	0.20	20	4%	80	60	0	5	40.7	**Very High**
ER-24	5/1/2013	EJS, WCO	50	L	6	2.5	2.4	1.5	0.25	35	9%	85	20	0	0	37.8	**High**
ER-25	5/1/2013	EJS, WCO	75	R	6	2.5	2.4	1.5	0.25	35	9%	85	20	0	0	37.8	**High**
ER-26	5/1/2013	EJS, WCO	200	L	7	2	3.5	0	0.00	0	0%	75	20	5	0	47	**Very High**
ER-27	5/1/2013	EJS, WCO	200	R	7	2	3.5	0	0.00	0	0%	75	20	5	0	47	**Very High**
ER-28	5/1/2013	EJS, WCO	75	R	9	2.5	3.6	0	0.00	0	0%	90	70	0	0	41	**Very High**

A total of 2,714 linear feet of bank were found to have severe erosion. The width of these streams ranged from 7 feet to 30 feet at the riffle reach bankfull height. Eleven banks with a total length of 1,087 feet had a BEHI rating of “High”, 15 reaches with a total length of 1,537 feet had a rating of “Very High”, and two reaches with a total length of 90 feet were “Extreme”. The banks ranged in height from four to ten feet with an average height of seven feet. However, the bankfull height ranged from 1.5 to 3 feet, with an average of 2 feet indicating that all streams were deeply channelized, entrenched. The root depth ranged from none to 3.5 feet with an average of 1.7 feet. Thus, only 30% of the study banks on average had root growth to aid in the stabilization of the bank and reduction of erosion. The bank angle ranged from 60 degrees to 95 degrees, indicating moderate to very high susceptibility to mass erosion. On average, only 22 percent of the banks had protection from sod mats, woody debris, or plant material. For the bank material adjustment, partial points were added based on the percentage of gravel or sand on the bank as opposed to silt / clay. Adjustments ranged from zero to five, with a one point adjustment on average. Some bank stratification adjustments were recorded but not commonly. One location, ER-21, had been altered due to agricultural channelization and piling soil along the stream. Therefore, this site could not be evaluated as typical bank erosion but was assigned a rating of "Extreme" due to the unconsolidated nature of the sediment.

TABLE 3 – NEAR BANK STRESS RATINGS FOR SEVERE EROSION REACHES IN CHESTNUT CREEK WATERSHED

ID	Radius of Curvature (ft)	Bankfull width at riffle reach (ft)	NBS (Rc/Wbkf ratio)	NBS Rating
ER-1	475	20	23.8	Very Low
ER-2	700	24	29.2	Very Low
ER-3	265	17	15.6	Very Low
ER-4	420	22	19.1	Very Low
ER-5	420	22	19.1	Very Low
ER-6	80	15	5.3	Very Low
ER-7	50	30	1.7	Very High
ER-8	280	12	23.3	Very Low
ER-9	225	16	14.1	Very Low
ER-10	240	11	21.8	Very Low
ER-11	100	16	6.3	Very Low
ER-12	120	7	17.1	Very Low
ER-13	195	10	19.5	Very Low
ER-14	130	12	10.8	Very Low
ER-15	85	10	8.5	Very Low
ER-16	255	9	28.3	Very Low
ER-17	265	16	16.6	Very Low
ER-18	270	14	19.3	Very Low
ER-19	475	15	31.7	Very Low
ER-20	450	15	30.0	Very Low
ER-21	475	15	31.7	Very Low
ER-22	145	10	14.5	Very Low
ER-23	125	20	6.3	Very Low
ER-24	675	17	39.7	Very Low
ER-25	675	17	39.7	Very Low
ER-26	175	20	8.8	Very Low
ER-27	175	20	8.8	Very Low
ER-28	65	12	5.4	Very Low

For each bank, the radius of curvature was measured at each site from aerial photographs, with estimated radii ranging from 50 feet to 700 feet. These large measurements, as compared to the stream width, indicate that most reaches with severe erosion were not located in sharp bends. All of the NBS ratings were “Very Low” with the exception of ER-7, which was “Very High”.

The bank erosion rates were predicted based on the Colorado USDA Forest Service data based on each bank’s BEHI and NBS ratings. The predicted erosion rates are shown in Table 4, page 7, an overall average of over 2 inches of soil loss per year. These rates (in feet per year) were multiplied by the length and height of the affected bank and then converted from cubic feet to tons (divided by 20.77). In total, 167.5 tons of sediment, per year, was predicted to be eroding from just the severely eroding banks in the watershed. This indicates that bank erosion is a significant contributor to the sediment load in the watershed and should be addressed through remediation activities including stream bank stabilization and natural stream channel restoration.

B. Potential Fecal Sources

Only two locations were noted as possible sources of fecal pollution, other than known permitted discharges, during the field visual assessments. These locations are shown in Exhibit 2 with pictures shown in the Appendix.

One location showed signs of cattle access to the stream via a trampled stream bank. Cattle which have access to streams can contribute to the overall fecal load at a greater rate, due to direct input, than cattle which have an alternative water source and are excluded from the stream.

The other potential fecal source identified during the visual survey was a rooster operation with about 50 animals in cages located near the stream. Field technicians noted a strong smell of feces from the location. Although some filtration could be provided by the narrow grass strip located between the cages and the stream, it is suspected that runoff from this site may contribute to the nitrogen and fecal bacteria loading in the watershed.

Other potential locations of fecal input may be located within the watershed but were not detected based on the visual survey from the stream corridor.

REFERENCES

Rosgen, Dave. 2006. Watershed Assessment of River Stability and Sediment Supply (WARSSS). Wildland Hydrology, Fort Collins, Colorado.

Third Rock Consultants. 2013. “Quality Assurance Project Plan: Chestnut Creek WBP.” Grant Number: C9994861-09. Prepared for Kentucky Division of Water, 200 Fair Oaks Lane Frankfort, KY 40601.

TABLE 4 – PREDICTED EROSION RATES AND ANNUAL LOADS FOR SEVERE EROSION REACHES IN CHESTNUT CREEK WATERSHED

ID	Bank	Reach Length (ft)	Study Bank Height (ft)	BEHI Adjective	NBS Rating	Erosion Rate (ft/yr)	Erosion Subtotal (tons/yr)
ER-1	L	150	4	High	Very Low	0.165	**4.77**
ER-2	R	108	6	Very High	Very Low	0.165	**5.15**
ER-3	L	80	5	High	Very Low	0.165	**3.18**
ER-4	L	100	5.5	Very High	Very Low	0.165	**4.38**
ER-5	R	100	5.5	High	Very Low	0.165	**4.38**
ER-6	L	38	4	Very High	Very Low	0.165	**1.21**
ER-7	L	100	5	High	Very High	0.872	**20.99**
ER-8	L	85	6	Very High	Very Low	0.165	**4.06**
ER-9	L	67	8	High	Very Low	0.165	**4.26**
ER-10	L	78	8.5	Very High	Very Low	0.165	**5.27**
ER-11	L	150	8	Very High	Very Low	0.165	**9.55**
ER-12	L	84	9	Very High	Very Low	0.165	**6.01**
ER-13	L	135	6.5	High	Very Low	0.165	**6.98**
ER-14	R	102	9	Very High	Very Low	0.165	**7.30**
ER-15	R	75	8	Very High	Very Low	0.165	**4.77**
ER-16	R	102	6.5	Very High	Very Low	0.165	**5.27**
ER-17	R	50	9	Very High	Very Low	0.165	**3.58**
ER-18	L	120	7.5	High	Very Low	0.165	**7.16**
ER-19	L	60	10	Extreme	Very Low	0.164	**4.74**
ER-20	L	60	10	High	Very Low	0.165	**4.77**
ER-21	R	30	10	Extreme	Very Low	0.164	**2.37**
ER-22	L	150	5.5	High	Very Low	0.165	**6.56**
ER-23	R	90	10	Very High	Very Low	0.165	**7.16**
ER-24	L	50	6	High	Very Low	0.165	**2.39**
ER-25	R	75	6	High	Very Low	0.165	**3.58**
ER-26	L	200	7	Very High	Very Low	0.165	**11.14**
ER-27	R	200	7	Very High	Very Low	0.165	**11.14**
ER-28	R	75	9	Very High	Very Low	0.165	**5.37**
		2,714 ft of severely eroding bank			**Total Erosion (tons/year):**		**167.5**

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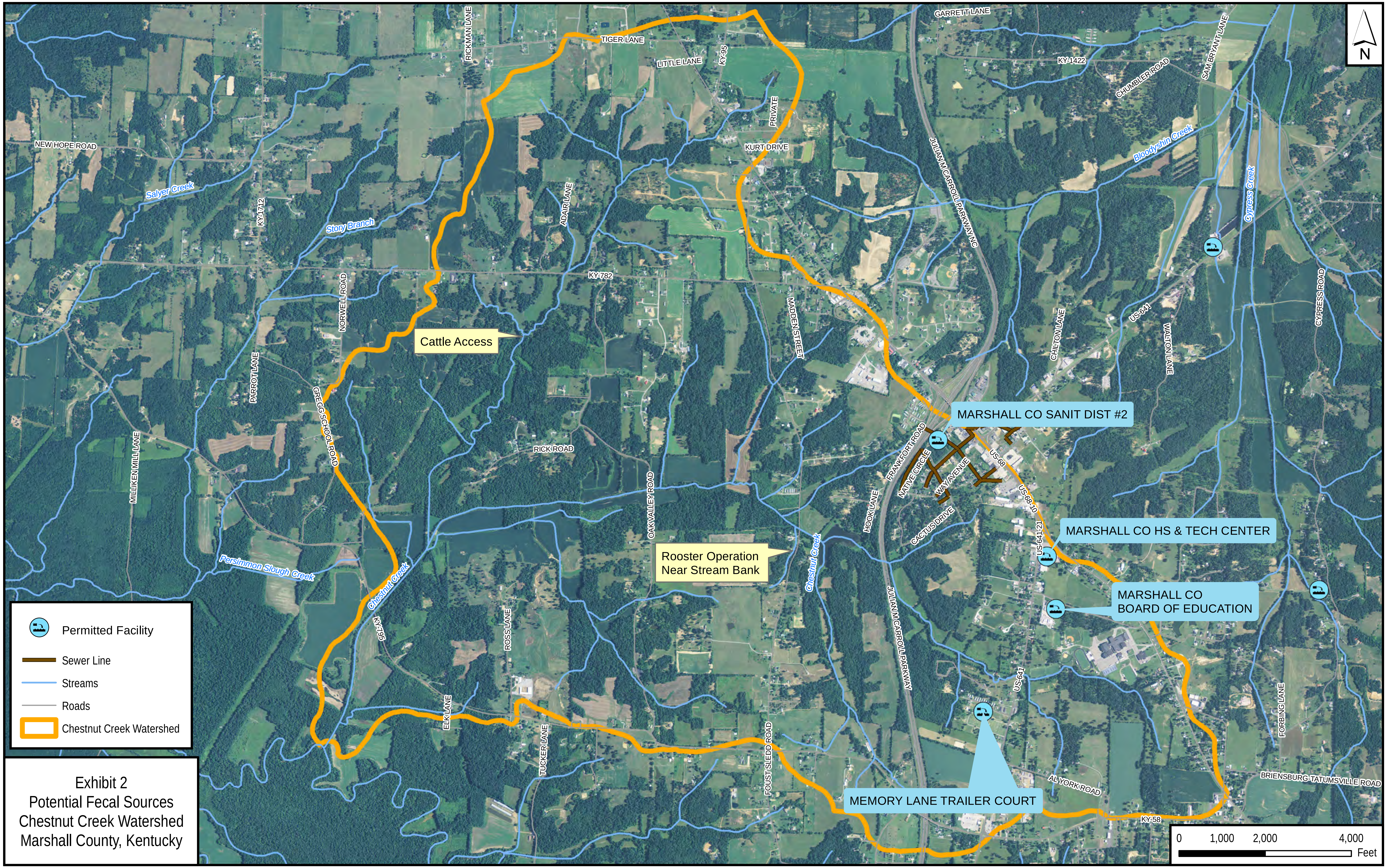

Exhibit 2
Potential Fecal Sources
Chestnut Creek Watershed
Marshall County, Kentucky

APPENDIX A – PHOTO LOG

E-coli source - cattle

E-coli source - roosters

ER-01

ER-02

ER-03

ER-04

ER-05

ER-06

ER-07

ER-07

ER-08

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ER-26 and ER-27

ER-26 and ER-27

ER-26 and ER-27

ER 26 and ER-27

ER-28

Habitat and Macroinvertebrate Assessment Report

Chestnut Creek Watershed
Marshall County, Kentucky

Prepared for
Friends of Clarks River
National Wildlife Refuge

October 17, 2013

Prepared by
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THIRD ROCK CONSULTANTS

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Environmental Analysis & Restoration

Table of Contents

I. INTRODUCTION

This report summarizes results for benthic macroinvertebrate collections and habitat assessments in the Chestnut Creek watershed. The survey was conducted under a Section 319(h) Nonpoint Source Implementation Program Cooperative Agreement (#C9994861-09) awarded by the Commonwealth of Kentucky, Energy and Environment Cabinet, Department for Environmental Protection, Division of Water (KDOW) to Friends of the Clarks River National Wildlife Refuge based on an approved work plan. The survey was conducted according to the preapproved Quality Assurance Project Plan (Third Rock 2013).

The benthic macroinvertebrate sampling was intended to evaluate the macroinvertebrate communities in the tributaries and headwaters of Chestnut Creek.

Habitat assessments were intended to supplement the biological and physicochemical data when determining the overall health of the stream reaches and stream-use designation. Additionally, the habitat assessments were intended to provide a baseline to document physical changes that occur over time and to identify potential areas for BMP implementation.

Benthic macroinvertebrates were collected by Third Rock Consultants, LLC (Third Rock) from seven sites within the Chestnut Creek watershed. Third Rock biologists also performed habitat assessments at these sites.

II. METHODS

A. Macroinvertebrates

Sampling for benthic macroinvertebrates was conducted according to KDOW's *Methods for Sampling Benthic Macroinvertebrate Communities in Wadeable Waters* (KDOW 2009b). Four of these sites are headwater sites (<5 mi^2 upstream watershed), but Site 8 near the mouth of the watershed is a wadeable stream (> 5 mi^2 upstream watershed). Descriptions of the five sampling sites are found in Table 1.

TABLE 1 – MACROINVERTEBRATE SAMPLING SITE DESCRIPTION

Site Name	Location	Latitude	Longitude
1	Headwater of Chestnut Creek with three package treatment plants and one mobile home park.	36.912251°	-88.345379°
4	Oak Valley Road Crossing of Chestnut Creek	36.922022°	-88.369952°
5	Southern UT to Chestnut Creek with pasture and croplands	36.918401°	-88.378839°
7	Near mouth of northern UT to Chestnut Creek	36.920019°	-88.387638°
8	Scale Road Crossing of Chestnut Creek, near the mouth	36.912072°	-88.392957°

Sampling was performed within the index periods for wadeable and headwater streams. The index period for wadeable streams is May 1 to September 30, and Site 8 was collected on June 25, 2013. For headwater streams, the index period is February 15 to May 31, and the four headwater sites were sampled on May 7, 2013. Sampling did not occur during periods of excessively high or low flow or within two weeks of a known scouring flow event.

Collection events consisted of a composited semi-quantitative sample and a composited qualitative (multi-habitat) sample. Semi-quantitative samples were collected from a known area in the most productive in-stream habitat (*i.e.,* riffle) to analyze the population composition of the macroinvertebrate community. In both headwater and wadeable streams, semi-quantitative sampling consisted of taking four 0.25 m^2 kick net samples from mid-riffle or the thalweg.

This was be accomplished using a 0.25 m^2, 600μm mesh kick net, dislodging benthos by vigorously disturbing the 0.25 m^2 (20 x 20 in.) of substrate in front of the net. Large rocks were hand washed with a brush into the net. The contents of the net were then washed, and all four samples were composited to yield a one m^2 semi-quantitative sample. The composited sample was partially field processed using a US No. 30 sieve (600μm) and wash bucket. Large stones, leaves and sticks were individually rinsed and inspected for organisms and then discarded. Small stones and sediment were removed by elutriation using the wash bucket and US No. 30 sieve. For headwater sites, two kick net samples were allocated to each of two distinct riffles (at minimum) that were separated by at least one pool or run. This was done to help reduce between-riffle variability.

Multi-habitat samples were collected to identify taxa present in stream habitats not sampled by the semi-quantitative sample (*i.e.,* root wads, undercut banks). This method sampled a variety of non-riffle habitats with the aid of an 800 x 900μm mesh triangular or D-frame dip net. A summary of the collection techniques used for wadeable and headwater streams is shown in Table 2 below and further described in the following sections.

In order to keep in-stream habitat intended for benthic macroinvertebrate sampling intact and undisturbed until the single and multi-habitat samples were collected, field personnel avoided walking through areas designated for collection of benthic macroinvertebrates until sampling was completed.

TABLE 2 – SUMMARY OF SAMPLING METHODS FOR MACROINVERTEBRATES

Technique	Sampling Device	Habitat	Replicates Composited for Wadeable Sites	Replicates Composited for Headwater Sites
Semi-Quantitaive				
$1m^2$ kicknet / seine	Kicknet / seine and wash bucket	Riffle	4 x $0.25m^2$	4 x $0.25m^2$
Multi-Habitat Sweep				
Undercut banks / roots	D-frame or triangular dip net and wash bucket	All applicable	3	3
Sticks / Wood			N/A	3
Emergent vegetation			3	N/A
Bedrock / slabrock			3	N/A
J. americana beds			3	N/A
Leaf packs		Riffle – Run – Pool	3	3
Silt, sand, fine gravel	US #10 Sieve	Margins	3	3
Aufwuchs sample	300 μm nitrex sampler / mesh	Riffle – Run - Pool	3	N/A
Rock pick	Fine-tipped forceps and wash bucket		15 total (5 each)	5 small boulders
Wood sample			3 to 6 linear meters	2 linear meters

After sampling was completed, all sampling gear was thoroughly cleaned to remove all benthic macroinvertebrates so that specimens would not be carried to the next site. The equipment was examined prior to sampling at the next site to ensure that no benthic macroinvertebrates were present. Habitat assessments were performed at each of the macroinvertebrates sites by Third Rock staff (as detailed in the following section).

Macroinvertebrate samples were delivered to Third Rock for identification according to *Laboratory Procedures for Macroinvertebrate Processing and Taxonomic Identification and Reporting* (KDOW 2009a). After identification, macroinvertebrate sampling results were evaluated through calculation of several community metrics prescribed by KDOW 2008. Results of community metrics at each station were combined to compute a Macroinvertebrate Bioassessment Index (MBI) score, ranging from 0 (worst) to 100 (best). MBI scores were compared to scoring criteria developed by KDOW to arrive at water quality ratings of Very Poor, Poor, Fair, Good, or Excellent.

B. Habitat Assessments

All habitat assessments were performed according to the US EPA's *Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers* (Barbour *et al.* 1999) and KDOW protocol (KDOW 2008). During habitat assessments, a visual assessment of 10 habitat parameters was used to characterize the stream "micro scale" habitat, the "macro scale" features, and the riparian and bank structure features that are most often influential in affecting the other parameters. Each of the parameters will be evaluated on a "Condition Category" scale from 0 to 20. The categories within this scale include "Optimal" for scores from 20 to 16, "Suboptimal" for scores from 15 to 11, "Marginal" for scores from 10 to 6, and "Poor" for scores from 5 to 0. The score for each parameter was summed to produce a final habitat score (maximum 200).

For parameters 1 to 5, a composite of the entire biological sampling reach is evaluated. These parameters include: 1) epifaunal substrate/ available cover, 2) embeddedness, 3) velocity/depth regime, 4) sediment deposition, and 5) channel flow status. For parameters 6 to 10, an area beginning approximately 100-m upstream of the sampling reach through the sampling reach was evaluated as a composite. These parameters include: 6) channel alteration, 7) frequency of riffles (or bends), 8) bank stability, 9) bank vegetative protection, and 10) riparian vegetative width. For parameters 8 to 10, each bank was scored independently from 10 to 0, facing downstream to determine left and right banks. At each sampling site, results were recorded on the High-Gradient Habitat Assessment Field Data Sheet. Photographs were taken to document upstream and downstream conditions at each site.

Habitat assessment results were compared to scoring criteria developed by KDOW for the region to arrive at habitat ratings of Poor, Fair, or Good.

III. RESULTS

A. Macroinvertebrates

MBI scores for the five sampled sites are shown in Exhibit 1, page 4. The MBI scores and metrics for each site are presented in Table 3, page 5. Data sheets for each site are contained in Appendix A.

Macroinvertebrate biotic indices (MBI) calculated for three of the five sampling stations in the Chestnut Creek watershed resulted in ratings of "fair." The other two sites were rated as "poor." The minimum MBI score for a "fair" rating is 24 for wadeable streams and 35 for headwater locations in the Mississippi Valley-Interior River (MVIR) Bioregion. For the "good" sites have a minimum MBI of 56 for headwater and 48 for

P:\Project_Files\Kentucky\KY12-053_FOCR_ChestnutCrk_WatershedPlan\Mapping\GIS\Macro.mxd SJE, 10/10/13

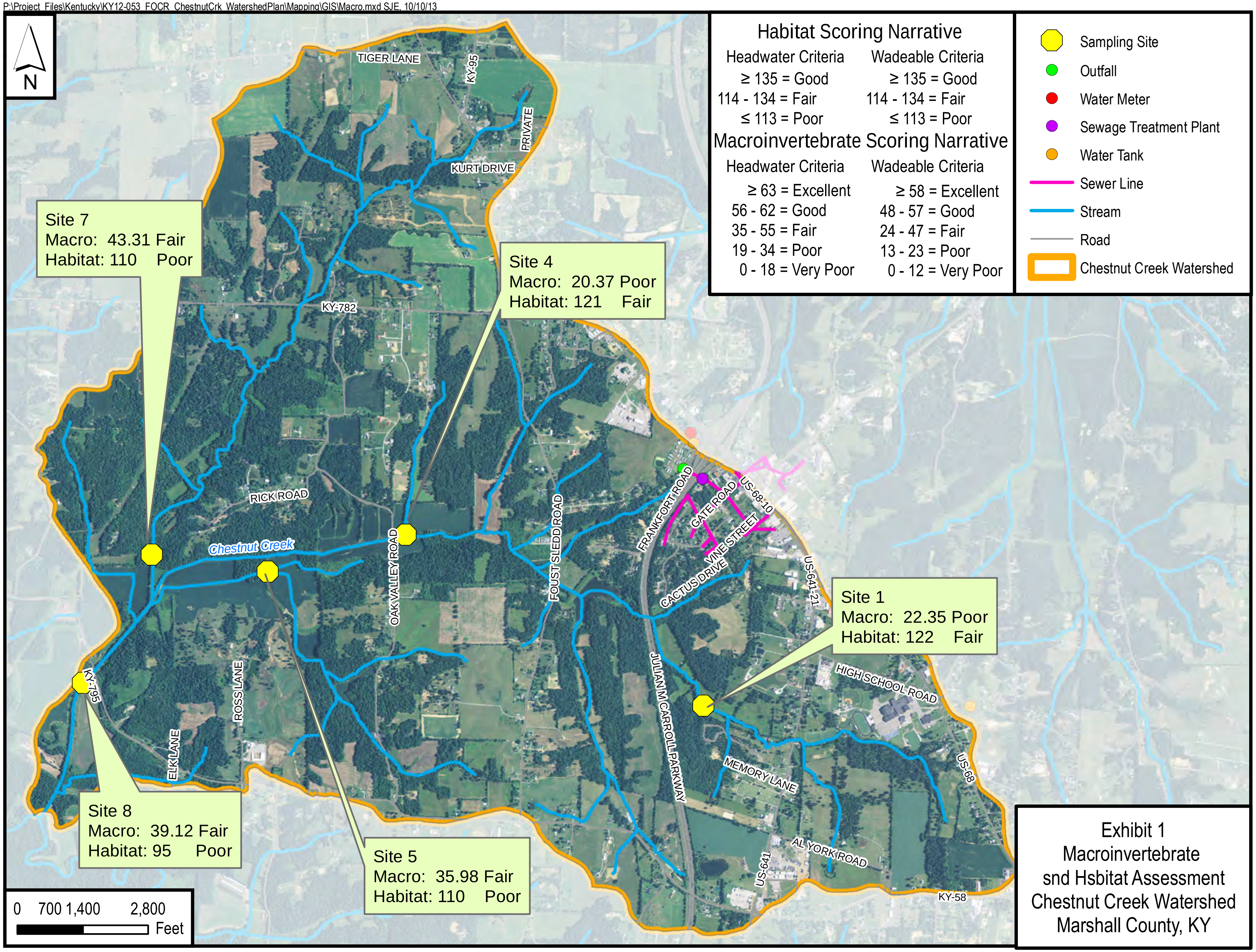


TABLE 3 – MBI SCORES AND METRICS

Site ID	Taxa Richness	EPT Richness	mHBI	Relative Abundance EPT (%)	% Ephemeroptera	% Chironomidae + Oligochaeta	%Clingers	MBI Score	MBI Rating
1	23	1	6.78	9.5	9.5	80.5	21.3	22.35	Poor
4	22	4	7.14	4.9	4.2	62.9	4.9	20.37	Poor
5	28	10	5.17	15	12.5	52.5	20	35.98	Fair
7	28	11	4.75	32.8	28.2	50.7	17.6	43.31	Fair
8	31	6	5.78	7.8	NA	62.8	43.6	39.12	Fair

wadeable sites, so no location is approaching this level.

The “poor” macroinvertebrate communities were located in the headwaters of the watershed with “fair” communities in the lower portion of the watershed. Both poor sites had low numbers of pollution intolerant EPT (ephemeroptera, plecoptera, and trichoptera) taxa and overall percentages. The EPT genera ranged from 1 species at Site 1 to 11 at Site 7, and the relative abundance ranged from 4.9% at Site 4 to 32.8% at Site 7. The overall number of genera collected ranged from 22 to 31 at a given site.

Most sites had 50-63% of pollution tolerant taxa such as chironomidae and annelida, as well as several tolerant members of Mollusca, but Site 1 had the most abundant numbers of these species at 80.5%. The abundance of clingers (taxa requiring stable substrates to cling to, such as gravel, boulders, root wads, etc) was less than 25% at all sites except Site 8, in which 43.6% of the individuals were in this group. Clingers are frequently an indicator of unstable substrate or high levels of siltation or embeddedness.

The modified Hilsenhoff biotic index (mHBI) scores the abundance of the generally pollution-sensitive insect groups of mayflies, stoneflies, and caddisflies. This number will generally decrease as water quality and/or habitat conditions increase. Scores ranged from 4.75 (excellent) at Site 7 to 7.14 (poor) at Site 4.

Based on these scores, the streams of Chestnut Creek are not supporting their warmwater aquatic habitat use in the upper reaches of the watershed and partially supporting this designated use in the lower portion of the watershed.

B. Habitat Assessment

Results from habitat assessments are presented in Table 4, page 8. Habitat assessment field data sheets are included in Appendix B. Photographs were taken in the field of each sampling reach, and included photographs of specific habitat features. A photo log of each site is included in Appendix C.

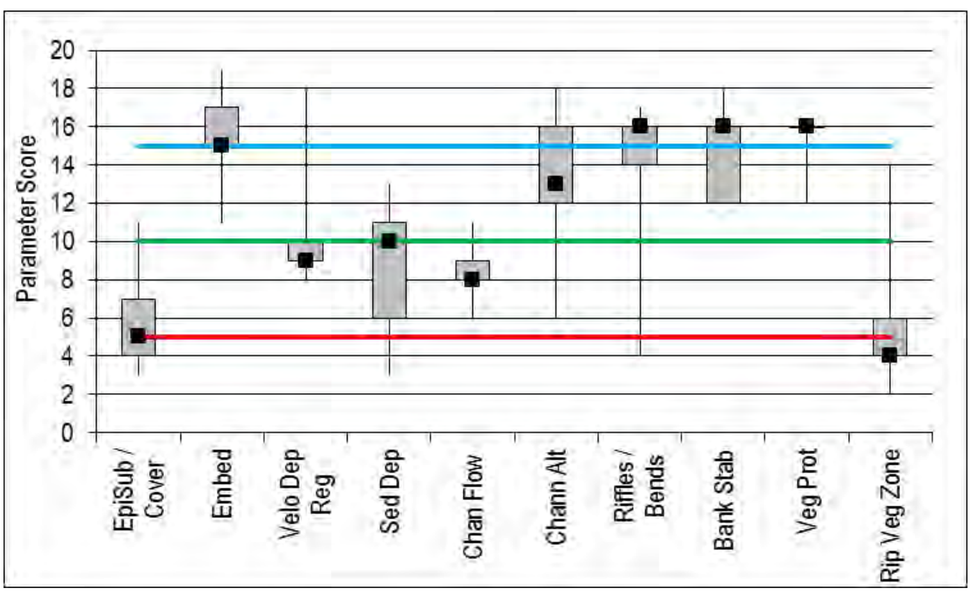
Instream water chemistry measurements, measured at the time of assessment, are presented in Table 4. All instream measurements were within normal ranges with specific conductivity very low throughout the watershed.

The range of results for each parameter is shown in the box plot chart in Figure 1, page 12. Riparian vegetation zone width was poor on average, as the lowest parameter overall. Median results for epifaunal substrate / available

TABLE 4 – HABITAT SCORES AND WATER CHEMISTRY RESULTS

Site ID	1	4	5	7	8
Date	5/1/2013	5/1/2013	5/1/2013	5/1/2013	6/25/2013
Water Temperature (°C)	17.5	9.9	20.8	16.9	Not Sampled
pH (SU)	7.0	6.9	7.0	6.9	
Dissolved Oxygen (mg/L)	9.9	8.0	10.8	8.4	
Dissolved Oxygen Saturation (%)	106	89	124	89	
Conductivity (µS/cm)	210	84.5	99.9	88.1	
Turbidity (NTU)	0	3	0	0	
Habitat Score	**122**	**121**	**110**	**110**	**95**
Habitat Rating	**Fair**	**Fair**	**Poor**	**Poor**	**Poor**
Epifaunal Substrate / Available Cover	11	7	4	5	3
Embeddedness	15	15	17	11	19
Velocity Depth	18	9	9	8	10
Sediment Deposition	10	11	13	6	3
Channel Flow	8	8	11	9	6
Channel Alteration	16	18	6	13	12
Frequency of Riffles	14	17	16	16	4
Bank Stability	12	16	16	12	18
Bank Vegetative Protection	12	16	16	16	16
Riparian Vegetative Zone Width	6	4	2	14	4

FIGURE 1 – CHESTNUT CREEK WATERSHED HABITAT PARAMETER SCORES



Note: Lines indicate the maximum and minimum results. Bars indicate the middle 50% of results. Values above the lines labeled "Marginal", "Suboptimal", and "Optimal" score in these respective categories. Values less than 5 are "Poor".

cover, velocity depth regime, and channel flow status were "Marginal."

Total habitat scores ranged from 95 to 122. Interestingly, the "fair" sites were each associated with "poor" MBI scores, and "poor" habitat sites had "fair" MBI scores. Habitat scores are only representative of the particular reach assessed, while macroinvertebrate communities are impacted by a larger area. However, improvement of habitat will be necessary to aid streams in supporting their designated use for warmwater aquatic habitat.

The gravelly, unstable substrate in most streams of the watershed do not provide for good substrate cover for macroinvertebrate species. Restoration efforts to provide increased instream niche habitat should aide in the recovery of macroinvertebrate community. Similarly, narrow riparian corridors are a problem in many areas of the watershed and should be expanded with no-mow zones and native plantings. Some sediment accumulation is occurring, which is linked to the bank erosion noted in other surveys. This sedimentation covers aquatic habitat and reduces the pool depth.

REFERENCES

Barbour, M.T., J. Gerritsen, B.D. Synder, and J.B. Stribling. 1999. Rapid Bioassessessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C.

Kentucky Department of Environmental Protection, Division of Water (KDOW). 2008. *Methods for Assessing Biological Integrity of Surface Waters in Kentucky.* Kentucky Department of Environmental Protection.

KDOW. 2009a. *Laboratory Procedures for Macroinvertebrate Processing and Taxonomic Identification and Reporting*.

KDOW. 2009b. *Methods for Sampling Benthic Macroinvertebrate Communities in Wadeable Waters*. Kentucky Department for Environmental Protection, Division of Water, Frankfort, Kentucky.

Third Rock Consultants. 2013. "Quality Assurance Project Plan: Chestnut Creek WBP." Grant Number: C9994861-09. Prepared for Kentucky Division of Water, 200 Fair Oaks Lane Frankfort, KY 40601.

APPENDICES

APPENDIX A – MACROINVERTEBRATE DATASHEETS

THIRDROCK CONSULTANTS

Macroinvertebrate Sample Chain of Custody
Project Information Sheet

Client Name: Friends of Clarks River National Wildlife Refuge Project Administrator: G. Fister Project Number: KY12-053 Due Date: ~~May 30, 2013~~ as possible

Sampling Site Location: Chestnut Creek County: Marshall State: KY

System Type: HW EcoRegion: Miss Valley Total Number of Samples: 8 Total Number of Containers: 10

Reporting Requirements: __ Laboratory Data Sheet; __ Excel Spreadsheet; __ MBI Calculations via __ e-Submittal; __ Hardcopy; __ Both

Samples Relinquished By: [signature] Date/Time: 5/6 4:20 Sample Received By: Marcia L. Wooton Date/Time: 5/6 4:20p

Samples Relinquished By: ________ Date/Time: ________ Sample Received By: ________ Date/Time: ________

Comments/Special Instructions: ________

Sample Reference ID	Qualitative or Quantitative	Collected By	Collection Date	Sample Type	Preservative	# of Containers Per Sample	Analysis Required (KDOW Protocol, ID Level; etc.)
Site 4	QT	WCO/JS	5/1/13	HW KN	EtOH	1	Standard KDOW (SS300)
	QL	↓	↓	NH	↓	1	↓
Site 1	QT	↓	↓	KN	↓	2	↓
	QL	↓	↓	↓	↓	2	↓
Site 7	QT	↓	↓	↓	↓	1	↓
	QL	↓	↓	↓	↓	1	↓
Site 5	QT	↓	↓	↓	↓	1	↓
	QL	↓	↓	↓ mlw	↓	1	↓

- Continue on Reverse for More Samples -

System Type: Headwater Stream; Wadeable Stream; Large River; Lotic; Other ________
EcoRegion: Bluegrass; Mountain; Pennyroyal; Mississippi Valley-Interior River Lowlands; Other ________
Sample Type: **KN** KickNet; **TK** Traveling Kick; **MH** Multihabitat; **S** Surber; **HD** Hester-Dendy Multiplate; **HDD** HD Deep; **HDS** HD Shallow; **OT** Other______; **NA** Not Available

MacLIMS: Client Setup/Login By mlw Date 5-11-13; Reported By ________ Date ________; Invoiced By ________ Date ________ 5/20/10

THIRDROCK CONSULTANTS

Macroinvertebrate Sample Chain of Custody
Project Information Sheet

(MacLIMS KY12-053A)

Client Name: FCRNWR Project Administrator: FBH Project Number: KY12-053 Due Date: as possible

Sampling Site Location: Chestnut Creek ~~State Road~~ – wadeable County: Morgan ?? State: KY

[redacted]: Wadeable **EcoRegion:** Miss Valley Total Number of Samples: 2 Total Number of Containers: 2

Reporting Requirements: __ Laboratory Data Sheet; __ Excel Spreadsheet; __ MBI Calculations via __ e-Submittal; __ Hardcopy; __ Both

Samples Relinquished By: [signature] Date/Time: 6-26-13 16:00 Sample Received By: Marcia L. Wooton Date/Time: 6-26-13 1600

Samples Relinquished By: ________ Date/Time: ________ Sample Received By: ________ Date/Time: ________

Comments/Special Instructions: ________

Sample Reference ID	Qualitative or Quantitative	Collected By	Collection Date	[redacted]	Preservative	# of Containers Per Sample	Analysis Required (KDOW Protocol, ID Level; etc.)
QUANT Site 8	QT	SJE	6-25-13	KN	EtOH	1	KDOW Protocol
QUAL Site 8	QL	SJE	6-25-13	MH	EtOH	1	KDOW Protocol

OS

- Continue on Reverse for More Samples -

[redacted]: Headwater Stream; Wadeable Stream; Large River; Lotic; Other ________
EcoRegion: Bluegrass; Mountain; Pennyroyal; Mississippi Valley-Interior River Lowlands; Other ________
[redacted]: KN KickNet; TK Traveling Kick; MH Multihabitat; S Surber; HD Hester-Dendy Multiplate; HDD HD Deep; HDS HD Shallow; OT Other ______; NA Not Available

MacLIMS: Client Setup/Login By mlw Date 9-18-13; Reported By ________ Date ________; Invoiced By ________ Date ________ 5/20/10

MACROINVERTEBRATE LABORATORY DATA SHEET

THIRDROCK CONSULTANTS
Lexington, Kentucky

Third Rock Pjt #:	KY12-053	Client Name:	InHouse - Friends of Clarks River NWR
Water Body:	Chestnut Creek	State/County:	KY / Marshall
Sample ID:	Site 1 QT	Collection Date:	5/1/2013
Collector:	Chelsey Olson, Jamie Storm	Sampling Method:	Kick Net
Sorter:	Tammie Fister	Sample Sorting:	Subsample
Taxonomist:	Chelsey Olson	No. Grids of 30 Picked:	2
		No. Organisms Picked:	327

Family or Taxon / Genus	No. Orgs.
ANNELIDA	
Naididae	2
AMPHIPODA	
ISOPODA	
DECAPODA	
EPHEMEROPTERA	
Caenis diminuta gr	31
ODONATA	
PLECOPTERA	
TRICHOPTERA	
MEGALOPTERA	
COLEOPTERA	
Stenelmis (A) 7	7
DIPTERA (CHIRONOMIDAE)	
Chironomus sp	1
Corynoneura sp	1
Cricotopus/Orthocladius gr	154
Dicrotendipes neomodestus	19
Diplocladius cultriger	1
Hydrobaenus sp	1
Larsia sp	2
Micropsectra sp	7
Paratanytarsus sp	21
Paratendipes albimanus	2
Potthastia sp	1
Rheotanytarsus exiguus gr	20
Tanytarsus sp	21
Thienemanniella xena	4
Thienemannimyia gr	6
Zavrelimyia sp	1
DIPTERA (OTHER)	
Bezzia/Palpomyia gr	1
Prosimulium sp	2
Simulium sp	18
MOLLUSCA	
Physella sp	5
OTHER TAXA	
Number of Individuals	328

THIRDROCK CONSULTANTS
Lexington, Kentucky

MACROINVERTEBRATE LABORATORY DATA SHEET

Third Rock Pjt #:	KY12-053	Client Name:	InHouse - Friends of Clarks River NWR
Water Body:	Chestnut Creek	State/County:	KY / Marshall
Sample ID:	Site 1 QL	Collection Date:	5/1/2013
Collector:	Chelsey Olson, Jamie Storm	Sampling Method:	Multihabitat
Sorter:	Brenda McGregor	Sample Sorting:	Subsample
Taxonomist:	Chelsey Olson	No. Grids of 30 Picked:	30
		No. Organisms Picked:	NA

Family or Taxon / Genus	No. Orgs.	Family or Taxon / Genus	No. Orgs.	Family or Taxon / Genus	No. Orgs.
ANNELIDA		PLECOPTERA		DIPTERA (CHIRONOMIDAE)	
Naididae				Corynoneura sp	
				Cricotopus/Orthocladius gr	
				Dicrotendipes neomodestus	
				Micropsectra sp	
AMPHIPODA				Paratanytarsus sp	
				Potthastia sp	
ISOPODA					
DECAPODA					
		TRICHOPTERA			
EPHEMEROPTERA					
Caenis diminuta gr					
				DIPTERA (OTHER)	
		MEGALOPTERA			
				MOLLUSCA	
ODONATA				Physella sp	
		COLEOPTERA			
				OTHER TAXA	
				Number of Individuals	-

THIRDROCK CONSULTANTS
Lexington, Kentucky

MACROINVERTEBRATE LABORATORY DATA SHEET

Third Rock Pjt #:	KY12-053	Client Name:	InHouse - Friends of Clarks River NWR
Water Body:	Chestnut Creek	State/County:	KY / Marshall
Sample ID:	Site 4 QT	Collection Date:	5/1/2013
Collector:	Chelsey Olson, Jamie Storm	Sampling Method:	Kick Net
Sorter:	Brenda McGregor	Sample Sorting:	Subsample
Taxonomist:	Chelsey Olson	No. Grids of 30 Picked:	6
		No. Organisms Picked:	301

Family or Taxon / Genus	No. Orgs.
ANNELIDA	
Naididae	9
AMPHIPODA	
Crangonyx sp	28
ISOPODA	
Lirceus fontinalis	50
DECAPODA	
EPHEMEROPTERA	
Nixe sp	8
Paraleptophlebia sp	4
ODONATA	
PLECOPTERA	
Isoperla sp	2
TRICHOPTERA	
MEGALOPTERA	
COLEOPTERA	
Hydroporus (L) 1	1
DIPTERA (CHIRONOMIDAE)	
Chironomus sp	11
Corynoneura sp	3
Cricotopus/Orthocladius gr	122
Dicrotendipes neomodestus	5
Hydrobaenus sp	3
Microtendipes pedellus gr	3
Stempellinella sp	1
Tanytarsus sp	23
Zavrelimyia sp	1
DIPTERA (OTHER)	
Bezzia/Palpomyia gr	4
Ormosia sp	1
Simulium sp	4
MOLLUSCA	
Physella sp	4
OTHER TAXA	
Turbellaria	1
Number of Individuals	288

THIRDROCK CONSULTANTS
Lexington, Kentucky

MACROINVERTEBRATE LABORATORY DATA SHEET

Third Rock Pjt #:	KY12-053	Client Name:	InHouse - Friends of Clarks River NWR
Water Body:	Chestnut Creek	State/County:	KY / Marshall
Sample ID:	Site 4 QL	Collection Date:	5/1/2013
Collector:	Chelsey Olson, Jamie Storm	Sampling Method:	Multihabitat
Sorter:	Tammie Fister	Sample Sorting:	Subsample
Taxonomist:	Chelsey Olson	No. Grids of 30 Picked:	30
		No. Organisms Picked:	NA

Family or Taxon / Genus	No. Orgs.
ANNELIDA	
AMPHIPODA	
Crangonyx sp	
ISOPODA	
Lirceus fontinalis	
DECAPODA	
EPHEMEROPTERA	
Callibaetis sp	
Nixe sp	
Paraleptophlebia sp	
ODONATA	

Family or Taxon / Genus	No. Orgs.
PLECOPTERA	
TRICHOPTERA	
MEGALOPTERA	
COLEOPTERA	

Family or Taxon / Genus	No. Orgs.
DIPTERA (CHIRONOMIDAE)	
Chironomus sp	
Cricotopus/Orthocladius gr	
Dicrotendipes neomodestus	
Zavrelimyia sp	
DIPTERA (OTHER)	
Bezzia/Palpomyia gr	
MOLLUSCA	
Physella sp	
OTHER TAXA	
Number of Individuals	-

THIRD ROCK CONSULTANTS
Lexington, Kentucky

MACROINVERTEBRATE LABORATORY DATA SHEET

Third Rock Pjt #:	KY12-053	Client Name:	InHouse - Friends of Clarks River NWR
Water Body:	Chestnut Creek	State/County:	KY / Marshall
Sample ID:	Site 5 QT	Collection Date:	5/1/2013
Collector:	Chelsey Olson, Jamie Storm	Sampling Method:	Kick Net
Sorter:	Tammie Fister	Sample Sorting:	Subsample
Taxonomist:	Chelsey Olson	No. Grids of 30 Picked:	30
		No. Organisms Picked:	257

Family or Taxon / Genus	No. Orgs.
ANNELIDA	
Naididae	3
AMPHIPODA	
Crangonyx sp	2
ISOPODA	
DECAPODA	
EPHEMEROPTERA	
Caenis diminuta gr	1
Nixe sp	9
Paraleptophlebia sp	18
Plauditus sp	2
ODONATA	

Family or Taxon / Genus	No. Orgs.
PLECOPTERA	
Amphinemura sp	2
Isoperla sp	3
TRICHOPTERA	
Wormaldia sp	1
MEGALOPTERA	
COLEOPTERA	
Agabus (L) 1	1
Stenelmis (A) 26 (L) 1	27

Family or Taxon / Genus	No. Orgs.
DIPTERA (CHIRONOMIDAE)	
Cardiocladius obscurus	1
Chironomus sp	1
Corynoneura sp	1
Cricotopus/Orthocladius gr	103
Hydrobaenus sp	1
Larsia sp	3
Micropsectra sp	3
Parametriocnemus sp	5
Polypedilum flavum	2
Thienemannimyia gr	3
DIPTERA (OTHER)	
Bezzia/Palpomyia gr	41
Prosimulium sp	3
Simulium sp	4
MOLLUSCA	
OTHER TAXA	
Number of Individuals	240

THIRDROCK CONSULTANTS
Lexington, Kentucky

MACROINVERTEBRATE LABORATORY DATA SHEET

Third Rock Pjt #:	KY12-053	Client Name:	InHouse - Friends of Clarks River NWR
Water Body:	Chestnut Creek	State/County:	KY / Marshall
Sample ID:	Site 5 QL	Collection Date:	5/1/2013
Collector:	Chelsey Olson, Jamie Storm	Sampling Method:	Multihabitat
Sorter:	Brenda McGregor	Sample Sorting:	Subsample
Taxonomist:	Chelsey Olson	No. Grids of 30 Picked:	30
		No. Organisms Picked:	NA

Family or Taxon / Genus	No. Orgs.
ANNELIDA	
Naididae	
AMPHIPODA	
ISOPODA	
DECAPODA	
EPHEMEROPTERA	
Ameletus sp	
Caenis diminuta gr	
Paraleptophlebia sp	
Plauditus sp	
Stenonema femoratum	
ODONATA	

Family or Taxon / Genus	No. Orgs.
PLECOPTERA	
Isoperla sp	
TRICHOPTERA	
Polycentropus sp	
MEGALOPTERA	
COLEOPTERA	
Agabus (L)	

Family or Taxon / Genus	No. Orgs.
DIPTERA (CHIRONOMIDAE)	
Cricotopus/Orthocladius gr	
Parametriocnemus sp	
Polypedilum illinoense gr	
Thienemannimyia gr	
Zavrelimyia sp	
DIPTERA (OTHER)	
Bezzia/Palpomyia gr	
Simulium sp	
MOLLUSCA	
OTHER TAXA	
Number of Individuals	-

Lexington, Kentucky

MACROINVERTEBRATE LABORATORY DATA SHEET

Third Rock Pjt #:	KY12-053	Client Name:	InHouse - Friends of Clarks River NWR
Water Body:	Chestnut Creek	State/County:	KY / Marshall
Sample ID:	Site 7 QT	Collection Date:	5/1/2013
Collector:	Chelsey Olson, Jamie Storm	Sampling Method:	Kick Net
Sorter:	Tammie Fister	Sample Sorting:	Subsample
Taxonomist:	Chelsey Olson	No. Grids of 30 Picked:	3
		No. Organisms Picked:	313

Family or Taxon / Genus	No. Orgs.	Family or Taxon / Genus	No. Orgs.	Family or Taxon / Genus	No. Orgs.
ANNELIDA		PLECOPTERA		DIPTERA (CHIRONOMIDAE)	
Naididae	3	Isoperla sp	6	Corynoneura sp	4
		Leuctra sp	6	Cricotopus/Orthocladius gr	139
				Eukiefferiella claripennis gr	3
				Larsia sp	2
AMPHIPODA				Micropsectra sp	1
Crangonyx sp	6			Zavrelimyia sp	1
ISOPODA					
Caecidotea sp	4				
Lirceus fontinalis	9				
DECAPODA					
		TRICHOPTERA			
		Polycentropus sp	1		
EPHEMEROPTERA		Rhyacophila ledra/fenestra	1		
Acerpenna sp	1				
Ameletus sp	4				
Caenis diminuta gr	1				
Nixe sp	30				
Paraleptophlebia sp	48			DIPTERA (OTHER)	
Plauditus sp	1			Bezzia/Palpomyia gr	15
				Pseudolimnophila sp	1
				Simulium sp	7
		MEGALOPTERA			
				MOLLUSCA	
ODONATA					
		COLEOPTERA			
		Stenelmis (A) 4 (L) 4	8		
				OTHER TAXA	
				Number of Individuals	302

THIRDROCK CONSULTANTS
Lexington, Kentucky

MACROINVERTEBRATE LABORATORY DATA SHEET

Third Rock Pjt #:	KY12-053	Client Name:	InHouse - Friends of Clarks River NWR
Water Body:	Chestnut Creek	State/County:	KY / Marshall
Sample ID:	Site 7 QL	Collection Date:	5/1/2013
Collector:	Chelsey Olson, Jamie Storm	Sampling Method:	Multihabitat
Sorter:	Tammie Fister	Sample Sorting:	Subsample
Taxonomist:	Chelsey Olson	No. Grids of 30 Picked:	30
		No. Organisms Picked:	NA

Family or Taxon / Genus	No. Orgs.
ANNELIDA	
AMPHIPODA	
ISOPODA	
Lirceus fontinalis	
DECAPODA	
Cambaridae	
EPHEMEROPTERA	
Nixe sp	
Paraleptophlebia sp	
Siphlonurus sp	
ODONATA	

Family or Taxon / Genus	No. Orgs.
PLECOPTERA	
Isoperla sp	
TRICHOPTERA	
MEGALOPTERA	
COLEOPTERA	

Family or Taxon / Genus	No. Orgs.
DIPTERA (CHIRONOMIDAE)	
Cricotopus/Orthocladius gr	
Parametriocnemus sp	
Rheotanytarsus exiguus gr	
DIPTERA (OTHER)	
Bezzia/Palpomyia gr	
MOLLUSCA	
OTHER TAXA	
Number of Individuals	-

MACROINVERTEBRATE LABORATORY DATA SHEET

THIRD ROCK CONSULTANTS
Lexington, Kentucky

Third Rock Pjt #:	KY12-053A	Client Name:	InHouse - Friends of Clarks River NWR
Water Body:	Chestnut Ceeek	State/County:	KY / Marshall
Sample ID:	Site 8 QT	Collection Date:	6/25/2013
Collector:	Steve Evans	Sampling Method:	Kick Net
Sorter:	Jamie Storm	Sample Sorting:	Subsample
Taxonomist:	Chelsey Olson	No. Grids of 30 Picked:	7
		No. Organisms Picked:	318

Family or Taxon / Genus	No. Orgs.	Family or Taxon / Genus	No. Orgs.	Family or Taxon / Genus	No. Orgs.
ANNELIDA		PLECOPTERA		DIPTERA (CHIRONOMIDAE)	
AMPHIPODA		TRICHOPTERA		Ablabesmyia mallochi	7
ISOPODA		Cheumatopsyche sp	73	Phaenopsectra sp	1
DECAPODA		Chimarra obscura	2	Polypedilum illinoense gr	1
EPHEMEROPTERA		MEGALOPTERA		Polypedilum flavum	116
Acerpenna pygmaea	12	COLEOPTERA		Rheocricotopus robacki	2
Baetis sp (Immature)	4	Stenelmis (L) 3	3	Rheotanytarsus exiguus gr	41
Caenis diminuta gr	5			Tanytarsus sp	4
ODONATA				Thienemannimyia gr	14
				DIPTERA (OTHER)	
				Bezzia/Palpomyia gr	1
				Simulium sp	10
				MOLLUSCA	
				OTHER TAXA	
				Number of Individuals	296

THIRDROCK CONSULTANTS
Lexington, Kentucky

MACROINVERTEBRATE LABORATORY DATA SHEET

Third Rock Pjt #:	KY12-053A	Client Name:	InHouse - Friends of Clarks River NWR
Water Body:	Chestnut Creek	State/County:	KY / Marshall
Sample ID:	Site 8 QL	Collection Date:	6/25/2013
Collector:	Steve Evans	Sampling Method:	Multihabitat
Sorter:	Tammie Fister	Sample Sorting:	Subsample
Taxonomist:	Chelsey Olson	No. Grids of 30 Picked:	30
		No. Organisms Picked:	NA

Family or Taxon / Genus	No. Orgs.	Family or Taxon / Genus	No. Orgs.	Family or Taxon / Genus	No. Orgs.
ANNELIDA		PLECOPTERA		DIPTERA (CHIRONOMIDAE)	
				Ablabesmyia mallochi	
				Chironomus sp	
				Dicrotendipes neomodestus	
				Dicrotendipes modestus/tritomus	
AMPHIPODA				Paratanytarsus sp	
Crangonyx sp				Phaenopsectra sp	
				Polypedilum illinoense gr	
				Polypedilum flavum	
ISOPODA				Tanytarsus sp	
				Thienemannimyia gr	
DECAPODA					
		TRICHOPTERA			
		Cheumatopsyche sp			
EPHEMEROPTERA		Chimarra obscura			
Acerpenna pygmaea					
Caenis diminuta gr					
Stenonema femoratum					
				DIPTERA (OTHER)	
				Culicidae (Damaged)	
		MEGALOPTERA			
		Chauloides sp		MOLLUSCA	
ODONATA				Lymnaea sp	
Coenagrionidae (Damaged)				Physella sp	
Gomphidae					
		COLEOPTERA			
		Cyphon (L)			
		Helochares (A)			
		Helocombus (A) (L)		OTHER TAXA	
		Lioporeus (A)		Belostoma sp	
				Number of Individuals	-

Sample ID	Taxa Name	Class	Order	Family	FFG	Count
Site 1 QT	Stenelmis sp	Insecta	Coleoptera	Elmidae	SC	7
Site 1 QT	Physella sp	Mollusca	Basommatophora	Physidae	SC	5
Site 1 QT	Bezzia/Palpomyia gr	Insecta	Diptera	Ceratopogonidae	PR	1
Site 1 QT	Naididae	Oligochaeta	Haplotaxida	Naididae	CG	2
Site 1 QT	Chironomus sp	Insecta	Diptera	Chironomidae	CG	1
Site 1 QT	Dicrotendipes neomodestus	Insecta	Diptera	Chironomidae	CG	19
Site 1 QT	Thienemannimyia gr	Insecta	Diptera	Chironomidae	PR	6
Site 1 QT	Cricotopus/Orthocladius gr	Insecta	Diptera	Chironomidae	CG	154
Site 1 QT	Caenis diminuta gr	Insecta	Ephemeroptera	Caenidae	CG	31
Site 1 QT	Prosimulium sp	Insecta	Diptera	Simuliidae	CF	2
Site 1 QT	Tanytarsus sp	Insecta	Diptera	Chironomidae	CF	21
Site 1 QT	Diplocladius cultriger	Insecta	Diptera	Chironomidae	CG	1
Site 1 QT	Thienemanniella xena	Insecta	Diptera	Chironomidae	CG	4
Site 1 QT	Paratendipes albimanus	Insecta	Diptera	Chironomidae	CG	2
Site 1 QT	Simulium sp	Insecta	Diptera	Simuliidae	CF	18
Site 1 QT	Corynoneura sp	Insecta	Diptera	Chironomidae	CG	1
Site 1 QT	Potthastia sp	Insecta	Diptera	Chironomidae	CG	1
Site 1 QT	Hydrobaenus sp	Insecta	Diptera	Chironomidae	SC	1
Site 1 QT	Zavrelimyia sp	Insecta	Diptera	Chironomidae	PR	1
Site 1 QT	Micropsectra sp	Insecta	Diptera	Chironomidae	CG	7
Site 1 QT	Rheotanytarsus exiguus gr	Insecta	Diptera	Chironomidae	CF	20
Site 1 QT	Larsia sp	Insecta	Diptera	Chironomidae	PR	2
Site 1 QT	Paratanytarsus sp	Insecta	Diptera	Chironomidae	CG	21
Site 1 QL	Corynoneura sp	Insecta	Diptera	Chironomidae	CG	NA
Site 1 QL	Dicrotendipes neomodestus	Insecta	Diptera	Chironomidae	CG	NA
Site 1 QL	Physella sp	Mollusca	Basommatophora	Physidae	SC	NA
Site 1 QL	Cricotopus/Orthocladius gr	Insecta	Diptera	Chironomidae	CG	NA
Site 1 QL	Naididae	Oligochaeta	Haplotaxida	Naididae	CG	NA
Site 1 QL	Micropsectra sp	Insecta	Diptera	Chironomidae	CG	NA
Site 1 QL	Potthastia sp	Insecta	Diptera	Chironomidae	CG	NA
Site 1 QL	Paratanytarsus sp	Insecta	Diptera	Chironomidae	CG	NA
Site 1 QL	Caenis diminuta gr	Insecta	Ephemeroptera	Caenidae	CG	NA
Site 4 QT	Bezzia/Palpomyia gr	Insecta	Diptera	Ceratopogonidae	PR	4
Site 4 QT	Tanytarsus sp	Insecta	Diptera	Chironomidae	CF	23
Site 4 QT	Zavrelimyia sp	Insecta	Diptera	Chironomidae	PR	1
Site 4 QT	Stempellinella sp	Insecta	Diptera	Chironomidae	CG	1
Site 4 QT	Hydrobaenus sp	Insecta	Diptera	Chironomidae	SC	3
Site 4 QT	Cricotopus/Orthocladius gr	Insecta	Diptera	Chironomidae	CG	122
Site 4 QT	Microtendipes pedellus gr	Insecta	Diptera	Chironomidae	CF	3
Site 4 QT	Ormosia sp	Insecta	Diptera	Tipulidae	CG	1
Site 4 QT	Corynoneura sp	Insecta	Diptera	Chironomidae	CG	3
Site 4 QT	Simulium sp	Insecta	Diptera	Simuliidae	CF	4
Site 4 QT	Hydroporus sp	Insecta	Coleoptera	Dytiscidae	PR	1
Site 4 QT	Paraleptophlebia sp	Insecta	Ephemeroptera	Leptophlebiidae	CG	4
Site 4 QT	Nixe sp	Insecta	Ephemeroptera	Heptageniidae	CG	8
Site 4 QT	Crangonyx sp	Malacostraca	Amphipoda	Crangonyctidae	SH	28
Site 4 QT	Lirceus fontinalis	Malacostraca	Isopoda	Asellidae	CG	50
Site 4 QT	Physella sp	Mollusca	Basommatophora	Physidae	SC	4
Site 4 QT	Chironomus sp	Insecta	Diptera	Chironomidae	CG	11

Sample ID	Taxa Name	Class	Order	Family	FFG	Count
Site 4 QT	Isoperla sp	Insecta	Plecoptera	Perlodidae	PR	2
Site 4 QT	Turbellaria	Turbellaria			CG	1
Site 4 QT	Naididae	Oligochaeta	Haplotaxida	Naididae	CG	9
Site 4 QT	Dicrotendipes neomodestus	Insecta	Diptera	Chironomidae	CG	5
Site 4 QL	Cricotopus/Orthocladius gr	Insecta	Diptera	Chironomidae	CG	NA
Site 4 QL	Dicrotendipes neomodestus	Insecta	Diptera	Chironomidae	CG	NA
Site 4 QL	Physella sp	Mollusca	Basommatophora	Physidae	SC	NA
Site 4 QL	Zavrelimyia sp	Insecta	Diptera	Chironomidae	PR	NA
Site 4 QL	Callibaetis sp	Insecta	Ephemeroptera	Baetidae	CG	NA
Site 4 QL	Nixe sp	Insecta	Ephemeroptera	Heptageniidae	CG	NA
Site 4 QL	Paraleptophlebia sp	Insecta	Ephemeroptera	Leptophlebiidae	CG	NA
Site 4 QL	Bezzia/Palpomyia gr	Insecta	Diptera	Ceratopogonidae	PR	NA
Site 4 QL	Crangonyx sp	Malacostraca	Amphipoda	Crangonyctidae	SH	NA
Site 4 QL	Lirceus fontinalis	Malacostraca	Isopoda	Asellidae	CG	NA
Site 4 QL	Chironomus sp	Insecta	Diptera	Chironomidae	CG	NA
Site 5 QT	Nixe sp	Insecta	Ephemeroptera	Heptageniidae	CG	9
Site 5 QT	Cricotopus/Orthocladius gr	Insecta	Diptera	Chironomidae	CG	103
Site 5 QT	Isoperla sp	Insecta	Plecoptera	Perlodidae	PR	3
Site 5 QT	Paraleptophlebia sp	Insecta	Ephemeroptera	Leptophlebiidae	CG	18
Site 5 QT	Thienemannimyia gr	Insecta	Diptera	Chironomidae	PR	3
Site 5 QT	Bezzia/Palpomyia gr	Insecta	Diptera	Ceratopogonidae	PR	41
Site 5 QT	Hydrobaenus sp	Insecta	Diptera	Chironomidae	SC	1
Site 5 QT	Stenelmis sp	Insecta	Coleoptera	Elmidae	SC	26
Site 5 QT	Agabus sp	Insecta	Coleoptera	Dytiscidae	PR	1
Site 5 QT	Prosimulium sp	Insecta	Diptera	Simuliidae	CF	3
Site 5 QT	Amphinemura sp	Insecta	Plecoptera	Nemouridae	SH	2
Site 5 QT	Wormaldia sp	Insecta	Trichoptera	Philopotamidae	CF	1
Site 5 QT	Stenelmis sp	Insecta	Coleoptera	Elmidae	SC	1
Site 5 QT	Cardiocladius obscurus	Insecta	Diptera	Chironomidae	PR	1
Site 5 QT	Plauditus sp	Insecta	Ephemeroptera	Baetidae	CG	2
Site 5 QT	Crangonyx sp	Malacostraca	Amphipoda	Crangonyctidae	SH	2
Site 5 QT	Polypedilum flavum	Insecta	Diptera	Chironomidae	SH	2
Site 5 QT	Micropsectra sp	Insecta	Diptera	Chironomidae	CG	3
Site 5 QT	Larsia sp	Insecta	Diptera	Chironomidae	PR	3
Site 5 QT	Corynoneura sp	Insecta	Diptera	Chironomidae	CG	1
Site 5 QT	Chironomus sp	Insecta	Diptera	Chironomidae	CG	1
Site 5 QT	Parametriocnemus sp	Insecta	Diptera	Chironomidae	CG	5
Site 5 QT	Naididae	Oligochaeta	Haplotaxida	Naididae	CG	3
Site 5 QT	Caenis diminuta gr	Insecta	Ephemeroptera	Caenidae	CG	1
Site 5 QT	Simulium sp	Insecta	Diptera	Simuliidae	CF	4
Site 5 QL	Caenis diminuta gr	Insecta	Ephemeroptera	Caenidae	CG	NA
Site 5 QL	Cricotopus/Orthocladius gr	Insecta	Diptera	Chironomidae	CG	NA
Site 5 QL	Polypedilum illinoense gr	Insecta	Diptera	Chironomidae	SH	NA
Site 5 QL	Parametriocnemus sp	Insecta	Diptera	Chironomidae	CG	NA
Site 5 QL	Thienemannimyia gr	Insecta	Diptera	Chironomidae	PR	NA
Site 5 QL	Naididae	Oligochaeta	Haplotaxida	Naididae	CG	NA
Site 5 QL	Agabus sp	Insecta	Coleoptera	Dytiscidae	PR	NA
Site 5 QL	Zavrelimyia sp	Insecta	Diptera	Chironomidae	PR	NA
Site 5 QL	Simulium sp	Insecta	Diptera	Simuliidae	CF	NA

Sample ID	Taxa Name	Class	Order	Family	FFG	Count
Site 5 QL	Bezzia/Palpomyia gr	Insecta	Diptera	Ceratopogonidae	PR	NA
Site 5 QL	Stenonema femoratum	Insecta	Ephemeroptera	Heptageniidae	SC	NA
Site 5 QL	Polycentropus sp	Insecta	Trichoptera	Polycentropodidae	PR	NA
Site 5 QL	Ameletus sp	Insecta	Ephemeroptera	Ameletidae	SC	NA
Site 5 QL	Paraleptophlebia sp	Insecta	Ephemeroptera	Leptophlebiidae	CG	NA
Site 5 QL	Plauditus sp	Insecta	Ephemeroptera	Baetidae	CG	NA
Site 5 QL	Isoperla sp	Insecta	Plecoptera	Perlodidae	PR	NA
Site 7 QT	Stenelmis sp	Insecta	Coleoptera	Elmidae	SC	4
Site 7 QT	Micropsectra sp	Insecta	Diptera	Chironomidae	CG	1
Site 7 QT	Eukiefferiella claripennis gr	Insecta	Diptera	Chironomidae	CG	3
Site 7 QT	Larsia sp	Insecta	Diptera	Chironomidae	PR	2
Site 7 QT	Zavrelimyia sp	Insecta	Diptera	Chironomidae	PR	1
Site 7 QT	Corynoneura sp	Insecta	Diptera	Chironomidae	CG	4
Site 7 QT	Rhyacophila ledra/fenestra	Insecta	Trichoptera	Rhyacophilidae	PR	1
Site 7 QT	Acerpenna sp	Insecta	Ephemeroptera	Baetidae	CG	1
Site 7 QT	Nixe sp	Insecta	Ephemeroptera	Heptageniidae	CG	30
Site 7 QT	Polycentropus sp	Insecta	Trichoptera	Polycentropodidae	PR	1
Site 7 QT	Crangonyx sp	Malacostraca	Amphipoda	Crangonyctidae	SH	6
Site 7 QT	Stenelmis sp	Insecta	Coleoptera	Elmidae	SC	4
Site 7 QT	Ameletus sp	Insecta	Ephemeroptera	Ameletidae	SC	4
Site 7 QT	Naididae	Oligochaeta	Haplotaxida	Naididae	CG	3
Site 7 QT	Pseudolimnophila sp	Insecta	Diptera	Tipulidae	PR	1
Site 7 QT	Cricotopus/Orthocladius gr	Insecta	Diptera	Chironomidae	CG	139
Site 7 QT	Paraleptophlebia sp	Insecta	Ephemeroptera	Leptophlebiidae	CG	48
Site 7 QT	Isoperla sp	Insecta	Plecoptera	Perlodidae	PR	6
Site 7 QT	Leuctra sp	Insecta	Plecoptera	Leuctridae	SH	6
Site 7 QT	Lirceus fontinalis	Malacostraca	Isopoda	Asellidae	CG	9
Site 7 QT	Caecidotea sp	Malacostraca	Isopoda	Asellidae	CG	4
Site 7 QT	Bezzia/Palpomyia gr	Insecta	Diptera	Ceratopogonidae	PR	15
Site 7 QT	Simulium sp	Insecta	Diptera	Simuliidae	CF	7
Site 7 QT	Plauditus sp	Insecta	Ephemeroptera	Baetidae	CG	1
Site 7 QT	Caenis diminuta gr	Insecta	Ephemeroptera	Caenidae	CG	1
Site 7 QL	Isoperla sp	Insecta	Plecoptera	Perlodidae	PR	NA
Site 7 QL	Rheotanytarsus exiguus gr	Insecta	Diptera	Chironomidae	CF	NA
Site 7 QL	Parametriocnemus sp	Insecta	Diptera	Chironomidae	CG	NA
Site 7 QL	Cricotopus/Orthocladius gr	Insecta	Diptera	Chironomidae	CG	NA
Site 7 QL	Bezzia/Palpomyia gr	Insecta	Diptera	Ceratopogonidae	PR	NA
Site 7 QL	Siphlonurus sp	Insecta	Ephemeroptera	Siphlonuridae	CG	NA
Site 7 QL	Cambaridae	Malacostraca	Decapoda	Cambaridae	CG	NA
Site 7 QL	Paraleptophlebia sp	Insecta	Ephemeroptera	Leptophlebiidae	CG	NA
Site 7 QL	Lirceus fontinalis	Malacostraca	Isopoda	Asellidae	CG	NA
Site 7 QL	Nixe sp	Insecta	Ephemeroptera	Heptageniidae	CG	NA
Site 8 QT	Phaenopsectra sp	Insecta	Diptera	Chironomidae	SC	1
Site 8 QT	Cheumatopsyche sp	Insecta	Trichoptera	Hydropsychidae	CF	73
Site 8 QT	Rheotanytarsus exiguus gr	Insecta	Diptera	Chironomidae	CF	41
Site 8 QT	Tanytarsus sp	Insecta	Diptera	Chironomidae	CF	4
Site 8 QT	Polypedilum illinoense gr	Insecta	Diptera	Chironomidae	SH	1
Site 8 QT	Ablabesmyia mallochi	Insecta	Diptera	Chironomidae	PR	7
Site 8 QT	Thienemannimyia gr	Insecta	Diptera	Chironomidae	PR	14
Site 8 QT	Polypedilum flavum	Insecta	Diptera	Chironomidae	SH	116

Sample ID	Taxa Name	Class	Order	Family	FFG	Count
Site 8 QT	Bezzia/Palpomyia gr	Insecta	Diptera	Ceratopogonidae	PR	1
Site 8 QT	Chimarra obscura	Insecta	Trichoptera	Philopotamidae	CF	2
Site 8 QT	Simulium sp	Insecta	Diptera	Simuliidae	CF	10
Site 8 QT	Baetis sp	Insecta	Ephemeroptera	Baetidae	CG	4
Site 8 QT	Acerpenna pygmaea	Insecta	Ephemeroptera	Baetidae	CG	12
Site 8 QT	Stenelmis sp	Insecta	Coleoptera	Elmidae	SC	3
Site 8 QT	Caenis diminuta gr	Insecta	Ephemeroptera	Caenidae	CG	5
Site 8 QT	Rheocricotopus robacki	Insecta	Diptera	Chironomidae	CG	2
Site 8 QL	Physella sp	Mollusca	Basommatophora	Physidae	SC	NA
Site 8 QL	Cheumatopsyche sp	Insecta	Trichoptera	Hydropsychidae	CF	NA
Site 8 QL	Chauloides sp	Insecta	Megaloptera	Corydalidae	PR	NA
Site 8 QL	Stenonema femoratum	Insecta	Ephemeroptera	Heptageniidae	SC	NA
Site 8 QL	Caenis diminuta gr	Insecta	Ephemeroptera	Caenidae	CG	NA
Site 8 QL	Belostoma sp	Insecta	Hemiptera	Belostomatidae	PR	NA
Site 8 QL	Acerpenna pygmaea	Insecta	Ephemeroptera	Baetidae	CG	NA
Site 8 QL	Paratanytarsus sp	Insecta	Diptera	Chironomidae	CG	NA
Site 8 QL	Dicrotendipes modestus/tritomus	Insecta	Diptera	Chironomidae	CG	NA
Site 8 QL	Phaenopsectra sp	Insecta	Diptera	Chironomidae	SC	NA
Site 8 QL	Chironomus sp	Insecta	Diptera	Chironomidae	CG	NA
Site 8 QL	Tanytarsus sp	Insecta	Diptera	Chironomidae	CF	NA
Site 8 QL	Polypedilum flavum	Insecta	Diptera	Chironomidae	SH	NA
Site 8 QL	Polypedilum illinoense gr	Insecta	Diptera	Chironomidae	SH	NA
Site 8 QL	Dicrotendipes neomodestus	Insecta	Diptera	Chironomidae	CG	NA
Site 8 QL	Helochares sp	Insecta	Coleoptera	Hydrophilidae	PR	NA
Site 8 QL	Lymnaea sp	Mollusca	Lymnophila	Lymnaeidae	SC	NA
Site 8 QL	Ablabesmyia mallochi	Insecta	Diptera	Chironomidae	PR	NA
Site 8 QL	Cyphon sp	Insecta	Coleoptera	Scirtidae	SC	NA
Site 8 QL	Lioporeus sp	Insecta	Coleoptera	Dytiscidae	PR	NA
Site 8 QL	Crangonyx sp	Malacostraca	Amphipoda	Crangonyctidae	SH	NA
Site 8 QL	Coenagrionidae	Insecta	Odonata	Coenagrionidae	PR	NA
Site 8 QL	Culicidae	Insecta	Diptera	Culicidae	CF	NA
Site 8 QL	Helocombus sp	Insecta	Coleoptera	Hydrophilidae	CG	NA
Site 8 QL	Gomphidae	Insecta	Odonata	Gomphidae	PR	NA
Site 8 QL	Helocombus sp	Insecta	Coleoptera	Hydrophilidae	CG	NA
Site 8 QL	Chimarra obscura	Insecta	Trichoptera	Philopotamidae	CF	NA
Site 8 QL	Thienemannimyia gr	Insecta	Diptera	Chironomidae	PR	NA

Third Rock Consultants, LLC
Macroinvertebrate Sample Sorting Efficiency Form

Client Name: FCRNWR
Sample ID: Chestnut creek site 8 QT
Third Rock Project #: KY12-053

Original Sorter: James Storm	Resorted By: T. Fister
Date Sorted: 7-5-13	Date Resorted: 10-15-13
# of Grids Sorted: 7	# of Grids Sorted: 7
# of Organisms Originally Sorted: 318	# Additional Organisms Recovered:

organisms originally sorted [318] ÷ (# additional organisms recovered [1] + # organisms originally sorted [318]) = % Sorting Efficiency [100]

Additional Organisms Located

Taxon	Number
Chironomidae gen sp 1	1
Total:	1

Comments: FCRNWR
Chestnut creek
KY12-053
Site 8 QT

Passed QA

Third Rock Consultants, LLC
Macroinvertebrate Sample Taxonomic & Enumeration Efficiency Form

Client Name: FCRNWR-Chestnut Creek
Sample ID: Site 7 QT
Third Rock Project #: KY12-053

Original Taxonomist: Chelsey Olson	Second Taxonomist: Bert Remley
Original Date Completed: 9/27/13	Review Date Completed: 10/7/13
# Organisms Enumerated (*Taxonomist 1*): 301	# Organisms Enumerated (*Taxonomist 2*): 298

Percent Difference in Enumeration (PDE) = 0.5

$$(301 - 298) \div (301 + 298) \times 100 = \%\ \text{Difference in Enumeration (PDE)}$$

n_1 = *# organisms counted by Taxonomist 1*
n_2 = *# organisms counted by Taxonomist 2*

Percent Taxonomic Disagreement (PTD) = 1.99

$$PTD = [\,1 - (295 \div 301)]\ X\ 100$$

$Comp_{pos}$ = *number of taxonomic agreements (see Taxonomic Comparison Form)*
N = *total number of organisms*

Comments: Passed QA/QC

Third Rock Consultants, LLC
Macroinvertebrate Sample Taxonomy Precision Form

Client Name: FCRNWR
Sample ID: Site 7 QT
Third Rock Project #: KY12-053

Taxon	Taxonomist 1	Taxonomist 2	# Agreements
Crangonyx sp	6	6	6
Stenelmis sp	4	4	4
Stenelmis sp	4	4	4
Bezzia/Palpomyia gr	15	16	15
Corynoneura sp	4	4	4
Cricotopus/Orthocladius gr	139	137	137
Eukiefferiella claripennis gr	3	3	3
Larsia sp	2	2	2
Micropsectra sp	1	1	1
Zavrelimyia sp	1	1	1
Simulium sp	7	7	7
Nixe sp	30	29	29
Ameletus sp	4	3	3
Acerpenna sp	1	1	1
Plauditus sp	1	1	1
Caenis diminuta gr	1	1	1
Paraleptophlebia sp	48	46	46
Caecidotea sp	4	4	4
Lirceus fontinalis	9	9	9
Leuctra sp	6	6	6
Isoperla sp	6	6	6
Polycentropus sp	1	1	1
Rhyacophila ledra/fenestra	1	1	1
Naididae	3	4	3
Pseudolimnophila	0	1	0
Totals:	**301**	**298**	**295**

Friends of Clarks River National Wildlife Refuge/Chestnut Creek - Wadeable Streams/Macroinvertebrate Results, 2013

StationID	StreamName	CollDate	Bioregion	Basin	CollMeth	G-TR	G-EPT	mHBI	m%EPT	%C+O	%ClngP	G-TR	G-EPT	HBI2	m%EPT	%CO	%ClngP	MBI	Rating
Site 8	Chestnut Creek	6/25/2013	MVIR	Clark's River	1 M2 KICKNET/Multihabitat	31	6	5.78	7.8	62.8	43.6	45.59	20.69	61.25	10.68	37.58	58.92	39.12	Fair

Friends of Clarks River National Wildlife Refuge/Chestnut Creek - Headwater Streams/Macroinvertebrate Results, 2013

StationID	StreamName	CollDate	Bioregion	Basin	CollMeth	G-TR	G-EPT	mHBI	m%EPT	%Ephem	%C+O	%ClngP	G-TR	G-EPT	HBI2	m%EPT	%Ephem	%C+O	%ClngP	MBI	Ratings
Site 1	Chestnut Creek	5/1/2013	MVIR	Clark's River	1 M2 KICKNET/Multihabitat	23	1	6.78	9.5	9.5	80.5	21.3	38.98	3.23	41.18	10.93	14.29	19.63	28.21	22.35	Poor
Site 4	Chestnut Creek	5/1/2013	MVIR	Clark's River	1 M2 KICKNET/Multihabitat	22	4	7.14	4.9	4.2	62.9	4.9	37.29	12.90	36.57	5.64	6.32	37.35	6.49	20.37	Poor
Site 5	Chestnut Creek	5/1/2013	MVIR	Clark's River	1 M2 KICKNET/Multihabitat	28	10	5.17	15	12.5	52.5	20	47.46	32.26	61.76	17.26	18.80	47.83	26.49	35.98	Fair
Site 7	Chestnut Creek	5/1/2013	MVIR	Clark's River	1 M2 KICKNET/Multihabitat	28	11	4.75	32.8	28.2	50.7	17.6	47.46	35.48	67.14	37.74	42.41	49.64	23.31	43.31	Fair

Table 18. MBI criteria for assigning narrative ratings for wadeable (a) and headwater streams (b) by bioregion. Based on either 75th/25th %ile or 50th/5th %ile cutoffs for "Excellent" and "Good" and further trisection of values below a rating of "Good".

Wadeable	50th and 5th %ile	50th and 5th %ile	50th and 5th %ile	75th and 25th %ile
Rating	BG	MT	PR	MVIR
Excellent	≥ 70	≥ 82	≥ 81	≥ 58
Good	61–69	75–81	72–80	48–57
Fair	41–60	50–74	49–71	24–47
Poor	21–40	25–49	25–48	13–23
Very Poor	0–20	0–24	0–24	0–12

Headwater

Rating	BG	MT	PR	MVIR
Excellent	≥ 58	≥ 83	≥ 72	≥ 63
Good	51–57	72–82	65–71	56–62
Fair	39–50	48–71	43–64	35–55
Poor	19–38	24–47	22–42	19–34
Very Poor	0–18	0–23	0–21	0–18

APPENDIX B – HABITAT ASSESSMENT FIELD DATA SHEETS

HABITAT ASSESSMENT FIELD DATA SHEET — HIGH GRADIENT STREAMS, PAGE 1

STREAM NAME: Chestnut Creek	**LOCATION:** Headwater of Chestnut Creek
STREAM WDTH (FT): 10-15 **DEPTH (in):** 4-36	**PERENNIAL** ☒ **INTERMITTENT** ☐ **EPHEMERAL** ☐
STATION #: Site 1 **RIVERMILE:**	**COUNTY:** Marshall **STATE:** KY
LAT: 36.912251° **LONG:** -88.345379°	**RIVER BASIN:** Clark
CLIENT: FCRWR	**PROJECT NO.** KY12-053
INVESTIGATORS/CREW: W. Olson / J. Storm	

FORM COMPLETED BY: W. Olson	**DATE:** May 1, 2013 **TIME:** 1 PM	**REASON FOR SURVEY:** Watershed Based Plan

Parameters to be evaluated in sampling reach

Habitat Parameter	Condition Category: Optimal	Suboptimal	Marginal	Poor
1. Epifaunal Substrate/ Available Cover	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are <u>not</u> new fall and <u>not</u> transient.	40-70% mix of stable habitat; well suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	20-40% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE: 11	20 19 18 17 16	15 14 13 12 **11**	10 9 8 7 6	5 4 3 2 1 0
2. Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
SCORE: 15	20 19 18 17 16	**15** 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
3. Velocity/Depth Regime	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (Slow is < 0.3 m/s, deep is > 0.5 m.)	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/depth regime (usually slow-deep).
SCORE: 18	20 19 **18** 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE: 10	20 19 18 17 16	15 14 13 12 11	**10** 9 8 7 6	5 4 3 2 1 0
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills > 75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE: 8	20 19 18 17 16	15 14 13 12 11	10 9 **8** 7 6	5 4 3 2 1 0

HABITAT ASSESSMENT FIELD DATA SHEET — HIGH GRADIENT STREAMS, PAGE 2

Parameters to be evaluated in sampling reach

Habitat Parameter	Condition Category: Optimal	Suboptimal	Marginal	Poor
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE: 12	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Frequency of Riffles (or bends)	Occurrence of riffles relatively frequent; ratio of distance between riffles divided by width of the stream < 7:1 (generally 5 to 7); variety of habitat is key. In streams where riffles are continuous, placement of boulders or other large, natural obstruction is important.	Occurrence of riffles infrequent; distance between riffles divided by the width of the stream is between 7 to 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by the width of the stream is between 15 to 25.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is a ration of > 25.
SCORE: 14	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
8. Bank Stability (score each bank) Note: determine left or right side by facing downstream.	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. < 5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE: 6 (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE: 6 (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0
9. Vegetative Protection (score each bank)	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or non-woody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE: 6 (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE: 6 (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters: little or no riparian vegetation due to human activities.
SCORE: 3 (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE: 3 (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0

TOTAL SCORE: 122

HABITAT ASSESSMENT FIELD DATA SHEET — HIGH GRADIENT STREAMS, PAGE 1

STREAM NAME: Chestnut Creek		LOCATION: Oak Valley Road Crossing	
STREAM WDTH (FT): 3	DEPTH (in): 2-6	PERENNIAL ☐ INTERMITTENT ☒	EPHEMERAL ☐
STATION #: Site 4	RIVERMILE:	COUNTY: Marshall	STATE: KY
LAT: 36.922022°	LONG: -88.369952°	RIVER BASIN: Clark	
CLIENT: FCRWR		PROJECT NO. KY12-053	
INVESTIGATORS/CREW: W. Olson / J. Storm			

FORM COMPLETED BY: W. Olson	DATE: May 1, 2013 TIME: 4 PM	REASON FOR SURVEY: Watershed Based Plan

Parameters to be evaluated in sampling reach

Habitat Parameter	Condition Category: Optimal	Suboptimal	Marginal	Poor
1. Epifaunal Substrate/ Available Cover	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient.	40-70% mix of stable habitat; well suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	20-40% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE: 7	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
2. Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
SCORE: 15	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
3. Velocity/Depth Regime	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (Slow is < 0.3 m/s, deep is > 0.5 m.)	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/depth regime (usually slow-deep).
SCORE: 9	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE: 11	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills > 75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE: 8	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

HABITAT ASSESSMENT FIELD DATA SHEET — HIGH GRADIENT STREAMS, PAGE 2

Parameters to be evaluated in sampling reach

Habitat Parameter	Condition Category: Optimal	Suboptimal	Marginal	Poor
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE: 18	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Frequency of Riffles (or bends)	Occurrence of riffles relatively frequent; ratio of distance between riffles divided by width of the stream < 7:1 (generally 5 to 7); variety of habitat is key. In streams where riffles are continuous, placement of boulders or other large, natural obstruction is important.	Occurrence of riffles infrequent; distance between riffles divided by the width of the stream is between 7 to 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by the width of the stream is between 15 to 25.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is a ration of > 25.
SCORE: 17	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
8. Bank Stability (score each bank) Note: determine left or right side by facing downstream.	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. < 5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE: 8 (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE: 8 (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0
9. Vegetative Protection (score each bank)	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or non-woody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE: 8 (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE: 8 (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters: little or no riparian vegetation due to human activities.
SCORE: 2 (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE: 2 (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0

TOTAL SCORE: 121

HABITAT ASSESSMENT FIELD DATA SHEET — HIGH GRADIENT STREAMS, PAGE 1

STREAM NAME: UT to Chestnut Creek	LOCATION: Southern UT to Chestnut Creek
STREAM WDTH (FT): 10 DEPTH (in): 2-8	PERENNIAL ☒ INTERMITTENT ☐ EPHEMERAL ☐
STATION #: Site 5 RIVERMILE:	COUNTY: Marshall STATE: KY
LAT: 36.918401° LONG: -88.378839°	RIVER BASIN: Clark
CLIENT: FCRWR	PROJECT NO. KY12-053
INVESTIGATORS/CREW: W. Olson / J. Storm	

FORM COMPLETED BY: W. Olson	DATE: May 1, 2013 TIME: 5 PM	REASON FOR SURVEY: Watershed Based Plan

Parameters to be evaluated in sampling reach

Habitat Parameter	Condition Category: Optimal	Suboptimal	Marginal	Poor
1. Epifaunal Substrate/ Available Cover	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are <u>not</u> new fall and <u>not</u> transient.	40-70% mix of stable habitat; well suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	20-40% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE: 4	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 **[4]** 3 2 1 0
2. Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
SCORE: 17	20 19 18 **[17]** 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
3. Velocity/Depth Regime	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (Slow is < 0.3 m/s, deep is > 0.5 m.)	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/depth regime (usually slow-deep).
SCORE: 9	20 19 18 17 16	15 14 13 12 11	10 **[9]** 8 7 6	5 4 3 2 1 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE: 13	20 19 18 17 16	15 14 **[13]** 12 11	10 9 8 7 6	5 4 3 2 1 0
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills > 75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE: 11	20 19 18 17 16	15 14 13 12 **[11]**	10 9 8 7 6	5 4 3 2 1 0

HABITAT ASSESSMENT FIELD DATA SHEET — HIGH GRADIENT STREAMS, PAGE 2

Parameters to be evaluated in sampling reach

Habitat Parameter	Condition Category: Optimal	Suboptimal	Marginal	Poor
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE: 6	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Frequency of Riffles (or bends)	Occurrence of riffles relatively frequent; ratio of distance between riffles divided by width of the stream < 7:1 (generally 5 to 7); variety of habitat is key. In streams where riffles are continuous, placement of boulders or other large, natural obstruction is important.	Occurrence of riffles infrequent; distance between riffles divided by the width of the stream is between 7 to 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by the width of the stream is between 15 to 25.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is a ration of > 25.
SCORE: 16	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
8. Bank Stability (score each bank) Note: determine left or right side by facing downstream.	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. < 5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE: 8 (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE: 8 (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0
9. Vegetative Protection (score each bank)	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or non-woody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE: 8 (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE: 8 (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters: little or no riparian vegetation due to human activities.
SCORE: 1 (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE: 1 (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0

TOTAL SCORE: 110

HABITAT ASSESSMENT FIELD DATA SHEET — HIGH GRADIENT STREAMS, PAGE 1

STREAM NAME: UT to Chestnut Creek	LOCATION: Near mouth of northern UT to Chestnut Creek
STREAM WDTH (FT): 6-12 DEPTH (in): 3-18	PERENNIAL ☒ INTERMITTENT ☐ EPHEMERAL ☐
STATION #: Site 7 RIVERMILE:	COUNTY: Marshall STATE: KY
LAT: 36.920019° LONG: -88.387638°	RIVER BASIN: Clark
CLIENT: FCRWR	PROJECT NO. KY12-053
INVESTIGATORS/CREW: W. Olson / J. Storm	

FORM COMPLETED BY: W. Olson	DATE: May 1, 2013 TIME: 7 PM	REASON FOR SURVEY: Watershed Based Plan

Parameters to be evaluated in sampling reach

Habitat Parameter	Condition Category: Optimal	Suboptimal	Marginal	Poor
1. Epifaunal Substrate/ Available Cover	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are <u>not</u> new fall and <u>not</u> transient.	40-70% mix of stable habitat; well suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	20-40% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE: 5	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
2. Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
SCORE: 11	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
3. Velocity/Depth Regime	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (Slow is < 0.3 m/s, deep is > 0.5 m.)	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/depth regime (usually slow-deep).
SCORE: 8	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE: 6	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills > 75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE: 9	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

HABITAT ASSESSMENT FIELD DATA SHEET — HIGH GRADIENT STREAMS, PAGE 2

Parameters to be evaluated in sampling reach

Habitat Parameter	Condition Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE: 13	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Frequency of Riffles (or bends)	Occurrence of riffles relatively frequent; ratio of distance between riffles divided by width of the stream < 7:1 (generally 5 to 7); variety of habitat is key. In streams where riffles are continuous, placement of boulders or other large, natural obstruction is important.	Occurrence of riffles infrequent; distance between riffles divided by the width of the stream is between 7 to 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by the width of the stream is between 15 to 25.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is a ration of > 25.
SCORE: 16	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
8. Bank Stability (score each bank) Note: determine left or right side by facing downstream.	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. < 5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE: 6 (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE: 6 (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0
9. Vegetative Protection (score each bank)	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or non-woody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE: 8 (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE: 8 (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters: little or no riparian vegetation due to human activities.
SCORE: 10 (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE: 4 (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0

TOTAL SCORE: 110

HABITAT ASSESSMENT FIELD DATA SHEET — HIGH GRADIENT STREAMS, PAGE 1

STREAM NAME: Chestnut Creek		LOCATION: Scale Road Crossing	
STREAM WDTH (FT): 25	DEPTH (in): 3-30	PERENNIAL ☒ INTERMITTENT ☐ EPHEMERAL ☐	
STATION #: Site 8	RIVERMILE:	COUNTY: Marshall	STATE: KY
LAT: 36.912072°	LONG: -88.392957°	RIVER BASIN: Clark	
CLIENT: FCRWR		PROJECT NO. KY12-053	
INVESTIGATORS/CREW: S. Evans			
FORM COMPLETED BY: S. Evans	DATE: June 25, 2013 TIME: 3 PM	REASON FOR SURVEY: Watershed Based Plan	

Parameters to be evaluated in sampling reach

Habitat Parameter	Condition Category: Optimal	Suboptimal	Marginal	Poor
1. Epifaunal Substrate/ Available Cover	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient.	40-70% mix of stable habitat; well suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	20-40% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE: 3	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
2. Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
SCORE: 19	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
3. Velocity/Depth Regime	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (Slow is < 0.3 m/s, deep is > 0.5 m.)	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/depth regime (usually slow-deep).
SCORE: 10	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE: 3	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills > 75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE:6	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

HABITAT ASSESSMENT FIELD DATA SHEET — HIGH GRADIENT STREAMS, PAGE 2

Parameters to be evaluated in sampling reach

Habitat Parameter	Condition Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE: 12	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Frequency of Riffles (or bends)	Occurrence of riffles relatively frequent; ratio of distance between riffles divided by width of the stream < 7:1 (generally 5 to 7); variety of habitat is key. In streams where riffles are continuous, placement of boulders or other large, natural obstruction is important.	Occurrence of riffles infrequent; distance between riffles divided by the width of the stream is between 7 to 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by the width of the stream is between 15 to 25.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is a ration of > 25.
SCORE: 4	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
8. Bank Stability (score each bank) Note: determine left or right side by facing downstream.	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. < 5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE: 9 (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE: 9 (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0
9. Vegetative Protection (score each bank)	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or non-woody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE: 8 (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE: 8 (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters: little or no riparian vegetation due to human activities.
SCORE: 2 (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE: 2 (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0

TOTAL SCORE: 95

APPENDIX C – PHOTO LOG

Site 1

Site 1

Site 4

Site 4

Site 5

Site 5

Site 7

Site 7

Site 8

Site 8

APPENDIX D

Data Quality Review

The data quality objectives established in the approved Quality Assurance Project Plan for the Clarks River WBP-BMP Implementation Project are shown in Table 1. A discussion of each objective with results observed follows.

Table 1. Data quality objectives established in the approved Quality Assurance Project Plan.

Parameter	**Data Quality Indicator**				
	Precision	**Bias**	**Representativeness**	**Comparability**	**Completeness**
E. coli	Field duplicates; Calculate RPD, but disqualification at the discretion of the project team based on quantitative and qualitative review of data	Lab Blanks, Positive Lab Control Sample with each media batch; Disqualification if %recovery exceeds 75% to 125%	Qualitative Records Review; Disqualification if records review shows inappropriate collection and/or analytical methodology	Qualitative Data Review; Disqualification if review shows inconsistent field and laboratory data	Quantitative Evaluation of Records; Disqualification if review shows incomplete record keeping. Target goal of 90% completeness with regards to the number of usable samples
Bacterial Source Tracking	Field duplicates; Disqualification if data review indicates large differences in results from duplicate samples	Laboratory Control Samples	Qualitative Records Review; Disqualification if records review shows inappropriate collection and/or analytical methodology	Qualitative Data Review; Disqualification if review shows inconsistent field and laboratory data	Quantitative Evaluation of Records; Disqualification if review shows incomplete record keeping. Target goal of 90% completeness with regards to the number of usable samples
Nitrate/ nitrite	Field duplicates; Disqualification if RPD>20%	Equipment Blanks, Equipment Calibration, Check Standards every 10 to 20 samples; Disqualification if %recovery exceeds 75% to 125%	Qualitative Records Review; Disqualification if records review shows inappropriate collection and/or analytical methodology	Qualitative Data Review; Disqualification if review shows inconsistent field and laboratory data	Quantitative Evaluation of Records; Disqualification if review shows incomplete record keeping. Target goal of 90% completeness with regards to the number of usable samples
Ammonia	Field duplicates; Disqualification if RPD>20%	Equipment Blanks, Equipment Calibration, Check Standards every 10 to 20 samples; Disqualification if %recovery exceeds 75% to 125%	Qualitative Records Review; Disqualification if records review shows inappropriate collection and/or analytical methodology	Qualitative Data Review; Disqualification if review shows inconsistent field and laboratory data	Quantitative Evaluation of Records; Disqualification if review shows incomplete record keeping. Target goal of 90% completeness with regards to the number of usable samples
Total Kjeldahl Nitrogen	Field duplicates; Disqualification if RPD>20%	Equipment Blanks, Equipment Calibration; Disqualification if %recovery exceeds 75% to 125%	Qualitative Records Review; Disqualification if records review shows inappropriate collection and/or analytical methodology	Qualitative Data Review; Disqualification if review shows inconsistent field and laboratory data	Quantitative Evaluation of Records; Disqualification if review shows incomplete record keeping. Target goal of 90% completeness with regards to the number of usable samples
Total Phosphorus	Field duplicates; Disqualification if RPD>20%	Equipment Blanks, Equipment Calibration; Disqualification if %recovery exceeds 75% to 125%	Qualitative Records Review; Disqualification if records review shows inappropriate collection and/or analytical methodology	Qualitative Data Review; Disqualification if review shows inconsistent field and laboratory data	Quantitative Evaluation of Records; Disqualification if review shows incomplete record keeping. Target goal of 90% completeness with regards to the number of usable samples

Orthophosphate	Field duplicates; Disqualification if RPD>20%	Equipment Blanks, Equipment Calibration; Disqualification if %recovery exceeds 75% to 125%	Qualitative Records Review; Disqualification if records review shows inappropriate collection and/or analytical methodology	Qualitative Data Review; Disqualification if review shows inconsistent field and laboratory data	Quantitative Evaluation of Records; Disqualification if review shows incomplete record keeping. Target goal of 90% completeness with regards to the number of usable samples
Carbonaceous Biochemical Oxygen Demand	Field duplicates; Disqualification if RPD>20%	Equipment Blanks, Equipment Calibration; Disqualification if %recovery exceeds 75% to 125%	Qualitative Records Review; Disqualification if records review shows inappropriate collection and/or analytical methodology	Qualitative Data Review; Disqualification if review shows inconsistent field and laboratory data	Quantitative Evaluation of Records; Disqualification if review shows incomplete record keeping. Target goal of 90% completeness with regards to the number of usable samples
Total Suspended Solids	Field duplicates; Disqualification if RPD>20%	Equipment Blanks, Equipment Calibration; Disqualification if %recovery exceeds 75% to 125%	Qualitative Records Review; Disqualification if records review shows inappropriate collection and/or analytical methodology	Qualitative Data Review; Disqualification if review shows inconsistent field and laboratory data	Quantitative Evaluation of Records; Disqualification if review shows incomplete record keeping. Target goal of 90% completeness with regards to the number of usable samples
Field Data	Field duplicates (one per sampling event per parameter); Disqualification if RPD>20%	Meter Calibration; Disqualification if %recovery exceeds 75% to 125%	Qualitative Records Review; Disqualification if records review shows inappropriate collection and/or analytical methodology	Qualitative Data Review; Disqualification if review shows inconsistent field and laboratory data	Quantitative Evaluation of Records; Disqualification if review shows incomplete record keeping. Target goal of 90% completeness with regards to the number of usable samples

Precision

With regards to precision, duplicate samples were collected in the field at a frequency of one duplicate sample for at least two of the analytical parameters (nitrate/nitrite, ammonia-nitrogen, TKN, total phosphorus, orthophosphate, carbonaceous biochemical oxygen demand and total suspended solids).The parameter selected as a duplicate for the different sampling events was selected at random. For each sampling event, one site was randomly selected to serve as a duplicate bacteriological (*E. coli)* sample. Due to lack of flow at some sites, however, field duplicate samples were not always able to be collected. In addition to field duplicates, the laboratory sometimes conducted duplicate analyses of samples. If the relative percent difference, calculated according to the formula below, was greater than 20% between duplicate samples, samples should not be included in any analysis for this project.

$$RPD\ (\%) = \frac{[X_1 - X_2]}{(X_1 + X_2)/2\backslash} \times 100$$

where,

RPD (%) = relative percent difference

X_1 = original sample concentration

X_2 = duplicate sample concentration

$$[X_1 - X_2] = \text{absolute value of } X_1 - X_2$$

Results for precision evaluations for field parameters have been included in Table 2. Only turbidity samples collected on 11/8/2011 will need to be disqualified from any analyses for this project.

Table 2. Field precision flags.

Parameter	QAPP Requirement	Field Precision Flags Based on Relative percent difference (RPD) between samples																				
		9/27/2011	**9/28/2011**	**10/26/2011**	**11/8/2011**	**12/13/2011**	**1/25/2015**	**2/23/2012**	**3/8/2012**	**4/3/2012**	**5/29/2012**	**6/14/2012**	**7/16/2012**	**8/13/2012**	**9/11/2012**	**9/3/2013**	**9/5/2013**	**9/6/2013**	**9/17/2013**	**9/30/2013**	**4/2/2014**	**5/9/2014**
Turbidity	RPD ≤ 20%	-		-	89	0.72	7.8	8.7	9.5	11	-	2.899	17.3	-	-	-	9.29	5.4	-	5.9	1.6	8
Conductivity	RPD ≤ 20%	-		0.2	-	0.1	2.6	3.3	0	0.1	-	0.11	-	-	-	-	0.07	14	-	1.4	0.9	0.3
pH	RPD ≤ 20%	0.13		-	-	0.28	1	-	-	0.4	-	-	-	-	-	0.3	1.08	0	-	0.1	0.1	0.3
Dissolved Oxygen (mg/L)	RPD ≤ 20%	0.96		-	-	0.27	0.1	4.7	0.1	1.4	48	-	-	-	-	7.9	2.67	0.8	-	0.5	0.6	0.3
Dissolved Oxygen (% Saturation)	RPD ≤ 20%		2.8	-	3.2	8.1	0.3	8.4	0.8	0.8	-	1.479	-	-	-	8.1	0.69	2	-	0.3	0.3	0.2
Temperature	RPD ≤ 20%	0.16		-	-	0.43	1	-	-	0	-	0.147	-	-	0.448	0.1	0.73	0.1	-	0	-	0.6

Results for precision evaluations for laboratory parameters have been included in Table 3. Based on these results, no samples will need to be excluded from analyses based on precision flags. Bacterial samples with a RPD greater than 20% will still be used in data analyses because of the great variability that can naturally occur between samples.

Table 3. Laboratory precision flags.

Parameter	QAPP	Laboratory Precision Flags Based on Relative percent difference (RPD) between samples

	Requirement	9/27/2011	9/28/2011	10/26/2011	11/8/2011	12/13/2011	1/25/2015	2/23/2012	3/8/2012	4/3/2012	5/29/2012	6/14/2012	7/16/2012	8/13/2012	9/11/2012	9/3/2013 (E. coli only)	9/5/2013 (E. coli only)	9/6/2013 (E. coli only)	9/17/2013 (E. coli only)	9/30/2013 (E. coli only)	4/2/2014	5/9/2014
E. coli	RPD Evaluation by Team	4.14		-	66.7	15.3	0	0	1.9	50	-	-	-	-	-	*Lab Error	14.6	10.37	-	71.4	-	171
Nitrate/nitrite	RPD ≤ 20%	-		-	-	-	-	-	-	1.4	-	-	-	-	-	-	-	-	-	-	-	-
Ammonia	RPD ≤ 20%	*Lab Error		-	-	-	-	-	-	17	-	-	-	-	-	-	-	-	-	-	-	-
Total Kjeldahl Nitrogen	RPD ≤ 20%	-		-	1.96	-	-	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Phosphorus	RPD ≤ 20%	-		-	-	12.3	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Orthophosphate	RPD ≤ 20%	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C-BOD	RPD ≤ 20%	1		6.8	-	0	11	8.3, 7.7	0, 10.7	4.9	10	5.5	11	-	13	-	-	-	-	-	-	-
Total Suspended Solids	RPD ≤ 20%	-		-	1	0	-	18.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Bias

In this project, bias for field samples was assessed with calibration standards. If the percent recovery for a calibration standard was outside the acceptable range of 75% to 125%, samples should be omitted from analyses. Calibration standards were run for each sampling event. If the percent recovery for positive control samples or equipment blanks in the laboratory was outside the acceptable range of 75% to 125%, samples should be omitted from analyses. The frequency of positive control samples and equipment blanks was at the discretion of laboratory personnel, but at a minimum included one positive control sample or equipment blank per batch of analytical samples. Samples analyzed as a group with a positive control sample or equipment blank exceeding 20% recovery will be disqualified from this study.

Percent recovery was calculated according to the formula below.

$$\% \text{ recovery} = X/T \times 100$$

where,

X = Measured concentration

T = True concentration

Results for field bias evaluations have been included in Table 4. Based on these results, turbidity samples collected on 7/16/2012, 8/13/2012, 4/2/2014, and 5/9/2014 should be excluded from analyses. Conductivity samples collected on 12/13/2011 should also be excluded from analyses.

Table 4. Field bias flags based on values observed with calibration standards.

Parameter	QAPP Requirement	Field Bias Flags																				
		9/27/2011	9/28/2011	10/26/2011	11/8/2011	12/13/2011	1/25/2015	2/23/2012	3/8/2012	4/3/2012	5/29/2012	6/14/2012	7/16/2012	8/13/2012	9/11/2012	9/3/2013	9/5/2013	9/6/2013	9/17/2013	9/30/2013	4/2/2014	5/9/2014
Turbidity	1.0 NTU standard; acceptable range 0.75 to 1.25 NTU, 10.0 NTU standard; acceptable range 7.5 to 12.5 NTU	1.13		0.95	1.02	0.88	1.09	0.90	1.00	0.91	0.95	1.03	0.56	0.61	-	0.98	0.97	0.86	0.93	9.93	0.42	0.51
Conductivity	1,000 µs/cm standard; acceptable range 750 to 1,250 µs/cm	1008		973	1014	742	1001	986	974	983	798	1338	1012	998	987	983	1009	987	989	1003	1000	1002
pH	4.0 buffer standard; acceptable range 3 to 5	4.00		3.85	4.14	4.12	3.81	4.34	4.56	4.28	4.03	4.02	4.05	4.00	4.00	4.22	3.99	3.96	3.53	3.85	4.11	3.95
pH	7.0 buffer standard; acceptable range 5.25 to 8.75	7.04		6.94	7.15	7.14	7.01	7.35	7.37	7.01	7.20	7.16	7.16	7.16	7.13	7.48	7.21	7.22	7.28	7.23	7.46	7.30
pH	10.0 buffer standard; acceptable range 7.5 to 12.5	10.17		9.89	10.05	10.05	9.87	10.22	9.94	9.60	10.03	9.95	9.99	9.98	9.96	10.01	9.83	0.03	9.96	0.20	10.00	9.81

Results for laboratory bias evaluations have been included in Table 5. Based on these results, ammonia samples collected on 10/26/2011 and 3/8/2012 should be omitted from analyses. TKN samples collected on 9/27/2011, 9/28/2011, 10/26/2011, and 2/23/2011 should also be omitted from analyses. Total phosphorus samples collected on 11/8/2011, 5/29/2012, 7/16/2012 and 9/11/2012 and orthophosphate samples collected on 7/16/2012 should not be included in data analyses.

Table 5. Laboratory bias flags based on blanks and positive control samples.

Parameter	QAPP Requirement	Laboratory Bias Flags																				
		9/27/2011	9/28/2011	10/26/2011	11/8/2011	12/13/2011	1/25/2015	2/23/2012	3/8/2012	4/3/2012	5/29/2012	6/14/2012	7/16/2012	8/13/2012	9/11/2012	9/3/2013 (E. coli only)	9/5/2013 (E. coli only)	9/6/2013 (E. coli only)	9/17/2013 (E. coli only)	9/30/2013 (E. coli only)	4/2/2014	5/9/2014
E. coli	Lab blanks, positive control samples; % recovery 75% to 125%													Zero flow – no sample collected		No QC reported	No QC reported	No QC reported	No QC reported	No QC reported	No QC reported	No QC reported
Nitrate/nitrite	Lab blanks, positive control samples; % recovery 75% to 125%													Zero flow – no sample collected								
Ammonia	Lab blanks, positive control samples; % recovery 75% to 125%			Calibration standard outside acceptable range			No QC reported		Calibration standard outside acceptable range					Zero flow – no sample collected								
Total Kjeldahl Nitrogen	Lab blanks, positive control samples; % recovery 75% to 125%	Spike sample outside acceptable range		Spike sample outside acceptable range				Spike sample outside acceptable range						Zero flow – no sample collected								

Total Phosphorus	Lab blanks, positive control samples; % recovery 75% to 125%			Spike sample outside acceptable range			No QC reported			Spike sample outside acceptable range		Spike sample outside acceptable range	Zero flow – no sample collected	Spike sample outside acceptable range							
Orthophosphate	Lab blanks, positive control samples; % recovery 75% to 125%				No QC reported							Spike sample outside acceptable range	Zero flow – no sample collected								
C-BOD	Lab blanks, positive control samples; % recovery 75% to 125%												Zero flow – no sample collected								
Total Suspended Solids	Lab blanks, positive control samples; % recovery 75% to 125%												Zero flow – no sample collected								
Bacterial Source Tracking	Lab blanks, positive control samples; % recovery 75% to 125%	Not scheduled for collection	Not scheduled for collection	Not scheduled for collection	Not scheduled for collection	Not scheduled for collection	Not scheduled for collection	Not scheduled for collection	Not scheduled for collection	Not scheduled for collection	Not scheduled for collection	Not scheduled for collection	Not scheduled for collection	Not scheduled for collection	Not scheduled for collection	Not scheduled for collection	Not scheduled for collection	Not scheduled for collection	Not scheduled for collection		

Representativeness

In this study, representativeness was assessed qualitatively by verifying that appropriate sample collection and analytical methods were followed throughout this process. Evaluations of sample handling and chain of custody records, sample preservation, and sample holding times were conducted as part of the data review process on the Field Activities Review forms and Laboratory Activities Review forms. No issues with representativeness were identified.

Comparability

In this study, comparability was assessed qualitatively by verifying that field and laboratory data were consistent in terms of methods and units of measure between sampling events. No issues with comparability were identified.

Completeness

In this study, completeness was assessed quantitatively through the following equation:

$$\% \text{ Completeness} = N/T \times 100$$

where,

N = number of usable results

T = total number of samples planned to be collected during study

In total, 2,404 field and lab samples were planned to be collected during this study. Due to unforeseen circumstances, such as sampling sites dry or unreachable, 1,393 samples were actually collected. Of those 1,393 samples collected, 1,264 samples were usable with no QA/QC issues identified, for a % completeness of 52.57%.

Appendix D
Chestnut Creek Data Summary
April, 2015

Raw data from the Chestnut Creek Watershed Management Plan project are included on the attached CD. A copy of this summary is also included on the CD. Water quality monitoring was conducted from September, 2011 through May, 2014 at eight sites along Chestnut Creek. A one-time sample was collected in October, 2014 at a location near the Draffenville Water Reclamation Plant outfall. During September, 2013, a series of samples were collected at the eight stream sites to evaluate bacterial levels. The results of the bacterial analyses are presented in Appendix Table A-2.

DATA ANALYSES

The one-time sample near the outfall is not included in the data analyses. The sample showed an E. coli level of 2420 MPN/100 mL, ammonia nitrogen at 0.43 mg/L and nitrite/nitrate nitrogen at 0.75 mg/L. The E. coli level is high, but the nitrogen compounds are similar to levels found at the stream sites.

The one month bacterial sampling complied with State guidelines on the number and frequency of samples, and was used to evaluate geometric means. Lack of flow reduced the number of samples collected at several sites. When the analytical results were above the maximum readable result of 2420 MPN/100 mL, that was the value used in the calculations. Sites 1 and 5 had geometric means of less than 200 MPN/100 mL. Sites 2, 3, 4, and 6 had geometric means of between 200 and 300 MPN/100 mL. Site 8 had a geometric mean of 338 MPN/100 mL, which included one abnormally high reading. Site 7 had a geometric mean of 480 MPN/100 mL, and the readings were consistently high.

The remainder of this summary addresses overall results from the eight stream sampling sites.

Mean Concentrations

Charts showing the arithmetic means and 95 percent statistical confidence levels for all field and laboratory parameters at each site are included in Appendix B. Appendix B also contains tables showing the numerical means and standard deviations of each parameter at each site.

Mean dissolved oxygen concentrations vary from a low of approximately 4 at Site 3 to a high of approximately 12 at Site 5. The difference in concentrations at Site 3 and Site 5 is the only statistically significant difference among all the sites. The degree of oxygen saturation follows an identical pattern.

The pH mean levels are around neutral, with no significant differences. Similarly, the mean temperatures are each site are not statistically different.

Although not statistically different, the mean levels of turbidity and suspended solids are slightly higher at Site 8, which is the site farthest downstream.

CBOD concentrations are generally low and not significantly different among the sites.

The mean conductivity level of approximately 400 uS/cm at Site 3 is significantly higher than the other sites. Site 3 is the first site downstream of the water reclamation plant. Ammonia nitrogen is also significantly higher at Site 3, but the nitrite/nitrate concentration is not. The conductivity and ammonia values, coupled with the nitrate/nitrite value could be indicators of operational problems at the water reclamation facility. TKN, which is the total of ammonia and organic nitrogen is also significantly higher at Site 3, probably because of the ammonia. While not significantly higher, the mean E.coli level is highest at Site 3. Arithmetic mean E. coli levels are higher than the State water quality criteria at all sites. The coliform data presented in this chart do not include data from the 30 day focused sampling.

Orthophosphate and total phosphorus mean concentrations are similar at each site except Site 3, which is significantly higher. Orthophosphate concentrations are typically about 0.05 mg/L with total phosphate about 20 percent higher. The mean concentrations at Site 3 are about 10 times higher than the other sites.

Correlations

Various correlations among the parameters were examined to identify trends and to assess possible sources. Appendix C includes a chart showing correlations among bacteria and solids and a chart showing correlations among nutrients. A table with the actual correlation coefficients is also included in Appendix C. Flow and the total precipitation in the 48 hours prior to sampling are included in the correlations.

The correlations between flow and all the other parameters are low, partly due to the intermittent flow conditions in this area. Samples could be collected at some events, but the flows could not be accurately measured. Precipitation shows a fair to good correlation with turbidity, suspended solids, and E. coli, indicating that runoff is a factor.

The correlations among the nutrient species were fair to good except for nitrite/nitrate. A negative correlation between ammonia and nitrate would be expected and did occur, but the correlation was essentially zero. Normally, a water reclamation facility would convert much of the incoming ammonia to nitrate, so this could be another indication of operational problems at the facility.

Mass Loadings

Mass loadings, or quantity in the case of E. coli, related to measured flow, were evaluated for E. coli, ammonia nitrogen, nitrite/nitrate nitrogen, orthophosphate, and total phosphorus. Charts showing the mass loadings are contained in Appendix D. The data are plotted on log scales to better indicate the mass loadings. Table D-1 shows the numerical results.

Appendix D also contains bar charts showing the average quantity or mass loadings at each site. Flow in several branches of Chestnut Creek is intermittent, but base flow in the main stream channel appears to be about 0.20 cubic feet per second (cfs) considering average discharge from the water reclamation facility. The average measured flows were as follows: Site 1 – 1.49 cfs, Site 2 – 2.2 cfs, Site 3 – 0.27 cfs, Site 4 – 1.5 cfs, Site 5 – 1.4 cfs, Site 6 – 0.5 cfs, Site 7 – 1.66 cfs, Site 8 – 5.22 cfs. Site 3 was a low flow site, but the mass inputs for ammonia and phosphorus were higher than all other sites except Site 8, the site farthest downstream.

Water quality criteria for the nutrient species have not been established. Using 240 MPN/100 mL for E. coli, 0.10 mg/L for total phosphorus, and 1.0 mg/L for total nitrogen yields 1174 million MPN/day for E. coli, 0.11 lbs/day for phosphorus, and 1.1 lbs/day for total nitrogen at base flow. Base flow undoubtedly varies at different locations in the watershed, but comprehensive flow data are not available.

At the overall average flow of 1.7 cfs, the yields are 9800 million MPN/day for E. coli, 0.94 lbs/day for phosphorus, and 9.4 lbs/day for total nitrogen. Obviously specific sites have lower or higher flows than the overall average, but broad observations can be made that the overall level of nutrients in the stream are generally less than what occurs at average levels.

The final charts in Appendix D are quantile plots of concentration and mass (or quantity) for E. coli, ammonia nitrogen, total nitrogen, orthophosphate phosphorus, and total phosphorus. Quantile plots show the proportion of results below a selected level. The charts confirm that phosphorus and ammonia concentrations are consistently much higher at site 3 compared to the other sites. On a mass basis, Site 3 typically has the highest levels of ammonia, although both sites 1 and 2 have a higher level once. For phosphorus, Sites 1, 2, 4, and 5, all show one-time levels higher than Site 3.

Appendix E contains a list of other maps and data sets prepared and/or furnished by Murray State University for the project.

Conclusions

Site 3 is impacted by the Draffenville Water Reclamation Plant, especially with regard to ammonia and phosphorus concentrations.

E.coli levels are consistently above State water quality criteria, and runoff appears to be a factor. Based on geometric means, the coliform levels are not excessively higher that the water quality criteria. During a focused, 30-day study, the highest geometric mean of 480 cfu/100mL occurred at Site 7. The levels of E. coli exceeded 2400 MPN/100 mL during a high flow event.

Based on estimated water quality criteria average concentration and average measured flows, the masses of nutrients are not really a major issue. Reducing the levels at Site 3 may be sufficient to maintain the entire stream at levels below the criteria.

Relative to chemical and bacterial water quality, inputs to Site 3 should be the focus of the watershed management plan.

Appendices

Appendix A – Data Summaries

Table A-1. Chestnut Creek Raw Data

Included on attached CD along with a copy of the data report.

Table A-2. Chesnut Creek E. Coli Sampling 2013 (5 in 30 days, MPN/100mL)

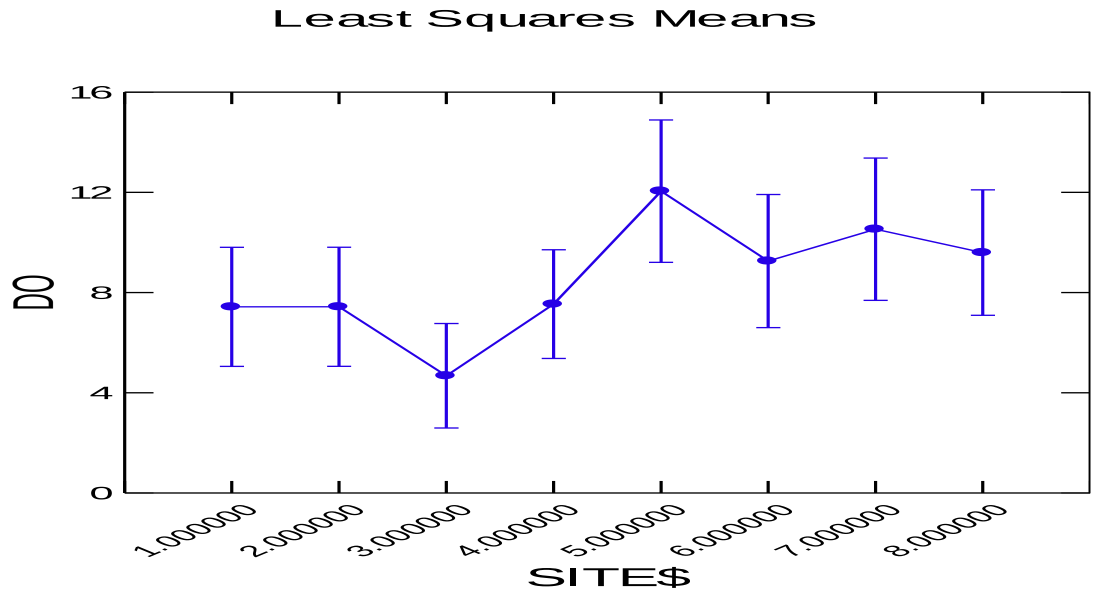
Site 1	Date Sampled	E.Coli	Site 5	Date Sampled	E.Coli
	9/3/2013	488		9/3/2013	158
	9/5/2013	66		9/5/2013	93
	9/6/2013	613		9/6/2013	50
	9/30/2013	99		9/30/2013	613
GeoMean		**154**	**GeoMean**		**145**

Site 2	Date Sampled	E.Coli	Site 6	Date Sampled	E.Coli
	9/3/2013	66		9/3/2013	411
	9/5/2013	69		9/5/2013	313
	9/6/2013	236		9/6/2013	159
	9/30/2013	2420		9/30/2013	272
GeoMean		**226**	**GeoMean**		**273**

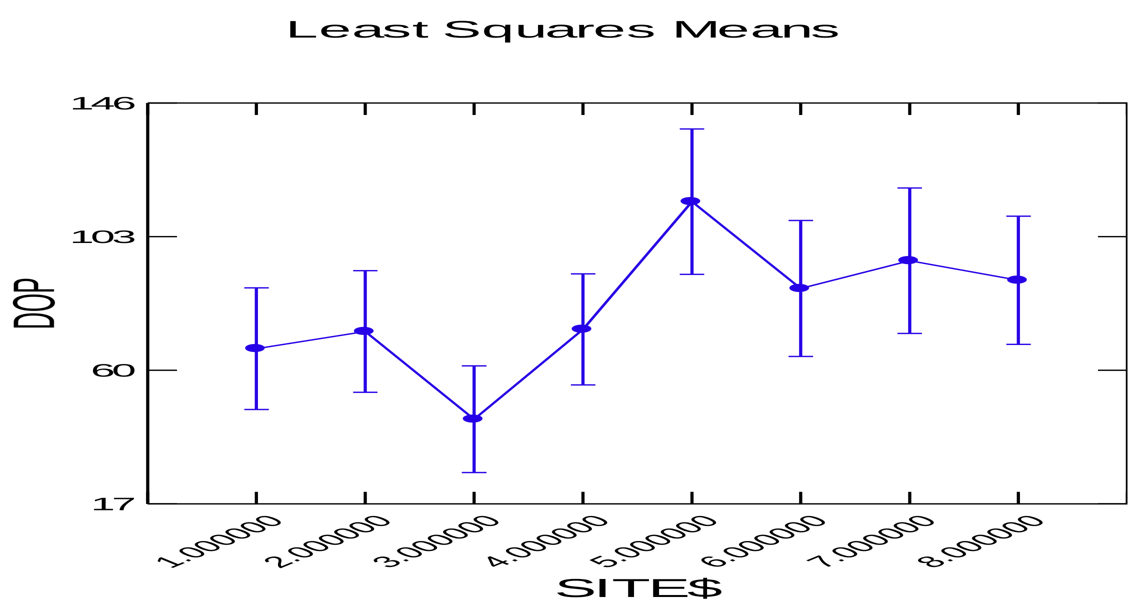
Site 3	Date Sampled	E.Coli	Site 7	Date Sampled	E.Coli
	9/3/2013	613		9/3/2013	649
	9/5/2013	233		9/5/2013	435
	9/6/2013	59		9/6/2013	326
	9/17/2013	199		9/30/2013	579
	9/30/2013	1120	**GeoMean**		**480**
GeoMean		**285**			

Site 4	Date Sampled	E.Coli	Site 8	Date Sampled	E.Coli
				9/3/2013	158
	9/3/2013	99		9/5/2013	138
	9/5/2013	120		9/6/2013	248
	9/6/2013	84		9/30/2013	2420
	9/30/2013	2420	**GeoMean**		**338**
GeoMean		**222**			

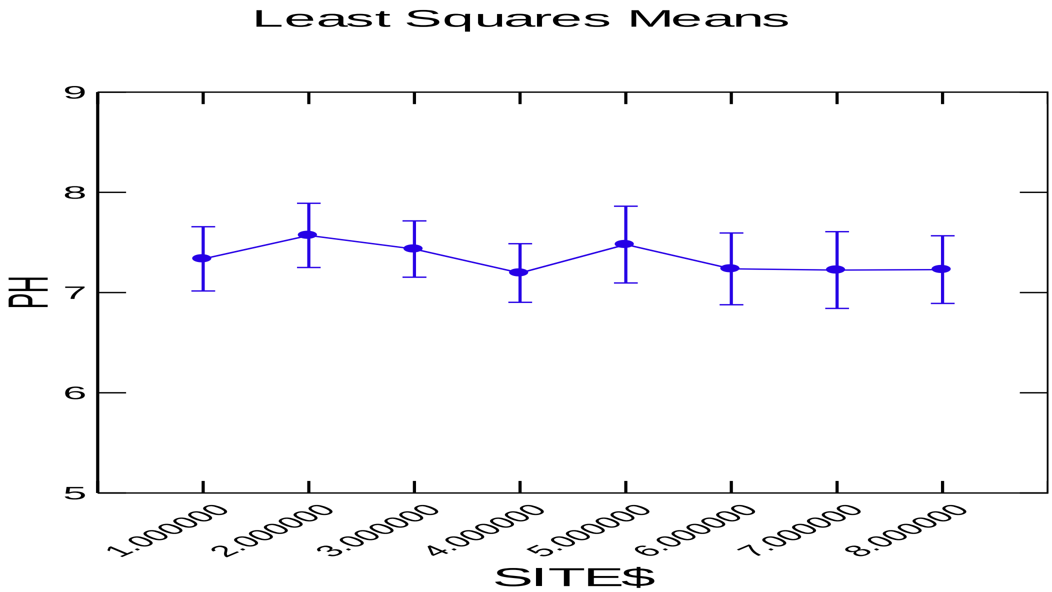
Appendix B – Descriptive Statistics



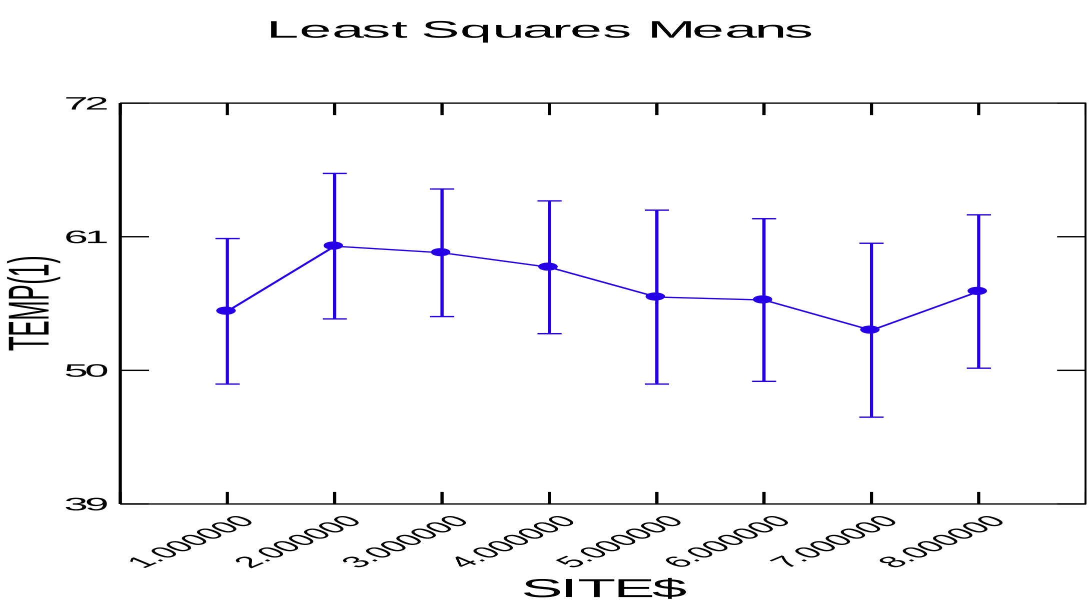
Arithmetic Mean and 95 Percent Confidence Interval for Dissolved Oxygen, mg/L.



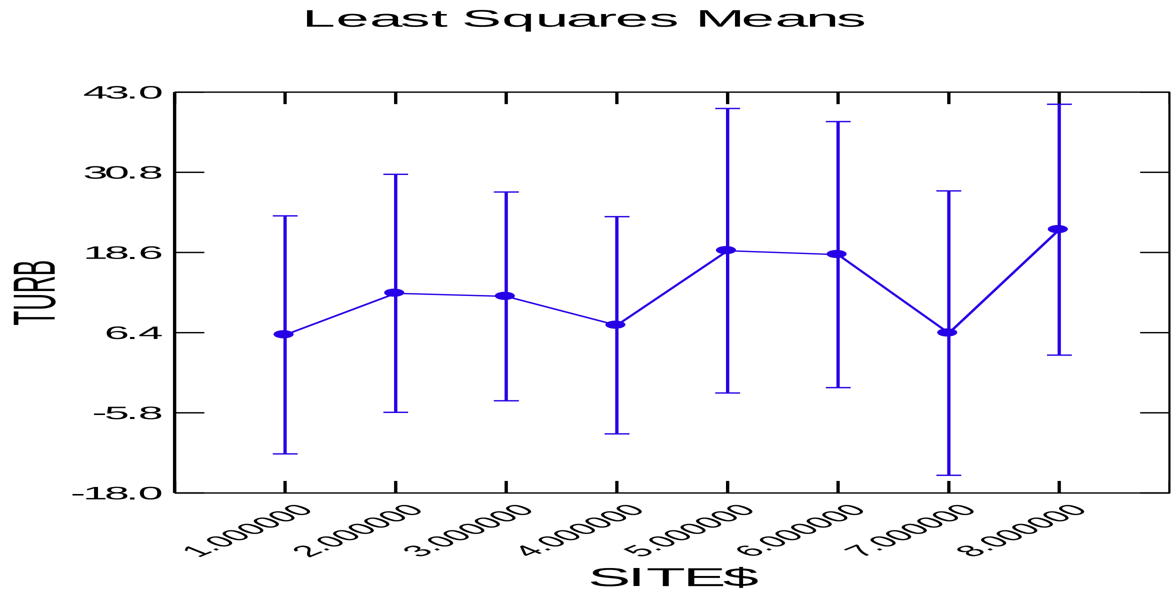
Arithmetic Mean and 95 Percent Confidence Interval for Oxygen Saturation Percent.



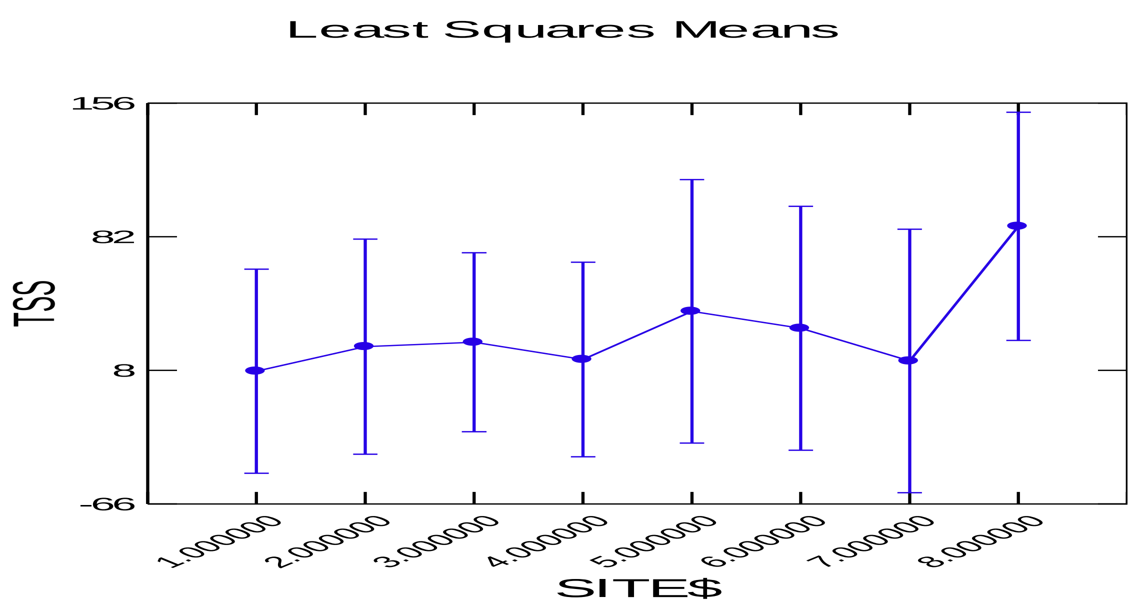
Arithmetic Mean and 95 Percent Confidence Interval for pH.



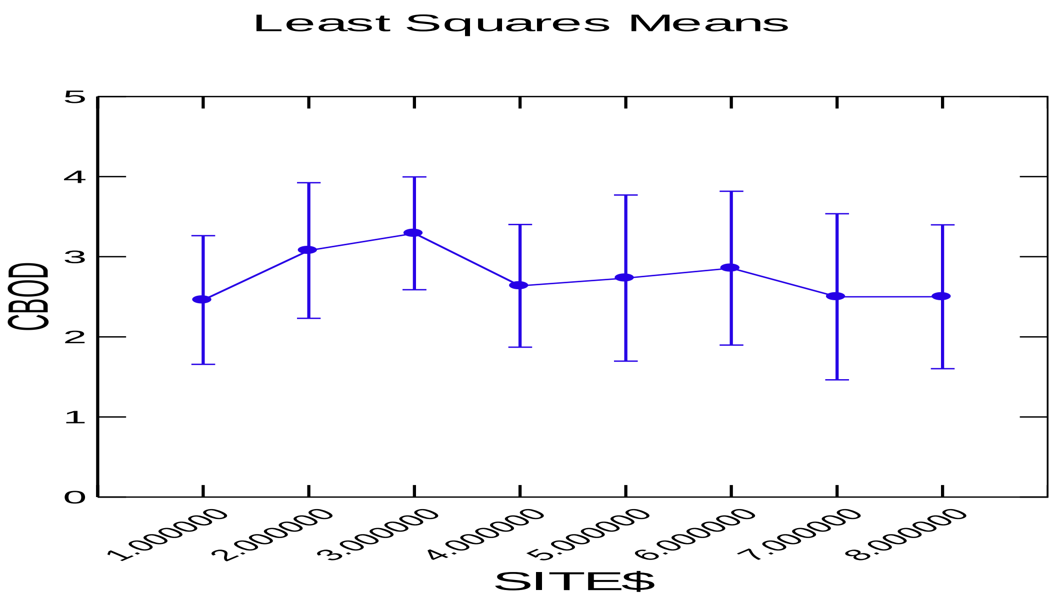
Arithmetic Mean and 95 Percent Confidence Interval for Temperature, Celsius.



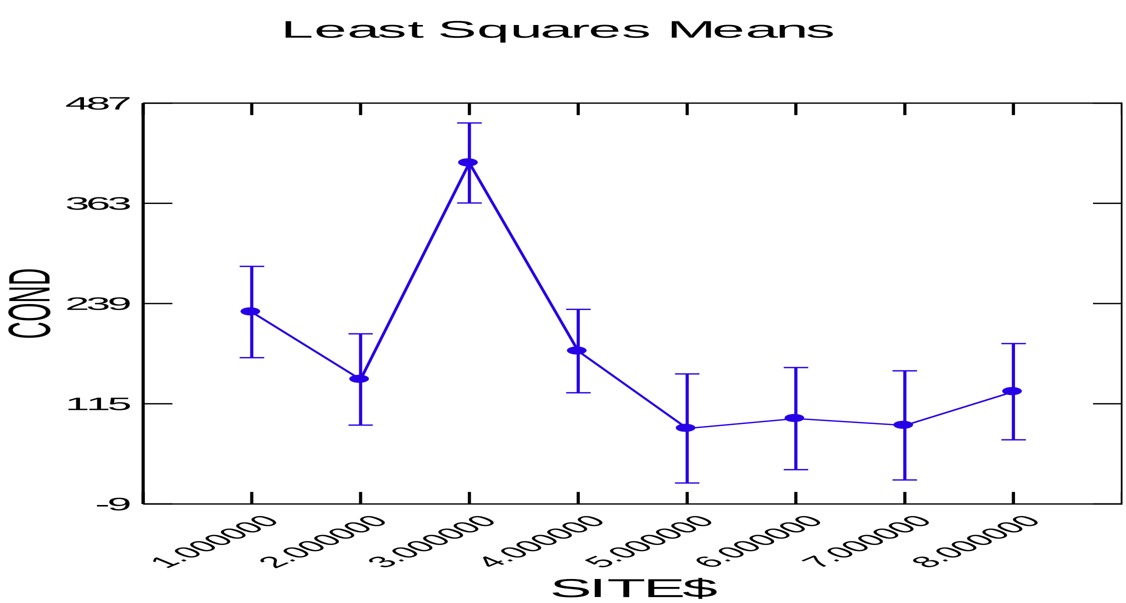
Arithmetic Mean and 95 Percent Confidence Interval for Turbidity, NTU.



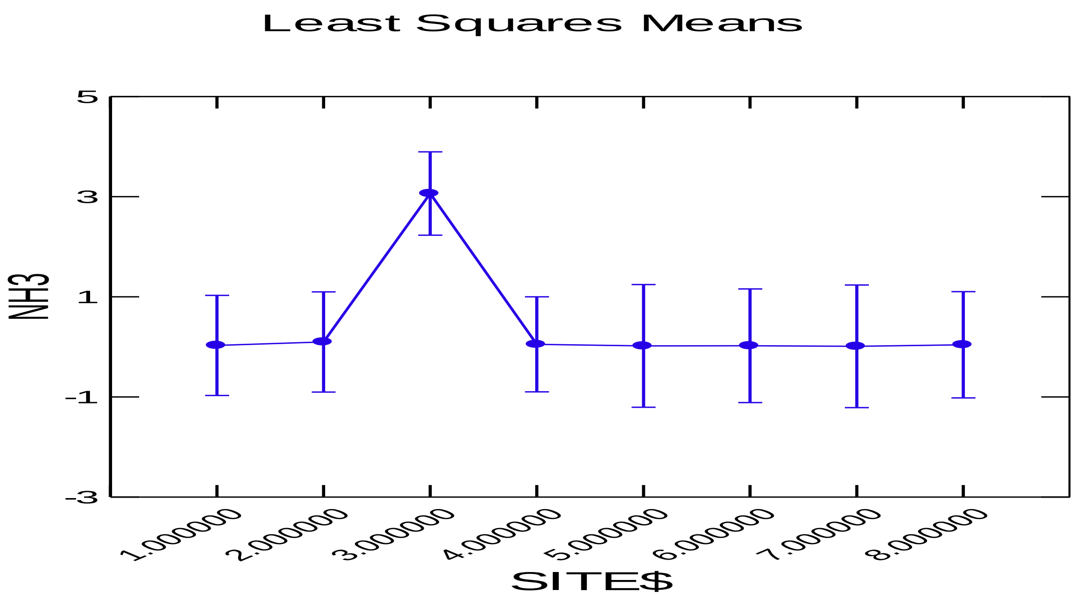
Arithmetic Mean and 95 Percent Confidence Interval for Suspended Solids, mg/L.



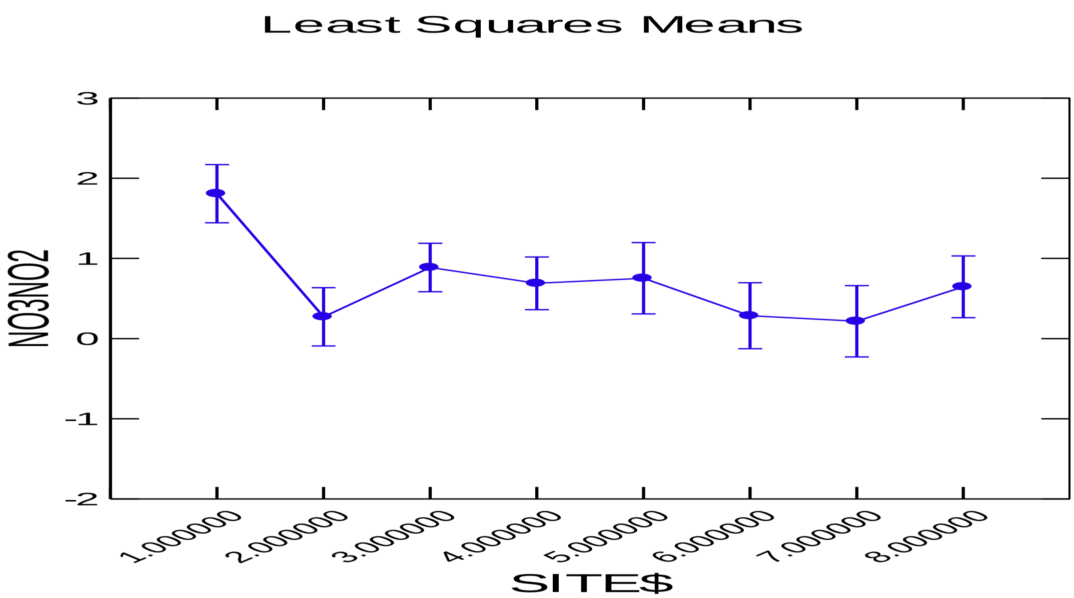
Arithmetic Mean and 95 Percent Confidence Interval for CBOD, mg/L.



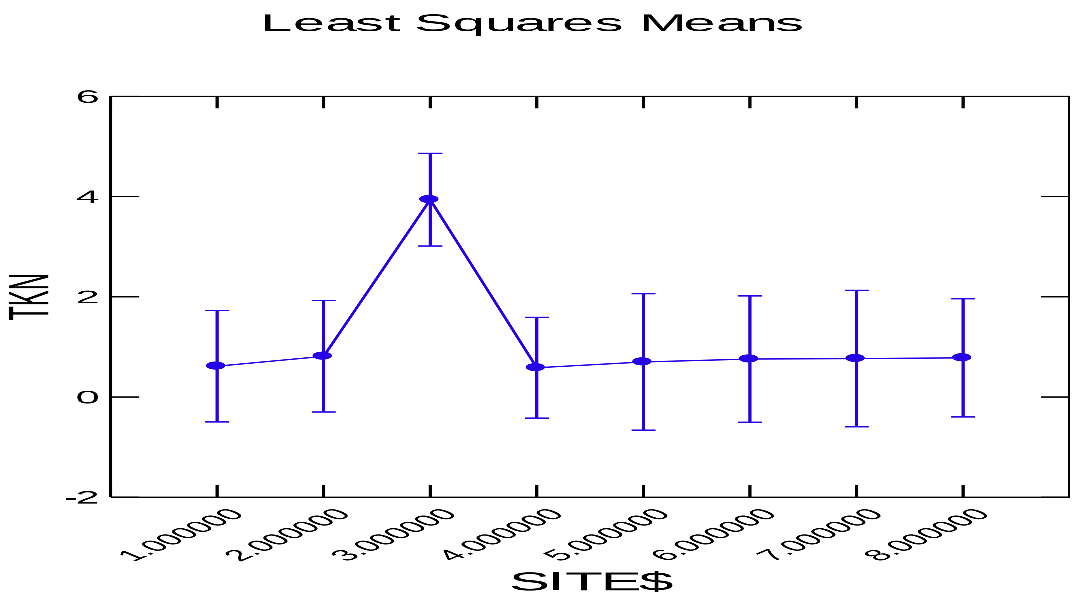
Arithmetic Mean and 95 Percent Confidence Interval for Conductivity, uS/cm.



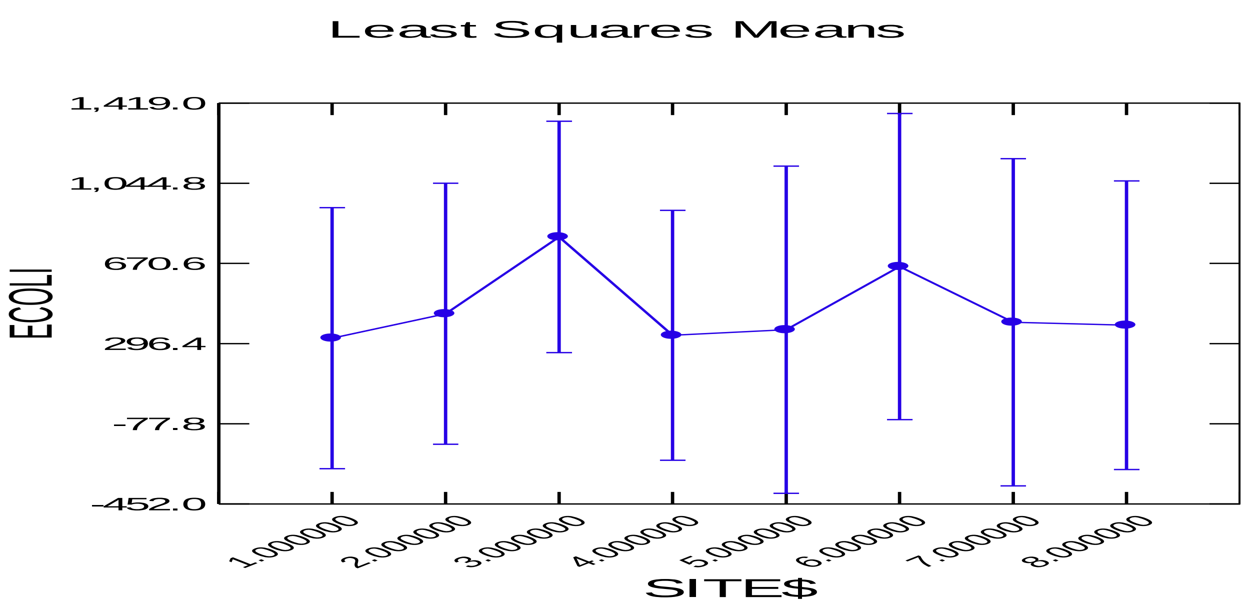
Arithmetic Mean and 95 Percent Confidence Interval for Ammonia Nitrogen, mg/L.



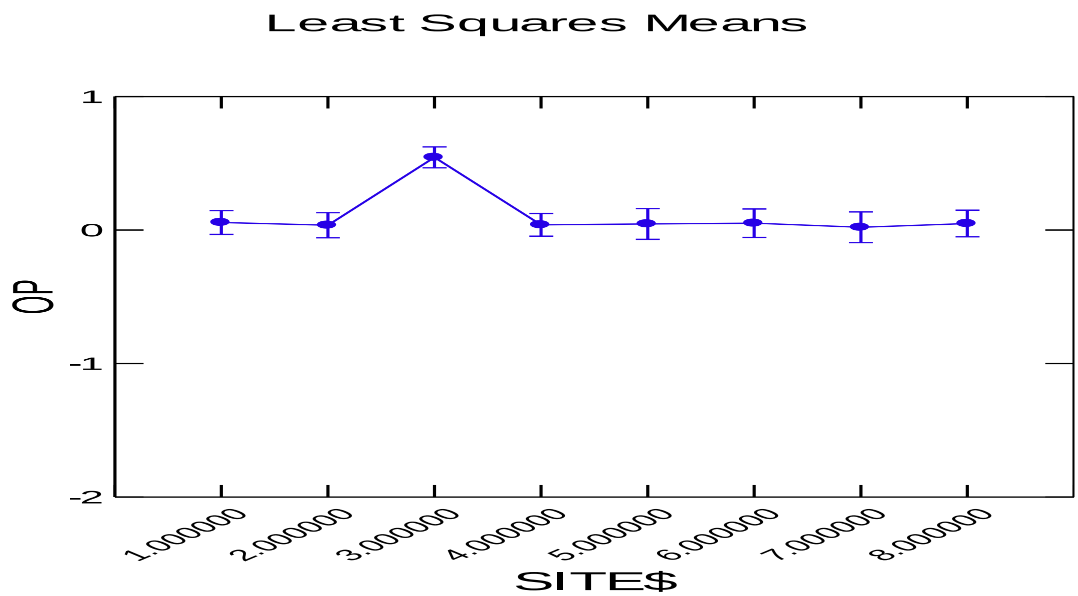
Arithmetic Mean and 95 Percent Confidence Interval for Nitrite/Nitrate mg/L.



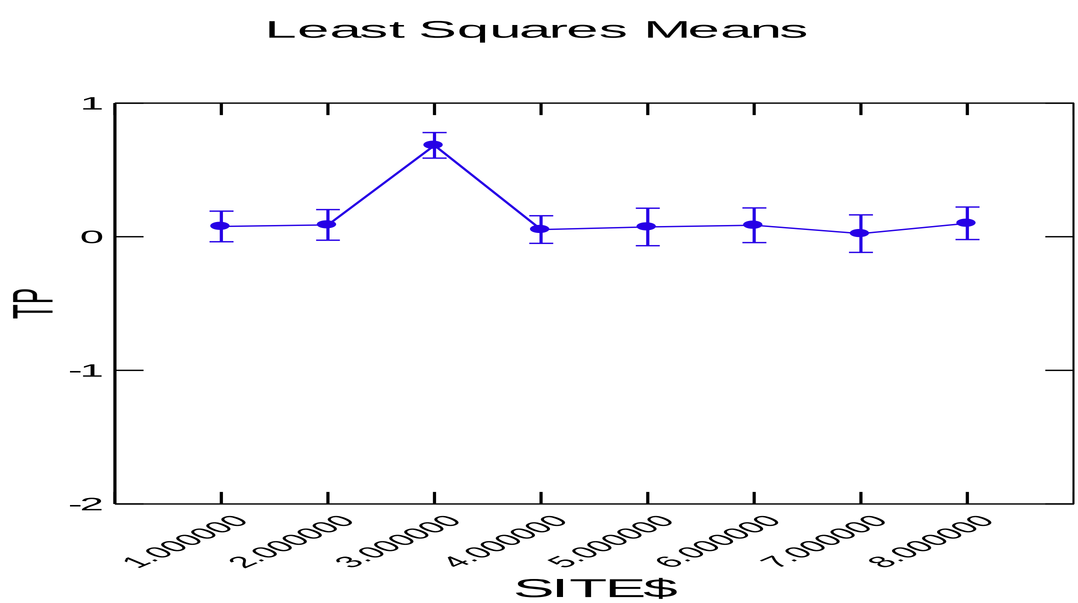
Arithmetic Mean and 95 Percent Confidence Interval for TKN, mg/L.



Arithmetic Mean and 95 Percent Confidence Interval for E. coli, MPN/100mL.



Arithmetic Mean and 95 Percent Confidence Interval for Orthophosphate, mg/L.



Arithmetic Mean and 95 Percent Confidence Interval for Total Phosphorus, mg/L.

Descriptive Statistics for Each Sampling Site

Results for SITE$ = 1.000000

	DO	PH	COND	TEMP(1)	TSS	TURB	NH3	NO3NO2	TKN	CBOD	OP	TP
N of Cases	10	10	10	10	10	10	9	9	9	10	10	9
Minimum	1.190	7.010	74.200	39.200	1.000	0.130	0.004	0.394	0.500	2.000	0.010	0.038
Maximum	12.380	8.030	349.100	67.300	56.000	53.300	0.083	3.605	1.500	3.600	0.180	0.240
Arithmetic Mean	7.428	7.336	228.470	54.860	7.500	6.056	0.029	1.808	0.614	2.460	0.057	0.077
Standard Deviation	4.189	0.319	82.013	9.229	17.116	16.612	0.030	1.063	0.332	0.619	0.049	0.063

Results for SITE$ = 2.000000

	DO	PH	COND	TEMP(1)	TSS	TURB	NH3	NO3NO2	TKN	CBOD	OP	TP
N of Cases	10	10	10	10	9	10	9	9	9	9	9	9
Minimum	1.190	7.190	69.000	43.000	2.000	0.140	0.040	0.063	0.510	2.000	0.010	0.020
Maximum	12.450	8.220	249.500	78.000	90.000	57.700	0.162	0.784	1.500	5.000	0.120	0.210
Arithmetic Mean	7.431	7.570	145.040	60.220	21.111	12.383	0.097	0.271	0.812	3.078	0.036	0.088
Standard Deviation	4.656	0.333	48.158	11.772	30.832	16.471	0.044	0.214	0.328	0.938	0.034	0.059

Results for SITE$ = 3.000000

	DO	PH	COND	TEMP(1)	TSS	TURB	NH3	NO3NO2	TKN	CBOD	OP	TP
N of Cases	13	13	13	13	13	13	13	13	13	13	13	13
Minimum	0.180	7.210	95.600	44.100	3.000	1.960	0.001	0.043	0.540	2.000	0.076	0.150
Maximum	11.570	7.720	889.000	75.200	200.000	75.100	10.065	2.145	12.000	9.000	1.000	1.200
Arithmetic Mean	4.678	7.434	412.900	59.677	23.538	11.910	3.063	0.887	3.938	3.292	0.544	0.684
Standard Deviation	3.966	0.170	188.566	9.728	53.330	19.854	3.354	0.620	3.616	1.994	0.301	0.321

Results for SITE$ = 4.000000

	DO	PH	COND	TEMP(1)	TSS	TURB	NH3	NO3NO2	TKN	CBOD	OP	TP
N of Cases	12	12	12	12	11	12	10	11	11	11	11	11
Minimum	2.100	6.440	92.300	45.000	1.000	0.060	0.006	0.216	0.500	2.000	0.010	0.015
Maximum	15.560	9.500	222.700	69.800	91.000	61.300	0.145	1.898	1.400	5.000	0.130	0.240
Arithmetic Mean	7.537	7.195	180.133	58.483	14.000	7.516	0.050	0.689	0.584	2.636	0.039	0.054
Standard Deviation	4.278	0.800	35.027	8.276	25.880	17.047	0.039	0.489	0.271	1.027	0.039	0.064

Results for SITE$ = 5.000000

	DO	PH	COND	TEMP(1)	TSS	TURB	NH3	NO3NO2	TKN	CBOD	OP	TP
N of Cases	7	7	7	7	6	7	6	6	6	6	6	6
Minimum	8.340	6.830	43.800	44.200	1.000	1.210	0.005	0.255	0.500	2.000	0.010	0.012
Maximum	16.040	9.170	110.000	68.300	160.000	88.700	0.051	1.023	1.700	4.000	0.190	0.260
Arithmetic Mean	12.046	7.479	84.414	56.029	40.667	18.860	0.018	0.752	0.700	2.733	0.046	0.073
Standard Deviation	2.295	0.802	25.214	9.056	65.307	32.404	0.016	0.298	0.490	0.766	0.071	0.094

Results for SITE$ = 6.000000

	DO	PH	COND	TEMP(1)	TSS	TURB	NH3	NO3NO2	TKN	CBOD	OP	TP
N of Cases	8	8	8	8	7	8	7	7	7	7	7	7
Minimum	5.350	6.620	55.470	44.200	1.000	0.700	0.005	0.070	0.500	2.000	0.010	0.011
Maximum	11.890	8.230	137.300	65.200	200.000	121.000	0.081	0.592	2.300	5.000	0.250	0.450
Arithmetic Mean	9.256	7.236	96.596	55.788	31.286	18.271	0.022	0.285	0.757	2.857	0.051	0.086
Standard Deviation	2.956	0.500	26.968	8.275	74.442	41.736	0.027	0.179	0.680	1.464	0.088	0.161

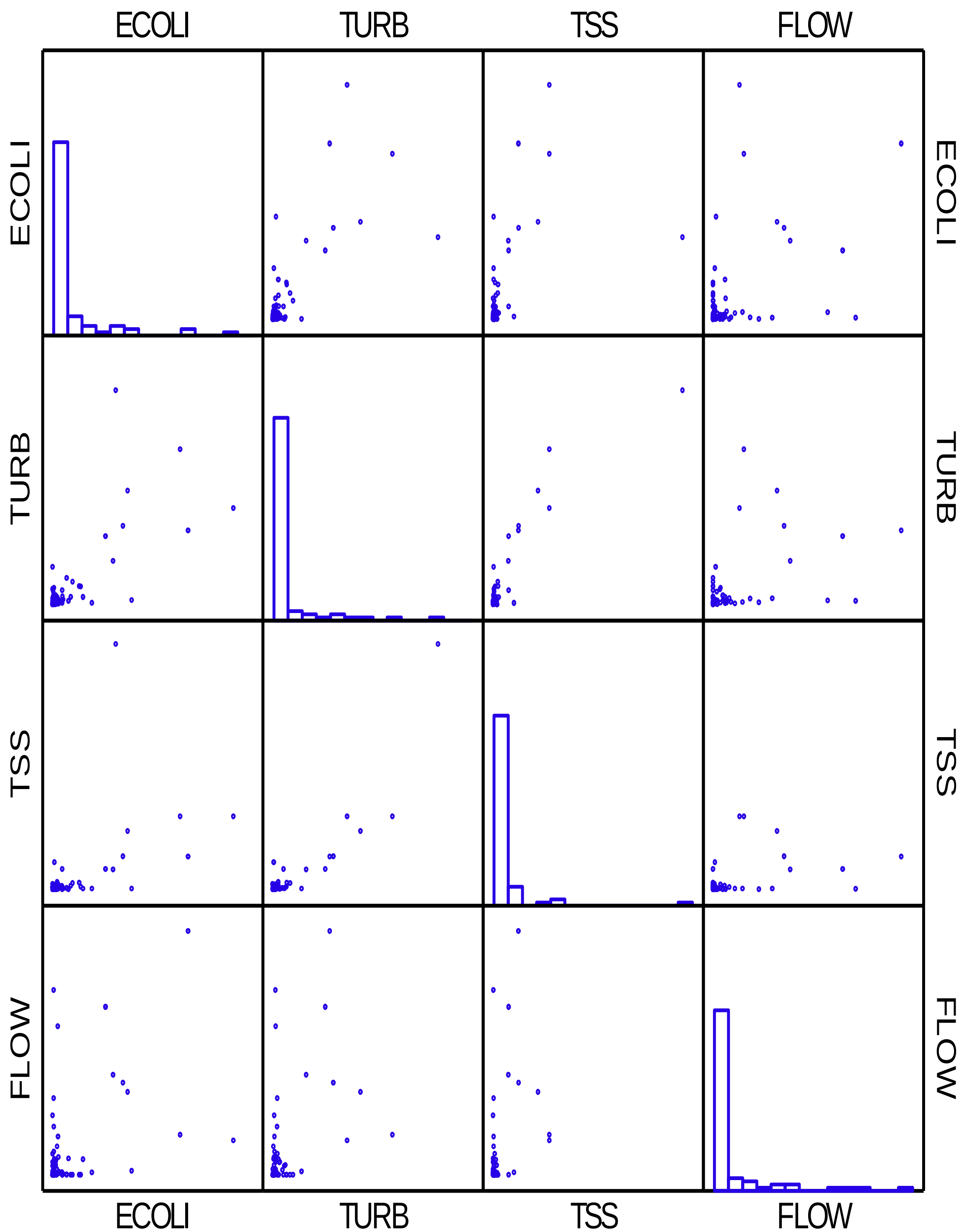
Results for SITE$ = 7.000000

	DO	PH	COND	TEMP(1)	TSS	TURB	NH3	NO3NO2	TKN	CBOD	OP	TP
N of Cases	7	7	7	7	6	7	6	6	6	6	6	6
Minimum	7.000	6.620	37.000	41.300	1.000	0.340	0.002	0.058	0.500	2.000	0.010	0.012
Maximum	13.920	8.030	128.000	64.400	55.000	34.000	0.028	0.505	2.100	5.000	0.035	0.046
Arithmetic Mean	10.527	7.224	88.157	53.300	13.167	6.326	0.010	0.216	0.767	2.500	0.021	0.023
Standard Deviation	2.494	0.537	29.384	8.913	21.085	12.229	0.009	0.195	0.653	1.225	0.009	0.012

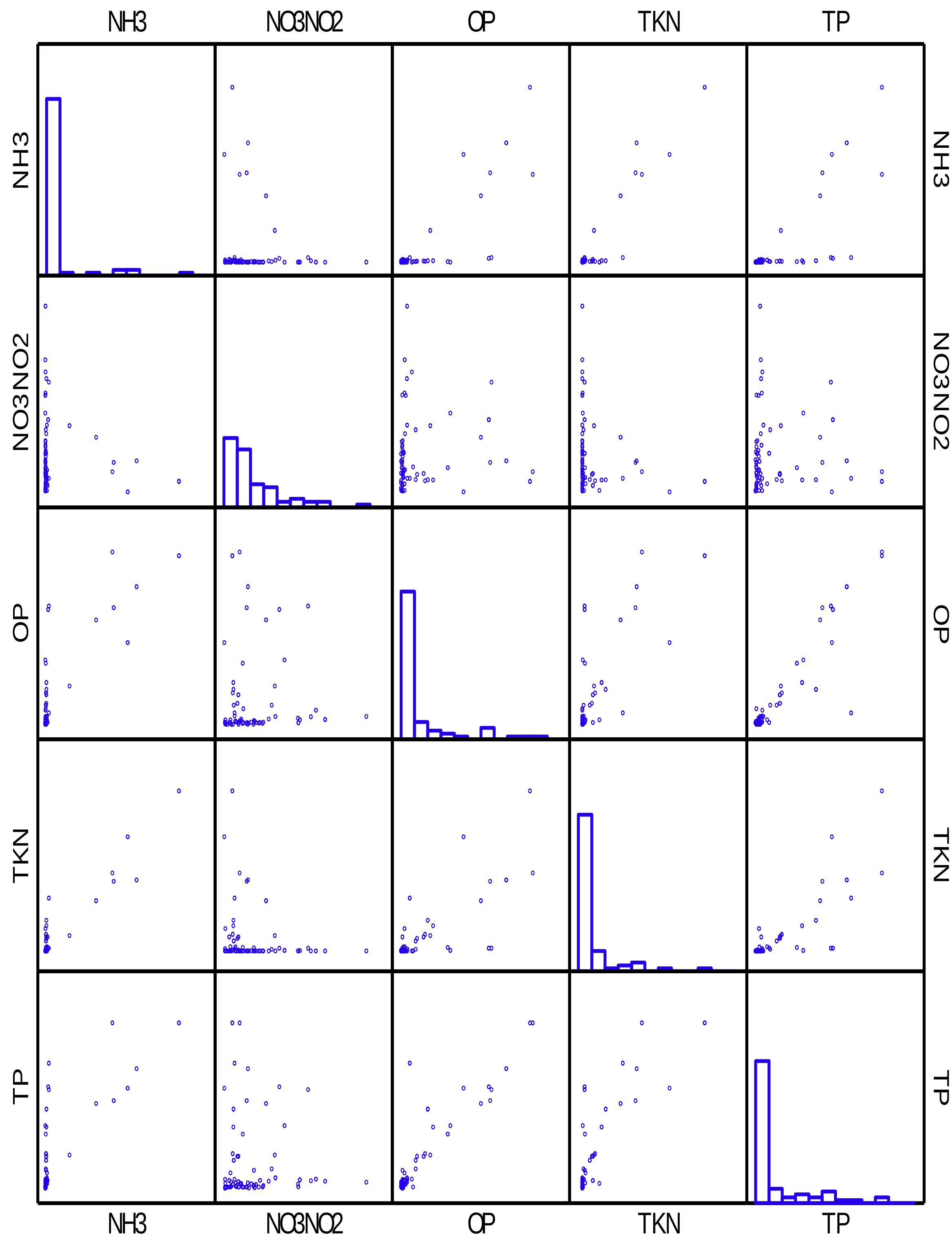
Results for SITE$ = 8.000000

	DO	PH	COND	TEMP(1)	TSS	TURB	NH3	NO3NO2	TKN	CBOD	OP	TP
N of Cases	9	9	9	9	8	9	8	8	8	8	8	8
Minimum	4.620	6.590	77.600	42.100	1.000	0.860	0.008	0.276	0.500	2.000	0.010	0.018
Maximum	14.570	7.820	195.100	68.200	670.000	167.000	0.120	1.325	2.700	5.000	0.210	0.580
Arithmetic Mean	9.594	7.229	129.878	56.489	87.750	22.063	0.041	0.646	0.781	2.500	0.049	0.101
Standard Deviation	3.383	0.330	33.717	9.839	235.340	54.503	0.039	0.352	0.775	1.069	0.067	0.195

Appendix C – Parameter Correlations



Correlations among E. coli, Turbidity, Suspended Solids, and Flow.

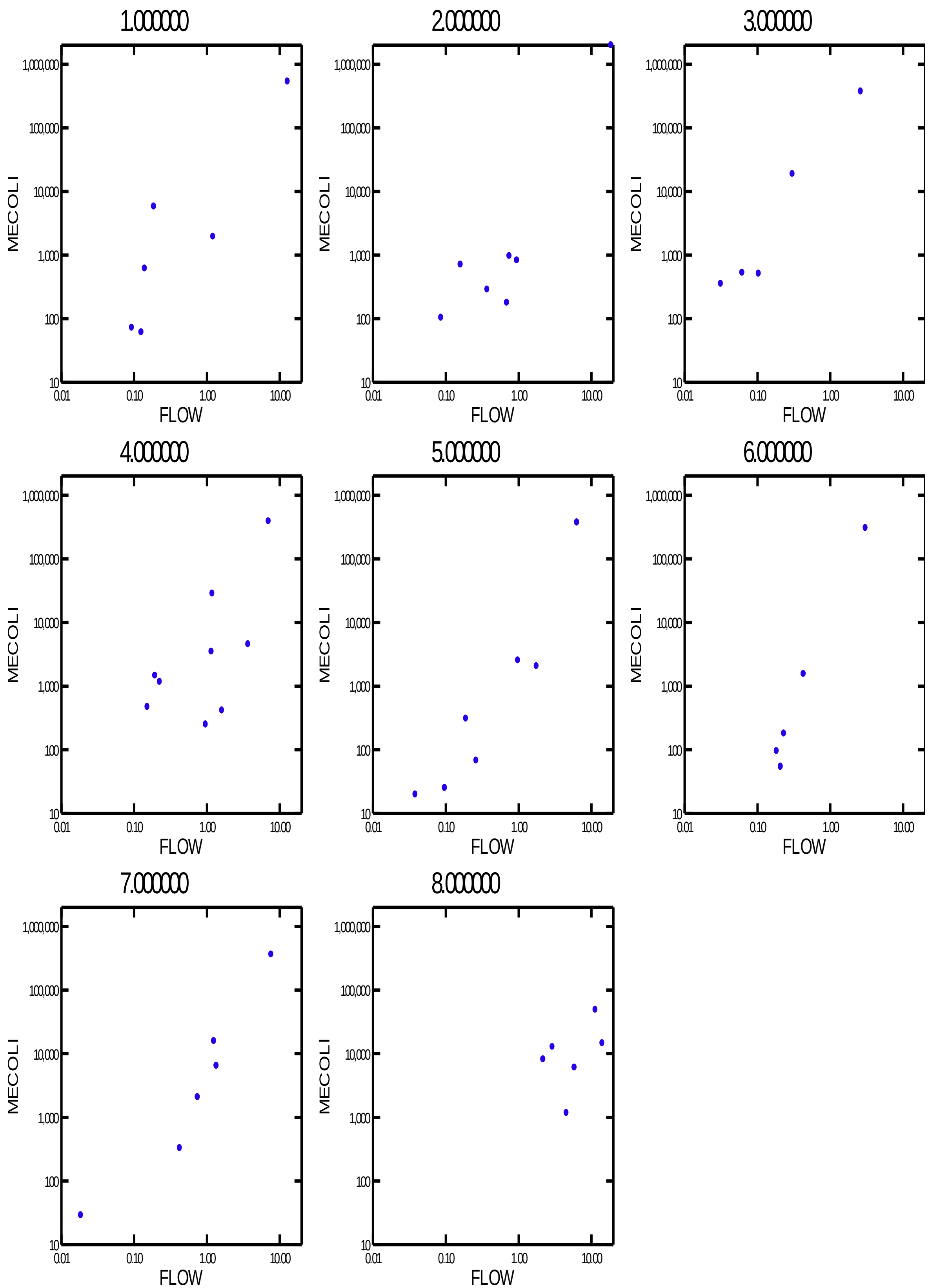


Correlations Among Nutrients.

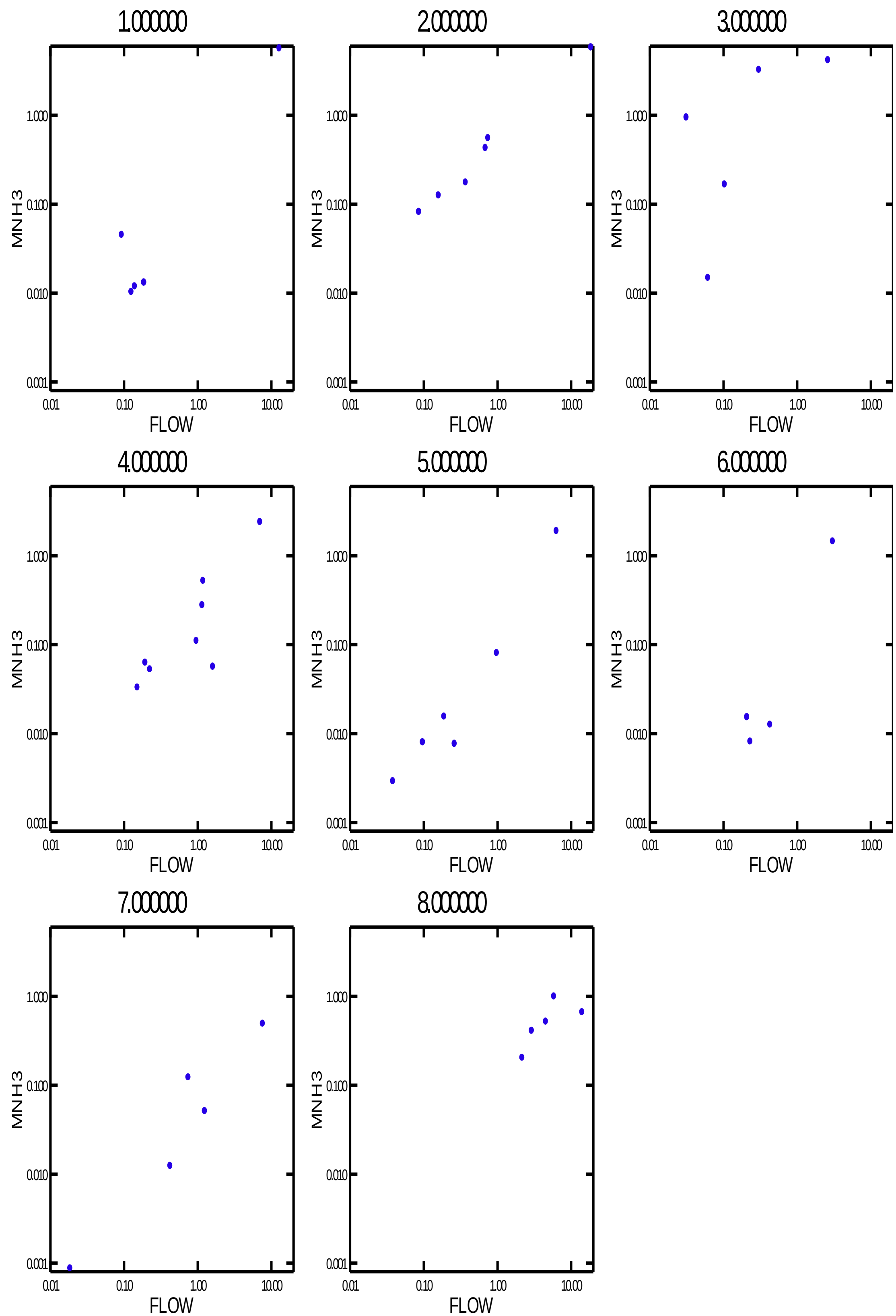
Pearson Correlation Matrix

	CBOD	COND	ECOLI	NH3	NO3NO2	OP	TKN	TP	TSS	TURB	FLOW	PCP48_
CBOD	1.000											
COND	-0.138	1.000										
ECOLI	0.484	-0.158	1.000									
NH3	0.257	0.458	0.027	1.000								
NO3NO2	-0.112	0.422	-0.138	-0.079	1.000							
OP	0.109	0.673	0.100	0.682	0.133	1.000						
TKN	0.514	0.316	0.345	0.900	-0.193	0.610	1.000					
TP	0.438	0.547	0.392	0.660	0.036	0.894	0.751	1.000				
TSS	0.530	-0.233	0.849	-0.031	-0.208	0.085	0.325	0.382	1.000			
TURB	0.482	-0.261	0.832	-0.004	-0.245	0.109	0.324	0.335	0.920	1.000		
FLOW	0.040	-0.261	0.498	-0.108	-0.204	-0.048	0.054	0.007	0.393	0.498	1.000	
PCP48_	0.361	-0.260	0.825	-0.086	-0.245	0.040	0.255	0.249	0.834	0.899	0.681	1.000

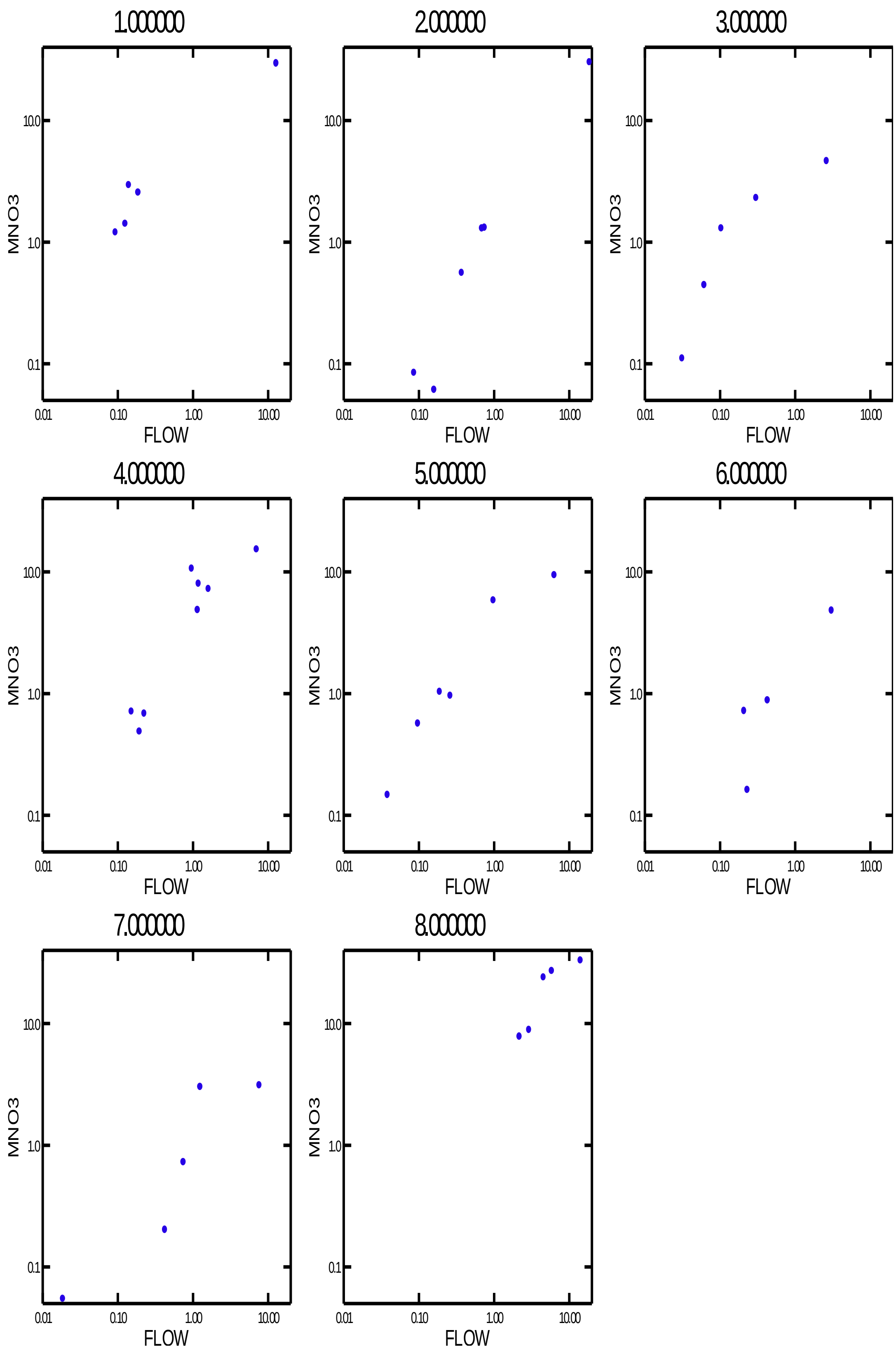
Appendix D – Mass Loadings



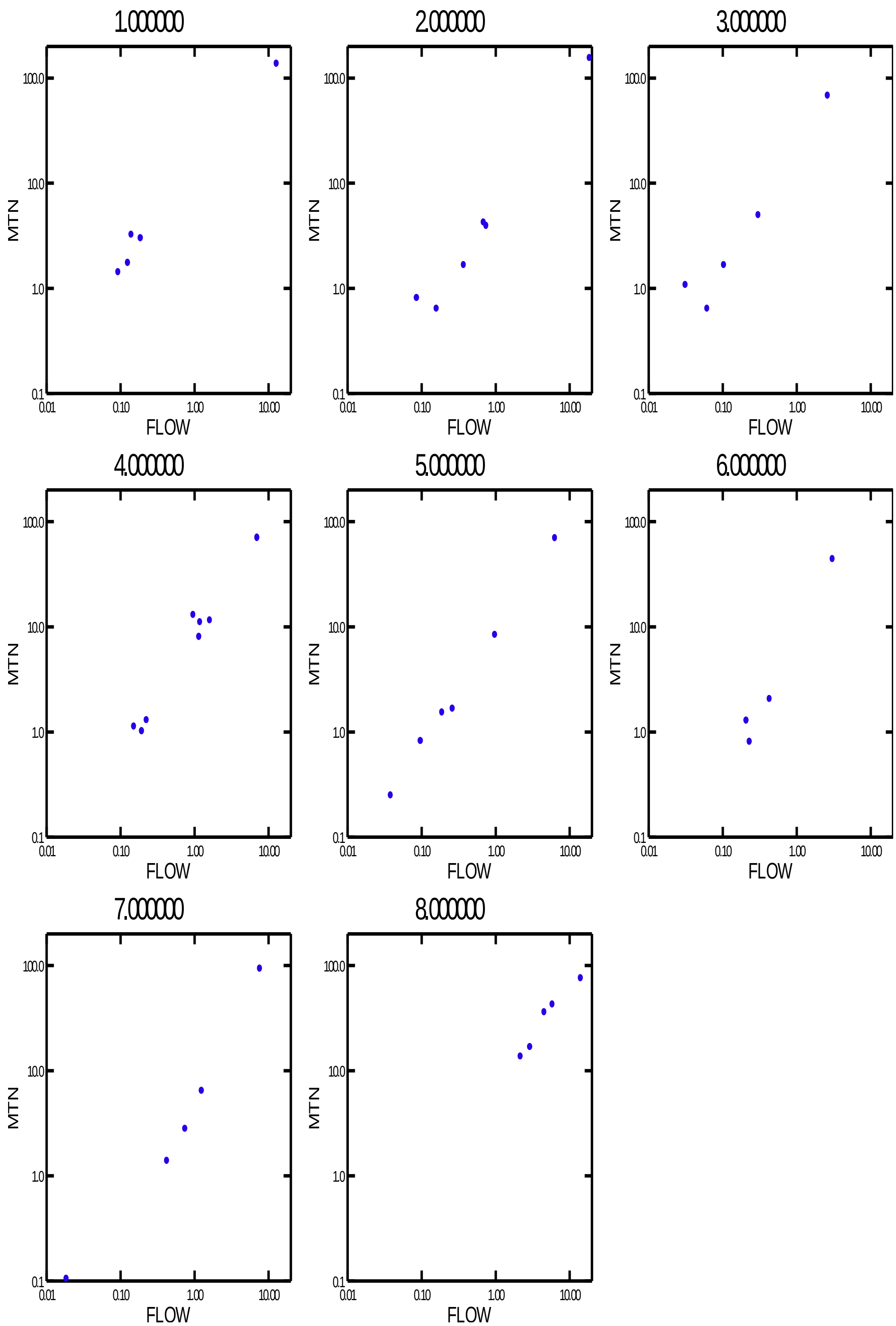
Quantity of E. coli (millions MPN/day) versus Flow (cfs).



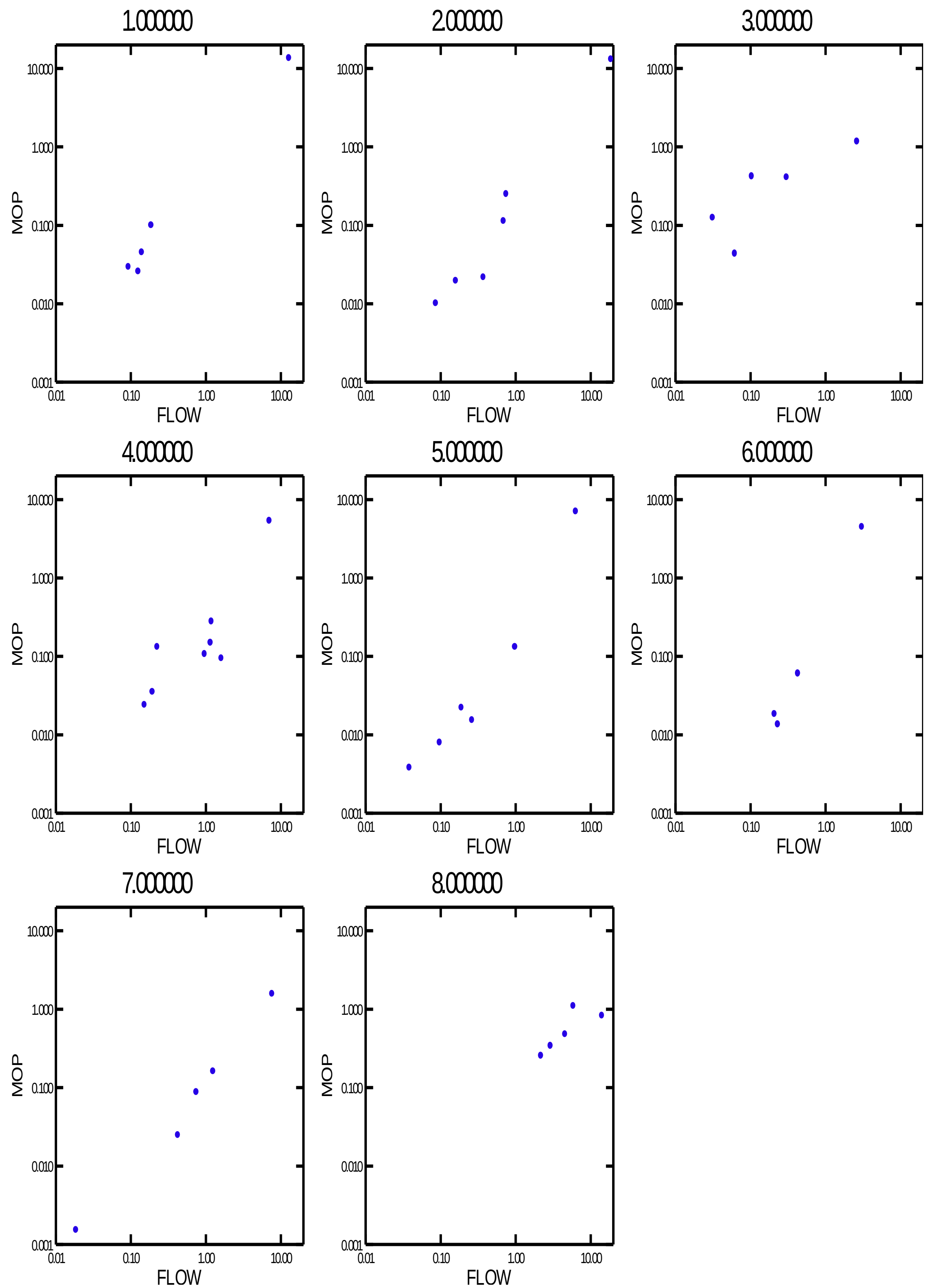
Mass of Ammonia Nitrogen (lbs/day) versus Flow (cfs).



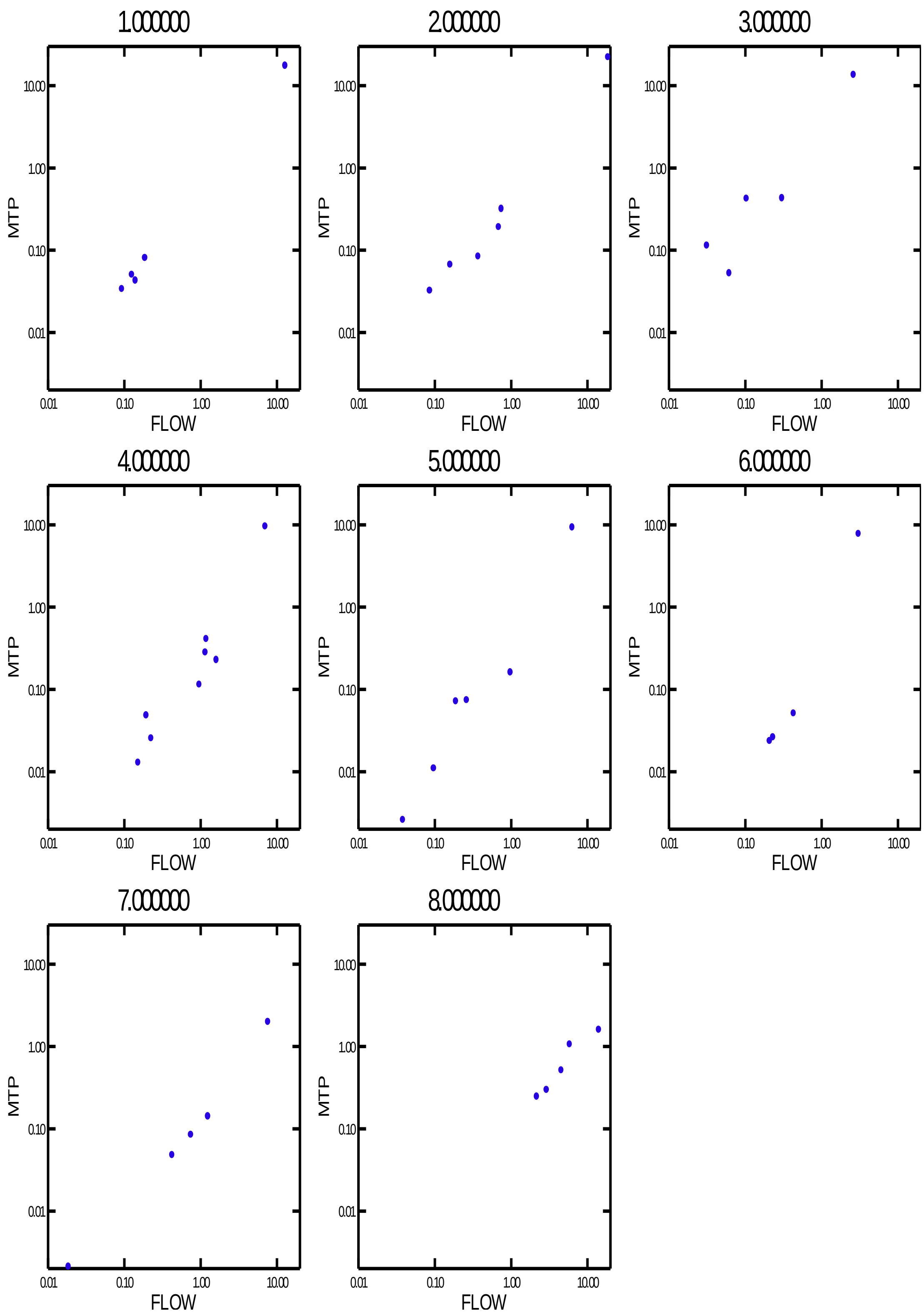
Mass of Nitrite/Nitrate Nitrogen (lbs/day) versus Flow (cfs).



Mass of Total Nitrogen (lbs/day) versus Flow (cfs).



Mass of Orthophosphate (lbs/day) versus Flow (cfs).



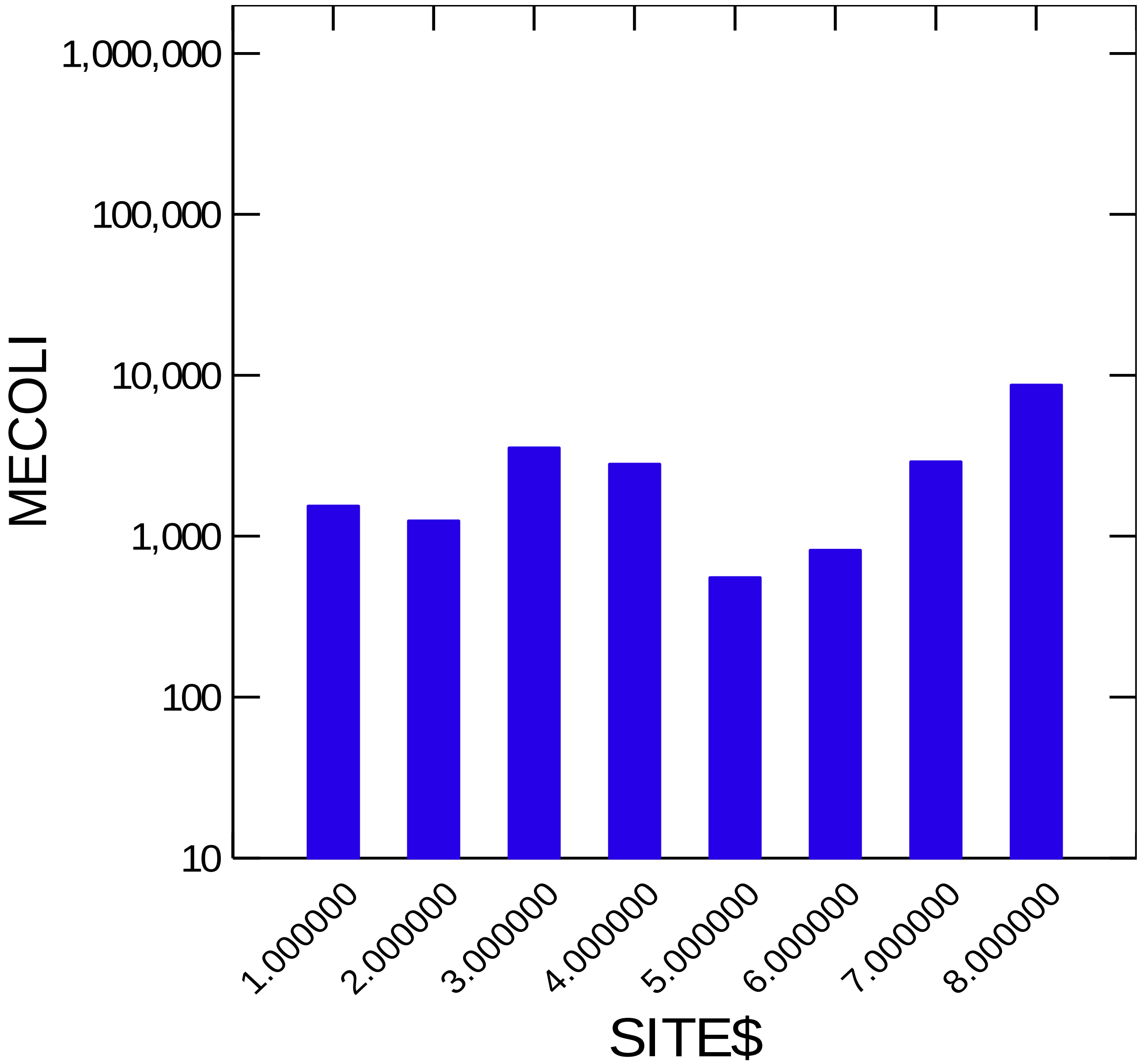
Mass of Total Phosphorus (lbs/day) versus Flow (cfs).

Table D-1. Mass (Quantity) Loadings Based on Measured Flow

Event	Site	E. coli million MPN/day	Ammonia lb/day	Nitrate lb/day	Total N lb/day	PO4 lb/day	Total P lb/day
I	1	0	0.000	0.000	0.000	0.000	0.000
I	2	0	0.000	0.000	0.000	0.000	0.000
I	3	0	0.000	0.000	0.000	0.000	0.000
I	4	1123	0.051	0.671	1.266	0.128	0.025
I	5						
I	6	0	0.000	0.000	0.000	0.000	0.000
I	7						
I	8	0	0.000	0.000	0.000	0.000	0.000
II	1	0	0.000	0.000	0.000	0.000	0.000
II	2						
II	3	0	0.000	0.000	0.000	0.000	0.000
II	4	0		0.000	0.000	0.000	0.000
II	5						
II	6						
II	7						
II	8						
III	1	0	0.000	0.000	0.000	0.000	0.000
III	2	0	0.000	0.000	0.000	0.000	0.000
III	3	0	0.000	0.000	0.000	0.000	0.000
III	4	0	0.000	0.000	0.000	0.000	0.000
III	5						
III	6						
III	7						
III	8						
IV	1	5608	0.013	2.502	2.927	0.097	0.078
IV	2	933	0.537	1.288	3.833	0.243	0.308
IV	3	18146	3.156	2.261	4.845	0.397	0.416
IV	4	27535	0.507	7.839	10.820	0.271	0.398
IV	5	2447	0.078	5.718	8.209	0.129	0.156
IV	6	1500	0.012	0.862	2.011	0.059	0.050
IV	7	15275	0.050	2.955	6.283	0.157	0.137
IV	8	5848	0.969	26.519	41.673	1.069	1.031
V	1	595	0.012	2.882	3.164	0.044	0.042
V	2	172	0.417	1.269	4.141	0.110	0.186
V	3	493	0.162	1.271	1.625	0.409	0.411
V	4	240	0.107	10.419	12.692	0.104	0.111
V	5	24	0.008	0.556	0.803	0.008	0.011
V	6	52	0.015	0.705	1.254	0.018	0.023
V	7	28	0.001	0.054	0.103	0.001	0.002

V	8	1134	0.505	23.489	35.135	0.466	0.499
VI	1	70	0.044	1.177	1.391	0.029	0.033
VI	2	277	0.171	0.547	1.628	0.021	0.081
VI	3	509	0.014	0.435	0.626	0.042	0.051
VI	4	402	0.055	7.095	11.266	0.092	0.221
VI	5	65	0.007	0.942	1.628	0.015	0.072
VI	6	173	0.008	0.158	0.789	0.013	0.025
VI	7	317	0.012	0.198	1.355	0.024	0.047
VI	8	14095	0.644	32.361	73.894	0.805	1.552
VII	1	515682	5.488	28.830	133.629	13.171	16.933
VII	2	1910784	5.629	29.526	151.359	12.745	21.506
VII	3	358959	4.040	4.549	66.430	1.137	13.130
VII	4	375762	2.327	15.002	68.615	5.215	9.283
VII	5	360287	1.841	9.205	68.050	6.859	9.050
VII	6	294691	1.409	4.714	43.124	4.349	7.548
VII	7	350909	0.479	3.050	91.159	1.525	1.932
VII	8						
VIII	1	0	0.000	0.000	0.000	0.000	0.000
VIII	2	0	0.000	0.000	0.000	0.000	0.000
VIII	3	0	0.000	0.000	0.000	0.000	0.000
VIII	4	455	0.032	0.698	1.099	0.023	0.013
VIII	5	19	0.003	0.144	0.244	0.004	0.003
VIII	6	0	0.000	0.000	0.000	0.000	0.000
VIII	7	0	0.000	0.000	0.000	0.000	0.000
VIII	8	12367	0.399	8.692	16.393	0.332	0.288
IX	1						
IX	2						
IX	3						
IX	4						
IX	5						
IX	6						
IX	7						
IX	8						
X	1						
X	2	683	0.122	0.060	0.627	0.019	0.065
X	3	0	0.000	0.000	0.000	0.000	0.000
X	4	1408	0.061	0.478	0.994	0.034	0.047
X	5						
X	6						
X	7						
X	8	0	0.000	0.000	0.000	0.000	0.000
XI	1						
XI	2						

XI	3						
XI	4						
XI	5						
XI	6						
XI	7						
XI	8						
XIII	1						
XIII	2						
XIII	3	341	0.920	0.109	1.053	0.122	0.110
XIII	4						
XIII	5						
XIII	6						
XIII	7						
XIII	8						
XIII	1						
XIV	1	1880					
XIV	2	796					
XIV	3	0					
XIV	4	4398					
XIV	5	1982					
XIV	6	92					
XIV	7	6247					
XIV	8	47279					
XV	1	59	0.010	1.388	1.704	0.025	0.049
XV	2	100	0.080	0.083	0.791	0.010	0.031
XV	3	0	0.000	0.000	0.000	0.000	0.000
XV	4	3370	0.270	4.767	7.835	0.145	0.273
XV	5	298	0.015	1.014	1.498	0.022	0.070
XV	6	0	0.000	0.000	0.000	0.000	0.000
XV	7	2006	0.119	0.711	2.739	0.085	0.082
XV	8	7889	0.198	7.655	13.353	0.248	0.239



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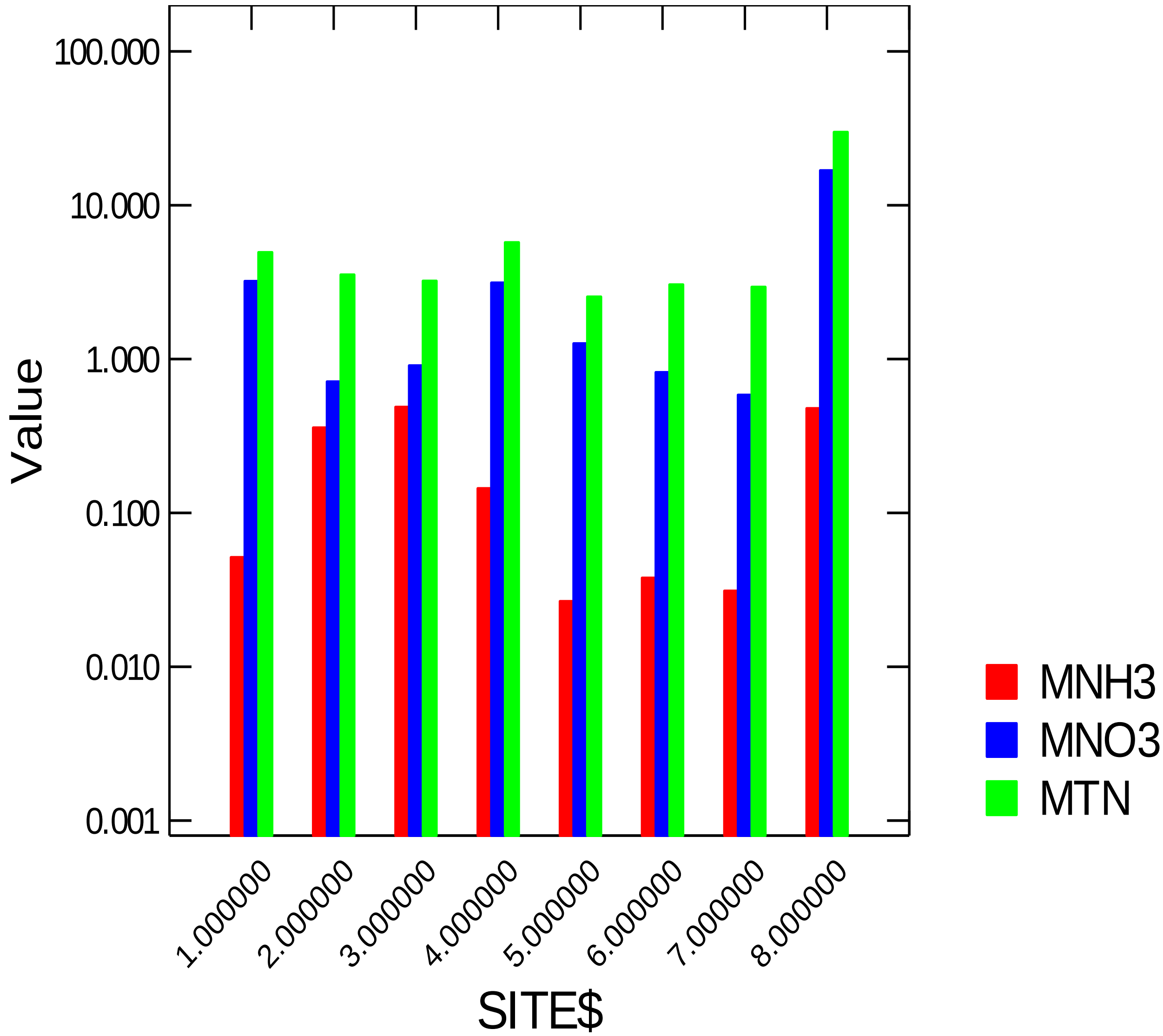
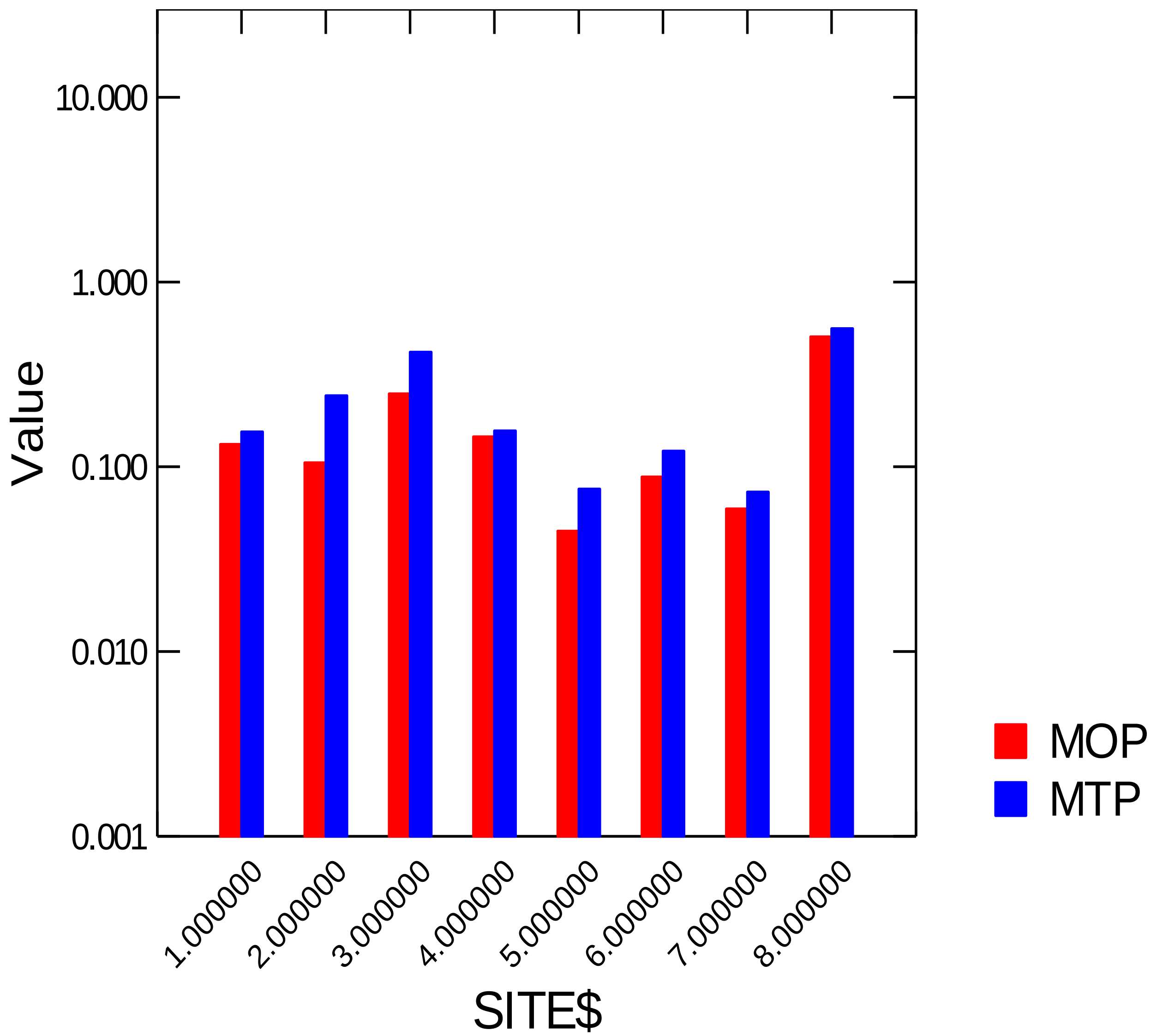
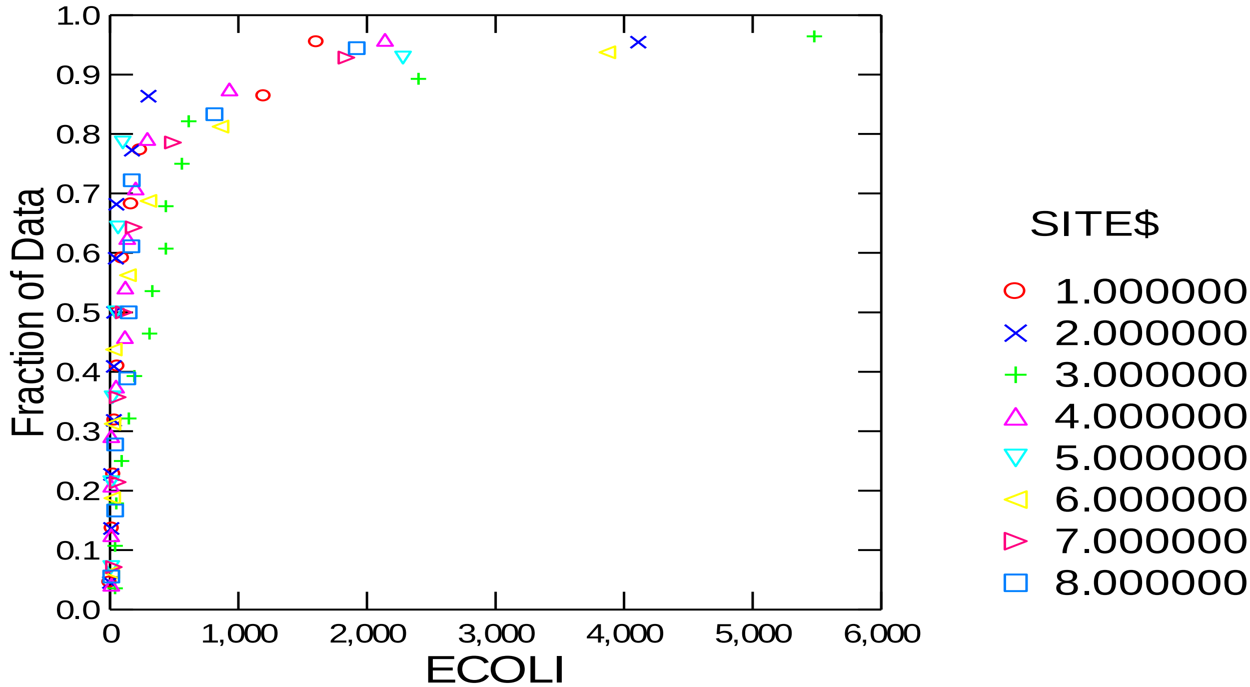
Average Quantity E. coli (millions MPN/day) by Site



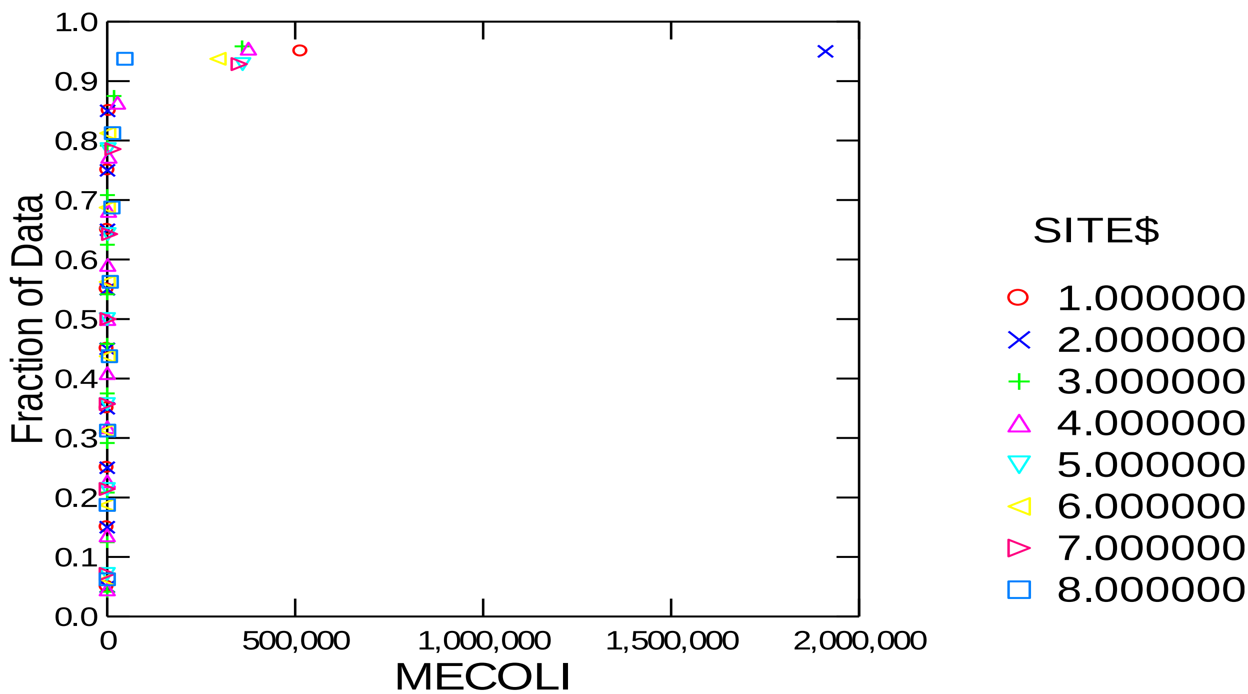
Average Mass Nitrogen Species (lbs/day) by Site



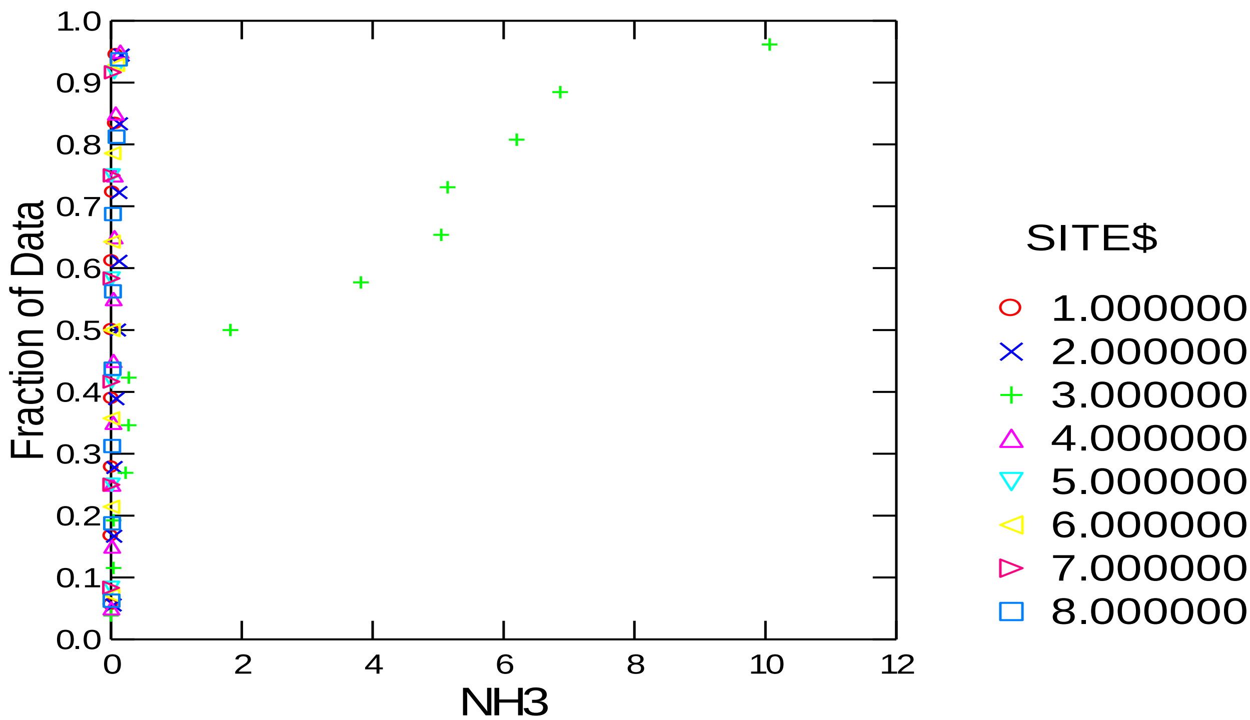
Average Mass Phosphorus Species (lbs/day) by Site



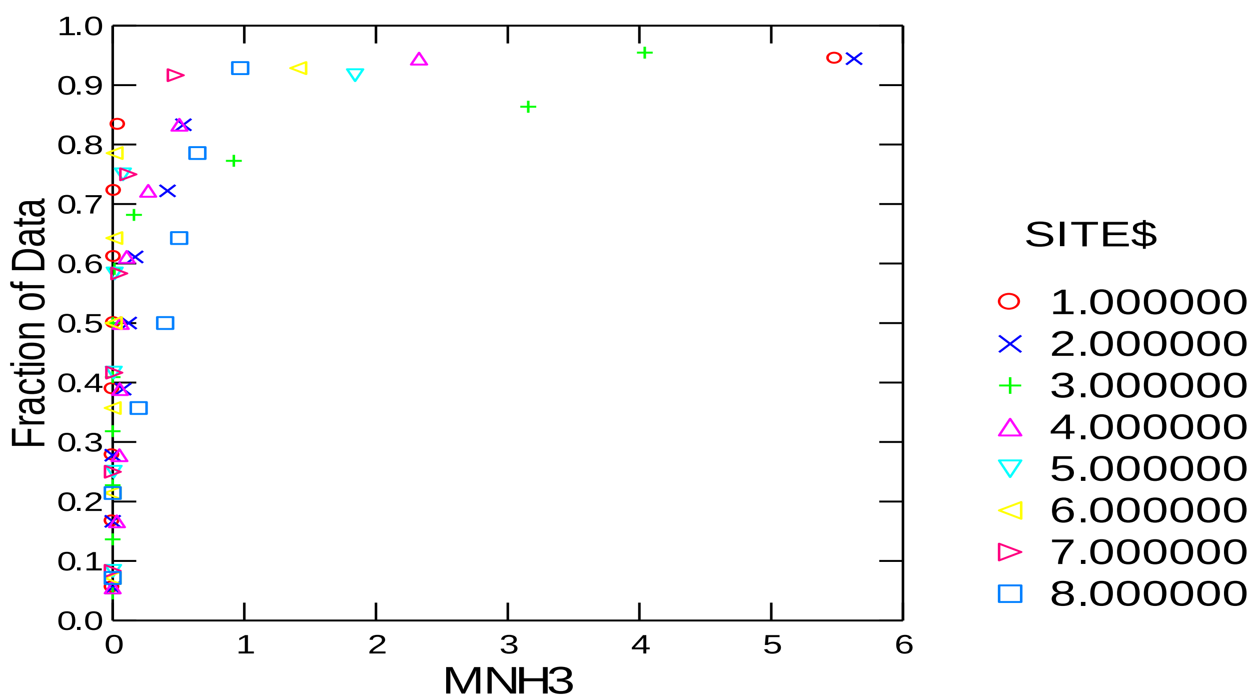
Quantile Plot of E coli Concentrations, MPN/100 mL.



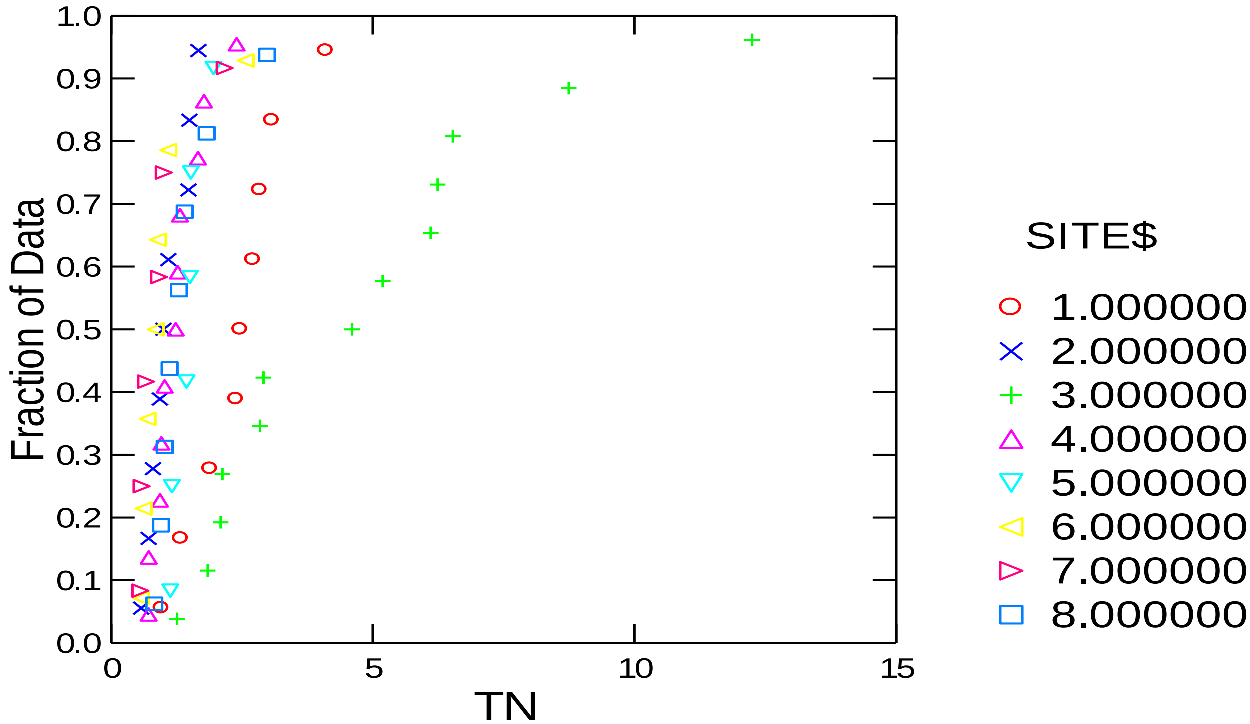
Quantile Plot of E coli Quantity, Millions MPN/day.



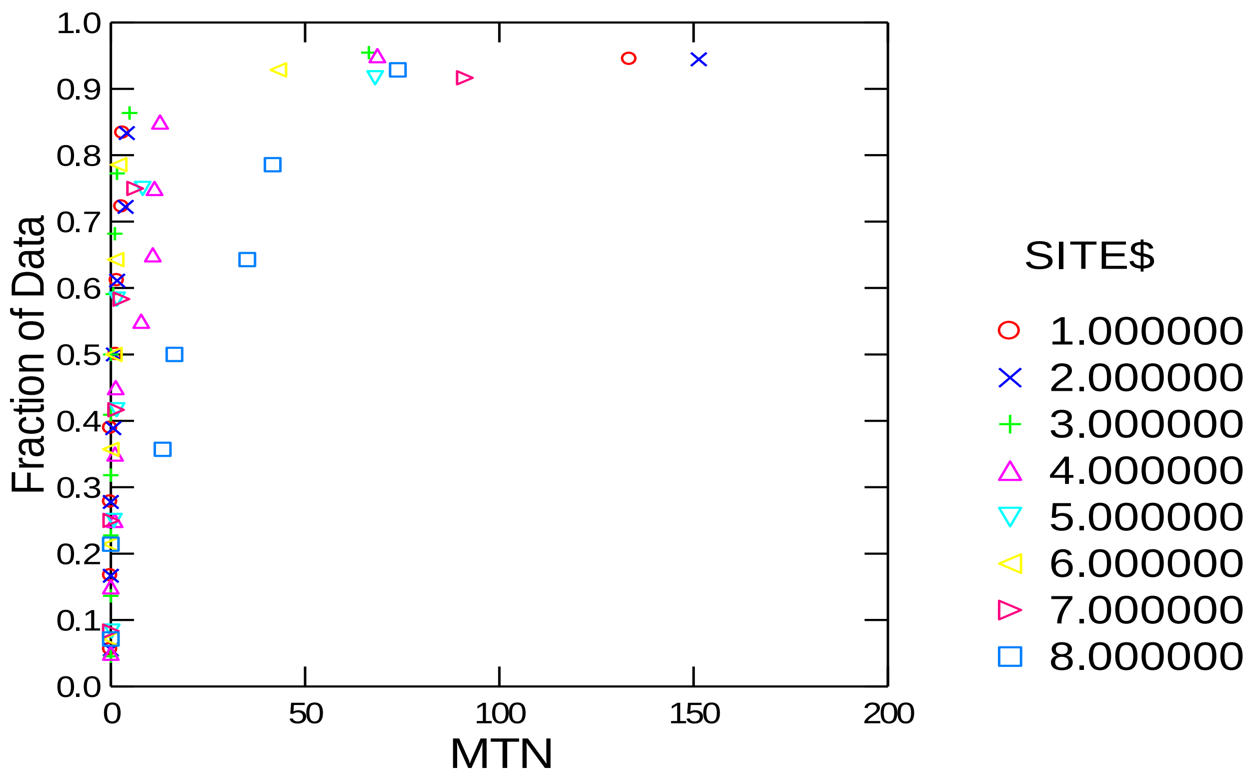
Quantile Plot of Ammonia Concentrations, mg/L.



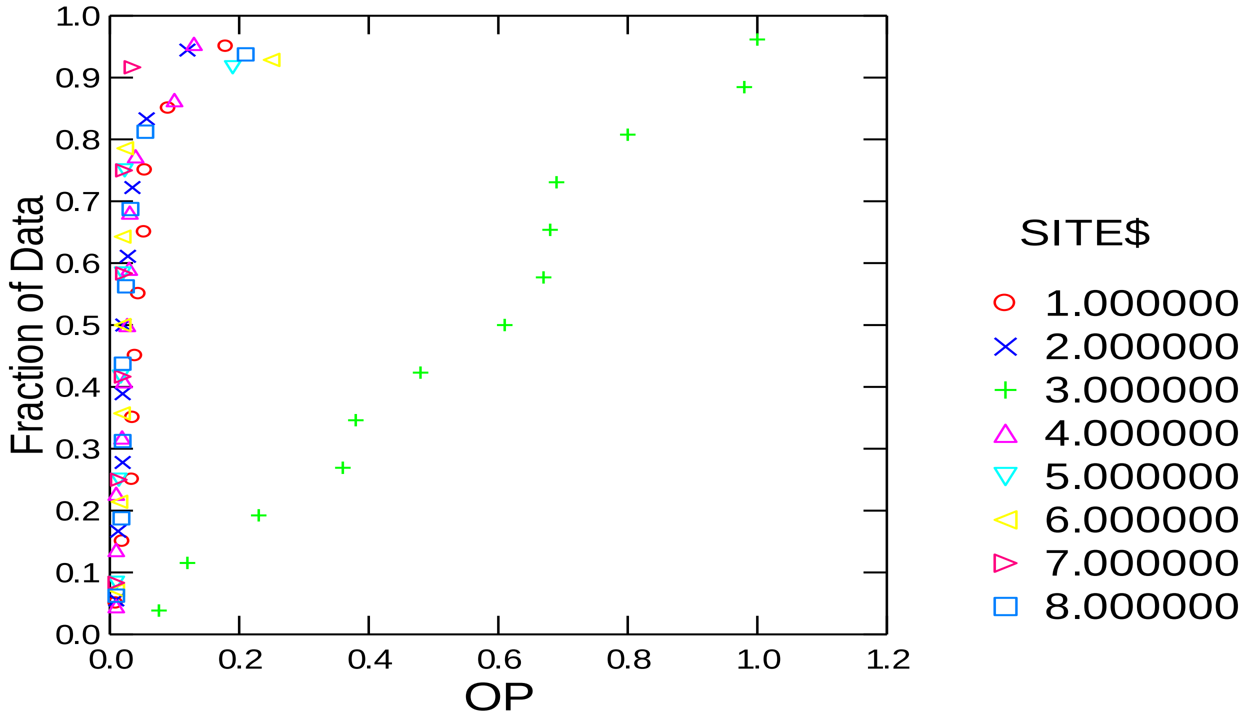
Quantile Plot of Ammonia Mass, lbs/day.



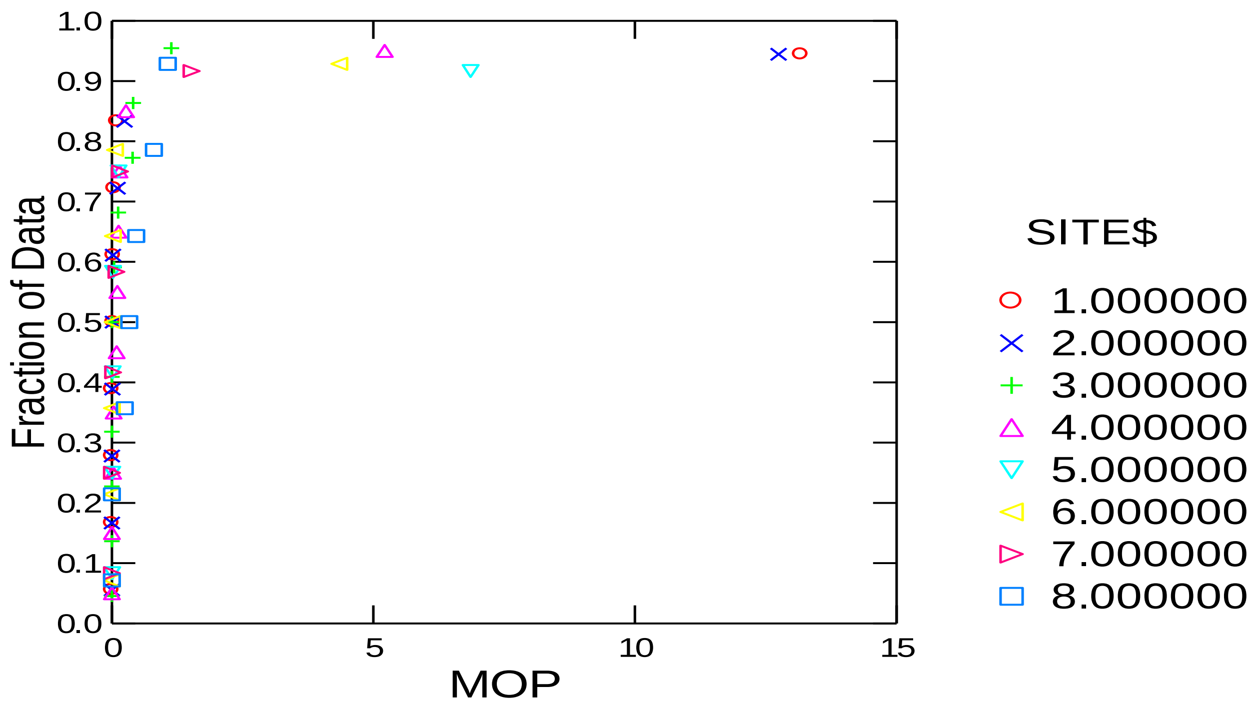
Quantile Plot of Total Nitrogen Concentrations, mg/L.



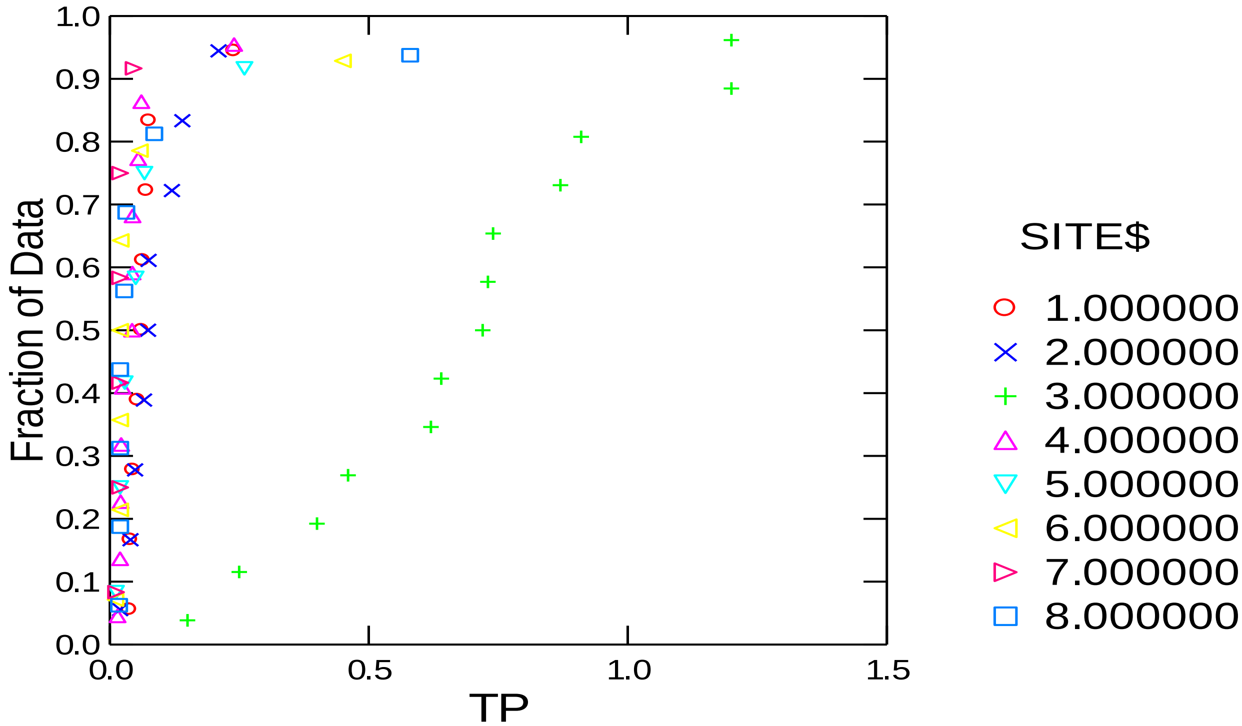
Quantile Plot of Total Nitrogen Mass, lbs/day.



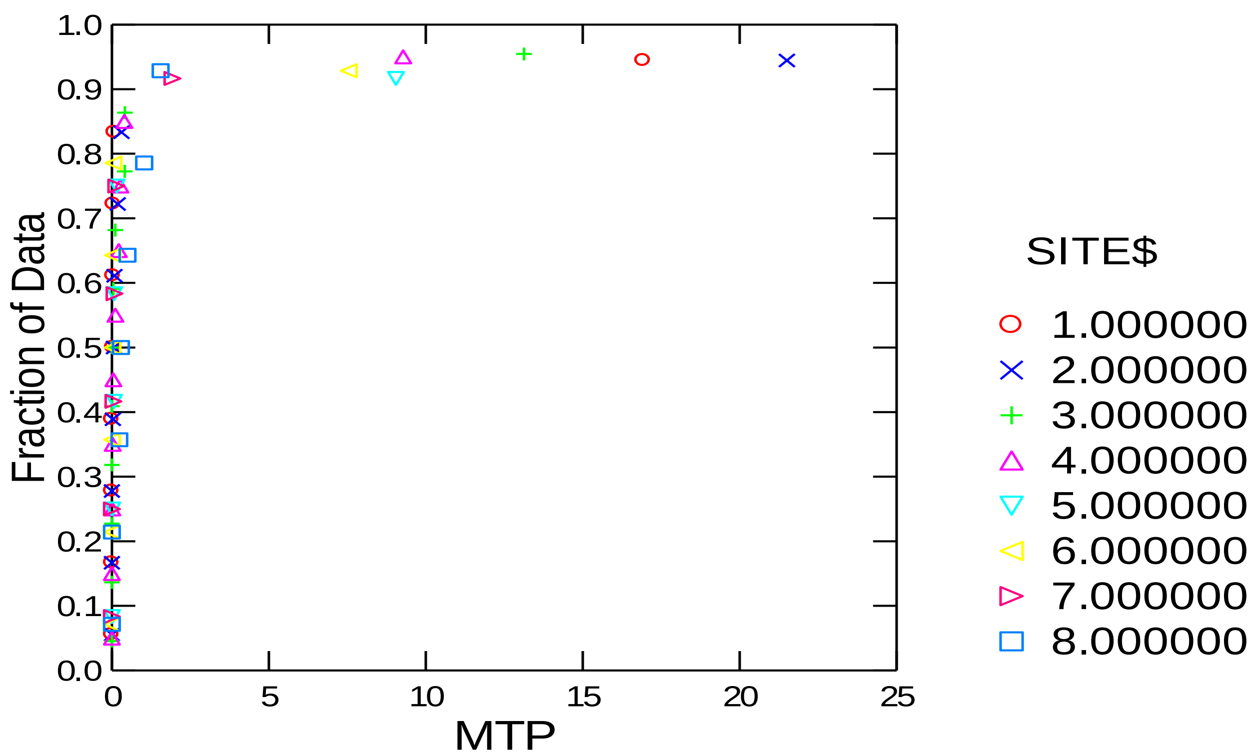
Quantile Plot of Orthophosphate Concentrations, mg/L.



Quantile Plot of Orthophosphate Mass, lbs/day.



Quantile Plot of Total Phosphorus Concentrations, mg/L.



Quantile Plot of Total Phosphorus Mass, lbs/day.

Appendix E – List of Maps and Data Sets

Chestnut Creek Watershed Plan Project

Maps, Posters, and Other Datasets Prepared by MSU

Mailing List – Addresses derived from Parcel data and watershed data

Watershed map for brochure and mailing

Stream Walk Poster, Google Earth file

Stream Walk Presentation (Powerpoint, 2012)

Earth Day Poster (2103)

Floodplain Poster

Sampling Results Maps: E. coli 2012

Topographic Map Poster

Digital Elevation Model Map Poster

Study Area Location Map

Topography Map – Hillshade and Topographic

Floodplain Map

Geology Map

Hydrology Map

Landcover 2006 Map

Landcover 2011 Map

Impervious Surfaces Map

Soil Series Map

Soils- Hydrologic Soils Group Map

Permitted Discharges Map

Places of Interest Map

Water and Waste Water Facilities Map

Precipitation Summary Data File – (KYMESONET data)

Land Cover Statistics by Subwatershed File

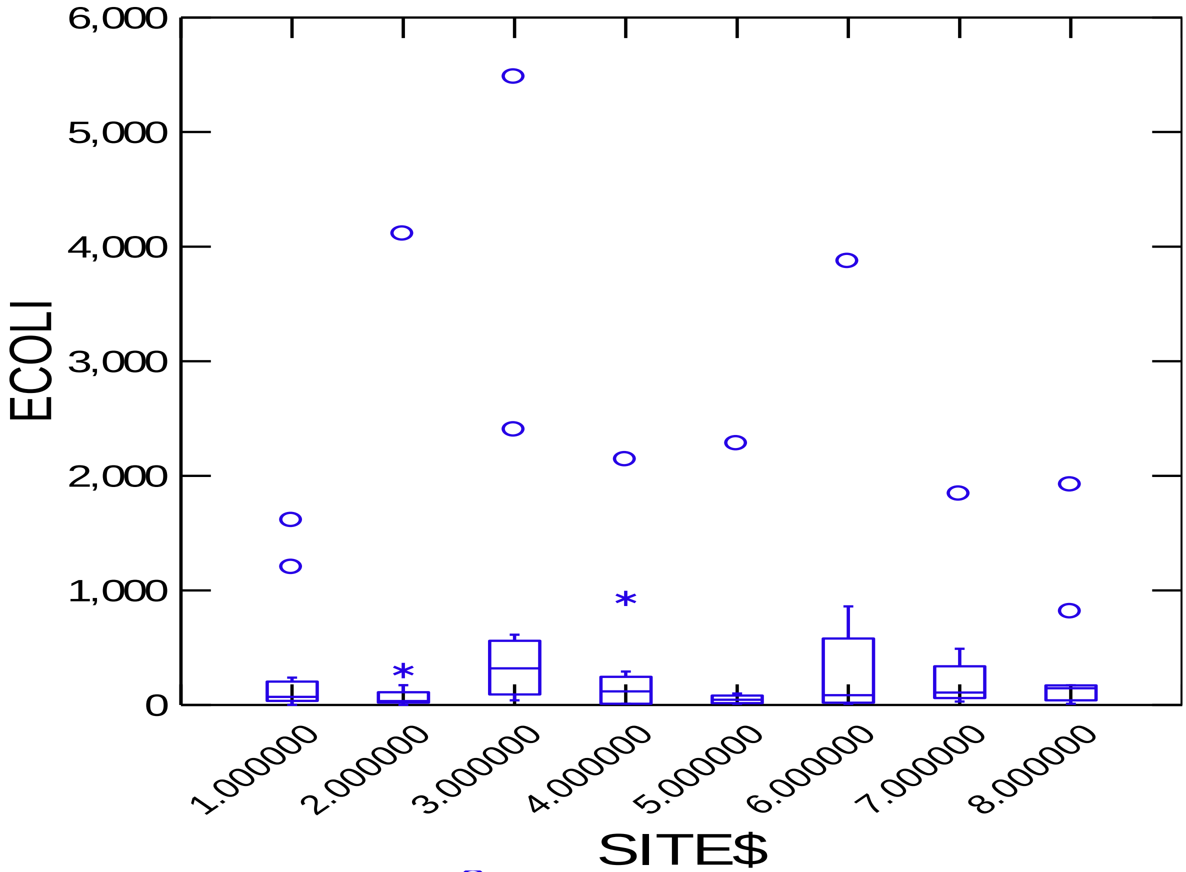
Color-Infrared Imagery (2010) Map

Sampling Results Summary Data File

Riparian Zones Draft Maps

Water Supply

Regulatory Status of Streams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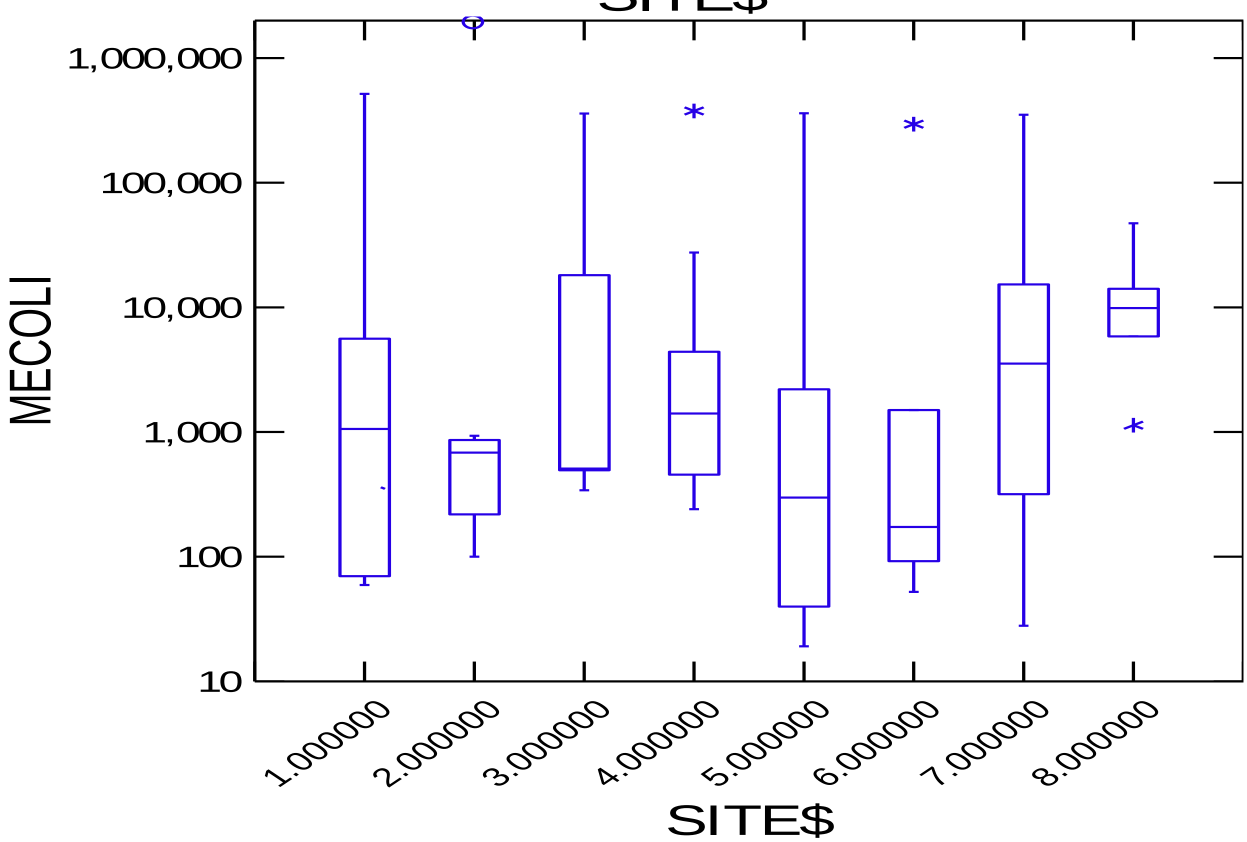
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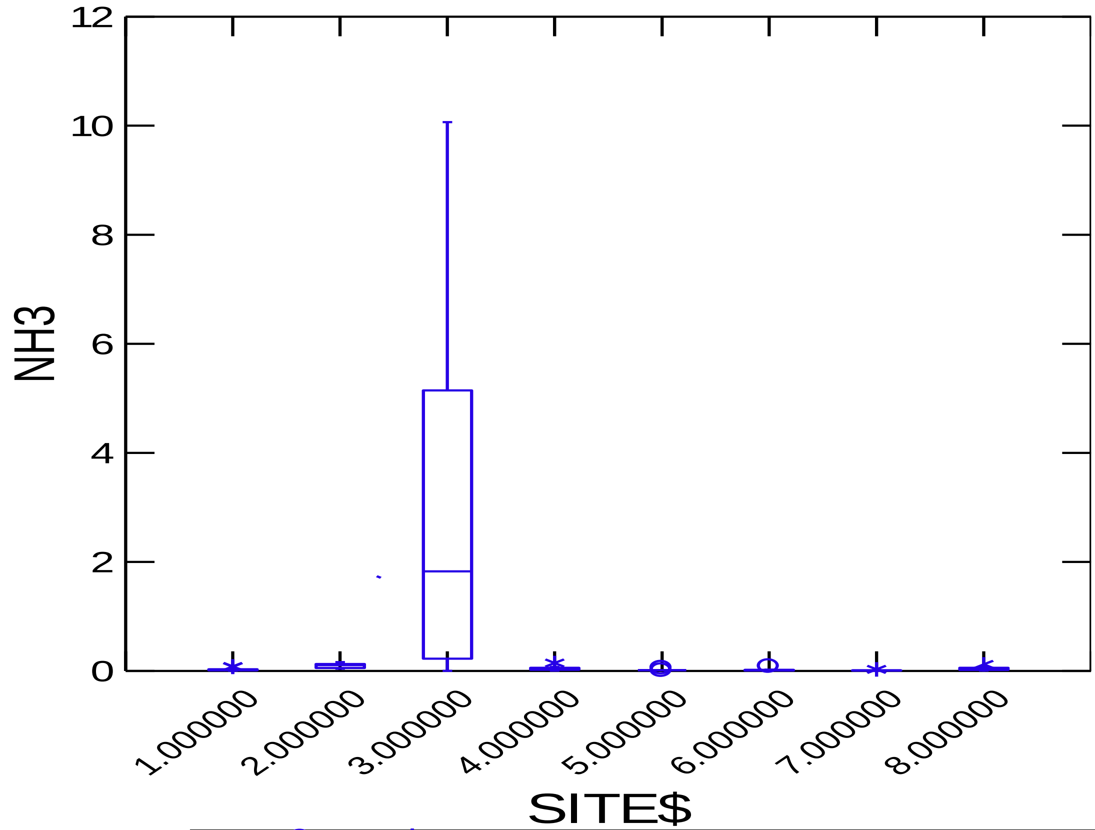
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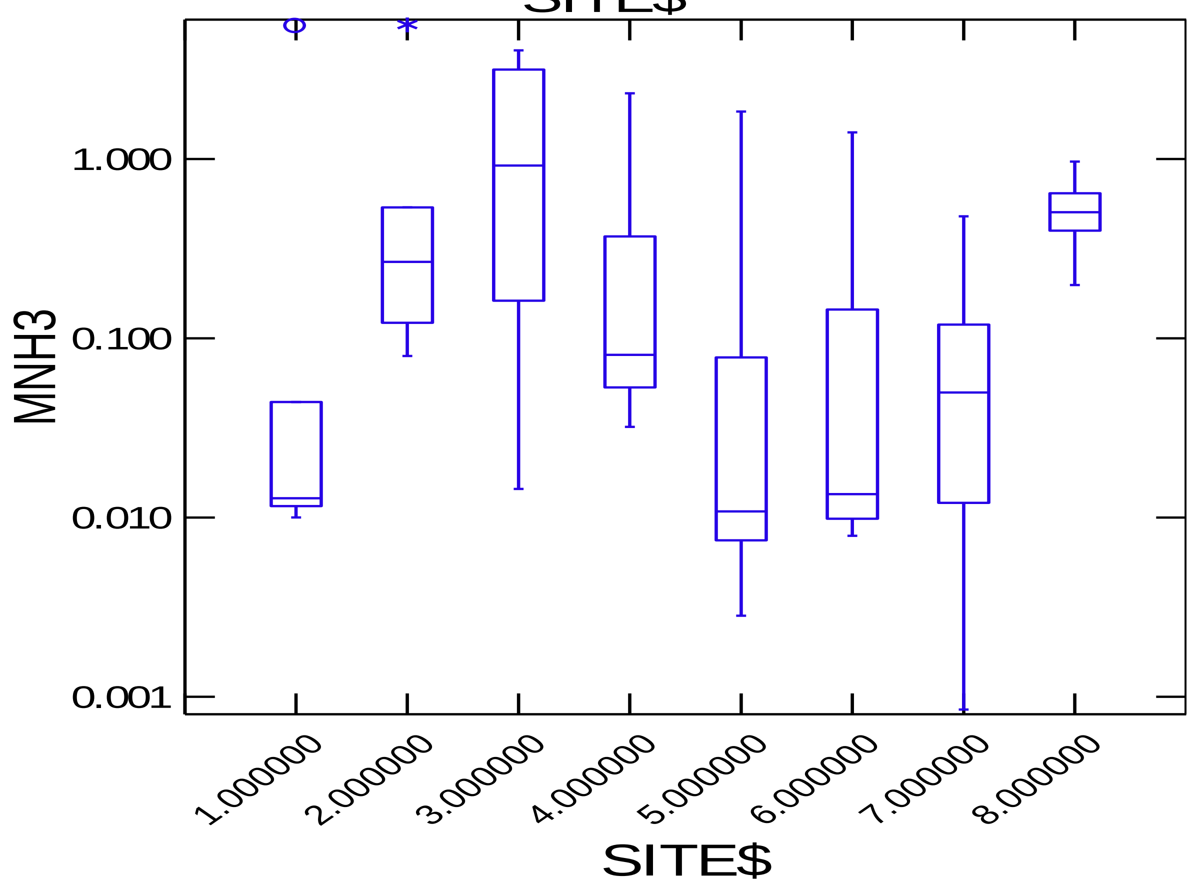
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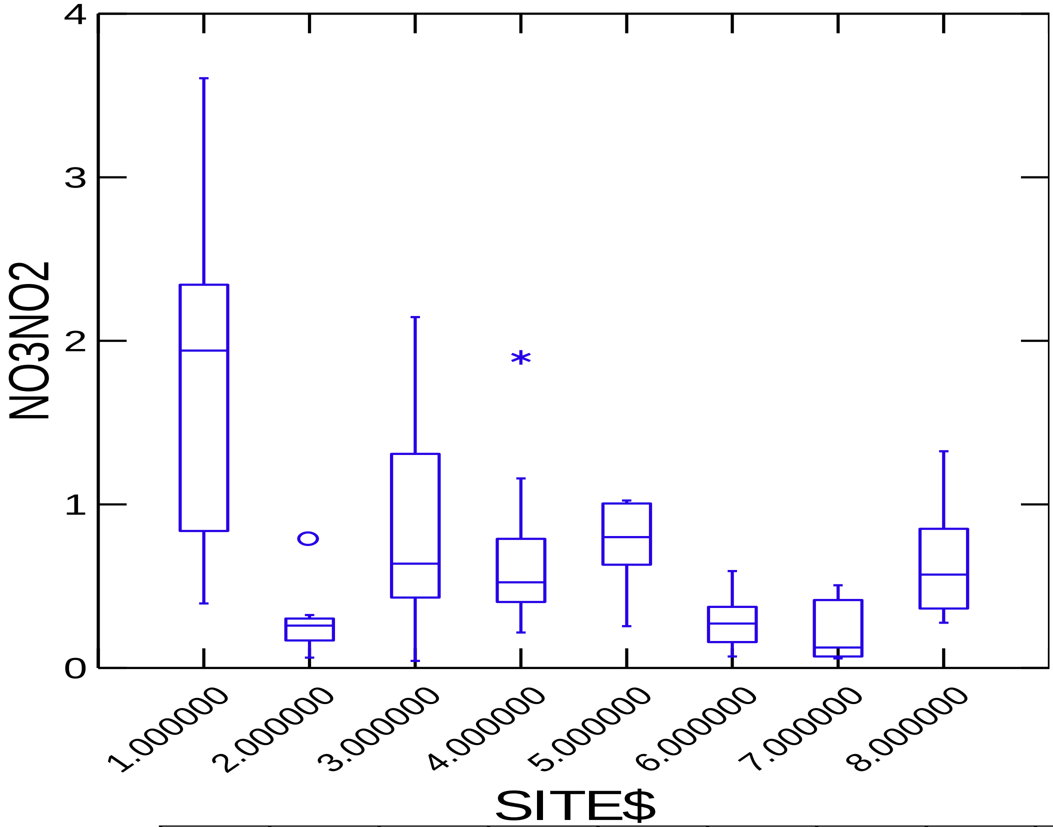

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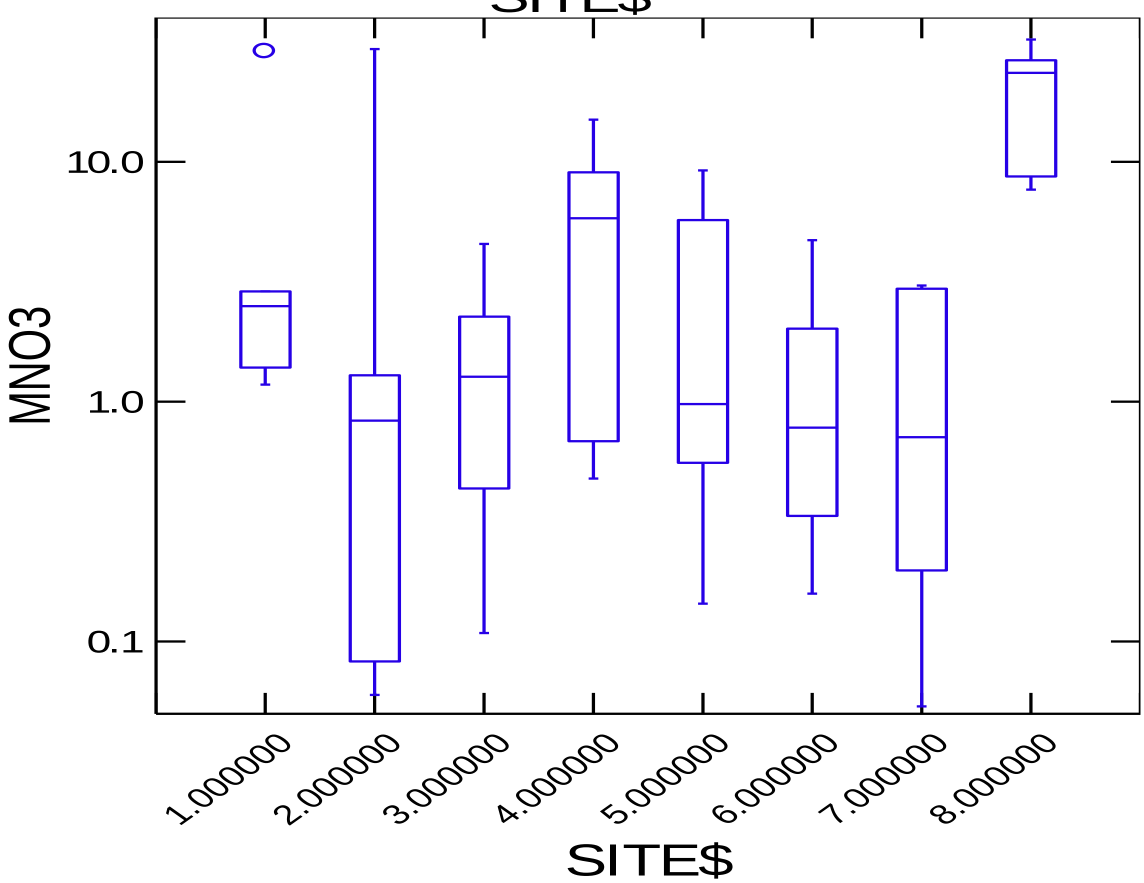

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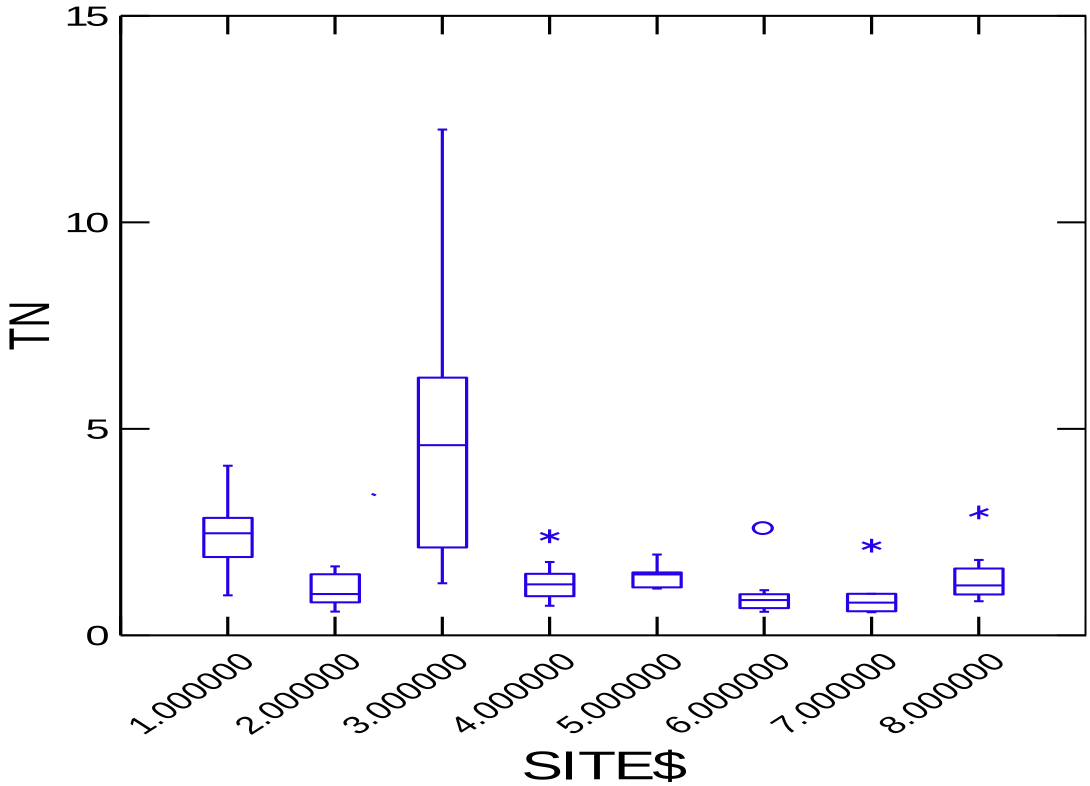
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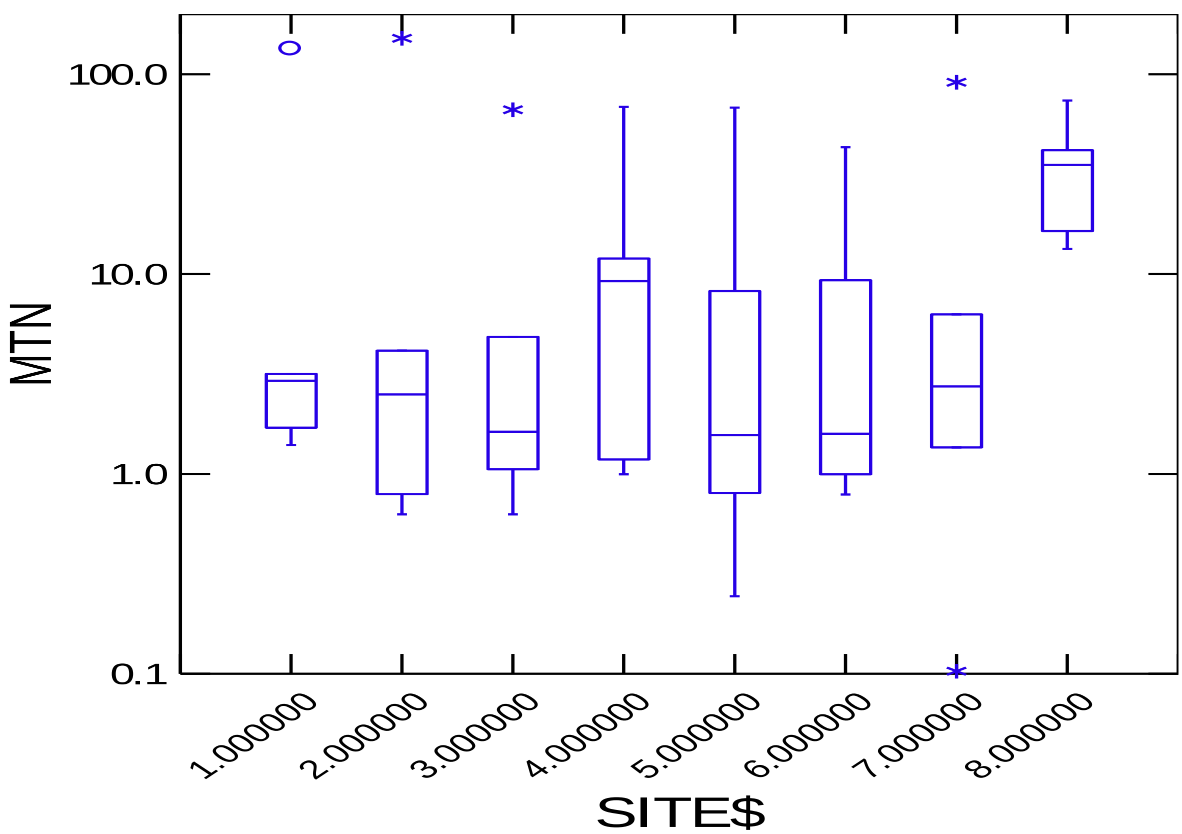
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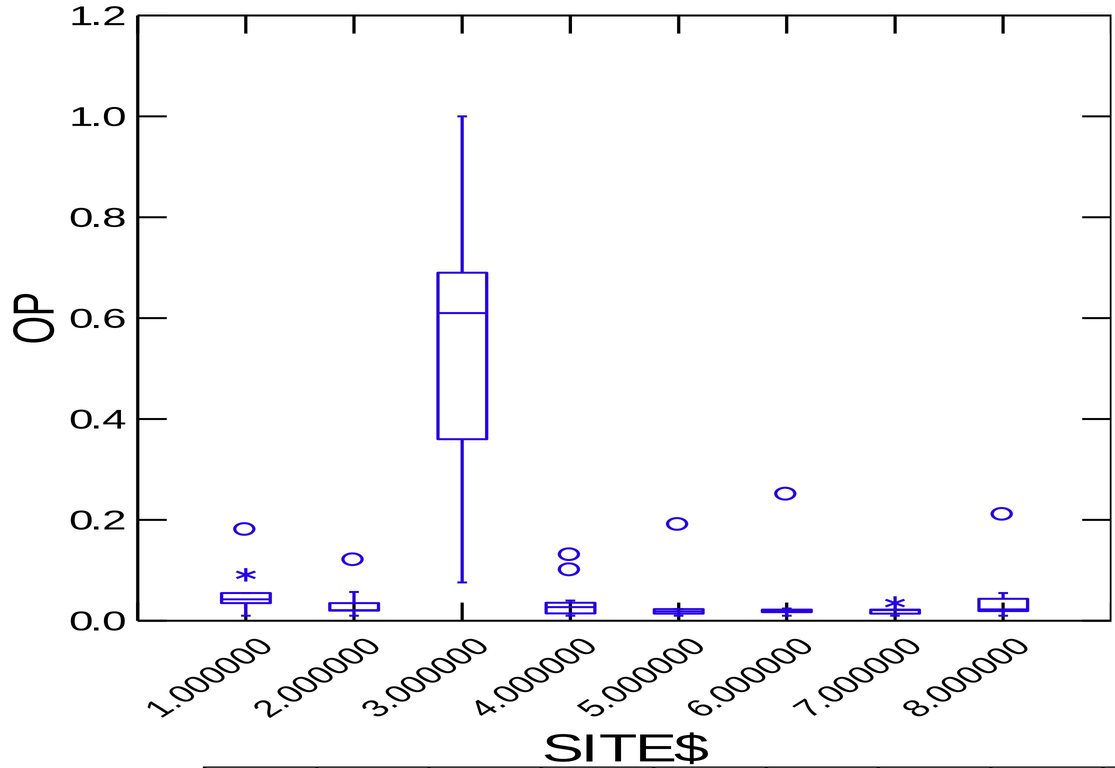
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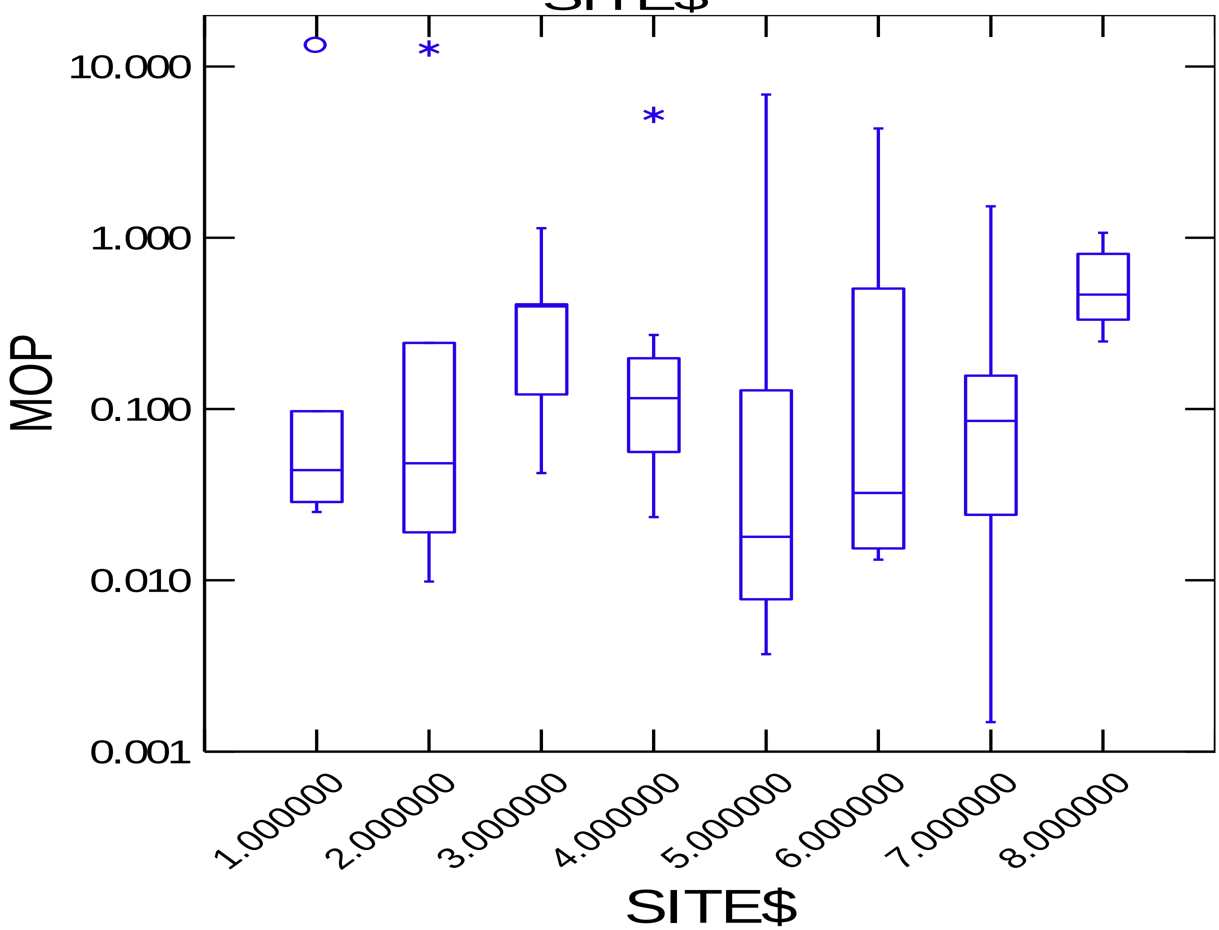
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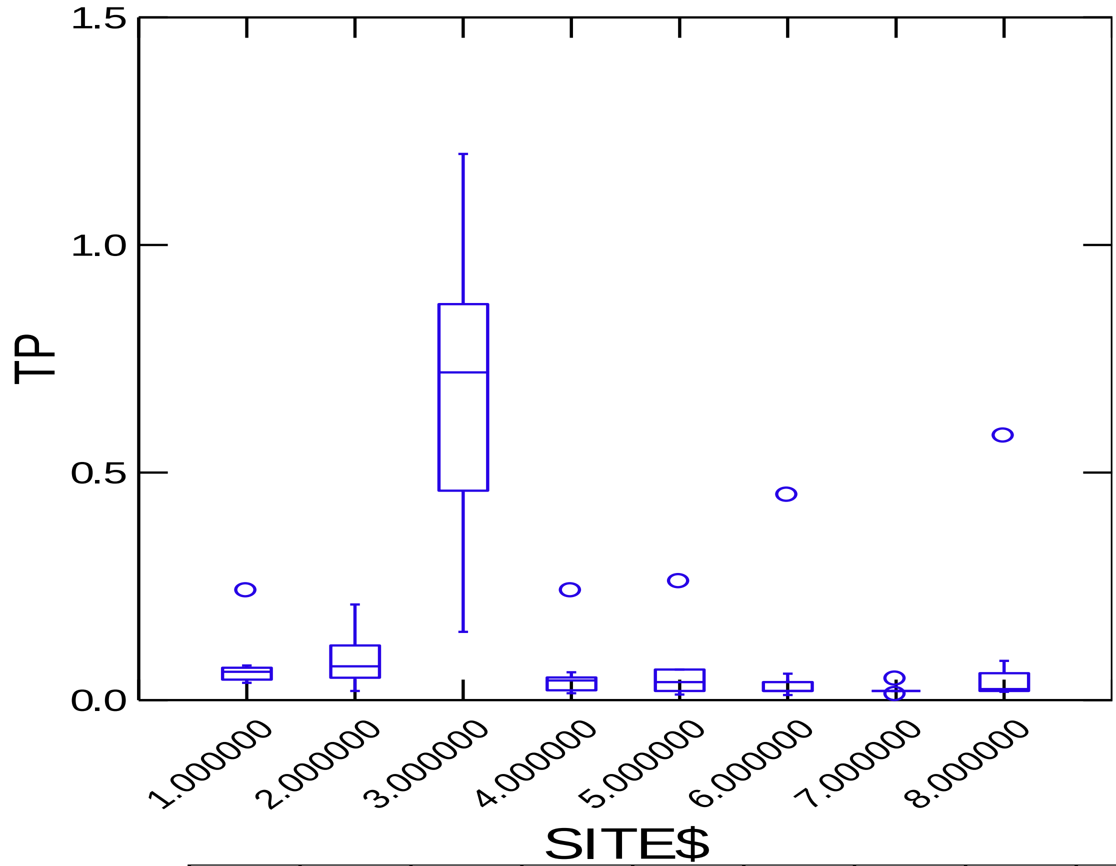
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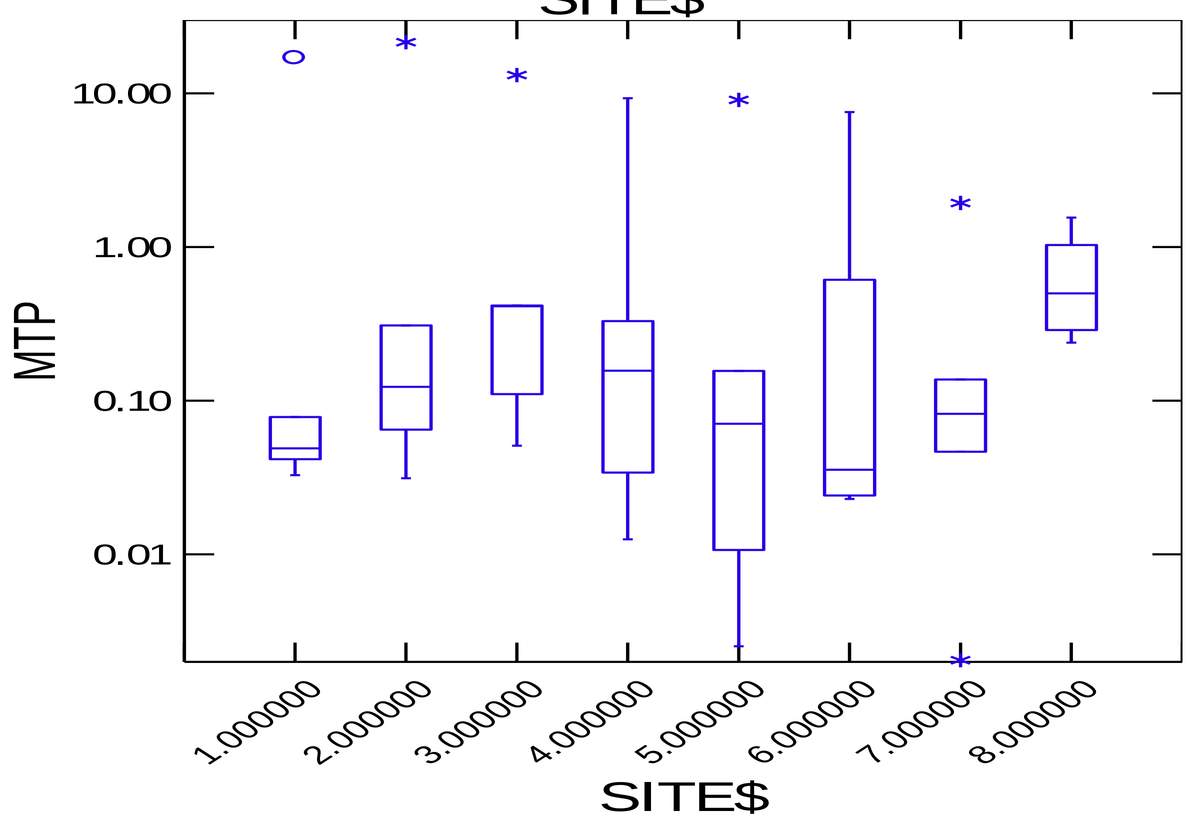
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SITE$

APPENDIX E

Results of Chestnut Creek Samples (received June 2014)

Samples were received on May 29, 2104 in a frozen condition. All samples were tested for Bacteriodetes concentrations using three assays, AllBac for total Bacteroidetes, HuBac for human-associated Bacteroidetes and BoBac for bovine-associated Bacteroidetes. A plasmid spike was used for all samples in all assays to determine whether the samples had PCR inhibitors which might produce a false negative result.

No samples had PCR inhibition as indicated by a >50% measurement of the expected plasmid concentrations for all assays (Table 1). This sample set included positive controls for the total human Bacteroidetes assays, consisting of a WWTP influent and effluent sample, and a negative control consisting of a field blank. The influent and effluent samples showed high concentrations of the total and human associated Bacteroidetes markers with 20 to 60 fold higher concentrations in the influent than the effluent. In the WWTP samples the percentage of the Bacteroidetes detected by the human specific marker was 26% and 8% for the influent and effluent samples, respectively. In the creek water samples the site with the highest positive Bacteroidetes measurements was the Chestnut Creek site 3 for both 04/02/2014 and 05/09/2014. Water samples from sites 1,2 and 4 collected on 04/02/2014 also had low positive concentrations (> 1 mg/L). However, the HuBac or BoBac Bacteroidete concentrations were below the detection limit (0. 5mg/L) for all creek water samples so the source of the Bacteroidetes is unknown.

Table 1. Bacteroidetes concentrations in mg/L equivalents in samples determined by the AllBac (total), HuBac (human-associated) and BoBac (bovine -associated). Values identified in red produced no PCR signal or were below 0.5 mg/L which is considered the detection limit. For each sample by assay the mean and standard deviation of triplicate reactions is provided. The % spike recovery is determined by the measurement of a plasmid spiked into a single reaction well for each sample and assay. The % human and % bovine concentration is determined as the mean of the human or bovine Bacteroidetes concentration divided by the total Bacteroidetes concentration X 100. The avg % spike recovery is the mean of the individual spike recovery determinations for the three assays.

Sample	AllBac			HuBac			BoBac			%Human	%Bovine	Avg %SpikeRec.
	Mean	Std	%Spike Rec	Mean	Std	%Spike Rec	Mean	Std	%Spike Rec.			
Influent_052214	5831.6	2335.7	102	1526.7	960.8	86	0.5		136	26	NQ	108
Effluent_052214	289.2	22.9	78	24.1	20.8	90	0.6	0.5	100	8	<0.5%	89
Chestnut Creek-1_040214	2.5	1.1	78	0.5		70	0.5		84	NQ	NQ	78
Chestnut Creek-2_040214	3.6	0.1	93	0.5		89	0.5		103	NQ	NQ	95
Chestnut Creek-3_040214	24.5	13.7	106	0.5		90	0.5		95	NQ	NQ	97
Chestnut Creek-4_040214	3.8	1.3	186	0.5		95	0.5		123	NQ	NQ	135
Chestnut Creek-5_040214	0.5		72	0.5		76	0.5		75	NQ	NQ	74
Chestnut Creek-6_040214	0.5		73	0.5		75	0.5		74	NQ	NQ	74
Chestnut Creek-7_040214	0.8	0.7	106	0.5		98	0.5		95	NQ	NQ	100
Chestnut Creek-8_040214	0.5		72	0.5		77	0.5		89	NQ	NQ	79
Chestnut Creek-1_050914	0.5		85	0.5		91	0.5		92	NQ	NQ	90
Chestnut Creek-2_050914	0.9	0.5	90	0.5		94	0.5		114	NQ	NQ	99
Chestnut Creek-3_050914	6.5	2.2	85	0.5		88	0.5		112	NQ	NQ	95
Chestnut Creek-4_050914	0.8	0.2	84	0.5		99	0.5		122	NQ	NQ	102
Chestnut Creek-5_050914	0.6	0.9	68	0.5		88	0.5		82	NQ	NQ	79
Chestnut Creek-6_050914	0.5		52	0.5		84	0.5		66	NQ	NQ	67
Chestnut Creek-7_050914	0.5	0.5	90	0.5		112	0.5		119	NQ	NQ	107
Chestnut Creek-8_050914	0.2	0.1	68	0.5		88	0.5		84	NQ	NQ	80
Chestnut Creek Blank	0.5		84	0.5		76	0.5		77	NQ	NQ	79

Appendix J. Refuge Biota

Plants of Clarks River National Wildlife Refuge

The USDA Plants Database (*http://plants.usda.gov/*) lists over a thousand species of plants found in Graves, Marshall, and McCracken Counties. Habitat suitable for all of these species may not be found on the refuge. A 2-year-long, refuge-wide survey is currently being conducted by Dr. Dwayne Estes of Austin Peay University in Clarksville, Tennessee. The final list is expected to top 800 species, the results will be reported as the information becomes available. Wildflowers and vines identified by refuge staff are provided below.

Wildflowers and Vines

This is a current list of wildflowers found on the refuge. A total of 54 families, 154 genera, and 223 species are represented. Members of the aster family comprise 56 species or 25 percent of the total. All flowers marked with an asterisk (*) are nonnative and may be invasive or harmful to native habitats.

Common Name	Scientific Name	Family Name
Arrowhead, Broadleaf or Duck Potato	*Sagittaria latifolia*	Alismataceae
Artichoke, Jerusalem	*Helianthus tuberous*	Asteraceae
Aster, False	*Boltonia asteroides*	Asteraceae
Aster, Late Purple	*Aster patens*	Asteraceae
Aster, Lowrie's	*Aster lowrieanus*	Asteraceae
Aster, Old-field	*Symphyotrichum pilosum*	Asteraceae
Aster, Small-headed	*Symphyotrichum racemosum*	Asteraceae
Aster, Smooth	*Aster laevis*	Asteraceae
Aster, White Heath	*Aster pilosus*	Asteraceae
Avens, White	*Geum canadense*	Rosaceae
Bachelor's Button *	*Centaurea cyanus*	Asteraceae
Beardtongue, Foxglove	*Penstemon digitalis*	Scrophulariaceae
Bedstraw	*Galium aparine*	Rubiaceae
Beefstake Plant *	*Perilla frutescens*	Lamiaceae
Bellflower, Tall	*Campanula americana*	Campanulaceae
Bindweed, Hedge	*Calystegia sepium*	Convolvulaceae
Bittercrest, Hoary *	*Cardamine hirsuta*	Brassicaceae
Bitterweed	*Helenium amarum*	Asteraceae
Blackberry, Southern	*Rubus argutus*	Rosaceae
Black-Eyed Susan	*Rudbeckia hirta*	Asteraceae
Blazing Star, Rough	*Liatris aspera*	Asteraceae
Blue-Eyed Grass, Stout	*Sisyrinchium angustifolium*	Iridaceae
Bluestar	*Amsonia tabernaemontana*	Apocynaceae
Bluet, Large or Summer	*Houstonia purpurea*	Rubiaceae
Bluet, Small	*Houstonia pusilla*	Rubiaceae
Boneset	*Eupatorium perfoliatum*	Asteraceae
Buckwheat, False	*Polygonum scandens var dumetorum*	Polygonaceae
Bush Clover, Smooth Creeping	*Lespedeza repens*	Fabaceae
Buttercup, Hairy	*Ranunculus hispidus*	Ranunculaceae
Butterfly Pea	*Clitoria mariana*	Fabaceae

Common Name	Scientific Name	Family Name
Butterfly Weed, Pleurisy-Root	*Asclepias tuberosa*	Asclepiadaceae
Butterweed	*Senecio glabellus*	Asteraceae
Buttonbush	*Cephalanthus occidentalis*	Rubiaceae
Buttonweed, Virginia	*Diodia virginiana*	Rubiaceae
Cabomba caroliniana		
Cardinal Flower	*Lobelia cardinalis*	Campanulaceae
Carex hystericina		
Chelone oblique var. speciosa		
Cinquefoil, Common	*Potentilla simplex*	Rosaceae
Clover, Red	*Trifolium pratense*	Fabaceae
Coneflower, Thinleaf	*Rudbeckia triloba*	Asteraceae
Coreopsis, Garden	*Coreopsis tinctoria*	Asteraceae
Corn Salad, Beaked	*Valerianella radiata*	Valerianaceae
Cranesbill, Carolina	*Geranium carolinianum*	Geraniaceae
Cress, Winter	*Barbarea vulgaris*	Brassicaceae
Cross Vine	*Bignonia capreolata*	Bignoniaceae
Crownbeard, White	*Verbesina virginica*	Asteraceae
Daisy, Oxeye *	*Chrysanthemum leucanthemum*	Asteraceae
Dandelion, False	*Pyrrhopappus carolinianus*	Asteraceae
Dandelion, Potato	*Krigia dandelion*	Asteraceae
Dayflower, Asiatic *	*Commelina communis*	Commelinaceae
Dayflower, Virginia	*Commelina virginica*	Commelinaceae
Daylily, Orange or Common *	*Hemerocallis fulva*	Liliaceae
Dead Nettle, Purple *	*Lamium purpureum*	Lamiaceae
Dodder, Common	*Cuscuta gronovii*	Cuscutaceae
Dragonhead, False; Obedient Plant	*Physostegia virginiana*	Lamiaceae
Elderberry, Common	*Sambucus canadensis*	Caprifoliaceae
Elephant's Foot, Leafy	*Elephantopus carolinianus*	Asteraceae
Evening Primrose, Common	*Oenothera biennis*	Onagraceae
Eyebane	*Chamaesyce nutans*	Euphorbiaceae
False Foxglove, Spreading	*Aureolaria patula*	Scrophulariaceae
Flag, Southern Blue	*Iris virginica*	Iridaceae
Flat-Topped Goldenrod, Miss. Valley	*Euthamia leptocephala*	Asteraceae
Flax, Common Yellow	*Linum medium var texanum*	Linaceae
Fleabane, Daisy	*Erigeron annuus*	Asteraceae
Fleabane, Marsh	*Pluchea camphorata*	Asteraceae
Fleabane, Philadelphia	*Erigeron philadelphicus*	Asteraceae
Fogfruit, Lanceleaf	*Phyla lanceolata*	Verbenaceae
Garlic, Wild or Canada	*Allium canadense*	Liliaceae
Gaura, Biennial	*Gaura biennis*	Onagraceae
Gerardia, Fascicled Purple	*Agalinis fasciculata*	Scrophulariaceae
Germander, American; Sage, Wood	*Teucrium canadense*	Lamiaceae
Goldenrod, Common	*Solidago canadensis*	Asteraceae
Goldenrod, Curtis'	*Solidago curtisii*	Asteraceae
Goldenrod, Early	*Solidago juncea*	Asteraceae
Goldenrod, Zigzag	*Solidago flexicaulis*	Asteraceae
Green Dragon	*Arisaema dracontium*	Araceae
Ground Cherry, Angular	*Physalis angulata*	Solanaceae
Ground Ivy	*Glechoma hederacea*	Lamiaceae

Common Name	Scientific Name	Family Name
Groundnut	*Apios americana*	Fabaceae
Hawkweed, Hairy	*Hieracium gronovii*	Asteraceae
Heal All, Selfheal	*Prunella vulgaris*	Lamiaceae
Hedge Nettle, Smooth	*Stachys tenuifolia*	Lamiaceae
Hemlock, Poison *	*Conium maculatum*	Lamiaceae
Hemlock, Water	*Cicuta maculata*	Apiaceae
Hempweed, Climbing	*Mikania scandens*	Asteraceae
Henbit	*Lamium amplexicaule*	Lamiaceae
Honeysuckle, Japanese *	*Lonicera japonica*	Caprifoliaceae
Hop Clover, Low	*Trifolium campestre*	Fabaceae
Horseweed	*Conyza canadensis*	Asteraceae
Hydrolea uniflora		
Iris brevicaulis		
Ipecac, American; Indian-physic	*Porteranthus stipulatus*	Rosaceae
Ironweed, New York	*Vernonia noveboracensis*	Asteraceae
Ironweed, Tall	*Vernonia gigantea*	Asteraceae
Jacob's Ladder, Greek Valerian	*Polemonium reptans*	Polemoniaceae
Jewelweed, Spotted Touch-Me-Not	*Impatiens capensis*	Balsaminaceae
Joe-Pye Weed, Hollow	*Eupatorium fistulosum*	Asteraceae
Knotweed, Virginia or Jumpseed	*Polygonum virginianum*	Polygonaceae
Lespedeza, Sericea *	*Lespedeza cuneata*	Fabaceae
Lettuce, Florida Blue	*Lactuca floridana*	Asteraceae
Lettuce, Prickly	*Lactuca serriola*	Asteraceae
Lizard's Tail	*Saururus cernuus*	Saururaceae
Lobelia, Downy	*Lobelia puberula*	Campanulaceae
Loosestrife, Lanceleaf	*Lysimachia lanceolata*	Primulaceae
Loosestrife, Winged	*Lythrum alatum*	Lythraceae
Love in a Puff, Balloon Vine	*Cardiospermum halicacabum*	Sapindaceae
Mallow, Prickly	*Sida spinosa*	Malvaceae
Mayapple	*Podophyllum peltatum*	Berberidaceae
Meadow Beauty, Maryland	*Rhexia mariana*	Melastomataceae
Mild Water-Pepper	*Polygonum hydropiperoides*	Polygonaceae
Milkweed, Aquatic	*Asclepias perennis*	Asclepiadaceae
Milkweed, Purple	*Asclepias purpurascens*	Asclepiadaceae
Milkweed, Swamp	*Asclepias incarnata*	Asclepiadaceae
Milkwort, Curtiss'	*Polygala curtissii*	Polygonaceae
Mint, Stone	*Cunila origanoides*	Lamiaceae
Mistflower	*Conoclinium coelestinum*	Asteraceae
Monkey Flower, Sharpwing	*Mimulus alatus*	Scrophulariaceae
Morning Glory, Common*	*Ipomoea purpurea*	Convolvulaceae
Morning Glory, Ivyleaf *	*Ipomoea hederacea*	Convolvulaceae
Morning Glory, Small White*	*Ipomoea lacunosa*	Convolvulaceae
Mountain Mint, Loomis'	*Pycnanthemum loomisii*	Lamiaceae
Mountain Mint, Narrowleaf	*Pycnanthemum tenuifolium*	Lamiaceae
Mullein, Common	*Verbascum thapsus*	Scrophulariaceae
Mullein, Moth	*Verbascum blattaria*	Scrophulariaceae
Mustard, Field	*Brassica rapa*	Brassicaceae
Naked-Flowered Tick Trefoil	*Desmodium nudiflorum*	Fabaceae
Nettle, Horse	*Solanum carolinense*	Solanaceae

Common Name	Scientific Name	Family Name
Nightshade, Common	*Solanum ptychanthum*	Solanaceae
Orchid, Purple Fringeless	*Platanthera peramoena*	Orchidaceae
Pansy, Field	*Viola rafinesquii*	Violaceae
Pea, Partridge	*Chamaecrista fasciculata*	Fabaceae
Peanut, Hog	*Amphicarpaea bracteata*	Fabaceae
Phlox, Downy	*Phlox pilosa*	Polemoniaceae
Phlox, Fall	*Phlox paniculata*	Polemoniaceae
Phlox, Smooth	*Phlox glaberrima*	Polemoniaceae
Phlox, Wild Blue or Woodland	*Phlox divaricata*	Polemoniaceae
Pilewort	*Erechtites hieraciifolia*	Asteraceae
Pimpernel, False	*Lindernia dubia*	Scrophulariaceae
Pink, Deptford *	*Dianthus armeria*	Caryophyllaceae
Pink, Fire	*Silene virginica*	Caryophyllaceae
Pink, Indian	*Spigelia marilandica*	Loganiaceae
Pink, Rose	*Sabatia angularis*	Gentianaceae
Pokeweed	*Phytolacca americana*	Phytolaccaceae
Potamogeton pulcher		
Prenanthes asprea		
Pussytoes, Plantainleaf	*Antennaria plantaginifolia*	Asteraceae
Quaker Ladies, Innocence	*Houstonia caerulea*	Rubiaceae
Queen Anne's Lace *	*Daucus carota*	Apiaceae
Ragweed, Common	*Ambrosia artemisiifolia*	Asteraceae
Ragweed, Great	*Ambrosia trifida*	Asteraceae
Ragweed, Lanceleaf	*Ambrosia bidentata*	Asteraceae
Rattlesnake Weed	*Hieracium venosum*	Asteraceae
Redstem, Valley	*Ammannia coccinea*	Lythraceae
Rose Mallow, Swamp	*Hibiscus moscheutos*	Malvaceae
Rose, Prairie	*Rosa setigera*	Rosaceae
Rue Anemone	*Thalictrum thalictroides*	Ranunculaceae
Ruellia, Hairy	*Ruellia caroliniensis*	Acanthaceae
Sage, Lyre-Leaved	*Salvia lyrata*	Lamiaceae
Sandvine	*Ampelamus albidus*	Asclepiadaceae
Seedbox	*Ludwigia alternifolia*	Onagraceae
Senna, Southern Wild	*Senna marilandica*	Fabaceae
Shepherd's Purse	*Capsella bursa-pastoris*	Brassicaceae
Sicklepod	*Senna obtusifolia*	Fabaceae
Skullcap, Downy	*Scutellaria incana*	Lamiaceae
Skullcap, Hairy	*Scutellaria elliptica*	Lamiaceae
Skullcap, Small	*Scutellaria parvula*	Lamiaceae
Smartweed, Common *	*Polygonum hydropiper*	Polygonaceae
Smartweed, Pennsylvania	*Polygonum pensylvanicum*	Polygonaceae
Smartweed, Scarlet	*Polygonum amphibium*	Polygonaceae
Snakeroot, Sampson’s	*Orbexilum pedunculatum*	Fabaceae
Snakeroot, Virginia	*Aristolochia serpentaria*	Aristolochiaceae
Sneezeweed, Autumn	*Helenium autumnale*	Asteraceae
Sneezeweed, Purple-Headed	*Helenium flexuosum*	Asteraceae
Soapwort, Bouncing Bet	*Saponaria officinalis*	Caryophyllaceae
Spanish Bayonet	*Yucca filamentosa*	Agavaceae
Spider Lily, Carolina	*Hymenocallis caroliniana*	Liliaceae

Common Name	Scientific Name	Family Name
Spiderwort, Virginia or Widow’s Tears	*Tradescantia virginica*	Commelinaceae
Spring Beauty, Virginia	*Claytonia virginica*	Portulacaceae
Spurge, Flowering	*Euphorbia corollata*	Euphorbiaceae
Spurge, Prostrate	*Chamaesyce maculata*	Euphorbiaceae
Spurge, Toothed	*Euphorbia dentata*	Euphorbiaceae
St. Andrew's Cross	*Hypericum hypericoides*	Clusiaceae
St. Johnswort, Coppery	*Hypericum denticulatum*	Clusiaceae
St. Johnswort, Dwarf	*Hypericum mutilum*	Clusiaceae
St. Johnswort, Spotted	*Hypericum punctatum*	Clusiaceae
Stonecrop, Ditch	*Penthorum sedoides*	Crassulaceae
Strawberry Bush	*Euonymus americana*	Celastraceae
Strawberry, Wild	*Fragaria virginiana*	Rosaceae
Sundrops	*Oenothera fruticosa*	Onagraceae
Sunflower, Hairy	*Helianthus mollis*	Asteraceae
Sunflower, Narrowleaf	*Helianthus angustifolius*	Asteraceae
Sunflower, Paleleaf Woodland	*Helianthus strumosus*	Asteraceae
Sunflower, Stiff-Haired	*Helianthus hirsutus*	Asteraceae
Sweet Cicely	*Osmorhiza longistylis*	Apiaceae
Sweet Clover, White *	*Melilotus albus*	Fabaceae
Tea, Prairie	*Croton monanthogynus*	Euphorbiaceae
Tearthumb, Arrow-leaved	*Polygonum sagittatum*	Polygonaceae
Thistle, Bull *	*Cirsium vulgare*	Asteraceae
Thistle, Nodding	*Carduus nutans*	Asteraceae
Thoroughwort, Late Flowering	*Eupatorium serotinum*	Asteraceae
Thyme, Basil *	*Calamintha nepeta*	Lamiaceae
Tickseed Sunflower, Ozark	*Bidens polylepis*	Asteraceae
Tobacco, Indian	*Lobelia inflata*	Campanulaceae
Toothwort, Cutleaf	*Dentaria laciniata*	Brassicaceae
Toothwort, Slender	*Dentaria heterophylla*	Brassicaceae
Trillium, Prairie or Recurved	*Trillium recurvatum*	Liliaceae
Trout Lily, White	*Erythronium albidum*	Liliaceae
Trumpet Creeper	*Campsis radicans*	Bignoniaceae
Turnsole, Indian Heliotrope *	*Heliotropium indicum*	Boraginaceae
Venus' Looking Glass	*Triodanis perfoliata*	Campanulaceae
Vervain, Blue	*Verbena hastata*	Verbenaceae
Vervain, White	*Verbena urticifolia*	Verbenaceae
Vetch, Crown *	*Coronilla varia*	Fabaceae
Vetch, Smooth	*Vicia dasycarpa*	Fabaceae
Violet, Common Blue	*Viola sororia var. sororia*	Violaceae
Violet, Marsh Blue	*Viola cucullata*	Violaceae
Violet, Yellow Woodland	*Viola pubescens*	Violaceae
Virgin's Bower	*Clematis virginiana*	Ranunculaceae
Water Primrose, Creeping	*Ludwigia peploides*	Onagraceae
Water Primrose, Wingstem	*Ludwigia decurrens*	Onagraceae
Waxweed, Blue	*Cuphea viscosissima*	Lythraceae
Wild Potato Vine	*Ipomoea pandurata*	Convolvulaceae
Wingstem	*Verbesina alternifolia*	Asteraceae
Wood Sorrel, Common Yellow*	*Oxalis stricta*	Oxalidaceae
Wood Sorrel, Illinois	*Oxalis illinoensis*	Oxalidaceae

Common Name	Scientific Name	Family Name
Wood Sorrel, Violet	*Oxalis violacea*	Oxalidaceae
Yam, Chinese *	*Dioscorea polystachya*	Dioscoreaceae
Yam, Wild	*Dioscorea villosa*	Dioscoreaceae
Yarrow, Milfoil	*Achillea millefolium*	Asteraceae

Shrubs and Trees

This is a list of trees found, or likely to be found, on the refuge. The list was generated by refuge staff and Martina Hines, ecologist for the Kentucky State Nature Preserves Commission during preparation of a refuge vegetation map. A total of 22 families, 33 genera, and 60 species are represented. There are 13 oak species which represent 22 percent of the total. The list will be updated pending completion of a 2-year refuge-wide plant survey by Austin Peay State University.

Common Name	Scientific Name	Family Name
Ash, Green	*Fraxinus pennsylvanica*	Oleaceae
Ash, Pumpkin	*Fraxinus profunda*	Oleaceae
Ash, White	*Fraxinus americana*	Oleaceae
Beech, American	*Fagus grandifolia*	Fagaceae
Birch, River	*Betula nigra*	Betulaceae
Birch, Sweet	*Betula lenta*	Betulaceae
Blackgum	*Nyssa sylvatica*	Nyssaceae
Boxelder	Acer negundo	Aceraceae
Buttonbush	*Cephalanthus occidentalis*	Rubiaceae
Cherry, Black	*Prunus serotina*	Rosaceae
Cottonwood, Eastern	*Populus deltoides*	Salicaceae
Cypress, Bald	*Taxodium distichum*	Cupressaceae
Dogwood, Flowering	*Cornus florida*	Cornaceae
Dogwood, Gray	*Cornus foemina racemosa*	Cornaceae
Dogwood, Swamp	*Cornus foemina*	Cornaceae
Elm, American	*Ulmus americana*	Ulmaceae
Elm, Winged	*Ulmus alata*	Ulmaceae
Farkleberry	*Vaccinium arboretum*	Ericaceae
Hickory, Mockernut	*Carya tomentosa*	Juglandaceae
Hickory, Pignut	*Carya glabra*	Juglandaceae
Hickory, Shagbark	*Carya ovata*	Juglandaceae
Hickory, Water	*Carya aquatica*	Juglandaceae
Holly, American	*Ilex opaca*	Aquifoliaceae
Hophornbeam	*Ostrya virginiana*	Betulaceae
Hornbeam, American	*Carpinus caroliniana*	Betulaceae
Locust, Black	*Robinia pseudoacacia*	Fabaceae
Locust, Water	*Gleditsia aquatica*	Fabaceae
Maple, Red	*Acer rubrum*	Aceraceae
Maple, Silver	*Acer saccharinum*	Aceraceae
Maple, Sugar	*Acer saccharum*	Aceraceae
Oak, Black	*Quercus velutina*	Fagaceae
Oak, Cherrybark	*Quercus pagoda*	Fagaceae

Common Name	Scientific Name	Family Name
Oak, Chestnut	*Quercus prinus*	Fagaceae
Oak, Northern Red	*Quercus rubra*	Fagaceae
Oak, Overcup	*Quercus lyrata*	Fagaceae
Oak, Pin	*Quercus palustris*	Fagaceae
Oak, Post	*Quercus stellata*	Fagaceae
Oak, Shumard	*Quercus shumardii*	Fagaceae
Oak, Southern Red	*Quercus falcata*	Fagaceae
Oak, Swamp Chestnut	*Quercus michauxii*	Fagaceae
Oak, Swamp White	*Quercus bicolor*	Fagaceae
Oak, White	*Quercus alba*	Fagaceae
Oak, Willow	*Quercus phellos*	Fagaceae
Pawpaw	*Asimina triloba*	Annonaceae
Persimmon	*Diospyros virginiana*	Ebenaceae
Planertree	*Planera aquatica*	Ulmaceae
Possumhaw	*Ilex decidua*	Aquifoliaceae
Redcedar, Eastern	*Juniperus virginiana*	Cupressaceae
Sassafras	*Sassafras albidum*	Lauraceae
Serviceberry, Downy	*Amelanchier arborea*	Rosaceae
Spicebush, Northern	*Lindera benzoin*	Lauraceae
Sugarberry	*Celtis laevigata*	Ulmaceae
Sweetgum	*Liquidambar styraciflua*	Hamamelidaceae
Sycamore, American	*Platanus occidentalis*	Platanaceae
Tuliptree	*Liriodendron tulipifera*	Magnoliaceae
Tupelo, Water	*Nyssa aquatica*	Nyssaceae
Walnut, Black	*Juglans nigra*	Juglandaceae
Willow, Black	*Salix nigra*	Salicaceae
Willow, Virginia	*Itea virginica*	Grossulariaceae
Winterberry, Common	*Ilex verticillata*	Aquifoliaceae

Insects of Clarks River National Wildlife Refuge

Butterflies and Moths

The Society of Kentucky Lepidopterists (*http://bioweb.wku.edu/faculty/Marcus/KYLeps.html*) lists nearly 600 species of butterflies and moths that occur in Graves, Marshall, and McCracken Counties. Society members have volunteered to survey the refuge, the results will be reported as the information becomes available. Habitat suitable for all of these species may not be found on the refuge. The list below is comprised of species that have been identified on the refuge. Nine families, 31 genera, and 34 species are represented.

Common Name	Scientific Name	Family Name
Brown, Appalachian	*Satyrodes appalachia*	Nymphalidae
Buckeye, Common	*Junonia coenia*	Nymphalidae
Checkered-Skipper, Common	*Pyrgus communis*	Hesperiidae
Clearwing, Snowberry	*Hemaris diffinis*	Sphingidae
Comma, Eastern	*Polygonia comma*	Nymphalidae

Common Name	Scientific Name	Family Name
Crescent, Pearl	*Phyciodes tharos*	Nymphalidae
Fritillary, Gulf	*Agraulis vanillae*	Nymphalidae
Fritillary, Variegated	*Euptoieta claudia*	Nymphalidae
Hairstreak, Gray	*Strymon melinus*	Lycaenidae
Harvester	*Feniseca tarquinius*	Lycaenidae
Lady, Painted	*Vanessa cardui*	Nymphalidae
Monarch	*Danaus plexippus*	Nymphalidae
Moth, Clymene	*Haploa clymene*	Arctiidae
Moth, Luna	*Actias luna*	Saturniidae
Mourning Cloak	*Nymphalis antiopa*	Nymphalidae
Orangetip, Falcate	*Anthocharis midea*	Pieridae
Question Mark	*Polygonia interrogationis*	Nymphalidae
Scape Moth, Yellow-collared	*Cisseps fulvicollis*	Arctiidae
Silkmoth, Promethea	*Callosamia promethea*	Saturniidae
Skipper, Silver-spotted	*Epargyreus clarus*	Hesperiidae
Skipper, Zabulon	*Poanes zabulon*	Hesperiidae
Snout, American	*Libytheana carinenta*	Nymphalidae
Sphinx, Banded	*Eumorpha fasciatus*	Sphingidae
Sphinx, Elm	*Ceratomia amyntor*	Sphingidae
Sulphur, Clouded	*Colias philodice*	Pieridae
Sulphur, Cloudless	*Phoebis sennae*	Pieridae
Sulphur, Orange	*Colias eurytheme*	Pieridae
Swallowtail, Black	*Papilio polyxenes*	Papilionidae
Swallowtail, Eastern Tiger	*Papilio glaucus*	Papilionidae
Swallowtail, Pipevine	*Battus philenor*	Papilionidae
Swallowtail, Zebra	*Eurytides marcellus*	Papilionidae
Tailed-Blue, Eastern	*Cupido comyntas*	Lycaenidae
White, Checkered	*Pontia protodice*	Pieridae
Wood-Nymph, Beautiful	*Eudryas grata*	Noctuidae
Amberwing, Eastern	*Perithemis tenera*	Libellulidae
Dancer, Blue-fronted	*Argia apicalis*	Coenagrionidae
Dancer, Blue-tipped	*Argia tibialis*	Coenagrionidae
Darner, Swamp	*Epiaeschna heros*	Aeshnidae
Dasher, Blue	*Pachydiplax longipennis*	Libellulidae
Jewelwing, Ebony	*Calopteryx maculata*	Calopterygidae
Meadowhawk, Blue-faced	*Sympetrum ambiguum*	Libellulidae
Pondhawk, Eastern	*Erythemis simplicicollis*	Libellulidae
Skimmer, Widow	*Libellula luctuosa*	Libellulidae
Whitetail, Common	*Plathemis lydia*	Libellulidae

Other Insects

Common Name	Scientific Name	Family Name
Aphid, Oleander	*Aphis nerii*	Aphididae
Beetle, American Carrion	*Necrophila americana*	Staphylinoidae
Bug, Assassin, Orange	*Pselliopus barberi*	Reduviidae
Bug, Box Elder	*Boisea trivittata*	Rhopalidae
Bug, Leaf-footed	*Acanthocephala terminalis*	Coreidae
Bug, Leaf-footed, Eastern	*Leptoglossus phyllopus*	Coreidae
Bug, Wheel	*Arilus cristatus*	Reduviidae
Cricket, Red-headed Brush	*Phyllopalpus pulchellus*	Gryllidae
Euphoria, Emerald	*Euphoria fulgida*	Scarabaeidae
Hunter, Caterpillar	*Calosoma scrutator*	Carabidae
Killer, Eastern Cicada	*Sphecius speciosus*	Carbronidae
Leaf Beetle, Milkweed	*Labidomera clivicollis*	Chrysomelidae
Meadow Katydid, Black-legged	*Orchelimum nigripes*	Tettigoniidae
Spittlebug, Two-lined	*Prospia bicincta*	Cercopidae
Stinkbug, Green	*Acrosternum hilare*	Pentatomidae
Tiger Beetle, Six-spotted	*Cicindela sexgutata*	Carabidae
Unnamed	*Chlaenius tricolor*	Carabidae

Freshwater Mussels of Clarks River National Wildlife Refuge

Freshwater mussels found or once found in the Lower Tennessee River watershed, of which the Clarks River is a part are listed below. Two families, 28 genera, and 43 species are represented. Surveys to locate other species are ongoing. Some mussels are listed by the Service as a candidate for listing (C) or endangered (E) under the Endangered Species Act of 1973 or a species of management concern (SOMC). Other mussels are listed by the Kentucky State Nature Preserves Commission (KSNPC) as Endangered (E) or a species of Special Concern (SC).

Species marked with an asterisk (*) occur on the refuge.

Common Name	Scientific Name	Family Name	USFWS	KSNPC
Bankclimber	*Plectomerus dombeyanus*	Unionidae		
Black Sandshell	*Ligumia recta*	Unionidae		
Bleufer	*Potamilus purpuratus*	Unionidae		E
Butterfly	*Ellipsaria lineolata*	Unionidae		
Deertoe *	*Truncilla truncata*	Unionidae		
Ebonyshell *	*Fusconaia ebena*	Unionidae		
Elephant Ear *	*Elliptio crassidens*	Unionidae		
Fanshell	*Cyprogenia stegaria*	Unionidae	EE	
Fawnsfoot	*Truncilla donaciformis*	Unionidae		
Flat Floater *	*Anodonta suborbiculata*	Unionidae		
Flutedshell *	*Lasmigona costata*	Unionidae		
Fragile Papershell *	*Leptodea fragilis*	Unionidae		
Giant Floater *	*Pyganodon grandis*	Unionidae		
Hickorynut	*Obovaria olivaria*	Unionidae		

Common Name	Scientific Name		Family Name	
Kidneyshell	*Ptychobranchus fasciolaris*	Unionidae		SC
Longsolid	*Fusconaia subrotunda*	Unionidae		
Mapleleaf *	*Quadrula quadrula*	Unionidae		
Mucket	*Actinonaias ligamentina*	Unionidae		
Ohio Pigtoe *	*Pleurobema cordatum*	Unionidae		
Orangefoot Pimpleback	*Plethobasus cooperianus*	Unionidae	E	E
Paper Pondshell *	*Utterbackia imbecillis*	Unionidae		
Pimpleback *	*Quadrula pustulosa*	Unionidae		
Pink Heelsplitter *	*Potamilus alatus*	Unionidae		
Pink Mucket	*Lampsilis abrupta*	Unionidae	E	E
Pistolgrip *	*Tritogonia verrucosa*	Unionidae		
Plain Pocketbook *	*Lampsilis cardium*	Unionidae		
Pocketbook *	*Lampsilis ovata*	Unionidae		E
Purple Lilliput *	*Toxolasma lividus*	Unionidae		E
Purple Wartyback	*Cyclonaias tuberculata*	Unionidae		
Pyramid Pigtoe	*Pleurobema rubrum*	Unionidae		E
Ring Pink	*Obovaria retusa*	Unionidae	E	E
Rock Pocketbook *	*Arcidens confragosus*	Unionidae		
Round Pigtoe	*Pleurobema sintoxia*	Unionidae		
Sheepnose	*Plethobasus cyphyus*	Unionidae		SC
Spectaclecase	*Cumberlandia monodonta*	Margaritiferidae		E
Spike	*Elliptio dilatata*	Unionidae		
Threehorn Wartyback *	*Obliquaria reflexa*	Unionidae		
Threeridge *	*Amblema plicata*	Unionidae		
Wabash Pigtoe *	*Fusconaia flava*	Unionidae		
Wartyback *	*Quadrula nodulata*	Unionidae		
Washboard *	*Megalonaias nervosa*	Unionidae		
White Heelsplitter *	*Lasmigona complanata*	Unionidae		
Yellow Sandshell *	*Lampsilis teres*	Unionidae		

Fish of Clarks River NWR

Fish found or once found in the Lower Tennessee River watershed, of which the Clarks River is a part are listed below. Twenty-one families, 60 genera, and 157 species are represented. Surveys to locate other species are ongoing. Some fish are listed by the Service as endangered (E) under the Endangered Species Act of 1973 or a species of management concern (SOMC). Other mussels are listed by the Kentucky State Nature Preserves Commission (KSNPC) as Threatened (T), Endangered (E); species of Special Concern (SC) or extirpated (X), no longer found in the watershed.

Species marked with an asterisk (*) occur on the refuge.

Common Name	Scientific Name	Family Name	USFWS	KSNPC
Bass, Largemouth *	*Micropterus salmoides*	Centrarchidae		
Bass, Rock	*Ambloplites rupestris*	Centrarchidae		
Bass, Smallmouth	*Micropterus dolomieu*	Centrarchidae		
Bass, Spotted *	*Micropterus punctulatus*	Centrarchidae		

Common Name	Scientific Name	Family Name	USFWS	KSNPC
Bass, Striped	*Morone saxatilis*	Moronidae		
Bass, White	*Morone chrysops*	Moronidae		
Bass, Yellow	*Morone mississippiensis*	Moronidae		
Bluegill *	*Lepomis macrochirus*	Centrarchidae		
Bowfin	*Amia calva*	Amiidae		
Buffalo, Bigmouth	*Ictiobus cyprinellus*	Catostomidae		
Buffalo, Black *	*Ictiobus niger*	Catostomidae		SC
Buffalo, Smallmouth *	*Ictiobus bubalus*	Catostomidae		
Bullhead, Black	*Ameiurus melas*	Ictaluridae		
Bullhead, Brown *	*Ameiurus nebulosus*	Ictaluridae		
Bullhead, Yellow *	*Ameiurus natalis*	Ictaluridae		
Burbot	*Lota lota*	Gadidae		SC
Carp, Bighead*	*Hypophthalmicthys nobilis*	Cyprinidae		
Carp, Common *	*Cyprinus carpio*	Cyprinidae		
Carp, Grass	*Ctenopharyngodon idella*	Cyprinidae		
Carp, Silver	*Hypophthalmicthys molitrix*	Cyprinidae		
Carpsucker, Highfin	*Carpiodes velifer*	Catostomidae		
Carpsucker, River	*Carpiodes carpio*	Catostomidae		
Catfish, Blue	*Ictalurus furcatus*	Ictaluridae		
Catfish, Channel *	*Ictalurus punctatus*	Ictaluridae		
Catfish, Flathead	*Pylodictis olivaris*	Ictaluridae		
Chub, Creek *	*Semotilus atromaculatus*	Cyprinidae		
Chub, River	*Nocomis micropogon*	Cyprinidae		
Chub, Silver	*Macrhybopsis storeriana*	Cyprinidae		
Chubsucker, Lake	*Erimyzon sucetta*	Catostomidae		T
Chubsucker, Western Creek	*Erimyzon claviformis*	Catostomidae		
Crappie, Black	*Pomoxis nigromaculatus*	Centrarchidae		
Crappie, White *	*Pomoxis annularis*	Centrarchidae		
Darter, Banded	*Etheostoma zonale*	Percidae		
Darter, Bandfin *	*Etheostoma zonistium*	Percidae		
Darter, Blackside *	*Percina maculata*	Percidae		
Darter, Bluebreast	*Etheostoma camurum*	Percidae		
Darter, Bluntnose	*Etheostoma chlorosoma*	Percidae		
Darter, Brighteye	*Etheostoma lynceum*	Percidae		E
Darter, Channel	*Percina copelandi*	Percidae		
Darter, Cypress *	*Etheostoma proeliare*	Percidae		T
Darter, Dusky *	*Percina sciera*	Percidae		
Darter, Fantail *	*Etheostoma flabellare*	Percidae		
Darter, Firebelly	*Etheostoma pyrrhogaster*	Percidae	SOMC	E
Darter, Goldstripe	*Etheostoma parvipinne*	Percidae		E
Darter, Greenside	*Etheostoma blennioides*	Percidae		
Darter, Guardian *	*Etheostoma oophylax*	Percidae		
Darter, Gulf	*Etheostoma swaini*	Percidae		E
Darter, Harlequin *	*Etheostoma histrio*	Percidae		
Darter, Johnny	*Etheostoma nigrum*	Percidae		
Darter, Mud	*Etheostoma asprigene*	Percidae		
Darter, Orangethroat	*Etheostoma spectabile*	Percidae		
Darter, Rainbow	*Etheostoma caeruleum*	Percidae		
Darter, Redline	*Etheostoma rufilineatum*	Percidae		

Common Name	Scientific Name	Family Name	USFWS	KSNPC
Darter, Relict	*Etheostoma chiensense*	Percidae	E	E
Darter, River *	*Percina shumardi*	Percidae		
Darter, Saddleback *	*Percina vigil*	Percidae		
Darter, Scaly Sand	*Ammocrypta vivax*	Percidae		X
Darter, Slabrock	*Etheostoma smithi*	Percidae		
Darter, Slenderhead	*Percina phoxocephala*	Percidae		
Darter, Slough *	*Etheostoma gracile*	Percidae		
Darter, Speckled *	*Etheostoma stigmaeum*	Percidae		
Darter, Stripetail *	*Etheostoma kennicotti*	Percidae		
Drum, Freshwater *	*Aplodinotus grunniens*	Sciaenidae		
Eel, American	*Anguilla rostrata*	Anguillidae		
Flier*	*Centrarchus macropterus*	Centrarchidae		
Gar, Alligator	*Atractosteus spatula*	Lepisosteidae	SOMC	E
Gar, Longnose	*Lepisosteus osseus*	Lepisosteidae		
Gar, Shortnose *	*Lepisosteus platostomus*	Lepisosteidae		
Gar, Spotted	*Lepisosteus oculatus*	Lepisosteidae		
Goldeye	*Hiodon alosoides*	Hiodontidae		
Goldfish	*Carassius auratus*	Cyprinidae		
Herring, Skipjack	*Alosa chrysochloris*	Clupeidae		
Hogsucker, Northern *	*Hypentelium nigricans*	Catostomidae		
Lamprey, American Brook	*Lampetra appendix*	Petromyzontidae		T
Lamprey, Chestnut	*Ichthyomyzon castaneus*	Petromyzontidae		SC
Logperch	*Percina caprodes*	Percidae		
Madtom, Brindled *	*Noturus miurus*	Ictaluridae		
Madtom, Brown	*Noturus phaeus*	Ictaluridae		E
Madtom, Elegant	*Noturus elegans*	Ictaluridae		
Madtom, Freckled *	*Noturus nocturnus*	Ictaluridae		
Madtom, Least	*Noturus hildebrandi*	Ictaluridae		E
Madtom, Mountain	*Noturus eleutherus*	Ictaluridae		
Madtom, Northern	*Noturus stigmosus*	Ictaluridae	SOMC	SC
Madtom, Tadpole	*Noturus gyrinus*	Ictaluridae		
Minnow, Bluntnose *	*Pimephales notatus*	Cyprinidae		
Minnow, Bullhead	*Pimephales vigilax*	Cyprinidae		
Minnow, Cypress	*Hybognathus hayi*	Cyprinidae		E
Minnow, Flathead	*Pimephales promelas*	Cyprinidae		
Minnow, Pugnose *	*Opsopoeodus emiliae*	Cyprinidae		
Minnow, Silvery *	*Hybognathus nuchalis*	Cyprinidae		
Minnow, Suckermouth *	*Phenacobius mirabilis*	Cyprinidae		
Mooneye	*Hiodon tergisus*	Hiodontidae		
Mosquitofish, Western *	*Gambusia affinis*	Poeciliidae		
Mudminnow, Central *	*Umbra limi*	Centrarchidae		T
Paddlefish	*Polydon spathula*	Polyodontidae		
Perch, Pirate *	*Aphredoderus sayanus*	Aphredoderidae		
Perch, White	*Morone americana*	Moronidae		
Perch, Yellow	*Perca flavescens*	Percidae		
Pickerel, Chain	*Esox niger*	Esocidae		SC
Pickerel, Grass *	*Esox americanus*	Esocidae		
Pike, Northern	*Esox lucius*	Esocidae		
Pumpkinseed	*Lepomis gibbosus*	Centrarchidae		

Common Name	Scientific Name	Family Name	USFWS	KSNPC
Quillback *	*Carpiodes cyprinus*	Catostomidae		
Redhorse*	*Moxostoma* spp.	Catostomidae		
Redhorse, Black	*Moxostoma duquesnei*	Catostomidae		
Redhorse, Blacktail	*Moxostoma poecilurum*	Catostomidae		E
Redhorse, Golden *	*Moxostoma erythrurum*	Catostomidae		
Redhorse, River	*Moxostoma carinatum*	Catostomidae		
Redhorse, Silver	*Moxostoma anisurum*	Catostomidae		
Redhorse, Smallmouth	*Moxostoma breviceps*	Catostomidae		
Sauger	*Sander canadensis*	Percidae		
Shad, Alabama	*Alosa alabamae*	Clupeidae	SOMC	E
Shad, Gizzard *	*Dorosoma cepedianum*	Clupeidae		
Shad, Threadfin	*Dorosoma pretenense*	Clupeidae		
Shiner, Bigeye *	*Notropis boops*	Cyprinidae		
Shiner, Blacktail	*Cyprinella venusta*	Cyprinidae		SC
Shiner, Bluntface	*Cyprinella camura*	Cyprinidae		E
Shiner, Channel	*Notropus wickliffi*	Cyprinidae		
Shiner, Emerald *	*Notropis atherinoides*	Cyprinidae		
Shiner, Ghost	*Notropis buchanani*	Cyprinidae		
Shiner, Golden	*Notemigonus crysoleucas*	Cyprinidae		
Shiner, Mimic	*Notropis volucellis*	Cyprinidae		
Shiner, Pallid	*Hybopsis amnis*	Cyprinidae	SOMC	E
Shiner, Red	*Cyprinella lutrensis*	Cyprinidae		
Shiner, Redfin *	*Lythrurus umbratilis*	Cyprinidae		
Shiner, Ribbon *	*Lythrurus fumeus*	Cyprinidae		
Shiner, River *	*Notropis blennius*	Cyprinidae		
Shiner, Rosyface	*Notropis rubellus*	Cyprinidae		
Shiner, Sand	*Notropis stramineus*	Cyprinidae		
Shiner, Scarlet	*Lythrurus fasciolaris*	Cyprinidae		
Shiner, Silverband	*Notropis shumardi*	Cyprinidae		
Shiner, Spotfin	*Cyprinella spiloptera*	Cyprinidae		
Shiner, Spottail	*Notropis hudsonius*	Cyprinidae		
Shiner, Steelcolor *	*Cyprinella whipplei*	Cyprinidae		
Shiner, Striped	*Luxilus chrysocephalus*	Cyprinidae		
Shiner, Taillight	*Notropis maculatus*	Cyprinidae		T
Silverside, Brook *	*Labidesthes sicculus*	Atherinidae		
Silverside, Inland	*Menidia beryllina*	Atherinidae		T
Stonecat	*Noturus flavus*	Ictaluridae		
Stoneroller, Central	*Campostoma anomalum*	Cyprinidae		
Stoneroller, Largescale *	*Campostoma oligolepis*	Cyprinidae		
Sucker, Blue	*Cycleptus elongatus*	Catostomidae		
Sucker, Spotted *	*Minytrema melanops*	Catostomidae		
Sucker, White	*Catostomus commersoni*	Catostomidae		
Sunfish, Banded Pygmy	*Elassoma zonatum*	Elassomatidae		
Sunfish, Bantam	*Lepomis symmetricus*	Centrarchidae		
Sunfish, Dollar	*Lepomis marginatus*	Centrarchidae		E
Sunfish, Green *	*Lepomis cyanellus*	Centrarchidae		
Sunfish, Longear *	*Lepomis megalotis*	Centrarchidae		
Sunfish, Orangespotted *	*Lepomis humilis*	Centrarchidae		
Sunfish, Redbreast	*Lepomis auritus*	Centrarchidae		

Common Name	Scientific Name	Family Name	USFWS	KSNPC
Sunfish, Redear	*Lepomis microlophus*	Centrarchidae		
Sunfish, Redspotted	*Lepomis miniatus*	Centrarchidae		T
Topminnow, Blackspotted *	*Fundulus olivaceus*	Fundulidae		
Topminnow, Blackstripe *	*Fundulus notatus*	Fundulidae		
Walleye	*Sander vitreus*	Percidae		
Warmouth *	*Lepomis gulosus*	Centrarchidae		

Crayfish of Clarks River NWR

Crayfish found in the Lower Tennessee River watershed, of which the Clarks River is a part, are listed below. One family, five genera, and 17 species are represented. Some crayfish are listed by the Kentucky State Nature Preserves Commission (KSNPC) as Threatened (T), Endangered (E) or species of Special Concern (SC).

Species marked with an astericks (*) occur on the refuge.

Common Name	Scientific Name	Family Name	KSNPC
Bigclaw Crayfish	*Orconectes placidus*	Cambaridae	
Blood River Crayfish	*Orconectes burri*	Cambaridae	T
Cajun Dwarf Crayfish	*Cambarellus shufeldtii*	Cambaridae	SC
Calico Crayfish	*Orconectes immunis*	Cambaridae	
Depression Crayfish	*Cambarus rusticiformis*	Cambaridae	
Devil Crayfish*	*Cambarus diogenes*	Cambaridae	
Digger Crayfish	*Fallicambarus fodiens*	Cambaridae	
Gray-Speckled Crayfish	*Orconectes palmeri palmeri*	Cambaridae	E
Painted Devil Crayfish	*Cambarus ludovicianus*	Cambaridae	
Painted Mudbug	*Cambarus species A*	Cambaridae	
Red Swamp Crayfish *	*Procambarus clarkii*	Cambaridae	
Saddle Crayfish*	*Orconectes durelli*	Cambaridae	
Shrimp Crayfish	*Orconectes lancifer*	Cambaridae	E
Swamp Dwarf Crayfish	*Cambarellus puer*	Cambaridae	E
Vernal Crayfish	*Procambarus viaeviridis*	Cambaridae	T
Western Highland Crayfish	*Orconectes tricuspis*	Cambaridae	
White River Crawfish *	*Procambarus acutus*	Cambaridae	

Amphibians and Reptiles of Clarks River NWR

The checklist of reptiles and amphibians below was generated by noted herpetologist John MacGregor of the KDFWR for the Jackson Purchase region, western Kentucky. Twenty-one families, 52 genera, and 87 species are represented. Habitat suitable for all the species listed below may not be found on the refuge.

Species marked with an asterisk (*) have been found on the refuge.

Salamanders

Common Name	Scientific Name	Family Name
Spotted Salamander *	*Ambystoma maculatum*	Ambystomatidae
Marbled Salamander *	*Ambystoma opacum*	Ambystomatidae
Mole Salamander *	*Ambystoma talpoideum*	Ambystomatidae
Smallmouth Salamander *	*Ambystoma texanum*	Ambystomatidae
Eastern Tiger Salamander*	*Ambystoma tigrinum tigrinum*	Ambystomatidae
3-toed Amphiuma	*Amphiuma tridactylum*	Amphiumidae
Eastern Hellbender	*Cryptobranchus alleganiensis*	Cryptobranchidae
Spotted Dusky Salamander	*Desmognathus conanti*	Plethodontidae
Southern Two-lined Salamander	*Eurycea cirrigera*	Plethodontidae
Three-lined Salamander	*Eurycea guttolineata*	Plethodontidae
Longtail Salamander *	*Eurycea longicauda*	Plethodontidae
Cave Salamander	*Eurycea lucifuga*	Plethodontidae
Four-toed Salamander *	*Hemidactylium scutatum*	Plethodontidae
Mudpuppy	*Necturus maculosus*	Proteidae
Central Newt *	*Notophthalmus viridescens*	Salamandridae
Northern Zigzag Salamander	*Plethodon dorsalis*	Plethodontidae
Northern Slimy Salamander *	*Plethodon glutinosus*	Plethodontidae
Mississippi Slimy Salamander*	*Plethodon mississippi*	Plethodontidae
N/S Red Salamander	*Pseudotriton ruber ssp.*	Plethodontidae
Western Lesser Siren *	*Siren intermedia nettingi*	Sirenidae

Frogs

Common Name	Scientific Name	Family Name
Cricket Frog *	*Acris crepitans*	Hylidae
American Toad *	*Bufo americanus*	Bufonidae
Fowler's Toad *	*Bufo fowleri*	Bufonidae
Eastern Narrowmouth Toad	*Gastrophryne carolinensis*	Microhylidae
Bird-voiced Treefrog	*Hyla avivoca*	Hylidae
Cope's Gray Treefrog *	*Hyla chrysoscelis*	Hylidae
Green Treefrog *	*Hyla cinerea*	Hylidae
Spring Peeper *	*Pseudacris crucifer*	Hylidae
Upland Chorus Frog *	*Pseudacris triseriata feriarum*	Hylidae
Northern Crawfish Frog *	*Rana areolata circulosa*	Ranidae
Bullfrog *	*Rana catesbeiana*	Ranidae
Green Frog *	*Rana clamitans*	Ranidae
Southern Leopard Frog *	*Rana sphenocephala*	Ranidae

Common Name	Scientific Name	Family Name
Wood Frog	*Rana sylvatica*	Ranidae
Eastern Spadefoot	*Scaphiopus holbrookii*	Pelobatidae

Lizards

Common Name	Scientific Name	Family Name
Six-lined Racerunner *	*Cnemidophorus sexlineatus*	Teiidae
Coal Skink	*Eumeces anthracinus*	Scincidae
Five-lined Skink *	*Eumeces fasciatus*	Scincidae
Southeastern Five-lined Skink	*Eumeces inexpectatus*	Scincidae
Broadhead Skink	*Eumeces laticeps*	Scincidae
Fence Lizard *	*Sceloporus undulatus*	Phrynosomatidae
Ground Skink *	*Scincella lateralis*	Scincidae

Snakes

Common Name	Scientific Name	Family Name
Copperhead *	*Agkistrodon contortrix*	Viperidae
Cottonmouth *	*Agkistrodon piscivorus leucostoma*	Viperidae
Worm Snake *	*Carphophis amoenus*	Colubridae
Scarlet Snake	*Cemophora coccinea*	Colubridae
Kirtland's Snake	*Clonophis kirtlandii*	Colubridae
Black Racer *	*Coluber constrictor*	Colubridae
Timber Rattlesnake	*Crotalus horridus*	Viperidae
Ringneck Snake *	*Diadophis punctatus*	Colubridae
Black Rat Snake *	*Elaphe o. obsoleta*	Colubridae
Mud Snake *	*Farancia abacura*	Colubridae
Eastern Hognose Snake	*Heterodon platirhinos*	Colubridae
Prairie Kingsnake *	*Lampropeltis calligaster*	Colubridae
Scarlet Kingsnake	*Lampropeltis elapsoides*	Colubridae
Black Kingsnake *	*Lampropeltis getula nigra*	Colubridae
Red Milk Snake	*Lampropeltis triangulum syspila*	Colubridae
Mississippi Green Water Snake	*Nerodia cyclopion*	Colubridae
Copperbelly x Yellowbelly *	*Nerodia e. flav. x neglecta*	Colubridae
Broad-banded Water Snake *	*Nerodia fasciata confluens*	Colubridae
Diamondback Water Snake *	*Nerodia rhombifer*	Colubridae
Midland Water Snake *	*Nerodia sipedon pleuralis*	Colubridae
Rough Green Snake *	*Opheodrys aestivus*	Colubridae
Pine Snake	*Pituophis melanoleucus*	Colubridae
Pigmy Rattlesnake	*Sistrurus miliarius streckeri*	Viperidae
Brown Snake *	*Storeria dekayi*	Colubridae
Northern Redbelly Snake *	*Storeria o. occipitomaculata*	Colubridae
Southeastern Crowned Snake	*Tantilla coronata*	Colubridae

Common Name	Scientific Name	Family Name
Western Ribbon Snake	*Thamnophis proximus*	Colubridae
Eastern Ribbon Snake *	*Thamnophis sauritus*	Colubridae
Eastern Garter Snake *	*Thamnophis sirtalis*	Colubridae
Western Earth Snake *	*Virginia valeriae elegans*	Colubridae

Turtles

Common Name	Scientific Name	Family Name
Smooth Softshell	*Apalone mutica*	Trionychidae
Spiny Softshell *	*Apalone spinifera*	Trionychidae
Common Snapping Turtle *	*Chelydra serpentina serpentina*	Chelydridae
Painted Turtle *	*Chrysemys picta ssp.*	Emydidae
Common Map Turtle	*Graptemys geographica*	Emydidae
Mississippi Map Turtle	*Graptemys kohnii*	Emydidae
Ouachita Map Turtle	*Graptemys ouachitensis*	Emydidae
False Map Turtle	*Graptemys pseudogeographica*	Emydidae
Mud Turtle *	*Kinosternon subrubrum*	Kinosternidae
Alligator Snapping Turtle	*Macrochelys temminckii*	Chelydridae
River Cooter	*Pseudemys concinna*	Emydidae
Musk Turtle *	*Sternotherus odoratus*	Kinosternidae
Eastern Box Turtle *	*Terrapene carolina carolina*	Emydidae
Red-eared Slider *	*Trachemys scripta elegans*	Emydidae

Mammals of Clarks River NWR

The refuge is located within the range of the animals found on the list below. A total of 15 families, 34 genera, and 43 species are represented. Efforts to locate the remaining species are ongoing.

Species marked with an asterisk (*) have been documented on the refuge.

Common Name	Scientific Name	Family Name	USFWS	KSNPC
Armadillo *	*Dasypus novemcinctus*	Daspodidae		
Bat, Eastern Red *	*Lasiurus borealis*	Vespertilionidae		
Bat, Evening *	*Nycticeius humeralis*	Vespertilionidae		S
Bat, Gray	*Myotis grisescens*	Vespertilionidae	E	T
Bat, Indiana	*Myotis sodalis*	Vespertilionidae	E	E
Bat, Silver-haired *	*Lasionycteris noctivagans*	Vespertilionidae		
Beaver *	*Castor canadensis*	Castoridae		
Bobcat *	*Lynx rufus*	Felidae		
Chipmunk, Eastern	*Tamias striatus*	Sciuridae		
Cotton Rat, Hispid	*Sigmodon hispidus*	Muridae		
Cottontail, Eastern *	*Sylvilagus palustris*	Leporidae		
Coyote *	*Canis latrans*	Canidae		

Common Name	Scientific Name	Family Name	USFWS	KSNPC
Deer, White-tailed *	*Odocoileus virginianus*	Cervidae		
Fox, Gray *	*Urocyon cinereoargenteus*	Canidae		
Fox, Red*	*Vulpes vulpes*	Canidae		
Harvest Mouse, Eastern *	*Reithrodontomys humulis*	Muridae		
Mink *	*Mustela vison*	Mustelidae		
Mole, Eastern	*Scalopus aquaticus*	Talpidae		
Mouse, Cotton *	*Peromyscus gossypinus*	Muridae		T
Mouse, Deer *	*Peromyscus maniculatus*	Muridae		
Mouse, Golden *	*Ochrotomys nuttalli*	Muridae		
Mouse, House *	*Mus musculus*	Muridae		
Mouse, Meadow Jumping *	*Zapus hudsonius*	Dipodidae		
Mouse, White-footed *	*Peromyscus leucopus*	Muridae		
Muskrat	*Ondatra zibethica*	Muridae		
Myotis, Northern *	*Myotis septentrionalis*	Vespertilionidae		
Myotis, Southeastern *	*Myotis austroriparius*	Vespertilionidae	SOMC	E
Opossum *	*Didelphis marsupialis*	Didelphidae		
Otter, River *	*Lutra canadensis*	Mustelidae		
Pipistrelle, Eastern *	*Pipistrellus subflavus*	Vespertilionidae		
Rabbit, Swamp *	*Sylvilagus aquaticus*	Leporidae		
Raccon *	*Procyon lotor*	Procyonidae		
Rice Rat, Marsh *	*Oryzomys palustris*	Muridae		
Shrew, Least	*Cryptotis parva*	Soricidae		
Shrew, Pygmy	*Sorex hoyi*	Soricidae		
Shrew, Southeastern*	*Sorex longirostris*	Soricidae		
Shrew, Southern Short-tailed *	*Blarina brevicauda*	Soricidae		
Squirrel, Eastern Fox *	*Sciurus niger*	Sciuridae		
Squirrel, Eastern Gray *	*Sciurus carolinensis*	Sciuridae		
Squirrel, Southern Flying *	*Glaucomys volans*	Sciuridae		
Vole, Prairie *	*Microtus ochrogaster*	Muridae		
Vole, Woodland *	*Microtus pinetorum*	Muridae		
Woodchuck *	*Marmota monax*	Sciuridae		

Birds of Clarks River NWR

The refuge is located within the range of the animals found on the list below. A total of 15 families, 34 genera, and 43 species are represented. Efforts to locate the remaining species are ongoing.

Species marked with an asterisk (*) have been documented on the refuge.

Common Name	Scientific Name	Order
Cooper's Hawk*	*Accipiter cooperii*	Falconiformes
Sharp-shinned Hawk*	*Accipiter striatus*	Falconiformes
Spotted Sandpiper*	*Actitis macularia*	Charadriiformes
Red-winged Blackbird*	*Agelaius phoeniceus*	Passeriformes
Wood Duck*	*Aix sponsa*	Anseriformes
Henslow's Sparrow	*Ammodramus henslowii*	Passeriformes
Grasshopper Sparrow	*Ammodramus savannarum*	Passeriformes

Common Name	Scientific Name	Order
Northern Pintail*	*Anas acuta*	Anseriformes
American Wigeon*	*Anas Americana*	Anseriformes
Northern Shoveler*	*Anas clypeata*	Anseriformes
Green-winged Teal*	*Anas crecca*	Anseriformes
Blue-winged Teal*	*Anas discors*	Anseriformes
Mallard*	*Anas platyrhynchos*	Anseriformes
American Black Duck*	*Anas rubripes*	Anseriformes
Gadwall*	*Anas strepera*	Anseriformes
Greater White-fronted Goose*	*Anser albifrons*	Anseriformes
American Pipit	*Anthus rubescens*	Passeriformes
Golden Eagle	*Aquila chrysaetos*	Falconiformes
Ruby-throated Hummingbird*	*Archilochus colubris*	Apodiformes
Great Egret*	*Ardea alba*	Ciconiiformes
Great Blue Heron*	*Ardea herodius*	Ciconiiformes
Ruddy Turnstone	*Arenaria interpres*	Charadriiformes
Lesser Scaup*	*Aythya affinis*	Anseriformes
Redhead*	*Aythya Americana*	Anseriformes
Ring-necked Duck*	*Aythya collaris*	Anseriformes
Greater Scaup*	*Aythya marila*	Anseriformes
Canvasback*	*Aythya valisineria*	Anseriformes
Tufted Titmouse*	*Baeolophus bicolor*	Passeriformes
Cedar Waxwing*	*Bombycilla cedrorum*	Passeriformes
American Bittern	*Botaurus lentiginosus*	Ciconiiformes
Canada Goose*	*Branta Canadensis*	Anseriformes
Great Horned Owl*	*Bubo virginianus*	Strigiformes
Cattle Egret*	*Bubulcus ibis*	Ciconiiformes
Bufflehead*	*Bucephala albeola*	Anseriformes
Common Goldeneye	*Bucephala clangula*	Anseriformes
Red-tailed Hawk*	*Buteo jamaicensis*	Falconiformes
Rough-legged Hawk	*Buteo lagopus*	Falconiformes
Red-shouldered Hawk*	*Buteo lineatus*	Falconiformes
Broad-winged Hawk*	*Buteo platypterus*	Falconiformes
Green Heron*	*Butorides virescens*	Ciconiiformes
Lapland Longspur	*Calcarius lapponicus*	Passeriformes
Least Sandpiper*	*Calibris minutilla*	Charadriiformes
Dunlin	*Calidris alpine*	Charadriiformes
Baird’s Sandpiper	*Calidris bairdii*	Charadriiformes
Red Knot	*Calidris canutus*	Charadriiformes
White-rumped Sandpiper*	*Calidris fuscicollis*	Charadriiformes
Stilt Sandpiper	*Calidris himantopus*	Charadriiformes
Western Sandpiper	*Calidris mauri*	Charadriiformes
Pectoral Sandpiper*	*Calidris melanotos*	Charadriiformes
Ring-billed Gull*	*Calidris melanotos*	Charadriiformes
Semipalmated Sandpiper	*Calidris pusilla*	Charadriiformes
Chuck-will’s-widow*	*Caprimulgus carolinensis*	Caprimulgiformes
Whip-poor-will*	*Caprimulgus vociferous*	Caprimulgiformes
Northern Cardinal*	*Cardinalis cardinalis*	Passeriformes
Pine Siskin	*Carduelis pinus*	Passeriformes

Common Name	Scientific Name	Order
American Goldfinch*	*Carduelis tristis*	Passeriformes
House Finch*	*Carpodacus mexicanus*	Passeriformes
Purple Finch*	*Carpodacus purpureus*	Passeriformes
Turkey Vulture*	*Cathartes aura*	Ciconiiformes
Veery*	*Catharus fuscescens*	Passeriformes
Hermit Thrush*	*Catharus guttatus*	Passeriformes
Gray-cheeked Thrush*	*Catharus minimus*	Passeriformes
Swainson's Thrush*	*Catharus ustulatus*	Passeriformes
Willet	*Catoptrophorus semipalmatus*	Charadriiformes
Brown Creeper	*Certhia Americana*	Passeriformes
Belted Kingfisher*	*Ceryle alcyon*	Coraciiformes
Chimney Swift*	*Chaetura pelagic*	Apodiformes
Semipalmated Plover	*Charadrius semipalmatus*	Charadriiformes
Killdeer*	*Charadrius vociferous*	Charadriiformes
Snow Goose	*Chen caerulescens*	Anseriformes
Ross's Goose	*Chen rossii*	Anseriformes
Black Tern	*Chlidonias niger*	Charadriiformes
Common Nighthawk*	*Chordeiles minor*	Caprimulgiformes
Northern Harrier*	*Circus cyaneus*	Falconiformes
Marsh Wren	*Cistothorus palustris*	Passeriformes
Yellow-billed Cuckoo*	*Coccyzus americanus*	Cuculiformes
Black-billed Cuckoo*	*Coccyzus erythropthalmus*	Cuculiformes
Northern Flicker*	*Colaptes auratus*	Piciformes
Northern Bobwhite*	*Colinus virginianus*	Galliformes
Rock Pigeon*	*Columba livia*	Columbiformes
Olive-sided Flycatcher*	*Contopus cooperi*	Passeriformes
Eastern Wood-Pewee*	*Contopus virens*	Passeriformes
Black Vulture*	*Coragyps atratus*	Ciconiiformes
American Crow*	*Corvus brachyrhyncos*	Passeriformes
Fish Crow*	*Corvus ossifragus*	Passeriformes
Blue Jay*	*Cyanocitta cristata*	Passeriformes
Trumpeter Swan*	*Cygnus buccinators*	Anseriformes
Tundra Swan	*Cygnus columbiabus*	Anseriformes
Mute Swan	*Cygnus olor*	Anseriformes
Black-throated Blue Warbler	*Dendroica caerulescens*	Passeriformes
Bay-breasted Warbler*	*Dendroica castanea*	Passeriformes
Cerulean Warbler*	*Dendroica cerilea*	Passeriformes
Yellow-rumped Warbler*	*Dendroica coronata*	Passeriformes
Prairie Warbler*	*Dendroica discolor*	Passeriformes
Yellow-throated Warbler*	*Dendroica dominica*	Passeriformes
Blackburnian Warbler	*Dendroica fusca*	Passeriformes
Magnolia Warbler*	*Dendroica magnolia*	Passeriformes
Palm Warbler	*Dendroica palmarum*	Passeriformes
Chestnut-sided Warbler	*Dendroica pensylvanica*	Passeriformes
Yellow Warbler*	*Dendroica petechia*	Passeriformes
Pine Warbler*	*Dendroica pinus*	Passeriformes
Blackpoll Warbler	*Dendroica striata*	Passeriformes
Cape May Warbler	*Dendroica tigrina*	Passeriformes

Common Name	Scientific Name	Order
Black-throated Green Warbler*	*Dendroica virens*	Passeriformes
Bobolink	*Dolichonyx oryzivorus*	Passeriformes
Pileated Woodpecker*	*Drryocopus pileatus*	Piciformes
Gray Catbird*	*Dumetella carolinensis*	Passeriformes
Little Blue Heron*	*Egretta caerulea*	Ciconiiformes
Snowy Egret*	*Egretta thula*	Ciconiiformes
Alder Flycatcher	*Empidonax alnorum*	Passeriformes
Yellow-bellied Flycatcher*	*Empidonax flaviventris*	Passeriformes
Least Flycatcher*	*Empidonax minimus*	Passeriformes
Willow Flycatcher	*Empidonax traillii*	Passeriformes
Acadian Flycatcher*	*Empidonax virescens*	Passeriformes
Horned Lark*	*Eremophila alpestris*	Passeriformes
Rusty Blackbird*	*Euphagus carolinus*	Passeriformes
Merlin	*Falco columbarius*	Falconiformes
Peregrine Falcon	*Falco rusticolus*	Falconiformes
American Kestrel*	*Falco sparverius*	Falconiformes
American Coot	*Fulica americana*	Gruiformes
Wilson’s Snipe	*Gallinago delicata*	Charadriiformes
Common Snipe*	*Gallinago gallinago*	Charadriiformes
Common Loon	*Gavia inmer*	Gaviiformes
Common Yellowthroat*	*Geothlypis trichas*	Passeriformes
Sandhill Crane	*Grus canadensis*	Gruiformes
Blue Grosbeak*	*Guiraca caerulea*	Passeriformes
Bald Eagle*	*Haliaeetus leucocephalus*	Falconiformes
Worm-eating Warbler*	*Helmitheros vermivorus*	Passeriformes
Black-necked Stilt	*Himantopus mexicanus*	Charadriiformes
Barn Swallow*	*Hirundo rustica*	Passeriformes
Wood Thrush*	*Hylocichla mustelina*	Passeriformes
Yellow-breasted Chat*	*Icteria virens*	Passeriformes
Baltimore Oriole*	*Icterus galbula*	Passeriformes
Orchard Oriole*	*Icterus spurius*	Passeriformes
Mississippi Kite*	*Ictinia mississippiensis*	Falconiformes
Dark-eyed Junco*	*Junco hyemalis*	Passeriformes
Loggerhead Shrike	*Lanius ludovicianus*	Passeriformes
Herring Gull	*Larus argentatus*	Charadriiformes
Bonaparte’s Gull	*Larus philadelphia*	Charadriiformes
Short-billed Dowitcher	*Limnodromus griseus*	Charadriiformes
Long-billed Dowitcher	*Limnodromus scolopaceus*	Charadriiformes
Swainson’s Warbler	*Limnothlypis swainsonii*	Passeriformes
Hooded Merganser*	*Lophodytes cucullatus*	Anseriformes
Red-bellied Woodpecker*	*Melanerpes carolinus*	Piciformes
Red-headed Woodpecker*	*Melanerpes erythrocephalus*	Piciformes
Wild Turkey*	*Meleagris gallopavo*	Galliformes
Swamp Sparrow	*Melospiza georgiana*	Passeriformes
Lincoln’s Sparrow	*Melospiza lincolnii*	Passeriformes
Song Sparrow*	*Melospiza melodia*	Passeriformes
Common Merganser	*Mergus merganser*	Anseriformes
Red-breasted Merganser	*Mergus serrator*	Anseriformes

Common Name	Scientific Name	Order
Northern Mockingbird*	*Mimus polyglottos*	Passeriformes
Black-and-white Warbler*	*Mniotilta varia*	Passeriformes
Brown-headed Cowbird*	*Molothrus ater*	Passeriformes
Great Crested Flycatcher*	*Myiarchus crinitus*	Passeriformes
Yellow-crowned Night-Heron*	*Nyctanassa violacea*	Ciconiiformes
Black-crowned Night-Heron*	*Nycticorax nycticorax*	Ciconiiformes
Connecticut Warbler*	*Oporornis agilis*	Passeriformes
Kentucky Warbler*	*Oporornis formosus*	Passeriformes
Mourning Warbler	*Oporornis philadelphia*	Passeriformes
Eastern Screech-Owl*	*Otus asio*	Strigiformes
Ruddy Duck	*Oxyura jamaicensis*	Anseriformes
Osprey*	*Pandion haliaetus*	Falconiformes
Northern Parula*	*Parula americana*	Passeriformes
House Sparrow*	*Passer domesticus*	Passeriformes
Savannah Sparrow	*Passerculus sandwichensis*	Passeriformes
Fox Sparrow	*Passerella iliaca*	Passeriformes
Indigo Bunting*	*Passerina cyanea*	Passeriformes
American White Pelican	*Pelecanus erythrorhynchos*	Pelecaniformes
Cliff Swallow*	*Petrochelidon pyrrhonota*	Passeriformes
Double-crested Cormorant*	*Phalacrocorax auritus*	Pelecaniformes
Wilson's Phalarope	*Phalaropus tricolor*	Charadriiformes
Rose-breasted Grosbeak*	*Pheucticus ludovicianus*	Passeriformes
Downy Woodpecker*	*Picoides pubescens*	Piciformes
Hairy Woodpecker*	*Picoides villosus*	Piciformes
Eastern Towhee*	*Pipilo erythrophthalmus*	Passeriformes
Scarlet Tanager*	*Piranga olivacea*	Passeriformes
Summer Tanager*	*Piranga rubra*	Passeriformes
American Golden-Plover*	*Pluvialis dominica*	Charadriiformes
Black-bellied Plover	*Pluvialis squatarola*	Charadriiformes
Horned Grebe	*Podiceps grisegena*	Podicipediformes
Pied-billed Grebe*	*Podilymbus podiceps*	Podicipediformes
Carolina Chickadee*	*Poecile carolinensis*	Passeriformes
Blue-gray Gnatcatcher*	*Polioptila caerulea*	Passeriformes
Vesper Sparrow	*Pooecetes gramineus*	Passeriformes
Sora*	*Porzana carolina*	Gruiformes
Purple Martin*	*Progne subis*	Passeriformes
Prothonotary Warbler*	*Protonotaria citrea*	Passeriformes
Common Grackle*	*Quiscalus guiscula*	Passeriformes
American Avocet	*Recurvisostra americana*	Charadriiformes
Ruby-crowned Kinglet*	*Regulus calendula*	Passeriformes
Golden-crowned Kinglet	*Regulus satrapa*	Passeriformes
Bank Swallow	*Riparia riparia*	Passeriformes
Eastern Phoebe*	*Sayornis phoebe*	Passeriformes
American Woodcock*	*Scolopax minor*	Charadriiformes
Ovenbird*	*Seiurus aurocapillus*	Passeriformes
Louisiana Waterthrush*	*Seiurus motacilla*	Passeriformes
Northern Waterthrush*	*Seiurus noveboracensis*	Passeriformes
American Redstart*	*Setophaga ruticilla*	Passeriformes

Common Name	Scientific Name	Order
Eastern Bluebird*	*Sialia sialis*	Passeriformes
Red-breasted Nuthatch	*Sitta canadensis*	Passeriformes
White-breasted Nuthatch*	*Sitta carolinensis*	Passeriformes
Yellow-bellied Sapsucker*	*Sphyrapicus varius*	Piciformes
Dickcissel*	*Spiza americana*	Passeriformes
American Tree Sparrow	*Spizella arborea*	Passeriformes
Chipping Sparrow*	*Spizella passerina*	Passeriformes
Field Sparrow	*Spizella pusilla*	Passeriformes
Northern Rough-winged Swallow*	*Stelgidopteryx serripennis*	Passeriformes
Caspian Tern	*Sterna caspia*	Charadriiformes
Forster’s Tern	*Sterna forsteri*	Charadriiformes
Barred Owl*	*Strix varia*	Strigiformes
Eastern Meadowlark*	*Sturnella magna*	Passeriformes
European Starling*	*Sturnus vulgaris*	Passeriformes
Tree Swallow*	*Tachycineta bicolor*	Passeriformes
Carolina Wren*	*Thryothorus ludovicianus*	Passeriformes
Brown Thrasher*	*Toxostoma rufum*	Passeriformes
Lesser Yellowlegs*	*Tringa flavipes*	Charadriiformes
Greater Yellowlegs*	*Tringa melanoleuca*	Charadriiformes
Solitary Sandpiper*	*Tringa solitaria*	Charadriiformes
House Wren*	*Troglodytes aedon*	Passeriformes
Winter Wren	*Troglodytes troglodytes*	Passeriformes
Buff-breasted Sandpiper	*Tryngites subruficollis*	Charadriiformes
American Robin*	*Turdus migratorius*	Passeriformes
Eastern Kingbird*	*Tyrannus tyrannus*	Passeriformes
Barn Owl	*Tyto alba*	Strigiformes
Orange-crowned Warbler	*Vermivora celata*	Passeriformes
Golden-winged Warbler	*Vermivora chrysoptera*	Passeriformes
Tennessee Warbler*	*Vermivora peregrina*	Passeriformes
Blue-winged Warbler*	*Vermivora pinus*	Passeriformes
Nashville Warbler*	*Vermivora ruficapilla*	Passeriformes
Yellow-throated Vireo*	*Vireo flavifrons*	Passeriformes
Warbling Vireo*	*Vireo gilvus*	Passeriformes
White-eyed Vireo*	*Vireo griseus*	Passeriformes
Red-eyed Vireo*	*Vireo olivaceus*	Passeriformes
Philadelphia Vireo	*Vireo philadelphicus*	Passeriformes
Blue-headed Vireo	*Vireo solitarius*	Passeriformes
Canada Warbler*	*Wilsonia canadensis*	Passeriformes
Hooded Warbler*	*Wilsonia citrina*	Passeriformes
Wilson’s Warbler	*Wilsonia pusilla*	Passeriformes
Mourning Dove*	*Zenaida macroura*	Columbiformes
White-throated Sparrow*	*Zonotrichia albicollis*	Passeriformes
White-crowned Sparrow	*Zonotrichia leucophrys*	Passeriformes

APPENDIX G
Chestnut Creek Watershed Plan
Benchmark Recommendations
Kentucky Division of Water
5/14/2015

Benchmark recommendations given here represent the best information available to the Kentucky Division of Water (KDOW) at this time. The goal is to provide estimates of typical in-stream concentrations below which it is unlikely that the given parameter would be a cause of aquatic life use impairment. As such, benchmarks are useful in identifying sub-basins with potential issues when setting priorities for further monitoring or for developing strategies for load reductions. In making these recommendations we considered regional and watershed-specific reference conditions, regional-scale patterns in biological effects, and relevant published literature. These benchmarks may be different than final targets for management endpoints; watershed-specific characteristics, practical considerations, and insight gained from early phase monitoring might suggest alternate values for that purpose. The Watershed Group may wish to discuss with KDOW alternative benchmarks and/or targets based on local information or consultation with experts familiar with the watershed. These benchmarks should be reviewed as more information becomes available on conditions in the watershed, including any specific issues that may be observed in the course of monitoring.

Benchmark Recommendations

Total P mg/L	0.07
TKN mg/L	0.5
Nitrate+Nitrite-N mg/L	1.2
Total N mg/L	1.5
Conductivity µS/cm at @25	150
TSS mg/L	10*
Turbidity NTU	15*

* Because of the limited reference TSS and Turbidity samples at higher flows, these benchmarks should be interpreted as average values for summer stable flow periods only for the purposes of screening data. If TSS and Turbidity targets are needed for the watershed plan please consult with the TA to determine an appropriate target.

Background Information

Ecoregional Reference Reaches:

The Reference Reach network of streams represents the least-impacted conditions for aquatic life in wadeable streams in the respective ecoregions. The project area lies within the Loess Plains (ecoregion 74b) of the Mississippi Valley. KDOW's Reference Reach grab sample data for this ecoregion are summarized below. Note: the majority of the samples from reference reach program are grab samples during biological sampling events, generally during summertime stable flows.

	Eco-region	Number Samples	MIN	MED	75^{th} percentile	90^{th} percentile	MAX
TP(mg/L)	74b	56	0.005	0.046	0.061	0.124	1.040

	Eco-region	Number Samples	MIN	MED	75th percentile	90th percentile	MAX
NN-N(mg/L)	74b	56	0.141	0.610	1.183	1.860	2.590
TKN(mg/L)	74b	56	0.100	0.125	0.359	0.666	1.300
TN(mg/L)	74b	56	0.245	0.929	1.480	2.281	2.781
Conductivity µS/cm	74b	72	50	101	115	154	178
TSS mg/L	74b	47	0.8	3.5	6.5	9.8	24.5
Turbidity NTU	74b	33	1.7	5.3	9.6	13.67	37.7

Panther Creek, Graves County (TRW001):

KDOW's Ambient Water Quality Network has a station on the Panther Creek in Graves County, TRW002. This location is also Reference Reach monitoring station for the ecoregion; the data above includes the samples taken under the Reference Reach program. Since the Ambient program collects water samples monthly year-round, these data better reflect of season- and flow-related variation.

	Number Samples	MIN	MED	75th percentile	90th percentile	MAX
TP(mg/L)	24	0.021	0.052	0.083	0.219	0.372
NN-N(mg/L)	24	0.005	0.542	0.832	1.017	1.370
TKN(mg/L)	24	0.100	0.288	0.530	0.989	1.100
TN(mg/L)	24	0.193	0.862	1.145	2.062	2.410
Conductivity µS/cm	12	43	70	72	84	91
TSS mg/L	24	0.8	3.5	7.6	15.0	24.0
Turbidity	2	6	-	-	-	44.9

Effects-based (empirical) thresholds:

The sub-watersheds fall in the Mississippi Valley - Interior River Bioregion. The nutrient benchmarks from a KDOW draft bioregional nutrient thresholds report are TP 0.07 mg/L, TN 1.4 mg/L. These numbers were Bioregion-wide estimates of biologically relevant thresholds that that may represent increased risk of nutrient impairment of aquatic life use in wadeable streams.

Literature-based thresholds

Literature guidelines for the boundary between oligotrophic and mesotrophic conditions are TP 0.025 mg/L and TN 0.700 mg/L. The boundary between mesotrophic and eutrophic conditions are given as TP 0.075 mg/L and 1.5 mg/L. Reference Reaches and watershed reference data summarized above suggest that minimally impacted streams in Ecoregion 74b are typically near the mesotrophic-eutrophic boundary. Maintaining a mesotrophic condition may be important in protecting native aquatic species and communities.