**Research Report**
**KTC-03-14/SPR193-98-1F**

# ASSESSMENT AND MODELING OF STREAM MITIGATION PROCEDURES

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**16. Abstract**

As population increases, so does the need to improve and augment the road network. Construction of new roadways or modification of existing roads often requires diversion or modification of streams. If a stream is disturbed, government regulations require mitigation or compensatory replacement of the affected area in a similar environment. Stream mitigation is of particular importance in Kentucky, as Kentucky ranks second in the United States for having the most miles of waterways. Consequently, stream mitigation has become a significant factor in roadway construction costs. To date, no studies have been made to assess the execution of the mitigation plans or to determine the performance of mitigation projects. In a move to rectify this situation, the Kentucky Transportation Cabinet requested this study.

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# EXECUTIVE SUMMARY

As population increases, so does the need to improve and augment the road network. Construction of new roadways or modification of existing roads often requires diversion or modification of streams. If a stream is disturbed, government regulations require mitigation or compensatory replacement of the affected area in a similar environment. Stream mitigation is of particular importance in Kentucky, as Kentucky ranks second in the United States for having the most miles of waterways. Consequently, stream mitigation has become a significant factor in roadway construction costs. To date, no studies have been made to assess the execution of the mitigation plans or to determine the performance of mitigation projects. In a move to rectify this situation, the Kentucky Transportation Cabinet requested this study.

Study tasks included: a literature search, review of stream performance models, review of Kentucky's and other agency's regulations pertaining to stream mitigation, identification of representative stream mitigation projects, and evaluation of those sites.

The literature search did not reveal any state or local regulations for stream disturbance mitigation. Several agencies have developed guidelines but there are no hard and fast rules. There are numerous models, but none of them are specifically geared toward stream disturbance mitigation.

Kentucky's Department of Environmental Analysis selected five representative stream mitigation sites for assessment. Site assessments were conducted on all five sites and included physical, chemical and biological data. In addition, Rapid Bioassessment Protocol (RBP-V) fish assessments were conducted by the University of Kentucky's Biology Department on the two largest sites. Assessments on all data were made.

As part of this study, a field handbook was developed to aid the evaluator in gathering data on stream mitigation projects. It is recommended that this tool be used for future stream mitigation evaluations.

# 1.0 INTRODUCTION

As population increases, so does the need to improve and augment the road network. Construction of new roadways or modification of existing roads often requires diversion or modification of streams. If a stream is disturbed, government regulations require mitigation or compensatory replacement of the affected area in a similar environment. Stream mitigation is of particular importance in Kentucky, as Kentucky ranks second in the United States for having the most miles of waterways. Consequently, stream mitigation has become a significant factor in roadway construction costs.

Undisturbed areas can usually handle storm water runoff. However, during construction of a new roadway, excessive stresses are put on the local environment. Trees are torn down, earth is moved, and silt and other contaminants enter waterways. Storm water runoff can carry a variety of pollutants from the roadway, including gas, oil, grease, flakes from automotive paint and pesticides or other chemicals. These types of changes in the environment often effect nearby streams significantly. In order to mitigate the impacts of highway construction it is important to monitor all changes in the stream. To date, no studies have been made to assess the execution of the mitigation plans or to determine the performance of mitigation projects. In a move to rectify this situation the Kentucky Transportation Cabinet requested this study.

## 1.1 STUDY BACKGROUND

The Kentucky Transportation Cabinet (KyTC) approved Research Study KYSPR 9-193, entitled "Assessment and Modeling of Stream Mitigation Procedures" in 1998. Five recent stream mitigation projects were to be evaluated. The two-year study term permitted mitigation project evaluation at high and low water periods. The objectives of the study include:

1. Identifying existing stream mitigation projects,
2. Collecting all documents (general and specific) related to those projects for further review,
3. Classifying the stream mitigation projects into logical categories,
4. Reviewing stream mitigation design models and identifying applicability to specific mitigation projects and pertinent metrics,
5. Conducting field assessments of the existing projects and obtaining relevant data,
6. Assessing the performance of the existing mitigation projects based on review of plans, regulations, field data, etc.,
7. Using the data from one site to test/calibrate the performance of one or more stream performance models,
8. Providing Kentucky Department of Highway (KyDOH) officials with performance assessments of existing mitigation projects and recommendations for repairs and future mitigation efforts, and
9. Preparing guidance documents to facilitate future inspections and tests of mitigation sites by KyDOH district personnel.

# 2.0 LITERATURE SEARCH

The first study task was to conduct a literature search. The literature search included a review of stream performance models and a review of Kentucky's and other agencies regulations pertaining to stream mitigation. The literature search is an important component of any study as a search will uncover the "state-of-the-art" methods and practices being utilized in a particular field. This search focused on regulations, guidelines and models.

## 2.1 REGULATIONS REVIEW

The Kentucky Natural Resources and Environmental Protection Cabinet (NREPC) has not developed Kentucky Administrative Regulations (KARs) for stream mitigation and neither have any of the surrounding state environmental agencies (Ohio, West Virginia, Virginia, Tennessee, Missouri, Illinois, and Indiana).

However, Kentucky's does have guidelines. NREPC has developed some general guidelines designed to assist applicants in the preparation and development of mitigation and monitoring plans for streams and wetlands mitigation. Kentucky's manual is titled Guidelines for Stream and Wetland Protection in Kentucky and can be found on the web site at:

http://water.nr.state.ky.us/dow/restore

These guidelines should be used in consultation with Kentucky Division of Water, state or federal fish and wildlife agencies, and the U.S. Army Corps of Engineers, the U.S. Environmental Protection Agency, the Natural Resources Conservation Service, or the local state government agencies responsible for stream and wetland protection.

The following guidelines for stream related impacts have been taken from the NREPC manual "Guidelines for Stream and Wetland Protection in Kentucky" (3)

"Detailed plan and profile drawings that involve more than 200 linear feet of physical disturbance to a blue stream should include this information:

**<u>Pre-Disturbance or Reference of the Surface Water:</u>**

1. Channel morphology; e.g., channel width, bank height (normal pool to high water mark), bank slope, stream gradient, pool to riffle ratio, run to bend ratio, bottom shape.
2. Location of aquatic habitats; e.g., pools, riffles, woody debris, log jams, rootwads, gravel bars (point bars), in-stream vegetation beds, substrate types, and composition.
3. Hydrology; e.g., stream flow at low flow; average annual flow. In an upper headwater situation, this data may not be generally available.
4. Riparian Zone composition and widths, including botanical species list. Stream shading, which is critical to maintaining water temperatures and canopy percentage, should be addressed.

5. Adjacent wetlands in accordance with the delineation manual currently being used by the U.S. Army corps of Engineers.
6. Sediment and erosion control measures (best management practices) to be used during construction; e.g., retention basins silt fencing, rock check dams, or vegetated buffer zones.

**Post-Disturbance -- Mitigation**

1. Minimizing net loss of stream length; i.e., replace meanders.
2. New channel morphology, which should be similar to the pre-disturbance morphology.
3. Restoration, creation, or enhancement of aquatic habitat.
4. Restoration of riparian zone including width and species list. For the purpose of protecting water quality and maintaining bank stability, a permanent vegetated buffer zone should be restored along each streambank in the project area. A minimum width of 50 feet on each side of the stream is suggested, but even a width of 15 feet can offer some water quality benefits. The revegetation plan needs to include an immediate herbaceous groundcover mixture, as well as trees and shrubs, which can be planted on a 12 feet by 12 feet spacing. A minimum of four tree species and three shrub species should be planted in the riparian zone. Exotic, invasive and nuisance species should not be planted.
5. Monitoring plans to determine the success of the mitigation should be developed that check habitat structures, bank stability, vegetation plantings, and silt control structures. Aquatic life will need to be monitored after post-construction when the watershed size is greater than one square mile.
6. Contingency plan that addresses possible failure of the various mitigation construction aspects; e.g., spot grading, reseeding, replanting, maintaining bank stability, and replacement of habitat structures.
7. Permanent protection and maintenance of the mitigated stream channel and riparian zone."

## 2.2 PERMITS

The Federal Government requires that several permits be obtained before a project begins. The majority of these permits "are aimed at protecting natural resource values and the integrity of the nation's water resources". A list of permits follows.

US Army Corps of Engineers®

The U.S. Army Corps of Engineers issues the following permits for the Federal government:

- Section 10, Rivers and Harbors Act of 1849. A permit is required if a project involves the construction of any structure that will change the course, condition, or capacity in the channel or along the banks of navigable water within the US.

- Section 404, Federal Clean Water Act. A "Letter of Permission" is required for work that will have a minimal impact, such as routine maintenance.

- Section 404, Federal Clean Water Act. Permit 3 is required when a project will repair, rehabilitate, or replace a structure that was destroyed by storms, fire, or floods within the past two years.

- Section 404, Federal Clean Water Act. Permit 13 is required when the sole purpose of a bank stabilization project is for erosion protection and the length of the project is less than 500 feet.

- Section 404, Federal Clean Water Act. Permit 14 is required when a transportation project will impact up to 0.5 acres at each non-tidal stream crossing or wetland area. For wetland impacts greater than 0.1 acres, a pre-construction notification, with mitigation, is required. The permit is regionally conditioned to limit the length of stream impact to 500 linear feet at each site. Stream channelization is not authorized under this permit.

- Section 404, Federal Clean Water Act. Permit 27 is required when activities include restoration of natural wetland hydrology, vegetation, and function to altered and degraded non-tidal wetlands, and restoration of natural functions of riparian areas on private lands, provided a wetland restoration or creation agreement has been developed.

The U.S. Fish and Wildlife Services issues the following permit for the Federal government:

- Endangered Species Act, Incidental Take Permit. This permit is required when an otherwise lawful activity may take listed species.

State agencies issue the following permits for the Federal government:

- Section 401, Federal Clean Water Act. The project will require water quality certification. State authority is given under KRS 224.

- Section 402, Federal Clean Water Act National Pollutant Discharge Elimination System (NPDES). This permit is required when pollution discharges come from either point source or non-point sources.

The state requires that a Water Quality Certification form be filled out for any project that will cause a stream disturbance. According to Bill Sampson, a former NREPC Kentucky Division of Water official,

"The Water Quality Certification (Section 401 of the Clean Water Act) is married to the Section 404 permitting program administered by the Corps of Engineers. Hence, 401/404 is a dual agency process involving the state and federal government. Section 401 provides states authority for activities within their borders. Pursuant to CWA, and federal action within waters of the U.S. may require a certification from the promulgating state agency."

The Commonwealth of Kentucky does not have a set of program specific rules. However, the 401 Water Quality Certification (WQC) often requires stream mitigation or restoration whenever stream relocation, filling of a stream or similar alterations are proposed (3, p. 12). Therefore, it is up to the Division of Water to evaluate the project and determine what kind of mitigation will be required.

State and Federal regulations address the following issues:

1) determining the adequacy of the mitigation plans,
2) assessing whether the mitigation projects were properly constructed,
3) assessing whether the mitigation project was performing properly,
4) determining whether follow up maintenance or remedial work is required on those projects.

**2.3 STREAM PERFORMANCE MODELS**

Data from field observations of streams can be used to model the performance of those and similar streams under observed conditions. Those models can then be used to predict future stream performance under similar conditions. The ability to predict stream performance is important to highway designers, especially where highway construction or maintenance activities result in stream disturbance. Since most highway construction projects are cost driven, the ability to predict stream behavior and thus design stream disturbance mitigation can have significant project cost implications.

This study focuses on post-construction evaluation of stream disturbance mitigation. Past mitigation efforts will be analyzed, but a more significant study product would be the development of a "tool" or a mitigation model to assist KyDOH personnel in evaluating mitigation projects. Numerous stream performance models were reviewed to identify a model well suited to this purpose or to identify the parameters critical to mitigation evaluation.

The literature search and review revealed that no current model adequately addresses all aspects of stream disturbance mitigation. Stream performance models reviewed are as follows:

**Erosion Models**

a). Erosion Productivity Impact Calculator (EPIC)
b). Soil and Water Assessment Tool (SWAT)

**Watershed Models**

a). Agricultural Non-Point Source (AGNPS)
b). Areal Non-point Source Watershed Environmental Response Simulation (ANSWERS)

c). Hydrological Simulation Program-FORTRAN (HSPF)
d). Precipitation-Runoff Modeling System (PRMS)/MMS Model

**GIS Systems**

a). Geographic Resource Analysis Support System (GRASS-GIS) (U.S. Army Corps of Engineers, 1987)
b). GRASS Waterworks
c). GISHYDRO (Maryland State Highway Administrators' Division of Bridge Design in Baltimore)
d). Hydrologic Data Development System GIS
e). GIS Water, Soil, and hydro-Environmental Decision Support System (WATERSHEDSS)

**Biological Assessment Models**

a). Wetland Evaluation Technique (WET)
b). Hollands-Magee Assessment Model
c). Index of Biotic Integrity (IBI)
d). Habitat Quality Index (HQI)
e). Ontario Trout Habitat Classification (OTHC)
f). Habitat Suitability Index (HIS)
g). Instream Flow Incremental Methodology (IFIM)

**Wetlands Model**

a). WDWBM
b). Integrated Lake Watershed Acidification (ILWAS)
c). EXTRAN
d). Evaluation for Planned Wetlands (EPW)

**Economic Models**

a). IMPLAN

The models determine

1) bank erosion,
2) biological impacts
3) sedimentation
4) flow characteristics and control (time and spatial variations), and
5) channel morphology.

The various parameters that can be used in the models are

1) GIS used to estimate wetland impacts,
2) type of stream,
3) size of mitigation project,
4) type of mitigation,
5) pollutant removal efficiency,
6) storm water impacts,
7) comparison to natural wetlands,

8) benefits and costs,
9) short term and long term, and
10) biological assessments.

After reviewing these models, it was determined that the AGNPS "CONCEPTS" model most closely fit the needs of this study. "CONCEPTS is a distributed, continuous, long-term channel evolution and water quality model for use in ungauged watershed systems" (13). However, the need still exists for the development of a model that deals strictly with stream disturbance mitigation. Data from this literature review and analyses of the five mitigation projects will be used to develop a mitigation evaluation tool. These preliminary tasks are not complete but some of the parameters, which will probably be involved, are; conformity to mitigation design, habitat assessment, riparian vegetation assessment, hydrological assessment, and a Rapid Bioassessment Protocol-V (RBP-V) for fish assemblages.

# 3.0 SITE CHARACTERISTICS

The second task was to identify the stream mitigation sites that were to be evaluated. The third task was to collect data from those sites.

## 3.1 SITE IDENTIFICATION

The Study Advisory Committee requested that five stream mitigation projects be evaluated. All five of the projects were to meet the following criteria:

- Have been completed within the last five to ten years
- Be representative of mitigation projects statewide

The Division of Environmental Analysis reviewed stream mitigation projects and identified five sites that meet, as closely as possible, those criteria. The sites are listed below. Two of the project sites are in Hardin County, one in Boyle County, one in Greenup County, and one in Bracken County (Figure 1). Due to the selection criteria and time constraints, sites in Western and Southeastern Kentucky were not included.

Site 1: KY 313, Cedar Creek, Hardin County (4-168.06)
Site 2: KY 313, Cedar Creek, Hardin County (4-168.09)
Site 3: U.S. 68, Doctors Fork, Boyle County
Site 4: AA Highway, Holts Creek, Bracken County
Site 5: KY 827, Coal Branch, Greenup County

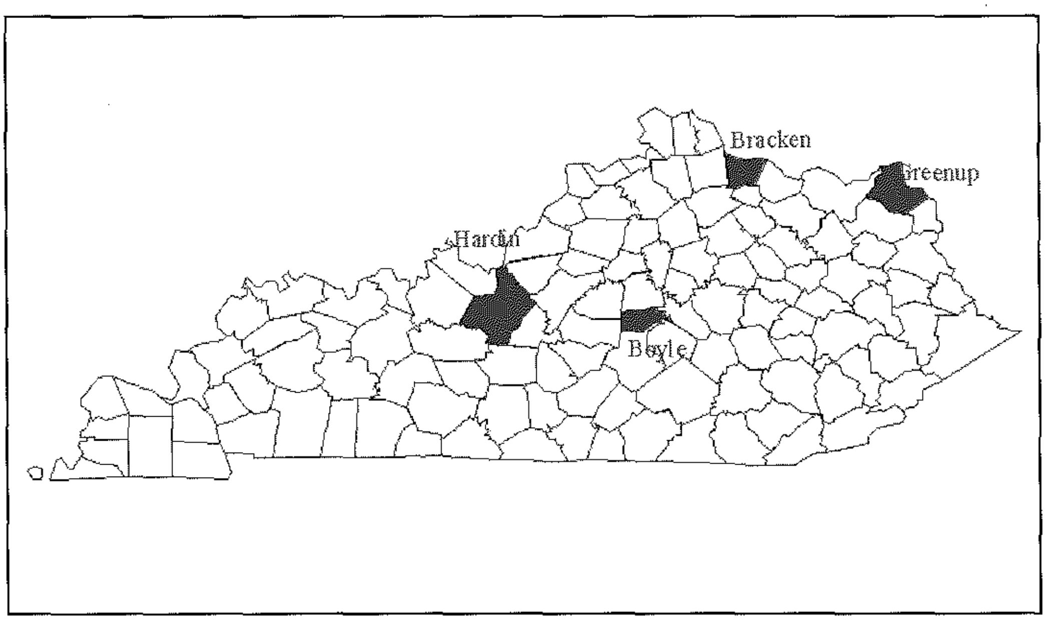



**Figure 1 Locations of selected stream mitigation sites in Kentucky.**

### 3.2 TYPES OF DATA

The Kentucky Transportation Center collected data from the five sites selected by the KyDOH, Division of Environmental Analysis. Data collected included the following:

1) Physical Data (physical description, plan comparison)
2) Chemical Data (water quality parameters)
3) Biological Data (habitat assessment, fish bioassessment at the two larger sites)

Physical data included visual descriptions such as number of riffles, pools, runs, length, width, depth, adherence to original grade line, etc. These items were all used to determine amounts of erosion and channel changes.

Chemical data included several things. All of the mitigation projects underwent chemical testing to determine the basic water quality of the streams. Water quality parameters include dissolved oxygen content, conductivity, pH and temperature. Stream flow measurements were taken at high and low flow periods.

Biological data was only gathered on two of the streams due to restricted funding. The two larger stream systems, Cedar Creek and Holt's Creek were selected because they were deep enough to sustain fish life year-round. A Rapid Bioassessment Protocol-V (RBP-V) for monitoring fish assemblages was conducted at these two sites and an Index of Biotic Integrity (IBI) was calculated for both. An EPA Habitat Assessment was also conducted on all five of the projects.

### 3.3 PHYSICAL DATA

Physical data is extremely important as it provides the researcher with a blueprint and the basic facts about an ecosystem. The physical data presents a great deal of information and includes:

- a physical description of the stream, and
- a comparison of existing conditions to the mitigation plan.

The mitigation plan usually lists construction techniques and planting instructions.

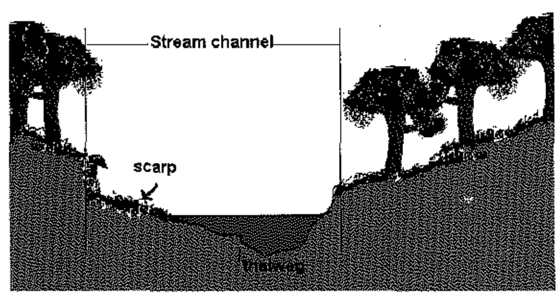



**Figure 2 Cross section of stream channel.**

#### 3.3.1 Physical Description.

Basically, all stream corridors have three parts: the stream channel, the floodplain, and the transitional upland fringe.

A stream channel is made up of two main parts:

- Thalweg. The deepest part of a stream channel is called the thalweg.

- Scarp. The sloped bank is called the scarp. It is made up of both an upper bank and a lower bank. "The lower bank begins at the normal water line and runs to the bottom of the stream. The upper bank extends from the break in the normal slope of the surrounding land to the normal high water line (10, p.5)". A cross-section of a stream channel can be found in Figure 2.

There are several components of a stream system. As the channel moves along it forms riffles, runs and pools.

- Riffle. "A riffle usually forms between two bends in the channel at the point where the thalweg crosses over from one side of the channel to the other.

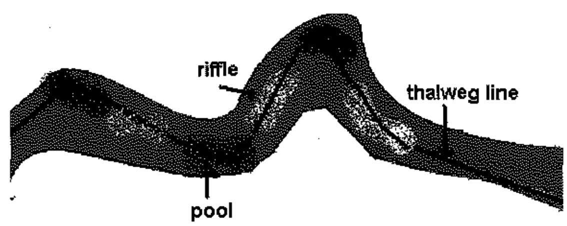



**Figure 3 Stream with pools and riffles.**

- Pool. Typically, a pool forms in the thalweg near the outside bank of bends. (19)".

- Runs or Glides. A run is the section of the stream that flows smoothly with very little turbulence at the surface of the water and is generally found between a pool and a riffle.

Figure 3 shows a thalweg line and the typical locations for pools and riffles.

- Substrate. The substrate refers to the materials at the bottom of the stream.

- Riparian Zone. The riparian zone refers to the area extending outward from the edge of the stream bank. 'The riparian zone is a buffer to pollutants entering a stream from runoff, controls erosion, and provides stream habitat and nutrient input into the stream. A healthy stream system generally has a healthy riparian zone. Reductions and impairment of riparian zones occur when roads, parking lots, fields, lawns, and other artificially cultivated areas, bare soil, rocks, or buildings are near the stream bank. (10, p.5)"

**Figure 4 Measuring depth of stream.**

The floodplain surrounds the stream and is often very fertile land. 'It is the low area of land that holds the overflow during a flood." (10, p. 5) The traditional upland fringe is the area above the floodplain leading to higher elevations.

### 3.3.2 Comparison of Existing Conditions to Mitigation Plan.

Remediation plans usually summarize all the pertinent details for a project. They will include: project length, project alternatives, and details about channel modifications. This also includes the particulars for any structure that will be permanently placed in-stream, i.e. box culverts, bridge piers, habitat enhancement devices, etc. Quite often details for the revegetation of stream banks and riparian zones are included as well.

Remediation often requires the planting of replacement trees and/or shrubs. Verification and identification of these plants is quite difficult for the layman so the State's Forestry Department was asked to help assess and survey the planted trees in the selected remediation sites. The state forest rangers identified and inspected the planted trees and made suggestions for future plantings in wet areas and remediated sites. They also recommended that trees indigenous to a particular area be specified in future remediation plans.

Although physical data (description, habitat assessment and comparison) is extremely important, it cannot stand alone or give the complete picture; therefore chemical data collection is also required.

## 3.4 CHEMICAL DATA (WATER QUALITY PARAMETERS)

Water quality is of utmost importance when evaluating a stream that has undergone a great change. The water quality parameters used in this study are all interconnected, yet each alone is an indicator of viability. Samples were taken at three locations:

- upstream from human impact,
- in the mitigated area, and
- downstream.

The comparison of the three samples helps determine the effect of human practices on stream life. The water samples collected in this study underwent several tests, some in the field and some in the laboratory.

Field tests included:
- Dissolved Oxygen (DO),
- pH,
- Conductivity or Total Dissolved Solids (TDS), and
- Temperature.

These tests are very important. "Dissolved Oxygen content, pH, and temperature are often used to predict whether or not humans have impacted a stream (7)." However, they are not the only measurements that can provide useful information.

Laboratory tests included:

- Alkalinity
- Hardness
- Total Suspended Solids (TSS)

NOTE: Settleable Solids testing was not done because of the water clarity.

### 3.4.1 Dissolved Oxygen

The dissolved oxygen (DO) content indicates how much oxygen is in the water and indicates the quality of the water. Dissolved oxygen comes from two main sources:

- **Atmosphere:** Most of the dissolved oxygen in water comes from the atmosphere. Oxygen is dissolved at the surface and is distributed by currents and turbulence.

- **Plant Life:** Dissolved oxygen is also produced by algae and aquatic plants as a by-product of photosynthesis. Because light is needed for photosynthesis, dissolved oxygen levels usually rise during the day and reach a peak in late afternoon.

The DO level indicates how viable a body of water is, as dissolved oxygen is required by fish, invertebrates, plants, and aerobic bacteria for respiration.

"Some animals such as mayflies, stone flies, caddis fly, and aquatic beetles, require high dissolved oxygen content to survive. Worms and fly larvae, which can survive in low dissolved oxygen rivers, are indicators of an unhealthy river. (12)" (Figure 5)

**Figure 5 Aquatic animals can sometimes be found on the rocks lying in the stream bed.**

There are several factors that affect the dissolved oxygen content of a water body. They are.

- **Organic Waste:** In general DO levels decrease in the summer because bacteria levels increase. As aquatic animals come out of their dormant period they become more active and require more oxygen to support higher metabolisms. They also produce more organic waste, which requires an increased number of bacteria to consume the waste. The more bacteria, the more oxygen is consumed. Organic waste doesn't just come from waste produced by aquatic animals, it comes from other sources as well, such as sewage, farm runoff, and some industrial discharges.

- **Water Flow**: During the summer months water levels are lower and therefore, the amount of air and water mixing decreases as there are less rapids and waterfalls.

The concentration of oxygen dissolved in water can be expressed in mg/l or as a percent saturation (Figure 6). "A DO level of 8mg/l is considered excellent (12)." "The ratio of the dissolved oxygen content (ppm) to the potential capacity (ppm) gives the percent saturation, which indicates the quality of the water. (11)"

**Figure 6 Dissolved Oxygen Testing.**

If the dissolved oxygen is depleted, major shifts in the aquatic organisms of a water body will result. When assessing stream mitigation these are all important factors to consider.

### 3.4.2 Conductivity and Total Dissolved Solids

Conductivity and Total Dissolved Solids (TDS) measure the presence of anions and cations in water and is an indicator of the purity of the water sample (Figure 9). Pure water is a very poor conductor of electricity and therefore the level of conductivity should be very low.

"High levels are usually caused by the presence of potassium, chloride, iron and other cations and anions with little or no toxic concerns. Some anions and cations are toxic such as lead arsenic, cadmium, nitrate, and others and a higher measure of conductivity/TDS warrants getting a clear understanding of its cause."(5)

**Figure 7 Conductivity testing of water.**

### 3.4.3 pH (potential-Hydrogen).

The pH level indicates acidity or alkalinity. The scale is from 1-14, with 7 being the neutral point, less than 7 is acidic and greater than 7 is alkaline. In streams certain organisms require a particular range of pH to survive.

### 3.4.4 Temperature.

Water temperature is very important as gases, such as oxygen, dissolves better in cold water. The warmer the water temperature, the lower the dissolved oxygen content.

### 3.4.5 Alkalinity

Alkalinity is an important water parameter as it measures the capacity of water to neutralize acid. It measures the amount of alkaline causing anions in water. "These anions or metals include calcium, magnesium, potassium, phosphorus, boron, silicone and others. There are many different combinations of anions. (5)". It is very difficult to compare water samples when they all have different ingredients; it is like comparing apples to oranges. Therefore, the total number of anions is converted to equivalent amounts of calcium carbonate ($CaCO3$) so that comparisons can be made. "The normal range for drinking water is 10-500 mg/L (5)."

### 3.4.6 Hardness

Hardness is another important water parameter as it measures the amount of minerals in the water, usually "it refers to the presence of calcium and magnesium. Both of these minerals are considered essential. However, the presence of iron and manganese can also contribute to the hardness of the water (5)." Like alkalinity, hardness measurements are converted to equivalent amounts of calcium carbonate ($CaCO3$).

### 3.4.7 Total Suspended Solids (TSS)

The Total Suspended Solids (TSS) test is related to conductivity and turbidity. "TSS are solids in water than can be trapped by a filter. TSS can include a wide variety of material, such as silt, decaying plant and animal matter, industrial wastes, and sewage. High concentrations of suspended solids can cause problems for stream health and aquatic life (6, p.1)"

**Figure 8 Collection of samples.**

If the level of Total Suspended Solids becomes too high a Domino Effect occurs.

"High levels of Total Suspended Solids can block sunlight from reaching the submerged vegetation. This in turn, will slow down photosynthesis, which will then reduce the amount of dissolved oxygen in the water. Plants will begin to die without light, and then more bacteria will be produced. Bacteria will use up more oxygen. The decrease in water clarity caused by TSS can affect the ability of fish to see and catch food. Suspended sediment can also clog fish gills, reduce growth rates, decrease resistance to disease, and prevent egg and larval development. When suspended solids settle to the bottom of a water body, they can smother the eggs of fish and aquatic insects, as well as suffocate newly hatched insect larvae. Settling sediments can fill in spaces between rocks which could have been used by aquatic organisms for homes. (6, p. 1)"

A list of factors affecting Total Suspended Solid levels are:

- Soil Erosion
- High Flow Rates
- Urban Runoff
- Wastewater and Septic System Effluent
- Decaying Plants and Animals, and
- Bottom-Feeding Fish

Evaluation of TSS after stream mitigation is therefore very important.

## 3.5 BIOLOGICAL DATA

Biological data is extremely important as biological indicators are used to analyze stream corridor conditions. The biological data presents a great deal of information and includes:

- a habitat assessment and if funding allows
- a fish bioassessment.

### 3.5.1 Habitat Assessment

Conducting a Habitat Assessment of an area forces the investigator to look closely at a stream and to determine its overall condition (Figure 4). The Environmental Protection Agency (EPA) has a standardized habitat assessment field data sheet that can be used for evaluation of streams. The U.S. Environmental Protection Agency's Habitat Assessment form for "High Gradient Streams" appears in Figures 5 and 6 on the following pages. This form is used to evaluate high gradient streams. Each habitat parameter is put into a condition category based on its score. The majority of the parameters are graded on a score of 1 – 20, with 0-5 point are rated poor, scores between 6-10 are marginal, scores between 11-15 are suboptimal, and scores between 16-20 are optimal. However, Bank Stability, Vegetative Protection, and Riparian Vegetative Zone Width are graded on a 1-10 scale because these categories evaluate both bank separately. A complete copy of the EPA Assessment form can be found in Appendix A.

### 3.5.2 Fish Bioassessment

Fish Bioassessment dramatically illustrates the viability of a stream. A bioassessment is done by shocking and seining the fish in the area to determine the length, size, and age of the fish (Figure 9). In order to accomplish this task three field stations must be set-up:

- above the remediation site (upstream)
- the remediated area, and
- below the remediated area (downstream).

This will verify that fish migration patterns are not interrupted. The best time to do an IBI is in spring or early fall. Most IBI's can be completed within a three-week time frame. An IBI is done in two phases, the first phase consists of a survey of the area, and the second phase is the actual collection of fish. An outline of the steps involved follows.

**Figure 9 Determining length, size and age of fish.**

Survey (this phase usually takes about two weeks):

1) Characterize the habitat
2) Classify habitat using Watershed Protocol 1997
3) Establish 3 to 5 undisturbed reference stations, with at least one downstream recovery site. If a reference site cannot be found on the stream being evaluated, then a nearby comparable stream will be used as the reference station.

Collection (this phase usually takes one week):

1) Collection of fish

For this project, two sites (Site 2, KY 313, Cedar Creek, in Hardin County (4-168.09) and Site 4, AA Highway, Holts Creek, in Bracken County were selected for monitoring fish assemblages. A Rapid Bioassessment Protocol (RPI) was conducted. This was done according to Environmental Protection Agency (EPA) guidelines. Only an EPA Protocol V (fish) was conducted because of monetary restrictions. If it was determined that a problem existed, only then would an EPA Protocol 3 (macro-invertebrates) be utilized.

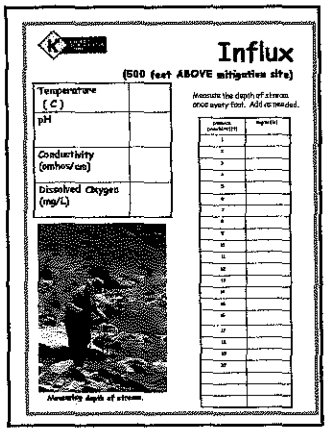
"Fish were collected using a combination of electro-shocking (i.e. backpack elecrofisher Smith-Root, Inc) and block-seining for both stream systems (Figure 10). The electro-shocking collections were limited to 1 hour per station to provide a standardized catch per unit of effort.

Developed
by

The Kentucky Transportation Center

for
The Kentucky Transportation Cabinet

April 2003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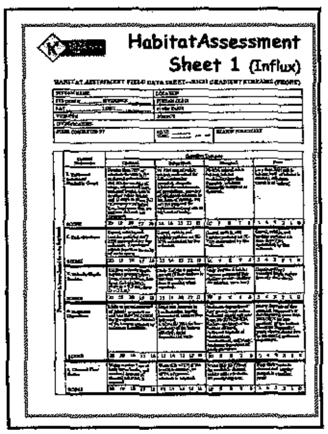
(500 feet ABOVE mitigation site)
Temperature (C)
pH
Conductivity (umhos/cm)
Dissolved Oxygen (mg/L)
Measure the depth of stream once every foot. Add as needed.
Measuring depth of stream.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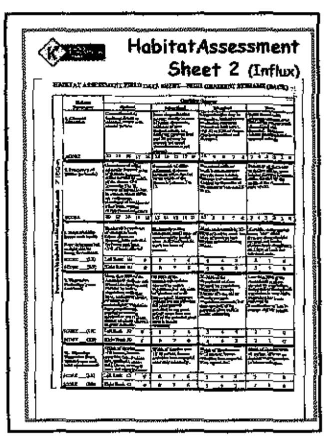
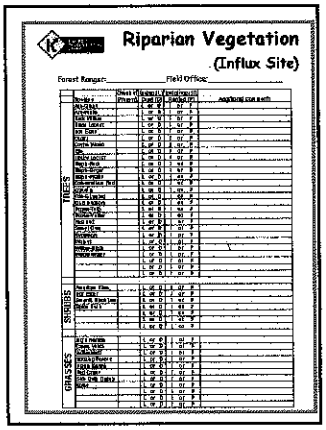
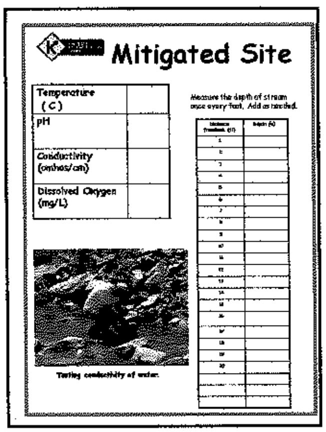
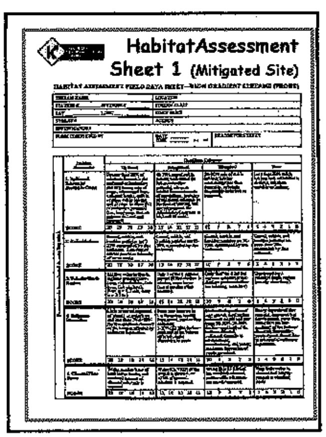
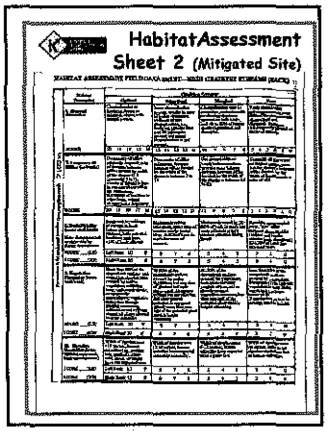
Sheet 1 (Influx)

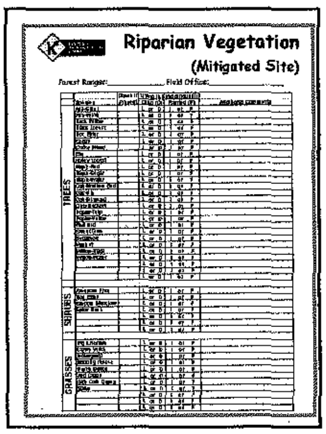

Habitat Assessment
Sheet 2 (Influx)

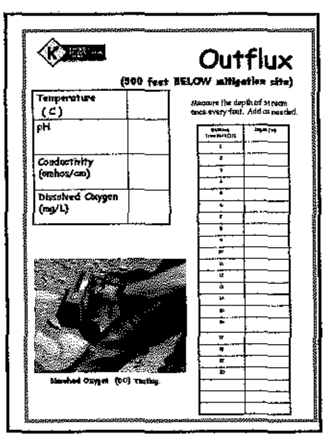

Riparian Vegetation
(Influx Site)
Forest Ranger:
Field Office:
TREES
SHRUBS
GRASSES

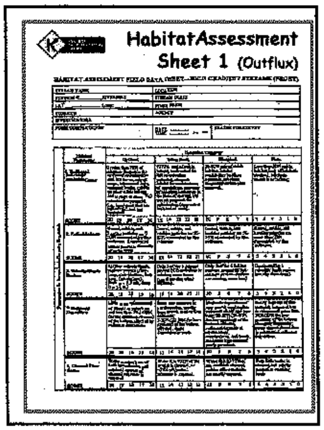

Mitigated Site
Temperature (C)
pH
Conductivity (mhos/cm)
Dissolved Oxygen (mg/L)
Measure the depth of stream once every foot. Add as needed.
Testing conductivity of water.

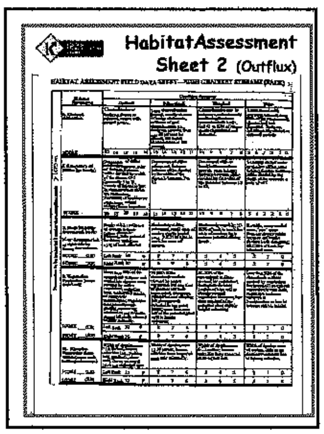

HabitatAssessment
Sheet 1 (Mitigated Site)


HabitatAssessment
Sheet 2 (Mitigated Site)


Riparian Vegetation
(Mitigated Site)
TREES
SHRUBS
GRASSES


Outflux
Temperature
pH
Conductivity
Dissolved Oxygen


HabitatAssessment
Sheet 1 (Outflux)


HabitatAssessment
Sheet 2 (Outflux)

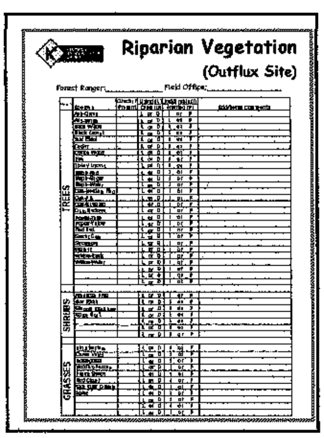

Riparian Vegetation
(Outflux Site)
TREES
SHRUBS
GRASSES

**Figure 10 Electro-shocking is used to collect fish.**

Collected fish were held in aerated buckets for identification, enumeration, and fish length measurement (Figure 11). Species that could not be identified in the field were preserved with 10% formalin and stored until laboratory identifications could be made. Remaining fish were returned to the stream after all collections were completed. Fish identifications were performed according to keys and descriptions found in Clay (1962), Eddy and Underhill (1978), Kuehne and Barbour (1983), and the Audubon Society (1988). Fish scoring criteria were based on methods given by U.S. EPA (1999) and Karr et al (1986). Fish collections were initiated at the downstream boundary and proceeded upstream."(20, p.3) See Appendix B for complete report.

**Figure 11 Collected fish were held in aerated buckets for identification, enumeration, and fish length measurement.**

## HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (FRONT)

| | |
|---|---|
| STREAM NAME | LOCATION |
| STATION #______ RIVERMILE______ | STREAM CLASS |
| LAT______ LONG______ | RIVER BASIN |
| STORET# | AGENCY |
| INVESTIGATORS | |
| FORM COMPLETED BY | DATE ______ TIME ______ AM PM / REASON FOR SURVEY |

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 | 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 | 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 | 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% (<20% for low-gradient streams) of the bottom affected by sediment deposition. | Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% (20-50% for low-gradient) of the bottom affected; slight deposition in pools. | Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% (50-80% for low-gradient) 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% (80% for low-gradient) of the bottom changing frequently; pools almost absent due to substantial sediment deposition. |
| SCORE | 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 | 20 19 18 17 16 | 15 14 13 12 11 | 10 9 8 7 6 | 5 4 3 2 1 0 |

**Figure 12 EPA Habitat Assessment Form - Page 1.**

## HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (BACK)

Parameters to be evaluated broader than sampling reach > 100 m

| 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** | 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 ratio of >25. |
| **SCORE** | 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 ___ (LB) | Left Bank 10 9 | 8 7 6 | 5 4 3 | 2 1 0 |
| SCORE ___ (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 nonwoody 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 ___ (LB) | Left Bank 10 9 | 8 7 6 | 5 4 3 | 2 1 0 |
| SCORE ___ (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 ___ (LB) | Left Bank 10 9 | 8 7 6 | 5 4 3 | 2 1 0 |
| SCORE ___ (RB) | Right Bank 10 9 | 8 7 6 | 5 4 3 | 2 1 0 |

**Figure 13 EPA Habitat Assessment Form - Page 2.**

# 4.0 SITE DATA

All five of the selected sites were assessed using physical and chemical data. The data collected provided a "thumbnail sketch" of the stream. Biological data provides a more complete picture of a stream, however fiscal constraints prohibited the collection of biological data at all sites. Therefore biological data was collected at only the two largest streams

Preliminary site assessments were conducted to determine which sites would have in-depth biological assessments. On March 26$^{th}$ and April 8$^{th}$, 1999 individuals from the University of Kentucky's Biological Science Department and the Kentucky Transportation Center visited the five mitigation projects. The preliminary visit allowed investigators to see the sites, determine the size of each project and decide what methods of evaluation were needed for each site. Monetary constraints on this project limited the amount of data that could be gathered, therefore, only the two largest streams, Cedar Creek and Holt's Creek, were selected for intensive biological data collections.

**Figure 14 Site assessment at Holt's Creek.**

## 4.1 SITE 1: KY 313, CEDAR CREEK1, HARDIN COUNTY (4-168.06)

The construction of KY 313 in Hardin County required modification of the unnamed tributary that runs alongside it. This mitigation site (although referred to as Cedar Creek1) is actually an unnamed tributary of Cedar Creek, Clear Creek and Mud Creek.

### 4.1.1 Physical Data

**Physical Description:**

Cedar Creek1 runs parallel to KY 313, which is about 100 yards south of the creek. On the north side of the creek, is a forested area. The creek itself is very shallow and is about six inches at the thalweg line. It is an intermittent stream and is almost completely dry in the summer.

**Stream characterization:** The stream is characterized by alternating pools, runs, and riffles. The water is slow moving and cool. There is relatively little shade.

**Watershed features:** Although the watershed is not pristine, it is fairly natural. Development in the surrounding area is minimal. Rain run-off is minimal from the roadway and the majority of the water percolates into the ground and through the soil to become ground water.

**Riparian vegetation:** The area south of the stream bank consists mostly of grasses. The area north of the stream bank consists of grasses and about 300 healthy, planted trees of 28 different varieties. However, they are very small in stature, cannot provide shade or contribute leaves as organic material into the water. The trees are small enough that they could be mowed down easily.

**In-stream features:** There are no man-made constructions in the water. There are several large rocks which provide small amounts of shade and places for aquatic life to hide.

**Sediment/substrate characteristics:** The bottom of the stream has a thin layer of sediment with relatively no increase in bar formation.

**Plan Comparison:**

This mitigation project was very basic and included two pipes, two box culverts, and approximately 10,000 feet of channel change varying in width from two to twelve feet. The channel runs from Station 535+11 to Station 763+00 and is generally parallel to, and north of, KY 313. Stone riffles and energy dissipaters were constructed as part of the mitigation plan. The channel flows at a depth of about 6 inches at its deepest spot during the spring and is probably an intermittent stream (Figure 15).

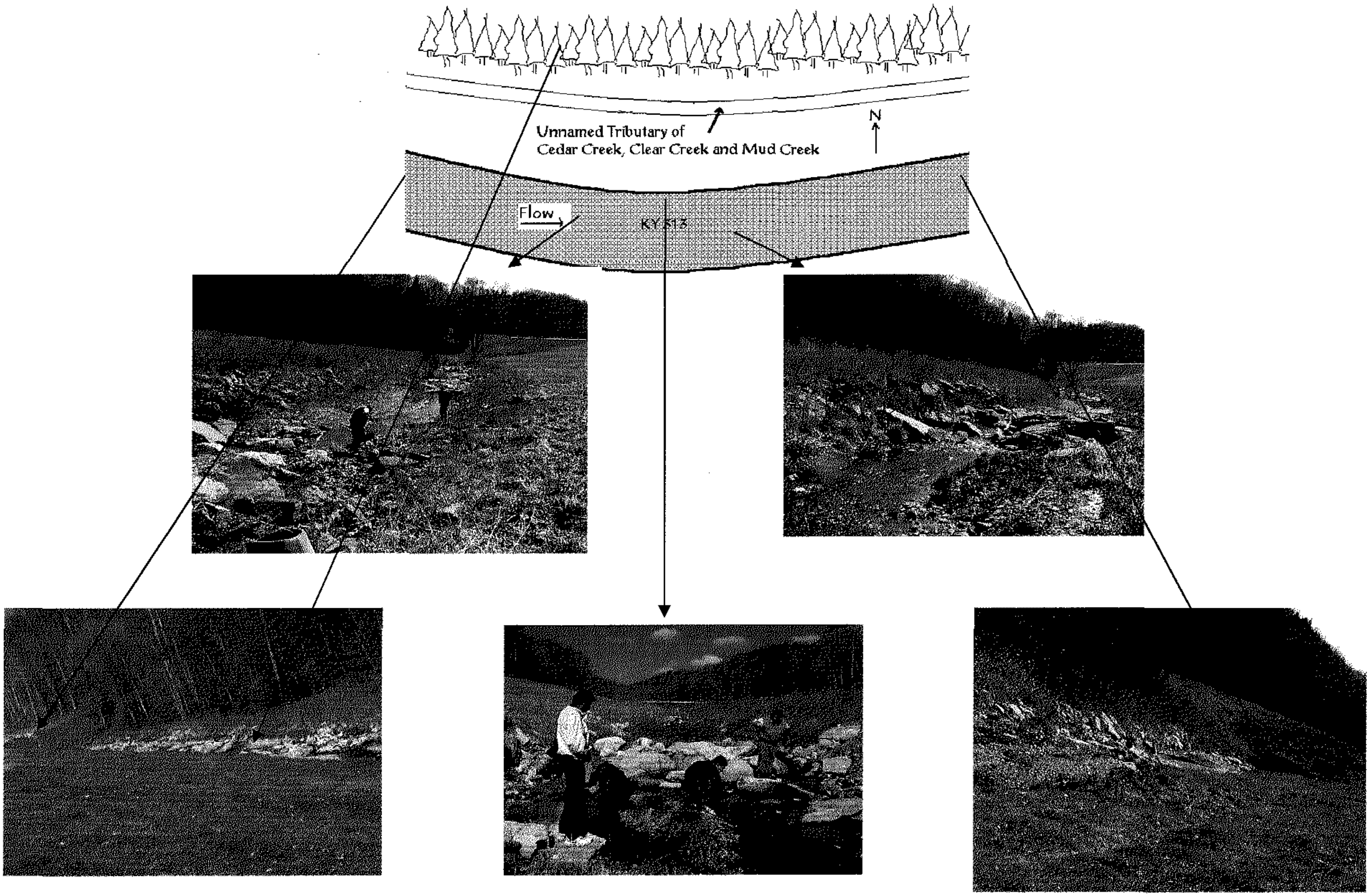



**Figure 15 Conceptual drawing and photographs of: KY 313, Cedar Creek1, Hardin County.**

**Revegetation:**

There is relatively no vegetation in the channel. If any was planted it has been washed away. What does grow in the area seems to be native to the area. There have been multiple trees planted on the left bank in an effort to restore it to its natural habitat. These trees are healthy, but it will take a very long time before the trees reach the height when they will be able to provide cover.

### 4.1.2 Chemical Data

"Results for water Quality measurement are given in Table 2 and were similar for all three sampling stations, except for a slight increase in hardness and total suspended solids from the upstream to the downstream station. Due to sample clarity, settleable solids were not measurable. Low-flow conditions prevented reliable measurements of stream discharge. Samples were measured using the following equipment: Dissolved Oxygen (DO) YSI Model 51A oxygen meter, (pH) Orion SA 250 pH meter, Conductivity Amber Science Model 604 conductivity meter.

Table 1. Chemical data for Cedar Creek1, Hardin County, KY. (7/15/99)

| Site 1: CEDAR CREEK1 | | Upstream | Remediated Area | Downstream |
|---|---|---|---|---|
| LAB TESTS | TSS/L (g) | 0.264 | 0.565 | 0.041 |
| | Hardness (mg CaCO3/L) | 671 | 597 | 578 |
| | Alkalinity (mg/L) | 199 | 149.4 | 156.8 |
| FIELD TESTS | Temperature (C) | 30.8 | 30.8 | 30.8 |
| | pH | 7.2 | 7.4 | 7.4 |
| | Conductivity(μmhos/cm) | 0.733 | 0.481 | 0.826 |
| | Dissolved Oxygen(mg/L) | 6.83 | 7.10 | 7.82 |

### 4.1.3 Biological Data

Minnows, snails and worms were readily observed at the lower reaches of the stream.

**Habitat Assessment:**

Habitat Assessment scores for Cedar Creek1 are presented in Table 1. The scores for all three stations were very similar. Each habitat parameter is put into a condition category based on its score. Parameters with 0-5 point are rated poor, scores between 6-10 are marginal, scores between 11-15 are suboptimal, and scores between 16-20 are optimal.

Table 2. Habitat Assessment Scores for Cedar Creek1, Hardin County, KY

| | Habitat Parameter | Stations | | | | | |
|---|---|---|---|---|---|---|---|
| | | Upstream | | Remediated | | Downstream | |
| | | Score | Category | Score | Category | Score | Category |
| 1 | Epifaunal Substrate/Available Cover | 2 | Poor | 2 | Poor | 4 | Suboptimal |
| 2 | Embeddedness | 8 | Marginal | 8 | Marginal | 8 | Marginal |
| 3 | Velocity/Depth Regime | 2 | Poor | 2 | Poor | 2 | Poor |
| 4 | Sediment Deposition | 11 | Suboptimal | 11 | Suboptimal | 11 | Suboptimal |
| 5 | Channel Flow Status | 6 | Marginal | 6 | Marginal | 6 | Marginal |
| 6 | Channel Alteration | 17 | Optimal | 17 | Optimal | 19 | Optimal |
| 7 | Frequency of Riffles | 12 | Suboptimal | 9 | Marginal | 12 | Suboptimal |
| 8a | Bank Stability-left bank | 7 | Suboptimal | 6 | Suboptimal | 7 | Suboptimal |
| 8b | Bank Stability-right bank | 7 | Suboptimal | 7 | Suboptimal | 7 | Suboptimal |
| 9a | Vegetative Protection-left bank | 1 | Poor | 1 | Poor | 4 | Marginal |
| 9b | Vegetative Protection-right bank | 1 | Poor | 0 | Poor | 4 | Marginal |
| 10a | Riparian Vegetative Zone Width-left bank | 1 | Poor | 1 | Poor | 2 | Poor |
| 10b | Riparian Vegetative Zone Width-right bank | 1 | Poor | 1 | Poor | 2 | Poor |
| | Total IBI Score = | 76 | | 71 | | 88 | |

## Riparian Vegetation Assessment:

Forester Robert Bean, State's Division of Forestry-Hardin county field office, identified the few trees that were planted in the mitigated site. He noted that the lack of grass cover acted as a barrier to other growth.

## 4.2 SITE 2: KY 313, CEDAR CREEK2, HARDIN COUNTY (4-168.06)

The construction of KY 313 in Hardin County required modification of the Cedar Creek. This mitigation site runs perpendicular to the roadway.

### 4.2.1 Physical Data

Physical Description:

During construction of KY 313 a bridge was erected over Cedar Creek running perpendicular to the roadway. Figure 16 shows its geographic location.

"Although there were 11 unnamed tributaries that drained into Cedar Creek, the stream area sampled was characteristic of a first-order system. The upstream site contained, riffle, run and pool areas and low-flow conditions were evident. The remediated site contained a pool, bridge abutments, and a modified rifle-run area that was restructured in part with riprap. This site also received a small unnamed tributary. The site located downstream of the remediated sector was less channelized, contained somewhat more riffle habitat, and exhibited increased flow due to a second unnamed tributary. (20, p. 4)"

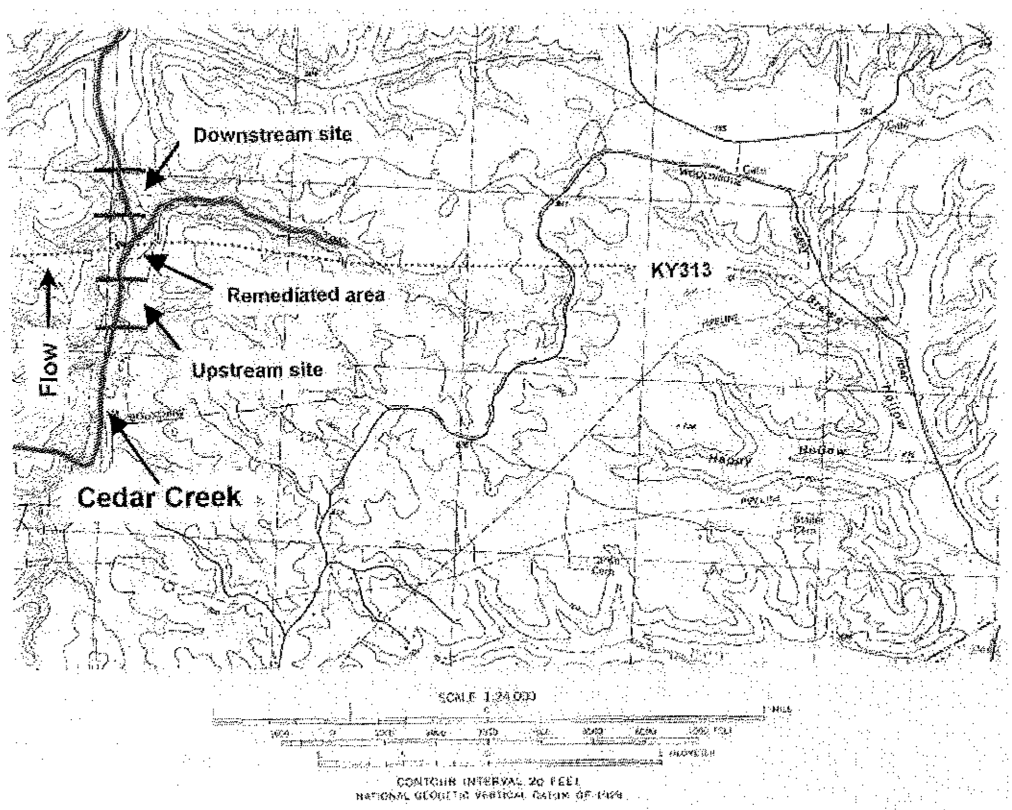



**Figure 16 Geographic location map of Cedar Creek. Prepared by UK's Biology Department.**

**Stream characterization:** The stream is characterized by alternating pools, runs, and riffles. The water is slow moving and cool. There is relatively little natural shade in the remediated area. However, the overpass casts a shadow over a portion of the site. The areas upstream and downstream have optimal shaded areas.

**Watershed features:** Although the watershed is not pristine, it is fairly natural. Development in the surrounding area is minimal. Rain run-off is minimal from the roadway and the majority of the water percolates into the ground and through the soil to become ground water.

**Riparian vegetation:** The upstream banks have optimal vegetative protection. However, both the banks in the remediated area were rated poor because of the reduced vegetation. The downstream bank recovered and was rated optimal.

**In-stream features:** "The upstream site contained riffle, run and pool areas and low-flow conditions were evident. The remediated site contained a pool, bridge abutments, and a modified riffle-run area that was restructured in part with riprap. This site also received a small unnamed tributary. The site located downstream of the remediated sector was less channelized; contained somewhat more riffle habitat, and exhibited increased flow due to a second unnamed tributary." (20, p.4).

**Figure 17 Shallow unnamed stream flows into Cedar Creek.**

**Sediment/substrate characteristics:** There was some new increase in bar formation and slight deposition of sediment in pools.

## Plan Comparison:

This project required a channel modification where the KY 313 bridge crosses Cedar Creek and an unnamed tributary to Cedar Creek north of the bridge (Figure 18). The mitigation plan involves 410 feet of Cedar Creek, approximately 5,500 feet (Station 478+50 to Station 5353+11) of channel changes of unnamed first and second-order tributaries, and two culverts. Stone riffles and deflectors were constructed. The unnamed stream varies from two-foot to six-foot in width and is very shallow even in the spring wet-season (Figure 17). Some bank erosion has occurred as a result of undercutting on the small branch that parallels the highway (Figure 19). A large pool is located in the main stream, just before the stream enters the forested area, and slightly upstream from where the unnamed stream enters Cedar Creek.

**Revegetation:** A limited number of trees and shrubs have been planted.

### 4.2.2 Chemical Data

"Results for water quality measurement are given in Table 4 and were similar for all three sampling stations, except for a slight increase in hardness and total suspended solids from the upstream to the downstream station. Due to sample clarity, settleable solids were not measurable. Low-flow conditions prevented reliable measurements of stream discharge. Samples were measured using the following equipment: Dissolved Oxygen (DO) YSI Model 51A oxygen meter, (pH) Orion SA 250 pH meter, Conductivity Amber Science Model 604 conductivity meter. (20, p. 4)

Table 3. Chemical data for Cedar Creek2, Hardin County, KY collected May 19, 1999 by UK's Biology Department.

| Site 2: CEDAR CREEK2 | | Upstream | Remediated Area | Downstream |
|---|---|---|---|---|
| LAB TESTS | TSS/L (mg/l) | 0.24 | 1.15 | 4.41 |
| | Hardness (mg CaCO3/L) | 174 | 194 | 244 |
| | Alkalinity (mg/L) | 172 | 176 | 168 |
| FIELD TESTS | Temperature (C) | 19.1 | 18.0 | 19.0 |
| | pH | 7.6 | 7.85 | 7.76 |
| | Conductivity(µmhos/cm) | 0.372 | 0.386 | 0.405 |
| | Dissolved Oxygen(mg/L) | 11.9 | 12.3 | 11.8 |

### 4.2.3 Biological Data and Assessment.

The University of Kentucky's Biology Department conducted habitat surveys and the Rapid Bioassessment Protocol (RBP) for monitoring fish assemblages. The RBP was used to calculate the Index of Biological Integrity (IBI). There were 22 varieties of fish collected at Cedar Creek. The number of fish collects and their length measurements were recorded. Results can be found in Tables 3 – 6 of Appendix B. Scoring criteria selected for IBI determinations are presented in Table 7, Appendix B.

"Two alternate IBI metrics were selected to better represent the stream system and these included criterion 4 (number of minnow species and criterion 8(proportion of insectivore species). In addition, criterion 9 (Proportion of top carnivores) were modified to include both piscivores and insectivores. From the IBI scores for Cedar Creek (Table 8, Appendix B) it was determined that the stations were all in the "Good" category. Nevertheless, values for abundance fluctuated among stations (Table 3, Appendix B). As might be expected, cyprinids increased in abundance with downstream progression. However, more centrarchids but few darters occurred within the remediated sector and these events probably were habitat related. The riprap added to the stream channel likely attracted more bass and sunfish but was less suitable for darters. The riprap also may have accounted for the higher frequency of larger cyprinids and centrarchids, based on length measurements (Tables 4-6, Appendix B).

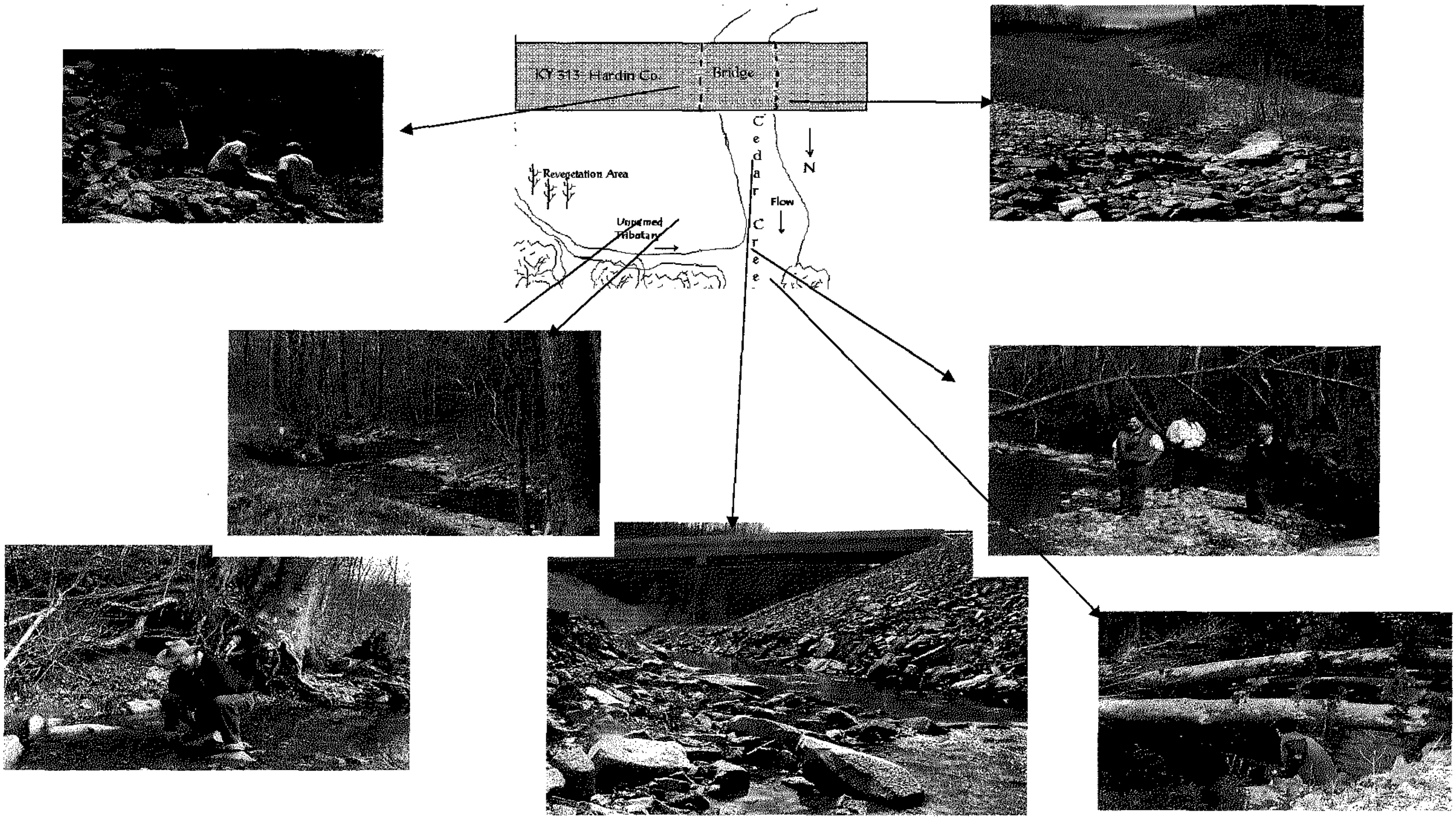



**Figure 18 Conceptual drawing and photographs of KY 313, Cedar Creek2, Hardin County.**

Although the remediated stream sector scored lowest for habitat quality due to less vegetative protection and less developed riparian zones( Table 2, Appendix B), the IBI scores reveals no significant difference with respect to fish metrics and the scores ranges from 50 to 54 (Table 2, Appendix B).

The highest metric scores for the remediated zone were

1) number of sunfish,
2) proportion of top carnivores and green sunfish, and
3) total number of species.

The lowest scores for the remediated zone were for

1) proportions of insectivorious species and
2) total number of individuals.

Habitat zones for the downstream site are illustrated in Figures 7 and 8, Appendix B.

**Habitat Assessment:**

Habitat Assessment scores for Cedar Creek2 are presented in Table 3. "Habitat assessment scores for Cedar Creek indicate a decrease in total IBI habitat score was observed at the remediated site, followed by recovery at the downstream site. The remediated station at Cedar Creek had a lower assessment value primarily due to reduced vegetative protection along both banks and poor riparian vegetative zones. The presence of riprap along the banks also reduced the score for channel alteration. (20, p. 5)"

Each habitat parameter is put into a condition category based on its score. Parameters with 0-5 point are rated poor, scores between 6 & 10 are marginal, scores between 11&15 are suboptimal, and scores between 16 & 20 are optimal.

Table 4. Habitat Assessment Scores for Cedar Creek2, Hardin County, KY 7/14/99)

| | | Stations | | | | | |
|---|---|---|---|---|---|---|---|
| | | Upstream | | Remediated | | Downstream | |
| | Habitat Parameter | Score | Category | Score | Category | Score | Category |
| 1 | Epifaunal Substrate/Available Cover | 14 | Suboptimal | 6 | Marginal | 11 | Suboptimal |
| 2 | Embeddedness | 14 | Suboptimal | 18 | Optimal | 14 | Suboptimal |
| 3 | Velocity/Depth Regime | 14 | Suboptimal | 9 | Marginal | 14 | Suboptimal |
| 4 | Sediment Deposition | 15 | Suboptimal | 15 | Suboptimal | 9 | Marginal |
| 5 | Channel Flow Status | 7 | Marginal | 7 | Marginal | 11 | Suboptimal |
| 6 | Channel Alteration | 19 | Optimal | 1 | Poor | 17 | Optimal |
| 7 | Frequency of Riffles | 13 | Suboptimal | 17 | Optimal | 10 | Marginal |
| 8a | Bank Stability-left bank | 7 | Suboptimal | 9 | Optimal | 7 | Suboptimal |
| 8b | Bank Stability-right bank | 2 | Poor | 9 | Optimal | 8 | Suboptimal |
| 9a | Vegetative Protection-left bank | 8 | Suboptimal | 1 | Poor | 8 | Suboptimal |
| 9b | Vegetative Protection-right bank | 5 | Marginal | 2 | Poor | 7 | Suboptimal |
| 10a | Riparian Vegetative Zone Width-left bank | 9 | Optimal | 1 | Poor | 10 | Optimal |
| 10b | Riparian Vegetative Zone Width-right bank | 9 | Optimal | 1 | Poor | 10 | Optimal |
| | Total IBI Score = | 136 | | 96 | | 136 | |

## Riparian Vegetation

Forester Robert Bean, State's Division of Forestry-Hardin county field office, identified an extensive variety of native trees, shrubs and grasses in the mitigated area. There were over approximately 300 trees planted in six rows, 12 feet apart. Some of the trees had girdles (tags) on them, which made it a little easier to identify their species. A couple of the trees had deer rubs on them. There was also evidence of Eastern tent caterpillars. Mr. Bean recommended that at least one row of trees be planted on the same side as the road.

**Figure 19 Bank erosion results from undercutting. This picture taken at Cedar Creek2.**

## 4.3 SITE 3: US 68, DOCTOR'S FORK, BOYLE COUNTY

The construction of US 68 in Boyle County required modification of the stream called Doctors Fork.

### 4.3.1 Physical Data

**Physical Description:**

Doctor's Fork runs parallel to US 68. It is bordered on the southeast (right bank) by farmland. The creek itself is very shallow and is about six inches at the thalweg line. This stream is quite shallow in the summer but must flood occasionally as there is evidence of undercutting and erosion.

**Figure 20 Doctor's Fork is bordered by farmland on one side and US 68 on the other side.**

**Stream characterization:** The stream is characterized by alternating pools, runs, and riffles. The water is slow moving and cool. There is relatively little shade.

**Watershed features:** Before the mitigated site the stream runs through a populated area and after the mitigated site it returns to a wooded area. The first portion of the mitigated site looks like it was freshly constructed. The banks are still equal distance apart (bull dozer width), but after the access road and before the culvert the stream becomes less uniform. It has experienced undercutting and erosion.

**Riparian vegetation:** The area south of the stream bank consists mostly of grasses. The area north of the stream bank consists of grasses and about 300 healthy, planted trees of 28 different varieties. However, they are very small in stature, cannot provide shade or contribute leaves as organic material into the water. The trees are small enough that they could be mowed down easily.

**In-stream features:** There are four box culverts in the stream.

**Sediment/substrate characteristics:** There are heavy deposits of fine material and increased bar development.

**Plan Comparison:**

This project required channel modification of Doctors Fork and unnamed tributaries to Doctors Fork for the realignment of US 68 approximately two miles west of Perryville in Boyle County (Figure 21). The mitigation plan includes four box culverts and approximately 1,000 feet of channel change from Station 23+00 to 231+00. A

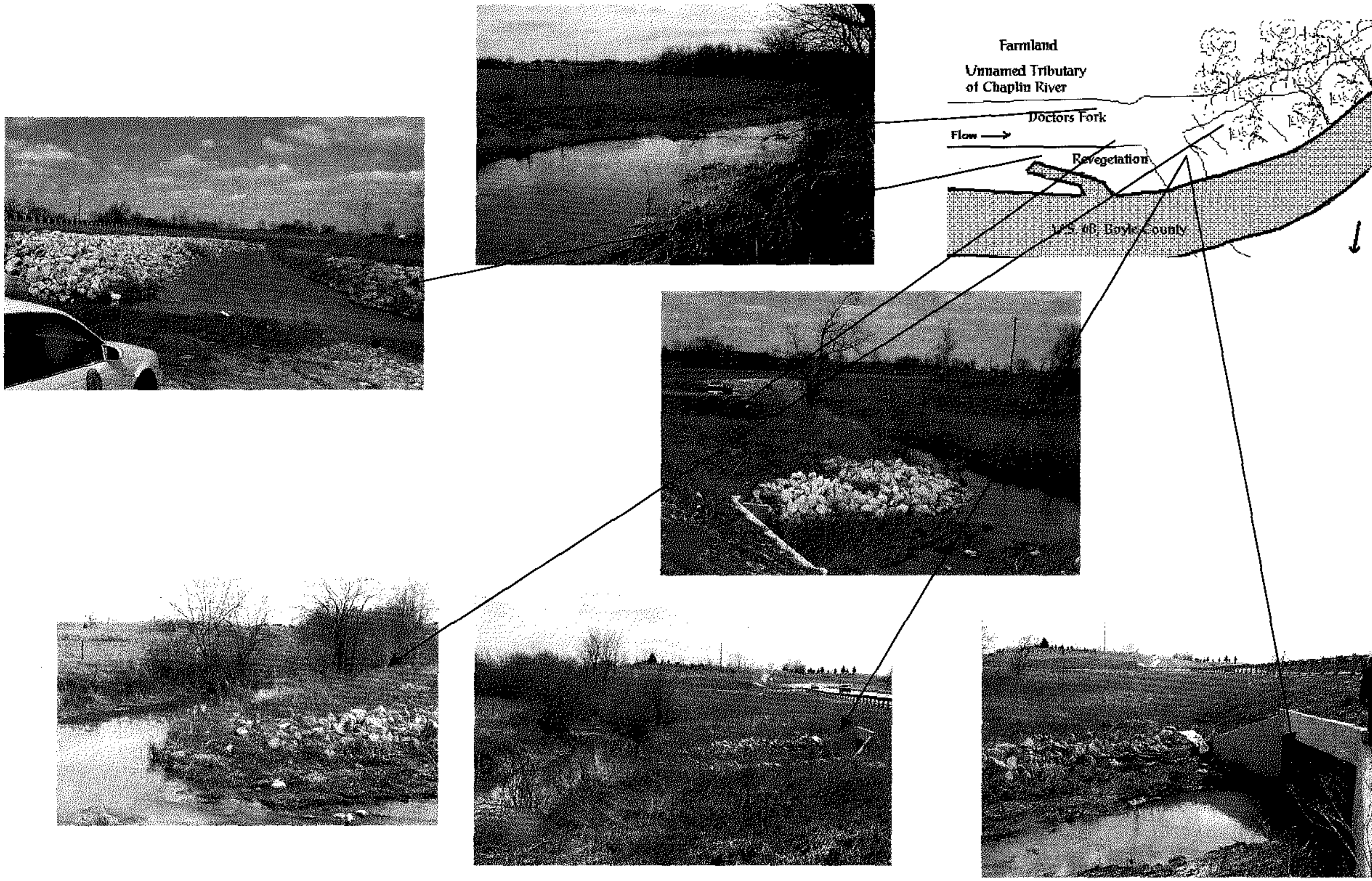



**Figure 21 Conceptual drawing and photographs of US 68, Doctors Fork, Boyle County.**

significant part of the mitigation is 350 feet of 30-foot wide channel change south of relocated US 68 beginning at Station 190+50 (Figure 22). The project is bordered by farmland on the southeast side. Runoff from the farmland is deposited in the stream.

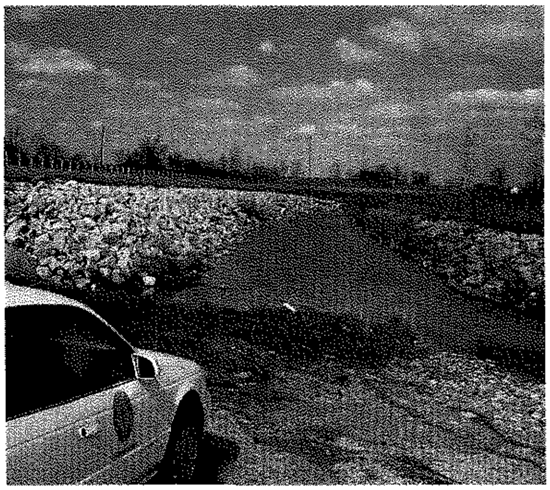


**Figure 22 Doctor's Fork has 350 feet of 30 foot channel change.**

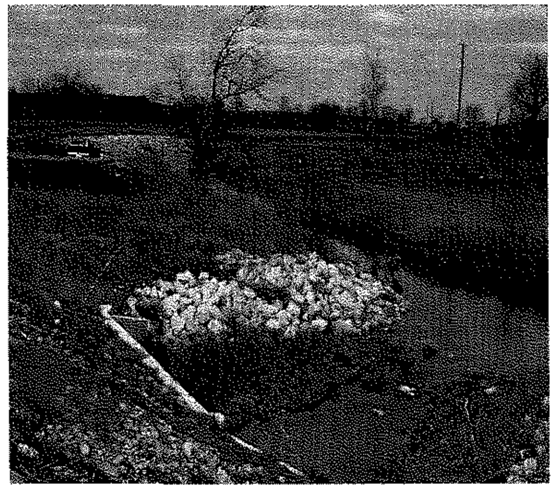


**Figure 23 Riprap is used around box culvert to prevent erosion. The 30-foot channel change is shown in the background.**

The stream runs west to east and travels through a wooded area. Culvert bottoms were constructed flush with the streambed and outlets were stabilized with stone (Figure 23).

**Revegetation:** Several small trees had been planted on the highway side of the stream near the box culvert. However, the number is minimal and the rest of the site has had no revegetation.

### 4.3.2 Chemical Data

"Results for water Quality measurement are given in Table 2 and were similar for all three sampling stations, except for a slight increase in hardness and total suspended solids from the upstream to the downstream station. Due to sample clarity, settleable solids were not measurable. Low-flow conditions prevented reliable measurements of stream discharge. Samples were measured using the following equipment: Dissolved Oxygen (DO) YSI Model 51A oxygen meter, (pH) Orion SA 250 pH meter, Conductivity Amber Science Model 604 conductivity meter.

Table 5. Chemical data for Doctor's Fork, Boyle County, KY.

| Site 3: DOCTOR'S FORK | | Upstream | Remediated Area | Downstream |
|---|---|---|---|---|
| LAB TESTS | TSS/L (g) | 0.427 | 0.228 | 0.112 |
| | Hardness (mg CaCO3/L) | 203 | 246 | 124 |
| | Alkalinity (mg/L) | 74.6 | 97 | 59.4 |
| FIELD TESTS | Temperature (C) | 33 | 33 | 33 |
| | PH | 7.1 | 7.3 | 7.25 |
| | Conductivity(μmhos/cm) | 0.276 | 0.265 | 0.284 |
| | Dissolved Oxygen(mg/L) | 8.1 | 7.5 | 7.9 |

### 4.3.3 Biological Data and Assessment.

Minnows, snails and worms were readily observed at the lower reaches of the stream.

**Habitat Assessment:**

Habitat Assessment scores for Doctor's Fork are presented in Table 6. The scores for all three stations were very similar. Each habitat parameter is put into a condition category based on its score. Parameters with 0-5 point are rated poor, scores between 6 & 10 are marginal, scores between 11&15 are suboptimal, and scores between 16 & 20 are optimal.

**Riparian Vegetation:**

Forester Glenn Detillo, State's Division of Forestry-Campbellsville field office, identified an extensive variety of native trees, shrubs and grasses in the downstream, undisturbed area. However, the riparian vegetation in the remediated and downstream areas was consisted only of seeded grass. In the remediated area, the grasses are not very abundant.

Table 6. Habitat Assessment Scores for Doctor's Fork, Boyle County, KY

| | | Stations | | | | | |
|---|---|---|---|---|---|---|---|
| | | Upstream | | Remediated | | Downstream | |
| | Habitat Parameter | Score | Category | Score | Category | Score | Category |
| 1 | Epifaunal Substrate/Available Cover | 7 | Marginal | 7 | Marginal | 18 | Optimal |
| 2 | Embeddedness | 8 | Marginal | 8 | Marginal | 17 | Optimal |
| 3 | Velocity/Depth Regime | 2 | Poor | 2 | Poor | 3 | Poor |
| 4 | Sediment Deposition | 1 | Poor | 1 | Poor | 2 | Poor |
| 5 | Channel Flow Status | 14 | Suboptimal | 12 | Suboptimal | 14 | Suboptimal |
| 6 | Channel Alteration | 14 | Suboptimal | 15 | Suboptimal | 17 | Optimal |
| 7 | Frequency of Riffles | 3 | Poor | 3 | Poor | 7 | Marginal |
| 8a | Bank Stability-left bank | 9 | Optimal | 9 | Optimal | 9 | Optimal |
| 8b | Bank Stability-right bank | 9 | Suboptimal | 7 | Suboptimal | 9 | Optimal |
| 9a | Vegetative Protection-left bank | 2 | Poor | 1 | Poor | 9 | Optimal |
| 9b | Vegetative Protection-right bank | 5 | Marginal | 3 | Marginal | 9 | Optimal |
| 10a | Riparian Vegetative Zone Width-left bank | 2 | Poor | 1 | Poor | 9 | Optimal |
| 10b | Riparian Vegetative Zone Width-right bank | 5 | Marginal | 5 | Marginal | 9 | Optimal |
| | Total IBI Score = | 81 | | 74 | | 132 | |

## 4.4 SITE 4: AA HIGHWAY, HOLTS CREEK, BRACKEN COUNTY

The construction of the AA highway in Bracken County required modification of the Holts Creek. This mitigation site runs parallel to the roadway.

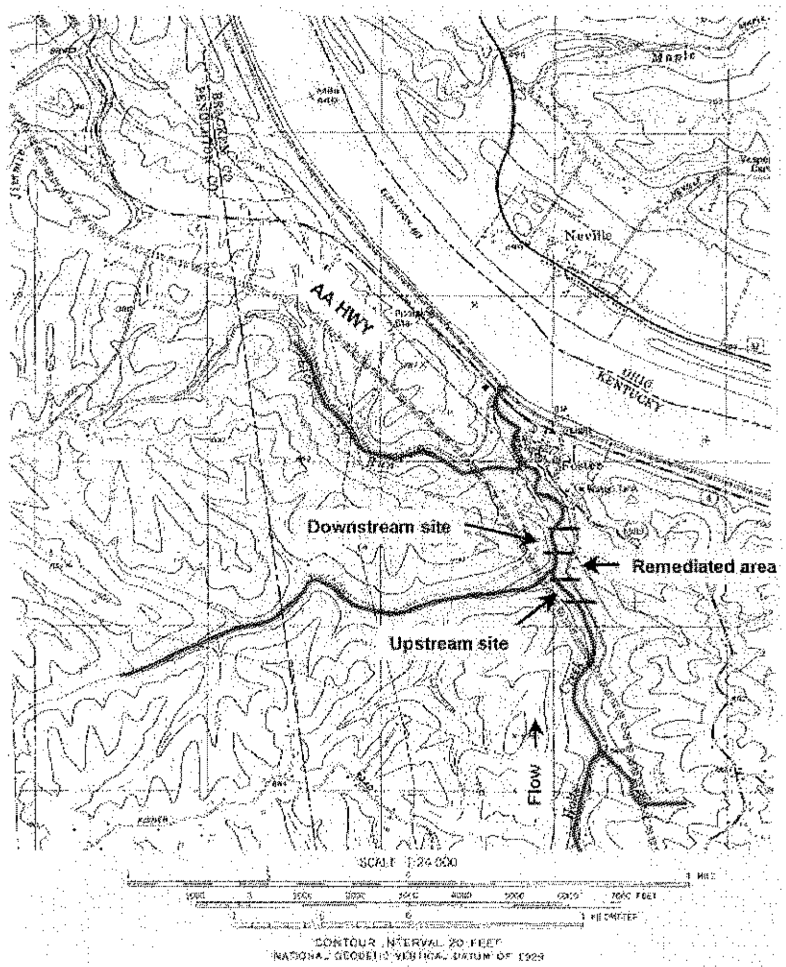



**Figure 24 Geographic location map of Holts Creek. Prepared by UK's Biology Department.**

### 4.4.1 Physical Data

**<u>Physical Description:</u>**

Two streams, West Holt's Creek and Holt's Creek combine to form a single stream that goes underground where the riprap and gravel have been deposited, about 350 feet from the confluence of the two creeks (Figure 26 & 27). After the two streams connect they become significantly more shallow.

"This is a large second-order stream system with a lower gradient than observed for Cedar Creek. In addition, there was a higher ratio of pool to riffle habitat, especially at the remediated and downstream monitoring stations. The remediated site contained a considerable proportion of riprap below a well developed pool (See Figure 11, Appendix B). The upstream study areas included a large shallow pool and considerable rocks and cobble in the run below. Riffle structure was less well developed (20, p. 6) ".

**Stream characterization:** The stream is characterized by alternating pools, runs, and riffles. There are two large pools in the remediated site. The water is slow moving and cool. There is relatively little shade in the remediated area. However, the areas upstream and downstream have optimal shaded areas.

**Watershed features:** Although the watershed is not pristine, it is fairly natural. Development in the surrounding area is minimal. According to the farmer whose land is adjacent to the state owned property, Holt's Creek floods during the springtime and covers the neighborhood roadway. This is evidenced by the deterioration of the residential road running parallel to the remediated site.

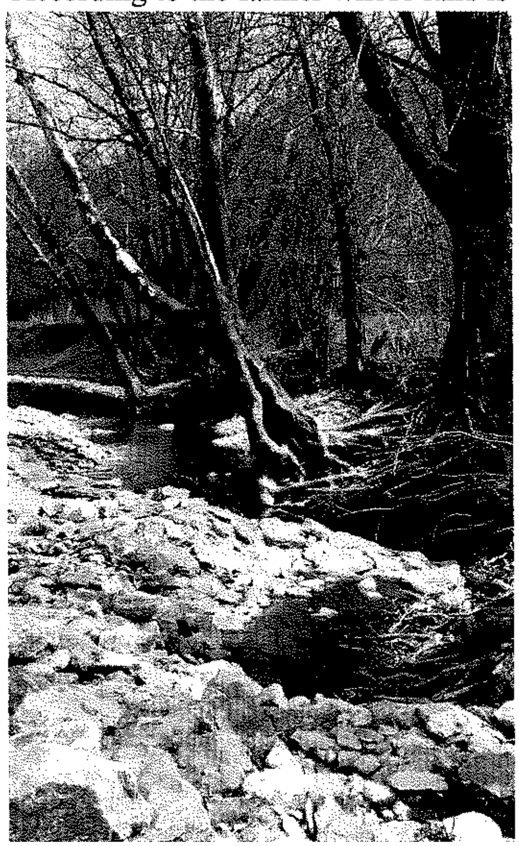


**Figure 25 Combined streams go underground. Undercutting has taken place at Holts Creek.**

**Riparian vegetation:** The vegetation consists of a multitude of trees, shrubs, bushes, and grasses. In the flood plain adjacent to the remediated site there are planted trees, not native to the area, and crown vetch that has gotten out of control. The State Forestry Department sent a Forest Ranger to help in the identification of the trees that were planted. A detailed list of those trees appears in Appendix C.

**In-stream features:** There are two large culverts that go under the AA.

**Sediment/substrate characteristics:** Some new sand bars have formed and there is slight deposition in the pools.

## Plan Comparison:

While conducting the evaluation, the owner of the farmland on the east side of the creek showed up. Mr. Hubert Nicson stated that, "Before construction, West Holts Creek used to have an island on the right side of the pool, and the creek flowed around it. I've seen the water backed up 30 feet above that headwall. That's a lot of water (5/5/99)." According to Mr. Nicson, the majority of the riprap came from Butler's Rock Quarry in the neighboring town. Some of the boulders weigh about 500 pounds. When the project was first completed those rocks were placed around the headwall. They are now in the middle of the channel.

The local residents feel that the headwalls are too small for the amount of water that flows through it during a storm. They requested a larger headwall but were refused. Mr. Nicson said, "Snag's Creek is 3 miles up the road and has an 18 foot circular pipe. However, the State said that they would condemn our land rather than change the headwall as it would be cheaper than making the culvert bigger."

### 4.4.2 Chemical Data

The results for water quality measurement are given in Table 7. "Temperature, pH, and conductivity were constant for the three monitoring stations. However, dissolved oxygen, alkalinity and hardness were somewhat higher at the upstream station and total suspended solids were appreciably higher.

Samples were measured using the following equipment: Dissolved Oxygen (DO) YSI Model 51A oxygen meter, (pH) Orion SA 250 pH meter, Conductivity Amber Science Model 604 conductivity meter.

Table 7. Chemical data for Holt's Creek, Bracken County, KY collected May 26, 1999 by UK's Biology Department.

| Site 4: HOLT'S CREEK | | Upstream | Remediated Area | Downstream |
|---|---|---|---|---|
| LAB TESTS | TSS/L (mg/l) | 66.39 | 5.74 | 3.44 |
| | Hardness (mg CaCO3/L) | 288 | 272 | 268 |
| | Alkalinity (mg/L) | 216 | 204 | 192 |
| FIELD TESTS | Temperature (C) | 20.4 | 20.4 | 20.4 |
| | pH | 7.75 | 7.56 | 7.66 |
| | Conductivity(μmhos/cm) | 0.540 | 0.528 | 0.536 |
| | Dissolved Oxygen(mg/L) | 11.6 | 9.8 | 8.4 |

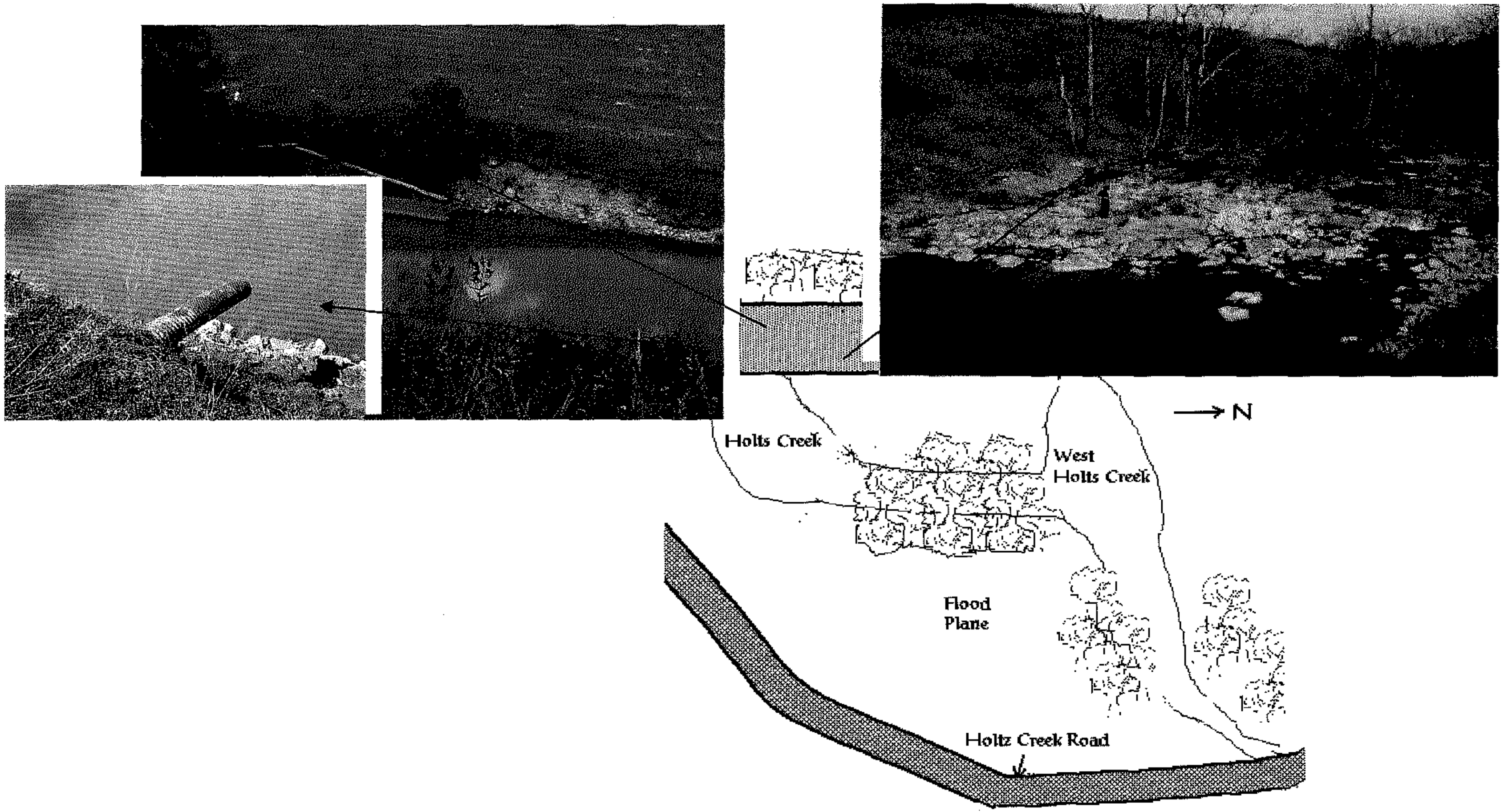



**Figure 26 Conceptual drawing and photographs of AA, Holts Creek, Bracken County.**

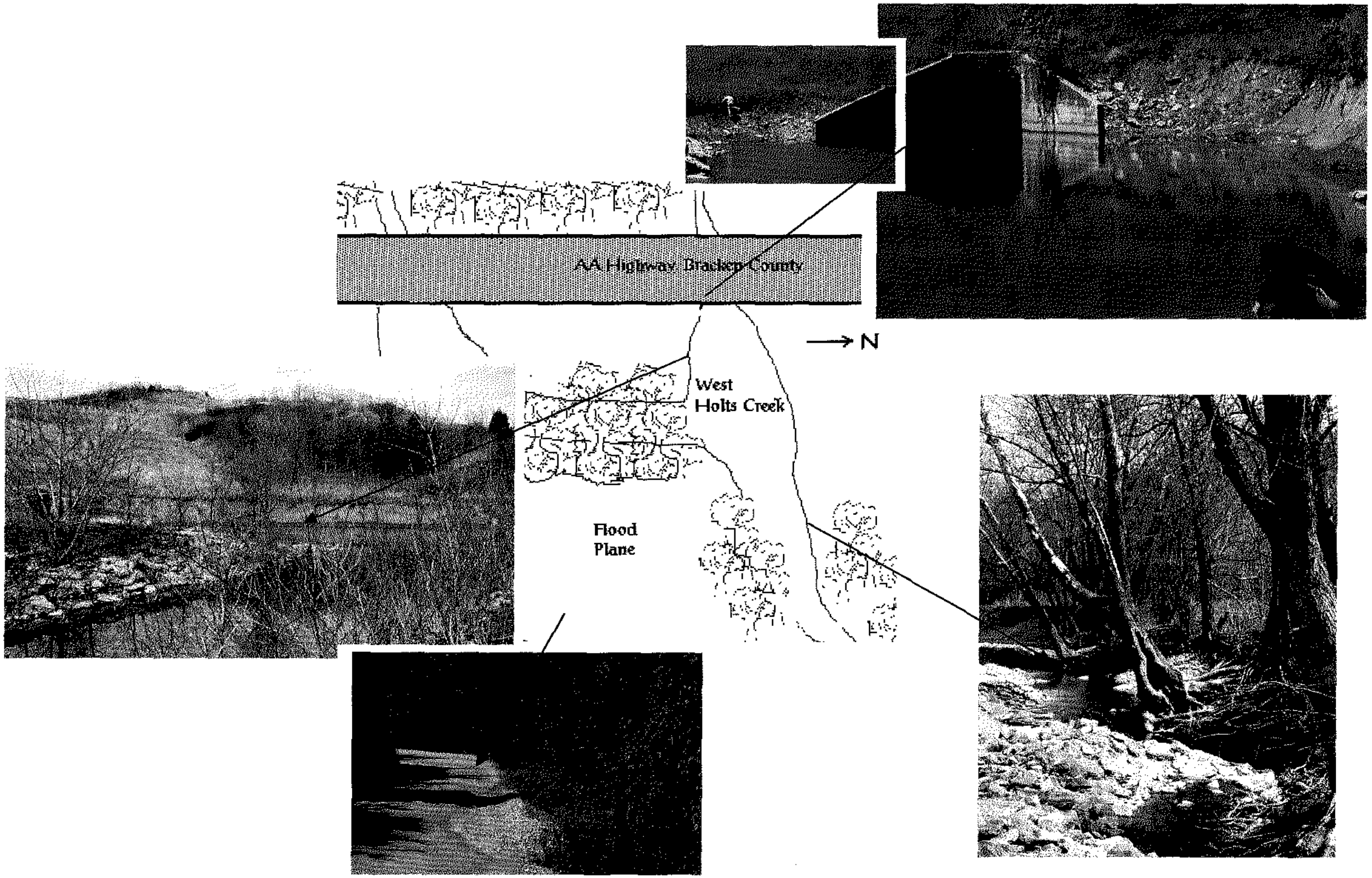



**Figure 27 Conceptual drawing and photographs of AA, Holts Creek, Bracken County.**

### 4.4.3 Biological Data

The University of Kentucky's Biology Department conducted habitat surveys and the Rapid Bioassessment Protocol (RBP) for monitoring fish assemblages. The RBP was used to calculate the Index of Biological Integrity (IBI). There were 22 varieties of fish collected at Holt's Creek. The number of fish collected and their length measurements were recorded. Results can be found in Tables 12 – 14 of Appendix B. Scoring criteria selected for IBI determinations are presented in Table 15, Appendix B.

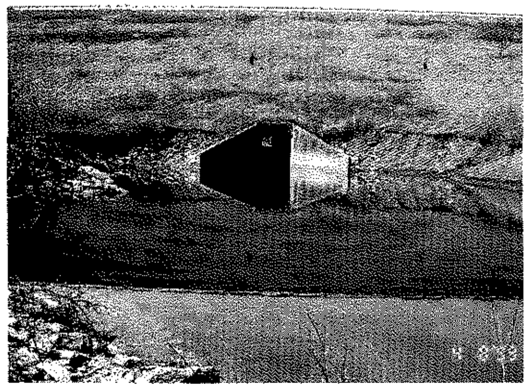


**Figure 28 Expansive pool development. Severe erosion on both sides of box culvert at West Holts Creek.**

"As with Cedar Creek, two alternate IBI metrics were selected to better represent the stream system and included criterion 4 (number of minnow species) and criterion 8 (proportion of insectivore species). In addition, criterion 9 (proportion of top carnivores) was modified to included both piscivores and insectivores. Fish abundance (Table 11, Appendix B) was appreciably higher for the remediated site, and this likely was due, in part, to the expansive pool development (Figure 28). Minnows, sunfish, and the rainbow darter mostly accounted for this increase. Major habitat modifications in this area included installation of a culvert over the tributary to Holts Creek and considerable riprap downstream of the pool (Figures 10, 11, 12, Appendix B). Rainbow darters were most abundant in the riffle area above the pool and the riprap below, whereas sunfish were concentrated mainly within the pool.

IBI values for Holt's Creek are presented in Table 16, Appendix B, and "Good" scores were observed for both the upstream and the remediated sampling sties. However, the downstream site scored only "Fair".

The lower score resulted primarily because of:

1) a lesser number of fish species
2) lower proportion of sunfish, and
3) reduced abundance.

These results were attributed to less habitat diversity. The downstream site was mainly a pool with top carnivores present, which may have accounted for the decrease in total number of species. Predominant fish species with habitat preferences are presented in Table 15, Appendix B. These taxa are typical of small stream systems in central Kentucky. (20, p. 7)."

**Habitat Assessment:**

Habitat Assessment scores for Holt's Creek are presented in Table 8 below.

Each habitat parameter is put into a condition category based on its score. The majority of the parameters are graded on a score of 1 – 20, with 0-5 point are rated poor, while scores between 6-10 are marginal, scores between 11-15 are suboptimal, and scores between 16-20 are optimal. However, Bank Stability, Vegetative Protection, and Riparian Vegetative Zone Width are graded on a 1-10 scale.

**Riparian Vegetation:**

Foresters James Wright and Lynn Brammer, State's Division of Forestry-Stamping Ground field office, identified an extensive variety of native trees, shrubs and grasses in all areas. There has been regeneration of sycamores. There is a thick layer of fescue which makes it hard to regenerate native species. Out of the 20 planted trees, 3 were dead, 6 were healthy and the others were questionable. The questionable trees appeared to have come back from root sprouts. There were deer trails among the riparian vegetation.

Table 8. Habitat Assessment Scores for Holt's Creek, Hardin County, KY

| | | Stations | | | | | |
|---|---|---|---|---|---|---|---|
| | | Upstream | | Remediated | | Downstream | |
| | Habitat Parameter | Score | Category | Score | Category | Score | Category |
| 1 | Epifaunal Substrate/Available Cover | 7 | Marginal | 7 | Marginal | 14 | Suboptimal |
| 2 | Embeddedness | 11 | Suboptimal | 12 | Suboptimal | 10 | Marginal |
| 3 | Velocity/Depth Regime | 14 | Suboptimal | 7 | Marginal | 14 | Suboptimal |
| 4 | Sediment Deposition | 13 | Suboptimal | 13 | Suboptimal | 10 | Marginal |
| 5 | Channel Flow Status | 9 | Marginal | 8 | Marginal | 12 | Suboptimal |
| 6 | Channel Alteration | 9 | Marginal | 7 | Marginal | 17 | Optimal |
| 7 | Frequency of Riffles | 7 | Marginal | 5 | Poor | 9 | Marginal |
| 8a | Bank Stability-left bank | 7 | Suboptimal | 1 | Poor | 4 | Marginal |
| 8b | Bank Stability-right bank | 7 | Suboptimal | 3 | Marginal | 1 | Poor |
| 9a | Vegetative Protection-left bank | 6 | Suboptimal | 2 | Poor | 2 | Poor |
| 9b | Vegetative Protection-right bank | 6 | Suboptimal | 4 | Marginal | 3 | Marginal |
| 10a | Riparian Vegetative Zone Width-left bank | 8 | Suboptimal | 4 | Marginal | 7 | Suboptional |
| 10b | Riparian Vegetative Zone Width-right bank | 8 | Suboptimal | 4 | Marginal | 5 | Marginal |
| | Total IBI Score = | 112 | | 77 | | 108 | |

## 4.5. SITE 5: KY 827, COAL BRANCH, GREENUP COUNTY

The construction of KY 827 in Greenup County required modification of Coal Branch.

### 4.5.1 Physical Data

**Physical Description:**

The mitigated portion of Coal Branch runs through a residential area. Upstream from the site it is very natural. Coal Branch is very shallow and is about six inches at the thalweg line. It is an intermittent stream and is almost completely dry in the summer.

**Stream characterization:** The stream is characterized by alternating pools, runs, and riffles. The water is slow moving and cool. There is relatively little shade.

**Watershed features:** The stream watershed is not very natural. The surrounding area contains a small neighborhood although development is minimal (about 5 houses). Rain run-off is minimal from the roadway and the majority of the water percolates into the ground and through the soil to become ground water.

**Riparian vegetation:** The area surrounding the mitigated side consists mostly of grasses. The mitigated area has been seeded, but it has not been very successful. Upstream from the mitigated site are a variety of native trees and bushes.

**In-stream features:** Portions of the banks in the mitigated area are made of concrete. Majority of the banks are fairly stable and contain riprap of varying sizes. The stream contains a culvert.

**Sediment/substrate characteristics:** There is a moderate deposition of new gravel, sand and sediment on old and new bars, and around obstructions.

**Plan Comparison:**

This site is situated in a rural residential area in Greenup County. Stream modification was required for the relocation of KY 827 over Coal Branch. The project runs from Station 10 + 060 to Station 10 + 354 and includes 750 feet of 6-foot wide channel change and an 85-foot long culvert. The project required modification of a backward S-shaped stream. The stream runs parallel to KY 827, crosses under the KY 827, and then parallels the road again running between KY 827 and the access road (Figure 29).

Approximately 500 feet before the start of the project, the stream is joined by another stream that passes through a cavern. The resident living next to this cavern has used it to store various types of machinery.

**Revegetation:** The area was seeded. However, grasses along the highway are growing better than the grasses along the access road.

### 4.5.2 Chemical Data

"Results for water Quality measurement are given in Table 10 and were similar for all three sampling stations, except for a slight increase in conductivity from the upstream to the downstream station. There was a significant decrease in total suspended solids, hardness and alkalinity from the upstream to the downstream station. Due to sample clarity, settleable solids were not measurable. Low-flow conditions prevented reliable measurements of stream discharge. Samples were measured using the following equipment: Dissolved Oxygen (DO) YSI Model 51A oxygen meter, (pH) Orion SA 250 pH meter, Conductivity Amber Science Model 604 conductivity meter.

Table 9. Chemical data for Coal Branch, Greenup County, KY on 7/9/99.

| Site 5: COAL BRANCH | | Upstream | Remediated Area | Downstream |
|---|---|---|---|---|
| LAB TESTS | TSS/L (g) | 0.345 | .359 | .361 |
| | Hardness (mg CaCO3/L) | 467 | 473 | 480 |
| | Alkalinity (mg/L) | 147 | 128.6 | 132 |
| FIELD TESTS | Temperature (C) | 33.9 | 34.4 | 32.9 |
| | pH | 8.1 | 8.0 | 7.4 |
| | Conductivity(μmhos/cm) | 376 | 296 | 851 |
| | Dissolved Oxygen(mg/L) | 8.4 | 9.01 | 5.52 |

### 4.3.3 Biological Data and Assessment.

Minnows, snails and worms were readily observed at the lower reaches of the stream (Figure 5).

**Habitat Assessment:**

Habitat Assessment scores for Coal Branch are presented in Table 9. The scores for all three stations were very similar.

Each habitat parameter is put into a condition category based on its score. Parameters with 0-5 point are rated poor, while scores between 6-10 are marginal, scores between 11-15 are suboptimal, and scores between 16-20 are optimal.

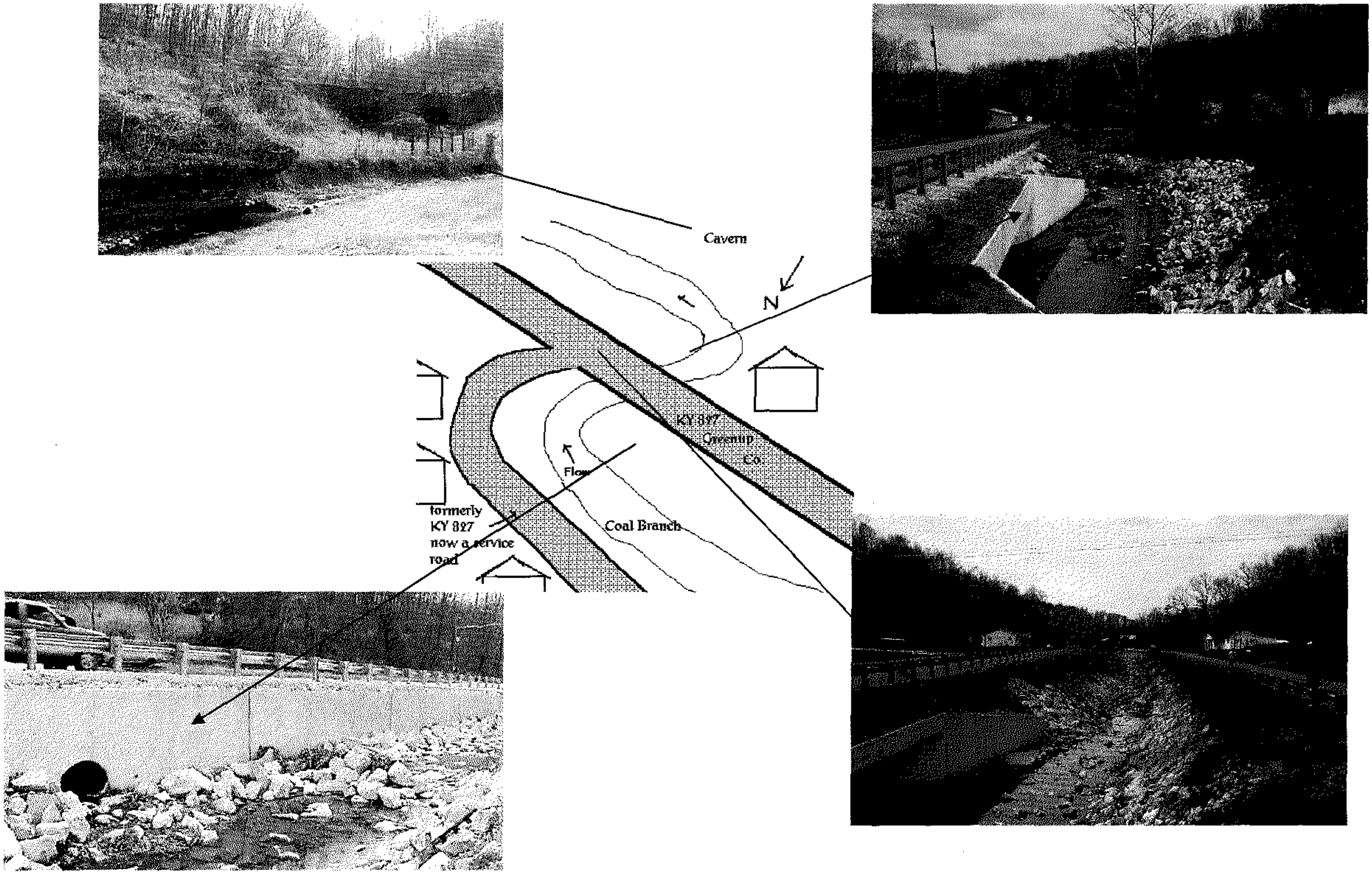



**Figure 29 Conceptual drawing and photographs of KY 827, Coal Branch, Greenup County.**

Table 10. Habitat Assessment Scores for Coal Branch, Greenup County, KY

| | Habitat Parameter | Stations | | | | | |
|---|---|---|---|---|---|---|---|
| | | Upstream | | Remediated | | Downstream | |
| | | Score | Category | Score | Category | Score | Category |
| 1 | Epifaunal Substrate/Available Cover | 18 | Optimal | 3 | Poor | 3 | Marginal |
| 2 | Embeddedness | 17 | Optimal | 8 | Marginal | 8 | Marginal |
| 3 | Velocity/Depth Regime | 7 | Marginal | 6 | Marginal | 7 | Marginal |
| 4 | Sediment Deposition | 17 | Optimal | 8 | Marginal | 8 | Marginal |
| 5 | Channel Flow Status | 3 | Poor | 3 | Poor | 3 | Poor |
| 6 | Channel Alteration | 18 | Optimal | 8 | Marginal | 14 | Suboptimal |
| 7 | Frequency of Riffles | 15 | Suboptimal | 13 | Suboptimal | 13 | Suboptimal |
| 8a | Bank Stability-left bank | 9 | Optimal | 9 | Optimal | 9 | Optimal |
| 8b | Bank Stability-right bank | 9 | Optimal | 9 | Optimal | 9 | Optimal |
| 9a | Vegetative Protection-left bank | 9 | Optimal | 1 | Poor | 1 | Poor |
| 9b | Vegetative Protection-right bank | 9 | Optimal | 1 | Poor | 1 | Poor |
| 10a | Riparian Vegetative Zone Width-left bank | 9 | Optimal | 1 | Poor | 1 | Poor |
| 10b | Riparian Vegetative Zone Width-right bank | 9 | Optimal | 1 | Poor | 1 | Poor |
| | Total IBI Score = | 132 | | 71 | | 78 | |

**Riparian Vegetation Assessment:**

Forester Floyd Willis, State's Division of Forestry-Morehead field office, identified an extensive variety of native trees, shrubs and grasses in the upstream, undisturbed area. However, the riparian vegetation in the remediated and downstream areas consisted only of seeded grass. In the remediated area, the grasses are not very abundant. Mr. Willis recommended planting black willow, sycamore, silver maple trees in similar areas.

# 5.0 SUMMARY AND CONCLUSIONS

The state of Kentucky is second only to Alaska in the number of miles of waterways that it contains. Therefore, transportation projects in Kentucky often require relocation of a stream or other body of water. When a body of water must be relocated, federal law requires that the changes be equal to or better than before. This process is referred to as mitigation.

In order to better mitigate the impacts of highway construction in the future, it is important to determine how well the process is currently working. To date, no studies have been made in Kentucky to assess the execution of the mitigation plans or to determine the performance of mitigation projects. In a move to rectify this situation the Kentucky Transportation Cabinet requested this study.

## 5.1 SUMMARY

Determining whether current mitigation processes are effective is at the core of this research report. The ideal situation for determining whether stream mitigation efforts were successful would be comparison of "before" mitigation data to "after" mitigation data. However, the "before" data for these five sites was very sketchy. There was no chemical data, no biological data and very sketchy physical data. Therefore the research team determined that the best way to determine whether the mitigation was successful was to use a biogeochemical approach.

A biogeochemical approach includes measurements of physical, chemical and biological processes. Measurements were recorded at the influx (upstream), inside the mitigated area, and at the outflux (downstream) of the stream five years after mitigation was completed. The Study Advisory Committee (SAC) selected the sites.

The physical descriptions were based on existing conditions and compared to the few design details that were available from the Kentucky Transportation Cabinet

The chemical descriptions were based on water samples that were tested on-site and samples taken back to the laboratory. The Biology Department of the University of Kentucky took their own samples of the two largest streams and their on-site and lab results were similar to the results obtained by the Research team and from the Civil Engineering Environmental lab. The chemical data for Cedar Creek 1 and Holts Creek are from the Biology Department.

The biological descriptions were based on Habitat Assessments and tree identification in the mitigated area. Fish collection and identification were also included for Cedar Creek1 and Holts Creek.

Habitat assessments are somewhat subjective as they are based on observations. If one person evaluates all the sites then their evaluations are most likely consistent and overtime an expertise is developed. However, the research team determined that evaluation of only five sites would not be sufficient to develop an expertise. To increase the expertise two of the researchers (Bernadette Dupont and Sudhir Palle) attended a Habitat Assessment class that was conducted by the Department of Environmental Analysis. To minimize subjectivity the same two researchers evaluated the streams and recorded their scores independently. They then conferred on each parameter to attain a final score. All the parameter scores were added together to obtain a final habitat assessment score for the site. This score was then used to determine whether the physical habitat supported the biological integrity of the stream.

Tree identification was conducted with the aid of the State Forestry Department. Several different field officers went with the research team to identify the trees in the mitigated area.

In an ecosystem everything is interwoven and often one piece of the puzzle depends on the other. Evaluation of stream mitigation projects isn't much different. As evidenced from this report interagency consultation was key in determining the success of a project. No one team had all the answers. Expertise was called on from many different departments and all made significant contributions to the overall result.

## 5.2 CONCLUSIONS

A comprehensive look at the physical, chemical, and biological data (if available) provided an indication of the degree of success for each stream. The following tables provide a synopsis of the parameters and indicate the degree of success for each stream.

### 5.2.1 Site 1 – Cedar Creek1

Table 11 combines physical, chemical and biological data to give an overall picture of the mitigated site.

Table 11. Overall picture of Cedar Creek1.

| | Site 1: CEDAR CREEK1 | | Upstream | Remediated Area | Downstream |
|---|---|---|---|---|---|
| Physical | PLAN COMPARISON | | N/A | Adheres | N/A |
| Chemical | LAB TESTS | TSS/L (mg/l) | 0.264 | 0.565 | 0.041 |
| | | Hardness (mg CaCO3/L) | 671 | 597 | 578 |
| | | Alkalinity (mg/L) | 199 | 149.4 | 156.8 |
| | FIELD TESTS | Temperature (C) | 30.8 | 30.8 | 30.8 |
| | | pH | 7.2 | 7.4 | 7.4 |
| | | Conductivity(□mhos/cm) | 0.733 | 0.481 | 0.826 |
| | | Dissolved Oxygen(mg/L) | 6.83 | 7.10 | 7.82 |
| Biological | HABITAT ASSESSMENT | | 132 | 71 | 78 |
| | IBI (Fish) | | N/A | N/A | N/A |

The physical data indicates adherence to the mitigation plan. There are over 300 healthy trees planted in the area, however they are too small to provide any vegetative protection.

The chemical data indicates that the remediated site has a lower hardness, alkalinity and slightly higher pH. This could indicate an influx of additional water from somewhere else.

The biological data was limited to a habitat assessment for this site. However, the overall score gives a good indication that the mitigated site is far from the Optimal score of 200. This area is in the lower half of the Marginal condition category.

It was determined that the mitigation plans for Cedar Creek1 were adequate. The mitigation project was properly constructed and was performing properly. The ripple habitat could be improved by introducing some gravel. The most apparent deficiency was insufficient protective and riparian vegetation.

### 5.2.2 Site 2 – Cedar Creek2

Table 12 combines physical, chemical and biological data to give an overall picture of the mitigated site.

Table 12. Overall picture of Cedar Creek2.

| | Site 2: CEDAR CREEK2 | | Upstream | Remediated Area | Downstream |
|---|---|---|---|---|---|
| Physical | PLAN COMPARISON | | N/A | Adheres | N/A |
| Chemical | LAB TESTS | TSS/L (mg/l) | 0.24 | 1.15 | 4.41 |
| | | Hardness (mg CaCO3/L) | 174 | 194 | 244 |
| | | Alkalinity (mg/L) | 172 | 176 | 168 |
| | FIELD TESTS | Temperature (C) | 19.1 | 18.0 | 19.0 |
| | | pH | 7.60 | 7.85 | 7.76 |
| | | Conductivity(□mhos/cm) | 0.372 | 0.386 | 0.405 |
| | | Dissolved Oxygen(mg/L) | 11.9 | 12.3 | 11.8 |
| Biological | HABITAT ASSESSMENT | | 136 | 96 | 136 |
| | IBI (Fish) | | 54 | 54 | 50 |

The physical data indicates adherence to the mitigation plan. The chemical data indicates a slight increase in the hardness and total suspended solids.

The biological data included both a habitat assessment and an IBI for this site. Paraphrasing the Biology team report, "the Habitat Assessment indicates a decrease in the condition at the mitigated site but it recovers at the downstream site. This is most likely due to reduced vegetation in the mitigated site. The IBI indicates a slight decrease in the downstream IBI score, but it still remains in the Good category. This decrease is because there were more centerarchids and less darters in the area, which is probably habitat related. Rip rap is also less suitable Overall there is no significant change in the biological data. (20, p. 6)

It was determined that the mitigation plans for Cedar Creek2 were adequate. The mitigation project was properly constructed and was performing properly. "There was no apparent blockage of fish migration potential or macroinvertibrate drift (20, p. 9)." The ripple habitat could be improved by introducing some gravel. The most apparent deficiency was insufficient protective and riparian vegetation.

### 5.2.3 Site 3 – Doctors Fork

Table 13 combines physical, chemical and biological data to give an overall picture of the mitigated site.

Table 13. Overall picture of Doctors Fork.

| | Site 3: DOCTORS FORK | | Upstream | Remediated Area | Downstream |
|---|---|---|---|---|---|
| Physical | PLAN COMPARISON | | N/A | Adheres | N/A |
| Chemical | LAB TESTS | TSS/L (mg/l) | 0.427 | 0.228 | 0.112 |
| | | Hardness (mg CaCO3/L) | 203 | 246 | 124 |
| | | Alkalinity (mg/L) | 74.6 | 97 | 59.4 |
| | FIELD TESTS | Temperature (C) | 33 | 33 | 33 |
| | | PH | 7.1 | 7.3 | 7.25 |
| | | Conductivity(μmhos/cm) | 0.276 | 0.265 | 0.284 |
| | | Dissolved Oxygen(mg/L) | 8.1 | 7.5 | 7.9 |
| Biological | HABITAT ASSESSMENT | | 81 | 74 | 132 |
| | IBI (Fish) | | N/A | N/A | N/A |

The physical data indicates adherence to the mitigation plan. The chemical data indicates an increase in alkalinity in the mitigated area and then a decrease in the downstream area. The hardness increases in the mitigated area and then decreased in the downstream area. This oddity might be contributed to runoff from the adjacent farmland.

The biological data was limited to a habitat assessment for this site. However, the overall score gives a good indication that the mitigated site is far from the Optimal score of 200. This area is in the lower half of the Marginal condition category.

It was determined that the mitigation plans for Doctor's Fork were adequate. The mitigation project was properly constructed and was performing properly. However, the mitigation site looks completely manmade and relatively little effort has been made to restore the stream to its original condition. The ripple habitat could be improved by introducing some gravel along with the riprap. The most apparent deficiency was insufficient protective and riparian vegetation.

### 5.2.4 Site 4 – Holts Creek

Table 14 combines physical, chemical and biological data to give an overall picture of the mitigated site.

Table 14. Overall picture of Holts Creek.

| | Site 4: HOLTS CREEK | | Upstream | Remediated Area | Downstream |
|---|---|---|---|---|---|
| Physical | PLAN COMPARISON | | N/A | Adheres | N/A |
| Chemical | LAB TESTS | TSS/L (mg/l) | 112 | 0.359 | 0.361 |
| | | Hardness (mg CaCO3/L) | 288 | 272 | 268 |
| | | Alkalinity (mg/L) | 216 | 204 | 192 |
| | FIELD TESTS | Temperature (C) | 20.4 | 20.4 | 20.4 |
| | | PH | 7.75 | 7.56 | 7.66 |
| | | Conductivity(□mhos/cm) | 0.540 | 0.528 | 0.536 |
| | | Dissolved Oxygen(mg/L) | 11.6 | 9.8 | 8.4 |
| Biological | HABITAT ASSESSMENT | | 112 | 77 | 108 |
| | IBI (Fish) | | 50 | 50 | 40 |

The physical data indicates adherence to the mitigation plan. The chemical data indicates a slight increase in the hardness and total suspended solids.

The biological data included both a habitat assessment and an IBI for this site. The Biology team report states that, "the Habitat Assessment indicates a lower score for the remediated site. Several factors contributed to the lower score for the remediated site and included the velocity/depth regime, habitat riffles, left bank stability, and left bank vegetation. Also low frequency of riffles and lack of bank stability produced a lower score for the remediated site. A decrease in the total habitat score was observed at the remediated site, followed by an increase at the downstream station. The IBI scores were good for both the upstream and the remediated sampling sites. However, the downstream site scored only Fair. The lower score resulted primarily because of 1) a lesser number of fish species, 2) lower proportion of sunfish, and 3) reduced abundance. There results were attributed to less habitat diversity."(20, p. 7)

It was determined that the mitigation plans for Holt's Creek were inadequate. The mitigation project failed to perform properly as there is evidence of severe erosion and channeling. Native vegetation is making a comeback along the stream banks as it was not completely removed. The ripple habitat could be improved by introducing some gravel along with the riprap, and having varying sizes of riprap. The most apparent deficiency was poor bank stability.

### 5.2.5 Site 5 – Coal Branch

Table 15 combines physical, chemical and biological data to give an overall picture of the mitigated site.

Table 15. Overall picture of Coal Branch.

| | Site 5: COAL BRANCH | | Upstream | Remediated Area | Downstream |
|---|---|---|---|---|---|
| Physical | PLAN COMPARISON | | N/A | Adheres | N/A |
| Chemical | LAB TESTS | TSS/L (mg/l) | 0.345 | 0.359 | 0.361 |
| | | Hardness (mg CaCO3/L) | 467 | 473 | 480 |
| | | Alkalinity (mg/L) | 147 | 128.6 | 132 |
| | FIELD TESTS | Temperature (C) | 33.9 | 34.4 | 32.9 |
| | | PH | 8.1 | 8.0 | 7.4 |
| | | Conductivity(□mhos/cm) | 0.376 | 0.296 | 0.851 |
| | | Dissolved Oxygen(mg/L) | 8.4 | 9.01 | 5.52 |
| Biological | HABITAT ASSESSMENT | | 132 | 71 | 78 |
| | IBI (Fish) | | N/A | N/A | N/A |

The physical data indicates adherence to the mitigation plan. The chemical data indicates a lower quality of water in the downstream area. The conductivity of the water in the downstream area is significantly increased and indicates a high salt content. The higher conductivity could be the result of a leakage from a salt pile, but it should be watched as there is a is a limited range of salt tolerance within a stream system. The pH and the alkalinity are both elevated in the downstream area. The DO level is also lower in the downstream area. These factors all indicate a lower quality of water. This could be because the water samples were taken during the summer when bacteria levels are increased. However, there could be other contributing factors such as waste dumping as this area is adjacent to a residence.

The biological data was limited to a habitat assessment for this site. However, the overall score gives a good indication that the mitigated site is far from the Optimal score of 200. This area is in the lower half of the Marginal condition category.

It was determined that the mitigation plans for Coal Branch were inadequate. The mitigation project was properly constructed and was performing properly, however, the stream system is unstable. This is probably due to channelizing and dredging the stream channels. The mitigation site looks completely manmade and relatively little effort has been made to restore the stream to its original condition. The ripple habitat could be improved by introducing some gravel along with the riprap. The most apparent deficiency was insufficient protective and riparian vegetation.

# 6.0 RECOMMENDATIONS

Evaluation of stream corridor restoration projects is not simple. Before a project starts it is important to determine the local conditions, (i.e. how much water the stream contains, when the water is flowing, etc.), so that stream mitigation efforts can handle the existing conditions. Gathering information about the kinds of soils and alluvial features within the channel and in the surrounding areas will help determine what processes will effect the stream channel. Chemical data is of primary concern as it is critical to sustaining life within the stream. The amount and variety of information about the living organisms that are associated with the stream system indicate the viability of a stream. Evaluating stream mitigation projects is not simple but it is important.

Not all projects can be evaluated in great detail, as funding and available personnel are limited. Therefore it is important to develop best practices, establish a consistent evaluation method, and utilize time saving tools when evaluating stream mitigation projects. Listed below are several recommendations for conducting future evaluations of stream mitigation projects.

1. Gather More Data. It was obvious from the beginning that more information would have been beneficial in evaluating each stream mitigation project. Data should be gathered for physical, chemical and biological processes. It should be gathered

   a). before the start of the project to establish conditions before construction;
   b). immediately after the completion of the project; (This establishes exactly what was done and what was planted, as sometimes the final product differs from the original plan.); and
   c). several years after the completion of the project. (In this case five years was the selected time period.)

2. Interagency Consultation. In an ecosystem everything is interwoven and often one piece of the puzzle depends on the other. Evaluation of stream mitigation projects isn't much different. As evidenced in this report, interagency consultation was key in determining the success of a project. No one team had all the answers. Expertise was called on from many different areas and all made significant contributions to the overall result. To conduct a complete and thorough evaluation, many experts would be needed to form the interagency team. The team would consist of the following:

   - Project Manager.
   - Field/Habitat Assessment Team.
   - Lab Technician.
   - Forester, Botonist, and/or Horticulturist.
   - Shocking and Seining Team.
   - Fish Identification Expert.

3. Field Handbook. Use the newly developed waterproof, field handbook to collect data. This handbook contains the following:

   a). List of equipment. Includes a complete list of equipment required to do the job.
   b). General Information sheet. Includes a table to record general information and a space to sketch a picture of the stream.
   c). Influx Data Sheet. Includes brief instructions, a table to log stream profile data, and a table to log chemical data gathered in the field.
   d). Habitat Assessment Sheets - Influx. Includes the EPA Habitat Assessment sheets for determining overall condition of the stream.
   e). Riparian Vegetation Sheet – Influx. Includes a checklist of common trees, shrubs and grasses used at mitigated sites.
   f). Mitigated Data Sheet. Includes brief instructions, a table to log stream profile data, and a table to log chemical data gathered in the field.
   g). Habitat Assessment Sheets - Mitigated. Includes the EPA Habitat Assessment sheets for determining overall condition of the stream.
   h). Riparian Vegetation Sheet – Mitigated. Includes a checklist of common trees, shrubs and grasses used at mitigated sites.
   i). Outflux Data Sheet. Includes brief instructions, a table to log stream profile data, and a table to log chemical data gathered in the field.
   j). Habitat Assessment Sheets - Outflux. Includes the EPA Habitat Assessment sheets for determining overall condition of the stream.
   k). Riparian Vegetation Sheet – Outflux. Includes a checklist of common trees, shrubs and grasses used at mitigated sites.

# 7.0 REFERENCES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# APPENDIX A – Habitat Assessment Survey Sheets

## INTENSIVE BIOSURVEY: HABITAT ASSESSMENT

Stream Name: ____________________

County: ____________ State: ____________

Investigators: ____________________

____________________

____________________

Site (description): ____________________

____________________

____________________

____________________

Latitude: ____________ Longitude: ____________

Site or Map Number: ____________________

Date: ____________ Time: ____________

**Weather in past 24 hours:**

- ❑ Storm (heavy rain)
- ❑ Rain (steady rain)
- ❑ Showers (intermittent rain)
- ❑ Overcast
- ❑ Clear/Sunny

**Weather now:**

- ❑ Storm (heavy rain)
- ❑ Rain (steady rain)
- ❑ Showers (intermittent rain)
- ❑ Overcast
- ❑ Clear/Sunny

# Sketch of site

On your sketch, note features that affect stream habitat, such as: riffles, runs, pools, ditches, wetlands, dams, riprap, outfalls, tributaries, landscape features, logging paths, vegetation, and roads.

## GENERAL CHARACTERISTICS

**1. Water appearance:** Page 92

| | | |
|---|---|---|
| θ Clear | θ Turbid | θ Orange |
| θ Milky | θ Dark brown | θ Greenish |
| θ Foamy | θ Oily sheen | θ Other ____________ |

**2. Water odor:** Page 92

| | | |
|---|---|---|
| θ Sewage | θ Fishy | θ None |
| θ Chlorine | θ Rotten eggs | θ Other |

**3. Water temperature:** Page 92

________ °C *or* ________ °F

**4. Approximate width of stream channel:** Page 93

________ feet θ Measured θ Estimated

## LOCAL LAND USE

*(within about 1/4 mile of the site; adjacent and upstream)*

**5. Land uses in the local watershed can potentially have an impact on a stream.** Check "1" if present, "2" if clearly having an impact on the stream. Page 93

| 1 | 2 | |
|---|---|---|
| **1** | **2** | **Residential** |
| θ | θ | Single-family housing |
| θ | θ | Multifamily housing |
| θ | θ | Lawns |
| θ | θ | Commercial/institutional |
| **1** | **2** | **Roads, etc.** |
| θ | θ | Paved roads or bridges |
| θ | θ | Unpaved roads |
| **1** | **2** | **Construction underway on:** |
| θ | θ | Housing development |
| θ | θ | Commercial development |
| θ | θ | Road bridge construction/repair |
| **1** | **2** | **Agricultural** |
| θ | θ | Grazing land |
| θ | θ | Feeding lots or animal holding areas |
| θ | θ | Cropland |
| θ | θ | Inactive agricultural land/fields |
| **1** | **2** | **Recreation** |
| θ | θ | Power boating |
| θ | θ | Golfing |
| θ | θ | Camping |
| θ | θ | Swimming/fishing/canoeing |
| θ | θ | Hiking/paths |
| **1** | **2** | **Other** |
| θ | θ | Mining or gravel pits |
| θ | θ | Logging |
| θ | θ | Industry |
| θ | θ | Oil and gas drilling |
| θ | θ | Trash dump |
| θ | θ | Landfills |

**HABITAT ASSESSMENT FIELD DATA SHEET** *ROCKY BOTTOM SAMPLING*

| Habitat Parameter | Category | | | |
|---|---|---|---|---|
| | Optimal | Suboptimal | Marginal | Poor |
| 1. Attachment Sites for Macro-invertebrates<br>Page 93 | Well developed riffle and run; riffle is as wide as stream and length extends 2 times the width of stream; cobble predominates; boulders and gravel common. | Riffle is as wide as stream but length is less than 2 times width; cobble less abundant; boulders and gravel common. | Run area may be lacking; riffle not as wide as stream and its length is less than 2 times the stream width; gravel or large boulders and bedrock prevalent; some cobble present. | Riffles or run virtually nonexistent; large boulders and bedrock prevalent; cobble lacking. |
| SCORE ___ | 20 19 18 17 16 | 15 14 13 12 11 | 10 9 8 7 6 | 5 4 3 2 1 0 |
| 2. Embeddedness<br>Page 93 | Fine sediment surrounds and fills in 0-25% of the living spaces around and in between the gravel, cobble, and boulders. | Fine sediment surrounds and fills in 25-50% of the living spaces around and in between the gravel, cobble, and boulders. | Fine sediment surrounds and fills in 50-75% of the living spaces around and in between the gravel, cobble, and boulders. | Fine sediment surrounds and fills in more than 75% of the living spaces around and in between the gravel, cobble, and boulders. |
| SCORE ___ | 20 19 18 17 16 | 15 14 13 12 11 | 10 9 8 7 6 | 5 4 3 2 1 0 |
| 3. Shelter for Fish<br>Page 93 | Snags, submerged logs, undercut banks, cobble and large rocks, or other stable habitat are found in over 50% of the site. | Snags, submerged logs, undercut banks, cobble and large rocks, or other stable habitat are found in over 30-50% of the site. | Snags, submerged logs, undercut banks, cobble and large rocks, or other stable habitat are found in over 10-30% of the site. | Snags, submerged logs, undercut banks, cobble and large rocks, or other stable habitat are found in less than 10% of the site. |
| SCORE ___ | 20 19 18 17 16 | 15 14 13 12 11 | 10 9 8 7 6 | 5 4 3 2 1 0 |
| 4. Channel Alteration<br>Page 93 | Stream straightening, dredging, artificial embankments, dams or bridge abutments absent or minimal; stream with meandering pattern. | Some stream straightening, dredging, artificial embankments or dams present, usually in areas of bridge abutments; no evidence of recent channel alteration activity. | Artificial embankments present to some extent on both banks; and 40 to 80% of stream site straightened, dredged, or otherwise altered. | Banks shored with gabion or cement; over 80% of the stream site straightened and disrupted. |
| SCORE ___ | 20 19 18 17 16 | 15 14 13 12 11 | 10 9 8 7 6 | 5 4 3 2 1 0 |
| 5. Sediment Deposition<br>Page 94 | 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 coarse gravel; 5-30% of the bottom affected; slight deposition in pools. | Moderate deposition of new gravel, coarse sand on old and new bars; 30-50% of the bottom affected; sediment deposits at stream obstructions and bends; moderate deposition in pools. | Heavy deposits of fine material, increased bar development; more than 50% of the bottom affected; pools almost absent due to substantial sediment deposition. |
| SCORE ___ | 20 19 18 17 16 | 15 14 13 12 11 | 10 9 8 7 6 | 5 4 3 2 1 0 |

| Habitat Parameter | Category | | | |
|---|---|---|---|---|
| | Optimal | Suboptimal | Marginal | Poor |
| 6. Stream Velocity and Depth Combinations<br>Page 94 | Slow (< 1 ft/s)/deep (> 1.5 ft); slow/shallow; fast/deep; fast/shallow combinations all present. | 3 of the 4 velocity/depth combinations are present; fast current areas generally dominate. | Only 2 of the 4 velocity/depth combinations present. Score lower if fast current areas missing. | Dominated by 1 velocity/depth category (usually slow/shallow areas). |
| SCORE ___ | 20 19 18 17 16 | 15 14 13 12 11 | 10 9 8 7 6 | 5 4 3 2 1 0 |
| 7. Channel Flow Status<br>Page 94 | Water reaches base of both lower banks and minimal amount of channel substrate is exposed. | Water fills >75% of the available channel; <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 ___ | 20 19 18 17 16 | 15 14 13 12 11 | 10 9 8 7 6 | 5 4 3 2 1 0 |
| 8. Bank Vegetative Protection (score each bank)<br>Page 95<br>Note: determine left or right side by facing downstream | More than 90% of the streambank surfaces covered by natural vegetation, including trees, shrubs, or other plants; 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 natural vegetation, but one class of plants is not well-represented; some vegetative disruption evident; more than one-half of the potential plant stubble height remaining. | 50-70% of the streambank surfaces covered by vegetation; 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 2 inches or less in average stubble height. |
| SCORE ___ (LB) | Left Bank 10 9 | 8 7 6 | 5 4 3 | 2 1 0 |
| SCORE ___ (RB) | Right Bank 10 9 | 8 7 6 | 5 4 3 | 2 1 0 |
| 9. Condition of Banks (score each bank)<br>Page 95 | Banks stable; no evidence of erosion or bank failure; little potential for future problems. | Moderately stable; infrequent, small areas of erosion mostly healed over. | Moderately unstable; up to 60% of banks in site have areas of erosion; high erosion potential during floods. | Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank collapse or failure; 60-100% of bank has erosional scars. |
| SCORE ___ (LB) | Left Bank 10 9 | 8 7 6 | 5 4 3 | 2 1 0 |
| SCORE ___ (RB) | Right Bank 10 9 | 8 7 6 | 5 4 3 | 2 1 0 |
| 10. Riparian Vegetative Zone Width (score each bank riparian zone)<br>Page 95 | Width of riparian zone >50 feet; no evidence of human activities (i.e., parking lots, roadbeds, clear cuts, mowed areas, or crops) within the riparian zone. | Width of riparian zone 35-40 feet. | Width of riparian zone 20-35 feet. | Width of riparian zone < 20 feet. |
| SCORE ___ (LB) | Left Bank 10 9 | 8 7 6 | 5 4 3 | 2 1 0 |
| SCORE ___ (RB) | Right Bank 10 9 | 8 7 6 | 5 4 3 | 2 1 0 |

| Habitat Parameter | Category | | | |
|---|---|---|---|---|
| | Optimal | Suboptimal | Marginal | Poor |
| 1. Shelter for Fish and Macro-invertebrates<br>Page 99 | Snags, submerged logs, undercut banks, rubble or other stable habitat found over 50% of the site, logs/snags are old fall. | Snags, submerged logs, undercut banks, rubble or other stable habitat found over 30-50% of the site; some old fall, but preponderance of new fall. | Snags, submerged logs, undercut banks, rubble or other stable habitat found over 10-30% of the site; appears unstable; some new fall. | Snags, submerged logs, undercut banks, rubble or other stable habitat found over less than 10% of the site; no old or new fall |
| SCORE ____ | 20 19 18 17 16 | 15 14 13 12 11 | 10 9 8 7 6 | 5 4 3 2 1 0 |
| 2. Pool Substrate Characterization<br>Page 100 | Pools have mixture of substrate materials, with gravel and firm sand prevalent; root mats and submerged vegetation common. | Pools have mixture of soft sand, mud, or clay substrate; mud may be dominant; some root mats and submerged vegetation present. | Pools have all mud or clay or sand substrate, little or no root mat; no submerged vegetation. | Pools have hard pan clay or bedrock substrate; no root mat or vegetation. |
| SCORE ____ | 20 19 18 17 16 | 15 14 13 12 11 | 10 9 8 7 6 | 5 4 3 2 1 0 |
| 3. Pool Variability<br>Page 100 | Even mix of large-shallow, large deep, small-shallow, small-deep pools. | Majority of pools large deep; very few shallow. | Shallow pools much more prevalent than deep pools. | Majority of pools small-shallow or pools absent. |
| SCORE ____ | 20 19 18 17 16 | 15 14 13 12 11 | 10 9 8 7 6 | 5 4 3 2 1 0 |
| 4. Channel Alteration<br>Page 100 | Stream straightening, dredging, artificial embankments, dams or bridge abutments absent or minimal; stream with meandering pattern. | Some stream straightening, artificial embankments or dams present, usually in areas of bridge abutments; no evidence of recent channel alteration activity. | Artificial embankments present to some extent on both banks; and 40 to 80% of stream site straightened, dredged, or otherwise altered. | Banks shored with gabion or cement; over 80% of the stream site straightened and disrupted. |
| SCORE ____ | 20 19 18 17 16 | 15 14 13 12 11 | 10 9 8 7 6 | 5 4 3 2 1 0 |
| 5. Sediment Deposition<br>Page 100 | Less than 20% of stream bottom affected by extensive sediment deposition; minor accumulation of fine and coarse material at snags and submerged vegetation; little or no enlargement of islands or point bars. | 20-50% of stream bottom affected by extensive sediment deposition; moderate accumulation; substantial sediment movement only during major storm event; some new increase in bar formation. | 50-80% of stream bottom affected by extensive sediment deposition; pools shallow, heavily silted; embankments may be present on both banks; frequent and substantial sediment movement during storm events. | Greater than 80% of stream bottom affected by extensive sediment deposition; Heavy deposits, mud, silt, and/or sand in braided or nonbraided channels; pools almost absent due to deposition. |
| SCORE ____ | 20 19 18 17 16 | 15 14 13 12 11 | 10 9 8 7 6 | 5 4 3 2 1 0 |
| 6. Channel Sinuosity<br>Page 100 | The bends in the stream would increase the stream length 3 to 4 times longer than it if was in a straight line. | The bends in the stream would increase the stream length 2 to 3 times longer than if it was in a straight line. | The bends in the stream would increase the stream length 2 to 1 times longer than if it was in a straight line. | Channel straight; waterway has been channelized. |
| SCORE ____ | 20 19 18 17 16 | 15 14 13 12 11 | 10 9 8 7 6 | 5 4 3 2 1 0 |

| Habitat Parameter | Category: Optimal | Suboptimal | Marginal | Poor |
|---|---|---|---|---|
| 7. Channel Flow Status <br> Page 100 | Water reaches base of both lower banks and minimal amount of channel substrate is exposed. | Water fills >75% of the available channel; <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 ____ | 20 19 18 17 16 | 15 14 13 12 11 | 10 9 8 7 6 | 5 4 3 2 1 0 |
| 8. Bank Vegetative Protection <br> Page 100 <br> Note: determine left or right side by facing downstream | More than 90% of the streambank surfaces 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; some vegetative disruption evident; more than one-half of the potential plant stubble height remaining. | 50-70% of the streambank surfaces covered by vegetation; 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 2 inches or less in average stubble height. |
| SCORE ____(LB) | Left Bank 10 9 | 8 7 6 | 5 4 3 | 2 1 0 |
| SCORE ____(RB) | Right Bank 10 9 | 8 7 6 | 5 4 3 | 2 1 0 |
| 9. Condition of Banks <br> Page 100 | Banks stable; no evidence of erosion or bank failure; little potential for future problems. | Moderately stable; infrequent, small areas of erosion mostly healed over. | Moderately unstable; up to 60% of banks in reach have areas of erosion; high erosion potential during floods. | Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank collapse or failure, 60-100% of bank has erosional scars. |
| SCORE ____(LB) | Left Bank 10 9 | 8 7 6 | 5 4 3 | 2 1 0 |
| SCORE ____(RB) | Right Bank 10 9 | 8 7 6 | 5 4 3 | 2 1 0 |
| 10. Riparian Vegetative Zone Width (score each bank riparian zone) <br> Page 100 | Width of riparian zone >50 feet; human activities (i.e. parking lots, roadbeds, clear cuts, lawns, or crops) have not affected riparian zone. | Width of riparian zone 35-40 feet. | Width of riparian zone 20-35 feet. | Width of riparian zone < 20 feet. |
| SCORE ____(LB) | Left Bank 10 9 | 8 7 6 | 5 4 3 | 2 1 0 |
| SCORE ____(RB) | Right Bank 10 9 | 8 7 6 | 5 4 3 | 2 1 0 |

Total Score ____

# HABITAT ASSESSMENT GUIDE

| Percent Similarity to Reference Score | Habitat Quality Category | General Attributes |
|---|---|---|
| > 90% | Excellent | Comparable to the best situation to be expected within an ecoregion. Excellent overall habitat structure conducive to supporting healthy biological community. |
| 75-88% | Good | Habitat structure slightly impaired. Diverse instream habitat generally well-developed. Some degradation of riparian zone and banks. A small amount of channel alteration may be present. |
| 60-73% | Fair | Loss of habitat compared to reference. Habitat is a major limiting factor to supporting a healthy biological community. |
| < 58% | Poor | Severe habitat alteration at all levels. |

NOTE: If your score falls between ranges consider the site's habitat assessment results and chemical data, if available, in making your decision.

## *Overall Assessment:*

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- ❑ Excellent
- ❑ Good
- ❑ Fair
- ❑ Poor

**COMMENTS:**

**APPENDIX B – School of Biological Sciences Report, UK**

# ASSESSMENT AND MODELING OF STREAM REMEDIATION PROCEDURES

## Project No. KYSPR-9-193

## Report To
## Kentucky Transportation Center

**David J. Price, Joseph R. Shaw, Julann A. Spromberg, Andrew Wigginton, Augus Sofyan, Greg Mayer and Wesley J. Birge**

**School of Biological Sciences**
**University of Kentucky**

**January 20, 2000**

## ASSESSMENT AND MODELING OF STREAM REMEDIATION PROCEDURES

### Project No. KYSPR-9-193

### INTRODUCTION

Two Kentucky streams were selected for habitat and fish bioassessments, including Cedar Creek and Holts Creek. Cedar Creek is located off KY 313 in Hardin County, KY (Figure 1) and Holts Creek is off AA Highway in Bracken County, KY (Figure 2). The streams were initially visited in March 26 and April 8, 1999 by both the Kentucky Transportation Center (KTC) and personnel from the University of Kentucky, School of Biological Sciences. During these reconnaissance trips, photographs and video were taken, monitoring sites were selected and the extent of work was determined. Habitat surveys and the Rapid Bioassessment Protocol (RBP) for monitoring fish assemblages were selected for use on these streams, according to guidelines presented by U.S. EPA (1999). RBP allowed the calculation of an Index of Biological Integrity (IBI). Stream physicochemical parameters included: stream characterization, watershed features, riparian vegetation, instream features, aquatic vegetation, water quality, sediment/substrate characteristics, and habitat assessments. General water quality monitoring also was included in the study plan (i.e. temperature, pH, conductivity, dissolved oxygen, alkalinity, hardness, total suspended solids, settleable solids). This study was based on a one-time survey of stream conditions in areas affected by highway construction.

### METHODS

#### Cedar Creek

Habitat assessments and fish sampling were conducted May 19, 1999 for Cedar Creek. Three collecting/monitoring stations (upstream, remediated area, and downstream) were identified within the stream system (Figures 3-8). These stream sectors were selected for optimum comparability and encompassed 100 river meters each. Karr *et al.* (1986) and U.S. EPA (1999) indicated that 100 meter reaches were sufficient for simple headwater streams. Surveyors flags were used to delineate the stream sections. Sampling stations were separated by 30.5-meter stream section.

#### Holts Creek

Habitat assessments and fish sampling were conducted May 26, 1999 for Holts Creek. As with Cedar Creek, three collecting/monitoring stations (upstream, remediated area, and downstream) were identified within the stream system (Figures 9-14). Site selections also were similar to the methods used for Cedar Creek, as described above. Habitat assessments were performed according to guidelines presented by U.S. EPA

(1999). Field data sheets for habitat assessment and physicochemical characterization were reproduced from U.S. EPA (1999, Appendix A-1; Form 1) and completed along with photographs and video of the sites.

As noted above, on-site water quality parameters also were measured during the collections, including temperature, pH, conductivity, and dissolved oxygen. Measurements were performed with a digital thermometer, an Orion SA 250 pH meter, an Amber Science Model 604 conductivity meter, and an YSI Model 51A oxygen meter. Additional water samples were returned to the lab for measurements of alkalinity, hardness, total suspended solids, and settleable solids using procedures described in Standard Methods (APHA, 1995).

**Fish Collections**

Fish were collected using a combination of electro-shocking (i.e. backpack elecrofisher, Smith-Root, Inc.) and block-seining for both stream systems. The electro-shocking collections were limited to 1 hour per station to provide a standardized catch per unit of effort. Collected fish were held in aerated buckets for identification, enumeration, and fish length measurements. Species that could not be identified in the field were preserved with 10% formalin and stored until laboratory identifications could be made. Remaining fish were returned to the stream after all collections were completed. Fish identifications were performed according to keys and descriptions found in Clay (1962), Eddy and Underhill (1978), Kuehne and Barbour (1983), and The Audubon Society (1988). Fish scoring criteria were based on methods given by U.S. EPA (1999) and Karr *et al.* (1986). Fish collections were initiated at the downstream boundary and proceeded upstream (Figure 3).

## RESULTS AND CONCLUSIONS

### Cedar Creek

#### A. Site Description

The geographic location of Cedar Creek is shown in Figure 1, whereas sampling stations and characteristics are presented in Figures 3 through 8. Although there were 11 unnamed tributaries that drained into Cedar Creek, the stream area sampled was characteristic of a first-order systems. The upstream site contained riffle, run and pool areas (Figure 3) and low-flow conditions were evident (Figure 4). The remediated site contained a pool, bridge abutments, and a modified riffle-run area that was restructures in part with riprap. This site also received a small unnamed tributary (Figures 5, 6). The site located downstream of the remediated sector was less channelized; contained somewhat more riffle habitat, and exhibited increased flow due to a second unnamed tributary.

#### B. Water Quality

Results from water quality measurements are given in Table 1 and were similar for all three sampling stations, except for a slight increase in hardness and total suspended solids from the upstream to the downstream station. Due to sample clarity, settleable solids were not measurable. Low-flow conditions prevented reliable measurements of stream discharge.

#### C. Habitat Assessment

Habitat assessment scores for Cedar Creek are presented in Table 2. A decrease in total IBI habitat score was observed at the remediated site, followed by recovery at the downstream site. The remediated station at Cedar Creek had a lower assessment value primarily due to reduced vegetative protection along both banks (Metrics 9a, 9b) and poor riparian vegetative zones. The presence of riprap along the banks (Figure 6) also reduced the score for channel alteration (Metrics 10a, 10b).

#### D. Fish Bioassessment

Number of fish species found at Cedar Creek are listed in Table 3. Length measurements were taken for all fish collected and are presented for the three stations in Tables 4 through 6. Scoring criteria selected for IBI determinations are presented in Table 7. Two alternate IBI metrics were selected to better represent the stream system and these included criterion 4 (number of minnow species) and criterion 8 (proportion of insectivore species). In addition, criterion 9 (proportion of top carnivores) was modified to include both piscivores and insectivores. From the IBI scores for Cedar Creek (Table 8) it was determined that the stations were all in the Good category. Nevertheless, values for abundance fluctuated among stations (Table 3). As might be expected, cyprinids increased in abundance with downstream progression. However, more centrarchids but fewer darters occurred within the remediated sector and these events probably were habitat related. The riprap added to the stream channel likely attracted more bass and sunfish but was less suitable for darters. The riprap also may have accounted for the higher frequency of larger cyprinids and centrarchids, based on length measurements (Tables 4-6).

Although the remediated stream sector scored lowest for habitat quality due to less vegetative protection and less developed riparian zones (Table 2), the IBI scores revealed no significant differences with respect to fish metrics and the scores ranged from 50 to 54 (Table 2). The highest metric scores for the remediated zone were 1) number of sunfish, 2) proportion of top carnivores and green sunfish, and 3) total number of species. The lowest scores were for 1) proportions of insectivorous species and 2) total numbers of individuals. Habitat zones for the downstream site are illustrated in Figures 7 and 8.

**Holts Creek**

**A. Site Description**

The geographic location of Holts Creek is shown in Figure 2 and monitoring stations selected for study are given in Figures 9-14. This was a larger, second-order stream system with a lower gradient than observed for Cedar Creek. In addition, there was a higher ratio of pool to riffle habitat, especially at the remediated and downstream monitoring stations (Figures 11-14). The former contained a considerable proportion of riprap below a well developed pool (Figure 11). The upstream study area included a large shallow pool and considerable rocks and cobble in the run below. Riffle structure was less well developed.

**B. Water Quality**

Temperature, pH, and conductivity were constant for the three monitoring stations. However, dissolved oxygen, alkalinity and hardness were somewhat higher at the upstream station and total suspended solids were appreciably higher (Table 9).

**C. Habitat Assessment**

Habitat assessment scores for Holts Creek are presented in Table 10 and were 112, 77, and 108 at upstream, remediated, and downstream sites, respectively. Factors that contributed to the lower score for the remediated site included the velocity/depth regime, habitat riffles, left bank stability and left bank vegetation (i.e. Metrics 3, 7, 8a, 9a in Table 10; Figures 11, 12). For Holts Creek, the low frequency of riffles and lack of bank stability (Figure 12) produced the lesser scores for the remediated site, while the other metrics were in the marginal range. A decrease in the total habitat score was observed at the remediated site, followed by an increase at the downstream station.

**D. Fish Bioassessment**

Number of fish species found at Holts Creek are given in Table 11 and length measurements are presented in Tables 12 through 14. Scoring criteria selected for IBI determinations for Holts Creek are presented in Table 15. As with Cedar Creek, two alternate IBI metrics were selected to better represent the stream system and included criterion 4 (number of minnow species) and criterion 8 (proportion of insectivore species). In addition, criterion 9 (proportion of top carnivores) was modified to include both piscivores and insectivores. Fish abundance (Table 11) was appreciably higher for the remediated site, and this likely was due, in part, to the expansive pool development (Figure 10). Minnows, sunfish, and the rainbow darter mostly accounted for this increase. Major habitat modifications in this area included installation of a culvert over the tributary to Holts Creek and considerable riprap downstream of the pool (Figures 10, 11, 12). Rainbow darters were most abundant in the riffle area above the pool and the riprap below, whereas sunfish were concentrated mainly within the pool.

IBI values for Holts Creek are presented in Table 16, and Good scores were observed for both the upstream and the remediated sampling sites. However, the downstream site scored only Fair. The lower score resulted primarily because of 1) a lesser number of fish species, 2) lower proportion of sunfish, and 3) reduced abundance (i.e. Metrics 1, 6, 10 in Table 16; Figures 13, 14). These results were attributed to less habitat diversity. The downstream site was mainly a pool with top carnivores present, which may have accounted for the decrease in total number of species. Predominant fish species with habitat preferences are presented in Table 15. These taxa are typical of small stream systems in central Kentucky.

## CONCLUSIONS

This investigation concerns an assessment of the effectiveness of stream restoration that followed highway reconstruction projects on two small freshwater streams in central Kentucky. Fish were selected as the biotic component for analysis and index of biological integrity (IBI) determinations were based on section eight of the recent U.S. EPA rapid bioassessment protocol (1999). This corresponds to Protocol V in the earlier draft by Plafkin *et al.* (1989). For general reference, fish species and habitat preferences are given in Table 17. Habitat assessments were based on section five (U.S. EPA, 1999) and this corresponds generally to the same section given in the first U.S. EPA draft (1989).

Specific findings are summarized below:

- The U.S. EPA rapid bioassessment protocol proved to be well suited for quantitative assessments of stream habitat and fish assemblages.
- Although habitat quality scored somewhat lower in the remediated sectors of Cedar and Holts Creeks, there was no apparent blockage of fish migration potential or macroinvertebrate drift. In addition, based on this study, there were no major impairments of overall stream productivity.
- The most apparent deficiencies in habitat restoration involved protective and riparian vegetation (e.g. Figure 6). This resulted in diminished bank stability (e.g. Figures 11-14) and increased prospects for bank erosion and downstream siltation.
- Continuous periodic observations of bank erosion should be considered and some future augmentation of remedial efforts might prove advisable.
- Riffle habitat could be improved in future highway restoration projects by using a mixture of riprap and gravel.

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Table 1. Water quality measurements from Cedar Creek collected May 19, 1999.

| Parameter | Sampling Site Upstream | Remediated | Downstream |
|---|---|---|---|
| Temperature ($^oC$) | 19.1 | 18.0 | 19.0 |
| pH | 7.60 | 7.85 | 7.76 |
| Conductivity (μmhos/cm) | 0.372 | 0.386 | 0.405 |
| Dissolved Oxygen (mg/L) | 11.9 | 12.3 | 11.8 |
| Alkalinity (mg/L) | 172 | 176 | 168 |
| Hardness (mg/L) | 174 | 194 | 244 |
| Total Suspended Solids (mg/L) | 0.24 | 1.15 | 4.41 |

Table 2. Habitat Assessment Scores for Cedar Creek, Hardin County, KY

| | | Sampling Site[a] | | | | | |
|---|---|---|---|---|---|---|---|
| | Metric | Upstream | | Remediated | | Downstream | |
| 1 | Epifaunal Substrate/Available Cover | 14 | S | 6 | M | 11 | S |
| 2 | Embeddedness | 14 | S | 18 | O | 14 | S |
| 3 | Velocity/Depth Regime | 14 | S | 9 | M | 14 | S |
| 4 | Sediment Deposition | 15 | S | 15 | S | 9 | M |
| 5 | Channel Flow Status | 7 | M | 7 | M | 11 | S |
| 6 | Channel Alteration | 19 | O | 1 | P | 17 | O |
| 7 | Frequency of Riffles | 13 | S | 17 | O | 10 | M |
| 8a | Bank Stability - Left bank | 7 | S | 9 | O | 7 | S |
| 8b | Bank Stability - Right bank | 2 | P | 9 | O | 8 | S |
| 9a | Vegetative protection - Left bank | 8 | S | 1 | P | 8 | S |
| 9b | Vegetative protection - Right bank | 5 | M | 2 | P | 7 | S |
| 10a | Riparian Vegetative Zone - Left bank | 9 | O | 1 | P | 10 | O |
| 10b | Riparian Vegetative Zone - Right bank | 9 | O | 1 | P | 10 | O |
| | Total IBI Score = | 136 | | 96 | | 136 | |

[a]Condition category rated as O = optimal, S = suboptimal, M = marginal, P = poor.

Table 3. Fish species and their abundance for three sampling sites collected May 19, 1999 from Cedar Creek, Hardin County, KY.

| Family<br>Common Name | Scientific Name | Trophic Guild[a] | Intolerant Species | Number of Individuals<br>Upstream | <br>Remediated | <br>Downstream |
|---|---|---|---|---|---|---|
| Cyprinidae | | | | | | |
| Stoneroller minnow | *Campostoma anomalum* | H | | 13 | 24 | 21 |
| Creek chub | *Semotilus atromaculatus* | I | | 7 | 6 | 3 |
| Bullhead minnow | *Pimephales vigilax* | O | | 1 | --- | --- |
| Suckermouth minnow | *Phenacobius mirabilis* | I | | 1 | --- | --- |
| Bluntnose minnow | *Pimephales notatus* | O | | --- | --- | 1 |
| Rosefin shiner | *Notropis ardens* | H/I | | 4 | 17 | 30 |
| Common shiner | *Notropis cornutus* | I | | --- | 1 | --- |
| River shiner | *Notropis blennius* | I | | --- | --- | 7 |
| | Total | | | 26 | 48 | 62 |
| Catostomidae | | | | | | |
| Northern hogsucker | *Hypentelium nigricans* | I | IS | 1 | --- | 4 |
| | Total | | | 1 | 0 | 4 |
| Centrarchidae | | | | | | |
| Largemouth bass | *Micropterus salmoides* | P | | 1 | 3 | --- |
| Rock bass | *Ambloplites rupestris* | I/P | IS | 1 | 1 | 3 |
| White crappie | *Pomoxis annularis* | I/P | | --- | --- | --- |
| Green sunfish | *Lepomis cyanellus* | I/P | | --- | 3 | --- |
| Bluegill | *Lepomis macrochirus* | I | | --- | --- | --- |
| Longear sunfish | *Lepomis megalotis* | I | IS | --- | --- | --- |
| Redear sunfish | *Lepomis microlophus* | I | | --- | 1 | --- |
| Pumpkinseed | *Lepomis gibbosus* | I | | --- | --- | --- |
| | Total | | | 2 | 8 | 3 |
| Percichthyidae | | | | | | |
| Striped bass | *Morone saxatilis* | I/P | | --- | --- | --- |
| | Total | | | 0 | 0 | 0 |
| Percidae | | | | | | |
| Fantail darter | *Etheostoma flabellare* | I | | 37 | 18 | 34 |
| Rainbow darter | *Etheostoma caeruleum* | I | | 71 | 30 | 51 |
| Orangethroat darter | *Etheostoma spectabile* | I | | 3 | 1 | 5 |
| Johnny darter | *Etheostoma nigrum* | I | | --- | --- | --- |
| | Total | | | 111 | 49 | 90 |

[a] Trophic guild include: Insectivores (I), Piscivores (P), Herbivores (H), and Omnivores (O).

Table 4. Length measurements for fish collected from the Upstream site in Cedar Creek.

| Family | Common Name | Scientific Name | Length (mm) | | | | | | | | | | | | | | | Count | Min | Max | Mean | Std Dev |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cyprinidae | Stoneroller minnow | *Campostoma anomalum* | 78 | 67 | 86 | 80 | 86 | 79 | 73 | 73 | 69 | 65 | 59 | 52 | 45 | | | 13 | 45 | 86 | 70 | 13 |
| | Creek chub | *Semotilus atromaculatus* | 125 | 85 | 73 | 64 | 55 | 95 | 79 | | | | | | | | | 7 | 55 | 125 | 82 | 23 |
| | Bullhead minnow | *Pimephales vigilax* | 86 | | | | | | | | | | | | | | | 1 | 86 | 86 | 86 | — |
| | Suckermouth minnow | *Phenacobius mirabilis* | 54 | | | | | | | | | | | | | | | 1 | 54 | 54 | 54 | — |
| | Rosefin shiner | *Notropis ardens* | 70 | 59 | 60 | 56 | | | | | | | | | | | | 4 | 56 | 70 | 61 | 6 |
| | | | | | | | | | | | | | | | | | | | | | | |
| Catostomidae | Northern hogsucker | *Hypentelium nigricans* | 105 | | | | | | | | | | | | | | | 1 | 105 | 105 | 105 | — |
| | | | | | | | | | | | | | | | | | | | | | | |
| Centrarchidae | Largemouth bass | *Micropterus salmoides* | 110 | | | | | | | | | | | | | | | 1 | 110 | 110 | 110 | — |
| | Rock bass | *Ambloplites rupestris* | 48 | | | | | | | | | | | | | | | 1 | 48 | 48 | 48 | — |
| | | | | | | | | | | | | | | | | | | | | | | |
| Percidae | Fantail darter | *Etheostoma flabellare* | 62 | 60 | 48 | 56 | 49 | 40 | 62 | 43 | 48 | 57 | 41 | 47 | 43 | 49 | 46 | | | | | |
| | | | 43 | 43 | 42 | 39 | 52 | 58 | 45 | 63 | 55 | 61 | 47 | 54 | 56 | 58 | 40 | | | | | |
| | | | 40 | 40 | 47 | 51 | 56 | 50 | 47 | | | | | | | | | 37 | 39 | 63 | 50 | 7 |
| | Rainbow darter | *Etheostoma caeruleum* | 51 | 52 | 45 | 48 | 46 | 46 | 46 | 43 | 42 | 51 | 44 | 45 | 45 | 42 | 47 | | | | | |
| | | | 45 | 40 | 46 | 56 | 45 | 48 | 41 | 44 | 38 | 42 | 42 | 43 | 50 | 55 | 44 | | | | | |
| | | | 44 | 44 | 44 | 45 | 48 | 45 | 47 | 46 | 44 | 45 | 42 | | | | | 41 | 38 | 56 | 46 | 4 |
| | Rainbow darter (female) | *Etheostoma caeruleum* | 51 | 54 | 52 | 55 | 45 | 41 | 44 | 44 | 56 | 33 | 45 | 48 | 40 | 34 | 43 | | | | | |
| | | | 42 | 43 | 39 | 41 | 55 | 42 | 46 | 45 | 42 | 35 | 47 | 41 | 41 | 42 | 41 | 30 | 33 | 56 | 44 | 4 |
| | Orangethroat darter | *Etheostoma spectabile* | 50 | 43 | 40 | | | | | | | | | | | | | 3 | 40 | 50 | 44 | 5 |

Table 5. Length measurements for fish collected from the Remediated site in Cedar Creek.

| Family | Common Name | Scientific Name | Length (mm) | | | | | | | | | | | | | | | Count | Min | Max | Mean | Std Dev |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cyprinidae | Stoneroller minnow | *Campostoma anomalum* | 109 | 107 | 119 | 105 | 87 | 112 | 92 | 80 | 90 | 90 | 91 | 62 | 106 | 89 | 93 | | | | | |
| | | | 110 | 94 | 124 | 113 | 81 | 103 | 50 | 76 | 65 | | | | | | | 24 | 50 | 124 | 94 | 18 |
| | Creek chub | *Semotilus atromaculatus* | 112 | 95 | 96 | 115 | 99 | 124 | | | | | | | | | | 6 | 95 | 124 | 107 | 12 |
| | Rosefin shiner | *Notropis ardens* | 82 | 69 | 78 | 61 | 60 | 62 | 46 | 55 | 47 | 57 | 57 | 55 | 64 | 65 | 57 | | | | | |
| | | | 68 | 73 | | | | | | | | | | | | | | 17 | 46 | 82 | 62 | 10 |
| | Common shiner | *Notropis cornutus* | 178 | | | | | | | | | | | | | | | 1 | 178 | 178 | 178 | — |
| | | | | | | | | | | | | | | | | | | | | | | |
| Centrarchidae | Largemouth bass | *Micropterus salmoides* | 156 | 178 | 230 | | | | | | | | | | | | | 3 | 156 | 230 | 188 | 38 |
| | Rock bass | *Ambloplites rupestris* | 89 | | | | | | | | | | | | | | | 1 | 89 | 89 | 89 | — |
| | Green sunfish | *Lepomis cyanellus* | 156 | 205 | 225 | | | | | | | | | | | | | 3 | 156 | 225 | 195 | 36 |
| | Redear sunfish | *Lepomis microlophus* | 106 | | | | | | | | | | | | | | | 1 | 106 | 106 | 106 | — |
| | | | | | | | | | | | | | | | | | | | | | | |
| Percidae | Fantail darter | *Etheostoma flabellare* | 69 | 59 | 40 | 50 | 47 | 60 | 47 | 47 | 50 | 45 | 56 | 42 | 40 | 46 | 45 | | | | | |
| | | | 56 | 52 | 56 | | | | | | | | | | | | | 18 | 40 | 69 | 50 | 8 |
| | Rainbow darter (male) | *Etheostoma caeruleum* | 51 | 47 | 55 | 50 | 44 | 45 | 50 | 45 | 50 | 45 | 41 | 40 | 45 | | | 13 | 40 | 55 | 47 | 4 |
| | Rainbow darter (female) | *Etheostoma caeruleum* | 62 | 40 | 46 | 45 | 44 | 37 | 46 | 44 | 45 | 46 | 42 | 42 | 47 | 48 | 40 | | | | | |
| | | | 35 | 39 | | | | | | | | | | | | | | 17 | 35 | 62 | 44 | 6 |
| | Orangethroat darter | *Etheostoma spectabile* | 50 | | | | | | | | | | | | | | | 1 | 50 | 50 | 50 | — |

Table 6. Length measurements for fish collected from the Downstream site in Cedar Creek.

| Family | Common Name | Scientific Name | Length (mm) | | | | | | | | | | | | | | | Count | Min | Max | Mean | Std Dev |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cyprinidae | Stoneroller minnow | *Campostoma anomalum* | 74 | 86 | 77 | 100 | 79 | 75 | 73 | 78 | 78 | 74 | 84 | 90 | 88 | 69 | 61 | | | | | |
| | | | 55 | 71 | 78 | 58 | 58 | 58 | | | | | | | | | | 21 | 55 | 100 | 74 | 12 |
| | Creek chub | *Semotilus atromaculatus* | 118 | 84 | 72 | | | | | | | | | | | | | 3 | 72 | 118 | 91 | 24 |
| | Bluntnose minnow | *Pimephales notatus* | 49 | | | | | | | | | | | | | | | 1 | 49 | 49 | 49 | — |
| | Rosefin shiner | *Notropis ardens* | 71 | 57 | 62 | 56 | 41 | 47 | 44 | 40 | 41 | 31 | 35 | 47 | 36 | 40 | 35 | | | | | |
| | | | 40 | 42 | 39 | 40 | 32 | 34 | 34 | 32 | 35 | 34 | 40 | 35 | 35 | 39 | 68 | 30 | 31 | 71 | 42 | 11 |
| | River shiner | *Notropis blennius* | 90 | 67 | 49 | 52 | 46 | 46 | 29 | | | | | | | | | 7 | 29 | 90 | 54 | 19 |
| | | | | | | | | | | | | | | | | | | | | | | |
| Catostomidae | Northern hogsucker | *Hypentelium nigricans* | 150 | 110 | 96 | 111 | | | | | | | | | | | | 4 | 96 | 150 | 117 | 23 |
| | | | | | | | | | | | | | | | | | | | | | | |
| Centrarchidae | Rock bass | *Ambloplites rupestris* | 82 | 86 | 50 | | | | | | | | | | | | | 3 | 50 | 86 | 73 | 20 |
| | | | | | | | | | | | | | | | | | | | | | | |
| Percidae | Fantail darter | *Etheostoma flabellare* | 56 | 63 | 49 | 38 | 44 | 36 | 48 | 52 | 42 | 42 | 44 | 43 | 47 | 52 | 45 | | | | | |
| | | | 61 | 62 | 66 | 55 | 48 | 50 | 45 | 50 | 39 | 47 | 47 | 45 | 42 | 50 | 56 | | | | | |
| | | | 47 | 50 | 60 | 53 | | | | | | | | | | | | 34 | 36 | 66 | 49 | 7 |
| | Rainbow darter | *Etheostoma caeruleum* | 53 | 57 | 39 | 44 | 47 | 45 | 50 | 48 | 47 | 54 | 55 | 42 | 45 | 39 | 41 | | | | | |
| | | | 48 | 42 | 43 | 48 | | | | | | | | | | | | 19 | 39 | 57 | 47 | 5 |
| | Rainbow darter (female) | *Etheostoma caeruleum* | 45 | 46 | 55 | 43 | 45 | 43 | 41 | 35 | 42 | 57 | 56 | 46 | 41 | 46 | 43 | | | | | |
| | | | 42 | 47 | 42 | 53 | 42 | 46 | 51 | 43 | 43 | 55 | 47 | 48 | 46 | 45 | 41 | | | | | |
| | | | 48 | 57 | | | | | | | | | | | | | | 32 | 35 | 57 | 46 | 5 |
| | Orangethroat darter | *Etheostoma spectabile* | 50 | 40 | 43 | 46 | 54 | | | | | | | | | | | 5 | 40 | 54 | 47 | 6 |

Table 7. Alternate index of biological integrity scoring criteria used for Cedar Creek, Hardin County, KY.

| Category | IBI Metric | Scoring Criteria 1 | 3 | 5 |
|---|---|---|---|---|
| Species Richness and Composition | 1. Total number of species | <3 | 4-10 | >11 |
| | 2. Number of darter species | 0-1 | 2-3 | >3 |
| | 3. Number of sunfish species | 0-1 | 2-3 | >3 |
| | 4. Number of minnow species[a] | 0-1 | 2-3 | >3 |
| | 5. Number of intolerant species | 0-1 | 2-3 | >3 |
| | 6. Proportion of green sunfish | >25% | 10-25% | <10% |
| Trophic Composition | 7. Proportion of omnivores | >45% | 20-45% | <20% |
| | 8. Proportion of insectivores species[a] | <20% | 20-45% | >45% |
| | 9. Proportion of top carnivores[b] | <1% | 1-5% | >5% |
| Fish Abundance and Condition | 10. Total number of individuals | <48 | 48-96 | >96 |
| | 11. Proportion of hybrids | >1% | 0-1% | 0% |
| | 12. Proportion of diseased individuals | >5% | 1-5% | <1% |

[a] Alternate IBI metric used.
[b] Includes pisicivores and piscivores + insectivores.

Table 8. IBI calculations for Cedar Creek, Hardin County, KY.

| | Sampling Site | | | | | |
|---|---|---|---|---|---|---|
| IBI Metric<br>Downstream | Upstream | | Remediated | | | |
| 1. Total number of species | 11 | (5)[a] | 11 | (5) | 10 | (3) |
| 2. Number of darter species | 3 | (5) | 3 | (5) | 3 | (5) |
| 3. Number of sunfish species | 2 | (3) | 4 | (5) | 1 | (1) |
| 4. Number of minnow species[b] | 5 | (5) | 4 | (5) | 5 | (5) |
| 5. Number of intolerant species | 2 | (3) | 1 | (1) | 2 | (3) |
| 6. Proportion of green sunfish | 0 | (5) | 3 | (5) | 0 | (5) |
| 7. Proportion of omnivores | 1 | (5) | 0 | (5) | 1 | (5) |
| 8. Proportion of insectivores species[b] | 90 | (5) | 74 | (5) | 84 | (5) |
| 9. Proportion of top carnivores[c] | 1 | (3) | 7 | (5) | 2 | (3) |
| 10. Total number of individuals | 140 | (5) | 105 | (5) | 159 | (5) |
| 11. Proportion of hybrids | 0 | (5) | 0 | (5) | 0 | (5) |
| 12. Proportion of diseased individuals | 0 | (5) | 4 | (3) | 0 | (5) |
| Total IBI Score | 54 | | 54 | | 50 | |
| Integrity Class | Good | | Good | | Good | |

[a] IBI Metric values (1,3,5) are given in parenthesis.
[b] Alternate IBI Metric.
[c] Includes all insectivores (I, I+H, and P+I).

Table 9. Water quality measurements from Holts Creek collected May 26, 1999.

| Parameter | Sampling Site: Upstream | Sampling Site: Remediated | Sampling Site: Downstream |
|---|---|---|---|
| Temperature (°C) | 20.4 | 20.4 | 20.4 |
| pH | 7.75 | 7.56 | 7.66 |
| Conductivity (μmhos/cm) | 0.540 | 0.528 | 0.536 |
| Dissolved Oxygen (mg/L) | 11.6 | 9.8 | 8.4 |
| Alkalinity (mg/L) | 216 | 204 | 192 |
| Hardness (mg/L) | 288 | 272 | 268 |
| Total Suspended Solids (mg/L) | 66.39 | 5.74 | 3.44 |

Table 10. Habitat Assessment Scores for Holts Creek, Bracken County, KY

| | | Sampling Site[a] | | | | | |
|---|---|---|---|---|---|---|---|
| | Metric<br>Downstream | Upstream | | Remediated | | | |
| 1 | Epifaunal Substrate/Available Cover | 7 | M | 7 | M | 14 | S |
| 2 | Embeddedness | 11 | S | 12 | S | 10 | M |
| 3 | Velocity/Depth Regime | 14 | S | 7 | M | 14 | S |
| 4 | Sediment Deposition | 13 | S | 13 | S | 10 | M |
| 5 | Channel Flow Status | 9 | M | 8 | M | 12 | S |
| 6 | Channel Alteration | 9 | M | 7 | M | 17 | O |
| 7 | Frequency of Riffles | 7 | M | 5 | P | 9 | M |
| 8a | Bank Stability - Left bank | 7 | S | 1 | P | 4 | M |
| 8b | Bank Stability - Right bank | 7 | S | 3 | M | 1 | P |
| 9a | Vegetative protection - Left bank | 6 | S | 2 | P | 2 | P |
| 9b | Vegetative protection - Right bank | 6 | S | 4 | M | 3 | M |
| 10a | Riparian Vegetative Zone - Left bank | 8 | S | 4 | M | 7 | S |
| 10b | Riparian Vegetative Zone - Right bank | 8 | S | 4 | M | 5 | M |
| | Total IBI Score = | 112 | | 77 | | 108 | |

[a]Condition category rated as O = optimal, S = suboptimal, M = marginal, P = poor.

Table 11. Fish species and their abundance for three sampling sites collected May 26, 1999 from Holts Creek, Bracken County, KY.

| Family / Common Name | Scientific Name | Trophic Guild[a] | Intolerant Species | Number of Individuals: Upstream | Remediated | Downstream |
|---|---|---|---|---|---|---|
| Cyprinidae | | | | | | |
| Stoneroller minnow | *Campostoma anomalum* | H | | 9 | 1 | --- |
| Creek chub | *Semotilus atromaculatus* | I | | 10 | 1 | --- |
| Bullhead minnow | *Pimephales vigilax* | O | | --- | --- | --- |
| Suckermouth minnow | *Phenacobius mirabilis* | I | | 4 | 52 | 1 |
| Bluntnose minnow | *Pimephales notatus* | O | | 33 | 32 | 11 |
| Rosefin shiner | *Notropis ardens* | H/I | | 1 | 6 | --- |
| Common shiner | *Notropis cornutus* | I | | --- | --- | --- |
| River shiner | *Notropis blennius* | I | | --- | --- | --- |
| | Total | | | 57 | 92 | 12 |
| Catostomidae | | | | | | |
| Northern hogsucker | *Hypentelium nigricans* | I | IS | --- | --- | --- |
| | Total | | | 0 | 0 | 0 |
| Centrarchidae | | | | | | |
| Largemouth bass | *Micropterus salmoides* | P | | 2 | 1 | 3 |
| Rock bass | *Ambloplites rupestris* | I/P | IS | 1 | --- | --- |
| White crappie | *Pomoxis annularis* | I/P | | 1 | --- | --- |
| Green sunfish | *Lepomis cyanellus* | I/P | | 42 | 74 | 7 |
| Bluegill | *Lepomis macrochirus* | I | | 16 | 68 | 7 |
| Longear sunfish | *Lepomis megalotis* | I | IS | 14 | 3 | 13 |
| Redear sunfish | *Lepomis microlophus* | I | | 4 | --- | --- |
| Pumpkinseed | *Lepomis gibbosus* | I | | --- | 2 | 1 |
| | Total | | | 80 | 148 | 31 |
| Percichthyidae | | | | | | |
| Striped bass | *Morone saxatilis* | I/P | | 1 | --- | --- |
| | Total | | | 1 | 0 | 0 |
| Percidae | | | | | | |
| Fantail darter | *Etheostoma flabellare* | I | | 1 | --- | --- |
| Rainbow darter | *Etheostoma caeruleum* | I | | 5 | 39 | 4 |
| Orangethroat darter | *Etheostoma spectabile* | I | | --- | --- | --- |
| Johnny darter | *Etheostoma nigrum* | I | | --- | 1 | --- |
| | Total | | | 6 | 40 | 4 |

[a] Trophic guild include: Insectivores (I), Piscivores (P), Herbivores (H), and Omnivores (O).

Table 12. Length measurements for fish collected from the Upstream site in Holts Creek.

| Family | Common Name | Scientific Name | Length (mm) | | | | | | | | | | | | | | | Count | Min | Max | Mean | Std Dev |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cyprinidae | Stoneroller minnow | *Campostoma anomalum* | 85 | 86 | 98 | 69 | 75 | 73 | 73 | 82 | 80 | | | | | | | 9 | 69 | 98 | 80 | 9 |
| | Creek chub | *Semotilus atromaculatus* | 92 | 115 | 74 | 72 | 79 | 74 | 72 | 67 | 70 | 64 | | | | | | 10 | 64 | 115 | 78 | 15 |
| | Suckermouth minnow | *Phenacobius mirabilis* | 26 | 25 | 25 | 22 | | | | | | | | | | | | 4 | 22 | 26 | 25 | 2 |
| | Bluntnose minnow | *Pimephales notatus* | 51 | 48 | 60 | 59 | 41 | 62 | 65 | 45 | 52 | 45 | 50 | 40 | 35 | 42 | 48 | | | | | |
| | | | 35 | 38 | 55 | 47 | 46 | 44 | 52 | 47 | 51 | 50 | 52 | 62 | 36 | 36 | 39 | | | | | |
| | | | 37 | 35 | 38 | | | | | | | | | | | | | 33 | 35 | 65 | 47 | 9 |
| | Rosefin shiner | *Notropis ardens* | 73 | | | | | | | | | | | | | | | 1 | 73 | 73 | 73 | — |
| | | | | | | | | | | | | | | | | | | | | | | |
| Centrarchidae | Largemouth bass | *Micropterus salmoides* | 271 | 285 | | | | | | | | | | | | | | 2 | 271 | 285 | 278 | 10 |
| | Rock bass (juvenile) | *Ambloplites rupestris* | 48 | | | | | | | | | | | | | | | 1 | 48 | 48 | 48 | — |
| | White crappie | *Pomoxis annularis* | 158 | | | | | | | | | | | | | | | 1 | 158 | 158 | 158 | — |
| | Green sunfish | *Lepomis cyanellus* | 80 | 84 | 108 | 104 | 136 | 115 | | | | | | | | | | 6 | 80 | 136 | 105 | 21 |
| | Green sunfish (juvenile) | *Lepomis cyanellus* | 53 | 36 | 40 | 36 | 42 | 42 | 38 | 35 | 39 | 39 | 36 | 47 | 43 | 50 | 51 | | | | | |
| | | | 56 | 54 | 47 | 49 | 47 | 51 | 36 | 46 | 43 | 45 | 37 | 38 | 35 | 40 | 44 | | | | | |
| | | | 38 | 34 | 40 | 34 | 30 | 34 | | | | | | | | | | 36 | 30 | 56 | 42 | 7 |
| | Bluegill (juvenile) | *Lepomis macrochirus* | 34 | 33 | 38 | 32 | 39 | 38 | 41 | 42 | 36 | 44 | 42 | 38 | 31 | 29 | 38 | | | | | |
| | | | 27 | | | | | | | | | | | | | | | 16 | 27 | 44 | 36 | 5 |
| | Longear sunfish | *Lepomis megalotis* | 96 | 93 | 94 | 114 | 145 | 94 | 116 | 86 | 116 | 102 | 94 | | | | | 11 | 86 | 145 | 105 | 17 |
| | Longear sunfish (juvenile) | *Lepomis megalotis* | 51 | 48 | 46 | | | | | | | | | | | | | 3 | 46 | 51 | 48 | 3 |
| | Redear sunfish | *Lepomis microlophus* | 112 | 103 | 160 | 107 | | | | | | | | | | | | 4 | 103 | 160 | 121 | 27 |
| | | | | | | | | | | | | | | | | | | | | | | |
| Percichthyidae | Striped bass | *Morone saxatilis* | 183 | | | | | | | | | | | | | | | 1 | 183 | 183 | 183 | — |
| | | | | | | | | | | | | | | | | | | | | | | |
| Percidae | Fantail darter | *Etheostoma flabellare* | 61 | | | | | | | | | | | | | | | 1 | 61 | 61 | 61 | — |
| | Rainbow darter | *Etheostoma caeruleum* | 52 | 53 | 45 | | | | | | | | | | | | | 3 | 45 | 53 | 50 | 4 |
| | Rainbow darter (juvenile) | *Etheostoma caeruleum* | 25 | 23 | | | | | | | | | | | | | | 2 | 23 | 25 | 24 | 1 |

Table 13. Length measurements for fish collected from the Remediated site in Holts Creek.

| Family | Common Name | Scientific Name | Length (mm) | | | | | | | | | | | | | | | Count | Min | Max | Mean | Std Dev |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cyprinidae | Stoneroller minnow | *Campostoma anomalum* | 91 | | | | | | | | | | | | | | | 1 | 91 | 91 | 91 | — |
| | Creek chub | *Semotilus atromaculatus* | 100 | | | | | | | | | | | | | | | 1 | 100 | 100 | 100 | — |
| | Suckermouth minnow | *Phenacobius mirabilis* | 17 | 23 | 28 | 24 | 20 | 22 | 23 | 25 | 24 | 26 | 21 | 22 | 23 | 17 | 19 | | | | | |
| | | | 24 | 22 | 18 | 19 | 25 | 25 | 20 | 24 | 23 | 25 | 23 | 23 | 23 | 22 | 23 | | | | | |
| | | | 17 | 20 | 21 | 19 | 23 | 22 | 23 | 24 | 19 | 20 | 25 | 22 | 27 | 22 | 21 | | | | | |
| | | | 22 | 18 | 20 | 25 | 22 | 21 | 21 | | | | | | | | | 52 | 17 | 28 | 22 | 3 |
| | Bluntnose minnow | *Pimephales notatus* | 60 | 66 | 59 | 34 | 43 | 34 | 39 | 43 | 45 | 37 | 29 | 31 | 36 | 37 | 35 | | | | | |
| | | | 34 | 33 | 35 | 40 | 36 | 37 | 44 | 42 | 42 | 38 | 38 | 50 | 36 | 20 | 20 | | | | | |
| | | | 64 | 62 | | | | | | | | | | | | | | 32 | 20 | 66 | 41 | 11 |
| | Rosefin shiner | *Notropis ardens* | 90 | 85 | 85 | 43 | 40 | 46 | | | | | | | | | | 6 | 40 | 90 | 65 | 24 |
| | | | | | | | | | | | | | | | | | | | | | | |
| Centrarchidae | Largemouth bass | *Micropterus salmoides* | 230 | | | | | | | | | | | | | | | 1 | 230 | 230 | 230 | — |
| | Green sunfish | *Lepomis cyanellus* | 96 | 82 | 77 | 131 | 96 | 82 | 95 | 68 | 63 | 97 | 76 | 98 | 78 | 73 | 80 | | | | | |
| | | | 84 | 82 | 80 | 40 | 48 | 58 | 57 | 66 | 69 | 54 | 40 | 46 | 33 | 32 | 33 | | | | | |
| | | | 43 | 47 | 52 | 57 | 54 | 37 | 50 | 40 | 58 | 35 | 36 | 33 | 41 | 31 | 36 | | | | | |
| | | | 46 | 47 | 48 | 40 | 37 | 43 | 44 | 36 | 43 | 37 | 40 | 43 | 42 | 36 | 35 | | | | | |
| | | | 34 | 35 | 36 | 38 | 35 | 38 | 38 | 38 | 37 | 38 | 33 | 36 | 32 | 40 | | 74 | 31 | 131 | 53 | 22 |
| | Bluegill | *Lepomis macrochirus* | 35 | 36 | 39 | 38 | 45 | 44 | 44 | 43 | 43 | 47 | 46 | 47 | 37 | 41 | 46 | | | | | |
| | | | 34 | 40 | 32 | 29 | 32 | 40 | 40 | 35 | 35 | 29 | 33 | 34 | 38 | 30 | 32 | | | | | |
| | | | 35 | 37 | 45 | 44 | 42 | 46 | 45 | 43 | 47 | 42 | 42 | 48 | 47 | 42 | 41 | | | | | |
| | | | 44 | 43 | 40 | 39 | 41 | 40 | 41 | 34 | 36 | 41 | 39 | 34 | 47 | 40 | 33 | | | | | |
| | | | 34 | 42 | 43 | 41 | 41 | 38 | 39 | 34 | | | | | | | | 68 | 29 | 48 | 40 | 5 |
| | Longear sunfish | *Lepomis megalotis* | 85 | 100 | 88 | | | | | | | | | | | | | 3 | 85 | 100 | 91 | 8 |
| | Pumpkinseed | *Lepomis gibbosus* | 137 | 113 | | | | | | | | | | | | | | 2 | 113 | 137 | 125 | 17 |
| | | | | | | | | | | | | | | | | | | | | | | |
| Percidae | Rainbow darter | *Etheostoma caeruleum* | 54 | 61 | 52 | 45 | 50 | 53 | 55 | 48 | | | | | | | | 8 | 45 | 61 | 52 | 5 |
| | Rainbow darter (female) | *Etheostoma caeruleum* | 44 | 58 | | | | | | | | | | | | | | 2 | 44 | 58 | 51 | 10 |
| | Rainbow darter (juvenile) | *Etheostoma caeruleum* | 25 | 26 | 22 | 23 | 25 | 23 | 23 | 25 | 23 | 23 | 24 | 22 | 23 | 21 | 25 | | | | | |
| | | | 23 | 21 | 24 | 23 | 23 | 24 | 24 | 25 | 18 | 22 | 22 | 20 | 18 | 23 | | 29 | 18 | 26 | 23 | 2 |
| | Johnny darter | *Etheostoma nigrum* | 56 | | | | | | | | | | | | | | | 1 | 56 | 56 | 56 | — |

Table 14. Length measurements for fish collected from the Downstream site in Holts Creek.

| Family | Common Name | Scientific Name | Length (mm) | | | | | | | | | | | | | Count | Min | Max | Mean | Std Dev |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cyprinidae | Suckermouth minnow | *Phenacobius mirabilis* | 23 | | | | | | | | | | | | | 1 | 23 | 23 | 23 | — |
| | Bluntnose minnow | *Pimephales notatus* | 39 | 47 | 39 | 42 | 34 | 36 | 39 | 43 | 47 | 39 | 39 | | | 11 | 34 | 47 | 40 | 4 |
| | | | | | | | | | | | | | | | | | | | | |
| Centrarchidae | Largemouth bass | *Micropterus salmoides* | 355 | 204 | 260 | | | | | | | | | | | 3 | 204 | 355 | 273 | 76 |
| | Green sunfish (juvenile) | *Lepomis cyanellus* | 53 | 33 | 25 | 22 | 22 | 19 | 21 | | | | | | | 7 | 19 | 53 | 28 | 12 |
| | Bluegill | *Lepomis macrochirus* | 156 | 138 | 142 | 131 | 152 | 151 | 54 | | | | | | | 7 | 54 | 156 | 132 | 35 |
| | Longear sunfish | *Lepomis megalotis* | 114 | 165 | 133 | 150 | 140 | 80 | 130 | 89 | 82 | 86 | 75 | 63 | 72 | 13 | 63 | 165 | 106 | 34 |
| | Pumpkinseed | *Lepomis gibbosus* | 168 | | | | | | | | | | | | | 1 | 168 | 168 | 168 | — |
| | | | | | | | | | | | | | | | | | | | | |
| Percidae | Rainbow darter | *Etheostoma caeruleum* | 64 | 62 | 61 | 54 | | | | | | | | | | 4 | 54 | 64 | 60 | 4 |

Table 15. Alternate index of biological integrity scoring criteria used for Holts Creek, Bracken County, KY.

| Category | IBI Metric | Scoring Criteria | | |
|---|---|---|---|---|
| | | 1 | 3 | 5 |
| Species Richness and Composition | 1. Total number of species | <3 | 4-10 | >11 |
| | 2. Number of darter species | 0-1 | 2-3 | >3 |
| | 3. Number of sunfish species | 0-1 | 2-3 | >3 |
| | 4. Number of minnow species[a] | 0-1 | 2-3 | >3 |
| | 5. Number of intolerant species | 0-1 | 2-3 | >3 |
| | 6. Proportion of green sunfish | >25% | 10-25% | <10% |
| Trophic Composition | 7. Proportion of omnivores | >45% | 20-45% | <20% |
| | 8. Proportion of insectivores species[a] | <20% | 20-45% | >45% |
| | 9. Proportion of top carnivores[b] | <1% | 1-5% | >5% |
| Fish Abundance and Condition | 10. Total number of individuals | <46 | 46-94 | >94 |
| | 11. Proportion of hybrids | >1% | 0-1% | 0% |
| | 12. Proportion of diseased individuals | >5% | 1-5% | <1% |

[a] Alternate IBI metric used.
[b] Includes pisicivores and piscivores + insectivores.

Table 16. IBI calculations for Holts Creek, Bracken County, KY.

| | Sampling Site | | | | | |
|---|---|---|---|---|---|---|
| IBI Metric<br>Downstream | Upstream | | Remediated | | | |
| 1. Total number of species | 15 | (5)[a] | 12 | (5) | 8 | (3) |
| 2. Number of darter species | 2 | (3) | 2 | (3) | 1 | (1) |
| 3. Number of sunfish species | 7 | (5) | 5 | (5) | 5 | (5) |
| 4. Number of minnow species[b] | 5 | (5) | 5 | (5) | 2 | (3) |
| 5. Number of intolerant species | 2 | (3) | 1 | (1) | 1 | (1) |
| 6. Proportion of green sunfish | 29 | (1) | 26 | (1) | 15 | (3) |
| 7. Proportion of omnivores | 23 | (3) | 11 | (5) | 23 | (3) |
| 8. Proportion of insectivores species[b] | 69 | (5) | 88 | (5) | 70 | (5) |
| 9. Proportion of top carnivores[c] | 33 | (5) | 27 | (5) | 21 | (5) |
| 10. Total number of individuals | 144 | (5) | 280 | (5) | 47 | (1) |
| 11. Proportion of hybrids | 0 | (5) | 0 | (5) | 0 | (5) |
| 12. Proportion of diseased individuals | 0 | (5) | 0 | (5) | 0 | (5) |
| Total IBI Score | 50 | | 50 | | 40 | |
| Integrity Class | Good | | Good | | Fair | |

[a] IBI Metric values (1,3,5) are given in parenthesis.
[b] Alternate IBI Metric.
[c] Includes all insectivores (I, I+H, and P+I).

Table 17. Descriptions of fish habitat preferences for species found in Cedar and Holts Creeks.

**Stoneroller minnow** (*Campostoma anomalum*)

Stoneroller minnows can be found in riffles, runs, and pools in small streams to medium sized rivers and head waters on gravel or bedrock with a moderate to steep gradient (The Audubon Society 1988).

**Creek chub** (*Semotilus atromaculatus*)

Creek chubs occur on sand, gravel, or bedrock in cloudy or clear streams and lakes (The Audubon Society 1988).

**Bullhead minnow** (*Pimephales vigilax*)

Bullhead minnows live in silt, sand, or gravel bottomed pools and runs of small streams to large rivers with clear to turbid water (Page and Burr 1991).

**Suckermouth minnow** (*Phenacobius mirabilis*)

This fish can be found in small to large rivers, with water from turbid to clear, and a gravel or rocky bottom. (Page and Burr 1991).

**Bluntnose minnow** (*Pimephales notatus*)

This species will live in the pools of sand, gravel, or rock bottomed streams, rivers, or lakes with clear to turbid waters (The Audubon Society 1988).

**Rosefin shiner** (*Notropis ardens*)

Rosefin shiners can be found in pools of small to moderate sized streams, with low to moderate flow and a sand gravel or rocky bottom (The Audubon Society 1988).

**Common shiner** (*Notropis cornutus*)

This fish prefers riffles and firm bottom pools in cool, clear streams and small rivers (The Audubon Society 1988).

**River shiner** (*Notropis blennius*)

The river shiner prefers medium to large rivers, usually in the main channel or pools over sand and gravel (Page and Burr 1991).

Table 17, continued. Descriptions of fish habitat preferences for species found in Cedar and Holts Creeks.

**Northern hogsucker** (*Hypentelium nigricans*)

This species prefers fast flowing, cool streams. In such streams, they can be found over a gravel or rocky substrate in riffles or in pools below riffles (The Audubon Society 1988).

**Largemouth bass** (*Micropterus salmonides*)

Largemouth bass can live in a variety of habitats from the pools of clear or slightly turbid streams and large rivers to ponds and swamps to large lakes and reservoirs. Often they are found with habitats with aquatic vegetation and muddy or sandy bottom (Page and Burr 1991).

**Rock bass** (*Ambloplites rupestris*)

This fish can be found in moderate sized rivers, smaller streams, and lakes in areas that have vegetation, brush, and/or a rocky bottom (Page and Burr 1991).

**White crappie** (*Pomoxis annularis*)

White crappie live in stream pools and backwaters, rivers, and lakes of virtually any size. They prefer a mud or sand substrate and can tolerate some turbidity (Page and Burr 1991).

**Green sunfish** (*Lepomis cyanellus*)

Green sunfish prefer slow moving streams and pools, lakes, or ponds. They can often be found in vegetation (Page and Burr 1991).

**Bluegill** (*Lepomis macrochirus*)

The familiar bluegill is commonly found among vegetation in lakes of varying sizes. They can also be found in rivers and the pools of streams (Page and Burr 1991).

**Longear sunfish** (*Lepomis megalotis*)

This fish can be found in lakes and reservoirs in addition to rock, gravel, or sand bottomed streams of moderate flow (The Audubon Society 1988).

Table 17, continued. Descriptions of fish habitat preferences for species found in Cedar and Holts Creeks.

**Redear sunfish** (*Lepomis microlophus*)

Redear sunfish are usually found in fairly still waters that have a sandy or silty bottom. These include lakes and ponds with vegetation, rivers, and slow streams (Page and Burr 1991).

**Pumpkinseed** (*Lepomis gibbosus*)

This sunfish frequents cool, shallow waters in slow streams or lakes. It prefers areas with vegetation (The Audubon Society 1988).

**Striped bass** (*Morone saxatillis*)

An introduced species, the striped bass is typically anadromous. It spawns in large rivers and lives its adult life in the ocean. It has been stocked in many rivers in the central United States, including the Ohio river, and is now a permanent resident of these and adjacent waters (The Audubon Society 1988, Page and Burr 1991).

**Fantail darter** (*Etheostoma flabellare*)

This fish lives in riffles with a gravel to rubble sized substrate, often in shallower areas away from the main current (Kuehne and Barbour 1983).

**Rainbow darter** (*Etheostoma caeruleum*)

Rainbow darters live in small rivers and streams with a moderate gradient. They prefer riffles with a gravel and rubble substrate (Kuehne and Barbour 1983).

**Orangethroat darter** (*Etheostoma spectabile*)

This species inhabits slow to fast flowing riffles, but avoid streams with too much flow. It lives in streams with sand, gravel, rubble, or bedrock bottoms. It prefers alkaline water, such as that flowing over limestone (Kuehne and Barbour 1983).

**Johnny darter** (*Etheostoma nigrum*)

The johnny darter is more tolerant of diverse habitat conditions than most darters, surviving in streams with diverse substrate, flow parameters and turbidity. It is most common in sandy or bedrock pools in streams of small to moderate size (Kuehne and Barbour 1983).

Figure 1. Cedar Creek, Hardin County, KY.

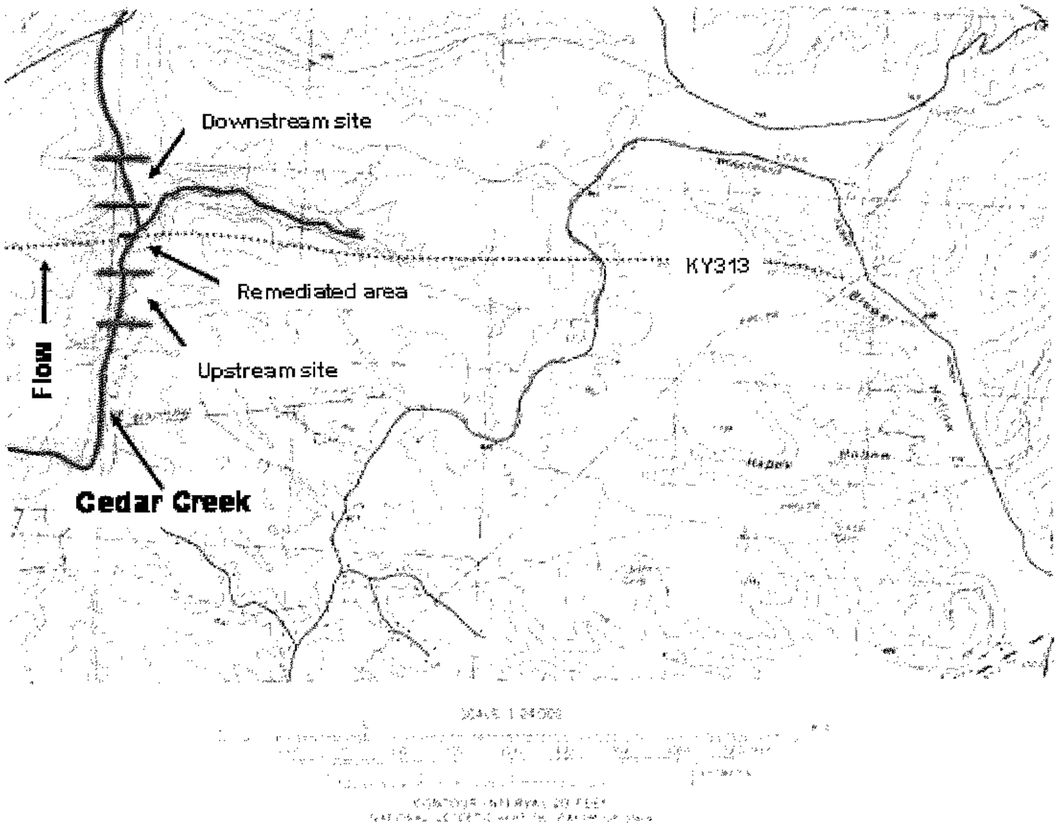


Figure 2. Holts Creek, Bracken, County, KY.

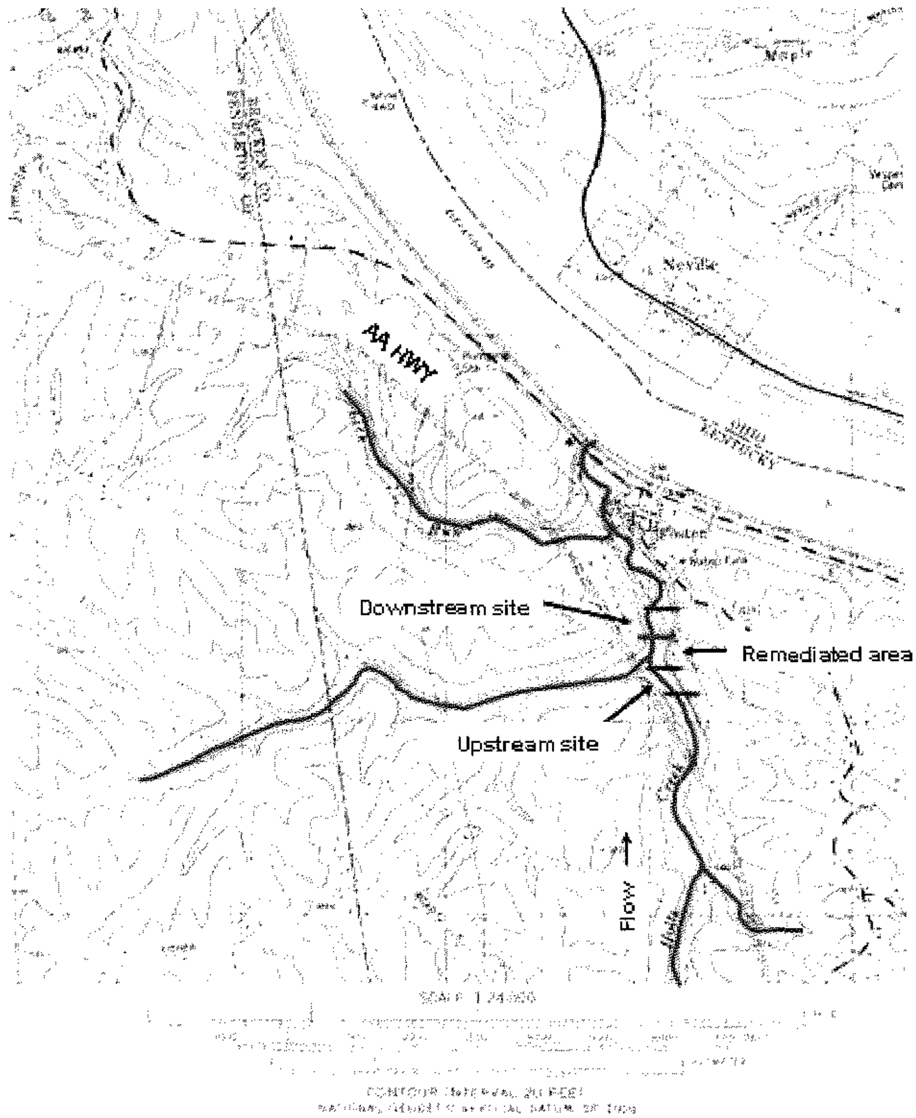


Figure 3. Upstream Site in Cedar Creek, Hardin County, KY

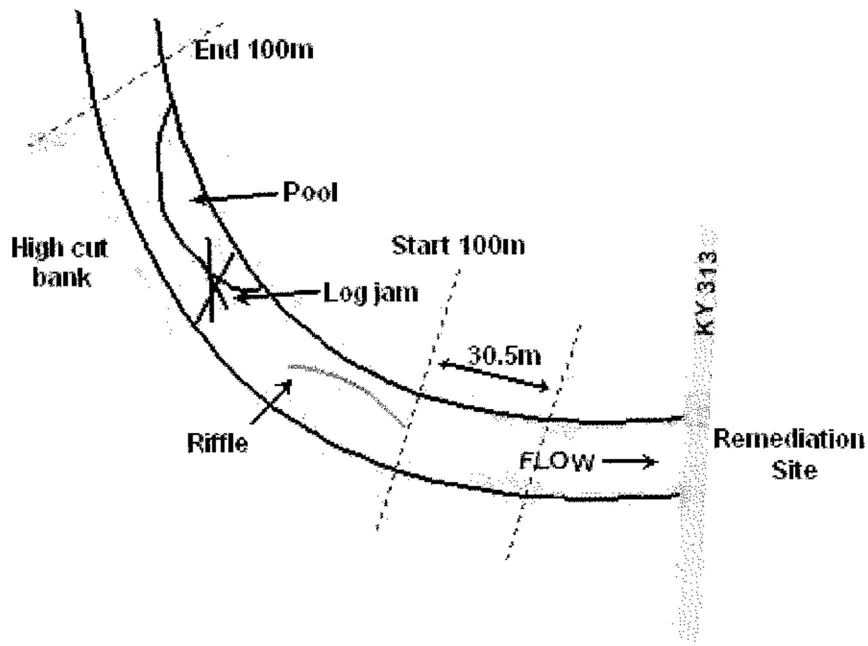
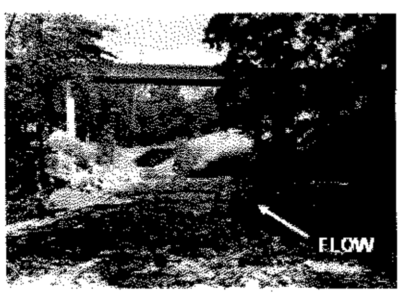
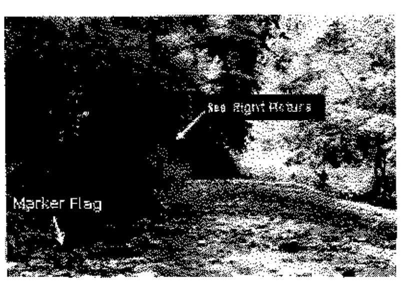


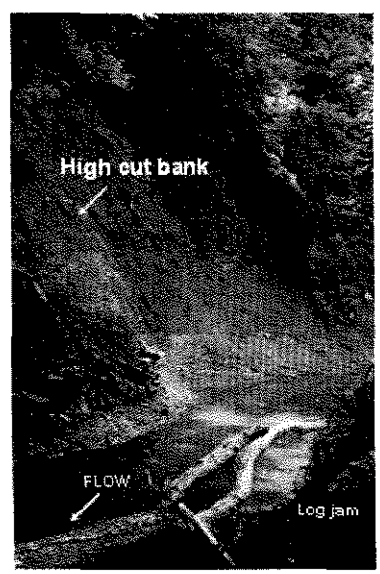

Figure 4. Upstream Site in Cedar Creek, Hardin County, KY.




Downstream View




Upstream View




Mid-site (Upstream View)

Figure 5. Remediated Site in Cedar Creek, Hardin County, KY

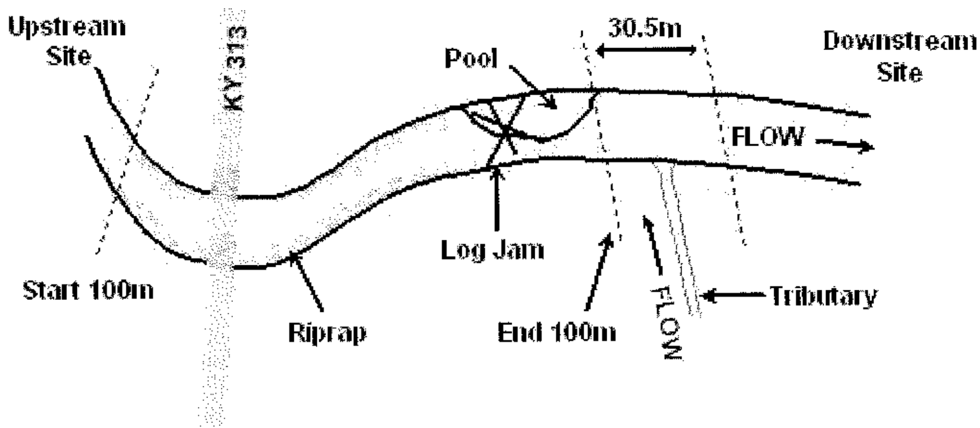



Figure 6. Remediated Sited in Cedar Creek, Hardin County, KY.

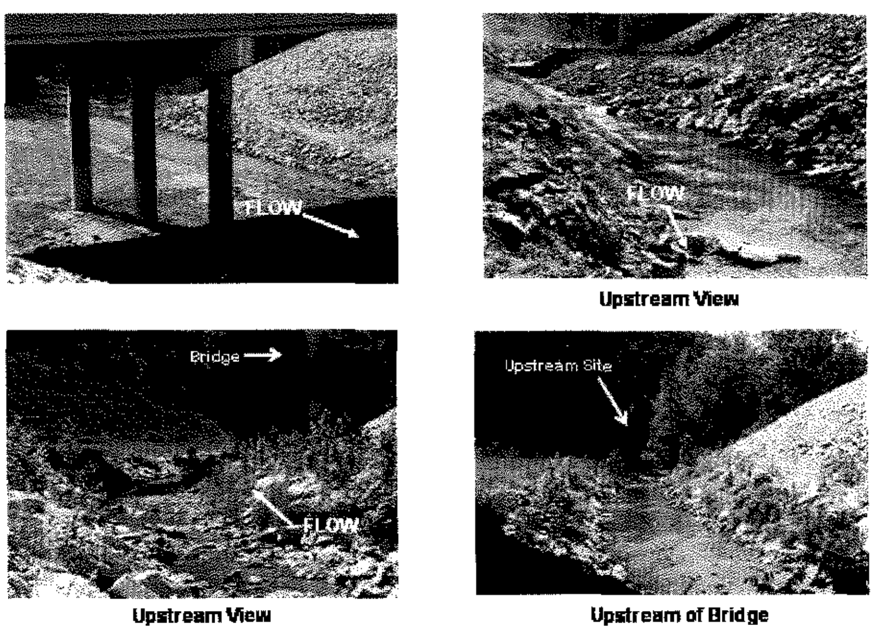


Figure 7. Downstream Site in Cedar Creek, Hardin County, KY

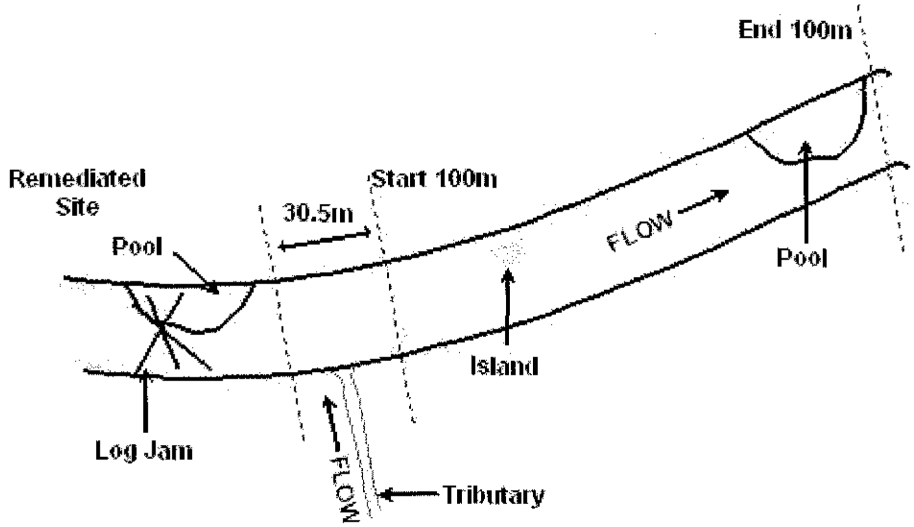



Figure 8. Downstream Site in Cedar Creek, Hardin County, KY.

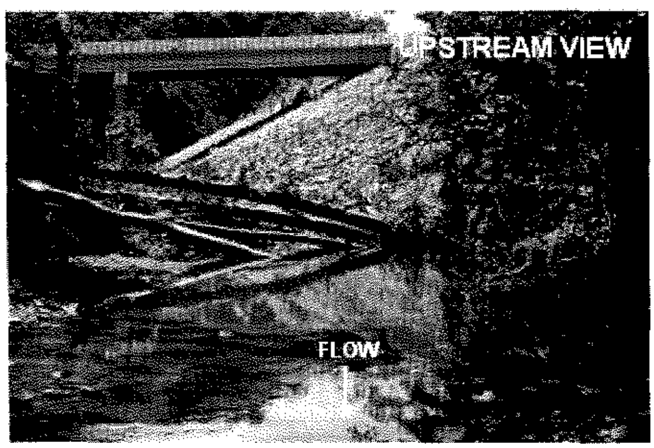



Figure 9. Upstream Site in Holts Creek, Bracken County, KY

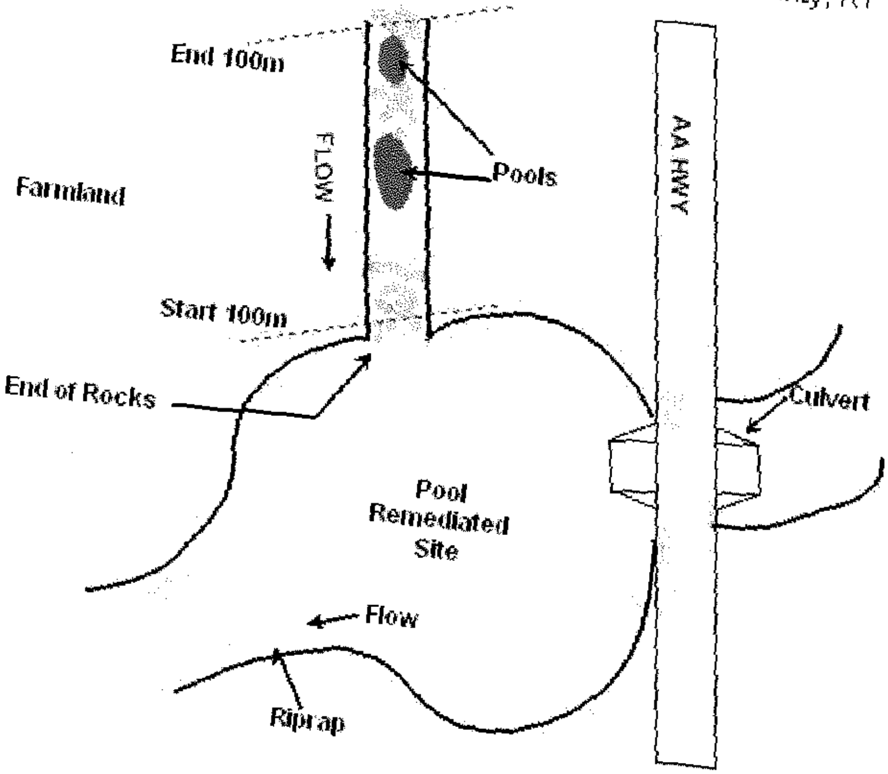
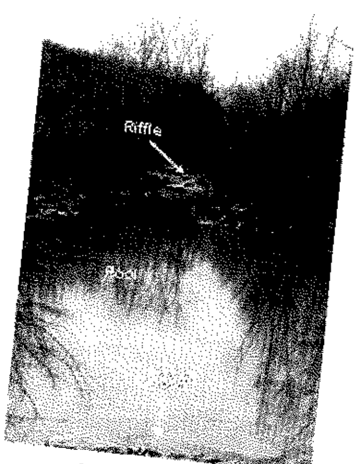
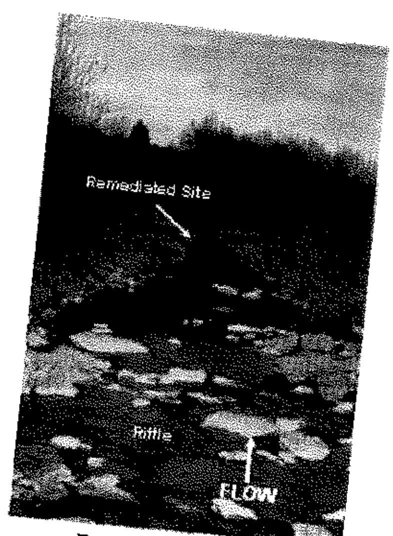



Figure 10. Upstream Site in Holts Creek, Bracken County, KY.




Upstream View




Downstream View