Determining Cost-Effectiveness of Best Management Practices in Sustainable Watershed Management: A Decision-Making Tool for Restoring Bullrun Creek

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Project Information

Summary:

Analysis of water quality data collected from Bullrun Creek showed decreasing trends in both sediment and Escherichia coli (E. coli) concentrations over the past four years. The decreases in these pollutant concentrations followed a series of best management practices installed within the watershed, although a direct correlation could not be established. Hydrologic modeling and GIS analysis determined that pasture improvements with riparian establishment were the most cost-efficient practices to reduce sediment and Escherichia coli in Bullrun Creek. Data from this study was utilized in the development of a Watershed Management Plan by the Bullrun Creek Restoration Partnership.

Introduction

The Role of Best Management Practices

There is increasing concern over degrading water quality in the United States, as water quality problems still affect over 40% of our national waters, such that many of these waters are too deteriorated for most uses (EPA, 2004). Further, non-point source pollution is implicated as a major source of degradation, thought to represent more than half of the nation's water quality problems (Copeland, 1999). After years of virtual stagnancy, water quality reform was keenly addressed by the Clinton Administration in 1997 with the Clean Water Action Plan, which was designed to remediate pollution and health hazards through the control of non-point source pollution and the development of management on a watershed basis. The Plan called for interagency collaboration at the state and federal levels, and also specifically called for public representation in the decision-making process of watershed management (62 Federal Register 60447-60449). U.S. Department of Agriculture programs that work in conjunction with the CWAP paradigm include the Conservation Reserve Program (CRP), the Environmental Quality Incentives Program (EQIP), and the Watershed Protection and Flood Prevention Act (P.L. 83-566), which is delivered through the Natural Resource Conservation Service (USDA 2003).

Such efforts in watershed management are largely based on the integration of a variety of best management practices (BMPs). Two major factors generally determine the adoption of a BMP; effectiveness and cost (Gitau et al., 2003). BMP effectiveness is largely based on the reduction of pollution, or increase in water quality that can be attributed to a BMP. Effectiveness is often maximized through the prioritization of target sites (White et al., 2003). Optimizing costs of BMP implementation is much more ambiguous. Factors that influence the success of a BMP include profitability, net returns, and the espousement of values and external costs, which vary greatly with perspectives of landowners and the general public (Gitau, et al., 2003). Many BMPs serve not only to improve environmental quality, but the health and productivity of farms and livestock as well. A study by Willms, et al. (2002) demonstrated that improved quality of waters consumed by cattle led to greater calf weight at birth and increased grazing. Moreover, they showed that improved water quality and forage conditions can optimize productivity. The CWAP and the USDA programs mentioned above benefit watershed management efforts through cost share programs, many of which are specifically designed for BMP construction and implementation (USDA, 2003).

BMP cost effectiveness may be readily approximated by comparing overall costs to predicted increases in water quality. What is increasingly difficult, however, is the determination of the real impact of a BMP on any particular site, and the interaction between combinations of BMPs, either successive within a site or within the watershed as a whole. Similarly, hydrologic dynamics are complex, ambiguous and inconsistent. Strategic management approaches, therefore, are often based on potential impacts and involve many assumptions. According to Gitau et al. (2003), the solution lies in “optimizing selection and placement of BMPs in order to determine the highest pollutant reduction at the least cost”. The study by Gitau et al. is one of few studies to undertake the task of predicting potential cost effectiveness of BMP implements, and serves as an archetype to the management ventures proposed for Bullrun Creek Watershed.

Best Management Practices in Bullrun Creek

Bullrun Creek drains a long narrow watershed in northeastern Tennessee. The 104 square mile tract runs NE to SW, parallel to the ridge and valley undulations of East Tennessee. The creek headwaters form in Grainger County and flow through Union, Knox and Anderson Counties before merging into Melton Hill Lake. Bullrun creek is currently classified by the Tennessee Department of Environment and Conservation (TDEC) as partially supporting (per CWA 313(d)), and has an initiated a Total Maximum Daily Load (TMDL) program. Water quality reports reflected impairment by sedimentation, channelization, habitat alteration and the presence of pathogens (TDEC 2000). Preliminary water quality data was observed by TDEC through a series of sampling events from September 2001 through October 2002. A review of this water quality data supported the suspect pollutant contributions (Burr 2003, pers. comm.)

Concern over the creek’s deteriorating water quality prompted the formation of the Bullrun Creek Restoration Partnership (BCRP). The BCRP is a stakeholder conglomerate that formed in 1999 with the goal of identifying and resolving sources of degraded water quality in Bullrun Creek. The Integrated Pollutant Source

Identification (IPSI) model developed by the Tennessee Valley Authority (TVA) suggests runoff from degraded pastures as a primary source of impairment, particularly for sediment and Escherichia coli (2002). Pastures account for nearly 25% of the landuse in Bullrun Creek Watershed, and the majority (85%) of these pastures are considered to be only poor to fair in quality (Hagerman, 2003). Pollutant additions from livestock operations are complicated in that pathogens may be delivered directly to waterways, but also when attached to soil particles. This leads to complex modes of delivery of pollutes from these sources, and erosional processes subsequently become pathogenic contributions (Glover 1996).
The BCRP, in conjunction with the Natural Resources Conservation Service (NRCS) and other governmental organizations, has assisted in funding the implementation of various best management practices (BMPs) through cost share programs. To date, 27 farms in the Bullrun Creek Watershed support over 125 BMPs (NRCS, 2003). The goal of the BCRP and its partners is to continue funding BMP implementation to help realize further water quality improvements. Programs set forth by the BCRP have also included technical and economic reports, public meetings and workshops. Currently, the BCRP is fostering the formation of a citizen stakeholder committee which will serve to represent the general public in the decision making process.
Effective best management practice planning mandates a holistic approach. Technical, economic, and social factors must be considered. The purpose of this study was to provide the BCRP with appropriate information to aid in decision making. Major importance was given to the continuation of stream data collection, and efforts to verify the cost effectiveness of BMPs. Primary objectives for this study involved an evaluation of water quality through stream sampling, indicators of BMP success, comprehensive modeling and BMP cost analysis.

Project Objectives:

1. Water samples from eight target sites in the watershed were collected and analyzed quarterly and following storm events in order to assess spatial and temporal trends in pollutant concentrations, and to help assess the viability of recent restoration efforts.

   Land-use changes and water quality benefits resulting from three BMP implements were modeled using IPSI to assist in watershed scale management planning.

   BMP scenarios that offered the most water quality benefits when modeled in IPSI were evaluated for practicality, cost-efficiency and overall optimality.

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Research

Materials and methods:

Methods
The methodology used in this study was standard procedure for water quality sampling, testing, and flow measurement. Additional methods involved basic comparative analysis, comprehensive hydrologic modeling using IPSI, and rudimentary cost and benefit assessment.

Watershed Description
Bullrun Creek is part of the Lower Clinch watershed (USGS HUC 06010207) in northeast Tennessee. The perennial creek is approximately 43 miles (70 km) in length, and drains 426 stream miles (686 km). The headwaters form in the southern corner of Grainger County and north Union county in upland hills with elevations greater than 1600 ft (500 m). The creek flows through rolling hills and narrow valleys and drops to 790 ft (240 m) elevation by the time it reaches the mouth at Clinch River. The drainage area is approximately 104 mi2 (269 km2), and has been delineated into 16 subwatersheds ranging from 1,112 to 6,558 acres in area.
Land use in the watershed, as identified by IPSI, is dominated by forest (81%), pasture (22%), and residential areas (12%), with small proportions held by commercial and industrial uses (~1.5% each). Minute fractions of the watershed are defined and use for row crop agriculture, mine quarries, and as wetland areas. Open water accounts for 0.5% of the watershed area. Of three areas classified as pasture, 84% are described as only fair in quality. Moreover, 15% of the pastures are downgraded to heavily overgrazed, while a mere 1% are classified as good. Very little of the pastures is defined as poor. The classification for pasture quality was established by the NRCS and TVA, with fair being described as approximately 50% vegetative coverage (grass) within each square yard of the area defined. Heavily overgrazed pastures were 25%-50% covered, while poor pastures were 25% or less covered (NRCS, pers. comm.).
Bullrun Creek is located in ecoregion 67f, described as southern limestone dolomite and rolling hills. The reference stream for Bullrun Creek is Big War Creek, located in Hancock County, also in 67f, but in the Upper Clinch watershed (TDEC 2000). Ecosystem reference stream acceptable concentration values are 6.12 mg/L for suspended sediment, 168.46 mg/L for dissolved solids, 174.58 mg/L for total solids and 161.4 cfu for E.coli (TDEC 2005). These values represent average concentration values over one year time range. Reference stream values serve as standards by which water quality goals may be set. References streams are not necessarily isolated from environmental impacts, but they are fully supporting within their defined uses.

Site Selection and Description
All sampling sites for this study were located in the Bullrun Creek watershed. All sites were chosen by TDEC, and were selected for one or more of the following; their proximity to potential pollutant sources, accessibility, or their location as representative for a segment of the watershed. A total of eight sites were sampled in this study. One each was set just above the confluence of North Fork branch and Upper Bullrun Creek. Two sites were chosen due to their proximity to point sources. Two sites were located on major tributaries just above the channel to observe any

their contributions, and two sites were sampled in the lower reaches of the creek.

Sampling Techniques

Sampling events took place on a quarterly basis between February 2004 and April 2005. Six instream sampling events occurred at low flow, and four occurred immediately following a storm event. Water samples were collected using a grab method at each site. Sampling bottles were sterilized and dried prior to the sampling date. Bottles were conditioned by rinsing with sample water, and submerged until filled to the appropriated level. All samples were kept on ice until tested in the laboratory, within a six hour time frame. All samples were duplicated and labeled immediately upon collection.

Water quality parameters of pH, temperature, electrical conductivity, and dissolved oxygen were observed onsite using a YSI 600XL multiparameter probe (Yellow Springs Instruments, Inc., Yellow Springs, OH). Stream width was measured with a tape and water depth using the rod of a portable flow meter. Flow velocity was measured using a Swoffer 3000 model fiber optic propeller flow meter (Swoffer Instruments, Seattle, Washington). Velocity readings were taken across the stream perpendicular to streamflow at calculated intervals. The distance between each measured interval was dependent on the dimensions of the channel and the flow rate. Flow rates were multiplied by the stream cross sectional area to calculate flow (Q) using the Velocity- Area method. Flow rates for the watershed were not calculated, due to the limited amount of data, and expression of high variation in streamflow, particularly for high flow storm events that exceeded bankfull capacity.

Laboratory Techniques

Water samples were tested for solids and E. coli concentrations in a laboratory setting. Sediment was tested for all planned sampling events and storm events. Suspended sediment was measured using silicate filters designed to trap particles 0.3 µicrons and smaller. The filters were preconditioned in an oven and weighed prior to testing. Sample bottles were shaken until particles were evenly suspended in the sample, and drawn through the conditioned filters into a flask with the use of a vacuum tube. The filters were carefully removed with metal forceps, and placed into small aluminum pans (also weighed). They were then heated in an oven at 103 degrees Celsius until dry, and then weighed again. The difference in mass represented the suspended sediment mass in the sample (Greenberg et al. 1992). This is expressed as a concentration per the volume of sample used in the analysis. Total sediment was measured by pouring a fixed volume of shaken sample directly into a tared aluminum pan, and heated by the same process. The additional mass was the total sediment mass in the sample. Dissolved solids were calculated as the difference between total and suspended solids (Greenberg et al. 1992).

Instream samples were tested for E. coli using the Most Probable Number method and IDEXX Colilert testing kits. Samples were collected at precisely 100 mL using conditioned plastic bottles as required by IDEXX. Seed was supplied to each sample bottle and dissolved, which was poured into a labeled tray. The trays were sealed and left to incubate at 35 degrees Celsius for 24 hours, then were viewed under short wave (450 nm) fluorescent lighting. Cells in the tray that were visible at this wavelength were positive for E. coli colonies. The visible cells were counted and the ratios were translated to concentration values using charts provided by IDEXX (IDEXX Laboratories, Westbrook, Maine).

Modeling Techniques

The Integrated Pollutant Source Identification (IPSI) model and tool was developed by TVA for use in water quality improvement efforts. IPSI is a multifaceted tool that consists of a Universal Soil Loss Equation (USLE) based hydrologic model, a GIS database developed from aerial photography, and a system of characterized landuse classifications. Bullrun Creek was initially analyzed by aerial photography, interpreted into GIS data, and loaded into the Integrated Pollutant Source Identification (IPSI) database as a TVA project (2003). IPSI differs from other hydrologic models in that its land use parameters that have been minutely qualified by GIS analysis, and also offers unique operations management components. However, this model lacks extensive field testing and calibration for Bullrun Creek. For purposes of this study, IPSI was used primarily as a planning tool to predict water quality benefits as related to operations managements in pasture improvements and riparian buffer zone development and in the restorative efforts of streambank stabilization.

A list of BMPs implemented between the 2001-2002 TDEC study and the 2004-2005 study was obtained through consultation with the Natural Resources Conservation Service (NRCS). The farm coordinates were integrated into a map of the Bullrun Creek watershed using the IPSI database and ArcGIS (Geographic Information System). The locations of these sites were expected to be of certain relevance, pending anticipated decreases in pollutant concentrations.

Pollution load models were simulated to reflect potential pollutant reductions resulting from varying BMP scenarios. Many types of pollutant sources exist in Bullrun Creek, However, practicality mandates priority to those sources that are excessive contributors, or prevalent in numbers. Practices in this study were thus narrowed to include only pasture improvements, riparian buffer growth, and streambank stabilization, due to their heightened direct impact on water quality. Pasture improvements and streambank stabilization implements were individually modeled to view water quality improvements at increasing percentages of improvements. Riparian buffers are not represented in IPSI and were not modeled for sediment control.

Research results and discussion:

Results and Discussion

The purposes of this study were to gain current hydrologic data through monitoring, and use this data to optimize a strategic watershed plan aimed at improving water quality. Water quality analysis illustrated a decreasing trend in sediment and Escherichia coli following a series of Best Management Practice (BMP) implementations. The practices are thought to be contributive to the decline in pollutes, although not enough data was substantiated as to derive any statistical correlation. Hydrologic predictions using the Integrated Pollutant Source Identification (IPSI) model indicated pasture improvements as the most cost-efficient BMP additions to this watershed. Water quality data and modeling outputs were delivered to the Bullrun Creek Restoration Partnership, a group of local stakeholders from both public and private sectors that work conjointly to improve the conditions of the creek. The BCRP utilized this information in their Watershed Restoration Plan recently submitted to and approved by the Environmental Protection Agency (EPA). A rough draft of this document is attached to this report.

Water Quality Analysis

A review of data from the 2001-2002 TDEC sampling events and the 2004-2005 sampling events reflected measurable decreases in the concentrations of pollutants found in the waters of each sampling site. Average concentrations for suspended solids and E. coli decreased by 43% and 46%, respectively. The analysis between sampling studies is limited to the suspended portion of sediment, as was the only parameter tested by TDEC in the first sampling series. The site at Bailey Road was not assessed by TDEC, and therefore no comparisons were made. Sites of particular hydrologic interest are discussed in further detail.

Hydrologic Anomalies in Bullrun Creek at Highway 25

The sampling site at the Highway 25 bridge is located approximately 5 miles north of the mouth of the creek, where it joins the Clinch River. This site is the hydrologically lowest of those sampled, thus it always reflects the highest flow volume of any sites during any given sampling event. However, the site does not always reflect the highest pollutant concentrations. Many factors may account for this departure, yet they can be summarized in three major dynamic processes. The first is a function of the flow rate. If pollutant concentrations are lower in subsequent hydrologic additions to the creek, then the resulting concentrations have been diluted and will yield lower values. Another dynamic arises from this site's proximity to the mouth of the creek, which causes flow to slow, or stop at times, and creates a lagoonal effect. Stilled waters increase retention time such that pollutants settle to the creek bed and out of the water volume. Other dynamics involve the instream processes that can absorb, trap, or modify pollutants on their course through the waterway. For example, heavy sediment particles may settle quickly, attach to, or even be filtered by, physical features in the channel (Haan, et al. 1994). Bacterial pollutants such as E. coli may die off, be immobilized if attached to sediment, or consumed by other biological processes, also which increase with retention time (Glover 1996). Sediment settling is evident by the fact that this site tested lower in sediment concentrations at low flows than the sampling site 12 miles upstream.

Site 1 data reflected a decrease of 14% in suspended solids and 59% in E.coli. The decrease in suspended solids is less than those observed in the rest of the watershed, which supports the evidence of lagoon type dynamics occurring here. Because fine particulates have the retention time to settle out at this site, sediment values are lower on average. Therefore, the percent reduction in sediment may be larger, but is not reflected between the two values.

A Comparison of Subwatersheds

Upper North Fork branch and Upper Bullrun Creek were utilized as a multiple watershed study within the Bullrun Creek study. Both watersheds are similarly sized, hydrologically analogous, and subject to the same climatic inputs. The greatest discrepancy between these sub-drainage areas is their associated land uses. Upper North Fork drains more urban and developed areas, including the city of Maynardville. Upper Bullrun Creek is predominantly agricultural, and hosts several BMP sites in its proximity. Both branches were sampled just above their confluence at the Highway 144 bridge.

Upper Bullrun Creek reflected a decrease of 67% in suspended sediment and 48% in E.coli, while Upper North Fork only expressed a decrease of 3% in suspended sediment, and 16% in E.coli. One explanation for the small decrease in sediment may be that this is more of an urban watershed, and has fewer sources of erosion. If the initial amount of sediment loss was relatively low, then improvements would be few. Decreases in E. coli may be the result of the participation of local utilities in sewer and septic maintenance and remediation efforts.

North Fork at Johnson Road

Site 7 chosen for its proximity to sewer outlet, and not initially for sediment, although a decrease of 45% in sediment was expressed by the data. This site is a small urban tributary that is not affected by any of the BMPs implemented by cost share programs. It may, rather, reflect the cessation of localized construction, which prevailed through the completion of a local subdivision and the 2004-2005 sampling events. E. coli concentrations, similarly, decreased by 56%, again likely being the result of the completion of utility work within the new subdivision, and rigorous remediation efforts by the local utility company.

Meeting TMDL Requirements

Site 2 is located on Bullrun Creek approximately 17 miles north of the creek's mouth at the Highway 441 bridge. Descriptively, it hydrologically complex and newly fallen trees lay in the creek, showing evidence of bank erosion and bank failure. At this point, Bullrun Creek drains two-thirds of the watershed by area, and a majority of tributaries. This sampling site is the most comprehensive representation of the watershed as a whole. The bridge at this site also hosts a flow sampling gauge operated by the USGS. Flow data for this site taken from the USGS website shows the average daily flow rate for 2004-2005 to be 40,700 cubic feet per second (cfs). The reference stream criterion for suspended sediment (TSS) is a yearly average of 6.12 mg/L (Arnwine 2000). However, the average TSS measured in Bullrun Creek for the years 2004-2005 is 12.8. This indicates that sediment in Bullrun Creek must be reduced by half to meet TMDL requirements. Data analysis between TDEC sampling years and 2004-2005 sampling reflect a 44% decrease in sediment and a 41% decrease in E. coli.

Storm Sample Data

Storm sample data was measure on four flooding events during 2004-2005. This data was analyzed for sediment concentrations, although that data is not relevant to this study. It may, however, provide information regarding total sediment load and storm event soil losses for future studies. The difficulty in relating storm data is due to the impossibility of calculating bankfill overflow (Haan 1994) and representing peak sediment losses within the local hydrograph.

Summary

Although the decreases in pollutant concentrations are relatively substantial, it is not justifiable to attribute reductions to the management practices that have been added to the watershed. Sediment dynamics and stream hydrology are far too complex to be aptly expressed with this small amount of data and these simplified correlative indices. It is also important to note that sampling methods and, to a larger degree, laboratory methods that were employed for each sampling series differ greatly. TDEC data was collected using automated flow meters and culturing techniques for E. coli, whereas propeller meters and IDEXX testing kits were used for this study, as described in the Methods and Materials section. TDEC also measured flow rates that averaged just over half (56%) of the rates measured in this study. Although the variation in those flow rates was often climatic in origin, deviation in sampling technique, and sampling error, were considered in analysis.

That being addressed, the pollutant concentration values expressed by the sampling series in this study are consistently lower, although by varying amounts, than those from the 2001-2002 TDEC sampling series. It is likely, although not certain, that the BMP additions contributed in part to these reductions. It should be noted that over 120 BMPs were implemented in the four years between the TDEC and UT sampling series.

Modeling Scenarios

Bullrun Creek was modeled using the Integrated Pollutant Source Identification program developed by TVA. The first modeling component investigated the potential pollution reductions of two selected management practices. Pasture management and streambank stabilization were observed separately to determine the impact of each individual practice at increasing levels of implementation. Compound effects were not taken into account.

Pollution Reduction Modeling Results

IPSI modeling of erosion and sediment delivery of pastures suggest that 93% of the sediment that is contributed by pastures could be prevented with pasture improvements. According to IPSI, pastures are currently contributing nearly 4, 000 tons of sediment to Bullrun Creek and its tributaries every year. A 50% improvement in all pastures could reduce this amount by nearly half. A 75% improvement of all pastures would further reduce sediment delivery to by two-thirds, and if all pastures were improved to good pastures, only 270 tons (a 93% reduction) would be delivered to the channel each year. Due to the fact that this model has not been calibrated for this creek, the pasture losses are not indicative of sampling data. The modeling component of IPSI is used relatively, and only as a management tool. Streambank stabilization improvements also offered great improvements in the reduction of sediment from bank erosion. Currently, over 52 miles of Bullrun Creek is identified as eroding, delivering 12,600 tons of sediment to the creek per year. Because streambank stabilization efforts serve to prevent erosion (beyond natural rates inherent of stream dynamics), the reduction in sediment delivery is directly proportional to the amount of stabilization. There fore, a 50% reduction is eroding banks would decrease sediment delivery to 6,300 tons per year. A 100% improvement in stream banks would leave 1200 tons delivered per year by natural processes.

GIS Analysis
Riparian buffers are not separated from other vegetation in the IPSI model, but were evaluated for management via GIS analysis. The land use- land classification scheme utilized in IPSI GIS allowed for the selection of riparian zones based on vegetation type, density and width, and by associated land uses. GIS indicated that 83,100 feet of streams in Bullrun Creek were described as open, meaning having no woody vegetation. 422,000 feet of streambanks were considered forested, although the quality of forests was not identified. Approximately 440,000 feet of streams border agricultural lands, where pastures predominate and a majority of these are in need of improvement. Riparian zones given priority for management were 14,000 feet that were located on agricultural lands, had no closed vegetation, and were subject to animal access. Second priority was given to the 2,980 feet of streams whose riparian zones were classified as grass with a density of less than 33%, and were less than 50 feet in width. Third priority was given to zones that were tree or shrub zones but were less than 33% and less than 50 feet in width; however, this numbered over 50,000 feet and should be further prioritized before BMP implementations.
Eroding streambanks were also analyzed using GIS such that priority contributors could be identified. Nearly 280,000 feet of streams are identified as eroding. 27, 550 feet of streambank were classified as both eroding and having animal access, while 6923 feet were eroding, allowed animal access, and were described as having open riparian zones. These stretches of the stream will lead in priority for streambank restoration initiatives.

Other considerations
Over 125,000 feet or riparian zones in Bullrun Creek have open animal access. This should be considered for fencing in pasture management implementations on a site specific basis. As a note regarding modeling, fencing, buffers and pasture managements will significantly reduce E. coli loadings by impeding soil delivery and preventing animal access to the creek. Delivery ratios were not calculated for E. coli in IPSI. Therefore, these components will be managed as soil loss prevention and consider E. coli as an indicator, rather than a modeling component.

Participation Summary

Educational & Outreach Activities

PARTICIPATION SUMMARY:

Education/outreach description:

Publications and Outreach
The data from this report was utilized in the Bullrun Creek Watershed Restoration Plan, written and proposed by TVA, NRCS and the Bullrun Creek Restoration Partnership. Water quality data from this project was also presented to the newly formed Bullrun Creek Watershed Association, a citizen stakeholder group, as an informational and management planning tool. The Bullrun Creek Restoration Partnership was recently granted government funding for best management practice implementation and further water quality testing and equipment.

Project Outcomes

Project outcomes:

Economic Analysis

Cost and Benefit Economic Analysis
A review of costs suggests that pasture improvements and streambank stabilization offer similar benefits when considering sediment reduction in weight per cost, approximately $.26 per pound of sediment reduced. However, the scope of the BMPs modeled in this study are limited in certain respects and have been approached for the most efficient management solutions.
Pasture improvements would potentially remove a large portion of sediment that is delivered to the creek. Based on IPSI modeling and NRCS cost listings, pasture improvements average $120 per acre, although this amount includes only hay and pasture plantings. It does not include any additional costs for crop conversion or any associated fencing or livestock management costs.
Streambank stabilization projects offer extremely effective erosional control if properly implemented. Like pasture managements, these measures prevent erosional processes, rather than control sediment. Stabilization projects offer sediment reduction for the same price per pound as do pasture improvements. However, these projects are usually limited in their effectiveness due to the scale in which they are needed. As such, these projects are also limited to 800 feet for cost share funding from government programs.
Cost assessment for riparian buffers cannot be determined for mass reduction using IPSI. However, riparian buffers considered as an extension of the prior BMP implements, and were so modeled for costs. When pasture improvements were calculated, any length that was stream adjacent was converted into a riparian zone. Similarly, streambank restoration efforts innately include the development of a riparian strip, though actual widths would vary when implemented on the ground. For cost assessment purposes, all streambank restoration implements were conjoined with riparian establishment, as were all pastures with stream adjacency. All buffers were evaluated at 50 feet in width and with appropriate lengths. Buffer establishment cost is based on the NRCS two-zone type using no chemicals, which averages $400 per acre, or 800 feet at the given width.

Cost Benefit Scenarios
Three BMP implement scenarios were derived to consider multiple options and costs. Each scenario has a theme based on the type of pollutant source. The first

scenario addresses the critical areas in the watershed that deliver the greatest pollution per area. These would include the highly eroding streambanks that have no riparian growth and are subject to animal access, and the pastures that are considered heavily overgrazed or poor. Complete remediation of these areas includes repairing the stream length, buffering the stream length and planting 2500 acres of pasture. The cost for this project scenario approximates $775,000, and prevents 1,340 tons of erosion per year.

The second scenario addresses strictly grasslands. This includes improvement of all pastures and establishment of grassed riparian zones that are considered low in density and are less than 50 feet in length. This project would require just over 15,000 acres of pasture planting, and approximately 3,000 linear feet (3.5 acres) of a 50 foot wide riparian field. The cost for this project is just over $1, 820,000 and would prevent 3500 tons of sediment from reaching the stream each year.

The third scenario addresses strictly animal operations management, including extension fencing, riparian establishment and pasture improvements. Specifically, implements would require 27,500 feet of exclusion fencing, 14,000 linear feet of 50 foot wide riparian buffer (16 acres), and a 50% improvement of all pastures. The total cost for this project is $950,000 and it prevents 1,640 tons of sediment from reaching the stream each year.

Costs were determined for the amount of sediment prevention for each scenario. Scenario 1 was the least expensive, averaging $475 per ton decreased. Scenario 2 was the second most cost-efficient, averaging $515 per ton of sediment decreased. Scenario 3 was the most expensive option, averaging $575 per ton of sediment loss prevented. However, this scenario becomes the least expensive option if the pasture component is targeted for heavily overgrazed and poor pastures only. The amended scenario decreases sediment loss to 1,300 tons per year; however the cost drops to $230 per ton.

External Cost Considerations

BMP selection and implementation needs not only be affordable to farmers and feasible for cost share programs, they must also be effective in order to serve their intended purposes and give value to the resources spent. The following three scenarios proved the most effective at removing sediment from Bullrun Creek and were analyzed for average costs

Pasture improvements prove the least expensive control for both pollutants, as it keeps sediment at source. Prevention always costs less than repair. Livestock in stream is thought to be a direct contributor of pathogens to a stream. However, the associated costs are too complex and site specific to deliver a meaningful rate. Variations that affect these costs include the length of stream to be fenced, the availability and costs of providing alternative watering sources, and the necessitation of additional alternative BMPs, such as heavy use protection pads or stream crossings. Fencing also serves to keep cattle out of stream and the grass acts as riparian buffer system to help filter sediment and E. coli. However, it can be expensive to maintain fences in swollen streams. Another external expense of fencing is alternative watering and water source costs for farmers. Complete pasture improvements and riparian planting are less expensive than streambank restoration alone, and with an 800 foot cap for cost share programs (NRCS), the two previous practices are more effective for this study. However, there is still a great need to repair creek banks.

Recommendations:

Areas needing additional study

Recommendations

The focus of this study is one of great use. However, the mechanisms for its development are intricate and sometimes ambiguous. The first recommendation for this study is the continuation of data collection, to better characterize the stream over time, and for use in model calibration. Certain components modeled in IPSI do not correlate with data from the field, whether sampling data or GIS interpretation. Another shortcoming of IPSI is the lack of modeling for riparian fields surrounding other land uses. Trapping efficiencies for buffers would be a valuable component to add to modeling efforts and cost analysis when using IPSI. TVA is presently undergoing attempts to calibrate IPSI for better utilization for Bullrun Creek and other regional watersheds.