The Ozarks Environmental and Water Resources Institute (OEWRI)
Missouri State University (MSU)

FINAL REPORT

Nonpoint Source Bank Erosion and Water Quality Impairment Assessment, James River at Rivercut Golf Course, Greene County, Missouri

Field work completed July 2013

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SCOPE AND OBJECTIVES

The James River Basin Partnership (JRBP) is working with Springfield/Greene County Parks and Recreation to implement a conservation easement along the bank of the James River in southern Greene County. This conservation easement is part of a Section 319 Grant from the Missouri Department of Natural Resources and the Environmental Protection Agency Region VII designed to reduce nonpoint source pollution to the James River. The Ozarks Environmental and Water Resources Institute (OEWRI) completed a bank erosion and nonpoint source pollution modeling study to determine the annual bank erosion rates and related sediment and nutrient loadings to the James River for the 4 km long easement segment. Additionally, a sub-reach scale assessment was conducted to identify areas of potential nonpoint source pollution based on field indicators of bank stability and erosion. Sediment released to the channel by erosion can supply excess nutrients to the river and cause sedimentation problems downstream. Runoff from developed and disturbed land area is also a source of sediment and nutrients to the river. Portions of the James River were listed on the 303D list of impaired waters for nutrients in 2001, and phosphorus (P) has been identified as the limiting factoring in eutrophic conditions in the basin (MDNR, 2001).

Riparian easements remove the potential for future development or other disturbances that can increase runoff and nonpoint loads to the river. The purpose of this assessment is to evaluate the effects of the riparian easement implementation on long-term sediment and nutrient loads in the James River to support 319 requirements and the goals of the James River TMDL. The objectives of the assessment are:

(1) Complete a field survey of the channel and adjacent riparian areas to determine the size and shape of the channel, substrate characteristics, and bank conditions to support nonpoint load reduction procedures;

(2) Determine bank erosion rates since 1996 using differences in channel and bank locations derived from aerial photographs. A GIS –based framework will be used to map channel locations and determine bank erosion rates; and

(3) Calculate load reductions due to different scenarios based on (i) land use management and (ii) expected geomorphic adjustments of the channel bed and banks using sediment budgeting approaches and the nonpoint model STEPL (Spreadsheet Tool for Estimating Pollutant Load).

(4) Make specific recommendations for reducing nonpoint source pollution from the study reach based on field observations.

SITE DESCRIPTION

The James River Basin (3,768 km^2) drains portions of Webster, Greene, Lawrence, Christian, Douglas, Taney, Stone, and Barry counties in southwest Missouri (MEC 2007; Figure 1). Land use within the basin ranges from pasture/grassland in the upper basin, to urban/suburban in the middle portions of the basin, to mostly forest in the lower basin (MEC 2007). The study site is located in the Middle James River Basin approximately 72 km (45 mi) upstream of Galena in Greene County. The 4.3 km study reach begins about 1.2 km upstream of the Cox Road Bridge and extends 3.1 km downstream of the bridge. The property where the approximately 4 km easement was established is owned by Springfield/Greene County Parks and Recreation located along the south bank of the river downstream of the bridge and along the east side of the river upstream (Figure 2). Downstream of the bridge the easement extends about 30 m (100 ft) from the south bank of the channel covering floodplain and bluff. Upstream of the bridge the easement ranges from 60-200 m (200-700 ft) wide. The total easement area is about 18.6 ha (46 acres).

The underlying geology of the site is mainly limestone of Mississippian age (Thomson 1986). Upland soils typically have a thin layer of loess over highly weathered residuum that can contain 10-40% chert fragments (Hughes 1982). Small tributary valleys contain alluvial deposits composed of stratified layers of chert gravel and silty alluvium. Main valley bottomlands have relatively deep accumulations of silty alluvium over coarse gravel. Limestone bluffs are common where the river meets the valley margin and bedrock is often exposed in the bed of the stream at these locations. Channel substrate consists of coarse gravel and cobbles with boulders common near bluffs.

Bankfull channel geometry through this area was described by DeWitt (2012) with field data collected in the summer of 2011. The bankfull discharge was estimated to be 177.1 m^3/s (6,254 ft^3/s) through a channel 53.1 m (174 ft) wide, 2.2 m (7.2 ft) deep, with a cross-sectional area of 113.9 m^2 (1,225 ft^2). The site is located halfway between two United States Geological Survey (USGS) gaging stations approximately 21 km (13.1 mi) upstream of Boaz (07052250) and 20 km (12.4 mi) downstream the gage near Springfield (07050700) (Table 1). Gage records indicate the present channel can contain 1.25-1.5 year recurrence interval flood, which is a typical flood frequency for relatively stable alluvial rivers (Leopold et al. 1964; Owen et al. 2011). However, excess gravel deposited in “disturbance reaches” can cause lateral migration and bank erosion particularly in areas flowing into and out of bedrock bluffs (Saucier 1983; McKenney et al. 1995; Jacobson and Gran 1999). Disturbance reaches have been identified in other areas of the James River Basin (Martin and Pavlowsky 2011).

METHODS

A combination of methods was used to assess bank erosion contributions to water quality degradation to the river from this site at different spatial and temporal scales. Field notes and photos were collected on July 11, 2013 describing the channel and bank conditions along the study reach at the sub-reach scale (see photo log). Long-term bank erosion rates were assessed by using both field surveys and comparing 1996 and 2008 aerial photographs over the entire study reach. The field based rapid geomorphic assessment was conducted to both verify channel geometry and to identify indicators erosion and channel instability. Finally, the water quality model STEPL was used to simulate changes in water quality using different land use scenarios. Specific methods used for each of these approaches are detailed below.

Reach-Scale Bank Erosion Assessment

For the reach-scale bank erosion assessment both field-based and aerial photography interpretation methods were used. Each method is described below:

Field-Based Assessment

Field-based assessments are useful for identifying basic indicators of geomorphic process such as; channel meandering, incision, aggradation, and widening. Furthermore, field observations help verify interpretations from aerial photography. For this study a modified rapid geomorphic assessment was used to describe the channel at pre-selected points along the study reach (Rosgen, 1996, Fitzpatrick et al., 1998). This specific assessment identifies channel units, bed morphology, bank conditions, and basic channel dimensions every 400 m along the study reach. Channel dimensions include bank heights from the thalweg that is representative of the bank conditions 200 m upstream and downstream of that point. The collection point is in the center of a channel cell that is represented by the information collected at that point. These data will be combined with erosion rates from historical aerial photography interpretations to estimate sediment contributions to the river.

Aerial Photography Interpretation

Historical aerial photography can be used to understand how rivers change over time. Historical aerial photographs of the area are available going all the way back to the 1940s. However, these photos were not able to be used for this study due to poor image resolution and high rectification error. For this study a USGS Digital Ortho Quadrangles (DOQ) collected March 10, 1996 with 1 m resolution was used as the baseline photo. This photo was compared to a 0.6 m color photo collected April 6, 2008. Photos were obtained via the internet from the USGS Earthexplorer website and came pre-rectified. Both banks were digitized for each photo series in ArcGIS for overlay analysis. A 400 m channel cell polygon feature was created with the location of the field-based assessment at the center of the cell (Figure 3). An average erosion rate between each photo series was calculated in each cell by creating an area of erosion within each using the digitized banks from each photo year and dividing that by the cell length.

Bank Erosion Calculations

Annual bank erosion was calculated using the following equation:

$$E_a = \sum (E_m * B_h * L_c * D_s) / P_y$$

Where:
E_a = annual erosion (Mg)
E_m = average erosion within all of the cells (m)
B_h = mean bank height of cell (m)
L_c = length of cell (m)
D_s = bulk density of soil (Mg/m^3) from soil survey
$P_{y =}$ length of time between photo years (yrs)

STEPL Water Quality Model

Water quality models are used to understand how nutrients and sediment move off the landscape from different types of land uses. By changing the land use type, or by adding different practices designed to reduce pollution, the impact of these changes can be evaluated. For this study the Spreadsheet Tool for Estimating Pollutant Load (STEPL) was used to look at the impact changes to the easement property would have on water quality. STEPL is a customizable spreadsheet-based model for use in Excel. Using simple algorithms, it calculates nutrient and sediment loads from different land uses and the load reductions from the implementation of BMPs. Annual nutrient loading is calculated based on the runoff volume and pollutant concentrations. The annual sediment load from sheet and rill erosion is calculated based on the Universal Soil Loss Equation (USLE) and the sediment delivery ratio. Accuracy is primarily limited by the wide variability in event mean concentrations (EMCs) across watersheds since EMCs drive the water quality calculations.

For this study, load results of existing conditions will be compared to several scenarios that change the hydrological and nutrient management characteristics of the site. Hydrological inputs into the model are controlled by soils information supplied by the user. Soils within the easement area were identified, clipped, and areas calculated using ArcGIS. The Hydrological Soil Group (HSG) was assigned to the appropriate soil mapping unit. Default curve numbers (CN) within STEPL were used for the forest, pasture, and cropland land use. The curve number for the pasture land use was modified using appropriate curve numbers for a meadow in fair condition from TR-55 (USDA, 1986). Greene County Missouri and the Springfield Regional Airport were selected within the STEPL user interface for rainfall and runoff data. Built-in default nutrient and sediment concentrations were used for each land use category within each scenario.

RESULTS AND DISCUSSION

Sub-Reach Descriptions

The 4 km study reach was classified into 14 sub-reaches based on changes in channel form, substrate, and bank conditions observed in the field. Sub-reach (SR) descriptions are given here:

<u>SR-1 Straight Reach #1 (Station 1.6-1.8 km)</u>
This is a relatively straight reach with a bluff present along the left bank. The right bank appears stable with a thin riparian buffer.

<u>SR-2 Disturbance Reach #1 (Station 1.8-2.2 km)</u>
The channel splits around a vegetated island and the channel that splits right appears to be an old channel location that appears to be slowly filling in over time. The right bank on the outside of the disturbance reach is actively eroding. The channel is adjacent to a bluff on the left bank.

<u>SR-3 Bridge/Road and Cutoff Channel Reach (Station 2.2-2.7 km)</u>
Cox Road runs along the side of the channel through this reach and rip rap has been placed along the left bank for much of the reach. A bridge has been placed over a cutoff channel near station 2.35 km. During high flow water moves through the cutoff channel and reenters the river at station 4.8 km. A thin riparian buffer exists along the floodplain on the right bank. A small tributary that appears to be connected to a wet weather spring enters the river at station 2.65 km.

<u>SR-4 Historical Meanderbelt Reach (Station 2.7-3.2 km)</u>
Bedrock is exposed along the toe of the right bank of the river through this reach. Lower floodplains are forming below the high floodplain surface in this reach. This indicates that the channel may have been over-widened and is now in the process of rebuilding its floodplain.

<u>SR-5 Ward Branch Confluence Reach (Disturbance Reach #2) (Station 3.2-3.8 km)</u>
A large delta bar has formed below the confluence of Ward Branch from station 3.3-3.4 causing erosion along the left bank of the river. This reach is also over-widened and has a lower floodplain developing below the upper floodplain surface.

<u>SR-6 Strath Terrace Reach #1 (Station 3.8-4.2 km)</u>
The river begins a 360 degree turn at this location as it enters the Rivercut Golf Course. The outside bend of the channel here is adjacent to bedrock exposed at the base of the right bank near the club house. The right bank is significantly higher than the alluvial left bank and is probably

an old strath river terrace resulting from downcutting through the bedrock. There is a narrow riparian buffer along the left bank and it appears to have moderate erosion.

SR-7 Meander Bend Reach (Station 4.2-4.5 km)

The river at this location is entering another 360 degree bend, but a lower floodplain is building along the right bank. The left bank has a narrow riparian buffer along the left bank and it appears to have moderate erosion.

SR-8 Mega Bar and Cutoff Channel Confluence Reach (Disturbance Reach #3) (Station 4.5-4.9 km)

There is a bedrock knickpoint at the beginning of this reach with a large mega bar complex downstream on the left side of the channel. The mega bar complex is forming at the point where the cutoff channel empties back into the river from station 2.35 km. The right bank of the river is adjacent to the golf course, has a poor riparian buffer, and rip rap has been placed along the toe.

SR-9 Bedrock Bluff Reach (Station 4.9-5.2 km)

The channel in this reach is straight and adjacent to a bedrock bluff along the left bank. The right bank appears to be a high floodplain that has a thin riparian buffer and moderate erosion.

SR-10 Bluff/Island Reach (Station 5.2-5.3 km)

The channel in this reach is straight but splits around a large vegetated center bar. The bedrock bluff extends along the left bank of the river. There is a high floodplain along the right bank that has a thin riparian buffer and appears to have moderate erosion.

SR-11 Straight Reach (Station 5.3-5.5 km)

The channel through this section is relatively straight. The bluff extends along the left bank through the reach with a narrow colluvium/alluvium bench formed at the base that is subject to erosion. Much like the reaches above, the right bank has a thin riparian buffer and has moderate erosion.

SR-12 Bedrock Knick/Disturbance Reach #4 (Station 5.5-5.7 km)

As the channel bends away from the bedrock bluff along the left bank a steep bedrock knickpoint creates a mega bar and a multi-thread channel through this reach. Bedrock is visible at the toe of the left bank that has a thin riparian buffer. The easement ends along the left bank at station 5.6 km.

SR-13 Strath Terrace Reach #2 (Station 5.7-5.8 km)
A short stretch of strath terrace is exposed along the right bank of the river through this reach. Similar to the reach upstream, bedrock is visible at the toe of the left bank that has a thin riparian buffer.

SR-14 Cutbank Reach (Station 5.8-5.9 km)
Just downstream of the strath terrace an active cutbank is eroding along the right bank. A gravel bar is building along the left bank of the river. This area is downstream of the easement, but is adjacent to the golf course property.

Long-Term Bank Erosion

River Morphology
Bedrock bluffs and natural obstructions have a major influence on the channel along the 4 km long study reach. Bluffs and bedrock along the bank toe were observed along the bank of the river along the easement for the majority of the reach length and bedrock can be found along the bed of the river frequently (Figure 4). When it occurs, bedrock in the bed and along bluffs limits the ability of the river to meander and scour the bed and is typical of streams in the Ozarks (Pavlowsky, 2004). Field measurements taken in July 2013 show the active channel width varies from about 26 m from 3.2-3.6 km up to 93 m from 4.4-4.8 km. The active channel refers to both the wetted part of the channel at low flow, but also the gravel bars located adjacent to the water, but set below the bank. The high active channel widths indicate areas where large bars are present in the channel. Bank heights vary from around 2.5-4.7 m through the study reach. Bank heights vary due to the age of the deposit from terraces that could be >10,000 years old to recently formed benches only formed over the last 100 years (Brakenridge 1981; Hajic et al. 2007; Owen et al. 2011). Colluvium/alluvium banks exist at the base of the bluffs along most of the reach with the exception of the bluff adjacent to the river from 4.8-5.2 km. Bank heights measured in the field were used to calculate total sediment volume lost to erosion from the historical aerial photography analysis.

Reach-Scale Erosion since 1996
The majority of bank erosion along the easement property is concentrated in the middle section of the study reach from 2.4-4.0 km and 4.4-4.8 km, while erosion in the remainder of the reach was less significant. Total bank erosion estimated from the aerial photos and field measurements along the property by 400 m cell varied from 0 along the bluffs to 7,782 m^3 (10,117 Mg) in the cell between 2.8-3.2 km since 1996 (Table 2). Average erosion for the reach over the 12 years this study covered was 2,506 m^3 and 3,258 Mg per cell. Total erosion for the entire 4 km reach was 25,064 m^3 and 32,583 Mg over those 12 years. Annual sediment loss ranged from 0-843 Mg/yr by cell for an average of 272 Mg (Figure 5). Results suggest >60% of the total erosion from the easement property is coming from banks located between stations 2.4-4.0 km in an area

thought to be experiencing widening over the 12 years between photos (Figure 6). Annual sediment eroded per unit length of stream varies from 0-2.11 Mg/m/year by 400 m cell. The annual average over this period has been 680 Mg/km/yr.

Soil particles can bind P and other nutrients at relatively high concentrations, so bank erosion has the potential to release large quantities of P to the aquatic environment. Therefore, the spatial trends of P release will be the same as sediment release from bank erosion analysis stated above. For this study an average soil P concentration of 300 ppm was used (Fredrick, 2001). An estimated 9,775 kg of P have been released from bank erosion through this reach since 1996. Annual P release by bank erosion varies by 400 m cell from 0-252.9 kg/yr with an average of 81 kg/yr per cell (Table 2). Annual P loss from bank erosion per unit length of stream varies from 0-0.63 kg/m/year by 400 m cell. The annual average over this period has been 0.2 Mg/km/yr.

STEPL Modeling Results

There are only two soil types within the easement area, the Dapue silt loam and the Goss/Gasconade rock outcrop (Table 3). Of the 18.3 ha (46 ac) within the easement area 16.3 ha are the Dapue silt loam in Hydrologic Soil Group (HSG) B and 2.3 ha are mapped the Goss/Gasconade rock outcrop with 1.9 ha in HSG B and 0.4 ha in HSG D. The groups were used in different land use scenarios in STEPL.

Existing Conditions

STEPL results show that most of the nutrients and sediment leaving the existing easement area are coming from the grasslands that are currently being managed for hay. The majority (66%) of the existing land use within the area is in forest, with the remainder in “meadow”. The meadow conditions are described as grasslands protected from grazing and are typically hayed (TR55). Using the existing land use in the model, the nitrogen (N) load is 51.8 kg/yr, the P load is 8.7 kg/yr, and the sediment load is 6.5 Mg/yr (Table 6, Figure 7). Of this 44.9 kg/yr of N, 5.6 kg/yr P, and 4.6 Mg/yr sediment is coming from the grasslands. Areas currently in forest have very low loads.

Scenario 1 – 100% Woods (fair)

Scenario 1 has the lowest modeled loads of all of the scenarios and suggests adding forested areas to marginal agricultural land can reduce nutrient and sediment entering local rivers and streams. This scenario is what might occur if all of the easement land was converted into forest land use. STEPL annual load results are 10.3 kg/yr N, 4.6 kg/yr P, and 2.7 Mg/yr sediment. These results indicate around a 47-80% drop in nutrients and sediment in this scenario compared to existing conditions.

Scenario 2 – 100% Meadow (fair)

Annual loads increase significantly when the forest land cover is removed from the model. This scenario is what may happen if the entire easement area was converted to grassland managed for hay. Annual loads for this scenario are 129.1 kg/yr N, 15.7 kg/yr P, and 12.2 Mg/yr sediment. These estimates are around twice as high as loads modeled from existing conditions. These estimates suggest that grasslands managed for hay can have significantly higher annual nutrient and sediment loads than forested lands.

Scenario 3 – 100% Pasture (fair)

Modeled annual loads increase again when grazing is introduced into the model for all of the land within the easement area. In this scenario all land within the easement area is converted to pasture land for grazing. Annual loads increase to 219.5 kg/yr N, 34.4 kg/yr P, and sediment is increases to 36.1 Mg/yr. These are 3-4 times higher than loads modeled from existing conditions. This suggests livestock can have an impact on nutrient loads in agriculture areas over those areas that are strictly managed for forage crops.

Scenario 4 – 88% Cropland (row) and 12% Pasture (fair)

Areas in cropland can significantly increase annual nutrient and sediment loads in agricultural areas. Model results from this scenario are 368.3 kg/yr N, 113.3 kg/yr P, and 157.4 Mg/yr sediment. Of this, 336.2 kg/yr of N, 108.1 kg/yr P and 151.6 Mg/yr of sediment would come from the 88% of the land in cropland only. These loads alone are higher than the other scenarios that included the entire easement area in the model. Conversion from existing hay and forest land use to cropland and pasture land use may increase nutrient and sediment loads by 7-22x within the easement area.

Implications for Nonpoint Source Pollution Reductions

Results of this study suggest conservation easements can reduce contributions of nutrients and sediment to the James River. Sediment and nutrient loads calculated from this study from the easement property for both bank erosion and runoff were extrapolated to the entire 41 km of the Middle James River and compared to annual loads at Boaz. Annual nutrient and sediment loads used for this project at the James River at Boaz gage came from recent data water quality data collected from 2007-2008 (Table 5, Hutchison, 2010). Annual loads at Boaz are 104,520 Mg of TSS, 1,302 Mg of TN, and 64 Mg of TP. It should be noted loads estimated here are about 70-80% lower than the TMDL estimate for TP in 2001 (MDNR, 2001). This reflects the decrease from wastewater treatment plants in the watershed that have been upgraded since 2001.

Using the nutrient and sediment yield from the reach-scale erosion estimates for the 41 km of the main stem of the Middle James River show that nearly 53% of sediment and 26% of the P load at Boaz is from bank erosion. By extrapolating the reach-scale bank erosion by unit length for both sides of the river over 41 km nets 55,760 Mg of sediment and16.4 Mg of P at Boaz (Table 6). If establishing a riparian corridor in conservation easement can reduce bank erosion by 25-50% and that was applied to the entire 41 km of the main stem of the Middle James River, the sediment load from bank erosion could be reduced 13-27% and P load from 6-13% at Boaz.

Conservation easements produce much lower reduction in nutrients and sediment at Boaz if they are applied to the entire Middle James River main stem when looking at runoff generated compared to bank erosion. Again, it was assumed the water quality runoff along the entire main stem of the river was similar to the existing conditions of the study reach. In this case 134 Mg of sediment, 1.07 Mg of N, and 0.18 Mg of P would be entering the river annually from runoff (Table 7). This accounts for about 0.08-0.3% of the sediment and nutrients at Boaz. If conservation easements were applied to the entire main stem of the Middle James River and that land converted into forest, the annual load from these areas would be 56 Mg of sediment, 0.21 Mg of N, and 0.09 Mg of P. That translates into about a 0.07-0.14% reduction in sediment and nutrients at Boaz.

RECOMMENDATIONS

The James River channel within the study segment has been fairly stable over the last decade that is likely due to the natural resistance provided by bedrock that is common along the bed and banks of the river. Rather than meandering, the river appears to have adjusted to disturbance by getting wider where it was able to and today it is in a quasi-equilibrium condition over much of the reach. This means it appears the river has adjusted to current conditions, but threats from increased watershed disturbance and climate change can restart the adjustment process similar to recent findings in the upper James and Finley rivers (Martin and Pavlowsky 2011; Owen et al. 2011). With that there are three specific recommendations that can help reduce the nonpoint source sediment and nutrient loads from the easement properties:

1. Expand Riparian Corridor - A thin riparian corridor exists within the easement along the right bank from 1.6-2.6 km and along the left bank from 3.2-4.4 km. This area appears to have moderate erosion based on the results of this study. Planting appropriate trees and other riparian vegetation within the easement can provide roughness during floods but also filter runoff from fertilizers that may be applied to the hay fields adjacent to the easement.

2. Monitor Disturbance Reaches - There are 4 disturbance reaches within or near the easement areas identified in this study that should be monitored in the future.

<u>Disturbance Reach #1</u> from1.8-2.2 km is within the future Kansas Expressway expansion would likely need to be stabilized. While the right-of-way (ROW) for the road expansion is not within the easement, the entire disturbance reach spans the ROW into easement areas upstream and downstream. Any remediation would have to take into account ROW and easement property for proper stabilization.

Disturbance Reach #2 is located from 3.2-3.8 km at the confluence with Ward Branch. There appears to by a high bedload entering the river from Ward Branch forming a delta bar at the mouth. Excess bedload is likely originating from bed and bank scour in the highly urbanized areas of Ward Branch upstream. The bar that has formed at the mouth is causing localized bank erosion, but it does not appear to be impacting the road or other infrastructure. This area should be monitored after large floods to watch out for any expansion of the disturbance.

Disturbance Reach #3 from 4.5-4.9 km is located at the confluence with the cutoff channel. This area has likely been a disturbance area for a long time. This area should be monitored for expansion, but it appears the golf course has placed rip rap at the toe of the bank opposite of the reach to arrest further bank erosion at this point.

Disturbance Reach #4 from 5.6-5.9 km is located just downstream of the easement along the golf course property. Moderately-high bank erosion has formed a cutbank below the bedrock knickpoint along the right bank adjacent to the golf course property near station 5.6 km.

3. Consider Bank Protection - Bank stabilization could be considered on about 2 km of bank in this reach. More specifically along the right bank from station 2.4-2.8 km, the left bank from station 2.8-3.9, and along the left bank from station 4.4-4.8 km.

4. Golf Course BMPs - While the golf course is not within the easement area, we suggest that JRBP should work with the golf course in implementing best management practices (BMPs) to reduce nonpoint source pollution of nutrients in runoff that leave the property. Also, bank erosion protection and riparian corridor enhancement may be suitable for the banks adjacent to the golf course from 4.9-5.5 km.

CONCLUSIONS

The JRBP has implemented a conservation easement along a 4 km reach of the James River in Greene County near the Rivercut Golf Course. This study estimates the annual nutrient and sediment loads from runoff and bank erosion using a combination of field-based rapid assessment, aerial photography interpretation, and STEPL water quality monitoring. There are 5 main conclusions from this study:

1. **Status of channel morphology and bank conditions.** Field-based rapid geomorphic assessment identified channel geometry and bank conditions every 400 m along the 4 km reach of the study area where the easement was established. This portion of the river is heavily influenced by bedrock that limits the ability of the channel to move laterally or down cut. However, there is evidence of channel widening and several disturbance reaches have been identified along the study reach.

2. **Reach-scale bank erosion rates calculated since 1996**. Reach-scale bank erosion was determined by aerial photography interpretation coupled with field-based bank height measurements to determine the annual sediment and P load from 1996-2008. A total of 25,064 Mg of sediment and 9,775 kg of P have entered the river from bank erosion over the 12 year span. That equals around 2,715 Mg/yr of sediment and 815 kg/yr of P. Average unit length loss from this section was 0.68 Mg/m/yr of sediment and 0.2 kg/m/yr of P. However, nearly 65% of the sediment and P is coming from bank erosion between stations 2.4-4.0 km. This suggests properly placed and installed bank stabilization projects have the potential to significantly reduce nutrient and sediment inputs to the river.

3. **STEPL water quality model created for easement area**. While the existing nonpoint sediment and nutrient loads from the existing land use is relatively low, model results of the water quality model indicate a 50-80% reduction in the nutrient and sediment load from the easement area can be achieved if it was all established in forest land cover. Furthermore, the conservation easement prohibits the establishment of more intensive agricultural practices on the property that could increase the nutrient and sediment load in the runoff from the easement area by 7-20 times compared to present conditions.

4. **Water quality model and bank erosion results applied to the entire river**. Conservation easements can be beneficial in reducing nonpoint source pollution by protecting banks from erosion and taking areas adjacent to the river out of agricultural production. The results of this study were applied to the entire main stem of the Middle James between the USGS gaging stations near Springfield and near Boaz. Assumptions were that the same conditions exist upstream and downstream of the study reach and that easements could reduce bank erosion from 25-50% by eliminating agricultural production and development from the bank edge and the area was allowed to become re-vegetated. Results suggest bank erosion protection from easements along the entire Middle James River could provide a 13-27% reduction in sediment and a 4-13% reduction in P at Boaz. Water quality benefits in runoff from easement areas are much less impressive with <0.1% reductions of sediment and nutrients at Boaz.

5. **Recommendations for reduction of nonpoint pollution.** The following four recommendations should be considered for reduction of nonpoint source pollution in the study area based on field observations from the rapid assessment performed in July 2013: (1) improve the riparian corridor within the easement areas; (2) monitor disturbance reaches especially adjacent to infrastructure; (3) approximately 2 km of bank protection could be considered ,and (4) work with the golf course to initiate BMPs particularly along the river bank.

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TABLES

Table 1. USGS Gaging Stations on James River near Study Site

ID	Name	Period of Record	Drainage Area (km^2)	Annual Mean Q (m^3/s)	10% Exceeds (m^3/s)	90% Exceeds (m^3/s)
07050700	James River near Springfield, MO	Oct. 1955 to present	637	6.7	13.9	0.31
07052250	James River near Boaz, MO	Sept. 23, 1972 to Oct. 1, 1980; Oct. 1, 2001 to present	1,197	14.8	30.9	1.9

Table 2. Reach-Scale Erosion Results

Mid Cell (km)	**Sed. (m^3)**	**Sed. (Mg)**	**Sed. (Mg/yr)**	**Sed. (Mg/m/yr)**	**P (kg)**	**P (kg/yr)**	**P (kg/m/yr)**
1.8	890	1,157	96	0.24	347	28.9	0.07
2.2	1,262	1,641	137	0.34	492	41.0	0.10
2.6	4,132	5,372	448	1.12	1,612	134.3	0.34
3	7,782	10,117	843	2.11	3,035	252.9	0.63
3.4	3,577	4,650	388	0.97	1,395	116.3	0.29
3.8	1,912	2,486	207	0.52	746	62.2	0.16
4.2	663	861	72	0.18	258	21.5	0.05
4.6	4,063	5,282	440	1.10	1,585	132.0	0.33
5	782	1,017	85	0.21	305	25.4	0.06
5.4	0	0	0	0.00	0	0.0	0.00
Total	25,064	32,583	2,715	6.79	9,775	815	2.04
Average	2,506	3,258	272	0.68	977	81	0.20

Table 3. Description of Soils in Easement Area

Soil Description	**HSG**	**Area (ac)**
Dapue silt loam, 0 to 3 percent slopes, rarely flooded	B	16.3
Goss/Gasconade soils, 0 to 2 percent slopes, occasionally flooded	B/D	4.6/1.1

Table 4. STEPL Modeling Results

Scenarios	HSG	Soil	Land Use (Condition)	Area (ha)	CN	TP (kg/yr)	TN (kg/yr)	TSS (Mg/yr)
Existing	B	Dapue	Meadow (Fair)	6.6	58	5.6	44.9	4.6
	B	Dapue	Woods (Fair)	9.8	60	2.4	5.3	1.5
	B	Goss/Gas.	Woods (Fair)	1.9	60	0.5	1.1	0.4
	D	Goss/Gas.	Woods (Fair)	0.4	79	0.2	0.5	0.1
1	B	Dapue	Woods (Fair)	16.3	60	3.9	8.7	2.3
	B	Goss/Gas.	Woods (Fair)	1.9	60	0.5	1.1	0.4
	D	Goss/Gas.	Woods (Fair)	0.4	79	0.2	0.5	0.1
2	B	Dapue	Meadow (Fair)	16.3	58	13.3	109.7	10.2
	B	Goss/Gas.	Meadow (Fair)	1.9	58	1.7	13.1	1.5
	D	Goss/Gas.	Meadow (Fair)	0.4	78	0.7	6.3	0.5
3	B	Dapue	Pasture (Fair)	16.3	69	29.1	187.3	30.3
	B	Goss/Gas.	Pasture (Fair)	1.9	69	4.0	23.1	4.5
	D	Goss/Gas.	Pasture (Fair)	0.4	84	1.3	9.1	1.3
4	B	Dapue	Cropland (Row)	16.3	78	108.1	336.2	151.6
	B	Goss/Gas.	Pasture (Fair)	1.9	69	4.0	23.1	4.5
	D	Goss/Gas.	Pasture (Fair)	0.4	84	1.3	9.1	1.3

Table 5. Annual Nutrient and Sediment Loads at Gages

USGS Gage Station	Drainage Area (km^2)	River Station (km)	TSS Load (Mg/yr)	TSS Yield (Mg/km^2/yr	TN Load (Mg/yr)	TN Yield (Mg/km^2/yr	TP Load (Mg/yr)	TP Yield (Mg/km^2/yr
James River near Springfield, MO	637	93.5	25,252	39.6	344	0.54	12	0.019
James River near Boaz, MO	1,197	53.5	104,520	87.3	1,302	1.09	64	0.053

Table 6. Estimated Reductions in Sediment and P from Bank Erosion in the Middle James River

	TSS	TP
Annual Load Boaz (Mg/yr)	104,520	64
Load per Unit Length from this study (Mg/km/yr)	680	0.2
Total from Bank Erosion (Mg/yr)	55,760	16.4
% at Boaz	53.3%	25.6%
Bank erosion load with 25% reduction (Mg/yr)	41,820	12.3
% Reduction at Boaz	13.3%	6.4%
Bank erosion load with 50% reduction (Mg/yr)	27,880	8.2
% Reduction at Boaz	26.7%	12.8%

Table 7. Estimated Reductions in Sediment, N and P from Runoff

	TSS	TN	TP
Annual Load Boaz (Mg/yr)	104,520	1,302	64
Existing Conditions			
Load per Unit Length from this study (Mg/km/yr)	1.63	0.013	0.0022
Total from 41 km of Easements (Mg/yr)	134	1.07	0.18
% at Boaz	0.128%	0.082%	0.28%
Forest			
Load per Unit Length (Mg/km/yr)	0.68	0.0025	0.0011
Total from 41 km of Easements	56	0.21	0.09
% at Boaz	0.053%	0.016%	0.14%
Reduction at Boaz	0.075%	0.066%	0.14%

FIGURES

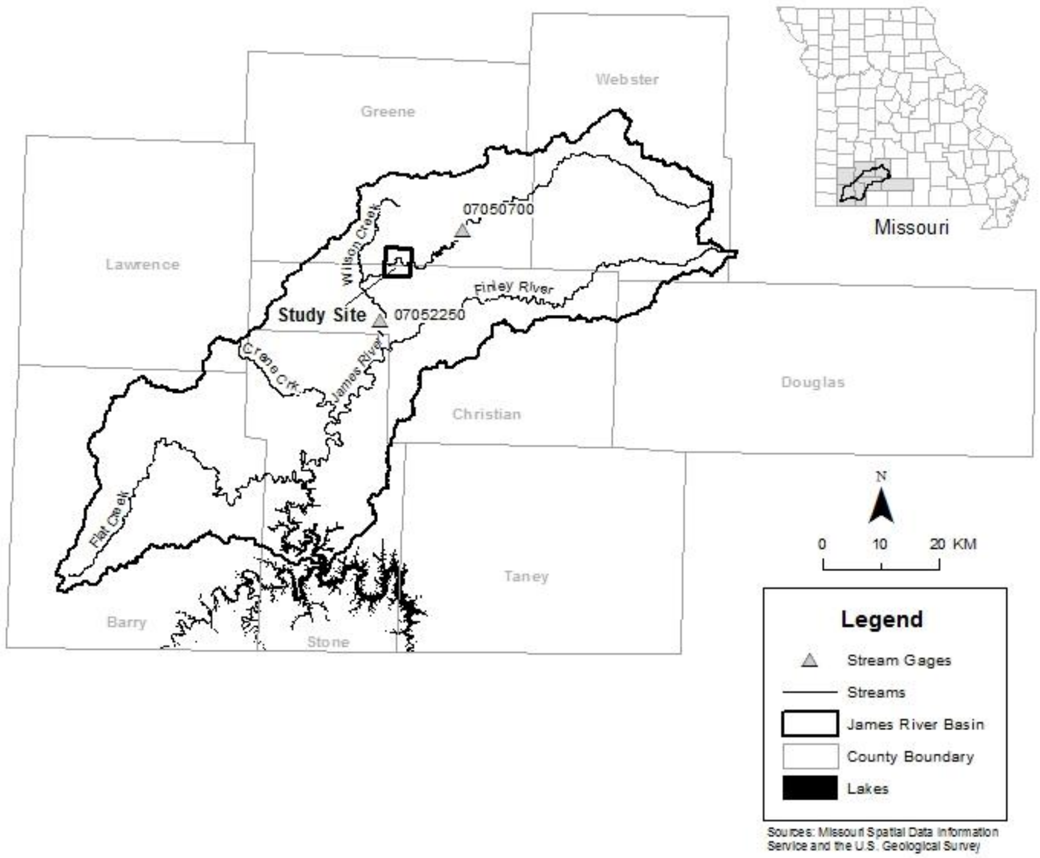

Figure 1. James River Basin.

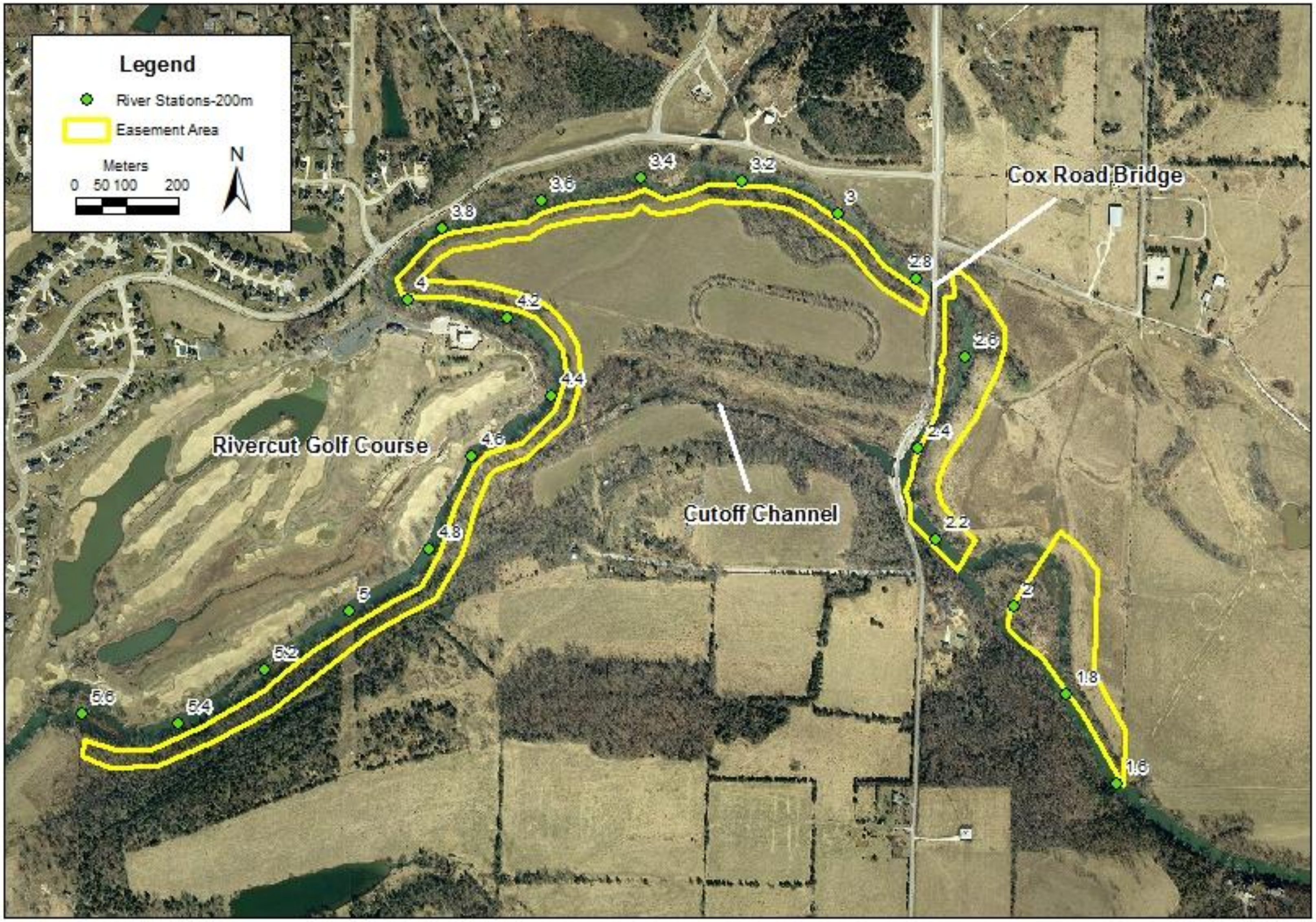

Figure 2. Study area map.

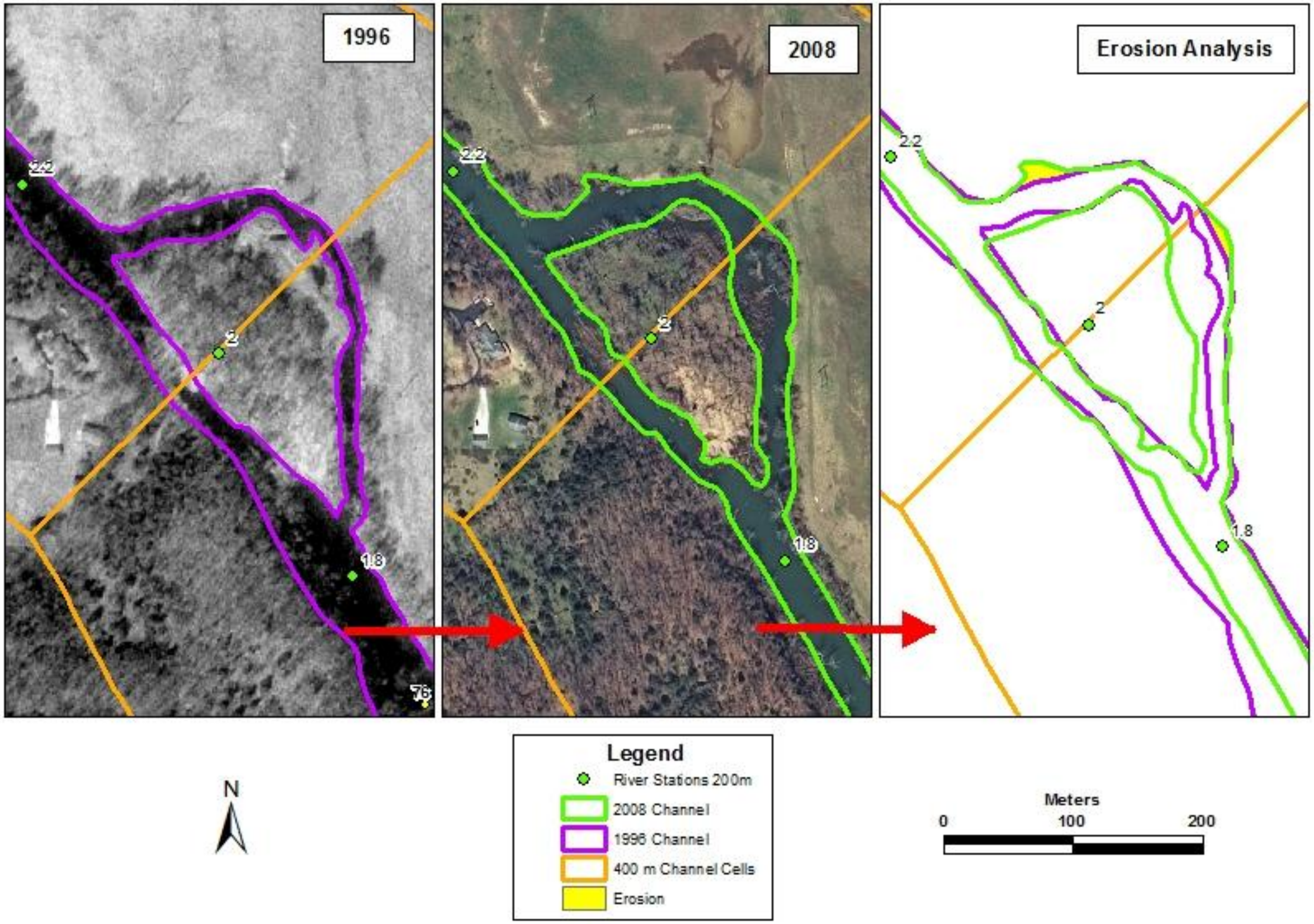

Figure 3. Aerial photo methods to define area of erosion since 1996.

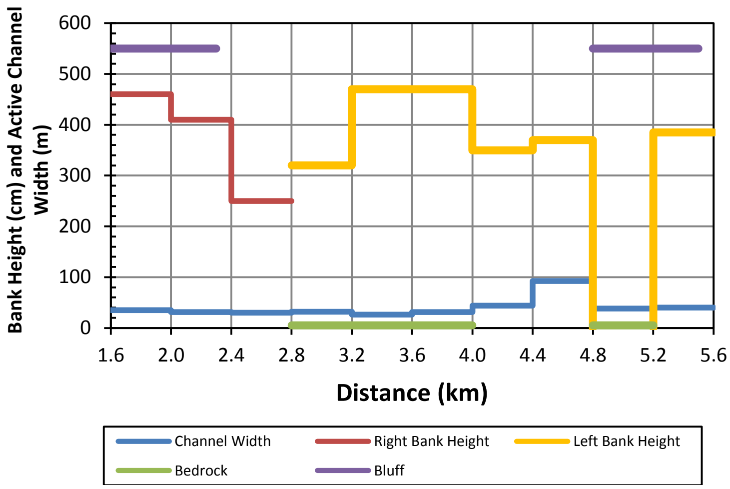

Figure 4. Bank and channel conditions in study reach.

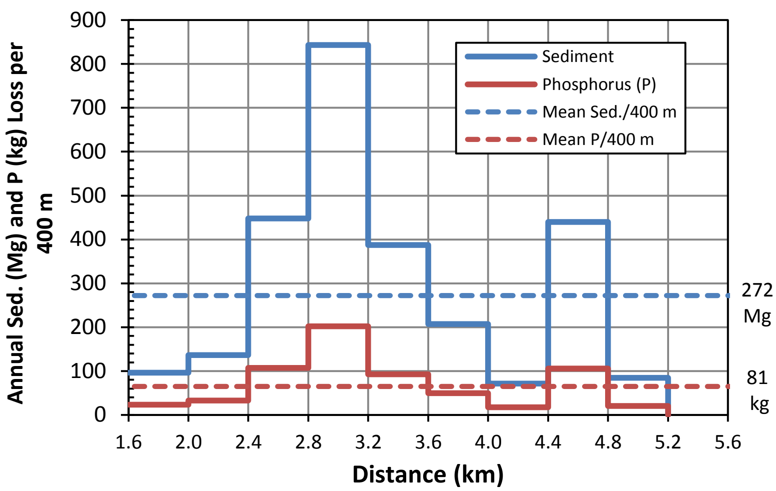

Figure 5. Annual sediment and P loss from bank erosion in study reach.

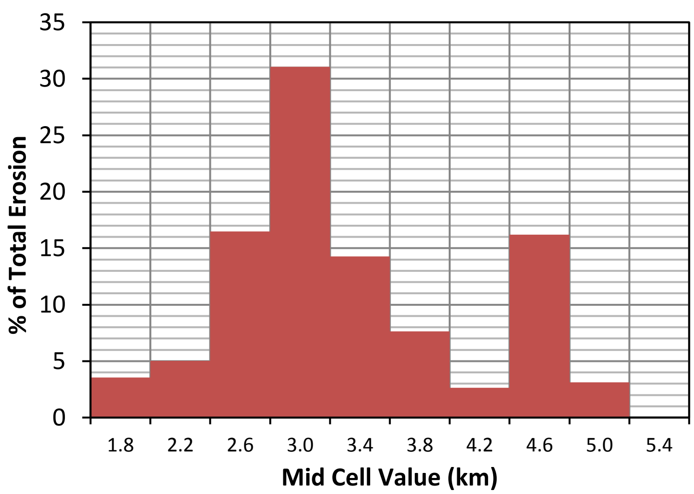

Figure 6. Percent of total erosion by cell.

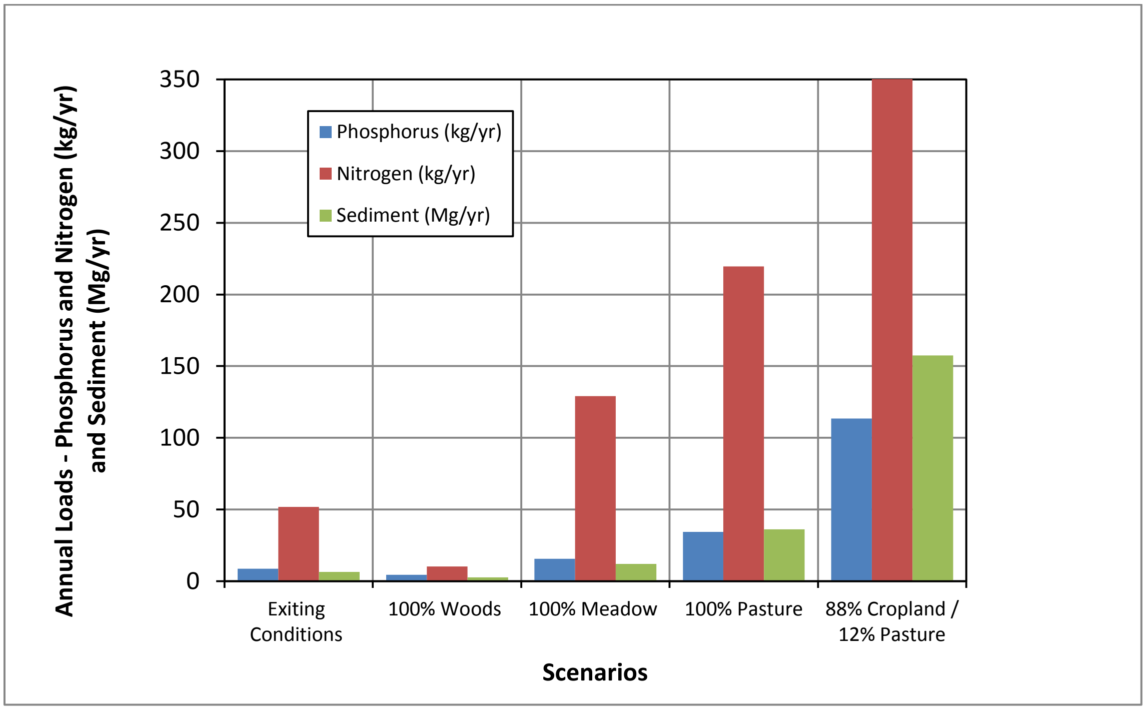

Figure 7. Annual nutrient and sediment loads from easement area from STEPL model.

PHOTOS

Photo 1. Straight reach looking downstream station 1.6 km

Photo 2. Secondary channel in disturbance reach station 1.8 km.

Photo 3. Rip rap along Cox Road at station 2.3 km.

Photo 4. Cox Road Bridge at station 2.7 km

Photo 5. Large delta bar forming at the mouth of Ward Branch station 3.35 km

Photo 6. Bank erosion across the channel from delta bar at station 3.4 km


Photo 7. Typical bank erosion between stations 3.4-3.8 km

Photo 8. Vegetated bars are forming below the strath terrace on the right with moderate bank erosion on the left at station 4.2 km

Photo 9. Rip rap lined bank adjacent to the golf course near disturbance reach at station 4.6 km

Photo 10. Bedrock at the base of the bank limits lateral erosion near station 5 km

Photo 11. Colluvium/alluvial bank erosion at the base of bluff near station 5.4 km


Photo 12. Bedrock knickpoint at disturbance reach at station 5.6 km


Photo 13. Secondary channel at disturbance reach at station 5.6 km


Photo 14. Strath terrace reach below disturbance reach at station 5.6 km


Photo 15. Cutbank erosion below last disturbance reach at station 5.6 km