

# WOLF RIVER WATERSHED STREAMBANK EROSION ASSESSMENT

ArcGIS® Comparison Study: 1991 vs. 2008 Aerial Photography

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Photo taken by: Anna Powell, KWO; Wolf River

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## Executive Summary

Wetlands and riparian areas are vital components of proper watershed function that, when wisely managed in context with a watershed system, can moderate and reduce sediment input into surface water supplies. Eroding streambanks have been recognized as a major contributor of sediment in Kansas waters.

The Wolf River Watershed Streambank Erosion Assessment, an ArcGIS® based Comparison Study, identifies areas of streambank and streambank gully erosion concerns to provide a better understanding of the Wolf River Watershed. This information is provided for the application of mitigation practices, a better understanding of watersheds and to reduce excessive sedimentation across Kansas. This comparison study is designed to guide prioritization of streambank restoration by identifying reaches of streams where erosion is most severe in individual watersheds.

The Kansas Water Office (KWO) 2011 assessment quantifies annual tons of sediment eroding from streambanks over a 17 year period between 1991 and 2008 within the Wolf River Watershed located in the Missouri Basin in Northeast Kansas. A total of 25 streambank erosion sites were identified, covering 13,500 feet of unstable streambank, transporting 28,600 tons (17.9 acre-feet) of sediment annually downstream and into the Missouri River. It should be noted that the identified streambank erosion locations are only a portion of all streambank erosion occurrences in the watershed. Only those streambank erosion sites covering an area of 1,500 sq. feet, or more, were identified. Streambank erosion sites were analyzed by six stream reaches. A substantial quantity of the identified eroded sediment in the watershed is transported annually from the mainstem Wolf River stream reach 2a (WR2a) and mainstem Wolf River stream reach 2b (WR2b); at roughly 14,349 and 8,926 tons (9 and 5.6 acre-feet) annually, respectively. These identified reaches account for an estimated 63 percent or \$606,600 of total stabilization cost needs in the watershed. Based on an average stabilization cost of \$71.50 per linear foot, conducting streambank stabilization practices for the identified erosion sites in the Wolf River watershed would cost approximately \$1 million.

The KWO completed the Wolf River Watershed Streambank Erosion Assessment for the Missouri River Basin Watershed Restoration and Protection Strategy (WRAPS) Stakeholder Leadership Team (SLT). Information contained in this assessment may be used by the Missouri River Basin WRAPS SLT to target streambank stabilization and riparian restoration efforts toward high priority stream reaches in the Wolf River Watershed. Similar assessments are ongoing in selected watersheds above reservoirs throughout Kansas and are available on the KWO website at [www.kwo.org](http://www.kwo.org) under KWO Programs & Projects: Watershed Unit Projects, or may be made available upon request to agencies and interested parties for the benefit of streambank and riparian restoration projects.

## Introduction

Wetlands and riparian areas are vital components of proper watershed function that, when wisely managed in context of a watershed system, can moderate and reduce sediment input. There is growing evidence that a substantial source of sediment in streams in many areas of the country is generated from stream channels and edge of field gullies (Balch, 2007).

Streambank erosion is a natural process that contributes a large portion of annual sediment yield, but acceleration of this natural process leads to a disproportionate sediment supply, stream channel instability, land loss, habitat loss and other adverse effects. Many land use activities can affect and lead to accelerated bank erosion (EPA, 2008). In most Kansas watersheds, this natural process has been accelerated due to changes in land cover and the modification of stream channels to accommodate agricultural, urban and other land uses.

A naturally stable stream has the ability, over time, to transport the water and sediment of its watershed in such a manner that the stream maintains its dimension, pattern and profile without significant aggregation or degradation (Rosgen, 1997). Streams significantly impacted by land use changes in their watersheds or by modifications to streambeds and banks go through an evolutionary process to regain a more stable condition. This process generally involves a sequence of incision (downcutting), widening and re-stabilizing of the stream. Many streams in Kansas are incised (SCC, 1999).

Streambank erosion is often a symptom of a larger, more complex problem requiring solutions that may involve more than just streambank stabilization (EPA, 2008). It is important to analyze watershed conditions and understand the evolutionary tendencies of a stream when considering stream stabilization measures. Efforts to restore and re-stabilize streams should allow the stream to speed up the process of regaining natural stability along the evolutionary sequence (Rosgen, 1997). A watershed-based approach to developing stream stabilization plans can accommodate the comprehensive review and implementation.

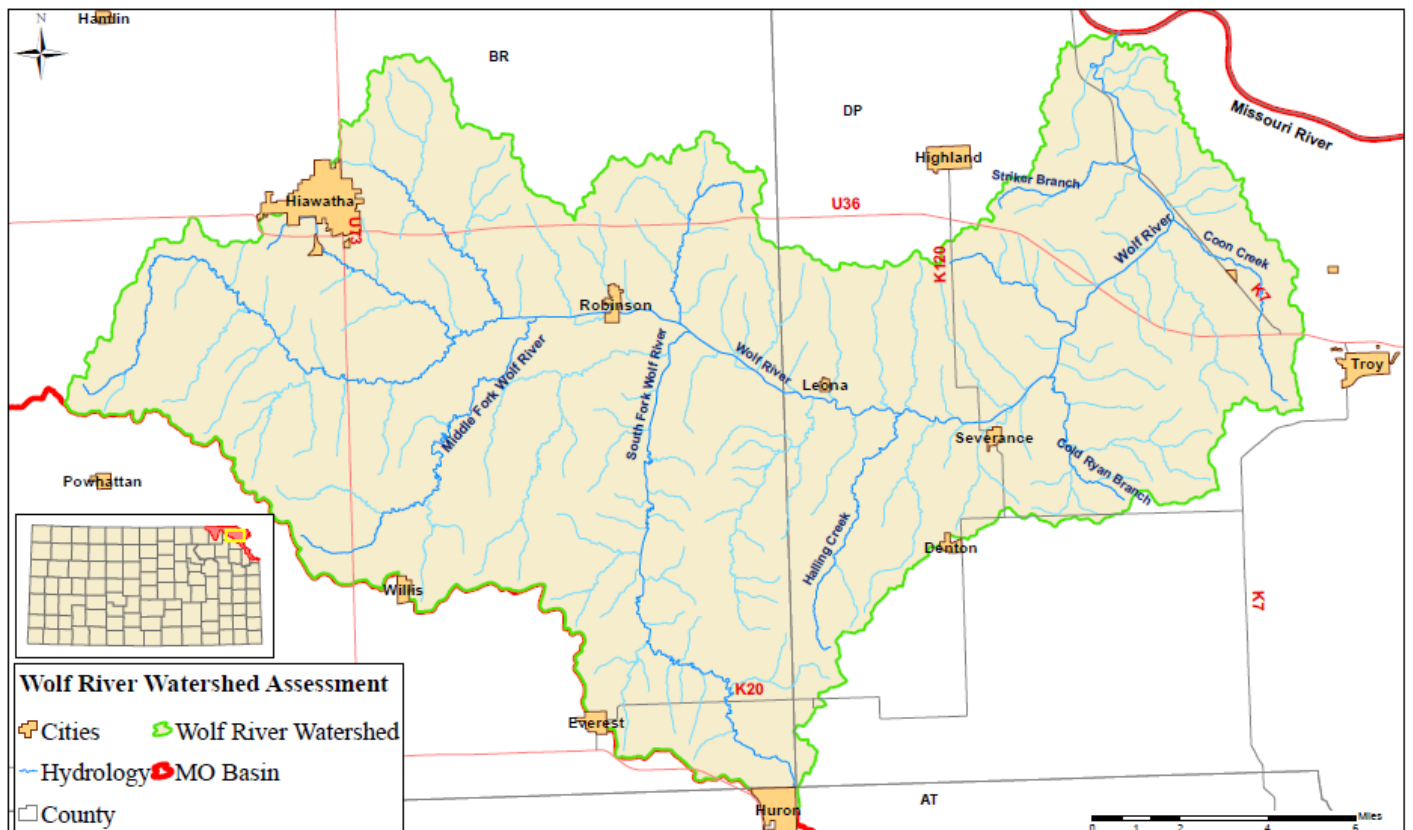
Additional research in Kansas documents the effectiveness of forested riparian areas on bank stabilization and sediment trapping (Geyer, 2003; Brinson, 1981; Freeman, 1996; Huggins, 1994). Vegetative cover based on rooting characteristics can mitigate erosion by protecting banks from fluvial entrainment and collapse by providing internal bank strength. Riparian vegetative type is an important tool that provides indicators of erosion occurrence from land use practices. Forested riparian areas are superior to grassland in holding banks during high flows, when most sediment is transported. When riparian vegetation is changed from woody species to annual grasses and/or forbs, sub-surface internal strength is weakened, causing acceleration of mass wasting processes (extensive sedimentation due to sub-surface instability) (EPA, 2008). The primary threats to wetlands and forested riparian areas are agricultural production and suburban/urban development.

## Study Area

The Missouri River Basin covers about 1,600 square miles of the northeastern corner of Kansas, including four 10-Digit Hydrologic Units Codes and fourteen 12-Digit Hydrologic Unit Codes. This area represents a small fraction of the entire Missouri River watershed which covers all or part of ten states and extends into Canada. The basin in Kansas covers all or part of Marshall, Nemaha, Brown, Doniphan, Atchison, Leavenworth and Wyandotte counties in Kansas and is the smallest of the 12 major basins in the State accounting for about two percent of the total land area (KWO, 2009).

Wolf River lies within the Wolf River Watershed, a 12-digit Hydrologic Unit Code subbasin of the Missouri River Basin, which covers a 248 square mile drainage area in portions of Brown and Doniphan counties in Northeast Kansas (Figure 1). Wolf River, a 46 mile tributary of the Missouri River, rises in Brown County, approximately 3 miles north of Powhattan, and flows generally eastward into Doniphan County, past the communities of Robinson, Leona and Severance. Near Severance, the river turns northward, flowing into the Missouri River approximately 8 miles southeast of White Cloud. The Wolf River Watershed is comprised of roughly 71% cropland, 25% grassland, 3% woodland and 0.5% urban (KDHE, 2001).

**Figure 1: Wolf River Watershed Assessment Area**

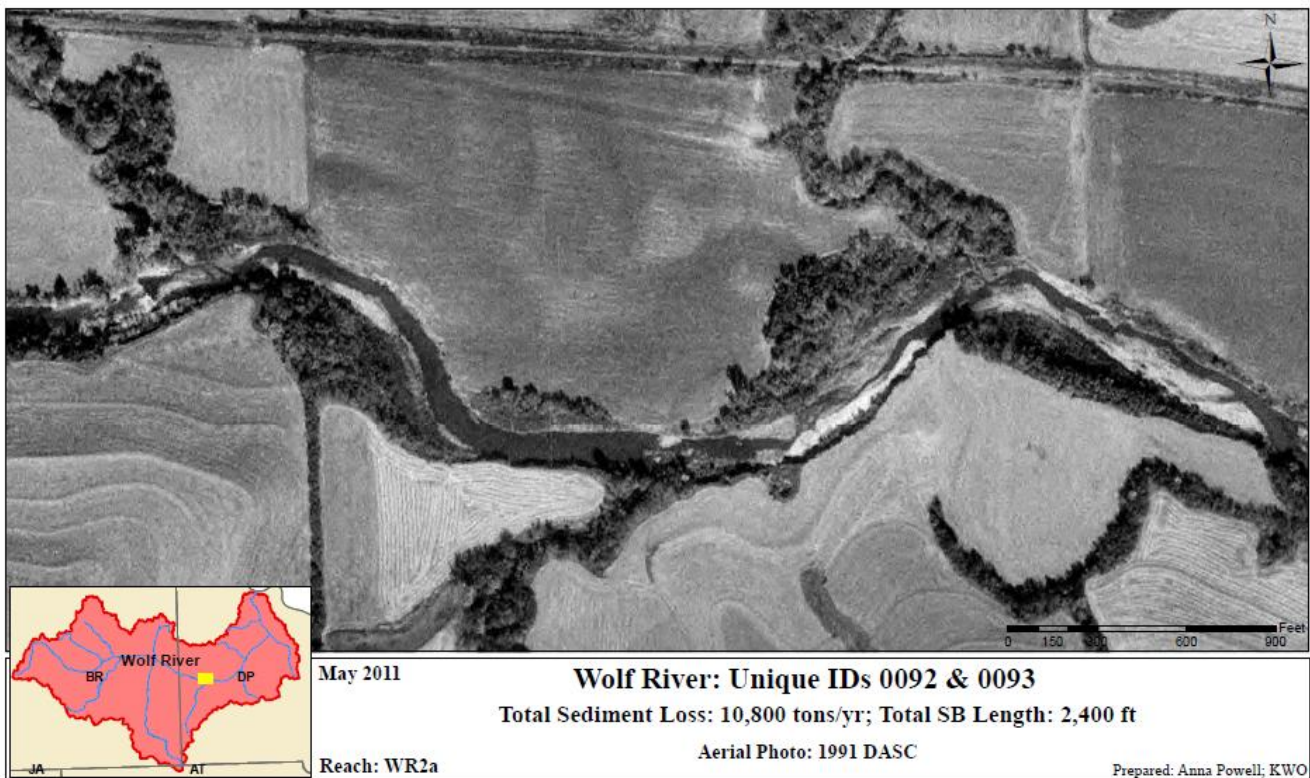


## Data Collection Methodology

The Wolf River streambank erosion assessment was performed using ArcGIS® software. The purpose of the assessment is to identify locations of streambank instability to prioritize restoration needs and slow sedimentation rates on the Wolf River. ArcMap®, an ArcGIS® geospatial processing program, was utilized to assess color aerial photography from 2008, provided by National Agriculture Imagery Program (NAIP), and compare it with 1991 black and white aerial photography, provided by the State of Kansas GIS Data Access & Support Center (DASC).

The streambank erosion assessment was performed by overlaying 2008 NAIP county aerial imagery onto 1991 DASC county aerial imagery (Figure 2 & 3). Using ArcMap® tools, “aggressive movement” of the streambank between 1991 DASC and 2008 NAIP aerial photos were identified, at a 1:6,000 scale, as a site of streambank erosion. “Aggressive movement” represents areas of 1,500 sq. feet or more of streambank movement between 1991 DASC and 2008 NAIP aerial photos. Streambank erosion sites were denoted by geographic polygons features “drawn” into the ArcGIS® software program through the ArcMap® editor tool (Figure 4). The polygon features were created by sketching vertices following the 2008 streambank and closing the sketch by following the 1991 streambank at a 1:2,500 scale. Data provided, based on the geographic polygon sites include: watershed location, unique ID, stream name, type of stream and type of riparian vegetation.

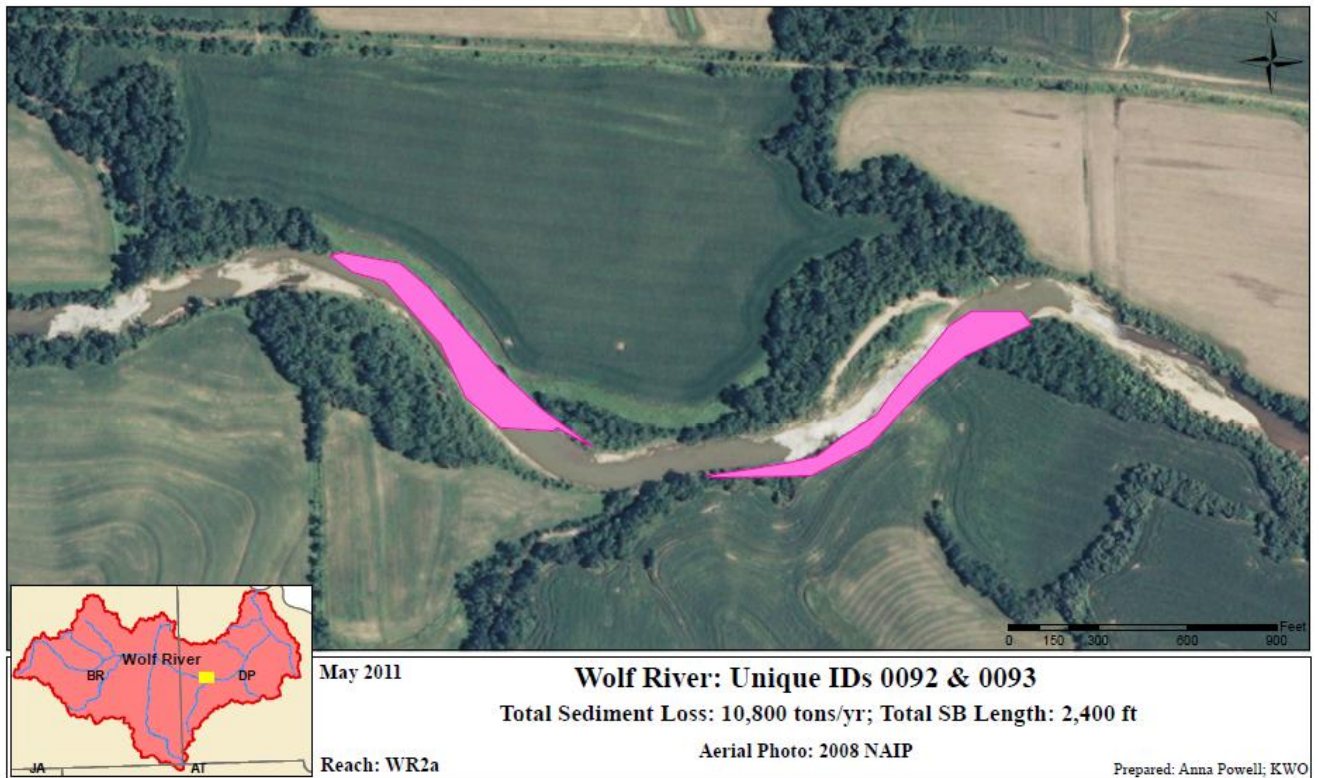
**Figure 2: 1991 DASC of a Streambank Erosion Site**



**Figure 3: 2008 NAIP of a Streambank Erosion Site**



**Figure 4: 2008 NAIP of a Streambank Erosion Site with Polygon**

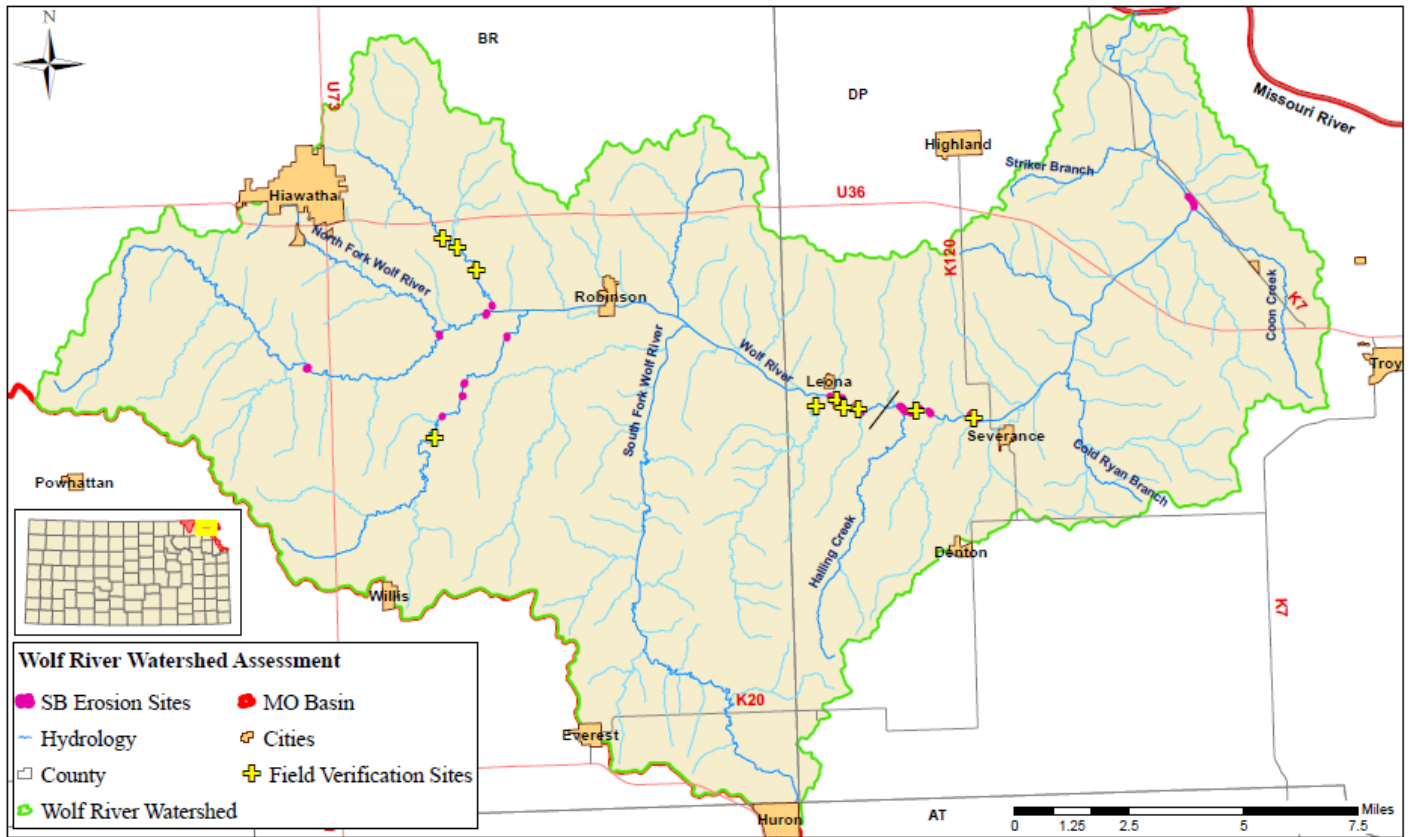


The streambank erosion assessment data also includes approximations of tons of soil loss from the erosion site. This portion of the assessment is performed by utilizing the identified erosion site polygon features. Tons of soil loss was estimated by incorporating perimeter, area and streambank length of the polygons into a regression equation. Perimeter and area were calculated through the *field calculator* application within the ArcGIS® software. The streambank length of identified erosion sites was computed through the application of a regression equation formulated by the KWO office. This equation was developed by taking data from the *Enhanced Riparian Area/Stream Channel Assessment for John Redmond Feasibility Study*, a report prepared by The Watershed Institute (TWI) and Gulf South Research Corporation (GSCR), and relating the erosion area (in sq. feet) and perimeter length of that erosion area (in feet) to the unstable stream bank length (in feet). The multiple regression formula of that fit (R-square = .999) is  $([Area\_SqFt]*.00067) + ([Perimtr\_ft]*.5089609)$ . The intercept of the model was forced to zero.

Tons of soil loss was estimated by first calculating the volume of sediment loss and then applying a bulk density estimate to that volume for the typical soil type of identified sites. The volume of sediment was found by multiplying bank height and surface area lost over the 17 year period between the 1991 and 2008 aerial photos and soil bulk density. This calculated volume is then divided by the 17 year period, to get the average rate of soil loss in mass/year (Avg Soil Loss Rate(Tons/yr)=[Area\_SqFt]\*[BankHgtFt]\*SoilDensity(lbs/ft<sup>3</sup>)/2000(lbs/ton)/([NAIP\_ComparisonPhotoYear]-[BaseAerialPhotoYear])).

To complete the analysis for the equation above for tons of soil lost, streambank height measurements of select identified erosion sites were needed. Streambank height measurements were obtained with the help of the Missouri River Basin WRAPS SLT. Several members of the SLT helped to identify and contact landowners at 10 of the identified streambank erosion sites (Figure 5). Vertical streambank heights were taken from these locations and recorded (Figure 6). Identified and measured locations were the basis for extrapolating streambank height measurements throughout the Wolf River Watershed.

Figures 5: Field Verification Sites



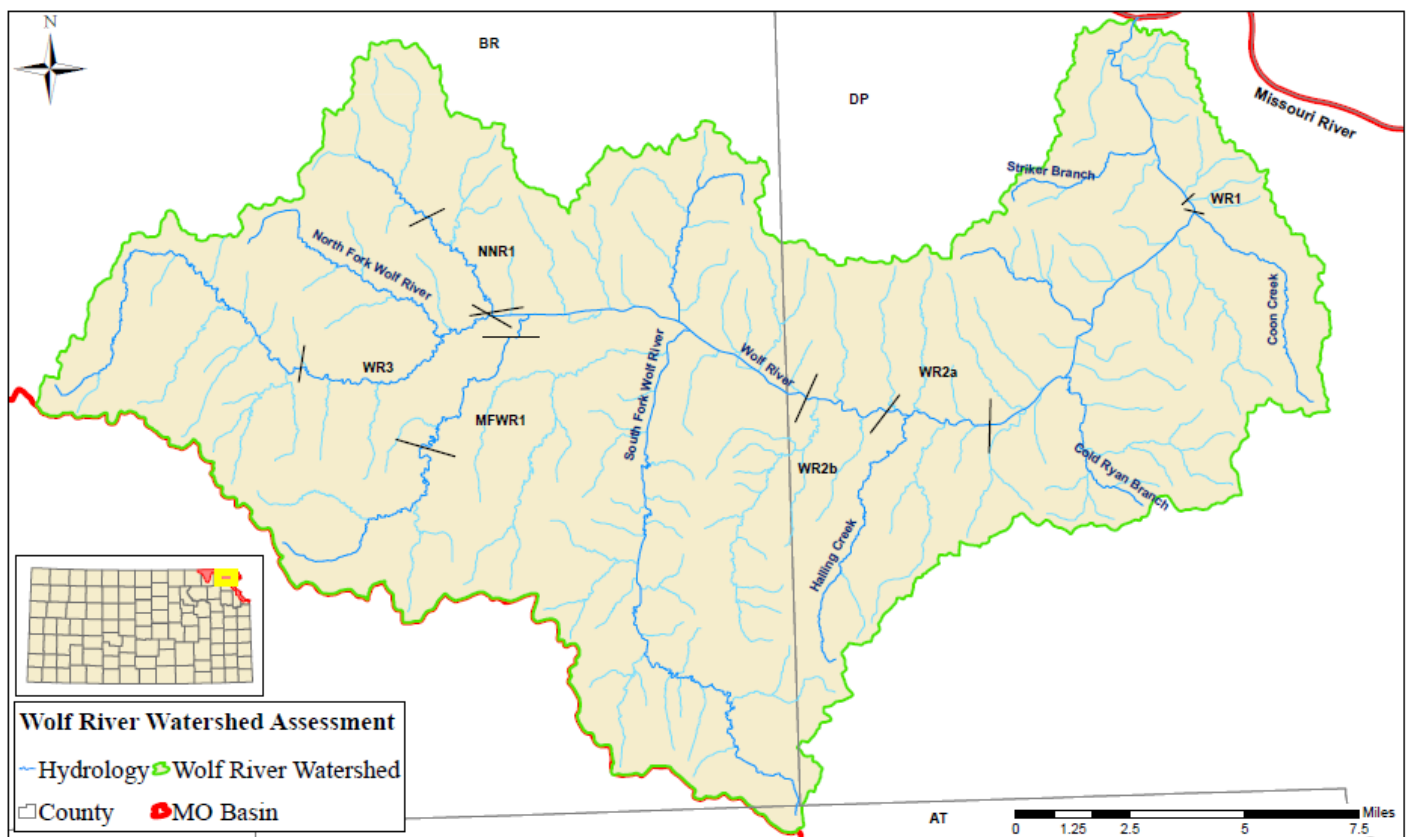
Figures 6: Field Verification Streambank Height Measurement



## Analysis

To adequately analyze streambank erosion sites, stream reach sections were delineated to better accommodate streambank rehabilitation project focus. Streambank erosion prioritization by stream reach sections include: WR1, WR2a, WR2b, WR3, MFWR1 and NNR1 (Figure 7). Stream reach sections were identified by the stream name and in numerical order from downstream to upstream. For example, WR1 is Wolf River stream reach 1. Streambank erosion sites were analyzed for: streambank length (feet) of the eroded bank; annual soil loss (tons); percent of streambank length with poor riparian condition (riparian area identified as having cropland or grass/crop streamside vegetation); estimated sediment reduction through the implementation of streambank stabilization BMPs at an 85% efficiency rate; and streambank stabilization cost estimates for eroded streambank sites. Streambank stabilization costs were derived from an average cost to implement streambank stabilization BMPs, as reported in the TWI *Kansas River Basin Regional Sediment Management Section 204 Stream and River Channel Assessment*; \$71.50 per linear foot was used to calculate average streambank stabilization costs (Figure 8).

**Figure 7: Wolf River Watershed Assessment by Stream Reach**



**Figure 8: TWI Estimated Costs to Implement Streambank Stabilization BMPs**

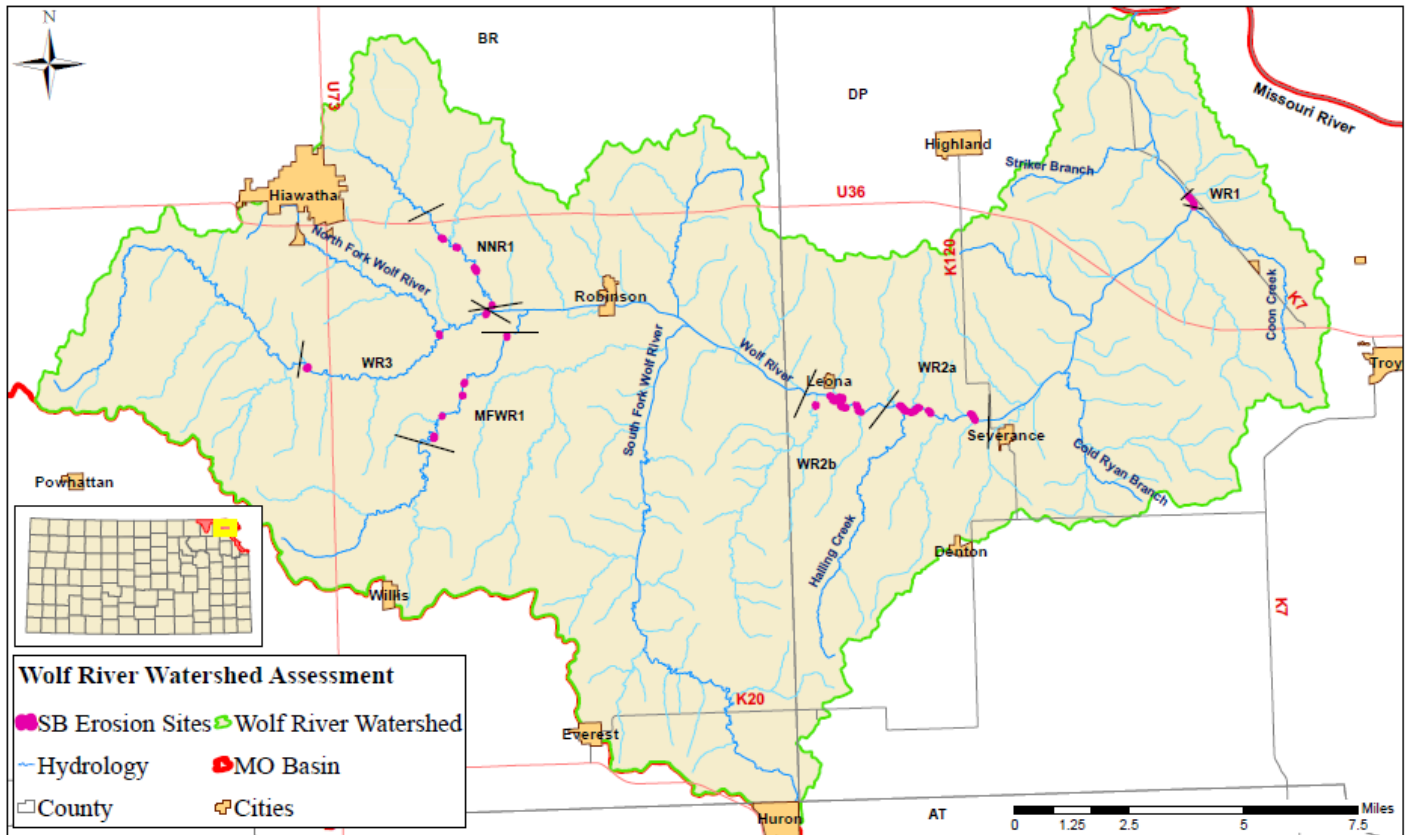
BMP Cost Description	Cost estimate per linear foot (in dollars)
1. Survey and design Rock delivery and placement As-built certification design Bank Shaping	\$50 - \$75
2. Vegetation (material and planting) Cover Crop Mulch Willow Stakes Bare root seedlings Grass filter strip	\$5
3. Contingencies Unexpected site conditions requiring extra materials and construction time	\$3 - \$5.5
<b>TOTAL</b>	<b>\$58-\$85.5</b>

## Results

The KWO 2011 assessment quantifies annual tons of sedimentation from streambank erosion between 1991 and 2008 within the Wolf River Watershed. A total of 25 streambank erosion sites, covering 13,500 feet of unstable streambank were identified, with 100% of the identified sites unstable streambanks found to have poor riparian condition (riparian area identified as having cropland or grass/crop streamside vegetation) (Figure 9). Sediment transport from identified streambank erosion sites accounts for 28,600 tons (17.9 acre-feet) of sediment per year transported from the Wolf River Watershed streams to the Missouri River annually.

A substantial quantity of the identified eroded sediment in the watershed is transported annually from the mainstem Wolf River stream reach 2a (WR2a) at roughly 14,300 tons (8.9 acre-feet) annually, and from mainstem Wolf River stream reach 2b (WR2b) at roughly 8,900 tons (5.6 acre-feet) annually (Table 1 & Figure 10). Combined, these identified reaches account for 81% of the total stabilization needs in the watershed and 62% or \$607,000 of total stabilization cost needs in the Wolf River Watershed. Based on the average stabilization costs of \$71.50 per linear foot, conducting streambank stabilization practices for the mainstem North Fork Ninescah River would cost approximately \$1 million with an estimated sediment reduction of 24,316 tons per year at an 85% stabilization efficiency (Table 1).

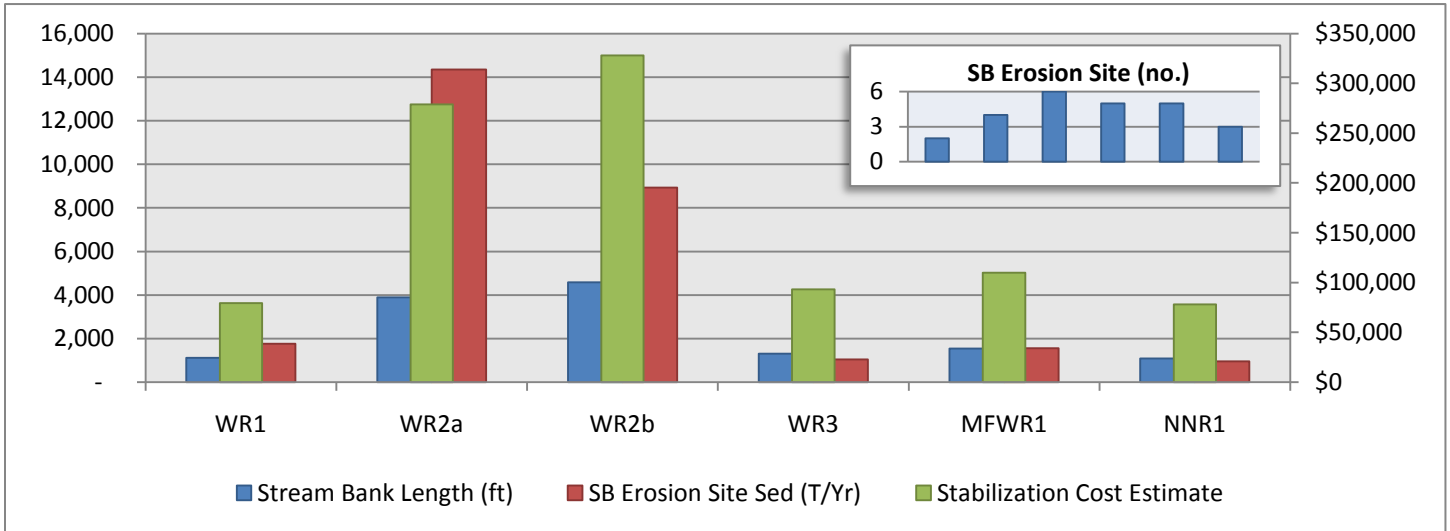
**Figure 9: Wolf River Watershed Streambank Erosion Assessment Map by Stream Reach**



**Table 1: Wolf River Watershed Streambank Erosion Assessment Table by Stream Reach**

STREAM REACH	STREAM BANK LENGTH (FT)	SB EROSION SITE SED (T/YR)	STABIL. COST ESTIMATE	SB EROSION SITE (NO.)	YIELD LOSS/BANK LENGTH	POOR RIPARIAN COND/SB LENGTH (FT)	EST. SED REDUCTION (T/YR)	% SB LENGTH W/ POOR RIPARIAN COND.
WR1	1,111	1,757	\$79,430	2	1.6	1,111	2,067	100.00%
WR2a	3,898	14,349	\$278,704	4	3.7	3,898	16,882	100.00%
WR2b	4,586	8,926	\$327,893	6	1.9	4,586	10,501	100.00%
WR3	1,303	1,050	\$93,171	5	0.8	1,303	1,236	100.00%
MFWR1	1,538	1,560	\$109,937	5	1.0	1,538	1,835	100.00%
NNR1	1,094	964	\$78,235	3	0.9	1,094	1,134	100.00%
<b>TOTAL</b>	<b>13,530</b>	<b>28,607</b>	<b>\$967,370</b>	<b>25</b>	<b>9.9</b>	<b>13,530</b>	<b>-24,316</b>	<b>100.00%</b>
Est Stabilization Cost/Linear Ft.			\$71.50	Stabilization/Restoration Efficiency			0.85	

**Figure 10: Wolf River Watershed Streambank Erosion Assessment Graph by Stream Reach**



**Conclusion**

The KWO completed this assessment for the Missouri Basin Watershed Restoration and Protection Strategy (WRAPS) Stakeholder Leadership Team (SLT). The Draft and Final report will be submitted for internal review at KWO. After internal review, the Draft and Final Report will be submitted to the Missouri Basin WRAPS SLT. Information contained in the assessment can be used by the Missouri Basin WRAPS SLT to target streambank stabilization and riparian restoration efforts toward high priority stream reaches on the mainstem Wolf River within the Missouri Basin Watershed.

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