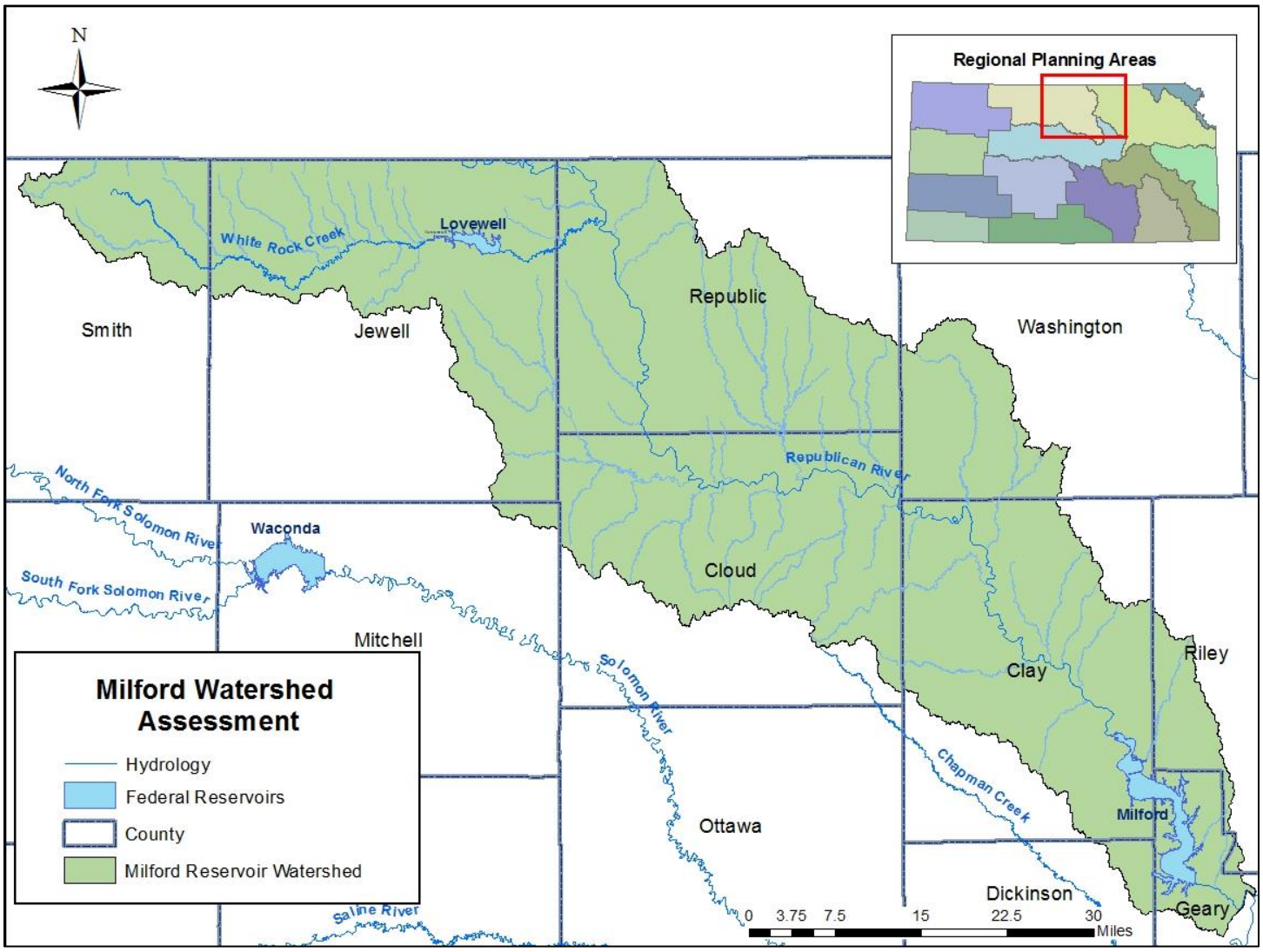
LOWER REPUBLICAN RIVER WATERSHED STREAMBANK EROSION ASSESSMENT

ArcGIS® Comparison Study: 1991 vs. 2012, 2015 Aerial Photography

UPDATED DRAFT: February 2017



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Executive Summary

Federal reservoirs are an important source of water supply in Kansas for approximately two-thirds of Kansas' citizens. The ability of a reservoir to store water over time is diminished as the capacity is reduced through sedimentation. In some cases reservoirs are filling with sediment faster than anticipated. Whether sediment is filling the reservoir on or ahead of schedule, it is beneficial to take efforts to reduce sedimentation to extend the life of the reservoir.

The Kansas Water Authority has established a *Reservoir Sustainability Initiative* (*RSI*) that seeks to integrate all aspects of reservoir input, operations and outputs into an operational plan for each reservoir to ensure water supply storage availability long into the future. Reduction of sediment input is part of this initiative.

The Lower Republican River Watershed Assessment, an ArcGIS® Comparison Study, was initiated to partially implement the *RSI*. This assessment identifies areas of streambank erosion to provide a better understanding of the Lower Republican River watershed for streambank restoration purposes and to increase understanding of streambank erosion to reduce excessive sedimentation in reservoirs across Kansas. The comparison study was designed to guide prioritization of streambank restoration by identifying reaches of streams where erosion is most severe in the watershed above Milford Lake.

The Kansas Water Office (KWO) 2017 assessment quantifies annual tons of sediment eroded from the Lower Republican River watershed between 1991 or 2003 and 2015 within the Lower Republican River watershed above Milford Reservoir in Kansas. A total of 59 streambank erosion sites were identified, covering 67,374 feet of unstable streambank and transporting 71,816 tons of sediment downstream per year, accounting for roughly 58 acre-feet per year of sediment accumulation in Milford Reservoir. 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 2,000 sq. feet, or more, were identified.

Results by HUC10 identified 1025001706 as the most active HUC10 for streambank degradation, accounting for 24,477 feet of unstable streambank; 13,384 tons (10 acre-feet of reservoir sedimentation) of sediment per year and 36 percent of total stabilization costs (Table 1 and Figure 7). Results by HUC12 identified 102500170604 as the most active HUC12 for streambank degradation, accounting for 21,063 feet of unstable streambank, 11,224 tons (9 acre-feet of reservoir sedimentation) of sediment per year, and 31 percent of total stabilization costs (Table 2 and Figure 9). Based on the average stabilization costs of $71.50 per linear foot, conducting streambank stabilization practices for the entire watershed would cost approximately $4.8 million.

The KWO updated this assessment for the Solomon-Republican and Kansas Regional Advisory Committee (SR, KS RAC) and the Milford Reservoir Watershed Restoration and Protection Strategy (WRAPS) Stakeholder Leadership Team (SLT). Information contained in the assessment feeds into a number of sections and and other assessments in SR, KS RAC and can be used by Milford Reservoir WRAPS SLT to target streambank stabilization and riparian restoration efforts toward high priority stream reaches within the Lower Republican River watershed above Milford Reservoir. Similar assessments are ongoing in selected watersheds above reservoirs throughout Kansas and are available on the KWO website at www.kwo.org, or may be made available upon request to agencies and interested parties for the benefit of streambank and riparian restoration projects.

Introduction

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 forested riparian areas are agricultural production and suburban/urban development.

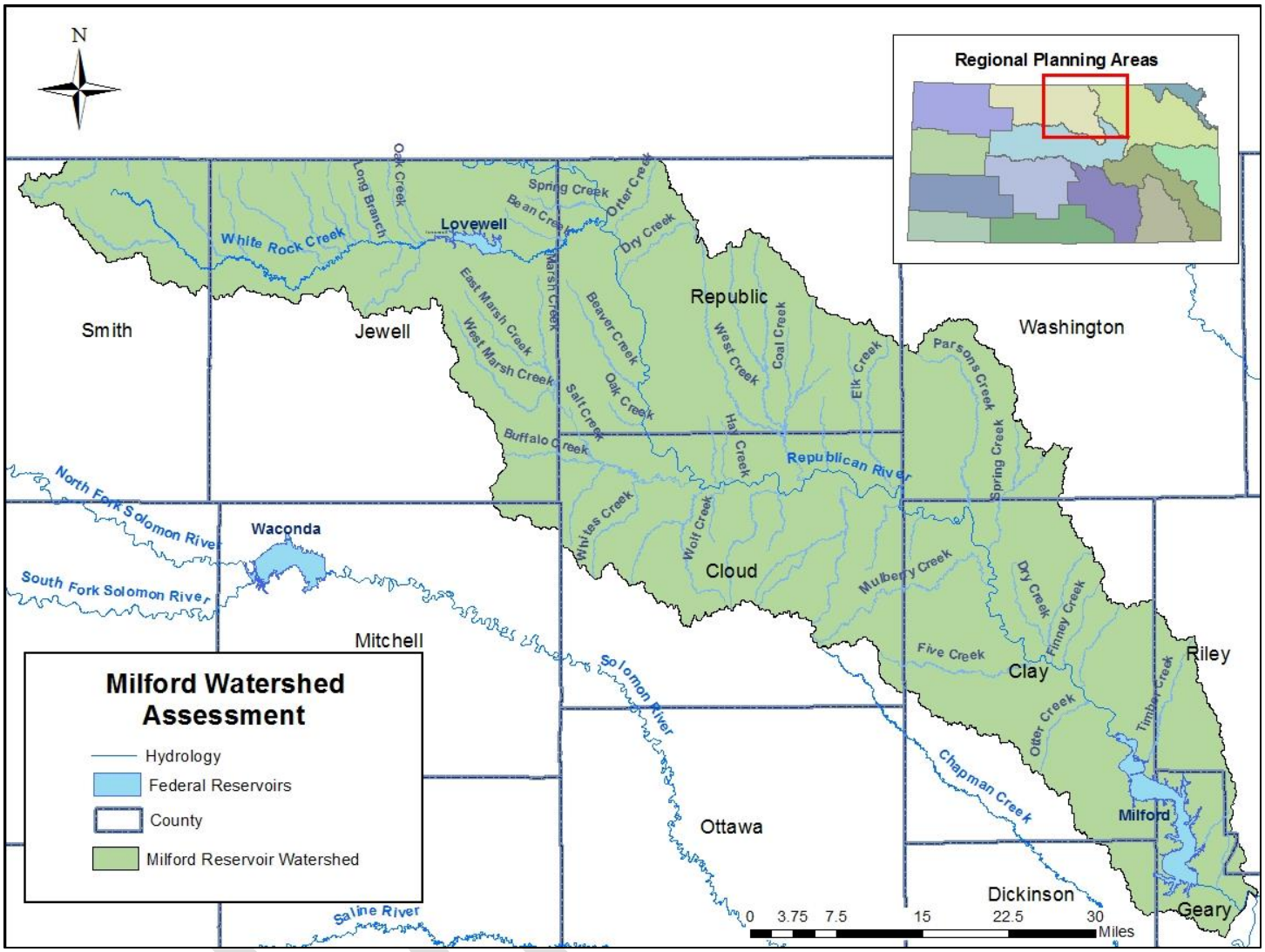
In Kansas, monitoring the extent of erosion losses is difficult, and current up-to-date inventories are needed. This assessment identifies areas with erosion concerns and estimates erosion losses to provide a better understanding of this watershed for mitigation purposes and for application of understanding to watersheds across Kansas.

Study Area

Milford Reservoir is located on the Lower Republican River, at river mile 8.3, 4 miles northwest of Junction City, Kansas and 65 miles west of Topeka, Kansas. The Lower Republican River Watershed in the Solomon-Republican Regional Planning Area (SR RPA) was assessed for streambank erosion with a primary focus on the Republican River mainstem from roughly Milford Reservoir to Concordia, Kansas (Figure 1). The Republican River watershed above Milford Reservoir drains approximately 3,796 square miles through portions of Jewel, Republic, Cloud and Clay counties. Authorized purposes of Milford Reservoir are flood control, navigation, water supply, water quality, recreation and fish and wildlife. Major tributaries to the Lower Republican River in the Milford Reservoir watershed include White Rock and Buffalo Creeks.

The multipurpose pool of the reservoir was filled in 1967. The original design life for sediment storage was 100 years with a design sediment rate of 1,730 acre-ft/year and an original multipurpose storage capacity set at 415,403 acre-feet. The most current bathymetric survey occurring in 2009 and performed by the U.S. Army Corps of Engineers, concluded that 10.9 percent of the 100-year design life for sediment storage in Milford Reservoir has been lost to date, calculating the current sedimentation rate at 1,007 acre-feet per year (1,073,000 tons/yr). The bathymetric survey also concluded that the current storage capacity at the reservoir is estimated at 307,133 acre-feet to date.

Figure 1: Lower Republican River Watershed Assessment Area



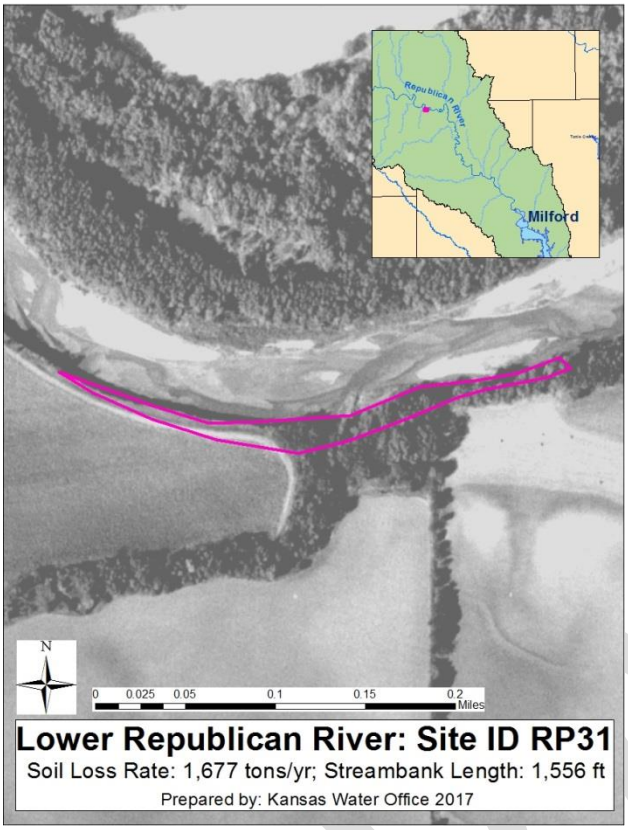
Data Collection Methodology

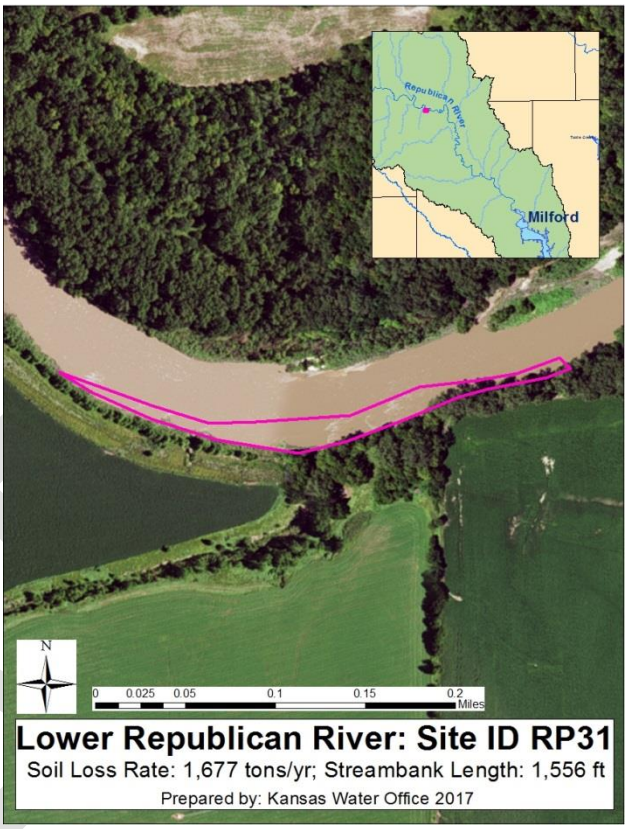
The Lower Republican River watershed streambank erosion assessment was performed using ArcGIS® software. The purpose of the assessment is to identify locations of streambank instability to prioritize restoration needs and slow sedimentation rates into Milford Reservoir. ArcMap®, an ArcGIS® geospatial processing program, was utilized to assess color aerial photography from 2015, provided by National Agriculture Imagery Program (NAIP), and compare it with 1991 Farm Service Agency (FSA) 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 a more recent NAIP aerial imagery onto 1991 FSA or 2003 aerial imagery (Figure 2). Using ArcMap® tools, "aggressive movement" of the streambank between 1991 FSA or 2003 and 2015 NAIP aerial photos were identified, at a 1:2,500 scale, as a site of streambank erosion. "Aggressive movement" represents areas of 2,000 sq. feet or more of streambank movement between 1991 FSA or 2003 and the more recent NAIP aerial photos. Streambank erosion sites were denoted by geographic polygons features "drawn" into the ArcGIS® software program through the ArcMap® editor tool. The polygon features were created by sketching vertices following the 2015 streambank and closing the sketch by following the 1991 or 2003 streambank at a 1:2,000 scale. Data

provided, based on the geographic polygon sites include: watershed location, site ID, stream name, type of stream and type of riparian vegetation.

Figure 2: 1991 FSA & 2015 NAIP of a Streambank Erosion Site on the Lower Republican River





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 is shown below. The intercept of the model was forced to zero.

$$\text{Estimated Streambank Length (ft)} = -0.00067A + 0.5089609P$$

Where:
A = Area (sq.ft)
P = Perimeter (ft)

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 21 year period between the 1991 and 2012 or 2015 aerial photos and soil bulk density. This calculated volume is then divided by the period between aerial photos to get average rate of soil loss in mass/year.

$$\text{Soil Loss Rate (ton/yr)} = \frac{(A \times BH \times \rho)/2000 \text{ (lb/ton)}}{\text{NAIP Comparison Photo (yr)} - \text{Base Aerial Photo (yr)}}$$

Where:
A = Area (sq.ft)
BH = Bank Height (ft)
P = Soil Density (lb/ft^3)

To complete the analysis for the equation above for tons of soil lost, streambank height measurements of select identified erosion sites were needed. The Kansas River Basin Regional Sediment Management Section, 204 Stream and River Channel Assessment, performed by the Gulf South Research Corporation (GRSC) and The Watershed Institute, Inc. (TWI), through contracts with the U.S. Army Corps of Engineers (Corps), was incorporated into this assessment. The project assembled a number of previously installed streambank stabilization/riparian restoration projects in the state. Included with many of those projects is streambank height including many surveyed bank heights on the projects in the Lower Republican River basin. Where no streambank elevations were available, Light Detection and Ranging (LiDAR) raster tiles available for the Milford Reservoir watershed were used to calculate stream bank heights at actively eroding sites.

Analysis

To adequately analyze streambank erosion sites streambank erosion sites were analyzed by 10-digit Hydrologic Unit Codes (HUC10s) and 12-digit Hydrologic Unit Codes (HUC12s) (Figure 4 and Figure 5). 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 6).

Figure 4: Lower Republican River Watershed Assessment Area HUC10s

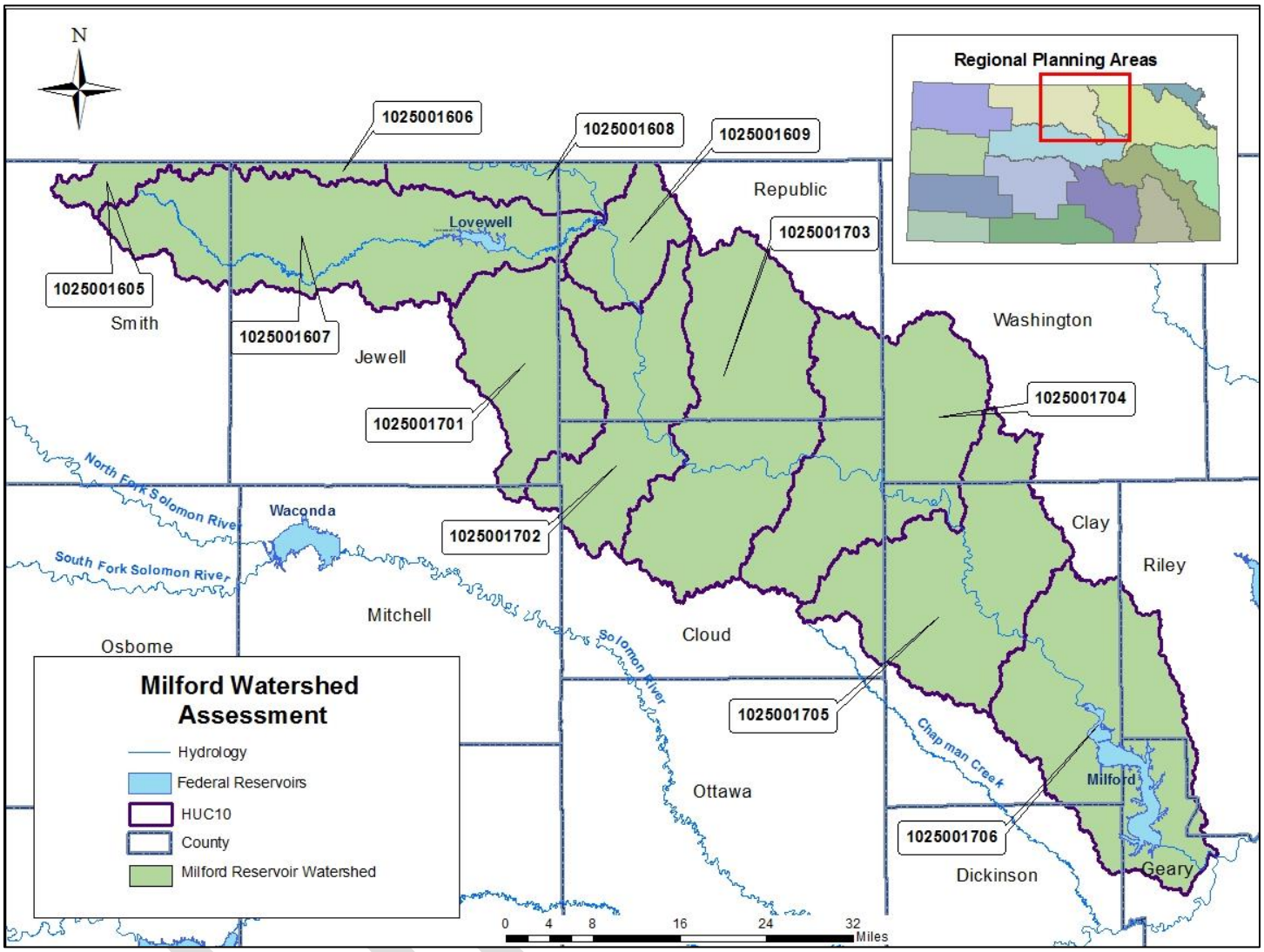


Figure 5: Lower Republican River Watershed Assessment Area HUC12s

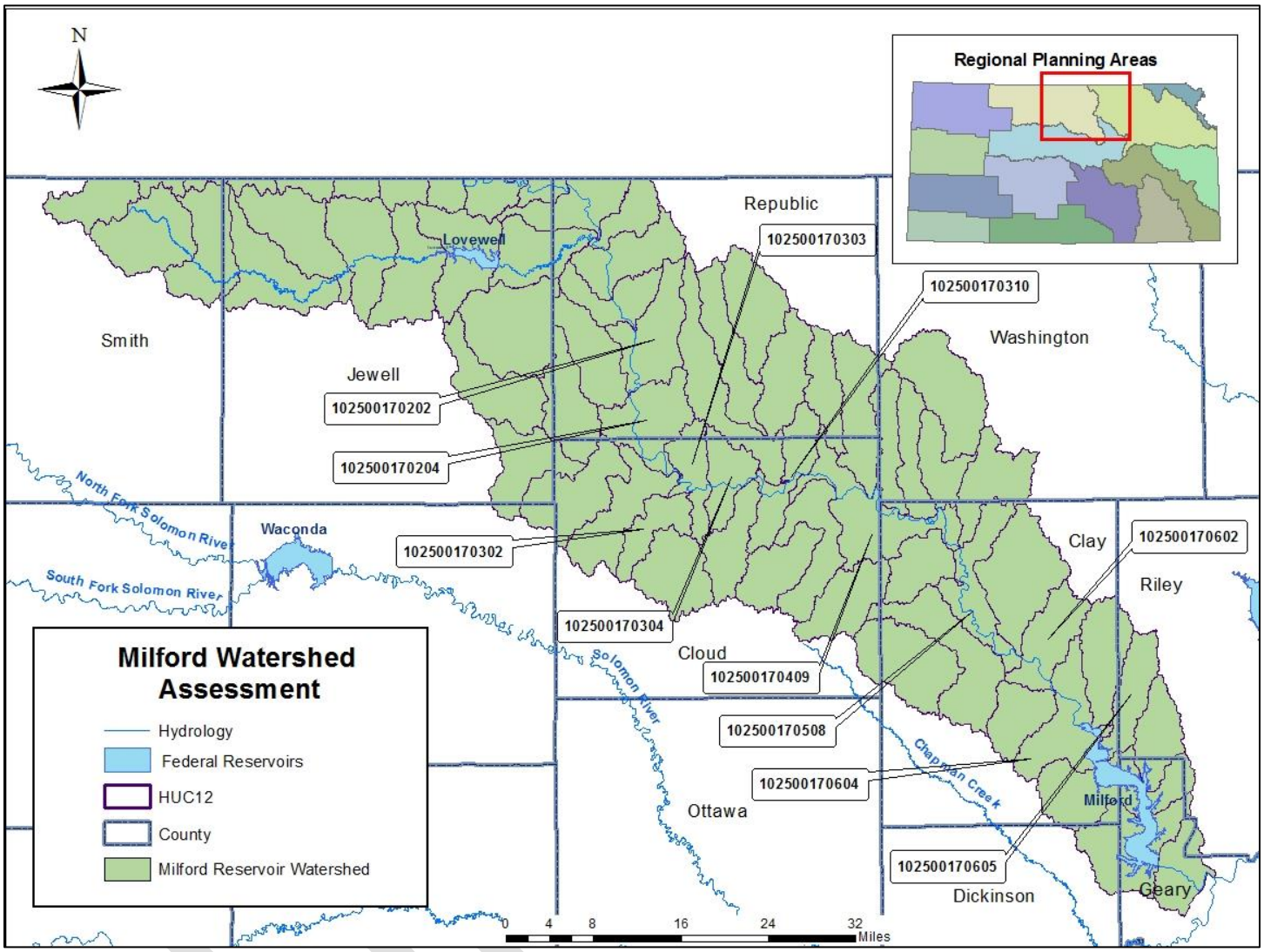


Figure 6: TWI Estimated Costs to Implement Streambank Stabilization BMPs

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
TOTAL	**$58-$85.5**

Results

The Kansas Water Office (KWO) 2017 assessment quantifies annual tons of sediment eroding from the Lower Republican River watershed between 1991 or 2003 and 2015 in Kansas. A total of 59 streambank erosion sites covering 67,374 feet of unstable streambank were identified. Sediment transport from identified streambank erosion sites accounts for roughly 71,816 tons of sediment downstream per year, accounting for roughly 58 acre-feet per year of sediment transported from the Lower Republican River and deposited in Milford Reservoir. This sediment load accounts for roughly 5.8 percent of the mean annual sedimentation rate based on the most recent bathymetric survey performed by a U.S. Army Corps of Engineers in 2009.

A substantial quantity of the identified eroded sediment in the watershed is transported annually from the main stem of the Lower Republican River. Results by HUC10 identified 1025001706 as the most active HUC10 for streambank degradation, accounting for 24,477 feet of unstable streambank, 13,384 tons of sediment per year, and 36 percent of total stabilization costs (Table 2 and Figure 8). Results by HUC12 identified 102500170604 as the most active HUC12 for streambank degradation, accounting for 21,063 feet of unstable streambank, 11,224 of sediment per year, and 31 percent of total stabilization costs (Table 3 and Figure 9). Based on the average stabilization costs of $71.50 per linear foot, conducting streambank stabilization practices for the entire watershed would cost approximately $4.8 million.

Table 1: Lower Republican River Watershed Streambank Erosion Assessment Table by HUC10

HUC10	Stream Bank Length (ft)	SB Erosion Site Total Soil Loss (T/Yr)	Stabilization Cost Estimate ($)	Poor Riparian Cond/SB Length (ft)	Est. Sed Reduction (T/Yr)	% of SB Length w Poor Riparian Condition	SB Erosion Sites (#)
1025001702	4,991	3,382	$356,849	1,419	-2,874	33.3%	6
1025001703	14,916	15,840	$1,066,460	9,522	-13,464	62.5%	16
1025001704	4,305	6,571	$307,821	3,357	-5,585	50.0%	4
1025001705	18,686	32,640	$1,336,076	14,456	-27,744	75.0%	16
1025001706	24,477	13,384	$1,750,071	19,249	-11,377	76.5%	17
Total	**67,375**	**71,816**	**$4,817,277**	**48,003**	**-61,044**	**66.1%**	**59**
Est Stabilization Cost/Linear Ft.		$71.50	**Stabilization/Restoration Efficiency**			85%	

Figure 7: Lower Republican River Watershed Streambank Erosion Assessment Graph by HUC10

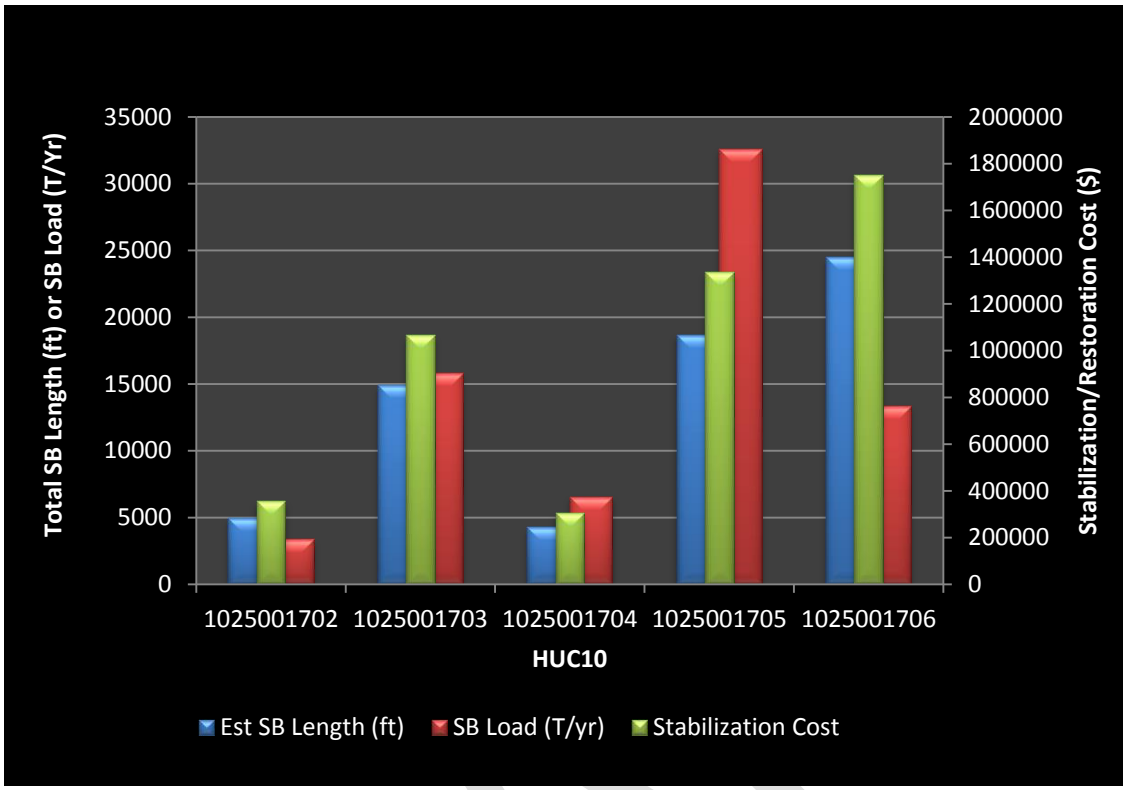


Figure 8: Lower Republican River Watershed Streambank Erosion Assessment Graph by HUC10

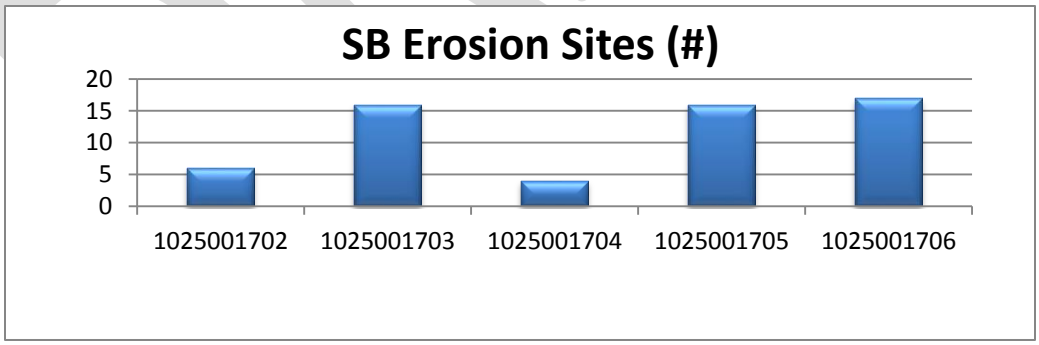


Table 2: Lower Republican River Watershed Streambank Erosion Assessment Table by HUC12

HUC12	Stream Bank Length (ft)	SB Erosion Site Total Soil Loss (T/Yr)	Stabilization Cost Estimate ($)	Poor Riparian Cond - SB Length (ft)	Est Sed Reduction (T/Yr)	% of SB Length w Poor Riparian Condition	SB Erosion Sites (#)
102500170202	1,772	1,114	$126,693	913.9	-947	50.0%	2
102500170204	4,077	2,865	$291,506	505.1	-2,435	60.0%	5
102500170302	417	195	$29,794	0.0	-166	0.0%	1
102500170303	2,197	1,558	$157,099	1,229.1	-1,325	50.0%	2
102500170304	2,177	2,193	$155,642	1,176.0	-1,864	66.7%	3
102500170310	10,125	11,894	$723,925	7,116.7	-10,110	70.0%	10
102500170409	4,305	6,571	$307,821	3,357.2	-5,585	50.0%	4
102500170508	18,686	32,640	$1,336,076	14,455.9	-27,744	75.0%	16
102500170602	997	1,197	$71,266	996.7	-1,017	100.0%	1
102500170604	21,063	11,224	$1,506,013	17,806.7	-9,541	91.7%	12
102500170605	1,559	366	$111,442	445.2	-311	33.3%	3
Total	**67,375**	**71,816**	**$4,817,277**	**48,002.6**	**-61,044**	**69.5%**	**59**
Est Stabilization Cost/Linear Ft.			$71.50	**Stabilization/Restoration Efficiency**			85%

Figure 9: Lower Republican River Watershed Streambank Erosion Assessment Graph by HUC12

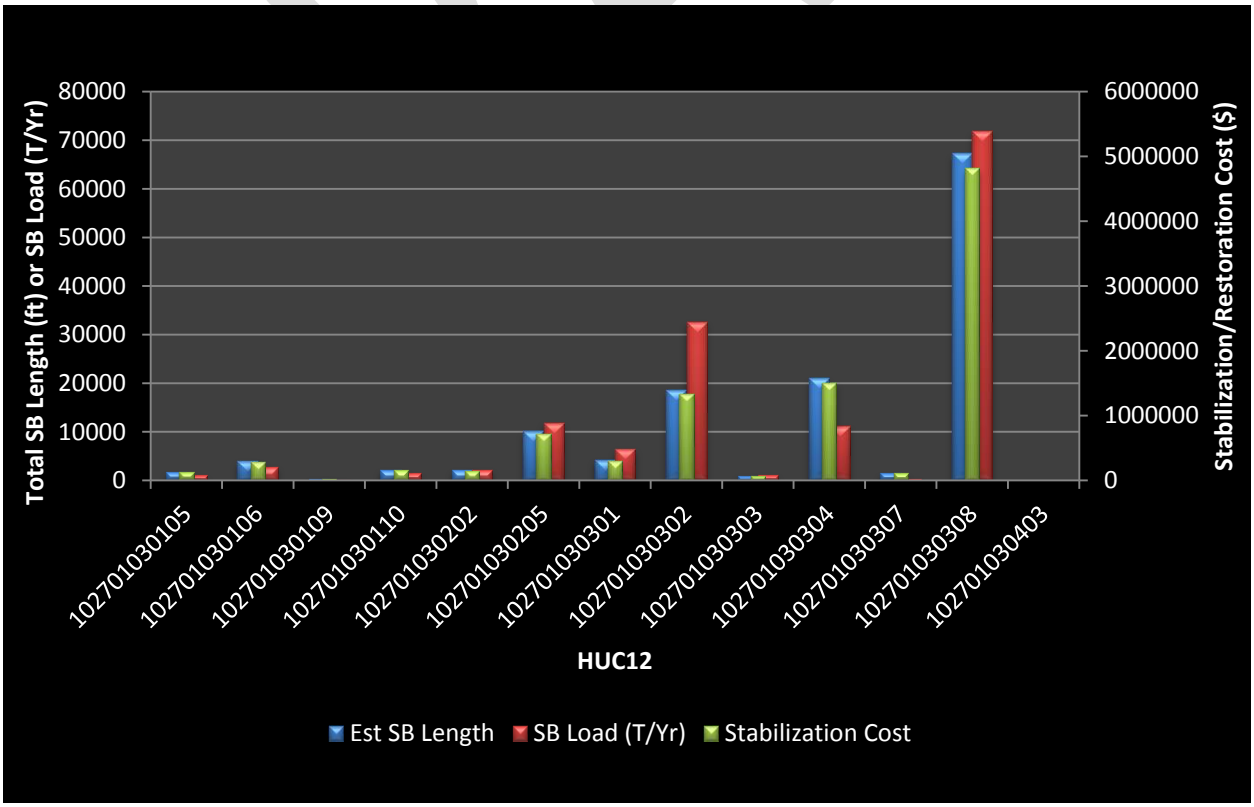
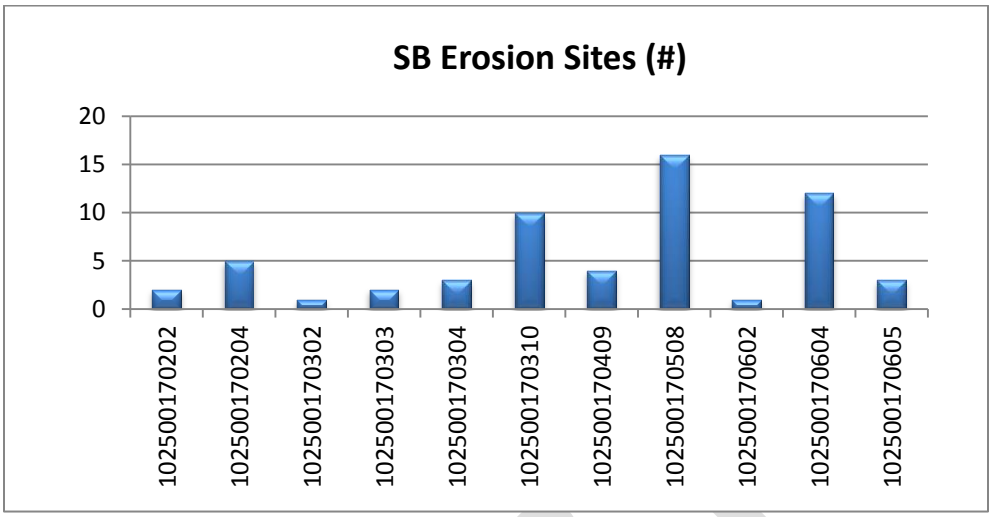


Figure 10: Lower Republican River Watershed Streambank Erosion Assessment Graph by HUC12



Conclusion

The KWO created this 2017 assessment for the Solomon- Republican and Kansas Regional Advisory Committee (SR, KS RAC) and the Milford Reservoir Watershed Restoration and Protection Strategy (WRAPS) Stakeholder Leadership Team (SLT). Information contained in the assessment can be used by the Milford Reservoir WRAPS SLT to target streambank stabilization and riparian restoration efforts toward high priority stream reaches within the Lower Republican River watershed above Milford Reservoir.

References

1. Balch, P. (2007). *Streambank and Streambed Erosion: Sources of Sedimentation in Kansas Reservoirs*. Unpublished White Paper.

2. Brinsen, M. M., B. L. Swift, R. C. Plantico, and J.S. Barclay. 1981. Riparian Ecosystems: Their Ecology and Status. U.S.D.I., Fish and Wildlife Service. FWS/OBS-80/17, Washington, D.C., 91 pp.

3. Freeman, Craig, Kansas Biological Survey. 1996. Importance of Kansas Forests and Woodlands, KS Walnut Council Annual Meeting, Topeka.

4. Geyer, W., Brooks, K., Neppl, T. 2003. Streambank Stability of Two Kansas River Systems During the 1993 Flood in Kansas, Transactions of the Kansas Academy of Science, Volume 106, no.1/2, p.48-53. (http://www.oznet.ksu.edu/library/forst2/srl122.pdf)

5. Huggins, D. G., Bandi, D. and Higgins, K. 1994. KBS Report # 60, Identifying riparian buffers that function to control nonpoint source pollution impacts to instream communities: feasibility study in the Delaware River Basin, Kansas.

6. Juracek, K.E. and Ziegler, A. (2007). *Estimation of Sediment Sources Using Selected Chemical Tracers in the Perry Lake and Lake Wabaunsee Basins, Northeast Kansas.*

7. Kansas State Conservation Commission. (1999). *Kansas River and Stream Corridor Management Guide*.

8. Kansas Water Plan. (2009). *Reservoir Sustainability Initiative.*

9. Mau, D.P., 2001, *Sediment depositional trends and transport of phosphorus and other chemical constituents, Cheney Reservoir watershed, south-central Kansas*: U.S. Geological Survey Water-Resources Investigations Report 01–4085, 40 p.

10. US Environmental Protection Agency. (2008). *Watershed Assessment of River Stability & Sediment Supply (WARSSS)* website: www.epa.gov/warsss/sedsource/streamero.htm

11. Rosgen, D. L. (1997). *A Geomorphological Approach to Restoration of Incised Rivers*. Proceedings of the Conference on Management of Landscapes Disturbed by Channel Incision, 1997.

12. TWI. (2010). *Kansas River Basin Regional Sediment management Section 204 Stream and River Assessment.*