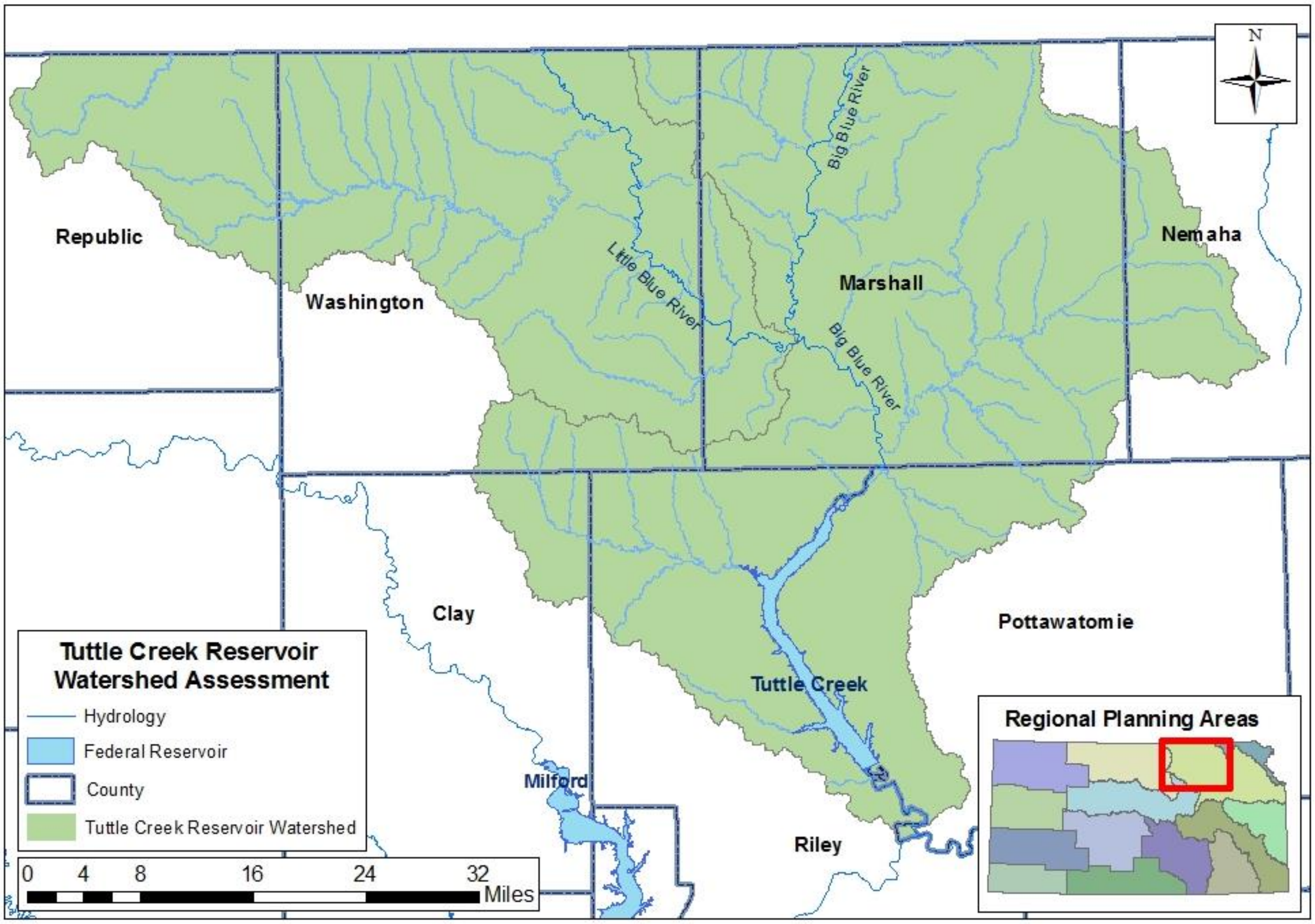
TUTTLE CREEK WATERSHED STREAMBANK EROSION ASSESSMENT

ArcGIS® Comparison Study: 1991, 2002, 2003 vs. 2015 Aerial Photography

UPDATED DRAFT: April 2017



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Executive Summary

Federal reservoirs are an important source of water supply in Kansas for roughly 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* 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 Tuttle Creek Watershed Streambank Erosion Assessment, an ArcGIS® Comparison Study, was initiated to partially implement the *Reservoir Sustainability Initiative*. This assessment identifies areas of streambank erosion to provide a better understanding of the Tuttle Creek 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 HUC10 and HUC12s where erosion is most severe in the watershed above Tuttle Creek Reservoir.

The KWO 2017 assessment quantifies annual tons of sedimentation from streambank erosion over the period between 1991, 2002, or 2003 and 2015 in the Tuttle Creek Watershed within the Kansas Regional Planning Area (KS RPA). A total of 367 streambank erosion sites, covering 300,258 feet of unstable streambank were identified. Eighty-nine percent of the identified streambank erosion sites were identified as having a poor riparian condition (riparian area identified as having cropland, grass/crop streamside vegetation or narrow woodland (single line of trees between stream and cropland/pastureland)). Sediment transport from identified streambank erosion sites accounts for 947,211 tons (768 acre-feet) of sediment per year transported from the Tuttle Creek Watershed streams to Tuttle Creek Reservoir annually, accounting for roughly 21 percent of the total load estimated from the most recent bathymetric survey performed by a U.S. Army Corps of Engineers contractor in 2009. 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 indicate HUC10(505) and HUC10(706) as the most active HUC10s for streambank degradation, accounting for 188,818 feet of unstable streambank; 795,840 tons (645 acre-feet) of sediment per year and 63 percent of total estimated stabilization costs (Figure 5, 6, 7 and Table 2). Results by HUC12 indicate HUC12(50502), HUC12(50503), HUC12(70601) and HUC12(70603) as the most active HUC12s for streambank degradation, accounting for 115,448 feet of unstable streambank; 548,492 tons (445 acre-feet) of sediment per year and 38 percent of total stabilization costs (Figure 8, 9, 10 and Table 3). Based on the average stabilization costs of $71.50 per linear foot, conducting streambank stabilization practices for the entire watershed would cost approximately $21.5 million.

The KWO completed this assessment for the Kansas Regional Advisory Committee (KS RAC) and the Tuttle Creek Watershed Restoration and Protection Strategy (WRAPS) Stakeholder Leadership Team (SLT). Information contained in this assessment can be used by the Tuttle Creek Watershed WRAPS SLT to target streambank stabilization and riparian restoration efforts toward high priority HUC10s or HUC12s in the Tuttle Creek Watershed. Similar assessments have been completed 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 (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). Riparian vegetative type is an important tool that provides indicators of erosion occurrence from land use practices. Vegetative cover based on rooting characteristics can mitigate erosion by protecting banks from fluvial entrainment and collapse by providing internal bank strength. 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.

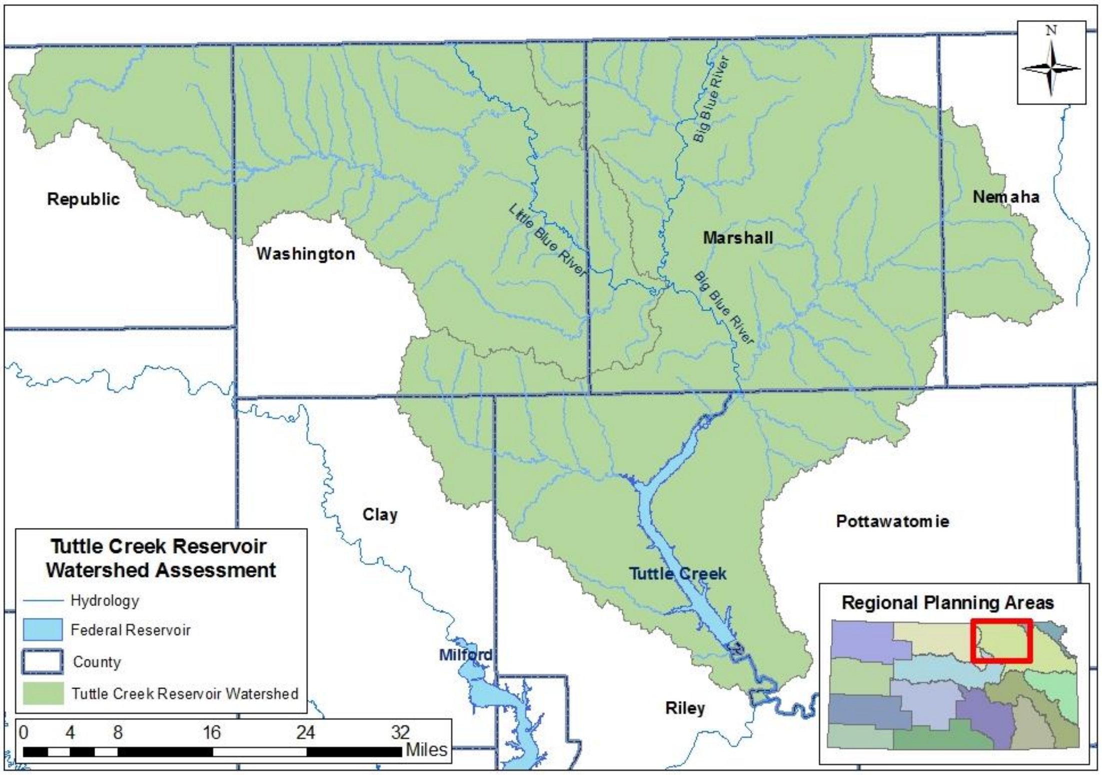
Study Area

Tuttle Creek Reservoir is a 14,000 acre impoundment located in northeast Kansas at the lower end of the Big Blue River. The watershed consists of a total area of 9,628 square miles with roughly three-fourths of the drainage area in Nebraska and the remainder in Kansas. Construction began on the reservoir in 1952; the federally authorized purposes are flood control, water supply, navigation, recreation and fish and wildlife management. The original conservation pool and maximum storage capacities of the reservoir were 425,312 acre-ft and 2,367,017 acre-ft, respectively. The most current bathymetric survey in 2009 concluded that 41.26 percent of the 50 year design life for sediment storage at Tuttle Creek Reservoir has been lost to date, calculating the current sedimentation rate at 3,594 acre-feet per year (3,669,474 tons/yr). The bathymetric survey also concluded that the current storage capacity at the reservoir is estimated at 249,830 acre-feet to date.

Outflow from Tuttle Creek Reservoir enters the Big Blue River about nine miles above its confluence with the Smoky Hill and Republican rivers near Manhattan, Kansas, where the three rivers join to form the Kansas River. Tuttle Creek Reservoir is a major source of water (up to 50% of the flow) for the Kansas River, which supplies public drinking water for the urban populations of Kansas City, Topeka and Lawrence (Tuttle Creek Lake Watershed Partners, 2005). Primary tributaries of Tuttle Creek Reservoir include Big Blue River, Little Blue River and Black Vermillion River. Major secondary tributaries in the assessment area include Coon Creek, Mill Creek, Robidoux Creek, North Fork Black Vermillion River, Clear Fork, West Fancy Creek, Mill Creek, Spring Creek, Carnahan Creek, Elm Creek and Swede Creek.

Land use within the Tuttle Creek Reservoir Watershed is primarily agricultural, with approximately 72% of the land area in corn, grain sorghum or other crops, 10% in pastureland and 10% in woodland. The long-term mean annual precipitation in the watershed is 32 inches (81 cm) with most of the precipitation falling between April and September. The topography of the project area is highly dissected with slopes ranging from 1% to greater than 10%. The predominate soil types within the watershed are silty clay loams (Tuttle Creek Reservoir Watershed Partners, 2005).

Figure 1: Tuttle Creek Watershed Assessment Area

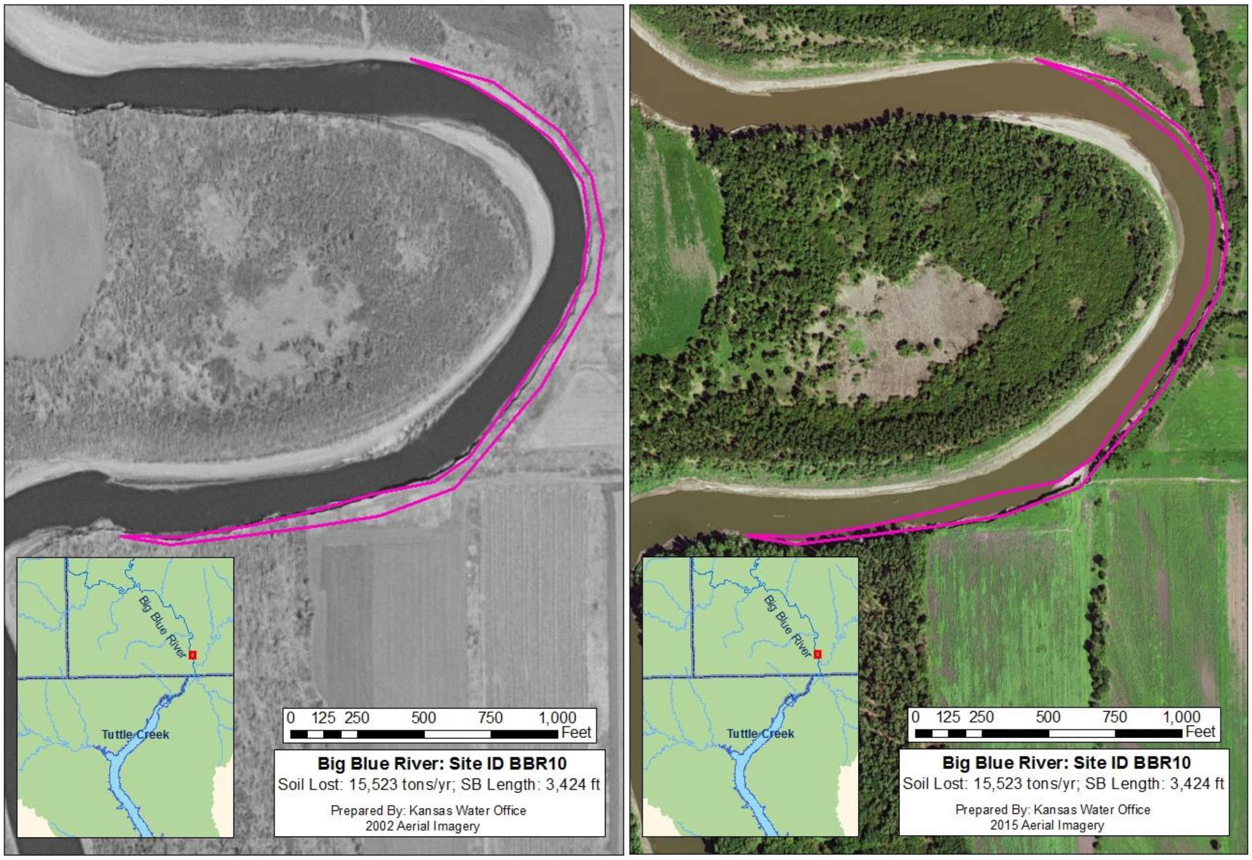


Data Collection Methodology

The Tuttle Creek 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 Perry Reservoir. ArcMap®, an ArcGIS® geospatial processing program, was utilized to assess color aerial photography from 2015 and compare it with 1991 or 2002 black and white aerial photography or 2003 color aerial photography, provided by the State of Kansas GIS Data Access & Support Center.

The streambank erosion assessment was performed by overlaying 2015 county aerial imagery onto 1991, 2002, or 2003 aerial imagery (Figure 2). Using ArcMap® tools, "aggressive movement" of the streambank between 1991, 2002 or 2003 and 2015 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, 2002 or 2003 and 2015 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, 2002, or 2003 streambank at a 1:2,000 scale. Data provided, based on the geographic polygon sites, include: watershed location, stream name, type of stream and type of riparian vegetation.

Figure 2: 2002 FSA & 2015 NAIP of a Streambank Erosion Site on the Big Blue 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 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 period between the 1991, 2002, or 2003 and 2015 aerial photos and soil bulk density. This calculated volume is then divided by the year period, to get the 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 the identified streambank erosion sites were needed. Streambank heights were estimated by using TWI's October 2010 *Kansas River Basin Regional Sediment Management Section 204 Stream and River Channel Assessment*. Data collection used in the reports' assessment included streambank height on five survey locations within the Tuttle Creek Reservoir watershed. Two survey locations were on the mainstem Big Blue River; one survey was on the Little Blue River and one on the Black Vermillion River, both significant Big Blue River tributaries. The survey locations were chosen through aerial photograph interpretation and input from KWO (TWI, 2010). The TWI assessment height data from the 4 locations was the base for extrapolating streambank height measurements throughout the Tuttle Creek Reservoir watershed within Kansas. Where no streambank elevations were available, Light Detection and Ranging (LiDAR) raster tiles available for the Tuttle Creek watershed were used to calculate streambank heights at actively eroding sites.

Analysis
Streambank erosion sites were analyzed by 10-digit Hydrologic Unit Codes (HUC10) and 12-digit Hydrologic Unit Codes (HUC12) that the Tuttle Creek WRAPS SLT identified as high priority watersheds (Figures 3, 4). 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, woodland, narrow woodland, 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 (Table 1).

Figure 3: Tuttle Creek Watershed Streambank Assessment by HUC10

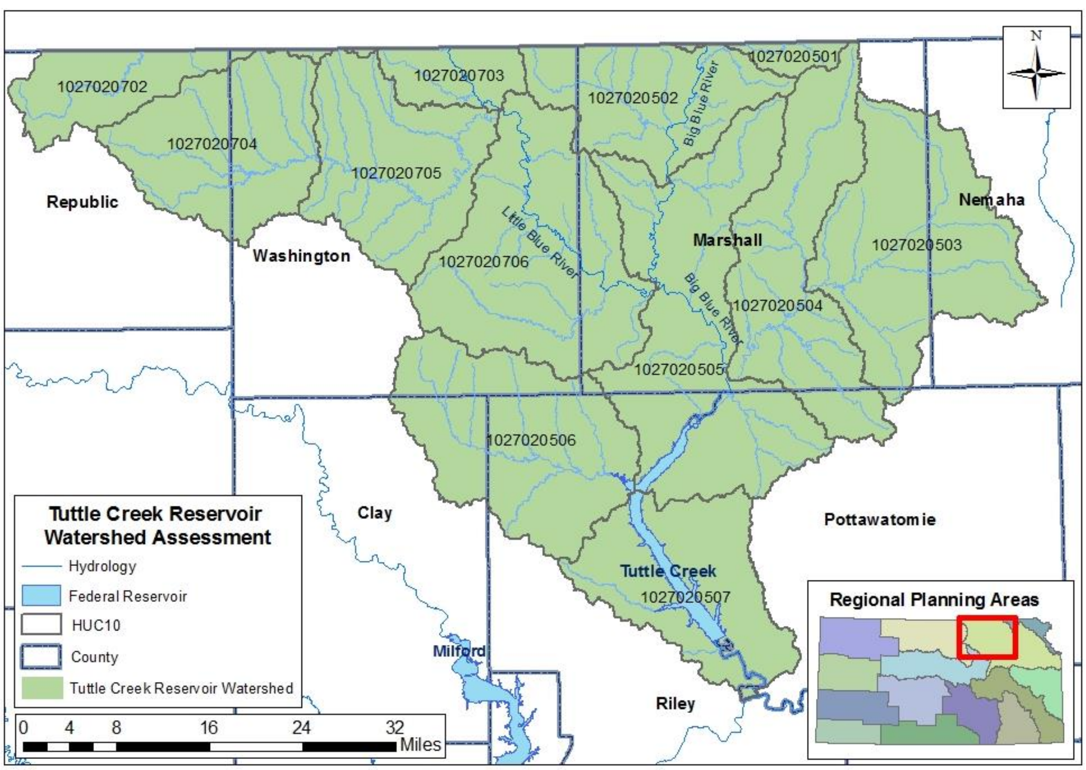


Figure 4: Tuttle Creek Watershed Streambank Assessment by HUC12

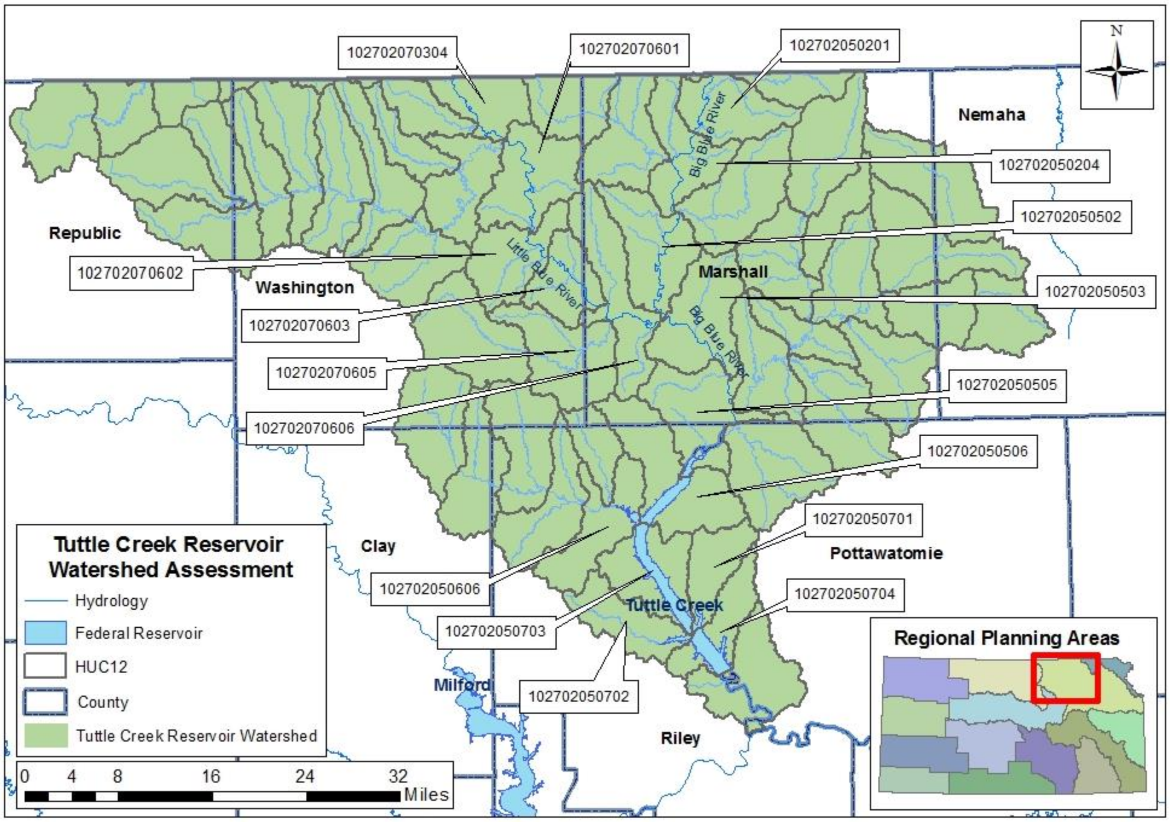


Table 1: TWI Estimated Costs to Implement Streambank Stabilization BMPs

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 KWO 2017 assessment quantifies annual tons of sedimentation from streambank erosion over the period between 1991, 2002, or 2003 and 2015 in the Tuttle Creek Watershed within the Kansas Regional Planning Area (KS RPA). A total of 367 streambank erosion sites, covering 300,258 feet of unstable streambank were identified. Eighty-nine percent of the identified streambank erosion sites were identified as having a poor riparian condition (riparian area identified as having cropland, grass/crop streamside vegetation or narrow woodland (single line of trees between stream and cropland/pastureland)). Sediment transport from identified streambank erosion sites accounts for 947,211 tons (768 acre-feet) of sediment per year transported from the Tuttle Creek Watershed streams to Tuttle Creek Reservoir annually, accounting for roughly 21 percent of the total load estimated from the most recent bathymetric survey performed by a U.S. Army Corps of Engineers contractor in 2009.

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Figure 5: Tuttle Creek Watershed Streambank Erosion Assessment Map by HUC10

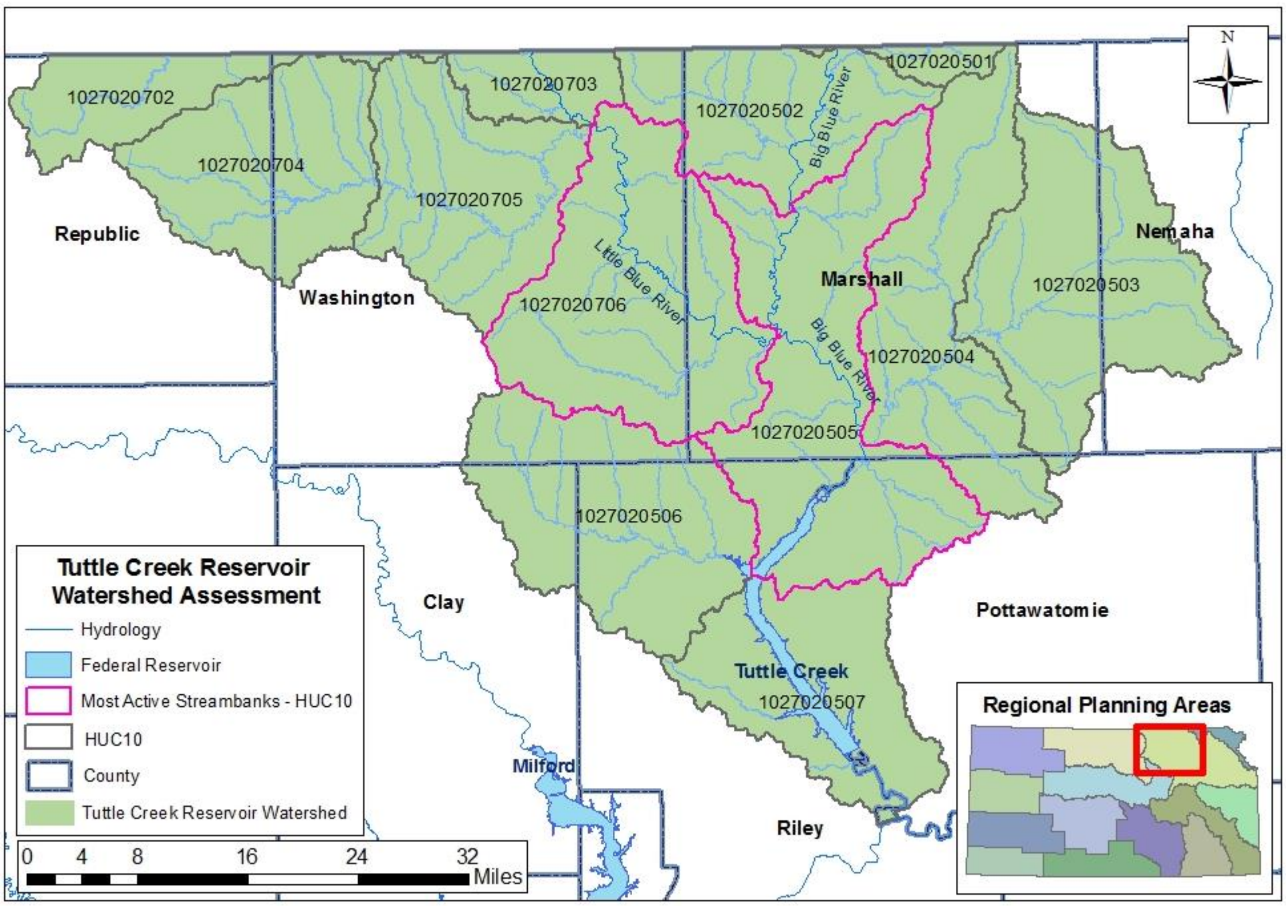


Table 2: Tuttle Creek Watershed Streambank Erosion Assessment Table by HUC10

HUC10 1027020...	Streambank Length (ft)	SB Erosion Site Total Soil Loss (T/Yr)	Stabilization Cost Estimate ($)	SB Erosion Sites (#)	Avg. Soil Loss/Bank Length (T/Yr/ft)	Poor Riparian Condition/SB Length (ft)	Est. Sed Reduction (T/Yr)	% SB Length w/ Poor Riparian Condition
HUC10(502)	24,707	38,367	$1,766,550	42	1.55	23,837	-32,612	96%
HUC10(503)	2,853	4,294	$203,975	7	1.51	2,853	-3,650	100%
HUC10(504)	35,500	43,747	$2,538,223	53	1.23	34,272	-37,185	97%
HUC10(505)	106,727	448,261	$7,630,948	81	4.20	92,855	-381,022	87%
HUC10(506)	5,256	2,788	$375,807	13	0.53	5,256	-2,370	100%
HUC10(507)	11,804	3,999	$844,001	32	0.34	11,433	-3,399	97%
HUC10(703)	14,876	41,646	$1,063,662	12	2.80	12,778	-35,399	86%
HUC10(704)	422	145	$30,190	3	0.34	252	-123	60%
HUC10(705)	16,022	16,385	$1,145,607	48	1.02	15,367	-13,927	96%
HUC10(706)	82,091	347,579	$5,869,489	76	4.23	70,486	-295,442	86%
Total	**300,258**	**947,211**	**$21,468,451**	**367**	**1.78**	**269,389**	**-805,129**	**89.72%**

Est. Stabilization Cost/Linear Ft.	$71.50	Stabilization/Restoration Efficiency 85%

Figure 6: Tuttle Creek Watershed Streambank Erosion Assessment Graph by HUC10

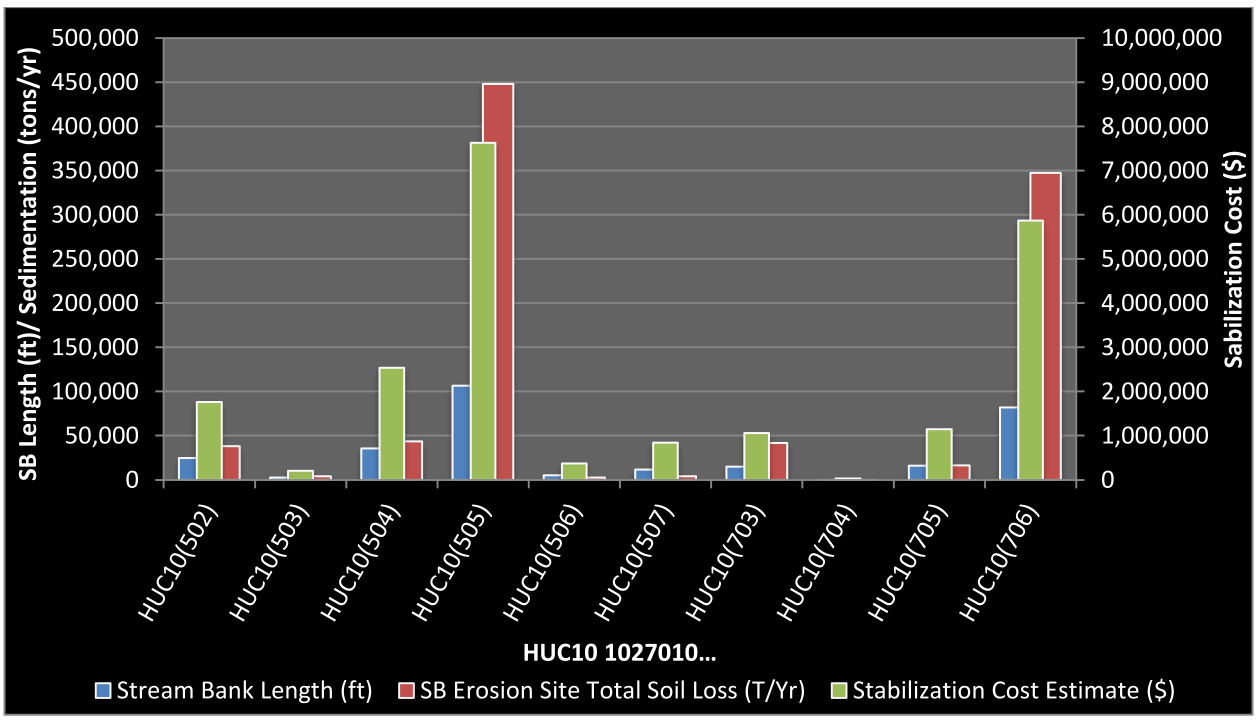


Figure 7: Tuttle Creek Watershed Streambank Erosion Assessment Graph by HUC10

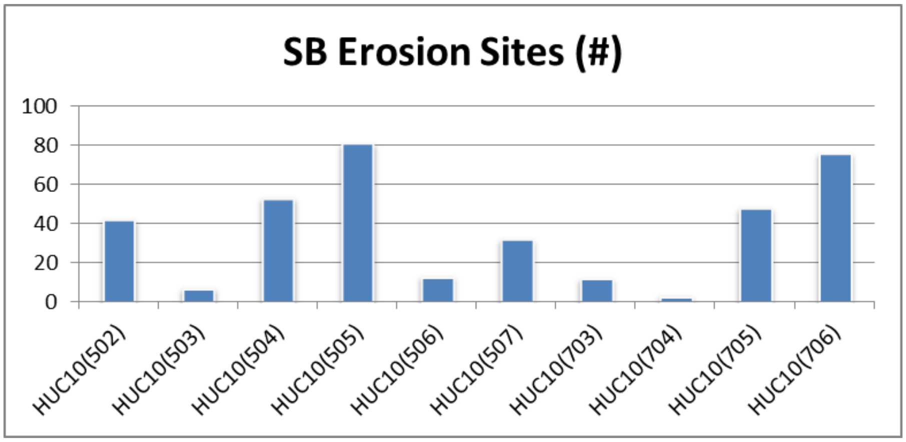


Figure 8: Tuttle Creek Watershed Streambank Erosion Assessment Map by HUC12

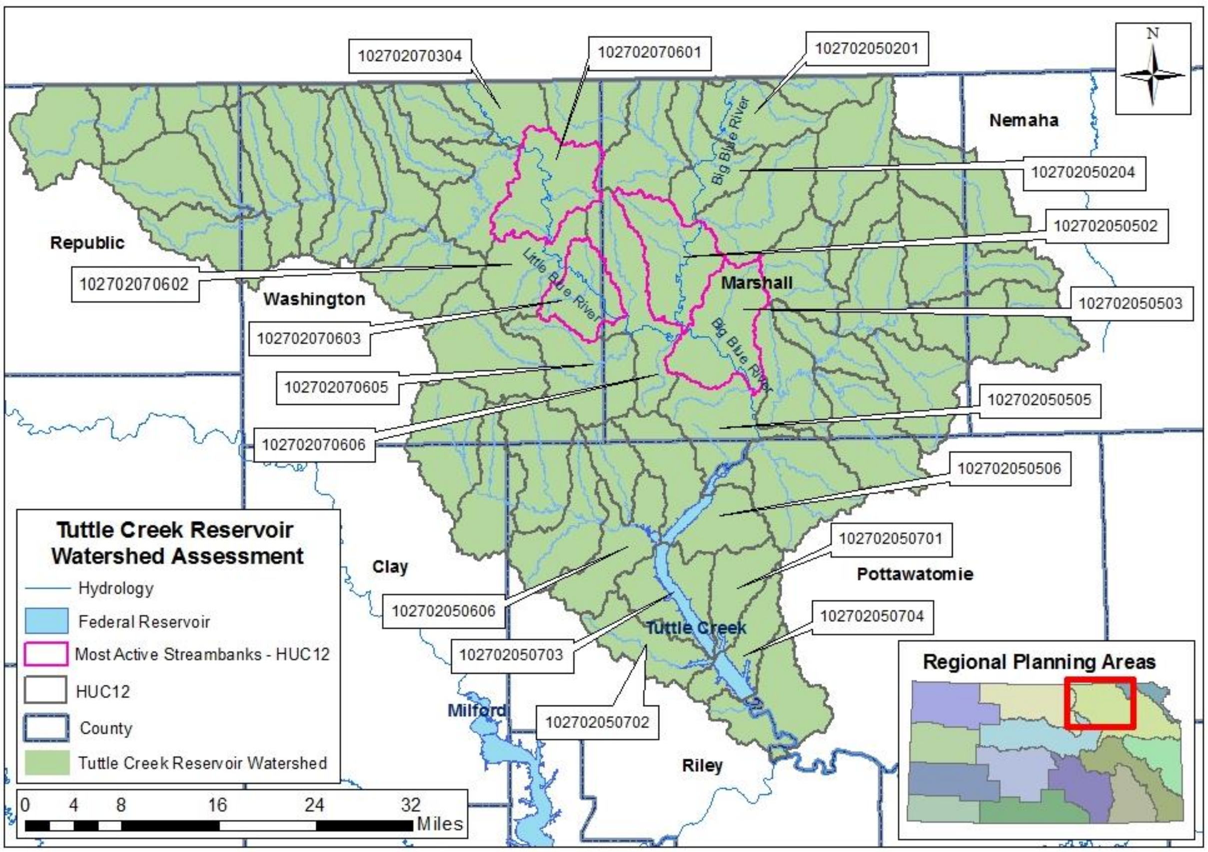


Table 3: Tuttle Creek Watershed Streambank Erosion Assessment Table by HUC12

HUC12 1027020…	Streambank Length (ft)	SB Erosion Site Total Soil Loss (T/Yr)	Stabilization Cost Estimate ($)	SB Erosion Sites (#)	Avg. Soil Loss/Bank Length (T/Yr/ft)	Poor Riparian Condition/SB Length (ft)	Est. Sed Reduction (T/Yr)	% SB Length w/ Poor Riparian Condition
HUC12(50201)	9,303	26,141	$ 665,131	7	2.81	9,303	-22,220	100%
HUC12(50203)	16,577	14,983	$ 1,185,264	37	0.90	15,707	-12,735	95%
HUC12(50204)	16,688	73,986	$ 1,193,177	14	4.43	11,956	-62,888	72%
HUC12(50301)	1,292	820	$ 92,356	4	0.63	1,292	-697	100%
HUC12(50302)	1,127	2,899	$ 80,547	1	2.57	1,127	-2,464	100%
HUC12(50306)	435	575	$ 31,073	2	1.32	435	-489	100%
HUC12(50401)	4,701	6,086	$ 336,099	11	1.29	4,701	-5,173	100%
HUC12(50403)	3,604	4,592	$ 257,710	7	1.27	3,604	-3,903	100%
HUC12(50404)	2,285	1,096	$ 163,347	8	0.48	2,285	-932	100%
HUC12(50405)	2,618	3,255	$ 187,219	4	1.24	1,941	-2,767	74%
HUC12(50406)	22,292	28,718	$ 1,593,848	23	1.29	21,742	-24,410	98%
HUC12(50502)	32,114	179,246	$ 2,296,138	20	5.58	32,114	-152,359	100%
HUC12(50503)	28,703	120,473	$ 2,052,292	17	4.20	27,086	-102,402	94%
HUC12(50504)	3,759	3,760	$ 268,738	8	1.00	3,269	-3,196	87%
HUC12(50505)	15,650	58,499	$ 1,118,941	7	3.74	10,734	-49,724	69%
HUC12(50506)	4,526	2,125	$ 323,577	10	0.47	4,241	-1,807	94%
HUC12(50602)	1,282	661	$ 91,697	3	0.52	1,282	-562	100%
HUC12(50603)	1,533	751	$ 109,607	5	0.49	1,533	-639	100%
HUC12(50604)	742	729	$ 53,026	1	0.98	742	-620	100%
HUC12(50605)	712	219	$ 50,932	2	0.31	712	-186	100%
HUC12(50606)	987	428	$ 70,545	2	0.43	987	-364	100%
HUC12(50701)	4,809	1,516	$ 343,862	12	0.32	4,809	-1,288	100%
HUC12(50702)	4,780	2,027	$ 341,747	14	0.42	4,780	-1,723	100%
HUC12(50703)	4,526	7,824	$ 323,626	6	1.73	4,526	-6,650	100%
HUC12(50704)	1,165	253	$ 83,320	2	0.22	794	-215	68%
HUC12(70304)	14,876	41,646	$ 1,063,662	12	2.80	12,778	-35,399	86%
HUC12(70404)	170	78	$ 12,169	1	0.46	-	-66	0%
HUC12(70405)	252	67	$ 18,021	2	0.27	252	-57	100%
HUC12(70501)	627	314	$ 44,808	4	0.50	627	-267	100%
HUC12(70502)	99	51	$ 7,096	1	0.52	99	-44	100%
HUC12(70503)	1,317	724	$ 94,196	6	0.55	1,317	-615	100%
HUC12(70505)	13,979	15,296	$ 999,507	37	1.09	13,323	-13,002	95%
HUC12(70601)	31,971	112,600	$ 2,285,949	25	3.52	23,327	-95,710	73%
HUC12(70602)	11,298	47,782	$ 807,818	9	4.23	8,918	-40,615	79%
HUC12(70603)	22,660	136,173	$ 1,620,189	20	6.01	21,164	-115,747	93%
HUC12(70605)	5,444	8,582	$ 389,250	11	1.58	5,444	-7,295	100%
HUC12(70606)	11,356	42,237	$ 811,966	12	3.72	10,439	-35,901	92%
Total	**300,258**	**947,211**	**$21,468,451**	**367**	**1.73**	**269,389**	**-805,129**	**89.72%**
Est Stabilization Cost/Linear Ft.			$71.50	Stablization/Restoration Efficiency			85%	

Figure 9: Tuttle Creek Watershed Streambank Erosion Assessment Graph by HUC12

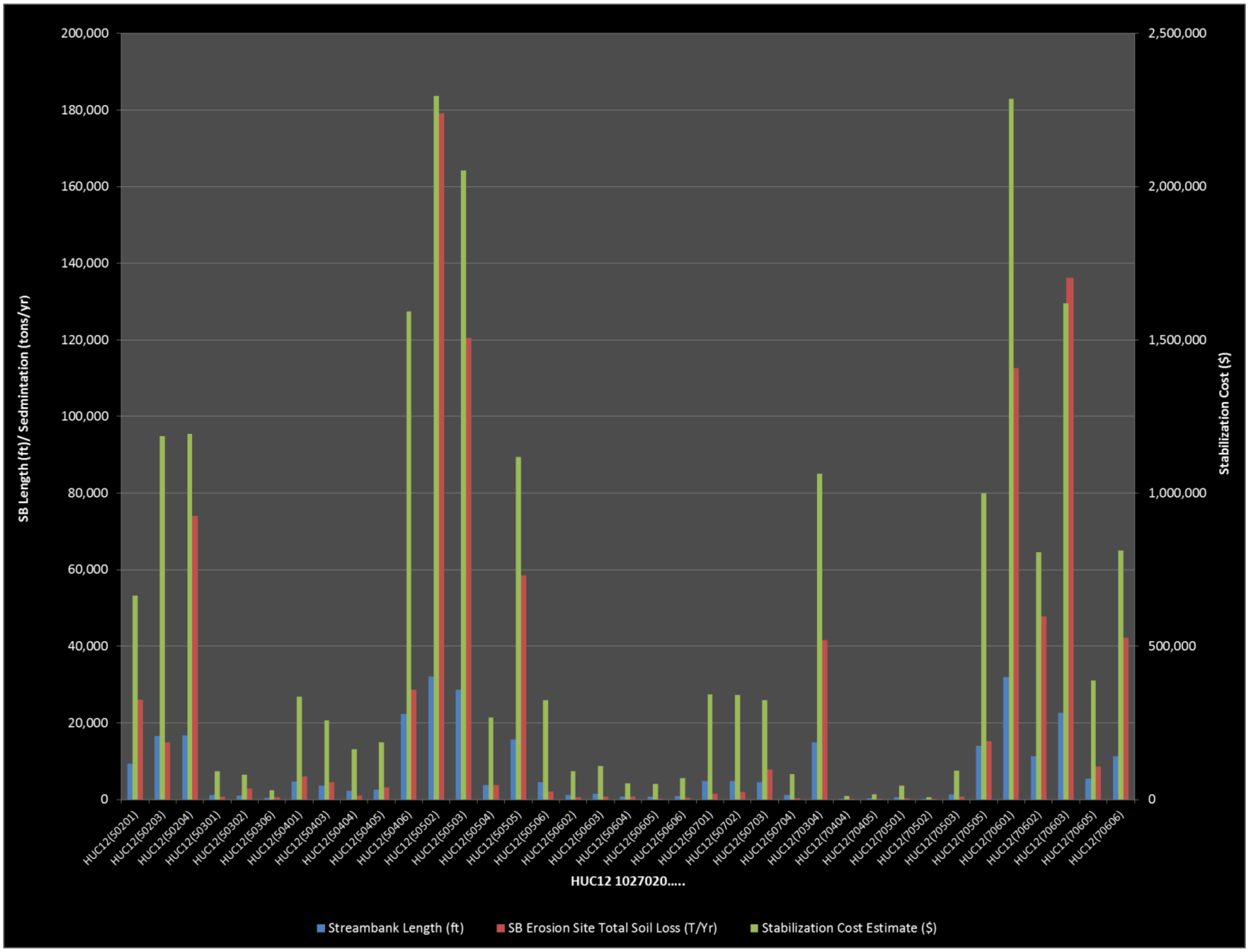
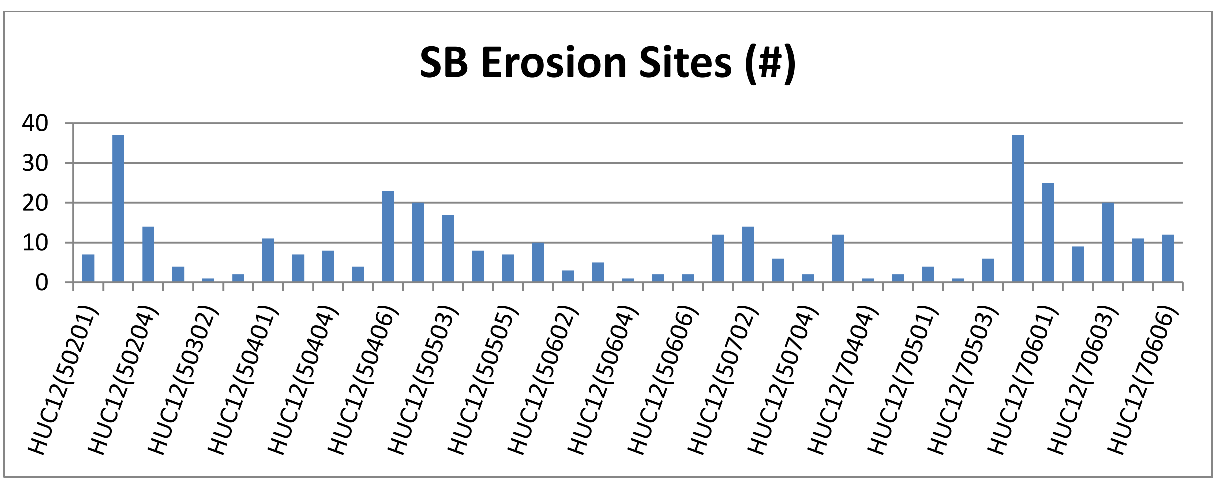


Figure 10: Tuttle Creek Watershed Streambank Erosion Assessment Graph by HUC12



Conclusion

KWO completed this assessment for the Kansas Regional Advisory Committee (KS RAC) and the Tuttle Creek Watershed Restoration and Protection Strategy (WRAPS) Stakeholder Leadership Team (SLT). Information contained in the assessment can be used by the KS RAC and the Tuttle Creek WRAPS SLT to target streambank stabilization and riparian restoration efforts toward high priority HUC10s and HUC12s within the Tuttle Creek Reservoir Watershed. Similar assessments have been conducted in watersheds above reservoirs throughout Kansas and will be made available to agencies and interested parties for the benefit of streambank and riparian restoration projects.

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