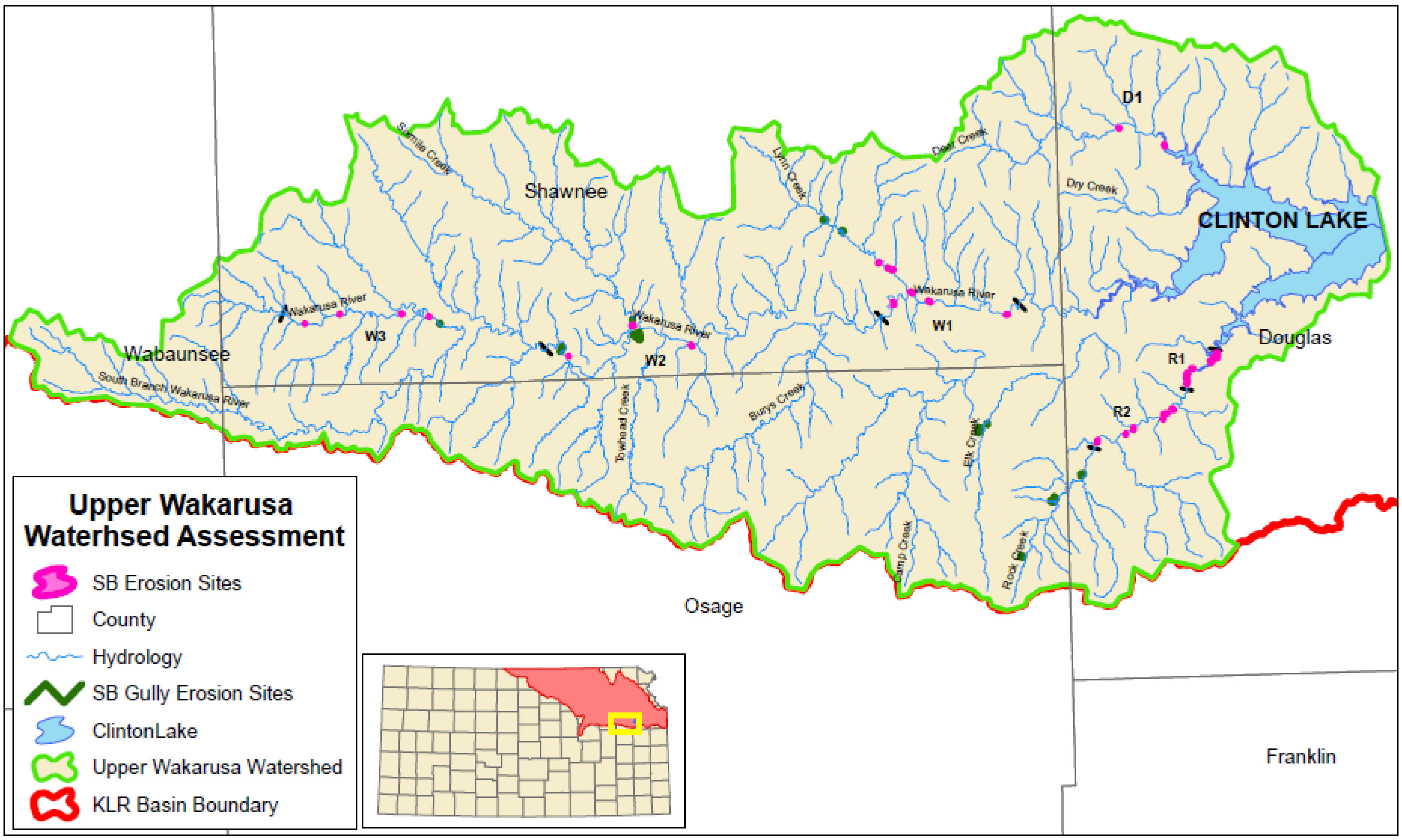
UPPER WAKARUSA WATERSHED STREAMBANK EROSION ASSESSMENT

ArcGIS® Comparison Study: 1991 vs. 2008 Aerial Photography

DRAFT April 2011



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Kansas Water Office

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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* 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 Upper Wakarusa Watershed Assessment, an ArcGIS® Comparison Study, was initiated to partially implement the *Reservoir Sustainability Initiative*. This assessment identifies areas of streambank erosion and streambank gully erosion to provide a better understanding of the Upper Wakarusa 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 Clinton Reservoir.

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 Upper Wakarusa Watershed in Kansas. A total of 28 streambank erosion sites were identified, covering 11,217 feet of unstable streambank and transporting 8,252 tons of sediment downstream per year; accounting for only 1% of the calculated annual sedimentation rate from the 2009 bathymetric survey. 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 1,500 sq. feet, or more, were identified. Streambank erosion sites were analyzed by stream reach and eight 12-digit Hydrologic Unit Codes (HUC12). A substantial quantity of sediment is transported each year from the mainstem Wakarusa River reach one (W1), at roughly 2,478 tons annually, and from Rock Creek reach one (R1), at roughly 3,306 tons annually. These identified reaches account for an estimated 61% or $487,000 of total stabilization cost needs in the watershed. Results by HUC12 identified 102701040104 and 102701040107 as the most active hydrologic unit codes for streambank degredation. HUC12 (104) accounts for 2,572 ft of unstable streambank and 2,561 tons of sediment per year; while HUC (107) accounted for 6,555 ft of unstable streambank and 4,499 tons of sediment per year. These HUC12s accounted for roughly 81% of unstable streambank, 86% of sedimentation and 81% of total stabilization costs. Based on the average stabilization costs of $71.50 per linear foot, conducting streambank stabilization practices for the entire watershed would cost approximately $802,000.

Streambank gully erosion sites were also assessed. Streambank gully erosion sites were identified as high, medium or low priority and were analyzed by stream reach and HUC12s. A total of 23 streambank gully sites identified were identified. Rock Creek and the Wakarusa River had the highest amount of streambank gully erosion sites, four each. HUC12s (102) and (107) had the greatest amount of gullies, at two and four respectively. Rock Creek and HUC12 (107), in which Rock

Creek is located, were the only areas to have high priority gullies identified; both having two. It should be noted that these two high priority gullies could be intermittent streams, but with exposed highly erodible soils and the inability to perform field verification, it was denoted as a high priority gully.

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 to provide a better understanding of the Upper Wakarusa Watershed for mitigation purposes and for application of understanding to watersheds across Kansas. Currently, two published reports by the Kansas Alliance for Wetlands & Streams have been completed within three HUC12 sub-watersheds in the Upper Wakarusa Watershed. These reports were a Level 1 and 2 Watershed Assessment identifying BMP implementation projects that would result in greater water quality benefits within the Deer Creek and the Lynn-Burys Creek Watersheds. There is also an assessment by The Watershed Institute and Gulf South Research Corporation within the Upper Wakarusa Watershed where stream channel morphologic and riparian assessments were conducted identifying future sediment control opportunities within the Wakarusa River watershed of the Kansas River basin. All three reports parallel and complement this assessment.

The KWO completed this assessment for the Upper Wakarusa Watershed Restoration and Protection Strategy (WRAPS) Stakeholder Leadership Team (SLT). Information contained in this assessment can be used by the Upper Wakarusa WRAPS SLT to target streambank stabilization and riparian restoration efforts toward high priority stream reaches or HUC12s in the Upper Wakarusa Watershed. Similar assessments are ongoing in selected watersheds above reservoirs throughout Kansas and are avialble 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

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.

Another form of erosion contributing to sedimentation in many watersheds in Kansas is the development of streambank gullies. Gullies develop from the wearing away of the surface soil along drainage channels by surface water runoff. Gullies are associated with the loss of vegetation on the soil and down cuts forming deep widening channels. The potential for surface erosion is associated in part with the amount of bare, compacted soil exposed to rainfall and runoff. Other factors contributing to gully development are high soil erodability; little ground cover; steep, long, continuous slopes; high intensity storms; high drainage density of the slope and close proximity to streams.

Study Area

Clinton Lake is located in Northeast Kansas on the Wakarusa River, at river mile 22.3 in Douglas County, four miles west of Lawrence, KS (Figure 1). The watershed drains an area of roughly 367mi^2, encompasses portions of Douglas, Osage, Shawnee and Wabaunsee counties and is part of the Kansas-Lower Republican River Basin, including eight 12-digit Hydrologic Unit Codes (HUC12) (Figure 2). The watershed originates at the eastern edge of the Flint Hills, at an elevation of approximately 1,200 feet, and Clinton Dam is at an elevation of 850 ft (UWW WRAPS, 2003). Clinton Lake is a multipurpose US Army Corps of Engineers (Corps) reservoir constructed in 1972, and filled in 1980, for the authorized purposes of flood control, water supply, water quality, recreation and fish and wildlife. The State of Kansas owns 80.8% of it for water supply storage. The reservoirs original storage capacity was 397,538 acre-ft with a designed sedimentation rate at 285 acre-ft/yr. In the most recent bathymetric survey, 2009, the calculated sedimentation rate was 324 acre-ft/yr, 39 acre-ft/yr more than the designed rate.

The Upper Wakarusa Watershed is comprised of three main branches of the Wakarusa River and eight main tributaries draining into Clinton Reservoir. The North Branch, Middle Branch and South Branch of the Wakarusa River converge with the headwaters of the Wakarusa River in western Shawnee County to form the mainstem of the river. Sixmile Creek, Towhead Creek, Burys Creek, Lynn Creek, Camp Creek, Deer Creek, Rock Creek and Elk Creek are all main tributaries that drain into Clinton Reservoir via the Wakarusa or the tributary itself. There are also a number of small streams, mostly unnamed, that contribute flow directly to the mainstem of the Wakarusa River.

Topography of the Upper Wakarusa Watershed varies from a nearly level floodplain to bluffs with slopes up to 30% along the south side of the valley. The north side of the valley is gentler, with slopes of two to ten percent common. In general, soils of the area are rated as medium/high hazard for slope/erodability. The upland soils are deep to moderately deep silt loams to silty clay loams, and are nearly level to strongly sloping, well drained to moderately well drained. Bottom-land soils are deep and friable with silty clay loam predominant. Lowland terraces and floodplains have deep, nearly level soils. The predominant soil is Mollisol, which is characteristically dark in color, often moist and well drained. The average soil permeability is 0.6 inches/hour. The watershed is also dominated by grassland/rangeland (~ 56%) and cropland (~ 27%). Within 1/8 mile of most streams, these percentages change to 38% grassland and 37% cropland, reflecting the common practice of extending the boundaries of cultivated fields close to stream banks to maximize crop production in better soils. Soil erosion since the onset of crop production in the watershed has resulted in a reduced moisture-holding ability and, consequently, crop yields have been reduced (UWW WRAPS, 2003).

Figure 1: Upper Wakarusa Watershed

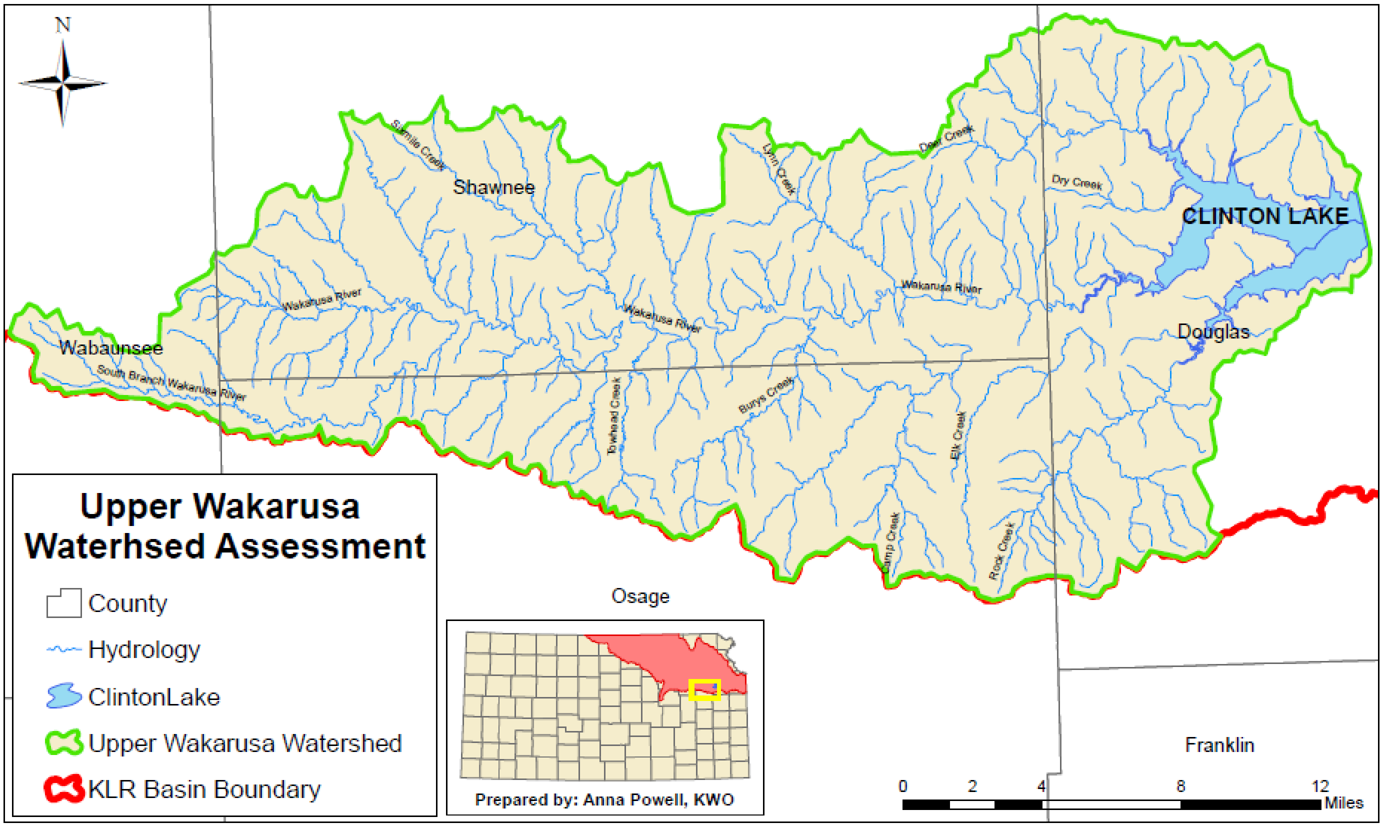
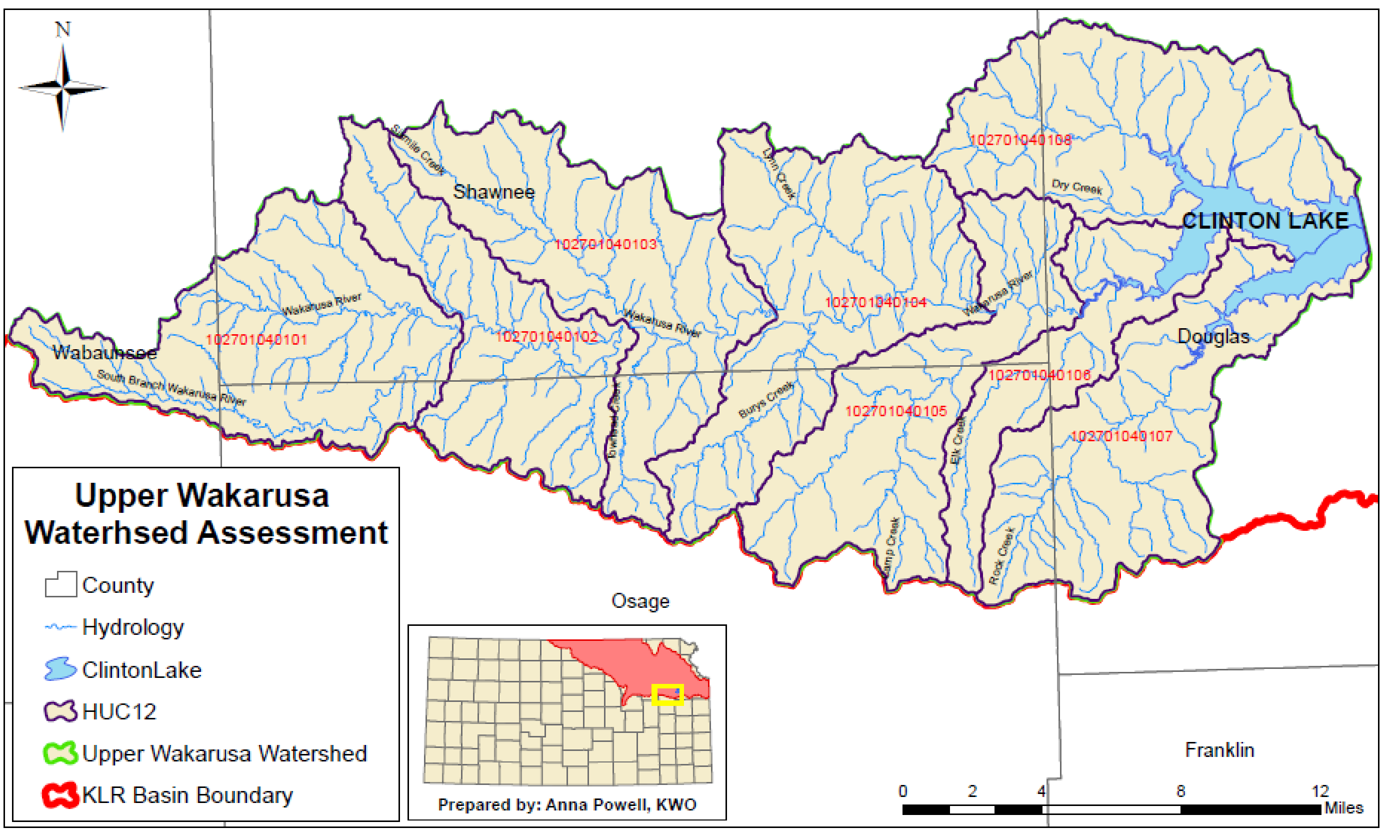


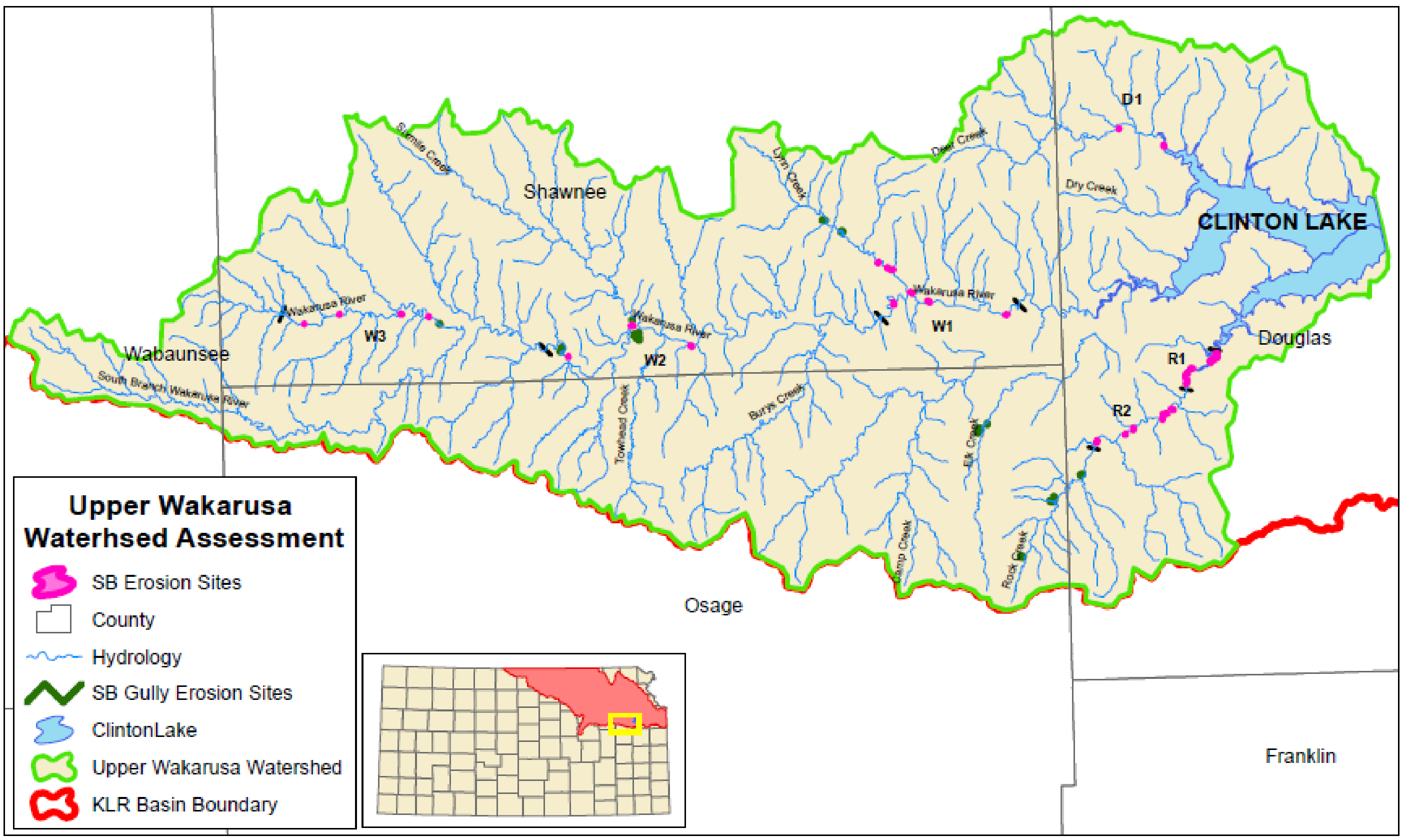
Figure 2: Upper Wakarusa Watershed Area HUC12s



Data Collection Methodology

The Upper Wakarusa 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 in the Upper Wakarusa Watershed. 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). Erosion sites identified in this assessment include locations of streambank erosion and streambank gully erosion (Figure 3).

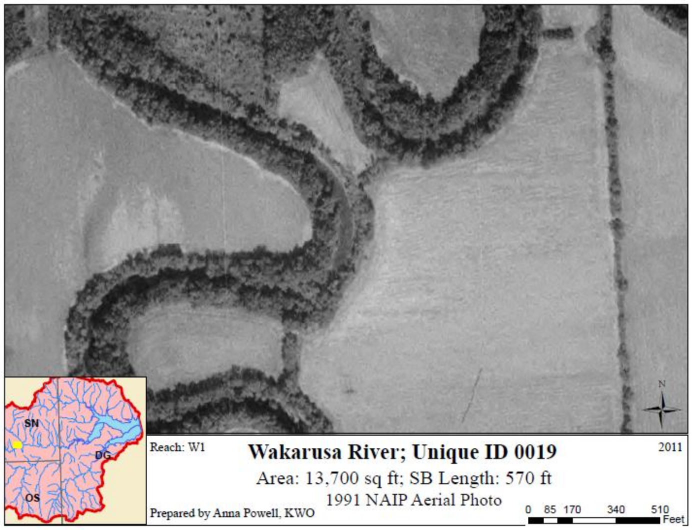
Figure 3: Upper Wakarusa River Watershed Assessment Area & Erosion Locations

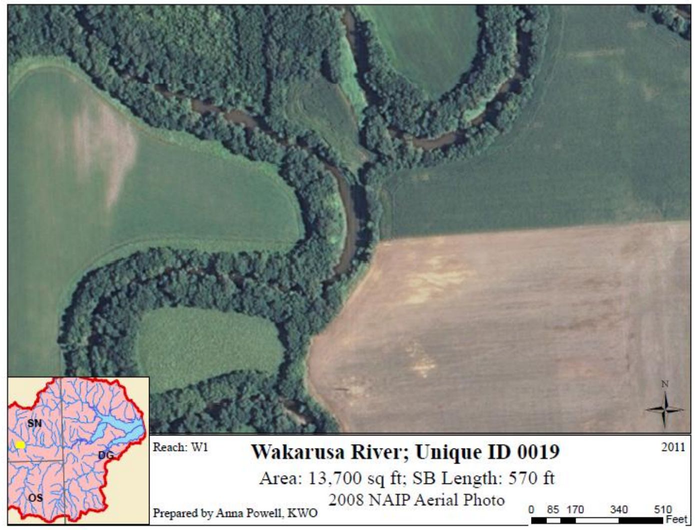


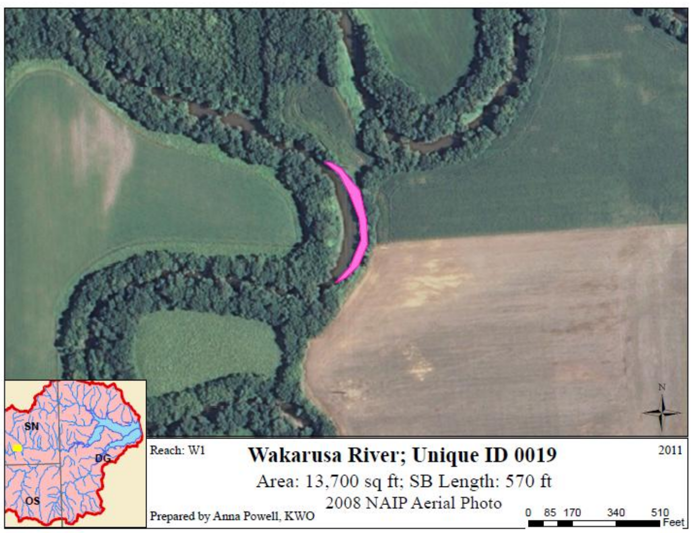
Streambank Erosion Assessment

The streambank erosion assessment was performed by overlaying 2008 NAIP county aerial imagery onto 1991 DASC county aerial imagery (Figure 4). Using ArcMap® tools, "aggressive movement" of the streambank between 1991DASC 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. 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 4: 1991 DASC & 2008 NAIP of a Wakarusa River Streambank Erosion Site







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.

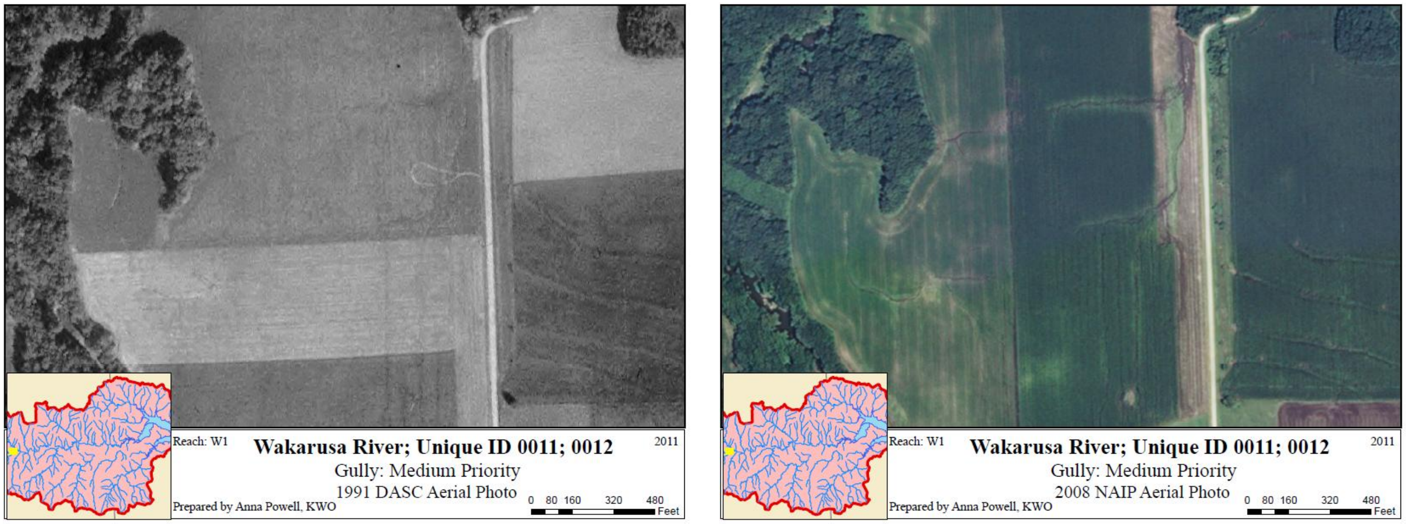
Tons of soil loss was estimated by first calculating the volume of sediment loss and then applying a bulk density estimate to that volume for the typical soil type of identified sites. The volume of sediment was found by multiplying bank height and surface area lost over the 17 year period between the 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^3)/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 from a TWI stream channel assessment above Clinton Reservoir and in the Deer Creek Watershed. Based on TWI's work, streambank heights were available from surveyed locations on stream reaches in: Deer Creek, Rock Creek, Lynn Creek, Wakarusa River near Glick Road and Wakarusa River near Ratner Road. These locations were the basis for extrapolating streambank height measurements throughout the Upper Wakarusa Watershed.

Streambank Gully Erosion Assessment

The streambank gully erosion assessment was performed with similar techniques and parallel the streambank erosion assessment by overlaying 2008 NAIP county aerial imagery onto 1991 DASC county aerial imagery (Figure 5). However, calculating tons of soil erosion was not part of this assessment. Using ArcMap® tools, streambank gully erosion was indicated by line features "drawn" into the ArcGIS® software program identified at a 1:6,000 scale. Once sites were identified, watershed location, unique ID, stream name, type of stream and type of riparian vegetation data was compiled on gully sites and categorized by high, medium or low priority. Classification as a low priority gully indicates that sheet erosion has been identified and a gully could form in the area that is perpendicular to the stream. A low priority gully does not have visible channel cutting or any visible streambank riparian erosion. A medium priority gully identifies visible channel cutting perpendicular to the streambank but no visible erosion of the riparian area of the streambank. High priority gullies identify a deeply incised channel cutting perpendicular to the stream, including a significant portion of the riparian area eroded from the streambank. In some instances, gully priority ratings were increased to a medium or high priority, even if they exhibit "low priority" gully identifiers, if there was a sizeable amount of land erosion or gullies identified in the same vicinity.

Figure 5: 1991 DASC & 2008 NAIP of a Wakarusa River Streambank Gully Erosion Site



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: D1, R1, R2, W1, W2 and W3 (Figure 6). Stream reach sections were identified by the first letter of the stream name and in numerical order from downstream to upstream. For example, stream reaches W1-W3 references three reaches on the Wakarusa River, proceeding from downstream to upstream along the river. Streambank erosion sites were also analyzed by eight 12-digit Hydrologic Unit Codes (HUC12s) (Figure 7). 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 6: Upper Wakarusa Watershed Streambank Assessment by Stream Reach

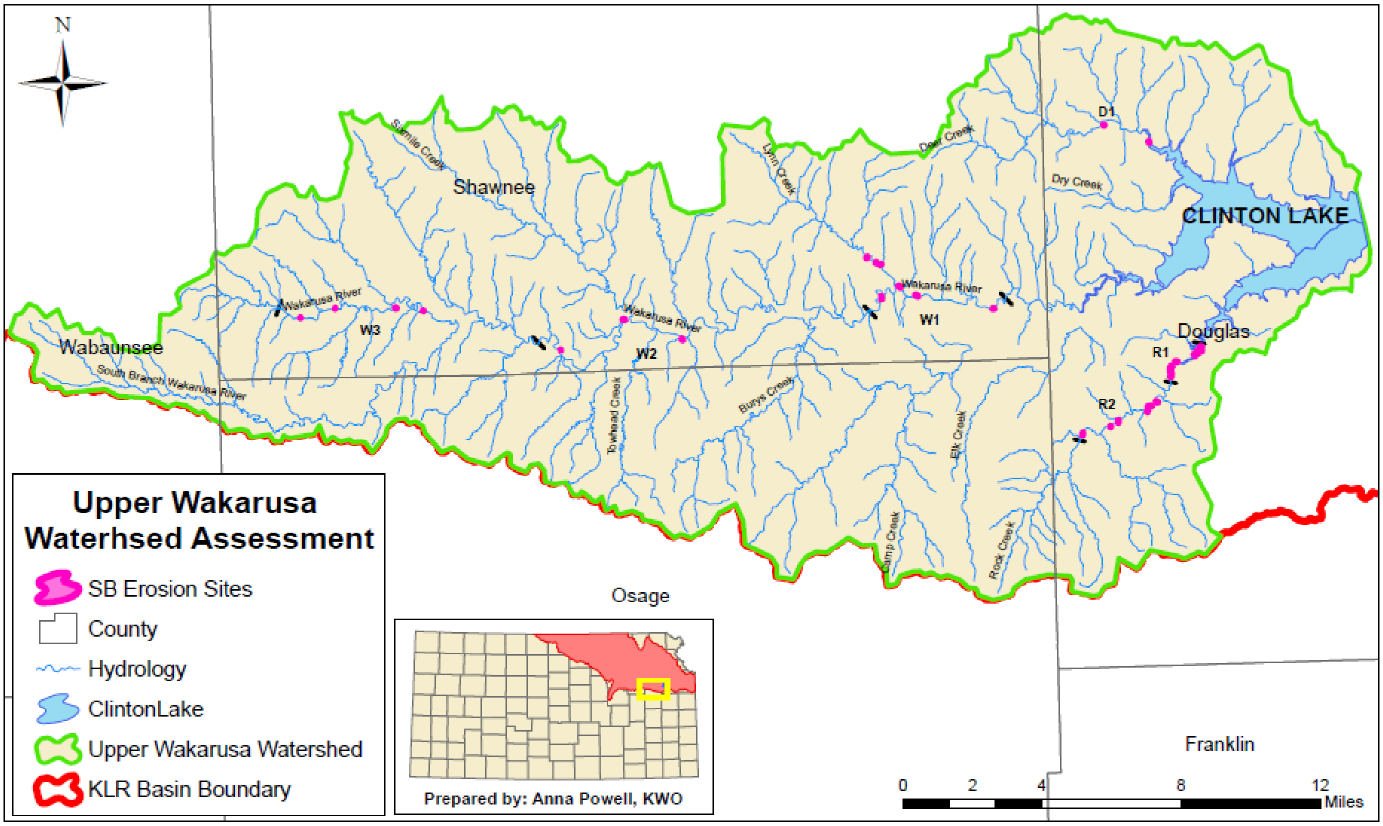


Figure 7: Upper Wakarusa Watershed Streambank Assessment by HUC12

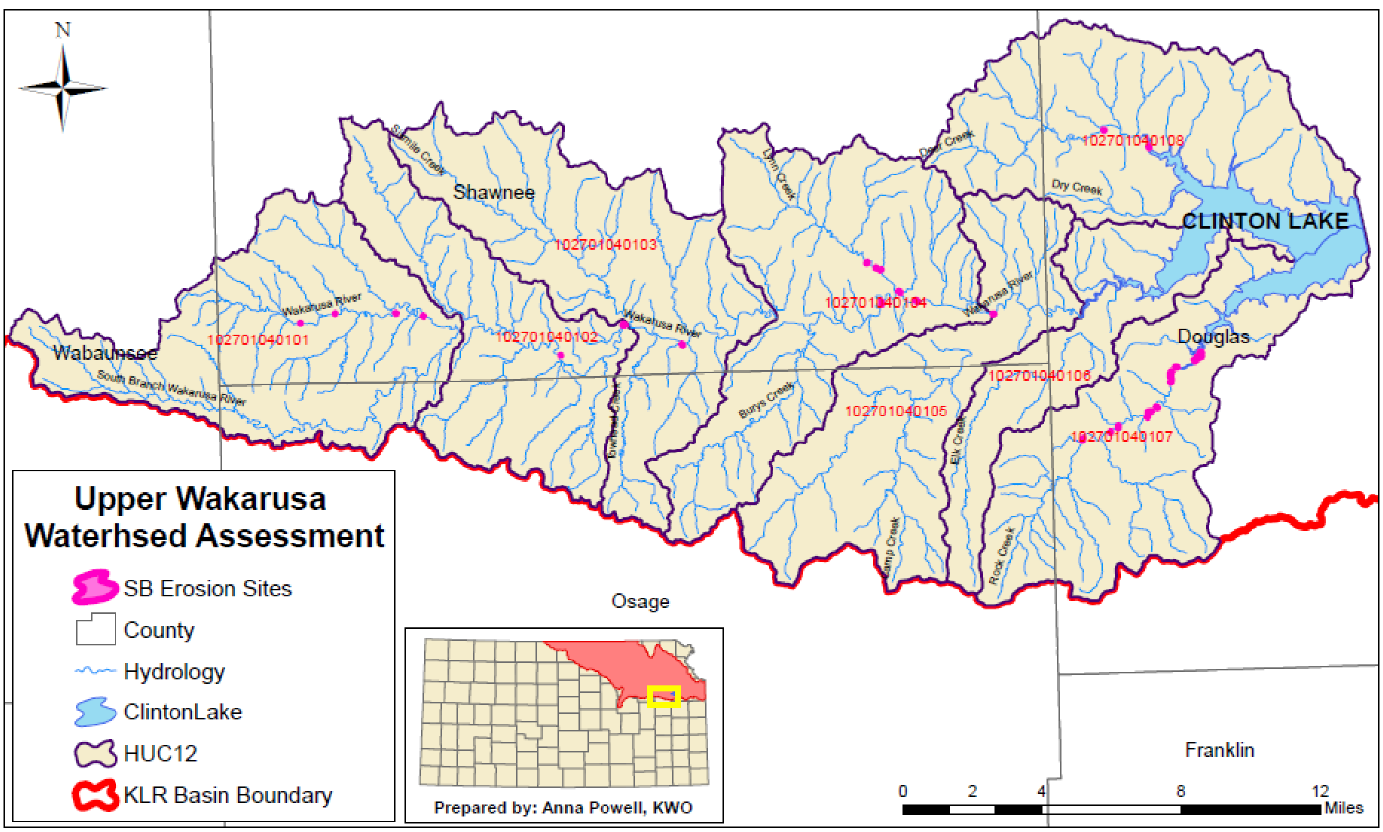


Figure 8: TWI Estimated Costs to Implement Streambank Stabilization BMPs

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
TOTAL	$58-$85.5

Streambank gullies were assessed based on the proportion of high, medium and low priority identifications within stream reach sections and eight 12-digit Hydrologic Unit Codes (HUC12s) (Figure 9), and can be used as supporting data for streambank erosion or streambank gully erosion rehabilitation prioritization (Figure 10). Explanation of prioritization is found in the data collection and methodology above. No further assessment was performed.

Figure 9: Upper Wakarusa Watershed Streambank Gully Assessment

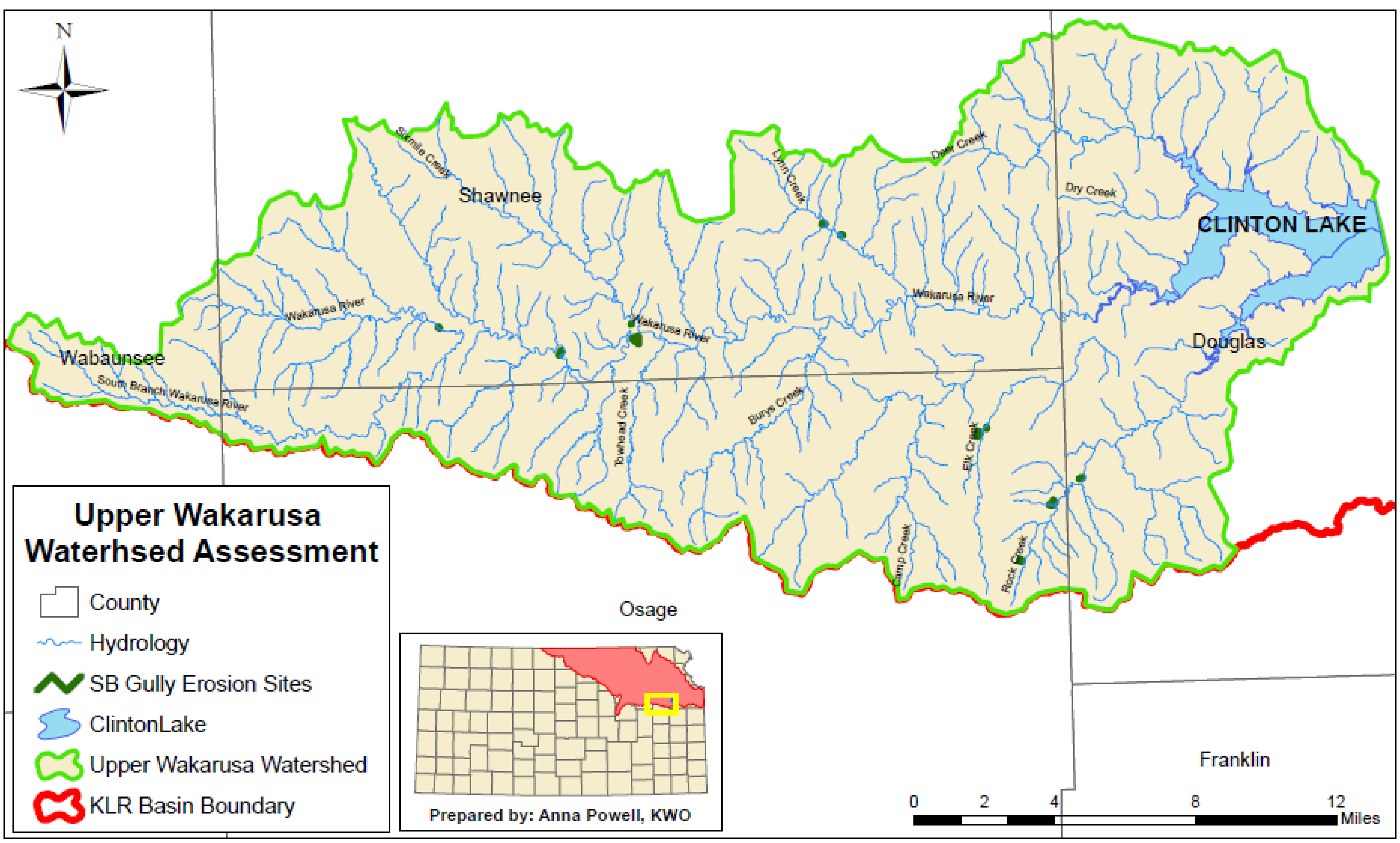
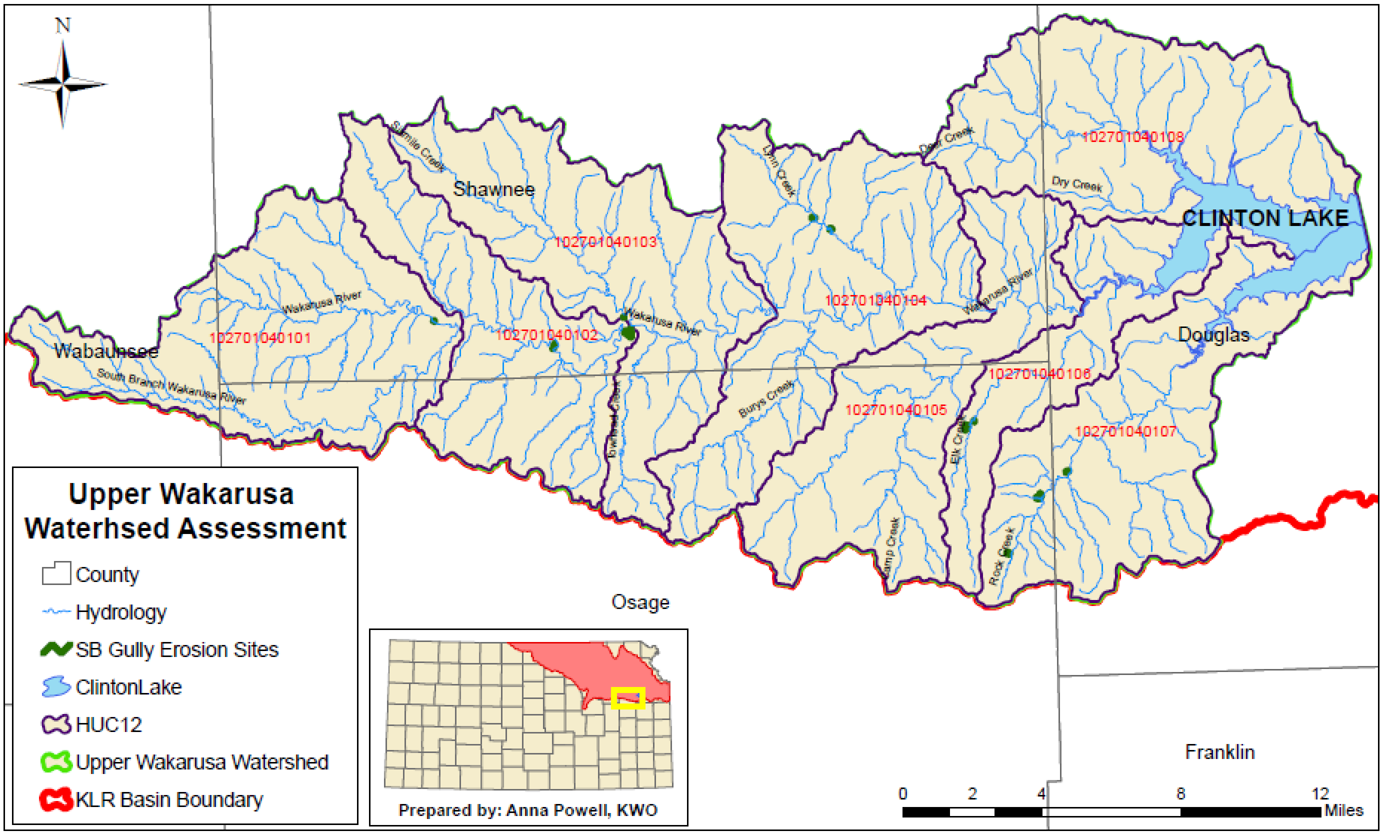


Figure 10: Upper Wakarusa Watershed Streambank Gully Assessment by HUC12s



Results

The KWO 2011 assessment quantifies annual tons of sedimentation from streambank erosion between 1991 and 2008 within the Upper Wakarusa Watershed in Kansas. A total of 28 streambank erosion sites, covering 11,217 feet of unstable streambank were identified, 46% of the unstable streambanks were identified as having poor riparian condition (riparian area identified as having cropland or grass/crop streamside vegetation). Sediment transport from identified streambank erosion sites accounts for 8,252 tons of sediment per year transported from the Upper Wakarusa Watershed streams to Clinton Reservoir annually; accounting for only 1% of the calculated sedimentation rate from the 2009 bathymetric survey.

A substantial quantity of the identified eroded sediment in the watershed is transported annually from the mainstem Wakarusa River reach one (W1) at roughly 2,478 tons annually, and from Rock Creek reach one (R1) at roughly 3,306 tons annually (Table 1 & Figure 11). These identified reaches account for an estimated 61% or $487,000 of total stabilization cost needs in the watershed. Results by HUC12 identified 102701040104 and 102701040107 as the most active hydrologic unit codes for streambank degredation. HUC12 (104) accounts for 2,572 ft of unstable streambank and 2,561 tons of sediment per year, while HUC12 (107) accounted for 6,555 ft of unstable streambank and 4,499 tons of sediment per year (Table 2 & Figure 12). These HUC12s accounted for roughly 81% of unstable streambank, 86% of sedimentation and 81% of total stabilization costs. Based on the average stabilization costs of $71.50 per linear foot, conducting streambank stabilization practices for the entire watershed would cost approximately $802,000 (Table 1).

Table 1: Upper Wakarusa Streambank Erosion Assessment Table by Stream Reach

Stream Reach	SB Length (ft)	SB Site Sed. (T/Yr)	Stabilization Cost Estimate	Erosion Sites (No.)	Yield Loss/ Bank Length	Poor Riparian Condition/Stream Bank Length (ft)	Est. Sed Reduction (T/Yr)	% Streambank Length w/ Poor Riparian Cond.
D1	1,148	916	$82,114	2	0.8	576	778	50.16%
R1	4,209	3,305	$300,983	6	0.8	0.00	2,810	0.00%
R2	1,950	1,098	$139,479	6	0.6	1,409	933	72.25%
W1	2,607	2,478	$186,456	7	1.0	1,833	2,106	70.32%
W2	515	205	$36,848	3	0.4	515	174	100.00%
W3	785	248	$56,140	4	0.3	785	211	100.00%
Total	**11,217**	**8,252**	**$802,022**	**28**	**3.8**	**5,120**	**-7,014**	**45.64%**
Est Stabilization Cost/Linear Ft.			$71.50	**Stabilization/Restoration Efficiency**			0.85	

Figure 11: Upper Wakarusa Watershed Streambank Erosion Assessment Graph by Stream Reach

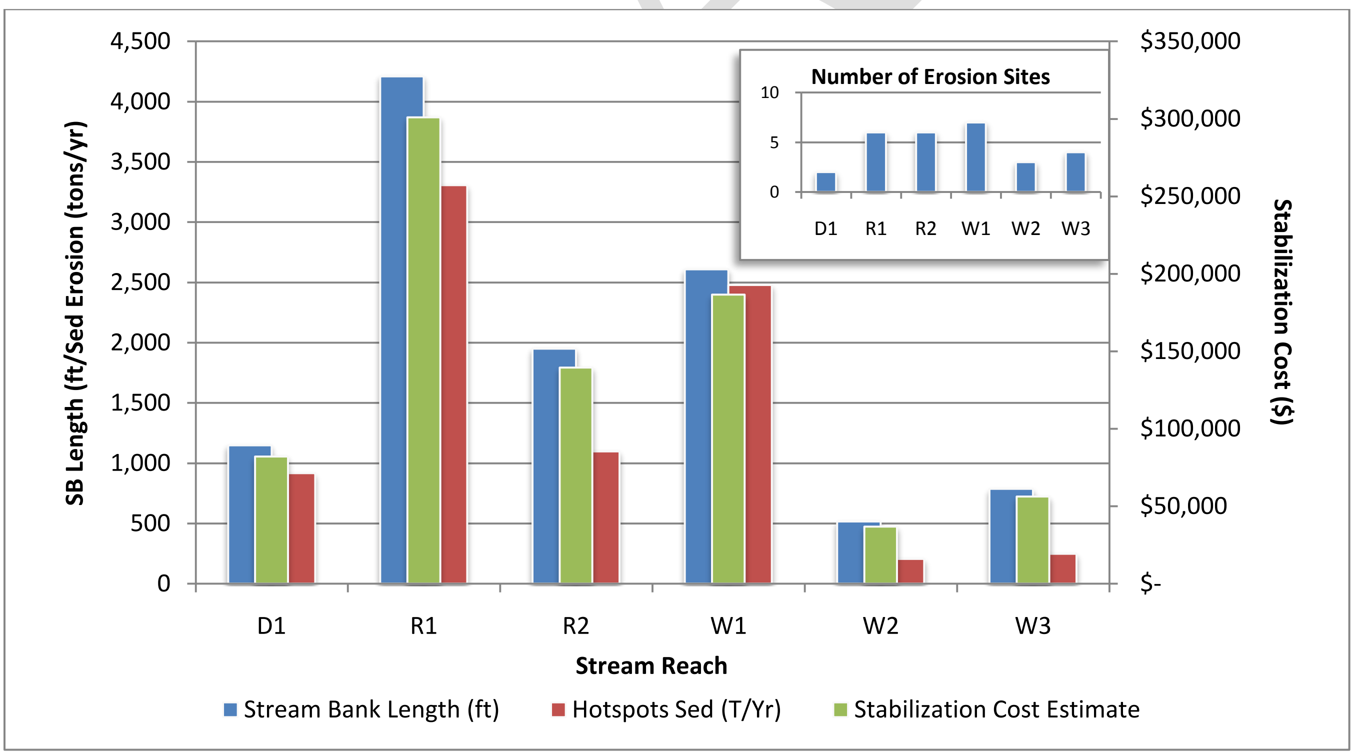
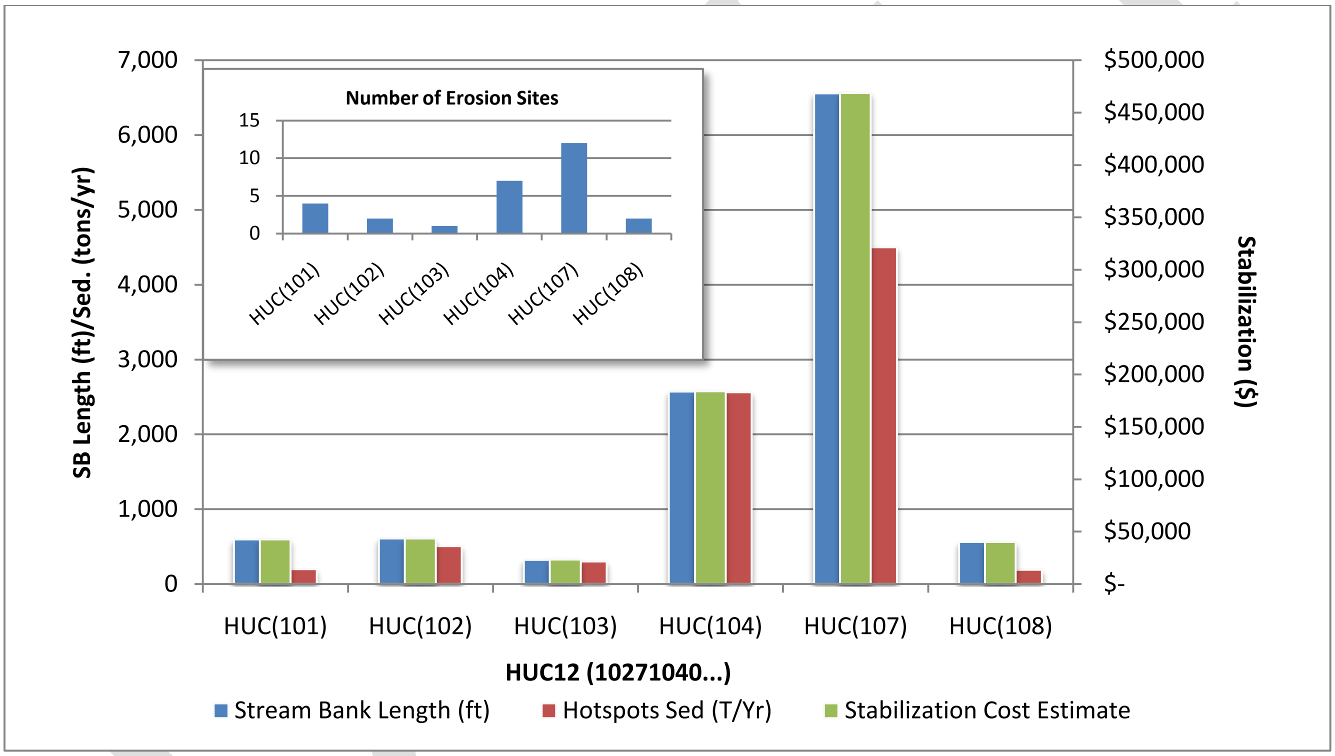


Table 2: Upper Wakarusa Streambank Erosion Assessment Table by HUC12

Reach HUC12 (102701040......)	SB Length (ft)	SB Site Sed. (T/Yr)	Stabilization Cost Estimate	Erosion Sites (No.)	Yield Loss/ Bank Length	Poor Riparian Condition/Stream Bank Length (ft)	Est. Sed Reduction (T/Yr)	% Streambank Length w/ Poor Riparian Cond.
HUC(101)	596	196	$42,651	4	0.3	596	167	100.00%
HUC(102)	608	5,03	$43,485	2	0.8	608	427	100.00%
HUC(103)	323	300	$23,128	1	0.9	323	255	100.00%
HUC(104)	2,572	2,561	$183,920	7	1.0	1,818	2,177	70.71%
HUC(107)	6,555	4,498	$468,701	12	0.7	1,330	3,824	20.30%
HUC(108)	561	1,90	$40,135	2	0.3	227	162	40.58%
Total	**11,217**	**8,252**	**$802,022**	**28**	**4.1**	**4,905**	**-7,014**	**43.73%**
Est Stabilization Cost/Linear Ft.			$71.50	**Stablization/Restoration Efficiency**			0.85	

Figure 12: Upper Wakarusa Watershed Streambank Erosion Assessment Graph by HUC12



Described in the data collection and methodology section above, streambank gully erosion sites were classified as high, medium and low priority. Figures 13 and 14 below identify the extent of high, medium and low priority streambank gullies by stream reach and HUC12s, with a total of 23 streambank gully erosion sites identified. Rock Creek and the Wakarusa River both had four gullies identified (Figure 13). HUC12s (102) and (107) had the greatest amount of total gullies, at two and four respectively (Figure 14). Rock Creek and HUC12 (107) were the only areas to have high priority gullies identified, two. It should be noted that these two high priority gullies could be intermittent streams, but with exposed highly erodible soils, it was denoted as a high priority streambank gully erosion site.

Figure 13: Upper Wakarusa Watershed Streambank Gully Erosion Assessment Graph by Stream Reach

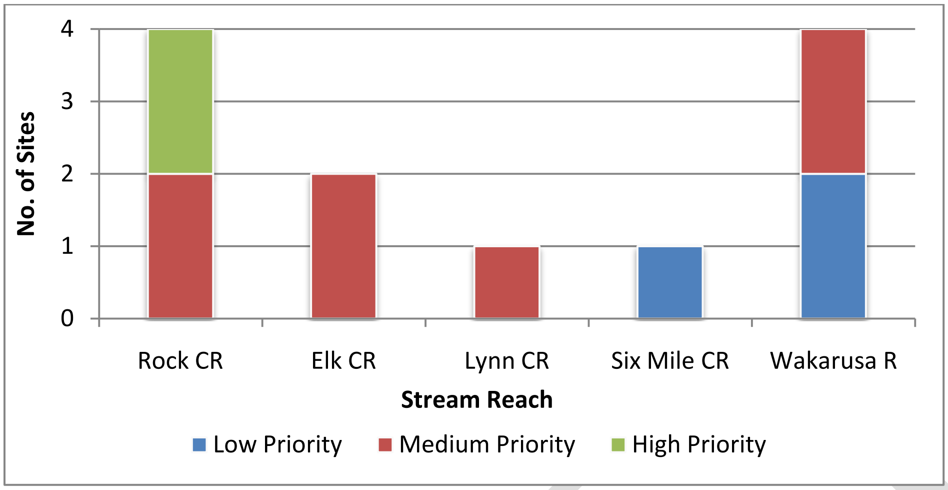
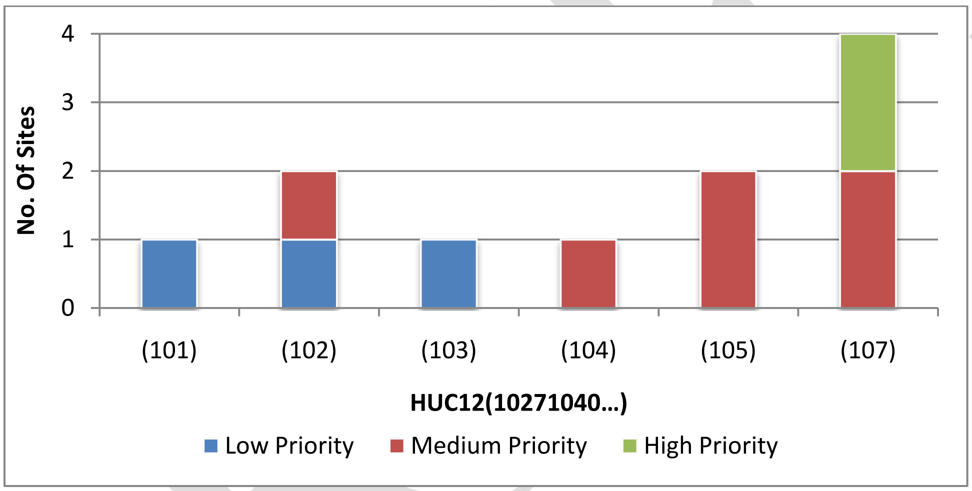


Figure 14: Upper Wakarusa Watershed Streambank Gully Erosion Assessment Graph by HUC12



Conclusion

The KWO is completed this assessment for the Upper Wakarusa 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 Upper Wakarusa WRAPS SLT. Information contained in the assessment can be used by the Upper Wakarusa WRAPS SLT to target streambank stabilization and riparian restoration efforts toward high priority stream reaches in the Upper Wakarusa River watershed.

References

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