LOWER ARKANSAS BASIN STREAMBANK EROSION ASSESSMENT

ArcGIS® Comparison Study: 1991 vs. 2010 Aerial Photography

DRAFT: October 2012

Photo taken by: Matt Unruh, KWO; Slate Creek, Sumner County

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Executive Summary

Federal reservoirs are a vital source of water supply in Kansas and provide water for approximately two-thirds of Kansas' citizens. The ability of a reservoir to store water over time starts to diminish as the capacity is reduced through sediment accumulation. 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 State of Kansas currently owns storage in thirteen federal reservoirs that are operated by the U.S. Army Corps of Engineers (USACE).

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

The Lower Arkansas Basin 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 Lower Arkansas basin for 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 Lower Arkansas basin, excluding the mainstem North Fork Ninnescah River, which was assessed by the Kansas Water Office (KWO) in 2011 study (KWO, 2011).

This assessment quantifies annual tons of sediment eroding from streambanks within the Lower Arkansas basin in south-central Kansas over a 19 year period between 1991 and 2010. A total of 145 actively eroding streambank sites were identified, covering 80,575 feet of unstable streambank and transporting a calculated 250,986 tons of sediment downstream per year. It should be noted that the identified streambank erosion locations are only a portion of all streambank erosion occurrences in the basin. Streambank erosion sites were analyzed by stream reach. Based on an average stabilization cost of $71.50 per linear foot, as reported in the TWI *Kansas River Basin Regional Sediment Management Section 204 Stream and River Channel Assessment*, conducting streambank stabilization practices on all 145 erosion sites would cost approximately $5.8 million.

Information contained in this assessment can be used by KWO, other agencies, and interested parties to target streambank stabilization and riparian restoration efforts toward high priority stream reaches in the Lower Arkansas basin. Similar assessments are ongoing in selected watersheds above and below 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

Streambank erosion is a natural process that contributes a large portion of annual sediment yield. Acceleration of this natural process can lead 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 (downward erosion), widening and re-stabilizing of the stream. A large number of 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 stabilizing the actual streambank (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.

Wetlands and riparian areas are vital components of proper watershed function that, when managed wisely in context of watershed systems, can moderate and reduce sediment input. Additional research in Kansas has found 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 reduce 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, 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.

Reservoirs are a vital source of water supply, provide recreational opportunities, support diverse aquatic habitat, and provide flood protection throughout Kansas. Excessive sediment can alter the aesthetic qualities of reservoirs and affect their water quality and useful life as well (Christensen, 2000). Sediment deposition in reservoirs can be attributed to many factors, including precipitation, topography, contributing-drainage area of the watershed, and differing soil types. Decreases in reservoir storage capacity from sediment deposition can affect reservoir allocations used for flood control, drinking-water supplies, recreation and wildlife habitat. Land use in the watershed has considerable effect on sediment loading in a reservoir. Intense agricultural use in the watershed, with limited or ineffective erosion prevention methods, can contribute large loads of sediment along with contaminants (such as phosphorus) to downstream reservoirs (Mau, 2001). Farming techniques that may help reduce soil erosion include "no-till" farming in which crops are cut and residue is not tilled into the land; planting cover crops such as clover and rye between crop rows; plowing in circular bands along the contours of the land to slow the flow of water and any topsoil it might carry down a slope and constructing step-like ridges, called terraces, by leveling sections of a hillside which reduces runoff by creating flatter terrain and shorter sections of slope.

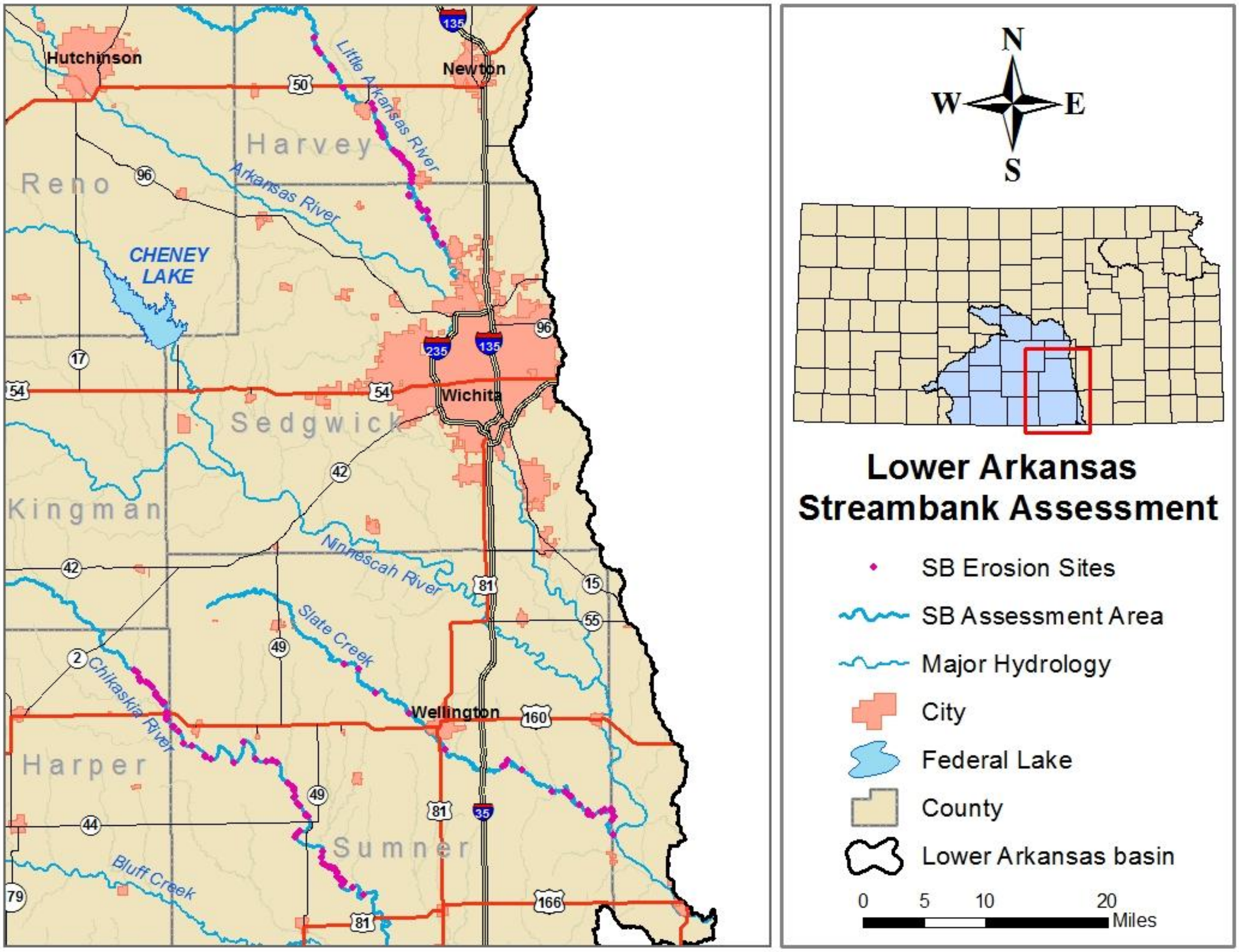
In Kansas, monitoring the extent of sediment loss due to streambank erosion is difficult, and current up-to-date inventories are needed. This assessment identifies areas with erosion concerns and estimates erosion losses to provide a better understanding of this watershed for restoration purposes and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

Study Area

The Lower Arkansas River Basin in Kansas is part of the Arkansas River basin. The Arkansas River originates in central Colorado, where it flows southeast into and across southern Kansas. The Arkansas River crosses the Kansas-Oklahoma border south of Arkansas City (Cowley County). The Arkansas basin in Kansas is divided into two basins, Upper and Lower, for planning purposes. The Lower Arkansas basin begins where Rattlesnake Creek confluences with the Arkansas River in southwestern Rice County. The only major federal reservoir in the basin is Cheney Reservoir. The Lower Arkansas basin covers 11,500 square miles of south central Kansas and includes all or part of 20 counties.

Photo taken by Matt Unruh, KWO; Slate Creek, Sumner County

Figure 1: Lower Arkansas Basin Assessment Area



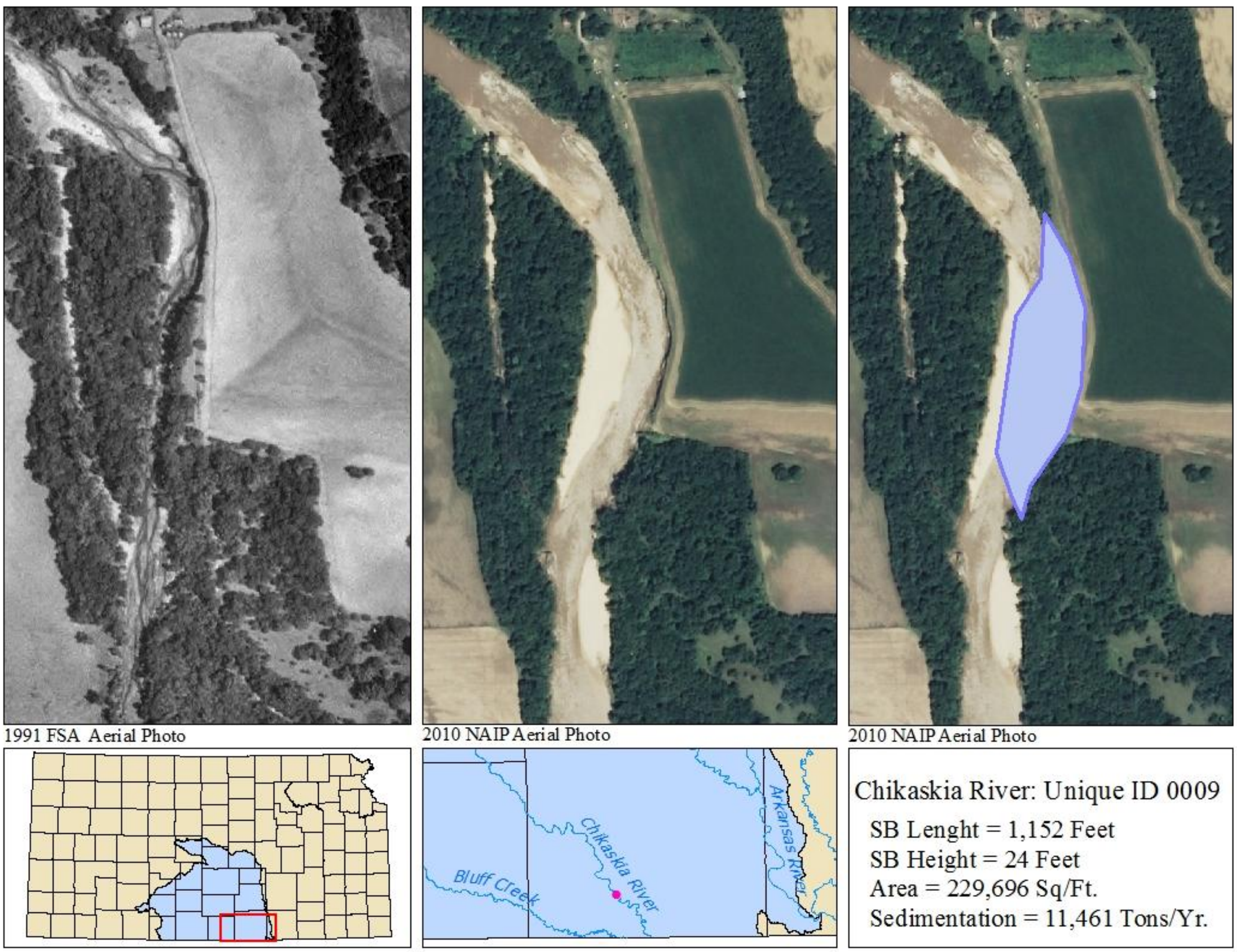
Data Collection Methodology

The Lower Arkansas basin streambank erosion assessment, excluding the mainstem North Fork Ninnescah River, which was assessed by the KWO in a 2011 study, was performed using ArcGIS® software (KWO 2011). The purpose of the assessment was to identify locations of streambank instability to prioritize restoration needs and slow sedimentation into reservoirs through implementation of streambank stabilization projects. ArcMap®, an ArcGIS® geospatial processing program, was utilized to assess color aerial photography from 2010, provided by National Agriculture Imagery Program (NAIP), and compare it with 1991 black and white aerial photography, provided by the Farm Service Agency (FSA).

The streambank erosion assessment was performed by overlaying 2010 NAIP county aerial imagery onto 1991 FSA county aerial imagery (Figure 2). Using ArcMap® tools, only those areas having "aggressive movement" of the streambank between 1991 FSA and 2010 NAIP aerial photos were identified, at a 1:4,000 scale, as a site of streambank erosion. "Aggressive movement" represents an area of roughly 2,500 sq. feet or more of streambank movement based on changes from 1991 FSA and 2010 NAIP aerial photos. Note that any erosion that covers an area smaller than roughly 2,500 sq. feet, incurs a high margin of error, making calculations unreliable. This error can be attributed to distortions between years when aerial photos are taken and digitally georeferencing, and due to shading attributed to leafing of trees in aerial photos when photos are taken in spring, summer and early fall months. Leafing can affect the ability to find the exact location of streambanks.

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 2010 streambank and closing the sketch by following the 1991 streambank at a 1:4,000 scale. Data provided, based on the geographic polygon sites include: basin location, unique ID, stream name, and type of riparian vegetation.

Figure 2: 1991 FSA & 2010 NAIP Streambank Erosion Site, Unique ID 0009, Chikaskia River



The streambank erosion assessment data also include approximations of tons of soil loss from the erosion site. This portion of the assessment was 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. 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 (sq. feet) and perimeter length of that erosion area (feet) to the unstable stream bank length (feet). The multiple regression formula of that fit (R-square = 0.999) is:

Estimated SB Length (Feet) = ([Area_SqFt]*-0.00067) + ([Perimtr_ft]*0.5089609)

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 19 year period between the 1991 and 2010 aerial photos and soil bulk density. This calculated volume is then divided by the 19 year period, to get the average rate of soil loss in mass/year:

Average Soil Loss Rate (Tons/Yr.) =
[Area_SqFt]*[BankHgtFt]*SoilDensity(lbs/ft^3)/2000(lbs/ton)/([NAIP_ComparisonPhotoYear]-[BaseAerialPhotoYear])

Soil Bulk Density was calculated by first determining the moist bulk density of the predominant soil in the basin where erosion sites were identified, using the USDA Web Soil Survey website. The predominant soil type in the Lower Arkansas basin is Elandco Canadian Association. Soils in this series are nearly level sloping, deep and well drained with loamy subsoil formed in alluvial sediments; located on the flood plains and low terraces with an average moist bulk density of 1.45 g/cc. This moist bulk density estimate was converted into pounds per cubic foot (ft^3) and reduced by 15% to get a dry bulk density estimate at 77 lbs/ft^3. This number was used for the typical bulk density of the predominant soil within the Lower Arkansas basin, and used in the Average Soil Loss Rate equation.

Streambank heights were measured in September and October 2012 with assistance from Sumner County Planning, Zoning, and Environmental Health, Harper and Cowley County Conservation Districts, and K-State Research and Extension. Streambank height measurements were obtained from a total of 18 sites on three separate streams throughout the Lower Arkansas basin (Figures 3, 4, & 5). Two height measurements were acquired at each field measurement site using a Leupold RX-1000 TBR laser rangefinder. The first measurement was completed using the laser rangefinder to estimate the number of yards and angle from a horizontal position at the top of one bank to the *nearest* streambank edge, where the water reaches the streambank. A second measurement was completed to estimate the number of yards and angle from a horizontal position at the top of a bank to the *farthest* (or opposite) streambank edge. The total height from the rangefinder elevation was calculated from each measurement and then the elevation from the rangefinder to the land surface was subtracted from the rangefinder elevation to obtain the streambank height. The remaining 127 streambank erosion sites that were not directly measured were interpolated from the 18 field verified streambank height measurements and were added to the data. These streambank height measurements were then used in the Average Soil Loss Rate equation.

Figure 3: Slate Creek Streambank Heights Measurements (in feet) & Locations

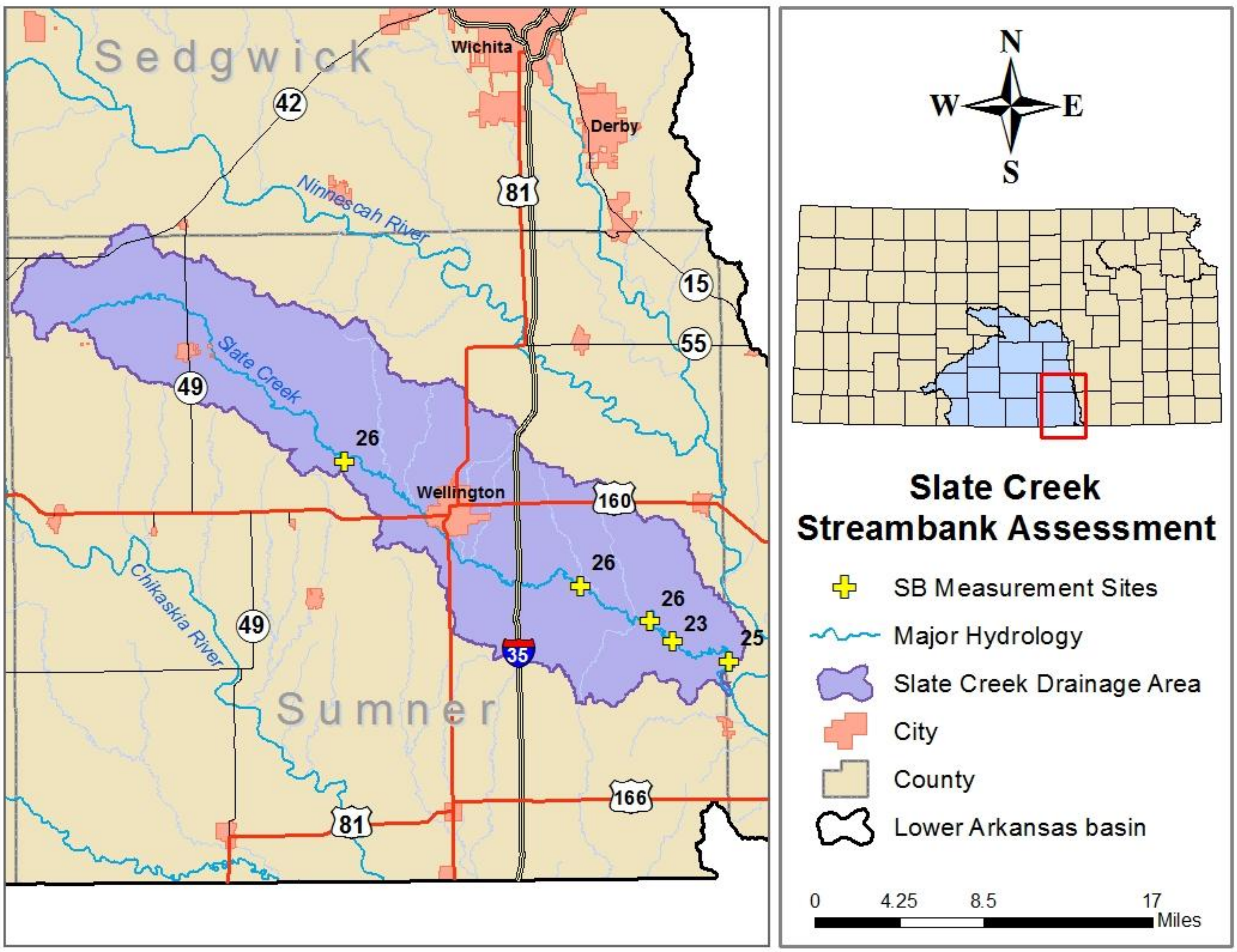


Figure 4: Chikaskia River Streambank Heights Measurements (in feet) & Locations

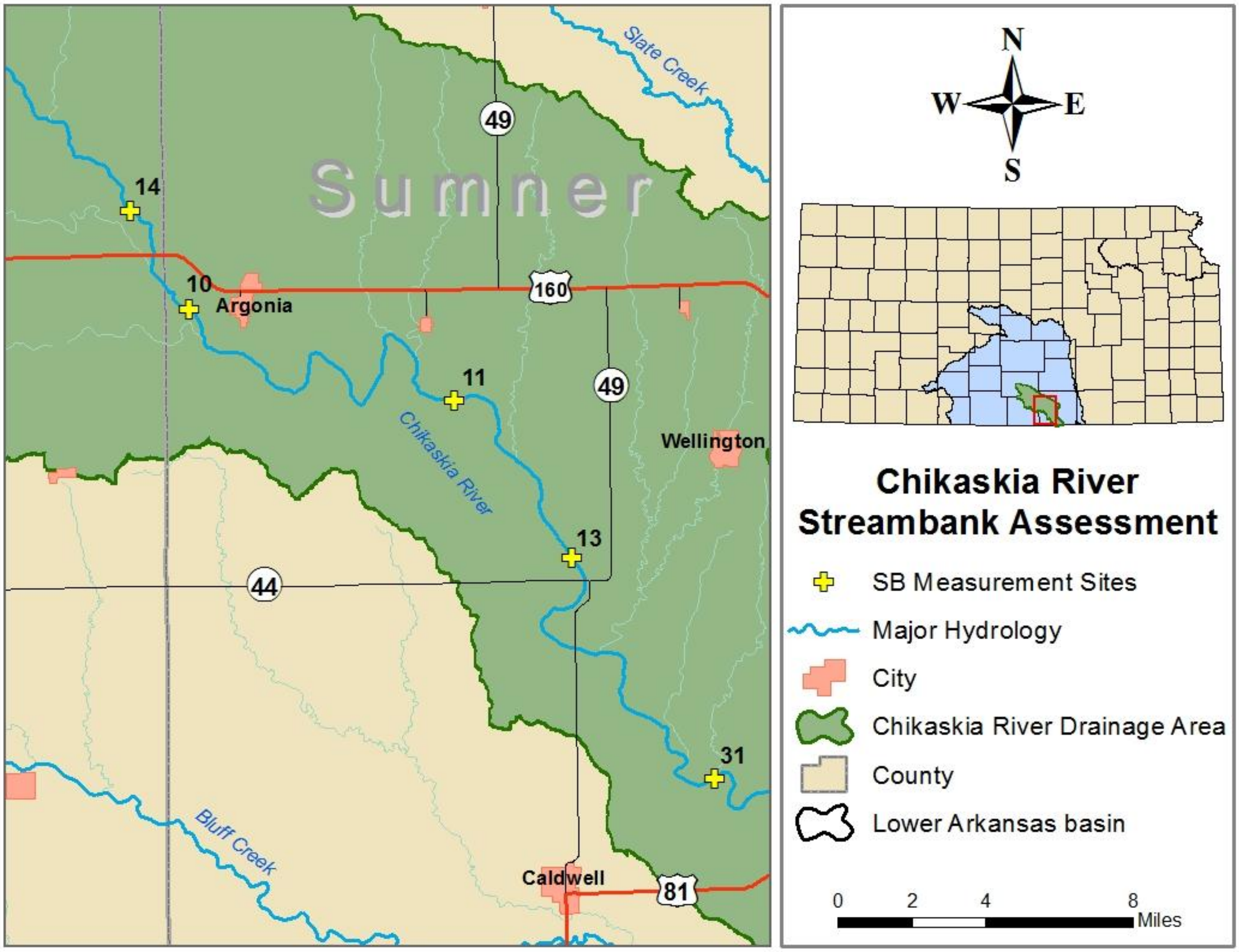
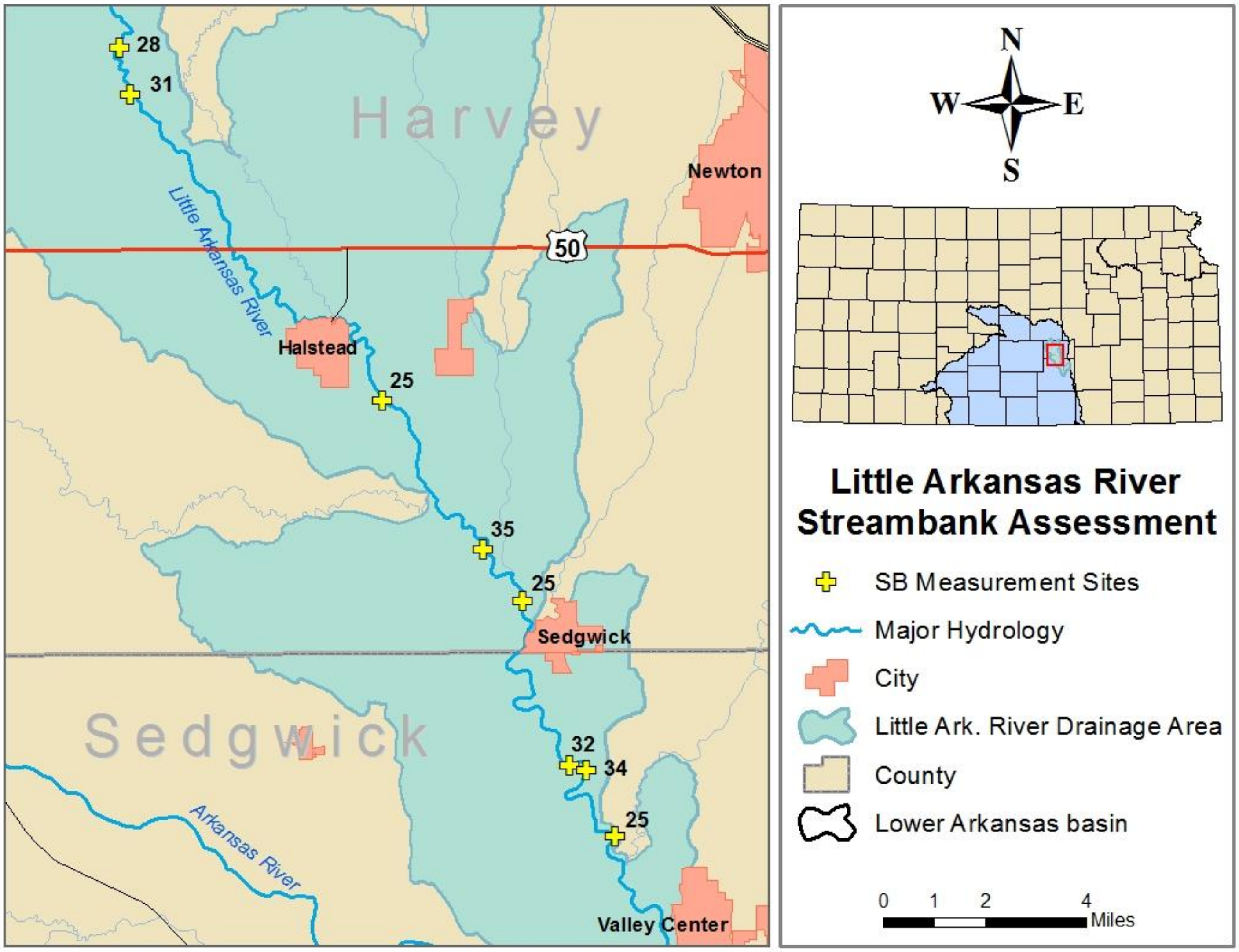


Figure 5: Little Arkansas River Streambank Heights Measurements (in feet) & Locations



Analysis

To adequately analyze streambank erosion sites, stream reach sections were delineated to better accommodate streambank restoration project focus. Streambank erosion prioritization by stream reaches include: Slate Creek, Chikaskia River and the Little Arkansas River. 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; grass/crop buffer includes riparian areas consisting of grasses and rangelands); estimated sediment reduction (through the implementation of streambank stabilization Best Management Practices (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 7).

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

This Lower Arkansas River Basin assessment quantifies annual tons of sediment eroding over a 19 year period between 1991 and 2010, excluding the mainstem North Fork Ninnescah River, which was assessed by KWO in a 2011 study (KWO 2011). A total of 145 streambank erosion sites (Figure 7, 8, & 9) were identified, covering 80,575 feet of unstable streambank and transporting 250,986 tons of sediment downstream per year (Table 1). Forty-four percent of the identified streambank erosion sites were identified as having a poor riparian condition (riparian area identified as having cropland or grass/crop streamside vegetation). A substantial quantity of the identified eroded sediment in the basin is transported annually from the streambanks of the Chikaskia River, accounting for approximately 175,633 tons of sediment annually or 70% of sediment eroding from all identified streambank erosion sites (Table 2). These identified reaches account for an estimated 70% or $3,573,570 of total stabilization cost needs in the basin (Figure 10). Based on the average stabilization costs of $71.50 per linear foot (*this is an estimate and may be higher or lower based on location*), conducting streambank stabilization practices for all 145 sites would cost approximately $5,761,042.

It is probable that high flow runoff events from range and agricultural lands via ephemeral gullies and bridge crossings that are continually undercut by high flow events could also be contributing to the sedimentation load. These occurrences were not a part of this assessment but should be assessed in the future.

Figure 7: Slate Creek Streambank Erosion Sites

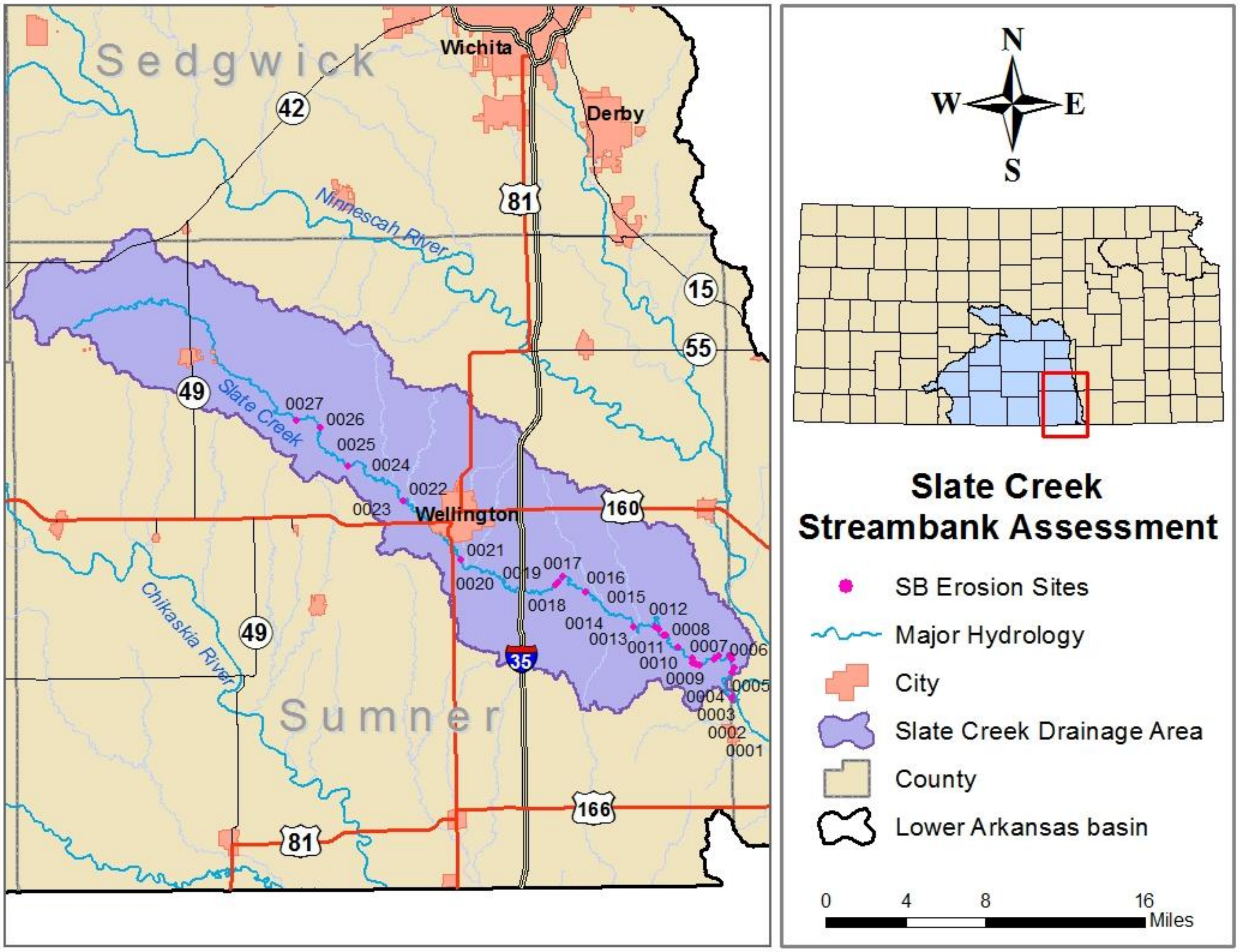


Figure 8: Chikaskia River Streambank Erosion Sites

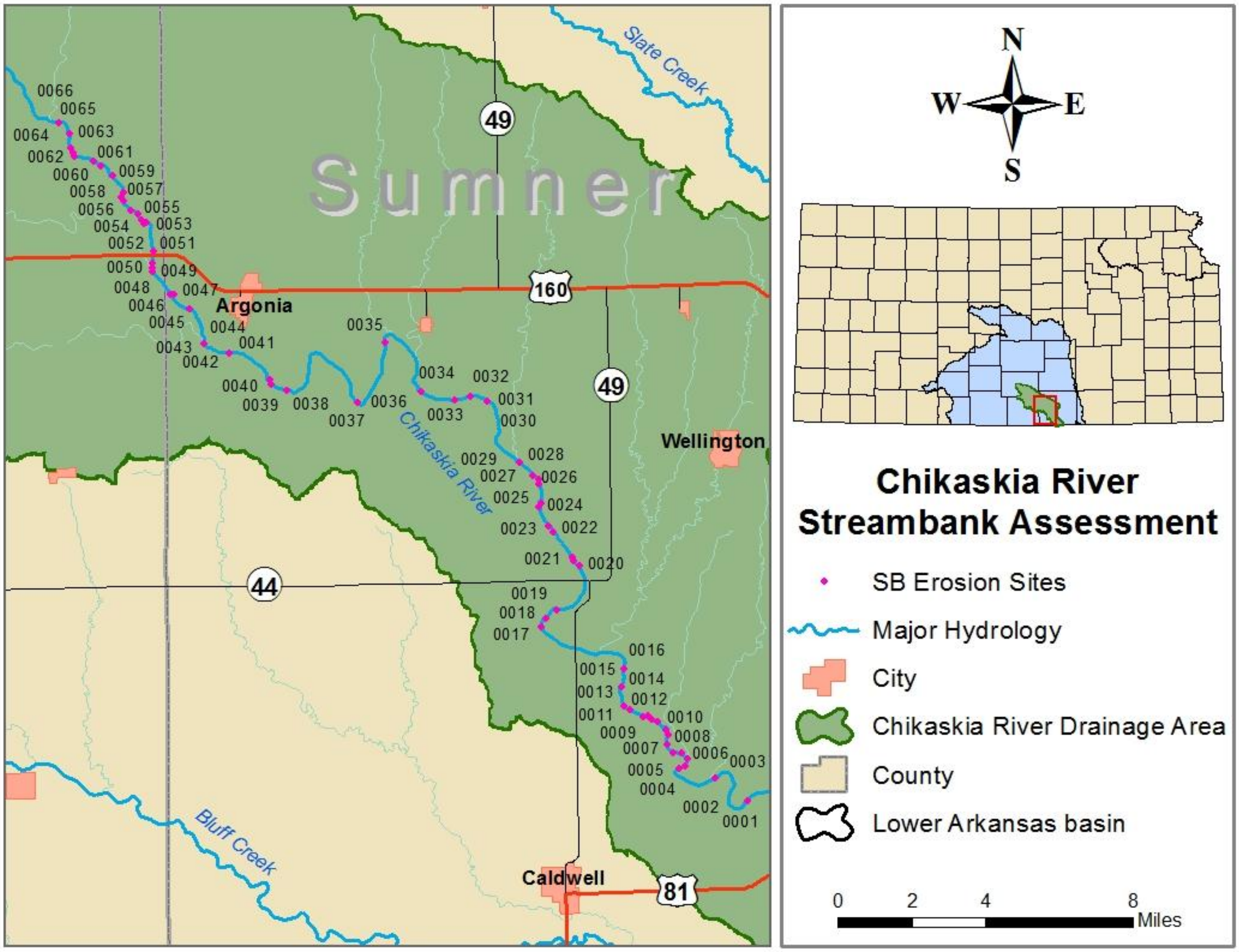


Figure 9: Little Arkansas River Streambank Erosion Sites

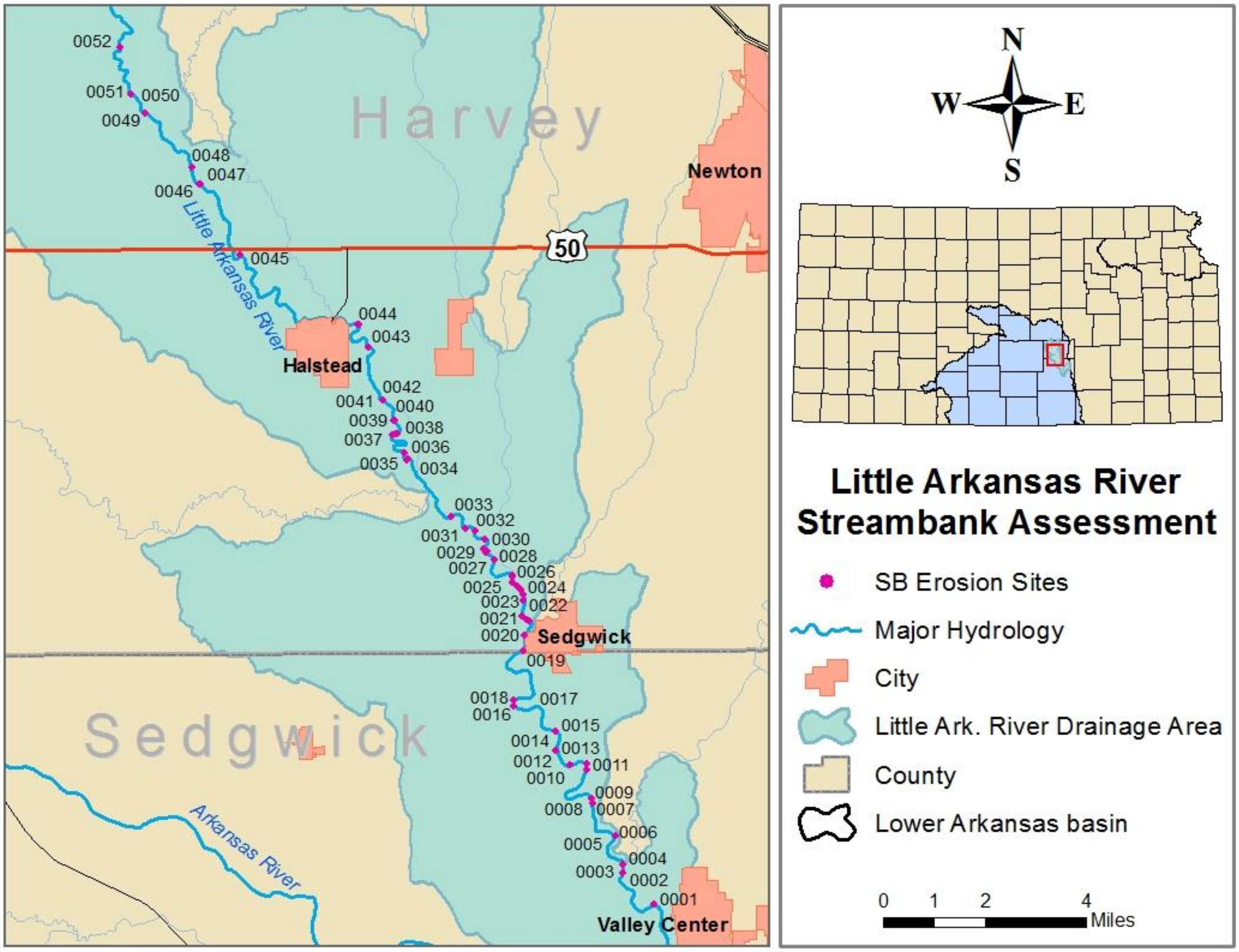


Table 1: Lower Arkansas Basin Streambank Erosion Assessment Table by Stream Reach

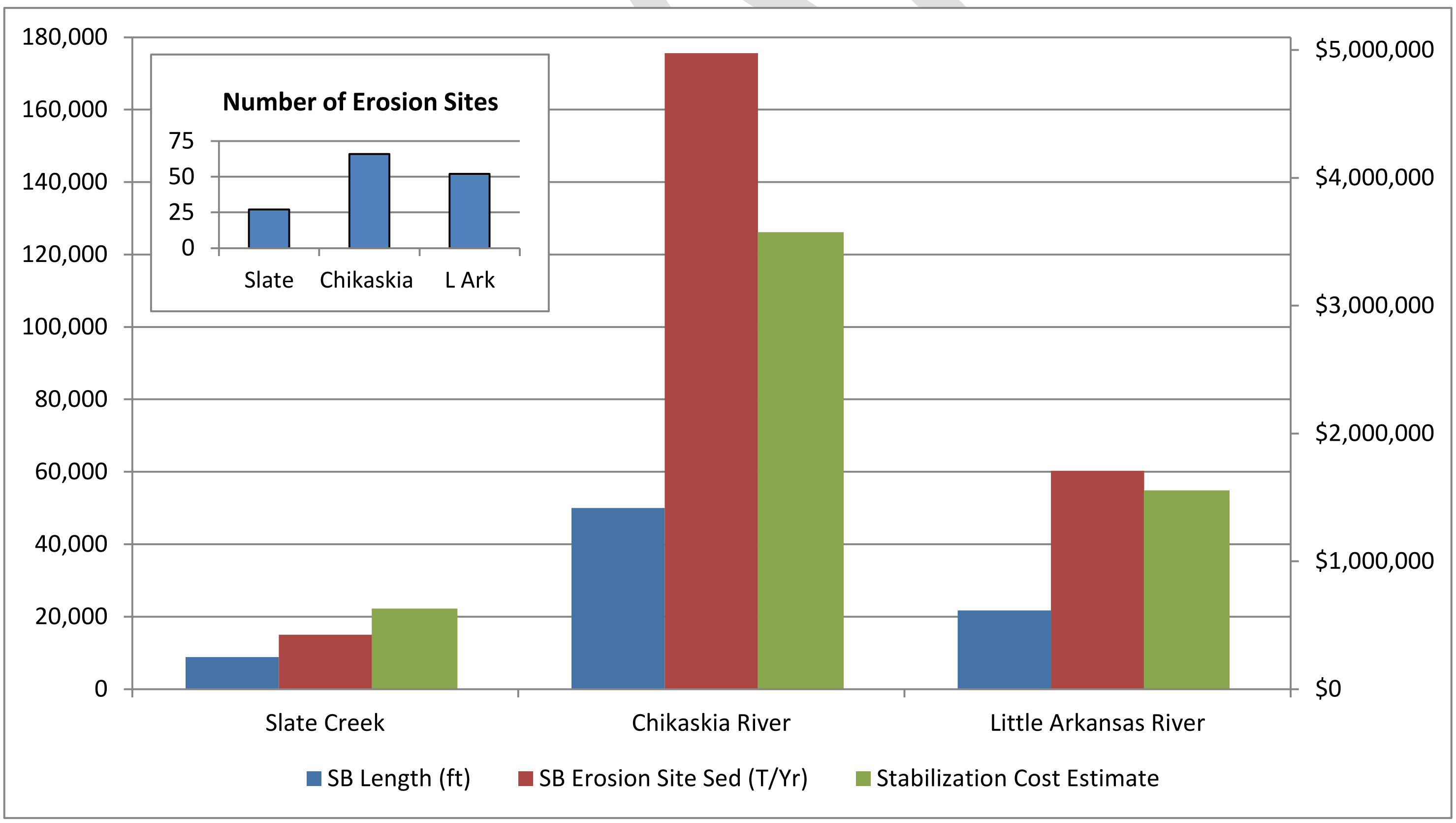
Stream Reach	SB Length (ft)	SB Erosion Site Sed (T/Yr)	Stabilization Cost Estimate	SB Erosion Sites (no.)	Yield Loss/ Bank Length (T/Yr/ft)	Poor Riparian Cond/SB Length (ft)	Est. Sed Reduction (T/Yr)	% SB Length w/ Poor Riparian Cond.
Slate Cr	8,831	15,055	$631,417	27	1.7	7,779	12,797	88.09%
Chikaskia R	49,980	175,633	$3,573,570	66	3.5	18,229	149,288	36.47%
Little Arkansas R	21,763	60,298	$1,556,055	52	2.8	9,363	51,253	43.02%
Total	**80,574**	**250,986**	**$5,761,042**	**145**	**8.0**	**35,371**	**213,338**	**43.90%**
Est Stabilization Cost/Linear Ft.			$71.50	**Stabilization/Restoration Efficiency**			0.85	

Table 2: Lower Arkansas Basin Streambank Sediment Load by Erosion Site (Tons/Yr.)

Unique ID	Slate Cr	Chikaskia R	Little Arkansas R
0001	858.2	1,843.0	430.8
0002	315.6	3,362.9	639.7
0003	321.8	2,798.7	1,187.8
0004	888.2	2,525.1	832.4
0005	677.4	2,258.8	254.5
0006	459.3	1,391.7	487.7
0007	472.8	33,303.3	3,071.2
0008	332.7	5,772.7	1,952.2
0009	413.9	11,460.6	2,295.9
0010	879.3	2,280.9	1,159.2
0011	443.6	3,477.0	549.5
0012	1,059.9	1,356.7	1,113.9
0013	322.3	1,612.4	1,181.9
0014	197.9	5,851.0	1,013.3
0015	1,335.6	1,061.4	1,344.7
0016	527.2	987.4	952.9
0017	1,132.0	2,345.4	1,130.9
0018	677.4	895.9	682.2
0019	364.0	1,251.5	952.6
0020	436.6	854.0	557.6
0021	452.3	818.0	1,510.6
0022	655.9	1,595.2	919.2
0023	605.1	1,523.5	3,098.1
0024	221.6	1,503.7	747.4
0025	274.7	1,427.0	578.2
0026	332.0	1,774.2	854.9
0027	398.2	1,524.9	1,195.0
0028		10,756.9	399.5
0029		1,261.1	1,927.8
0030		1,688.8	730.3
0031		1,090.9	418.9
0032		1,273.6	675.8
0033		963.4	1,104.4
0034		3,520.8	2,197.7
0035		1,615.4	1,767.4
0036		3,695.7	1,251.6
0037		1,102.4	774.8
0038		5,247.8	2,040.8
0039		1,105.1	1,445.2
0040		1,270.6	1,760.5
0041		837.7	2,185.3
0042		1,429.3	994.1
0043		1,000.6	2,666.5
0044		538.1	1,996.7
0045		3,554.9	1,482.6
0046		550.3	829.0

0047		1,213.2	652.0
0048		412.9	604.0
0049		1,080.0	510.6
0050		504.8	491.1
0051		919.4	372.2
0052		1,797.5	324.9
0053		1,844.7	
0054		897.8	
0055		4,635.6	
0056		248.3	
0057		652.9	
0058		3,931.2	
0059		349.3	
0060		758.5	
0061		2,570.9	
0062		8,636.1	
0063		720.1	
0064		582.0	
0065		892.7	
0066		3,625.2	

Figure 10: Lower Arkansas Basin Streambank Erosion Assessment Graph by Stream Reach



Conclusion

The KWO 2012 assessment quantifies annual tons of sediment eroding over a 19 year period between 1991 and 2010 within the Lower Arkansas basin. A total of 145 streambank erosion sites were identified, covering 80,575 feet of unstable streambank and transporting 250,986 tons of sediment downstream per year. A substantial quantity of the identified eroded sediment in the basin is transported annually from the streambanks of the Chikaskia River, accounting for approximately 175,633 tons of sediment annually or 70% of sediment eroding from all identified streambank erosion sites. These identified reaches account for an estimated $5,761,042 of total stabilization cost needs in the basin.

The KWO completed this assessment to partially implement the *Reservoir Sustainability Initiative*, established by the Kansas Water Authority, which seeks to integrate all aspects of reservoir input, operations and outputs into an operational plan for each reservoir to ensure water supply storage availability into the future. Information contained in the assessment can be used by the KWO, other agencies, and interested parties to target streambank stabilization and riparian restoration efforts toward high priority stream reaches within the Lower Arkansas basin.

References

1. Arnold, J. G., P. M. Allen, G. Berhardt. 1993. *A Comprehensive Surface-Groundwater Flow Model*. J. Hydrol. 142:47-69.

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 Office. (2011). *Mainstem North Fork Ninnescah River Streambank Erosion Assessment*. Study: http://www.kwo.org/projects_programs/Steambank_Assessments/Rpt_LARK_CH_SBErosionAssessment_041211_ap.pdf

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

10. 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.

11. Natural Resources Conservation Service. *Soil Survey of Sedgwick County, KS*. April, 1979.

12. Neitsch, S. L., J. G. Arnold, J. R. Kiniry, J. R. Williams. 2001. *Soil and Water Assessment Tool: User's Manual, Version 2001*. Grassland, Soil and Water Research Laboratory, ARS, Temple, TX.

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

14. 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.

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