EL DORADO LAKE WATERSHED STREAMBANK EROSION ASSESSMENT

ArcGIS® Comparison Study: 1991 vs. 2008 Aerial Photography

DRAFT: June 2011

Photo By: El Dorado WRAPS SLT; Satchel Creek, Butler Co, KS

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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 El Dorado Lake Watershed 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 El Dorado Lake 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 El Dorado Lake.

The Kansas Water Office (KWO) 2011 assessment quantifies annual tons of sediment eroding from the El Dorado Lake Watershed over a 17 year period between 1991 and 2008 within the upper Walnut basin in southeastern Kansas. A total of 15 streambank erosion sites were identified, covering 3,772 feet of unstable streambank and transporting 740 tons of sediment downstream per year; accounting for roughly 0.47 acre-feet per year of sediment accumulation in El Dorado Lake each year. 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. Based on the average stabilization costs of $71.50 per linear foot, conducting streambank stabilization practices for the entire watershed would cost approximately $269,670.

The KWO completed this assessment for the El Dorado Lake Watershed Restoration and Protection Strategy (WRAPS) Stakeholder Leadership Team (SLT). Information contained in this assessment can be used by the El Dorado Lake Watershed WRAPS SLT to target streambank stabilization and riparian restoration efforts toward high priority stream reaches in the El Dorado Lake Watershed. 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

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.

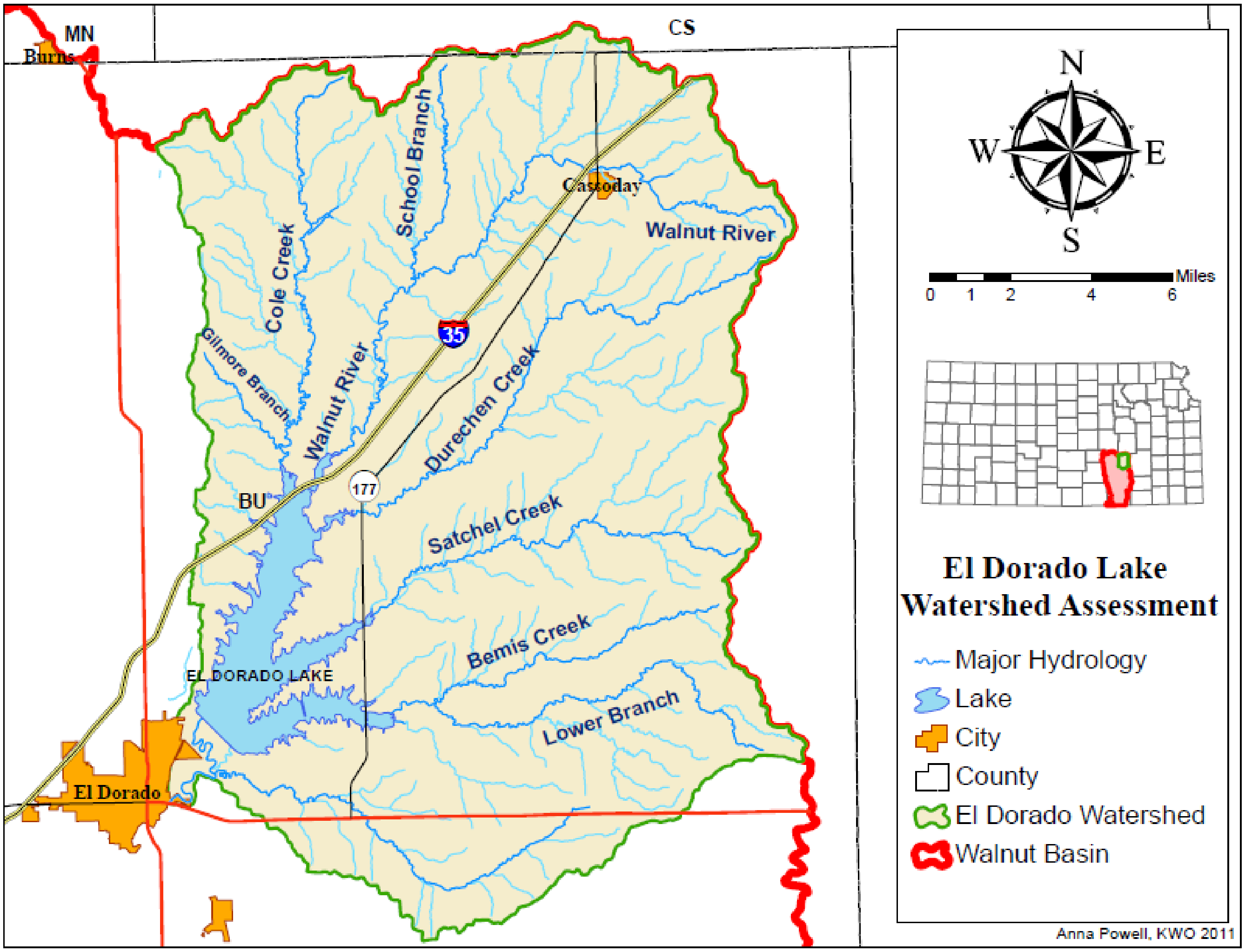
Reservoirs are a vital source of water supply, provide recreational opportunities, support diverse aquatic habitat, and provide flood protection throughout Kansas. Excessive sediment can alter the aesthetic qualities of reservoirs and affect their water quality and useful life (Christensen, 2000). Sediment 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 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 non-cash 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 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 mitigation purposes and for application of understanding to watersheds across Kansas.

Study Area

El Dorado Lake is an 8,495 acre impoundment that drains approximately 234 mi^2 in portions of Butler and Chase counties in the upper northeast portion of the Walnut River Basin. El Dorado Lake was constructed on river mile 114.7 on the Walnut River, a tributary of the Arkansas River, approximately two miles northeast of El Dorado, and completed in 1981 by the U.S. Army Corps of Engineers (USACE) (Figure 1). El Dorado Lake was designed with a 100 year design life for sediment storage at 134 acre-feet/yr, with an original storage capacity in the multipurpose pool at 163,942 acre-feet. The most recent bathymetric survey performed at the lake was in 2004, with a storage capacity ay 158,630 acre-feet, a surface area of 7,911 acres and a sedimentation rate of 219 acre-feet/year; a 4.04% storage capacity lost to date. The reservoir is both federally and state authorized for flood control, fish and wildlife, water quality, water supply and recreation.

Figure 1: El Dorado Lake Watershed Assessment Area



Tributaries of El Dorado Lake include the East Branch of the Walnut River, Bemis Creek, Satchel Creek, Cole Creek, School Branch and Durechen Creek. Based on the 2006 Soil and Water Assessment Tool (SWAT) model performed by USACE, land use in the El Dorado Lake Watershed consists of grasslands devoted to rangeland and cattle grazing that account for 72%, croplands account for 12%, managed pasture/hay land account for 11%, with the remainder distributed between other minor land uses (Figure 2). SWAT (Arnold et al., 1993) is a basin-scale model "...developed to predict the impact of land management practices on water, sediment, and agricultural chemical yields in large complex watersheds with varying soils, land use and management conditions over long periods of time" (Neitsch et al., 2001). Water supply storage in the lake is contracted through USACE for the City of El Dorado and accounts for 142,900 acre-feet.

The Verdigris-Brewer-Norge Association is the predominant soil series along the main tributaries in the El Dorado Lake Watershed. These soils occupy 18 percent of Butler County and are classified as nearly level slopping, deep soils that have a silt loam or silty clay loam surface layer and a silt clay subsoil, on flood plains and terraces. Verdigris, Brewer and Norge soils account for roughly 50 percent, 10 percent and 10 percent of the soil association, respectively. Except for areas of Verdigris soils that are frequently flooded, most of the acreage of this association is cultivated (NRCS, 2010).

Figure 2: 2006 El Dorado Lake Watershed SWAT Model Results

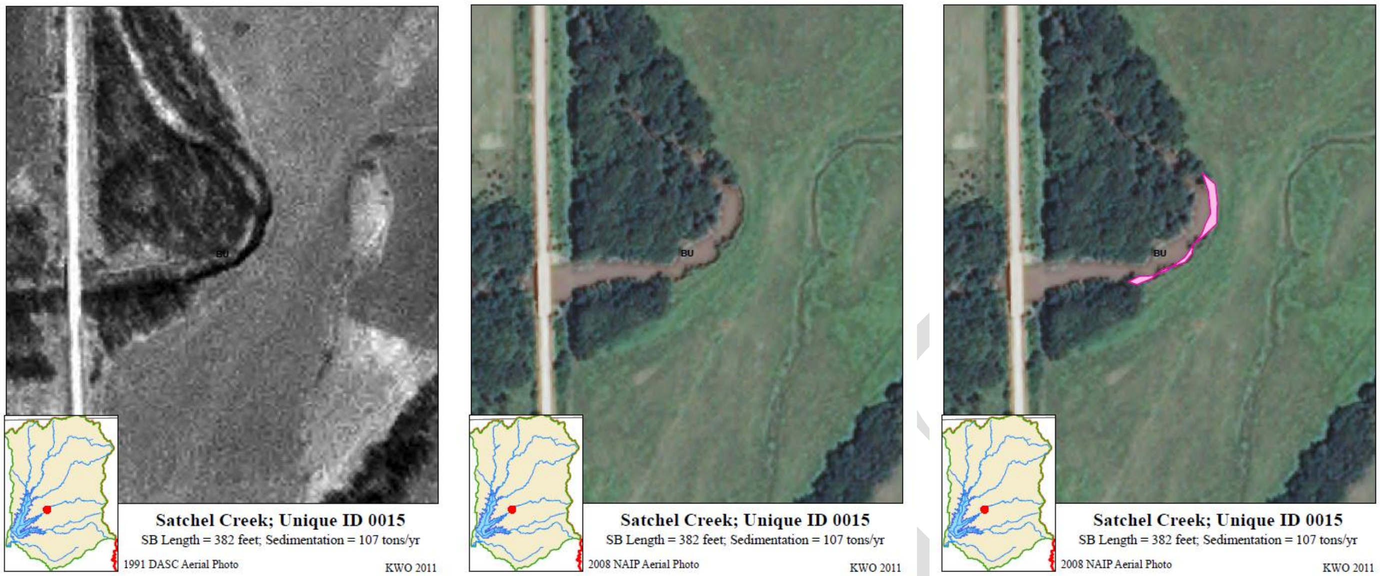
El Dorado Lake Watershed Land-Cover		
Land Use/Cover	**Acres**	**Percent Cover**
Open Water	9,372.6	5.98
Low Density Residential	65.2	0.04
High Density Residential	26.0	0.02
Commercial/Industrial Transportation	572.7	0.37
Bare Rock/Sand/Clay	19.4	0.01
Quarries/Strip Mines/Gravel Pits	20.2	0.01
Deciduous Forest	371.0	0.58
Evergreen Forest	21.1	0.01
Mixed Forest	64.1	0.04
Shrubland	4,169.8	2.66
Grasslands/Herbaceous	113,970.7	72.69
Pasture/Hay	16,556.9	10.55
Row Crops	8,306.5	5.30
Small Grains	1,236.3	0.79
Urban/Recreational Grasses	197.5	0.13
Woody Emergents	30.3	0.02
Emergent Herbaceous Wetlands	1,263.8	0.81
Total	156,780.1	100.10

Data Collection Methodology

The El Dorado Lake 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 El Dorado Lake through implementation of streambank stabilization projects. ArcMap®, an ArcGIS® geospatial processing program, was utilized to assess color aerial photography from 2008, provided by National Agriculture Imagery Program (NAIP), and compare it with 1991 black and white aerial photography, provided by the State of Kansas GIS Data Access & Support Center (DASC).

The streambank erosion assessment was performed by overlaying 2008 NAIP county aerial imagery onto 1991 DASC county aerial imagery (Figure 3). Using ArcMap® tools, areas of "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 3: 1991 DASC & 2008 NAIP of a Streambank Erosion Site Unique ID 0015 on Satchel Creek



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:

Estimated SB Length (Feet) = ([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:

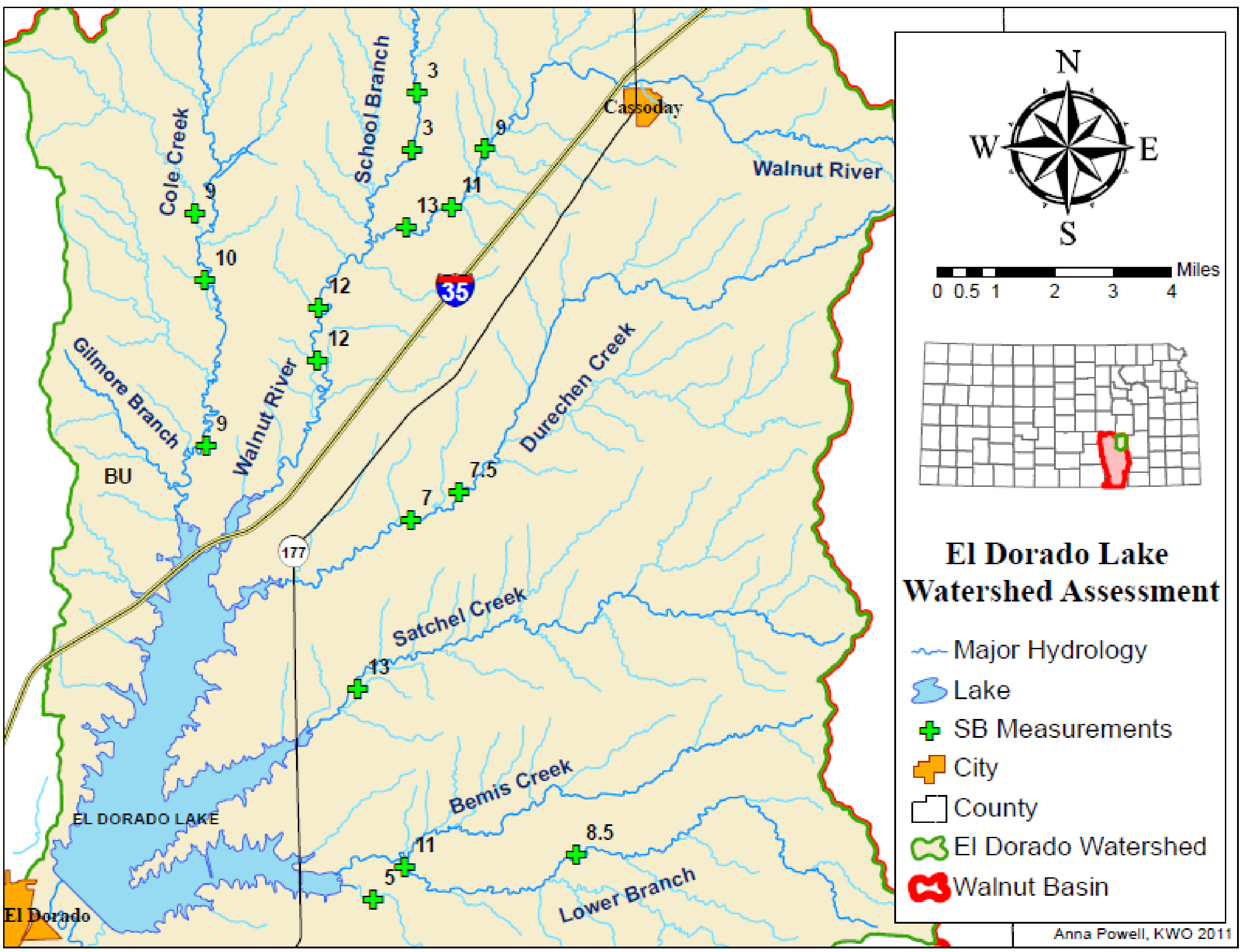
Average Soil Loss Rate (Tons/yr) =

[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 subwatershed where erosion sites were identified, using the USDA Web Soil Survey website. The predominant soil type along in the El Dorado Lake Watershed is Verdigris-Brower-Norge Association. These soil series are nearly level slopping, deep soils that have silt loam or silty clay loam surface layer and a silty clay subsoil; located on the flood plains and terraces with an average moist bulk density of 1.45 g/cc. This moist bulk density estimate was converted into pounds per cubic foot and reduced by 15% to get a dry bulk density estimate at 77 lbs/ft^3. This dry bulk density is compared to the dry bulk density calculator on a soil texture triangle, at 14% sand 20% clay and 80% silt, as a second comparative estimate at roughly 1.46 g/cc or 77 lbs/ft^3. Based on the two methods, 77 lbs/ft^3 was used for the typical bulk density of the predominant soil within the El Dorado Lake Watershed, and used in the Average Soil Loss Rate equation.

Streambank height measurements were obtained with the help of El Dorado Lake WRAPS SLT, Friends University and Wildhourse Riverworks from an El Dorado streambank assessment in October 2010. Streambank height measurements were obtained from sixteen separate sites on seven separate streams throughout the El Dorado Lake Watershed (Figure 4). These field verified streambank height measurements were the basis for extrapolating streambank height measurements for the identified streambank erosion sites in the El Dorado Lake Watershed and were used in the Average Soil Loss Rate equation.

Figure 4: El Dorado WRAPS SLT Streambank Heights Measurements (in feet) and Locations



Analysis

To adequately analyze streambank erosion sites, stream reach sections were delineated to better accommodate streambank rehabilitation project focus. Streambank erosion prioritization by stream reaches include: Cole Creek, School Creek, Walnut River, Durechen Creek and Satchel Creek. 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 5).

Figure 5: 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 2011 assessment quantifies annual tons of sediment eroding from the El Dorado Lake Watershed over a 17 year period between 1991 and 2008 within the Walnut River Basin in southeastern Kansas. A total of 15 streambank erosion sites (Figure 6) were identified, covering 3,772 feet of unstable streambank and transporting 740 tons of sediment downstream per year; accounting for roughly 0.47 acre-feet per year of sediment accumulation in El Dorado Lake each year (Table 1). Compared to the actual sedimentation rate based on the 2004 bathymetric survey performed by the Oklahoma Water Resources Board, sediment from the identified streambank erosion sites contributes roughly 0.2 percent of the estimated 219 acre-feet/yr from the entire watershed. Ninety-six 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 watershed is transported annually from the School Branch, accounting for roughly 1,591tons of sediment annually or 42 percent of sediment eroding from all identified streambank erosion sites. These identified reaches account for an estimated 42 percent or $113,749 of total stabilization cost needs in the watershed (Figure 7). 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 the entire watershed would cost approximately $269,670.

Based on the calculated sedimentation rate from the bathymetric survey, sediment from the identified streambank erosion sites contributes roughly 0.2 percent of the estimated 219 acre-feet/yr. It is probable that high flow event runoffs from rangelands and agricultural lands via ephemeral gullies, and bridge crossings that are continually undercut by high flow events could be contributing to the sedimentation rate. These occurrences were not a part of this assessment but should be assessed in the future.

Figure 6: El Dorado Lake Watershed Streambank Erosion Sites

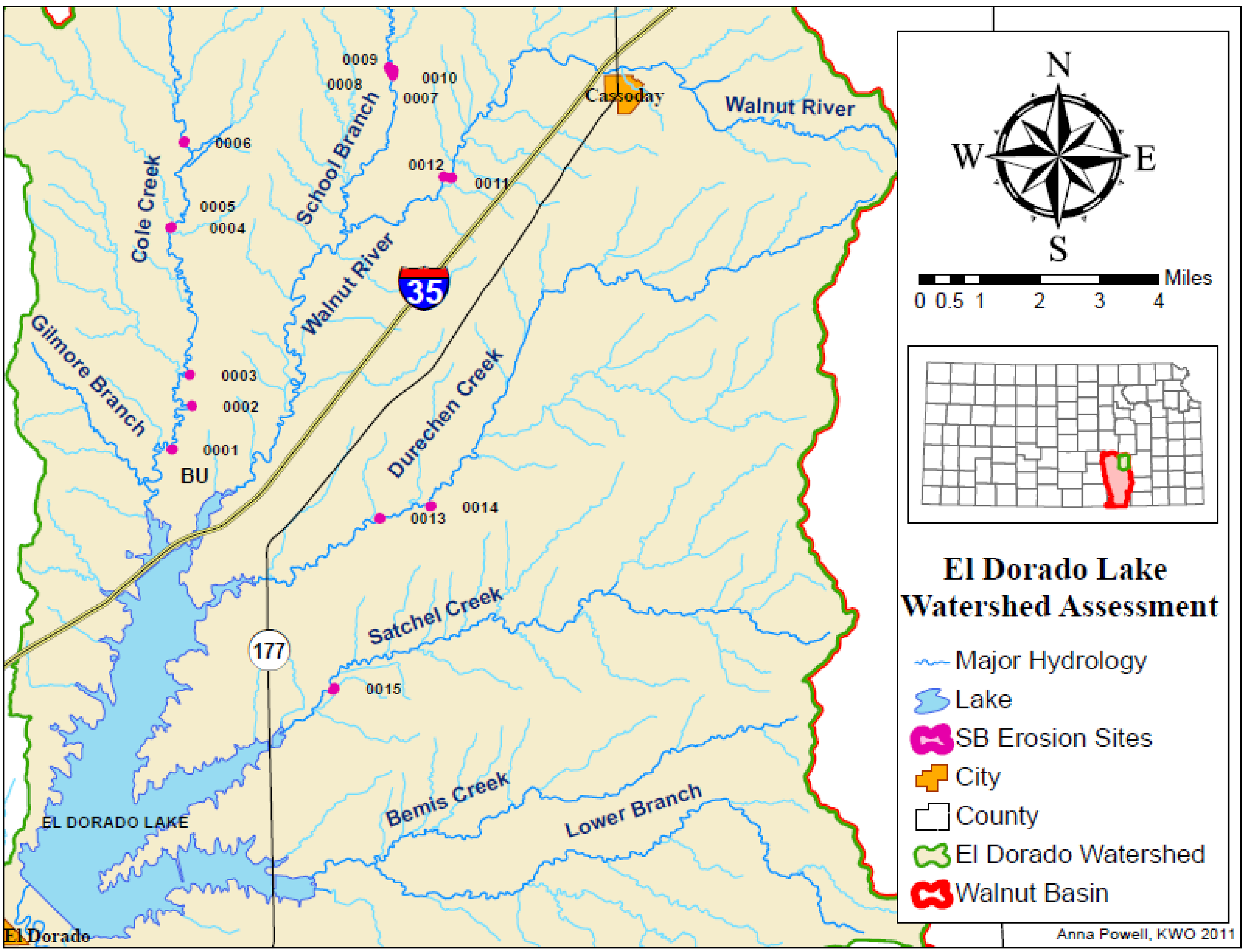
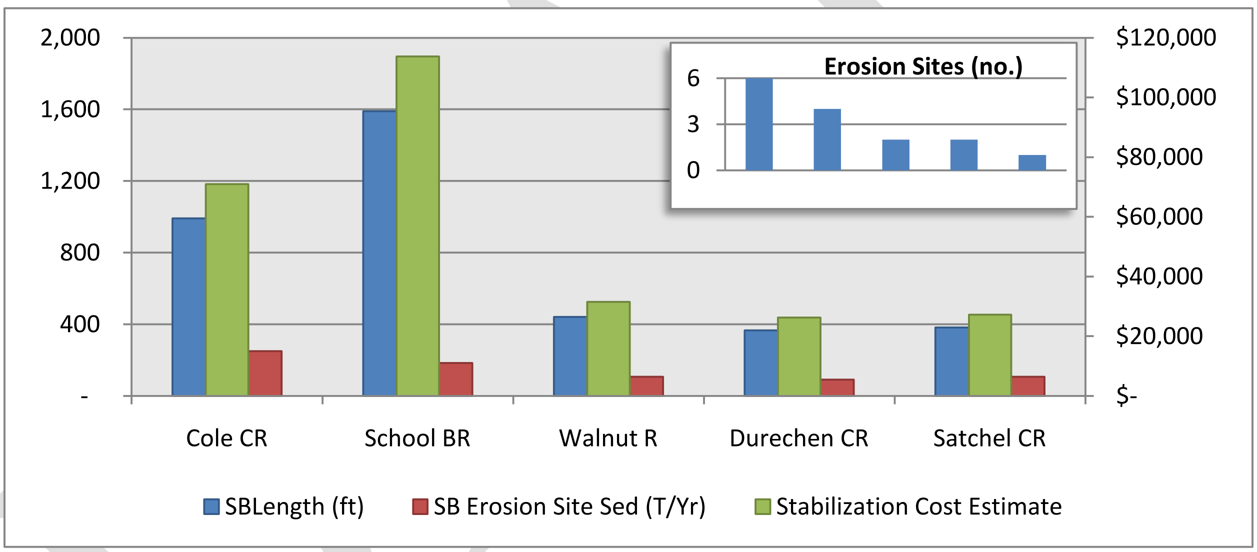


Table 1: El Dorado Lake Watershed Streambank Erosion Assessment Table by Stream Reach

Stream Reach	SB Length (ft)	SB Erosion Site Sed (T/Yr)	Stabilization Cost Estimate	SB Erosion Sites (no.)	Yield Loss/ Bank Length	Poor Riparian Cond/SB Length (ft)	Est. Sed Reduction (T/Yr)	% SB Length w/ Poor Riparian Cond.
Cole CR	992	251	$70,910	6	0.3	992	212.93	100.00%
School BR	1,591	184	$113,749	4	0.1	1,591	156.41	100.00%
Walnut R	441	107	$31,508	2	0.2	303	90.92	68.75%
Durechen CR	367	91	$26,230	2	0.2	367	77.17	100.00%
Satchel CR	381	107	$27,272	1	0.3	381	91.33	100.00%
Total	**3,772**	**740**	**$269,670**	**15**	**1.1**	**3,634**	**-629**	**96.35%**
Est Stabilization Cost/Linear Ft.			$71.50	**Stabilization/Restoration Efficiency**			0.85	

Figure 7: El Dorado Lake Watershed Streambank Erosion Assessment Graph by Stream Reach



Conclusion

The KWO completed this assessment for the El Dorado Lake 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 El Dorado Lake WRAPS SLT. Information contained in the assessment can be used by the El Dorado River WRAPS SLT to target streambank stabilization and riparian restoration efforts toward high priority stream reaches within the El Dorado Lake Watershed.

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