UPPER FALL RIVER WATERSHED EROSION ASSESSMENT

ArcGIS® Comparison Study: 1991 vs. 2006 Aerial Photography

Photo taken by: Anna Powell, 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 Fall River Watershed Assessment, an ArcGIS® Comparison Study, was initiated to partially implement the *Reservoir Sustainability Initiative*. This assessment identifies areas of streambank erosion and streambank and rangeland gully erosion concerns to provide a better understanding of the Upper Fall River watershed for streambank restoration purposes and to increase understanding of streambank erosion to reduce excessive sedimentation in reservoirs across Kansas. The comparison study was designed to guide prioritization of streambank restoration by identifying reaches of streams where erosion is most severe in the watershed above Fall River Reservoir.

The Kansas Water Office (KWO) 2011 assessment quantifies annual tons of sedimentation from streambanks between 1991 and 2006 within the Upper Fall River watershed in Kansas, and estimates about 40,364 tons of sediment is transported from the Upper Fall River watershed to the reservoir annually. This calculated amount accounts for only 12% of the total sediment load estimated in the KDHE determined Total Maximum Daily Load (TMDL). It should be noted that this 12% of sedimentation identified in the streambank erosion assessment accounts for only a portion of all streambank erosion locations within the Upper Fall River watershed. Only those streambank erosion sites observed as having streambank movement that covered an area about 1,500 sq. feet or more were identified within the assessment. A bathymetric survey performed in 1990 indicated that storage capacity in the multi-purpose pool, which contains public water supply storage, had been reduced by approximately 38% since the reservoir was filled in 1949; the original storage capacity was 30,401 acre-ft. A substantial portion of this sediment is transported from the main stem Fall River and its tributaries East and West Branch Fall River, Otter Creek and Spring Creek. Based on estimated stabilization costs

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of $71.50 per linear foot from an assessment conducted by The Watershed Institute, Inc. (TWI), streambank stabilization for the entire watershed from the 2011 assessment, identifying erosion between 1991 and 2006, would cost approximately $1.4 million. The streambank and rangeland gully erosion assessment did not quantify annual tons of soil loss. However, locations of gully erosion were identified for prioritization purposes using 2008 and 2010 NAIP aerial imagery.

The KWO completed this assessment for the Fall River Watershed Restoration and Protection Strategy (WRAPS) Stakeholder Leadership Team (SLT). Information contained in this assessment can be used by the Fall River WRAPS SLT to target streambank stabilization and riparian restoration efforts toward high priority stream reaches or HUC12s in the Upper Fall River watershed. Similar assessments are ongoing in selected watersheds above reservoirs throughout Kansas and will be made available upon request to agencies and interested parties for the benefit of streambank and riparian restoration projects.

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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 into reservoirs. 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 increased 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 United States Geological Survey (USGS) study in the Perry Lake watershed indicated that stream channels and banks are a significant contributor to reservoir sedimentation in addition to land surface erosion (Juracek, 2007). 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 stream beds 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 complement 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, crops and/or forbs, sub-surface internal strength is weakened, causing acceleration of mass wasting

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processes (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 Kansas watersheds is the development of streambank and rangeland gullies. Gullies develop from the wearing away of the surface soil along drainage channels by concentrated 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; minimal ground cover; steep, long, continuous slopes; high intensity storms; high drainage density of the slope; and close proximity to streams.

Rangelands in Kansas are natural ecosystems where the native vegetation consists predominantly of grasses, grass-like plants, forbs or shrubs. It is important for land managers and technical assistance specialists to be able to assess the health of rangelands in order to know where to focus management efforts. Ecological processes functioning within a normal range of variation support a diverse mixture of plant and animal communities. These ecological processes include: the water cycle—the capture, storage, and redistribution of precipitation; energy flow—conversion of sunlight to plant and animal matter; and nutrient cycles—the cycle of nutrients such as nitrogen and phosphorus through the physical and biotic components of the environment (USGS, 2002).

A 2010 National Resources Inventory (NRI), a statistical survey of natural resource conditions and trends, estimated rangeland health on non-Federal land in the United States. Non-Federal land included privately owned lands, tribal and trust lands and lands controlled by state and local governments. Figure 1 is a map representing data on soil and site stability, the capacity of the site to limit redistribution and loss of soil resources (including nutrients and organic matter) by wind and water, surveyed by the 2010 NRI. The survey found that Kansas has roughly 6% moderate departure rating based upon rills, water flow patterns, pedestals and terracettes, bare ground, gullies, wind scour and depositional areas, soil resistance to erosion, soil surface loss or degradation and soil compaction (NRI 2010).

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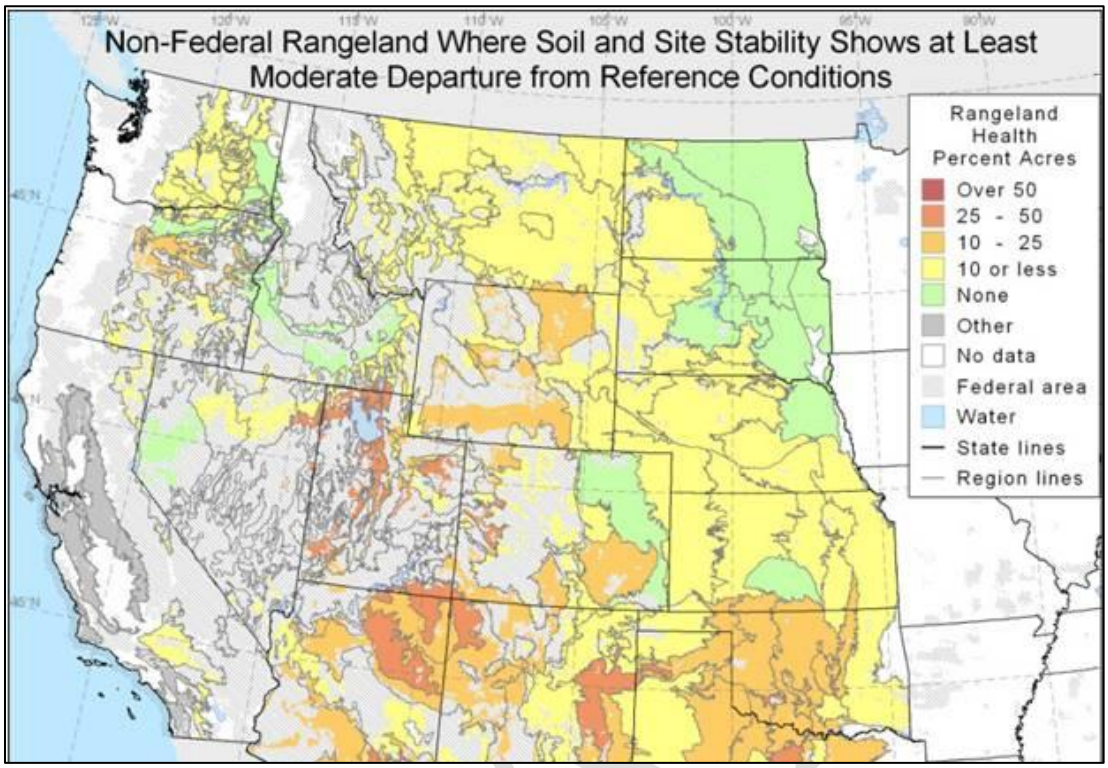
Figure 1: Non-Federal rangeland where soil and site stability shows at least moderate departure from reference conditions



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 Fall River watershed for mitigation purposes and for application of understanding to watersheds across Kansas.

Study Area

Fall River Reservoir is constructed on Fall River in Greenwood County at river mile 54.2, about 4 miles northeast of the city of Fall River. The watershed drains about 585 square miles and includes portions of Butler, Chase, Elk and Greenwood counties, with the majority in Greenwood County. The Upper Fall River watershed is comprised of fourteen 12-digit Hydrologic Unit Codes (HUC12) (Figure 2). The U.S. Army Corps of Engineers (Corps), Tulsa District began construction of the reservoir in 1946 for flood control, water supply and water quality control. Gates were closed in early 1949 and the conservation pool filled June 1949. The original conservation pool and maximum storage capacities of the reservoir were 30,400 acre-ft and 264,994 acre-ft, respectively.

Figure 2: Upper Fall River Watershed Study Area by HUC12

Major tributaries in the watershed include East and West Branch Fall River, Otter Creek and Spring Creek. Headwaters of these tributaries are characterized as high gradient streams with mostly gravel substrate and are bordered to various degrees by deciduous woodlands intermixed with grassland along the alluvial floodplain. Most crops are grown in the floodplains and where this is the case, the native riparian cover has been converted to cropland, contributing to unstable streambanks.

Geomorphic studies have indicated that over half of the first, second and third order streams in the Upper Fall River watershed have been lost through impoundment and inundation. Tributary channels tend to be slightly entrenched with moderate width to depth ratios and sinuosity and moderately low slopes (<2%). Most channels are gravel. Studied stream channel segments controlled by watershed structures were shown to be stable and often aggrading as bankfull discharges were diminished by impoundment and the resulting flows lack the power to move larger sediment out of the channel, pools and riffles. Generally, sediment supplies were low, either because of trapping by watershed structures or lack of source material in the Flint Hills ecoregion. There is an implication that diminished sediment supplies from the tributaries could induce main channel erosion along the Fall River as flowing water seeks equilibrium with its transporting sediment load.

Land use in the watershed is typical of the Flint Hills ecoregion where cultivation has been minimal due to shallow, rocky soils, resulting in largely unbroken native tall grass prairie. Grazing land or grassland is the predominant land use, covering 88% of the watershed. Row crop agriculture, which occurs primarily in the floodplains of creeks and the river, makes up six percent of the land use; wooded areas, four percent; urban areas, one percent and water resources occupy the remaining one percent of the watershed.

Data Collection Methodology

The Upper Fall River watershed streambank erosion assessment was performed using ArcGIS® software. The assessment identifies locations of streambank instability to prioritize restoration needs along streambanks to slow sedimentation rates in Fall River Reservoir. ArcMap®, an ArcGIS® geospatial processing program, was utilized to assess color aerial photography from 2006, provided by National Agriculture Imagery Program (NAIP), and compare it with 1991 black and white aerial photography, provided by Data Access & Support Center (DASC). Erosion sites identified in this assessment include locations of streambank erosion and streambank and rangeland gully erosion.

The streambank assessment was performed by overlaying 2006 county aerial imagery onto 1991 county aerial imagery (Figure 3). Using ArcMap® tools, streambank erosion sites were identified by locating aggressive movement of the streambank between the 1991 and 2006 aerial photos, or a movement of streambank that covered an area about 1,500 sq. feet, or more. Streambank erosion sites were denoted by geographic polygons features “drawn” into the ArcGIS® software program. Data provided, based on geographic polygons include: watershed location, unique ID, stream name, type of stream and type of riparian vegetation. Tons of soil loss and streambank length of the erosion sites were also identified as part of the streambank erosion assessment.

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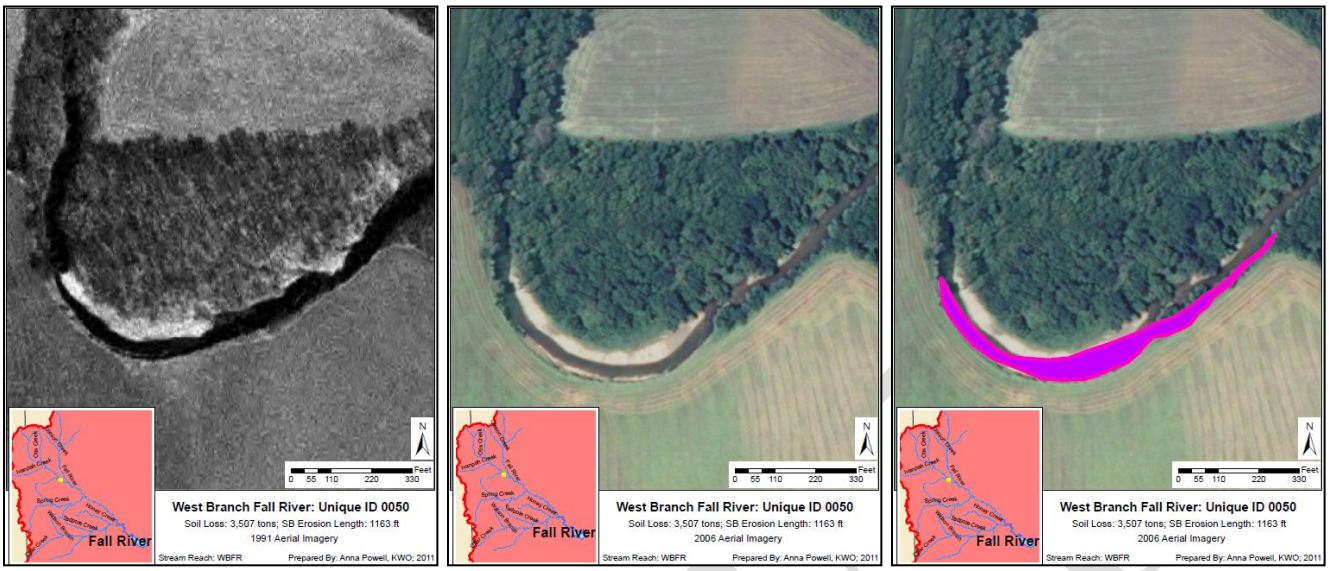
Figure 3: 1991 DASC & 2006 NAIP of a West Branch Fall River Streambank Erosion Site



The streambank erosion assessment data include approximations of tons of soil loss from the erosion site. This portion of the assessment is performed with the use of polygon features identified as high priority, aggressive erosion locations in the ArcGIS® software. Tons of soil loss was estimated by incorporating perimeter, area and streambank length of these polygons into a regression equation. Perimeter and area are estimated through the *field calculator* application within the ArcGIS® software based on the drawn polygons. These calculations are used to calculate approximate streambank length of the eroded location, using a regression equation formulated by Chris Gnau, KWO. This equation was estimated by taking data from the *Enhanced Riparian Area/Stream Channel Assessment for John Redmond Feasibility Study* report prepared by TWI and relating the erosion area (in square feet) and perimeter length of that erosion area (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.

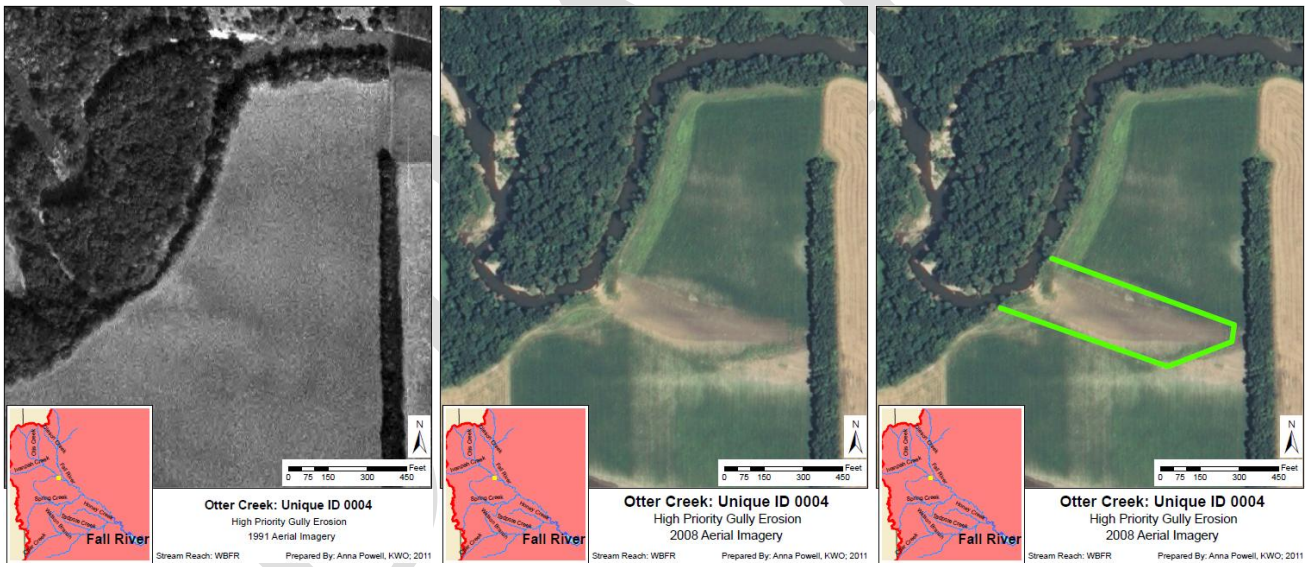
Tons of soil loss is estimated by first calculating the volume of sediment loss and then applying a bulk density estimate to that volume for the typical soil type of the streambank sites identified in the assessment. The volume of sediment was found by multiplying bank height, surface area lost between the 1991 and 2006 aerial photos and soil bulk density. This volume is used to divide by the number of years between the aerial photos used to identify the hot spots, 1991 and 2006, 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 the identified streambank erosion sites are needed. Streambank heights for each identified streambank erosion site were estimated by first doing on the ground measurements on 10 of the identified streambank erosion sites

throughout the watershed. These 10 sites were the basis for extrapolating streambank height measurements throughout the Upper Fall River Reservoir Creek Reservoir watershed within Kansas.

The streambank gully erosion assessment was performed with similar techniques as the streambank erosion assessment. 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. Gully data was compiled and categorized by high, medium or low priority as another effort in rehabilitation prioritization. The identification of 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 indicate 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 (Figure 4). 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, gullies were increased to a medium or high priority, even if they exhibit "low priority" gully identifiers, if there was a visibly identifiable sizeable amount of land erosion or gullies present in the same vicinity.

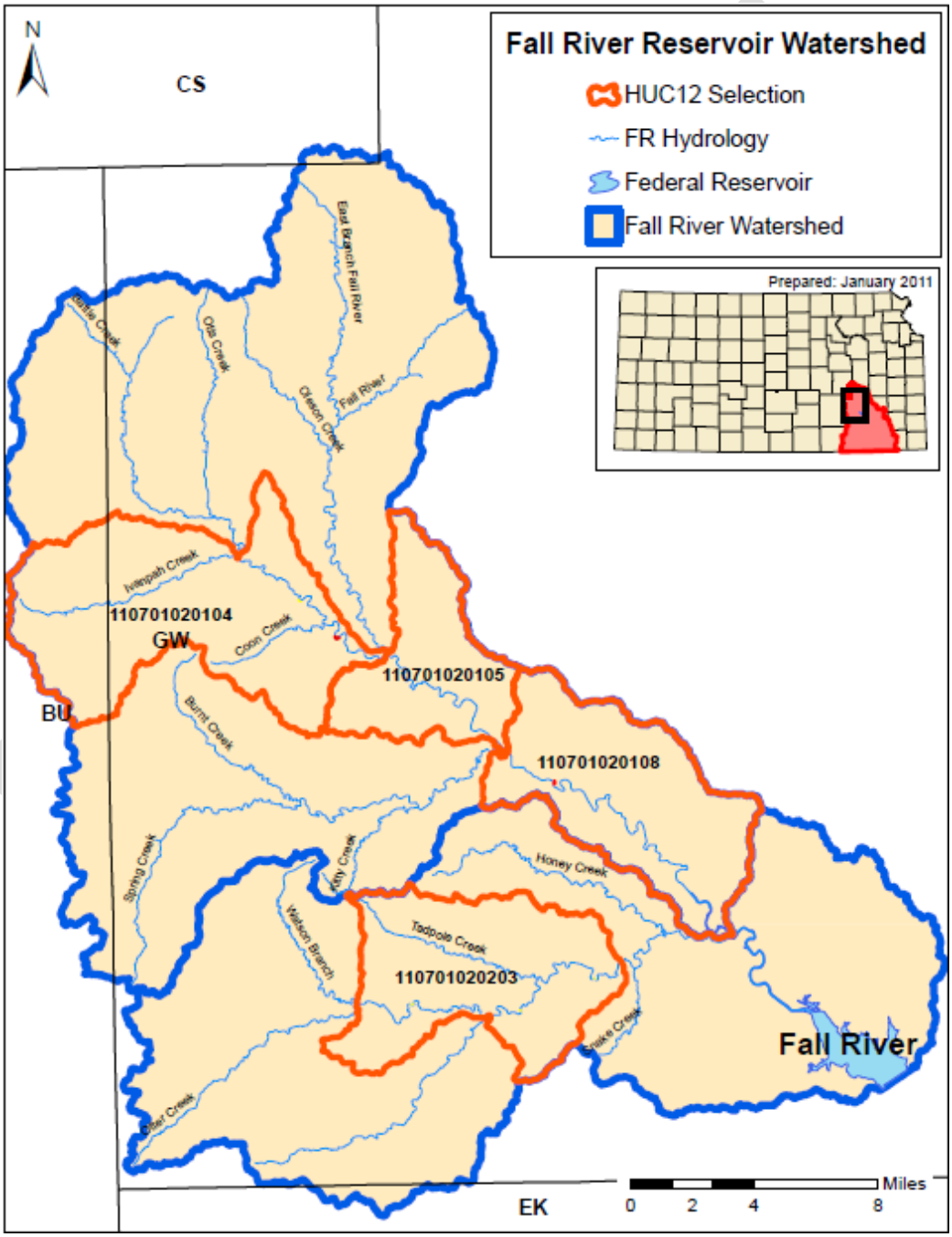
Figure 4: 1991 DASC & 2008 NAIP of a High Priority Gully Erosion on Otter Creek



The rangeland gully erosion assessment was performed by a visual analysis of the 2010 aerial imagery; 2008 NAIP aerial imagery was used as support. With the use of ArcMap®, an ArcGIS® geospatial processing program, rangeland gully erosion was identified by visually locating what appear to be signs of cow paths, winter feeding areas, blown-out grassed waterways, eroding landscape due to water/wind erosion and sand pits. Locations not identified as rangeland gully erosion included locations that appeared to be intermittent streams that followed a well defined path and did not appear to have an extensively cutting and widening channel. These identified locations were denoted by geographic polygons features "drawn" into the ArcGIS® software program. An approximate 1:4,000 scale in the ArcMap® software was used to identify location of erosion within four high

priority HUC 12 areas. These high priority HUC12s were chosen for the rangeland erosion assessment because they represent the highest streambank erosion rates found in the streambank erosion assessment. These HUC12 areas are: 110701020104, 110701020105, 110701020108 and 110701020203 (Figure 5). Data provided based on these geographic polygons include: watershed location, unique ID, the HUC12 that the polygon is located within and area of the rangeland gully erosion. Tons of soil loss and streambank length of the erosion sites were not identified as part of the rangeland erosion assessment.

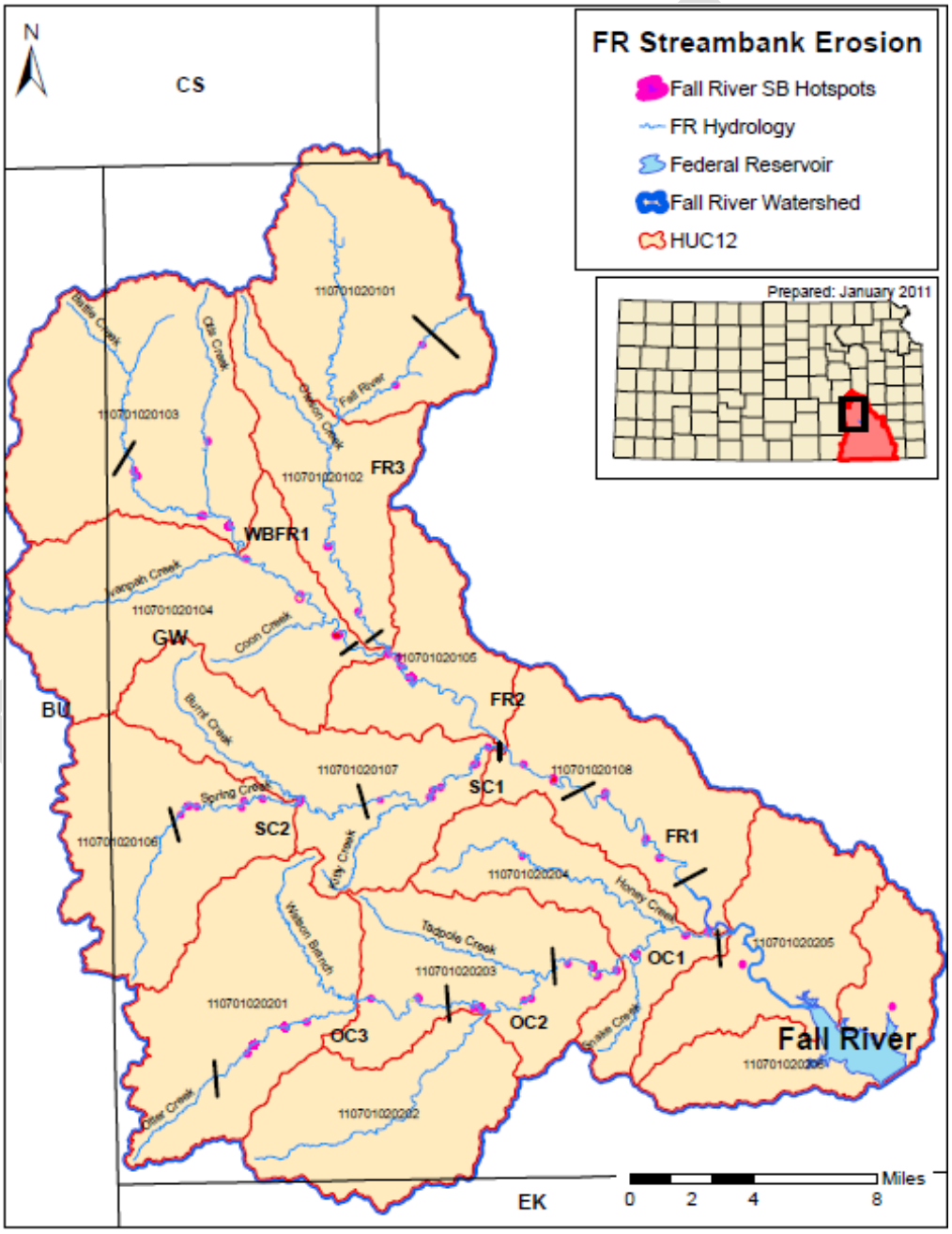
Figure 5: Rangeland Gully Erosion Assessment Areas by HUC12



Analysis

To best assess sites indicated as having streambank erosion, watershed sections were delineated to better accommodate streambank rehabilitation project focus. Streambank erosion hotspots were analyzed for prioritization purposes by stream reach sections initially and later analyzed by thirteen HUC12s found within the Upper Fall River watershed area (Figure 6). Analyzing streambank erosion sites by HUC12s was performed as a prioritization effort to assess rangeland gully erosion, and is discussed below.

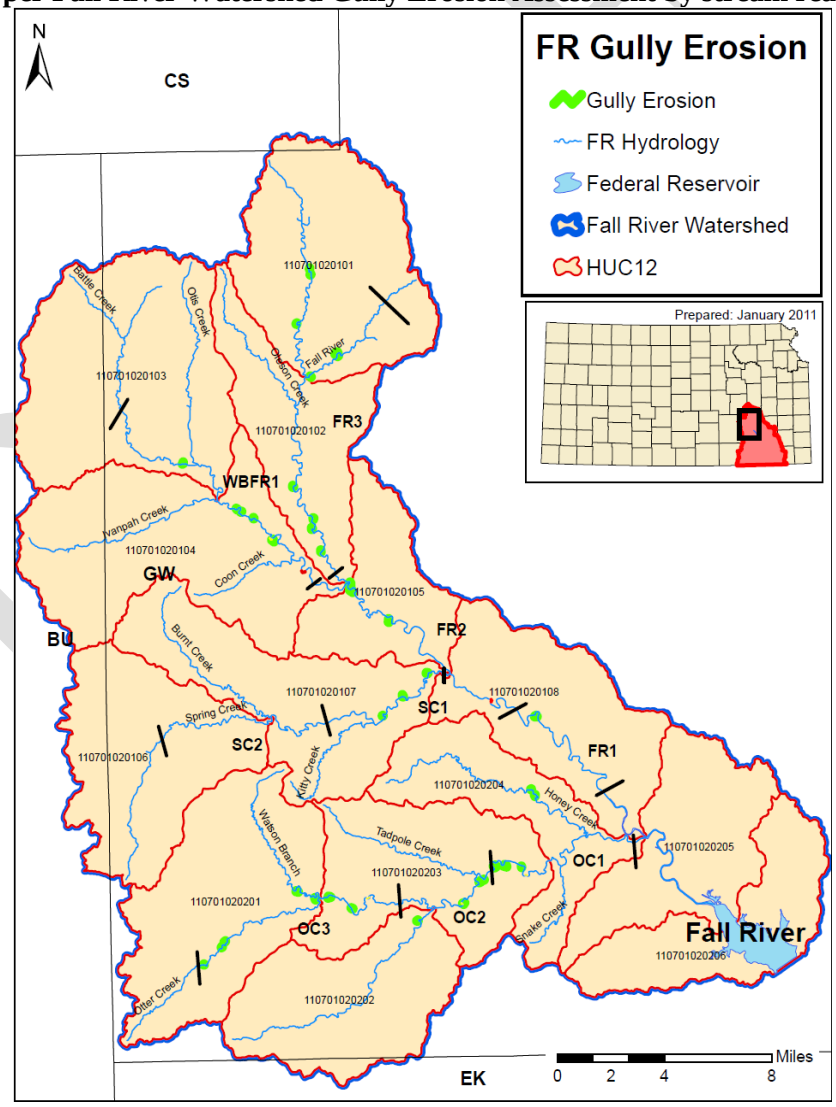
Figure 6: Upper Fall River Watershed Streambank Erosion Assessment by Stream Reach & 12-digit Hydrologic Unit Codes (HUC12)



The streambank erosion prioritization by stream reach sections include: FR1, FR2, FR3, OC1, OC2, OC3, SC1, SC2 and WBFR1. Reach sections are named by the stream reach they are located on and in numerical order from downstream to upstream. For example, stream reaches FR1 to FR3 references three reaches identifies on Fall River, proceeding from south (downstream) to north (upstream) along the river. Streambank erosion sites are assessed by the streambank length (feet) of the eroded bank, annual soil loss (tons) from the eroded area between 1991 and 2006, percent of streambank length with poor riparian condition (riparian area identified as having cropland or grass/crop buffer), estimated sediment reduction at an 85% efficiency rate with the use of buffers and filter strips and streambank stabilization cost estimates for eroded streambank sites.

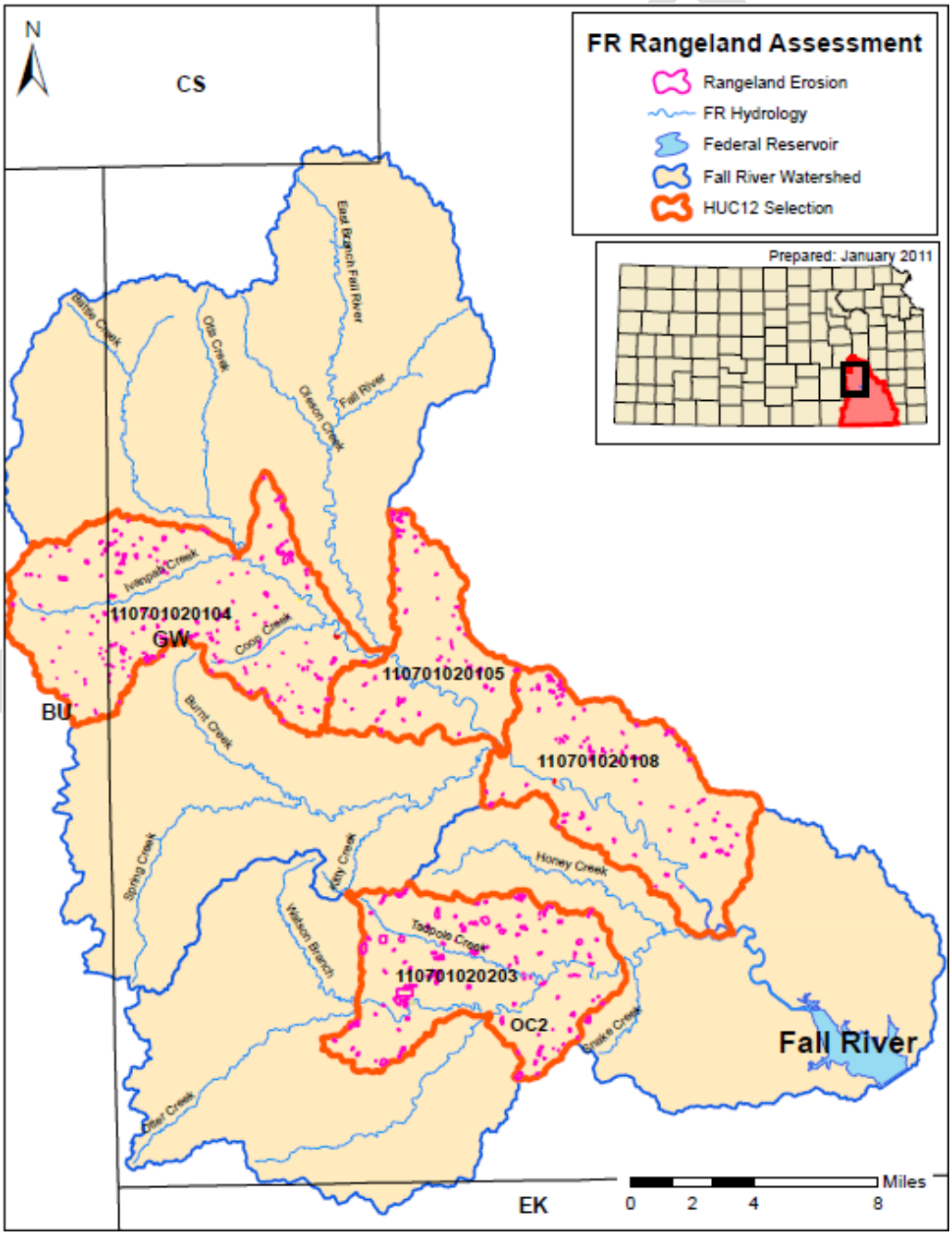
Streambank gullies were assessed based on the proportion of high, medium and low priority identifications within stream reach sections and HUC12 areas, and can be used as supporting data for streambank erosion or rangeland gully erosion rehabilitation prioritization (Figure 7). Explanation of prioritization is found in the data collection and methodology above. No further assessment was performed

Figure 7: Upper Fall River Watershed Gully Erosion Assessment by stream reach & HUC12



The rangeland gully erosion assessment was performed within four HUC12 areas identified from the streambank erosion assessment, but no further analysis of the rangeland erosion assessment was carried out. The identified HUC12 areas are 110701020104, 110701020105, 110701020108 and 110701020203, and comprise the main stem Fall River; major tributaries Otter Creek and West Branch Fall River; and minor tributaries including Tadpole Creek, Coon Creek and Nanpah Creek (Figure 8). Tons of soil losses for identified sites were not assessed as part of the rangeland gully erosion assessment. Currently, the Kansas Department of Health and Environment is in the process of performing a more extensive assessment of rangeland erosion based on this initial 2011 assessment and will be presenting their findings in the near future.

Figure 8: Upper Fall River Watershed Rangeland Gully Erosion Assessment by HUC12



Results

The Kansas Water Office 2011 assessment quantifies annual tons of sedimentation from streambank erosion between 1991 and 2006 within the Upper Fall River watershed in Kansas. A total of 64 hot-spots covering 19,691 feet, indicating substantial streambank erosion, were identified. In 2008, the Upper Fall River WRAPS project used EPA Section 319 funds and State Water Plan funds to perform a GIS based assessment of areas along streams where buffers are lacking or should be installed. The study identified 19,300 feet of streambanks in need of buffers, an almost identical identification in feet of streambank instability to this 2011 assessment. This 2011 assessment also estimates approximately 40,364 tons of sediment being transported from the Upper Fall River watershed to the reservoir annually. This calculated amount accounts for only 12% of the total load estimated in the high priority TMDL for eutrophication/siltation has been developed for the reservoir by KDHE. The TMDL estimates that 324,000 tons of sediment per year enters Fall River Reservoir from its watershed. However, it should be noted that this 12% of sedimentation identified is only a portion of all streambank erosion locations in the watershed. Only those streambank erosion sites that covered an area 1,500 sq. feet, or more, were identified. A substantial majority of the sediment is transported from the mainstem Fall River, Otter Creek, West Branch Fall River and Spring Creek contributing approximately 15,940; 12,820; 7,710 and 3,900 tons of sedimentation annually, respectively (Figure 9). The Fall River mainstem accounts for about 34% of the total stabilization cost needs in the watershed totaling $478,370. Costs and percentages for Otter Creek are $391,950 (16%); for West Branch Fall River, $302,545 (21%) and for Spring Creek, $235,020 (17%). Based on estimated stabilization costs of $71.50 per linear foot from an assessment conducted by The Watershed Institute, Inc. (TWI), streambank stabilization for the entire watershed from the 2011 assessment would cost roughly $1.4 million (Table 1).

Figure 9: Upper Fall River Watershed Streambank Erosion Assessment Graph by Stream Reach

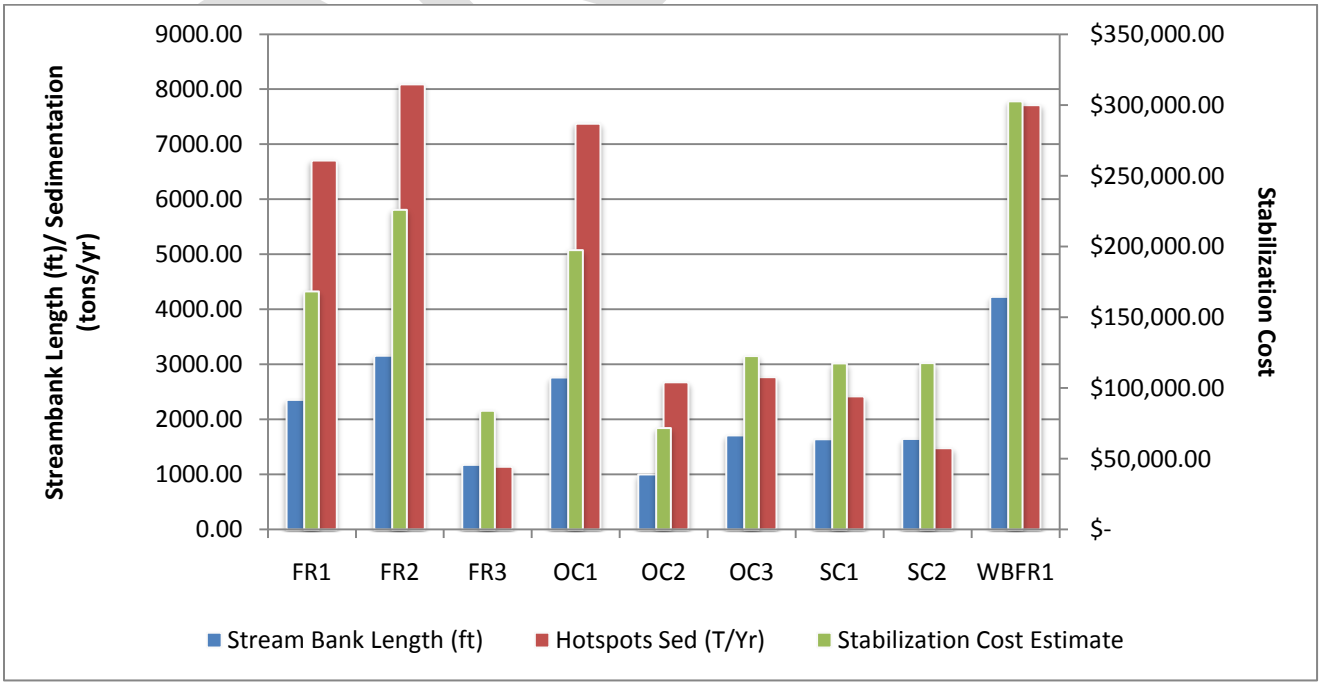


Table 1: Upper Fall River Watershed Streambank Erosion Table by Stream Reach

Reach	Stream Bank Length (ft)	Hotspots Sed (T/Yr)	Stabilization Cost Estimate	Hotspots (no.)	Yield Loss/ Bank Length	Poor Riparian Condition/Stream Bank Length (ft)	Est. Sed Reduction (T/Yr)	% SB Length w/ Poor Riparian Cond.
FR1	2355.21	6706.82	$ 168,397.69	7	2.8	1665.11	5,700.79	70.70%
FR2	3160.49	8088.64	$ 225,974.95	7	2.6	3160.49	6,875.34	100.00%
FR3	1174.80	1143.88	$ 83,998.33	4	1.0	1174.80	972.30	100.00%
OC1	2762.83	7375.49	$ 197,542.09	8	2.7	1917.24	6,269.16	69.39%
OC2	1004.75	2674.26	$ 71,839.89	4	2.7	715.46	2,273.12	71.21%
OC3	1714.31	2767.29	$ 122,573.14	6	1.6	1493.73	2,352.20	87.13%
SC1	1641.09	2418.05	$ 117,337.71	8	1.5	1453.02	2,055.34	88.54%
SC2	1645.92	1479.42	$ 117,682.99	8	0.9	1645.92	1,257.50	100.00%
WBFR 1	4231.41	7709.76	$ 302,545.75	11	1.8	3899.05	6,553.30	92.15%
Total	**19,691**	**40,364**	**$1,407,893**	**63**	**17.5**	**17,125**	**-34,309**	**86.97%**
Est Stabilization Cost/Linear Ft.			$71.50		**Stabilization/Restoration Efficiency**		0.85	

As discussed in the data collection and methodology section above, streambank gullies where categorized as high, medium and low priority. Figure 10 below identifies the extent of high, medium and low priority streambank gullies identified by stream reach, while Figure 11 identifies the extent of streambank gullies by HUC12. The assessment of streambank gullies by stream reach identified FR3 as contributing the highest amount of total streambank gullies (11) and was one of two with the highest amount of high priority streambank gullies (4); OC1 being the second, also with 11 total gullies identified. Stream reach OC3 was third with the highest total streambank gullies (7). When streambank gullies were assessed by HUC12 areas, 110701020203 (encompassing portions of stream reaches OC1, OC2 and OC3) and 110701020101 (encompassing portions of stream reach FR3) topped the charts with 8 and 7 total streambank gully sites, respectively.

Figure 10: Upper Fall River Watershed Streambank Gully Erosion Assessment by Stream Reach

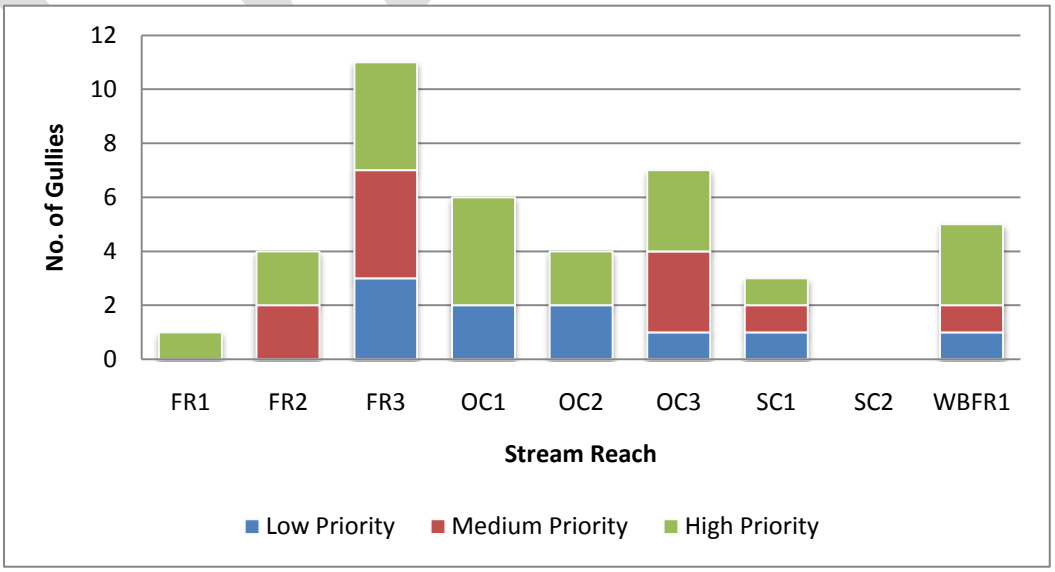
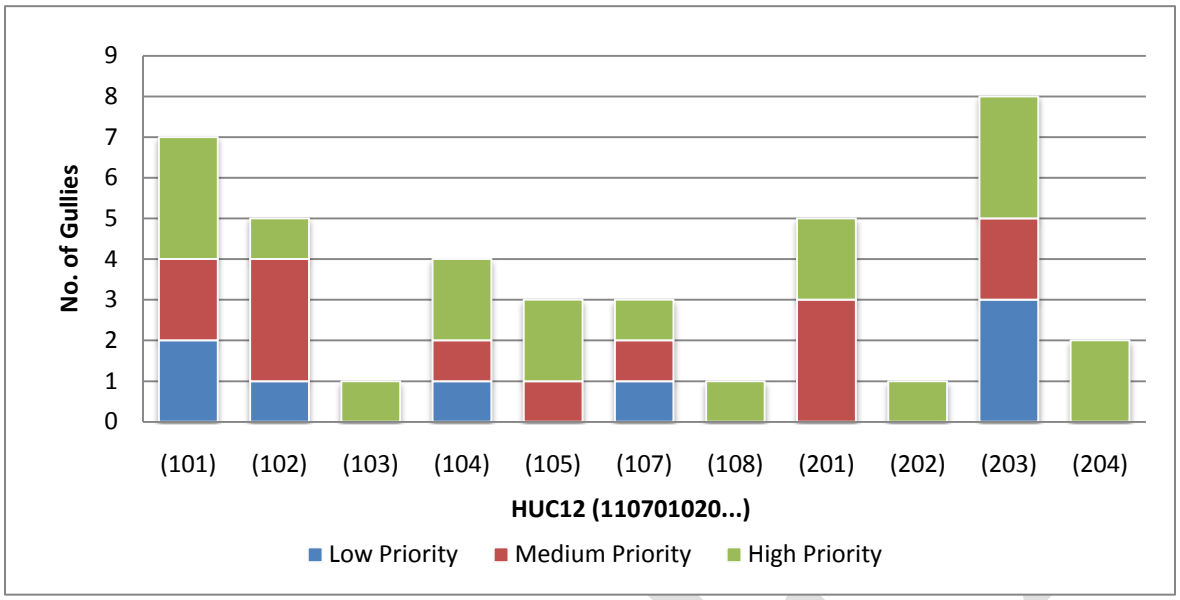
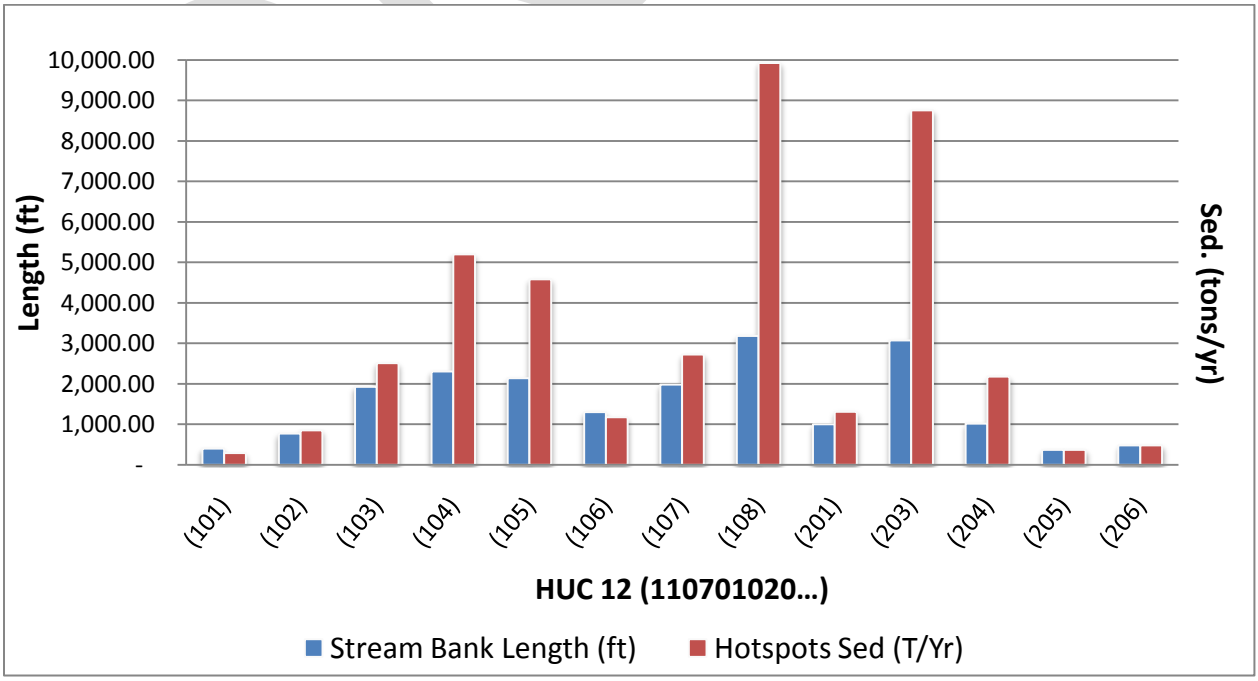


Figure 11: Upper Fall River Watershed Streambank Gully Erosion Assessment by HUC12



Analysis of streambank erosion sites by HUC12s was performed as a prioritization effort to assess rangeland gully erosion (Figure 12). The rangeland gully erosion sites were identified within four of these HUC12 areas (110701020104, 110701020105, 110701020108 and 110701020203), but no analysis of the rangeland erosion assessment beyond identification was performed. Currently, the Kansas Department of Health and Environment is in the process of performing a more extensive assessment of rangeland erosion based on this initial 2011 assessment and will be presenting their findings in the near future. Tons of soil loss was also not quantified in this assessment for streambank and rangeland gully erosion.

Figure 12: Upper Fall River Watershed Streambank Erosion Assessment Graph by HUC 12



It should also be noted that gully erosion can contribute a tremendous amount of sediment at the watershed scale and can occur in both cropland and grassland. The amount of sediment input is based on rainfall/runoff and gully frequency within a given watershed. Buffer installation costs vary widely.

Conclusion

KWO completed this assessment for the Fall River Watershed Restoration and Protection Strategy (WRAPS) Stakeholder Leadership Team (SLT). Similar assessments are being 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. Information contained in this assessment can be used by the Fall River WRAPS SLT to target streambank stabilization and riparian restoration projects to the highest priority streams in the watershed.

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