Kansas Heritage Streams: Identification and Protection of Healthy Watersheds

Kansas Department of Health and Environment
Bureau of Water
Watershed Planning, Monitoring, and Assessment

Cover photographs: Top left, Fourmile Creek, Morris County; top center, Grouse Creek, Cowley County; top right, Nescatunga Creek, Comanche County; bottom left, Illinois Creek, Wabaunsee County; bottom center, Sevenmile Creek, Riley County; bottom right, Thompson Creek, Kiowa County

KANSAS HERITAGE STREAMS:

IDENTIFICATION AND PROTECTION OF HEALTHY WATERSHEDS

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Executive Summary

In a state such as Kansas, with a majority of its lands under private ownership, the concept of a pristine, reference-caliber watershed may be idealistic. However, there remain a number of areas in Kansas that have undergone comparably little change over the past two centuries. This project builds upon previous efforts to identify, monitor, and adequately protect these high quality watersheds and their associated streams (see Angelo et al. 2010). Healthy watersheds and their associated streams generally are home to unspoiled landscapes and diverse plant and animal assemblages and represent an integral part of the state's natural heritage. For many Kansans, these watersheds and their associated streams are worthy of conservation from a purely aesthetic (quality-of-life) point of view.

In July 2009, KDHE began to assemble a large suite of existing geographical databases, each relevant to the identification and study of reference ecosystems. A watershed disturbance index was developed using these databases and applied in the evaluation and ranking the state's nearly 100,000 (NHDPlus) catchments and corresponding stream reaches. Predictive computer models were developed relating watershed disturbance scores to the prevailing diversity of native fishes, freshwater mussels, and aquatic insects. Disturbance scores varied significantly among ecoregions, but the best scores in all ecoregions were associated with the headwater catchments of large grassland areas.

The disturbance score results were summarized and interpreted, and several streams in both the Flint Hills and Gypsum Hills/High Plains geographic regions were targeted for enhanced environmental monitoring following field-based reconnaissance activities. Monitoring activities examined the biological, surface water chemistry, streamflow conditions, and landscape features to verify the results of the earlier, landscape-based disturbance analysis, which identified the state's most probable "least altered" watersheds. A total of six streams were selected for environmental monitoring activities, they were: Fourmile Creek (Morris Co.), upper Grouse Creek (Cowley Co.), Illinois Creek (Wabaunsee Co.), Sevenmile Creek (Riley Co.), Nescatunga Creek (Comanche Co.), and Thompson Creek (Kiowa Co.). Across Kansas, the calculated watershed disturbance scores ranged from 0.000 to 0.425 for all catchments; scores were standardized to range from 0.00 to 100.00. The six selected watersheds were in the top 7 – 33 percentiles among watersheds across the state and each watershed was within the 20-to-50th percentile of its respective ecoregion.

Biological surveys were performed to assess physical habitat and biological conditions in the selected streams. Collectively, five of the six streams (all except Thompson Creek) experienced deteriorated flow conditions induced by the pervasive drought, resulting in invertebrate diversity lower than usually found in reference caliber streams. Therefore, biological community metrics scores for the six selected streams were compared to two separate datasets compiled by KDHE. The first comparisons were made to the last 10 years of data obtained through the statewide stream biological monitoring program (SBMP). The SBMP examines the structural attributes of aquatic macroinvertebrate assemblages from nearly 200 targeted monitoring sites on larger streams and rivers (fourth-to-seventh order) that serve as integrator sites for large watersheds. Second, because the six selected streams are all smaller systems that might not be expected to maintain the same high numbers of taxa as larger streams, the resulting metrics also were

compared to a population of approximately 215 sites randomly sampled within the statewide stream probabilistic monitoring program (SPMP) during 2006 – 2010. When compared to the state's larger streams and rivers, only Thompson Creek consistently ranked within the top 25 percent for metric scores. This is likely due to its extremely consistent flow regime made possible by the large groundwater inputs in the headwaters of this stream. Several of the heritage streams fared better when compared to typical Kansas streams. All streams but Grouse Creek had at least one sample that put them in the top 25 percent of small order streams.

To assist in the interpretation of selected heritage stream water chemistry data sets, KDHE's statewide ambient stream chemistry monitoring program data (2002 through August 2012) for some 300 sites were used in this assessment. Surface water quality samples were collected and analyzed by KDHE for parameters typically considered to be important physico-chemical and microbiological water quality indicators. The parameters selected for the water quality testing indicated no measureable contaminate concentrations exceeded current applicable Kansas surface water quality criteria for the six heritage streams. Often considered an analogous measurement to estimate sediment loading, total suspended solids concentrations demonstrated median concentrations at or just above the laboratory's minimum quantification limit (MQL) of 10 milligrams per liter (mg/L). Median nutrient concentrations were considered low except for Thompson Creek (elevated nitrate) and Sevenmile Creek (modest phosphorus enrichment). Measured concentrations of copper, lead, and zinc have not exceeded the applicable (hardness-dependent) water quality criteria for the protection of aquatic life from acute and chronic toxicity. In the last ten years, KDHE has documented an average atrazine detection rate of thirty-seven percent for monitored stream sites (MQL = 0.3 µg/L). Conversely, only one of the 82 samples taken from the six heritage streams had a detectable concentration above the MQL. *Escherichia coli (E. coli*) are usually relatively harmless microorganisms that live in large numbers in the intestinal tract of warm-blooded animals. While these bacteria may not directly cause disease, high quantities of *E. coli* are indicative of a degraded sanitary condition and suggest the presence of other, disease causing agents. Although elevated *E. coli* levels were measured at times on all six heritage streams, a majority of samples were low in bacteria and likely in compliance with state surface water quality standards. Finally, all six heritage streams generally exhibited exceptional water quality attributes (e.g., well buffered and aerated, low organic loading), especially when compared to all other sites from the corresponding quantitative ecoregions; verified, where available, by their long-term water quality monitoring data.

Streams selected for study lacked permanent flow gages: therefore, long-term flow characteristics and the extent of hydrologic alteration were estimated using USGS database containing extrapolated flow estimates (Perry et al. 2002). During the study, an effort was made to obtain streamflow data for comparative (quality control) purposes and to assess the relative hydrologic conditions at the time of sampling. Due to the exceptional drought that occurred across Kansas in 2011 and 2012, many streams across the state were reduced to very low water levels. The six streams selected for this study were no different, with several of them being pooled or, in one case, completely dry during a scheduled flow data collection attempt.

In an attempt to evaluate and classify the streams from a geomorphological perspective, KDHE contracted with The Watershed Institute to complete fluvial geomorphological surveys for the six heritage streams using the Rosgen classification system. Those data were used for geomorphic characterization, morphological description, and an abbreviated stream condition assessment involving additional pool measurements, lateral channel stability analysis, and, in gravelly bottomed streams, riffle-pool counts and point bar particle size analyses. The physical/geomorphological characterizations of all the six heritage streams demonstrated good (stable) ratings based on their 1) low or slight entrenchment, 2) moderate to high sinuosity, 3) low to moderate near bank stress, and 4) low to moderate sediment supply-stability.

Data obtained during the field-based activities described above have been used to (a) confirm the reference stature of the study streams and (b) justify their designation as exceptional state waters. The importance assigned to heritage streams implies that a concerted effort should be made to maintain (and, if possible, improve) the chemical, physical, and biological condition of these aquatic ecosystems. Owing to the paucity of minimally impacted streams in Kansas, it would be desirable to extend protection to those remaining segments to maintain their ecological integrity in the face of altered land use and development in their watersheds and activities in and along their channels. The preeminent water quality protections are based on the Kansas Surface Water Quality Standards which serve to restore and maintain the chemical, physical and biological integrity of Kansas waters.

Given that no NPDES permitted facilities discharge to any of the six heritage reaches, the primary protection for these reaches lies in the antidegradation policy of the water quality standards. As existing or proposed Exceptional State Waters, heritage streams are protected by antidegradation because, "*Wherever surface waters of the state constitute exceptional state waters, discharges shall be allowed only if existing uses and existing water quality are maintained and protected.*" Permitting under Section 404 can minimize impacts on Kansas heritage streams, especially if they are designated as ESWs, but the regulatory program does not prohibit all activities. Nonetheless, assigning ESW status to heritage streams should ensure further permit review and help preclude unwarranted impacts.

Section 303(d) of the Clean Water Act allows States to develop discretionary, informational, protection-oriented TMDLs, as resources allow. A protection-based TMDL establishes the baseline of water quality to be maintained, pursuant to the Kansas antidegradation policy. KDHE has prepared a protection-based TMDL for total suspended solids and phosphorus on Grouse Creek that can justify directing funds that support installation of best management practices along the creek. No other local resource management group associated with the other five heritage streams has requested a TMDL to facilitate financial resources for protection activities. Most groups saw detriments in excessive government (KDHE and EPA) oversight over their activities if a TMDL was developed. However, as an alternative strategy, since Kansas develops stream TMDLs on a watershed basis, heritage tributaries to monitored, impaired mainstem streams will be included and protected by any restoration TMDL established for the mainstem.

The identification of minimum desirable streamflows to preserve, maintain or enhance baseflows for in-stream water uses relative to water quality and aquatic life uses is a core policy of Kansas. Of the six heritage streams, three are tributaries to streams with 1984 minimum desirable streamflows. These heritage streams have no flow allocation or minimum level established for them specifically, but could be subject to water right administration caused by deficient flows on their respective mainstem streams. Administrative regulations applied to individual water rights by the Division of Water Resources may be more effective in preventing dewatering of any of these streams.

Kansas water agencies have a number of programs to provide financial assistance to landowners to incentivize application of best management practices to protect potential heritage streams, through watershed planning. While several watershed plans have some aspects of water quality protection, most plans deal with implementing TMDLs that restore water quality. Since the presence of minimally impacted watersheds supporting high quality streams is a function of the stewardship ethos of individual landowners in those watersheds, the intervention of government under the guise of assistance in protecting those lands and waters is often viewed as both intrusive and unnecessary. Hence, a majority of initiatives taken by Kansas natural resource agencies to protect high quality land and water resources have been rebuffed.

The State's role in protection activities should focus on educating the public on the benefits of heritage caliber streams, obtaining monitoring data to document and characterize such streams and to stand in readiness to respond to local initiatives and requests for assistance. Opportunities for government to initiate action of its own will be consistent with its existing authorities to regulate impacting activities, although there may be less of a role for government in dealing with impacts from unregulated non-point sources of pollutants.

While the social and political nature of Kansas tends to limit the role of state government in protecting these heritage streams, there are number of actions that can be undertaken to minimize future alteration of these heritage streams and their watersheds.

1. Continue to collect physical, geomorphic, chemical and biological data from streams located in minimally impacted watersheds as time, opportunity and resources allow.

2. Continue to educate the citizens of Kansas on the benefit and value of heritage streams, describing their characteristics and the factors that make them of such high quality.

3. In the short term, upgrade the classification of Sevenmile, Fourmile and Nescatunga Creeks as Exceptional State Waters. In the long term, seek opportunities to establish streams flowing through Federal lands as ONRWs.

4. As needed, establish protection-based TMDLs for heritage streams to maintain water quality and the existing designated uses of those streams, consistent with the antidegradation policy of the Kansas Surface Water Quality Standards.

5. Any wasteload allocations established though a protection-based TMDL will maintain existing water quality and require any potential future new or expanded discharger, subject to a NPDES permit.

6. Load allocations of pollutants established under a protection-based TMDL should be reduced through application of appropriate Best Management Practices on non-point sources to abate the discharge of those pollutants.

7. Such protection-based TMDLs will be a High Priority for implementation, consistent with similar designations made for restoration-based TMDLs cited in the *Kansas Water Plan*.

8. As a High Priority TMDL, its implementation should receive full consideration for funding through the cost-share programs managed by Kansas Department of Agriculture's Division of Conservation, as resources allow.

9. For heritage streams that are tributary to impaired waters that are subject to a TMDL, provide for protective load allocations to the heritage streams as part of the watershed-based water quality restoration TMDL.

10. KDHE should send a letter to the Chief Engineer of the Kansas Department of Agriculture's Division of Water Resources requesting he utilize his existing authorities to protect the six heritage streams from dewatering and loss of in-stream uses.

11. Utilize Watershed Restoration and Protection Strategy (WRAPS) groups, basin advisory committees, watershed districts, non-governmental organizations, conservation groups and other interested citizen groups to promote the benefit and value of heritage streams through public presentations, conservation awards, signage at sites of protective management practices and recognition of collaborative efforts in statewide forums.

12. Continue to use the 401 certification process to apply protective conditions on activities that potentially impact heritage stream systems.

13. Abide by the antidegradation policy within the Kansas Surface Water Quality Standards in reviewing proposed NPDES permits for discharges into heritage streams.

14. Stand ready to provide technical, educational and financial support for local initiatives to protect high quality waters through KDHE's Section 319 program and the conservation programs of the Kansas Department of Agriculture's Division of Conservation.

15. Partner with non-governmental organizations, such as The Nature Conservancy, on opportunities to protect minimally impacted watershed lands and the waters that they produce.

Acknowledgements

First and foremost we thank the Kansas landowners who allowed us the privilege of conducting activities on the streams coursing through their property; without their cooperation none of this would have been possible. Scott Satterthwaite and Ann D'Alfonso (KDHE); Paul Ingle (Flint Hills Resource Conservation & Development); Alan Hynek (Fort Riley Environmental Division); and Roger Black and Ronnie Whiteman (Watershed District #92) all were instrumental in helping us gain land access to several of the streams. Field work and data collection assistance was provided by Brock Emmert (The Watershed Institute); William Beck (Kansas Forest Service); and Ed Carney, Diana Lehmann, Clint Goodrich, Kevin Olson, Jeff Scott, Shawn Weber, Elizabeth Smith, and [1]Robert Angelo (KDHE). The processing of environmental samples and analytical services was provided by Eugenia Akers, Marie Jean Ayala, Jon Brady, Mary Clippinger, Jim Cook, Julie Delong, Connie Ellis, Mike Johannes, Hal Kennedy, Terri Lammers, Kevin Neal, Elizabeth Paris, Ron Peterson, Emily Reichart, Nancy Roberts, Lindsey Simpson, Mary Trickett, Emma Wanamaker (KDHE, Kansas Health and Environment Laboratories). Informative discussion and insight related to gauging the level of interest of a varied group of landowners and stakeholders to this project was provided by Mike Beam (Kansas Livestock Association); Steve Swaffar (Kansas Farm Bureau); Kerry Wedel (KDHE); Paul Liechti (Kansas Biological Survey); Eric Johnson (Kansas Department of Wildlife, Parks, and Tourism); Susan Metzger and Debra Baker (Kansas Water Office); as well as stakeholders of the Neosho Headwaters/John Redmond Reservoir and the Grouse-Silver Creek Watershed WRAPS Projects. Cathy Colglazier (KDHE) provided administrative support in the preparation and delivery of quarterly reports and the tracking of project expenditures. Finally, Robert Angelo, in whom the vision for this project began, provided a number of helpful comments and observations in a comprehensive review of this report.

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1. Introduction

This report was prepared by the Kansas Department of Health and Environment (KDHE) and submitted to the United States Environmental Protection Agency (EPA) in fulfillment of the terms of a Healthy Watershed Initiative Demonstration Grant, awarded under Section 104(b)(3) of the Clean Water Act. It builds upon previous efforts to identify, monitor, and adequately protect and conserve minimally altered watersheds and stream reaches in Kansas (Angelo et al. 2010). These resources play a crucial role in modern water pollution control programs, in that knowledge obtained through their study is applied in the characterization of the baseline ecological condition, the development of surface water quality criteria, the identification of water quality-impaired streams, the performance of statewide water quality assessments, and the formulation of restoration goals for environmentally degraded water bodies.

1.1 Overview of Previous Efforts

In July 2009, KDHE began to assemble a large suite of existing geographical databases, each relevant to the identification and study of reference ecosystems. A watershed disturbance index was developed using these databases and applied in the evaluation and ranking the state's nearly 100,000 (NHDPlus) catchments and corresponding stream reaches. Predictive computer models were developed relating watershed disturbance scores to the prevailing diversity of native fishes, freshwater mussels, and aquatic insects. Results were summarized and interpreted for the state as a whole and for five quantitative ecoregions delineated as part of the study.

Disturbance scores varied significantly among quantitative ecoregions, but the lowest (best) scores in all ecoregions were associated with the headwater catchments of large grassland areas. Watersheds with exceptionally low scores were concentrated primarily in the Flint Hills, Smoky Hills, and Gypsum Hills/High Plains and a few isolated areas in northwestern and extreme southwestern Kansas. Heavily disturbed watersheds were prevalent in far-eastern Kansas and in the central and southwestern portions of the state. Geographical location and stream size were significant predictors of species richness. However, regression models incorporating disturbance score as an independent variable also indicated that the number of species inhabiting a given stream tended to decline as the level of human activity in the surrounding catchment increased.

Governmental planning documents, statistical abstracts, permit applications, unpublished databases, and published and unpublished reports were examined for environmental and societal trends potentially bearing on the integrity of least disturbed watersheds and high quality (heritage) stream reaches in Kansas. Based on this assessment, a number of stressors (e.g., prevailing land and water use practices/patterns, non-native species infestations) were found to threaten the quality of these watersheds and stream reaches. Several measures were recommended for protecting and maintaining the physical, chemical, and biological condition of these exceptional waters.

1.2 Scope of current report

This report is a follow-up study in the identification and conservation of reference stream reaches in Kansas. The first part of this document provides a general overview of the methods used to characterize the landscape features, biological, surface water chemistry, and streamflow conditions for the six heritage streams. The second part summarizes the results obtained during the project. The remainder of this document discusses several measures considered to protect and maintain the physical, chemical, and biological condition of these exceptional waters. These measures include (1) enhanced monitoring of heritage streams; (2) designation of heritage streams as either exceptional state waters or outstanding national resource waters; (3) development of total maximum daily loads (TMDLs) for selected heritage streams using the antidegradation provision of the Kansas surface water quality standards; (4) establishment of in-stream flow protection (minimum desirable streamflows) for heritage streams pursuant to State water appropriation law; (5) wider utilization of conservation easements and other incentive-based programs for protecting and improving the condition of these waters; (6) incorporation of heritage streams in watershed management plans developed pursuant to the Kansas watershed restoration and protection strategy (WRAPS); and (7) inclusion of the above goals in the *Kansas Water Plan*, the state's overarching water resource planning document.

2. Methods

2.1 Reconnaissance and selection of heritage-caliber streams

The following streams were selected initially for inclusion in the heritage stream project based largely on their calculated watershed disturbance scores (see Angelo et al. 2010): Fourmile Creek (Morris Co.); Grouse Creek (Cowley Co.); Nescatunga Creek (Comanche Co.); Rock Creek (Chase Co.); Sevenmile Creek (Riley Co.); and Thompson Creek (Kiowa Co.). Field reconnaissance work was completed in early 2011 for all six streams. Landowner permission was secured for five of the six streams. KDHE personnel were unable to secure landowner permission to access Rock Creek. Therefore, Illinois Creek (Wabaunsee Co.), a stream with similar disturbance and watershed characteristics, was selected as a replacement for Rock Creek, and landowner permission to access the stream was secured.

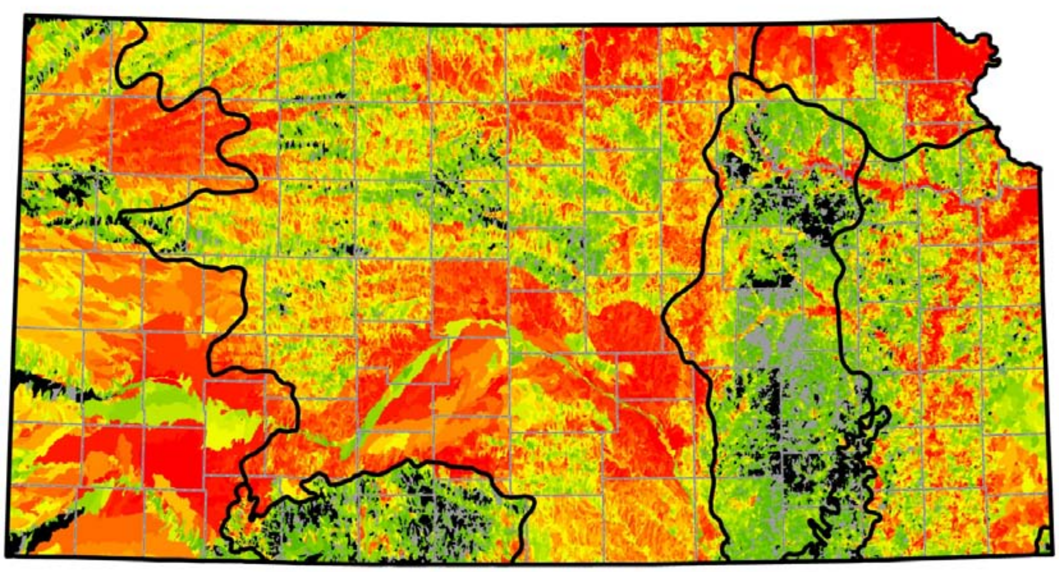

Figure 1. Anthropogenic disturbance map developed using the watershed disturbance method (Angelo et al. 2010). Black lines depict Level III ecoregions developed by previous researchers using best professional judgment (e.g., Chapman et al. 2001).

Figure 1 above, presents a map illustrating the calculated level of disturbance in watersheds across the state, according to analysis conducted (and subsequently refined) by KDHE (Angelo et al. 2010). Watersheds are mapped in different colors, ranging from green (least disturbed condition) to red (most disturbed condition) and watersheds in the 90^{th} ('best'10%) and 95^{th} ('best' 5%) percentiles are mapped in grey and black, respectively. Overall, the Flint Hills region of Kansas represents the largest area of somewhat contiguous least disturbed land in the state. Similarly, the Gypsum Hills/High Plains represents a large area of least disturbed land. Within these regions, there are concentrated areas of very high quality watersheds (i.e. groups of smaller catchments in the 10^{th} and 5^{th} percentiles). These areas were the focus of field reconnaissance procedures and were the areas from which the final target watersheds and their associated waterways were selected.

Table 1 presents a listing of streams that performed very well with regard to the calculated disturbance index. Several streams in both the Flint Hills and Gypsum Hills/High Plains geographic regions were targeted for computer-assisted desktop reconnaissance as well as more rigorous field based evaluations. All of these streams are in the top rankings of streams statewide: however, there were factors discovered during the field surveys that prevented some of them from being used in this particular study. Examples of disturbances found during field reconnaissance that were not captured in the desktop analysis included cattle overwintering areas near the stream, recently constructed or undocumented watershed impoundments, in-stream barriers such as low head dams or perched culverts and bridges, and historical channelization of the stream channel and/or smaller rivulet tributaries. Whereas the small Flint Hills streams are better able to maintain base flow due to spring and groundwater inputs, several of the smaller streams in the Gypsum Hills region were eliminated because of concern over the potential lack of permanent flow in this slightly more arid region. In the end, six streams were chosen for monitoring activities, they are: Fourmile Creek (Morris Co.), upper Grouse Creek (Cowley Co.), Illinois Creek (Wabaunsee Co.), Sevenmile Creek (Riley Co.), Nescatunga Creek (Comanche Co.), and Thompson Creek (Kiowa Co.).

Table 1. Streams evaluated during the initial stage of site selection. Streams shown in bold are those that were selected, after field reconnaissance, for monitoring activities.

Flint Hills streams		Gypsum Hills/High Plains streams	
Coyne Branch (Chase Co.)	Kuenzli Creek (Wabaunsee Co.)	Bear Creek (Barber Co.)	N. Br. Medicine Lodge River (Kiowa Co.)
Dodds Creek (Morris Co.)	Nehring Creek (Wabaunsee Co.)	Big Sandy Creek (Barber Co.)	Mustang Creek (Comanche Co.)
Fourmile Creek (Morris Co.)	Rock Creek (Chase Co.)	Cedar Creek (Barber Co.)	**Nescatunga Creek** (Comanche Co.)
Grouse Creek (Cowley Co.)	Schaffer Creek (Chase Co.)	Hackberry Creek (Barber Co.)	Red Creek (Comanche Co.)
Humboldt Creek (Geary Co.)	School Creek (Morris Co.)	Indian Creek (Comanche Co.)	**Thompson Creek** (Kiowa Co.)
Illinois Creek (Wabaunsee Co.)	**Sevenmile Creek** (Riley Co.)	Little Bear Creek (Barber Co.)	

2.2. Biological sample collection and analysis

During 2011, Kansas and much of the southern plains suffered the worst drought conditions seen in decades. Many reports compared the drought to conditions experienced during the 1930's. Stream levels were at historical lows and many streams in the region were pooled or, in other instances, completely dry. As water levels decrease and streams pool, the biota is crowded out of the preferred habitat and into marginal areas. Invertebrate richness and diversity suffer as a result of a lack of suitable habitat, rising water temperatures and declining dissolved oxygen levels, as well as from increased predation resulting from crowding. During the first round of biological sampling in 2011, five of the six streams (all except Thompson Creek) were experiencing these deteriorating conditions, resulting in invertebrate diversity lower than usually found in reference caliber streams. The first round of biological assessments in 2011 was conducted as follows:

Fourmile Creek: July 14
Grouse Creek: July 25 (replicate samples)
Illinois Creek: July 26
Thompson Creek: August 1
Nescatunga Creek: August 1
Sevenmile Creek: August 16

Water levels remained low throughout the remainder of the sampling season, so it was decided to postpone the second site assessment until more representative conditions returned. In addition to the lack of water, landowner permission was lost at two streams (Thompson and Illinois creeks) late in 2011 preventing any further activity at these sites.

An attempt was made to conduct a second biological assessment at the remaining sites in 2012, despite continuing drought conditions. Biological monitoring was conducted at upper Grouse and Fourmile creeks on March 12, 2012, and at Nescatunga Creek on June 26, 2012. Data obtained in previous years from Thompson, Illinois, and Nescatunga creeks also were considered in this study (see Table 3).

Quantitative macroinvertebrate samples were obtained using a time-based "equal effort" method essentially equivalent to EPA's Rapid Bioassessment Protocol III. During each sampling event, macroinvertebrate specimens were collected by two individuals using D-frame nets and forceps. Sampling was conducted for thirty minutes or a combined duration of one person-hour. An effort was made to sample all macrohabitats (riffles, pools, runs) and microhabitats present at the site within the allotted time period. Specimens of a given taxon were collected in numbers roughly proportional to their relative abundance in the stream community. All biological samples were processed according to established KDHE protocols and samples were identified in-house to the highest practical level of taxonomic resolution (generally genus or genus/species). These data were entered into KDHE's PENV Oracle database.

2.3. Stream chemistry sample collection and analysis

To assist in the interpretation of selected heritage stream water chemistry data sets, KDHE's ambient stream chemistry monitoring program data (2002 through August 2012) for some 300 sites were used in this assessment. In addition, Rock, Sevenmile, and upper Grouse creeks were added to the monitoring network in 2011 to accommodate the goals of the heritage stream initiative. In contrast, Fourmile, Illinois, Nescatunga, and Thompson creeks have been monitored as part of the statewide stream chemistry network for many years. Rock Creek was reassigned to an inactive status at the end of December 2011 and subsequently not evaluated in this study.

Quarterly water quality sampling activities commenced in 2011 but on numerous occasions a lack of flowing water prevented the procurement of representative samples from five of the six candidate heritage streams, the only exception being Thompson Creek. All sampling and analytical methods complied with approved stream chemistry monitoring program quality assurance management procedures (KDHE 2007b). Chemical parameters included total suspended solids (TSS), inorganic nutrients (total nitrogen and total phosphorus), total recoverable trace metals (copper, lead, and zinc), atrazine, and the microbiological parameter, *Escherichia coli (E. coli*). All duplicate samples were averaged and monitoring stations having less than five data points for the selected chemical parameters were excluded from this analysis. Reservoir outfall stations were not included.

Descriptive statistics (means, standard deviations, and percentiles) for data sets containing some censored observations were estimated for the combined quantitative ecoregions and stream flow categories applying semi-parametric and nonparametric methods, such as robust regression on order statistics, and Kaplan-Meier methods (Helsel 2005, 2012). The temporal trends derived from Thompson Creek's nitrate data were evaluated using the nonparametric seasonal Kendall test (Helsel 2005, 2012).

Figure 2 depicts the distribution of network monitoring stations partitioned by Kansas quantitative ecoregions developed by KDHE (Angelo et al. 2010). Additionally, stations were partitioned by median flow estimates for Kansas stream segments developed by United States Geological Survey (USGS) (Perry et al. 2002). Three groups categorized the estimated median flows expressed as cubic feet per second (cfs): F1 (< 10 cfs), F2 (10 – 100 cfs), F3 (>100 cfs).

2.4 Flow measurements

During the course of this study, KDHE procured two streamflow measurement devices: the SonTek FlowTracker acoustic Doppler velocimeter and SonTek M9 RiverSurveyor acoustic Doppler current profiler. Standard operating procedures were prepared for conducting real-time streamflow measurements using these devices and staff was trained in the proper use and care of these instruments. During the study, an effort was made to obtain streamflow data for each of the six selected streams. Due to the exceptional drought that occurred across Kansas in 2011 and 2012, many streams across the state were reduced to very low water levels. The six streams selected for this study were no different, with several of them being pooled or, in one case, completely dry during a scheduled flow data collection attempt.

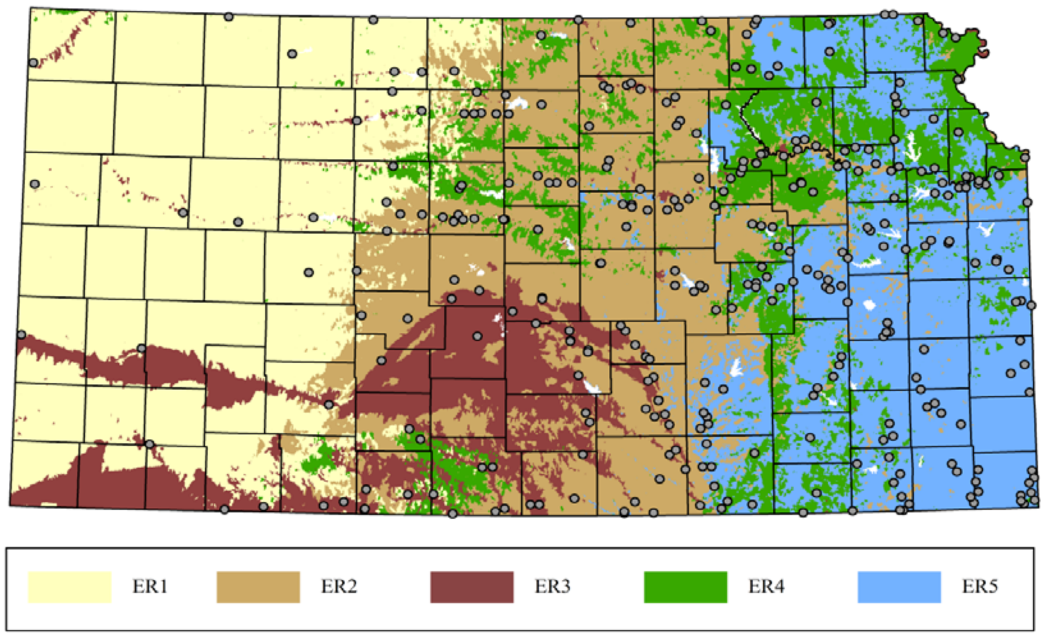

Figure 2. Kansas quantitative ecoregional map with network stream chemistry monitoring stations. White polygons depict major reservoirs and wetland complexes; black lines depict county boundaries.

2.5 Heritage stream geomorphological assessment

To assess the geomorphologic features of the six heritage streams, KDHE contracted with The Watershed Institute to complete fluvial geomorphological surveys for specific stream reaches within each watershed using the Rosgen classification system. KDHE requested the geomorphic survey data be of sufficient scope and quality to accommodate a Level 1 assessment (geomorphic characterization), a Level 2 assessment (morphological description), and an abbreviated Level 3 assessment (stream condition assessment involving additional pool measurements, lateral channel stability analysis, and, in gravelly bottomed streams, the performance of riffle pool counts and point bar particle size analyses). Appendix B contains the fluvial geomorphology report that provides detailed information on data collection background and methodology, and summarizes the findings from each of the six heritage stream survey sites.

2.6 Recognition of stream heritage stature

The selected heritage streams will be nominated for designation as exceptional state waters or outstanding national resource waters (ONRW), if not already designated as such. This action will coincide with the next formal review/revision of the Kansas surface water quality standards and ultimately will require public review and EPA approval. Under the antidegradation provisions of the standards, classified waters are partitioned into different protective tiers (KDHE 2010d). The highest tier (Tier 3) includes ONRWs. This designation generally is reserved for aquatic ecosystems located in large parks, game preserves, and wildlife refuges.

New or expanded discharges of wastewater and other anthropogenic disturbances that could permanently degrade water quality are prohibited in ONRWs. Exceptional state waters (Tier 2.5; see section 4.4.1, this report) exhibit "remarkable quality" or "significant recreational or ecological value" and likewise are provided an enhanced level of protection under the standards. Although new or expanded discharges theoretically could be authorized by KDHE, permit limits would provide in all cases for the maintenance and protection of existing water quality and the designated uses of the streams.

2.7 Development of protection-based TMDLs

KDHE will develop protection-based TMDLs for the selected heritage streams based on the antidegradation considerations presented in paragraph 2.6, above. These TMDLs will establish limits on allowable loadings of phosphorus and total suspended solids and will protect and maintain existing water quality with respect to these parameters. This effort is expected to create an opportunity for mitigation in the face of increasing watershed development pressures; i.e., the TMDLs will provide the selected streams and associated watersheds enhanced protection against further declines in water quality, while accommodating development in other, less environmentally sensitive locations.

2.8 *Establishment of in-stream flow protection*

Reference and heritage quality stream reaches are threatened by many factors falling outside the general purview of the Clean Water Act and the regulatory jurisdiction of KDHE. For example, dewatering of some reaches could result from the granting of water appropriation permits under the authority of the Chief Engineer, Division of Water Resources (DWR), Kansas Department of Agriculture. KDHE have met with representatives from DWR and other state agencies to evaluate streamflow management options applicable to water bodies included in this study. One such option, the establishment of minimum desirable streamflows, would reduce the potential for future changes in the hydrology of reference streams by discouraging the development of large reservoirs, watershed impoundments, and water diversions within the contributing catchments.

2.9 Interagency planning and cooperation enhancement

Several governmental agencies administer programs that promote the voluntary adoption of agricultural best management practices and/or the restoration and protection of riparian areas and adjacent surface waters. Some of these programs also offer financial incentives to participating landowners. To date, available funding has been used primarily to improve conditions in heavily degraded watersheds. As part of this project, KDHE personnel met with representatives from the State Conservation Commission (SCC), the Kansas Water Office (KWO), the Kansas Forestry Service, the Kansas Department of Wildlife, Parks and Tourism (KDWP&T), the Natural Resources Conservation Service, and the Farm Service Agency to encourage the application of a portion of these funds in high quality watersheds containing reference streams. KDHE also met with representatives from prominent conservation organizations (Kansas Chapter of the Nature Conservancy, State Association of Kansas Watersheds, Kansas Alliance for Wetlands and Streams) and farm groups (Kansas Livestock Association, Kansas Farm Bureau) to gauge their level of interest in reference stream protection/conservation and to explore opportunities for future collaboration.

WRAPS groups have been established throughout much of Kansas and are now positioned to include reference streams in their watershed planning and protection efforts. These groups were encouraged by KDHE to incorporate reference stream considerations in their nine-element watershed management plans during the Kansas WRAPS work group meeting early in 2011. KDHE met individually with representatives of the Grouse-Silver Creek Watershed WRAPS, the Neosho Headwater WRAPS, and the Cottonwood River WRAPS to discuss the implications and benefits of designating streams within their respective WRAPS boundaries as heritage streams. As appropriate, watershed districts also will be encouraged to incorporate similar considerations in their general plans (i.e., alongside their traditional plans for watershed development).

The conservation and protection of reference ecosystems should be included among the shared goals of all natural resource agencies in Kansas. The next revision of the *Kansas Water Plan* seemingly would provide an ideal opportunity for articulating these shared goals and obtaining public feedback. Pursuant to K.S.A. 82a-901 et seq., this planning document establishes a multi-agency framework for addressing water-related issues within the state. Responsibility for its preparation and maintenance rests chiefly with the KWO. Therefore, KDHE will work with KWO during the upcoming year to incorporate changes in the Kansas Water Plan that underscore the ecological and regulatory importance of reference streams and facilitate the long-term protection/conservation of these exceptional aquatic systems.

3. Quantitative results

3.1 Watershed disturbance scores for six selected candidate heritage streams

Across Kansas, the calculated watershed disturbance scores (Angelo et al. 2010) ranged from 0.000 to 0.425 for all catchments. These values were standardized to range from 0.00 to 100.00, and both the original and standardized values are presented in Table 2 for the six selected watersheds. Table 2 also presents the percentiles in which the six streams are located. This was calculated both statewide and within ecoregions.

Table 2. Watershed disturbance score summary for the six candidate heritage streams.

	Quantitative	Watershed Disturbance Score		Percentile	
Stream name	Ecoregion	Original	Standardized	Statewide	Ecoregion
Fourmile Creek	4	0.049	11.54	20.2	49.3
Sevenmile Creek	4	0.033	7.87	7.1	19.8
Illinois Creek	4	0.045	10.49	16.4	41.8
Grouse Creek	5	0.065	15.23	32.8	36.3
Nescatunga Creek	3	0.046	10.73	17.3	22.6
Thompson Creek	3	0.048	11.29	19.3	24.9

3.2 Biological attributes for six candidate heritage streams

3.2.1. Macroinvertebrate community metrics

Community metrics were calculated for each biological sample in order to interpret the data in terms of biotic condition (*i.e.,* integrity). Specifically, the selected metrics assessed the response of macroinvertebrate communities to oxygen demanding organic pollutants and nutrient enrichment. They included 1) Macroinvertebrate Biotic Index (MBI), a family level tolerance based biotic index (Davenport and Kelly 1983), 2) Kansas Biotic Index (KBI-NO), a genus/species level tolerance-based biotic index (Huggins and Moffett 1988), 3) Ephemeroptera, Plecoptera, and Trichoptera Index (EPT), which is simply a count of the number of EPT taxa present, and 4) EPT abundance (EPT-ABUND), which is the percentage of individual organisms in a sample that belong to EPT. Raw scores for each of these metrics are presented in Table 3.

Table 3. Metric scores for all samples at the six selected streams. A lower score represents higher quality in MBI and KBI-NO, whereas a higher score indicates higher quality in EPT and EPT-ABUND.

Stream Name	Sample Date	MBI	KBI-NO	EPT	EPT-ABUND (%)
Fourmile Creek	07/14/2011	4.56	2.58	16	49
Fourmile Creek	03/12/2012	5.23	3.09	4	24
Sevenmile Creek	07/25/2011	4.52	2.77	11	58
Illinois Creek	09/09/2002	5.74	3.15	5	11
Illinois Creek	08/08/2003	4.78	3.09	8	38
Illinois Creek	09/24/2004	4.4	2.69	9	73
Illinois Creek	07/14/2005	4.74	2.96	19	62
Illinois Creek	08/24/2006	6.29	3.11	4	8
Illinois Creek	06/24/2008	5.06	2.65	10	44
Illinois Creek	08/02/2010	4.67	2.83	10	56
Illinois Creek	07/26/2011	5.67	3.09	10	40
Grouse Creek	07/25/2011	5.59	2.65	10	15
Grouse Creek	03/12/2012	5.48	3.2	5	10
Nescatunga Creek	07/30/2007	4.01	2.79	8	50
Nescatunga Creek	05/27/2009	3.58	2.47	10	71
Nescatunga Creek	08/02/2011	6.25	2.73	1	2
Nescatunga Creek	06/26/2012	5.06	2.9	5	19
Thompson Creek	06/20/2000	4.26	2.62	12	60
Thompson Creek	07/11/2001	3.98	2.23	14	57
Thompson Creek	09/27/2004	4.14	2.25	11	69
Thompson Creek	11/02/2005	4.40	2.55	10	72
Thompson Creek	07/12/2006	4.21	2.49	13	68
Thompson Creek	05/12/2008	3.80	2.31	11	50
Thompson Creek	05/19/2010	3.34	2.43	8	91
Thompson Creek	08/01/2011	4.04	2.62	9	76

Metric scores for the six selected streams were compared to two separate datasets compiled by KDHE. First, comparisons were made to the last 10 years of data obtained through the statewide stream biological monitoring program (SBMP). The SBMP examines the structural attributes of aquatic macroinvertebrate assemblages from nearly 200 targeted monitoring sites throughout most of the state. Samples normally are obtained from 60–65 sites each year, including 45 core stations and 15–20 rotational stations. These sites are typically larger streams and rivers that serve as integrator sites for large watersheds. Approximately 50 percent of these sites are located on fifth or sixth order streams and 80 percent are located on fourth to seventh order streams (KDHE 2007a).

Second, because the six selected streams are all smaller systems and small systems might not be expected to maintain the same high numbers of taxa as large systems (*i.e.,* SBMP sites), the resulting metrics also were compared to a population of approximately 215 sites sampled within the statewide stream probabilistic monitoring program (SPMP) during 2006–2010. SPMP sites are chosen at random throughout the state, so comparing the reference sites to the random sites should show how the selected streams stack up against "typical" streams distributed across the state. Naturally, a greater proportion of these streams are in the smaller (first to third order) category (KDHE 2007c).

The two comparisons are presented in Table 4 (SBMP) and Table 5 (SPMP). Percentiles for each of the four metrics also are averaged to give an idea of the overall ranking of a particular sample. Average scores greater than 0.75 (i.e., top 25th %; scores for MBI and KBI were inverted) are shown in bold.

Table 4. Percentiles compared to Stream Biological Monitoring Program.

Stream Name	Sample Date	MBI Percentile	KBI-NO Percentile	EPT Percentile	EPT-ABUND Percentile	Average Percentile
Fourmile Creek	7/14/2011	0.49	0.71	0.72	0.47	0.59
Fourmile Creek	3/12/2012	0.13	0.08	0.02	0.10	0.08
Sevenmile Creek	7/25/2011	0.53	0.40	0.31	0.66	0.47
Illinois Creek	9/9/2002	0.05	0.05	0.03	0.03	0.04
Illinois Creek	8/8/2003	0.35	0.08	0.13	0.26	0.20
Illinois Creek	9/24/2004	0.64	0.55	0.18	**0.91**	0.57
Illinois Creek	7/14/2005	0.38	0.14	**0.90**	0.73	0.54
Illinois Creek	8/24/2006	0.01	0.07	0.02	0.01	0.03
Illinois Creek	6/24/2008	0.18	0.61	0.24	0.39	0.36
Illinois Creek	8/2/2010	0.41	0.29	0.24	0.61	0.39
Illinois Creek	7/26/2011	0.06	0.08	0.24	0.30	0.17
Grouse Creek	7/25/2011	0.07	0.61	0.24	0.04	0.24
Grouse Creek	3/12/2012	0.09	0.04	0.03	0.03	0.04
Nescatunga Creek	7/30/2007	**0.93**	0.36	0.13	0.50	0.48
Nescatunga Creek	5/27/2009	**1.00**	**0.83**	0.27	**0.88**	**0.75**
Nescatunga Creek	8/2/2011	0.01	0.48	0.00	0.01	0.12
Nescatunga Creek	6/26/2012	0.18	0.19	0.03	0.07	0.12
Thompson Creek	6/20/2000	**0.77**	0.66	0.39	0.70	0.63
Thompson Creek	7/11/2001	**0.94**	**0.98**	0.54	0.65	**0.78**
Thompson Creek	9/27/2004	**0.86**	**0.98**	0.31	**0.85**	**0.75**
Thompson Creek	11/2/2005	0.64	**0.75**	0.24	**0.90**	0.63
Thompson Creek	7/12/2006	**0.81**	**0.81**	0.46	**0.84**	**0.73**
Thompson Creek	5/12/2008	**0.97**	**0.96**	0.31	0.50	0.68
Thompson Creek	5/19/2010	**1.00**	**0.87**	0.13	**1.00**	**0.75**
Thompson Creek	8/1/2011	**0.92**	0.66	0.18	**0.94**	0.67

Several of the heritage streams fared better when compared to what might be considered the average Kansas stream (SPMP). All streams but Grouse Creek had at least one sample that put them in the top 25 percent of metrics when compared to SPMP samples. Fourmile Creek's first sample scored very well, whereas the second sample was not as good. This could have been due to the second sample being an early spring sample as well as being a sample following a very dry summer and fall. Sevenmile Creek was pooled at the time of sampling, yet it still scored within the top 25 percent of average metrics. Illinois Creek only had one sample that put it above the 75th percentile, even though Illinois Creek has exceptionally good water quality. Much of the sample reach here is bedrock, which isn't the best habitat for EPT diversity. In years when Nescatunga Creek remained flowing, it scored very well with some average metric scores putting it in the top 10 percent of streams. Thompson Creek had the best scores of any of the selected streams, consistently placing in the top 10 to 15 percent of metrics.

Table 5. Percentiles compared to Stream Probabilistic Monitoring Program.

Stream Name	Sample Date	MBI Percentile	KBI-NO Percentile	EPT Percentile	EPT-ABUND Percentile	Average Percentile
Fourmile Creek	7/14/2011	0.65	**0.85**	**0.98**	**0.77**	**0.81**
Fourmile Creek	3/12/2012	0.31	0.31	0.33	0.49	0.36
Sevenmile Creek	7/25/2011	0.68	0.69	**0.83**	**0.87**	**0.77**
Illinois Creek	9/9/2002	0.15	0.21	0.46	0.32	0.28
Illinois Creek	8/8/2003	0.52	0.31	0.69	0.66	0.54
Illinois Creek	9/24/2004	0.73	**0.78**	0.73	**0.97**	**0.80**
Illinois Creek	7/14/2005	0.55	0.47	**1.00**	**0.92**	0.73
Illinois Creek	8/24/2006	0.08	0.27	0.33	0.25	0.23
Illinois Creek	6/24/2008	0.40	**0.81**	**0.78**	0.74	0.68
Illinois Creek	8/2/2010	0.59	0.61	**0.78**	**0.85**	0.71
Illinois Creek	7/26/2011	0.18	0.31	**0.78**	0.67	0.48
Grouse Creek	7/25/2011	0.20	**0.81**	**0.78**	0.41	0.55
Grouse Creek	3/12/2012	0.23	0.16	0.46	0.30	0.29
Nescatunga Creek	7/30/2007	**0.91**	0.67	0.69	**0.78**	**0.76**
Nescatunga Creek	5/27/2009	**0.99**	**0.93**	**0.78**	**0.95**	**0.91**
Nescatunga Creek	8/2/2011	0.09	0.72	0.06	0.10	0.24
Nescatunga Creek	6/26/2012	0.40	0.54	0.46	0.43	0.45
Thompson Creek	6/20/2000	**0.80**	**0.83**	**0.89**	**0.88**	**0.85**
Thompson Creek	7/11/2001	**0.93**	**0.99**	**0.96**	**0.87**	**0.94**
Thompson Creek	9/27/2004	**0.85**	**0.99**	**0.83**	**0.95**	**0.90**
Thompson Creek	11/2/2005	0.73	**0.88**	**0.78**	**0.95**	**0.84**
Thompson Creek	7/12/2006	**0.83**	**0.91**	**0.93**	**0.94**	**0.90**
Thompson Creek	5/12/2008	**0.97**	**0.98**	**0.83**	**0.78**	**0.89**
Thompson Creek	5/19/2010	**0.99**	**0.94**	0.69	**1.00**	**0.91**
Thompson Creek	8/1/2011	**0.90**	**0.83**	0.73	**0.98**	**0.86**

3.3 Stream chemistry attributes for six candidate heritage streams

3.3.1. Total suspended solids

Total suspended solids (TSS) refers to the measurement of particles suspended in water. The solids in a water sample are gravimetrically determined using a glass fiber filter and weighing retained residue after drying. Water with high TSS is largely attributable to erosion of crop soils; other factors include stream channelization, lack of riparian zone, bank instability, construction and maintenance of roadways and bridges, expansion of utility infrastructure, and ongoing urban/residential development. Sporadic and ongoing stream siltation can affect the stream's ability to support a diverse aquatic life due to the smothering effect on aquatic insect habitats, freshwater mussel beds and fish spawning areas. Historically, KDHE has used a guideline value of 100 mg/L for aquatic life support for beneficial use impairments of streams. Table 6 compares TSS data obtained from the state's five quantitative ecoregions and to that obtained from corresponding heritage streams sites. All heritage stream sites demonstrate median concentrations of TSS at or just above the laboratory minimum quantification limit (MQL) of 10 milligram per liter (mg/L).

Table 6. Total suspended solids data summary. KDHE's strategy for dealing with nondetected (ND) data involves the use of semi-parametric and nonparametric methods, such as robust regression on order statistics and Kaplan-Meier (Helsel 2005, 2012). In cases where the summary statistics reflect mostly ND data (> 80%), a less than (<) sign is used to indicate that the value shown is an upper estimate of the actual concentration. All available data for the period (2002-2012) were applied in this analysis. N = number of samples; ND = number of nondetect samples; ER3, ER4 and ER5 = Kansas quantitative ecoregions; F1, F2, and F3 = median flow category (< 10, 10-100, and > 100 cfs, respectively).

Variable		N	ND	Mean	Min.	Max.	SD.	Percentiles		
								25th	50th	75th
TSS(mg/L)										
ER3F1:	Nescatunga	17	6	20	< 10	98	22	< 10	11	18
	Thompson	54	13	13	< 10	46	9	< 10	12	18
	All other sites	89	5	52	< 10	234	50	16	33	62
ER4F1:	Illinois	50	43	< 10	< 10	14	4	< 10	< 10	< 10
	Sevenmile*	6	3	15	< 10	24	7	< 10	13	23
	All other sites	454	179	45	< 10	3315	184	< 10	11	31
ER4F2:	Fourmile	17	6	18	< 10	92	20	< 10	11	18
	All other sites	561	90	77	< 10	1780	182	12	26	61
ER5F2:	Grouse*	6	3	11	< 10	22	8	< 10	< 10	20
	All other sites	1633	303	69	< 10	5530	232	10	21	44

* Only 2011-2012 data

3.3.2. Nutrients

The major limiting nutrients in surface water are total nitrogen (TN) and total phosphorus (TP). TN is a measure of the sum of the nitrate (N), nitrite (N), and organic bound nitrogen determined by total Kjeldahl nitrogen analyses, which measures both ammonia and organic nitrogen. TP is a measure of both inorganic and organic forms of phosphorus. Phosphorus can be present in dissolved or particulate form. Elevated concentrations of nutrients may cause excessive algal growth, thereby contributing to enriched conditions in surface waters resulting in taste and odor problems and fish kills. Sources include sewage treatment plants, factories, urban/residential runoff, and agricultural runoff. Most minimally impacted watersheds in Kansas should have median nutrient concentrations below 1.2 mg/L of TN and 0.07 mg/L of TP, respectively (KDHE unpublished data). All candidate heritage sites in this study have median nutrient concentrations below the aforementioned thresholds except for Thompson Creek and Sevenmile Creek (see Table 7 and text below). TN concentration was estimated by summing Kjeldahl nitrogen (MQL = 0.10), nitrate (MQL = 0.10), and nitrite (MQL = 0.05) values. Concentrations of Kjeldahl nitrogen and nitrate below the MQL were set to one-half the MQL and concentrations of nitrite below the MQL to zero. The less than "<" sign was carried forward in the analysis if both Kjeldahl nitrogen and nitrate were reported as nondetects (104 cases: 30 stations) and treated as censored data. The laboratory MQL for total phosphorus (TP) was 0.02 mg/L.

Table 7. Nutrient data summary. KDHE's strategy for dealing with nondetected (ND) data involves the use of semi-parametric and nonparametric methods, such as robust regression on order statistics and Kaplan-Meier (Helsel 2005, 2012). In cases where the summary statistics reflect mostly ND data (> 80%), a less than (<) sign is used to indicate that the value shown is an upper estimate of the actual concentration. All available data for the period (2002-2012) were applied in this analysis. N = number of samples; ND = number of nondetect samples; ER3, ER4 and ER5 = Kansas quantitative ecoregions; F1, F2, and F3 = median flow category (< 10, 10-100, and > 100 cfs, respectively).

Variable		N	ND	Mean	Min.	Max.	SD.	Percentiles		
								25th	50th	75th
TN (mg/L)										
ER3F1:	Nescatunga	17	0	0.47	0.27	0.95	0.19	0.33	0.43	0.53
	Thompson	54	0	2.44	1.78	3.68	0.39	2.09	2.47	2.70
	All other sites	89	0	1.58	0.25	3.59	0.76	1.09	1.55	2.12
ER4F1:	Illinois	50	19	0.25	< 0.10	1.11	0.21	< 0.10	0.20	0.29
	Sevenmile*	6	0	0.47	0.21	1.01	0.31	0.27	0.37	0.69
	All other sites	454	30	1.81	< 0.10	15.66	2.15	0.44	1.08	2.15
ER4F2:	Fourmile	17	1	0.54	< 0.10	1.90	0.42	0.37	0.42	0.55
	All other sites	561	17	1.18	< 0.10	8.64	1.06	0.46	0.89	1.48
ER5F2:	Grouse*	6	0	0.91	0.28	2.83	0.96	0.37	0.73	0.84
	All other sites	1633	37	1.23	< 0.10	9.78	1.11	0.55	0.93	1.45
TP (mg/L)										
ER3F1:	Nescatunga	17	4	0.03	< 0.02	0.12	0.02	0.02	0.03	0.04
	Thompson	54	8	0.03	< 0.02	0.09	0.01	0.03	0.03	0.04
	All other sites	89	0	0.25	0.03	0.91	0.23	0.08	0.15	0.41
ER4F1:	Illinois	50	24	0.03	< 0.02	0.08	0.01	< 0.02	0.02	0.03
	Sevenmile*	6	0	0.16	0.09	0.27	0.07	0.10	0.15	0.20
	All other sites	454	57	0.25	< 0.02	4.57	0.43	0.03	0.10	0.27
ER4F2:	Fourmile	17	1	0.08	< 0.02	0.18	0.03	0.06	0.08	0.09
	All other sites	561	22	0.19	< 0.02	1.77	0.22	0.05	0.11	0.23
ER5F2:	Grouse*	6	0	0.07	0.03	0.12	0.04	0.03	0.08	0.09
	All other sites	1633	40	0.18	< 0.02	2.33	0.21	0.07	0.12	0.20

* Only 2011-2012 data

In the upper portion of the Thompson Creek drainage basin, the application of nitrogen fertilizer for crop production seemingly is having an impact on the downstream water quality, as revealed by persistently elevated nitrate concentrations. Since at least 2002, when KDHE initiated water chemistry monitoring in the watershed, the stream has exhibited a significant upward trend (springtime only, see Table 8) in nitrate concentration (tau = 0.55; p = 0.01, seasonal Kendall's test; Fig. 3). This trend suggests that during ample springtime precipitation, the nitrogen is moving through the soil, leaching into the underlying groundwater, and emerging from natural springs located along the banks of the creek in the mid-section of the watershed. During the other seasons and the year as a whole, nitrate concentrations are exhibiting no significant upward trends, though they remain elevated.

Table 8. Trend evaluations for nitrate concentrations in Thompson Creek, by season.

Season of the year	Observations (2002-2012)	Kendall's tau value	*p*-value
Fall	10	0.156	0.5844
Spring	13	0.551	0.0103
Summer	13	0.000	1.0000
Winter	18	-0.076	0.9395
Combined seasons	54	0.133	0.2109

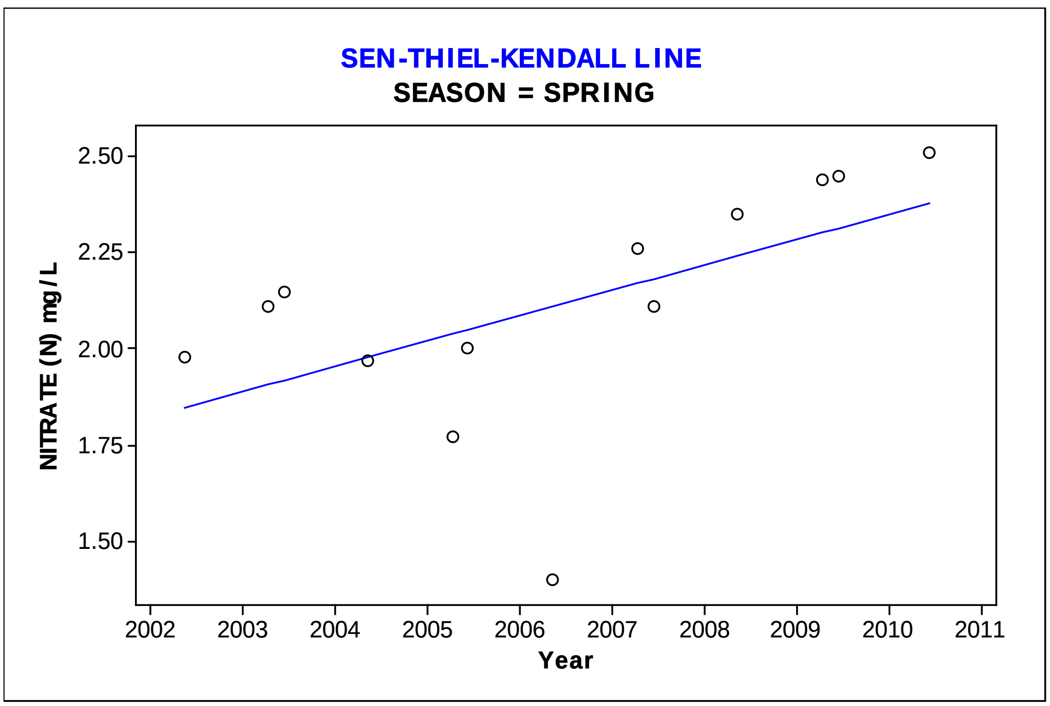

Figure 3. The trend line depicted above is based on nonparametric regression analysis (see text). Water chemistry data are derived from KDHE's long-term stream chemistry monitoring program (unpublished data; see also KDHE 2007b).

Sevenmile Creek shows a modest phosphorus enrichment that cannot be attributed to agricultural practices. Because the majority of the watershed is located on a military base, the elevated phosphorus levels likely stem from the use of phosphorus-containing munitions, and the runoff of residual material into the stream (see ATSDR 1997). Given the limited chemical data set for this stream, more water samples will need to be analyzed to truly characterize the variance in the phosphorus concentrations.

3.3.3 Trace metals

Elevated trace metal (e.g., copper, lead, zinc) concentrations can be acutely and chronically toxic to aquatic life. Impacts are dependent on the hardness of the water and other chemical factors that inhibit the sorption or binding of metals in biological tissues. In southeast Kansas, a former mining region, median metal concentrations can be higher than 6.0 µg/L for copper, 3.0 µg/L for lead, and 6,000 µg/L for zinc. Statewide, total recoverable concentrations of copper, lead, and zinc tend to increase due to siltation during times of storm runoff. For the six selected heritage streams, concentrations of copper, lead, and zinc have not exceeded the applicable (hardness-dependent) water quality criteria for the protection of aquatic life from acute and chronic toxicity. Summary metal statistics are presented in Table 9 and Table 10 for the three Kansas ecoregions and six selected heritage streams. The laboratory MQL for copper, lead, and zinc is 1.0 µg/L.

Table 9. Trace metals data summary. KDHE's strategy for dealing with nondetected (ND) data involves the use of semi-parametric and nonparametric methods, such as robust regression on order statistics and Kaplan-Meier (Helsel 2005, 2012). In cases where the summary statistics reflect mostly ND data (> 80%), a less than (<) sign is used to indicate that the value shown is an upper estimate of the actual concentration. All available data for the period (2002-2012) were applied in this analysis. N = number of samples; ND = number of nondetect samples; µg/L = micrograms per liter; ER3, ER4 and ER5 = Kansas quantitative ecoregions; F1, F2, and F3 = median flow category (< 10, 10-100, and > 100 cfs, respectively).

Variable		N	ND	Mean	Min.	Max.	SD.	Percentiles		
								25^{th}	50^{th}	75th
Copper (µg/L)										
ER3F1:	Nescatunga	17	2	2.1	< 1.0	4.6	1.2	1.1	1.6	3.1
	Thompson	54	26	1.1	< 1.0	5.7	0.6	< 1.0	1.0	1.4
	All other sites	89	0	4.5	1.1	18.8	2.7	2.4	3.8	6.2
ER4F1:	Illinois	50	24	1.5	< 1.0	6.7	1.1	< 1.0	1.0	1.7
	Sevenmile*	6	1	1.6	< 1.0	2.5	0.5	1.3	1.5	1.8
	All other sites	454	48	3.4	< 1.0	39.8	3.1	1.8	2.9	4.1
ER4F2:	Fourmile	17	1	2.3	< 1.0	3.5	0.8	1.6	2.3	2.8
	All other sites	561	6	3.9	< 1.0	27.5	3.5	2.1	2.8	4.3
ER5F2:	Grouse*	6	0	2.2	1.3	3.9	1.0	1.5	1.9	2.7
	All other sites	1633	31	4.0	< 1.0	64.0	4.0	2.2	3.0	4.3

* Only 2011-2012 data

Table 10. Trace metals data summary (continued). KDHE's strategy for dealing with nondetected (ND) data involves the use of semi-parametric and nonparametric methods, such as robust regression on order statistics and Kaplan-Meier (Helsel 2005, 2012). In cases where the summary statistics reflect mostly ND data (> 80%), a less than (<) sign is used to indicate that the value shown is an upper estimate of the actual concentration. All available data for the period (2002-2012) were applied in this analysis. N = number of samples; ND = number of nondetect samples; µg/L = micrograms per liter; ER3, ER4 and ER5 = Kansas quantitative ecoregions; F1, F2, and F3 = median flow category (< 10, 10-100, and > 100 cfs, respectively).

Variable		N	ND	Mean	Min.	Max.	SD.	Percentiles		
								25th	50th	75th
Lead (µg/L)										
ER3F1:	Nescatunga	16	13	< 1.4	< 1.0	7.2	< 1.5	< 1.0	< 1.0	< 1.0
	Thompson	54	53	< 1.0	< 1.0	1.1	<0.01	<1.0	< 1.0	<1 .0
	All other sites	89	24	3.6	< 1.0	21.0	3.7	< 1.0	2.1	4.4
ER4F1:	Illinois	50	47	< 1.0	< 1.0	1.6	< 0.1	< 1.0	< 1.0	< 1.0
	Sevenmile*	6	6	< 1.0	< 1.0	1.3	< 0.1	< 1.0	< 1.0	< 1.0
	All other sites	454	321	1.1	< 1.0	67.7	2.4	< 1.0	< 1.0	1.2
ER4F2:	Fourmile	17	15	< 1.1	< 1.0	2.3	< 0.3	< 1.0	< 1.0	< 1.0
	All other sites	561	321	1.7	< 1.0	56.0	3.7	< 1.0	< 1.0	1.8
ER5F2:	Grouse*	6	5	< 1.0	< 1.0	1.3	< 0.1	< 1.0	< 1.0	< 1.0
	All other sites	1633	915	1.8	< 1.0	77.1	3.6	< 1.0	< 1.0	1.9
Zinc (µg/L)										
ER3F1:	Nescatunga	17	7	5.9	< 5.0	9.0	1.2	< 5.0	5.0	6.0
	Thompson	54	37	< 5.0	< 5.0	16.0	2.7	< 5.0	< 5.0	5.5
	All other sites	89	6	18.1	< 5.0	54.0	12.6	9.0	13.0	26.0
ER4F1:	Illinois	50	31	< 5.0	< 5.0	15.0	2.8	< 5.0	< 5.0	6.0
	Sevenmile*	6	6	< 5.0	< 5.0	< 5.0	0.0	< 5.0	< 5.0	< 5.0
	All other sites	454	132	11.9	< 5.0	272.5	17.2	< 5.0	7.0	14.0
ER4F2:	Fourmile	17	8	7.4	< 5.0	28.0	5.7	< 5.0	5.0	7.5
	All other sites	561	150	11.3	< 5.0	128.0	13.2	< 5.0	7.0	11.0
ER5F2:	Grouse*	6	6	< 5.00	< 5.0	< 5.0	0.0	< 5.0	< 5.0	< 5.0
	All other sites	1633	410	101.7	< 5.0	14456	890.3	< 5.0	7.0	11.0

* Only 2011-2012 data

3.3.4 Atrazine

Atrazine is a chlorotriazine herbicide used to control broadleaf and grassy weeds in major crops. The presence of atrazine and its metabolites in surface water is attributable to widespread agricultural use and runoff, especially during the planting and growing season. Smaller, low order, streams tend to have flashier, higher concentrations as well as chronic baseflow inputs. Research suggests these high-level (pulse) and low-level (extended duration) exposures can cause loss of aquatic plant life that ultimately can affect the benthic insect species richness and total abundance. In the last ten years, KDHE has documented an average atrazine detection rate of thirty-seven percent for monitored stream sites (MQL = 0.3 µg/L). Conversely, only one of the 82 samples taken from the six heritage streams had a detectable concentration above the MQL. Summary statistics for atrazine concentrations are presented in Table 11 for the three represented Kansas ecoregions and six selected heritage streams.

Table 11. Atrazine data summary. KDHE's strategy for dealing with nondetected (ND) data involves the use of semi-parametric and nonparametric methods, such as robust regression on order statistics and Kaplan-Meier (Helsel 2005, 2012). In cases where the summary statistics reflect mostly ND data (> 80%), a less than (<) sign is used to indicate that the value shown is an upper estimate of the actual concentration. All available data for the period (2002-2012) were applied in this analysis. N = number of samples; ND = number of nondetect samples; µg/L = micrograms per liter; ER3, ER4 and ER5 = Kansas quantitative ecoregions; F1, F2, and F3 = median flow category (< 10, 10-100, and > 100 cfs, respectively).

Variable		N	ND	Mean	Min.	Max.	SD.	Percentiles		
								25th	50th	75th
Atrazine (µg/L)										
ER3F1:	Nescatunga	10	10	< 0.3	< 0.3	< 0.3	0.0	< 0.3	< 0.3	< 0.3
	Thompson	26	26	< 0.3	< 0.3	< 0.3	0.0	< 0.3	< 0.3	< 0.3
	All other sites	47	32	0.6	< 0.3	5.6	1.4	< 0.3	< 0.3	0.4
ER4F1:	Illinois	25	25	< 0.3	< 0.3	< 0.3	0.0	< 0.3	< 0.3	< 0.3
	Sevenmile*	5	5	< 0.3	< 0.3	< 0.3	0.0	< 0.3	< 0.3	< 0.3
	All other sites	280	224	< 0.5	< 0.3	26.0	< 1.7	< 0.3	< 0.3	< 0.3
ER4F2:	Fourmile	11	10	< 0.4	< 0.3	0.9	< 0.2	< 0.3	< 0.3	< 0.3
	All other sites	295	198	1.0	< 0.3	17.0	7.4	< 0.3	< 0.3	0.5
ER5F2:	Grouse*	5	5	< 0.3	< 0.3	< 0.3	0.0	< 0.3	< 0.3	< 0.3
	All other sites	920	617	0.7	< 0.3	32.0	3.1	< 0.3	< 0.3	0.5

* Only 2011-2012 data

3.3.5 Escherichia coli

Escherichia coli (E. coli) are usually relatively harmless microorganisms that live in large numbers in the intestinal tract of warm-blooded animals. They aid in the digestion of food and production of certain vitamins. *E. coli* bacteria are passed through the fecal excrement of humans, livestock, and wildlife. These organisms can enter streams or creeks through runoff. While these bacteria may not directly cause disease, high quantities of *E. coli* are indicative of a degraded sanitary condition and suggest the presence of other, disease causing agents. However, while a single stream water quality bacteria sample can provide a good idea of general bacterial quality, it is not enough to legally assess compliance with state surface water quality standards. The water quality standard for primary contact recreation is based on *E. coli* with a numeric criterion predicated on a geometric mean of at least five separate samples collected in separate 24-hour periods during a 30-day assessment period (evaluated according to recreation class of water body). Although elevated *E. coli* levels were measured at times on all six heritage streams, a majority of samples were low in bacteria and likely in compliance with state surface water quality standards. Summary *E. coli* statistics are presented in Table 12 for the three represented Kansas ecoregions and six selected heritage streams. The laboratory MQL for *E. coli* is 10 MPN/100 mL.

Table 12. *Escherichia coli* (*E. coli*) data summary. KDHE's strategy for dealing with nondetected (ND) data involves the use of semi-parametric and nonparametric methods, such as robust regression on order statistics and Kaplan-Meier (Helsel 2005, 2012). In cases where the summary statistics reflect mostly ND data (> 80%), a less than (<) sign is used to indicate that the value shown is an upper estimate of the actual concentration. All available data for the period (2002-2012) were applied in this analysis. N = number of samples; ND = number of nondetect samples; MPN/100 mL = most probable number per 100 milliliters; ER3, ER4 and ER5 = Kansas quantitative ecoregions; F1, F2, and F3 = median flow category (< 10, 10-100, and > 100 cfs, respectively).

Variable		N	ND	Mean	Min.	Max.	SD.	Percentiles		
								25th	50th	75th
E. Coli (MPN/100 mL)										
ER3F1:	Nescatunga	17	1	320	< 10	2382	564	73	108	309
	Thompson	45	2	326	< 10	7701	1138	52	86	185
	All other sites	71	7	692	< 10	8664	1641	20	120	350
ER4F1:	Illinois	41	6	151	< 10	1439	293	20	31	119
	Sevenmile*	6	1	210	< 10	904	345	10	109	169
	All other sites	374	37	529	< 10	41058	2447	20	75	259
ER4F2:	Fourmile	14	1	294	< 10	3076	805	20	63	173
	All other sites	458	44	1295	< 10	98670	6663	20	74	298
ER5F2:	Grouse*	6	1	128	< 10	341	128	20	148	197
	All other sites	1387	124	952	< 10	64882	3899	30	98	309

* Only 2011-2012 data

3.4 Streamflow measurements

Due to the exceptional drought that occurred across Kansas in 2011and 2012, many streams across the state were reduced to very low water levels. The six streams selected for this study were no different, with several of them being pooled or, in one case, completely dry during the flow data collection attempts. Activities related to this task were conducted as follows:

Fourmile Creek

The sampling location was visited on July 6, 2011. Discharge measurements were taken and a "tapedown" landmark was installed on the upstream side of the bridge. Discharge measured using the SonTek FlowTracker yielded a value of 1.11 cfs. The tapedown distance was 25.92 feet to the water surface. Discharge was measured again on March 12, 2012 following one of the few significant precipitation events over the two year period. Fourmile Creek was flowing well and discharge was calculated as being 35.57 cfs with a tapedown distance of 24.82 feet to the water surface. A final discharge measurement was conducted on June 12, 2012. At this time and monitoring location, Fourmile Creek had again been reduced to a trickle. Discharge was measured at just 0.06 cfs with the tapedown distance being 26.07 feet.

Illinois Creek

The sampling location was visited on July 26, 2011 at which time it was discovered that surface flow had ceased in the stream. Only scattered pools of water remained in the vicinity of the sampling site. There were no subsequent visits to this site due to the landowner withdrawing permission to access the stream.

Thompson Creek

The sampling location was visited and discharge measurements were taken on August 1, 2011 using the SonTek FlowTracker. A discharge value of 3.21 cfs was measured on this date. There were no subsequent visits to this site due to the landowner withdrawing permission to access the stream.

Nescatunga Creek

The sampling location was visited on August 1, 2011 with intent to measure discharge, but the stream was completely dry at the sampling point.

Grouse Creek

The sampling location was visited on August 2, 2011 with intent to measure discharge, but the site was pooled. A "tapedown" landmark was installed on the upstream side of the bridge and tapedown distance was 20.46 feet to the water surface. The site was revisited and discharge measurements were taken on March 12, 2012 (119.02 cfs, 19.87 feet tapedown) and June 12, 2012 (1.41 cfs, 20.40 feet tapedown).

Sevenmile Creek

The sampling location was visited on August 15, 2011. Flow in the stream was reduced to a trickle and discharge was measured, using the SonTek FlowTracker, at 0.14 cfs.

In addition to in-field measurements, a USGS database containing extrapolated flow estimates (Perry et al. 2002) was intersected with the watershed catchments derived from the NHDPlus used in the initial KDHE study (Angelo et al. 2010) in order to obtain site specific flow estimates (median stream base flow) for the six sample locations. These estimates were used in order to classify the selected streams into three flow categories (<10, 10-100, >100 cfs) for portions of this study. Estimated median stream base flow for the six streams were as follows: Fourmile Creek 4.95 cfs; Illinois Creek 4.77 cfs; Grouse Creek 28.37 cfs; Sevenmile Creek 5.13 cfs; Nescatunga Creek 4.28 cfs; Thompson Creek 2.6 cfs.

3.5 Stream geomorphological characterizations of six heritage streams

As a measure of the "physical integrity," a geomorphic assessment attempts to characterize the stream channel stability and provide insight to the overall health of a watershed. Furthermore, it can identify land use-related disturbances (e.g., human alterations) and other factors causing channel instability, and provide critical information to direct restoration and watershed management activities. As noted by the hydrologist, David Rosgen,

> *Separating the difference between anthropogenic versus geologic processes in channel adjustment is a key to prevention/mitigation/restoration of disturbed*

systems. The adverse consequence of stream channel instability (dis-equilibrium) is associated with increased sediment supply, land productivity change, land loss, fish habitat deterioration, changes in both short and long-term channel evolution and loss of physical and biological function (Rosgen 2001).

In an attempt to characterize and assess the stability conditions for the six heritage streams, this report considers the following stream features: 1) general geomorphic description, 2) composition of bed and banks, 3) bank cover and stability and, 4) channel and bed stability or erosion potential. Table 13 presents stream stability interpretations were developed by The Watershed Institute (TWI) following the methodology of Rosgen (1996, 2000).

Fourmile Creek

A Flint Hills stream of sequential short riffles and long, shallow, pools. Stream is composed of a bedrock substrate with significant bedrock outcrops along the banks. Banks are well vegetated and wooded. The streambed is of steep gradient but low/slow erosion potential. Fourmile Creek's channel type (C3) is moderately sensitive to disturbance, but can recover naturally if the disturbance is removed. The stream provides moderate sediment supply to the stream system, banks are moderately erodible, and vegetation is very important to maintain stream stability. The sediment competence calculations (a measure of bed stability) indicted the stream reach is degrading. However, TWI suggested that the results were biased owing to bedrock falls that increase the local water surface slope.

Fourmile Creek – Morris County

Sevenmile Creek

A Flint Hills stream with sequential short riffles and long pools. Stream channel has high sinuosity. Stream substrate is mostly bedrock and is the coarsest of the six heritage streams. Banks are well rooted, but bank cover is low. The stream has the highest bed stability of the six heritage streams and a low and slow erosion potential. Sevenmile Creek's channel type (E3) has a high sensitivity to disturbance, but has good recovery potential if instability is corrected. The stream provides low sediment supply to the stream system, banks have a very low erodibility, and vegetation is very important to maintain stream stability. The bed stability appears to be good.

Sevenmile Creek – Riley County

Illinois Creek

A Flint Hills stream with sequential short riffles and long pools. Stream substrate is mainly bedrock. Stream has a very good wooded riparian bank cover and high bank stability. Erosion potential is rated as low and slow. Illinois Creek's channel type (E3) has a high sensitivity to disturbance, but has good recovery potential if instability is corrected. The stream provides low sediment supply to the stream system, banks have a very low erodibility, and vegetation is very important to maintain stream stability. The bed stability appears to be good.

Illinois Creek – Wabaunsee County

Grouse Creek

A Flint Hills stream with a diverse riffle/pool sequence. Stream channel bed is mainly bedrock in the upper reaches but alluvial deposits downstream. Stream banks are mostly fine particulate material with low bank cover. Stream has a moderate erosion potential and has the highest sediment supply rating of the six heritage streams. Grouse Creek's channel type (C4) has a high sensitivity to disturbance, but has good recovery potential if instability is corrected. The stream provides moderate sediment supply to the stream system, banks have a very high potential for erodibility, and therefore vegetation is very critical to maintain stream stability. The bed stability appears to be aggrading.

Grouse Creek – Cowley County

Nescatunga Creek

A GypsumHills/High Plains stream with an undulating bed typical of many sand bottomed streams. Stream bed and banks are primarily sand. Stream has good bank cover and is very well vegetated. Stream is considered to have a moderate erosion potential, mainly from the sandy nature of the soils. However, the stream has good energy dissipation during typical flood events, leading to a low sediment supply rating. Nescatunga Creek's channel type (E5) has a very high sensitivity to disturbance because the sandy channels are extremely susceptible to erosion. The stream provides moderate sediment supply to the stream system, banks are moderately erodible, and vegetation is very important to maintain stream stability. The stream competence rating (infers bed stability) was originally developed for assessing gravel and cobble-bed bottom streams, and therefore not applicable for assessing and rating sand dominated streambed systems.

Nescatunga Creek – Comanche County

Thompson Creek

A GypsumHills/High Plains stream with a glide/pool sequence (no true riffles). Stream has high sinuosity. Stream channel bed is mostly sand and some gravel, with banks of a sand/silt/clay mixture. Banks are heavily grazed but the stream has little visual evidence of erosion and has a low sediment supply rating. Thompson Creek's channel type (E5) has a very high sensitivity to disturbance because the sandy channels are extremely susceptible to erosion. The stream provides low sediment supply to the stream system, and vegetation is very important to maintain stream stability. The stream competence rating was originally developed for assessing gravel and cobble-bed bottom streams, and therefore not applicable for assessing and rating sand dominated streambed systems.

Thompson Creek – Kiowa County

Table 13. Geomorphology classification summaries for the six heritage streams surveyed by [1]TWI.

Stream/survey reach	Rosgen stream type/bed stability	Bank types identified	Bank erodibility hazard index (BEHI) rating	Near-bank stress (NBS) rating	Sediment supply-stability rating
Fourmile	C3/1	Type 1	Low	Low	
		Type 2	Moderate	Low	
		Type 3	Moderate	Moderate	
		Dominant reach:	Moderate	Low	Moderate
Sevenmile	E3/1	Type 1	Moderate	Low	
		Type 2	Very low	Low	
		Type 3	Very low	Low	
		Dominant reach:	Very low	Low	Low
Illinois	E3/1	Type 1	Very low	Low	Low
Grouse	C4/1	Type 1	Moderate	Moderate	
		Type 2	High	Moderate	
		Type 3	High	Low	
		Dominant reach:	High	Moderate	Moderate
Nescatunga	E5	Type 1	Moderate	Low	
		Type 2	High	Moderate	
		Dominant reach:	Moderate	Moderate	Low
Thompson	E5	NA	NA	NA	Low

NA – Not assessed

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[1]See Appendix B for explanation of measures and metrics used in geomorphological assessments.

4. Policy and Discussion

4.1. Protecting Kansas Heritage Streams – A Review of Available Authorities

Owing to the paucity of minimally impacted streams in Kansas, it would be desirable to extend protection to those remaining segments to maintain their ecological integrity in the face of altered land use and development in their watersheds and activities in and along their channels. The preeminent water quality protections are based on the Kansas Surface Water Quality Standards (K.A.R. 28-16-28b, *et seq*). Each State is charged, under the Clean Water Act (33 U.S.C. §1251, *et seq*), with the responsibility to adopt water quality standards which serve to 1) achieve a level of water quality that provides for the protection and propagation of fish, shellfish and wildlife and for recreation in and on the water, where attainable, and 2) restore and maintain the chemical, physical and biological integrity of the Nation's waters.

4.1.1. Water Quality Standards and Antidegradation Policy

Water quality standards have three components: use designations for the waters of the State; numeric and narrative criteria to protect the designated uses and an antidegradation policy. To provide water quality protection for heritage streams in Kansas, the first step is to ensure that those streams are identified as classified waters and listed as such in the Kansas Surface Water Register. Classification has multiple purposes: the assignment of designated uses to streams beyond the [fishable/swimmable] goals of the Clean Water Act; the application of numeric criteria to protect the designated uses; and the classification of those streams relative to the antidegradation policy of the water quality standards.

All waters in Kansas have default designated uses that include expected aquatic life support, food procurement, and primary contact recreation. Those uses may be modified or rebutted through use attainability analyses, which evaluate the capability of a given water to support at least those uses, as well as possibly domestic water supply, livestock, industrial, irrigation water supply, or ground water recharge. Aquatic life support uses may be altered to Special or Restricted uses depending upon the condition of the habitat and fauna present in the water. Recreational use may be refined to indicate if primary (immersion) activities are supported or secondary (contact only) activities are supported by the physical conditions of the water body. Food procurement may be rebutted in the absence of edible forms of aquatic or semiaquatic life for human consumption. Specific protocols outline the evidence sought to confirm the potential of the water to support other beneficial uses (http://www.kdheks.gov/environment/qmp/download/SWUDP_QAMP.pdf).

Water quality criteria are either narrative or numeric in form. The narrative criteria apply to all waters of the State, even if those waters are not classified. Such criteria are intended to protect all waters from harmful effects or impairment from substances of artificial origin (K.A.R. 28-16-28e(b)). These substances may include toxics, radionuclides, and microorganisms in harmful amounts, solid materials such as trash and rubbish, floating debris, oil and grease, sludge and fine solids, taste and odor producing substances or color and turbidity producing substances. Narrative criteria for nutrients or suspended solids call for controlling their introduction into surface waters so as to not cause impacts to aquatic life, recreation use or the production of drinking water.

Numeric criteria, which only apply to classified waters, provide a quantitative measure of water quality useful in assessing the relative health and integrity of the water. Such criteria can be expressions of desired conditions, e.g., dissolved oxygen levels of at least 5 mg/l, or maximum concentrations of substances that should not be exceeded frequently, e.g., 3 µg/l atrazine. Numeric criteria apply to specific designated uses assigned to each water and are the basis for most limitations placed on wastewater discharges via National Pollutant Discharge Elimination System (NPDES) permits. It should be noted that numeric criteria may represent the water quality goals for waters influenced by non-point sources of pollution, but these criteria are not binding to non-point sources.

Given that no NPDES permitted facilities discharge to any of the six candidate heritage reaches, the primary protection for these reaches lies in the antidegradation policy of the water quality standards. The EPA sorts waters of the United States into the following protective tiers based on their existing quality and perceived social and ecological value:

Tier 1 *maintains and protects existing uses and water quality conditions necessary to support such uses. Tier 1 requirements are applicable to all surface waters.*

Tier 2 *maintains and protects high quality waters, i.e., waters where existing conditions are better than necessary to support CWA "fishable/swimmable" uses. Water quality can be lowered in such waters. However, State and Tribal Tier 2 programs identify procedures that must be followed and questions that must be answered before a reduction in water quality can be allowed. In no case may water quality be lowered to a level which would interfere with existing or designated uses.*

Tier 3 *maintains and protects water quality in ONRWs. Except for certain temporary changes, water quality cannot be lowered in such waters. Outstanding National Resource Waters generally include the highest quality waters of the United States. However, the ONRW classification also offers special protection for waters of exceptional ecological significance, i.e., those which are important, unique, or sensitive ecologically.*

Kansas recognizes three antidegradation categories: General Purpose Waters, Exceptional State Waters and ONRWs. The following definitions apply to these categories, pursuant to K.A.R.28-16-28b:

> *(y) "Exceptional state waters" means any of the surface waters or surface water segments that are of remarkable quality or of significant recreational or ecological value, are listed in the surface water register as defined in subsection (ddd), and are afforded the level of water quality protection under the antidegradation provisions of K.A.R. 28-16-28c(a) and the mixing zone provisions of K.A.R. 28-16-28c(b).*
>
> *(cc) "General purpose waters" means any classified surface water that is not classified as an outstanding national resource water or an exceptional state water.*
>
> *(pp) "Outstanding national resource water" means any of the surface waters or surface water segments of extraordinary recreational or ecological significance identified in the surface water register, as defined in subsection (ddd), and afforded the highest level of*

water quality protection under the antidegradation provisions of K.A.R. 28-16-28c(a) and the mixing zone provisions of K.A.R. 28-16-28c(b).

Interfacing the Kansas definitions with the EPA tier structure, General Purpose waters can be viewed as Tier 1 or 2 depending on the pollutant. Outstanding National Resource Waters correspond to Tier 3. Exceptional State Waters may be viewed as belonging to Tier 2.5, which combines the excellent water quality assumed by Tier 2 waters with significant ecological or recreation value, as defined at the State (rather than national) level.

Within the context of Kansas surface water quality standards, antidegradation means "*the regulatory actions and measures taken to prevent or minimize the lowering of water quality in surface waters of the state, including those streams, lakes, and wetlands in which existing water quality exceeds the level required for maintenance and protection of the existing uses.*" (K.A.R. 28-16-28a(c)).

Consistent with the intent of the national antidegradation policy, the standards endeavor to prevent the lowering of water quality by <u>future</u> actions. Therefore, the typical trigger of an antidegradation review is the proposed introduction of a new or expanded point source discharge, subject to the provision of the NPDES permitting process. The antidegradation policy of Kansas expressed in K.A.R. 28-16-28c(a), reads:

(1) General Purpose Waters

(A) Levels of water quality in surface waters of the state shall be maintained to protect the existing uses of those surface waters. **[Tier 1]**

(B) For all surface waters of the state, if existing water quality is better than applicable water quality criteria established in these regulations, that existing water quality shall be fully maintained and protected. Water quality may be lowered only if the department finds, after full satisfaction of the intergovernmental coordination and public participation requirements on antidegradation contained in the Kansas antidegradation policy, as defined in K.A.R. 28-16-28b (ff), that a lowering of water quality is needed to allow for important social or economic development in the geographical area in which the waters are located. In allowing the lowering of water quality, the maintenance and protection of existing uses shall be ensured by the department, and the highest statutory and regulatory requirements for all new and existing point sources of pollution and all cost-effective and reasonable best management practices for nonpoint sources of pollution shall be achieved. **[Tier 2]**

(2) Wherever surface waters of the state constitute exceptional state waters, discharges shall be allowed only if existing uses and existing water quality are maintained and protected. **[Tier 2.5]**

(3) Wherever surface waters of the state constitute an outstanding national resource waters water, existing uses and existing water quality shall be maintained and protected.

New or expanded discharges shall not be allowed into outstanding national resource water. **[Tier 3]**

Temporary sources of pollution that produce only ephemeral surface water quality degradation which is not harmful to existing uses, may be allowed by the department. Thus, the antidegradation policy is insurance against permanent change to water quality, unless social and economic reasons dictate such a change is warranted. The State categories of water relative to antidegradation also dictate mixing zone policy for existing and new dischargers into each type of those waters, with more strict conditions imposed for the higher tiers.

Kansas has seven Tier 3 ONRWs: Big and Little Salt Marshes at Quivira National Wildlife Refuge, Cheyenne Bottoms, Flint Hills National Wildlife Refuge, Kirwin National Wildlife Refuge, Kirwin Lake, and the waters in the Cimarron National Grasslands. Essentially all of these waters, except Kirwin Lake are wetlands of national prominence. Also, all except Cheyenne Bottoms and Kirwin Lake are Federal land holdings. With the exception of Sevenmile Creek on the Fort Riley Military Reservation, the candidate heritage streams flow through predominantly private lands. There are other high quality streams such as Fox and Palmer Creeks flowing through the Tallgrass Prairie National Preserve in Chase County that might garner support for ONRW status. While Sevenmile, Fox, and Palmer Creeks may ultimately be classified as ONRWs, most proposed heritage streams flowing through private lands are likely to be classified in Kansas as Tier 2.5 Exceptional State Waters.

There are 70 stream segments and eight lakes or wetlands currently designated as Exceptional State Waters on the Kansas Surface Water Register. These include three of the candidate heritage streams, Thompson Creek, Illinois Creek and Grouse Creek. Steps are underway within the Watershed Planning, Monitoring and Assessment Section of KDHE to upgrade the classification of Sevenmile, Fourmile and Nescatunga Creeks from General Purpose to Exceptional State Waters through the triennial review process for the Kansas Water Quality Standards. Chemical and biological data from these streams are being analyzed to address the standard of “remarkable quality or significant ecological value” embedded within the definition of Exceptional State Waters. The Surface Water Register should be modified in 2013 to classify the three creeks as Exceptional State Waters (ESWs). Efforts to upgrade Sevenmile, Fox and Palmer Creeks to ONRW status will be undertaken in the future.

Since these streams are currently unimpacted by point source influences yet flow through private lands which could transition to development, the ESW classification does provide some safeguards against activities altering the existing high water quality. That protection is not iron-clad, however, as the antidegradation policy will allow for some degradation in quality if there are pervasive social or economic reasons, if only in a mixing zone established within the ESW, pursuant to the provisions of the Kansas surface water quality standards. Nonetheless, the standard for Exceptional State Waters is that existing uses and existing water quality are maintained and protected, which is a daunting challenge for new wasteloads.

Additionally, the provisions of the antidegradation policy extend to new and expanded discharges but not to non-point sources of pollution that result from changes in land use or unpermitted activities within the watershed of any heritage stream. Therefore, altered water quality may be seen in Tier 2 and 2.5 waters without recourse to remedy the situation, except, "*all cost-effective and reasonable best management practices for nonpoint sources of pollution shall be achieved.*" Achievement, in many cases will be subject to the availability of incentive funds and the willingness of the individual landowner/producer to participate in the cost-share programs offered by the U.S. Department of Agriculture or the Division of Conservation in the Kansas Department of Agriculture.

Provisions of the Kansas antidegradation policy also have some influence on the other permitting program of the Clean Water Act, the Section 404 program regulating dredge and fill activities in the nation's waterways. While some significant activities in the State require an individual 404 permit from the Corps of Engineers, a majority of activities are covered by general Nationwide Permits conditioned by specific requirements for Kansas waters. The Corps determines if an activity requires an individual permit or is covered by a Nationwide Permit, but all permits require KDHE to issue a Section 401 certification, assuring the intended activity will not cause a violation of the Kansas Water Quality Standards. This certification becomes part of the actual 404 permit which authorizes the Corps to enforce the 401 conditions. KDHE also issues certifications for State permitted stream channel modifications and floodplain fill activities regulated by the Kansas Department of Agriculture's Division of Water Resources (DWR). However, certifications issued for these permits are not automatically incorporated into the DWR permit, pursuant to the Kansas Environmental Coordination Act (K.S.A. 82a-325, *et seq*). The Chief Engineer of DWR needs to explicitly state those conditions in the State permit for them to be binding on the applicant.

The surface water quality standards authorize the water quality certification process to cover certain activities falling within and outside the purview of the Clean Water Act. For example, K.A.R. 28-16-28f states:

> *(c) Water quality certification. No action identified in this subsection shall be taken unless the department has issued a water quality certification for the following:*
> *(1) Any action requiring a federal license or permit pursuant to the federal clean water act;*
> *(2) any action subject to the permitting provisions of K.S.A. 65-165, and amendments thereto;*
> *(3) any water development project subject to the provisions of K.S.A. 82a-325 et seq., and amendments thereto; and*
> *(4) any action undertaken by any Kansas state agency that, in the opinion of the secretary, has a potential water quality impact.*

The essence of the 401 certification process in Kansas is to require potential 404 or State permittees to prepare and follow a project water quality protection plan which identifies how the intended activity may discharge pollutants to the waters of the State and sets out structural and management measures to be implemented to prevent or minimize those discharges. In situations where project impacts are likely to occur in or within a ½ mile of an ONRW or Exceptional State Water in Kansas, the protection plan is also submitted to KDHE to expedite any subsequent review and response by the applicable KDHE field office. KDHE does not approve the permit or the plan, however, it may advise the Corps to deny the application or add conditions to the authorization of the activity under the general permit to minimize impacts.

Violations of the water quality certification are subject to fines of $10,000 per violation per day. The enforcement is after-the-fact so impacts to any water of the State, including the Tier 2.5 and Tier 3 waters may still occur. A regional condition by the Corps on the Nationwide Permits in Kansas is for the permittee to notify the Corps before construction of any regulated activity in high quality, high value waters, including ONRWs, Exceptional State Waters and waters supporting Special Aquatic Life (those that "contain combinations of habitat types and indigenous biota not found commonly in the state or … that contain representative populations of threatened or endangered species" see K.A.R.28-16-28d(a)(1) and (b)(2)(A)).

Such notification is intended to preclude impacts to those waters from occurring through proposed activities. A map of such waters is located at: (http://www.nwk.usace.army.mil /Portals/29/docs/regulatory/nationwidepermits/2012/DesignatedWaters_14Oct2011.pdf).

Nationally, the Corps will not authorize certain activities with Nationwide Permits if they result in discharges of dredge and fill into "Designated Critical Resource Waters" (Condition No. 22). These include waters designated by a State as having particular environmental or ecological significance, such as ONWR or State natural heritage sites. Activities not authorized for Nationwide Permits pursuant to this national condition could include outfalls and intakes, utility lines, roads and bridges, return water from contained disposal areas, hydropower projects, coal or other types of mining, residential, commercial or industrial development, flood control facilities, dredging of basins, agricultural activities, facilities for recreation or stormwater management, or renewable energy generation upon the Corps determination of "not exceeding minimal impact threshold." These activities could be conducted under individual 404 permits, however.

Permitting under Section 404 can protect water quality and minimize impacts on Kansas heritage streams, especially if they are designated as ONRWs or Exceptional State Waters, but the regulatory program does not prohibit all activities. Some impacts still may occur despite safeguards instituted by 401 certificates. Nonetheless, assigning ESW status to heritage streams should ensure further permit review and help to preclude unwarranted impacts.

One concept that was explored during this Healthy Watershed/Heritage Stream Initiative was the possibility of brokering tradeoffs within in a given watershed district. Using the disturbance index for the small subwatersheds comprising the overall watershed, high quality areas may be interspersed with areas that showed greater impact. The concept suggested the high quality subwatersheds be spared any development of watershed projects impounding those streams in exchange for facilitated development of watershed structures at more impacted sites. Projects impacting streams are subject to the Kansas Stream Mitigation Guidelines (http://www.nwk.usace.army.mil/Portals/29/docs/regulatory/mitigation/KSMG_Guidance_25Jun2010.pdf) which compute debits for the impacts and credits from compensatory benefits provided by such projects subject to 404 permitting.

The concept would have lowered standards for meeting compensation for projects in the marginal sites by securing the integrity of the high quality sites, analogous to EPA's 2003 Water Quality Trading Policy (http://water.epa.gov/type/watersheds/trading/finalpolicy2003.cfm).

However, a major constraint to offsetting impacts is the insistence that water quality standards or the integrity of the aquatic resources are maintained at the site of impact. Lacking development of a mitigation bank, in-lieu fee program or a permittee's mitigation plan, current mitigation policies limit any subwatershed tradeoff arrangements. Conversely, the Kansas Stream Mitigation Guidelines do provide a level of protection to high quality streams by accounting for major debits in impacting those streams by impoundment or other disturbance that must be compensated by those activities. The requirements for mitigation invoke a disincentive to impact high value stream systems.

4.1.2 Total Maximum Daily Loads

Section 303(d) of the Clean Water Act requires States to identify and list waters that are impaired, i.e., that are not meeting their applicable water quality standards, and to prepare total maximum daily loads (TMDLs) to encourage the restoration of those impaired waters by reducing the pollutant loads from point and non-point sources. The allocated wasteloads to point sources are implemented through the NPDES permit program and the load allocations for non-point sources are implemented by installation of best management practices, albeit on a voluntary basis. Traditionally, the TMDL program has been a restoration-oriented effort, attempting to restore water quality to a point where designated uses are fully supported once again. However, federal regulations at 40 CFR 130.7(e) also support the development of protection-based TMDLs:

> *For the specific purpose of developing information and as resources allow, each State shall identify all segments within its boundaries which it has not identified under paragraph (b) of this section and estimate for such waters the TMDLs with seasonal variations and margins of safety, for those pollutants which the Regional Administrator identifies under section 304(a)(2) as suitable for such calculation and for thermal discharges, at a level that would assure protection and propagation of a balanced indigenous population of fish, shellfish and wildlife. However, there is no requirement for such loads to be submitted to EPA for approval, and establishing TMDLs for those waters identified in paragraph (b) of this section shall be given higher priority.*

This provision allows for informational, protection-oriented TMDLs to be developed at a State's discretion and as resources allow. Clearly, such TMDLs are a lower priority in the overall mission of Section 303(d) to restore water quality. Additionally, these protection-based TMDLs remain under State control and are not subject to EPA approval. Otherwise, protection-based TMDLs may take the same form as restorative TMDLs, with the major difference that the computed loads that exist now are attaining water quality and, therefore, are to be maintained against any future new or expanded loadings from point and non-point sources.

A protection-based TMDL establishes the baseline of water quality to be maintained. Care must be given that such a TMDL upholds the State's antidegradation policy, since that policy is also part of the water quality standards. Any potential increase in wasteloads from point sources into a Tier 2.5 water will need to a) discharge at the existing water quality of the receiving water, b) offset its wasteload by reducing existing wasteloads of other point sources or reducing loads from existing non-point sources, or, c) avoid discharging to the stream altogether by using alternative means of disposal. Future pollutant loadings must continue to fully support the designated uses of the water, as well maintain existing water quality. Changes in non-point source pollutant loads require attempts to abate any impacts through the installation of corrective best management practices. Establishing protection-based TMDLs as a high priority for Federal and State funding can facilitate financial assistance for installing those beneficial practices.

The first task of a TMDL is to identify the specific waterbody and impaired designated use. Water quality and ancillary data are analyzed to establish a linkage between pollutant sources and the impairment to water quality. Current pollutant loads are estimated and allowable loads are determined and allocated to point and non-point sources. The TMDL identifies possible State programs that might be directed toward its implementation and provides general guidance to those programs as to how to address the impairment. Follow-up monitoring and a re-visitation schedule for possible TMDL revision is established as the last step.

TMDLs accomplish nothing if they are not implemented. The Kansas TMDL program is linked to the *Kansas Water Plan* through a planning process that engages basin advisory committees in each of the State's 12 major river basins to identify applicable State water programs that may be directed toward the pertinent issues within each respective basin. Since 2000, those TMDLs that were deemed high priority for implementation by the basin advisory committees were placed in each individual basin plan's water quality section. Thereupon, those basin plans provide guidance to the State water agencies as to what programs should be used to address water quality restoration issues in specific water bodies within the basin. Those programs utilize their allocated portion of the State Water Plan Fund (SWPF) to address the specific basin issues. The State Water Plan Fund expended $15 million in 2012 on water program activities. Not all TMDLs are ranked as high priority by the basin advisory committees; therefore, the *Kansas Water Plan* guidance narrows the geographic scope of implementation to restore water quality to select waters and focuses on practices that are effective in abating the specific pollutants identified as impairing those waters.

The principal program applied toward the implementation of TMDLs is the Kansas Department of Agriculture's Division of Conservation non-point source pollution control program (http://www.ksda.gov/doc/content/430). That program had $2.9 million of SWPF allocated to financially assist installation of best management practices in 2012. An additional $267,000 was available to support installation of water quality buffers around streams and another $299,000 supported riparian and wetland management and protection efforts. The local vehicles to enroll individual landowners into the cost-share incentive conservation programs are the 105 county conservation districts. These districts participate in watershed management activities in the drainages underlying their administrative boundaries, often times participating on Watershed Restoration and Protection Strategy (WRAPS) groups present within their county. While there are provisions for addressing district identified needs, much of the cost-share funds are directed toward applications in specific watersheds having TMDLs on specific pollutants. Hence, TMDLs through the *Kansas Water Plan* process support a targeted implementation effort.

On the national front, debate continues over the balance between watershed efforts designed to restore waters versus protect waters. Current guidance for upcoming section 319 non-point source grants requires that watershed project funds go toward restoring impaired waters, unless a

State has identified protecting unimpaired waters as a priority under its updated NPS management plan (http://water.epa.gov/polwaste/nps/upload/final-draft-public-comment-319-guidelines2.pdf). Even then, EPA expects a limited amount of watershed project funds to be used in protection activities. Current Kansas priorities for the section 319 program place the limited amount of funding available for watershed implementation toward restoring waters.

National efforts led by EPA to develop a ten-year vision for the TMDL program also touch upon protection as a point of emphasis. One of the vision goal statements pertaining to protection states: "*For the 2016 reporting cycle and beyond, in addition to the traditional TMDL development priorities and schedules for waters in need of restoration, States identify protection planning priorities and schedules for healthy waters, in a manner consistent with each State's systematic prioritization*." That goal leaves it to each State's discretion as to how much emphasis will be placed on protection of waters. Discussions between EPA and the States reveal two trains of thought on the matter: those States that want to begin to emphasize protection (typically coastal states with high population density) and those States that will continue to have restoration as their priority. A companion debate centers on whether TMDLs are the appropriate instrument to provide protection to good quality waters or if watershed plans themselves are sufficiently effective in marshalling resources to support protection of waters. Use of TMDLs for protection tends to be the exception rather than the rule based on the discussions among the States.

The vast majority of TMDLs prepared in Kansas since 2000 have had water quality restoration as their mission. There have been occasional protection-based TMDLs, such as a 2007 TMDL intended to prevent eutrophication in Wyandotte County Lake (http://www.kdheks.gov/tmdl/mo/WyandotteCoLake_2007.pdf). That TMDL was prepared to support local protection efforts by the Wyandotte County Conservation District and the Kansas City Unified Government's MS4 stormwater program. Without local entities willing and able to implement TMDLs, such TMDLs accomplish little toward restoration or protection. The emphasis in Kansas continues to be restoration. Although NDPES permitting provides a regulatory mechanism for implementating wasteload allocations that are consistent with the antidegradation policy and that protect existing water quality, non-point source load reduction for protection purposes must be at the behest of the local implementing agency.

With the exception of the Cowley County Conservation District and the Grouse Creek Watershed District/WRAPS, locals have been silent as to protection initiatives. The Grouse Creek WRAPS has undertaken protection of Grouse Creek, a candidate heritage stream, as a core mission. Their draft WRAPS watershed plan applies EPA's 9-element watershed planning toward maintaining current loads of total suspended solids and total phosphorus in six subwatersheds of Grouse Creek and attempting to reduce pollutant loads at higher runoff conditions to protect the water quality of the stream system. KDHE has prepared a draft protection TMDL for TSS and phosphorus on Grouse Creek and, in concert with the Grouse Creek watershed, will advocate for its inclusion in the Lower Arkansas and/or Walnut Basin Plans of the *Kansas Water Plan* as a high priority TMDL. Thereafter, the Cowley County Conservation District can apply to the Division of Conservation for funds that support installation of best management practices along the creek. The TMDL is included in this report as Appendix E.

No other local resource management group associated with the other five candidate heritage streams has requested a TMDL to facilitate financial resource acquisition for protection activities. In Kansas, TMDLs still have a negative connotation in some quarters as a regulatory instrument to be avoided at all costs. Local agencies and groups, including conservation districts, WRAPS and the Department of the Army (for Sevenmile Creek flowing through Fort Riley), saw no benefit in developing a TMDL for the heritage stream in their jurisdiction. Conversely, most saw detriments in excessive government (KDHE and EPA) oversight over their activities if a TMDL was developed. The incentive of possible enhanced funding through the State Water Planning Process was not sufficiently strong to be able overcome inherent reticence in interacting with governmental water quality agencies with a regulatory function. Therefore, it is likely the use of protection-based TMDLs in Kansas will come about through local initiatives and requests for such an approach rather than through any proposals of KDHE.

However, an alternative strategy has emerged to use the TMDL process to establish protective load allocations to heritage streams. Several of the candidate streams are tributary to streams that are on the current Section 303(d) list of impaired waters in Kansas. Those impairments can be caused by either total phosphorus or total suspended solids or both. TMDL development over the next decade will focus extensively on both pollutants. Since Kansas develops stream TMDLs on a watershed basis, tributaries to the monitored main stem stream that shows impairment will be included in the TMDL. Because of that approach, heritage streams tributary to those impaired streams may be brought under the restoration TMDL for the main stem. For example, Fourmile Creek is tributary to the Neosho River above John Redmond Reservoir. The lower reaches of the Neosho River are cited as impaired by total phosphorus and slated for TMDL development in 2014. By extending the watershed coverage of the TMDL up the Neosho River to Council Grove, protective load allocations might be set for Fourmile Creek. Similar situations can arise with development of phosphorus and suspended solids TMDLs for the upper and middle Kansas Rivers that could extend protection to Sevenmile and Illinois Creeks in 2015.

4.1.3 In-stream Flow Protection

The candidate heritage streams are marked by a relatively unaltered hydrology, i.e., a flow regime that maintains itself during dry periods and has been minimally impacted by impoundments. Two factors in the disturbance scoring for small watersheds are a) the presence of impoundments such as watershed dams that alter the natural flow period and b) the presence of significant diversions of water for subsequent uses, such as irrigation, stockwatering, or industrial purposes. That these six streams were selected as candidate heritage streams reflects the general lack of impoundments and water diversions in their watersheds.

One of the policies of the State Water Resource Planning Act, K.S.A. 82a-928(i), reads: *"the identification of minimum desirable streamflows to preserve, maintain or enhance baseflows for in-stream water uses relative to water quality, fish, wildlife, aquatic life, recreation, general aesthetics and domestic uses and for the protection of existing water rights."* Kansas has a minimum desirable streamflow statute that assigns in-stream flows on 23 streams at 33 locations with a priority date of April 12, 1984 (http://www.ksda.gov/appropriation/content/301). Water appropriation permits or water rights with priority dates after that date are subject to administration and cessation of flow diversion if streamflows fall below the minimum desirable streamflow requirements identified in K.S.A. 82a-703c. State law at K.S.A. 82a-703a requires,

> *Whenever the legislature enacts legislation establishing a minimum desirable streamflow for any watercourse in this state, the chief engineer shall withhold from appropriation that amount of water deemed necessary to establish and maintain for the identified watercourse the desired minimum streamflow*.

Between 1984 and 1990, the legislature enacted minimum desirable streamflows on those 23 streams, pursuant to K.S.A.82a-703a. K.S.A. 82a-703b sunset the April 12, 1984 priority date for any minimum desirable streamflow established after July 1, 1990. Therefore, any new minimum streamflow would have a priority date tied to the date it was enacted by the legislature. Any water rights or water appropriation permits with priority dates before April 12, 1984 (or some later date for newly enacted minimum desirable streamflows) would not be subject to administration for that particular minimum desirable streamflow. Therefore, the potential utility of any new minimum desirable streamflow is limited to future water appropriations and diversion on a given watercourse. A 1984 priority date for new minimum desirable streamflows in Kansas cannot be retroactively applied to waters now found to be highly valued.

Of the six candidate heritage streams, three are tributaries to streams with 1984 minimum desirable streamflows. Illinois Creek is a tributary to Mill Creek in Wabaunsee County (MDS = 2 cfs in October and 35 cfs in June), Thompson Creek is a tributary to the Medicine Lodge River in Kiowa and Barber Counties (1 cfs in August and September and 60 cfs in March and April) and Fourmile Creek is a tributary to the upper Neosho River as monitored by the Americus gage (5 cfs year-round). These candidate heritage streams have no flow allocation or minimum level established for them specifically, but could be subject to water right administration caused by deficient flows on their respective mainstem streams.

Administration of minimum desirable streamflows is consistent with the protocols of water right administration in Kansas: investigation and intervention come after a complaint is filed. In this case, streamflows have to drop below the minimum streamflow level for seven consecutive days before the Kansas Water Office requests the Division of Water Resources begin the administration process. Experience with minimum streamflows over the past two decades indicates when streamflow falls below the desired levels, it reflects pervasive dry conditions with perhaps some aggravation caused by diversions, a majority of which are senior in priority to the minimum streamflows anyway. Recovery of streamflow to the minimum desired level never occurs until weather conditions turn favorable with the return of rain. Administration of junior water diversions could reduce the impact of any water withdrawals and effectively extend the period of flow on that stream, but the stream will remain below the desired level. With the drought conditions of 2011-2012, minimum desirable streamflow administration is in effect as of December 2012 on Mill Creek and the Medicine Lodge River (http://www.ksda.gov /appropriation/content/301). Thirteen surface water rights have been enjoined from diverting water from Mill Creek since mid-June, while four rights have been curtailed on the Medicine Lodge River since June. Neither stream has reached the desired minimum streamflow set for December.

Administration for minimum streamflows focuses on surface water diversions since their curtailment can yield rapid resumption of the previously diverted streamflow. Enforcement on alluvial ground water rights typically occurs only after analysis of the impact of shutting off such wells on streamflow recovery. If the time lag between cessation of pumping and resulting increase in streamflow extends over a month or more, the administrative action is viewed as futile. Wells located close to the stream channel have the most immediate impact on streamflow, either by inducing surface flow back into the alluvium toward the well's cone of depression caused by pumping or by intercepting up-gradient flow in the alluvium from reaching the stream channel. The addition of more pumping wells in the alluvium and greater distances from the channel introduces more complexity to the analysis of which wells should be shut down to protect streamflow. As withdrawals from the alluvium and any underlying geologic formations increase, the likelihood increases that stream baseflow will be lost over the long term.

Prevention of dewatering streams by withholding water from appropriation before water rights are granted would seem to be more effective than after-the-fact administration of an already depleted stream. Administrative regulations of the Division of Water Resources in 1994 began to base approval of applications to divert ground or surface water on safe yield policies, stating *"…the approval of any new application to appropriate groundwater or surface water for beneficial use, except for domestic use, temporary use and term permits for five years or less, shall not cause the safe yield of the source of water supply to be exceeded, neither shall it otherwise prejudicially and unreasonably affect the public interest. The approval of term permits shall not allow impairment nor prejudicially and unreasonably affect the public interest"* [K.A.R. 5-3-10].

Considerations for the safe yield and availability of surface water for diversion include: *"the streamflow shall not be stopped at the first riffle below the point of diversion while diversion is taking place under the authority of that water right or permit.* " [K.A.R. 5-3-15(c)(3)] and *"During the period July 1 through September 30 each calendar year, no direct diversions of water shall be permitted unless written permission is obtained from the chief engineer or the chief engineer's authorized representative."* [K.A.R. 5-3-15(c)(6)].

Those two provisions for safe yield consideration should effectively protect any stream from being dewatered during the critical warm-season months, at least from surface water diversions. For appropriations from unconfined aquifers (alluvium), the safe yield policies identify the percentage of calculated recharge to surface and ground waters that is available for appropriation, less any authorized quantities already in place to be appropriated. For the six candidate heritage streams, the percentage of recharge available for appropriation is: Illinois Creek (Mill Creek) – 100%; Sevenmile Creek (Kansas River) – 75%; Fourmile Creek (Neosho River) – 75%; Thompson Creek (Medicine Lodge River) – 50%; Nescatunga Creek (Salt Fork Arkansas River) – 50%; and Grouse Creek – 50%.

No existing appropriations exist on Fourmile or Illinois Creeks, but some active irrigation water rights are in the headwaters of Thompson Creek, where the southern extent of the Big Bend Prairie Aquifer provides ground water and baseflow to the upper tributaries of the Medicine Lodge River. Similarly, the headwaters of Nescatunga Creek have some irrigation ground water rights associated with the Big Bend Prairie Aquifer, part of the High Plains Aquifer in south-central Kansas. A number of alluvial wells for irrigation are located along the lowest reach of Sevenmile Creek, where it emerges from the Fort Riley Military Reservation and enters the Kansas River near Ogden. There are no water rights on the creek within Fort Riley. Some ground water wells are present along Grouse Creek to supply the City of Dexter and there is a cluster of irrigation wells just above the confluence with Silver Creek, but there has been no active use of those wells for over a decade. No water rights exist in the candidate heritage reach of Grouse Creek above Cambridge.

Impoundment of water also is viewed as a diversion under Kansas water appropriation law. There are a number of water appropriation permits associated with watershed dams on tributaries to Grouse, Silver and Illinois Creeks. Watershed structures were considered within the disturbance index used to evaluate small watersheds. A general lack of such structures was noted in the six candidate heritage streams. For example, upper Grouse Creek lacks impoundments, whereas watershed structures sponsored by the Grouse –Silver Creek Watershed District No. 92 are located on tributaries to Grouse and Silver Creeks below Cambridge and Burden, respectively.

Provisions may be made to bypass natural inflows through such structures to satisfy downstream water rights. Ongoing debate has commenced on the expectation of such bypasses or releases from stored water to augment downstream flows during drier conditions. In some situations, such a condition has been attached to Section 404 permits required by the Corps of Engineers, although the management of water quantity is typically viewed as the purview of the Chief Engineer, not the Federal government. The ecological impacts of impoundment overshadow any augmentation of low flows from storage; the reduction in peak flows can alter channel morphology and resulting habitat. As the amount of intervening drainage increases with distance from the watershed dam, any positive or negative impact of impounding the stream becomes less definitive to the downstream reaches.

The ongoing debates have moved from the impacts of a single structure to the cumulative impact of multiple structures within a watershed. Those debates currently are rooted in the issue of stream mitigation credits and debits for new structures proposed by watershed districts and others. Kansas is working on plans with watershed districts to establish long term baseline conditions for watersheds that have undergone little or modest development to date in order to monitor the cumulative impacts that may occur with each incremental addition of a structure over time.

As seen by the chemical and biological sampling on many of the candidate heritage streams, the pervasive drought conditions of 2011 – 2012 have introduced considerable stress on the biota of the streams as well as affecting water quality under very low flows. The dry conditions have potentially incited violations of water appropriation law including overpumping both rates and quantities of water, construction of temporary channel impoundments to facilitate diversion of surface water or to raise the water table level around nearby alluvial wells. In some cases, some unpermitted diversions have occurred in order to deliver water to finish high market value crops that historically were in dryland farming.

Additionally, the proliferation of energy development and concurrent increased demand for water has diminished available supplies and altered reuse patterns. Much of that demand has been met through the state issuing term permits to appropriate water for a limited period of time (typically one year). The limited duration of diverting water may still impart short-term impacts to streams, particularly since term permits may be extended a year at a time for a maximum of five years. Alternatively, temporary permits allowing diversion of up to four million gallons over a six month period may also be employed to meet water demands of energy development, including hydraulic fracturing operations. Despite regulatory safeguards to protect the safe yield of the supply system and the public interest, some impacts, such as dewatering of streams, may occur under the transient timeframe of term or temporary permits. Conversely, the reuse of wastewater as a water supply source for energy operations has been on the rise as well, which would reduce the amount of return flows to streams but also lower the loading of pollutants such as nutrients into those streams. However, the watersheds considered in this study are marked by a lack of wastewater generating facilities that could serve as supplemental sources of water for energy and industrial development.

4.1.4 Incentive Programs, the Willingness for Participation and the State's Role in Protection

As previously noted, the state agencies have a number of programs to provide financial assistance to individuals and landowners to incentivize application of best management practices to protect the high water quality of potential heritage streams. In addition to the cost-share programs of the Kansas Department of Agriculture's Division of Conservation, funded by the State Water Plan Fund, the Kansas Department of Health and Environment's Watershed Management Section oversees issuance of Section 319 grant funds for non-point source pollution control projects pursuant to the implementation of watershed plans developed through the Watershed Restoration and Protection Strategy process.

Those watershed plans, incorporating EPA's 9-elements of watershed planning - (http://water.epa.gov/polwaste/nps/upload/2008_04_18_NPS_watershed_handbook_handbook.pdf), establish priorities and goals relative to water quality within identified watersheds and characterize the existing load conditions that represent the impaired condition or, in cases of healthy waters, the baseline of good water quality. Necessary load reductions (or maintenance of compliant loads) and the suite of best management practices that are well suited to achieve those reductions are described. Critical areas, necessary technical and financial resources to implement the selected practices, and the timeline of implementation toward the reduction goals are declared in the watershed plan. Finally, an education and information plan and a monitoring scheme is designed to incite participation in the available programs to provide assistance resources, to monitor the degree of participation in implementation, and to evaluate progress toward achieving the desired load reductions.

As stated previously, the majority of watershed plans in Kansas are dedicated toward restoring water quality in streams and lakes. Among the 31 9-element watershed plans approved or awaiting approval by KDHE, only the watershed plans for Grouse Creek and Melvern Lake are dominated by a protection philosophy. Several watershed plans do have some aspects of protection, particularly source water protection, such as protecting Madison City Lake as a part of the Toronto Lake Watershed plan.

The distribution of WRAPS groups (see Figure 4) is not statewide and only two of the six candidate heritage streams lie within watersheds with existing WRAPS groups: Grouse Creek WRAPS and Fourmile Creek within the Neosho Headwaters WRAPS. While the Grouse Creek WRAPS enthusiastically embraced the concept of protection of the water quality of Grouse Creek, the Neosho Headwaters WRAPS was taciturn in getting involved with KDHE on the heritage stream initiative. Additionally, early in this project, discussions with the Cottonwood WRAPS, regarding the possibility of the WRAPS enlisting the landowners along Rock Creek in Chase County to participate in the project, were rapidly rebuffed. The Stakeholder Leadership Team managing that WRAPS directed KDHE to contact the landowners in the Rock Creek Watershed directly to find out if the landowners wanted to get involved in the HWI, including obtaining water quality samples on their portions of Rock Creek. Subsequent conversations with those landowners by KDHE and the Chase County Extension Agent also displayed major unease in participating in the project with the State.

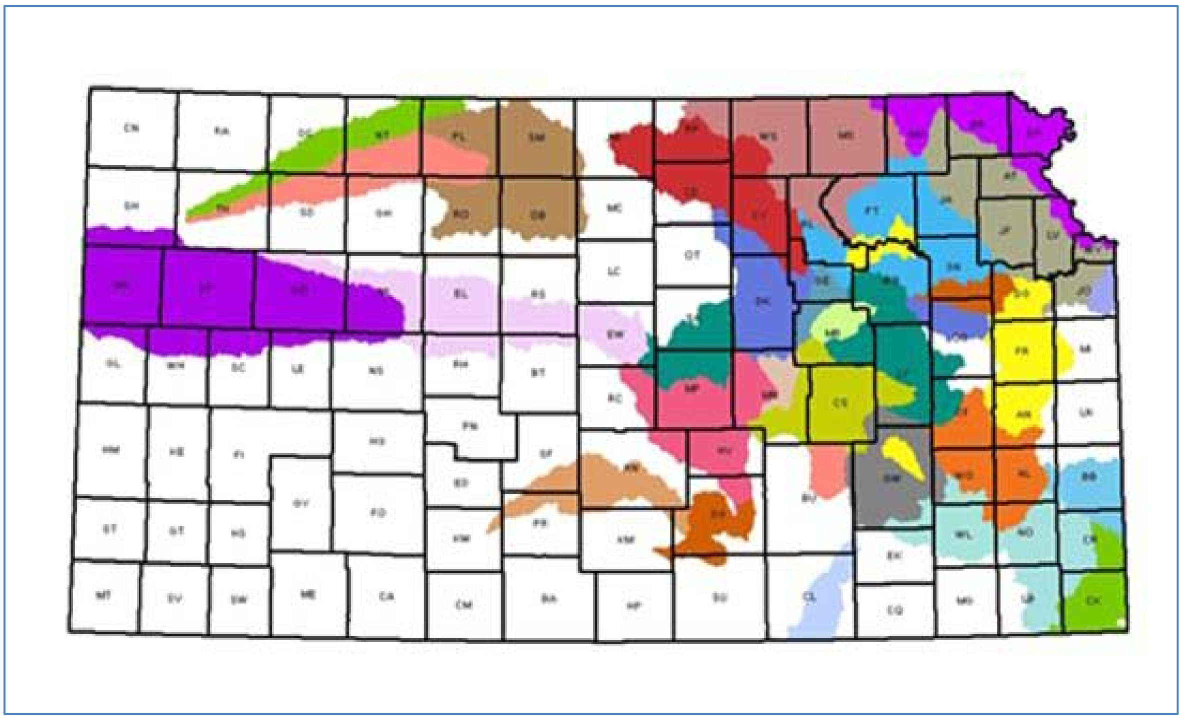

Figure 4. Distribution of Watershed Restoration and Protection Strategy Groups (WRAPS) in Kansas.

The initial meeting with one of the principal landowners set the tone for all subsequent discussions. The landowners were very suspicious that there would be some negative impact to the landowners in the watershed if a state or federal agency would be allowed to take water quality samples on Rock Creek. They were worried that an endangered species would be found and some type of regulation would be put in place that would limit the ability of the landowners to use their land in any way. Unless all the landowners in the watershed were on-board with allowing any water quality monitoring, they would deny access to the stream. In the end, they felt the risk was too high and did not give KDHE permission to take water quality samples.

A similar attitude was expressed in the Neosho Headwaters WRAPS although permission to sample Fourmile Creek was obtained. However, the WRAPS was adamant in not placing water quality protection as a core objective in its watershed plan, opting instead to emphasize reduction in phosphorus and sediment loads into John Redmond Reservoir and concomitant achievement of dissolved oxygen criteria on Allen and Dows Creeks.

Episodes such as these highlight a key aspect of trying to introduce protection concepts into water quality management in Kansas: there is a latent distrust in government among the population, especially in rural areas where most potential heritage streams are located. In a state that is ranked #13 in the nation in terms of land area, estimates of percentage of public lands within in Kansas range from 0.92 – 1.6% (see http://www.nrcm.org/documents/publiclandownership.pdf).

A majority of Federal land holdings in Kansas are with the Corps of Engineers for lands inundated by and around federal reservoirs, followed by military bases and the national grasslands and national wildlife refuges. State holdings are led by Cheyenne Bottoms and a number of state parks, state fishing lakes and wildlife management areas (wetlands). The state's ONRW are tied to the Cimarron National Grasslands and National Wildlife Refuges (Marais des Cygnes NWR, excepted), as well as Cheyenne Bottoms. Public access to military or tribal lands is minimal.

Conversely, 98 – 99% of land in Kansas is privately held and landowners exhibit a cautious attitude regarding the intent of government initiatives such as the HWI. Furthermore, when discussing the concept of "protection", the connotation among private landowners was, "Protect this land and stream from whom? Me?" The presence of minimally impacted watersheds supporting high quality stream systems is a tribute and function of the stewardship ethos of individual landowners in those watersheds. The intervention of government under the guise of assistance in protecting those lands and waters is viewed as both intrusive and unnecessary. Hence, a majority of initiatives taken by Kansas natural resource agencies to protect high quality land and water resources have been rebuffed, including the HWI, conservation easements offered by the Kansas Department of Wildlife, Parks and Tourism, and land acquisition.

As an example, the Tallgrass Prairie National Preserve in Chase County came into being only after creating a public/private partnership between the National Park Service and the Nature Conservancy who purchased the land from the original landowners. The likelihood of successfully adding the preserve into the National Park System was dubious until the Nature Conservancy brokered a deal that kept the prairie lands from exclusive Federal control.

The use of non-governmental and nonprofit organizations such as the Nature Conservancy, the Kansas Alliance for Wetlands and Streams, the Kansas Land Trust, or the Kansas Grazing Lands Coalition, a venture supported by the Kansas Livestock Association, have been more successful in obtaining protection of high quality lands. Such success stems from using the private marketplace as a vehicle for maintaining the landowner as the principal party in securing and managing those lands to maintain their heritage, which in some cases, includes agricultural production such as grazing. Governmental initiatives for protection are most successful using these NGOs as the delivery agents for program participation in Kansas.

Given the reliance on incentive-based management practices which are voluntary in nature, the application of those practices is subject to the ebb and flow of commodity pricing that introduces opportunity costs for participation. Mandatory elements and standards in the application process and design of practices and reporting and maintenance requirements act as disincentives for some producers to participate in government programs. But a latent distrust of government, or, at best, the view that government is relegated to problem solving, may present the most formidable barrier to encouraging protection efforts where there is no obvious problem to solve, hence, no rationale for government to be involved. NGO's tend to have a more patient timeline than agency programs for individuals to enter agreements for protecting resources. Coincidentally, the relative permanence of those agreements likely is enhanced through the use of market-based approaches than the traditional cost-share arrangements favored by government. Even when there is local interest in protection efforts, divergent views on what protection means can put a damper on cooperative ventures. For example, the Grouse Creek WRAPS, comprising individual landowners in the watershed, wanted to support one of their members' economic projects to develop gravel dredging from the channel of upper Grouse Creek, notwithstanding the fact that resource extraction runs counter to the concept of protecting a heritage stream. The different perspectives between KDHE and the WRAPS on this issue created a strained relationship relative to future plans for the heritage stream project.

In short, program participation for protection efforts in Kansas can be successful if it is initiated at the local level as opposed to a state or Federal initiative. Aligning the appropriate programs to meet a protection-based objective can be accomplished through watershed planning or establishing protection-based TMDLs, which then can leverage financial assistance from those cost-share programs. As such, the State's role in protection activities is educating the public on the benefits of heritage caliber streams, obtaining monitoring data to document and characterize such streams and to stand in readiness to respond to local initiatives and requests for assistance. Opportunities for government to initiate action of its own to protect the conditions seen on streams exhibiting high quality that reflects a minimally disrupted watershed will be consistent with its existing authorities to regulate impacting activities.

There may be less of a role for government in dealing with activities that lie outside its purview, such as impacts from non-point sources of pollutants. State programs should facilitate local activities for protection and provide financial assistance for implementation, provide information on the intended project through data acquisition and analysis and assist outreach efforts to distribute that information to garner support for the project. In order to secure the priority of a geographically specific protection effort, State-supported watershed plans or TMDLs should be incorporated as part of the *Kansas Water Plan*, thereby providing motivation for state programs to assist protection activities and projects in that geographic location. As such, non-regulatory protection of candidate heritage streams outside of those flowing through public lands in Kansas will be likely be an ad hoc exercise initiated by a local watershed group or nonprofit organization acting in concert with landowners.

4.2. Summary of Protection Analysis

The use of water quality standards and their antidegradation policy provisions gives relatively unimpacted streams protection against future point source activities and discharges of pollutant loads. Of the six candidate heritage streams described in this study, three; Nescatunga, Fourmile and Sevenmile Creeks are now proposed as Exceptional State Waters within the context of Kansas' Surface Water Register. Such designation as Tier 2.5 waters will maximize protection against future loadings, short of prohibiting any such discharges from entering those streams.

The streams' status as ESWs will also maximize consideration of their protection from activities subject to Section 404 permitting. Again, while not an ironclad guarantee of protecting existing water quality, their designation will place any proposed activity in full view of the state agency and public review processes for comment and suggested conditions to offset any potential impacts to the affected waters.

For Kansas, protection of heritage streams from loads generated by non-point sources of pollution, likely reflecting alteration in historic land use is best provided by incorporation in watershed-based plans or protection-based TMDLs. Subsequently, incorporation of those Clean Water Act products into the Kansas Water Plan provides clear guidance to state agencies to direct programs to assist protection efforts on specific waters in each of the State's 12 major river basins and opens a pathway to use the State Water Plan Fund to expedite assistance of those efforts. Nonetheless, practices to blunt the impact from non-point sources will continue to follow a voluntary approach that leaves the decisions in the hands of individual producers and landowners.

Given the predominant private land holdings in Kansas, high quality streams exist because of low demographic stresses in their watersheds and limited alteration of their land surface. The retention of the natural hydrologic, geochemical and biological processes that produce high quality water also reflects a highly developed stewardship ethic on the part of the landowners in those watersheds. The vision of those landowners will largely dictate the future condition of such heritage-caliber streams in Kansas.

However, one role of government is to facilitate and support initiatives brought about on behalf of local interests, either through watershed groups or non-governmental organizations, such as the Nature Conservancy. Efforts by government to initiate protective actions dealing with land use and activities lying outside the regulatory realm of the Clean Water Act will likely be rebuffed in Kansas. Such public sector initiatives might be successful where the watershed is largely held as public or governmental land, including military reservations or national preserves. For private lands, the potential benefits of financial incentives are likely not sufficient to override historic reluctance to engage government agencies in joint management ventures.

5. Conclusion

The Clean Water Act, section 101 (a), defines the ecological condition of surface waters in terms of their "chemical, physical, and biological integrity." In this study, an attempt was made to verify the caliber of the candidate reference streams with this definition in mind. Specifically, the study considered selected water quality attributes, hydrological and geomorphological characterizations, and biological features in the assessment of the six candidate heritage streams.

Surface water quality samples were collected and analyzed by KDHE for parameters typically considered to be important physico-chemical and microbiological water quality indicators. The parameters selected for the water quality testing indicated no measureable contaminate concentrations exceeded current applicable Kansas surface water quality criteria for the six heritage streams. Although elevated *E. coli* levels were measured at times on all six heritage streams, a majority of samples were low in bacteria and likely in compliance with state surface water quality standards. Finally, all six heritage streams generally exhibited exceptional water quality attributes (e.g., well buffered and aerated, low organic loading), especially when compared to all other sites from the corresponding quantitative ecoregions; verified, where available, by their long-term water quality monitoring data.

A measure of physical integrity, the physical/geomorphological assessments for each heritage stream demonstrated good (stable) ratings characterized by 1) low or slight entrenchment, 2) moderate to high sinuosity, 3) low to moderate near bank stress, and 4) low to moderate sediment supply-stability. Only Grouse Creek rated high (unstable) for bank stability due to stream reaches with steep or high banks and poor vegetation cover, giving it the highest for erosion potential in all heritage stream surveys.

With the exception of Thompson Creek, biological metrics calculated for the heritage streams were lower than expected for reference caliber streams. This was likely a direct result of the statewide drought and deteriorating in-stream conditions experienced in 2011 and 2012. Thompson Creek maintains stable baseflow owing to its consistent and prolific groundwater inputs which, apparently, allows sensitive invertebrate taxa to persist in even the worst periods of drought. When considering data obtained outside of the time constraints of this particular study (*i.e.*, in years with normal stream levels), it is evident that these same streams are indeed capable of maintaining the highest levels of biological integrity (*e.g.*, Nescatunga Creek ranking in the 90^{th} percentile in 2009). Documenting the rate of biological recovery and recolonization of these high quality systems should prove quite interesting upon the return of favorable abiotic conditions.

Throughout this report and the one that preceded it under the Healthy Watershed Initiative, the terms “reference stream” and “heritage stream” have been used interchangeably. For the purposes of this report, a distinction is drawn between the two terms, with “heritage stream” being the operative expression for both attribute characterization and protection policy analysis. While both expressions share a characteristic of minimal disturbance or impact and consequent high quality, reference streams also serve to guide other aspects of water quality management. For example, Kansas’ Water Quality Monitoring and Assessment Strategy for 2011 – 2015, includes among its recommendations:

Recommendation #5: Identify and protect reference-caliber stream reaches

> *Reference streams, or the highest quality streams in a given region, play a critical role in modern water pollution control programs. Knowledge obtained through their study is applied in the characterization of the baseline ecological condition, the development of surface water quality criteria, the identification of water quality-impaired streams, the*

> *performance of statewide water quality assessments, and the formulation of restoration goals for environmentally degraded water bodies.* (KDHE 2010e).

Common usage of reference streams among State and Federal agencies refers to their role in developing biological standards and criteria, as applied to streams with varying levels of human impact.

In contrast, heritage streams link the lack of disturbances within a given watershed to the high quality chemical, physical, and biological characteristics of the stream draining that catchment. A heritage stream becomes the focus of protection efforts to maintain its current state based on its own merits, rather than its potential use for other water quality management programs. A heritage stream may serve as a reference stream, but the emphasis is to maintain its inter-generational condition, to protect the tradition of historic land use and management that has yielded the current, high quality aquatic environment.

Finally, initiatives with the greatest potential (i.e., recommendations) for protecting and preserving these heritage streams are listed below. These recommendations underscore the ecological and historic importance of heritage streams and promote their long-term maintenance and protection.

6. Recommendations

GIS analyses and field reconnaissance and sampling indicate that there remain a number of high quality, minimally impacted watersheds throughout Kansas that support streams of significant ecological value and good water quality. While the social and political nature of Kansas tends to limit the role of state government in protecting these areas, there are number of actions that can be undertaken to minimize future alteration and disruption of these heritage streams and their watersheds. What follow are a series of recommendations that state agencies should implement to attempt to protect these high quality waters.

1. Continue to collect physical, geomorphic, chemical and biological data from streams located in minimally impacted watersheds as time, opportunity and resources allow.

2. Continue to educate the citizens of Kansas on the benefit and value of heritage streams, describing their characteristics and the factors that make them of such high quality.

3. In the short term, upgrade the classification of Sevenmile, Fourmile and Nescatunga Creeks as Exceptional State Waters. In the long term, endeavor to establish Sevenmile, Fox and Palmer Creeks flowing through Federal lands as ONRWs.

4. As needed, establish protection-based TMDLs for heritage streams to maintain water quality and the existing designated uses of those streams, consistent with the antidegradation policy of the Kansas Surface Water Quality Standards.

5. Any wasteload allocations established though a protection-based TMDL will maintain existing water quality and require any potential future new or expanded discharger,

subject to a NPDES permit, to either a) meet the existing water quality of the heritage stream at the outfall of the discharge; b) offset any increase in pollutant wasteloads with a concomitant reduction in current wasteloads of existing dischargers or reduction in pollutant loads emanating from non-point sources of that pollutant; or, c) use an alternative means of disposing of the wastewater rather than discharge to the heritage stream.

6. Load allocations of pollutants established under a protection-based TMDL should be reduced through application of appropriate Best Management Practices on non-point sources to abate the discharge of those pollutants.

7. Such protection-based TMDLs will retain a High Priority for implementation, consistent with similar designations made for restoration-based TMDLs cited in the *Kansas Water Plan*.

8. As a High Priority TMDL, its implementation should receive full consideration for funding through the cost-share programs managed by Kansas Department of Agriculture's Division of Conservation, as resources allow.

9. For candidate heritage streams that are tributary to impaired waters that are subject to a TMDL, provide for protective load allocations to the heritage streams as part of the watershed-based water quality restoration TMDL.

10. KDHE should send a letter to the Chief Engineer of the Kansas Department of Agriculture's Division of Water Resources requesting he utilize his existing authorities to a) impose any conditions of Clean Water Act Section 401 certifications on DWR permitted activities in these six candidate heritage streams, and b) incorporate any applicable conditions on permits to appropriate water from these six candidate heritage streams to protect them from dewatering and loss of in-stream uses.

11. Utilize Watershed Restoration and Protection Strategy (WRAPS) groups, basin advisory committees, watershed districts, non-governmental organizations, conservation groups and other interested citizen groups to promote the benefit and value of heritage streams through public presentations, conservation awards, signage at sites of protective management practices and recognition of collaborative efforts in statewide forums.

12. Continue to use the 401 certification process to apply protective conditions on activities that potentially impact heritage stream systems.

13. Abide by the antidegradation policy within the Kansas Surface Water Quality Standards in reviewing proposed NPDES permits for discharges into heritage streams.

14. Stand ready to provide technical, educational and financial support for local initiatives to protect high quality waters through KDHE's Section 319 program and the conservation programs of the Kansas Department of Agriculture's Division of Conservation.

15. Partner with non-governmental organizations, such as the Kansas Land Trust and The Nature Conservancy, on opportunities to protect minimally impacted watershed lands and the waters that they produce.

These recommendations provide a starting point for continued pursuit of protecting heritage-caliber streams in Kansas. As issues arise regarding protection of high quality waters, policy deliberation should be embraced under the auspice of the *Kansas Water Plan.*

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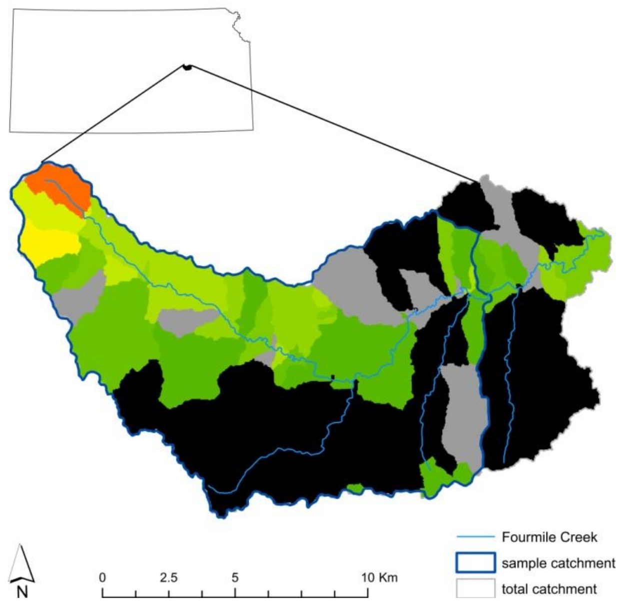
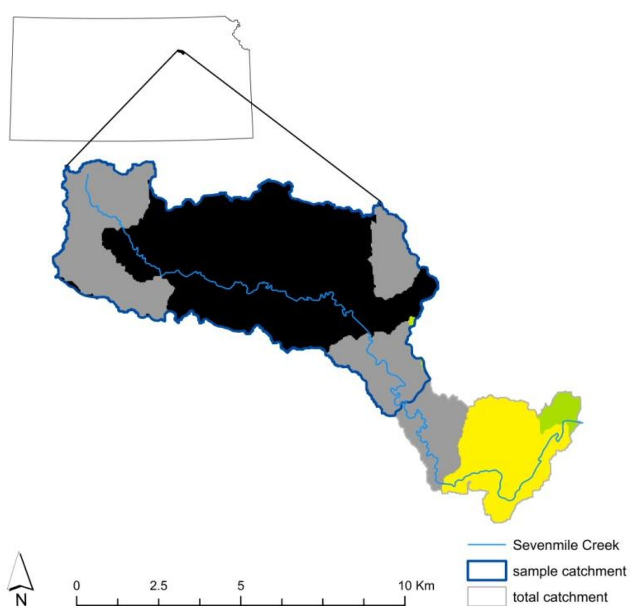
Appendix A. Description of monitored heritage watersheds.

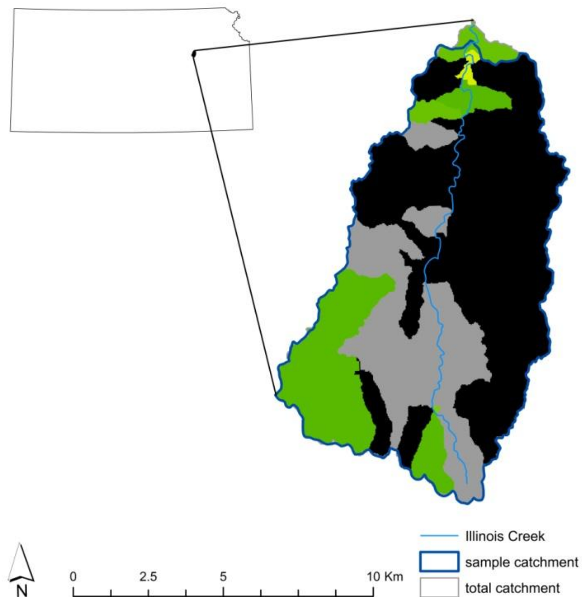
Fourmile Creek is a Flint Hills stream draining approximately 180 km^2 of southern Morris County. The sampling point for the stream is above its confluence with the Neosho River, approximately 27 km down the 35 km long stream and encompasses about 140 km^2 of the entire drainage. The portion of the watershed upstream from the sampling point consists of about 85% grassland, 6% cultivated row crop, 4% forest, and 5% other.



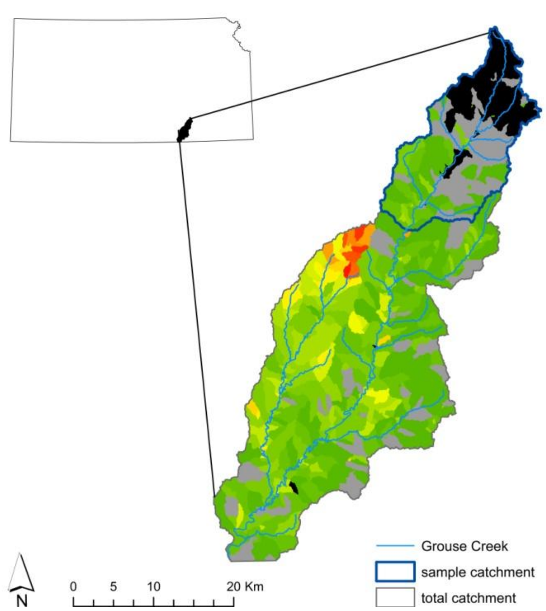
Sevenmile Creek originates on the Fort Riley Military Reservation and maintains a very high level of sinuosity as it flows for 32 km before emptying into the Kansas River. The sampling point on Fort Riley encompasses 48 km^2 of the total 62 km^2 watershed and is 74% grassland, 20% forested, 4% developed, and 2% other.



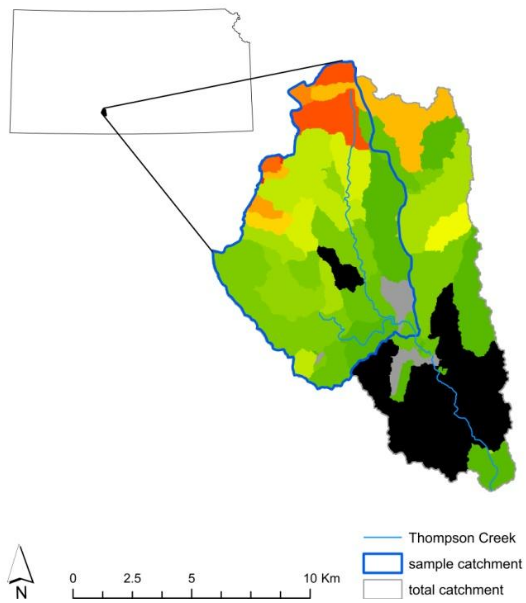
The sampling location on Illinois Creek was very near the terminus of the 20 km long stream, just before it flows into West Branch Mill Creek. This location encompasses 89 km^2 of the total 91 km^2 watershed which is composed of 90% grassland, 2% crop, 5% forested, 3% other.



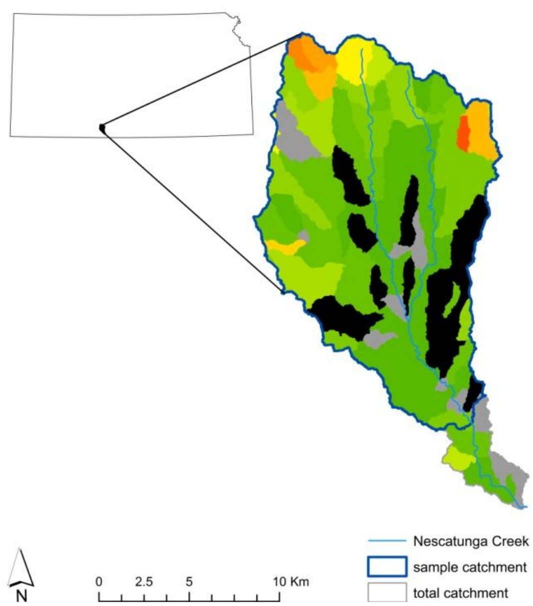
Grouse Creek is the largest of the streams selected with the entire watershed draining 1,043 km^2 of the southern Flint Hills in, primarily, Cowley County. The stream begins in portions of Butler and Elk counties and flows in a southwesterly manner for 117 km before emptying into the Arkansas River. The area of focus for this study was approximately the upper one fourth of the entire watershed. The land area upstream from the sampling point is about 245 km^2 and consists of approximately 94% grassland, 2% row crop, and 4% other.



The sampling location halfway down the heavily spring-fed Thompson Creek watershed encompasses about 70 km^2 of the entire 135 km^2 drainage. Land cover upstream from this point is approximately 72% grassland, 25% row crop, and 3% other. Most row crop in this basin is confined to the upper reaches of the watershed and occurs in the uplands, leaving an intact, buffered grassland valley for the stream to flow through.



Nescatunga Creek is a small system draining 213 km^2 as it flows for 33 km through the southwest tablelands region and into the Salt Fork Arkansas River. The sampling point is near the terminus of the stream and captures 200 km^2 of the watershed which is composed of 83% grassland, 13% row crop, and 4% other.



Appendix B. Fluvial geomorphology report prepared by: The Watershed Institute, Inc.

KANSAS DEPARTMENT OF HEALTH AND ENVIRONMENT

HERITAGE STREAM STUDY

FLUVIAL GEOMORPHOLOGY REPORT

PREPARED BY:

THE WATERSHED INSTITUTE

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February 2012

1.0 INTRODUCTION

Kansas Department of Health and Environment (hereinafter, "KDHE") tasked the Watershed Institute, Inc. (hereinafter, "TWI") to complete fluvial geomorphology surveys at six heritage or reference stream sites. Specifically, TWI collected field data sufficient to accommodate a geomorphologic characterization, morphological description, and stream condition assessment using procedures developed by Rosgen (1996). This document provides information on data collection background and methodology, and summarizes the findings from each of the six survey sites. TWI included all pertinent electronic files, photos, and ArcGIS shapefiles in the attached CD.

2.0 STUDY AREA

KDHE selected the six Kansas heritage stream sites. The six surveys locations are: Fourmile Creek (Morris County), Sevenmile Creek (Riley County), Illinois Creek (Wabaunsee County), Grouse Creek (Cowley County), Nescatunga Creek (Comanche County), and Thompson Creek (Kiowa County). The dates TWI completed field activities are provided in Table 1.

Table 1: Dates of TWI Field Activities

Survey Site	Survey Date(s)
Fourmile Creek	7/14/2011, 7/22/2011
Sevenmile Creek	8/16/2011, 8/26/2011
Illinois Creek	9/8/2011, 9/9/2011
Grouse Creek	10/4/2011, 10/13/2011
Nescatunga Creek	11/1/2011
Thompson Creek	11/2/2011

3.0 DATA COLLECTION BANKGROUND

To best determine channel condition and stability, TWI used methods and procedures defined in Rosgen (1996), which developed a hierarchy of river inventory and assessment protocols consisting of four levels, with each successive level building on the former (Keane 2004). The levels include: (I) Geomorphic Characterization, (II) Morphological Description, (III) Stream State or Condition, and (IV) Validation. TWI chose the Rosgen system for the following reasons (Rosgen 1994):

1. Based on process, as well as form
2. Employs consistent, objective, quantitative, and reproducible measures (Keane 2004)

3. Predicts a river's behavior from its appearance
4. Develops specific hydraulic and sediment relationships for a given stream type and its state
5. Extrapolates site-specific data to stream reaches having similar characteristics
6. Provides basis for communication among water resource professionals
7. Results from measured morphologic characteristics and river-formed variables obtained from hundreds of actual river sites
8. Incorporates all three dimensions of channel form while accounting for differences in channel forming materials (Thorne 1997).

Level I and II data collection procedures characterize and describe channel morphology. Rosgen used this information to develop a stream classification system (see Figure 1). The Level III assessment evaluates stream state or condition. TWI completed an abbreviated Level III assessment evaluating only streambank and streambed stability.

4.0 DATA COLLECTION METHODOLOGY AND ANALYSIS

Data collection procedures are presented in seven categories: Drainage Basin Area, Channel Dimension, Channel Materials, Channel Pattern, Channel Profile, Streambank Stability, Bar Sample, and Channel Stability Assessments.

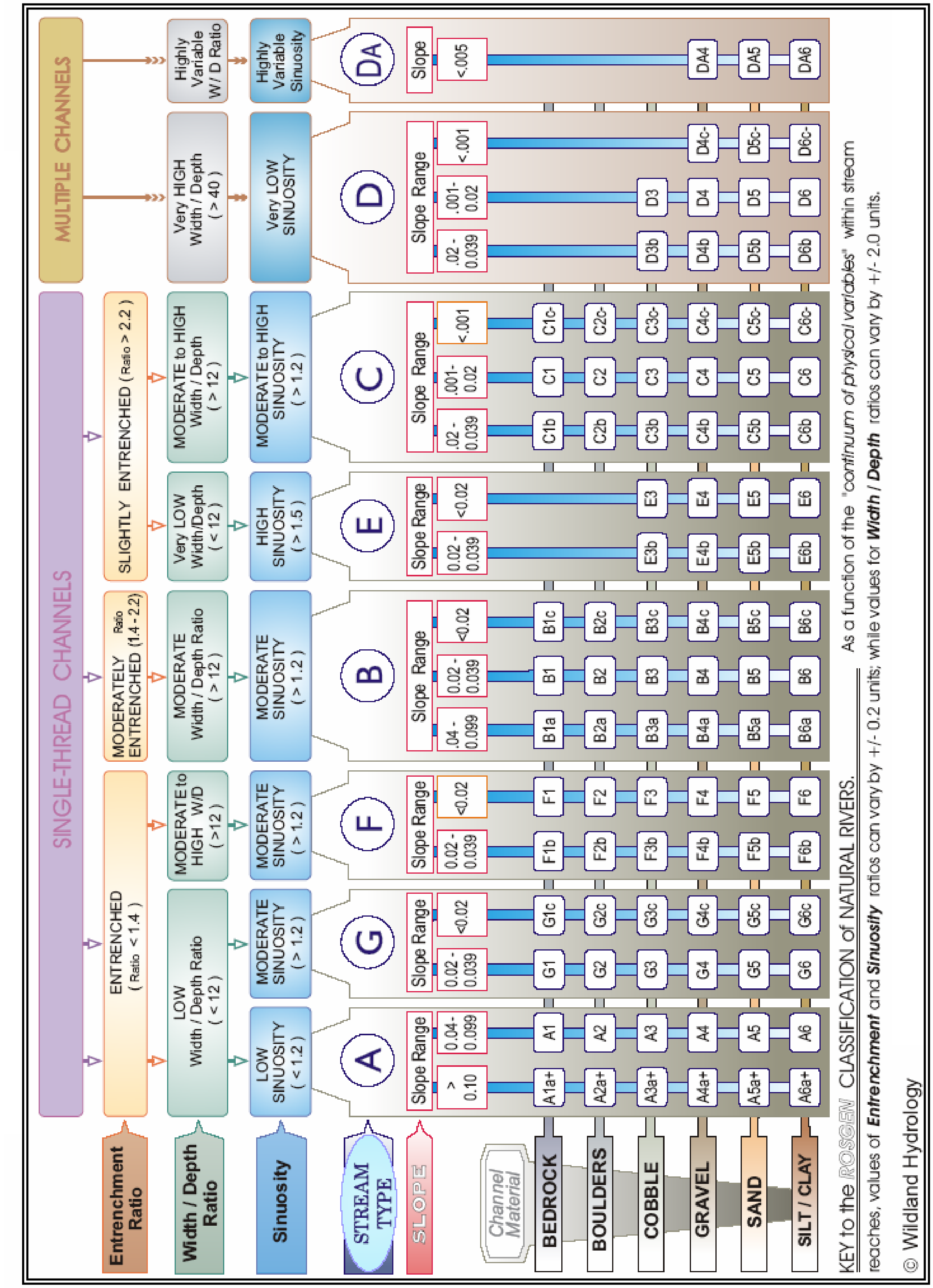
3.1 Drainage Basin Area

TWI recorded a Latitude/Longitude coordinate using a Global Positioning System (hereinafter, "GPS") unit at each survey reach. The coordinates were loaded into ArcGIS software, and overlaid onto U.S. Geological Survey (hereinafter, "USGS") digital raster graphs (hereinafter, "DRG") and 12-digit hydrologic unit code (hereinafter, "HUC") boundaries. TWI used ArcGIS to delineate each drainage area—using the DRG as a guide—by cutting HUC polygons to the appropriate size. ArcGIS calculated the area of the subdivided HUC boundary, resulting in each survey's drainage area.

3.2 Channel Dimension

TWI surveyed riffle and pool channel cross sections to obtain channel dimension parameters. The number of cross sections varied among sites, based on identified changes in bank stability conditions. The cross section surveys represent typical channel dimensions for each bank condition. At least one cross section was surveyed at a riffle, if present, or cross-over reach for stream classification purposes. TWI used a Leica TCR407 Total Station to survey each cross section. Each cross section was oriented

Figure 1: Rosgen Stream Classification System (Rosgen 1996)



perpendicular to flow, and data were recorded at regular intervals to accurately depict the channel shape. In addition to the regular measurement intervals, special features on the cross sections were also documented. These features included edge of water, channel thalweg, terraces, rooting depth elevations, and bankfull stage indicators. Bankfull indicators included change in bank angle, vegetation changes, and top of sediment deposits. The cross section data were imported from the Leica TCR407 Total Station into RIVERMorph stream restoration software which was used to plot the survey data.

3-3 Channel Materials

TWI conducted channel material surveys or "pebble counts" at each survey site. Channel materials are the rocks, pebbles, and sediments that make up the stream bed. TWI used the Wolman (1954) pebble count procedure to characterize the channel materials. This procedure measures the intermediate axis (*i.e.*, width) of randomly selected pebbles. TWI collected a survey reach pebble count and a riffle pebble count (if present). The survey reach pebble count provides information on the size distribution of the stream bed and bank rocks, pebbles, and sediment of the entire survey reach and is used to classify each stream reach. The riffle pebble count provides information on the size distribution of the active channel bed at a chosen riffle. TWI used information from the riffle pebble count to estimate channel bed roughness and particle entrainment.

To ensure random sampling, TWI collected pebbles by blindly reaching down until touching a particle (*e.g*., gravel, cobble, boulder, and bedrock), and then measuring the particle sample's intermediate axis. For small materials such as sands and silt/clay, TWI collected a small pinch of material and the dominant size was determined by visually comparing the sample to a sand grain sizing folder. TWI discarded the samples from collection transects so that the same particles would not be measured a second time. TWI measured approximately 100 samples per count. All pebble count data were entered into RIVERMorph, which was used to calculate the cumulative percentages of samples and group the results into size categories. Additionally, RIVERMorph calculated sediment size and determined the percent composition for each size class (*e.g*., silt/clay, sand, gravel, boulder, cobble, and bedrock).

3-4 Channel Pattern

TWI used aerial photography to measure channel patterns and quantify variations in meander geometry (*i.e.*, sinuosity). Measurements included the lateral extent of meanders (*i.e.*, belt width), the wavelengths of meanders (which documented meander lengths), and the degree of curvature in meanders (*i.e.*, radius of curvature). To determine sinuosity, TWI measured the ratio of stream to valley length in the vicinity of the survey. TWI measured multiple meanders to document the variability of pattern dimensions.

TWI analyzed channel patterns with RIVERMorph, which allows a user to scale selected aerial photographs using a GIS interface. For this project, TWI used 2008 aerial photography from the USDA National Agriculture Imagery Program (U.S. Department of Agriculture Farm Service Agency 2008). RIVERMorph provides tools to measure sinuosity, meander wavelength, belt width, and radius of curvature. It determines the minimum, average, and maximum values for each parameter measured and records the values in a database. The channel pattern information is provided in the summary data sheets in the attached CD.

3-5 Channel Profile

TWI surveyed a longitudinal profile along each study reach, equaling at least two meander wavelengths or 20 times the bankfull width. Using the Leica TCR407 Total Station, TWI surveyed the water surface, bankfull indicators, right and left top-of-bank, and thalweg. The bankfull indicators included "top-of-bank" or a change in bank slope. The left and right top-of-banks were plotted to determine bank height ratios.

The Total Station longitudinal profile survey data were imported into the RIVERMorph software to plot the data. Field identified bankfull indicators served as the basis for determining the bankfull slope. After TWI determined channel dimension, pattern, and profile parameters, each reach was classified using the Rosgen classification system (see Figure 1).

3-6 Streambank Stability

To determine streambank erosion potential, TWI used the Bank Erodibility Hazard Index (hereinafter, "BEHI") assessment to obtain a semi-quantitative, channel stability assessment for rating streambank erosion potential (Rosgen 1996). The assessment ranks the following series of parameters as important factors in streambank resistance to erosion:

- Ratio of streambank height to bankfull height.
- Ratio of riparian vegetation rooting depth to streambank height.
- Rooting density percentage.
- Composition of streambank materials.
- Streambank angle.
- Bank material stratigraphy and presence of soil lenses.
- Bank surface protection provided by debris and vegetation.

TWI scored each parameter based on cross section survey data and visual observations, and determined the appropriate BEHI numeric index rating for each parameter. The numeric parameter ratings are then summed to achieve an overall erosion potential score. BEHI summarizes erosion potential (based on total score) as low, moderate, high, very high, and extreme. When streambank parameters changed, TWI noted the location on the longitudinal profile survey and then assessed the new streambank condition. TWI surveyed a cross section for every observed streambank condition. TWI entered the BEHI data into RIVERMorph, and the software calculated the BEHI variables and overall BEHI rating.

In addition to BEHI, TWI collected data to determine near-bank stress (hereinafter, "NBS") calculations to rate bank stability. NBS determination is used to identify potential disproportionate energy distribution in the near-bank region that can lead to accelerated bank erosion (Rosgen 2006). To determine the NBS, TWI used the ratio of the near-bank maximum depth (hereinafter, "d_{nb}") to mean bankfull depth (hereinafter, "d_{bkf}"). RIVERMorph calculated the d_{nb}/d_{bk} ratio from surveyed cross sections. The ratios were then rated based on the NBS ratings developed by Rosgen (2006) as presented in Table 2.

Table 2: Near-Bank Stress Rating for d_{nb}/d_{bkf}

d_{nb}/d_{bkf} Ratio	NBS Rating
< 1.00	Very Low
1.00 - 1.50	Low
1.51 – 1.80	Moderate
1.81 – 2.50	High
2.51 – 3.00	Very High
> 3.00	Extreme

Source: Rosgen 2006

3-7 Bar Sample

TWI collected a bar sample at survey sites with gravel and cobble dominated deposits to estimate stream channel scour/deposition potential. The collection protocol followed the bar/bulk sample of representative channel material subject to movement from Rosgen (2000). The Rosgen protocol is as follows:

1. A bottomless bucket is placed on a typical point within the downstream third of the lateral or point bar approximately half the distance between the thalweg and bankfull stage.
2. The two largest particles at the surface from the bottomless bucket are individually measured (intermediate axis) and weighed.

3. Materials are excavated from the bottomless bucket to a depth twice the diameter of the largest surface particle. The excavated material is placed in another bucket.
4. The excavated channel materials are wet sieved. The sieves are 2 millimeters (hereinafter, “mm”), 4 mm, 8 mm, 16 mm, 31.5 mm, and 63 mm.
5. All sieved materials are weighed by size class.

Rosgen (2000) developed a field and analytical procedure for competence and entrainment calculations. Riffle pebble count, bar sample, determination of water surface slope, and bankfull mean depth are the data requirements for the procedure and is valid only for gravel and cobble-bed streams. To infer bed stability, the calculated mean depth and bankfull water surface slope required to entrain the largest particle in bar sample is compared to the existing mean depth and bankfull water surface slope. If these ratios equal 1, the channel has the proper competence to move sediment. If the ratio is less than 1, the stream’s competence is less than required and suggests potential aggradation. A ratio greater than 1 indicates excess competence or shear stress indicating potential degradation. TWI completed this analysis at Fourmile Creek, Sevenmile Creek, Illinois Creek, and Grouse Creek and the data are presented in a bed stability worksheet (see Figure 2) in the attached CD.

3-8 Channel Stability Assessments

TWI noted additional parameters during the field surveys to characterize the sediment supply. The parameters included observed meander patterns (see Figure 3) and depositional patterns (see Figure 4), and variables used determine the Pfankuch Channel Stability Rating (see Figure 5) (Pfankuch 1975). TWI used these parameters plus information collected from the channel cross section, BEHI, and NBS to asses overall channel stability in regards to sediment supply. The document titled, “Sediment Supply-Stability Summary” that is provided in the attached CD details the procedure to rate sediment supply.

Figure 2: Sediment Competence Calculations to Assess Bed Stability (from Rosgen 2006)

Worksheet 5-15. Sediment competence calculation form to assess bed stability.

Stream:			Stream Type:		
Location:			Valley Type:		
Observers:			Date:		
Enter required information					
	D_{50}	Riffle bed material D_{50} (mm)			
	$\hat{D}_{50}$	Bar sample D_{50} (mm)			
	D_{max}	Largest particle from bar sample (ft)		(mm)	304.8 mm/ft
	S	Existing bankfull water surface slope (ft/ft)			
	d	Existing bankfull mean depth (ft)			
	γ_s	Submerged specific weight of sediment			
Select the appropriate equation and calculate critical dimensionless shear stress					
	$D_{50}/\hat{D}_{50}$	Range: 3 – 7	Use EQUATION 1: $\tau^* = 0.0834 \left(D_{50}/\hat{D}_{50} \right)^{-0.872}$		
	D_{max}/D_{50}	Range: 1.3 – 3.0	Use EQUATION 2: $\tau^* = 0.0384 \left(D_{max}/D_{50} \right)^{-0.887}$		
	τ^*	Bankfull Dimensionless Shear Stress	EQUATION USED:		
Calculate bankfull mean depth required for entrainment of largest particle in bar sample					
	d	Required bankfull mean depth (ft)	$d = \frac{\tau^* \gamma_s D_{max}}{S}$		
	Check: ☐ Stable ☐ Aggrading ☐ Degrading				
Calculate bankfull water surface slope required for entrainment of largest particle in bar sample					
	S	Required bankfull water surface slope (ft/ft)	$S = \frac{\tau^* \gamma_s D_{max}}{d}$		
	Check: ☐ Stable ☐ Aggrading ☐ Degrading				
Sediment competence using dimensional shear stress					
	Bankfull shear stress $\tau = \gamma dS$ (lbs/ft^2) (substitute hydraulic radius, R, with mean depth, d)				
	Moveable particle size (mm) at bankfull shear stress **(Figure 5-54)**				
	Predicted shear stress required to initiate movement of D_{max} (mm) **(Figure 5-54)**				
	Predicted mean depth required to initiate movement of D_{max} (mm) $d = \frac{\tau}{\gamma S}$				
	Predicted slope required to initiate movement of D_{max} (mm) $S = \frac{\tau}{\gamma d}$				

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Figure 3: Meander Patterns (Rosgen 1996)

B-1	Point bars
B-2	Point Bars with Few Mid Channel Bars
B-3	Many Mid Channel Bars
B-4	Side Bars
B-5	Diagonal Bars
B-6	Main Branching with Many Mid Bars and Islands
B-7	Mixed Side Bar and Mid Channel Bars (Exceeding 2 - 3 X Width)
B-8	Delta Bars

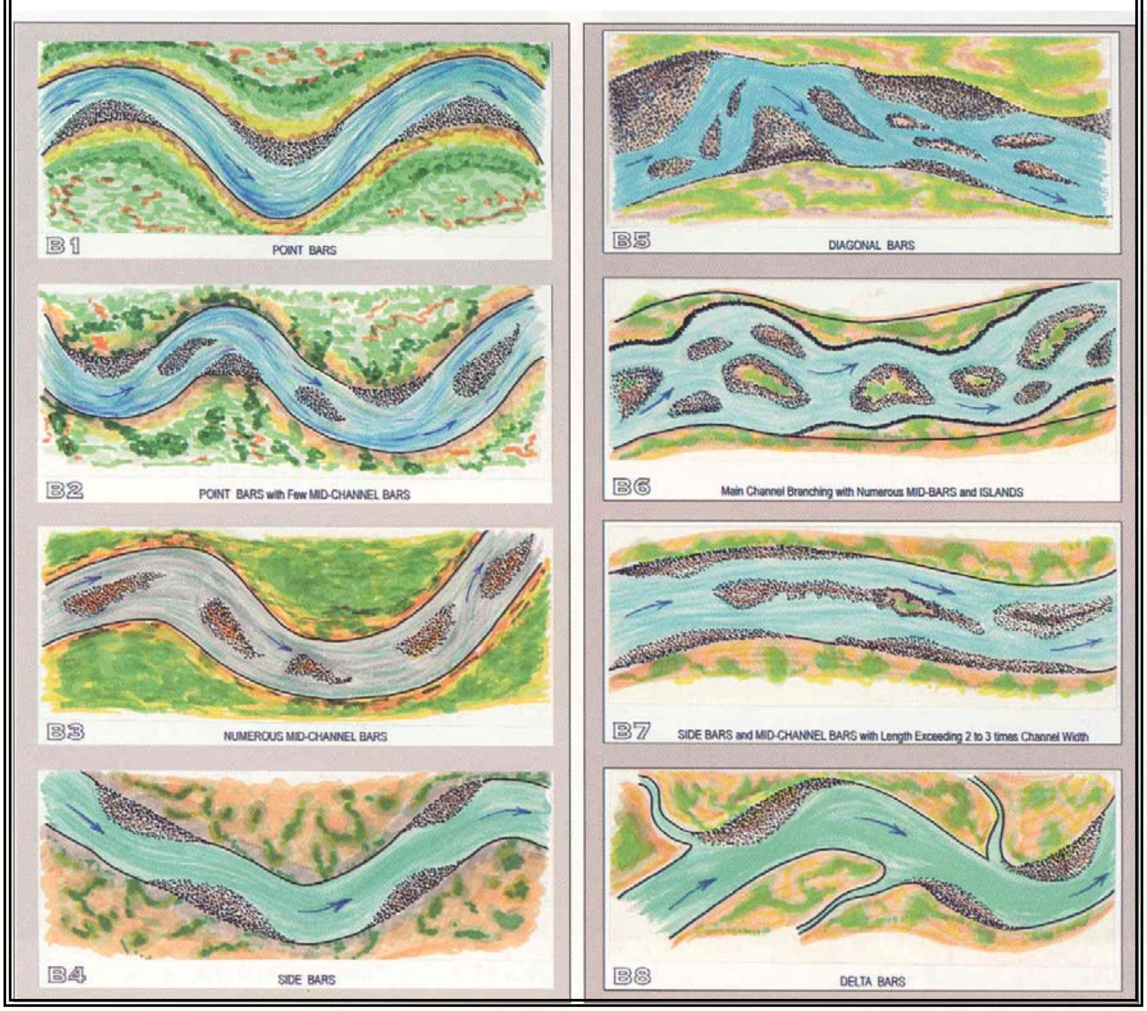

Figure 4: Depositional Patterns (Rosgen 1996)

M-1	Regular Meander
M-2	Tortuous Meander
M-3	Irregular Meander
M-4	Truncated Meanders
M-5	Unconfined Meander Scrolls
M-6	Confined Meander Scrolls
M-7	Distorted Meander Loops
M-8	Irregular with Oxbows, Oxbow Cutoffs

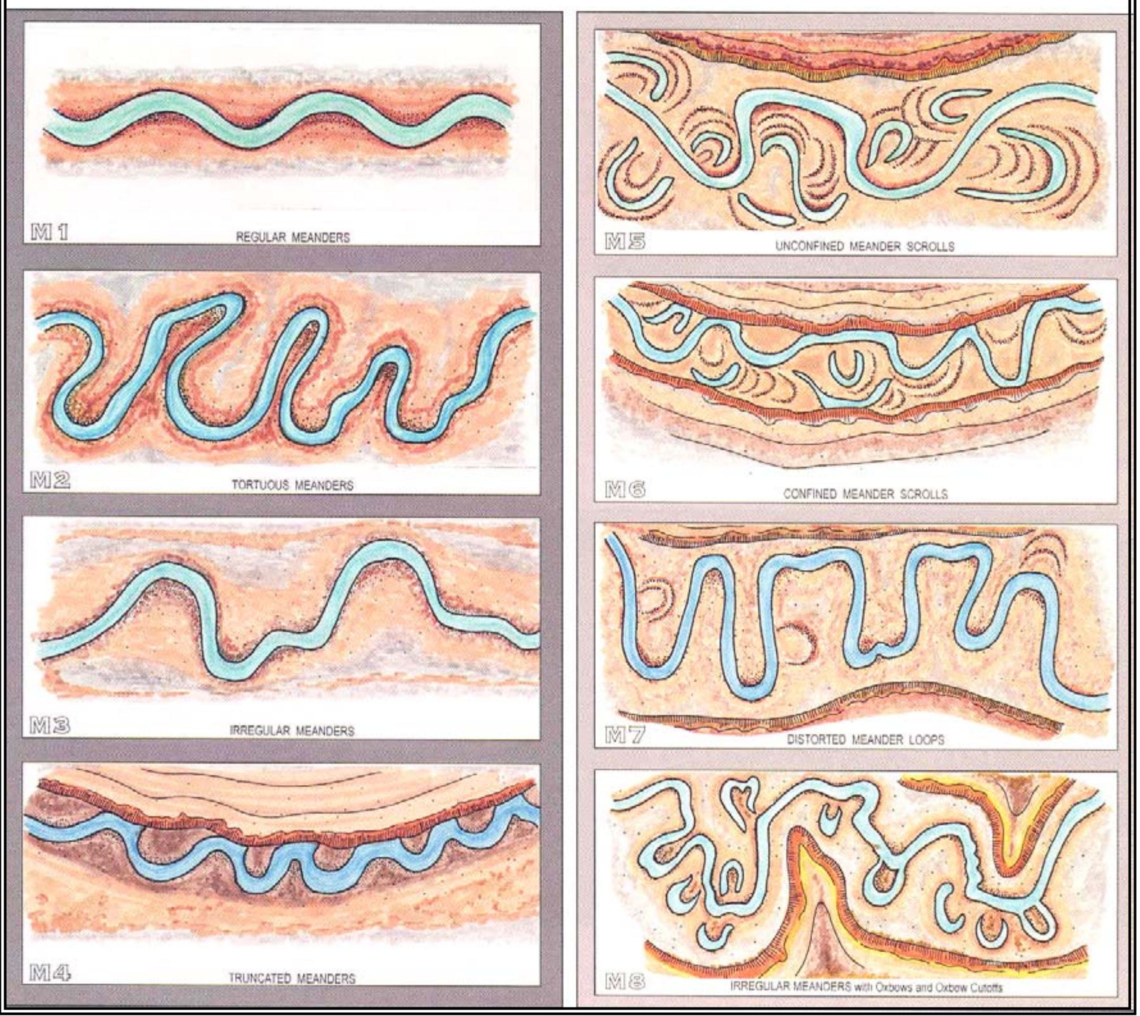

Figure 5: Pfankuch (1975) Channel Stability Rating Procedure (from Rosgen 2006)

Worksheet 5-7. Pfankuch (1975) stream channel stability rating procedure, as modified by Rosgen (1996, 2001b).

Stream: **Location:** **Valley Type:** **Observers:** **Date:**

Location	Key	Category	Excellent Description	Rating	Good Description	Rating	Fair Description	Rating	Poor Description	Rating
Upper banks	1	Landform slope	Bank slope gradient <30%.	2	Bank slope gradient 30–40%.	4	Bank slope gradient 40–60%.	6	Bank slope gradient > 60%.	8
	2	Mass erosion	No evidence of past or future mass erosion.	3	Infrequent. Mostly healed over. Low future potential.	6	Frequent or large, causing sediment nearly yearlong.	9	Frequent or large, causing sediment nearly yearlong OR imminent danger of same.	12
	3	Debris jam potential	Essentially absent from immediate channel area.	2	Present, but mostly small twigs and limbs.	4	Moderate to heavy amounts, mostly larger sizes.	6	Moderate to heavy amounts, predominantly larger sizes.	8
	4	Vegetative bank protection	> 90% plant density. Vigor and variety suggest a deep, dense soil-binding root mass.	3	70–90% density. Fewer species or less vigor suggest less dense or deep root mass.	6	50–70% density. Lower vigor and fewer species from a shallow, discontinuous root mass.	9	<50% density plus fewer species & less vigor indicating poor, discontinuous and shallow root mass.	12
Lower banks	5	Channel capacity	Bank heights sufficient to contain the bankfull stage. Width/depth ratio departure from reference width/depth ratio = 1.0. Bank-Height Ratio (BHR) = 1.0.	1	Bankfull stage is contained within banks. Width/depth ratio departure from reference width/depth ratio = 1.0–1.2. Bank-Height Ratio (BHR) = 1.0–1.1.	2	Bankfull stage is not contained. Width/depth ratio departure from reference width/depth ratio = 1.2–1.4. Bank-Height Ratio (BHR) = 1.1–1.3.	3	Bankfull stage is not contained; over-bank flows are common with flows less than bankfull. Width/depth ratio departure from reference width/depth ratio > 1.4. Bank-Height Ratio (BHR) > 1.3.	4
	6	Bank rock content	> 65% with large angular boulders. 12"+ common.	2	40–65%. Mostly boulders and small cobbles 6–12".	4	20–40%. Most in the 3–6" diameter class.	6	<20% rock fragments of gravel sizes, 1–3" or less.	8
	7	Obstructions to flow	Rocks and logs firmly imbedded. Flow pattern w/o cutting or deposition. Stable bed.	2	Some present causing erosive cross currents and minor pool filling. Obstructions fewer and less firm.	4	Moderately frequent, unstable obstructions move with high flows causing bank cutting and pool filling.	6	Frequent obstructions and deflectors cause bank erosion yearlong. Sediment traps full, channel migration occurring.	8
	8	Cutting	Little or none. Infrequent raw banks <6".	4	Some, intermittently at outcurves and constrictions. Raw banks may be up to 12".	6	Significant. Cuts 12–24" high. Root mat overhangs and sloughing evident.	12	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	16
	9	Deposition	Little or no enlargement of channel or point bars.	4	Some new bar increase, mostly from coarse gravel.	8	Moderate depostion of new gravel and coarse sand on old and some new bars.	12	Extensive deposit of predominantly fine particles. Accelerated bar development.	16
Bottom	10	Rock angularity	Sharp edges and corners. Plane surfaces rough.	1	Rounded corners and edges. Surfaces smooth and flat.	2	Corners and edges well rounded in 2 dimensions.	3	Well rounded in all dimensions, surfaces smooth.	4
	11	Brightness	Surfaces dull, dark or stained. Generally not bright.	1	Mostly dull, but may have <35% bright surfaces.	2	Mixture dull and bright, i.e., 35–65% mixture range.	3	Predominantly bright, > 65%, exposed or scoured surfaces.	4
	12	Consolidation of particles	Assorted sizes tightly packed or overlapping.	2	Moderately packed with some overlapping.	4	Mostly loose assortment with no apparent overlap.	6	No packing evident. Loose assortment, easily moved.	8
	13	Bottom size distribution	No size change evident. Stable material 80–100%.	4	Distribution shift light. Stable material 50–80%.	8	Moderate change in sizes. Stable materials 20–50%.	12	Marked distribution change. Stable materials 0–20%.	16
	14	Scouring and deposition	<5% of bottom affected by scour or deposition.	6	5–30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	12	30–50% affected. Deposits and scour at obstructions, constrictions and bends. Some filling of pools.	18	More than 50% of the bottom in a state of flux or change nearly yearlong.	24
	15	Aquatic vegetation	Abundant growth moss-like, dark green perennial. In swift water, too.	1	Common. Algae forms in low velocity and pool areas. Moss here, too.	2	Present but spotty, mostly in backwater. Seasonal algae growth makes rocks slick.	3	Perennial types scarce or absent. Yellow-green, short-term bloom may be present.	4
			Excellent total =		Good total =		Fair total =		Poor total =	

Stream type	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	C5	C6	D3	D4	D5	D6
Good (Stable)	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107	67-98
Fair (Mod. unstable)	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132	99-125
Poor (Unstable)	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+

Stream type	DA3	DA4	DA5	DA6	E3	E4	E5	E6	F1	F2	F3	F4	F5	F6	G1	G2	G3	G4	G5	G6
Good (Stable)	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63	60-85	60-85	85-110	85-110	90-115	80-95	40-60	40-60	85-107	85-107	90-112	85-107
Fair (Mod. unstable)	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86	86-105	86-105	111-125	111-125	116-130	96-110	61-78	61-78	108-120	108-120	113-125	108-120
Poor (Unstable)	87+	87+	87+	87+	87+	97+	97+	87+	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+

Grand total =	
Existing stream type =	
*Potential stream type =	
Modified channel stability rating =	

*Rating should be adjusted to potential stream type, not existing.

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5.0 RESULTS

The attached CD contains all of the data relating to cross section surveys, longitudinal profiles, pebble counts, stream classification, geomorphology summary data, bed stability, and Pfankuch assessments. Also included are all photographs taken by TWI and an Excel spreadsheet that briefly describes each photograph. TWI will provide a brief summary of findings in the following subsections.

5.1 Fourmile Creek

Fourmile Creek is a stream within the Flint Hills ecoregion that drains approximately 55 square miles. Fourmile Creek classified as a C3/1 stream as the streambed consisted of bedrock through much of the reach. Table 3 shows a summary of the classification parameters.

Table 3: Fourmile Creek Classification Summary

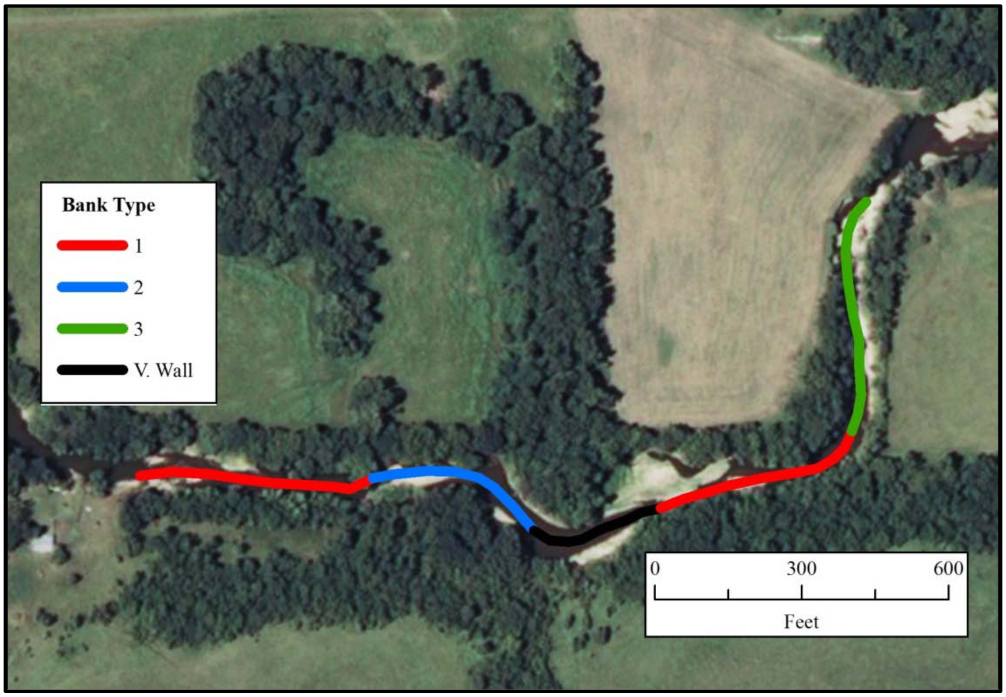
Entrenchment Ratio	Width/Depth Ratio	Sinuosity	Slope Ratio	Channel Material Size (mm)	Rosgen Stream Type*
2.9	16.9	1.27	0.00348	90	C3/1

Through much of the survey reach, the creek flows against the south valley wall. These banks are often high with bedrock outcrops. The valley wall is well vegetated with mature timber except for one short outside meander bend. At one time, the creek did flow north across the valley forming a large meander. Based on aerial photograph measurements, the old meander is approximately 2,300 feet long. TWI does not know when the meander was cutoff, but it is not recent. The meander cutoff has affected the local channel morphology. Currently, there are large gravel deposits where the current channel intersects the relic channel. TWI surveyed cross section 2 just upstream where the channel meandered north. At this location, there is a large, vegetated mid bar that diverts water along the left and right banks. As a result, both banks show signs of erosion.

The longitudinal profile is characterized by short riffles and long, shallow pools. Towards the end of the survey, the creek flows over a small bedrock falls. As with most limestone outcrops, the rate of streambed erosion is fairly slow. The bedrock streambed produces a fairly steep localized gradient for a stream with a drainage area as large as Fourmile Creek. The bank heights increase towards the downstream stream end indicating that the channel is more vertically confined. At the lower end, there is not a consistent floodplain feature.

TWI identified three bank conditions or types in the BEHI assessment (see Figure 6). TWI did not evaluate the short segment where the valley wall is vertical. In this segment, the bank height exceeds 40 feet, and TWI deemed it unsafe to survey. TWI characterized bank type 1 in two fairly straight segments. The bank full elevation was connected to a narrow floodplain feature on the left bank. Both banks are well vegetated and TWI rated the BEHI assessment as "low." TWI also rated the NBS as "low" using data from cross section 1.

Figure 6: Fourmile Creek Bank Types



Bank type 2 is located where the channel began to meander south to the vertical valley wall. The left bank is much higher and steeper. TWI observed many exposed and undercut roots in the left bank. As a result, the BEHI rated as "moderate." The NBS remained low as the streambed was fairly uniform due to the bedrock streambed.

TWI identified the third bank type where the creek began to flow away from the south valley wall. The banks are higher than bank type 2 resulting in a higher score, but overall "moderate" BEHI rating. One reason for the increased bank heights is the bedrock falls. TWI used cross section 3 for the BEHI assessment that is located downstream from the bedrock falls. The drop in streambed elevation causes the overall bank height to increase thus increasing the erosion potential. The NBS rating was also "moderate." TWI observed signs of active erosion along the right bank that included exposed roots and undercut banks above the bedrock outcrop. The dominant reach BEHI/NBS scores were "moderate"/"low."

The sediment competence calculations indicate that the stream reach is degrading. Based on the bar sample, the bankfull mean depth required to entrain the largest particle in the bar sample is 4.0 feet. The existing mean depth is 5.3 feet. TWI suggests that the results are biased due to the bedrock falls that creates an increase in the local water surface slope. Since the streambed is predominately bedrock, the rate of streambed degradation is slow. However, lateral erosion appears greatest in this area since the creek is not connected to a floodplain feature.

Finally, TWI assessed the sediment supply using the procedure from the *Sediment Supply-Stability Summary* document located in the attached CD. TWI rated the survey reach as "moderate." Table 4 shows the results from this summary.

Table 4: Fourmile Creek Sediment Supply Summary

Dominant BEHI/NBS	Width/ Depth	Bank Height Ratio	Pfankuch	Stream Successional Stage	Depositional Pattern	Meander Pattern
7	5	5	12	2	2	33

5-2 Sevenmile Creek

TWI classified the Sevenmile Creek Survey as an E3/1 stream type (see Table 5). Sevenmile Creek is located in the Flint Hills Ecoregion and drains approximately 18.1 square miles. The channel sinuosity is very high in the vicinity of the survey reach. For most of the survey reach, the stream flowed over bedrock. The bar deposits consist of course substrate predominately consisting of course gravels and cobbles. The Sevenmile Creek survey has the coarsest substrate of the Flint Hills streams surveyed in the heritage study. The bankfull elevation is uniform with the left bank floodplain throughout the entire survey. The right bank is connected to the floodplain at the beginning and end of the survey reach. For most of the survey, the right bank is along the valley wall.

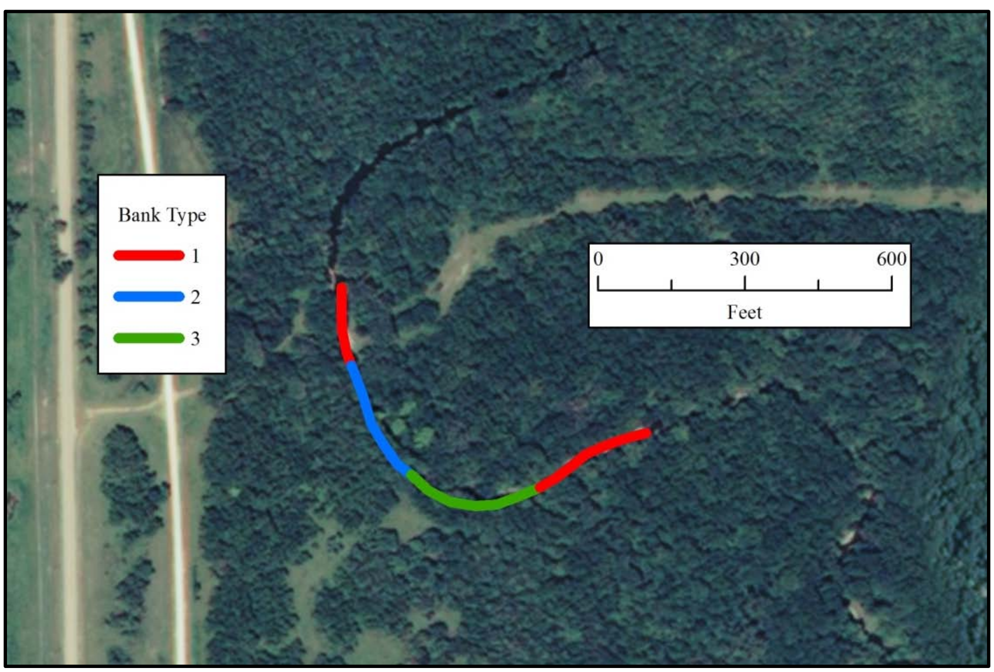
Table 5: Sevenmile Creek Classification Summary

Entrenchment Ratio	Width/Depth Ratio	Sinuosity	Slope Ratio	Channel Material Size (mm)	Rosgen Stream Type*
3.7	10.7	3.06	0.00487	231	E3/1

The longitudinal profile is characterized by short riffles and long, shallow pools. The bedrock streambed creates a uniform streambed with little depth diversity. There is one relatively deep pool as the stream begins to scour into alluvium instead of bedrock. The profile shows the bankfull elevation and left bank nearly at the same elevation. This indicates a stream that is connected to a floodplain with bank height ratio of 1.0.

TWI identified three bank types (see Figure 7). Bank type 1 is found where both banks are connected to a floodplain. The bank height ratio is 1.0 and the roots extend down through the entire bank. The only parameter that scored poorly is surface protection. Most of the banks have exposed soils and little cover. The BEHI assessment scored as "moderate" and the NBS as "low" using cross section 1 for NBS calculations.

Figure 7: Sevenmile Creek Bank Types



Bank type 2 began where the creek flows against the valley wall. The right bank height ratio went from 1.0 to 4.2. The lower bank consisted of bedrock, greatly improving the bank stability due to high erosion resistance. As a result, the BEHI rated "very low." The bedrock streambed creates a uniform depth across the entire wetted width and the NBS rated "low" using cross section 2 for the NBS calculations.

Bank type 3 is located along the valley wall where the vegetation becomes less dense. The roots extend about half-way down the bank and there is little surface protection. This segment is also influenced by bedrock in the lower bank, generating a "very low" BEHI rating. TWI observed limestone layers that are undercut, but the erosional process appears slow and the creek will not likely move the large limestone boulders. The NBS rated as "low" using cross section 3 in the NBS calculations. The overall or dominant BEHI/NBS rating is "very low"/"low."

The sediment competence calculations indicate that bed stability is good. The sediment supply assessment resulted in a low rating (see Table 6). Of the four Flint Hill creek surveys, Sevenmile Creek data indicates the best stability. The survey reach is connected to a well defined floodplain. Connection to a floodplain allows for runoff events to spread laterally creating energy dissipation and less shear stress is applied to the streambed and banks.

Table 6: Sevenmile Creek Sediment Summary

Dominant BEHI/NBS	Width/ Depth	Bank Height Ratio	Pfankuch	Stream Successional Stage	Depositional Pattern	Meander Pattern
1	1	1	7	1	1	12

5.3 Illinois Creek

Illinois Creek classified as an E3/1 stream type (see Table 7). The survey is located in the Flint Hill Ecoregion and drains about 34.7 square miles. Throughout most of the survey reach, the stream flows against the valley wall and over bedrock. There is a narrow floodplain feature along the right bank before the bank slopes up to the adjacent field elevation. For each cross section survey, TWI surveyed from the top of the left bank valley wall to the right bank ending at the adjacent field. The cross sections also reflect the current riparian width of mature woody vegetation.

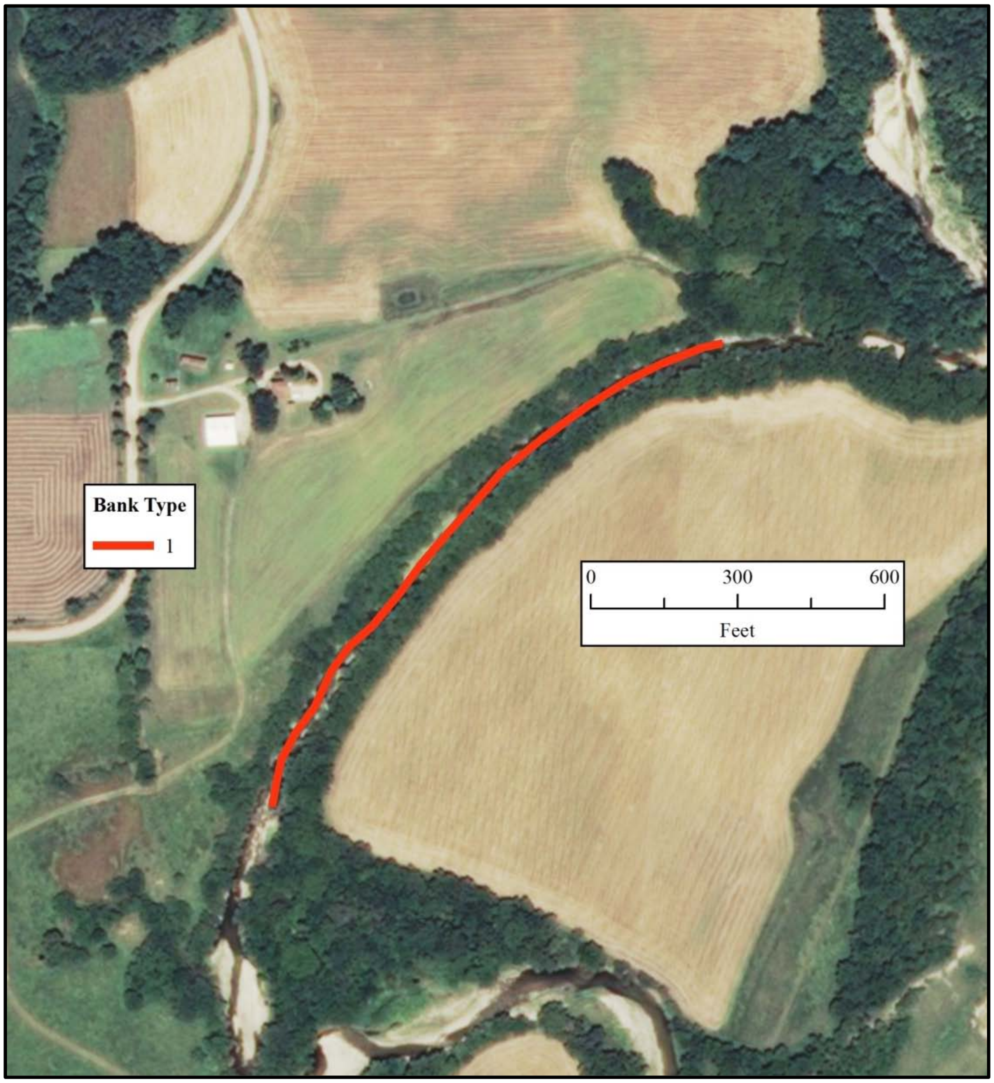
Table 7: Illinois Creek Classification Summary

Entrenchment Ratio	Width/Depth Ratio	Sinuosity	Slope Ratio	Channel Material Size (mm)	Rosgen Stream Type*
1.7	9.3	1.50	0.00164	73	E3/1

The longitudinal profile consists of very short riffles and long, shallow pools. Most of the streambed is limestone bedrock. Just before the crossing (downstream extent of longitudinal profile), a small bedrock falls creates an increase in the local stream gradient. The erosion of the limestone bedrock appears slow. TWI staff surveyed the same area in 2003 and there does not appear to be much change in the bedrock falls. The longitudinal profile also shows the left and right bank much higher compared to the bankfull elevation in the upstream portion. The left and right bank elevations gradually decrease while moving downstream. At the beginning of the survey, the bank height ratio is 2.2 suggesting the stream is incised and cannot easily access a floodplain. At the downstream extent, the bank height ratio is 1.1 suggesting that the stream can access a floodplain feature that is slightly higher than the bankfull elevation.

TWI identified only one bank type since the creek flows along the valley wall (see Figure 8). The right bank is much higher that the bankfull elevation, but is fairly well vegetated and contains bedrock outcrops providing good erosion resistance. The BEHI rated "very low" due to the bedrock influence. The NBS rating was "low" due to a uniform streambed influenced by the bedrock. There is some evidence of erosion along the left bank that includes exposed tree roots and trees leaning out over the channel. The erosion appears slow and more shear stress is likely applied to the right bank during runoff events based on the channel pattern. The mature woody vegetation contributes to streambank stability as the banks are fairly high on both sides and only a narrow floodplain feature that helps dissipate energy. The mature woody vegetation increases the root density and has rooting depths that encompass the entire bank. These parameters strengthen the bank stability.

Figure 8: Illinois Creek Bank Type



The sediment competence calculation suggests that the streambed is stable. The sediment supply assessment resulted in a low rating (see Table 8).

Table 8: Illinois Creek Sediment Supply Summary

Dominant BEHI/NBS	Width/ Depth	Bank Height Ratio	Pfankuch	Stream Successional Stage	Depositional Pattern	Meander Pattern
1	1	8	7	1	1	19

5-4 Grouse Creek

Grouse Creek classified as a C4/1 stream type (see Table 9). This site is located in the Flint Hills Ecoregion and drains 94.4 square miles. Bedrock influences the upstream portion, but most of the streambed is alluvium. Grouse Creek was not flowing at the time of the survey but water was present in pools. As a result, TWI did not obtain water facet slopes. The riparian corridor is fragmented with some banks having wide woody vegetation corridors and other banks with scattered woody vegetation. Towards the end of the survey, the creek meanders north and then makes a tight bend back to the south. The meander radius is very small and a “neck” cutoff will soon occur creating an oxbow meander. TWI observed several chutes where flood flows have cut across the meander. When the cutoff occurs, it will shorten the channel by approximately 600-700 feet (assuming the cutoff occurs at the narrowest location).

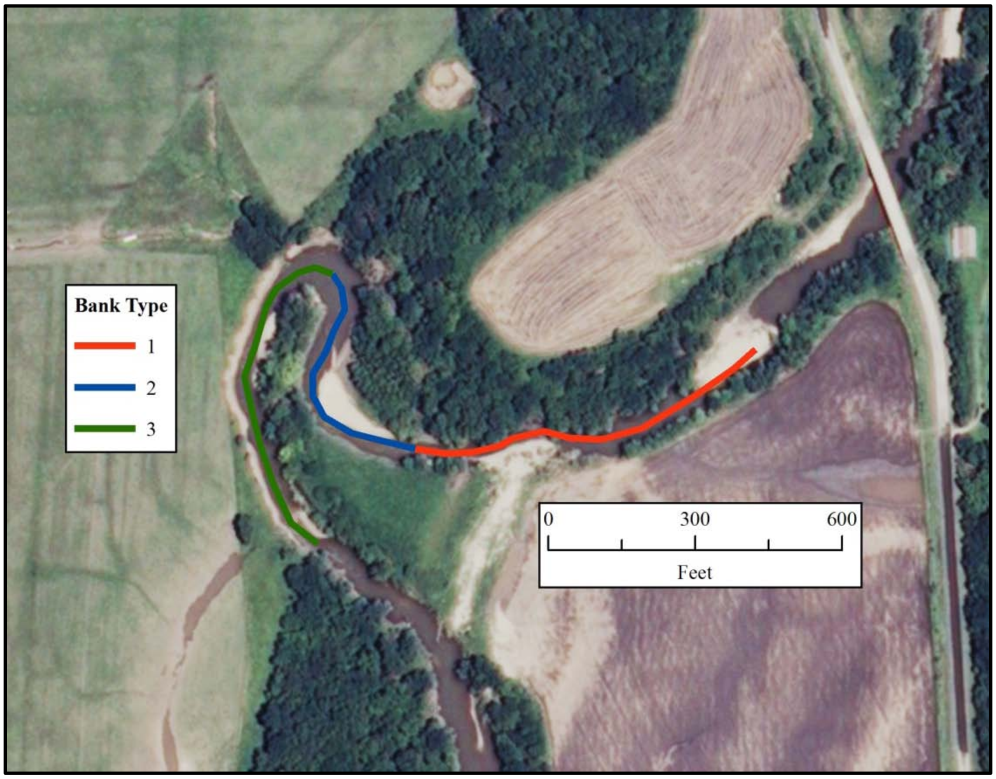
Table 9: Grouse Creek Classification Summary

Entrenchment Ratio	Width/Depth Ratio	Sinuosity	Slope Ratio	Channel Material Size (mm)	Rosgen Stream Type*
3.1	22.8	1.58	0.00130	18	C4/1

The longitudinal profile consisted of a diverse riffle/pool sequence. Riffle lengths varied from 30 feet to over 100 feet. Pools also varied in length ranging from 28 feet to over 270 feet. The pools also have good depth diversity. Maximum bankfull pool depths ranged from 8.5 feet to 13.0 feet. Of all the heritage stream profiles, the Grouse Creek profile was the most diverse. The average left and right banks criss-cross in the profile indicating at least one bank is fairly high (compared to the bankfull elevation) at all times. TWI did not find a consistent bankfull feature and the bank height ratios ranged from 1.2 to 1.5. Grouse Creek is able to spread out during high runoff events, but is takes a fairly high magnitude flow to reach the adjacent field elevations. As a result, more shear stress is confined to a smaller cross sectional area compared to streams that are well connected to a floodplain.

TWI identified 3 bank types (see Figure 9). Bank type 1 occurs in the first 819 feet. The high bank is normally two times the bankfull elevation. The wooded riparian corridor on the left bank is fairly narrow and the rooting density is poor even though roots do extent through the entire bank. Surface protection is also poor and the BEHI assessment rated as “moderate.” TWI used the average NBS calculations from cross section 1 and 2 resulting in the “moderate” rating.

Figure 9: Grouse Creek Bank Types



Bank type 2 begins where the creek meanders to the north. This is the location where the creek will eventually develop a cutoff. The left bank has very little woody vegetation on top of bank. The rooting depth only extends about 3 feet into the bank and there is very little surface protection. The BEHI rated as “high” and the NBS rated as “moderate.” TWI used the average NBS calculations from cross section 3 and 4.

Bank type 3 begins where the creek flows against a high, right bank. The banks along this segment are the highest in the survey reach. There are scattered shrubs and grasses at top of bank, and the roots extend down about one-third the bank height. Again, surface protection is poor. The BEHI rated “high” and the NBS rated “low.” TWI used cross section 5 to calculate the NBS score. Bank type 2 and 3 scored the highest for erosion potential in all heritage stream surveys. However, TWI did not observe many areas of excess sedimentation of fine grained materials. The pools adjacent to these bank types were deep with little signs of filling. Bank materials are dominated by silt/clay particles that are easily entrained during high flow events. The dominant BEHI/NBS rating was “high”/”moderate.”

The sediment competence calculation suggests that the streambed is aggrading. The calculated mean depth and average water surface slope are much higher than the existing mean depth and average slope.

The survey also has a much higher width/depth ratio compared to the other Flint Hills surveys. Wider, shallower streams typically have less shear stress since water depths are lower and channel roughness is higher. The survey reach did have extensive gravel deposits upstream of the meander loop. Just upstream of the survey reach is a segment with bedrock control. TWI did not survey this area in order to stay away from the county road bridge; however, this reach may have a steeper gradient and have the ability to move sediment to the survey reach. The surveyed reach can dissipate energy vertically with the deep pools as well as laterally by the meander loop. Once the meander is cutoff, the stream slope will increase to near the average water surface slope calculated to move the largest bar particle.

Due to the high banks and the high streambank erosion potential, the sediment supply assessment rating was "moderate." The actual score was the highest score of the heritage stream surveys (see Table 10).

Table 10: Grouse Creek Sediment Supply Summary

Dominant BEHI/NBS	Width/ Depth	Bank Height Ratio	Pfankuch	Stream Successional Stage	Depositional Pattern	Meander Pattern
14	2	5.5	7	12	1	41.5

5-5 Nescatunga Creek

Nescatunga Creek classified as an E5 stream type (see Table 11). The survey is located in the Southwestern Tablelands Ecoregion and has a drainage area of 76.8 square miles. The riparian area consists of grasses with scattered trees dominated by eastern cottonwood and eastern red cedar. Along the creek banks, TWI observed willow, wild plum, grasses, and sedges. There are terrace features on both banks with a well defined floodplain in-between. TWI surveyed each cross section from the left terrace to right terrace. Sand is the dominate particle size in both the streambed and streambanks. As a result, TWI only conducted a reach pebble count for particle size analysis. TWI did not perform a sediment competence calculation as all particles are moving during a bankfull flow event.

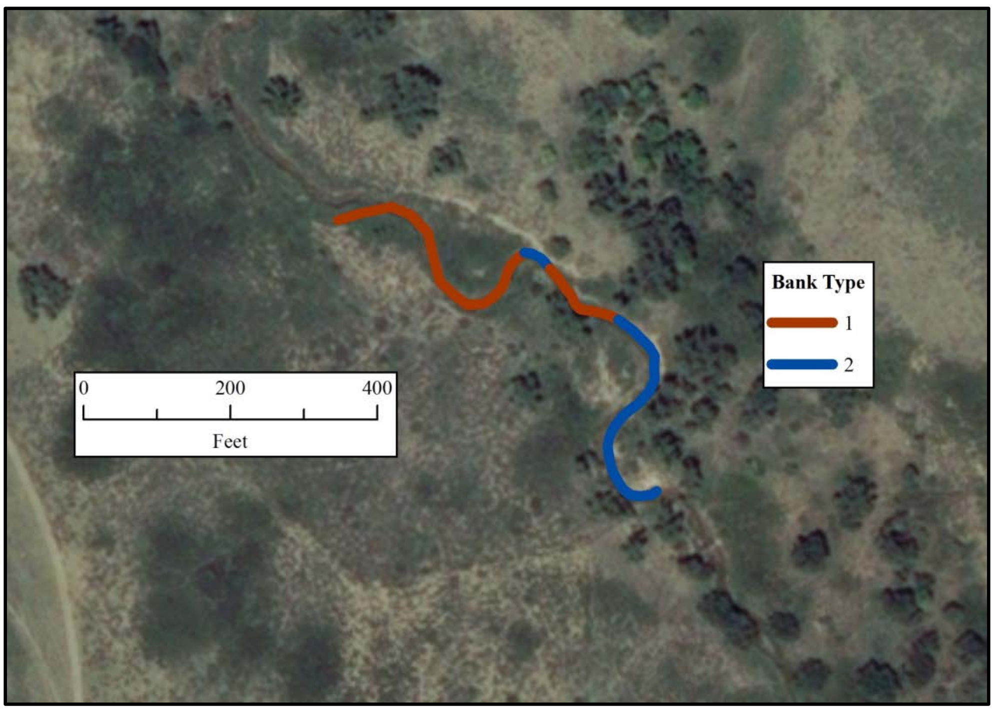
Table 11: Nescatunga Creek Classification Summary

Entrenchment Ratio	Width/Depth Ratio	Sinuosity	Slope Ratio	Channel Material Size (mm)	Rosgen Stream Type*
3.7	9.5	1.28	0.00284	0.43	E5

The longitudinal profile consists of an undulating thalweg; typical for sand bed streams. The right bank average closely matched the bankfull elevation throughout the entire survey. The left bank matched bankfull elevations for part of the profile, but the creek cuts into the left terrace increasing the bank height. The thalweg gradually drops through the profile and TWI did not observe any sudden changes in streambed elevation.

TWI identified two bank types (see Figure 10). Bank Type 1 is located where Nescatunga Creek is connected to the floodplain on both banks resulting in a bank height ratio of 1.0. The banks are well vegetated and the surface protection is good. The BEHI rating is "moderate" due to a bank material scoring adjustment. For sand, 10 points are added to the BEHI score as sand is poorly packed and easily erodible. TWI used cross section 1 and 2 to determine the average NBS rating of "low."

Figure 10: Nescatunga Creek Bank Types



Bank type 2 is where the creek flows against the left terrace. The bank height ratio exceeds 4 due to the bank height increase. The root density and surface protection are much lower yielding a "high" BEHI rating. The NBS rating is "moderate" and it is likely that banks easily erode during runoff events. TWI used cross section 3 and 4 to calculate an average NBS score. TWI determined a dominant BEHI/NBS rating of "moderate"/"moderate" for the entire survey reach.

Since the incipient point of flooding is at the bankfull stage, the creek has the ability to spread out during small magnitude flows. This reduces the shear stress applied to the high banks since energy is dissipated across the floodplain. As a result, the sediment supply assessment rated as "low" (see Table 12).

Table 12: Nescatunga Creek Sediment Supply Summary

Dominant BEHI/NBS	Width/ Depth	Bank Height Ratio	Pfankuch	Stream Successional Stage	Depositional Pattern	Meander Pattern
8	1	1	3	1	1	15

5.6 Thompson Creek

TWI classified Thompson Creek as an E5 stream type (see Table 13). The survey is located in the Southwestern Tablelands Ecoregion and has a drainage area of 26.8 square miles. Due to a recent change in the grazing and hunting lease, TWI was not able to complete the entire geomorphology survey. TWI only completed the longitudinal profile before learning of the land management change. As a result, TWI did not complete any cross section surveys or BEHI and NBS assessments. TWI used data collected form a 2002 Thompson Creek geomorphology survey to complete the stream classification. The 2002 survey did overlap in the 2011 profile and TWI has provided KDHE with the report and data from the 2002 survey on January 24, 2012. TWI is not able to summarize BEHI and NBS due to the lack of data. The riparian corridor is mainly grass with scattered trees. The grass appears to be heavily grazed. The streambed consists mostly of sands and fine gravels and the banks are a mixture of sands, silt, and clay. Thompson Creek is extremely sinuous in this area with a sinuosity over 2.

Table 13: Thompson Creek Classification Summary

Entrenchment Ratio	Width/Depth Ratio	Sinuosity	Slope Ratio	Channel Material Size (mm)	Rosgen Stream Type*
2.2	13.4	2.09	0.00312	0.23	E5

The longitudinal profile consists of an undulating streambed. At least one bank is at the bankfull elevation throughout the survey reach. The other bank is about 1 to 2 feet higher and is typically located on the outside bend of the meander. TWI observed some bank slumping along outside bends, but the erosion process appears to be slow. TWI gathered enough information to assess the sediment supply that rated as "low" (see Table 14).

Table 14: Thompson Creek Sediment Supply Summary

Dominant BEHI/NBS	Width/ Depth	Bank Height Ratio	Pfankuch	Stream Successional Stage	Depositional Pattern	Meander Pattern
7	1	1	1	1	1	12

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Appendix C. Taxonomic data from biological samples for the six heritage streams (2000-2012).

Stream Name	Date	Phylum	Class	Order	Family	Genus	Specific Epithet
Fourmile Creek	07/14/2011	Annelida	Clitellata	Haplotaxida	Naididae	*Branchiura*	*sowerbyi*
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Coleoptera	Elmidae	*Dubiraphia*	
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Coleoptera	Elmidae	*Microcylloepus*	*pusillus*
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Coleoptera	Elmidae	*Stenelmis*	
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Coleoptera	Elmidae	*Stenelmis*	*bicarinata*
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Coleoptera	Elmidae	*Stenelmis*	*crenata*
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Coleoptera	Elmidae	*Stenelmis*	*sexlineata*
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Coleoptera	Elmidae	*Stenelmis*	*vittipennis*
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Coleoptera	Haliplidae	*Peltodytes*	*litoralis*
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Anacaena*	
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Berosus*	
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Laccobius*	
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Tropisternus*	
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Coleoptera	Hydrophilidae		
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Coleoptera	Scirtidae		
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Diptera	Ceratopogonidae	*Atrichopogon*	
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Diptera	Ceratopogonidae		
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Diptera	Chironomidae	*Ablabesmyia*	
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Diptera	Chironomidae	*Clinotanypus*	
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Diptera	Chironomidae	*Dicrotendipes*	
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Diptera	Chironomidae	*Einfeldia*	
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Diptera	Chironomidae	*Microtendipes*	
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Diptera	Chironomidae	*Nanocladius*	
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Diptera	Chironomidae	*Phaenopsectra*	
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Diptera	Chironomidae	*Polypedilum*	
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Diptera	Chironomidae	*Procladius*	
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Diptera	Chironomidae	*Stictochironomus*	
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Diptera	Chironomidae	*Thienemannimyia*	
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Diptera	Chironomidae	*Tribelos*	
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Diptera	Chironomidae	*Xenochironomus*	
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Diptera	Chironomidae		
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Diptera	Tabanidae	*Tabanus*	

Appendix C. Taxonomic data from biological samples for the six heritage streams (2000-2012) (continued).

Stream Name	Date	Phylum	Class	Order	Family	Genus	Specific Epithet
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Diptera	Tipulidae	*Hexatoma*	
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Ephemeroptera	Baetidae	*Acerpenna*	*pygmaea*
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Ephemeroptera	Baetidae	*Baetis*	
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Ephemeroptera	Baetidae	*Procloeon*	
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Ephemeroptera	Caenidae	*Caenis*	
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Ephemeroptera	Ephemeridae	*Hexagenia*	*limbata*
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Ephemeroptera	Heptageniidae	*Maccaffertium*	
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Ephemeroptera	Heptageniidae	*Stenonema*	*femoratum*
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Ephemeroptera	Leptohyphidae	*Tricorythodes*	
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae	*Leptophlebia*	
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Hemiptera	Corixidae	*Palmacorixa*	
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Hemiptera	Gerridae	*Aquarius*	
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Hemiptera	Gerridae	*Metrobates*	
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Hemiptera	Nepidae	*Ranatra*	
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Hemiptera	Pleidae	*Neoplea*	
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Hemiptera	Veliidae	*Microvelia*	
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Hemiptera	Veliidae	*Rhagovelia*	
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Megaloptera	Corydalidae	*Corydalus*	*cornutus*
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Megaloptera	Sialidae	*Sialis*	
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Odonata	Coenagrionidae	*Argia*	
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Odonata	Coenagrionidae	*Enallagma*	
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Odonata	Gomphidae	*Hagenius*	*brevistylus*
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Plecoptera	Perlidae	*Neoperla*	
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Trichoptera	Helicopsychidae	*Helicopsyche*	
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Trichoptera	Hydropsychidae	*Cheumatopsyche*	
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Trichoptera	Hydropsychidae	*Hydropsyche*	*valanis*
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Trichoptera	Leptoceridae	*Ceraclea*	
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Trichoptera	Leptoceridae	*Oecetis*	
Fourmile Creek	07/14/2011	Arthropoda	Insecta	Trichoptera	Philopotamidae	*Chimarra*	*obscura*
Fourmile Creek	07/14/2011	Arthropoda	Malacostraca	Amphipoda	Hyallelidae	*Hyalella*	*azteca*
Fourmile Creek	07/14/2011	Arthropoda	Malacostraca	Decopoda	Cambaridae	*Orconectes*	
Fourmile Creek	07/14/2011	Mollusca	Bivalvia	Heterodontida	Pisidiidae	*Musculium*	*transversum*
Fourmile Creek	07/14/2011	Mollusca	Gastropoda	Basommatophora	Lymnaeidae		

Appendix C. Taxonomic data from biological samples for the six heritage streams (2000-2012) (continued).

Stream Name	Date	Phylum	Class	Order	Family	Genus	Specific Epithet
Fourmile Creek	07/14/2011	Mollusca	Gastropoda	Basommatophora	Physidae	*Physella*	
Fourmile Creek	07/14/2011	Platyhelminthes	Turbellaria	Tricladida	Planariidae	*Dugesia*	
Fourmile Creek	03/12/2012	Annelida	Clitellata	Haplotaxida	Naididae	*Branchiura*	*sowerbyi*
Fourmile Creek	03/12/2012	Annelida	Clitellata	Rhynchobdellida	Glossiphoniidae		
Fourmile Creek	03/12/2012	Arthropoda	Insecta	Coleoptera	Dytiscidae	*Neoporus*	*dimidiatus*
Fourmile Creek	03/12/2012	Arthropoda	Insecta	Coleoptera	Elmidae	*Stenelmis*	*bicarinata*
Fourmile Creek	03/12/2012	Arthropoda	Insecta	Coleoptera	Elmidae	*Stenelmis*	*decorata*
Fourmile Creek	03/12/2012	Arthropoda	Insecta	Coleoptera	Elmidae	*Stenelmis*	*sexlineata*
Fourmile Creek	03/12/2012	Arthropoda	Insecta	Coleoptera	Gyrinidae	*Dineutus*	
Fourmile Creek	03/12/2012	Arthropoda	Insecta	Coleoptera	Haliplidae	*Peltodytes*	*litoralis*
Fourmile Creek	03/12/2012	Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Berosus*	
Fourmile Creek	03/12/2012	Arthropoda	Insecta	Diptera	Chironomidae	*Chironomus*	
Fourmile Creek	03/12/2012	Arthropoda	Insecta	Diptera	Chironomidae	*Clinotanypus*	
Fourmile Creek	03/12/2012	Arthropoda	Insecta	Diptera	Chironomidae	*Cricotopus/Orthocladius*	
Fourmile Creek	03/12/2012	Arthropoda	Insecta	Diptera	Chironomidae	*Paratendipes*	
Fourmile Creek	03/12/2012	Arthropoda	Insecta	Diptera	Chironomidae		
Fourmile Creek	03/12/2012	Arthropoda	Insecta	Diptera	Simuliidae	*Simulium*	
Fourmile Creek	03/12/2012	Arthropoda	Insecta	Diptera	Tabanidae	*Tabanus*	
Fourmile Creek	03/12/2012	Arthropoda	Insecta	Ephemeroptera	Caenidae	*Caenis*	
Fourmile Creek	03/12/2012	Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae	*Leptophlebia*	
Fourmile Creek	03/12/2012	Arthropoda	Insecta	Hemiptera	Corixidae	*Corisella*	
Fourmile Creek	03/12/2012	Arthropoda	Insecta	Hemiptera	Corixidae	*Trichocorixa*	
Fourmile Creek	03/12/2012	Arthropoda	Insecta	Lepidoptera	Crambidae	*Petrophila*	
Fourmile Creek	03/12/2012	Arthropoda	Insecta	Odonata	Corduliidae	*Macromia*	
Fourmile Creek	03/12/2012	Arthropoda	Insecta	Odonata	Libellulidae		
Fourmile Creek	03/12/2012	Arthropoda	Insecta	Plecoptera	Capniidae	*Allocapnia*	
Fourmile Creek	03/12/2012	Arthropoda	Insecta	Trichoptera	Limnephilidae	*Pycnopsyche*	
Fourmile Creek	03/12/2012	Arthropoda	Malacostraca	Isopoda	Asellidae	*Caecidotea*	
Fourmile Creek	03/12/2012	Mollusca	Gastropoda	Basommatophora	Physidae	*Physella*	
Sevenmile Creek	07/25/2011	Arthropoda	Insecta	Coleoptera	Elmidae	*Dubiraphia*	
Sevenmile Creek	07/25/2011	Arthropoda	Insecta	Coleoptera	Elmidae	*Microcylloepus*	*pusillus*
Sevenmile Creek	07/25/2011	Arthropoda	Insecta	Coleoptera	Elmidae	*Stenelmis*	
Sevenmile Creek	07/25/2011	Arthropoda	Insecta	Coleoptera	Elmidae	*Stenelmis*	*sexlineata*

Appendix C. Taxonomic data from biological samples for the six heritage streams (2000-2012) (continued).

Stream Name	Date	Phylum	Class	Order	Family	Genus	Specific Epithet
Sevenmile Creek	07/25/2011	Arthropoda	Insecta	Coleoptera	Hydrophilidae		
Sevenmile Creek	07/25/2011	Arthropoda	Insecta	Diptera	Ceratopogonidae		
Sevenmile Creek	07/25/2011	Arthropoda	Insecta	Diptera	Chironomidae	*Polypedilum*	
Sevenmile Creek	07/25/2011	Arthropoda	Insecta	Diptera	Chironomidae	*Procladius*	
Sevenmile Creek	07/25/2011	Arthropoda	Insecta	Diptera	Chironomidae	*Thienemannimyia*	
Sevenmile Creek	07/25/2011	Arthropoda	Insecta	Diptera	Chironomidae		
Sevenmile Creek	07/25/2011	Arthropoda	Insecta	Diptera	Stratiomyidae	*Stratiomys*	
Sevenmile Creek	07/25/2011	Arthropoda	Insecta	Diptera	Tabanidae	*Tabanus*	
Sevenmile Creek	07/25/2011	Arthropoda	Insecta	Ephemeroptera	Baetidae	*Acerpenna*	*pygmaea*
Sevenmile Creek	07/25/2011	Arthropoda	Insecta	Ephemeroptera	Baetidae	*Centroptilum*	
Sevenmile Creek	07/25/2011	Arthropoda	Insecta	Ephemeroptera	Caenidae	*Caenis*	
Sevenmile Creek	07/25/2011	Arthropoda	Insecta	Ephemeroptera	Ephemeridae	*Hexagenia*	*limbata*
Sevenmile Creek	07/25/2011	Arthropoda	Insecta	Ephemeroptera	Heptageniidae	*Stenacron*	*interpunctatum*
Sevenmile Creek	07/25/2011	Arthropoda	Insecta	Ephemeroptera	Heptageniidae	*Stenonema*	*femoratum*
Sevenmile Creek	07/25/2011	Arthropoda	Insecta	Ephemeroptera	Leptohyphidae	*Tricorythodes*	
Sevenmile Creek	07/25/2011	Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae	*Leptophlebia*	
Sevenmile Creek	07/25/2011	Arthropoda	Insecta	Hemiptera	Corixidae	*Trichocorixa*	
Sevenmile Creek	07/25/2011	Arthropoda	Insecta	Hemiptera	Gerridae	*Rheumatobates*	
Sevenmile Creek	07/25/2011	Arthropoda	Insecta	Hemiptera	Pleidae	*Neoplea*	
Sevenmile Creek	07/25/2011	Arthropoda	Insecta	Hemiptera	Veliidae	*Microvelia*	
Sevenmile Creek	07/25/2011	Arthropoda	Insecta	Megaloptera	Sialidae	*Sialis*	
Sevenmile Creek	07/25/2011	Arthropoda	Insecta	Odonata	Aeshnidae	*Nasiaeschna*	*pentacantha*
Sevenmile Creek	07/25/2011	Arthropoda	Insecta	Odonata	Calopterygidae	*Calopteryx*	*maculata*
Sevenmile Creek	07/25/2011	Arthropoda	Insecta	Odonata	Coenagrionidae	*Argia*	
Sevenmile Creek	07/25/2011	Arthropoda	Insecta	Odonata	Gomphidae	*Gomphus*	*externus*
Sevenmile Creek	07/25/2011	Arthropoda	Insecta	Plecoptera	Perlidae	*Neoperla*	
Sevenmile Creek	07/25/2011	Arthropoda	Insecta	Trichoptera	Hydropsychidae	*Cheumatopsyche*	
Sevenmile Creek	07/25/2011	Arthropoda	Insecta	Trichoptera	Philopotamidae	*Chimarra*	*obscura*
Sevenmile Creek	07/25/2011	Arthropoda	Malacostraca	Decopoda	Cambaridae	*Orconectes*	
Sevenmile Creek	07/25/2011	Mollusca	Bivalvia	Heterodontida	Pisidiidae	*Musculium*	*transversum*
Sevenmile Creek	07/25/2011	Mollusca	Gastropoda	Basommatophora	Physidae	*Physella*	
Illinois Creek	09/09/2002	Annelida	Clitellata	Arhynchobdellid	Erpobdellidae		
Illinois Creek	09/09/2002	Annelida	Clitellata	Rhynchobdellida	Glossiphoniidae		

Appendix C. Taxonomic data from biological samples for the six heritage streams (2000-2012) (continued).

Stream Name	Date	Phylum	Class	Order	Family	Genus	Specific Epithet
Illinois Creek	09/09/2002	Arthropoda	Insecta	Coleoptera	Dytiscidae	*Neoporus*	*dimidiatus*
Illinois Creek	09/09/2002	Arthropoda	Insecta	Coleoptera	Elmidae	*Dubiraphia*	
Illinois Creek	09/09/2002	Arthropoda	Insecta	Coleoptera	Haliplidae	*Peltodytes*	*edentulus*
Illinois Creek	09/09/2002	Arthropoda	Insecta	Coleoptera	Haliplidae	*Peltodytes*	*litoralis*
Illinois Creek	09/09/2002	Arthropoda	Insecta	Coleoptera	Haliplidae	*Peltodytes*	*sexmaculatus*
Illinois Creek	09/09/2002	Arthropoda	Insecta	Coleoptera	Hydrochidae	*Hydrochus*	
Illinois Creek	09/09/2002	Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Enochrus*	
Illinois Creek	09/09/2002	Arthropoda	Insecta	Diptera	Chironomidae	*Chironomus*	
Illinois Creek	09/09/2002	Arthropoda	Insecta	Diptera	Chironomidae	*Clinotanypus*	
Illinois Creek	09/09/2002	Arthropoda	Insecta	Diptera	Chironomidae	*Stictochironomus*	
Illinois Creek	09/09/2002	Arthropoda	Insecta	Ephemeroptera	Caenidae	*Caenis*	
Illinois Creek	09/09/2002	Arthropoda	Insecta	Ephemeroptera	Heptageniidae	*Stenacron*	*interpunctatum*
Illinois Creek	09/09/2002	Arthropoda	Insecta	Ephemeroptera	Heptageniidae	*Stenonema*	*femoratum*
Illinois Creek	09/09/2002	Arthropoda	Insecta	Hemiptera	Belostomatidae	*Belostoma*	
Illinois Creek	09/09/2002	Arthropoda	Insecta	Hemiptera	Gerridae	*Trepobates*	
Illinois Creek	09/09/2002	Arthropoda	Insecta	Megaloptera	Sialidae	*Sialis*	
Illinois Creek	09/09/2002	Arthropoda	Insecta	Odonata	Calopterygidae	*Calopteryx*	*maculata*
Illinois Creek	09/09/2002	Arthropoda	Insecta	Odonata	Coenagrionidae	*Argia*	
Illinois Creek	09/09/2002	Arthropoda	Insecta	Odonata	Coenagrionidae	*Enallagma*	
Illinois Creek	09/09/2002	Arthropoda	Insecta	Odonata	Coenagrionidae	*Ischnura*	
Illinois Creek	09/09/2002	Arthropoda	Insecta	Odonata	Gomphidae	*Gomphus*	*externus*
Illinois Creek	09/09/2002	Arthropoda	Insecta	Odonata	Libellulidae	*Erythemis*	*simplicicollis*
Illinois Creek	09/09/2002	Arthropoda	Insecta	Odonata	Libellulidae	*Pachydiplax*	*longipennis*
Illinois Creek	09/09/2002	Arthropoda	Insecta	Odonata	Libellulidae	*Plathemis*	*lydia*
Illinois Creek	09/09/2002	Arthropoda	Insecta	Trichoptera	Leptoceridae	*Ceraclea*	*flava*
Illinois Creek	09/09/2002	Arthropoda	Insecta	Trichoptera	Limnephilidae	*Pycnopsyche*	
Illinois Creek	09/09/2002	Arthropoda	Malacostraca	Amphipoda	Hyallelidae	*Hyalella*	*azteca*
Illinois Creek	09/09/2002	Arthropoda	Malacostraca	Decopoda	Cambaridae	*Orconectes*	
Illinois Creek	09/09/2002	Arthropoda	Malacostraca	Decopoda	Cambaridae	*Orconectes*	*neglectus*
Illinois Creek	09/09/2002	Mollusca	Bivalvia	Heterodontida	Pisidiidae	*Pisidium*	
Illinois Creek	09/09/2002	Mollusca	Gastropoda	Basommatophora	Ancylidae	*Ferrissia*	
Illinois Creek	09/09/2002	Mollusca	Gastropoda	Basommatophora	Lymnaeidae	*Fossaria*	
Illinois Creek	09/09/2002	Mollusca	Gastropoda	Basommatophora	Physidae	*Physella*	

Appendix C. Taxonomic data from biological samples for the six heritage streams (2000-2012) (continued).

Stream Name	Date	Phylum	Class	Order	Family	Genus	Specific Epithet
Illinois Creek	09/09/2002	Mollusca	Gastropoda	Basommatophora	Planorbidae	*Planorbula*	
Illinois Creek	08/08/2003	Arthropoda	Insecta	Coleoptera	Dytiscidae	*Neoporus*	*dimidiatus*
Illinois Creek	08/08/2003	Arthropoda	Insecta	Coleoptera	Elmidae	*Dubiraphia*	*minima*
Illinois Creek	08/08/2003	Arthropoda	Insecta	Coleoptera	Elmidae	*Microcylloepus*	*pusillus*
Illinois Creek	08/08/2003	Arthropoda	Insecta	Coleoptera	Haliplidae	*Peltodytes*	*litoralis*
Illinois Creek	08/08/2003	Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Berosus*	
Illinois Creek	08/08/2003	Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Enochrus*	
Illinois Creek	08/08/2003	Arthropoda	Insecta	Diptera	Chironomidae	*Stictochironomus*	
Illinois Creek	08/08/2003	Arthropoda	Insecta	Diptera	Chironomidae	*Thienemannimyia*	
Illinois Creek	08/08/2003	Arthropoda	Insecta	Diptera	Stratiomyidae	*Stratiomys*	
Illinois Creek	08/08/2003	Arthropoda	Insecta	Ephemeroptera	Caenidae	*Caenis*	
Illinois Creek	08/08/2003	Arthropoda	Insecta	Ephemeroptera	Ephemeridae	*Hexagenia*	
Illinois Creek	08/08/2003	Arthropoda	Insecta	Ephemeroptera	Heptageniidae	*Stenacron*	*interpunctatum*
Illinois Creek	08/08/2003	Arthropoda	Insecta	Ephemeroptera	Heptageniidae	*Stenonema*	*femoratum*
Illinois Creek	08/08/2003	Arthropoda	Insecta	Ephemeroptera	Leptohyphidae	*Tricorythodes*	
Illinois Creek	08/08/2003	Arthropoda	Insecta	Hemiptera	Belostomatidae	*Belostoma*	
Illinois Creek	08/08/2003	Arthropoda	Insecta	Hemiptera	Gerridae	*Trepobates*	
Illinois Creek	08/08/2003	Arthropoda	Insecta	Hemiptera	Veliidae	*Microvelia*	
Illinois Creek	08/08/2003	Arthropoda	Insecta	Megaloptera	Corydalidae	*Corydalus*	*cornutus*
Illinois Creek	08/08/2003	Arthropoda	Insecta	Megaloptera	Sialidae	*Sialis*	
Illinois Creek	08/08/2003	Arthropoda	Insecta	Odonata	Coenagrionidae	*Argia*	
Illinois Creek	08/08/2003	Arthropoda	Insecta	Odonata	Coenagrionidae	*Ischnura*	
Illinois Creek	08/08/2003	Arthropoda	Insecta	Odonata	Libellulidae	*Erythemis*	*simplicicollis*
Illinois Creek	08/08/2003	Arthropoda	Insecta	Trichoptera	Hydropsychidae	*Cheumatopsyche*	
Illinois Creek	08/08/2003	Arthropoda	Insecta	Trichoptera	Limnephilidae	*Pycnopsyche*	
Illinois Creek	08/08/2003	Arthropoda	Insecta	Trichoptera	Polycentropodidae	*Cyrnellus*	*fraternus*
Illinois Creek	08/08/2003	Arthropoda	Malacostraca	Amphipoda	Hyallelidae	*Hyalella*	*azteca*
Illinois Creek	08/08/2003	Arthropoda	Malacostraca	Decopoda	Cambaridae	*Orconectes*	*neglectus*
Illinois Creek	08/08/2003	Mollusca	Gastropoda	Basommatophora	Physidae	*Physella*	
Illinois Creek	08/08/2003	Mollusca	Gastropoda	Basommatophora	Planorbidae	*Planorbula*	
Illinois Creek	09/24/2004	Arthropoda	Insecta	Coleoptera	Dytiscidae	*Heterosternuta*	*wickhami*
Illinois Creek	09/24/2004	Arthropoda	Insecta	Coleoptera	Dytiscidae	*Hydroporus*	
Illinois Creek	09/24/2004	Arthropoda	Insecta	Coleoptera	Dytiscidae	*Neoporus*	*dimidiatus*

Appendix C. Taxonomic data from biological samples for the six heritage streams (2000-2012) (continued).

Stream Name	Date	Phylum	Class	Order	Family	Genus	Specific Epithet
Illinois Creek	09/24/2004	Arthropoda	Insecta	Coleoptera	Elmidae	*Dubiraphia*	
Illinois Creek	09/24/2004	Arthropoda	Insecta	Coleoptera	Haliplidae	*Peltodytes*	*litoralis*
Illinois Creek	09/24/2004	Arthropoda	Insecta	Coleoptera	Scirtidae		
Illinois Creek	09/24/2004	Arthropoda	Insecta	Diptera	Ceratopogonidae	*Culicoides*	
Illinois Creek	09/24/2004	Arthropoda	Insecta	Diptera	Chironomidae	*Ablabesmyia*	
Illinois Creek	09/24/2004	Arthropoda	Insecta	Diptera	Chironomidae	*Chironomus*	
Illinois Creek	09/24/2004	Arthropoda	Insecta	Diptera	Chironomidae	*Cryptochironomus*	
Illinois Creek	09/24/2004	Arthropoda	Insecta	Diptera	Chironomidae	*Larsia*	
Illinois Creek	09/24/2004	Arthropoda	Insecta	Diptera	Chironomidae	*Microtendipes*	
Illinois Creek	09/24/2004	Arthropoda	Insecta	Diptera	Chironomidae	*Polypedilum*	
Illinois Creek	09/24/2004	Arthropoda	Insecta	Diptera	Chironomidae	*Thienemanniella*	
Illinois Creek	09/24/2004	Arthropoda	Insecta	Diptera	Chironomidae	*Thienemannimyia*	
Illinois Creek	09/24/2004	Arthropoda	Insecta	Diptera	Simuliidae	*Simulium*	
Illinois Creek	09/24/2004	Arthropoda	Insecta	Diptera	Tabanidae	*Tabanus*	
Illinois Creek	09/24/2004	Arthropoda	Insecta	Diptera	Tipulidae	*Hexatoma*	
Illinois Creek	09/24/2004	Arthropoda	Insecta	Ephemeroptera	Baetidae	*Baetis*	
Illinois Creek	09/24/2004	Arthropoda	Insecta	Ephemeroptera	Caenidae	*Caenis*	
Illinois Creek	09/24/2004	Arthropoda	Insecta	Ephemeroptera	Ephemeridae	*Hexagenia*	
Illinois Creek	09/24/2004	Arthropoda	Insecta	Ephemeroptera	Heptageniidae	*Stenonema*	*femoratum*
Illinois Creek	09/24/2004	Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae	*Choroterpes*	
Illinois Creek	09/24/2004	Arthropoda	Insecta	Hemiptera	Veliidae	*Microvelia*	
Illinois Creek	09/24/2004	Arthropoda	Insecta	Megaloptera	Corydalidae	*Corydalus*	*cornutus*
Illinois Creek	09/24/2004	Arthropoda	Insecta	Megaloptera	Sialidae	*Sialis*	
Illinois Creek	09/24/2004	Arthropoda	Insecta	Odonata	Calopterygidae	*Calopteryx*	*maculata*
Illinois Creek	09/24/2004	Arthropoda	Insecta	Odonata	Coenagrionidae	*Argia*	
Illinois Creek	09/24/2004	Arthropoda	Insecta	Trichoptera	Hydropsychidae	*Cheumatopsyche*	
Illinois Creek	09/24/2004	Arthropoda	Insecta	Trichoptera	Hydropsychidae	*Hydropsyche*	*betteni*
Illinois Creek	09/24/2004	Arthropoda	Insecta	Trichoptera	Hydroptilidae	*Hydroptila*	
Illinois Creek	09/24/2004	Arthropoda	Insecta	Trichoptera	Philopotamidae	*Chimarra*	*obscura*
Illinois Creek	09/24/2004	Arthropoda	Malacostraca	Amphipoda	Hyallelidae	*Hyalella*	*azteca*
Illinois Creek	09/24/2004	Arthropoda	Malacostraca	Decopoda	Cambaridae	*Orconectes*	*neglectus*
Illinois Creek	09/24/2004	Mollusca	Gastropoda	Basommatophora	Ancylidae	*Ferrissia*	
Illinois Creek	09/24/2004	Mollusca	Gastropoda	Basommatophora	Lymnaeidae	*Fossaria*	

Appendix C. Taxonomic data from biological samples for the six heritage streams (2000-2012) (continued).

Stream Name	Date	Phylum	Class	Order	Family	Genus	Specific Epithet
Illinois Creek	09/24/2004	Mollusca	Gastropoda	Basommatophora	Physidae	*Physella*	
Illinois Creek	07/14/2005	Arthropoda	Insecta	Coleoptera	Dytiscidae	*Copelatus*	*glyphicus*
Illinois Creek	07/14/2005	Arthropoda	Insecta	Coleoptera	Dytiscidae	*Neoporus*	*dimidiatus*
Illinois Creek	07/14/2005	Arthropoda	Insecta	Coleoptera	Elmidae	*Stenelmis*	
Illinois Creek	07/14/2005	Arthropoda	Insecta	Coleoptera	Haliplidae	*Peltodytes*	*litoralis*
Illinois Creek	07/14/2005	Arthropoda	Insecta	Coleoptera	Helophoridae	*Helophorus*	
Illinois Creek	07/14/2005	Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Berosus*	
Illinois Creek	07/14/2005	Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Paracymus*	
Illinois Creek	07/14/2005	Arthropoda	Insecta	Coleoptera	Scirtidae		
Illinois Creek	07/14/2005	Arthropoda	Insecta	Diptera	Chironomidae	*Ablabesmyia*	
Illinois Creek	07/14/2005	Arthropoda	Insecta	Diptera	Chironomidae	*Chironomus*	
Illinois Creek	07/14/2005	Arthropoda	Insecta	Diptera	Chironomidae	*Cricotopus*	
Illinois Creek	07/14/2005	Arthropoda	Insecta	Diptera	Chironomidae	*Cryptochironomus*	
Illinois Creek	07/14/2005	Arthropoda	Insecta	Diptera	Chironomidae	*Glyptotendipes*	
Illinois Creek	07/14/2005	Arthropoda	Insecta	Diptera	Chironomidae	*Microtendipes*	
Illinois Creek	07/14/2005	Arthropoda	Insecta	Diptera	Chironomidae	*Polypedilum*	
Illinois Creek	07/14/2005	Arthropoda	Insecta	Diptera	Chironomidae	*Procladius*	
Illinois Creek	07/14/2005	Arthropoda	Insecta	Diptera	Chironomidae	*Stictochironomus*	
Illinois Creek	07/14/2005	Arthropoda	Insecta	Diptera	Chironomidae	*Thienemanniella*	
Illinois Creek	07/14/2005	Arthropoda	Insecta	Diptera	Chironomidae	*Thienemannimyia*	
Illinois Creek	07/14/2005	Arthropoda	Insecta	Diptera	Simuliidae	*Simulium*	
Illinois Creek	07/14/2005	Arthropoda	Insecta	Diptera	Tabanidae	*Tabanus*	
Illinois Creek	07/14/2005	Arthropoda	Insecta	Ephemeroptera	Baetidae	*Baetis*	
Illinois Creek	07/14/2005	Arthropoda	Insecta	Ephemeroptera	Baetidae	*Callibaetis*	
Illinois Creek	07/14/2005	Arthropoda	Insecta	Ephemeroptera	Baetidae	*Fallceon*	*quilleri*
Illinois Creek	07/14/2005	Arthropoda	Insecta	Ephemeroptera	Baetidae	*Procloeon*	
Illinois Creek	07/14/2005	Arthropoda	Insecta	Ephemeroptera	Caenidae	*Caenis*	
Illinois Creek	07/14/2005	Arthropoda	Insecta	Ephemeroptera	Heptageniidae	*Stenacron*	*interpunctatum*
Illinois Creek	07/14/2005	Arthropoda	Insecta	Ephemeroptera	Heptageniidae	*Stenonema*	*femoratum*
Illinois Creek	07/14/2005	Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae	*Choroterpes*	
Illinois Creek	07/14/2005	Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae	*Neochoroterpes*	
Illinois Creek	07/14/2005	Arthropoda	Insecta	Hemiptera	Corixidae	*Trichocorixa*	
Illinois Creek	07/14/2005	Arthropoda	Insecta	Hemiptera	Gerridae	*Neogerris*	*hesione*

Appendix C. Taxonomic data from biological samples for the six heritage streams (2000-2012) (continued).

Stream Name	Date	Phylum	Class	Order	Family	Genus	Specific Epithet
Illinois Creek	07/14/2005	Arthropoda	Insecta	Lepidoptera	Crambidae	*Petrophila*	
Illinois Creek	07/14/2005	Arthropoda	Insecta	Megaloptera	Corydalidae	*Corydalus*	*cornutus*
Illinois Creek	07/14/2005	Arthropoda	Insecta	Odonata	Coenagrionidae	*Enallagma*	
Illinois Creek	07/14/2005	Arthropoda	Insecta	Plecoptera	Perlidae	*Neoperla*	
Illinois Creek	07/14/2005	Arthropoda	Insecta	Trichoptera	Hydropsychidae	*Cheumatopsyche*	
Illinois Creek	07/14/2005	Arthropoda	Insecta	Trichoptera	Hydropsychidae	*Hydropsyche*	*arinale*
Illinois Creek	07/14/2005	Arthropoda	Insecta	Trichoptera	Hydropsychidae	*Hydropsyche*	*betteni*
Illinois Creek	07/14/2005	Arthropoda	Insecta	Trichoptera	Hydropsychidae	*Hydropsyche*	*scalaris*
Illinois Creek	07/14/2005	Arthropoda	Insecta	Trichoptera	Hydropsychidae	*Potamyia*	*flava*
Illinois Creek	07/14/2005	Arthropoda	Insecta	Trichoptera	Hydroptilidae	*Hydroptila*	
Illinois Creek	07/14/2005	Arthropoda	Insecta	Trichoptera	Philopotamidae	*Chimarra*	*feria*
Illinois Creek	07/14/2005	Arthropoda	Insecta	Trichoptera	Philopotamidae	*Chimarra*	*obscura*
Illinois Creek	07/14/2005	Arthropoda	Insecta	Trichoptera	Polycentropodidae	*Polycentropus*	
Illinois Creek	07/14/2005	Arthropoda	Malacostraca	Amphipoda	Hyallelidae	*Hyalella*	*azteca*
Illinois Creek	07/14/2005	Arthropoda	Malacostraca	Decopoda	Cambaridae	*Orconectes*	
Illinois Creek	07/14/2005	Arthropoda	Malacostraca	Decopoda	Cambaridae	*Orconectes*	*neglectus*
Illinois Creek	07/14/2005	Mollusca	Gastropoda	Basommatophora	Physidae	*Physella*	
Illinois Creek	08/24/2006	Arthropoda	Insecta	Coleoptera	Dytiscidae	*Heterosternuta*	*diversicornis*
Illinois Creek	08/24/2006	Arthropoda	Insecta	Coleoptera	Dytiscidae	*Heterosternuta*	*wickhami*
Illinois Creek	08/24/2006	Arthropoda	Insecta	Coleoptera	Dytiscidae	*Neoporus*	*dimidiatus*
Illinois Creek	08/24/2006	Arthropoda	Insecta	Coleoptera	Haliplidae	*Peltodytes*	*edentulus*
Illinois Creek	08/24/2006	Arthropoda	Insecta	Coleoptera	Haliplidae	*Peltodytes*	*litoralis*
Illinois Creek	08/24/2006	Arthropoda	Insecta	Coleoptera	Haliplidae	*Peltodytes*	*sexmaculatus*
Illinois Creek	08/24/2006	Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Berosus*	
Illinois Creek	08/24/2006	Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Enochrus*	
Illinois Creek	08/24/2006	Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Tropisternus*	
Illinois Creek	08/24/2006	Arthropoda	Insecta	Coleoptera	Staphylinidae		
Illinois Creek	08/24/2006	Arthropoda	Insecta	Diptera	Chironomidae	*Clinotanypus*	
Illinois Creek	08/24/2006	Arthropoda	Insecta	Diptera	Chironomidae	*Procladius*	
Illinois Creek	08/24/2006	Arthropoda	Insecta	Diptera	Chironomidae		
Illinois Creek	08/24/2006	Arthropoda	Insecta	Diptera	Culicidae	*Culex*	
Illinois Creek	08/24/2006	Arthropoda	Insecta	Diptera	Tabanidae	*Tabanus*	
Illinois Creek	08/24/2006	Arthropoda	Insecta	Ephemeroptera	Baetidae	*Callibaetis*	

Appendix C. Taxonomic data from biological samples for the six heritage streams (2000-2012) (continued).

Stream Name	Date	Phylum	Class	Order	Family	Genus	Specific Epithet
Illinois Creek	08/24/2006	Arthropoda	Insecta	Ephemeroptera	Baetidae	*Fallceon*	*quilleri*
Illinois Creek	08/24/2006	Arthropoda	Insecta	Ephemeroptera	Caenidae	*Caenis*	
Illinois Creek	08/24/2006	Arthropoda	Insecta	Ephemeroptera	Heptageniidae	*Stenacron*	*interpunctatum*
Illinois Creek	08/24/2006	Arthropoda	Insecta	Hemiptera	Belostomatidae	*Belostoma*	
Illinois Creek	08/24/2006	Arthropoda	Insecta	Hemiptera	Gerridae	*Aquarius*	
Illinois Creek	08/24/2006	Arthropoda	Insecta	Hemiptera	Veliidae	*Microvelia*	
Illinois Creek	08/24/2006	Arthropoda	Insecta	Megaloptera	Corydalidae	*Corydalus*	*cornutus*
Illinois Creek	08/24/2006	Arthropoda	Insecta	Megaloptera	Sialidae	*Sialis*	
Illinois Creek	08/24/2006	Arthropoda	Insecta	Odonata	Coenagrionidae	*Argia*	
Illinois Creek	08/24/2006	Arthropoda	Insecta	Odonata	Gomphidae		
Illinois Creek	08/24/2006	Arthropoda	Insecta	Odonata	Libellulidae	*Erythemis*	
Illinois Creek	08/24/2006	Arthropoda	Insecta	Odonata	Libellulidae	*Erythemis*	*simplicicollis*
Illinois Creek	08/24/2006	Arthropoda	Insecta	Odonata	Libellulidae	*Libellula*	
Illinois Creek	08/24/2006	Arthropoda	Insecta	Odonata	Libellulidae		
Illinois Creek	08/24/2006	Arthropoda	Insecta	Odonata			
Illinois Creek	08/24/2006	Arthropoda	Malacostraca	Amphipoda	Hyallelidae	*Hyalella*	*azteca*
Illinois Creek	08/24/2006	Arthropoda	Malacostraca	Decopoda	Cambaridae	*Orconectes*	
Illinois Creek	08/24/2006	Arthropoda	Malacostraca	Decopoda	Cambaridae	*Orconectes*	*neglectus*
Illinois Creek	08/24/2006	Mollusca	Gastropoda	Basommatophora	Physidae	*Physella*	
Illinois Creek	08/24/2006	Nematomorpha	Gordiodea	Gordiida	Gordiidae	*Gordius*	
Illinois Creek	06/24/2008	Arthropoda	Insecta	Coleoptera	Dytiscidae	*Heterosternuta*	*wickhami*
Illinois Creek	06/24/2008	Arthropoda	Insecta	Coleoptera	Dytiscidae	*Neoporus*	*dimidiatus*
Illinois Creek	06/24/2008	Arthropoda	Insecta	Coleoptera	Elmidae	*Dubiraphia*	
Illinois Creek	06/24/2008	Arthropoda	Insecta	Coleoptera	Elmidae	*Microcylloepus*	
Illinois Creek	06/24/2008	Arthropoda	Insecta	Coleoptera	Haliplidae	*Peltodytes*	*litoralis*
Illinois Creek	06/24/2008	Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Berosus*	
Illinois Creek	06/24/2008	Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Tropisternus*	
Illinois Creek	06/24/2008	Arthropoda	Insecta	Diptera	Chironomidae	*Cricotopus*	*trifascia*
Illinois Creek	06/24/2008	Arthropoda	Insecta	Diptera	Chironomidae	*Cryptochironomus*	
Illinois Creek	06/24/2008	Arthropoda	Insecta	Diptera	Chironomidae	*Parachironomus*	
Illinois Creek	06/24/2008	Arthropoda	Insecta	Diptera	Chironomidae	*Polypedilum*	
Illinois Creek	06/24/2008	Arthropoda	Insecta	Diptera	Chironomidae	*Stictochironomus*	
Illinois Creek	06/24/2008	Arthropoda	Insecta	Diptera	Chironomidae	*Thienemannimyia*	

Appendix C. Taxonomic data from biological samples for the six heritage streams (2000-2012) (continued).

Stream Name	Date	Phylum	Class	Order	Family	Genus	Specific Epithet
Illinois Creek	06/24/2008	Arthropoda	Insecta	Diptera	Chironomidae		
Illinois Creek	06/24/2008	Arthropoda	Insecta	Diptera	Simuliidae	*Simulium*	
Illinois Creek	06/24/2008	Arthropoda	Insecta	Diptera	Tabanidae	*Tabanus*	
Illinois Creek	06/24/2008	Arthropoda	Insecta	Diptera	Tipulidae	*Hexatoma*	
Illinois Creek	06/24/2008	Arthropoda	Insecta	Ephemeroptera	Baetidae	*Baetis*	
Illinois Creek	06/24/2008	Arthropoda	Insecta	Ephemeroptera	Baetidae	*Fallceon*	*quilleri*
Illinois Creek	06/24/2008	Arthropoda	Insecta	Ephemeroptera	Baetidae	*Plauditus*	
Illinois Creek	06/24/2008	Arthropoda	Insecta	Ephemeroptera	Caenidae	*Caenis*	
Illinois Creek	06/24/2008	Arthropoda	Insecta	Ephemeroptera	Heptageniidae	*Stenonema*	*femoratum*
Illinois Creek	06/24/2008	Arthropoda	Insecta	Ephemeroptera	Isonychiidae	*Isonychia*	
Illinois Creek	06/24/2008	Arthropoda	Insecta	Ephemeroptera	Leptohyphidae	*Tricorythodes*	
Illinois Creek	06/24/2008	Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae	*Choroterpes*	
Illinois Creek	06/24/2008	Arthropoda	Insecta	Hemiptera	Gerridae	*Aquarius*	
Illinois Creek	06/24/2008	Arthropoda	Insecta	Hemiptera	Veliidae	*Rhagovelia*	
Illinois Creek	06/24/2008	Arthropoda	Insecta	Megaloptera	Corydalidae	*Corydalus*	*cornutus*
Illinois Creek	06/24/2008	Arthropoda	Insecta	Megaloptera	Sialidae	*Sialis*	
Illinois Creek	06/24/2008	Arthropoda	Insecta	Odonata	Coenagrionidae	*Argia*	
Illinois Creek	06/24/2008	Arthropoda	Insecta	Odonata	Coenagrionidae	*Enallagma*	
Illinois Creek	06/24/2008	Arthropoda	Insecta	Plecoptera	Perlidae	*Neoperla*	
Illinois Creek	06/24/2008	Arthropoda	Insecta	Trichoptera	Hydropsychidae	*Cheumatopsyche*	
Illinois Creek	06/24/2008	Arthropoda	Malacostraca	Amphipoda	Hyallelidae	*Hyalella*	*azteca*
Illinois Creek	06/24/2008	Arthropoda	Malacostraca	Decopoda	Cambaridae	*Orconectes*	
Illinois Creek	06/24/2008	Mollusca	Gastropoda	Basommatophora	Physidae	*Physella*	
Illinois Creek	08/02/2010	Annelida	Clitellata	Branchiobdellid	Branchiobdellidae	*Cambarincola*	
Illinois Creek	08/02/2010	Arthropoda	Insecta	Coleoptera	Dytiscidae	*Neoporus*	*dimidiatus*
Illinois Creek	08/02/2010	Arthropoda	Insecta	Coleoptera	Elmidae	*Dubiraphia*	
Illinois Creek	08/02/2010	Arthropoda	Insecta	Coleoptera	Elmidae	*Microcylloepus*	
Illinois Creek	08/02/2010	Arthropoda	Insecta	Coleoptera	Gyrinidae	*Gyretes*	
Illinois Creek	08/02/2010	Arthropoda	Insecta	Coleoptera	Hydrophilidae		
Illinois Creek	08/02/2010	Arthropoda	Insecta	Coleoptera	Scirtidae		
Illinois Creek	08/02/2010	Arthropoda	Insecta	Diptera	Ceratopogonidae	*Ceratopogon*	
Illinois Creek	08/02/2010	Arthropoda	Insecta	Diptera	Chironomidae	*Ablabesmyia*	
Illinois Creek	08/02/2010	Arthropoda	Insecta	Diptera	Chironomidae	*Cricotopus*	

Appendix C. Taxonomic data from biological samples for the six heritage streams (2000-2012) (continued).

Stream Name	Date	Phylum	Class	Order	Family	Genus	Specific Epithet
Illinois Creek	08/02/2010	Arthropoda	Insecta	Diptera	Chironomidae	*Cricotopus*	*bicinctus*
Illinois Creek	08/02/2010	Arthropoda	Insecta	Diptera	Chironomidae	*Cryptochironomus*	
Illinois Creek	08/02/2010	Arthropoda	Insecta	Diptera	Chironomidae	*Polypedilum*	
Illinois Creek	08/02/2010	Arthropoda	Insecta	Diptera	Chironomidae	*Rheotanytarsus*	
Illinois Creek	08/02/2010	Arthropoda	Insecta	Diptera	Chironomidae	*Stictochironomus*	
Illinois Creek	08/02/2010	Arthropoda	Insecta	Diptera	Chironomidae	*Tanytarsus*	
Illinois Creek	08/02/2010	Arthropoda	Insecta	Diptera	Chironomidae	*Thienemanniella*	
Illinois Creek	08/02/2010	Arthropoda	Insecta	Diptera	Chironomidae	*Thienemannimyia*	
Illinois Creek	08/02/2010	Arthropoda	Insecta	Diptera	Chironomidae		
Illinois Creek	08/02/2010	Arthropoda	Insecta	Diptera	Simuliidae	*Simulium*	
Illinois Creek	08/02/2010	Arthropoda	Insecta	Diptera	Tipulidae	*Hexatoma*	
Illinois Creek	08/02/2010	Arthropoda	Insecta	Diptera	Tipulidae	*Tipula*	
Illinois Creek	08/02/2010	Arthropoda	Insecta	Diptera	Tipulidae		
Illinois Creek	08/02/2010	Arthropoda	Insecta	Ephemeroptera	Baetidae	*Baetis*	
Illinois Creek	08/02/2010	Arthropoda	Insecta	Ephemeroptera	Baetidae	*Fallceon*	*quilleri*
Illinois Creek	08/02/2010	Arthropoda	Insecta	Ephemeroptera	Baetidae		
Illinois Creek	08/02/2010	Arthropoda	Insecta	Ephemeroptera	Caenidae	*Caenis*	
Illinois Creek	08/02/2010	Arthropoda	Insecta	Ephemeroptera	Heptageniidae	*Stenacron*	*interpunctatum*
Illinois Creek	08/02/2010	Arthropoda	Insecta	Ephemeroptera	Heptageniidae	*Stenonema*	*femoratum*
Illinois Creek	08/02/2010	Arthropoda	Insecta	Ephemeroptera	Leptohyphidae	*Tricorythodes*	
Illinois Creek	08/02/2010	Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae	*Neochoroterpes*	
Illinois Creek	08/02/2010	Arthropoda	Insecta	Hemiptera	Corixidae	*Sigara*	
Illinois Creek	08/02/2010	Arthropoda	Insecta	Hemiptera	Gerridae	*Aquarius*	
Illinois Creek	08/02/2010	Arthropoda	Insecta	Hemiptera	Veliidae	*Rhagovelia*	
Illinois Creek	08/02/2010	Arthropoda	Insecta	Megaloptera	Corydalidae	*Corydalus*	*cornutus*
Illinois Creek	08/02/2010	Arthropoda	Insecta	Megaloptera	Sialidae	*Sialis*	
Illinois Creek	08/02/2010	Arthropoda	Insecta	Odonata	Calopterygidae	*Hetaerina*	*americana*
Illinois Creek	08/02/2010	Arthropoda	Insecta	Trichoptera	Hydropsychidae	*Cheumatopsyche*	
Illinois Creek	08/02/2010	Arthropoda	Insecta	Trichoptera	Hydropsychidae		
Illinois Creek	08/02/2010	Arthropoda	Insecta	Trichoptera	Limnephilidae	*Pycnopsyche*	
Illinois Creek	08/02/2010	Arthropoda	Insecta	Trichoptera	Polycentropodidae	*Polycentropus*	
Illinois Creek	08/02/2010	Arthropoda	Malacostraca	Amphipoda	Hyallelidae	*Hyalella*	*azteca*
Illinois Creek	08/02/2010	Arthropoda	Malacostraca	Decopoda	Cambaridae	*Orconectes*	*virilis*

Appendix C. Taxonomic data from biological samples for the six heritage streams (2000-2012) (continued).

Stream Name	Date	Phylum	Class	Order	Family	Genus	Specific Epithet
Illinois Creek	07/26/2011	Arthropoda	Insecta	Coleoptera	Dytiscidae	*Neoporus*	*dimidiatus*
Illinois Creek	07/26/2011	Arthropoda	Insecta	Coleoptera	Elmidae	*Dubiraphia*	
Illinois Creek	07/26/2011	Arthropoda	Insecta	Coleoptera	Gyrinidae	*Gyrinus*	
Illinois Creek	07/26/2011	Arthropoda	Insecta	Coleoptera	Haliplidae	*Peltodytes*	*sexmaculatus*
Illinois Creek	07/26/2011	Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Anacaena*	
Illinois Creek	07/26/2011	Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Enochrus*	
Illinois Creek	07/26/2011	Arthropoda	Insecta	Coleoptera	Scirtidae		
Illinois Creek	07/26/2011	Arthropoda	Insecta	Diptera	Ceratopogonidae		
Illinois Creek	07/26/2011	Arthropoda	Insecta	Diptera	Chironomidae	*Chironomus*	
Illinois Creek	07/26/2011	Arthropoda	Insecta	Diptera	Chironomidae	*Krenopelopia*	
Illinois Creek	07/26/2011	Arthropoda	Insecta	Diptera	Chironomidae	*Microtendipes*	
Illinois Creek	07/26/2011	Arthropoda	Insecta	Diptera	Chironomidae	*Polypedilum*	
Illinois Creek	07/26/2011	Arthropoda	Insecta	Diptera	Chironomidae	*Procladius*	
Illinois Creek	07/26/2011	Arthropoda	Insecta	Diptera	Chironomidae	*Pseudochironomus*	
Illinois Creek	07/26/2011	Arthropoda	Insecta	Diptera	Chironomidae	*Stictochironomus*	
Illinois Creek	07/26/2011	Arthropoda	Insecta	Diptera	Chironomidae	*Thienemannimyia*	
Illinois Creek	07/26/2011	Arthropoda	Insecta	Diptera	Chironomidae		
Illinois Creek	07/26/2011	Arthropoda	Insecta	Ephemeroptera	Baetidae	*Baetis*	
Illinois Creek	07/26/2011	Arthropoda	Insecta	Ephemeroptera	Baetidae	*Fallceon*	*quilleri*
Illinois Creek	07/26/2011	Arthropoda	Insecta	Ephemeroptera	Caenidae	*Caenis*	
Illinois Creek	07/26/2011	Arthropoda	Insecta	Ephemeroptera	Ephemeridae	*Hexagenia*	*limbata*
Illinois Creek	07/26/2011	Arthropoda	Insecta	Ephemeroptera	Heptageniidae	*Stenacron*	*interpunctatum*
Illinois Creek	07/26/2011	Arthropoda	Insecta	Ephemeroptera	Heptageniidae	*Stenonema*	*femoratum*
Illinois Creek	07/26/2011	Arthropoda	Insecta	Ephemeroptera	Leptohyphidae	*Tricorythodes*	
Illinois Creek	07/26/2011	Arthropoda	Insecta	Hemiptera	Gerridae	*Aquarius*	
Illinois Creek	07/26/2011	Arthropoda	Insecta	Hemiptera	Veliidae	*Microvelia*	
Illinois Creek	07/26/2011	Arthropoda	Insecta	Hemiptera	Veliidae	*Rhagovelia*	
Illinois Creek	07/26/2011	Arthropoda	Insecta	Megaloptera	Corydalidae	*Corydalus*	*cornutus*
Illinois Creek	07/26/2011	Arthropoda	Insecta	Megaloptera	Sialidae	*Sialis*	
Illinois Creek	07/26/2011	Arthropoda	Insecta	Odonata	Coenagrionidae	*Argia*	
Illinois Creek	07/26/2011	Arthropoda	Insecta	Odonata	Corduliidae	*Macromia*	
Illinois Creek	07/26/2011	Arthropoda	Insecta	Trichoptera	Hydropsychidae	*Cheumatopsyche*	
Illinois Creek	07/26/2011	Arthropoda	Insecta	Trichoptera	Hydropsychidae	*Hydropsyche*	*betteni*

Appendix C. Taxonomic data from biological samples for the six heritage streams (2000-2012) (continued).

Stream Name	Date	Phylum	Class	Order	Family	Genus	Specific Epithet
Illinois Creek	07/26/2011	Arthropoda	Insecta	Trichoptera	Philopotamidae	*Chimarra*	*feria*
Illinois Creek	07/26/2011	Arthropoda	Malacostraca	Amphipoda	Hyallelidae	*Hyalella*	*azteca*
Illinois Creek	07/26/2011	Arthropoda	Malacostraca	Decopoda	Cambaridae	*Orconectes*	*neglectus*
Illinois Creek	07/26/2011	Mollusca	Gastropoda	Basommatophora	Ancylidae	*Ferrissia*	
Illinois Creek	07/26/2011	Mollusca	Gastropoda	Basommatophora	Lymnaeidae		
Illinois Creek	07/26/2011	Mollusca	Gastropoda	Basommatophora	Physidae	*Physella*	
Grouse Creek	07/25/2011	Annelida	Clitellata	Haplotaxida	Naididae	*Branchiura*	*sowerbyi*
Grouse Creek	07/25/2011	Arthropoda	Insecta	Coleoptera	Dryopidae	*Helichus*	
Grouse Creek	07/25/2011	Arthropoda	Insecta	Coleoptera	Dytiscidae	*Neoporus*	*dimidiatus*
Grouse Creek	07/25/2011	Arthropoda	Insecta	Coleoptera	Elmidae	*Dubiraphia*	
Grouse Creek	07/25/2011	Arthropoda	Insecta	Coleoptera	Elmidae	*Stenelmis*	
Grouse Creek	07/25/2011	Arthropoda	Insecta	Coleoptera	Elmidae	*Stenelmis*	*bicarinata*
Grouse Creek	07/25/2011	Arthropoda	Insecta	Coleoptera	Elmidae	*Stenelmis*	*sexlineata*
Grouse Creek	07/25/2011	Arthropoda	Insecta	Coleoptera	Haliplidae	*Peltodytes*	*litoralis*
Grouse Creek	07/25/2011	Arthropoda	Insecta	Coleoptera	Heteroceridae		
Grouse Creek	07/25/2011	Arthropoda	Insecta	Coleoptera	Hydraenidae	*Ochthebius*	
Grouse Creek	07/25/2011	Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Anacaena*	
Grouse Creek	07/25/2011	Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Berosus*	
Grouse Creek	07/25/2011	Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Enochrus*	
Grouse Creek	07/25/2011	Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Laccobius*	
Grouse Creek	07/25/2011	Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Tropisternus*	
Grouse Creek	07/25/2011	Arthropoda	Insecta	Coleoptera	Hydrophilidae		
Grouse Creek	07/25/2011	Arthropoda	Insecta	Coleoptera	Scirtidae		
Grouse Creek	07/25/2011	Arthropoda	Insecta	Diptera	Ceratopogonidae		
Grouse Creek	07/25/2011	Arthropoda	Insecta	Diptera	Chironomidae	*Axarus*	
Grouse Creek	07/25/2011	Arthropoda	Insecta	Diptera	Chironomidae	*Dicrotendipes*	
Grouse Creek	07/25/2011	Arthropoda	Insecta	Diptera	Chironomidae	*Polypedilum*	
Grouse Creek	07/25/2011	Arthropoda	Insecta	Diptera	Chironomidae		
Grouse Creek	07/25/2011	Arthropoda	Insecta	Diptera	Tabanidae	*Tabanus*	
Grouse Creek	07/25/2011	Arthropoda	Insecta	Ephemeroptera	Baetidae	*Baetis*	
Grouse Creek	07/25/2011	Arthropoda	Insecta	Ephemeroptera	Baetidae	*Centroptilum*	
Grouse Creek	07/25/2011	Arthropoda	Insecta	Ephemeroptera	Caenidae	*Caenis*	
Grouse Creek	07/25/2011	Arthropoda	Insecta	Ephemeroptera	Heptageniidae	*Maccaffertium*	*m. integrum*

Appendix C. Taxonomic data from biological samples for the six heritage streams (2000-2012) (continued).

Stream Name	Date	Phylum	Class	Order	Family	Genus	Specific Epithet
Grouse Creek	07/25/2011	Arthropoda	Insecta	Ephemeroptera	Heptageniidae	*Stenacron*	*interpunctatum*
Grouse Creek	07/25/2011	Arthropoda	Insecta	Ephemeroptera	Heptageniidae	*Stenonema*	*femoratum*
Grouse Creek	07/25/2011	Arthropoda	Insecta	Ephemeroptera	Leptohyphidae	*Tricorythodes*	
Grouse Creek	07/25/2011	Arthropoda	Insecta	Hemiptera	Corixidae	*Palmacorixa*	
Grouse Creek	07/25/2011	Arthropoda	Insecta	Hemiptera	Veliidae	*Rhagovelia*	
Grouse Creek	07/25/2011	Arthropoda	Insecta	Megaloptera	Corydalidae	*Corydalus*	*cornutus*
Grouse Creek	07/25/2011	Arthropoda	Insecta	Megaloptera	Sialidae	*Sialis*	
Grouse Creek	07/25/2011	Arthropoda	Insecta	Odonata	Aeshnidae	*Nasiaeschna*	*pentacantha*
Grouse Creek	07/25/2011	Arthropoda	Insecta	Odonata	Coenagrionidae	*Argia*	
Grouse Creek	07/25/2011	Arthropoda	Insecta	Odonata	Coenagrionidae	*Enallagma*	
Grouse Creek	07/25/2011	Arthropoda	Insecta	Odonata	Gomphidae	*Arigomphus*	
Grouse Creek	07/25/2011	Arthropoda	Insecta	Odonata	Gomphidae	*Dromogomphus*	
Grouse Creek	07/25/2011	Arthropoda	Insecta	Trichoptera	Hydropsychidae	*Cheumatopsyche*	
Grouse Creek	07/25/2011	Arthropoda	Insecta	Trichoptera	Philopotamidae	*Chimarra*	*obscura*
Grouse Creek	07/25/2011	Arthropoda	Insecta	Trichoptera	Polycentropodidae	*Polycentropus*	
Grouse Creek	07/25/2011	Arthropoda	Malacostraca	Amphipoda	Hyallelidae	*Hyalella*	*azteca*
Grouse Creek	07/25/2011	Arthropoda	Malacostraca	Decopoda	Cambaridae	*Orconectes*	
Grouse Creek	07/25/2011	Mollusca	Bivalvia	Heterodontida	Corbiculidae	*Corbicula*	*fluminea*
Grouse Creek	07/25/2011	Mollusca	Bivalvia	Heterodontida	Pisidiidae	*Musculium*	*transversum*
Grouse Creek	07/25/2011	Mollusca	Bivalvia	Heterodontida	Pisidiidae	*Sphaerium*	*striatinum*
Grouse Creek	07/25/2011	Mollusca	Gastropoda	Basommatophora	Physidae	*Physella*	
Grouse Creek	07/25/2011	Mollusca	Gastropoda	Basommatophora	Planorbidae	*Planorbella*	
Grouse Creek	07/25/2011	Mollusca	Gastropoda	Neotaenioglossa	Hydrobiidae	*Cincinnatia*	*integra*
Grouse Creek	03/12/2012	Annelida	Clitellata	Haplotaxida	Naididae	*Branchiura*	*sowerbyi*
Grouse Creek	03/12/2012	Arthropoda	Insecta	Coleoptera	Dryopidae	*Helichus*	
Grouse Creek	03/12/2012	Arthropoda	Insecta	Coleoptera	Dytiscidae	*Neoporus*	*dimidiatus*
Grouse Creek	03/12/2012	Arthropoda	Insecta	Coleoptera	Elmidae	*Stenelmis*	
Grouse Creek	03/12/2012	Arthropoda	Insecta	Coleoptera	Elmidae	*Stenelmis*	*bicarinata*
Grouse Creek	03/12/2012	Arthropoda	Insecta	Coleoptera	Hydrophilidae		
Grouse Creek	03/12/2012	Arthropoda	Insecta	Diptera	Chironomidae	*Cricotopus/Orthocladius*	
Grouse Creek	03/12/2012	Arthropoda	Insecta	Diptera	Chironomidae	*Krenopelopia*	
Grouse Creek	03/12/2012	Arthropoda	Insecta	Diptera	Chironomidae	*Paratendipes*	
Grouse Creek	03/12/2012	Arthropoda	Insecta	Diptera	Chironomidae		

Appendix C. Taxonomic data from biological samples for the six heritage streams (2000-2012) (continued).

Stream Name	Date	Phylum	Class	Order	Family	Genus	Specific Epithet
Grouse Creek	03/12/2012	Arthropoda	Insecta	Diptera	Tabanidae	*Tabanus*	
Grouse Creek	03/12/2012	Arthropoda	Insecta	Diptera	Tipulidae	*Hexatoma*	
Grouse Creek	03/12/2012	Arthropoda	Insecta	Ephemeroptera	Caenidae	*Caenis*	
Grouse Creek	03/12/2012	Arthropoda	Insecta	Ephemeroptera	Heptageniidae	*Maccaffertium*	
Grouse Creek	03/12/2012	Arthropoda	Insecta	Ephemeroptera	Heptageniidae	*Stenonema*	*femoratum*
Grouse Creek	03/12/2012	Arthropoda	Insecta	Hemiptera	Corixidae	*Trichocorixa*	
Grouse Creek	03/12/2012	Arthropoda	Insecta	Plecoptera	Capniidae	*Allocapnia*	
Grouse Creek	03/12/2012	Arthropoda	Insecta	Plecoptera	Perlodidae		
Grouse Creek	03/12/2012	Arthropoda	Malacostraca	Decopoda	Cambaridae	*Orconectes*	
Grouse Creek	03/12/2012	Mollusca	Bivalvia	Heterodontida	Corbiculidae	*Corbicula*	*fluminea*
Grouse Creek	03/12/2012	Mollusca	Gastropoda	Neotaenioglossa	Hydrobiidae	*Cincinnatia*	*integra*
Nescatunga Creek	07/30/2007	Arthropoda	Insecta	Coleoptera	Dryopidae	*Helichus*	
Nescatunga Creek	07/30/2007	Arthropoda	Insecta	Coleoptera	Dytiscidae	*Heterosternuta*	*wickhami*
Nescatunga Creek	07/30/2007	Arthropoda	Insecta	Coleoptera	Dytiscidae	*Neoporus*	*dimidiatus*
Nescatunga Creek	07/30/2007	Arthropoda	Insecta	Coleoptera	Elmidae	*Dubiraphia*	*minima*
Nescatunga Creek	07/30/2007	Arthropoda	Insecta	Coleoptera	Elmidae	*Microcylloepus*	*pusillus*
Nescatunga Creek	07/30/2007	Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Enochrus*	
Nescatunga Creek	07/30/2007	Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Paracymus*	
Nescatunga Creek	07/30/2007	Arthropoda	Insecta	Diptera	Chironomidae	*Polypedilum*	
Nescatunga Creek	07/30/2007	Arthropoda	Insecta	Diptera	Chironomidae	*Thienemannimyia*	
Nescatunga Creek	07/30/2007	Arthropoda	Insecta	Ephemeroptera	Baetidae	*Fallceon*	*quilleri*
Nescatunga Creek	07/30/2007	Arthropoda	Insecta	Ephemeroptera	Baetidae	*Pseudocloeon*	
Nescatunga Creek	07/30/2007	Arthropoda	Insecta	Ephemeroptera	Caenidae	*Caenis*	
Nescatunga Creek	07/30/2007	Arthropoda	Insecta	Ephemeroptera	Heptageniidae	*Heptagenia*	
Nescatunga Creek	07/30/2007	Arthropoda	Insecta	Ephemeroptera	Heptageniidae	*Heptagenia*	*elegantula*
Nescatunga Creek	07/30/2007	Arthropoda	Insecta	Ephemeroptera	Isonychiidae	*Isonychia*	
Nescatunga Creek	07/30/2007	Arthropoda	Insecta	Ephemeroptera	Leptohyphidae	*Tricorythodes*	
Nescatunga Creek	07/30/2007	Arthropoda	Insecta	Hemiptera	Veliidae	*Rhagovelia*	
Nescatunga Creek	07/30/2007	Arthropoda	Insecta	Hemiptera	Veliidae		
Nescatunga Creek	07/30/2007	Arthropoda	Insecta	Odonata	Calopterygidae	*Hetaerina*	*americana*
Nescatunga Creek	07/30/2007	Arthropoda	Insecta	Odonata	Coenagrionidae	*Argia*	
Nescatunga Creek	07/30/2007	Arthropoda	Insecta	Odonata	Gomphidae	*Erpetogomphus*	*designatus*
Nescatunga Creek	07/30/2007	Arthropoda	Insecta	Odonata	Gomphidae	*Progomphus*	*obscurus*

Appendix C. Taxonomic data from biological samples for the six heritage streams (2000-2012) (continued).

Stream Name	Date	Phylum	Class	Order	Family	Genus	Specific Epithet
Nescatunga Creek	07/30/2007	Arthropoda	Insecta	Trichoptera	Hydropsychidae	*Cheumatopsyche*	
Nescatunga Creek	07/30/2007	Arthropoda	Insecta	Trichoptera	Leptoceridae	*Nectopsyche*	*candida*
Nescatunga Creek	07/30/2007	Arthropoda	Malacostraca	Amphipoda	Hyallelidae	*Hyalella*	*azteca*
Nescatunga Creek	07/30/2007	Arthropoda	Malacostraca	Decopoda	Cambaridae	*Orconectes*	
Nescatunga Creek	05/27/2009	Arthropoda	Insecta	Coleoptera	Dryopidae	*Helichus*	
Nescatunga Creek	05/27/2009	Arthropoda	Insecta	Coleoptera	Dytiscidae	*Neoporus*	*dimidiatus*
Nescatunga Creek	05/27/2009	Arthropoda	Insecta	Coleoptera	Dytiscidae		
Nescatunga Creek	05/27/2009	Arthropoda	Insecta	Coleoptera	Elmidae	*Dubiraphia*	
Nescatunga Creek	05/27/2009	Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Tropisternus*	
Nescatunga Creek	05/27/2009	Arthropoda	Insecta	Diptera	Chironomidae	*Polypedilum*	
Nescatunga Creek	05/27/2009	Arthropoda	Insecta	Diptera	Chironomidae	*Procladius*	
Nescatunga Creek	05/27/2009	Arthropoda	Insecta	Diptera	Chironomidae	*Stictochironomus*	
Nescatunga Creek	05/27/2009	Arthropoda	Insecta	Diptera	Chironomidae	*Thienemannimyia*	
Nescatunga Creek	05/27/2009	Arthropoda	Insecta	Diptera	Tipulidae		
Nescatunga Creek	05/27/2009	Arthropoda	Insecta	Ephemeroptera	Baetidae	*Fallceon*	*quilleri*
Nescatunga Creek	05/27/2009	Arthropoda	Insecta	Ephemeroptera	Baetidae	*Pseudocloeon*	
Nescatunga Creek	05/27/2009	Arthropoda	Insecta	Ephemeroptera	Baetidae		
Nescatunga Creek	05/27/2009	Arthropoda	Insecta	Ephemeroptera	Caenidae	*Caenis*	
Nescatunga Creek	05/27/2009	Arthropoda	Insecta	Ephemeroptera	Ephemeridae	*Hexagenia*	*limbata*
Nescatunga Creek	05/27/2009	Arthropoda	Insecta	Ephemeroptera	Heptageniidae	*Heptagenia*	*elegantula*
Nescatunga Creek	05/27/2009	Arthropoda	Insecta	Ephemeroptera	Isonychiidae	*Isonychia*	
Nescatunga Creek	05/27/2009	Arthropoda	Insecta	Ephemeroptera	Leptohyphidae	*Tricorythodes*	
Nescatunga Creek	05/27/2009	Arthropoda	Insecta	Hemiptera	Corixidae	*Sigara*	
Nescatunga Creek	05/27/2009	Arthropoda	Insecta	Hemiptera	Corixidae	*Trichocorixa*	
Nescatunga Creek	05/27/2009	Arthropoda	Insecta	Hemiptera	Nepidae	*Nepa*	*apiculata*
Nescatunga Creek	05/27/2009	Arthropoda	Insecta	Hemiptera	Veliidae	*Rhagovelia*	
Nescatunga Creek	05/27/2009	Arthropoda	Insecta	Odonata	Calopterygidae	*Hetaerina*	*americana*
Nescatunga Creek	05/27/2009	Arthropoda	Insecta	Odonata	Coenagrionidae	*Argia*	
Nescatunga Creek	05/27/2009	Arthropoda	Insecta	Odonata	Gomphidae	*Erpetogomphus*	*designatus*
Nescatunga Creek	05/27/2009	Arthropoda	Insecta	Odonata	Gomphidae	*Gomphus*	*externus*
Nescatunga Creek	05/27/2009	Arthropoda	Insecta	Odonata	Gomphidae	*Gomphus*	*militaris*
Nescatunga Creek	05/27/2009	Arthropoda	Insecta	Odonata	Gomphidae	*Progomphus*	*obscurus*
Nescatunga Creek	05/27/2009	Arthropoda	Insecta	Odonata	Libellulidae	*Libellula*	*pulchella*

Appendix C. Taxonomic data from biological samples for the six heritage streams (2000-2012) (continued).

Stream Name	Date	Phylum	Class	Order	Family	Genus	Specific Epithet
Nescatunga Creek	05/27/2009	Arthropoda	Insecta	Odonata	Libellulidae		
Nescatunga Creek	05/27/2009	Arthropoda	Insecta	Plecoptera	Perlidae	*Perlesta*	
Nescatunga Creek	05/27/2009	Arthropoda	Insecta	Trichoptera	Hydropsychidae	*Cheumatopsyche*	
Nescatunga Creek	05/27/2009	Arthropoda	Insecta	Trichoptera	Leptoceridae	*Nectopsyche*	*diarina*
Nescatunga Creek	05/27/2009	Arthropoda	Malacostraca	Decapoda	Cambaridae	*Procambarus*	*simulans*
Nescatunga Creek	05/27/2009	Arthropoda	Malacostraca	Decopoda	Cambaridae	*Orconectes*	
Nescatunga Creek	05/27/2009	Mollusca	Gastropoda	Basommatophora	Physidae	*Physella*	
Nescatunga Creek	08/01/2011	Arthropoda	Insecta	Coleoptera	Dytiscidae	*Heterosternuta*	*wickhami*
Nescatunga Creek	08/01/2011	Arthropoda	Insecta	Coleoptera	Haliplidae	*Peltodytes*	*litoralis*
Nescatunga Creek	08/01/2011	Arthropoda	Insecta	Coleoptera	Hydrochidae	*Hydrochus*	
Nescatunga Creek	08/01/2011	Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Anacaena*	
Nescatunga Creek	08/01/2011	Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Berosus*	
Nescatunga Creek	08/01/2011	Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Enochrus*	
Nescatunga Creek	08/01/2011	Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Tropisternus*	
Nescatunga Creek	08/01/2011	Arthropoda	Insecta	Coleoptera	Hydrophilidae		
Nescatunga Creek	08/01/2011	Arthropoda	Insecta	Diptera	Ceratopogonidae		
Nescatunga Creek	08/01/2011	Arthropoda	Insecta	Diptera	Chironomidae	*Tanypus*	
Nescatunga Creek	08/01/2011	Arthropoda	Insecta	Ephemeroptera	Caenidae	*Caenis*	
Nescatunga Creek	08/01/2011	Arthropoda	Insecta	Odonata	Coenagrionidae	*Argia*	
Nescatunga Creek	08/01/2011	Arthropoda	Insecta	Odonata	Gomphidae	*Erpetogomphus*	*designatus*
Nescatunga Creek	08/01/2011	Arthropoda	Insecta	Odonata	Gomphidae	*Gomphus*	*externus*
Nescatunga Creek	08/01/2011	Arthropoda	Insecta	Odonata	Gomphidae	*Progomphus*	*obscurus*
Nescatunga Creek	08/01/2011	Arthropoda	Insecta	Odonata	Libellulidae		
Nescatunga Creek	08/01/2011	Arthropoda	Malacostraca	Decopoda	Cambaridae	*Orconectes*	
Nescatunga Creek	08/01/2011	Mollusca	Gastropoda	Basommatophora	Lymnaeidae	*Fossaria*	
Nescatunga Creek	08/01/2011	Mollusca	Gastropoda	Basommatophora	Physidae	*Physella*	
Nescatunga Creek	06/26/2012	Arthropoda	Insecta	Coleoptera	Dryopidae	*Helichus*	
Nescatunga Creek	06/26/2012	Arthropoda	Insecta	Coleoptera	Dytiscidae	*Heterosternuta*	*diversicornis*
Nescatunga Creek	06/26/2012	Arthropoda	Insecta	Coleoptera	Dytiscidae	*Heterosternuta*	*wickhami*
Nescatunga Creek	06/26/2012	Arthropoda	Insecta	Coleoptera	Dytiscidae	*Laccophilus*	
Nescatunga Creek	06/26/2012	Arthropoda	Insecta	Coleoptera	Dytiscidae	*Neoporus*	*dimidiatus*
Nescatunga Creek	06/26/2012	Arthropoda	Insecta	Coleoptera	Dytiscidae	*Uvarus*	
Nescatunga Creek	06/26/2012	Arthropoda	Insecta	Coleoptera	Elmidae	*Dubiraphia*	

Appendix C. Taxonomic data from biological samples for the six heritage streams (2000-2012) (continued).

Stream Name	Date	Phylum	Class	Order	Family	Genus	Specific Epithet
Nescatunga Creek	06/26/2012	Arthropoda	Insecta	Coleoptera	Gyrinidae	*Dineutus*	
Nescatunga Creek	06/26/2012	Arthropoda	Insecta	Coleoptera	Haliplidae	*Peltodytes*	*litoralis*
Nescatunga Creek	06/26/2012	Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Anacaena*	
Nescatunga Creek	06/26/2012	Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Berosus*	
Nescatunga Creek	06/26/2012	Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Enochrus*	
Nescatunga Creek	06/26/2012	Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Laccobius*	
Nescatunga Creek	06/26/2012	Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Tropisternus*	
Nescatunga Creek	06/26/2012	Arthropoda	Insecta	Coleoptera	Hydrophilidae		
Nescatunga Creek	06/26/2012	Arthropoda	Insecta	Diptera	Chironomidae	*Procladius*	
Nescatunga Creek	06/26/2012	Arthropoda	Insecta	Diptera	Chironomidae	*Stictochironomus*	
Nescatunga Creek	06/26/2012	Arthropoda	Insecta	Diptera	Chironomidae	*Thienemannimyia*	
Nescatunga Creek	06/26/2012	Arthropoda	Insecta	Diptera	Stratiomyidae	*Stratiomys*	
Nescatunga Creek	06/26/2012	Arthropoda	Insecta	Ephemeroptera	Caenidae	*Caenis*	
Nescatunga Creek	06/26/2012	Arthropoda	Insecta	Ephemeroptera	Heptageniidae	*Heptagenia*	*elegantula*
Nescatunga Creek	06/26/2012	Arthropoda	Insecta	Ephemeroptera	Isonychiidae	*Isonychia*	
Nescatunga Creek	06/26/2012	Arthropoda	Insecta	Megaloptera	Sialidae	*Sialis*	
Nescatunga Creek	06/26/2012	Arthropoda	Insecta	Odonata	Aeshnidae	*Nasiaeschna*	*pentacantha*
Nescatunga Creek	06/26/2012	Arthropoda	Insecta	Odonata	Calopterygidae	*Hetaerina*	*americana*
Nescatunga Creek	06/26/2012	Arthropoda	Insecta	Odonata	Coenagrionidae	*Argia*	
Nescatunga Creek	06/26/2012	Arthropoda	Insecta	Odonata	Gomphidae	*Progomphus*	*obscurus*
Nescatunga Creek	06/26/2012	Arthropoda	Insecta	Odonata	Libellulidae	*Sympetrum*	*corruptum*
Nescatunga Creek	06/26/2012	Arthropoda	Insecta	Trichoptera	Hydropsychidae	*Cheumatopsyche*	
Nescatunga Creek	06/26/2012	Arthropoda	Insecta	Trichoptera	Leptoceridae	*Nectopsyche*	*diarina*
Nescatunga Creek	06/26/2012	Mollusca	Gastropoda	Basommatophora	Lymnaeidae	*Fossaria*	
Nescatunga Creek	06/26/2012	Mollusca	Gastropoda	Basommatophora	Physidae	*Physella*	
Nescatunga Creek	06/26/2012	Platyhelminthes	Turbellaria	Tricladida	Planariidae	*Dugesia*	
Thompson Creek	06/20/2000	Arthropoda	Insecta	Coleoptera	Dytiscidae	*Hydroporus*	
Thompson Creek	06/20/2000	Arthropoda	Insecta	Coleoptera	Elmidae	*Dubiraphia*	
Thompson Creek	06/20/2000	Arthropoda	Insecta	Coleoptera	Elmidae	*Microcylloepus*	*pusillus*
Thompson Creek	06/20/2000	Arthropoda	Insecta	Coleoptera	Helophoridae	*Helophorus*	
Thompson Creek	06/20/2000	Arthropoda	Insecta	Coleoptera	Hydrochidae	*Hydrochus*	
Thompson Creek	06/20/2000	Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Berosus*	
Thompson Creek	06/20/2000	Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Paracymus*	

Appendix C. Taxonomic data from biological samples for the six heritage streams (2000-2012) (continued).

Stream Name	Date	Phylum	Class	Order	Family	Genus	Specific Epithet
Thompson Creek	06/20/2000	Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Tropisternus*	
Thompson Creek	06/20/2000	Arthropoda	Insecta	Coleoptera	Ptiliidae		
Thompson Creek	06/20/2000	Arthropoda	Insecta	Diptera	Chironomidae	*Chironomus*	
Thompson Creek	06/20/2000	Arthropoda	Insecta	Diptera	Chironomidae	*Cricotopus*	
Thompson Creek	06/20/2000	Arthropoda	Insecta	Diptera	Chironomidae	*Cryptochironomus*	
Thompson Creek	06/20/2000	Arthropoda	Insecta	Diptera	Chironomidae	*Phaenopsectra*	
Thompson Creek	06/20/2000	Arthropoda	Insecta	Diptera	Chironomidae	*Polypedilum*	
Thompson Creek	06/20/2000	Arthropoda	Insecta	Diptera	Chironomidae	*Thienemannimyia*	
Thompson Creek	06/20/2000	Arthropoda	Insecta	Diptera	Tipulidae	*Tipula*	
Thompson Creek	06/20/2000	Arthropoda	Insecta	Ephemeroptera	Baetidae	*Baetis*	
Thompson Creek	06/20/2000	Arthropoda	Insecta	Ephemeroptera	Ephemeridae	*Hexagenia*	
Thompson Creek	06/20/2000	Arthropoda	Insecta	Ephemeroptera	Heptageniidae	*Heptagenia*	*elegantula*
Thompson Creek	06/20/2000	Arthropoda	Insecta	Ephemeroptera	Isonychiidae	*Isonychia*	
Thompson Creek	06/20/2000	Arthropoda	Insecta	Ephemeroptera	Leptohyphidae	*Tricorythodes*	
Thompson Creek	06/20/2000	Arthropoda	Insecta	Ephemeroptera	Polymitarcyidae	*Ephoron*	*album*
Thompson Creek	06/20/2000	Arthropoda	Insecta	Hemiptera	Corixidae	*Sigara*	
Thompson Creek	06/20/2000	Arthropoda	Insecta	Hemiptera	Corixidae	*Trichocorixa*	
Thompson Creek	06/20/2000	Arthropoda	Insecta	Hemiptera	Veliidae	*Rhagovelia*	
Thompson Creek	06/20/2000	Arthropoda	Insecta	Megaloptera	Sialidae	*Sialis*	
Thompson Creek	06/20/2000	Arthropoda	Insecta	Odonata	Calopterygidae	*Calopteryx*	*maculata*
Thompson Creek	06/20/2000	Arthropoda	Insecta	Odonata	Calopterygidae	*Hetaerina*	*americana*
Thompson Creek	06/20/2000	Arthropoda	Insecta	Odonata	Coenagrionidae	*Argia*	
Thompson Creek	06/20/2000	Arthropoda	Insecta	Odonata	Coenagrionidae	*Argia*	*bipunctulata*
Thompson Creek	06/20/2000	Arthropoda	Insecta	Odonata	Gomphidae	*Erpetogomphus*	*designatus*
Thompson Creek	06/20/2000	Arthropoda	Insecta	Odonata	Gomphidae	*Gomphus*	*externus*
Thompson Creek	06/20/2000	Arthropoda	Insecta	Plecoptera	Perlidae	*Perlesta*	
Thompson Creek	06/20/2000	Arthropoda	Insecta	Trichoptera	Helicopsychidae	*Helicopsyche*	*borealis*
Thompson Creek	06/20/2000	Arthropoda	Insecta	Trichoptera	Hydropsychidae	*Cheumatopsyche*	
Thompson Creek	06/20/2000	Arthropoda	Insecta	Trichoptera	Hydropsychidae	*Hydropsyche*	*simulans*
Thompson Creek	06/20/2000	Arthropoda	Insecta	Trichoptera	Leptoceridae	*Nectopsyche*	*diarina*
Thompson Creek	06/20/2000	Arthropoda	Insecta	Trichoptera	Philopotamidae	*Chimarra*	*feria*
Thompson Creek	06/20/2000	Arthropoda	Malacostraca	Amphipoda	Hyallelidae	*Hyalella*	*azteca*
Thompson Creek	06/20/2000	Arthropoda	Malacostraca	Decopoda	Cambaridae	*Orconectes*	

Appendix C. Taxonomic data from biological samples for the six heritage streams (2000-2012) (continued).

Stream Name	Date	Phylum	Class	Order	Family	Genus	Specific Epithet
Thompson Creek	06/20/2000	Mollusca	Gastropoda	Basommatophora	Physidae	*Physella*	
Thompson Creek	06/20/2000	Platyhelminthes	Turbellaria	Tricladida	Planariidae	*Dugesia*	
Thompson Creek	07/11/2001	Annelida	Clitellata	Hirudinea			
Thompson Creek	07/11/2001	Arthropoda	Insecta	Coleoptera	Elmidae	*Dubiraphia*	
Thompson Creek	07/11/2001	Arthropoda	Insecta	Coleoptera	Elmidae	*Microcylloepus*	*pusillus*
Thompson Creek	07/11/2001	Arthropoda	Insecta	Coleoptera	Elmidae	*Stenelmis*	*sexlineata*
Thompson Creek	07/11/2001	Arthropoda	Insecta	Coleoptera	Haliplidae	*Haliplus*	
Thompson Creek	07/11/2001	Arthropoda	Insecta	Coleoptera	Helophoridae	*Helophorus*	
Thompson Creek	07/11/2001	Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Helocombus*	
Thompson Creek	07/11/2001	Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Paracymus*	
Thompson Creek	07/11/2001	Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Tropisternus*	
Thompson Creek	07/11/2001	Arthropoda	Insecta	Coleoptera			
Thompson Creek	07/11/2001	Arthropoda	Insecta	Diptera	Chironomidae	*Cricotopus*	
Thompson Creek	07/11/2001	Arthropoda	Insecta	Diptera	Chironomidae	*Paratendipes*	
Thompson Creek	07/11/2001	Arthropoda	Insecta	Diptera	Chironomidae	*Pentaneura*	
Thompson Creek	07/11/2001	Arthropoda	Insecta	Diptera	Chironomidae	*Stictochironomus*	
Thompson Creek	07/11/2001	Arthropoda	Insecta	Diptera	Simuliidae	*Simulium*	
Thompson Creek	07/11/2001	Arthropoda	Insecta	Diptera	Tipulidae	*Tipula*	
Thompson Creek	07/11/2001	Arthropoda	Insecta	Ephemeroptera	Baetidae	*Acentrella*	
Thompson Creek	07/11/2001	Arthropoda	Insecta	Ephemeroptera	Baetidae	*Acerpenna*	*pygmaea*
Thompson Creek	07/11/2001	Arthropoda	Insecta	Ephemeroptera	Baetidae	*Baetis*	
Thompson Creek	07/11/2001	Arthropoda	Insecta	Ephemeroptera	Heptageniidae	*Heptagenia*	*elegantula*
Thompson Creek	07/11/2001	Arthropoda	Insecta	Ephemeroptera	Heptageniidae	*Stenacron*	*interpunctatum*
Thompson Creek	07/11/2001	Arthropoda	Insecta	Ephemeroptera	Isonychiidae	*Isonychia*	
Thompson Creek	07/11/2001	Arthropoda	Insecta	Ephemeroptera	Leptohyphidae	*Tricorythodes*	
Thompson Creek	07/11/2001	Arthropoda	Insecta	Ephemeroptera	Polymitarcyidae	*Ephoron*	*album*
Thompson Creek	07/11/2001	Arthropoda	Insecta	Hemiptera	Corixidae	*Sigara*	
Thompson Creek	07/11/2001	Arthropoda	Insecta	Hemiptera	Gerridae	*Gerris*	
Thompson Creek	07/11/2001	Arthropoda	Insecta	Hemiptera	Veliidae	*Rhagovelia*	
Thompson Creek	07/11/2001	Arthropoda	Insecta	Odonata	Calopterygidae	*Hetaerina*	*americana*
Thompson Creek	07/11/2001	Arthropoda	Insecta	Odonata	Coenagrionidae	*Argia*	*bipunctulata*
Thompson Creek	07/11/2001	Arthropoda	Insecta	Odonata	Gomphidae	*Erpetogomphus*	*designatus*
Thompson Creek	07/11/2001	Arthropoda	Insecta	Plecoptera	Perlidae	*Perlesta*	

Appendix C. Taxonomic data from biological samples for the six heritage streams (2000-2012) (continued).

Stream Name	Date	Phylum	Class	Order	Family	Genus	Specific Epithet
Thompson Creek	07/11/2001	Arthropoda	Insecta	Trichoptera	Helicopsychidae	*Helicopsyche*	*borealis*
Thompson Creek	07/11/2001	Arthropoda	Insecta	Trichoptera	Hydropsychidae	*Cheumatopsyche*	
Thompson Creek	07/11/2001	Arthropoda	Insecta	Trichoptera	Hydropsychidae	*Hydropsyche*	*simulans*
Thompson Creek	07/11/2001	Arthropoda	Insecta	Trichoptera	Hydroptilidae	*Hydroptila*	
Thompson Creek	07/11/2001	Arthropoda	Insecta	Trichoptera	Leptoceridae	*Nectopsyche*	*diarina*
Thompson Creek	07/11/2001	Arthropoda	Malacostraca	Amphipoda	Hyallelidae	*Hyalella*	*azteca*
Thompson Creek	07/11/2001	Arthropoda	Malacostraca	Decopoda	Cambaridae	*Orconectes*	
Thompson Creek	07/11/2001	Mollusca	Bivalvia	Heterodontida	Pisidiidae	*Pisidium*	
Thompson Creek	07/11/2001	Mollusca	Gastropoda	Basommatophora	Lymnaeidae	*Lymnaea*	
Thompson Creek	07/11/2001	Mollusca	Gastropoda	Basommatophora	Physidae	*Physella*	
Thompson Creek	07/11/2001	Platyhelminthes	Turbellaria	Tricladida	Planariidae	*Dugesia*	
Thompson Creek	09/27/2004	Annelida	Clitellata	Haplotaxida			
Thompson Creek	09/27/2004	Annelida	Clitellata	Hirudinea			
Thompson Creek	09/27/2004	Arthropoda	Insecta	Coleoptera	Elmidae	*Dubiraphia*	*minima*
Thompson Creek	09/27/2004	Arthropoda	Insecta	Coleoptera	Elmidae	*Macronychus*	*glabratus*
Thompson Creek	09/27/2004	Arthropoda	Insecta	Coleoptera	Elmidae	*Microcylloepus*	*pusillus*
Thompson Creek	09/27/2004	Arthropoda	Insecta	Coleoptera	Ptiliidae		
Thompson Creek	09/27/2004	Arthropoda	Insecta	Diptera	Chironomidae	*Cricotopus*	
Thompson Creek	09/27/2004	Arthropoda	Insecta	Diptera	Chironomidae	*Cryptotendipes*	
Thompson Creek	09/27/2004	Arthropoda	Insecta	Diptera	Chironomidae	*Nanocladius*	
Thompson Creek	09/27/2004	Arthropoda	Insecta	Diptera	Chironomidae	*Polypedilum*	
Thompson Creek	09/27/2004	Arthropoda	Insecta	Diptera	Simuliidae	*Simulium*	
Thompson Creek	09/27/2004	Arthropoda	Insecta	Ephemeroptera	Baetidae	*Acentrella*	
Thompson Creek	09/27/2004	Arthropoda	Insecta	Ephemeroptera	Baetidae	*Baetis*	
Thompson Creek	09/27/2004	Arthropoda	Insecta	Ephemeroptera	Heptageniidae	*Heptagenia*	*elegantula*
Thompson Creek	09/27/2004	Arthropoda	Insecta	Ephemeroptera	Heptageniidae	*Heptagenia*	*flavescens*
Thompson Creek	09/27/2004	Arthropoda	Insecta	Ephemeroptera	Isonychiidae	*Isonychia*	
Thompson Creek	09/27/2004	Arthropoda	Insecta	Ephemeroptera	Leptohyphidae	*Tricorythodes*	
Thompson Creek	09/27/2004	Arthropoda	Insecta	Hemiptera	Corixidae	*Sigara*	
Thompson Creek	09/27/2004	Arthropoda	Insecta	Hemiptera	Veliidae	*Rhagovelia*	
Thompson Creek	09/27/2004	Arthropoda	Insecta	Megaloptera	Corydalidae	*Corydalus*	*cornutus*
Thompson Creek	09/27/2004	Arthropoda	Insecta	Odonata	Calopterygidae	*Hetaerina*	*americana*
Thompson Creek	09/27/2004	Arthropoda	Insecta	Odonata	Gomphidae	*Erpetogomphus*	*designatus*

Appendix C. Taxonomic data from biological samples for the six heritage streams (2000-2012) (continued).

Stream Name	Date	Phylum	Class	Order	Family	Genus	Specific Epithet
Thompson Creek	09/27/2004	Arthropoda	Insecta	Odonata	Gomphidae	*Gomphus*	*externus*
Thompson Creek	09/27/2004	Arthropoda	Insecta	Plecoptera	Taeniopterygidae	*Taeniopteryx*	*burksi*
Thompson Creek	09/27/2004	Arthropoda	Insecta	Trichoptera	Helicopsychidae	*Helicopsyche*	*borealis*
Thompson Creek	09/27/2004	Arthropoda	Insecta	Trichoptera	Hydropsychidae	*Cheumatopsyche*	
Thompson Creek	09/27/2004	Arthropoda	Insecta	Trichoptera	Hydropsychidae	*Hydropsyche*	*simulans*
Thompson Creek	09/27/2004	Arthropoda	Insecta	Trichoptera	Leptoceridae	*Nectopsyche*	*diarina*
Thompson Creek	09/27/2004	Arthropoda	Malacostraca	Amphipoda	Hyallelidae	*Hyalella*	*azteca*
Thompson Creek	09/27/2004	Arthropoda	Malacostraca	Decopoda	Cambaridae	*Orconectes*	
Thompson Creek	09/27/2004	Mollusca	Bivalvia	Heterodontida	Pisidiidae	*Pisidium*	
Thompson Creek	09/27/2004	Mollusca	Gastropoda	Basommatophora	Physidae	*Physella*	
Thompson Creek	09/27/2004	Platyhelminthes	Turbellaria	Tricladida	Planariidae	*Dugesia*	
Thompson Creek	11/02/2005	Arthropoda	Insecta	Coleoptera	Dytiscidae	*Agabus*	
Thompson Creek	11/02/2005	Arthropoda	Insecta	Coleoptera	Dytiscidae	*Laccophilus*	
Thompson Creek	11/02/2005	Arthropoda	Insecta	Coleoptera	Elmidae	*Microcylloepus*	*pusillus*
Thompson Creek	11/02/2005	Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Tropisternus*	
Thompson Creek	11/02/2005	Arthropoda	Insecta	Diptera	Chironomidae	*Chironomus*	
Thompson Creek	11/02/2005	Arthropoda	Insecta	Diptera	Chironomidae	*Cricotopus*	
Thompson Creek	11/02/2005	Arthropoda	Insecta	Diptera	Chironomidae	*Eukiefferiella*	
Thompson Creek	11/02/2005	Arthropoda	Insecta	Diptera	Simuliidae	*Simulium*	
Thompson Creek	11/02/2005	Arthropoda	Insecta	Diptera	Tipulidae	*Tipula*	
Thompson Creek	11/02/2005	Arthropoda	Insecta	Ephemeroptera	Baetidae	*Fallceon*	*quilleri*
Thompson Creek	11/02/2005	Arthropoda	Insecta	Ephemeroptera	Baetidae	*Plauditus*	
Thompson Creek	11/02/2005	Arthropoda	Insecta	Ephemeroptera	Heptageniidae	*Heptagenia*	
Thompson Creek	11/02/2005	Arthropoda	Insecta	Ephemeroptera	Isonychiidae	*Isonychia*	
Thompson Creek	11/02/2005	Arthropoda	Insecta	Ephemeroptera	Leptohyphidae	*Tricorythodes*	
Thompson Creek	11/02/2005	Arthropoda	Insecta	Hemiptera	Corixidae	*Sigara*	
Thompson Creek	11/02/2005	Arthropoda	Insecta	Hemiptera	Corixidae	*Trichocorixa*	
Thompson Creek	11/02/2005	Arthropoda	Insecta	Odonata	Calopterygidae	*Hetaerina*	*americana*
Thompson Creek	11/02/2005	Arthropoda	Insecta	Odonata	Coenagrionidae	*Argia*	
Thompson Creek	11/02/2005	Arthropoda	Insecta	Odonata	Gomphidae	*Erpetogomphus*	*designatus*
Thompson Creek	11/02/2005	Arthropoda	Insecta	Odonata	Libellulidae	*Libellula*	
Thompson Creek	11/02/2005	Arthropoda	Insecta	Plecoptera	Perlidae	*Perlesta*	
Thompson Creek	11/02/2005	Arthropoda	Insecta	Plecoptera	Taeniopterygidae	*Taeniopteryx*	*burksi*

Appendix C. Taxonomic data from biological samples for the six heritage streams (2000-2012) (continued).

Stream Name	Date	Phylum	Class	Order	Family	Genus	Specific Epithet
Thompson Creek	11/02/2005	Arthropoda	Insecta	Trichoptera	Helicopsychidae	*Helicopsyche*	*borealis*
Thompson Creek	11/02/2005	Arthropoda	Insecta	Trichoptera	Hydropsychidae	*Cheumatopsyche*	
Thompson Creek	11/02/2005	Arthropoda	Insecta	Trichoptera	Hydropsychidae	*Hydropsyche*	*simulans*
Thompson Creek	11/02/2005	Arthropoda	Malacostraca	Amphipoda	Hyallelidae	*Hyalella*	*azteca*
Thompson Creek	11/02/2005	Mollusca	Bivalvia	Heterodontida	Pisidiidae	*Pisidium*	
Thompson Creek	11/02/2005	Mollusca	Gastropoda	Basommatophora	Physidae	*Physella*	
Thompson Creek	11/02/2005	Platyhelminthes	Turbellaria	Tricladida	Planariidae	*Dugesia*	
Thompson Creek	07/12/2006	Annelida	Clitellata	Arhynchobdellid	Erpobdellidae		
Thompson Creek	07/12/2006	Arthropoda	Insecta	Coleoptera	Elmidae	*Macronychus*	*glabratus*
Thompson Creek	07/12/2006	Arthropoda	Insecta	Coleoptera	Elmidae	*Microcylloepus*	*pusillus*
Thompson Creek	07/12/2006	Arthropoda	Insecta	Coleoptera	Haliplidae	*Peltodytes*	*litoralis*
Thompson Creek	07/12/2006	Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Anacaena*	
Thompson Creek	07/12/2006	Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Tropisternus*	
Thompson Creek	07/12/2006	Arthropoda	Insecta	Coleoptera	Hydrophilidae		
Thompson Creek	07/12/2006	Arthropoda	Insecta	Diptera	Chironomidae	*Endochironomus*	
Thompson Creek	07/12/2006	Arthropoda	Insecta	Diptera	Chironomidae	*Microtendipes*	
Thompson Creek	07/12/2006	Arthropoda	Insecta	Diptera	Chironomidae	*Pentaneura*	
Thompson Creek	07/12/2006	Arthropoda	Insecta	Diptera	Chironomidae	*Polypedilum*	
Thompson Creek	07/12/2006	Arthropoda	Insecta	Diptera	Chironomidae	*Rheotanytarsus*	
Thompson Creek	07/12/2006	Arthropoda	Insecta	Diptera	Chironomidae	*Thienemannimyia*	
Thompson Creek	07/12/2006	Arthropoda	Insecta	Diptera	Chironomidae		
Thompson Creek	07/12/2006	Arthropoda	Insecta	Diptera	Simuliidae	*Simulium*	
Thompson Creek	07/12/2006	Arthropoda	Insecta	Diptera	Stratiomyidae	*Odontomyia*	
Thompson Creek	07/12/2006	Arthropoda	Insecta	Diptera	Stratiomyidae	*Stratiomys*	
Thompson Creek	07/12/2006	Arthropoda	Insecta	Diptera	Tabanidae	*Chrysops*	
Thompson Creek	07/12/2006	Arthropoda	Insecta	Diptera	Tabanidae		
Thompson Creek	07/12/2006	Arthropoda	Insecta	Diptera	Tipulidae	*Tipula*	
Thompson Creek	07/12/2006	Arthropoda	Insecta	Ephemeroptera	Baetidae	*Fallceon*	*quilleri*
Thompson Creek	07/12/2006	Arthropoda	Insecta	Ephemeroptera	Baetidae	*Plauditus*	
Thompson Creek	07/12/2006	Arthropoda	Insecta	Ephemeroptera	Baetidae	*Pseudocloeon*	
Thompson Creek	07/12/2006	Arthropoda	Insecta	Ephemeroptera	Baetidae		
Thompson Creek	07/12/2006	Arthropoda	Insecta	Ephemeroptera	Caenidae	*Caenis*	
Thompson Creek	07/12/2006	Arthropoda	Insecta	Ephemeroptera	Heptageniidae	*Heptagenia*	*elegantula*

Appendix C. Taxonomic data from biological samples for the six heritage streams (2000-2012) (continued).

Stream Name	Date	Phylum	Class	Order	Family	Genus	Specific Epithet
Thompson Creek	07/12/2006	Arthropoda	Insecta	Ephemeroptera	Isonychiidae	*Isonychia*	
Thompson Creek	07/12/2006	Arthropoda	Insecta	Ephemeroptera	Leptohyphidae	*Tricorythodes*	
Thompson Creek	07/12/2006	Arthropoda	Insecta	Ephemeroptera	Polymitarcyidae	*Ephoron*	*album*
Thompson Creek	07/12/2006	Arthropoda	Insecta	Hemiptera	Corixidae	*Corisella*	
Thompson Creek	07/12/2006	Arthropoda	Insecta	Hemiptera	Corixidae	*Trichocorixa*	
Thompson Creek	07/12/2006	Arthropoda	Insecta	Hemiptera	Veliidae	*Rhagovelia*	
Thompson Creek	07/12/2006	Arthropoda	Insecta	Odonata	Aeshnidae	*Aeshna*	*umbrosa*
Thompson Creek	07/12/2006	Arthropoda	Insecta	Odonata	Calopterygidae	*Hetaerina*	*americana*
Thompson Creek	07/12/2006	Arthropoda	Insecta	Odonata	Coenagrionidae	*Argia*	
Thompson Creek	07/12/2006	Arthropoda	Insecta	Odonata	Gomphidae	*Erpetogomphus*	*designatus*
Thompson Creek	07/12/2006	Arthropoda	Insecta	Odonata	Gomphidae	*Gomphus*	*externus*
Thompson Creek	07/12/2006	Arthropoda	Insecta	Odonata	Gomphidae		
Thompson Creek	07/12/2006	Arthropoda	Insecta	Plecoptera	Perlidae	*Perlesta*	
Thompson Creek	07/12/2006	Arthropoda	Insecta	Plecoptera	Perlidae		
Thompson Creek	07/12/2006	Arthropoda	Insecta	Trichoptera	Helicopsychidae	*Helicopsyche*	
Thompson Creek	07/12/2006	Arthropoda	Insecta	Trichoptera	Helicopsychidae	*Helicopsyche*	*borealis*
Thompson Creek	07/12/2006	Arthropoda	Insecta	Trichoptera	Hydropsychidae	*Cheumatopsyche*	
Thompson Creek	07/12/2006	Arthropoda	Insecta	Trichoptera	Hydropsychidae	*Hydropsyche*	*simulans*
Thompson Creek	07/12/2006	Arthropoda	Insecta	Trichoptera	Hydropsychidae		
Thompson Creek	07/12/2006	Arthropoda	Insecta	Trichoptera	Leptoceridae	*Nectopsyche*	*diarina*
Thompson Creek	07/12/2006	Arthropoda	Malacostraca	Amphipoda	Hyallelidae	*Hyalella*	*azteca*
Thompson Creek	07/12/2006	Arthropoda	Malacostraca	Decopoda	Cambaridae	*Orconectes*	*virilis*
Thompson Creek	07/12/2006	Mollusca	Bivalvia	Heterodontida	Pisidiidae	*Pisidium*	
Thompson Creek	07/12/2006	Mollusca	Gastropoda	Basommatophora	Lymnaeidae	*Stagnicola*	
Thompson Creek	07/12/2006	Platyhelminthes	Turbellaria	Tricladida	Planariidae	*Dugesia*	
Thompson Creek	05/12/2008	Annelida	Clitellata	Arhynchobdellid	Erpobdellidae	*Erpobdella*	
Thompson Creek	05/12/2008	Annelida	Clitellata	Branchiobdellid	Branchiobdellidae	*Cambarincola*	
Thompson Creek	05/12/2008	Arthropoda	Insecta	Coleoptera	Elmidae	*Dubiraphia*	
Thompson Creek	05/12/2008	Arthropoda	Insecta	Coleoptera	Elmidae	*Macronychus*	*glabratus*
Thompson Creek	05/12/2008	Arthropoda	Insecta	Coleoptera	Elmidae	*Microcylloepus*	*pusillus*
Thompson Creek	05/12/2008	Arthropoda	Insecta	Diptera	Chironomidae	*Eukiefferiella*	
Thompson Creek	05/12/2008	Arthropoda	Insecta	Diptera	Chironomidae	*Paratendipes*	
Thompson Creek	05/12/2008	Arthropoda	Insecta	Diptera	Chironomidae	*Stictochironomus*	

Appendix C. Taxonomic data from biological samples for the six heritage streams (2000-2012) (continued).

Stream Name	Date	Phylum	Class	Order	Family	Genus	Specific Epithet
Thompson Creek	05/12/2008	Arthropoda	Insecta	Diptera	Stratiomyidae	*Stratiomys*	
Thompson Creek	05/12/2008	Arthropoda	Insecta	Diptera	Tabanidae		
Thompson Creek	05/12/2008	Arthropoda	Insecta	Ephemeroptera	Baetidae	*Fallceon*	*quilleri*
Thompson Creek	05/12/2008	Arthropoda	Insecta	Ephemeroptera	Baetidae	*Plauditus*	
Thompson Creek	05/12/2008	Arthropoda	Insecta	Ephemeroptera	Baetidae	*Pseudocloeon*	
Thompson Creek	05/12/2008	Arthropoda	Insecta	Ephemeroptera	Heptageniidae	*Heptagenia*	*elegantula*
Thompson Creek	05/12/2008	Arthropoda	Insecta	Ephemeroptera	Heptageniidae		
Thompson Creek	05/12/2008	Arthropoda	Insecta	Ephemeroptera	Isonychiidae	*Isonychia*	
Thompson Creek	05/12/2008	Arthropoda	Insecta	Ephemeroptera	Leptohyphidae	*Tricorythodes*	
Thompson Creek	05/12/2008	Arthropoda	Insecta	Hemiptera	Corixidae	*Palmacorixa*	
Thompson Creek	05/12/2008	Arthropoda	Insecta	Hemiptera	Corixidae	*Sigara*	
Thompson Creek	05/12/2008	Arthropoda	Insecta	Odonata	Calopterygidae	*Calopteryx*	*maculata*
Thompson Creek	05/12/2008	Arthropoda	Insecta	Odonata	Calopterygidae	*Hetaerina*	
Thompson Creek	05/12/2008	Arthropoda	Insecta	Odonata	Calopterygidae	*Hetaerina*	*americana*
Thompson Creek	05/12/2008	Arthropoda	Insecta	Odonata	Coenagrionidae	*Argia*	
Thompson Creek	05/12/2008	Arthropoda	Insecta	Odonata	Gomphidae	*Erpetogomphus*	*designatus*
Thompson Creek	05/12/2008	Arthropoda	Insecta	Odonata	Gomphidae	*Gomphus*	*externus*
Thompson Creek	05/12/2008	Arthropoda	Insecta	Odonata	Gomphidae		
Thompson Creek	05/12/2008	Arthropoda	Insecta	Odonata	Libellulidae		
Thompson Creek	05/12/2008	Arthropoda	Insecta	Plecoptera	Perlidae	*Perlesta*	
Thompson Creek	05/12/2008	Arthropoda	Insecta	Plecoptera	Perlidae		
Thompson Creek	05/12/2008	Arthropoda	Insecta	Trichoptera	Helicopsychidae	*Helicopsyche*	*borealis*
Thompson Creek	05/12/2008	Arthropoda	Insecta	Trichoptera	Hydropsychidae	*Cheumatopsyche*	
Thompson Creek	05/12/2008	Arthropoda	Insecta	Trichoptera	Hydropsychidae	*Hydropsyche*	*simulans*
Thompson Creek	05/12/2008	Arthropoda	Insecta	Trichoptera	Leptoceridae	*Nectopsyche*	*diarina*
Thompson Creek	05/12/2008	Arthropoda	Malacostraca	Amphipoda	Hyallelidae	*Hyalella*	*azteca*
Thompson Creek	05/12/2008	Arthropoda	Malacostraca	Decopoda	Cambaridae	*Orconectes*	
Thompson Creek	05/12/2008	Mollusca	Bivalvia	Heterodontida	Pisidiidae	*Pisidium*	
Thompson Creek	05/12/2008	Mollusca	Gastropoda	Basommatophora	Physidae	*Physella*	
Thompson Creek	05/12/2008	Platyhelminthes	Turbellaria	Tricladida	Planariidae	*Dugesia*	
Thompson Creek	05/19/2010	Arthropoda	Insecta	Coleoptera	Dryopidae	*Helichus*	
Thompson Creek	05/19/2010	Arthropoda	Insecta	Coleoptera	Elmidae	*Dubiraphia*	*minima*
Thompson Creek	05/19/2010	Arthropoda	Insecta	Coleoptera	Elmidae	*Heterelmis*	*vulnerata*

Appendix C. Taxonomic data from biological samples for the six heritage streams (2000-2012) (continued).

Stream Name	Date	Phylum	Class	Order	Family	Genus	Specific Epithet
Thompson Creek	05/19/2010	Arthropoda	Insecta	Coleoptera	Elmidae	*Microcylloepus*	
Thompson Creek	05/19/2010	Arthropoda	Insecta	Diptera	Chironomidae	*Brillia*	
Thompson Creek	05/19/2010	Arthropoda	Insecta	Diptera	Chironomidae	*Stictochironomus*	
Thompson Creek	05/19/2010	Arthropoda	Insecta	Diptera	Chironomidae	*Zavrelimyia*	
Thompson Creek	05/19/2010	Arthropoda	Insecta	Diptera	Tipulidae		
Thompson Creek	05/19/2010	Arthropoda	Insecta	Ephemeroptera	Baetidae	*Plauditus*	
Thompson Creek	05/19/2010	Arthropoda	Insecta	Ephemeroptera	Heptageniidae	*Heptagenia*	
Thompson Creek	05/19/2010	Arthropoda	Insecta	Ephemeroptera	Heptageniidae		
Thompson Creek	05/19/2010	Arthropoda	Insecta	Ephemeroptera	Isonychiidae	*Isonychia*	
Thompson Creek	05/19/2010	Arthropoda	Insecta	Ephemeroptera	Leptohyphidae	*Tricorythodes*	
Thompson Creek	05/19/2010	Arthropoda	Insecta	Odonata	Calopterygidae	*Calopteryx*	*maculata*
Thompson Creek	05/19/2010	Arthropoda	Insecta	Odonata	Gomphidae	*Erpetogomphus*	*designatus*
Thompson Creek	05/19/2010	Arthropoda	Insecta	Odonata	Gomphidae	*Gomphus*	
Thompson Creek	05/19/2010	Arthropoda	Insecta	Plecoptera	Perlidae	*Perlesta*	
Thompson Creek	05/19/2010	Arthropoda	Insecta	Trichoptera	Hydropsychidae	*Cheumatopsyche*	
Thompson Creek	05/19/2010	Arthropoda	Insecta	Trichoptera	Hydropsychidae	*Hydropsyche*	*simulans*
Thompson Creek	05/19/2010	Arthropoda	Insecta	Trichoptera	Hydropsychidae		
Thompson Creek	05/19/2010	Arthropoda	Insecta	Trichoptera	Leptoceridae		
Thompson Creek	05/19/2010	Arthropoda	Malacostraca	Decopoda	Cambaridae		
Thompson Creek	05/19/2010	Mollusca	Gastropoda	Basommatophora	Lymnaeidae	*Fossaria*	
Thompson Creek	08/01/2011	Annelida	Clitellata	Rhynchobdellida	Glossiphoniidae		
Thompson Creek	08/01/2011	Arthropoda	Insecta	Coleoptera	Dytiscidae	*Uvarus*	
Thompson Creek	08/01/2011	Arthropoda	Insecta	Coleoptera	Elmidae	*Dubiraphia*	
Thompson Creek	08/01/2011	Arthropoda	Insecta	Coleoptera	Elmidae	*Heterelmis*	*vulnerata*
Thompson Creek	08/01/2011	Arthropoda	Insecta	Coleoptera	Elmidae	*Microcylloepus*	*pusillus*
Thompson Creek	08/01/2011	Arthropoda	Insecta	Coleoptera	Elmidae	*Stenelmis*	
Thompson Creek	08/01/2011	Arthropoda	Insecta	Diptera	Chironomidae	*Polypedilum*	
Thompson Creek	08/01/2011	Arthropoda	Insecta	Diptera	Chironomidae		
Thompson Creek	08/01/2011	Arthropoda	Insecta	Ephemeroptera	Baetidae	*Fallceon*	*quilleri*
Thompson Creek	08/01/2011	Arthropoda	Insecta	Ephemeroptera	Baetidae	*Pseudocloeon*	
Thompson Creek	08/01/2011	Arthropoda	Insecta	Ephemeroptera	Heptageniidae	*Heptagenia*	*elegantula*
Thompson Creek	08/01/2011	Arthropoda	Insecta	Ephemeroptera	Isonychiidae	*Isonychia*	
Thompson Creek	08/01/2011	Arthropoda	Insecta	Ephemeroptera	Leptohyphidae	*Tricorythodes*	

Appendix C. Taxonomic data from biological samples for the six heritage streams (2000-2012) (continued).

Stream Name	Date	Phylum	Class	Order	Family	Genus	Specific Epithet
Thompson Creek	08/01/2011	Arthropoda	Insecta	Hemiptera	Veliidae	*Rhagovelia*	
Thompson Creek	08/01/2011	Arthropoda	Insecta	Odonata	Calopterygidae	*Hetaerina*	*americana*
Thompson Creek	08/01/2011	Arthropoda	Insecta	Odonata	Coenagrionidae	*Argia*	
Thompson Creek	08/01/2011	Arthropoda	Insecta	Odonata	Gomphidae	*Erpetogomphus*	*designatus*
Thompson Creek	08/01/2011	Arthropoda	Insecta	Trichoptera	Hydropsychidae	*Cheumatopsyche*	
Thompson Creek	08/01/2011	Arthropoda	Insecta	Trichoptera	Hydropsychidae	*Hydropsyche*	*simulans*
Thompson Creek	08/01/2011	Arthropoda	Insecta	Trichoptera	Hydropsychidae	*Potamyia*	*flava*
Thompson Creek	08/01/2011	Arthropoda	Insecta	Trichoptera	Hydropsychidae		
Thompson Creek	08/01/2011	Arthropoda	Insecta	Trichoptera	Leptoceridae	*Nectopsyche*	*diarina*
Thompson Creek	08/01/2011	Arthropoda	Malacostraca	Decopoda	Cambaridae	*Orconectes*	

Appendix D. Water quality monitoring data for the six heritage streams (2002-2012).

Stream Name	Date	Atrazine µg/L	MQL	Copper µg/L	MQL	Lead µg/L	MQL	Nitrate mg/L	MQL	Nitrite mg/L	MQL	TKN mg/L	MQL	TN mg/L	MQL	TP mg/L	MQL	TSS mg/L	MQL	Zinc µg/L	MQL	*E.coli* MPN/100	MQL
Fourmile Cr.	01/23/2003			3.5		1.0	<	0.1	<	0.05	<	0.20		0.25		0.06		10	<	10.0			
Fourmile Cr.	03/13/2003	0.3	<	1.6		1.0	<	0.1	<	0.05	<	0.35		0.40		0.05		10	<	5.0	<		
Fourmile Cr.	05/29/2003			2.3		1.0	<	0.1	<	0.05	<	0.39		0.44		0.08		23		6.0			
Fourmile Cr.	07/17/2003	0.3	<	2.1		1.0	<	0.1	<	0.05	<	0.37		0.42		0.09		18		7.0		20	
Fourmile Cr.	09/18/2003			2.4		1.0	<	0.28		0.05	<	0.24		0.52		0.07		14		5.0	<	181	
Fourmile Cr.	11/13/2003	0.3	<	1.6		1.0	<	0.1	<	0.05	<	0.10	<	0.10	<	0.08		10	<	28.0		63	
Fourmile Cr.	01/18/2007			1.2		1.0	<	1.63		0.05	<	0.27		1.90		0.02	<	18		5.0	<	10	<
Fourmile Cr.	03/15/2007	0.3	<	3.0		1.0	<	0.1	<	0.05	<	0.61		0.66		0.09		10		5.0		10	
Fourmile Cr.	05/03/2007			2.7		1.0	<	0.1	<	0.05	<	0.50		0.55		0.07		11		5.0	<	173	
Fourmile Cr.	07/19/2007	0.3	<	3.5		1.5		0.1	<	0.05	<	0.34		0.39		0.08		12		8.0		146	
Fourmile Cr.	09/06/2007			1.6		1.0	<	0.1	<	0.05	<	0.22		0.27		0.07		11		6.0		75	
Fourmile Cr.	11/15/2007	0.3	<	2.8		1.0	<	0.1	<	0.05	<	0.28		0.33		0.1		10	<	5.0		41	
Fourmile Cr.	01/18/2011	0.3	<	1.0	<	1.0	<	0.15		0.05	<	0.23		0.38		0.06		10	<	5.0	<	20	
Fourmile Cr.	04/11/2011	0.3	<	3.4		2.3		0.37		0.09		0.77		1.23		0.18		92		11.5		3076	
Fourmile Cr.	07/05/2011	0.92		2.1		1.0	<	0.13		0.05	<	0.38		0.51		0.1		15		5.0	<	10	
Fourmile Cr.	02/15/2012	0.3	<	1.6		1.0	<	0.37		0.05	<	0.18		0.55		0.05		10	<	5.0	<	20	
Fourmile Cr.	05/01/2012	0.3	<	2.3		1.0	<	0.1	<	0.05	<	0.32		0.37		0.1		21		5.0	<	269	
Grouse Cr.	03/01/2011	0.3	<	1.9		1.0	<	0.48		0.05	<	0.25		0.73		0.03		10		5.0	<	341	
Grouse Cr.	06/01/2011	0.3	<	1.3		1.0	<	0.1	<	0.08		0.31		0.44		0.04		22		5.0	<	20	
Grouse Cr.	09/07/2011	0.3	<	2.7		1.3		0.1	<	0.05	<	0.79		0.84		0.08		19		5.0	<	10	<
Grouse Cr.	10/10/2011			3.9		1.0	<	0.62		0.2		2.01		2.83		0.09		10	<	5.0	<	197	
Grouse Cr.	02/28/2012	0.3	<	1.6		1.0	<	0.1	<	0.05	<	0.32		0.37		0.03		10	<	5.0	<	52	
Grouse Cr.	05/22/2012	0.3	<	1.5		1.0	<	0.1	<	0.05	<	0.23		0.28		0.12		10	<	5.0	<	148	

Trace metal = Total recoverable; TKN = Total Kjeldahl nitrogen; TN = Total nitrogen (calculated); TP = Total phosphorus (as P); TSS = Total suspended solids; MPN/100 = Most probable number / 100 mL; MQL = Minimum quantification limit

Appendix D. Water quality monitoring data for the six heritage streams (2002-2012) (continued).

Stream Name	Date	Atrazine µg/L	MQL	Copper µg/L	MQL	Lead µg/L	MQL	Nitrate mg/L	MQL	Nitrite mg/L	MQL	TKN mg/L	MQL	TN mg/L	MQL	TP mg/L	MQL	TSS mg/L	MQL	Zinc µg/L	MQL	*E.coli* MPN/100	MQL
Illinois Cr.	02/14/2002			1.7		1.0	<	0.07		0.05	<	0.18		0.25		0.02		2		7.0			
Illinois Cr.	04/11/2002	0.3	<	1.7		1.0	<	0.1	<	0.05	<	0.10	<	0.10	<	0.04		10	<	7.0			
Illinois Cr.	06/13/2002			1.2		1.0	<	0.15		0.05	<	0.10	<	0.20		0.03		10	<	7.0			
Illinois Cr.	08/15/2002	0.3	<	1.3		1.0	<	0.1	<	0.05	<	0.27		0.32		0.02		10	<	5.0	<		
Illinois Cr.	10/17/2002			2.6		1.0	<	0.1	<	0.05	<	0.10	<	0.10	<	0.02	<	10	<	13.0			
Illinois Cr.	12/23/2002	0.3	<	5.4		1.0	<	0.1	<	0.05	<	0.10		0.15		0.03		10	<	11.0			
Illinois Cr.	01/23/2003			1.8		1.2		0.1	<	0.05	<	0.10	<	0.10	<	0.02	<	10	<	15.0			
Illinois Cr.	03/13/2003	0.3	<	1.8		1.0	<	0.1	<	0.05	<	0.24		0.29		0.02	<	10	<	5.0	<		
Illinois Cr.	05/29/2003			1.5		1.0	<	0.1	<	0.05	<	0.17		0.22		0.03		10	<	5.0	<		
Illinois Cr.	07/17/2003	0.3	<	2.4		1.0	<	0.1	<	0.05	<	0.12		0.17		0.02	<	10	<	6.0		20	
Illinois Cr.	09/18/2003			1.3		1.0	<	0.1	<	0.05	<	0.13		0.18		0.02		10	<	5.0	<	1119	
Illinois Cr.	11/13/2003	0.3	<	1.0	<	1.0	<	0.1	<	0.05	<	0.10	<	0.10	<	0.02	<	10	<	5.0		31	
Illinois Cr.	02/12/2004	0.3	<	1.7		1.0	<	0.1	<	0.05	<	0.10	<	0.10	<	0.02	<	10	<	6.0		10	
Illinois Cr.	04/15/2004			1.4		1.0	<	0.1	<	0.05	<	0.28		0.33		0.02	<	10	<	5.0		31	
Illinois Cr.	06/17/2004	0.3	<	1.5		1.0	<	0.28		0.05	<	0.26		0.54		0.04		11		6.0		474	
Illinois Cr.	08/12/2004			1.0	<	1.0	<	0.1	<	0.05	<	0.10	<	0.10	<	0.03		10	<	6.0		40	
Illinois Cr.	10/14/2004	0.3	<	2.5		1.0	<	0.1	<	0.05	<	0.82		0.87		0.06		10	<	7.0		10	
Illinois Cr.	12/02/2004			1.0	<	1.0	<	0.1	<	0.05	<	0.10	<	0.10	<	0.08		10	<	5.0	<	31	
Illinois Cr.	01/20/2005			1.2		1.0	<	0.1	<	0.05	<	0.10	<	0.10	<	0.04		10	<	6.0		75	
Illinois Cr.	03/17/2005	0.3	<	1.0		1.0	<	0.1	<	0.05	<	0.10	<	0.10	<	0.02	<	10	<	5.0	<	10	<
Illinois Cr.	05/12/2005			1.0	<	1.0	<	0.1	<	0.05	<	0.10	<	0.10	<	0.02	<	10	<	5.0	<	86	
Illinois Cr.	07/07/2005	0.3	<	1.0	<	1.0	<	0.1	<	0.05	<	0.10	<	0.10	<	0.02	<	10	<	5.0	<	31	
Illinois Cr.	09/08/2005			2.5		1.0	<	0.1	<	0.05	<	0.10	<	0.10	<	0.02	<	10	<	5.0	<	122	
Illinois Cr.	11/03/2005	0.3	<	1.0	<	1.0	<	0.1	<	0.05	<	0.10	<	0.10	<	0.02	<	10	<	5.0	<	368	

Trace metal = Total recoverable; TKN = Total Kjeldahl nitrogen; TN = Total nitrogen (calculated); TP = Total phosphorus (as P); TSS = Total suspended solids; MPN/100 = Most probable number / 100 mL; MQL = Minimum quantification limit

Appendix D. Water quality monitoring data for the six heritage streams (2002-2012) (continued).

Stream Name	Date	Atrazine µg/L	MQL	Copper µg/L	MQL	Lead µg/L	MQL	Nitrate mg/L	MQL	Nitrite mg/L	MQL	TKN mg/L	MQL	TN mg/L	MQL	TP mg/L	MQL	TSS mg/L	MQL	Zinc µg/L	MQL	*E.coli* MPN/100	MQL
Illinois Cr.	02/09/2006	0.3	<	1.0	<	1.0	<	0.1	<	0.05	<	0.10	<	0.10	<	0.02	<	10	<	5.0	<	10	<
Illinois Cr.	04/13/2006			1.8		1.0	<	0.1	<	0.05	<	0.10	<	0.10	<	0.03		10		5.0	<	10	
Illinois Cr.	06/15/2006	0.3	<	1.0	<	1.0	<	0.1	<	0.05	<	0.24		0.29		0.02	<	10	<	5.0	<	52	
Illinois Cr.	08/17/2006			1.0	<	1.0	<	0.1	<	0.05	<	0.38		0.43		0.02		10	<	5.0	<	31	
Illinois Cr.	10/12/2006	0.3	<	1.0	<	1.0	<	0.1	<	0.05	<	0.10	<	0.10	<	0.02	<	10	<	5.0	<	86	
Illinois Cr.	12/05/2006			1.0	<	1.0	<	0.1	<	0.05	<	0.21		0.26		0.02	<	10	<	9.0		20	
Illinois Cr.	01/18/2007	0.3	<	1.0	<	1.0	<	0.1	<	0.05	<	0.24		0.29		0.02	<	10	<	5.0	<	10	<
Illinois Cr.	03/15/2007			1.1		1.0	<	0.1	<	0.05	<	0.29		0.34		0.02		10	<	5.0	<	10	<
Illinois Cr.	05/03/2007	0.3	<	2.8		1.6		0.1	<	0.05	<	0.46		0.51		0.04		14		6.0		565	
Illinois Cr.	07/19/2007			1.4		1.1		0.1	<	0.05	<	0.11		0.16		0.02	<	10	<	7.0		122	
Illinois Cr.	09/06/2007	0.3	<	6.7		1.0	<	0.1	<	0.05	<	0.10	<	0.10	<	0.02	<	10	<	5.0	<	98	
Illinois Cr.	02/12/2008			1.0		1.0	<	0.1	<	0.05	<	0.13		0.18		0.02	<	10	<	6.0		10	<
Illinois Cr.	04/15/2008	0.3	<	1.3		1.0	<	0.1	<	0.05	<	0.18		0.23		0.02	<	10	<	5.0	<	20	
Illinois Cr.	06/10/2008			1.0	<	1.0	<	0.1	<	0.05	<	0.15		0.20		0.02		10	<	5.0	<	20	
Illinois Cr.	08/12/2008	0.3	<	1.0	<	1.0	<	0.1	<	0.05	<	0.16		0.21		0.04		10		5.0	<	119	
Illinois Cr.	10/14/2008			1.0	<	1.0	<	0.1	<	0.05	<	0.21		0.26		0.04		13		5.0	<	1439	
Illinois Cr.	01/20/2009	0.3	<	1.0	<	1.0	<	0.1	<	0.05	<	0.10	<	0.10	<	0.02	<	10	<	5.0	<	10	
Illinois Cr.	03/10/2009			1.0	<	1.0	<	0.1	<	0.05	<	0.10	<	0.10	<	0.04		10	<	5.0	<	31	
Illinois Cr.	05/26/2009	0.3	<	1.0	<	1.0	<	0.17		0.05	<	0.10	<	0.22		0.02	<	10	<	5.0	<	199	
Illinois Cr.	09/08/2009	0.3	<	1.0	<	1.0	<	0.35		0.05	<	0.10	<	0.40		0.04		10	<	5.0	<	393	
Illinois Cr.	03/10/2010			1.4		1.0	<	0.15		0.05	<	0.52		0.67		0.08		14		6.0		288	
Illinois Cr.	06/21/2010	0.3	<	1.0	<	1.0	<	0.46		0.05	<	0.65		1.11		0.05		10	<	5.0	<	63	
Illinois Cr.	09/08/2010			1.0	<	1.0	<	0.43		0.05	<	0.10	<	0.48		0.03		10	<	5.0	<	31	
Illinois Cr.	01/18/2011			1.0	<	1.0	<	0.18		0.05	<	0.10	<	0.23		0.02		10	<	5.0	<	10	<

Trace metal = Total recoverable; TKN = Total Kjeldahl nitrogen; TN = Total nitrogen (calculated); TP = Total phosphorus (as P); TSS = Total suspended solids; MPN/100 = Most probable number / 100 mL; MQL = Minimum quantification limit

Appendix D. Water quality monitoring data for the six heritage streams (2002-2012) (continued).

		Atrazine		Copper		Lead		Nitrate		Nitrite		TKN		TN		TP		TSS		Zinc		*E.coli*	
Stream Name	Date	µg/L	MQL	µg/L	MQL	µg/L	MQL	mg/L	MQL	mg/L	MQL	mg/L	MQL	mg/L	MQL	mg/L	MQL	mg/L	MQL	µg/L	MQL	MPN/100	MQL
Illinois Cr.	04/11/2011	0.3	<	1.0	<	1.0	<	0.1	<	0.05	<	0.19		0.24		0.02	<	10	<	5.0	<	41	
Illinois Cr.	07/05/2011			1.0	<	1.0	<	0.33		0.05	<	0.10		0.43		0.02		10	<	5.0	<	63	
Nescatunga Cr.	01/13/2004			1.0		1.1		0.45		0.05	<	0.10	<	0.50		0.02		11		5.0	<	521	
Nescatunga Cr.	03/09/2004	0.3	<	2.1		1.0	<	0.32		0.05	<	0.45		0.77		0.03		30		7.0		73	
Nescatunga Cr.	05/11/2004			1.0	<	1.0	<	0.1	<	0.05	<	0.31		0.36		0.02	<	10	<	5.0		657	
Nescatunga Cr.	07/13/2004	0.3	<	4.0		1.0	<	0.1	<	0.05	<	0.28		0.33		0.04		32		9.0		108	
Nescatunga Cr.	09/14/2004			3.9		1.0	<	0.1	<	0.05	<	0.22		0.27		0.04		10	<	8.0		98	
Nescatunga Cr.	11/09/2004	0.3	<	3.2		1.0	<	0.1	<	0.05	<	0.22		0.27		0.03		10	<	7.0		85	
Nescatunga Cr.	01/15/2008	0.3	<	1.4				0.21		0.05	<	0.22		0.43		0.02	<	10		5.0	<	63	
Nescatunga Cr.	03/11/2008			1.6		1.0	<	0.1	<	0.05	<	0.33		0.38		0.02		11		5.0		110	
Nescatunga Cr.	05/13/2008	0.3	<	3.1		1.0	<	0.1	<	0.05	<	0.43		0.48		0.04		18		6.0		169	
Nescatunga Cr.	07/15/2008			1.2		1.0	<	0.1	<	0.05	<	0.24		0.29		0.05		36		6.0		309	
Nescatunga Cr.	09/09/2008	0.3	<	2.2		7.2		0.1	<	0.05	<	0.48		0.53		0.03		11		5.0	<	229	
Nescatunga Cr.	11/04/2008			1.0		1.0	<	0.1	<	0.05	<	0.22		0.27		0.02		10	<	5.0	<	41	
Nescatunga Cr.	03/01/2010	0.3	<	4.6		1.0	<	0.2		0.05	<	0.20		0.40		0.02	<	10	<	6.0		10	<
Nescatunga Cr.	06/07/2010	0.3	<	2.4		1.3		0.39		0.05	<	0.56		0.95		0.12		98		6.0		2382	
Nescatunga Cr.	08/30/2010	0.3	<	1.1		1.0	<	0.51		0.05	<	0.23		0.74		0.03		11		5.0	<	96	
Nescatunga Cr.	11/29/2010	0.3	<	1.2		1.0	<	0.46		0.05	<	0.11		0.57		0.03		13		5.0	<	31	
Nescatunga Cr.	05/08/2012			1.0	<	1.0	<	0.16		0.05	<	0.28		0.44		0.02	<	10	<	5.0	<	462	
Sevenmile Cr.	02/07/2011	0.3	<	1.0	<	1.0	<	0.1	<	0.05	<	0.16		0.21		0.09		10	<	5.0	<	10	<
Sevenmile Cr.	05/23/2011	0.3	<	1.3		1.0	<	0.1	<	0.05	<	0.32		0.37		0.15		24		5.0	<	63	
Sevenmile Cr.	08/08/2011	0.3	<	2.5		1.0	<	0.39		0.05	<	0.62		1.01		0.2		23		5.0	<	904	
Sevenmile Cr.	11/28/2011	0.3	<	1.8		1.0	<	0.1	<	0.05	<	0.22		0.27		0.13		10	<	5.0	<	169	
Sevenmile Cr.	03/06/2012	0.3	<	1.4		1.0	<	0.1	<	0.05	<	0.24		0.29		0.1		10	<	5.0	<	10	

Trace metal = Total recoverable; TKN = Total Kjeldahl nitrogen; TN = Total nitrogen (calculated); TP = Total phosphorus (as P); TSS = Total suspended solids; MPN/100 = Most probable number / 100 mL; MQL = Minimum quantification limit

Appendix D. Water quality monitoring data for the six heritage streams (2002-2012) (continued).

Stream Name	Date	Atrazine µg/L	MQL	Copper µg/L	MQL	Lead µg/L	MQL	Nitrate mg/L	MQL	Nitrite mg/L	MQL	TKN mg/L	MQL	TN mg/L	MQL	TP mg/L	MQL	TSS mg/L	MQL	Zinc µg/L	MQL	*E.coli* MPN/100	MQL
Sevenmile Cr.	06/19/2012			1.5		1.0	<	0.1	<	0.09		0.55		0.69		0.27		15		5.0	<	109	
Thompson Cr.	01/16/2002			1.0	<	1.0	<	2.43		0.05	<	0.27		2.70		0.03		3		5.0	<		
Thompson Cr.	03/12/2002	0.3	<	1.0		1.0	<	2.28		0.05	<	0.17		2.45		0.03		10		16.0			
Thompson Cr.	05/14/2002			2.6		1.0	<	1.98		0.05	<	0.10	<	2.03		0.03		10	<	7.0			
Thompson Cr.	07/16/2002	0.3	<	1.4		1.0	<	2.22		0.05	<	0.31		2.53		0.05		23		5.0	<		
Thompson Cr.	09/10/2002			1.4		1.0	<	2.56		0.05	<	0.41		2.97		0.03		13		12.0			
Thompson Cr.	11/05/2002	0.3	<	1.0	<	1.0	<	2.37		0.05	<	0.10		2.47		0.03		10	<	7.0			
Thompson Cr.	02/11/2003			1.2		1.0	<	2.34		0.05	<	0.13		2.47		0.04		19		5.0	<		
Thompson Cr.	04/08/2003	0.3	<	1.0	<	1.0	<	2.11		0.05	<	0.10	<	2.16		0.02	<	10	<	6.0			
Thompson Cr.	06/10/2003			1.7		1.0	<	2.15		0.05	<	0.49		2.64		0.05		27		5.0			
Thompson Cr.	08/12/2003	0.3	<	1.4		1.0	<	2.24		0.05	<	0.38		2.62		0.04		24		5.5		184	
Thompson Cr.	10/14/2003			1.0	<	1.0	<	2.22		0.05	<	0.10	<	2.27		0.03		10	<	5.0		75	
Thompson Cr.	01/13/2004			1.0		1.0	<	2.44		0.05	<	0.10	<	2.49		0.02		15		5.0	<	10	<
Thompson Cr.	03/09/2004	0.3	<	1.2		1.0	<	2.21		0.05	<	0.38		2.59		0.02		18		6.0		31	
Thompson Cr.	05/11/2004			1.0	<	1.0	<	1.97		0.05	<	0.12		2.09		0.04		12		5.0	<	86	
Thompson Cr.	07/13/2004	0.3	<	1.0		1.0	<	2.02		0.05	<	0.33		2.35		0.04		15		6.0		272	
Thompson Cr.	09/14/2004			1.0	<	1.0	<	1.25		0.33		0.30		1.88		0.04		10		5.0		75	
Thompson Cr.	11/09/2004	0.3	<	1.4		1.0	<	1.93		0.05	<	0.14		2.07		0.03		10		5.0	<	98	
Thompson Cr.	04/12/2005	0.3	<	1.0	<	1.0	<	1.77		0.05	<	0.10	<	1.82		0.02	<	10	<	6.0		31	
Thompson Cr.	06/07/2005			1.0		1.0	<	2		0.05	<	0.10	<	2.05		0.04		34		5.0	<	97	
Thompson Cr.	08/09/2005	0.3	<	1.0	<	1.0	<	2.08		0.05	<	0.10	<	2.13		0.03		11		5.0	<	161	
Thompson Cr.	10/11/2005			1.0	<	1.0	<	1.93		0.05	<	0.10	<	1.98		0.02	<	18		5.0	<	563	
Thompson Cr.	12/13/2005	0.3	<	1.0	<	1.0	<	2.37		0.05	<	0.10	<	2.42		0.02	<	19		5.0	<	75	
Thompson Cr.	01/10/2006	0.3	<	1.0	<	1.0	<	2.44		0.05	<	0.10	<	2.49		0.02	<	10		5.0	<	63	

Trace metal = Total recoverable; TKN = Total Kjeldahl nitrogen; TN = Total nitrogen (calculated); TP = Total phosphorus (as P); TSS = Total suspended solids; MPN/100 = Most probable number / 100 mL; MQL = Minimum quantification limit

Appendix D. Water quality monitoring data for the six heritage streams (2002-2012) (continued).

Stream Name	Date	Atrazine µg/L	MQL	Copper µg/L	MQL	Lead µg/L	MQL	Nitrate mg/L	MQL	Nitrite mg/L	MQL	TKN mg/L	MQL	TN mg/L	MQL	TP mg/L	MQL	TSS mg/L	MQL	Zinc µg/L	MQL	*E.coli* MPN/100	MQL
Thompson Cr.	03/14/2006			1.0	<	1.0	<	2.15		0.05	<	0.10	<	2.20		0.02	<	14		5.0	<	31	
Thompson Cr.	05/09/2006	0.3	<	1.0	<	1.0	<	1.4		0.05	<	0.38		1.78		0.05		18		8.0		7701	
Thompson Cr.	07/11/2006			1.5		1.0	<	1.81		0.05	<	0.10	<	1.86		0.03		12		5.0	<	246	
Thompson Cr.	09/12/2006	0.3	<	1.0	<	1.0	<	1.7		0.05	<	0.32		2.02		0.03		10	<	5.0	<	359	
Thompson Cr.	11/07/2006			1.5		1.0	<	1.87		0.05	<	0.10	<	1.92		0.02		10		7.0		85	
Thompson Cr.	04/10/2007			1.1		1.0	<	2.26		0.05	<	0.46		2.72		0.04		19		5.0	<	109	
Thompson Cr.	06/12/2007	0.3	<	1.0	<	1.0	<	2.11		0.05	<	0.34		2.45		0.03		10		5.0	<	146	
Thompson Cr.	08/14/2007			1.2		1.0	<	1.78		0.05	<	0.37		2.15		0.03		14		5.0	<	323	
Thompson Cr.	10/09/2007	0.3	<	1.0		1.0	<	1.95		0.05	<	0.11		2.06		0.02	<	10		6.0		52	
Thompson Cr.	12/04/2007			1.0	<	1.0	<	2.37		0.05	<	0.12		2.49		0.02		10	<	5.0	<	52	
Thompson Cr.	01/15/2008	0.3	<	5.7		1.0	<	2.33		0.05	<	0.15		2.48		0.03		13		5.0		41	
Thompson Cr.	03/11/2008			1.4		1.0	<	1.91		0.05	<	0.29		2.20		0.03		11		5.0	<	31	
Thompson Cr.	05/13/2008	0.3	<	1.0	<	1.0	<	2.35		0.05	<	0.36		2.71		0.03		10		5.0	<	85	
Thompson Cr.	07/15/2008			1.0	<	1.0	<	1.89		0.05	<	0.19		2.08		0.04		23		5.0	<	185	
Thompson Cr.	09/09/2008	0.3	<	1.3		1.1		1.97		0.05	<	0.49		2.46		0.03		13		5.0	<	173	
Thompson Cr.	11/04/2008			1.0	<	1.0	<	1.98		0.05	<	0.17		2.15		0.03		10	<	5.0	<	144	
Thompson Cr.	02/10/2009			1.8		1.0	<	2.15		0.05	<	0.37		2.52		0.04		18		5.0	<	31	
Thompson Cr.	04/14/2009	0.3	<	1.0	<	1.0	<	2.44		0.05	<	0.26		2.70		0.04		11		5.0	<	10	<
Thompson Cr.	06/16/2009			1.0	<	1.0	<	2.45		0.05	<	0.50		2.95		0.04		14		5.0	<	52	
Thompson Cr.	08/11/2009	0.3	<	1.0	<	1.0	<	2.5		0.05	<	0.34		2.84		0.04		10	<	5.0	<	120	
Thompson Cr.	03/02/2010	0.3	<	1.1		1.0	<	2.48		0.05	<	0.16		2.64		0.03		10	<	5.0	<	84	
Thompson Cr.	06/08/2010			1.0	<	1.0	<	2.51		0.09		0.15		2.75		0.03		12		5.0	<	605	
Thompson Cr.	08/31/2010	0.3	<	1.0	<	1.0	<	2.57		0.12		0.36		3.05		0.05		19		5.0	<	739	
Thompson Cr.	11/30/2010			1.1		1.0	<	2.84		0.05	<	0.25		3.09		0.03		10	<	5.0	<	20	

Trace metal = Total recoverable; TKN = Total Kjeldahl nitrogen; TN = Total nitrogen (calculated); TP = Total phosphorus (as P); TSS = Total suspended solids; MPN/100 = Most probable number / 100 mL; MQL = Minimum quantification limit

Appendix D. Water quality monitoring data for the six heritage streams (2002-2012) (continued).

Stream Name	Date	Atrazine µg/L	MQL	Copper µg/L	MQL	Lead µg/L	MQL	Nitrate mg/L	MQL	Nitrite mg/L	MQL	TKN mg/L	MQL	TN mg/L	MQL	TP mg/L	MQL	TSS mg/L	MQL	Zinc µg/L	MQL	*E.coli* MPN/100	MQL
Thompson Cr.	01/03/2011		0.3	<	1.2		1.0	<	3.03		0.05	<	0.65		3.68		0.09		46		5.0	<	158
Thompson Cr.	04/04/2011				1.0	<	1.0	<	2.5		0.05	<	0.38		2.88		0.02	<	19		5.0	<	10
Thompson Cr.	07/11/2011		0.3	<	1.0	<	1.0	<	2.42		0.07		0.28		2.77		0.04		15		5.0	<	496
Thompson Cr.	10/03/2011				1.1		1.0	<	2.49		0.05	<	0.21		2.70		0.02		10	<	14.0		199
Thompson Cr.	02/06/2012				2.3		1.0	<	2.22		0.05	<	0.25		2.47		0.03		10	<	5.0	<	10
Thompson Cr.	05/07/2012		0.3	<	1.5		1.0	<	1.82		0.08		0.17		2.07		0.03		15		5.0	<	86
Thompson Cr.	08/06/2012				1.1		1.0	<	2.3		0.09		0.64		3.03		0.08		29		5.0	<	467

Trace metal = Total recoverable; TKN = Total Kjeldahl nitrogen; TN = Total nitrogen (calculated); TP = Total phosphorus (as P); TSS = Total suspended solids;
MPN/100 = Most probable number / 100 mL; MQL = Minimum quantification limit

Appendix E. Grouse Creek Watershed Total Maximum Daily Load.

LOWER ARKANSAS BASIN TOTAL MAXIMUM DAILY LOAD

Waterbody / Assessment Unit (AU): Grouse Creek Watershed
Water Quality Threats: Total Phosphorus and Total Suspended Solids

1. INTRODUCTION AND PROBLEM IDENTIFICATION

Subbasin: Kaw Lake **Counties:** Elk, Butler and Cowley

HUC8: 11060001
HUC10 (HUC12): 01 (01 and 02) and 02 (01, 02, 03, 04, 05, 06, 07 and 08)

Ecoregion: Flint Hills (28)

Drainage Area: 396 Square Miles above confluence with Otter Creek

Water Quality Limited Segments:

Main Stem	**Tributaries**	
Grouse Creek (15)	Silver Creek (17)	Pebble Cr (26)
		Snake Cr (25)
		Plum Cr (33)
Grouse Creek (16)	Crabb Creek (29)	
	Turkey Creek (27)	
	Bullington Creek (28)	
	School Creek (31)	
	Blue Branch (30)	
	Cedar Creek (32)	
	Goose Creek (34)	
	Gardners Branch (39)	
	Franklin Creek (35)	
	Ferguson Creek (38)	
	Riley Creek (37)	
	Waggoner Creek (36)	

Designated Uses: All streams and segments support Expected Aquatic Life; Grouse Creek segment 15 supports Primary Contact Recreation B; Grouse Creek segment 16, Crabb Creek, Waggoner Creek, Silver Creek and Snake Creek support Primary Contact Recreation C; all other streams support Secondary Contact Recreation b; Grouse Creek segments 15 and 16 support all other designated uses as do Silver Creek, Plum Creek, Crabb Creek, Gardners Branch, and Waggoner Creek; Pebble, Snake, School Creeks and Blue Branch support Food Procurement, Irrigation Use and Livestock Watering; Turkey Creek supports those uses as well as Groundwater Recharge; Cedar Creek supports all designated uses except Food Procurement; Goose Creek supports Irrigation Use and Livestock Watering; Bullington Creek supports those uses plus Groundwater Recharge;

Franklin Creek supports Food Procurement and Livestock Watering; Ferguson and Riley Creeks do not support any designated uses other than Secondary Contact Recreation and Expected Aquatic Life.

303(d) Listings: None for SC531 and SC761 on Grouse Creek; Dissolved Oxygen TMDL at SC706 on Silver Creek since 2000.

Impaired Use: None, protecting designated uses from threats of excessive sediment and phosphorus.

Water Quality Criteria:

Suspended Solids: Suspended solids added to surface waters by artificial sources shall not interfere with the behavior, reproduction, physical habitat, or other factors related to the survival and propagation of aquatic or semiaquatic life or terrestrial wildlife. In the application of this provision, suspended solids associated with discharges of pre-sedimentation sludge from water treatment facilities shall be deemed noninjurious to aquatic and semiaquatic life and terrestrial wildlife, if these discharges comply fully with the requirement of paragraphs (b)(6) and (8) and paragraph (c)(2)(D) of this regulation. (K.A.R. 28-16-28e(c)(2)(B)).

Nutrients: The introduction of plant nutrient into surface waters designated for domestic water supply use shall be controlled to prevent interference with the production of drinking water (K.A.R. 28-16-28e(c)(3)(D)).

The introduction of plant nutrients into streams, lakes, or wetlands from artificial sources shall be controlled to prevent the accelerated succession or replacement of aquatic biota or the production of undesirable quantities or kinds of aquatic life (K.A.R. 28-16-28e(c)(2)(A)).

The introduction of plant nutrients into surface waters designated for primary or secondary contact recreational use shall be controlled to prevent the development of objectionable concentrations of algae or algal by-products or nuisance growths of submersed, floating, or emergent aquatic vegetation (K.A.R. 28-26-28e(c)(7)(A)).

2. CURRENT WATER QUALITY CONDITION AND DESIRED ENDPOINT

Level of Support for Designated Uses under 2012 – 303(d): Fully supporting all designated uses except Expected Aquatic Life on Silver Creek (Dissolved Oxygen).

Stream Monitoring Sites and Period of Record: Active KDHE permanent routine ambient stream chemistry sampling station SC531, located on Grouse Creek ½ mile South of Silverdale; period of record is 1990-2012 (**Figure 1**). Active KDHE rotational ambient stream chemistry sampling station SC706, located on Silver Creek at US-166 Highway bridge 2 ½ miles North and 2 ½ miles East of Silverdale; period of record is 1996, 2000, 2004, 2008 and 2012. New KDHE ambient stream chemistry station SC761 on Grouse Creek, 6.3 miles North of Cambridge; period of record is 2011-2012. Biological data collected at SC531 (1994-1998, 2003, and 2005) and SC761 (2011-2012).

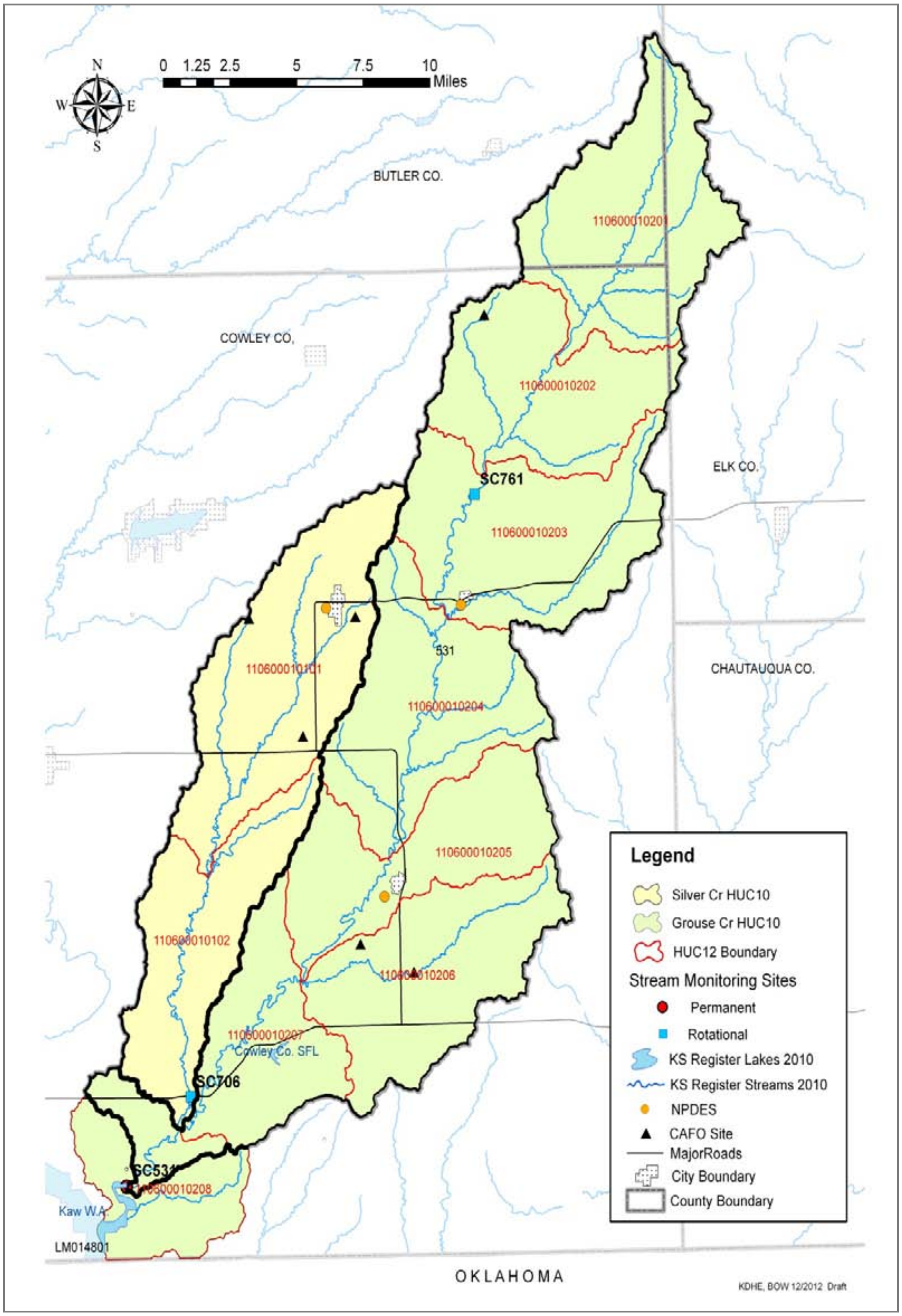

Figure 1. Grouse Creek base map with NPDES and State CAFO facilities.

Hydrology: Grouse Creek is marked by fairly strong flow under normal conditions but little baseflow once dryness is prevalent. Silver Creek is the major tributary (101 sq.mi) and contributes normal flows and runoff, but little baseflow support. The upper reaches of both Grouse Creek and Silver Creek have a propensity to go dry. Most of the tributaries to Grouse Creek are small, ranging in drainage area from 6 to 13 square miles. The exceptions are Cedar Creek (33 sq.mi) and Crabb Creek (39 sq.mi) which each contribute 11-12% of the average flow seen on the lower reach of Grouse Creek. Plum, Snake and Pebble Creeks comprise respectively 9, 19 and 15 square miles of drainage within the Silver Creek subwatershed. Since there are no flow gages on Grouse Creek or its tributaries, these flow estimates (**Table 1**) are taken from Perry, 2004. If Grouse Creek is similar to the nearby Caney River (**Figure 2**), runoff occurs sometime during the March through June time period. Flows decreased markedly during the summer and fall.

Table 1. Long term flow conditions in cfs for streams within the Grouse Creek watershed (Perry, 2004).

Stream	Drainage Area	Mean Flow (cfs)	Baseflow (75%)	Normal Flow (50%)	Runoff (10%)
Grouse Creek nr Cambridge	93.6 sq.mi	57 cfs	1 cfs	7.3 cfs	77 cfs
Grouse Creek abv Cedar Crk	113 sq.mi	66 cfs	1.8 cfs	9.1 cfs	94 cfs
Cedar Creek	34 sq.mi	22 cfs	0.2 cfs	1.8 cfs	29 cfs
Grouse Creek abv Crabb Crk	226 sq.mi	126 cfs	4.1 cfs	18 cfs	189 cfs
Crabb Crk	39 sq.mi	24 cfs	0.3 cfs	3.2 cfs	32 cfs
Grouse Creek abv Silver Crk	284 sq.mi	156 cfs	5.3 cfs	23 cfs	240 cfs
Upper Silver Creek	30 sq.mi	15 cfs	0.0 cfs	1.5 cfs	18 cfs
Snake Creek	19 sq.mi	9.1 cfs	0.0 cfs	0.7 cfs	9.5 cfs
Lower Silver Creek	101 sq.mi	49 cfs	1.2 cfs	6.3 cfs	65 cfs
Lower Grouse Creek above Otter Creek	396 sq.mi	204 cfs	7.3 cfs	31 cfs	321 cfs

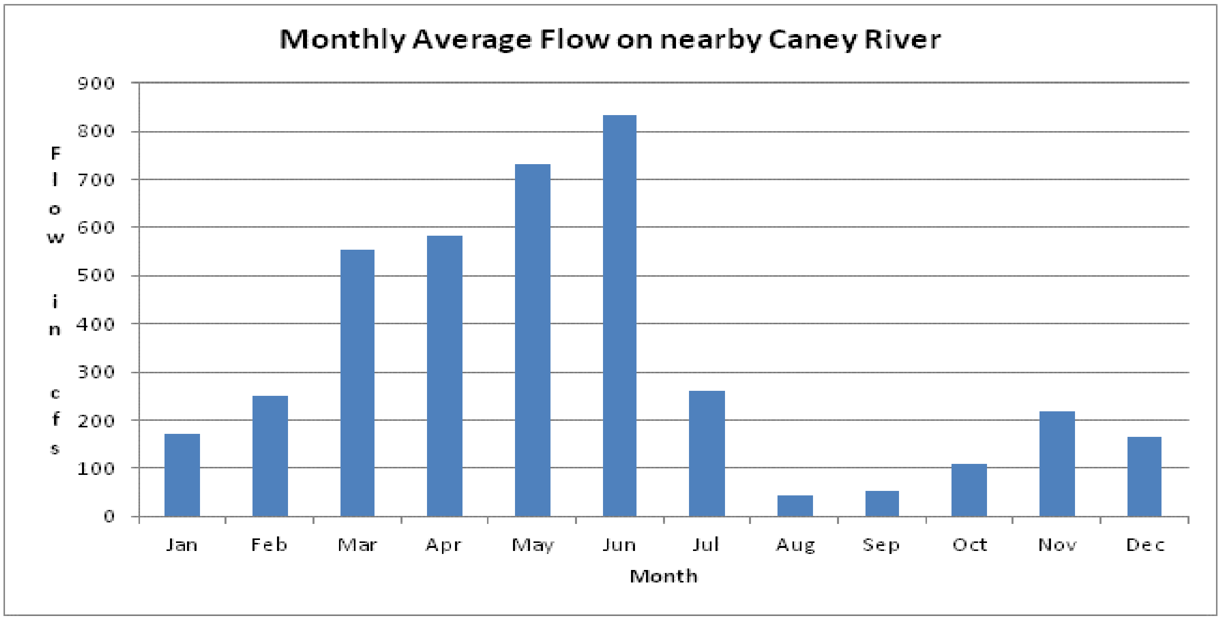

Figure 2. Average monthly flows on nearby Caney River.

Current Condition: This TMDL intends to identify the current loads of phosphorus and total suspended solids that need to be maintained to continue the high biological integrity seen on Grouse Creek. Some reduction in loads under runoff conditions can further buttress the high quality seen at the stream monitoring sites. The three stations in the Grouse Creek watershed show overall good quality in terms of stream chemistry (**Table 2**). Average concentrations of TP and TSS may reflect influence of runoff conditions when compared to the overall median values for those two pollutants. As an indicator of high primary productivity, pH values could be well over the state criterion of 8.5. Of 161 samples taken at the three monitoring locations over 1990 – 2012, only one sample had a pH over 8.5 (8.7). Along with the low sestonic (floating) chlorophyll-a concentrations sampled on lower Grouse Creek, the stream chemistry suggests the stream system is not overburdened with phosphorus that is fueling planktonic growth in either the water column or attached to the stream substrate.

Although there are no streamflow gages on Grouse Creek, estimates of flow condition could be made by looking at flows on nearby Caney and Elk Rivers and assigning their joint average percentile of flow exceedance into three categories of runoff, normal flow and baseflow. Flows were estimated on the days of sampling and those samples were placed in the appropriate flow condition category. Over time, phosphorus concentrations under normal and baseflow conditions were similar (**Figures 3 and 4**). Runoff events tended to elevate concentrations. Similar patterns are seen for total suspended solid concentrations on lower Grouse Creek (**Figures 5 and 6**).

Table 3 indicates the average and quartile concentrations of total phosphorus and TSS on lower Grouse Creek at the three flow conditions. The few samples collected in 2011 and 2012 on upper Grouse Creek near Cambridge were taken during the severe drought and represent normal or baseflow conditions. Concentrations of phosphorus and TSS were similar to those at the lower station during non-runoff conditions (**Table 2**).

Table 2. Water Quality Statistics for Grouse Creek watershed monitoring sites.
(all values are in mg/l, except chlorophyll *a* is in µg/l)

Stream	Period	Statistic	Total P	TSS	TN	DO	#DO < 5 mg/l	Turbidity	Chlorophyll-a
Lower Grouse Creek	1990-1999	Average	0.093	58	----	9.05	1 (4.7)	20	----
		Median	.080	27	----	8.5	----	12	----
	2000-2012	Average	0.113	82	0.76	9.5	0	46	9.4
		Median	0.066	23	0.56	9.0	----	13	6.0
Silver Creek	1996, 2000, 04, 08, 12	Average	0.104	43	0.904	9.5	2 (3.9, 4.3)	24	----
		Median	0.075	16	0.885	9.15	----	9	----
Upper Grouse Creek	2011, 2012	Average	0.065	14	0.947	7.94	1 (4.21)	12	----
		Median	0.064	<10	0.609	6.8	---	9	----

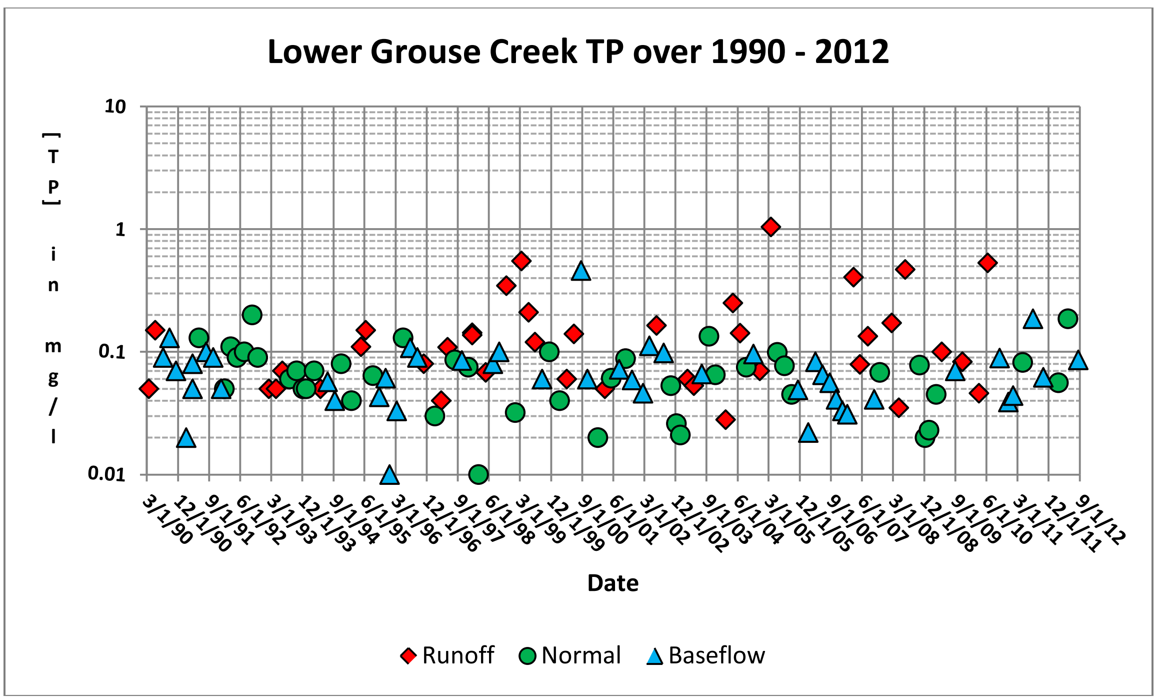

Figure 3. Total phosphorus concentrations on lower Grouse Creek (1990-2012).

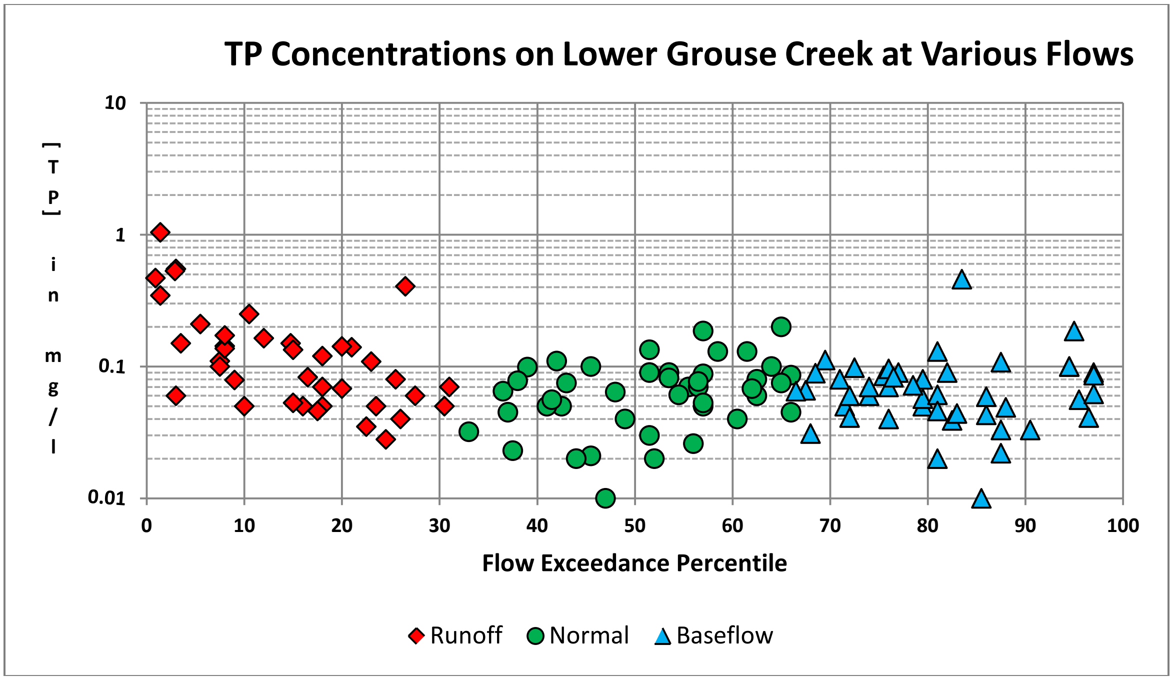

Figure 4. Lower Grouse Creek TP concentrations as function of flow condition.

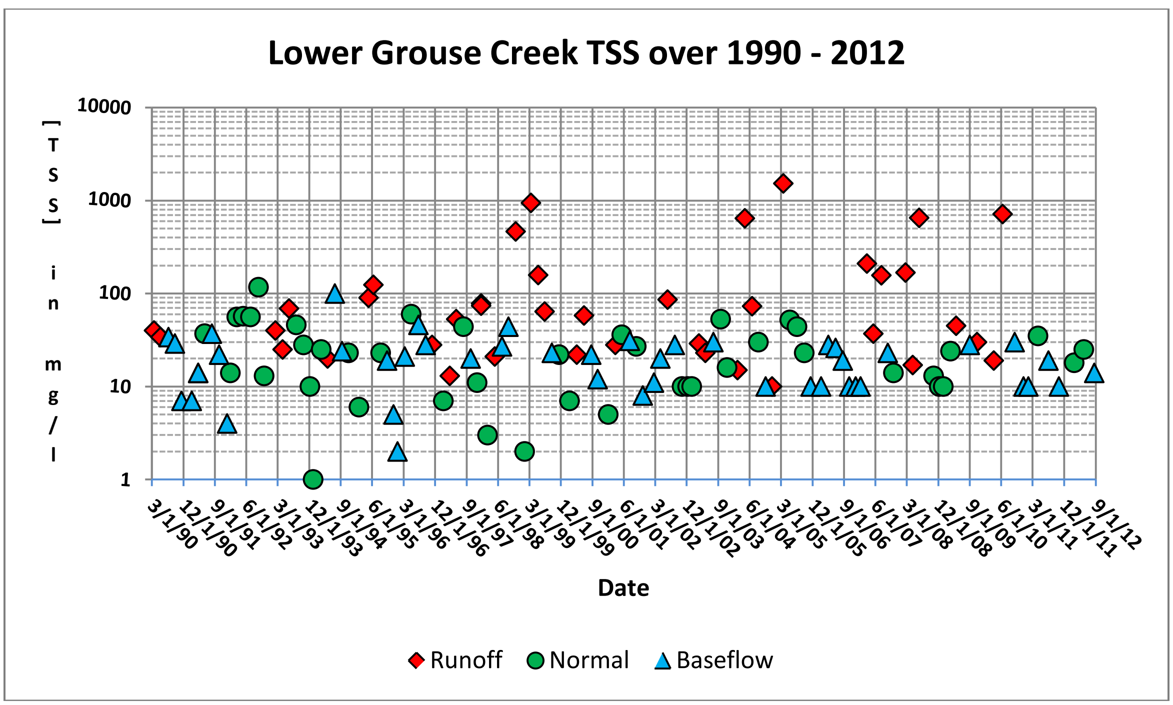

Figure 5. TSS concentrations on lower Grouse Creek (1990-2012).

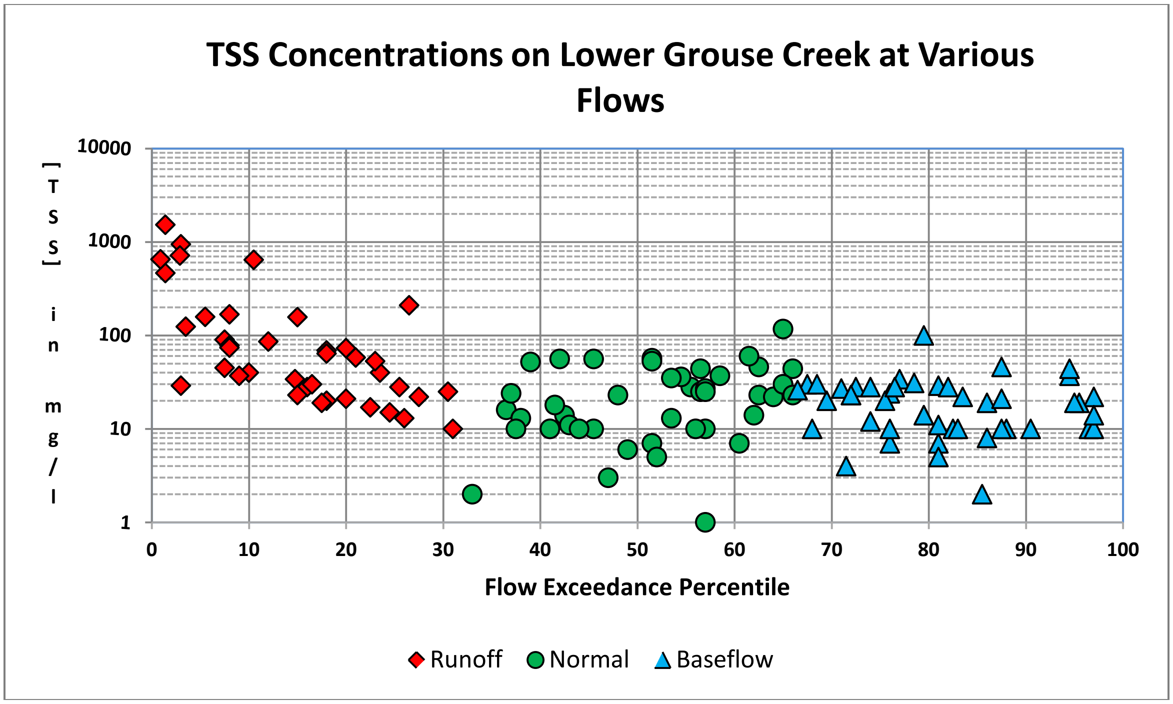

Figure 6. Lower Grouse Creek TSS concentrations as function of flow condition.

Table 3. Average and quartile concentrations of TP and TSS on lower Grouse Creek at various flow conditions.

Pollutant	Flow Condition	Average Concentration	Lower Quartile	Median	Upper Quartile
Phosphorus	**Runoff**	0.169 mg/l	0.053 mg/l	0.109 mg/l	0.164 mg/l
	Normal Q	0.072 mg/l	0.045 mg/l	0.068 mg/l	0.090 mg/l
	Baseflow	0.076 mg/l	0.044 mg/l	0.064 mg/l	0.090 mg/l
Suspended Solids	**Runoff**	177 mg/l	25 mg/l	53 mg/l	157 mg/l
	Normal Q	26 mg/l	<10 mg/l	23 mg/l	37 mg/l
	Baseflow	21 mg/l	<10 mg/l	20 mg/l	28 mg/l

From concurrent samples, there was some correlation between pollutants of TP and TSS on response variables of dissolved oxygen and turbidity but weak and not significant relations with chlorophyll a (**Table 4**). Their relationship with dissolved oxygen is inverse but not particularly strong. The relationships among turbidity, TP and TSS are fairly strong and direct, which is logical since phosphorus is typically attached to sediment which is a chief cause of turbidity.

Table 4. Correlations between TP, TSS and response variables (significance [α=0.10] in bold font).

Parameter	**Dis.O2**			
Turb	-0.080	**Turbidity**		
Log Chl-a	-0.279	0.251	**Log Chlorophyll-a**	
Log TP	**-0.471**	**0.632**	0.296	**Log TP**
LogTSS	**-0.380**	**0.673**	0.230	**0.808**

On Silver Creek, sampled only 5 years over 1996 – 2012, concentrations of TP and TSS were similar across all three flow conditions (**Figures 7 – 10**). Examination of the concentration statistics for the three flow conditions shows the lowest concentrations at normal flow while concentrations at baseflow and runoff were elevated (**Table 5**).

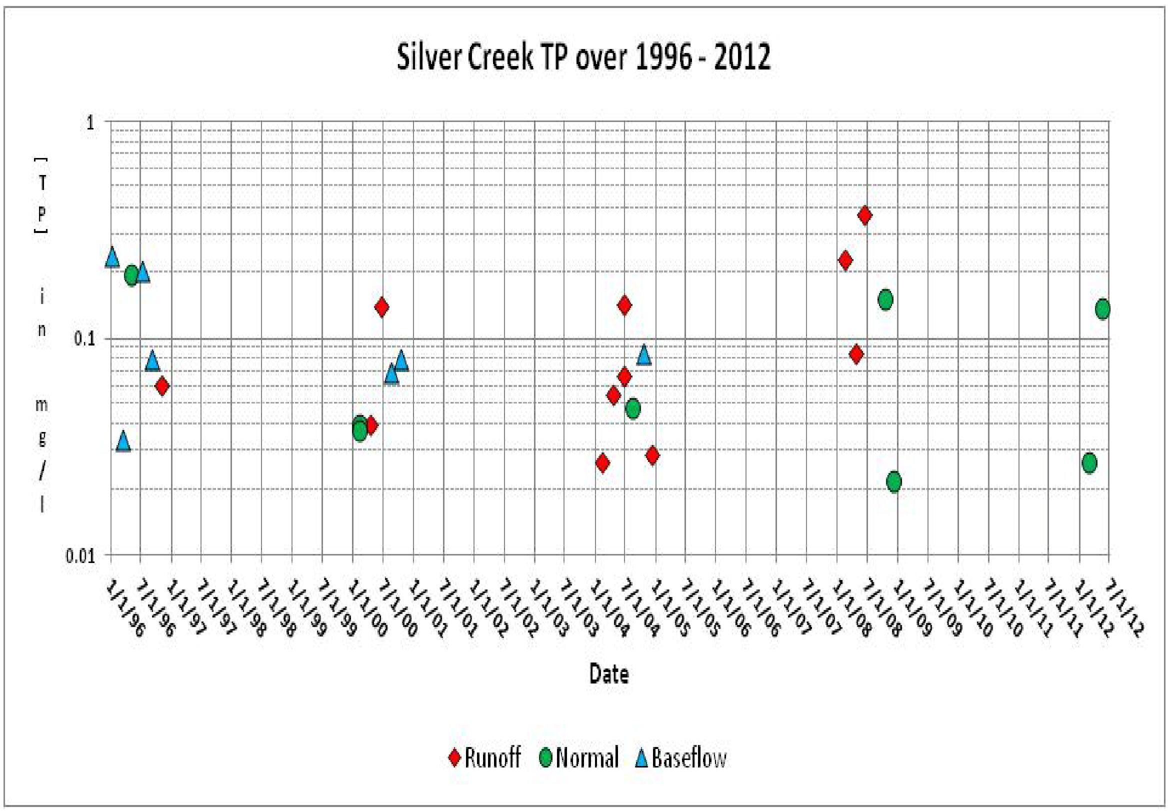

Figure 7. Total phosphorus concentrations on Silver Creek (1996-2012).

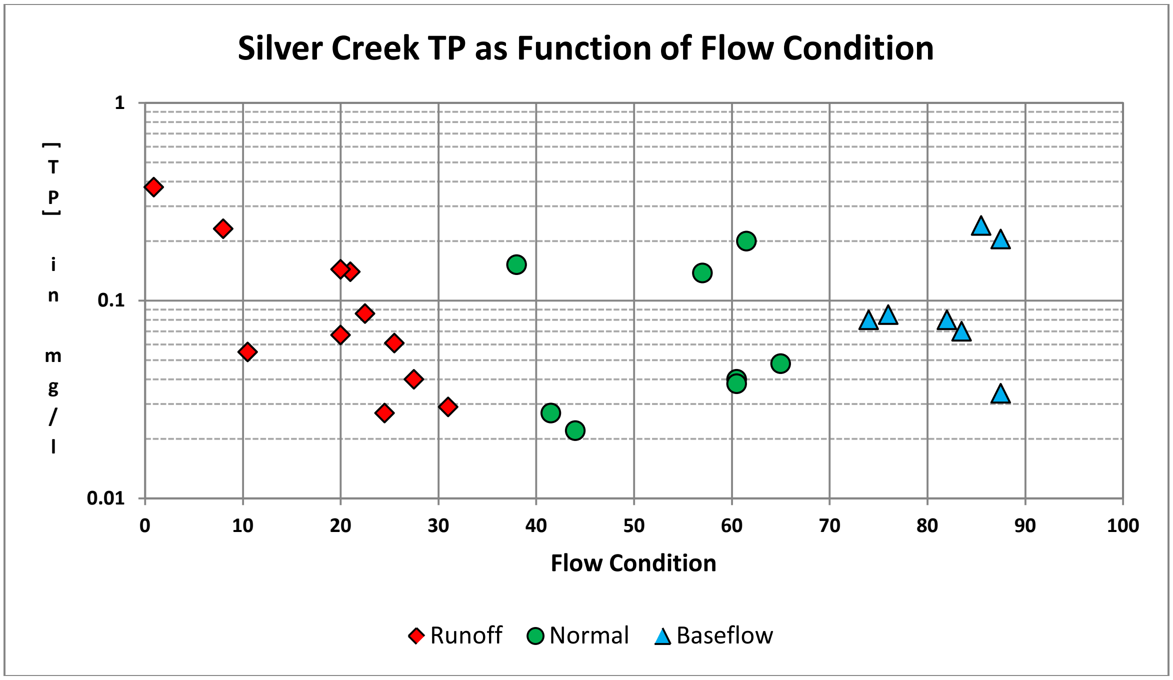

Figure 8. Silver Creek TP as a function of flow condition.

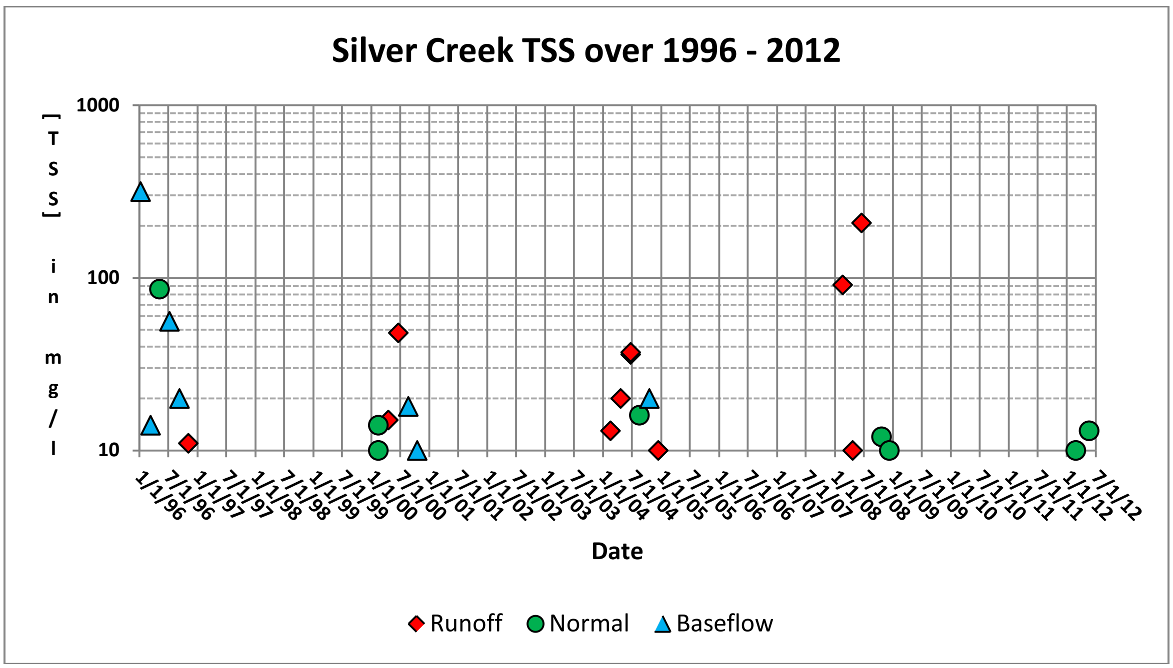

Figure 9. Silver Creek TSS concentrations (1996-2012).

Table 5. Average and quartile concentrations of TP and TSS on Silver Creek at various flow conditions.

Pollutant	Flow Condition	Average Concentration	Lower Quartile	Median	Upper Quartile
Phosphorus	Runoff	0.114 mg/l	0.040 mg/l	0.067 mg/l	0.144 mg/l
	Normal Q	0.083 mg/l	0.030 mg/l	0.044 mg/l	0.149 mg/l
	Baseflow	0.113 mg/l	0.070 mg/l	0.080 mg/l	0.205 mg/l
Suspended Solids	Runoff	49 mg/l	12 mg/l	28 mg/l	77 mg/l
	Normal Q	12 mg/l	<10 mg/l	12 mg/l	14 mg/l
	Baseflow	65 mg/l	14 mg/l	20 mg/l	56 mg/l

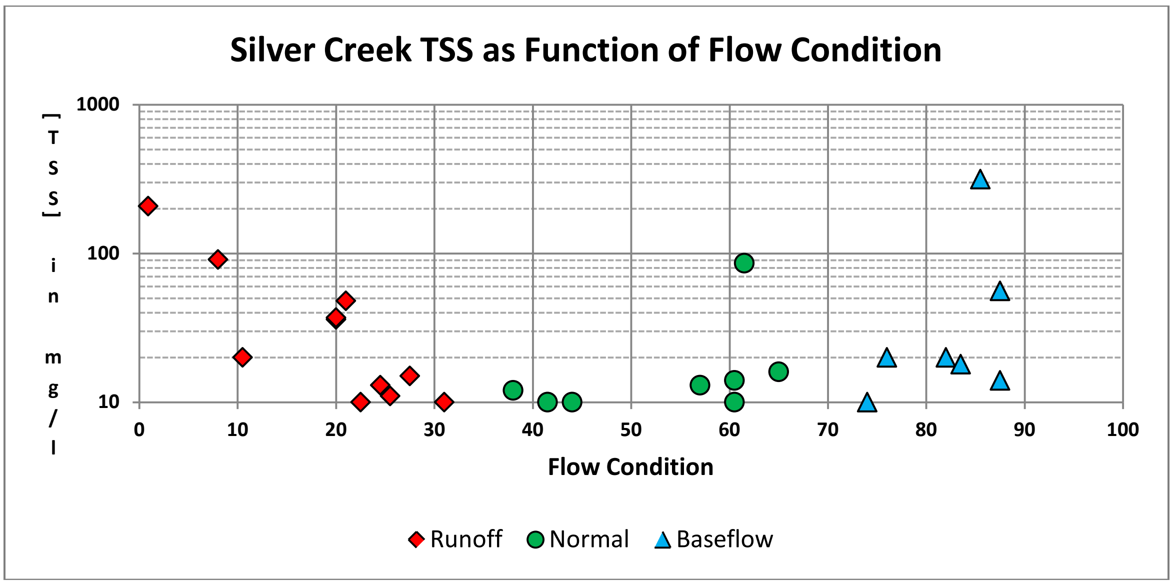

Figure 10. Silver Creek TSS as function of flow condition.

Biology: Macroinvertebrate sampling has occurred on lower Grouse Creek in seven years over 1994 – 2005 and three times on upper Grouse Creek in 2011 and 2012. Recently, KDHE updated its aquatic life use support (ALUS) multimetric index. The new scoring criteria were based on candidate reference stream and stream probabilistic network site data from 1990-2010 (N=1172). Five metrics were selected to provide measures of community richness, composition, dominance, and tolerance to oxygen demanding pollutants.

Following EPA's Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers (Barbour et al., 1999), metric percentiles were quadrisected and a scoring scale of 1 to 4 was assigned to the quadrisects, with 4 representing the highest or best quality score (**Table 6**). The ALUS score was then derived by averaging the scores of the five metrics. Any average score near 4.0 was considered a high quality biological community. Any score near 1.0 was considered a severely degraded biological community. A score greater than or equal to 2.51 was considered supporting of aquatic life while lower scores were considered non-supporting.

Table 6. ALUS multi-metric index scoring criteria based on SBMP candidate reference stream and network site data (1990-2010). MBI = Macroinvertebrate Biotic Index (Davenport and Kelly, 1983); KBI-N = Kansas Biotic Index for nutrients and oxygen demanding substances (Huggins and Moffett, 1988); EPT = number of Ephemeroptera, Plecoptera, Trichoptera taxa; EPT % ABUND = percent sample relative abundance of EPT; SHAN EVN = Shannon's Evenness Index.

Score	MBI	KBI	EPT	EPT%	SHAN EVN
4	< 4.19	< 2.53	>15	> 63	> 0.846
3	4.19-4.44	2.53-2.68	13-15	54-63	0.815-0.846
2	4.45-4.80	2.69-2.83	11-12	41-53	0.773-0.814
1	> 4.80	> 2.83	< 11	< 41	< 0.773

Average multimetric scores for Grouse Creek near Silverdale ranged from 2.4 to 3.6; six of the seven years of sampling yielded scores greater than 3.2. Only 2005 had a low score of 2.4, mostly because of a lower count of mayflies, stoneflies and caddisflies in the macroinvertebrate population, as well as the sampling occurring in November. The upper portion of Grouse Creek near Cambridge was sampled in 2011 and 2012 and had poor scores (1-2.2). The sampling time for the upper reaches coincided with severe drought and the stream habitat was severely dewatered, diminishing the diversity and presence of macroinvertebrates associated with good water quality. **Figures 11 and 12** show the pattern of Macroinvertebrate Biotic Index scores and the percentage of sampled counts that were pollution intolerant orders of Ephemeroptera, Plecoptera and Trichoptera. The lower reaches of Grouse Creek likely benefited by a more robust hydrology supporting habitat conditions in the stream channel whereas the upper site suffered from severely diminished flow.

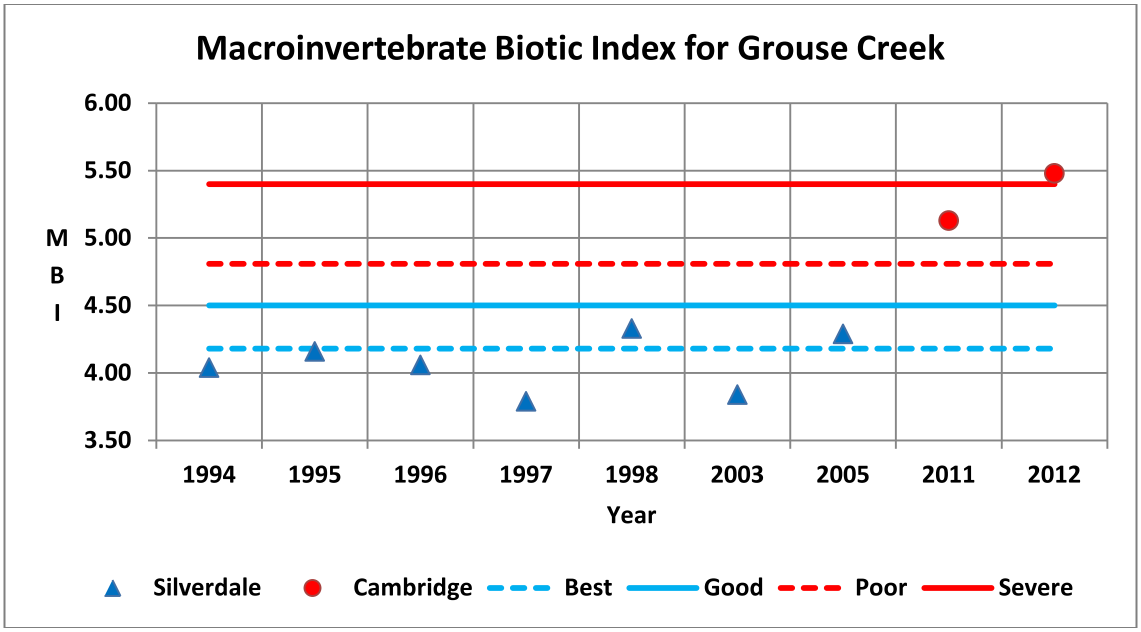

Figure 11. MBI scores for Grouse Creek (1994-2012).

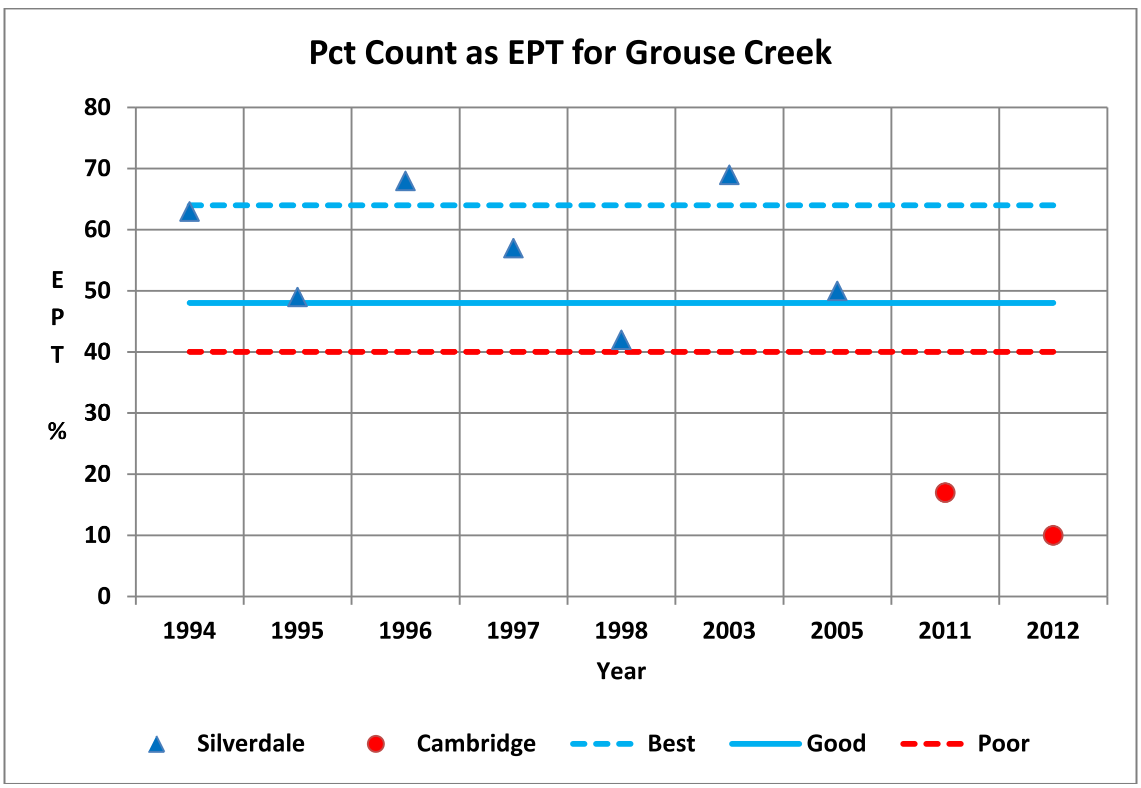

Figure 12. Percentage of sample counts comprising Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies) on Grouse Creek.

Because biological sampling occurs typically once a year and not in conjunction with stream chemistry sampling, correlations are harder to derive. Individual metric values for MBI and the percent count of EPT were correlated with the median sample values of certain parameters for each specific year of biological sampling (**Table 7**). When viewed from an annual basis, any relationship between dissolved oxygen and TP and TSS is essentially absent, while the pollutants' remain significantly correlated with turbidity. Chlorophyll-a in the stream is not related to any of the variables as before. The biological metrics are related to one another and MBI has a strong relationship with TSS with worsening scores occurring with higher TSS levels. No such relationship exists with the EPT metric and TSS or TP.

Table 7. Correlation of biological metrics with annual median values of other parameters (significance [α=0.10] in bold font).

Parameter	**Dis. O2**					
Turbidity	0.106	**Turbidity**				
Log Chl-a	-0.481	0.280	**Log Chl-a**			
MBI	-0.224	0.592	------	**MBI**		
% EPT	-0.133	-0.346	------	**-0.719**	**% EPT**	
Log TP	-0.148	**0.356**	0.034	0.368	-0.445	**Log TP**
Log TSS	0.017	**0.362**	-0.433	**0.801**	-0.419	**0.385**

Desired Endpoints of Water Quality (Implied Load Capacity for TP and TSS) in Grouse and Silver Creeks:

The ultimate endpoint for this TMDL will be to maintain the Kansas Water Quality Standards fully supporting chronic aquatic life support from the impacts of excessive phosphorus or total suspended solids. The current ambient conditions that coincide with evidence of a strongly supported aquatic community will be maintained. Since the only stress of excessive loads occurs under runoff conditions, any restoration efforts will be directed at reducing the concentration of TP and TSS under those conditions which will serve as a margin of safety.

The following endpoints will define maintenance of the water quality standards pertaining to aquatic life support and will be determined at the biological monitoring site located on Grouse Creek near Silverdale.

1. **The upper quartile of the MBI biological metric will remain below 4.2.**
2. **The lower quartile of the EPT Count Percent will remain above 50%.**
3. **Median sestonic chlorophyll-a concentrations will remain below 6 µg/l.**

The following milestones will assess the baseline of current acceptable water quality conditions in the watershed.

1. **Maintain the median TP concentrations on Grouse Creek at or below 0.065 mg/l (Figure 13).**
2. **Maintain the median TSS concentrations on Grouse Creek at or below 20 mg/l (Figure 14).**
3. **Reduce the median TP concentrations on Silver Creek to 0.065 mg/l (Figure 15).**
4. **Reduce the upper quartile TSS concentration on Silver Creek to a comparable level of the upper quartile TSS concentration on Grouse Creek – 30 mg/l (Figure 16).**

The following goals are established for load reduction under runoff conditions to further assure the achievement of the primary normal flow milestones for Grouse Creek.

1. **Reduce the median TP concentration on Grouse Creek under runoff conditions to the normal flow upper quartile TP value – 0.090 mg/l (Figure 13).**
2. **Reduce the median TSS concentration on Grouse Creek under runoff conditions to the normal flow upper quartile TSS value – 30 mg/l (Figure 14).**

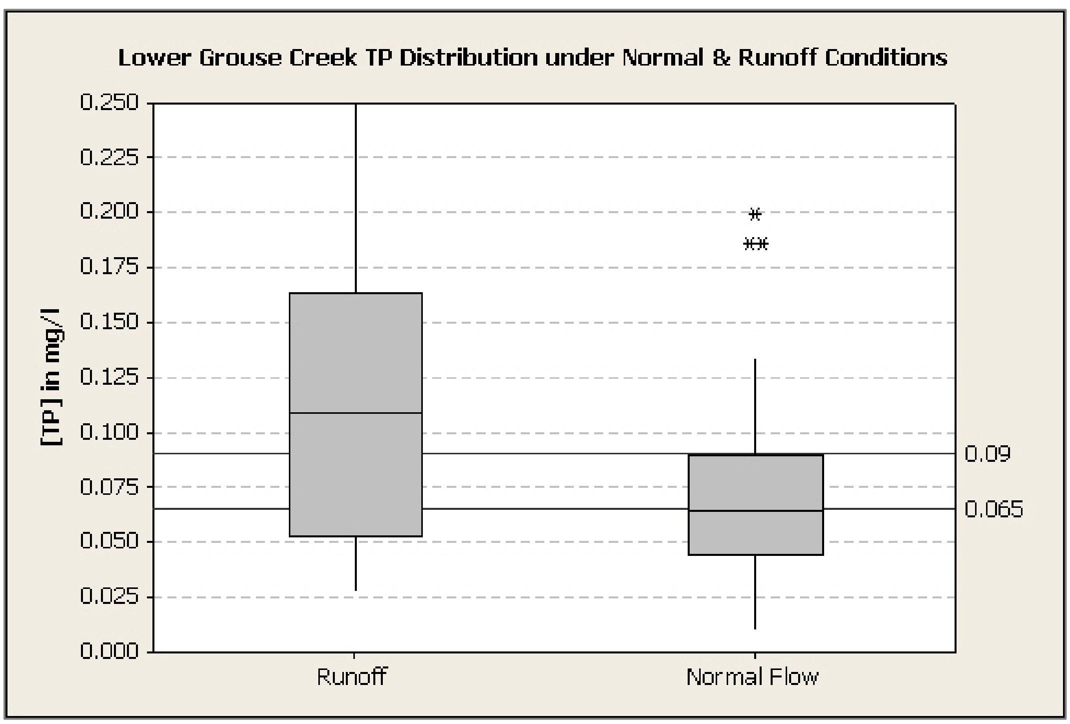

Figure 13. Distribution of TP on Grouse Creek under normal flow and runoff.

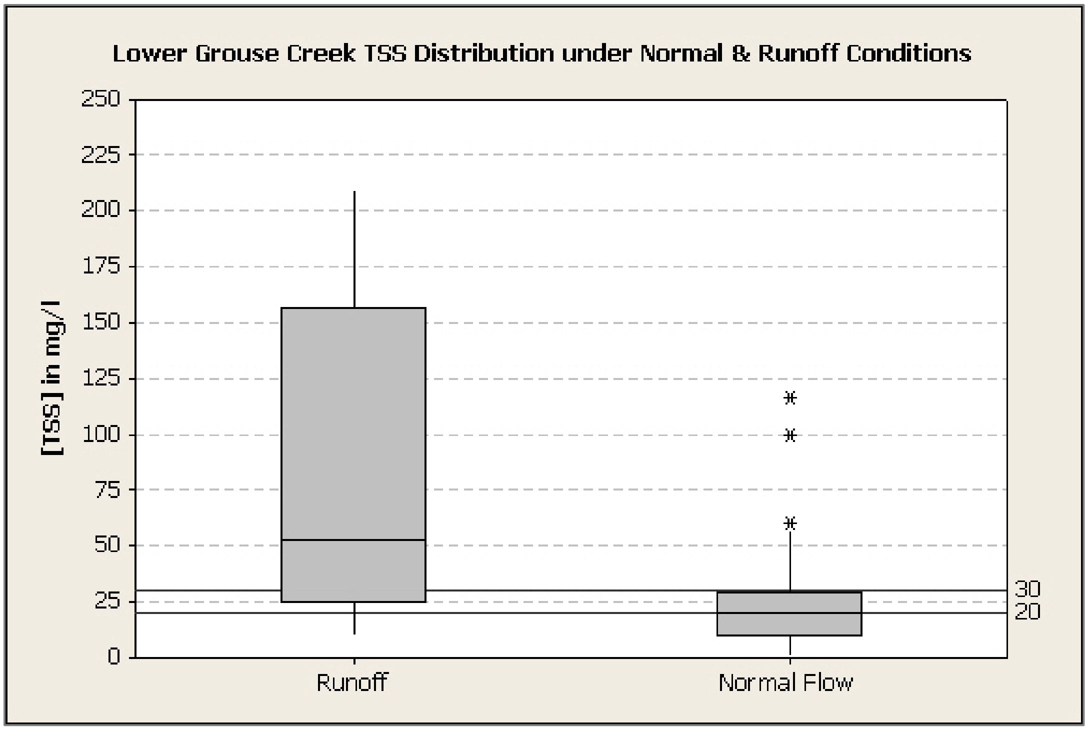

Figure 14. Distribution of TSS on Grouse Creek under normal flow and runoff.

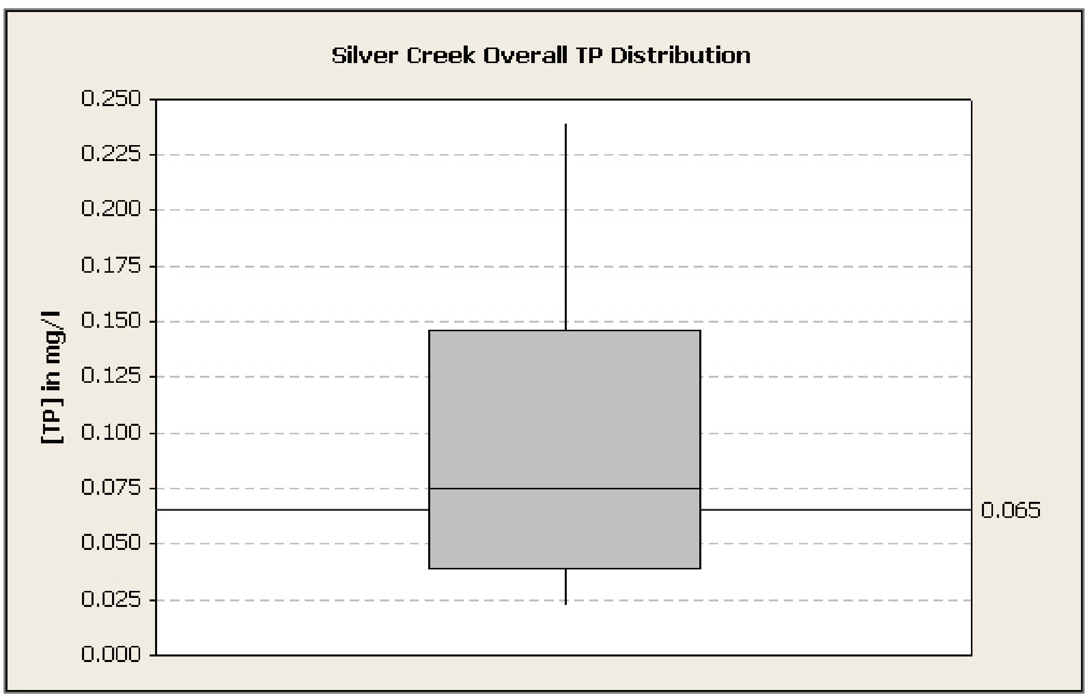

Figure 15. Overall distribution of TP on Silver Creek.

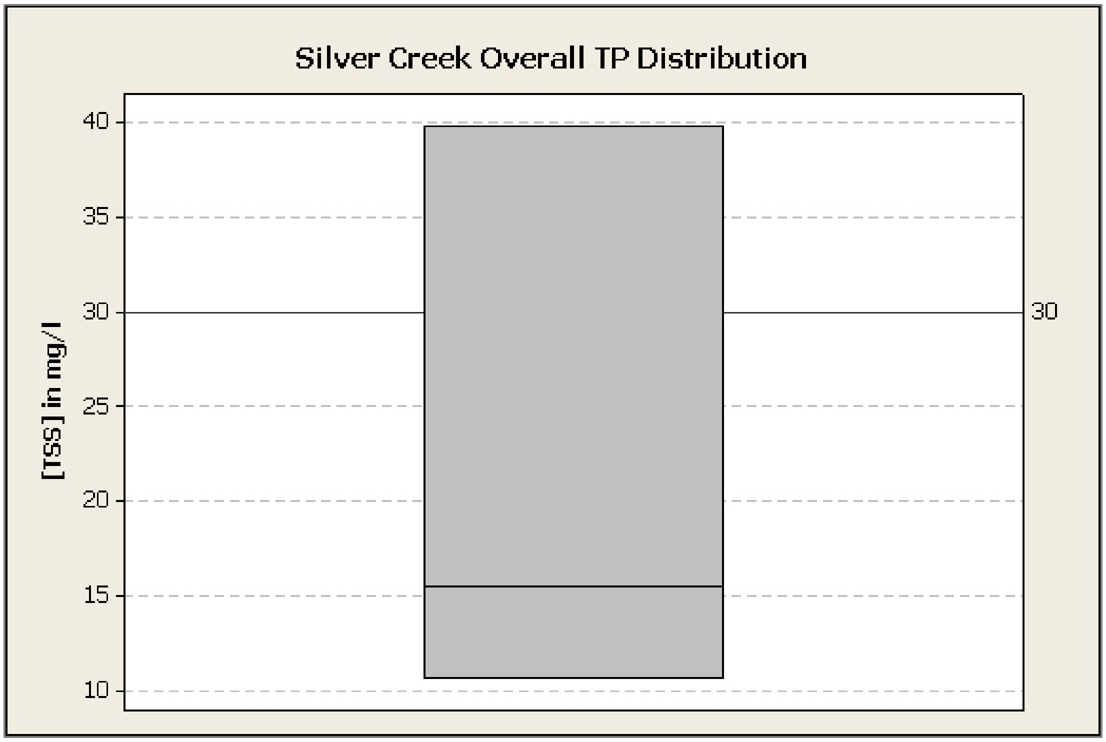

Figure 16. Overall distribution of TSS on Silver Creek.

3. SOURCE INVENTORY AND ASSESSMENT

Land Use: Grouse Creek's watershed is located in the Bluestem Hills land use area, often referred to as the Flint Hills tall grass prairie. Ten HUC 12 subwatersheds comprise the Grouse watershed; 8 along Grouse Creek and two on Silver Creek (**Figure 1**). The watershed is chiefly range and pasture which is primarily native grasses (**Table 8**). Approximately 11% of the land area is cropland of which wheat, corn, soybeans, alfalfa and sorghum are the major crops. Proportionately, most of the cropland is along Silver Creek, whereas Grouse Creek's watershed is overwhelmingly grass- and woodland with cropland concentrated along riparian areas (**Figure 17**). Agricultural production is the primary industry in the watershed.

The Grouse Creek watershed above the confluence of Otter Creek, below which is the headwater area of Kaw Lake in Oklahoma, covers 396 square miles and includes about 216 linear miles of riparian area on Silver Creek and 489 linear miles on Grouse Creek.

KDHE evaluation of disturbance among the small subwatersheds comprising Grouse Creek shows extensive areas of little disturbance (**Figures 18 and 19**). The headwaters of Silver Creek is really the only area with 'widespread' areas of disturbance. There is a high proportion of cultivated land in that area, while Grouse Creek shows just the opposite pattern (**Figure 17**). The watershed has six floodwater detention dams on tributaries to Grouse and Silver Creek that controlling 31.8 square miles of drainage. These dams were constructed under the management of the Grouse-Silver Creek

Watershed District #92 general plan and funded by state and county sources. Based on the KDHE analysis, these impoundments seem to have only localized impacts.

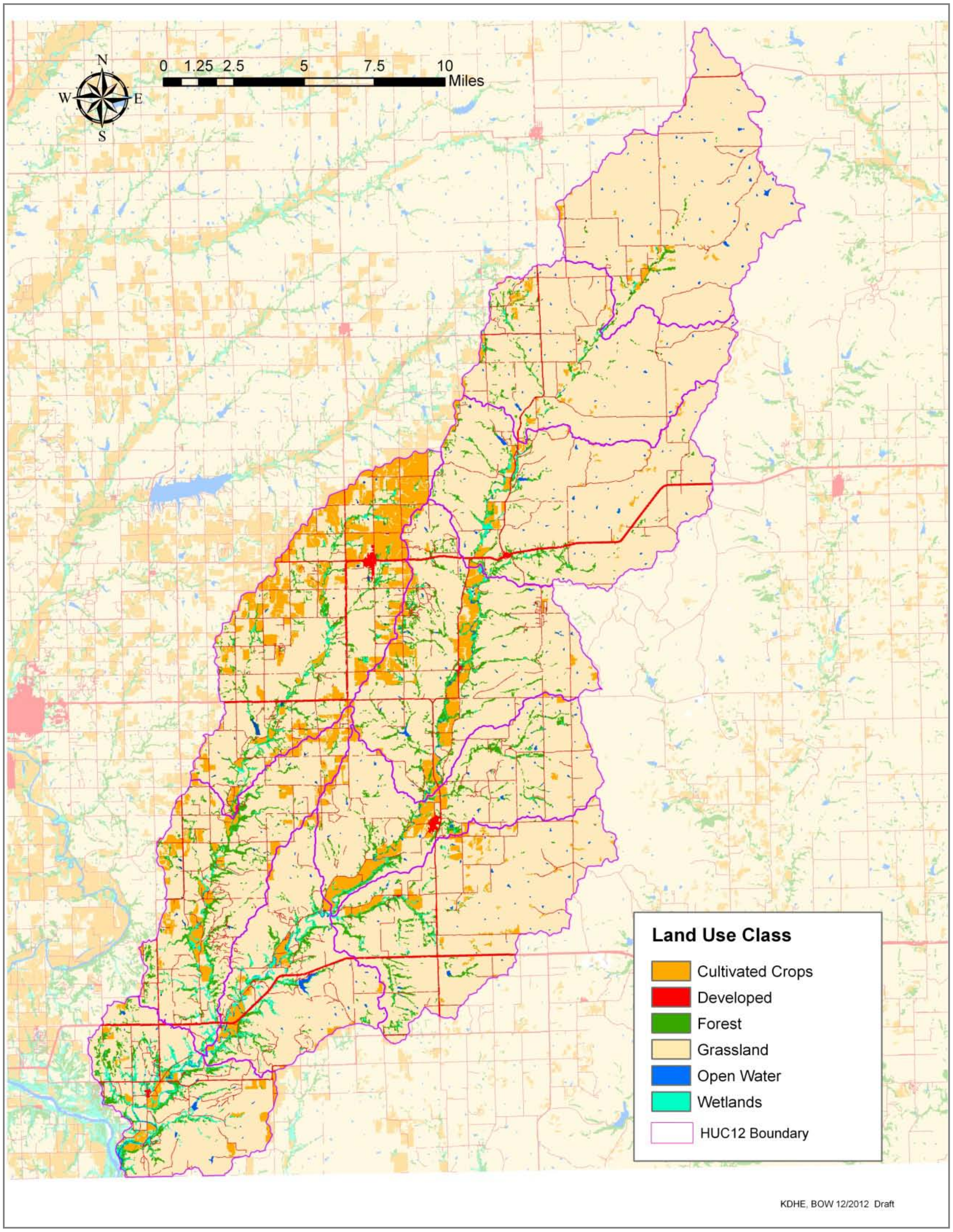

Figure 17. Land use in Grouse Creek watershed.

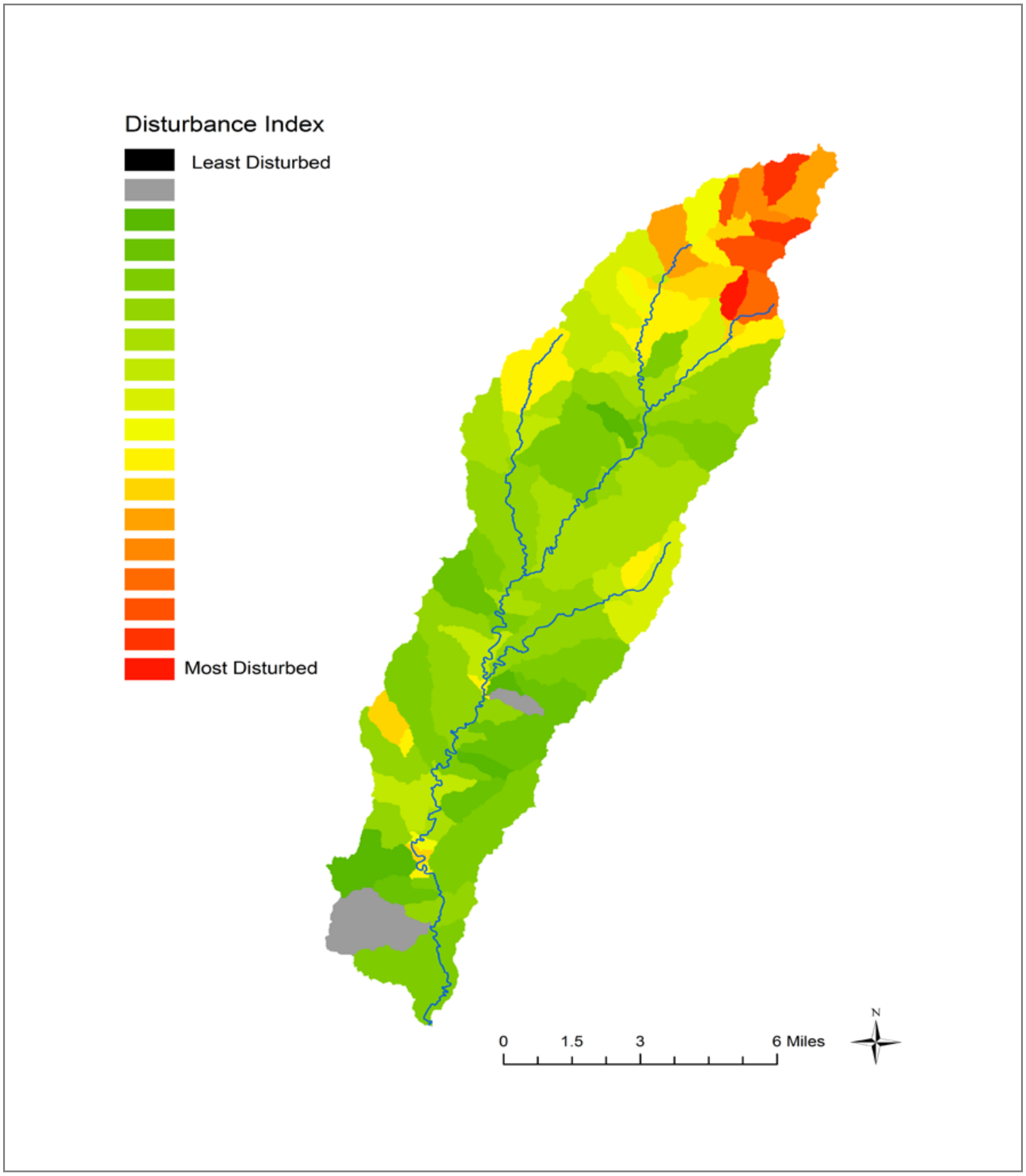

Figure 18. KDHE disturbance analysis of Grouse Creek subwatershed.

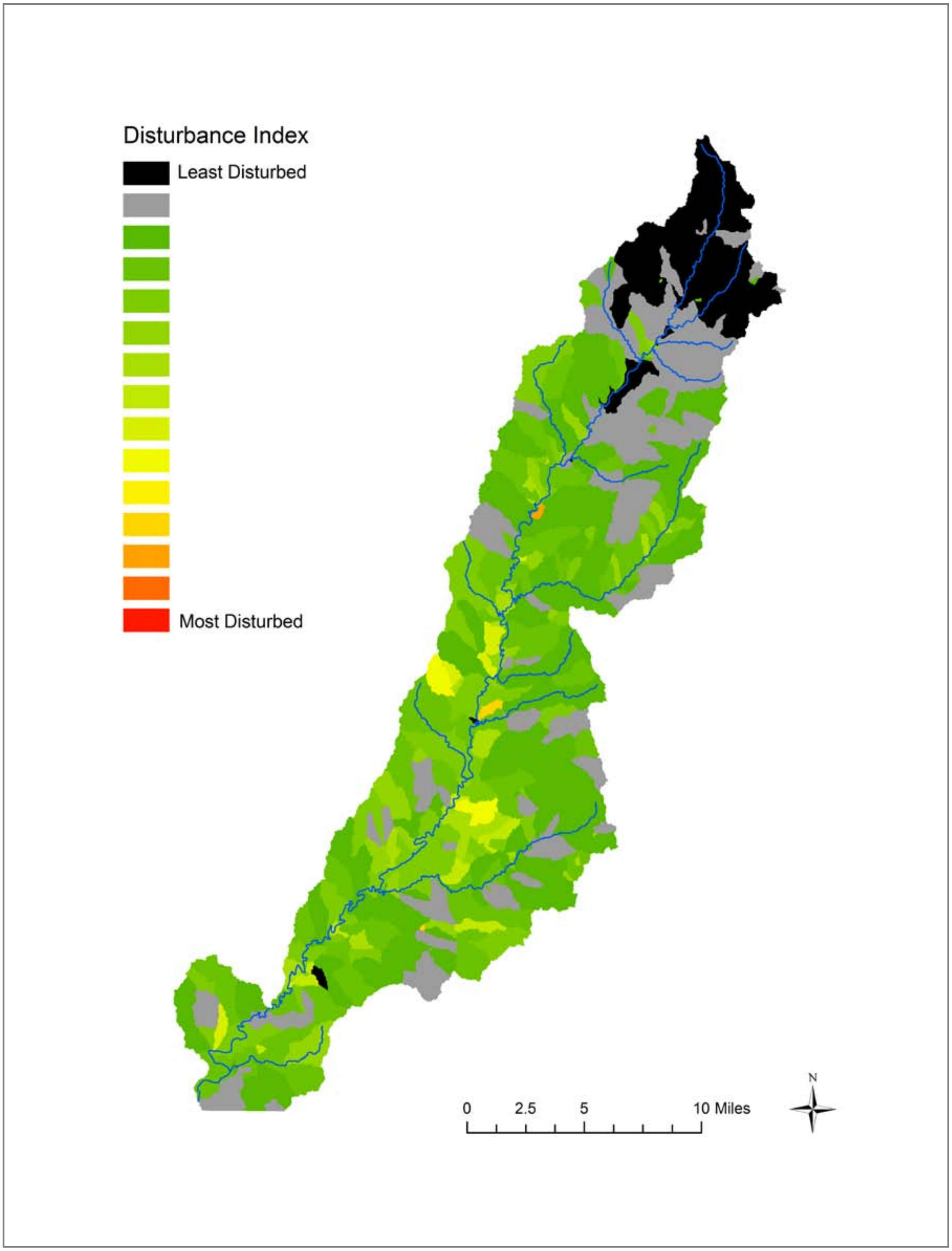

Figure 19. KDHE disturbance analysis of Silver Creek subwatershed.

Table 8. Proportion of land use in Grouse Creek watershed (11060001).

Watershed HUC10/12	% Grassland	% Cropland	% Woodland	%Development
		Silver Creek		
0101	45%	31%	16%	8%
0102	54%	20%	19%	7%
		Grouse Creek		
0201	92%	3%	2%	3%
0202	85%	4%	6%	5%
0203	80%	5%	9%	6%
0204	63%	13%	18%	6%
0205	66%	12%	16%	6%
0206	81%	5%	9%	5%
0207	69%	9%	16%	7%
0208	65%	8%	20%	7%
Overall	**70%**	**11%**	**13%**	**6%**

Livestock Waste Management Systems: Grasslands in the area support the largest cow herds of any Kansas county and are the destination of thousands of stockers each year. Approximately 52,000 head of cattle graze the prairie annually. There are four state-permitted confined animal feeding operations and two certified operations in the watershed with another certified operation under construction (**Figure 1**). **Table 9** provides the attributes of the seven facilities. All of these livestock facilities have

Table 9. State permitted animal feeding operations in Grouse Creek watershed.

Permit No.	Permit Type	Facility Type	Federal Animal Units	HUC12 Location
A-ARCL-SA04	Certification	Swine	90	110600010101 (Up. Silver Crk)
A-ARCL-B001	Permit	Beef	700	110600010101 (Up. Silver Crk)
A-ARCL-BA10	Certification (planned)	Beef	998	110600010101 (Up. Silver Crk)
A-ARCL-M001	Permit	Dairy	450	110600010202 (Goose Crk)
A-ARCL-S010	Permit	Swine	990	110600010206 (Crabb Crk)
A-ARCL-BA03	Certification	Beef	600	110600010206 (Crabb Crk)
A-ARCL-B002	Permit	Beef	980	110600010208 (Lo Grouse Crk)

waste management systems designed to minimize runoff entering their operation and detain runoff emanating from their facilities. Typically, these facilities are designed to manage a 25-year, 24-hour rainfall/runoff event in addition to two weeks of normal wastewater from their operations. Such an event is associated with streamflows that occur less than 1-5% of the time. It is unlikely TP or TSS loading is attributable to properly operated permitted facilities, especially given the low concentrations of those pollutants seen on stream in the Grouse Creek watershed, even during runoff periods.

Population Density and On-Site Waste Systems: Cowley County has a 2010 population of 36,311. Population in cities with centralized sanitary sewer systems in the county (Arkansas City, Winfield, Dexter, Burden, Cambridge, Atlanta, Geuda Springs, and Udall) comprises 74% of the county population (26,737). That leaves approximately 9574 people served by on-site waste systems. While the population density of Cowley County is 32.3 people per square mile; most of that population is located within the incorporated cities. The "rural" population density, considering Cowley is the 7th largest county in the state, is only 9.4 people per square mile. Such a light density does not present much stress on the stream systems in the county and, again, because of the lack of degraded water quality seen in Grouse Creek, is not likely to be of significant impact to the streams of the watershed.

Point Sources: There are three permitted NPDES waste treatment facilities located within the Grouse Creek watershed (**Figure 1**). **Table 10** displays the characteristics of those three facilities. All three are detention/retention lagoon systems; Cambridge is designed not to discharge, the other two will discharge low flows. All three towns served by these systems have seen population decline in the past decade: Burden (-5%), Dexter (-24%) and Cambridge (-20%). Burden peaked in population in 1960; it currently has 92% of that peak number. Cambridge peaked in 1930 (now at 30% of peak) and Dexter peaked in 1910 (now with 54% of peak). Therefore, the current facilities are likely to manage any wasteloads from current and future populations. For the discharging lagoon systems, total suspended solids are limited (80 mg/l monthly average/120 mg/l weekly average) as is Biochemical Oxygen Demand (30 mg/l /45 mg/l). Dexter averages 22 mg/l BOD and 66 mg/l TSS while Burden averages 21 mg/l and 53 mg/l, respectively (**Table 11**). Phosphorus is neither limited or monitored in Kansas lagoon systems.

Table 10. NPDES point sources in Grouse Creek watershed.

Facility	KS Permit #	NPDES #	Type	Design Flow	Receiving Stream	Permit Expires
City of Burden	M-AR14-OO02	KS0088455	3-cell lagoon	0.0612 MGD	Silver Creek	3/31/17
City of Dexter	M-AR30-OO01	KS0022667	3-cell lagoon	0.058 MGD	Grouse Creek	6/30/17
City of Cambridge	M-AR18-NO01	KSJ000462	Non-discharging lagoon	0.0 MGD	Cedar Creek	12/31/13

Table 11. Burden and Dexter wastewater statistics (2004-2012),

City	Pollutant	Average	Maximum	Number of Samples	Number > weekly average	Number > monthly average
Dexter	BOD	22 mg/l	52 mg/l	30	2	7
Dexter	TSS	66 mg/l	127 mg/l	36	4	11
Burden	BOD	21 mg/l	40 mg/l	33	0	4
Burden	TSS	53 mg/l	114 mg/l	32	0	7

4. ALLOCATION OF POLLUTION REDUCTION RESPONSIBILITY

Since this TMDL is oriented toward protecting the condition of Grouse Creek and its tributaries from excessive loading of TSS and TP, maintenance of current loads of those two pollutants will be the focus of its implementation. Current loads will be expressed as loads resulting from application of the desired median endpoints of TSS and TP to baseflows and normal flows, given that those current conditions have yielded a high quality, diverse aquatic community.

Point Sources: Both discharging facilities (the cities of Dexter and Burden) operate three-cell lagoons for their wastewater treatment. By design, these systems effectively remove most of the suspended material entering their treatment works. They generally contribute only a small portion of the TSS load into the streams and report TSS monitoring data that frequently fall well below their permit limits. Even with limits of 80 mg/l, the cumulative wastewater discharge would have to be well over 0.1 MGD to exert a significant impact to the stream. Estimated current discharges from the two cities are about 0.08 MGD and the two waste streams must traverse two separate stream reaches before potentially comingling in the lower Grouse Creek reach.

Additionally, the TSS generated by lagoon systems is usually biological in nature, e.g., algae masses, etc. The TSS addressed by the TMDL is dominated by sediment and its scour and depositional impacts to the stream channel habitat and biota. Therefore, lagoon wastewater treatment systems will be given broad latitude to continue to operate under current permit expectations unless it is demonstrated that these lagoon discharges are impairing Grouse Creek.

Waste load allocations are determined by multiplying design flow times the permit limit, and as design flows are singular values assigned in the permit, the waste load allocation remains constant over all flows. **Table 12** presents the applicable wasteload allocations for TP and TSS for Burden and Dexter. Under baseflow conditions, the full wasteload allocations will exceed the load capacity of Grouse and Silver Creek. Under those situations, there will be some in-stream assimilation of TP in the unnamed tributaries before reaching the classified streams, lower discharge rates because of evaporation off the lagoons lowering the hydraulic loading, and settling of any TSS entering the unnamed tributaries. Therefore, the applicable baseflow wasteloads are expected to match up with the load capacity of the receiving stream reach. Once normal flows occur, the full wasteload allocations may be allowed. Any future wasteloads would have to be offset by equivalent reductions in load allocations from non-point sources.

All other facilities, such as Cambridge or the animal feeding operations in the watershed, will have wasteload allocations of zero because they are not expected to discharge these pollutants to the stream system.

Table 12. TP and TSS loads and wasteload allocations for Burden and Dexter.

City	Design Flow	Est. Current Flow	Expected [TP]	TSS Limit	Current TP Load	TP WLA	Current TSS Load	TSS WLA
Burden	0.0612 MGD	0.0535 MGD	2 mg/l	80 mg/l	0.89 #//d	1.02 #/d	255.9 #/d	441.8 #/d
Dexter	0.580 MGD	0.0278 MGD	2 mg/l	80 mg/l	0.46 #/d	0.97 #/d	165.6 #/d	418.7 #/d

Non-point Sources: A majority of the loading into the Grouse Creek stream system is generated from non-point sources in the watershed. Since the chemical and biological integrity of Grouse Creek is high during baseflow and normal flow conditions, the gross load allocations assigned to non-point sources are established to maintain current loading patterns and desired water quality. **Tables 13 and 14** show the load allocations and load capacities for total phosphorus and total suspended solids to be maintained along various reaches of Grouse Creek and Silver Creek. Non-point source loads within each incremental reach can be distributed to activities along Grouse Creek or the tributaries that enter Grouse Creek within that reach. Baseflow is defined by the estimated lower quartile (75%) flow in each of those reaches, while normal flow is established as median flow.

Defined Margin of Safety: The margin of safety is both implicit with the assumption that the WLAs from Burden and Dexter will occur despite low population and that they would arrive undiminished to the receiving streams. But, because this TMDL is protection oriented, there will be an explicit expression of the margin of safety that applies to establishing load capacities under runoff conditions. Any occasional excursions from the desired endpoints for TSS or TP occur during seasonal runoff. Since current loadings during high flow are apparently not sufficiently impactful to cause a diminishment in the biological integrity of Grouse Creek nor excessively high concentrations of TSS or TP once the runoff event ends, any efforts to reduce pollutant loadings during runoff will work to further bolster the maintenance of the normal flow milestones and biological conditions. Runoff will be represented as the upper decile flow found on the reaches of Grouse and Silver Creeks. **Table 15** shows the applicable load allocations and capacities for TP and TSS during runoff. A seasonal load capacity will be expressed as 90 days of the desired daily loads. Any targeted reduction efforts during the runoff season will further increase the probability of maintaining water quality standards on Grouse Creek.

Table 13. TP load allocations and capacities at baseflow and normal flow on Grouse Creek.

Stream Location	Med. [TP] mg/l	Baseflow				Normal Flow			
		Flow (cfs)	WLA (#/d)	LA (#/d)	LC (#/d)	Flow (cfs)	WLA (#/d)	LA (#/d)	LC (#/d)
@ Cambridge	0.065	1.0	0.0	0.4	0.4	7.3	0.0	2.6	2.6
abv Cedar NPS				0.2				0.6	
Above Cedar Crk	0.065	1.8	0.0	0.6	0.6	9.1	0.0	3.2	3.2
Dexter WLA		0.09	0.8			0.1	1.0		
abv Crabb NPS		4.0		0.0		17.9		2.1	
Above Crabb Crk	0.065	4.1	0.8	0.6	1.4	18.0	1.0	5.3	6.3
abv Silver NPS				0.5				1.8	
Above Silver Crk	0.065	5.3	0.8	1.1	1.9	23.0	1.0	7.1	8.1
Burden WLA		0.10	0.4			0.1	1.0		
Silver Crk NPS		1.1		0.0		6.2		1.2	
Silver Creek	0.065	1.2	0.4	0.0	0.4	6.3	1.0	1.2	2.2
Lower Grouse NPS				0.3				0.6	
Lower Grouse Creek	0.065	7.3	1.2	1.4	2.6	31.0	2.0	8.9	10.9

Table 14. TSS load allocations and capacities at baseflow and normal flow on Grouse Creek.

Stream Location	Med. [TSS] mg/l	Baseflow				Normal Flow			
		Flow (cfs)	WLA (#/d)	LA (#/d)	LC (#/d)	Flow (cfs)	WLA (#/d)	LA (#/d)	LC (#/d)
@ Cambridge	20	1.0	0.0	108.0	108.0	7.3	0.0	788.4	788.4
abv Cedar NPS				86.4				194.4	
Above Cedar Crk	20	1.8	0.0	194.4	194.4	9.1	0.0	982.8	982.8
Dexter WLA		0.09	248.4			0.1	418.7		
abv Crabb NPS		4.0		0.0		17.9		542.5	
Above Crabb Crk	20	4.1	248.4	194.4	442.8	18.0	418.7	1525	1944
abv Silver NPS				129.6				540.0	
Above Silver Crk	20	5.3	248.4	324.0	572.4	23.0	418.7	2065	2484
Burden WLA		0.10	129.6			0.1	441.8		
Silver Crk NPS		1.1		0.0		6.2		238.6	
Silver Creek	20	1.2	129.6	0.0	129.6	6.3	441.8	238.6	680.4
Lower Grouse NPS				86.4				183.6	
Lower Grouse Creek	20	7.3	378.0	410.4	788.4	31.0	860.5	2488	3348

Table 15. TP and TSS load allocations and capacities during runoff on Grouse Creek**.**

Stream Location	Runoff Flow (cfs)	Desired [TP] mg/l	TP WLA #/d	TP LA #/d	TP Load Capacity	Desired [TSS] mg/l	TSS WLA #/d	TSS LA #/d	TSS Load Capacity
@ Cambridge	77	0.090	0.0	37.4	37.4	30	0.0	12474	12474
abv Cedar NPS				8.3				2754	
Above Cedar Crk	94	0.090	0.0	45.7	45.7	30	0.0	15228	15228
Dexter WLA	.09		1.0				418.7		
abv Crabb NPS	188.9			46.2				14971	
Above Crabb Crk	189	0.090	1.0	90.9	91.9	30	418.7	30199	30618
abv Silver NPS				24.8				8262	
Above Silver Crk	240	0.090		115.7	116.6	30	418.7	38461	38880
Burden WLA	0.10		1.0				441.8		
Silver Crk NPS	64.9			30.6				10088	
Silver Creek	65	0.090	1.0	30.6	31.6	30	441.8	10088	10530
Lower Grouse NPS				7.8				2592	
Lower Grouse Creek	321	0.090	2.0	154	156	30	860.5	51142	52002

State Water Plan Implementation Priority: Protection TMDLs are the exception to the norm in Kansas. Nonetheless, there is a current Watershed Restoration and Protection Strategy group housed within the Grouse-Silver Creek Watershed District #92 that is ready, willing and able to implement protective practices along the creeks in the watershed. There is currently a High Priority Dissolved Oxygen TMDL for Silver Creek that can concurrently be aided by implementation of this TMDL. This TMDL will be **High Priority** for implementation.

Nutrient Reduction Framework Priority Ranking: The Grouse Creek watershed lies within the Kaw Lake Subbasin (HUC8: 11060001) which is outside the top 16 HUC 8s targeted for State action on nutrient reduction.

Priority Stream Subwatersheds: The long-range priority focus for maintaining the chemical and biological quality of Grouse Creek is on four subwatersheds: 0102 (Lower

Silver Creek), 0205 (Plum-Grouse Creek), 0206 (Crabb Creek) and 0207 (Panther-Grouse Creek). Additionally, attention is drawn to the two upper subwatersheds: 0201 (Waggoner Creek) and 0202 (Gardners Branch). The allocations and load capacities determined for Silver Creek should be used to guide implementation in lower Silver Creek. The allocations and capacities for the location on Grouse Creek above Silver Creek (including Crabb Creek) should guide implementation in the 0206 and 0207 subwatersheds. The allocations and capacities for Grouse Creek above Crabb Creek but below Cedar Creek can guide implementation in subwatershed 0205. Finally, the allocations and capacities for Grouse Creek at Cambridge will guide implementation in the upper two subwatersheds of Grouse Creek.

Implementation should be keyed to load reductions necessary to achieve the capacities under runoff conditions. The WRAPS may plan and schedule load reductions over time for smaller areas within the applicable subwatersheds analyzed by this TMDL. Therefore, planned load reductions may not align tightly with the margin of safety capacities and allocations of this TMDL, but, given the dynamics of storm flow pollutant loading in this watershed, any designed reduction during runoff will serve to maintain the endpoints and milestones of this TMDL. After a five-year period of implementation, both the plan and TMDL may be revisited for adjustments to planning and implementing load reductions.

5. IMPLEMENTATION

Desired Implementation Activities: Standard nutrient and sediment management and erosion control to abate loads during runoff events will be the primary implementation activities for this TMDL. Such activities will center on application of no-till farming, grassed waterways, vegetative buffers, terraces, cover crops and nutrient management plans on cropland areas. Livestock impacts will be managed by feeding site relocations, development of off-stream watering systems and grazing management. Some streambank stabilization may be applied in spots, as will treatment wetlands and on-site wastewater treatment system upgrades.

Implementation Programs Guidance:

NPDES and State Permits – KDHE:

a. Monitor effluent from the discharging lagoon systems to confirm low wasteload contributions of TP and TSS to Grouse and Silver Creeks.
b. Inspect permitted livestock facilities to ensure compliance.
c. Ensure pollution prevention practices are employed by animal feeding operations and ensure manure is managed, including proper land application rates that will prevent runoff of applied manure.

Nonpoint Source Pollution Technical Assistance – KDHE

a. Support implementation projects for reduction of runoff loads of TP and TSS from cropland, including erosion and sediment control practices.
b. Provide technical assistance on practices geared to the establishment of vegetative buffer strips.
c. Guide federal programs, such as the Environmental Quality Improvement Program and Conservation Security Program, to support installation of cropland and grazing Best Management Practices in Grouse Creek watershed.
d. Coordinate and support the Grouse Creek WRAPS group to incorporate a long-term plan to comprehensively reduce the loading and delivery of runoff-borne TSS and TP in the Grouse Creek watershed.
e. Encourage the review and revision of the WRAPS watershed plan in 2017 to incorporate information from implementation and monitoring efforts.

Water Resource Cost Share and Nonpoint Source Pollution Control Programs – KDA-DOC:

a. Apply conservation farming practices, including terraces and waterways, sediment control basins, and constructed wetlands in cropland.
b. Provide sediment control practices to minimize erosion and sediment and nutrient transport from cropland and grassland in the watershed.
c. Support installation of livestock management practices.

Riparian Protection Program – KDA – DOC:

a. Establish or re-establish natural riparian systems, including vegetative filter strips along small tributaries.
b. Develop riparian restoration projects in cropland and grazed areas.

Buffer Initiative Program – KDA-DOC:

a. Install buffer strips along small streams.
b. Work in conjunction with federal Conservation Reserve Enhancement Program and Conservation Security Program to hold marginal riparian land out of production.

Extension Outreach and Technical Assistance – Kansas State University:

a. Educate agriculture producers on cropland and livestock management and effective BMPs that reduce nutrient and sediment runoff.
b. Provide technical assistance on buffer strip design, techniques to minimize cropland runoff and construction of livestock feed and watering sites.
c. Provide planning assistance to local interests to support WRAPS activities in the Grouse Creek watershed.

Time Frame for Implementation: Pollutant reduction strategies and pollutant source assessment should be initiated within the Grouse Creek watershed in 2013 through the 9-element watershed plan for the Grouse-Silver Creek WRAPS. Pollutant reduction practices and implementation activities within the watershed should be initiated by 2013 and continue through 2020.

Targeted Participants: The primary participants for implementation will be agricultural operations immediately adjacent to streams within the watershed. Watershed District and Conservation district personnel and county extension agents should conduct a detailed assessment of sources adjacent to streams within the watershed over 2013 in conjunction with the 9-element watershed plan of the WRAPS. Implementation activities should target those areas that are located within a half mile of the streams within the watershed.

Milestone for 2017: In accordance with the long-range TMDL development schedule for the State of Kansas and the WRAPS watershed plan, the year 2017 marks the next cycle of 303(d) and 319 review of implementation data, stream chemistry and biological data for the Grouse Creek watershed. Runoff concentrations should show some reduction and median TP and TSS values during normal flow should be at or below current concentrations on Grouse Creek.

Delivery Agents: The primary deliver agents for program participation will be the Cowley County Conservation District, the Kansas State University Extension Service and the Grouse-Silver Creek WRAPS team (Grouse-Silver Creeks Watershed District #92). Implementation decisions and scheduling will be guided by planning documents prepared through the Grouse-Silver Creek WRAPS.

Reasonable Assurances:
Authorities: The following authorities may be used to direct activities in the watershed to reduce pollution.

1. K.S.A. 65-171d empowers the Secretary of KDHE to prevent water pollution and to protect the beneficial uses of the waters of the state through required treatment of sewage and established water quality standards and to require permits by persons having a potential to discharge pollutants into the waters of the state.

2. K.S.A. 2-1915 empowers the Kansas Department of Agriculture’s Division of Conservation (formerly State Conservation Commission) to develop programs to assist the protection, conservation and management of soil and water resources in the state, including riparian areas.

3. K.S.A. 75-5657 empowers the Division of Conservation to provide financial assistance for local project work plans developed to control nonpoint source pollution.

4. K.S.A. 82a-901, et. seq. empowers the Kansas Water Office to develop a state water plan directing the protection and maintenance of surface water quality for the waters of the state.

5. K.S.A. 82a-951 creates the State Water Plan Fund to finance the implementation of the *Kansas Water Plan*, including selected Watershed Restoration and Protection Strategies.

6. The *Kansas Water Plan* and the Lower Arkansas and Walnut Basin Plans provide the guidance to state agencies to coordinate programs intent on protecting water quality and to target those programs to geographic areas of the state for high priority in implementation.

Funding: The State Water Plan Fund annually generates $16-18 million and is the primary funding mechanism for implementing water quality protection and pollutant reduction activities in the state through the *Kansas Water Plan*. The state water planning process, overseen by the Kansas Water Office, coordinates and directs programs and funding toward watersheds and water resources of highest priority. Typically, the state allocates at least 50% of the fund programs supporting water quality protection through the WRAPS program. This watershed and its TMDL are High Priority consideration for funding.

Effectiveness: Nutrient and sediment control has been proven effective through conservation tillage, including no-till, contour farming, and use of grass waterways and buffer strips and filters. Proper implementation of comprehensive livestock and waste management plans and practices has been effective in reducing nutrient runoff associated with livestock and secured streambanks and channels from livestock trampling.

6. MONITORING

KDHE will continue to collect chemical and biological samples from Grouse and Silver Creeks at the permanent station on lower Grouse Creek and the rotational sites on Silver and upper Grouse Creek. The next scheduled visits to the rotational sites will be in 2014. Macroinvertebrate sampling and sestonic (floating) chlorophyll-a samples will be collected at both the lower and upper Grouse Creek sites. Additional sampling, such as ongoing efforts by Southwestern College, may be sponsored by the Grouse-Silver Creek WRAPS within the watershed to assess improvement in possible contributing areas.

7. FEEDBACK

Public Notice: An active internet website was established at http://www.kdheks.gov/tmdl/index.htm to convey information to the public on the general establishment of TMDLs and specific TMDLs for the Lower Arkansas Basin.

Public Hearing: Since this is a protection TMDL, no approval from EPA is necessary and a Public Hearing on the TMDL was foregone.

Basin Advisory Committee: The Walnut Basin Advisory Committee met to discuss this TMDL on March, 2013. (Under planning protocols of the Kansas Water Office, the

Grouse Creek Watershed falls under the Walnut Basin Advisory Committee for planning purposes.

Watershed Restoration and Protection Strategy Group: This TMDL has been reviewed in 2013 by the Grouse-Silver Creek WRAPS group.

Milestone Evaluation: In 2017, evaluation will be made as to the degree of implementation which has occurred within the watershed pursuant to the Grouse-Silver Creek WRAPS 9-element plan. Subsequent decisions will be made regarding the implementation approach, priority of allotting resources for implementation and the need for additional or follow up implementation in this watershed at the next TMDL cycle for this watershed in 2017 with consultation from local stakeholders and WRAPS teams.

Developed January 25, 2013

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Appendix A. Classified Streams in Grouse Creek watershed.

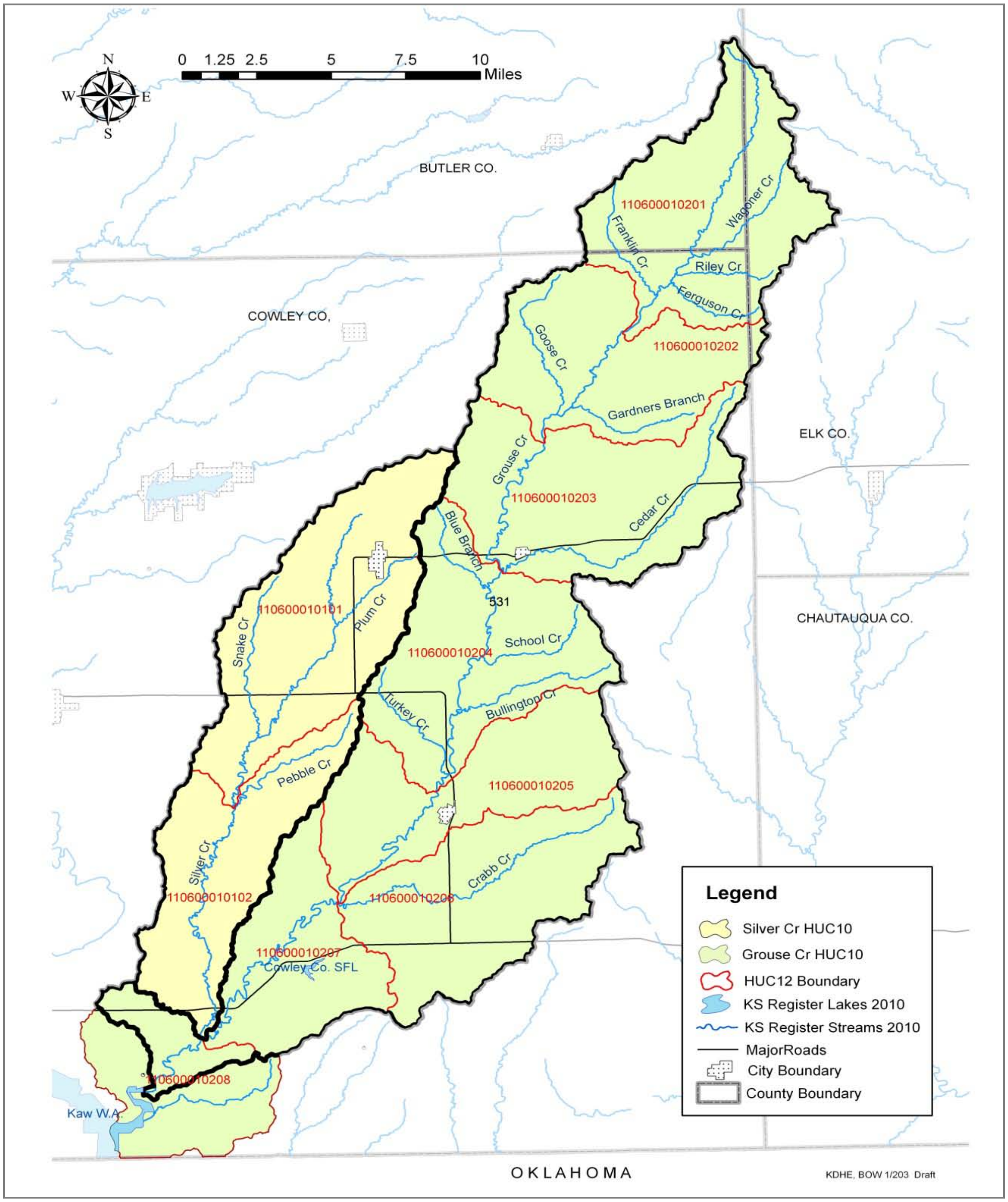

Figure A.1. Classified streams in Grouse Creek watershed.

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