Water Quality Improvement Plan for

Silver Creek

Clayton County, Iowa

Total Maximum Daily Load
for Sediment and Ammonia

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General Report Summary

What is the purpose of this report?

This Water Quality Improvement Plan serves multiple purposes. First, it is a resource for guiding locally-driven water quality improvements in Silver Creek. Second, it satisfies the Federal Clean Water Act requirement to develop a Total Maximum Daily Load (TMDL) report for all federally impaired waterbodies. As an impaired waterbody, Silver Creek is eligible for financial assistance to improve water quality. This document is meant to help guide watershed improvement efforts to remove Silver Creek from the federal 303(d) list of impaired waters.

What is wrong with Silver Creek?

Silver Creek is not supporting its Class B (WW-2) aquatic life designated use. Class B (WW-2) is defined as small warmwater streams which support fish populations primarily composed of minnows and other nongame species. Silver Creek was first added to the Section 303(d) Impaired Waters List in 2002 following biological sampling in 2000. It was determined that the Silver Creek biological community was impaired based on assessment of the fish and benthic macroinvertebrate communities. Benthic macroinvertebrates are animals that are larger than 0.5 mm and lack backbones.

Because the cause (stressor) of the poor condition of the biological community was unknown, a method called Stressor Identification (SI) was used to determine the primary stressors in Silver Creek. The SI procedure relates impairments described by biological assessments to one or more specific causal agents (stressors) and separates water quality (pollutant) impacts from habitat alteration impacts. The SI determined that the primary pollutant related causal factors in the Silver Creek water quality impairment are sediment and ammonia. The Stressor Identification document can be found at http://www.iowadnr.gov/water/watershed/tmdl/files/final.si_silver10tmdl.pdf.

What is causing the problem?

Excess sediment negatively impacts a stream's biological community in two ways. First, deposits of fine sediment on the bottom of the channel bury vital habitat used by fish and benthic macroinvertebrates. Second, suspended sediments can impair respiration by clogging gills and can reduce visibility, making it harder for predators to find their prey. Ammonia can affect stream life at both acute and chronic levels. Acute levels of ammonia kill fish and benthic macroinvertebrates in the stream. Chronic levels of ammonia are lower but, with repeated exposure, they can reduce growth and hatching rates, cause damage to gill, liver, or kidney tissue, and increase susceptibility to disease.

Sediment and ammonia can originate from point or nonpoint sources, or a combination of both. Point sources of pollution are easily identified sources that enter a waterbody at a distinct location, such as a wastewater treatment plant outfall. Nonpoint sources of pollution are discharged in a more indirect and diffuse manner, and are often more difficult to locate and quantify. Nonpoint source pollution is usually carried by rainfall or snowmelt over the land surface and into a nearby lake or stream.

The area of land that drains to a lake or stream is called a watershed. Watershed runoff often carries pollutants with it that can degrade water quality. In Silver Creek, the primary nonpoint pollution sources are soil erosion from agricultural land uses, and direct deposition of ammonia via defecation or urination by livestock with access to streams. Both of these nonpoint sources can be reduced by implementing land management practices that control soil loss and livestock stream access. Modeling has demonstrated that the two point sources in the watershed—the City of Monona Wastewater Treatment Plant and the Swiss Valley Farms Creamery—are not contributing to the sediment and ammonia impairments in the lower (impaired) section of Silver Creek.

What can be done to improve Silver Creek?

To improve water quality and the overall health of Silver Creek, the amount of sediment and ammonia entering the stream must be reduced. A combination of land and animal management practices must be implemented in the watershed to obtain necessary reductions. Potential watershed improvement measures include:

- increased use of conservation tillage,
- adoption of manure and fertilizer application strategies to reduce ammonia loss,
- construction of grass waterways, buffer strips, terraces, and sediment control basins,
- restricting access of livestock to stream and providing permanent watering structures away from the stream, and
- rotational grazing.

Who is responsible for a cleaner Silver Creek?

Everyone who lives or works in the Silver Creek watershed has a role in water quality improvement. Because the pollutants are from non-point sources, voluntary management of land and animals will be required to see positive results. Much of the land in the watershed is in agricultural production, and financial assistance is often available from government agencies to individual landowners willing to adopt changes in tillage practices and manure management. Financial assistance may also be available for the restoration of wetlands that naturally filter sediment and nutrients from water before it enters the stream. Improving water quality in Silver Creek will require a collaborative effort of citizens and agencies with a genuine interest in protecting the stream now and in the future.

Technical Elements of the TMDL

Name and geographic location of the impaired or threatened waterbody for which the TMDL is being established:	Silver Creek, located in Clayton County Hydrologic Unit Code: HUC8 07060004 IDNR Waterbody ID: IA 01-TRK-0381_0 Section 16 T94N R5W (Mouth) Section 32 T95N R5W (confluence with unnamed tributary)
Surface water classification and designated uses:	A1 Primary Contact Recreation B(WW-2) Aquatic Life
Impaired beneficial uses:	B(WW-2) Aquatic Life
Identification of the pollutants and applicable water quality standards:	Biological targets are based on the Fish Index of Biotic Integrity (FIBI) and Benthic Macroinvertebrate Index of Biotic Integrity (BMIBI). Stream segments having FIBI or BMIBI scores below the 25th percentile of reference sites are considered impaired. In order to meet the biological targets, secondary targets are set for delivered sediment and ammonia. Measurements from the monitored Silver Creek stream segments are compared to stream reference sites within the same ecological region. These biotic index targets are set for scores equaling or exceeding the 25th percentile of regional reference sites.
Quantification of the pollutant loads that may be present in the waterbody and still allow attainment and maintenance of water quality standards:	Sediment target is set at 3285 tons per year (maximum daily load = 154 tons/day) Ammonia target: 12.33 lbs per day
Quantification of the amount or degree by which the current pollutant loads in the waterbody, including the pollutants from upstream sources that are being accounted for as background loading, deviate from the pollutant loads needed to attain and maintain water quality standards:	The long term average for sediment indicates an annual load of 14,930.4 tons per year. Ammonia loads are episodic and exceed toxicity given stream temperature and pH conditions.
Identification of pollution source categories:	Nonpoint source pollutants have been identified as sources of impairments to Silver Creek. They include runoff from agricultural land uses and livestock with direct access to the stream.

Wasteload allocations (WLA) for pollutants from point sources:	There are two point sources contributing sediment into Silver Creek. Swiss Valley Creamery 50.2 tons/year and Monona Waste Water Treatment Plants: 14.2 tons/year During low flow the point sources are hydrologically disconnected from the watershed via sinkhole drainage. Therefore there is no WLA given for ammonia
Load allocations (LA) for pollutants from nonpoint sources:	The sediment LA is set to 2892.1 tons per year or 135.57 tons per day based on a 78 percent reduction from the current load. Ammonia LA is set at 11.10 lbs/day based on meeting Iowa Water Quality Standards (WQS).
A margin of safety:	An explicit margin of safety (MOS) of 10 percent was used for the sediment TMDL. An explicit of 10 percent MOS was used for the ammonia TMDL.
Consideration of seasonal variation:	Seasonal variation is accounted for in the calculation of the TMDL via statistical analysis including a coefficient of variation.
Reasonable assurance that load allocations will be met:	Load allocations can be achieved voluntarily by participation in a watershed management plan with implementation of best management practices.
Allowance for reasonably foreseeable increases in pollutant loads:	Nearly all available land for intensive agriculture is currently under such use and livestock populations appear stable. The Monona WWTP has treatment capacity for a 29 percent population growth (based on 2000 census data), although the population appears to be declining. Therefore no allowance for an increase in pollutant loads was given.
Implementation plan:	Although not required by the Clean Water Act, a general Implementation Plan is included in this report to assist managers in removing this stream from the 303(d) Impaired Waters List.

1. Introduction

The Federal Clean Water Act requires all states to develop lists of impaired waterbodies that are not meeting water quality standards (WQS) and designated uses. This list of impaired waterbodies is referred to as the state's 303(d) list. In addition to developing the 303(d) list, a Water Quality Improvement Plan, or Total Maximum Daily Load (TMDL) report, must also be developed for each impaired waterbody included on the list. Silver Creek was first added to the Section 303(d) Impaired Waters List in 2002 following biological sampling in 2000 as part of the Iowa Department of Natural Resources (IDNR) stream biocriteria project. It was determined that the Silver Creek biological community was impaired based on assessment of the fish and benthic macroinvertebrate communities. Benthic macroinvertebrates are animals that are larger than 0.5 mm and lack backbones. These animals live on rocks, logs, sediment, debris and aquatic plants during some period in their life. They include crayfish, mussels, snails, aquatic worms, and the immature forms of aquatic insects such as stonefly and mayfly nymphs.

Because the cause (stressor) of the poor condition of the biological community was unknown, a method called Stressor Identification (SI) was used to determine the existing stressors in Silver Creek. The process involves "critically reviewing available information, forming possible stressor scenarios that might explain the impairment, analyzing those scenarios, and producing conclusions about which stressor or stressors are causing the impairment" (U.S. EPA 2000). The SI determined that excess sediment and ammonia were causing the impairment in Silver Creek. The document can be found at:
http://www.iowadnr.gov/Environment/WaterQuality/WatershedImprovement/WatershedResearchData/WaterImprovementPlans/PublicMeetingsPlans.aspx

Document name: si silver10tmdl.pdf

A TMDL is a calculation of the maximum amount of a pollutant a waterbody can receive without exceeding the water quality standards. The TMDL is allocated to permitted point sources (wasteload allocations), nonpoint sources (load allocations), and an allowance for a margin of safety to account for uncertainty in the TMDL calculation. The TMDL calculation is represented by the following general equation:

$$TMDL = LC = \Sigma\ WLA + \Sigma\ LA + MOS$$

Where:

TMDL	=	total maximum daily load
LC	=	loading capacity
Σ WLA	=	sum of wasteload allocations (point sources)
Σ LA	=	sum of load allocations (nonpoint sources)
MOS	=	margin of safety (to account for uncertainty)

One purpose of this Water Quality Improvement Plan for Silver Creek, located in Clayton County in northeast Iowa, is to serve as the TMDL for sediment and ammonia. The second purpose of the plan is to provide local stakeholders and watershed managers with a tool to promote awareness of water quality issues, guide watershed improvement efforts, and assist the development of a Watershed Management Plan and subsequent funding applications for water quality improvement projects.

The water quality parameters addressed by this plan are sediment and ammonia, which are adversely affecting the biological community in Silver Creek. The plan outlines a phased approach to TMDL development and implementation. A phased approach is helpful when the origin, interaction, and quantification of pollutants contributing to water quality problems are complex and difficult to fully understand and predict.

The TMDL includes an assessment of existing pollutant loads to the stream and a determination of how much of a specific pollutant the stream can tolerate and still meet water quality standards and support its designated uses. The allowable amount of pollutant the stream can receive is the loading capacity, also called the target load. The TMDL also includes a description of potential solutions to the water quality problem. This group of solutions is generally defined as a system of best management practices (BMPs) that will improve water quality in Silver Creek with the ultimate goal of supporting all designated uses. These BMPs are outlined in the implementation plan in Chapter 6. A water quality monitoring plan designed to help assess water quality improvement and BMP effectiveness is provided in Chapter 7.

This Water Quality Improvement Plan will be of little value to real water quality improvement unless a Watershed Management Plan is developed and watershed improvement activities and BMPs are implemented. This will require the active engagement of local stakeholders and the collaboration of several state and local agencies. Completion of the TMDL should also be followed by several other actions, including:

- collection of biological and water quality data as part of an ongoing monitoring plan,
- evaluation of collected data, and
- modification of the targets and/or implementation plan (if necessary).

Monitoring is a crucial element in assessing attainment of water quality standards and designated uses, determining if water quality is improving, degrading, or remaining unchanged, and assessing the effectiveness of implementation activities and the possible need for additional BMPs.

2. Description and History of Silver Creek

The Silver Creek watershed includes a total of 17,909 acres (28.1 square miles) in the northwest portion of Clayton County, extending east from Luana to the outskirts of Monona, to a point where Silver Creek empties into Roberts Creek about three miles north of St. Olaf. The main stem flows in a south-southeasterly direction. The impaired segment is the lower 4.9 miles of the main stem, from the confluence with an unnamed tributary to the confluence with Roberts Creek (Fig. 2-1).

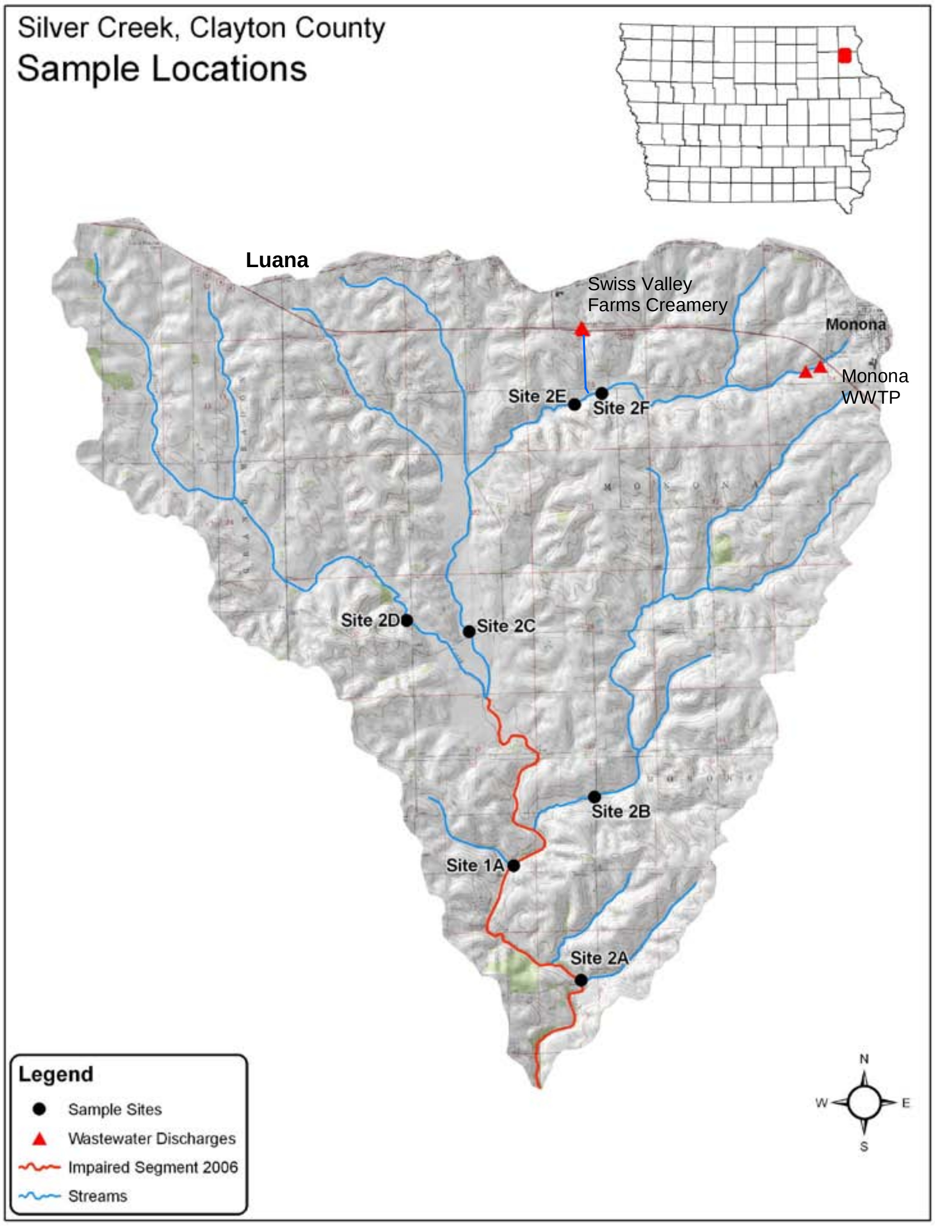

Figure 2-1. The Silver Creek watershed with the impaired stream segment, TMDL sampling sites (Site 1A—2000, Sites 2A-F—2006), and point sources.

2.1. Silver Creek

Hydrology. Silver Creek flows near the towns of Luana and Monona through a largely agricultural landscape to its junction with Roberts Creek. Approximately 17 miles downstream, Roberts Creek joins the Turkey River just south of the town of Elkader. The Silver Creek basin consists of a single HUC 12 sub-watershed with several small, unnamed tributaries. The Silver Creek watershed contains numerous sinkholes (common in the karst geology of the region), many of which are located in or around the channel. Surface flow from this and many surrounding watersheds contributes to groundwater flow, which eventually resurfaces outside the Silver Creek watershed at Big Spring (Halberg et al. 1983). These geological features directly impact stream flow in Silver Creek. It was noted during the 2006 Rapid Assessment of Stream Conditions Along Length (RASCAL) assessment that a large percentage of stream flow enters the groundwater system at several sinkholes located along the channel (Fig. 2-2) and that springs contribute to the stream flow of Silver Creek in several locations (Fig. 2-3), possibly influencing water quality (Palas 2007).

Figure 2-2. In-stream sinkhole in Silver Creek.

Morphometry & Substrate. The main channel of Silver Creek has a slope (measurement of a change in elevation in feet per mile of channel) of 16.72 feet/mile and a sinuosity ratio of 774.24, indicating that the stream has not been excessively channelized. An average basin slope of 8.53 percent and a stream density (ratio of stream miles to square miles of the basin) of 1.46 indicate that surface flows reach the stream very quickly. Less than 11 percent of Silver Creek has a vegetated riparian buffer zone width of more than 60 feet and there are several areas with notable bank erosion. Silver Creek substrates are dominated by silt and sand, with only a few stretches with cobble substrate in the lower portion of the watershed.

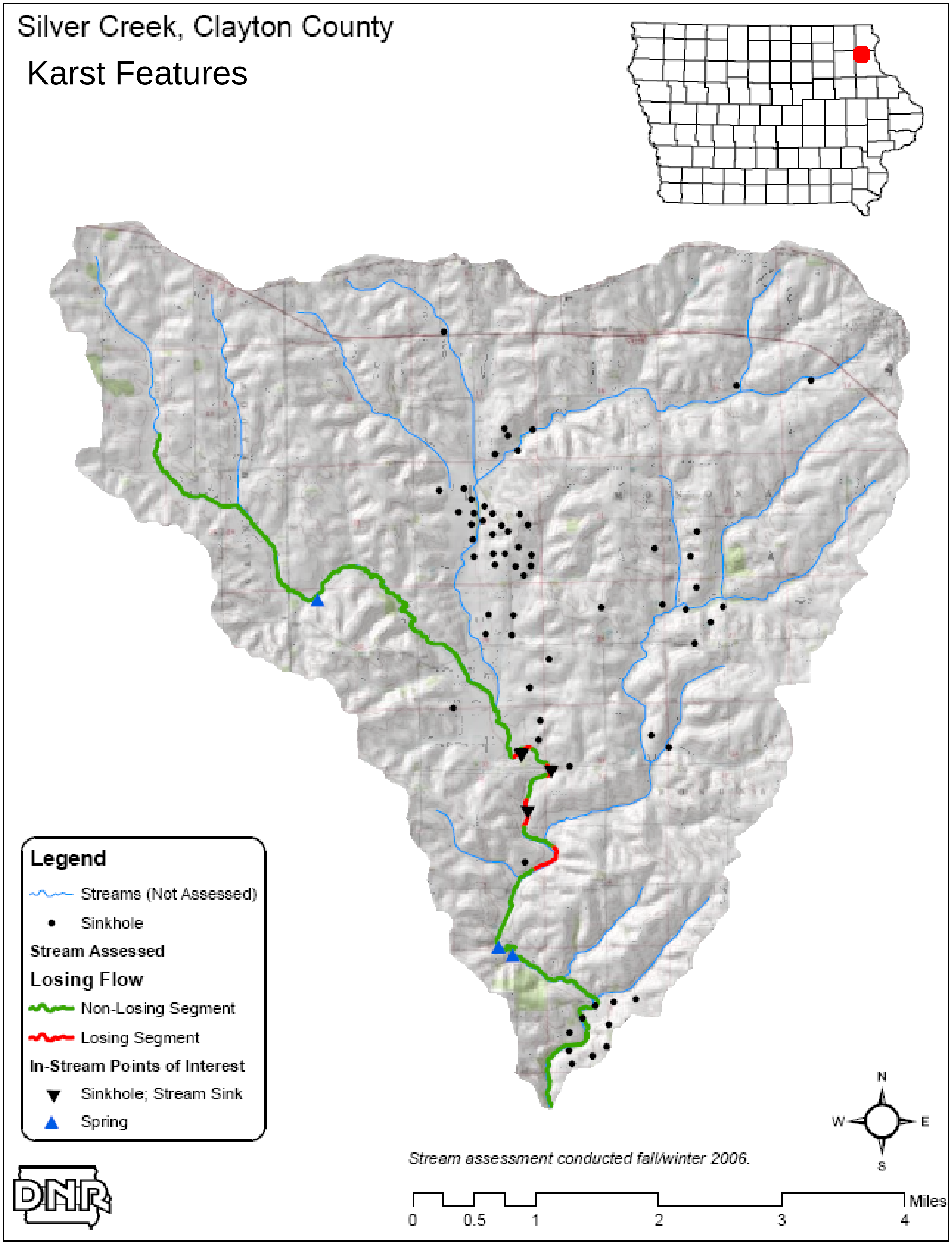

Figure 2-3. Locations of springs, sinkholes, and in-stream sinks in the Silver Creek watershed.

2.2. The Silver Creek Watershed

Land Use. Current land use in the watershed is dominated by agriculture (Table 2-1). According to the 2006 RASCAL analysis and tablet PC land cover/land use assessment, approximately 87 percent of the 17,909 acres in the watershed are devoted to row crop agriculture (Palas 2007). Livestock is also prevalent in the area. Based on the assessment, cattle graze more than 41 percent of the stream channel, with higher percentages in the lower portion of the watershed. This coincides with an analysis of 2002-2006 aerial imagery that shows most hay and small grains production concentrated in the south and western portions of the watershed.

Table 2-1. 2002 land uses in the Silver Creek watershed.

Land cover	Area, acres	Percent of total
Corn	7,300.7	40.8
Ungrazed and CRP grassland	76.8	0.4
Soybeans	4,404.7	24.6
Alfalfa	891.8	5.0
Roads, barren, unknown	2,182.5	12.2
Forest	436.0	2.4
Grazed grassland	1,077.6	6.0
Commercial industrial	604.5	3.4
Other row crop	245.3	1.4
Residential	579.7	3.2
Water and wetlands	109.0	0.6
Total	**17,908.6**	**100.0**

There are an estimated 2,946 cattle, 6,566 hogs, and 102 sheep held in pastures and feedlots in the watershed. These estimates are based on the 2002 Census of Agriculture for Clayton County. Although livestock inventories vary throughout the year depending on sale and slaughter rates, it is assumed that the census number is representative of the average population for the year. The county level data was reduced by calculating the percentage of the county that is part of the watershed, assuming an even distribution of livestock. Runoff from livestock can deliver substantial quantities of nutrients, oxygen demanding pollutants, and ammonia to streams depending on factors such as proximity to surface water, number and type of livestock, and manure controls.

Soils, climate, and topography. The watershed is within the bedrock-dominated terrain of the Driftless Area of the Paleozoic Plateau ecoregion (52b), which is strikingly different from the rest of Iowa (Fig. 2-4). Steep slopes and bluffs, higher relief, sedimentary rock outcrops, dense forests, and unique boreal forest microhabitats differentiate this ecoregion from the Western Corn Belt Plains (47) to the west (Prior 1991; Griffith et al., 1994). The Silurian Escarpment, a prominent physiographic feature that helps define the southern and western boundary of this ecoregion, separates the mostly cropland area of the west from the mixed land use of the driftless area. Dissolution of limestone and dolomite rocks results in karst features such as sinkholes, caves, and springs, and makes groundwater vulnerable to contamination. The streams of this region are located in entrenched valleys, and have cool waters with high gradients flowing over rocky substrates. The fish communities found here reflect a preference for cool, clear water with relative consistency of flow.

The geological composition of Silver Creek's watershed (fractured limestone bedrock covered by a thin layer of soil) increases the threat of agricultural pollutants to the groundwater. The soil survey report for Clayton County documents over 60 sinkholes in the Silver Creek watershed, including locations in or adjacent to the stream channel (Fig. 2-3). At these points, nearly all of the surface water flow enters the groundwater system, eventually resurfacing outside the Silver Creek watershed at Big Spring (Halberg et al. 1983).

The climate is typical of the Midwest, with most of the annual rainfall occurring from late spring through early fall. Spring and summer rainfall can be intense, with large amounts of rain occurring in short time spans. High intensity rainfall increases the potential for localized flooding and soil erosion. From January 1990 to December 2008, average annual precipitation at the National Weather Service (NWS) COOP station located in Waukon (15 miles north of watershed) was 41.3 inches (IEM 2008).

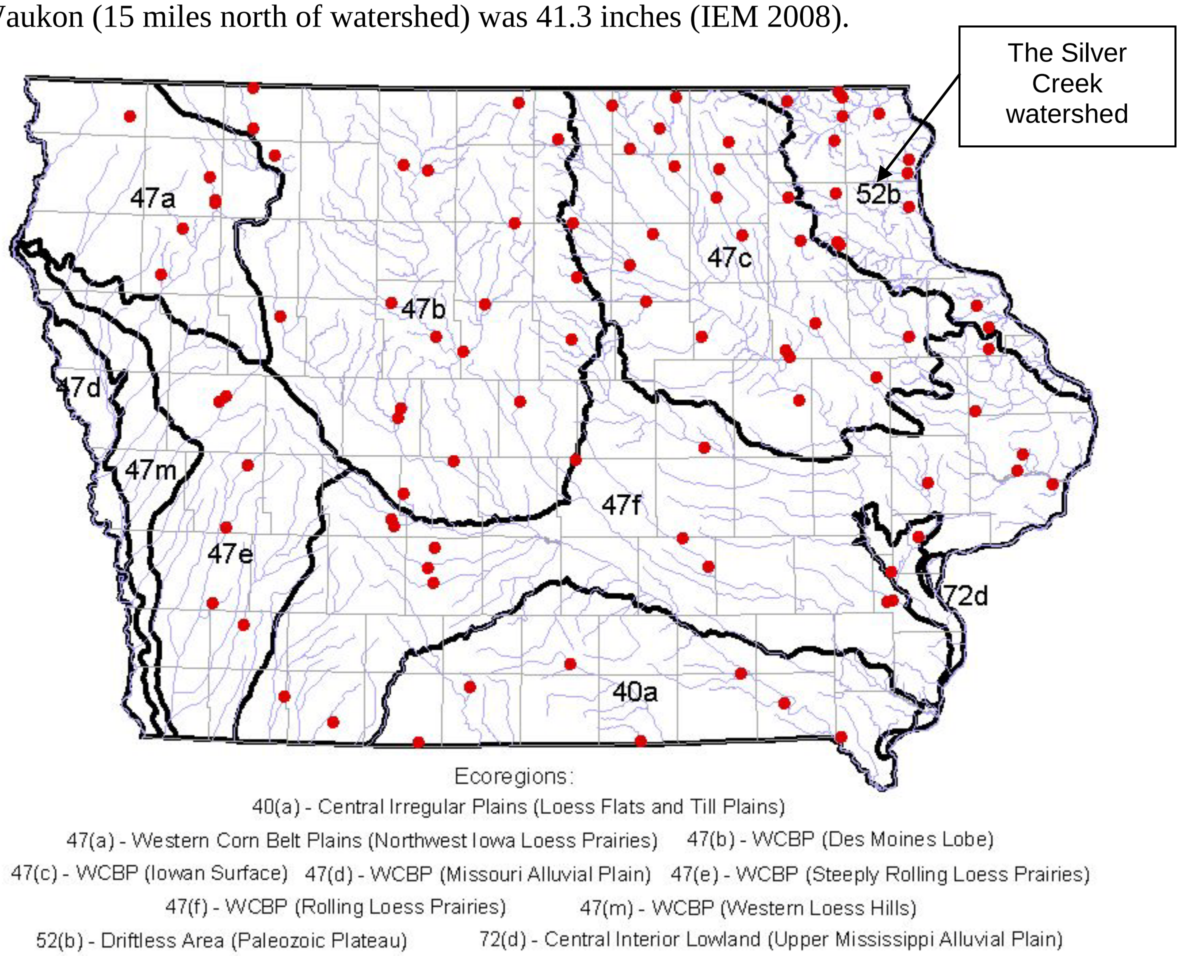

Figure 2-4. Iowa ecoregions and wadeable stream reference sites (red dots). The Silver Creek watershed is under the two in ecoregion 52b.

3. Problem Identification

3.1. Applicable water quality standards.

The Iowa stream classification document designates the protected aquatic life use for Silver Creek, Clayton County as B (WW-2). Class B (WW-2) streams are small warmwater streams which support fish primarily composed of minnows and other nongame species. In 1998, the aquatic life use was assessed as "partially supporting" based on a 1991 stream use assessment. Biological assessments conducted in 2000 at one site in the stream confirmed that the biological community in Silver Creek did not meet expectations, so the stream was added to the 2002 303(d) Impaired Waters List as "not supporting" its aquatic life use.

The methods used to determine support of aquatic life use include calculating a series of biological metrics that reflect stream water quality and habitat integrity from the biological sampling data collected. The metrics are based on the numbers and types of benthic macroinvertebrate and fish species that were collected. The biological metrics were combined to make a fish index of biotic integrity (FIBI) and a benthic macroinvertebrate index (BMIBI). The biotic indexes rank the biological integrity of a stream sampling reach on a scale from 0 (minimum) to 100 (maximum). Table 3-1 shows general qualitative scoring guidelines for the two indexes.

Table 3-1. Qualitative scoring guidelines for the BMIBI and FIBI.

Biological Condition Rating	BMIBI	FIBI
Poor	0 - 30	0 -25
Fair	31 - 55	26 - 50
Good	56 - 75	51 - 70
Excellent	76 - 100	71 - 100

Biological sampling from reference streams in Iowa's ecoregions has been used to derive target BMIBI and FIBI scores for each ecoregion (See Section 2, Fig. 2-4). The reference stream BMIBI and FIBI scores shown are the minimum scores for biological integrity that support aquatic life use in ecoregion 52b (Table 3-2). Below these values a stream is considered either partially or not supporting designated uses. The stream is then listed for a biological impairment of undetermined cause based on low FIBI and/or BMIBI scores. The Silver Creek BMIBI and FIBI scores are well below the ecoregion 52b biological impairment conditions (Table 3-3).

Table 3-2. Reference criteria for assessing biological integrity.

Ecoregion	BMIBI	FIBI
52B Ref. (Paleozoic Plateau)	61	52

IDNR staff followed the SI protocols to determine the cause of the Silver Creek biological impairment. The SI procedure relates impairments described by biological assessments to one or more specific causal agents (stressors) and also separates water quality (pollutant) impacts from habitat alteration impacts. The SI determined that the primary pollutant related causal factors in the Silver Creek water quality impairment are sediment and ammonia.

The State of Iowa Water Quality Standards (WQS) are published in the Iowa Administrative Code (IAC), Environmental Protection Rule 567, Chapter 61. Although the State of Iowa does not have numeric criteria for sediment, narrative water quality criteria do apply. Chapter 61.3(2) of the WQS contains the general water quality criteria, which are applicable to all surface waters. These narrative criteria require that waters be free of "aesthetically objectionable conditions" and "substances…in quantities which would produce undesirable or nuisance aquatic life". The State of Iowa does have numeric criteria for ammonia in Chapter 61.3(3). The ammonia standards vary depending on the pH and temperature of the water; therefore, there is no single numeric criterion for ammonia. The WQS can be accessed on the web at http://www.iowadnr.com/water/standards/files/chapter61.pdf.

3.2. Problem statement.

In 2002, the stream was assessed as "not supporting" because the 2000 monitoring assessment revealed poor biological integrity. The FIBI and BMIBI scores for Silver Creek from the 2000 sampling and additional biological sampling in 2005 are shown in Table 3-3. BMIBI and FIBI scores from sampling locations (See Section 2, Fig. 2-1) in the Silver Creek watershed generally indicate poor to fair biological condition based on the ratings in Table 3-1. The shaded columns list the Biological Impairment Criteria (BIC) that are determined from the range of IBI scores sampled from ecoregion 52b reference stream sites. The Silver Creek BMIBI and FIBI scores are below the ecoregion biological impairment conditions, which is strong evidence that the biological impairment is consistent across space and time.

Table 3-3. Index of Biotic Integrity scores for benthic macroinvertebrates (BMIBI) and fish (FIBI) from the Silver Creek Watershed.

Site	Year	BMIBI	BMIBI Biological Impairment Criterion (BIC)	FIBI	FIBI Biological Impairment Criterion (BIC)
Site 1A	2000	46	61	41	52
Site 2A	2005	26	61	19	52
Site 2E	2005	41	61	30	52

Data sources. Full biological sampling was performed at one location in 2000 (Site 1A) and two locations in 2005 (Sites 2A and 2E), with rapid bioassessment protocol (RBP) sampling at two additional sites in 2005 (Sites 2D and 2F) (See Section 2, Fig. 2-1). Water quality samples were collected from three Silver Creek sites (2A, 2D, and 2E) biweekly from July through October 2006, monthly from November 2006 to March of 2007, and biweekly from April through June 2007. Although planned, water quality sampling was not possible at two sites (Sites 2B and 2C) because there was no flowing water at those sites in the summer of 2006. Additionally, diurnal temperature and dissolved oxygen fluctuations were monitored in 2007 at site 2A in May (for 14 days) and September (for 18 days). These data were used to determine the stressors that were causing the biological impairment in Silver Creek.

After the initial water quality data was collected, the first modeling attempts indicated a need for better resolution data for longitudinal modeling. Based on the aspects of the model that would not calibrate, it was determined that more water quality data directly downstream of the point sources were needed to better understand their influence in the watershed. Additional sampling sites were chosen and bi-weekly water samples were collected from June through September 2008 at two new sites (3A and 3B) and three sites from the original sampling plan from 2005 (2A, 2C, and 2E) (Fig. 3-1).

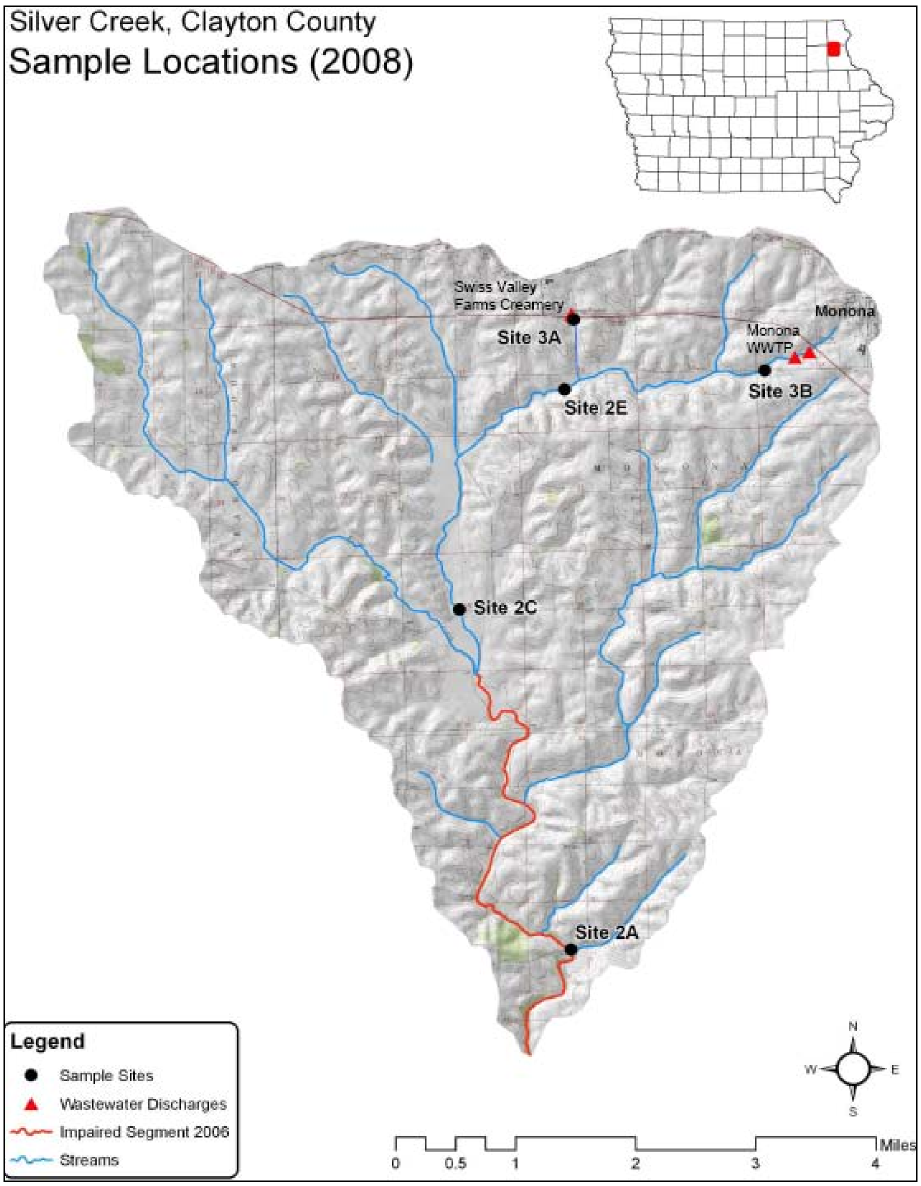

Figure 3-1. Additional sampling sites for June-September 2008 data collection.

Point Sources: There are two National Pollution Discharge Elimination System (NPDES) permitted point sources in the Silver Creek watershed; a wastewater treatment plant (WWTP) for the City of Monona and an industrial site, the Swiss Valley Farms Creamery (Table 3-4). The City of Monona had a population of 1,550 (2000 U.S. Census data), but the population appears to be declining according to real estate estimates.

Table 3-4. Point Sources in the Silver Creek Watershed.

Facility	Monona (WWTP)	Swiss Valley Farms (Industrial)
IA NPDES #	2264001	2200100
EPA #	IA0036927	IA0003808
Treatment type	Activated sludge	Activated sludge
5-day Carbonaceous Biochemical Oxygen Demand (CBOD5) (mg/L)[1]	25 (30 day avg.)	35[2]/19[3]/13[4] (30 day avg.)
Total Suspended Solids (TSS) (mg/L)[1]	30	66 (30 day avg.)
pH[1]	6.0-9.0	6.0-9.0
Population equiv.	2,179	11,976
Design flow (MGD)[5]	0.312/0.1341/0.971	0.0/0.0/0.18

1. These are the NPDES permit limits for these facilities for CBOD5, TSS, and pH.
2. CBOD5 permit values for January and February for creamery
3. CBOD5 permit values for Mar. - June and Sept. – Dec. for creamery
4. CBOD5 permit values for July and August for creamery.
5. Average wet flow/Average dry flow/Maximum wet flow

The point sources do not significantly contribute to the delivered sediment load. However, because the two point sources do have permit limits for total suspended solids (TSS), continuous discharge loads of TSS from the Monona WWTP and the creamery are included in the TMDL analysis and TSS wasteload allocations for the facilities are included.

Modeling indicated that ammonia discharged from the point sources does not reach the impaired section during low flow because the water drains into a large sink hole in the upper portion of the impaired segment. Even so, continuous discharge loads of ammonia from the Monona WWTP and the creamery are included in the TMDL analysis and ammonia wasteload allocations for the facilities are included. These were included because Iowa does have a water quality standard for ammonia and, during high flow, a portion of this water bypasses the sinkhole.

3.3. Interpreting Silver Creek Data.

According to the Methodology for Developing Iowa's 2004 Section 303(d) List of Impaired Waters, reference stream FIBI and BMIBI scores shown in Table 3-2 for the watershed ecoregion are considered 'supporting' the aquatic life use. Silver Creek will be considered no longer impaired when the ecoregion 52b BICs are met.

Sediment. Although there are not specific numerical water quality standards for sediment, excessive sediment can adversely impact aquatic life as demonstrated in the Silver Creek SI process. Silver Creek has been shown to have quantities and coverage of stream bottom silt much higher than found in the reference streams for the ecoregion. This excess sediment adversely affects aquatic life. As shown in Table 3-5, the percentage of the substrate measured as silt was well outside the ecoregion inter-quartile range at sites 1A in 2000 and 2A and 2E in 2005. Typical levels of silt substrate in healthy streams in this ecoregion are much lower, with a mean of 18 percent and a median of 15 percent for Paleozoic Plateau reference sites.

The embeddedness of the streambed in riffle areas also impacts aquatic life. Riffles are shallow stretches of a stream where the current is above the average stream velocity and water forms small rippled waves as a result. Riffles often consist of a rocky bed of gravel or other small stones and are important habitat for benthic macroinvertebrates and juvenile fish. The riffle embeddedness rating indicates the percent of the coarse substrate area that has the interstitial spaces (area between rocks) filled by fine sediment and is scored on a scale of 1-5 (Table 3-6). In conjunction with copious bottom algae, the excess silt alters the physical habitat by crowding out benthic macroinvertebrates, changing the available food sources, and causing a negative shift in community composition (BMIBI score). The loss of interstitial spaces impacts fish reproductive activity and alters the organisms that are available as food (FIBI score).

Table 3-5. Comparison of altered substrate indicators at sites 1A, 2A, and 2E to the ecoregion reference sites.

Parameter	Site 1A (2000)	Site 2A (2005)	Site 2E (2005)	Ecoregion 52b Reference Range[2]
Substrate silt fraction[1]	60	90	70	8.5 to 29.67
Embedded riffle rating (Table 3-6)	5	4	3	1.93 to 2.43

1. Percent of bottom covered by silt. One measurement taken at each site.
2. Reference conditions are measured as the inter-quartile range (25^{th} percent value to 75^{th} percent value).

Table 3-6. Embedded riffle rating and related percent embeddedness of coarse substrate.

Embedded riffle rating	Percent of Coarse Substrate Embedded
1	0-20 %
2	20-40 %
3	40-60 %
4	60-80 %
5	80-100 %

Ammonia. Un-ionized ammonia is directly toxic to aquatic invertebrates and fish. Iowa has water quality standards designed to protect aquatic life against acute and chronic toxicity from un-ionized ammonia. The criteria are expressed as total ammonium ion concentration from which un-ionized ammonia concentration can be determined as a function of pH and temperature. For a given concentration of total ammonium ion, an increase in pH and/or temperature will result in an increase in un-ionized ammonia concentration. The water quality standards for acute and chronic ammonia toxicity for a range of pH conditions are shown in Table 3-7.

Table 3-7. Acute and Chronic WQS for Total Ammonia at 20°C, pH 8-9.

pH	Acute Criterion, mg/L - N	Chronic Criterion, mg/L - N
8.0	8.40	1.71
8.1	6.95	1.47
8.2	5.72	1.26
8.3	4.71	1.07
8.4	3.88	0.906
8.5	3.20	0.765
8.6	2.65	0.646
8.7	2.20	0.547
8.8	1.84	0.464
8.9	1.56	0.397
9.0	1.32	0.342

There were violations of Iowa's chronic ammonia WQS on two consecutive sampling occasions in the summer of 2006 at site 2A. On July 26th the ammonia level measured was 0.75 mg/L and the chronic criterion was 0.74 mg/L. On August 7th the ammonia level measured was 3.6 mg/L with a chronic criterion of 2.4 mg/L. These ammonia violations are not known to be associated with a runoff event or spill of animal waste or fertilizer. While ammonia violations occurred in the unnamed tributary to which the point sources discharge, they did not correspond with ammonia violations in the impaired section of Silver Creek. Modeling has shown that the sinkhole removes most of the water during low flow conditions. Additionally, as evidenced by the lack of water at site 2C in 2005, the water from the point sources never reached the impaired segment of Silver Creek in 2005.

High ammonia concentrations in Silver Creek are likely caused by runoff from manure and direct deposition by livestock with stream access and can cause serious water quality problems in three major ways:

1. Acute levels of ammonia kill fish and benthic macroinvertebrates in the stream.
2. Chronic levels of ammonia are lower but, with repeated exposure, they can reduce growth and hatching rates, cause damage to gills, liver, or kidneys, and increase susceptibility to disease.
3. Ammonia exerts an oxygen demand (OD) in streams through nitrification, depleting dissolved oxygen (DO). In addition, there is often an additional OD from heterotrophic bacteria growth and metabolism of organic components in manure.

4. TMDL for Sediment

A Total Maximum Daily Load (TMDL) for sediment is required for Silver Creek by the Federal Clean Water Act. This chapter quantifies the maximum amount of sediment that Silver Creek can tolerate without violating the state's water quality standards.

4.1. TMDL Target

General description of the pollutant. Excess fine sediments reduce the availability of favorable spawning habitat for fish and buries desirable habitat for benthic macroinvertebrates, thus reducing BMIBI and FIBI scores. Reducing sediment delivery in Silver Creek will improve BMIBI and FIBI scores by reducing streambed silt, embeddedness in riffle coarse substrates, suspended solids and turbidity, and increasing the size and quality of riffle and pool habitat.

Silt and sediment are naturally transported by streams and rivers. However, excessive sediment loads delivered from upland watershed sources via sheet, rill, and gully erosion can result in sediment deposition (siltation) of streams, causing a loss of aquatic habitat and reduced channel transport capacity. Excessive turbidity and siltation can be detrimental for sight-feeding fish, benthic-dwelling organisms, and basic aquatic life functions. Alterations to a stream's natural hydrologic regime, such as channelization and/or artificial drainage, can cause an imbalance in the natural discharge-sediment load equilibrium of the stream and lead to bed and bank degradation, contributing to excessive siltation/sedimentation (Lane, 1955).

Selection of environmental conditions. The SI performed on Silver Creek found that one of the specific causes of impairment to the benthic macroinvertebrate and fish communities is excessive siltation/sedimentation of the streambed. Critical or seasonal environmental conditions do not apply. Siltation/sedimentation poses long-term, chronic threats for aquatic life, and therefore does not warrant consideration for acute seasonal impacts.

Sources of water body pollutant loading. The major sources of sediment to Silver Creek include sheet and rill erosion and stream bank erosion. Point source inputs from the Monona Water Treatment Plant and the Swiss Valley Creamery are minor and account for less than one half of one percent of the total input. The estimated annual load from each source is as follows:

Sheet and rill erosion as estimated by RUSLE (see appendix D):	12,202 tons/year
Stream bank erosion (see appendix D):	2,664 tons/year
Swiss Valley Creamery:	50.2 tons/year
Monona Waste Water Treatment Plants:	14.2 tons/year
Total:	**14,930.4 tons/year**

Water body pollutant loading capacity (TMDL). The goal for Silver Creek is to reduce the average siltation/sedimentation rate of the streambed from its current level (average of 80 percent silt substrates between two sites) to that of the mean percentile of data for reference streams in the Paleozoic Plateau Ecoregion (18 percent silt). To achieve this, in-stream siltation/sedimentation of the channel would need to be reduced by 78 percent from current levels. Assuming that the relationship between external sediment delivery to the stream and the siltation/sedimentation rate of the streambed will remain proportional and constant over time, the external sediment loading reduction needed to achieve the TMDL target is also 78 percent. Based on the long term annual average sediment loading of 14,930.4 tons/year, the load capacity for sediment is 3,285 tons/year (avg. 9 tons/day).

In November of 2006, The U.S. Environmental Protection Agency (EPA) issued a memorandum entitled *Establishing TMDL "Daily" Loads in Light of the Decision by the U.S. Court of Appeals for the D.C. circuit in Friends of the Earth, Inc. v. EPA, et al., No. 05-5015, (April 25, 2006) and Implications for NPDES Permits.* In the context of the memorandum, EPA

> *"…recommends that all TMDLs and associated load allocations and wasteload allocations include a daily time increment. In addition, TMDL submissions may include alternative, non-daily pollutant load expressions in order to facilitate implementation of the applicable water quality standards…"*

As recommended by EPA, the loading capacity of Silver Creek for sediment is expressed as a daily maximum load, in addition to the allowable average annual load of 3,285 tons/year described above. The annual average load is more applicable to the assessment of in-stream water quality and water quality improvement actions, while the daily maximum load expression satisfies the legal uncertainty addressed in the EPA memorandum.

The maximum daily load was estimated from the annual average load using a statistical approach that is outlined in more detail in Appendix D. This approach uses a lognormal distribution to calculate the daily maximum from the long-term (e.g., annual) average load. The methodology for this approach is taken directly from a follow-up guidance document entitled *Options for Expressing Daily Loads in TMDLs* (EPA, 2007), and was issued shortly after the November 2006 memorandum cited previously. This methodology can also be found in EPA's 1991 *Technical Support Document for Water Quality Based Toxics Control*. Using this approach, the allowable maximum daily load (loading capacity) for sediment in Silver Creek is calculated to be 154 tons/day.

Decision criteria for water quality standards attainment. The decision criteria for water quality standards attainment in Silver Creek are based on meeting biological conditions typical of healthy reference streams for this ecoregion. This would require achieving and maintaining a BMIBI score of at least 61 and a FIBI score of at least 52.

4.2. Pollution Source Assessment

Existing load. Existing sediment loads delivered to Silver Creek are not regularly monitored, therefore long-term approximations of the annual sediment loads were estimated based on the Revised Universal Soil Loss Equation (RUSLE) and a cursory assessment of gullies and eroding stream banks present in the watershed. The annual existing load of sediment delivered to the stream is estimated to be 14,930.4 tons/year.

Departure from load capacity. The target for sediment loading to Silver Creek is 3,285 tons per year. Existing daily loads of sediment in the stream are 14,930.4 tons/year on average (Fig. 4-1). A 78 percent reduction in current annual sediment delivery to the stream is needed to achieve the TMDL target.

Identification of pollutant sources. Sediment is delivered to the stream during rain events from nonpoint sources throughout the watershed. Sheet and rill erosion occurring in agricultural fields represents the dominant source of sediment in the Silver Creek watershed (Fig. 4-2). The second largest source is stream bank erosion. Point sources account for less than one half of one percent.

Allowance for increases in pollutant loads. Most of the land area in the Silver Creek watershed available for row crop farming is currently under such land use practice. Stream channels in the watershed appear to be mostly stable at this time and are not expected to degrade or widen excessively in the coming years. Additionally, the population of Monona appears to be declining from a high of 1,550 in 2000 according to real estate estimates. Therefore, no allowance for increased sediment loads was given in the TMDL.

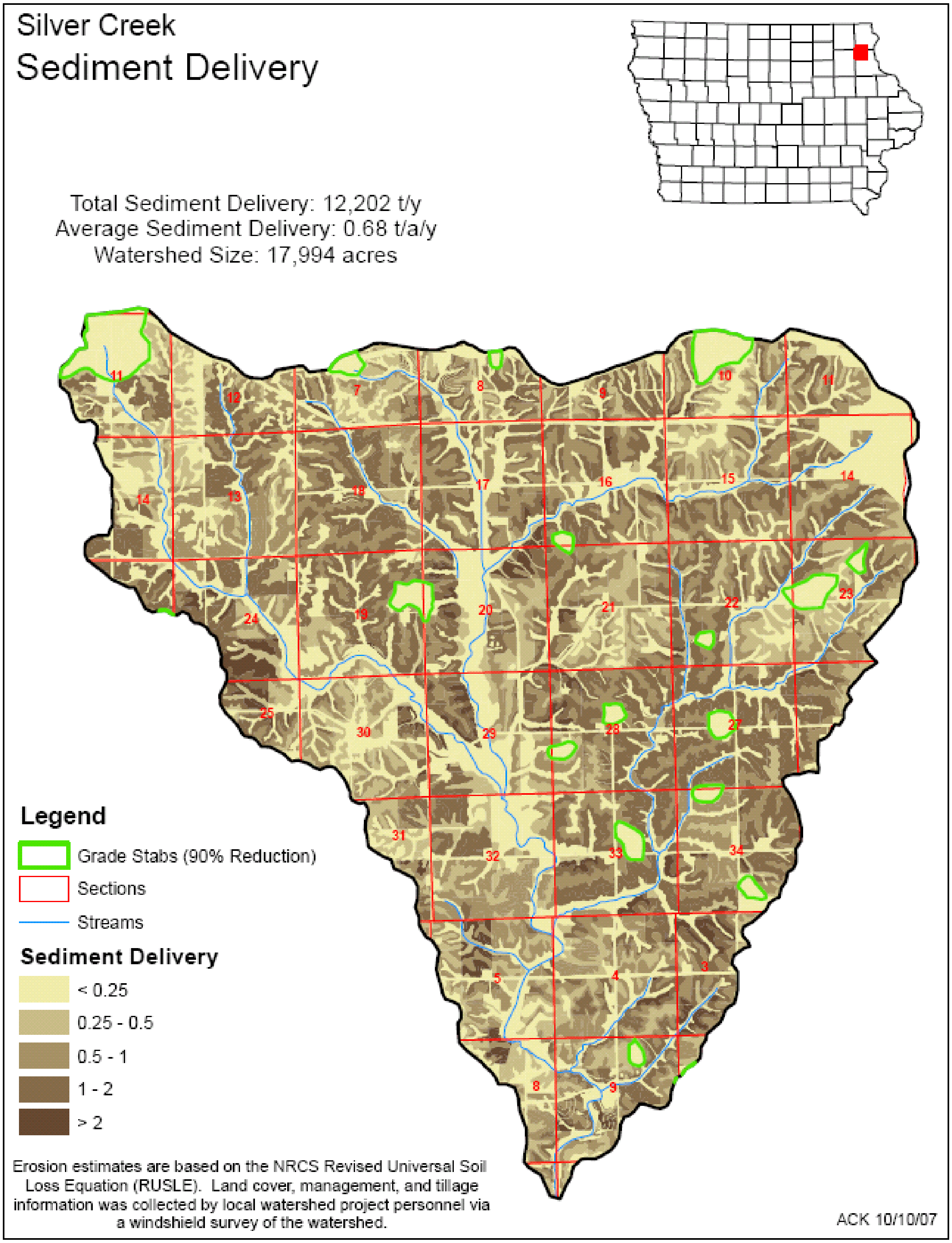

Figure 4-1. RUSLE estimate of sediment delivery in the Silver Creek watershed based on 2002 photography.

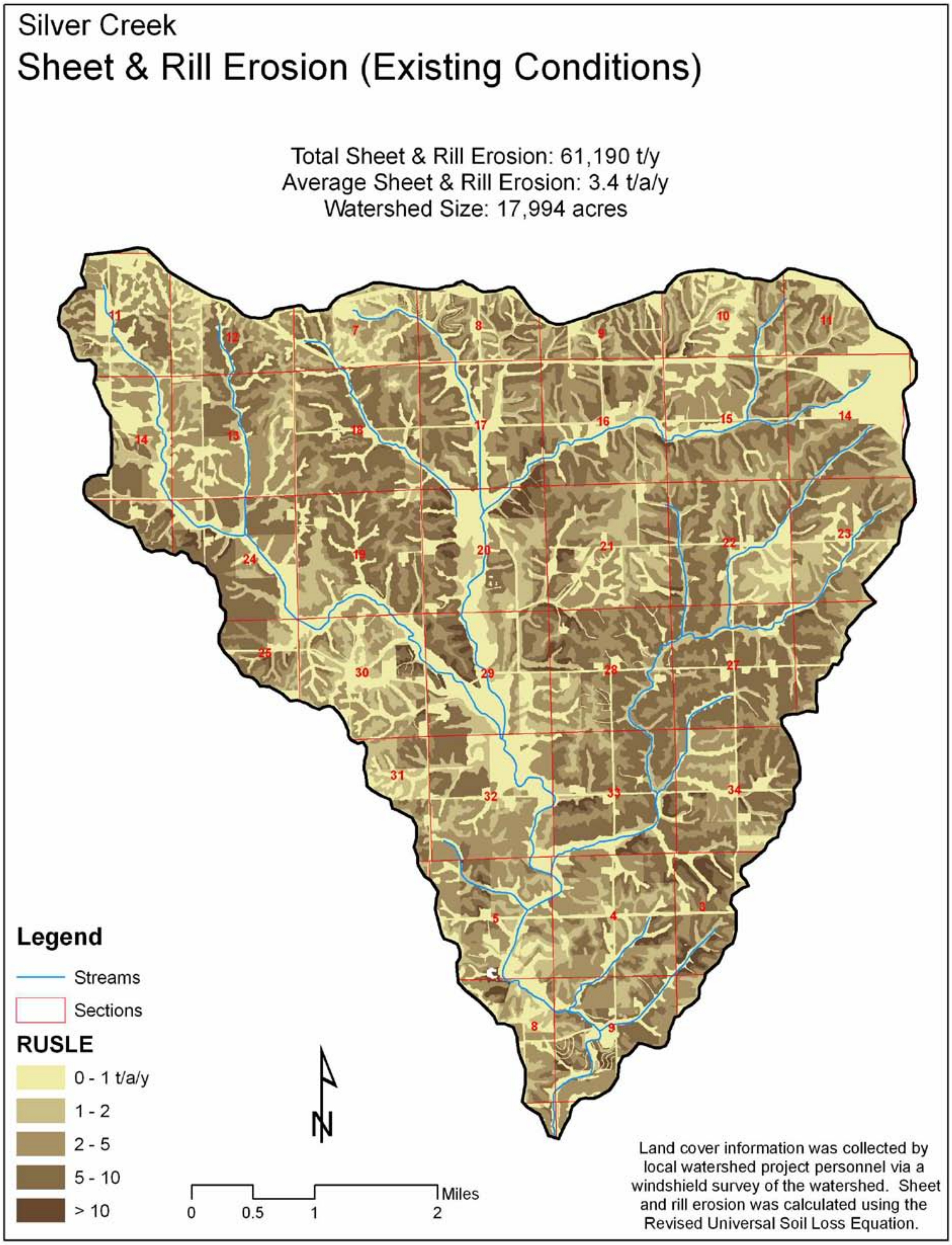

Figure 4-2. RUSLE estimate of sheet and rill erosion in the Silver Creek watershed based on 2002 photography**.**

4.3. Pollutant Allocation

Wasteload allocation. A wasteload allocation represents the portion of the TMDL attributed to point sources in the watershed. The only point source dischargers in the Silver Creek watershed are the City of Monona Wastewater Treatment Plant and the Swiss Valley Farms Creamery. Neither of these permitted facilities contribute a significant amount of sediment to the watershed. Even under the conservative assumption of both facilities discharging maximum daily loads at maximum flow capacity the sum of the contribution from both facilities would be less than one half of one percent of the total sediment load. Therefore no reductions were made to current permitted levels for these facilities resulting in the following WLAs:

Swiss Valley Creamery:	50.2 tons/year
Monona Waste Water Treatment Plants:	14.2 tons/year

Load allocation. The load allocation (LA) represents the portion of the TMDL attributed to nonpoint sources in the watershed. In Silver Creek, 99.6 percent of the existing sediment loads originate from nonpoint sources; therefore, the load allocation is 2,892.1 tons/year.

Margin of safety. To account for uncertainties in data or modeling, a margin of safety is a requirement of all TMDLs. For this TMDL, an explicit margin of safety of ten percent was used to account for uncertainties in nonpoint source sediment delivery. Furthermore, estimates of long term sediment loading were based on the absence of existing conservation practices which provides an additional implicit margin of safety.

4.4. Reasonable Assurance

Reasonable assurance for the reduction of nonpoint source loading is given by the availability of technical and financial assistance for conservation practices and watershed improvement grants. Funding made available to local stakeholder groups on an annual basis provides an opportunity for local citizens and landowners to seek their own solutions with technical guidance from state and local government agencies.

4.4. TMDL Summary

The following equation represents the Total Maximum Daily Load (TMDL) and its components for Silver Creek:

$$TMDL = LC = \Sigma\ WLA + \Sigma\ LA + MOS$$

Where:	TMDL	=	total maximum daily load
	LC	=	loading capacity
	Σ WLA	=	sum of wasteload allocations (point sources)
	Σ LA	=	sum of load allocations (nonpoint sources)
	MOS	=	margin of safety (to account for uncertainty)

Once the loading capacity, wasteload allocations, load allocations, and margin of safety have all been determined for the Silver Creek watershed, the general equation above can be expressed for the Silver Creek TMDL for sediment.

Expressed as the maximum annual average, which is helpful for water quality assessment and watershed management:

TMDL = LC = Σ WLA (64.4 tons/yr) + Σ LA (2,892.1 tons/yr)
+ MOS (328.5 tons/yr) = **3,285 tons/year sediment**

Expressed as the maximum daily load:

TMDL = LC = Σ WLA (3.01 tons/day) + Σ LA (135.57 tons/day)
+ MOS (15.4 tons/day) = **154 tons/day sediment**

5. Total Maximum Daily Load (TMDL) for Ammonia

A Total Maximum Daily Load (TMDL) for ammonia is required for Silver Creek by the Federal Clean Water Act. This chapter will quantify the maximum amount of ammonia that Silver Creek can tolerate without violating the state's water quality standards.

5.1. TMDL Target

General description of the pollutant. The stressor identification process identified episodic high levels of ammonia that lead to depleted dissolved oxygen conditions and toxicity issues for fish and benthic macroinvertebrates within the impaired segment of Silver Creek. Targets for ammonia toxicity are given in Table 3-7 (Section 3). Ammonia enters the stream as episodic events corresponding with run-off events or from defecation and elimination from livestock with direct access to the stream (Figure 5-1).

Figure 5-1. Silver Creek flowing through a cattle pasture.

Selection of environmental conditions. Ammonia toxicity is dependent on pH and temperature. Higher levels of ammonia will deplete oxygen levels within streams through the process of nitrification. In addition to ammonia toxicity, depleted oxygen levels are stressful to aquatic life. Because of the temperature and oxygen demand concerns, the critical period will be in the summer during times of higher temperatures and low-flow conditions when any inputs of ammonia to the stream will have greater impacts.

Water body pollutant loading capacity (TMDL). The TMDL was based on violating numeric water quality standards of either ammonia toxicity at an average pH and temperature for the stream in a summer month or the dissolved oxygen criteria by inputting ammonia. To simulate this, a model was built in QUAL2K. Appendix D outlines in detail the modeling approach used to achieve these results.

Decision criteria for water quality standards attainment. The decision criteria for water quality standards attainment in Silver Creek are based on meeting water quality standards for chronic ammonia toxicity and/or minimum dissolved oxygen criteria.

5.2. Pollution Source Assessment

Existing load. Ammonia toxicity is dependent on temperature and pH. Controlling the chronic ammonia toxicity in Silver Creek requires controlling episodic releases as opposed to reducing an existing load. Therefore, an existing load would consist of episodic events at given temperature and pH conditions. Ammonia also depletes dissolved oxygen. Therefore any source assessment must also consider the effects of episodic ammonia releases on the dissolved oxygen levels of the stream.

Identification of pollutant sources. The main pollutant sources to the impaired segment are nonpoint sources consisting of run-off from open feedlots and from defecation and elimination from livestock with direct access to the stream.

Allowance for increases in pollutant loads. No changes in land use are expected. Additionally, the population of Monona appears to be declining from a high of 1,550 in 2000 according to real estate estimates and the design capacity of the facility is for a population of 2,179. Therefore, there are no allowances for pollutant load increases.

5.3. Pollutant Allocation

Wasteload allocation. The Wasteload Allocation (WLA) is the sum of the wasteload allocations of the Monona WWTP and the Swiss Valley Farms Creamery. However these are not hydrologically connected to the impaired segment of Silver Creek as they are drained by a large in-stream sink hole during low-flow conditions before reaching the impaired segment. Therefore, a WLA is not applicable to this TMDL.

Load allocation. Nonpoint sources responsible for the ammonia impairment in the impaired section include runoff from animal feeding operations and livestock with direct access to, and defecating or urinating in, the stream. The daily load allocation was determined based on modeling (Appendix D) and is set at 11.10 lbs/day.

Margin of safety. The statutes and regulations require that a TMDL include a margin of safety to account for any lack of knowledge concerning the relationship between load and wasteload allocations and water quality. EPA guidance explains that the margin of safety (MOS) may be implicit (i.e., incorporated into the TMDL through conservative assumptions in the analysis) or explicit (i.e., expressed in the TMDL as loadings set aside for the MOS). An explicit margin of safety of ten percent was incorporated into the Silver Creek Ammonia TMDL.

5.4. Reasonable Assurance

Reasonable assurance for the reduction of nonpoint source loading is given by the availability of technical and financial assistance for conservation practices and watershed improvement grants. Funding made available to local stakeholder groups on an annual basis provides an opportunity for local citizens and landowners to implement their own solutions with technical guidance from state and local government agencies.

5.5. TMDL Summary

The following equation represents the TMDL and its components for Silver Creek:

$$TMDL = LC = \Sigma\, WLA + \Sigma\, LA + MOS$$

Where:	TMDL	=	total maximum daily load
	LC	=	loading capacity
	Σ WLA	=	sum of wasteload allocations (point sources)
	Σ LA	=	sum of load allocations (nonpoint sources)
	MOS	=	margin of safety (to account for uncertainty)

Once the loading capacity, wasteload allocations, load allocations, and margin of safety have all been determined for the Silver Creek watershed, the general equation above can be expressed for the Silver Creek TMDL for ammonia.

Expressed as a daily average:

$$\mathbf{TMDL} = LC = \Sigma\, WLA\ (n/a) + \Sigma\, LA\ (11.10\ lbs/day) + MOS\ (1.23) = \mathbf{12.33\ lbs/day}$$

6. Implementation Plan

This implementation plan is not a requirement of the Federal Clean Water Act. However, the Iowa Department of Natural Resources recognizes that technical guidance and support are critical to achieving the goals outlined in this TMDL. Therefore, this plan is included to be used by local professionals, watershed managers, and citizens to support decision-making and planning. The best management practices (BMPs) listed below represent a comprehensive list of tools that may help achieve water quality goals if applied in an appropriate manner; however, it is up to land managers, citizens, and local conservation technicians to determine exactly how best to implement them.

6.1. General Approach and Reasonable Timeline

Initiative and action by local landowners and citizens are crucial to improving the overall health of any watershed. This is especially true of the Silver Creek watershed because most of the land is privately owned. Watershed work and improvements to the creek should proceed in conjunction with a comprehensive monitoring system that will adequately characterize daily, seasonal, and annual pollutant loadings in the creek as well as the health of the biological community as improvements to the watershed are made.

General approach. The existing loads, loading targets, a general listing of BMPs needed to improve water quality and the health of the biological community, and a monitoring plan to assess progress are established in this TMDL. Ideally, the TMDL would be followed by the development of a watershed management plan. The watershed management plan should include more comprehensive and detailed strategies to better guide the implementation of specific BMPs. Other ongoing tasks required to obtain real and significant water quality improvements include continued monitoring, assessment of the biological community, assessment of water quality trends, assessment of WQS attainment, and adjustment of proposed BMP types, locations, and implementation schedule based on measured results.

Timeline. Development of a comprehensive watershed management plan takes time—perhaps as long as one to three years. Implementation of watershed BMPs could take upwards of five to ten years, depending on funding, willingness of landowner participation, and time needed for design and construction of any structural BMPs. Realization and documentation of water quality benefits and improvement in the biological community may take 10 years or longer, depending on weather patterns, amount of data collected, and the successful location, design, construction, and maintenance of BMPs. Utilization of the monitoring plan as outlined in Chapter 7 should begin immediately to establish baseline conditions, and should continue throughout implementation of BMPs and beyond.

6.2. Best Management Practices

The two major pollutants contributing to the impairment of Silver Creek are excess sediment and episodic ammonia toxicity. While both of these are the by-product of land management, they require different approaches to remediate them.

Sediment erosion and delivery to a waterbody are best controlled with land management and conservation practices that reduce bare ground and slow soil erosion, thereby slowing and reducing sediment loads delivered to streams. These practices include such things as vegetated buffer strips, terraces, contour farming, no-till practices, water and sediment control structures, sediment basins, and grassed waterways. Additionally, targeted bank and stream stabilization practices and restricting cattle access to the stream would help reduce in-stream sediment delivery. Currently, less than 11 percent of the main stem has a riparian zone of more than 60 feet and more than 81 percent of Silver Creek is flanked by pasture and row crops and has a riparian zone of less than 10 feet (Figure 6-1) (Palas 2007). Fifteen acres of filter strips in the headwater area of Silver Creek represent the largest continuous block of land enrolled in the Conservation Reserve Program (CRP) in the watershed and only 74 acres total of the 17,991 acre watershed are enrolled in CRP.

Figure 6-1. Current land use adjacent to Silver Creek in much of the watershed.

Targeted bank and stream stabilization practices would help reduce in-stream sediment delivery. Riprap is one of the more commonly used stream bank stabilization techniques. It is a permanent cover of rock used to stabilize stream banks, provide in-stream channel stability, and provide a stabilized outlet below concentrated flows. It is generally used on stream banks at the toe (bottom) of the slope, with other structures placed up-slope to prevent soil movement.

Soil bioengineering is a method of using vegetation to stabilize a site with or without structural controls. Some refer to bioengineering as softening the traditional rock-the-bank approach because non-invasive vegetation is used to blend the site into its surrounding landscape. Chapter 18 of the USDA Soil Conservation Service (now Natural Resource Conservation Service (NRCS)) Engineering Field Handbook is one of the most comprehensive sources of information on soil bioengineering. Chapter 18 describes soil bioengineering as a combination of biological and ecological concepts to arrest and prevent shallow slope failures and erosion.

Using RUSLE, it is possible to estimate soil loss reduction with certain land management and conservation practices. This is done by changing the existing conditions to create a landscape with the ideal practices in place. For Silver Creek, three scenarios were created: 1) placing terraces in areas with C slopes or greater, 2) using no-till practices on all crop land in the watershed, and 3) a combination of these practices (Figures 6-2 through 6-4). Table 6-1 gives the estimated percent reduction in sheet and rill erosion and ultimate sediment delivery with these practices as indicated by RUSLE.

Table 6-1. RUSLE estimated soil loss reduction with land management practices.

	Existing Conditions (2006)	Terraces on C slopes or greater	Percent Reduction	No-till for all cropland	Percent Reduction	Combination of terraces and no-till	Percent Reduction
Sheet & Rill Erosion (tons/yr)	61,190	50,832	17	27,514	55	22,899	63
Average Erosion (tons/acre/yr)	3.40	2.82		1.53		1.27	
Sediment Delivery (tons/yr)	12,202	10,126	17	5,496	55	4,567	63
Average Delivery (tons/acre/yr)	0.68	0.56		0.31		0.25	

This is just an example of the effect certain BMPs can have on reducing sediment delivery to Silver Creek. Even with 100 percent implementation of these two BMPs, the sediment reduction does not meet the target reduction of 78 percent, demonstrating that it is unlikely that only one or two BMPs will suffice. Rather, a comprehensive package of BMPs will be required to address the issues that have led to the excessive sedimentation in Silver Creek (Table 6-2).

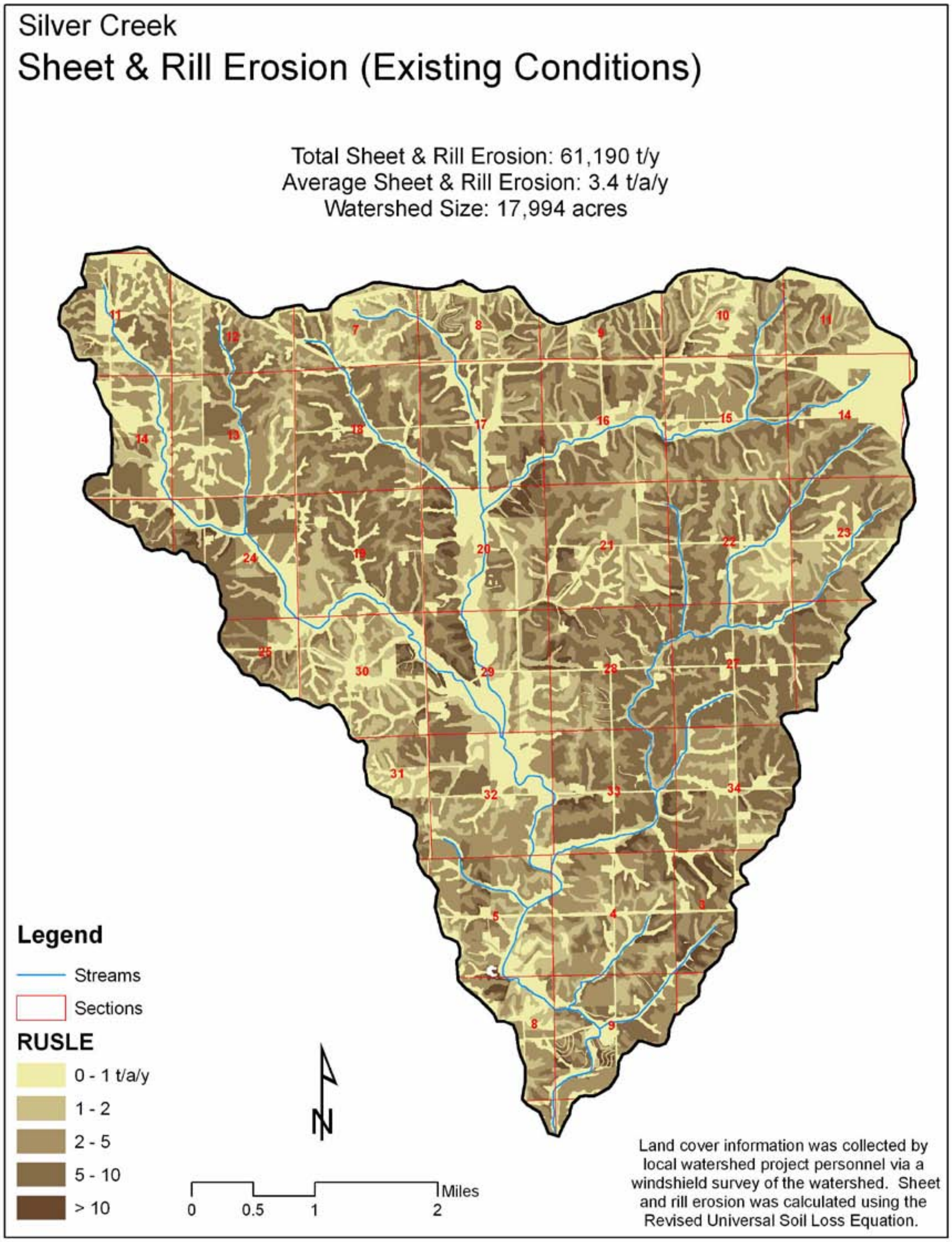

Figure 6-2. Current RUSLE sediment loss estimates with existing land uses.

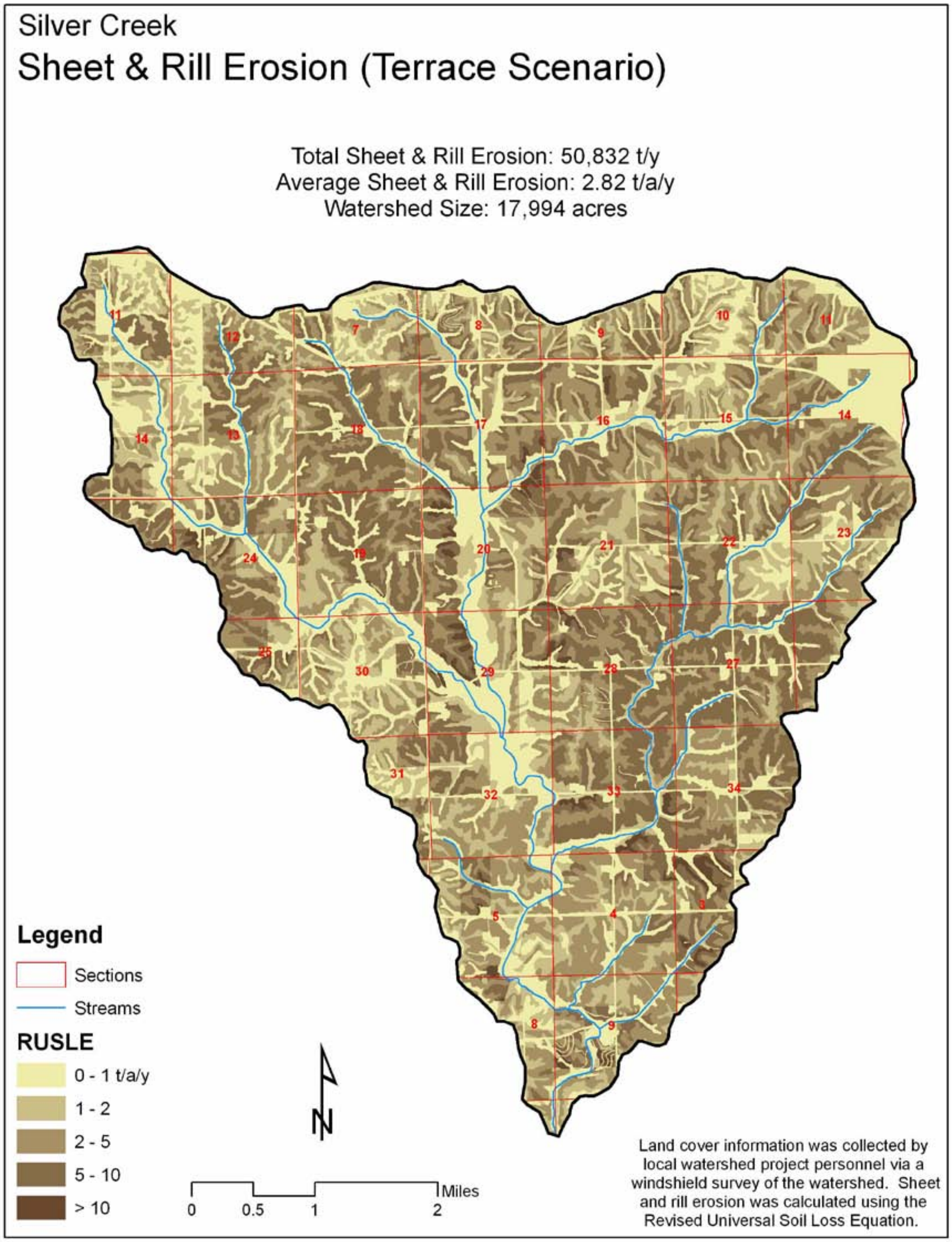

Figure 6-3. Reductions in soil loss with implementation of terracing on appropriate sites on the landscape. This results in a 17 percent reduction in erosion.

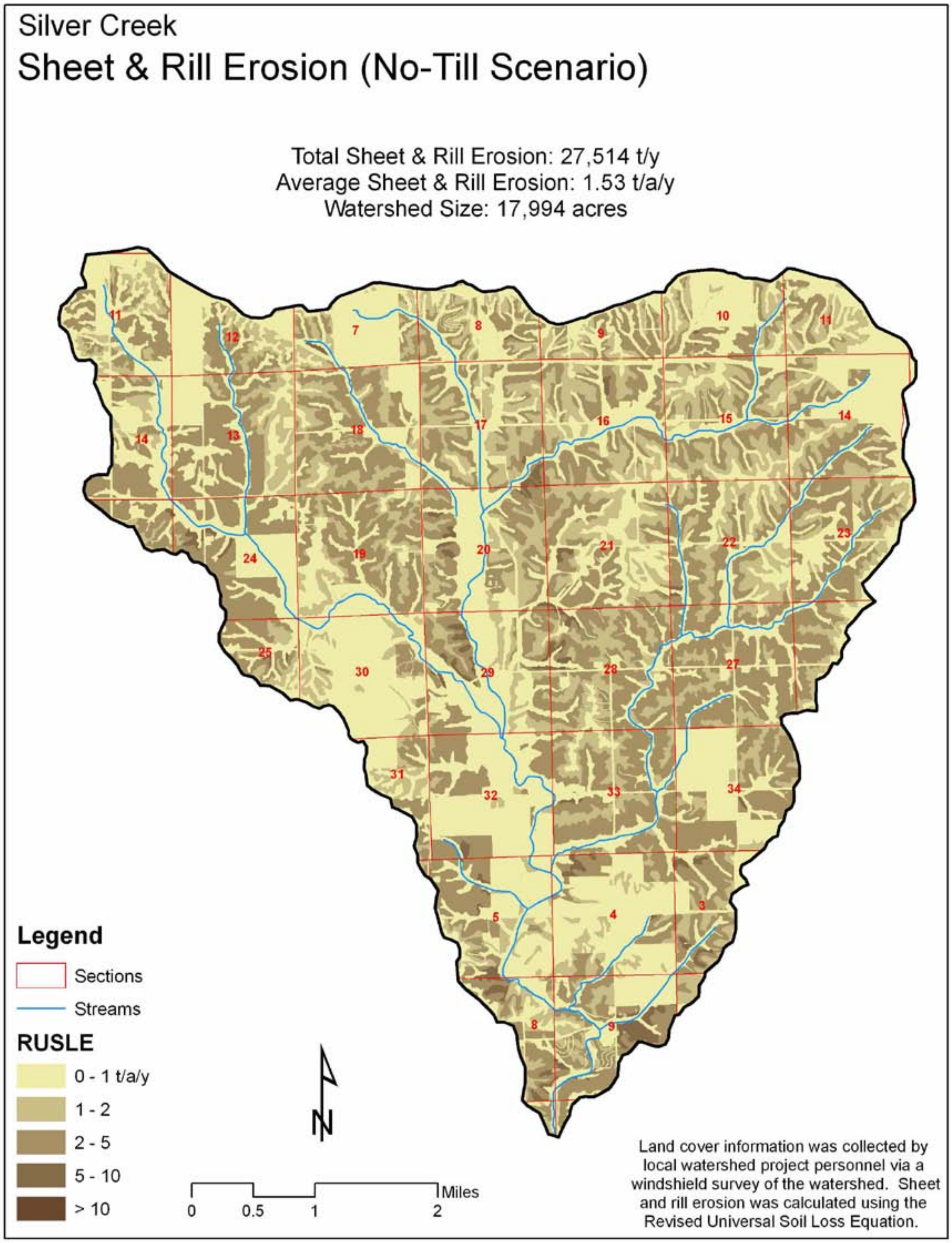

Figure 6-4. Reductions in soil loss with implementation of no-till farming on appropriate sites on the landscape. This results in a 55 percent reduction in erosion.

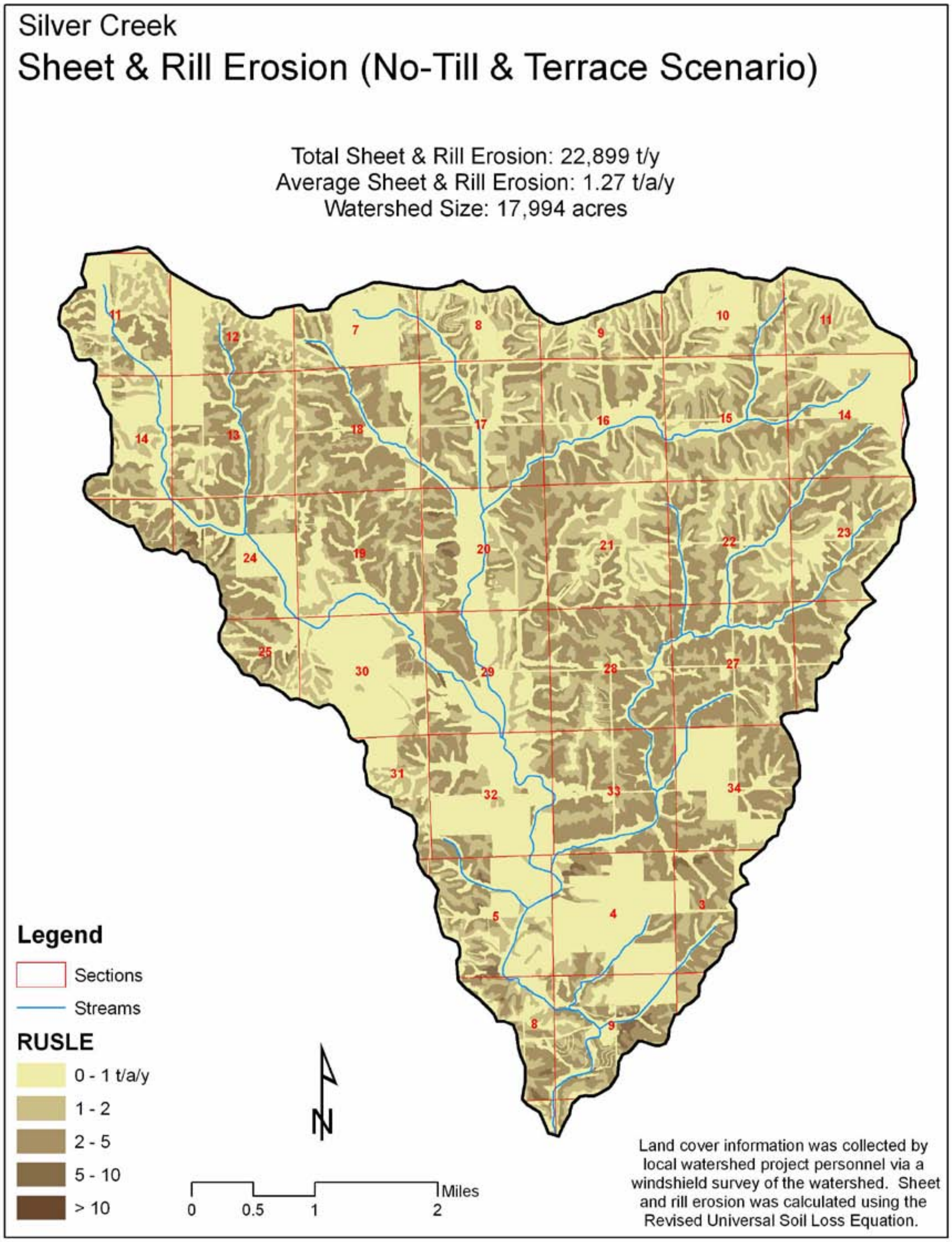

Figure 6-5. Reductions in soil loss with implementation of no-till farming and terracing on appropriate sites on the landscape. This results in a 63 percent reduction in erosion.

Controlling episodic ammonia toxicity is more complicated, since toxicity is dictated by water temperature and pH. However, controlling how much ammonia reaches the stream via runoff from animal feeding operations and limiting livestock access to streams would greatly limit ammonia inputs. Animal feeding operations can best control manure releases by constructing and maintaining proper retaining structures. Restricting livestock access to the stream by fencing them out and providing alternate watering structures and shading away from the stream would limit the time spent in or near the stream and help prevent episodic ammonia inputs.

In summary, no single BMP will be able to sufficiently reduce pollutant loads to Silver Creek. Rather, a comprehensive package of BMPs will be required to address the issues that have led to the poor condition of the biological community in Silver Creek. Table 6-2 identifies some potential BMPs that could reduce the inputs of sediment and ammonia. This list is not all-inclusive, and further investigation may reveal some alternatives to be more or less feasible and applicable to site-specific conditions than others. Development of a more detailed watershed management plan would be helpful in selecting, locating, and implementing the most effective and comprehensive package of BMPs practicable, and would maximize opportunities for future technical and funding assistance.

Table 6-2. Potential BMPs for water quality improvement.

BMP or Activity	Sedimentation Reduction Potential	Ammonia Reduction Potential
Conservation Tillage:		
Moderate vs. Intensive Tillage	Moderate	NA
No-Till vs. Intensive Tillage	High	NA
No-Till vs. Moderate Tillage	High	NA
Cover Crops	High	NA
Diversified Cropping Systems	Moderate	NA
In-Field Vegetative Buffers	High	NA
Terraces	High	NA
Streambank stabilization		
Riprap installation	Moderate	NA
Soil bioengineering	Moderate	NA
Pasture/Grassland Management:		
Livestock Exclusion from Streams	Moderate	High
Rotational vs. Constant Intensive Grazing	Moderate	Moderate
Seasonal vs. Constant Intensive Grazing	Moderate	Moderate
Riparian Buffers	Moderate	Moderate
Wetlands	High	High

7. Future Monitoring

Water quality monitoring is a critical element in assessing the current status of water resources and historical trends. Furthermore, monitoring is necessary to track the effectiveness of water quality improvements made in the watershed and document the status of the waterbody in terms of achieving total maximum daily loads. Also, because the impaired use is for aquatic life, biological sampling is critical to document any improvement in the biological community that may result from implementation efforts within the watershed and to demonstrate improvements in FIBI and BMIBI scores to a level that exceeds ecoregion biological impairment criteria.

Future water quality monitoring in the Silver Creek watershed can be agency-led, volunteer-based, or a combination of both. The Iowa Department of Natural Resources (IDNR) Watershed Monitoring and Assessment Section administers a water quality monitoring program that provides training to interested volunteers. This program is called IOWATER. More information can be found at the program web site: http://www.iowater.net/Default.htm.

Biological monitoring should be conducted by a professional organization such as the University of Iowa Hygienic Lab (UHL) to ensure accuracy and consistency of methods.

7.1. Monitoring Plan to Track TMDL Effectiveness

Currently, due to resource limitations, there are no plans for water quality monitoring or biological sampling in the Silver Creek watershed.

7.2. Idealized Plan for Future Watershed Projects

The ideal monitoring plan for Silver Creek would involve water chemistry sampling, biological sampling, habitat sampling, and continuous sampling for dissolved oxygen and temperature (Table 7-1) at select sites in the watershed (Figure 7-1).

Table 7-1. Idealized monitoring plan for Silver Creek.

Component	Sample Frequency	Parameters/Details
Water chemistry sampling	Bi-weekly- March to October Monthly- November to February	All common parameters listed in Appendix A of the Iowa Water Monitoring Plan 2000 (http://wqm.igsb.uiowa.edu/publications/plan2000.htm)
Benthic Macroinvertebrate and Fish sampling	Annually	Should be done to track improvement in benthic macroinvertebrates and fish and evaluate changes in species susceptible to ammonia toxicity and low DO.
Habitat sampling	Annually	Concurrently with the biological sampling, habitat assessment should take place according to IDNR protocols. Will track improvement in habitat conditions that may be contributing to the impairment such as sedimentation and substrate embeddedness.
Continuous DO and temperature	Continuously from June to October	Dissolved oxygen autosampler deployment according to UHL protocols (6 minute intervals)

While resources may not currently be available to implement this type of monitoring plan, this strategy should be incorporated into the Silver Creek Watershed Management Plan discussed in Section 6. Then, as funding becomes available to support watershed improvement efforts, this monitoring plan can be implemented by the local watershed group(s).

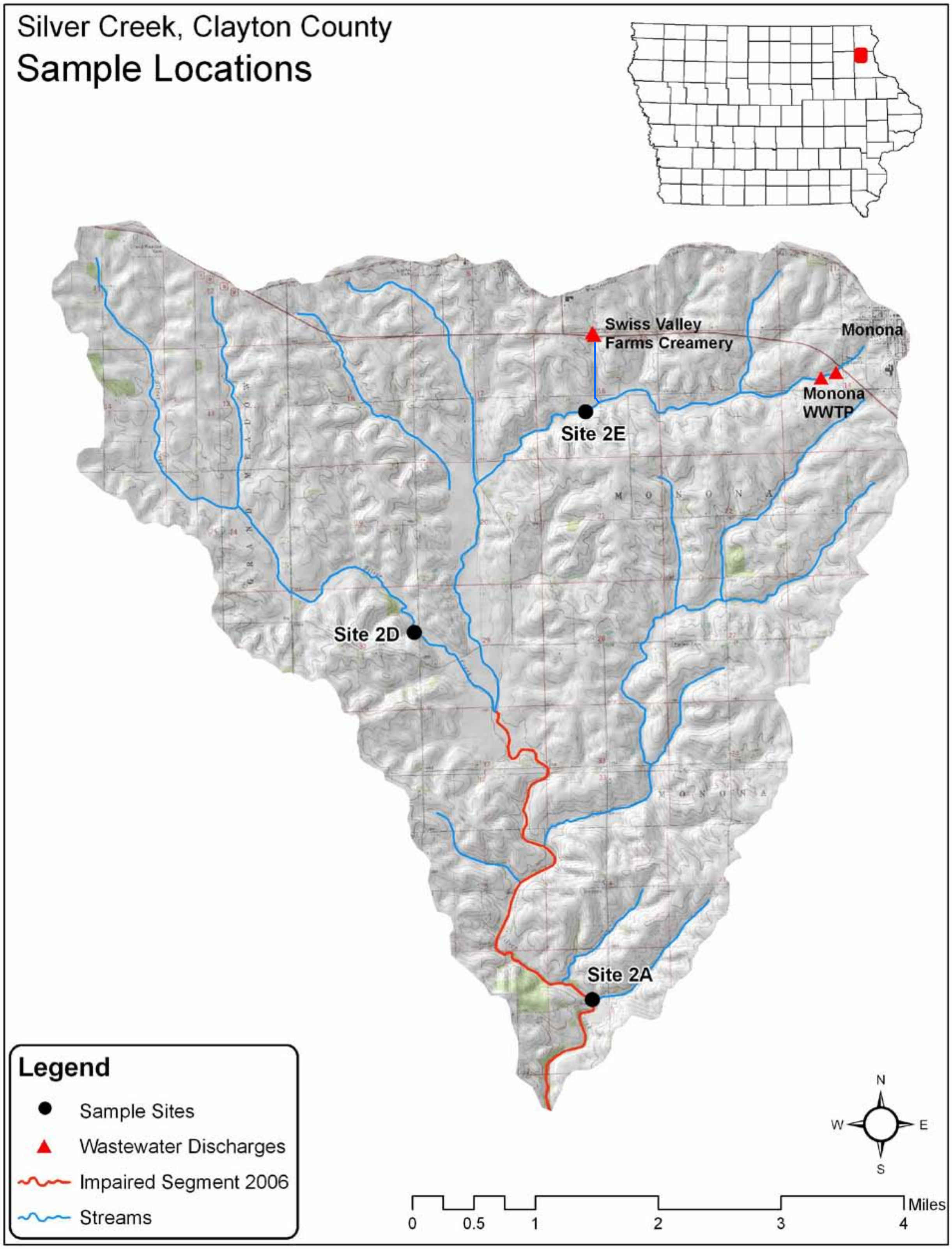

Figure 7-1. Recommended sample sites for idealized monitoring plan.

8. Public Participation

Public involvement is important in the TMDL process because it is the land owners, tenants, and citizens who directly manage land and live in the watershed that determine the water quality in Silver Creek. During the development of this TMDL, considerable effort was made to ensure that the local watershed project coordinator was involved in the process to agree on feasible and achievable goals for the water quality in Silver Creek.

8.1. Public Meetings

An informal meeting to discuss Silver Creek was held in Elkader, Iowa on October 9, 2007. This meeting included representatives from the Silver Creek Watershed Project, IDNR, and commissioners for the Clayton County Soil and Water Conservation District.

A formal public meeting was held at the Luana Savings Bank in Luana, Iowa, from 6:00 to 8:00 pm on January 14, 2010. Nearly 20 people attended, indicating that there is local support of water quality improvement efforts. The primary purposes of the meeting were to present the draft of the Silver Creek TMDL to the public, and to provide stakeholders with an opportunity to ask questions and offer input.

Key agency attendees included:

- IDNR – Watershed Improvement Section (TMDL)
- IDNR – Section 319 Program
- IDNR – Field Office 1
- IDALS – Division of Soil Conservation (Regional Coordinator)

Key stakeholder groups represented included:

- Rural residents, land owners, and agricultural producers
- Swiss Valley Farms Creamery, Monona
- Silver Creek Watershed Project

8.2. Written Comments

The draft TMDL was posted on the Iowa Department of Natural Resources website on December 31, 2009 and comments were accepted from December 31, 2009 to February 1, 2010.

No public comments were received for the Silver Creek TMDLs.

9. References

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Appendix A --- Glossary of Terms and Acronyms

303(d) list: Refers to section 303(d) of the Federal Clean Water Act, which requires a listing of all public surface waterbodies (creeks, rivers, wetlands, and lakes) that do not support their general and/or designated uses. Also called the state's "Impaired Waters List."

305(b) assessment: Refers to section 305(b) of the Federal Clean Water Act, it is a comprehensive assessment of the state's public waterbodies' ability to support their general and designated uses. Those bodies of water which are found to be not supporting or just partially supporting their uses are placed on the 303(d) list.

319: Refers to Section 319 of the Federal Clean Water Act, the Nonpoint Source Management Program. Under this amendment, States receive grant money from EPA to provide technical & financial assistance, education, & monitoring to implement local nonpoint source water quality projects.

AFO: Animal Feeding Operation. A lot, yard, corral, building, or other area in which animals are confined and fed and maintained for 45 days or more in any 12-month period, and all structures used for the storage of manure from animals in the operation. Open feedlots and confinement feeding operations are considered to be separate animal feeding operations.

Base flow: Sustained flow of a stream in the absence of direct runoff. It can include natural and human-induced stream flows. Natural base flow is sustained largely by groundwater discharges.

Benthic Macroinvertebrates Animals without backbones, that are larger than 0.5 mm (the size of a pencil dot). These animals live on rocks, logs, sediment, debris and aquatic plants during some period in their life. They include crayfish, mussels, snails, aquatic worms, and the immature forms of aquatic insects such as stonefly and mayfly nymphs.

BMIBI: Benthic Macroinvertebrate Index of Biotic Integrity. An index-based scoring method for assessing the biological health of streams and rivers (scale of 0-100) based on characteristics of bottom-dwelling invertebrates.

BMP: Best Management Practice. Any structural or upland soil or water conservation practice, such as terraces, grass waterways, sediment retention ponds, reduced tillage systems, etc.

CBOD5	5-day Carbonaceous Biochemical Oxygen Demand. Measures the rate of oxygen use by micro-organisms to oxidize hydrocarbons in a sample of water at a temperature of 20°C and over an elapsed period of five days in the dark.
Confinement feeding operation	An animal feeding operation (AFO) in which animals are confined to areas which are totally roofed.
Credible data law:	Refers to 455B.193 of the Iowa Administrative Code, which ensures that water quality data used for all purposes of the Federal Clean Water Act are sufficiently up-to-date and accurate.
Cyanobacteria (blue-green algae):	Members of the phytoplankton community that are not true algae but can photosynthesize. Some species can be toxic to humans and pets.
Designated use(s):	Refer to the type of economic, social, or ecologic activities that a specific waterbody is intended to support. See Appendix B for a description of all general and designated uses.
DNR (or IDNR):	Iowa Department of Natural Resources.
Ecoregion:	A system used to classify geographic areas based on similar physical characteristics such as soils and geologic material, terrain, and drainage features.
EPA (or USEPA):	United States Environmental Protection Agency.
FIBI:	Fish Index of Biotic Integrity. An index-based scoring method for assessing the biological health of streams and rivers (scale of 0-100) based on characteristics of fish species.
FSA:	Farm Service Agency (United States Department of Agriculture). Federal agency responsible for implementing farm policy, commodity, and conservation programs.
General use(s):	Refer to narrative water quality criteria that all public waterbodies must meet to satisfy public needs and expectations. See Appendix B for a description of all general and designated uses.
GIS:	Geographic Information System(s). A collection of map-based data and tools for creating, managing, and analyzing spatial information.

Gully erosion: Soil movement (loss) that occurs in defined upland channels and ravines that are typically too wide and deep to fill in with traditional tillage methods.

HEL: Highly Erodible Land. Defined by the USDA Natural Resources Conservation Service (NRCS), it is land which has the potential for long term annual soil losses to exceed the tolerable amount by eight times for a given agricultural field.

Integrated report: Refers to a comprehensive document which combines the 305(b) assessment with the 303(d) list, as well as narratives and discussion of overall water quality trends in the state's public waterbodies. The Iowa Department of Natural Resources submits an integrated report to the EPA biennially in even numbered years.

LA: Load Allocation. The portion of the loading capacity attributed to (1) the existing or future nonpoint sources of pollution and (2) natural background sources. Wherever possible, nonpoint source loads and natural loads should be distinguished. (The total pollutant load is the sum of the waste load and load allocations.)

Load: The total amount of pollutants entering a waterbody from one or multiple sources, measured as a rate, as in weight per unit time or per unit area.

MOS: Margin of Safety. A required component of the TMDL that accounts for the uncertainty in the response of the waterbody to loading reductions.

MS4: Municipal Separate Storm Sewer System. A conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, or storm drains) owned and operated by a state, city, town, borough, county, parish, district, association, or other public body (created by or pursuant to state law) having jurisdiction over disposal of sewage, industrial wastes, stormwater, or other wastes, including special districts under state law such as a sewer district, flood control district or drainage district, or similar entity, or an Indian tribe or an authorized Indian tribal organization, or a designated and approved management agency under section 208 of the Clean Water Act (CWA) that discharges to waters of the United States.

Nonpoint source pollution:	Pollution that is not released through pipes but rather originates from multiple sources over a relatively large area. Nonpoint sources can be divided into source activities related either to land or water use including failing septic tanks, improper animal-keeping practices, forestry practices, and urban and rural runoff.
NPDES:	National Pollution Discharge Elimination System. The national program for issuing, modifying, revoking and reissuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements, under Section 307, 402, 318, and 405 of the Clean Water Act. Facilities subjected to NPDES permitting regulations include operations such as municipal wastewater treatment plants and industrial waste treatment facilities, as well as some MS4s.
NRCS:	Natural Resources Conservation Service (United States Department of Agriculture). Federal agency which provides technical assistance for the conservation and enhancement of natural resources.
Open feedlot	An unroofed or partially roofed animal feeding operation (AFO) in which no crop, vegetation, or forage growth or residue cover is maintained during the period that animals are confined in the operation.
Periphyton:	Algae that are attached to substrates (rocks, sediment, wood, and other living organisms).
Phytoplankton:	Collective term for all self-feeding (photosynthetic) organisms suspended in the water quality which provide the basis for the aquatic food chain. Includes many types of algae and cyanobacteria.
Point source pollution:	Pollutant loads discharged at a specific location from pipes, outfalls, and conveyance channels from either municipal wastewater treatment plants or industrial waste treatment facilities. Point sources are generally regulated by an NPDES permit.
PPB:	Parts per Billion. A measure of concentration which is the same as micrograms per liter (µg/l).
PPM:	Parts per Million. A measure of concentration which is the same as milligrams per liter (mg/l).

Riparian:	Refers to site conditions that occur near water, including specific physical, chemical, and biological characteristics that differ from upland (dry) sites.
RUSLE:	Revised Universal Soil Loss Equation. An empirical model for estimating long term, average annual soil losses due to sheet and rill erosion.
Secchi disk:	A device used to measure transparency in waterbodies. The greater the Secchi depth (measured in meters), the more transparent the water.
Sediment delivery ratio:	A value, expressed as a percent, which is used to describe the fraction of gross soil erosion which actually reaches a waterbody of concern.
Seston:	All particulate matter (organic and inorganic) in the water column.
Sheet & rill erosion	Soil loss which occurs diffusely over large, generally flat areas of land.
SI:	Stressor Identification. A process by which the specific cause(s) of a biological impairment to a waterbody can be determined from cause-and-effect relationships.
Storm flow (or stormwater):	The fraction of discharge (flow) in a river which arrived as surface runoff directly caused by a precipitation event. *Stormwater* generally refers to runoff which is routed through some artificial channel or structure, often in urban areas.
STP:	Sewage Treatment Plant. General term for a facility that processes municipal sewage into effluent released to public waters according to the conditions of an NPDES permit.
SWCD:	Soil and Water Conservation District. Agency which provides local assistance for soil conservation and water quality project implementation, with support from the Iowa Department of Agriculture and Land Stewardship.
TMDL:	Total Maximum Daily Load. As required by the Federal Clean Water Act, a comprehensive analysis and quantification of the maximum amount of a particular pollutant that a waterbody can tolerate while still meeting its general and designated uses.

TSI (or Carlson's TSI):	Trophic State Index. A standardized scoring system (scale of 0-100) used to characterize the amount of algal biomass in a lake or wetland.
TSS:	Total Suspended Solids. The quantitative measure of seston, all materials, organic and inorganic, which are held in the water column.
Turbidity:	The degree of cloudiness or murkiness of water caused by suspended particles.
UAA:	Use Attainability Analysis. A protocol used to determine which (if any) designated uses apply to a particular waterbody. (See Appendix B for a description of all general and designated uses.)
UHL:	University Hygienic Laboratory (University of Iowa). Provides physical, biological, and chemical sampling for water quality purposes in support of beach monitoring and impaired water assessments.
USGS:	United States Geologic Survey (United States Department of the Interior). Federal agency responsible for implementation and maintenance of discharge (flow) gauging stations on the nation's waterbodies.
Watershed:	The land (measured in units of surface area) which drains water to a particular body of water or outlet.
WLA:	Wasteload Allocation. The portion of a receiving waterbody's loading capacity that is allocated to one of its existing or future point sources of pollution (e.g., permitted waste treatment facilities). Alternatively, the allowable pollutant load that an NPDES permitted facility may discharge without exceeding water quality standards.
WQS:	Water Quality Standards. Defined in Chapter 61 of Environmental Protection Commission [567] of the Iowa Administrative Code, they are the specific criteria by which water quality is gauged in Iowa.
WWTP:	Wastewater Treatment Plant. General term for a facility which processes municipal, industrial, or agricultural waste into effluent released to public waters or land applied according to the conditions of the facility's NPDES permit.

Zooplankton: Collective term for all animal plankton suspended in the water column which serve as secondary producers in the aquatic food chain and the primary food source for larger aquatic organisms.

Appendix B --- General and Designated Uses of Iowa's Waters

Introduction

Iowa's water quality standards (Environmental Protection Commission [567], Chapter 61 of the Iowa Administrative Code) provide the narrative and numerical criteria by which water bodies are judged when determining the health and quality of our aquatic ecosystems. These standards vary depending on the type of water body (lakes vs. rivers) and the assigned uses (general use vs. designated uses) of the water body that is being dealt with. This appendix is intended to provide information about how Iowa's water bodies are classified and what the use designations mean, hopefully providing a better general understanding for the reader.

All public surface waters in the state are protected for certain beneficial uses, such as livestock and wildlife watering, aquatic life, non-contact recreation, crop irrigation, and other incidental uses (e.g. withdrawal for industry and agriculture). However, certain rivers and lakes warrant a greater degree of protection because they provide enhanced recreational, economical, or ecological opportunities. Thus, all public bodies of surface water in Iowa are divided into two main categories: *general* use segments and *designated* use segments. This is an important classification because it means that not all of the criteria in the state's water quality standards apply to all water ways; rather, the criteria which apply depend on the use designation & classification of the water body.

General Use Segments

A general use segment water body is one which does not maintain perennial (year-round) flow of water or pools of water in most years (i.e. ephemeral or intermittent waterways). In other words, stream channels or basins which consistently dry up year after year would be classified as general use segments. Exceptions are made for years of extreme drought or floods. For the full definition of a general use water body, consult section 61.3(1) in the state's published water quality standards, which became effective on March 22, 2006 (Environmental Protection Commission [567], Chapter 61 of the Iowa Administrative Code).

General use waters are protected for the beneficial uses listed above, which are: livestock and wildlife watering, aquatic life, non-contact recreation, crop irrigation, and industrial, agricultural, domestic and other incidental water withdrawal uses. The criteria used to ensure protection of these uses are described in section 61.3(2) in the state's published water quality standards, which became effective on March 22, 2006 (Environmental Protection Commission [567], Chapter 61 of the Iowa Administrative Code).

Designated Use Segments

Designated use segments are water bodies which maintain flow throughout the year, or at least hold pools of water which are sufficient to support a viable aquatic community (i.e. perennial waterways). In addition to being protected for the same beneficial uses as the general use segments, these perennial waters are protected for more specific activities such as primary contact recreation, drinking water sources, or cold-water fisheries. There are a total of thirteen different designated use classes (Table B-1) which may apply, and a water body may have more than one designated use. For definitions of the use classes and more detailed descriptions, consult section 61.3(1) in the state's published water quality standards, which became effective on March 22, 2006 (Environmental Protection Commission [567], Chapter 61 of the Iowa Administrative Code).

Table B-1. Designated use classes for Iowa water bodies.

Class prefix	Class	Designated use	Brief comments
A	A1	Primary contact recreation	Supports swimming, water skiing, etc.
	A2	Secondary contact recreation	Limited/incidental contact occurs, such as boating
	A3	Children's contact recreation	Urban/residential waters that are attractive to children
B	B(CW1)	Cold water aquatic life – Type 2	Able to support coldwater fish (e.g. trout) populations
	B(CW2)	Cold water aquatic life – Type 2	Typically unable to support consistent trout populations
	B(WW-1)	Warm water aquatic life – Type 1	Suitable for game and nongame fish populations
	B(WW-2)	Warm water aquatic life – Type 2	Smaller streams where game fish populations are limited by physical conditions & flow
	B(WW-3)	Warm water aquatic life – Type 3	Streams that only hold small perennial pools which extremely limit aquatic life
	B(LW)	Warm water aquatic life – Lakes and Wetlands	Artificial and natural impoundments with "lake-like" conditions
C	C	Drinking water supply	Used for raw potable water
Other	HQ	High quality water	Waters with exceptional water quality
	HQR	High quality resource	Waters with unique or outstanding features
	HH	Human health	Fish are routinely harvested for human consumption

Designated use classes are determined based on a Use Attainability Analysis, or UAA. This is a procedure in which the water body is thoroughly scrutinized, using existing knowledge, historical documents, and visual evidence of existing uses, in order to determine what its designated use(s) should be. This can be a challenging endeavor, and as such conservative judgment is applied to ensure that any potential uses of a water body are allowed for. Changes to a water body's designated uses may only occur based on a new UAA, which depending on resources and personnel, can be quite time consuming.

It is relevant to note that on March 22, 2006, a revised edition of Iowa's water quality standards became effective which significantly changed the use designations of the state's surface waters. Essentially, the changes that were made consisted of implementing a "top down" approach to use designations, meaning that all water bodies should receive the highest degree of protection applicable until a UAA could be performed to ensure that a particular water body did not warrant elevated protection. For more information about Iowa's water quality standards and UAAs, contact the Iowa DNR's Water Quality Bureau.

Appendix C --- Water Quality Data

See Stressor Identification document for water quality data prior to 2008

Table C-1. Water quality data from supplemental monitoring in 2008 (see Figure 4-1 in Section 4 for site locations).

	Site 2A							Site 2C						
	7/16/08	7/31/08	8/11/08	8/27/08	9/11/08	9/24/08	10/7/08	7/16/08	7/31/08	8/11/08	8/27/08	9/11/08	9/24/08	10/7/08
Ammonia N as N (mg/L)	0.08	0.09	<0.05	<0.05	<0.05	<0.05	<0.05	0.89	<0.05	<0.05	4.5	0.22	<0.05	<0.05
CBOD (5 day) (mg/L)	<2	<2	<2	4	3	17	10	<2	<2	<2	5	<2	<2	<2
Chloride(mg/L)	27	29	26	26	31	28	25	53	85	140	200	140	170	220
Chlorophyll a (µg/L)	1	3	6	99	74	460	290	<1	2	2	9	4	3	6
Diss. Inorg. Carbon (mg/L)	58	63	63	64	63	57	57	6.2	69	78	100	78	91	104
DOC (mg/L)	2.1	2.5	2.7	3.7	3.8	4.6	4.8	2.1	3.4	4.1	7.7	4.2	4.2	4.5
DO (mg/L)	8.3	6.3	7.3	13.4	10.6	14.0	17.3	10.1	9.2	6.7	5.0	7.9	10.8	7.2
E. coli (#/100mL)	480	3200	520	190	440	2700	440	4200	1500	1400	390	450	330	450
pH	8.2	8.2	8.2	8.7	8.5	8.6	8.5	8.2	8.2	8.1	8.0	8.2	8.4	8.0
Temp. (^oC)	22.4	24.3	19.1	17.4	14.8	18.7	13.9	20.5	23.4	16.3	16.0	16.0	19.5	14.0
Flow (cfs)	9.6	ND	0.8	0.3	0.3	<1	<1	3.4	ND	<0.1	0.2	0.1	<1	<1
NO3+NO2 as N (mg/L)	14	14	12	6.7	6.3	5.4	2.6	12	9.9	9.3	7.1	6.9	5.8	10
Ortho Phos. as P (mg/L)	0.21	0.2	0.2	0.14	0.08	0.07	0.02	0.74	1.5	2.4	4.5	3.2	4	5.1
Total Dis Solids (mg/L)	400	420	420	390	390	370	320	460	560	700	900	730	810	940
TKN as N (mg/L)	0.7	0.7	0.7	1.4	1.1	3.7	2.1	1.2	0.7	0.9	6	1.1	0.8	1
Total Org. Carbon (mg/L)	4.4	3.7	4.5	5.6	6.6	15	10	3.3	4	5.3	8.4	5.1	6.1	5.7
Total Phos. as P (mg/L)	0.28	0.28	0.29	0.35	0.26	0.48	0.22	0.75	1.6	2.5	4.8	3.4	4	5
TSS (mg/L)	56	31	41	46	65	68	32	17	14	28	11	100	35	99
TVSS (mg/L)	8	7	9	14	15	28	17	3	3	5	3	11	5	9
Turbidity (NTU)	36	24	34	30	39	39	20	8.4	4.5	12	9.7	41	32	36

Table C-1 (continued).

	Site 2E							Site 3A							Site 3B						
	7/16	7/31	8/11	8/27	9/11	9/24	10/7	7/16	7/31	8/11	8/27	9/11	9/24	10/7	7/16	7/31	8/11	8/27	9/11	9/24	10/7
Ammonia N as N (mg/L)	2.5	4.8	6.1	5.7	8	5.2	3.7	5	0.97	2.3	2.5	3.9	0.23	0.56	0.12	0.46	0.1	<0.05	2.6	<0.05	<0.05
CBOD (5 day) (mg/L)	<2	3	8	3	<2	<2	5	3	6	14	<2	3	4	6	<2	15	<2	<2	3	<2	<2
Chloride(mg/L)	58	130	160	130	160	160	150	100	150	170	150	160	180	120	98	62	170	200	82	220	220
Chlorophyll a (µg/L)	<1	1	2	9	<1	<1	6	<1	<1	<1	5	2	9	<1	1	30	1	2	9	13	6
Diss. Inorg. Carbon (mg/L)	65	81	92	87	94	93	90	78	86	96	89	97	97	88	66	29	59	60	31	59	49
DOC (mg/L)	2.9	4.8	9.8	4.4	4.8	3.5	5.1	9.1	8.6	15	6.1	7.9	6.1	7.7	1.9	17	3.3	3.4	3.3	3.5	7.5
DO (mg/L)	8.3	5.7	7.0	5.5	5.1	2.8	4.5	4.8	4.3	5.4	4.7	4.8	5.3	5.0	9.2	6.6	9.8	12.2	4.2	11.8	8.8
E. coli (#/100mL)	580	420	160	420	390	390	890	60	10	50	280	50	60	70	3400	82000	5300	620	18000	1400	310
pH	8.1	8.1	8.1	8.2	8.2	8.1	8.0	7.5	7.6	7.6	7.7	7.6	7.7	7.4	8.0	7.9	8.1	8.3	7.6	8.7	7.9
Temp. (°C)	21.7	27.3	27.1	27.1	26.1	30.2	22.1	32.7	31.8	30.3	32.0	32.1	32.7	31.0	17.6	20.4	17.0	17.6	16.3	20.6	14.2
Flow (cfs)	4	ND	2.6	1.4	1.9	1.5	2	1.3	ND	0.8	0.8	1.4	2	1.5	0.9	ND	0.4	0.2	0.6	<1	<1
NO3+NO2 as N (mg/L)	10	5.6	3.6	6.1	4.9	4.2	3.7	6.1	3.5	3.3	7	3.7	4.8	4.1	5.2	2.3	6.9	3.6	3.6	2.3	11
Ortho Phos. as P (mg/L)	0.9	2.6	3.3	3.3	4.7	3.6	4.6	2.7	2.9	3.4	3.8	4.7	3.5	3.2	0.28	0.46	2.2	0.71	0.4	0.4	1.1
Total Dis Solids (mg/L)	470	660	750	720	770	770	720	630	720	820	780	800	850	700	540	330	630	660	290	670	670
TKN as N (mg/L)	4.9	9.6	13	8	8.4	7.2	6.7	18	13	15	6.6	11	1.7	6.9	0.4	3.1	0.8	1	2.9	0.4	0.6
Total Org. Carbon (mg/L)	5.4	8.1	12	6.6	6.1	6.1	5.8	11	11	22	7.4	9.7	9	9.9	2.3	28	3.9	4	4.4	4	8.6
Total Phos. as P (mg/L)	1.1	3.1	3.8	3.6	4.8	3.7	4.6	3	3.2	4.2	4.1	5	3.8	3.6	0.28	0.85	2.2	0.73	0.46	0.43	1.1
TSS (mg/L)	16	25	16	31	10	3	41	12	13	26	5	11	12	17	2	160	2	<1	4	2	92
TVSS (mg/L)	7	12	10	13	2	1	19	11	11	22	5	10	9	15	1	34	1	<1	2	<1	37
Turbidity (NTU)	4.7	2.6	8	3.2	4.1	2.1	15	3.7	2.2	13	4.6	4.1	4.8	7.9	1	62	1.1	1	7.2	1.2	3.9

Appendix D --- Modeling, Equations and Methodology

Two modeling techniques were used in the development of this TMDL. The first modeling technique used was the Revised Universal Soil Loss Equation (RUSLE) which was used to calculate soil loss and sediment delivery in the watershed. The second model used was the QUAL2K surface water quality model. This model was used to model surface water conditions observed in Silver Creek, identify sources of the ammonia impairment and calculate the minimum load of nitrogen compounds that could lead to ammonia violations within the stream.

D.1. The RUSLE Equation

The Universal Soil Loss Equation (USLE) was developed by the U.S. Department of Agriculture (USDA) based on data collected beginning in the 1930's and originally published in 1965. With additional research and data, the Revised Universal Soil Loss Equation was published in 1997 by the USDA-Natural Resource Conservation Service (NRCS). The current equation is:

$$A = R * K * LS * C * P$$

Where:	A	=	Average annual soil loss in tons per acre per year
	R	=	Rainfall/runoff erosivity
	K	=	Soil erodibility
	LS	=	Hillslope length and steepness
	C	=	Cover-management
	P	=	Support practice

While factors such as rainfall and hillslope are fixed in the watershed, other factors such as cover management and support practice can be revised to reflect a change in land use. For Silver Creek, Clayton County, a RUSLE model was developed to represent current conditions. This model was made using current GIS land use coverages and information gained through communications with NRCS personnel working in the Silver Creek watershed.

Sheet and rill erosion: ArcView GIS is used to calculate soil loss for sheet and rill erosion, using RUSLE. RUSLE C and P factors are gathered by means of field level watershed assessments. RUSLE K and LS factors are derived from statewide digital soils data and Digital Elevation Models (DEMs). Precipitation information (RUSLE R factor) exists in a county based dataset. Inputs to the equation vary based on soil type, land use, and slope; which results in output at a sub-field scale. Output units are tons/acre/year.

Sediment delivery is then calculated using ArcView, based on the "Erosion and Sediment Delivery" method developed by the state geologist for Iowa NRCS (USDA-NRCS 1998). This method uses sediment delivery ratios (SDRs), which have been derived from numerous sediment surveys and vary based on the landform regions and drainage areas of the watersheds in Iowa. Multiplying the sheet and rill erosion rate with the SDR value and the acreage yields a sediment delivery value in tons/year.

D.2. Calculating Bank Erosion

An assessment of the main channel identified areas of unstable and eroding banks (See Stressor Identification document Appendix 2, Figure 2-20,). These sections were measured for length and height. NRCS provides generalized lateral erosion rates; however, a study conduced by Zaimes et al. (2004) provided revised recession rates for different Iowa regions and landuses. Since these recession rates were specific to Iowa soils, these rates were preferred over the NRCS rates. Annual erosion was calculated using the Direct Volume Method:

(Eroding area) **x** (Lateral Recession Rate) **x** (Density) **/** 2000 lbs/day

The calculation was performed for each stretch of bank that was identified as eroding. A density of 1.33 g/ml was applied. For banks with pasture as the adjacent landuse a recession rate of 295 mm/year was used. For banks with row crop as the adjacent landuse, a recession of 253 mm/year was used. The total loss per section was calculated and subsequently added together to calculate the total loss (Table D-1). A sediment delivery ratio of 100% was assumed.

Table D-1. Calculation of bank sediment loss

Length of Bank (mi)	Bank Height (ft)	Land Use	LRR (mm/yr)*	Density (g/ml)	Erosion in (tons/yr)
0.4	5	Pasture	295	1.33	424.3
0.1	5	Pasture	295	1.33	106.1
0.4	8	Pasture	295	1.33	678.9
0.2	8	Pasture	295	1.33	339.4
0.13	8	Pasture	295	1.33	220.6
0.2	10	Pasture	295	1.33	424.3
0.13	6	Pasture	295	1.33	165.5
0.13	8	Row Crop	253	1.33	189.2
0.1	8	Row Crop	253	1.33	145.6
0.13	5	Row Crop	253	1.33	118.3
0.14	5	Row Crop	253	1.33	127.4
				TOTAL	2939.5

** Lateral Recession Rate*

D.3. Calculating a Daily Expression for Sediment

As a result of the D.C. Circuit Court of Appeals decision in Friends of the Earth, Inc. v. EPA et al., No 05-5015, EPA recommended all future TMDLs and associated load allocations and waste load allocations be expressed in terms of a daily time increment (EPA 2006). Generally, TMDL analytical approaches that result in longer (non-daily) averaging periods may continue to be used to demonstrate consistency with applicable water quality criteria. However, all final TMDL submissions should include an adequate expression of daily loads in addition to any longer-term loading expression that may be developed as a result of the TMDL analysis (EPA 2006). In response to this ruling, the EPA drafted the document "Options for Expressing Daily Loads in TMDLs", providing technical support and methods acceptable to EPA for calculating daily loads in given situations (EPA 2007).

Establishing a sediment TMDL for Silver Creek posed a unique challenge in that there are no direct measurements of how much sediment is entering the stream. The Options for Expressing Daily Loads in TMDLs document presents a similar case study in which a statistical approach is considered to be the best option for identifying a maximum daily load that corresponds to the allowable average load. The method calculates the daily maximum based on a long term average and considers variation. This method is represented by the equation:

$$MDL = LTA \times e^{[z\sigma - .05\sigma^2]}$$

Where: MDL = maximum daily limit
LTA = long term average
z = z statistic of the probability of occurrence
σ^2 = $\ln(CV^2 + 1)$
CV = coefficient of variation

The document also provides Table D-2 to aid in calculation of the MDL.

Table D-2. Multipliers used to convert an LTA to MDL.

Averaging Period (days)	Recurrence interval	Z-score	Coefficient of variation								
			0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8
30	96.8 %	1.849	1.41	1.81	2.39	2.87	3.30	3.67	3.99	4.26	4.48
60	98.4%	2.135	1.50	2.11	2.80	3.50	4.18	4.81	5.37	5.87	6.32
90	98.9%	2.291	1.54	2.24	3.05	3.91	4.76	5.57	6.32	7.00	7.62
120	99.2%	2.397	1.58	2.34	3.24	4.21	5.20	6.16	7.06	7.89	8.66
180	99.4%	2.541	1.62	2.47	3.51	4.66	5.87	7.06	8.20	9.29	10.3
210	99.5%	2.594	1.64	2.52	3.61	4.84	6.13	7.42	8.67	9.86	11.0
365	99.7%	2.778	1.70	2.71	4.00	5.51	7.15	8.83	10.5	12.13	13.7

For Silver Creek, a long term load of 3,285 tons per year is needed to reach the desired 78 percent reduction. The coefficient of variation (CV) is the ratio of the standard deviation to the mean of the data set. For sediment, the standard deviation and mean of TSS were used, which results in a value of 2.34. The z statistic for probability of occurrence used for this TMDL is based on an averaging period of 365 days resulting in a z-score of 2.778. This yields a final LTA multiplier of 17.11 and results in a MDL of 154 tons/day.

D.4. QUAL2K Modeling Framework for Simulating River and Stream Water Quality Version 2.04

The QUAL2K model was developed in 2006 by Steve Chapra, Greg Pelletier and Hua Tao (Chapra et al. 2006). This version is an update to the QUAL2E model (Brown and Barnwell 1987) and was designed to model river and stream water quality. The QUAL2K model is a steady state, one-dimensional model for a well-mixed branched system with or without multiple tributaries. The variables of heat budget, temperature and water quality are simulated on a 24-hour time scale. Point source loads, non-point source loads, and withdrawals are simulated. Additional assumptions for specific variables will be discussed within the model inputs section.

This model was used to model surface water conditions observed in Silver Creek, identify sources of the ammonia impairment, and calculate the minimum load of nitrogen compounds that could lead to ammonia violations within the stream. Therefore, a steady state model capable of handling low flow conditions, nitrogen transformations, and daily DO and temperature data was necessary.

Model Segmentation and Hydraulics. QUAL2K represents a river as a series of reaches that have constant hydraulic characteristics (i.e. width, slope, substrate). The system can be broken into main stem and tributaries, and the model is capable of generating individual data and plots for each of these stems. For Silver Creek, Clayton County, the first step in model development was determining which of the tributaries are contributing at low flow conditions, which was complicated by a complex karst geological system that removes a large volume of water from the main stem of the creek. The most prominent karst feature is a large sinkhole in the main channel just south of the confluence of the main channel and the un-named tributary to the north. It has been observed several times that under normal to low flow conditions this sink hole actually drains the entire main channel dry. Therefore, during the critical low flow periods for ammonia this sinkhole effectively creates a sub-water shed whose hydrology is disconnected from any inputs from the northern portion of the Silver Creek watershed (Figure D-1).

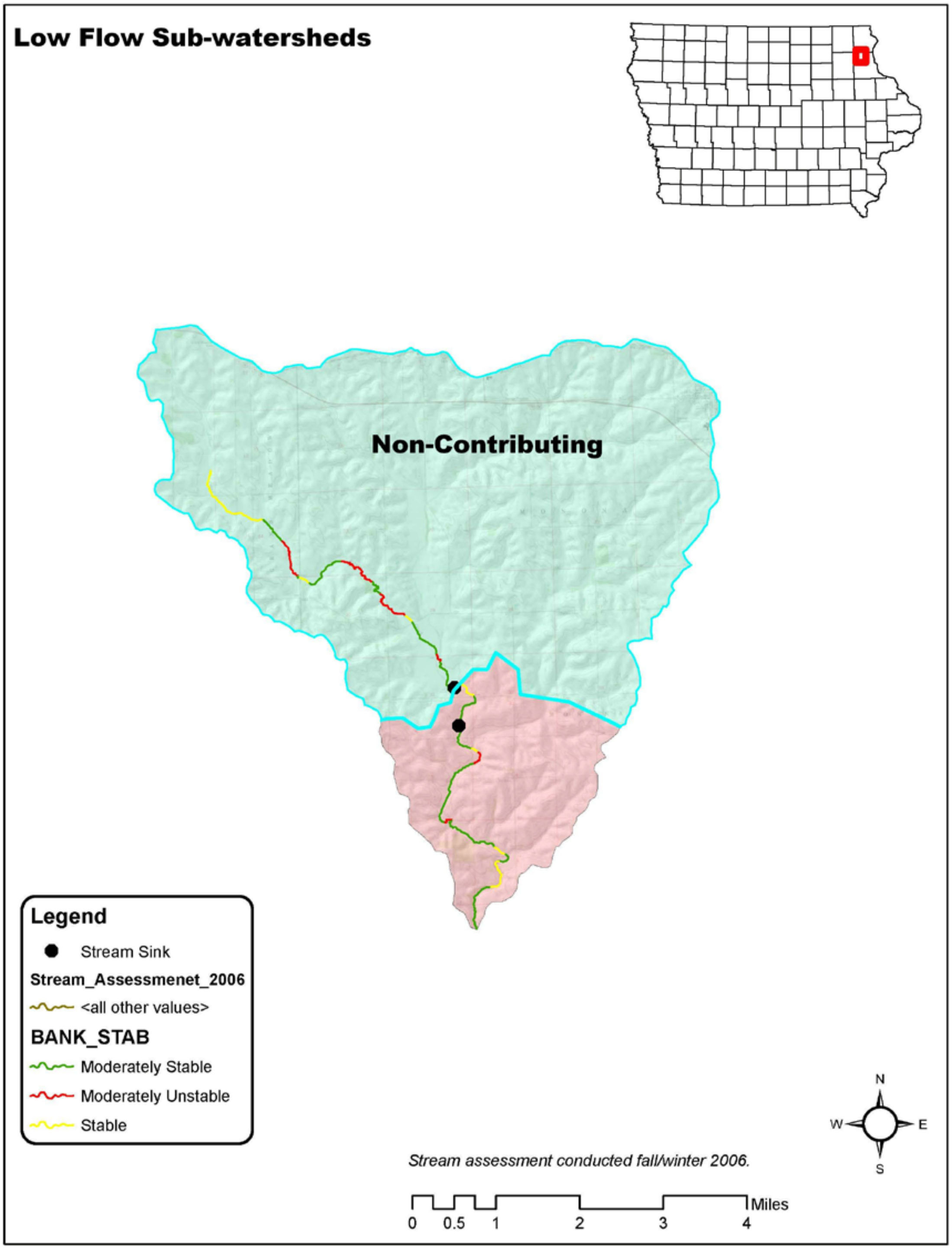


Figure D-1. Division of Silver Creek into sub-watersheds that do and do not contribute to Silver Creek main channel during low flow due to sinkhole drainage.

D.5. Modeling Scheme

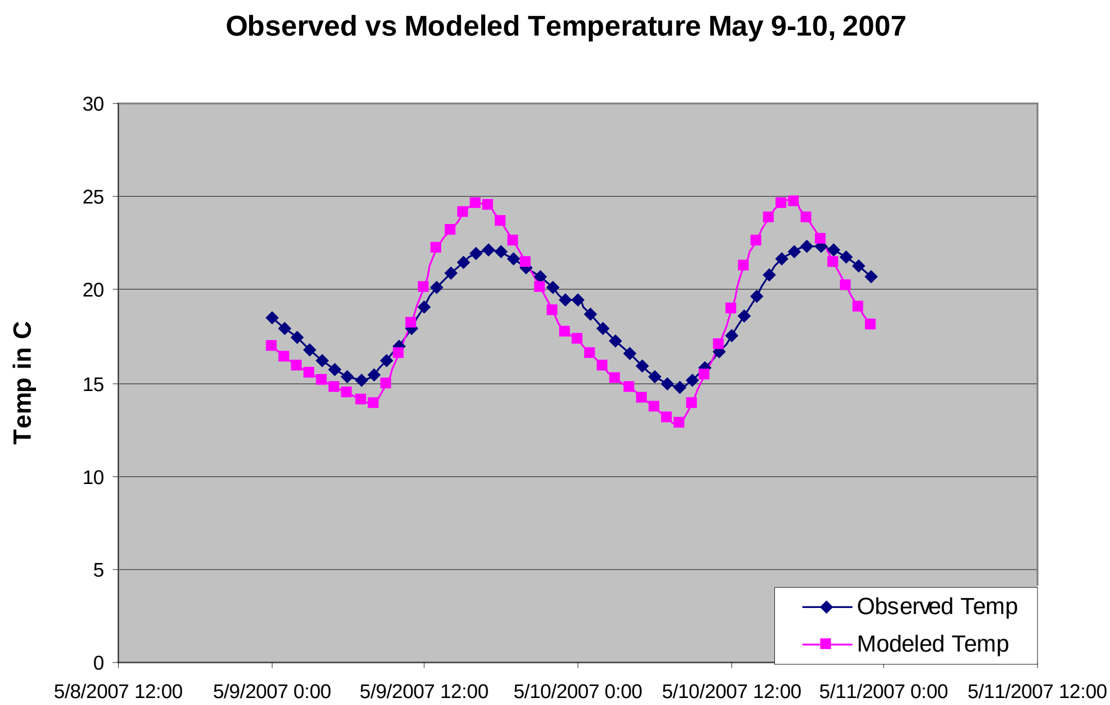
The data available for Silver Creek spans three sampling years from 2006-2008. Although there is a large amount of data, large gaps in the collected data made model calibration difficult. The two major problems were lack of continuous DO and temperature data during the water quality sampling events that yielded ammonia violations, and a lack of longitudinal data between critical sampling locations. An attempt to rectify this lack of data was made in 2008. However, during that sampling cycle no ammonia violations were observed in the impaired segment. Therefore, three separate QUAL2K models were built to accommodate these issues with available data. Each model will be discussed in depth in the results and calibration sections. Here they will be briefly reviewed for how each model was used in developing the TMDL.

The first model was built using data from 2006 and 2007 to design a steady-state base flow conditions model. This was calibrated to available continuous DO and temperature data that did not correspond with storm events or periods of high flow. This served as a base model. This model was then used to produce scenarios under which ammonia violations would occur.

D.6. Steady State Base Flow Model Calibrated for Temperature and DO

Limited continuous DO and temperature data was gathered for the Silver Creek watershed during 2007. The continuous data included breaks in the data when equipment malfunctioned. To calibrate the 24-hour DO and temperature model, a span of continuous data was chosen. This span of time was checked against precipitation records to ensure no rain events occurred. This was done to ensure steady state base flow conditions were modeled correctly. The model was calibrated to a 48-hour period of time from midnight May 9, 2007 to midnight May 11, 2007. The model was calibrated for both a curve fit for diurnal temperature and DO (Fig. D-2 and D-3) as well as a regression analysis for observed versus modeled data for temperature and DO (Fig. D-2 and D-3). The model was not considered calibrated until regression analysis yielded r-square values greater than 0.8. Stream flow was also calibrated at the mouth of the stream to ensure proper interaction between the stream and major sinkholes.

Once this initial model was calibrated, all physical parameters, light and heat inputs, and stoichiometric rates (Tables D-3 and D-4) remained the same in the subsequent models. The only variables allowed to change were weather related or water quality variables to model given conditions for different seasons and sampling events. It was assumed the rates and inputs that yielded a calibrated DO and temperature model were the governing equations for this system and would serve as base and boundary conditions.



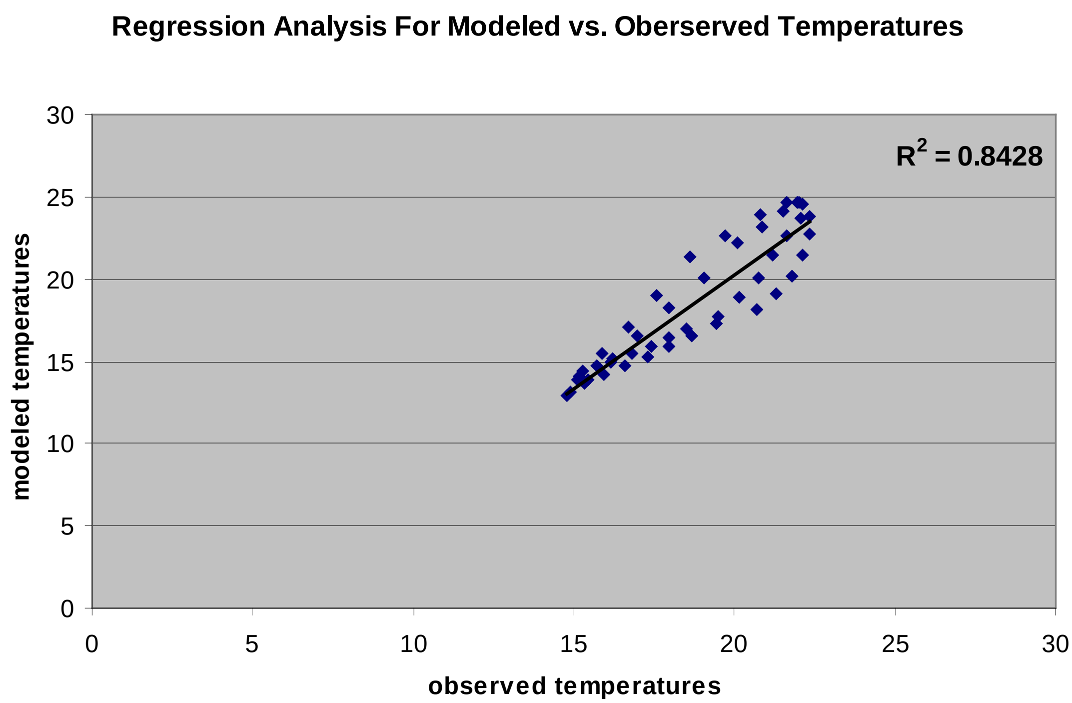
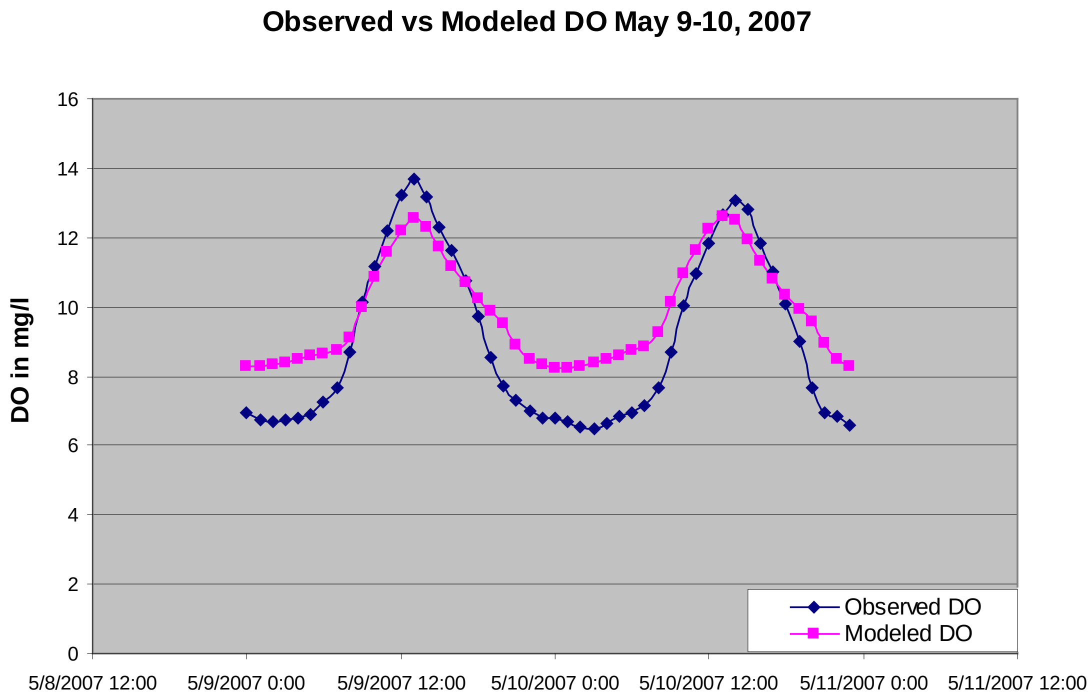


Figure D-2. Curves comparing observed and modeled temperature data in degrees Celsius and associated regression curve.



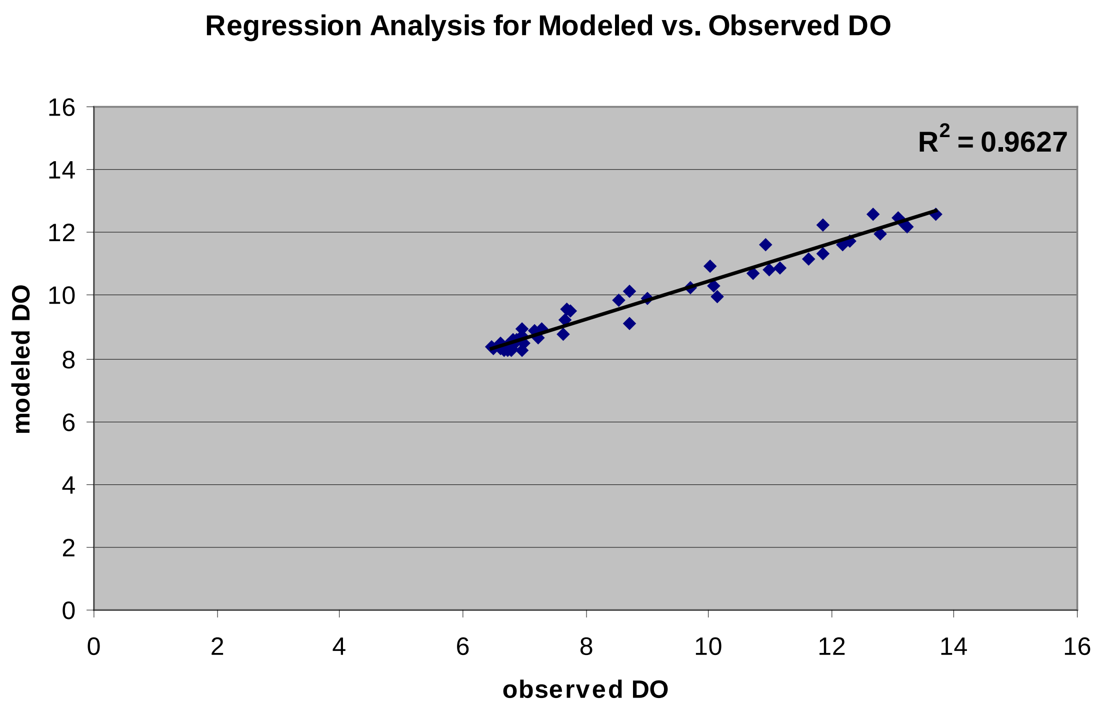


Figure D-3. Curves comparing observed and modeled DO data in mg/L and associated regression curve.

Table D-3. Physical hydrologic parameter inputs for Silver Creek mainstem and two contributing tributaries.

Reach Number	Reach length (km)	Downstream Latitude	Downstream Longitude	Location Upstream (km)	Location Downstream (km)	Element Number >=1	Elevation Upstream (m)	Elevation Downstream (m)	Downstream Latitude Degrees	Downstream Latitude Minutes	Downstream Latitude Seconds	Downstream Longitude Degrees	Downstream Longitude Minutes	Downstream Longitude Seconds
1	1.00	42.50	72.00	10.0	9.0	2	321.8	318.2	42.00	30	0	72.00	0	0
2	1.00	42.50	72.00	9.0	8.0	2	314.6	311.0	42.00	30	0	72.00	0	0
3	1.00	42.50	72.00	8.0	7.0	2	311.0	307.4	42.00	30	0	72.00	0	0
4	1.00	42.50	72.00	7.0	6.0	2	307.4	303.8	42.00	30	0	72.00	0	0
5	1.00	42.50	72.00	6.0	5.0	2	303.8	300.2	42.00	30	0	72.00	0	0
6	1.00	42.50	72.00	5.0	4.0	2	300.2	296.6	42.00	30	0	72.00	0	0
7	1.00	42.50	72.00	4.0	3.0	2	296.6	293.0	42.00	30	0	72.00	0	0
8	1.00	42.50	72.00	3.0	2.0	2	293.0	289.4	42.00	30	0	72.00	0	0
9	1.00	42.50	72.00	2.0	1.0	2	289.4	285.8	42.00	30	0	72.00	0	0
10	1.05	42.50	72.00	1.0	0.0	2	285.800	280.000	42.00	30	0	72.00	0	0

Hydraulic Model (Weir Overrides Manning Formula; Manning Formula Override Rating Curves)

Weir Height (m)	Weir Width (m)	adam	bdam	Rating Curves Velocity Coefficient	Rating Curves Velocity Exponent	Rating Curves Depth Coefficient	Rating Curves Depth Exponent	Manning Formula Channel Slope	Manning Formula Manning n	Manning Formula Bot Width m	Manning Formula Side Slope	Prescribed Dispersion m2/s	Bottom Algae Coverage	Bottom SOD Coverage
0.0000	0.0000	1.2500	0.9000	0.0000	0.000	0.0000	0.000	0.0030	0.0600	2.00	0.0000	0.00	50.00%	5.00%
0.0000	0.0000	1.2500	0.9000	0.0000	0.000	0.0000	0.000	0.0030	0.0600	5.00	0.0000	0.00	50.00%	5.00%
0.0000	0.0000	1.2500	0.9000	0.0000	0.000	0.0000	0.000	0.0030	0.0600	5.00	0.0000	0.00	50.00%	5.00%
0.0000	0.0000	1.2500	0.9000	0.0000	0.000	0.0000	0.000	0.0030	0.0600	7.00	0.0000	0.00	50.00%	5.00%
0.0000	0.0000	1.2500	0.9000	0.0000	0.000	0.0000	0.000	0.0030	0.0600	7.00	0.0000	0.00	50.00%	5.00%
0.0000	0.0000	1.2500	0.9000	0.0000	0.000	0.0000	0.000	0.0030	0.0600	7.00	0.0000	0.00	50.00%	5.00%
0.0000	0.0000	1.2500	0.9000	0.0000	0.000	0.0000	0.000	0.0030	0.0600	7.00	0.0000	0.00	50.00%	5.00%
0.0000	0.0000	1.2500	0.9000	0.0000	0.000	0.0000	0.000	0.0030	0.0600	7.00	0.0000	0.00	50.00%	5.00%
0.0000	0.0000	1.2500	0.9000	0.0000	0.000	0.0000	0.000	0.0030	0.0600	7.00	0.0000	0.00	50.00%	5.00%
0.0000	0.0000	1.2500	0.9000	0.0000	0.000	0.0000	0.000	0.0030	0.0600	7.00	0.0000	0.00	50.00%	5.00%

Table D-4 Water column rates and governing equations.

QUAL2K

Stream Water Quality Model

Silver_creek _2 (7/26/2006)

Water Column Rates

Parameter	Value	Units	Symbol
Stoichiometry:			
Carbon	40	gC	gC
Nitrogen	7.2	gN	gN
Phosphorus	1	gP	gP
Dry weight	100	gD	gD
Chlorophyll	1	gA	gA
Inorganic suspended solids:			
Settling velocity	0.3	m/d	v_i
Oxygen:			
Reaeration model	Thackston-Dawson		
User reaeration coefficient α	3.93		α
User reaeration coefficient β	0.5		β
User reaeration coefficient γ	1.5		γ
Temp correction	1.024		θ_a
Reaeration wind effect	None		
O2 for carbon oxidation	2.69	gO_2/gC	r_{oc}
O2 for NH4 nitrification	4.57	gO_2/gN	r_{on}
Oxygen inhib model CBOD oxidation	Half saturation		
Oxygen inhib parameter CBOD oxidation	0.60	mgO2/L	K_{socf}
Oxygen inhib model nitrification	Exponential		
Oxygen inhib parameter nitrification	0.60	L/mgO2	K_{sona}
Oxygen enhance model denitrification	Exponential		
Oxygen enhance parameter denitrification	0.60	L/mgO2	K_{sodn}
Oxygen inhib model phyto resp	Exponential		
Oxygen inhib parameter phyto resp	0.60	L/mgO2	K_{sop}
Oxygen enhance model bot alg resp	Exponential		
Oxygen enhance parameter bot alg resp	0.60	L/mgO2	K_{sob}
Slow CBOD:			
Hydrolysis rate	0.1	/d	k_{hc}
Temp correction	1.07		θ_{hc}
Oxidation rate	0.1	/d	k_{dcs}
Temp correction	1.047		θ_{dcs}

Fast CBOD:			
Oxidation rate	**0.23**	**/d**	k_{dc}
Temp correction	**1.047**		θ_{dc}
Organic N:			
Hydrolysis	**0.2**	**/d**	k_{hn}
Temp correction	**1.07**		θ_{hn}
Settling velocity	**0.1**	**m/d**	v_{on}
Ammonium:			
Nitrification	**1**	**/d**	k_{na}
Temp correction	**1.07**		θ_{na}
Nitrate:			
Denitrification	**0**	**/d**	k_{dn}
Temp correction	**1.07**		θ_{dn}
Sed denitrification transfer coeff	**0**	**m/d**	v_{di}
Temp correction	**1.07**		θ_{di}
Organic P:			
Hydrolysis	**0.2**	**/d**	k_{hp}
Temp correction	**1.07**		θ_{hp}
Settling velocity	**0.1**	**m/d**	v_{op}
Inorganic P:			
Settling velocity	**1**	**m/d**	v_{ip}
Inorganic P sorption coefficient	**0**	**L/mgD**	K_{dpi}
Sed P oxygen attenuation half sat constant	**0.05**	**mgO$_2$/L**	k_{spi}
Phytoplankton:			
Max Growth rate	**2.5**	**/d**	k_{gp}
Temp correction	**1.07**		θ_{gp}
Respiration rate	**0.1**	**/d**	k_{rp}
Temp correction	**1.07**		θ_{rp}
Death rate	**0.2**	**/d**	k_{dp}
Temp correction	**1.07**		θ_{dp}
Nitrogen half sat constant	**25**	**ugN/L**	k_{sPp}
Phosphorus half sat constant	**5**	**ugP/L**	k_{sNp}
Inorganic carbon half sat constant	**1.30E-05**	**moles/L**	k_{sCp}
Light model	**Half saturation**		
Light constant	**60**	**langleys/d**	K_{Lp}
Ammonia preference	**25**	**ugN/L**	k_{hnxp}
Settling velocity	**0.5**	**m/d**	v_a
Bottom Algae:			
Growth model	**Zero-order**		
Max Growth rate	**50**	**mgA/m^2/d or**	C_{gb}

		/d	
Temp correction	**1.07**		θ_{gb}
First-order model carrying capacity	**1000**	**mgA/m²**	$a_{b,max}$
Respiration rate	**0.5**	**/d**	k_{rb}
Temp correction	**1.07**		θ_{rb}
Excretion rate	**0.09**	**/d**	k_{eb}
Temp correction	**1.07**		θ_{db}
Death rate	**0.1**	**/d**	k_{db}
Temp correction	**1.07**		θ_{db}
External nitrogen half sat constant	**120**	**ugN/L**	k_{sPb}
External phosphorus half sat constant	**100**	**ugP/L**	k_{sNb}
Inorganic carbon half sat constant	**1.30E-05**	**moles/L**	k_{sCb}
Light model	**Half saturation**		
Light constant	**60**	**langleys/d**	K_{Lb}
Ammonia preference	**25**	**ugN/L**	k_{hnxb}
Subsistence quota for nitrogen	**0.72**	**mgN/mgA**	q_{0N}
Subsistence quota for phosphorus	**0.1**	**mgP/mgA**	q_{0P}
Maximum uptake rate for nitrogen	**150**	**mgN/mgA/d**	ρ_{mN}
Maximum uptake rate for phosphorus	**5**	**mgP/mgA/d**	ρ_{mP}
Internal nitrogen half sat constant	**0.9**	**mgN/mgA**	K_{qN}
Internal phosphorus half sat constant	**0.13**	**mgP/mgA**	K_{qP}
Detritus (POM):			
Dissolution rate	**0.5**	**/d**	k_{dt}
Temp correction	**1.07**		θ_{dt}
Fraction of dissolution to fast CBOD	**1.00**		F_f
Settling velocity	**0.1**	**m/d**	v_{dt}
Pathogens:			
Decay rate	**0.6**	**/d**	k_{dx}
Temp correction	**1.07**		θ_{dx}
Settling velocity	**1**	**m/d**	v_x
Light efficiency factor	**1.00**		α_{path}
pH:			
Partial pressure of carbon dioxide	**347**	**ppm**	p_{CO2}

D.7. Validating Model to Water Quality Data

After the base flow conditions model was calibrated, the next step was to validate the model using grab sample data collected at various times of the year. The model was validated to the parameters of temperature, DO, nitrate, ammonia, total phosphorus, pH and flow for that given event (Table D-5). Of the sampling data available to validate the model, sampling events during or directly following a precipitation event were not used. This is because the sink holes would be bypassed by the higher flow, creating conditions outside of a base flow condition. Additionally, ammonia violations were only observed during periods of low flow.

Table D-5. Results of model validation run for July 26, 2006 comparing observed conditions to modeled.

Parameter	Observed	Modeled
Temperature (C)	28.2	26.4
DO (mg/L)	7.9	7.3
NO_3 (mg/L)	2.4	2.2
NH_3 (mg/L)	0.75	0.48
TP (mg/L)	0.87	0.65
pH	8.2	8.8
Flow (m^3/s)	0.01	0.01

D.8. Using calibrated and validated model to calculate TMDL for Ammonia

The final model scenario was used to locate the sources of ammonia causing the impairment and determine how much ammonia was needed to produce a violation of Iowa's water quality standards. Once this was determined, the modeled load was used to calculate the TMDL.

The first task required examining land uses within the impaired segment of the watershed to determine which non-point sources contribute ammonia to the stream. There are two open feedlots within close proximity to the impaired section of the watershed (Fig. D-5). Runoff from these two operations along with livestock with direct access to the stream act as nonpoint sources of ammonia. These two operations were entered into the model as discharge sources. The model was then run with different discharge rates to produce ammonia violations at the most critical conservative conditions. These conditions were assumed to be a temperature of 20° C or greater, a pH of 8.2 or greater and a flow of 0.01 m^3/s. Different discharge rates and concentrations were used until violation occurred. This rate multiplied by the given concentration resulted in a daily release of 12.33 lbs. This was determined to be the maximum daily load the stream could assimilate and still meet water quality standards.

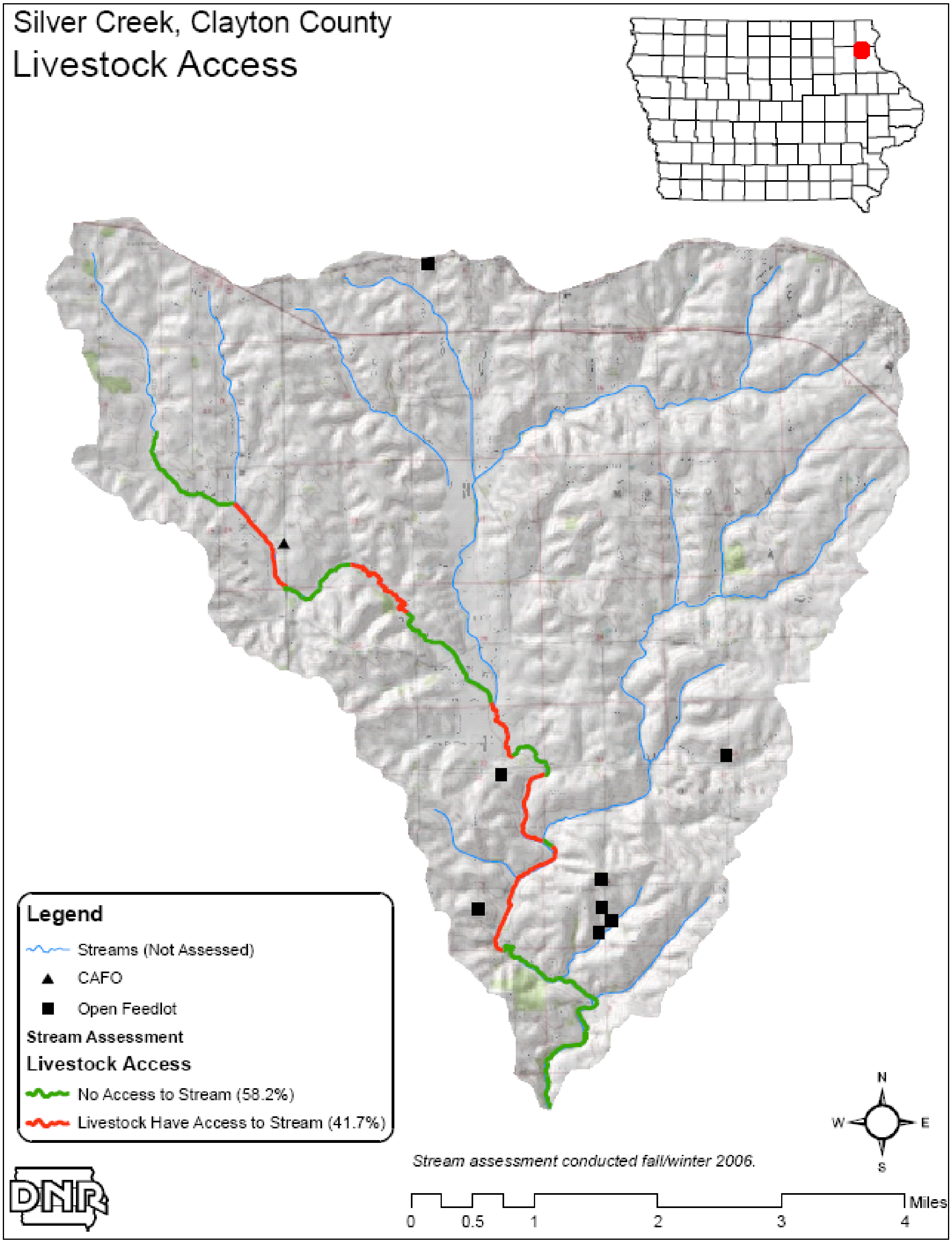


Figure D-4. Segments of Silver Creek where livestock have direct access and locations of AFO/CAFOs within watershed.

D.9. References

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Appendix E --- Public Comments

The draft TMDL was posted on the Iowa Department of Natural Resources website on December 31, 2009 and comments were accepted from December 31, 2009 to February 1, 2010. On January 14, 2010, a public meeting was held in Luana, Iowa to obtain comments and input.

No public comments were received for the Silver Creek TMDLs.