Stressor Identification
for

Hecker Creek
Allamakee County, Iowa

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Watershed Improvement Section
&
Watershed Monitoring and Assessment Section

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Executive Summary

A Stressor Identification (SI) was completed for Hecker Creek (Segment IA 01-YEL-0155_0), located in southern Allamakee County near the town of Postville, Iowa. Hecker Creek is a tributary of the Yellow River. This waterbody is identified on Iowa's Section 303(d) list of impaired waters as impaired for aquatic life use, cause unknown. The SI process 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 goal of this SI was to determine the primary cause(s) of the biological impairment including any pollutant(s) for which a Total Maximum Daily Load (TMDL) is required.

The first biological assessment of Hecker Creek occurred in the summer of 2000 after a fish kill investigation in the Yellow River, downstream of the confluence with Hecker Creek, earlier that year. The assessment uncovered evidence of biological impairment of both 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.

Further biological sampling conducted in 2006 and 2007 showed improvements in the benthic macroinvertebrate community in both years. However, Ephemeroptera (mayfly) richness was low, and the percentage of Ephemeroptera, Plecoptera (stonefly), and Trichoptera (caddisfly) (EPT) taxa had dramatically decreased. Low numbers of EPT taxa often indicate water quality problems. The fish community improved in 2006, but was comprised of mostly pollution tolerant species, and declined again in 2007. Stream data and information about the watershed were reviewed to determine the cause(s) of impairment.

Despite some data limitations, the evidence was sufficient to identify the following primary stressors, either of which is capable of causing biological impairment in the Hecker Creek watershed:

- elevated concentrations of chloride and total dissolved solids (TDS);
- habitat alteration and decrease in habitat complexity

Depending upon sources and types of stressors, they can manifest as short-term acute impacts or long-term chronic impacts to aquatic biota. To restore the biological condition of the stream, TMDLs (also known as Water Quality Improvement Plans), National Pollutant Discharge Elimination System (NPDES) permits, and/or implementation plans need to address each of the primary stressors by focusing on all ways these stressors, including their sources, lead to the biological impairment in this watershed.

The chloride/TDS issue is the result of inputs from one permitted facility only and will be managed in the NPDES permit for the facility. The current permit expired in 2008. A new permit cannot be written until the completion of the Use Attainability Analysis, at which time adjustments to the permit can be made to lower the levels of chloride in Hecker Creek to protect aquatic organisms. By that time, Iowa should also have finalized the chloride water quality standards. There are also no significant nonpoint source inputs of chloride in the Hecker Creek watershed. The other identified stressor is poor habitat quality, which is not a pollutant. Therefore a TMDL is not needed to address this impaired waterbody.

1. Introduction

This Stressor Identification (SI) for Hecker Creek (Segment IA 01-YEL-0155_0) was completed to determine the cause(s) of the biological impairment, including any pollutant(s) for which a Total Maximum Daily Load (TMDL) is required. The SI includes a review of available data for the entire watershed of Hecker Creek including non-listed segments. A major goal of this SI was to determine whether the impairment was caused by a pollutant (e.g. ammonia) or a non-pollutant stressor (e.g. channelization), the former of which may potentially require a TMDL. Regardless of whether or not the stressor is defined as a pollutant, a complete SI identifies all causal agents and pathways responsible for impairing the aquatic biological community.

1.1. Watershed Features

Hecker Creek is a warm water stream located in Allamakee County, Iowa, within the Yellow River watershed (Figure 1-1). The watershed is within the bedrock-dominated terrain of the Paleozoic Plateau—Driftless Area ecoregion (52b), which covers portions of northeast Iowa, southeast Minnesota, southwest Wisconsin, and a small portion of northwest Illinois. Steep slopes and bluffs, higher relief, sedimentary rock outcrops, dense forests, and unique boreal microhabitats differentiate this ecoregion from the Western Corn Belt Plains to the west (Prior 1991; Griffith et al., 1994) (Appendix A, Figure A-1). 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 in the Iowa portion of this region are located in entrenched valleys and have cool waters with higher gradients flowing over rocky substrates.

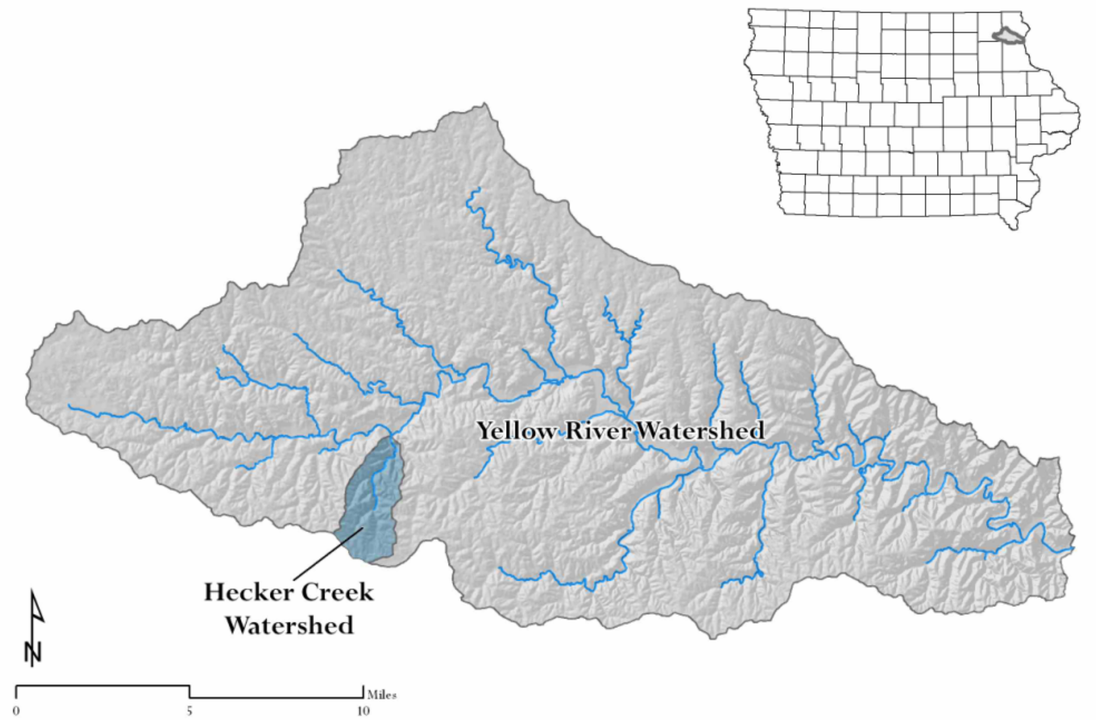


Figure 1-1. The location of the Hecker Creek watershed within the Yellow River watershed.

The Hecker Creek watershed includes a total of 2,977 acres (4.65 square miles) in the southeast portion of the county, extending north from the outskirts of Postville, to a point where Hecker Creek joins the Yellow River about five miles north of Postville (Figure 1-2). During normal flow conditions, the primary channel of Hecker Creek extends for about 5 miles. The surface topography is characterized by a branching drainage pattern that directs streams and runoff north toward the Yellow River. Elevations range from approximately 1,160 feet above mean sea level at the headwaters near Postville to 940 feet above mean sea level along the Yellow River valley (Figure 1-3). An average basin slope of 8.53 percent (the average slope of the watershed) and a stream density of 1.46 (the ratio of stream miles to square miles of the basin) indicate that surface flows reach the stream quickly.

The bedrock surface in northeast Iowa has been shaped extensively by erosion from ancient streams and glaciers. Primary bedrock outcrops in the area are shale and dolomite of the Maquoketa formation, and the limestone and dolomite of the Galena Group. Karst features associated with dissolution of carbonate rocks can form sinkholes at the surface. The geological composition of Hecker Creek's watershed increases the threat of agricultural pollutants contaminating groundwater. Unconsolidated glacial drift and loess deposits are found on the highest points near the headwaters, and bedrock outcrops become more prevalent farther to the north in Hecker Creek and the Yellow River valleys. The Maquoketa formation exists primarily in the southern portion of the watershed, but is absent along the Hecker Creek valley due to erosion into the Galena limestone.

In the summer of 2005, Northeast Iowa Resource Conservation & Development, Inc. (NEIARC&D) conducted a series of dye tracer studies in the Yellow River watershed. Flouroscein/uranine dye was placed into the stream at a point upstream of the sinkhole in Hecker Creek (Figure 1-3 and 1-4). Direct water sampling and activated charcoal packets were used to determine if the dye was present in various streams, drilled wells, and springs following dye injection. Dye from Hecker Creek resurfaced about four miles away at the Stonehouse Spring approximately 19 hours after input (Figure 1-5). As evidenced by the study, surface water in karst landscapes can disappear underground through sinkholes and stream sinks, and readily mixes with groundwater before reappearing at springs miles away. The direct surface to groundwater interactions make karst aquifers highly susceptible to contamination.

Current land use in the watershed is dominated by agriculture (Appendix B, Fig. B-19). According to a tablet PC land cover assessment conducted in 2007, approximately 62 percent of the 2,977 acres in the watershed are devoted to row crop agriculture and livestock production (Paul Berland, NEIARC&D). Based on the Rapid Assessment of Stream Conditions Along Length (RASCAL) assessment, cattle graze approximately 47 percent of the stream channel; however, there are no open feedlots or confined animal feeding operations (CAFO) in the watershed (Appendix B, Fig. B-20). The Hecker Creek watershed includes one permitted point source: the AgriProcessors, Inc. kosher meat-processing plant located at the headwaters of Hecker Creek (Figure 1-2). The plant processes beef, lamb, turkey, and chicken.

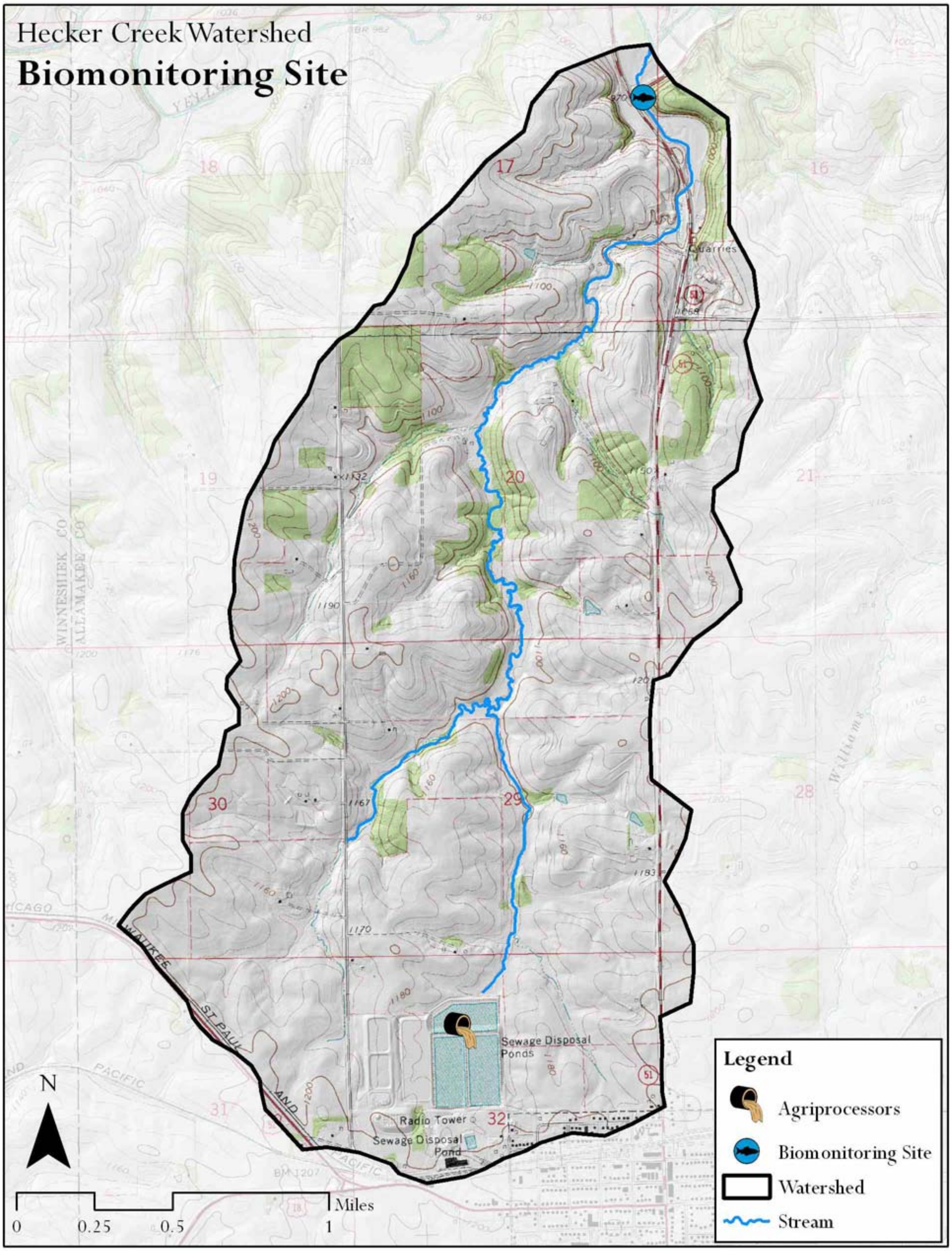


Figure 1-2. The Hecker Creek watershed with TMDL sampling site and point source.

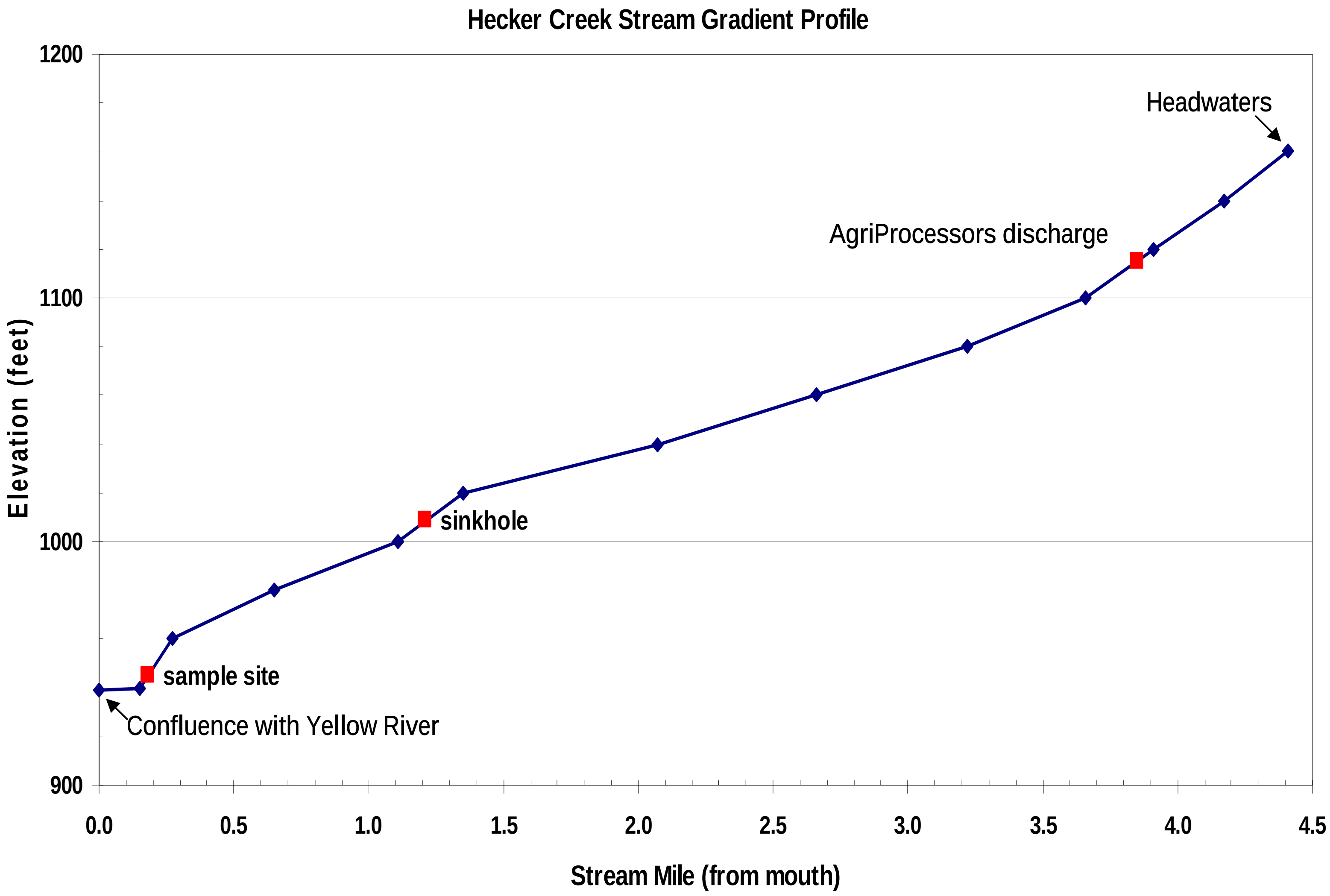


Figure 1-3. Hecker Creek stream gradient profile.

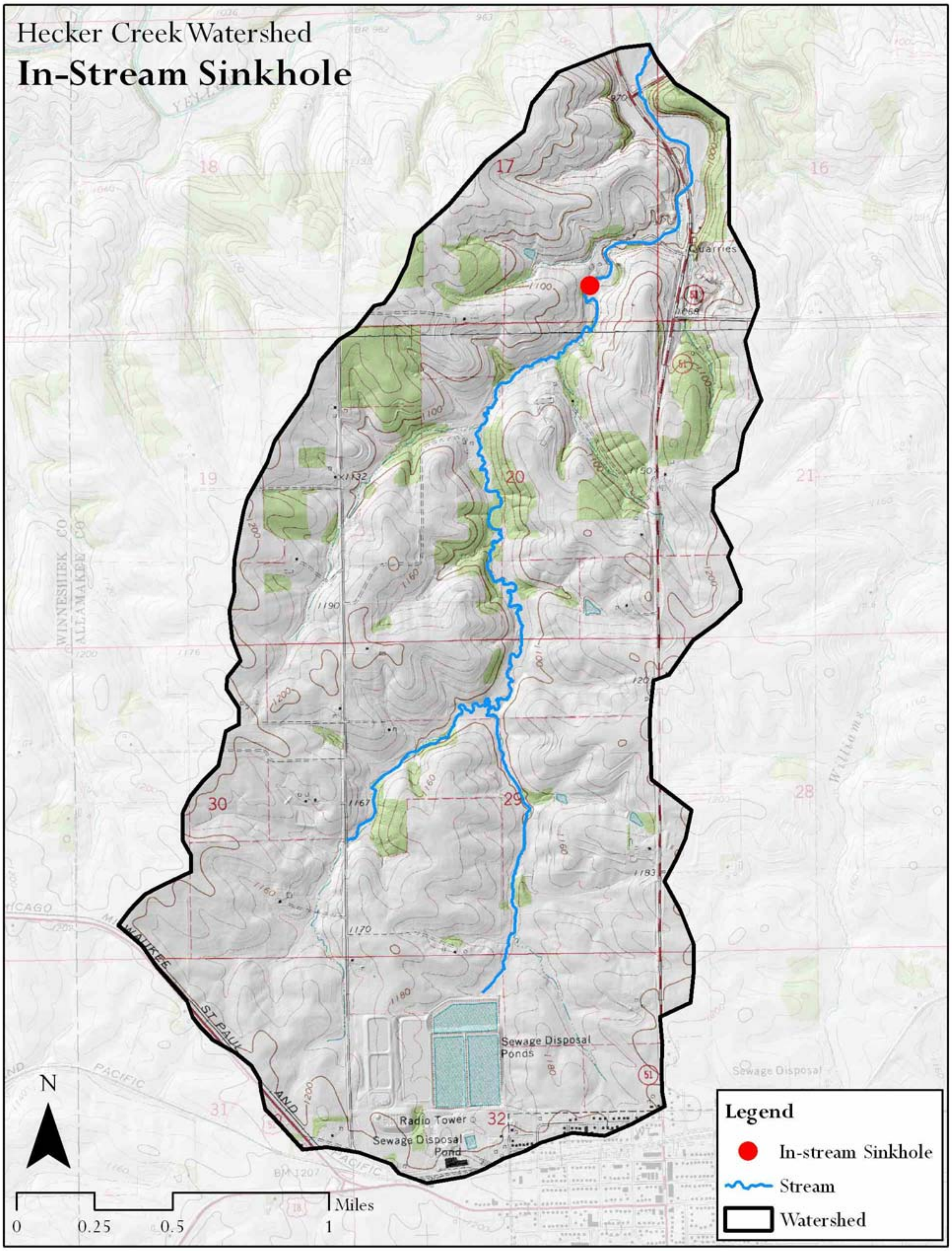


Figure 1-4. Location of in-stream sinkhole in the Hecker Creek watershed.

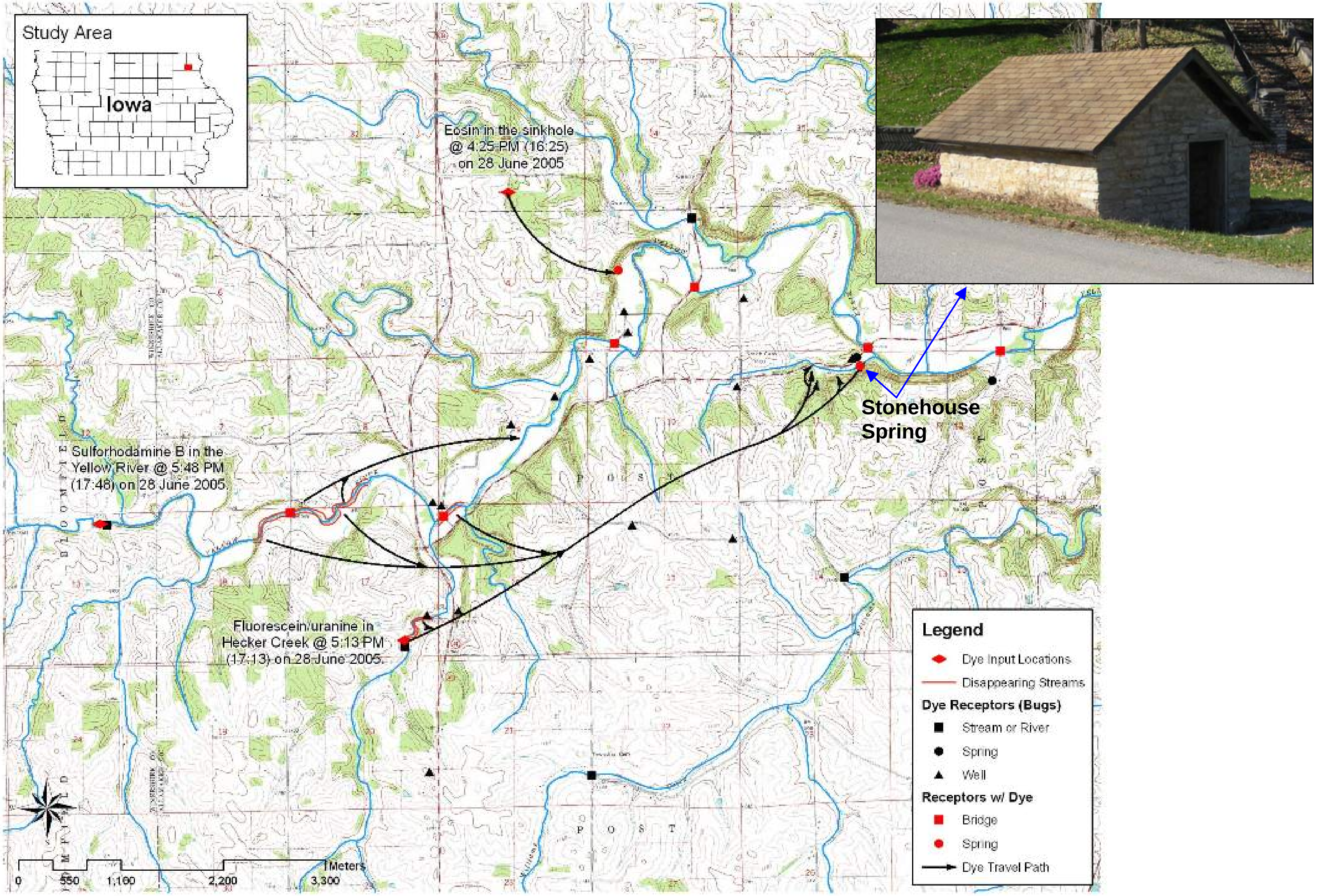


Figure 1-5. Dye tracer study conducted in Hecker Creek and Yellow River in 2005 by Northeast Iowa Resource Conservation & Development, Inc. Courtesy of Paul Berland (NEIARC&D)

Until October 2006, Hecker Creek received wastewater discharges from the City of Postville Industrial waste stabilization lagoons. The lagoons received the wastewater from AgriProcessors and another meat-processing plant, Iowa Turkey Products, Inc. The Iowa Turkey Products plant was closed in 2004 after a fire destroyed the facility. Discharges from the waste stabilization lagoons occurred during discrete time periods. During dry conditions, Hecker Creek had little or no natural flow from the watershed (Fig. 1-6). When the Postville lagoons discharged under such conditions, the water in the creek was essentially all wastewater. During wetter periods, discharges from the plant mixed with runoff from the watershed, and the resulting water quality was a blend of wastewater and runoff from nonpoint sources.

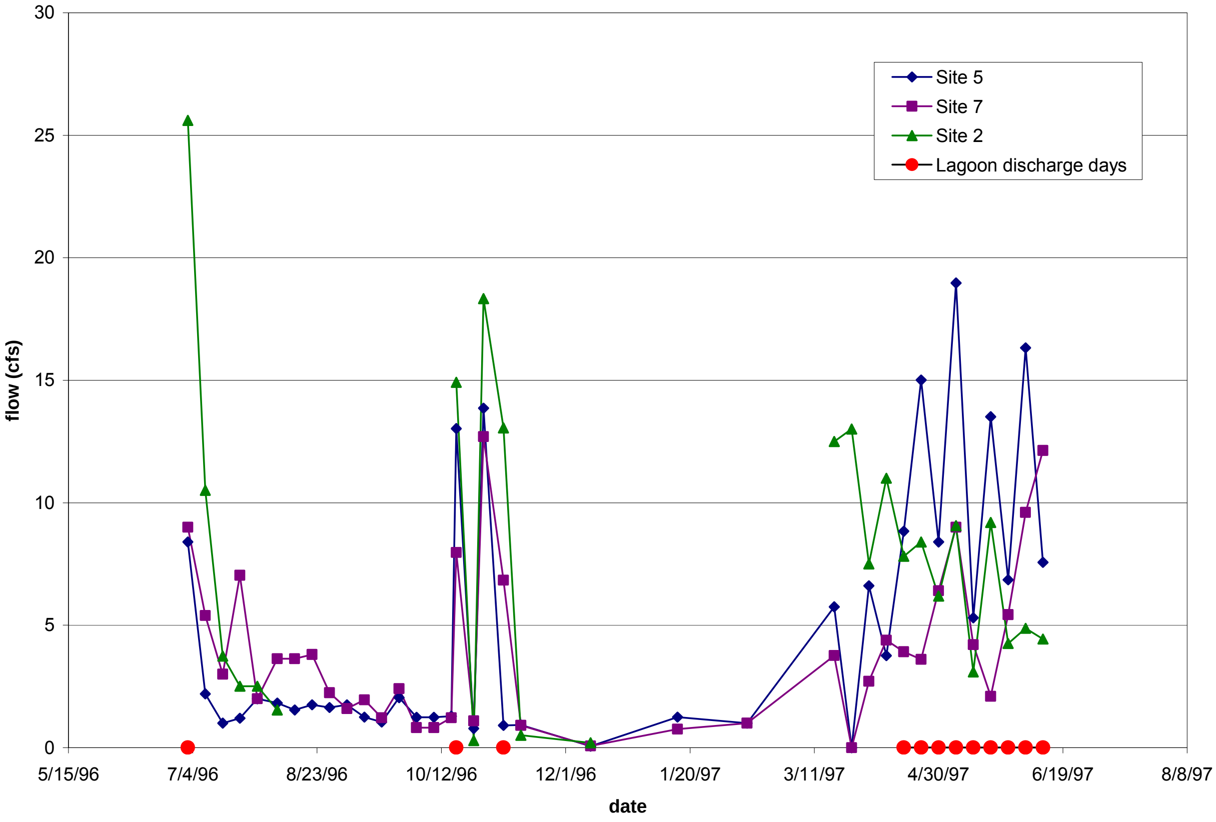


Figure 1-6. Flow in the Hecker Creek watershed in relation to discharges from the Postville Industrial wastewater lagoons in 1996 and 1997 as sampled by Fox Engineering Associates, Inc. Site 5 is upstream site, site 2 is downstream site and site 7 is between them. (Appendix B, Fig. B-1).

This range of conditions caused considerable variability in water quality in the creek. Field reports from water quality sampling staff indicated that prior to the new treatment facility coming online, Hecker Creek would have green or red colored water when the lagoons were discharging. Additionally, the algae that grew in Hecker Creek were unique. It was also noted during the 2007 sampling season (after the treatment plant went online) that the drastic color changes in the water had not occurred, but the stream still experienced occasional turbidity.

In October 2006, AgriProcessors began treating waste in an activated sludge treatment plant that continually discharges to Hecker Creek. Facility statistics and effluent limits can be found in Table 1-1. There is also a gravel quarry (Green Quarry, run by Bruening Rock Products, Inc.) in the watershed; however the discharge permits show they discharge into the Yellow River, not Hecker Creek.

Table 1-1. Facility information for Hecker Creek watershed point source. Permit conditions apply through 2013.

Facility	**AgriProcessors, Inc. (Industrial)**
IA NPDES #	0375102
EPA #	IA0077135
Treatment type	Activated sludge
5-day Carbonaceous Biochemical Oxygen Demand (CBOD5) (mg/L)[1]	30 (30 day avg.)
Total Suspended Solids (TSS) (mg/L) [1]	39 (30 day avg.)
Chloride (mg/L) [1]	1,671 (30 day avg. and maximum)
pH [1]	6.0-9.0
Ammonia nitrogen (mg/L) [1]	19[2] / 14[3] / 13[4] / 11[5] (30 day avg.)
Population equiv.	110,778
Design flow (MGD)	0.88

1. These are the NPDES permit limits for this facility for CBOD5, TSS, Chloride, pH, and Ammonia.
2. Ammonia permit values for January and February.
3. Ammonia permit values for March – June and October – December.
4. Ammonia permit values for July and September.
5. Ammonia permit values for August.

1.2. Stream Flow and Water Quality

Hecker Creek contains an instream sinkhole (common in the karst topography of the region), which directly impacts stream flow in Hecker Creek. Surface flows from this and surrounding watersheds contribute to groundwater flow, which eventually resurfaces at various springs in the region (P. Berland unpublished data). Flow monitoring data from 2000 demonstrate there is a decrease in flow, likely due to the instream sinkhole (Figure 1-4). On August 30, 2000 flow was 3.90 cubic feet per second (cfs) upstream of the sinkhole and 3.39 cfs downstream of the sinkhole (loss of 0.51 cfs). On October 3, 2000, flow was 4.37 cfs upstream of the sinkhole and 3.7 cfs downstream of the sinkhole (loss of 0.67 cfs). At both sampling dates, discharge from the Postville waste stabilization lagoons was approximately 3.87 cfs.

The nearest U.S. Geological Survey (USGS) stream flow gauge is on the Yellow River near Ion (Gauge No. 05389000), approximately 26 miles downstream of Hecker Creek. While this gauge measures flow from a much larger watershed, it illustrates flow patterns in the region during the sampling period evaluated for the SI and provides a general sense of the seasonal flow patterns that occurred during the data collection period. Stream discharge data from this gauge (Figure 1-7) show a seasonal flow pattern with some similarities to those recorded at the TMDL monitoring site at Hecker Creek (Figure 1-8). However, there are significant gaps in the flow data for Hecker Creek. Also, the small watershed size and the effects of contributions from the lagoons (before October 2006) and the treatment plant (after 2006) make Hecker Creek hydrologically unique compared to the Yellow River at the USGS gauge site. Additionally, the Yellow River is heavily influenced by the inputs from the Livingood Spring, which contributes up to 100 percent of the flow at its confluence with the Yellow River (approximately 2.5 miles downstream of Hecker Creek). Upstream of the Livingood Spring, the Yellow River periodically runs completely dry due to instream sinkholes above Hecker Creek, which could limit fish recruitment into Hecker Creek (Figure 1-9).

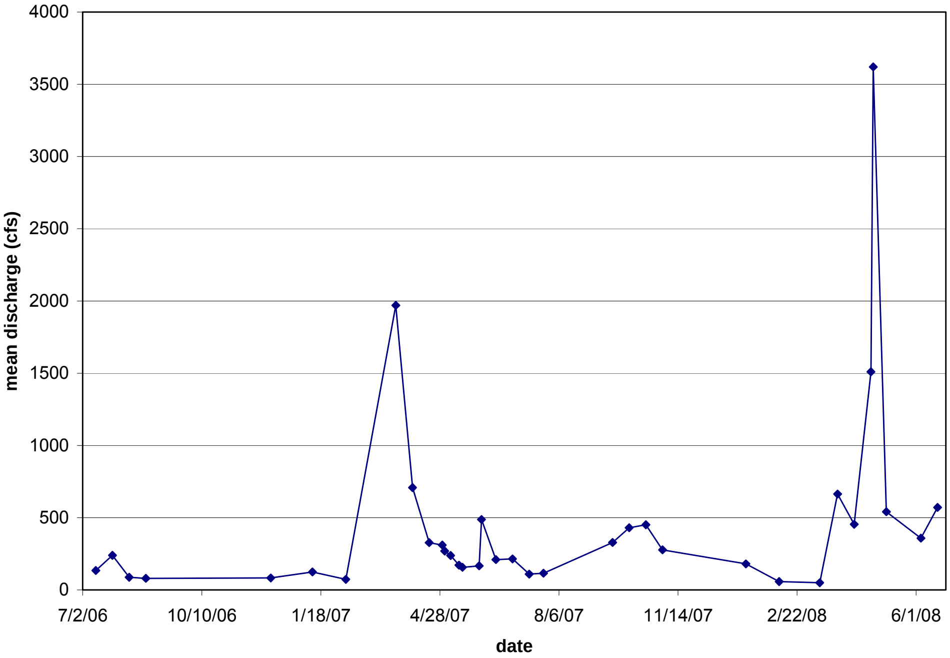


Figure 1-7. USGS stream flow gauge mean flow for the Yellow River near Ion, Iowa on dates flow was sampled in Hecker Creek.

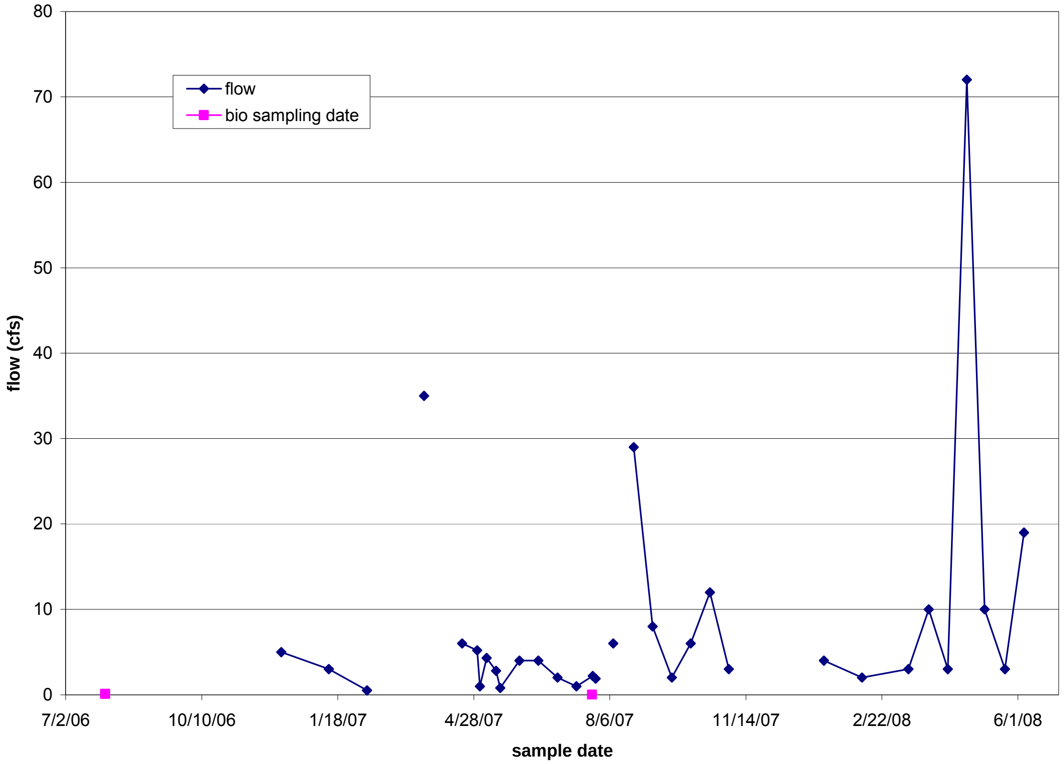


Figure 1-8. Hecker Creek stream discharge monitoring. Breaks in line indicate gaps in the flow data (i.e. other water quality data was collected, but not flow).

Figure 1-9. The Yellow River approximately 0.25 miles upstream of the Hecker Creek confluence on October 22, 2008.

During the 2007 RASCAL assessment, it was determined that springs contribute to the stream flow of Hecker Creek in several locations (Figure 1-10), which may influence water quality. Relatively high specific conductance and pH levels measured in Hecker Creek substantiate the important influence of groundwater contributions from the underlying limestone bedrock aquifer. Specific conductance is a measure of how well water can conduct an electrical current. Conductivity increases with increasing amount and mobility of ions. Some rock and soil release ions easily when water flows over them; for example, if water flows over rocks containing calcite ($CaCO_3$), such as limestone, calcium (Ca^{2+}) and carbonate (CO_3^{2-}) ions will dissolve into the water. Therefore, specific conductance will increase as will pH. Water quality characteristics measured at Hecker Creek are generally indicative of intensive agricultural land uses (nitrogen, phosphorus, and total suspended solids (TSS)/turbidity) and point source inputs (chloride/total dissolved solids (TDS)) (Appendix B; Table B-2). Concentrations of these parameters at the monitoring site were elevated compared to levels at ecoregion reference stream sites and with a local comparison site within the Yellow River watershed (Appendix B, Table B-9 and Fig. B-2).

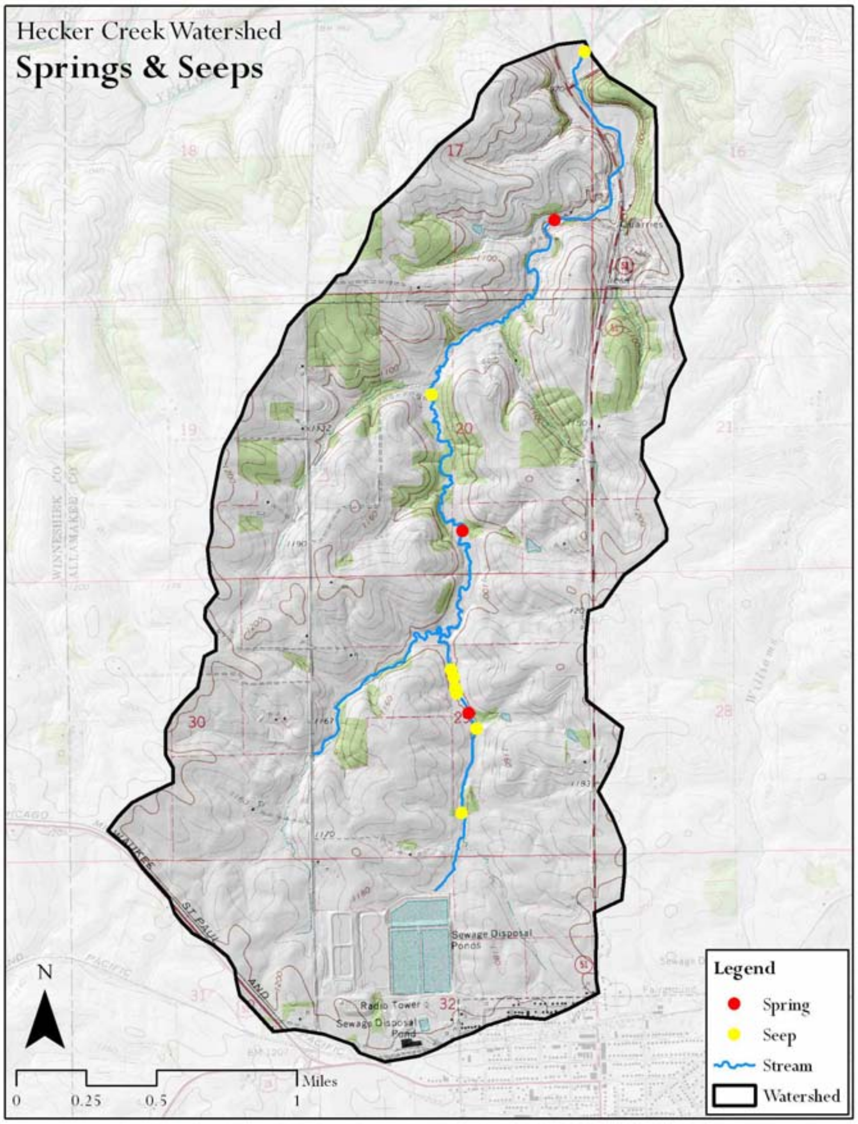


Figure 1-10. Locations of seeps and springs in the Hecker Creek watershed based on 2007 RASCAL assessment

Sampling conducted in 1996-97 by Fox Engineering Associates, Inc. (Fox Engineering Associates 1997) shows that degraded water quality conditions existed in the Hecker Creek watershed prior to the more recently documented problems (Appendix B; Table B-1 and Figure B-1). Comparing historical monitoring information to the more recently collected data suggests that the wastewater discharges had much greater impacts before stricter effluent limits were given to the point source (Figures 1-11 and 1-12). The Fox Engineering survey findings include elevated levels of ammonia, total dissolved solids, chloride, and biochemical oxygen demand (BOD).

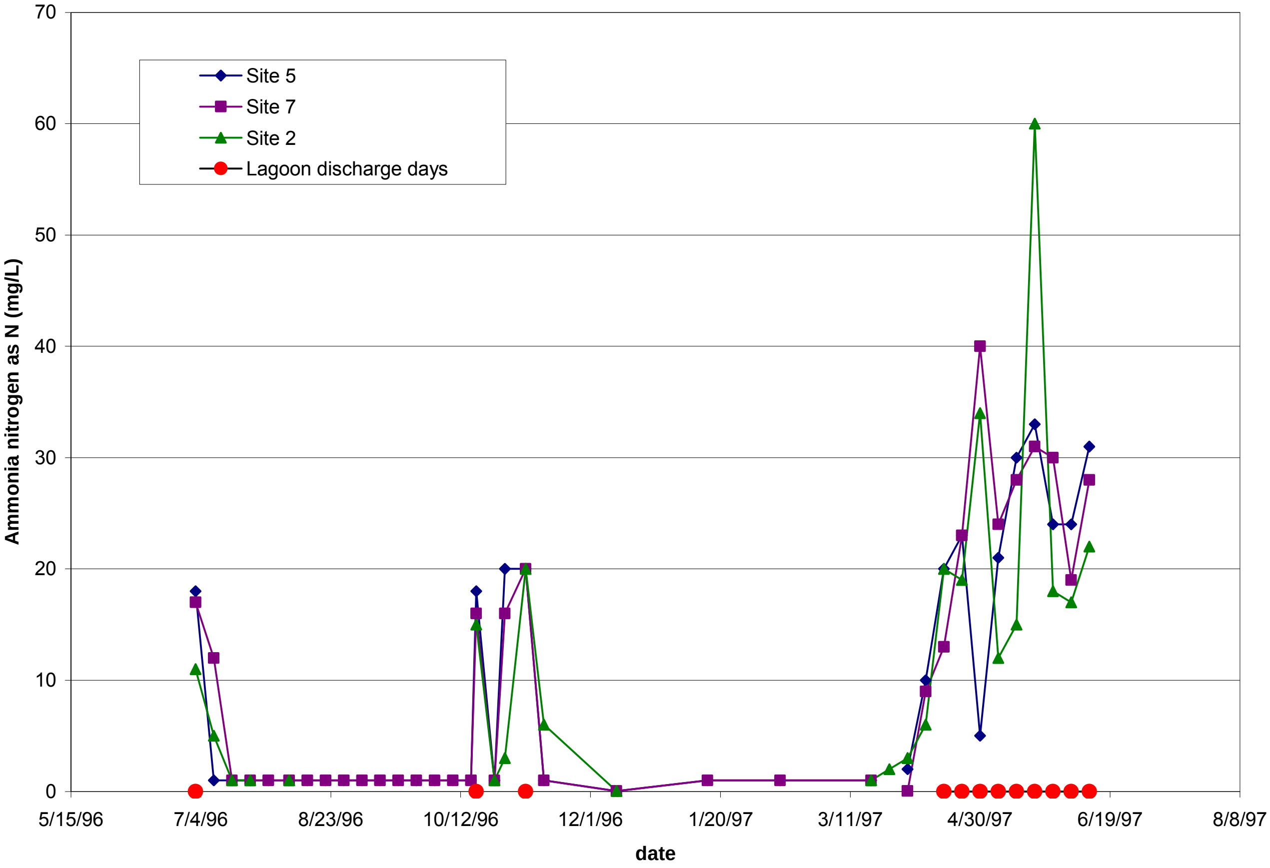


Figure 1-11. Ammonia levels in Hecker Creek related to treatment lagoon discharges from 1996-97 study by Fox Engineering Associates, Inc. Site 5 is the upstream site, site 2 is the downstream site and site 7 is between them. (Appendix B, Figure B-1).

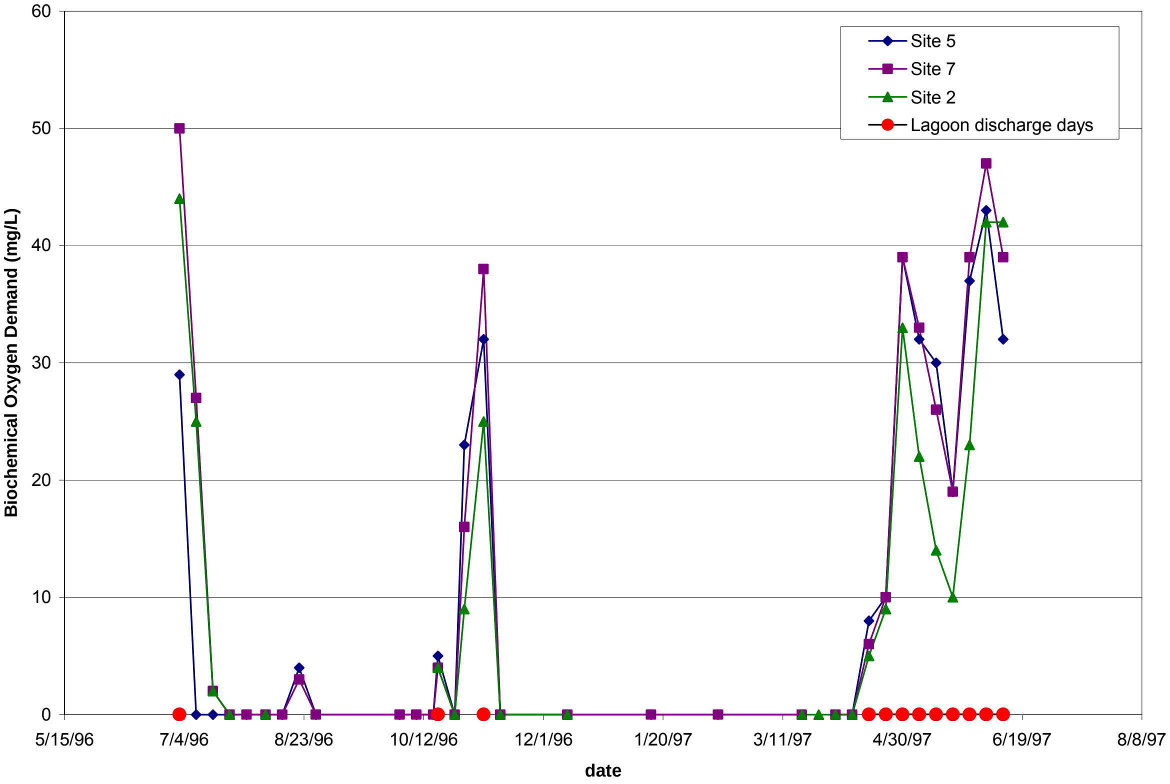


Figure 1-12. Biochemical oxygen demand levels in Hecker Creek related to treatment lagoon discharges from 1996-97 study by Fox Engineering Associates, Inc. Site 5 is the upstream site, site 2 is the downstream site and site 7 is between them. (Appendix B, Figure B-1).

1.3. Biological Impairment

Hecker Creek was first added to the Section 303(d) impaired waters list in 2002, based on biological sampling conducted in 2000 as a follow-up to a fish kill earlier that year. A series of biological metrics that reflect stream water quality and habitat integrity were calculated from sampling data collected at a site approximately 0.2 miles upstream of the confluence with the Yellow River (Figure 1-2). The biological metrics are based on the numbers and types of benthic macroinvertebrate taxa and fish species collected in the stream sampling reach. 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.

Each metric contains unique information about the stream biological community (i.e. different methods of feeding, pollution sensitivity, and habitat use) and reflects distinctive responses to environmental disturbances (i.e. pollution, changes in habitat). The biological metrics were combined to make a fish community index of biotic integrity (FIBI) and a benthic macroinvertebrate index (BMIBI). The indexes rank the biological integrity of a stream sampling reach on a rising scale from 0 (minimum) to 100 (maximum). Table 1-2 shows general qualitative scoring guidelines for the two indexes.

Table 1-2. 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 (Appendix A, Figure A-1). Reference streams were chosen to represent the least disturbed (i.e. most natural) streams in the ecoregion. The reference stream BMIBI and FIBI scores shown are the minimum scores for biological integrity that support aquatic life use in ecoregion 52b (Table 1-3). 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 2000 FIBI score for Hecker Creek was 15 (poor) and the BMIBI score was 52 (fair). The aquatic life use was assessed as not supporting.

Table 1-3. Reference criteria for assessing biological integrity.

Ecoregion	BMIBI	FIBI
Paleozoic Plateau (52b)	61	52

The stream was investigated as part of a fish kill that occurred on the Yellow River on March 17, 2000, where an estimated 4,800 fish were killed. According to the IDNR fish kill database: *"Dead fish were observed both upstream and downstream of the Smith Rd. bridge on the Yellow River, but only below the confluence with the unnamed tributary (Hecker Creek) in section 17 north of Postville. Water turbid and green, with high flow. The kill affected a 3.1 mile segment of the Yellow River. Dead fish were not observed in the unnamed tributary (Hecker Creek) that enters into the Yellow River in Section 17."* IDNR Field Office 1 investigated the City of Postville Industrial Lagoons on the evening of March 17, 2000 as part of the fish kill investigation. They found that all of the valves within the treatment system had been opened sometime "*on or around Saturday, March 11, 2000 by an unnamed, uncertified city employee*" which was "*not standard operating procedure and directly affected the overall quality of the discharging water.*" Water sampling taken on March 17, 2000 found ammonia levels of 73 mg/L from the lagoon discharge, 48 mg/L in Hecker Creek, and 0.2 mg/L in the Yellow River upstream of the confluence with Hecker Creek and 24 mg/L downstream (in the fish kill segment).

Biological sampling was repeated in 2006 and 2007 at the original site in the Hecker Creek watershed (Figure 1-2) and at a site on an unnamed tributary to the Yellow River (Segment No. IA 01-YEL-0150_0) (Appendix B, Figure B-2) for local comparison. The BMIBI and FIBI scores from both sites met the BICs for the 2006 sampling season but failed to meet the BICs in 2007, confirming the biological impairment first documented in 2000 (Table 1-4). The BMIBI and FIBI scores from the local comparison site showed a similar pattern of passing scores in 2006 and failing scores in 2007, indicating there may be something impacting the biota on a larger scale within the Yellow River watershed. However, the individual metrics indicate there are many differences between the watersheds.

Table 1-4. Scores for indices of biological integrity for benthic macroinvertebrates and fish from biological sampling in 2000, 2006, and 2007.

	Hecker Creek			Local comparison site		BIC for Ecoregion 52b
	2000	2006	2007	2006	2007	
FIBI	16	54	30	63	36	52
BMIBI	53	61	70	53	70	61

The BMIBI and FIBI results are the primary evidence of aquatic life use impairment in the Hecker Creek watershed. However, for diagnosing stream problems, the IBIs are not as useful as the individual metrics that comprise them. Each metric contains unique information about the stream biological community and reflects distinctive responses to environmental disturbances. Therefore, the metrics from the Hecker Creek site (Appendix B; Tables B-5 and B-6) have been analyzed in an effort to extract more specific information about the biological impairment and what the metric responses suggest about the types and magnitude of environmental stressors affecting the aquatic community.

The FIBI and BMIBI metric scores were analyzed two ways: 1) by comparing the metric scores to regional reference site metric scores and 2) independently analyzing by site, the metric score contribution (or lack of) to the overall index score (Appendix B, Table B-5 and B-6). Based on the FIBI metric analysis, it was determined that metrics of concern were as follows: higher pollution tolerance index values for both 2006 and 2007, low species diversity, low numbers of native species, lack of benthic invertivores, low catch per unit effort in 2000, 2006, and 2007, and low numbers of fish captured in 2000 (38) and 2007 (35). The low numbers of fish in these samples are one reason why the FIBI scores do not meet ecoregion reference expectations. At these low fish abundance levels, all of the proportional abundance metrics are capped at 2.5 points (normally the maximum possible score is 10). Thus, the FIBI scoring system does not allow the reference benchmark to be met or exceeded at low levels of fish abundance.

While the BMIBI score has improved greatly since 2000, Ephemeroptera (mayfly) richness is still low, and the percentage of Ephemeroptera, Plecoptera (stonefly), and Trichoptera (caddis fly) (EPT) taxa has dramatically decreased. Low numbers or lack of EPT taxa often indicate water quality problems. Additionally, the Modified Hilsenhoff Biotic Index (MHBI) scores (used to place a stream along an organic pollution gradient) have increased each year, indicating a greater degree of impairment. This metric responds to increased levels of organic waste and nutrient loading that lead to lower dissolved oxygen levels.

The FIBI and BMIBI scores for the local comparison site showed overall trends similar to Hecker Creek (Table 1-4). However, individual metrics show that there are significant differences between the two sites. The FIBI metric analysis for the Hecker Creek site indicated a very low percentage of benthic invertivores (fish that eat benthic macroinvertebrates) in both years; however, the local comparison site was dominated by benthic invertivores. Also, unlike Hecker Creek, the local comparison site had good tolerance index values (indicating the fish in the creek were less tolerant of pollution) in both years, and the number of fish caught was nearly three times greater than in Hecker Creek. The BMIBI metric analysis for the local comparison site showed low numbers and percentages of EPT taxa and Ephemeroptera taxa in 2006. However, by 2007 most of those scores had improved to a level above the ecoregion average, whereas Hecker Creek experienced a decline. Additionally, the MHBI scores for the local comparison site were low for both years, indicating that it had lower levels of organic pollution than Hecker Creek.

2. Stressor Identification Process

Iowa's SI procedures (IDNR 2005b) are adapted from technical guidance documents developed by the U.S. Environmental Protection Agency (EPA) (2000, 2005). The EPA also supports an on-line resource named "Causal Analysis/Diagnosis Decision Information System" (CADDIS) (http://cfpub.epa.gov/caddis/) where SI-related information and tools are available.

2.1. Candidate Causes and Theoretical Associations

Candidate causes for SI analysis are chosen from the IDNR generalized list of aquatic life use impairment causes (IDNR 2005b). The list includes most of the pollutant and non-pollutant based causal agents known to adversely impact aquatic life in Iowa's rivers and streams. It is important to note that candidate causes are identified at varying scales and degrees of separation from the proximate stressor that actually elicits an adverse in-stream biological response. For example, high levels of nutrients (nitrogen or phosphorus) are not harmful to aquatic life by themselves, but they can lead to algal blooms which can lead to low levels of dissolved oxygen that are harmful.

Conceptual models (Appendix C) are used to illustrate the mechanisms and pathways that link activities or sources in a watershed (i.e. excessive fertilizer application) with proximate stressors (i.e. low dissolved oxygen). From this perspective, an impairment cause can be viewed more broadly as encompassing the stressor itself (i.e. low dissolved oxygen), the activities or sources that produce the stressor (algal blooms), and the mechanism(s) and pathway(s) by which the stressor is manifested in a stream (i.e. excessive fertilizer application). Conceptual models are also a useful means of organizing the evidence review process, which is discussed in the next section.

A ranking process is used to reduce the master list of candidate causes to a manageable size. After a cursory review of sampling data, watershed land use, and other pertinent information, each candidate cause is assigned a rating (high, medium, low) based upon the relative probability any given cause, by itself, could be responsible for the observed impairment. For those parameters that were not assessed during the sampling, the rating of no data (ND) was applied. The final ratings are obtained by consensus opinion among SI team members. Candidate causes ranked as high or moderate probability are selected for the analysis of causal association. While not completely eliminated, candidate causes ranked as low probability or ND are not advanced for further consideration. Low probability candidate causes can be reconsidered should the evidence analysis process fail to identify any likely causes from the primary list. Additionally, the candidate causes not evaluated due to a lack of data can be revisited with further monitoring data.

The results of the candidate cause rating process for the Hecker Creek watershed biological impairments are displayed in Table 2-1.

Table 2-1: Hecker Creek Aquatic life use impairment candidate causes and probability rankings: (1) high; (2) medium; (3) low; (ND) no data.

Toxins (sediment and water)

Metals	
● Arsenic	ND
● Cadmium	ND
● Chromium	ND
● Copper	ND
● Lead	ND
● Mercury	ND
● Selenium	ND
● Zinc	ND
● Other	
Non-metals	
● Chlorine	2
● Cyanide	ND
● Oil / grease	ND
● PAHs	ND
● Pharmaceuticals	ND
● SOCs	ND
● Un-ionized ammonia	1.5
● Other	
Pesticides	
● Fungicides	ND
● Herbicides	ND
● Insecticides	ND
● Other	

Water Quality Characteristics

● Chlorophyll a	2
● Dissolved oxygen	2
● Nutrients	
Nitrogen	1
Phosphorus	1
● pH	2
● Salinity / TDS / Chloride	1
● Turbidity / TSS	1
● Water temperature	3

Habitat Alterations

● Bank erosion	1.5
● Channel incision/loss of flood plain connectivity	2
● Channel straightening	2
● Dewatering	1.5
● Excessive algae/macrophyte growth	1.5
● Flow impoundment	3
● Lack of woody debris/roughness/structure	2
● Physical barriers	2
● Riparian vegetation loss	2
● Sedimentation	1.5

Hydrologic Alterations

● Flow diversion—sinkholes	2
● Flow regulations—dams	3
● Pumping (withdrawals)	3
● Subsurface tile drainage	2
● Urban stormwater outfalls	3
● Wetland loss	3

Exotic/Introduced Species and Other Biotic Factors

● Competition	3
● Disease	2
● Endocrine disruption	ND
● Harvest	3
● Refugia depletion/isolations	2
● Predation	3

3. Analysis of Associations

The analysis of associations is a multi-step process comprised of thirteen types of evidence consideration (Table 3-1). The analysis begins with a consideration of the temporality and spatial co-occurrence of the stressor and effect. These two considerations examine the evidence indicating whether a given stressor and detrimental stream biological response occur at the same time in the same place.

Table 3-1. Evidence considerations for analysis of stressor-effect associations (U.S. EPA, May 2005: Handbook for characterizing causes. Eighth Edition)**.**

Evidence Consideration	Description
Temporality	The effect occurs when the candidate cause occurs and the effect is absent when the candidate cause is absent.
Spatial Co-occurrence	The effect occurs where the candidate cause occurs, and the effect is absent where the candidate cause is absent.
Biological gradient	Effects decline as exposure declines over space and time.
Complete causal pathway	A causal pathway is present representing the sequence of events that begins with the release or production of a stressor from a source and ends with an adverse biological response.
Mechanistically plausible causal pathway	Evidence is available from the site or elsewhere that the causal mechanism is plausible.
Plausible effect given stressor-response relationship	Site exposures are at levels that cause effects in the laboratory, in the field, or in ecological process models.
Consistency of association	Repeated observation of the effect and candidate cause in different places or times especially if the methods of measurements are diverse.
Analogy	Similar candidate causes have been shown to cause similar effects.
Specificity of cause	Specific effect occurs with only a few causes
Manipulation of exposure	Toxicity tests, controlled studies, or field experiments (site specific or elsewhere) demonstrate that the candidate cause can induce the observed effect.
Predictive performance	Candidate cause results in other predicted conditions not encompassed by the initially observed effects.
Evidence Consistency	The hypothesized relationship between cause and effect is consistent across all available evidence.
Evidence Coherence	There are no inconsistencies in evidence or some inconsistencies that can be explained by a possible mechanism.

The Hecker Creek data set was inadequate for examining temporal relationships of stressors and effects. In this SI and others, a major hindrance to considering this line of evidence is the lack of coordinated monitoring for stressors and effects over time. In Hecker Creek, there was not a clear sequence of evidence demonstrating the stressor(s) were introduced in the stream first, followed by detrimental biological effects. Likewise, the available evidence was inadequate to determine that effects preceded stressor onset.

3.1. Stressor Co-occurrence and Stressor-Response Relationships

The evidence considerations for Spatial Co-occurrence and Plausible Effect Given Stressor-Response Relationship involved comparing sampling data from the Hecker Creek watershed with data collected for the IDNR stream biological assessment program. Hecker Creek sampling data and benchmarks reviewed for the stressor co-occurrence and stressor-response evidence considerations are summarized in Appendix B, Table B-5. In addition to water quality and stream habitat data, diurnal temperature and dissolved oxygen (DO) fluctuations were monitored in May 2007 for 14 days (Appendix B; Figure B-14). These data were used to determine if violations of the DO standard had occurred, to track temperature change, and to document the degree of diurnal fluctuations in DO levels and temperature. The data were also used to estimate stream metabolism rates including: community respiration, net and gross primary production, and production:respiration ratio. The estimates were obtained using the single station method (Odum 1956; Bott 1996), which calculates the incremental rate of change in DO concentration over a 24-hour period measured at a single stream monitoring station.

For stressor co-occurrence, Hecker Creek stressor indicator data and RASCAL observations were compared with interquartile data ranges (25th to 75th percentile) for stream reference sites within the Paleozoic Plateau ecoregion. In cases when reference data were not available, Hecker Creek sampling data were compared with data from the statewide probabilistic (random) survey of perennial streams, a sampling project adapted from the U.S. EPA's Regional Environmental Monitoring and Assessment Program (REMAP). In some cases, other benchmarks, such as maximum or minimum ecoregion reference values, state water quality standards, or mean values from statewide random survey sites were applied in lieu of the reference interquartile range. Additionally, known associations between environmental conditions and biological responses and data from published literature were also used where appropriate. A stressor was deemed present at a site when the appropriate indicator value exceeded the benchmark value.

The next step was to determine whether the stressor exists at a level that is expected to elicit adverse effects to the aquatic community. This analysis of stressor response was done by examining stressor-response relationship curves developed from Iowa's statewide stream bioassessment database, which contains sites with BMIBI and/or FIBI scores as well as water quality and stream habitat measurements. A description of conditional probability, one technique used to evaluate stressor-response relationships, is in Appendix A.

3.2. Complete Causal Pathway

Following the evaluation of stressor co-occurrence and stressor-response relationships, the data were reviewed to determine the plausibility of hypothesized causal pathways linking sources to biological impairment. Similar to the approach used for considering co-occurrence and stressor-response relationships, Hecker Creek data were compared to data from ecoregion reference sites, statewide random survey sites, or primary literature. The indicator data and other relevant information were evaluated qualitatively and/or quantitatively to assess the evidence support for each hypothesized causal pathway. The results of this process are shown in the causal pathway conceptual model diagrams in Appendix C.

4. Strength of Evidence

The U.S. EPA (2005) handbook for characterizing causes served as the primary guidance document for evidence analysis and ranking. The main types of evidence consideration used in this SI are: *Plausible Effect Given Stressor-Response Relationship; Complete Causal Pathway and Consistency of Association*. All of these incorporated data from Hecker Creek along with ecoregion-specific or statewide sampling data (Table 4-1). The Hecker Creek sampling data were not sufficient to perform the *Temporality, Spatial Co-occurrence,* and *Biological Gradient* evidence considerations. *Analogy* was not used because no analogous stressor-response scenarios were identified. Other lines of evidence were selectively applied depending on the stressor and data/evidence.

Table 4-1. Summary of strength of evidence analysis results for proximate stressors.

	Evidence Consideration													
Proximate Stressor	Temporality	Co-occurrence	Biological gradient	Complete causal pathway	Mechanistically plausible causal pathway	Plausible effect given stressor-response relationship	Consistency of association	Analogy	Specificity of cause	Manipulation of exposure	Predictive performance	Evidence Consistency	Evidence Coherence	Final Rating
↑ low flow frequency and magnitude	o	o	o	-	--	-	-	NA	o	o	NA	+	+	-
↑ peak flow frequency and magnitude	o	o	o	+	++	+	+	NA	o	o	NA	+	+	-
Change in daily/seasonal flow patterns	---	o	o	+	+++	o	-	NA	o	o	NA	+	+	-
↑ suspended sediment	o	o	o	+	++	++	+	NA	o	o	NA	+	+	+
↑ deposited fine sediment	o	o	o	+++	+++	+	+	NA	o	+++	NA	+	+	+
↑ or change in sestonic algae	o	o	o	+++	++	+	-	NA	o	o	NA	+	+	o
↑ or change in benthic algae/macrophytes	o	o	o	+++	+++	+	+	NA	o	o	NA	+	+	o
↓ allochthonous food resources	o	o	o	+++	++	+	+	NA	o	o	NA	+	+	-
↓ primary producers (algae and macrophytes)	o	o	o	-	+	o	-	NA	o	o	NA	+	+	-
↓ dissolved oxygen	o	o	o	+	+	-	+	NA	o	+++	NA	+	+	+
↓ temperature	o	o	o	+++	++	-	-	NA	o	o	NA	+	+	-
↑ temperature	o	o	o	+	++	o	+	NA	o	o	NA	+	+	-
↑ Ammonia	o	o	o	+++	+++	+	+++	NA	o	+++	NA	+	+	+
↓ macro-habitat complexity	o	o	o	+++	+++	+	+	NA	o	o	NA	+	+	++
↓ instream cover/epifaunal micro-habitat	o	o	o	+++	+++	+	+	NA	o	o	NA	+	+	+
↓ colonization potential	o	o	o	+	++	o	-	NA	o	o	NA	+	+	o
Disease	o	o	o	+	++	-	+	NA	o	o	NA	+	+	-
↑ kills (fish and benthic macroinvertebrates)	o	o	o	+	+	o	+	NA	o	o	NA	+	+	-
↑ chloride/TDS	o	o	o	+++	+++	+++	+	NA	o	+++	NA	+	+	++

NA = not applicable, o = ambiguous or not enough evidence; +,++,+++ = rating levels for supporting evidence; -, --, --- = rating levels for not supporting evidence (after U.S. EPA 2005)

4.1. Primary Causes

The proximate stressors identified in the SI process (not ranked by order of importance) are: chloride/TDS and habitat alteration and decrease in habitat complexity. The supporting evidence for each primary cause (i.e., proximate stressor and associated causal pathways) is described below.

<u>Chloride/TDS</u>
Total dissolved solids in general, and chloride in particular, can be directly toxic to aquatic invertebrates and fish. Although chloride is an essential element for maintaining normal physiological functions in all aquatic organisms, elevated or fluctuating concentrations of this substance can be detrimental. More specifically, exposure to elevated levels of chloride in water can disrupt osmoregulation in aquatic organisms, leading to impaired survival, growth, and/or reproduction. Because excess chloride is most frequently actively excreted from animal tissues via the kidneys or equivalent renal organs to achieve osmoregulatory balance, the bioaccumulation potential of chloride is low. Several factors such as dissolved oxygen concentration, temperature, exposure time, and the presence of other contaminants influence chloride toxicity. However, few studies have systematically evaluated the influence of confounding variables on chloride toxicity in aquatic environments.

The criteria in the NPDES permit issued to AgriProcessors states that the chronic criterion for chloride in the Yellow River immediately downstream of the confluence with Hecker Creek is 372 mg/L and the acute criterion is 860 mg/L. Because Hecker Creek was classified as a general use stream, the aquatic life was only to be protected from acute levels of chloride (860 mg/L). Based on the draft Use Attainability Assessment (UAA), the lower portion of Hecker Creek, including the sampling site, will be reclassified as a Class B (WW2) water (small warmwater streams which support fish populations primarily composed of minnows and other nongame species), which will require a higher level of protection for aquatic life in the stream.

Iowa DNR is in the process of developing water quality standards designed to protect aquatic life against acute and chronic toxicity from chloride. Under the draft Iowa Water Quality Standard for chloride (http://www.iowadnr.gov/water/standards/chloride.html), the new acute criterion for Hecker Creek would be 706 mg/L and the chronic criterion would be 436 mg/L. Because chloride toxicity depends on water hardness and sulfate levels, the new standard for Hecker Creek was calculated using the local value for hardness (350 mg/L) from the 2000 sampling date and the state default value for sulfate (63 mg/L). The acute and chronic values would be lower (629 mg/L and 389 mg/L) if the default statewide hardness (200 mg/L) was used. Because of this variation in acute and chronic values, further sampling to determine hardness and sulfate values for Hecker Creek is needed.

Regardless of which standard value is used for chloride, there is strong evidence that Hecker Creek has a chloride/TDS problem (Figure 4-1). Out of 99 samples, 50 percent were above the NPDES permit chronic level of 372 mg/L and 64 percent were above the EPA chronic value of threshold 230 mg/L. Additionally, 24 percent of samples were above the acute criterion of 860 mg/L.

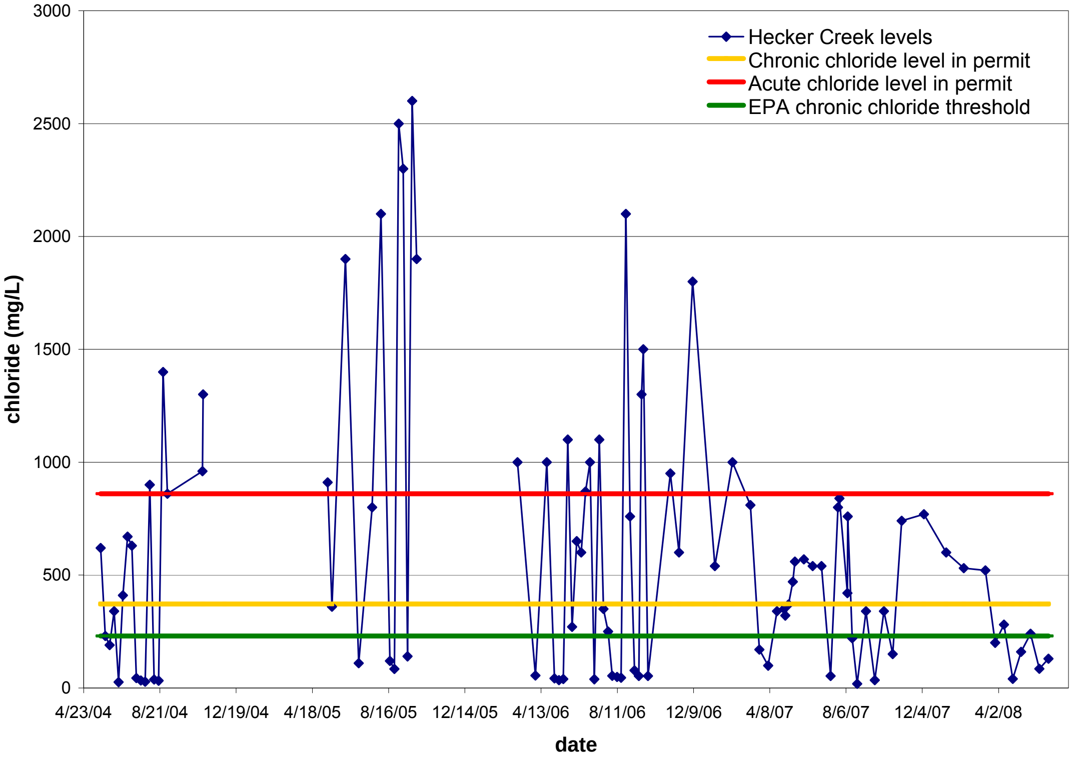


Figure 4-1. Comparison of chloride levels in Hecker Creek with EPA and AgriProcessors NPDES permit threshold levels.

Compared to ecoregion reference sites, Hecker Creek has elevated levels of TDS, with the minimum level of TDS in Hecker Creek (380 mg/L) just under the maximum of the ecoregion reference sites (400 mg/L). Even after the new treatment plant went online, the median TDS level in Hecker Creek was 2.5 times greater than the ecoregion maximum. Chloride was not sampled at ecoregion reference sites, so results of statewide sampling that included chloride (215 sites; includes REMAP and TMDL sampling) were used for comparison. The average from the statewide sampling was 30.4 mg/L, compared with an average of 662.3 mg/L for Hecker Creek. Additionally, analysis of data collected on July 24, 2007 during biosampling at Hecker Creek and the local comparison site show that Hecker Creek has higher levels of TDS (1900 mg/L) and chloride (800 mg/L) than the local comparison site (370 mg/L and 17 mg/L respectively).

Data plots of chloride and TDS versus BMIBI levels in Iowa streams suggest a limiting relationship at higher levels of chloride and TDS. The relationship appears to be even stronger for the percent Ephemeroptera (mayfly) data metric. Although relatively few BMIBI samples have been collected from streams having high TDS and chloride levels, available data from the stream bioassessment program shows a substantial decline in the percentage of mayflies when TDS and chloride levels exceed roughly 750 and 100 respectively (Appendix B, Figure B-3 and B-4). While there appears to be overall relationships between TDS and chloride and reduced FIBI scores (Appendix B, Figure B-5 and B-6), individual metrics, such as catch per unit effort (Appendix B, Figure B-7 and B-8) and number of fish caught per 500 feet (Appendix B, Figure B-9 and B-10) appear to be more sensitive. The drawback of the stressor-response plots is that they are only comparing one stressor, and it is likely that there are multiple stressors working in conjunction causing the response.

Habitat alterations and decrease in habitat complexity

The elements of habitat alteration and decrease in habitat complexity that are of most concern in Hecker Creek are channelization and channel gradient, a lack of pools and water depth, a lack of in-stream cover for fish, and embedded rock substrates.

Channelized streams lack the diversity of depth and velocity of natural streams (Hubbard et al. 1993). In studies conducted in Iowa, the effects of channelization included reduced amounts of woody debris and habitat complexity, which were associated with reduced fish species diversity and abundance (Paragamian 1987; Heitke 2006). A comparison of the stream channel in the lower portion of the watershed in 1950 versus 2006 reveals that the channel has been artificially straightened (Figure 4-2). From aerial photographs, it was determined that the channel length and sinuosity were reduced by about 25 percent between 1930 and 2006 (Table 4-2).

Table 4-2. Changes in channel length and sinuosity in the lower portion of the Hecker Creek watershed over time.

Year	1930	1950	2006	Percent reduction 1930 to 2006
Channel Length (m)	1692	1593	1257	26
Sinuosity	1.65	1.58	1.25	24

Straightening increases gradient and creates a more homogeneous channel. The sampling site in Hecker Creek is located in the area with the steepest gradient in the watershed (see Figure 1-3). Because of the steep gradient and the relative straightness of the channel, there is evidence indicating that high scouring flows occur along the sampled segment on Hecker Creek. The habitat data from 2006 and 2007 indicate there are no sand substrates at the site, and little to no silt deposition. Instead, the substrate in the channel is dominated by gravel, cobble, and boulders. This is a good indication that shear velocities are causing bed scour and transporting fine sediments out of this site.

Figure 4-2. Comparison of stream channel in 1950 versus 2006 in lower portion of Hecker Creek. Shown on 2006 aerial photo of watershed.

The channel in Hecker Creek is largely composed of shallow riffle-run habitat (Figure 4-3). Riffles are shallow stretches of a stream where the current is above the average stream velocity and where the water forms small rippled waves as a result. It often consists of a rocky bed of gravel or other small stones. The accumulation of course substrates at the riffle of a natural channel is due to the elevated flow velocities at this location compared to other portions of the channel network. Since the Hecker Creek channel has been altered by channelization, little to no natural sediment/bed sorting takes place, creating an artificial riffle-run situation. A run is a shallow, smoothly flowing segment of the stream. Pools are segments where the water depth is above average and the stream velocity is low. Pools and deep water are important habitat for fish, especially during summer when they can act as a refuge from high temperatures and low flow conditions. Pools are also important during high flow conditions when they provide some refuge from higher currents. This is especially important in Hecker Creek because, as discussed, the steep gradient can lead to high current velocity given adequate water inputs. Additionally, pools and deeper water can provide protection from predators such as herons and raccoons.

Generally, a wide range of depths are desirable for fish habitat. The segment sampled in Hecker Creek lacks pools and areas of deeper water. The average transect depth at the sampling site in Hecker Creek was below the minimum value measured for ecoregion reference sites (Table 4-3). Additionally, the maximum depth measured at the sample site in Hecker Creek was lower than the shallowest maximum depth measured at an ecoregion reference site. In fact, to find a pool frequency greater than 1 per 250 feet of stream length, fish need to swim more than a mile upstream (Figure 4-4).

Table 4-3. Comparison of depth, pool habitat, and riffle habitat in Hecker Creek with ecoregion reference site data.

Year	2000	2006	2007	Ecoregion reference data
Average transect depth (feet)	0.37	0.32	0.36	Minimum - 0.51
Maximum depth (feet)	1.3	1.2	1.5	Minimum - 1.95
Percent of stream reach as pool	21.4	8.9	14.3	Interquartile range - 30.35-46.43
Percent of stream reach as shallow riffle	42.9	35.7	35.7	Interquartile range - 14.05-26.77

Compared to the ecoregion interquartile range of the percent of the reach as pool habitat, Hecker Creek fell far below (Table 4-3). Additionally, the percent of the reach as shallow riffle habitat in the ecoregion interquartile range was significantly less than Hecker Creek. In ecoregion and statewide sampling, there is a general pattern of increasing FIBI levels with increasing riffle habitat. This is probably because riffles provide abundant food and refuge for bottom feeding and dwelling fish. Many of these sensitive species are intolerant of nutrient enrichment and sedimentation. However, when riffle habitat reaches levels of 35 percent or greater, like those observed at the Hecker Creek bioassessment site, the FIBI scores appear to decline. The reason might be that when riffle habitat becomes dominant, other important habitat niches (e.g., slow flowing runs and pools) are rare or absent, and these niches are required for optimum fish assemblage balance.

Individual fish data metrics are even more illuminating. For example, there is a relationship between maximum depth and sucker species richness (Appendix B, Figure B-11). Additionally, there is a relationship between percent macrohabitat as riffle and adjusted catch per unit effort (Appendix B, Figure B-12) and number of fish caught per 500 feet (Appendix B, Figure B-13).

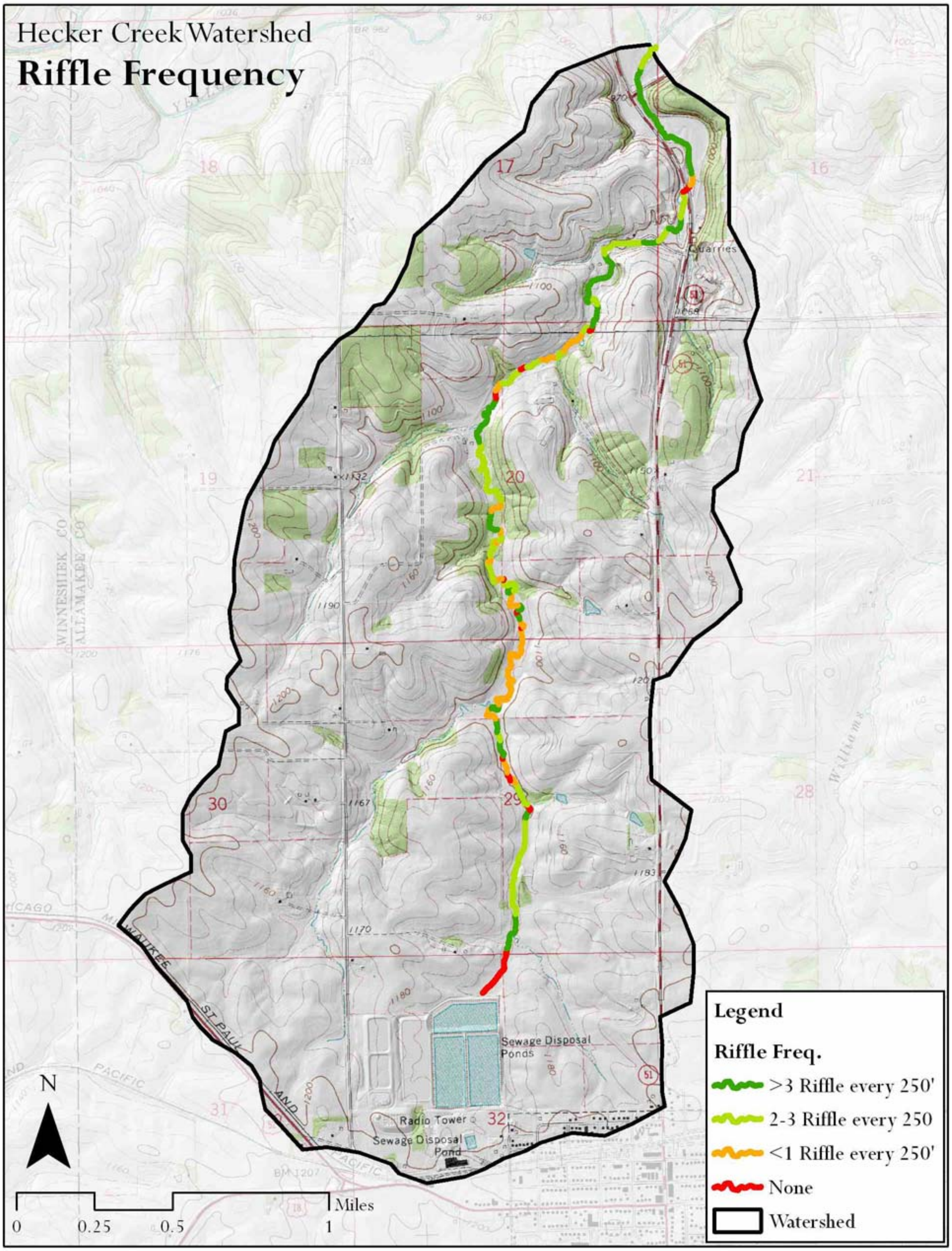


Figure 4-3. Riffle habitat in Hecker Creek.

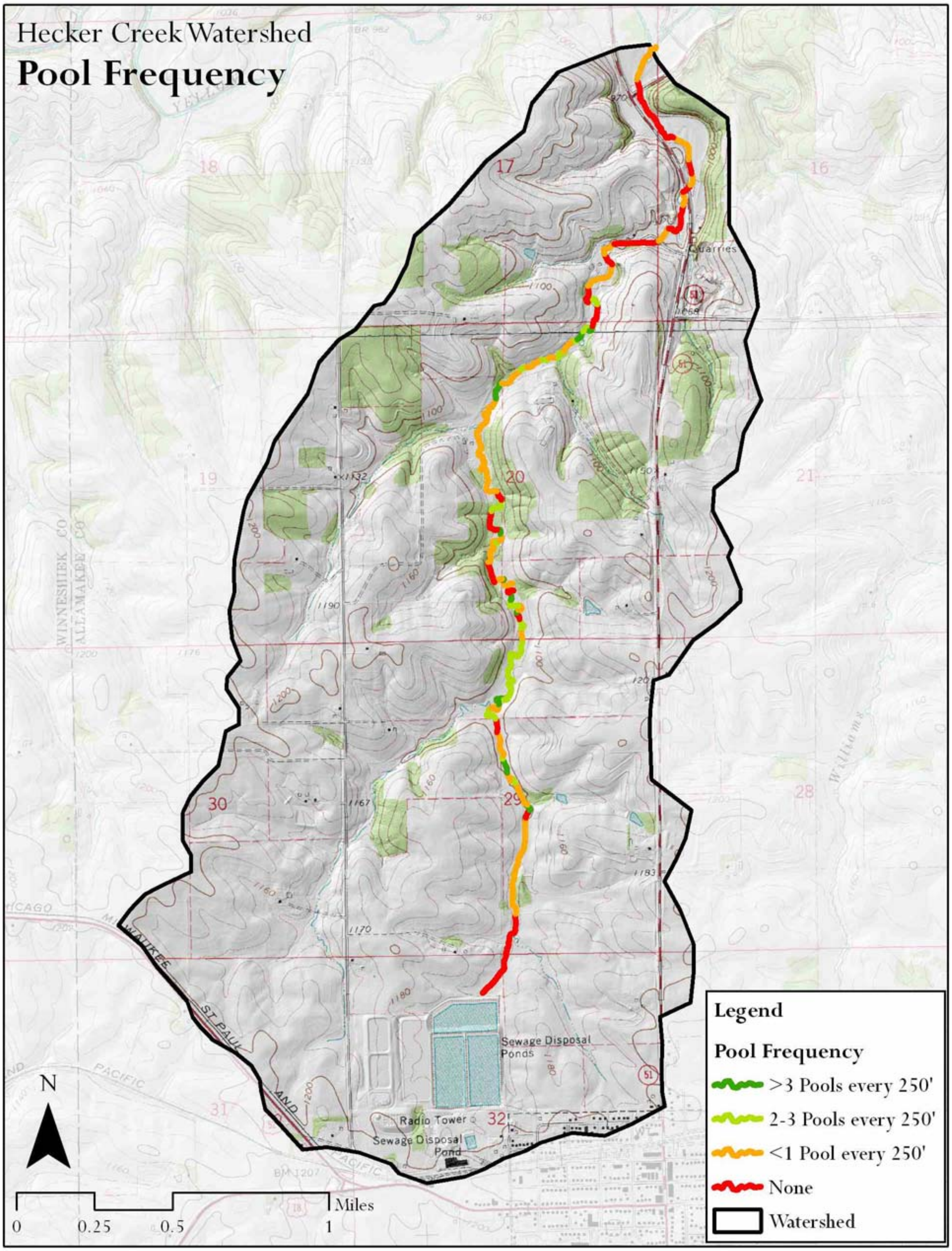


Figure 4-4. Frequency of pool habitat at least 3 feet deep in Hecker Creek.

Another factor likely contributing to the lack of deep water is the influence of the sinkhole in the lower section of Hecker Creek. As measured in summer 2000, the sinkhole removed approximately 15 percent of the flow from the stream when the flow was around 4 cfs. At lower flows, it is likely that the sinkhole removes a greater overall percentage of the flow. Evidence suggests sinkholes in the region do not remove surface flow at a constant rate but change seasonally based on the openness of the sinkhole. The amount of debris and sediments accumulated in the sinkhole may influence the rate of water removal and sinkholes have been known to enlarge after large rain events. The high level of uncertainty associated with the functioning of the in-stream sinkholes make it difficult to determine what level of impact they have on the system in any given season. Sinkholes are not limited to Hecker Creek. There are sinkholes located in the Yellow River which, at times, remove all flow upstream of the confluence with Hecker Creek. During these dry periods, Hecker Creek is the only source of flow in the Yellow River until the confluence with Livingood Spring (2.5 miles downstream). This lack of water can be a serious barrier to fish movement in and out of Hecker Creek and may influence the number of fish present.

In addition to the lack of pool habitat to provide cover for fish, there is a lack of woody debris in the stream reach at the sampling site. Woody debris provides refuge from high flows and overhead cover that are important for fish viability. No woody debris was observed during the biosampling sessions in 2000, 2006, or 2007, while the interquartile range for average percent woody debris was 0.5-1.25 percent.

Embeddedness is the degree to which coarse rock substrates such as gravels, cobbles, and boulders are surrounded or embedded within fine sediment particles. Embeddedness is often evaluated in riffles or shallow runs where current velocities are normally high enough to prevent excessive fine sediment accumulation. As embeddedness increases, the large and small spaces between rocks become filled with fine sediment particles making this important habitat niche less suitable for invertebrates and fish, which utilize it for feeding, shelter, spawning, and egg incubation.

The examination of stressor-response plots from Iowa streams indicated embeddedness ratings above 3.0 are associated with a higher probability of FIBI levels that are considered biologically impaired in the Paleozoic Plateau ecoregion. The embeddedness ratings at the sampling site increased from 1.67 in 2000 to 2.67 in 2006 and 3.00 in 2007, which corresponds with a qualitative embeddedness range of less than 25 percent in 2000 to 50-75 percent in 2007. The ecoregion reference site 75th percentile embeddedness rating is 2.43, which is roughly equivalent to 30-50 percent of the coarse substrate embedded with fine sediment. Additionally, the RASCAL assessment noted that 30.3 percent of the cobble in the stream was mostly embedded. While the levels of embeddedness in Hecker Creek have not exceeded the levels at which biological impairments occur, the increase in embedded substrates in Hecker Creek since 2000 suggests that sedimentation may become an issue in the future.

4.2. Secondary Stressors

Total suspended solids/turbidity, dissolved oxygen, and ammonia were identified as potential secondary stressors. A stressor is identified as secondary if the evidence was insufficient to conclude that the stressor by itself is capable of significantly degrading the biological condition of the stream or if there was not enough data to conclusively determine stressor-biota relationships. There are a number of reasons that a lack of data may exist, such as a lack of research data outlining biologically significant thresholds for a given pollutant. Additionally, some stressors are manifested only during certain in-stream conditions or are episodic in nature and inherently difficult to capture. These stressors have the potential to affect the biota under certain conditions, but an episodic pulse or manifestation of the stressor was not captured by the project monitoring.

Total Suspended Solids/Turbidity

Elevated levels of suspended solids and turbidity directly and indirectly impact stream aquatic communities leading to increased dominance of tolerant species. Direct impacts include diminished success of sight feeding fish and increased respiratory stress for sensitive invertebrates with external gill structures. Indirect impacts are related to sedimentation and embeddedness of fine particles. The highest TSS (4,300 mg/L) and turbidity (1,400 NTU) levels observed in Hecker Creek were sampled in spring 2008 during elevated flow conditions (storm event). The median event levels of TSS (845 mg/L) and turbidity (305 NTU) for Hecker Creek exceeded the 75th percentile (TSS = 360 mg/L and turbidity = 240 NTU) of statewide sites that had storm event monitoring (Appendix B, Table B-5). However, levels of TSS and turbidity monitored during base flow conditions were not elevated relative to typical levels measured at least disturbed stream reference sites in the Paleozoic Plateau ecoregion.

An examination of published research data studying the effects of exposure to TSS and turbidity on fish and invertebrates found that these studies generally focus on long term chronic impacts and not on the effects of short term event driven spikes in TSS and turbidity levels. While it seems likely storm event driven spikes in TSS and turbidity could negatively impact biota in Hecker Creek, there is no numerical evidence to support this hypothesis. Should research prove that there is a quantifiable effect, it may be necessary to reclassify TSS and turbidity as a primary stressor.

Potential sources of suspended solids and turbidity in the watershed include: sheet and rill erosion from agricultural fields, gully erosion, stream bed/bank erosion, and re-suspension of fine sediment by livestock with access to the stream. The estimated average potential sheet and rill erosion rate based on the 2007 watershed assessment is 4.8 tons/acre/year (Appendix B; Figure B-18). Approximately 54 percent of the watershed area is in row crop (Appendix B; Figure B-19) and cattle graze 39 percent of the stream channel with direct access to the stream (Appendix B; Figure B-20), indicating relatively high sediment delivery potential.

Streambank erosion occurs in isolated areas throughout the watershed. Length and severity of erosive features are highly dependent on riparian land use. Excessive bank erosion/sloughing, and livestock access were noted along much of the main channel during the RASCAL analysis (Figure 4-5 and 4-6). While streambank stability and vegetative conditions in some stream reaches were rated as relatively good, 25.2 percent of the channel was rated as moderately unstable or unstable (Appendix B; Figure B-21). Taken as a whole, there is evidence indicating bank erosion and cattle grazing activities are contributing suspended solids and turbidity in Hecker Creek.

Figure 4-5. Bank erosion in Hecker Creek.

Figure 4-6. Cattle access to stream in Hecker Creek.

Field observations indicate that problems with sediment transport and cycling exist in this watershed. Sampling crews noted that large sand and gravel deposits would form around the double box culvert just downstream of the biological sampling reach after every major storm event. The storm sampling equipment and stream stage gauging equipment deployed at a cross section adjacent to the bridge were routinely buried by sediment after storm events. The formation of sediment fans and the subsequent restriction of flow through the double box culvert under County Road W60 is a chronic problem. Upon contacting the state Department of Transportation (DOT) garage, it was determined that regular maintenance of this bridge crossing has been necessary for many years. Approximately every two years, maintenance staff from the regional DOT office remove large woody debris piles from the upstream end of the bridge and use excavators to dredge the sand and gravel deposits out of the channel within approximately 50 feet up and downstream of the box culvert (Figure 4-7).

This evidence suggests that, at the very least, channel instabilities exist at the reach scale in Hecker Creek. The build-up of heavy sediments at the bridge crossing (box culvert) is a reflection of the increased gradient along the biological sampling site. During storm events, water passes through this site at high velocities causing suspension of heavy sediments. As the water and associated sediment load reach the culvert, flow is constricted and the water slows down, depositing sand and gravel.

Figure 4-7. Hecker Creek at County Road W60 Bridge after Iowa DOT channel maintenance in 2004.

Dissolved Oxygen

Depending on severity, reduced levels of dissolved oxygen can cause impacts to aquatic life ranging from acute mortality to chronic stressed behavior and diminished biological functions. Available monitoring data for Hecker Creek indicate that historically, dissolved oxygen levels have fallen below limits set in Iowa's water quality standards (never below 4.0 mg/L, and above 5.0 mg/L for at least 16 hours/day). In 2004 and 2005 there were eight samples in which dissolved oxygen levels were below 5.0 mg/L, with four of those below 4.0 mg/L. Since the new water treatment protocols went into effect for AgriProcessors' effluent in fall 2006, dissolved oxygen levels in the Hecker Creek watershed have greatly improved. The average DO level in 2004-2006 (before the new treatment) was 6.84 mg/L and the minimum was 1.1 mg/L. After the new facility began treating effluent, the average DO level (Sept. 2006 – June 2008) was 11.83 mg/L and the minimum reading was 7.5 mg/L.

Currently, dissolved oxygen levels observed during monitoring in Hecker Creek are suitable for aquatic life; however, the potential that oxygen levels could fall below water quality standards still exists. For example, Hecker Creek has some of the highest levels of total phosphate (Appendix B, Figures B-15– B-17) and nitrate+nitrite nitrogen in the state (Table 4-4), which may lead to excessive primary production (algal blooms) and dissolved oxygen sags.

Table 4-4. Comparison of nutrient and chlorophyll a levels in Hecker Creek, ecoregion 52b reference sites, and statewide data.

Parameter	Hecker Creek	Ecoregion 52b reference data	Statewide data
Nitrate + Nitrite nitrogen (mg/L)	Median = 8.5 Maximum = 33	Interquartile range = 2.15-4.3 Maximum = 6.7	Interquartile range = 1.75-8.4 Maximum = 26 N = 447
Total Phosphate (mg/L)	Median = 2.2 Maximum = 6.7 Minimum = 0.36	Interquartile range = 0.1-0.15 Maximum = 0.2	Interquartile range = 0.1-0.2 Maximum = 2.5 N= 449
Periphyton chlorophyll a (µg/cm^2)	Mean = 44.5	Interquartile range = 7.9-19.9	
Sediment chlorophyll a (µg/cm^2)	Mean = 17.5	Interquartile range = 3.6-11.6	

Hecker Creek also has high levels of both periphyton chlorophyll a and sediment chlorophyll a (Table 4-4). It was noted during biological sampling that the percent of in-stream substrate covered by macrophytes has increased from less than 25 percent in 2000 to 50-75 percent in 2006 and the algal community has shifted from non-filamentous to filamentous. Given the evidence of excessive nutrient inputs and elevated primary producer activity, it is somewhat surprising that no DO sags have been observed during the last two years of monitoring. One explanation for this may be that the steep gradient and riffle habitat of the sample site could be providing enough re-aeration of the water to compensate for in-stream oxygen consumption. Since this steep gradient and cobble/boulder stream profile does not exist in much of the rest of Hecker Creek, there is potential for low DO problems elsewhere in the stream. Additionally, there was no continuous diurnal dissolved oxygen monitoring during the low flow conditions in late summer when problems with dissolved oxygen are most likely to occur. Low levels of DO are most likely to occur during the late night/early morning hours, due to the inability of plants and algae to produce oxygen via photosynthesis in the dark. Continuous monitoring would capture these sags in DO that bi-weekly daytime grab sampling may have missed.

Shading from riparian vegetation can also help maintain cooler stream temperatures. Riparian canopy coverage in the Hecker Creek watershed is highly variable. Some areas are significantly shaded while many other areas have no shade. The establishment of woody riparian vegetation in unshaded stream reaches of the Hecker Creek watershed could help maintain acceptable dissolved oxygen levels by helping maintain cooler water temperatures and reducing sunlight that supports excessive levels of primary production.

The extent to which depressed DO levels contribute to the impairment could not be determined using available data. Given the lack of diurnal sampling during low-flow conditions and the absence of water quality violations since the new treatment facility began operating in fall 2006, it is the determination of the SI team that a TMDL should not be calculated for dissolved oxygen. Any future monitoring of this water body should include more extensive, continuous DO data collection at multiple sites in the watershed.

Ammonia

Un-ionized ammonia is directly toxic to aquatic invertebrates and fish. Iowa has water quality standards designed to protect aquatic life against acute or 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. Historically, Hecker Creek had high levels of ammonia. In the sampling done by Fox Engineering Associates, Inc. in 1996-97, 14 of 23 samples taken at site 2 (closest corresponding site to the biological sampling site) violated the acute water quality criteria for ammonia and 18 of 23 samples violated the chronic criteria.

Unfortunately, during the 2004–2006 DNR sampling, pH was not measured, so it is impossible to say whether or not there were any exceedences of the ammonia criteria during that time period. In the 2006-2008 DNR/UHL monitoring there was only one exceedence of the ammonia criteria. In March 2008, the ammonia level sampled in Hecker Creek was 2 mg/L which exceeded the chronic criterion of 1.79 mg/L for the corresponding temperature and pH measurements.

Given the data collected during the assessment phase of this project, it is unlikely that elevated ammonia levels are currently contributing significantly to the impairment in this watershed. Due to the episodic nature of ammonia spikes in stream systems, it is possible that our monitoring network missed short duration increases in ammonia. It is recommended that any future water quality monitoring plans include a screening for ammonia levels in the stream.

5. From SI to TMDL

Because the SI process for Hecker Creek was initiated pursuant to an Iowa Section 303(d) listing for biological impairments with unknown causes, the primary stressors determined by the SI are communicated in terms of standard cause and source codes as specified in U.S. EPA guidance for the 2004 Integrated Report and the IDNR 305(b) assessment protocol (IDNR 2005). The 305(b)/303(d) candidate cause list is shown in Table 5-1. The primary stressors identified by this SI, translated into 305(b)/303(d) cause codes are: Salinity/TDS/Chlorides (1300) and Other habitat alterations (1600).

Table 5-1. The candidate causes with associated cause codes as used by the 305(b) assessment/303(d) listing methodology.

Cause Code	Cause Name	Cause Code	Cause Name	Cause Code	Cause Name
0	Cause Unknown	570	Selenium	1300	Salinity/TDS/Chlorides
100	Unknown toxicity	580	Zinc	1400	Thermal modifications
200	Pesticides	600	Unionized Ammonia	1500	Flow alteration
250	Atrazine	700	Chlorine	1600	Other habitat alterations
300	Priority organics	720	Cyanide	1700	Pathogens
400	Non-priority organics	750	Sulfates	1800	Radiation
410	PCB's	800	Other inorganics	1900	Oil and grease
420	Dioxins	900	Nutrients	2000	Taste and odor
500	Metals	910	Phosphorus	2100	Suspended solids
510	Arsenic	920	Nitrogen	2200	Noxious aquatic plants
520	Cadmium	930	Nitrate	2210	Algal Growth/Chlorophyll a
530	Copper	990	Other	2400	Total toxics
540	Chromium	1000	pH	2500	Turbidity
550	Lead	1100	Siltation	2600	Exotic species
560	Mercury	1200	Organic enrichment/Low DO		

5.1. Cause Elimination and Evidence Uncertainty

It is important to remember the SI process uses a weight of evidence approach that is not synonymous with dose-response experimental studies. Therefore, the conclusions reached in this SI must be viewed cautiously with the understanding that correlation and association do not necessarily prove cause and effect. One of the larger uncertainties in this SI results from the fact the available data was spatially limited because there was only one sampling site. Additionally, although there is approximately four years worth of data, there are large gaps in data for flow, pH, and many other parameters. Because of these limitations, the importance of certain stressors either could have been masked or exaggerated. Another source of uncertainty is the lack of appropriate benchmarks or criteria for evaluating the significance of some proximate stressors or causal pathway indicators. The process is also limited by a lack of readily available data analysis techniques that could help identify useful patterns and associations in the data set.

There is also uncertainty associated with ranking the relative importance of primary stressors. In this SI, it is assumed that each primary stressor is individually capable of causing the biological impairment. However, some stressors are known to exert a greater detrimental impact upon certain aspects of stream biological health than others. For example, certain benthic-oriented metrics of the fish IBI are known to respond more strongly to sedimentation impacts than other types of stressors. These subtle distinctions are not fully addressed within the current SI process.

A number of candidate causes/stressors were excluded from consideration based upon best professional judgment and knowledge of the watershed (Table 2-1). These causes/stressors were all ranked as low probability of contributing to the stream biological impairment or not considered due to lack of data. For example, pharmaceuticals and endocrine disruptors could be contributing to the impairment due to the presence of the meat packing plant as pharmaceuticals and hormones are commonly given to livestock. However, these compounds were not sampled for; therefore there is no data to support this hypothesis. If management actions designed to alleviate the primary causal agents identified in this SI fail to restore the biological community to unimpaired status, the evidence will again be reviewed and the excluded causes/stressors can be reconsidered. An excluded candidate cause/stressor might also be reconsidered if new data or information provided compelling evidence the cause/stressor plays an important role in the impairment.

Another issue of concern is the similarity in the IBI scores for Hecker Creek and the local comparison site. While the Hecker Creek confluence is in the segment of the Yellow River that sometimes runs dry (upstream of the Livingood Spring) (Figure 1-9), the local reference site is not. Therefore, while lack of flow in the Yellow River could be a barrier to fish movement into Hecker Creek, that is not an issue at the local reference site. There is likely some other influence in the Yellow River watershed that is causing the similarities in the overall IBI scores that monitoring efforts did not capture.

5.2. Conclusions

Despite existing data limitations, the evidence was sufficient to identify the following primary stressors, either of which is capable of causing biological impairment in the Hecker Creek watershed:

- elevated concentrations of chloride and total dissolved solids;
- habitat alteration and a decrease in habitat complexity

The chloride/TDS issue is the result of inputs from one permitted facility only and will be managed in the National Pollutant Discharge Elimination System (NPDES) permit for the facility. The current permit expired in 2008. A new permit cannot be written until the completion of the Use Attainability Analysis, at which time adjustments to the permit can be made to lower the levels of chloride in Hecker Creek to protect aquatic organisms. By that time, Iowa should also have finalized the chloride water quality standards. There are also no significant nonpoint source inputs of chloride in the Hecker Creek watershed. The other identified stressor is poor habitat quality, which is not a pollutant. Therefore a TMDL is not needed to address this impaired waterbody.

6. Implementation Plan

While a TMDL is not required to address the stressors identified for Hecker Creek, the Iowa Department of Natural Resources recognizes that technical guidance and support are critical to reducing the stressors identified in this document. Therefore, this implementation plan is included to be used by local professionals, watershed managers, and citizens for decision-making support and planning purposes. 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

Initiative and action by local landowners and citizens are crucial to improving the overall health of any watershed. This is especially true of the Hecker Creek watershed in which most of the land is privately owned. Improvements to the stream should proceed in conjunction with a comprehensive monitoring system that will adequately characterize the conditions in the creek as improvements are made.

Ideally, the SI would be followed by the development of a thorough stream restoration plan. The plan should include more comprehensive and detailed actions to better guide the implementation of specific BMPs to improve the habitat in Hecker Creek. Other ongoing tasks required to obtain real and significant improvements include continued monitoring to assess water quality trends, habitat parameters, and attainment of adequate FIBI and BMIBI scores, and adjustment of proposed BMP types, locations, and implementation schedule. Utilization of the monitoring plan as outlined in Chapter 7 should begin immediately to establish a baseline, and should continue throughout implementation of BMPs and beyond.

6.2. Best Management Practices

The two major stressors contributing to the impairment of Hecker Creek are excess chloride and habitat alterations and a reduction in habitat complexity. The chloride levels in Hecker Creek will be addressed in the NPDES permit for the AgriProcessors facility once the Use Attainability Analysis for Hecker Creek and Iowa chloride standards are finalized. However, without habitat and stream channel improvements, the fish community in Hecker Creek is still likely to score poorly compared to ecoregion criteria. There are various BMPs that can be used to help restore the habitat in Hecker Creek, each with different effectiveness and costs (Table 6-1). No single BMP will be able to sufficiently improve the condition of Hecker 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 Hecker Creek. Table 6-1 identifies some potential BMPs that could improve the habitat in Hecker Creek. 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. Development of a more detailed stream restoration 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 6-1. Potential BMPs to improve fish habitat in Hecker Creek.

BMP or Activity	Habitat restoration potential	Cost
Stream channel reconstruction	High	High
Strategic placement of boulders in stream	Moderate	Moderate
Reduce sediment inputs from upstream	Moderate	Moderate

Stream channel reconstruction

The best option to improve the habitat for fish is to restore the stream ecosystem to normal function by reconstructing the stream channel. This would involve re-meandering the stream channel (Figure 6-1) and creating riffle-run-pool sequences that would provide the varying depths and velocities that are best for aquatic life. By increasing the sinuosity of the stream, the length of the channel is increased and the channel gradient is decreased, which should reduce the high current velocities seen during storm events. By decreasing the velocity of the water, large woody debris will be able to accumulate in the stream, providing habitat and cover for fish and benthic macroinvertebrates. While this is the best alternative in terms of restoring habitat, it is also the most expensive and would require major construction.

Strategic placement of boulders in stream

This alternative would be less costly, but would also provide fewer ecosystem services than channel reconstruction. It would involve placing boulders in the stream in strategic locations. These boulders would provide refuges for fish from high flows during storm events and may help to trap large woody debris in the channel. It would then be possible for some pools to form behind debris dams. This alternative would not change the location or gradient of the channel, and there is no guarantee that the debris dams and subsequent pools would form.

Reduce sediment inputs from upstream

The effectiveness of the two previous options will be reduced if nothing is done to reduce sediment inputs from upstream sources. To reduce sedimentation, eroding banks in the upper portion of the watershed will need to be stabilized. The best method for achieving streambank stability on a system-wide scale is to exclude cattle from the stream and allow vegetation to colonize the riparian corridor. The stream corridor could be enrolled in the NRCS/USDA buffer program. A minimum of 120 feet on either side of the channel could be planted into perennial vegetation and the cattle could be fenced out of this area. Off site water could be supplied to cattle by installing nose pumps and other no/low energy water supply technologies. Limited access to the channel could be provided by installing several strategically placed cattle crossings. This would allow cattle access to both sides of the stream while also providing them with a place to cool off and drink water. For more information about stream buffers and grazing management, contact the local NRCS office.

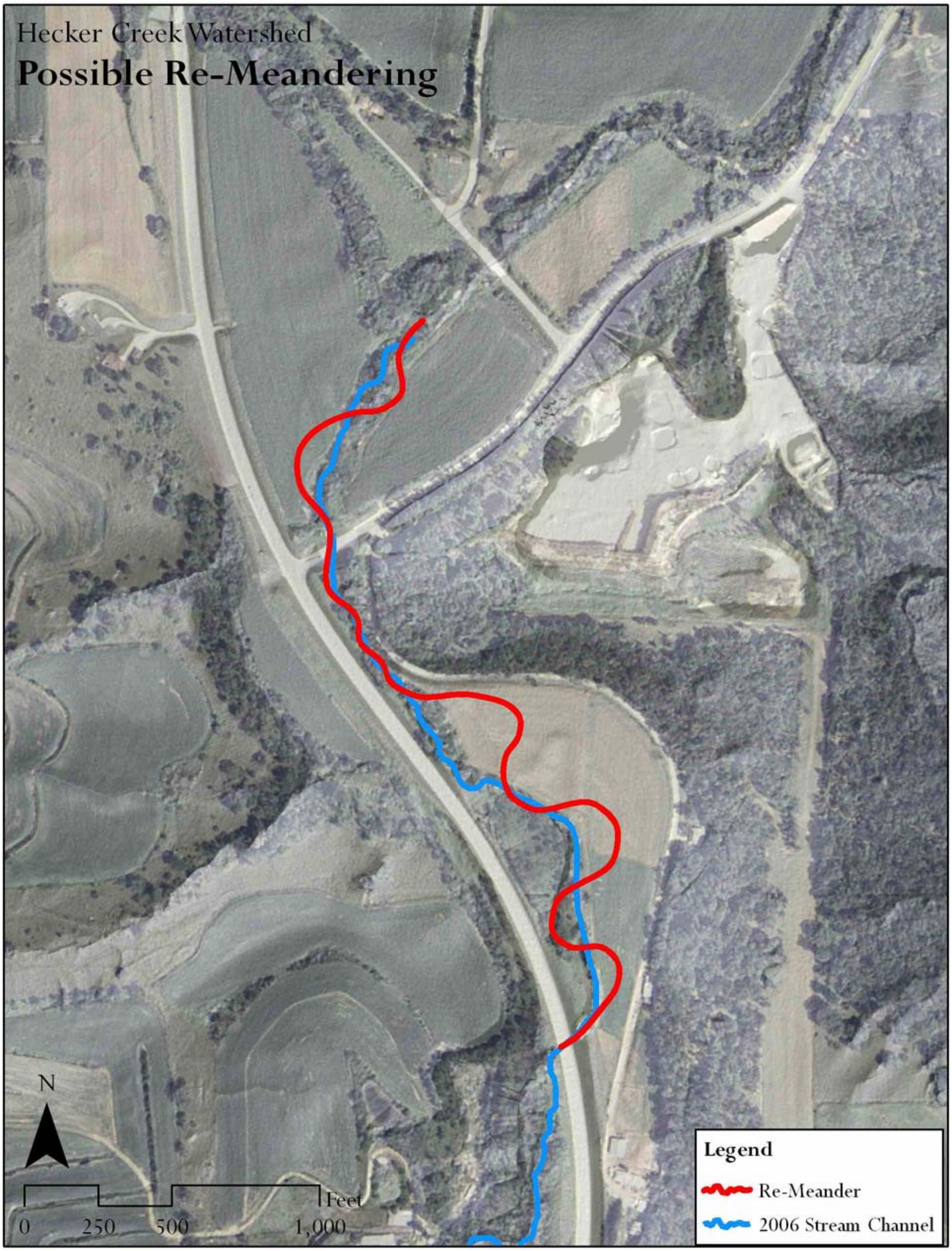


Figure 6-1. Rough sketch of possible re-meandering of channel in lower portion of Hecker Creek. (Provided only as an example, not based on stream restoration guidelines.)

7. Monitoring Plan

While a TMDL is not required to address the stressors identified for Hecker Creek, continued 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. Also, because the impaired use is for aquatic life and the primary stressor is habitat alteration and decrease in habitat complexity, biological and habitat sampling are necessary to document any improvement in the biological community that may result in Hecker Creek attaining its designated use. However, currently, there are no plans for water quality monitoring or biological or habitat sampling in the Hecker Creek watershed.

Future water quality monitoring in the Hecker Creek watershed can be agency-led, volunteer-based or a combination of both. The IDNR Watershed Monitoring and Assessment Section administers a water quality monitoring program that provides training to interested volunteers. This program is called IOWATER, and more information can be found at the program web site: http://www.iowater.net/Default.htm. It is important that volunteer-based monitoring efforts include an approved water quality monitoring plan, called a Quality Assurance Project Plan (QAPP), in accordance with Iowa Administrative Code (IAC) 567-61.10(455B) through 567-61.13(455B). The IAC can be viewed here: http://www.iowadnr.com/water/standards/files/chapter61.pdf. Failure to prepare an approved QAPP will prevent the use of data to assess a waterbody's status on the state's 303(d) list – the list that assesses waterbodies and their designated uses as impaired. 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. Idealized Plan for Future Watershed Projects

Should funding for monitoring become available, the ideal monitoring plan for Hecker Creek would involve water chemistry sampling, biological sampling, habitat sampling, and continuous sampling for dissolved oxygen and temperature (Table 7-1) at the original sampling site plus at least one other site in a section of Hecker Creek that has not been modified. This would help separate the effects of the point sources (chloride) from the habitat/channel alteration impacts.

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

Component	Sample Frequency	Parameters/Details
Water chemistry sampling	Weekly from March to October Monthly from 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) Additional parameters to sample for accurate determination of chloride permit levels: Hardness and Sulfate
Biological Sampling	Annually	Monitoring should be done to track improvement in benthic macroinvertebrate and fish communities.
Habitat sampling	Concurrently with biological sampling	According to IDNR protocols, this sampling will track improvement in habitat conditions that may be contributing to the impairment.
Continuous dissolved oxygen and temperature	Continuously (6-minute intervals) from June to October	Dissolved oxygen autosampler deployment according to IDNR protocols

8. Public Participation

Public involvement is important because it is the land owners, tenants, and citizens who directly manage land and live in the watershed that determine the water quality in Hecker Creek.

8.1. Public Meeting

A meeting to discuss the results of the Hecker Creek SI was held in Postville, Iowa on July 21, 2009. This meeting was attended by approximately 35 stakeholders representing IDNR Field Office 1, IDNR Fisheries, AgriProcessors, Inc., Northeast Iowa RC&D, Inc., Allamakee County SWCD, Allamakee County Board of Supervisors, Iowa Department of Agriculture and Land Stewardship, the Iowa Senate, Northeast Iowa Citizens for Clean Water, the Postville City Council, the Postville newspaper, and local landowners and residents.

8.2. Written Comments

During the public comment period, the DNR received one comment from local citizens, submitted via e-mail. DNR's response to the e-mail was met with a subsequent e-mail. The communication chain is attached in Appendix D.

9. References

Bott, T.L. 1996. Chapter 25:533-556. Primary productivity and community respiration. In Methods in Stream Ecology. F.R. Hauer and G.A. Lamberti, editors. Academic Press.

Griffith, G.E., J.M. Omernik, T.F. Wilton, and S. M. Pierson. 1994. Ecoregions and sub-ecoregions of Iowa: a framework for water quality assessment and management. Jour. Iowa Acad. Sci. 10(1): 5-13.

Fox Engineering Associates, Inc. 1997. 1996-97 stream sampling program on unnamed creek at Postville, Iowa. Final Report.

Heitke, J.D., C.L. Pierce, G.T. Gelwicks, G.A. Simmons, and G.L. Siegwarth. 2006. Habitat, land cover, and fish assemblage relationships in Iowa streams: preliminary assessment in an agricultural landscape. Pages 287-304 *in* R.M. Hughes, L.Wang, and P.W. Seelbach, editors. Influences of landscapes on stream habitats and biological assemblages. American Fisheries Society, Symposium 48, Bethesda, Maryland.

Hubbard, D.W., D.C. Jackson, and D.J. Ebert. 1993. Channelization. Pages 135-156. In C.F. Bryan and D.A. Rutherford, editors. Impacts on warmwater streams: Guidelines for evaluation, Second Edition. Southern Division, American Fisheries Society, Little Rock, Arkansas.

IDNR. 2005a. Methodology for Iowa's 2004 water quality assessment, listing, and reporting pursuant to Sections 305(b) and 303(d) of the federal Clean Water Act. Iowa Department of Natural Resources, Des Moines, Iowa. [online]. Available at: http://www.iowadnr.com/water/tmdlwqa/wqa/303d/2004/2004FinalMethodology.pdf. May 2005.

IDNR. 2005b. Steps for stressor identification. January 28, 2005. Watershed Improvement Section, Environmental Services Division, Iowa Department of Natural Resources. 4p.

Odum, H.T. 1956. Primary production in flowing waters. Limnology and Oceanography 1:102-117.

Paragamian, V.L. 1987. Standing stocks of fish in some Iowa streams, with a comparison of channelized and natural stream reaches in the southern Iowa Drift Plain. Proceedings of the Iowa Academy of Science 94:128-134.

Prior, J.C. 1991. Landforms of Iowa. University of Iowa Press. Iowa City, Iowa. 153p.

U.S. EPA. 2000. Stressor Identification Guidance Document. U.S. Environmental Protection Agency. December 2000.

U.S. EPA. 2005. Handbook for characterizing causes: Eighth Edition.

Appendix A—Methods

A.1. Reference Sites

Reference sites in Iowa represent contemporary stream conditions that are least disturbed by human activities. A number of important watershed, riparian and instream characteristics were evaluated as part of the reference site selection process (Griffith et al. 1994; Wilton 2004). Representation is also an important consideration. Reference sites strive to represent desirable, natural qualities that are attainable among other streams within the same ecoregion. As they are used in bioassessment, reference sites define biological conditions against which other streams are compared. Therefore, they should not represent stream conditions that are anomalous or unattainable within the ecoregion.

Currently, there are 96 reference sites used by IDNR for stream biological assessment purposes (Figure A-1). Reference condition is the subject of a significant amount of research and development throughout the U.S. The IDNR will continue to refine Iowa's reference condition framework as new methods and technologies become available.

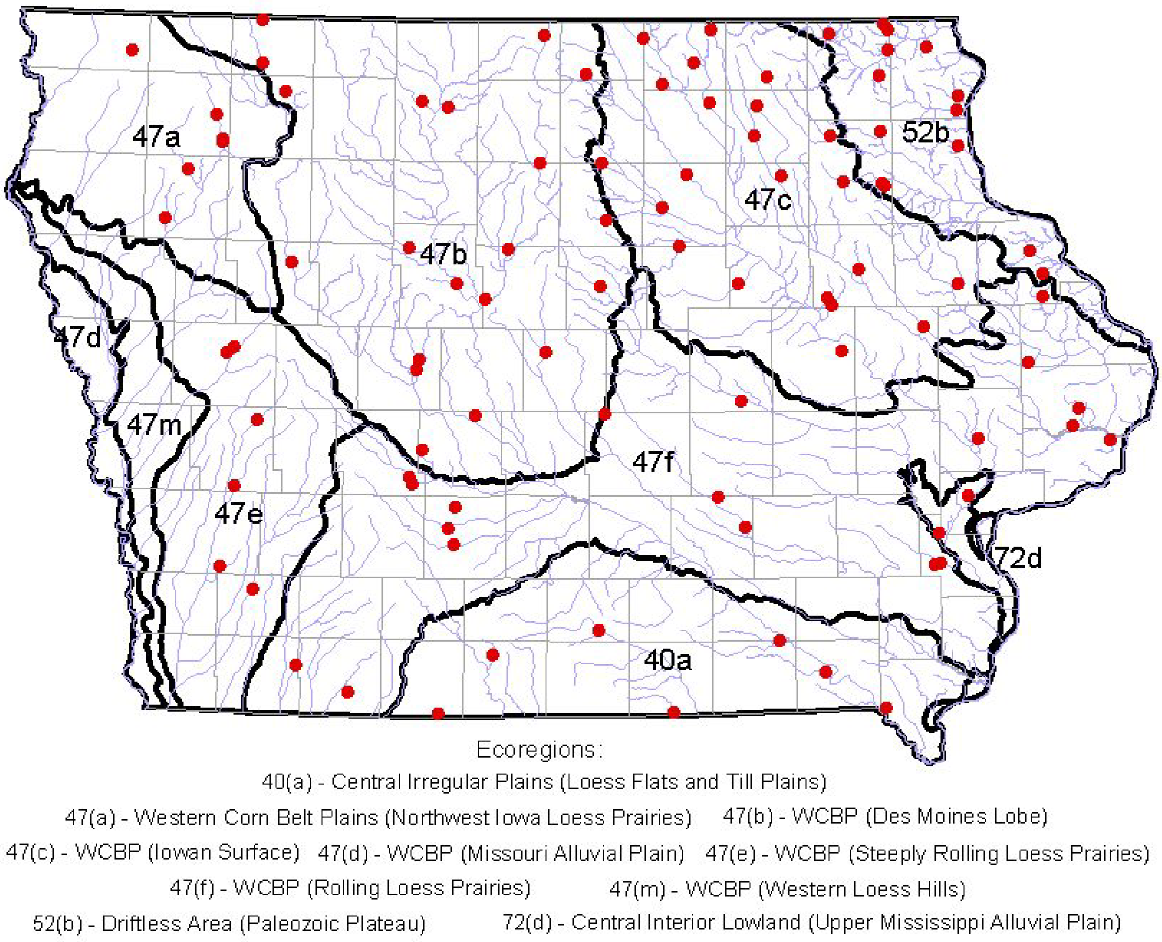


Figure A-1. Iowa ecoregions and wadeable stream reference sites: 1994 – 2000.

A.2. Sampling Procedures

Standard procedures for sampling stream benthic macroinvertebrates and fish assemblages are used to ensure data consistency between sampling sites and sampling years (IDNR 2001a, 2001b). Sampling is conducted during a three-month index period (July 15 – October 15) in which stream conditions and the aquatic communities are relatively stable. A representative reach of stream ranging from 150-350 meters in length is defined as the sampling area.

Two types of benthic macroinvertebrate samples are collected at each site: 1) Standard-Habitat samples are collected from natural rock or artificial wood substrates in flowing water; 2) a Multi-Habitat sample is collected by handpicking organisms from all identifiable and accessible types of benthic habitat in the sampling area. The multi-habitat sample data improve the estimation of taxa richness for the entire sample reach. Benthic macroinvertebrates are identified in the laboratory to the lowest practical taxonomic endpoint.

Fish are sampled using direct current (DC) electrofishing gear. In shallow streams, one or more battery-powered backpack shockers are used, and a tote barge, generator-powered shocker is used in deeper, wadeable streams. Fish are collected in one pass through the sampling reach proceeding downstream to upstream. The number of individuals of each species is recorded, and individual fish are examined for external abnormalities, such as deformities, eroded fins, lesions, parasites, and tumors. Most fish are identified to species in the field; however, small or difficult to identify fish are examined under a dissecting microscope in the laboratory.

Physical habitat is systematically evaluated at each stream sampling site. A series of instream and riparian habitat variables are estimated or measured at 10 stream channel transects that are evenly spaced throughout the sampling reach. Summary statistics are calculated for a variety of physical habitat characteristics, and these data are used to describe the stream environment and provide a context for the interpretation of biological sampling results.

A.3. Biological Indices

Biological sampling data from reference sites were used to develop a Benthic Macroinvertebrate Index of Biotic Integrity (BMIBI) and a Fish Index of Biotic Integrity (FIBI) (Wilton 2004). The BMIBI and FIBI are described as multi-metric or composite indices because they combine several individual measures or metrics. A metric is an ecologically relevant and quantifiable attribute of the aquatic biological community. Useful metrics can be cost-effectively and reliably measured, and will respond predictably to environmental disturbances.

Each index is comprised of twelve metrics that reflect a broad range of aquatic community attributes (Table A-1). Metric scoring criteria are used to convert raw metric data to normalized scores ranging from 0 (poor) –10 (optimum). The normalized metric scores are then combined to obtain the BMIBI and FIBI scores, which both have a possible scoring range from 0 (worst) – 100 (best). Qualitative categories for BMIBI and FIBI scores are listed in Table A-2 and A-3. A detailed description of the BMIBI and FIBI development and calibration process can be obtained at the IDNR web page: http://wqm.igsb.uiowa.edu/wqa/bioassess.html (Wilton 2004).

Table A-1. Data metrics of the Benthic Macroinvertebrate Index of Biotic Integrity (BMIBI) and the Fish Index of Biotic Integrity (FIBI).

BMIBI Metrics	**FIBI Metrics**
1. MH*-taxa richness	1. # native fish species
2. SH*-taxa richness	2. # sucker species
3. MH-EPT richness	3. # sensitive species
4. SH-EPT richness	4. # benthic invertivore species
5. MH-sensitive taxa	5. % 3-dominant fish species
6. % 3-dominant taxa (SH)	6. % benthic invertivores
7. Biotic index (SH)	7. % omnivores
8. % EPT (SH)	8. % top carnivores
9. % Chironomidae (SH)	9. % simple lithophil spawners
10. % Ephemeroptera (SH)	10. fish assemblage tolerance index
11. % Scrapers (SH)	11. adjusted catch per unit effort
12. % Dom. functional feeding group (SH)	12. % fish with DELTs

* MH, Multi-habitat sample; SH, Standard-habitat sample.

Table A-2. Qualitative scoring guidelines for the BMIBI.

Biological Condition Rating	**Characteristics of Benthic Macroinvertebrate Assemblage**
76-100 (Excellent)	High numbers of taxa are present, including many sensitive species. EPT taxa are very diverse and dominate the benthic macroinvertebrate assemblage in terms of abundance. Habitat and trophic specialists, such as scraper organisms, are present in good numbers. All major functional feeding groups (ffg) are represented, and no particular ffg is excessively dominant. The assemblage is diverse and reasonably balanced with respect to the abundance of each taxon.
56-75 (Good)	Taxa richness is slightly reduced from optimum levels; however, good numbers of taxa are present, including several sensitive species. EPT taxa are fairly diverse and numerically dominate the assemblage. The most-sensitive taxa and some habitat specialists may be reduced in abundance or absent. The assemblage is reasonably balanced, with no taxon excessively dominant. One ffg, often collector-filterers or collector-gatherers, may be somewhat dominant over other ffgs.
31-55 (Fair)	Levels of total taxa richness and EPT taxa richness are noticeably reduced from optimum levels; sensitive species and habitat specialists are rare; EPT taxa still may be dominant in abundance; however, the most-sensitive EPT taxa have been replaced by more-tolerant EPT taxa. The assemblage is not balanced; just a few taxa contribute to the majority of organisms. Collector-filterers or collector-gatherers often comprise more than 50% of the assemblage; representation among other ffgs is low or absent.
0-30 (Poor)	Total taxa richness and EPT taxa richness are low. Sensitive species and habitat specialists are rare or absent. EPT taxa are no longer numerically dominant. A few tolerant organisms typically dominate the assemblage. Trophic structure is unbalanced; collector-filterers or collector-gatherers are often excessively dominant; usually some ffgs are not represented. Abundance of organisms is often low.

Table A-3. Qualitative scoring guidelines for the FIBI.

Biological Condition Rating	Characteristics of Fish Assemblage
71-100 (Excellent)	Fish (excluding tolerant species) are fairly abundant or abundant. A high number of native species are present, including many long-lived, habitat specialist, and sensitive species. Sensitive fish species and species of intermediate pollution tolerance are numerically dominant. The three most abundant fish species typically comprise 50% or less of the total number of fish. Top carnivores are usually present in appropriate numbers and multiple life stages. Habitat specialists, such as benthic invertivore and simple lithophilous spawning fish are present at near optimal levels. Fish condition is good; typically less than 1% of total fish exhibit external anomalies associated with disease or stress.
51-70 (Good)	Fish (excluding tolerant species) are fairly abundant to very abundant. If high numbers are present, intermediately tolerant species or tolerant species are usually dominant. A moderately high number of fish species belonging to several families are present. The three most abundant fish species typically comprise two-thirds or less of the total number of fish. Several long-lived species and benthic invertivore species are present. One or more sensitive species are usually present. Top carnivore species are usually present in low numbers and often one or more life stages are missing. Species that require silt-free, rock substrate for spawning or feeding are present in low proportion to the total number of fish. Fish condition is good; typically less than 1% of the total number of fish exhibits external anomalies associated with disease or stress.
26-50 (Fair)	Fish abundance ranges from lower than average to very abundant. If fish are abundant, tolerant species are usually dominant. Native fish species usually equal ten or more species. The three most abundant species typically comprise two-thirds or more of the total number of fish. One or more sensitive species, long-lived fish species or benthic habitat specialists such as suckers (Catostomidae) are present. Top carnivore species are often, but not always present in low abundance. Species that are able to utilize a wide range of food items including plant, animal and detritus are usually more common than specialized feeders, such as benthic invertivore fish. Species that require silt-free, rock substrate for spawning or feeding are typically rare or absent. Fish condition is usually good; however, elevated levels of fish exhibiting external anomalies associated with disease or stress are not unusual.
0-25 (Poor)	Fish abundance is usually lower than normal or, if fish are abundant, the assemblage is dominated by a few or less tolerant species. The number of native fish species present is low. Sensitive species and habitat specialists are absent or extremely rare. The fish assemblage is dominated by just a few ubiquitous species that are tolerant of wide-ranging water quality and habitat conditions. Pioneering, introduced and/or short-lived fish species are typically the most abundant types of fish. Elevated levels of fish with external physical anomalies are more likely to occur.

A.4. Plausibility of Stressor-Response Relationships

Graphical and quantitative analysis methods were used to examine the plausibility that various stressors occur at levels that are sufficient to impair the aquatic community of Hecker Creek. The data analysis utilized biological and environmental indicator data collected primarily from wadeable streams during 1994-2003 as part of Iowa's stream biological assessment program. Scatter plots were created and visually examined to identify relationships between stressor indicators and biological response variables (i.e., benthic macroinvertebrate and fish IBIs). Regression coefficients were calculated to help identify stressor indicators that were significantly related with IBI levels. Examples of the scatter plot and simple regression analysis approach are displayed in Appendix B (Figures B-3 – B-13 and B-15 – B-17).

Conditional Probability (CP) is a promising technique for stressor-response analysis (Paul and McDonald 2005). This approach was used to evaluate SI data for the Little Floyd River, the North Fork Maquoketa River, and Hecker Creek. CP computations were obtained for many stressor-response relationships, and the results were graphically displayed for visual interpretation (see Figure A-2 [a-d]).

Essentially, the CP analysis method seeks to identify stressors that occur at levels associated with an increased probability of observing biological impairment. In the Little Floyd River example, biological impairment is defined as not achieving a BMIBI score or FIBI score that is greater than or equal to the impairment criteria established from regional reference sites in the Northwest Iowa Loess Plains (47a) ecoregion. For this ecoregion, the BMIBI criterion is 53 and the FIBI criterion is 40. Figure A-2 shows the data analysis output from one stressor-response relationship (i.e., TSS-FIBI). Similar types of comparisons were made for stressor and causal pathway indicator data available for the Silver Creek watershed.

The example CP output shown in Figure A-2 provides evidence of TSS as a primary stressor that is associated with impaired fish assemblage condition. Figure A-2(a) shows the stressor-response pattern where increasing levels of the stressor (TSS) are generally associated with decreasing levels of the fish assemblage IBI. Figure A-2(b) shows separation of the TSS Cumulative Distribution Function (CDF) for unimpaired sites compared with the CDF representing stressor levels at impaired sites. Generally, unimpaired sites have lower TSS levels than impaired sites. For example, the interquartile range of unimpaired sites is approximately 10-30 mg/L compared with 20-60 mg/L for impaired sites. Figure A-2(c) shows CP computation output where the probability of observing impairment is plotted against stressor levels. At any given stressor level on the x-axis, the probability of impairment for sites where the stressor is less than or equal to the specified level can be obtained from the curve. For example, the probability of impairment among all sites is approximately 0.25 for sites with TSS less than or equal to 20 mg/L, the median TSS concentration of unimpaired sites. In contrast, Figure A-2(d) shows the probability of observing impairment at sites where the stressor level exceeds a specified level of criterion. In this case, the probability of impairment is approximately 0.5 for streams such as the Little Floyd River, O'Brien County where the TSS concentration exceeds 30 mg/L, the median level for impaired sites. The increased slope in the curve that is observable in Figure A-2(d) is consistent with an increased probability of impairment, and the slope increase occurs in the same range as stressor levels found in the Little Floyd River. The evidence shown in these plots is evidence that TSS levels in the Little Floyd are a plausible stressor associated with increased probability of biological impairment.

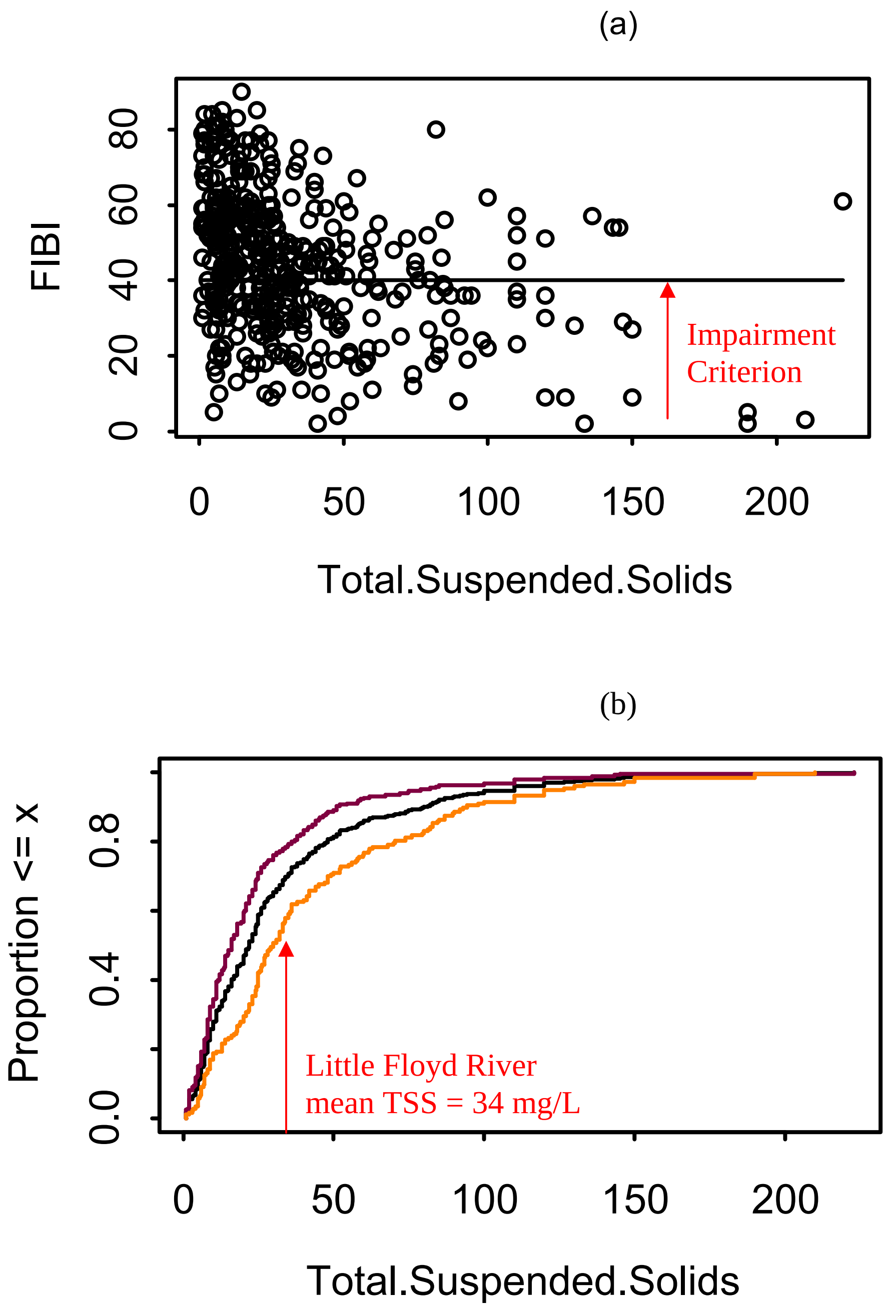


Figure A-2. Conditional Probability (CP) analysis using example data from the Little Floyd River, O'Brien County; **(a)** Fish Index of Biotic Integrity (FIBI) relationship with Total Suspended Solids (TSS). Data are from the Iowa stream bioassessment database for summer-fall sample index period: 1994-2003. Solid black line represents biological impairment criterion (FIBI=40) for Northwest Iowa Loess Prairies (47a) ecoregion. **(b)** Cumulative Distribution Function (CDF) of TSS for unimpaired sites (FIBI≥40; maroon); impaired sites (FIBI<40; red); all sites (black). Little Floyd River mean TSS (34 mg/L) for 3 sample sites exceeds median value of impaired sites.

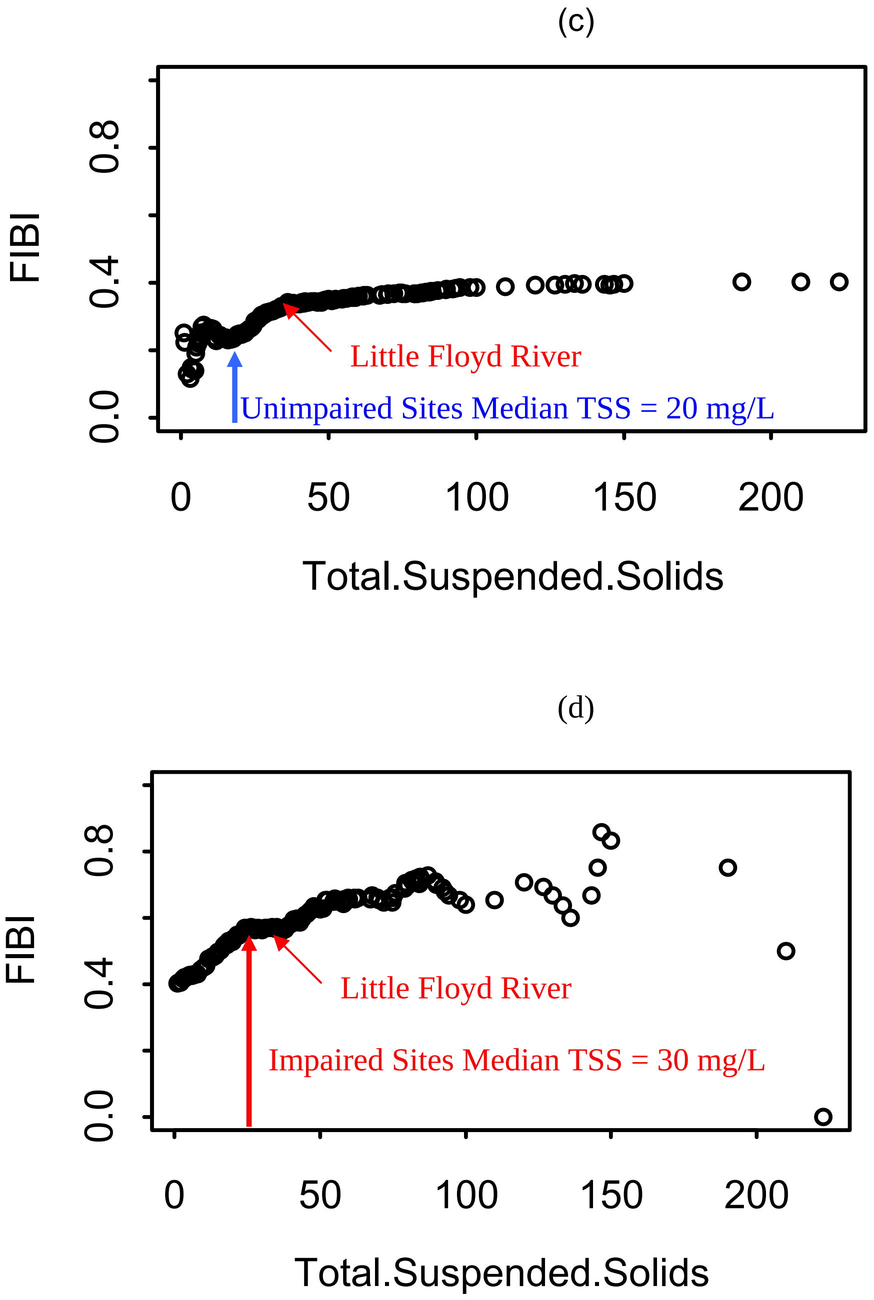


Figure A-2 (continued). **(c)** Conditional Probability (CP) plot displaying the probability of observing an impairment (i.e., FIBI<40) when the observed stressor level is less than or equal to a specified level or criterion. For example the probability of impairment is approximately 0.25 for sites with TSS less than or equal to 20 mg/L, the median value of unimpaired sites (see Figure 1-2(a)). **(d)** CP plot displaying the probability of observing an impairment (i.e., FIBI<40) when the observed stressor level exceeds a specified level or criterion. For example the probability of impairment is approximately 0.50 for stream sites such as Little Floyd River sites with TSS exceeding 30 mg/L, the median of impaired sites (see Figure 1-2(a)).

A.5. References

Griffith, G.E., J.M. Omernik, T.F. Wilton, and S. M. Pierson. 1994. Ecoregions and subecoregions of Iowa: a framework for water quality assessment and management. Journal of the Iowa Academy of Science. 10(1):5-13.

IDNR. 2001a. Biological sampling procedures for wadeable streams and rivers in Iowa. June 30, 1994 revised May 3, 2001. Iowa Department of Natural Resources, Environmental Protection Division, Water Resources Section. Des Moines, Iowa. 15 p. + appendices.

IDNR. 2001b. Habitat evaluation procedures for wadeable streams and rivers in Iowa. June 30, 1994 revised May 3, 2001. Iowa Department of Natural Resources, Environmental Protection Division, Water Resources Section. Des Moines, Iowa. 17 p. + appendices

Paul, J. F. and M. E. McDonald. 2005. Development of Empirical, Geographically Specific Water Quality Criteria: A Conditional Probability Analysis Approach. J. Amer. Water Res. Assoc. 41:1211-1223.

Wilton, T.F. 2004. Biological Assessment of Iowa's Wadeable Streams. Project Report. Iowa Department of Natural Resources, Environmental Protection Division, TMDL and Water Quality Assessment Section. Des Moines, Iowa. http://wqm.igsb.uiowa.edu/wqa/bioassess.html

Appendix B

Data Summary

Table B-1. Water quality data from 1996-97 Fox Engineering Associates, Inc. sampling. (ND = no data).

Site	date	flow (mgd)	temp (F)	pH	BOD (mg/L)	NH3 nitrogen (mg/L)	DO (mg/L)	Dissolved Solids (mg/L)	Chloride (mg/L)
1	8/7/96	ND	69	7.9	0	2	8	1000	603
1	10/25/96	ND	46	7.9	0	2	9	465	230
1	3/26/97	ND	40	7.6	0	1	12	523	136
1	4/2/97	ND	54	7.8	0	5	10	650	152
1	4/9/97	ND	38	7.8	0	3	13	610	99
1	4/16/97	ND	48	7.9	2	2	12	380	10
1	4/23/97	ND	48	7.6	29	<1	9	1	15
1	4/30/97	ND	52	7.8	6	1	12	0	250
1	5/7/97	ND	63	7.9	2	2	10.1	758	105
1	5/14/97	ND	46	8.3	4	3	10.2	641	109
1	5/21/97	ND	48	7.3	3	100	10.5	724	204
1	5/28/97	ND	52	7.3	22	3	8.8	0.9	456
1	6/4/97	ND	61	8	9	2	11.2	800	200
1	6/11/97	ND	59	8.1	10	2	5	800	300
2	7/2/96	16.55	76	8.1	44	11	6	1185	650
2	7/9/96	6.79	68	7.9	25	5	6	300	30
2	7/16/96	2.42	76	8.7	2	1	8	280	34
2	7/23/96	1.62	74	8.6	0	1	9	264	32
2	7/30/96	1.62	72	ND	ND	ND	9	ND	ND
2	8/7/96	1	81	8.7	0	1	8	360	30
2	10/18/96	9.64	49	8	4	15	10	2480	1340
2	10/25/96	0.19	44	8.1	0	1	11	400	95
2	10/29/96	11.85	49	8	9	3	11	1110	650
2	11/6/96	8.44	41	8.4	25	20	14	2250	1678
2	11/13/96	0.33	32	8.2	0	6	13	550	156
2	12/11/96	0.13	32	8.1	0	<1	14	440	60
2	3/19/97	8.08	37	7.7	0	1	14	430	40
2	3/26/97	8.41	40	8.1	0	2	13	336	51
2	4/2/97	4.85	57	8.6	0	3	14	420	96
2	4/9/97	7.11	42	8.4	0	6	14	600	190
2	4/16/97	5.05	46	8.4	5	20	13	1068	199
2	4/23/97	5.43	46	8.3	9	19	14	1284	220
2	4/30/97	4	54	8.5	33	34	12	1288	880
2	5/7/97	5.86	51	8.2	22	12	12	1011	665
2	5/14/97	2	45	8.9	14	15	11	1011	164
2	5/21/97	5.94	ND	8.2	10	60	12	1749	880
2	5/28/97	2.75	50	8.1	23	18	11	1	800
2	6/4/97	3.15	63	8.1	42	17	8.9	1400	900
2	6/11/97	2.87	61	8.1	42	22	7.8	1600	700
3	7/2/96	14.54	74	8.4	8	2	8	520	194
3	7/9/96	4.85	66	8.2	2	1	9	320	27
3	7/16/96	4.85	75	8.6	0	1	8	320	30
3	7/23/96	4.85	74	8.5	0	1	9	320	34
3	7/30/96	4.85	73	8.6	0	1	9	ND	ND
3	8/7/96	4.85	80	8.5	0	1	9	330	32
3	8/14/96	4.07	75	8.5	0	1	9	300	38
3	8/21/96	4.07	75	8.5	0	1	8	280	49
3	8/28/96	2.91	71	8.5	0	1	12	300	42
3	9/4/96	3.88	72	8.4	ND	1	9	310	35
3	9/11/96	3.88	69	8.2	ND	1	11	320	28
3	9/18/96	1.94	62	8.3	ND	1	10	330	30
3	9/25/96	1.94	64	8.2	0	1	12	305	31
3	10/2/96	1.94	66	8.1	ND	1	10	300	39
3	10/18/96	48.47	49	8	5	14	9	2500	1513
3	10/25/96	4.34	44	7.9	0	1	11	350	50
3	10/29/96	5.3	48	7.8	7	2	10	870	368
3	11/6/96	1.06	41	8.4	32	15	12	1750	1234

Table B-1 (cont.)

Site	date	flow (mgd)	temp (F)	pH	BOD (mg/L)	NH3 nitrogen (mg/L)	DO (mg/L)	Dissolved Solids (mg/L)	Chloride (mg/L)
3	11/13/96	2.71	32	8.2	0	1	14	360	57
3	12/11/96	1.94	32	8.2	0	<1	17	375	34
3	1/15/97	3.88	32	7.6	0	1	14	325	39
3	2/12/97	6.01	33	7.8	0	1	13	335	24
3	3/19/97	48.48	37	7.8	0	1	14	380	33
3	3/26/97	38.78	39	8	0	1	13	288	29
3	4/2/97	29.09	52	8.3	0	1	14	320	36
3	4/9/97	42.66	38	8.3	0	3	15	340	50
3	4/16/97	27.15	46	8.5	3	5	15	687	6
3	4/23/97	38.78	45	8.3	4	3	13	550	10
3	4/30/97	17.84	54	8.3	9	5	11	410	179
3	5/7/97	30.25	49	8.3	1	3	12	448	119
3	5/14/97	24.89	45	9	7	3	15	410	62
3	5/21/97	31.8	48	8.2	4	15	12	643	328
3	5/28/97	18.1	49	8.2	8	3	11	0	134
3	6/4/97	21.72	64	8.1	11	3	10	600	200
3	6/11/97	24.05	62	8.2	10	4	7.4	700	300
4	7/2/96	15.51	75	8.5	1	1	10	360	47
4	7/9/96	15.51	67	8.3	0	1	11	32	28
4	7/16/96	1.31	77	8.6	0	1	10	330	27
4	7/23/96	9.69	75	8.5	0	1	10	325	30
4	7/30/96	9.69	75	8.6	0	1	10	ND	ND
4	8/7/96	8.2	79	8.5	0	1	10	325	28
4	8/14/96	6.46	78	8.6	0	1	11	310	34
4	8/21/96	6.88	76	8.5	0	1	10	300	40
4	8/28/96	6.26	72	8.5	0	1	13	320	35
4	9/4/96	5.62	75	8.5	ND	1	10	315	31
4	9/11/96	4.36	70	8.3	ND	1	13	315	27
4	9/18/96	2.97	63	8.4	ND	1	12	325	31
4	9/25/96	2.12	63	8.2	ND	1	12	315	28
4	10/2/96	1.4	67	8	0	1	13	310	33
4	10/9/96	0.36	54	7.7	0	1	10	340	38
4	10/16/96	0	55	7.6	0	1	10	305	36
4	10/25/96	3.18	44	7.7	0	1	12	290	37
4	10/29/96	1.27	49	7.9	5	1	11	400	68
4	11/6/96	3.14	40	8.2	0	1	14	370	61
4	11/13/96	1.89	33	8.3	0	1	15	360	49
4	12/11/96	4.85	33	8.1	0	<1	15	350	35
4	1/15/97	9.7	ND	7.6	0	1	14	300	30
4	2/12/97	4.95	ND	7.9	0	1	13	330	22
4	3/19/97	46.54	37	7.9	0	1	14	330	37
4	3/26/97	17.46	39	8	0	1	13	283	27
4	4/2/97	49.13	52	8.3	0	<1	14	294	30
4	4/9/97	28.44	38	8.3	0	2	16	310	23
4	4/16/97	18.1	47	8.4	3	<1	16	326	3
4	4/23/97	35.29	44	8.3	3	<1	14	335	4
4	4/30/97	18.87	54	8.4	6	<1	11	268	53
4	5/7/97	31.29	49	8.3	0	1	12	313	52
4	5/14/97	18.1	46	9	7	2	16	308	25
4	5/21/97	25.87	48	8.2	4	2	13	308	49
4	5/28/97	11.12	49	8.2	4	<1	12	0	13
4	6/4/97	34.13	63	8.3	7	<1	10.4	400	100
4	6/11/97	19.01	63	8.2	1	<1	14.2	300	100
5	7/2/96	5.43	72	8	29	18	6	1160	691
5	7/9/96	1.42	61	8.2	0	1	10	325	26
5	7/16/96	0.65	68	8.2	0	1	10	365	33
5	7/23/96	0.78	70	8.2	0	1	9	370	35
5	7/30/96	1.29	69	8.3	0	1	9	ND	ND
5	8/7/96	1.18	76	8.2	0	1	9	330	33

Table B-1 (cont.)

Site	date	flow (mgd)	temp (F)	pH	BOD (mg/L)	NH3 nitrogen (mg/L)	DO (mg/L)	Dissolved Solids (mg/L)	Chloride (mg/L)
5	8/14/96	1	74	8.4	0	1	11	360	39
5	8/21/96	1.13	75	8.3	4	1	11	360	49
5	8/28/96	1.06	69	8.3	0	1	13	365	45
5	9/4/96	1.13	71	8.2	ND	1	10	350	40
5	9/11/96	0.81	71	8.4	ND	1	14	360	41
5	9/18/96	0.68	63	8.5	ND	1	14	370	45
5	9/25/96	1.32	60	8.3	ND	1	10	450	42
5	10/2/96	0.8	66	8.1	0	1	11	520	109
5	10/9/96	0.8	52	8.1	0	1	11	625	213
5	10/16/96	0.83	59	8.2	0	1	15	470	115
5	10/18/96	8.42	51	7.8	5	18	8	2580	2460
5	10/25/96	0.51	45	8.1	0	1	12	450	100
5	10/29/96	8.96	51	7.9	23	20	11	2300	2218
5	11/6/96	0.59	40	8.3	32	20	13	2130	1824
5	11/13/96	0.6	33	8.1	0	1	16	410	68
5	12/11/96	0.04	33	8.1	0	<1	16	420	60
5	1/15/97	0.81	ND	7.7	0	1	13	365	43
5	2/12/97	0.65	ND	7.8	0	1	14	340	24
5	3/19/97	3.72	37	8	0	1	14	435	41
5	4/2/97	4.27	55	8.2	0	2	17	433	124
5	4/9/97	2.43	41	8.2	0	10	15	720	240
5	4/16/97	5.71	51	8.2	8	20	12	1075	215
5	4/23/97	9.7	54	8.3	10	23	12	1240	257
5	4/30/97	5.43	54	8.4	39	5	11	1560	880
5	5/7/97	12.26	44	8.5	32	21	12	1008	594
5	5/14/97	3.43	49	8.8	30	30	12	972	523
5	5/21/97	8.73	48	8.4	19	33	11	1696	197
5	5/28/97	4.43	57	8.6	37	24	11	1	880
5	6/4/97	10.55	71	8.3	43	24	8.5	1600	900
5	6/11/97	4.89	70	8.2	32	31	9.7	1800	700
6	7/2/96	1.29	66	8.1	1	1	9	340	34
6	7/9/96	1.42	61	8.2	0	1	10	325	26
6	7/16/96	0.65	68	8.2	0	1	10	340	29
6	7/23/96	0.39	67	8.2	0	1	10	330	28
6	7/30/96	0.65	68	8.3	0	1	10	ND	ND
6	8/7/96	0.66	71	8.2	0	1	10	335	26
6	8/14/96	0.27	73	8.3	0	1	9	330	32
6	8/21/96	0.32	70	8.2	5	1	9	340	31
6	8/28/96	0.71	72	8.2	0	1	12	330	34
6	9/4/96	0.32	72	8.5	ND	1	9	325	33
6	9/11/96	0.26	63	8.3	ND	1	10	320	25
6	9/18/96	0.19	62	8.3	ND	1	11	315	28
6	9/25/96	0.32	65	8.3	ND	1	12	340	26
6	10/2/96	0.32	53	8.2	0	1	12	340	28
6	10/9/96	0.27	59	8.2	0	1	12	360	33
6	10/16/96	0.28	ND	8.2	0	1	14	350	38
6	10/25/96	0.32	45	8.1	0	1	14	330	35
6	10/29/96	0.09	50	8	5	1	14	360	50
6	11/6/96	0.32	42	8.1	0	1	14	350	48
6	11/13/96	0.27	33	8.1	0	1	17	370	48
6	12/11/96	0.02	32	8.1	0	<1	15	350	32
6	1/15/97	0.26	ND	7.6	0	1	14	310	33
6	2/12/97	0.49	ND	7.8	0	1	14	370	26
6	3/19/97	2.33	36	8.1	0	1	14	330	30
6	4/2/97	1.94	55	8.3	0	1	18	296	43
6	4/9/97	1.43	40	8.1	0	3	17	330	40
6	4/16/97	1.46	53	8.3	2	<1	14	398	6
6	4/23/97	1.27	52	8.3	3	<1	14	367	5
6	4/30/97	1.07	57	8.7	3	<1	15	255	74

Table B-1 (cont.)

Site	date	flow (mgd)	temp (F)	pH	BOD (mg/L)	NH3 nitrogen (mg/L)	DO (mg/L)	Dissolved Solids (mg/L)	Chloride (mg/L)
6	5/7/97	1.85	58	8.5	0	<1	15	325	64
6	5/14/97	1.91	48	8.8	5	2	16	366	31
6	5/21/97	0.85	48	8	4	1	15	307	34
6	5/28/97	1.98	56	8.3	6	3	14	0	28
6	6/4/97	1.09	66	8.3	4	<1	13.6	500	0
6	6/11/97	0.62	63	8.2	3	<1	12.6	300	100
7	7/2/96	5.82	75	7.9	50	17	6	1290	850
7	7/9/96	3.49	67	7.8	27	12	6	365	36
7	7/16/96	1.94	74	8.4	2	1	10	360	35
7	7/23/96	4.55	72	8.3	0	1	11	365	38
7	7/30/96	1.29	71	8.5	0	1	12	ND	ND
7	8/7/96	2.35	79	8.5	0	1	12	360	37
7	8/14/96	2.35	75	8.4	0	1	11	375	43
7	8/21/96	2.46	74	8.3	3	1	11	390	44
7	8/28/96	1.45	72	8.3	0	1	13	370	48
7	9/4/96	1.03	74	8.3	ND	1	11	360	44
7	9/11/96	1.26	70	8.2	ND	1	10	375	42
7	9/18/96	0.79	64	8.3	ND	1	11	370	45
7	9/25/96	1.56	60	8.2	ND	1	13	440	39
7	10/2/96	..53	66	8.2	0	1	12	410	74
7	10/9/96	0.53	51	8.2	0	1	14	450	175
7	10/16/96	0.79	58	8.2	0	1	13	470	117
7	10/18/96	5.15	48	7.9	4	16	10	2550	2050
7	10/25/96	0.71	45	8.2	0	1	12	435	86
7	10/29/96	8.21	50	8	16	16	13	1930	1504
7	11/6/96	4.42	41	8.4	38	20	15	2310	1856
7	11/13/96	0.59	33	8.1	0	1	16	540	65
7	12/11/96	0.05	32	8	0	<1	14	420	58
7	1/15/97	0.49	ND	7.8	0	1	12	350	40
7	2/12/97	0.65	ND	7.9	0	1	14	345	25
7	3/19/97	2.43	38	8	0	1	14	410	38
7	4/2/97	1.75	54	8.4	0	<1	17	389	109
7	4/9/97	2.84	40	8.1	0	9	15	650	272
7	4/16/97	2.53	43	8.3	6	13	13	1140	6
7	4/23/97	2.33	55	8.5	10	23	13	1337	240
7	4/30/97	4.14	54	8.7	39	40	13	144	880
7	5/7/97	5.82	62	8.4	33	24	12	1083	681
7	5/14/97	2.72	48	8.8	26	28	12	1195	491
7	5/21/97	1.36	48	8.5	19	31	12	1846	394
7	5/28/97	3.51	60	8.7	39	30	14	1	880
7	6/4/97	6.21	72	8.4	47	19	13.1	1400	900
7	6/11/97	7.84	69	8.2	39	28	10.9	1800	700

Table B-2. Water quality data from 2000 UHL/DNR sampling.

Date	Ammonia Nitrogen as N (mg/L)	Atrazine Screen (µg/L)	CBOD (mg/L)	Dissolved Oxygen (mg/L)	Field pH	Field Temp. (°C)	Flow Rate (cfs)	Nitrate + Nitrite Nitrogen as N (mg/L)	Specific Conductance (µmhos/cm)	TKN (mg/L)	Total Dissolved Solids (mg/L)	Total Hardness (mg/L as CaCO3)	Total Phosphate as P (mg/L)	Total Suspended Solids (mg/L)	Turbidity (NTU)
8/16/2000	< 0.1	0.22	2	8.9	8.1	18.5	1.4	2	3200	1.6	2070	350	2.9	6	6

Table B-3. Water quality data from 2004-2006 DNR sampling.

Date	5/20/04	5/27/04	6/3/04	6/10/04	6/17/04	6/24/04	7/1/04	7/8/04	7/15/04	7/22/04	7/29/04	8/5/04	8/12/04	8/19/04	8/26/04
Ammonia Nitrogen as N (mg/L)	8.6	3.5	3.9	1.1	0	0.97	0	0.19	0	0	0	0	0	0	0.2
Chloride(mg/L)	620	230	190	340	26	410	670	630	44	33	27	900	37	32	1400
Chlorophyll a (water) (µg/L)															
Dissolved Inorganic Carbon (mg/L)															
Dissolved Organic Carbon (mg/L)															
Dissolved Oxygen (mg/L)	5	5.4	8.3	4.5	6.2	6.8	6.1	6.8	6.9	6.7	5.6	6	10.2	7.5	5.9
E. coli (#/100mL)	1,500	880	2,500	18,000	5,300	2,900	320	6,400	520	12,000	2,900	7,100	220	460	4,100
pH															
Temperature (^{o}C)	20.1	13.6	12.5	17.6	17	14.1	18.8	15.5	18.2	19.6	19.2	17.5	13.3	14.3	20.5
Nitrate + nitrite as N (mg/L)	7.4	8	7.5	9.3	5.5	9.9	8	9.1	6	4.6	2.3	2.4	2.7	1.9	1.1
Ortho Phosphate as P (mg/L)	3.5	1.4	1.3	1.9	0.21	1.6	2	1.7	0.46	0.31	0.17	1.6	0.32	0.32	1.4
Specific Conductance (µmhos/cm)	2972	1413	1289	791	660	1933	2972	2883	667	717	562	3586	340	316	2460
Total Dissolved Solids (mg/L)															
Total Kjeldahl Nitrogen as N (mg/L)	11	5.1	6.2	3.4	1	3.3	2.1	1.9	0.72	0.85	0.56	2	0.62	0.4	0.65
Total Organic Carbon (mg/L)															
Total Phosphate as P (mg/L)	4.3	1.5	1.5	2.1	0.26	1.8	2.2	2.3	0.49	0.35	0.22	1.8	0.34	0.34	2
Total Suspended Solids (mg/L)															
Turbidity (NTU)		11	9	8	5		9.2	10	3.9	11	3.4	12	5	9	10

Table B-3. (continued).

Date	9/2/04	10/27/04	10/28/04	2/8/05	5/12/05	5/19/05	6/9/05	6/30/05	7/21/05	8/4/05	8/18/05	8/25/05	9/1/05	9/8/05	9/15/05	9/22/05
Ammonia Nitrogen as N (mg/L)	0				1.7	0.08	0.26	0.22	0.47	0.05	0.49	0	0.27	0.28	0	1.1
Chloride(mg/L)	860	960	1300		910	360	1900	110	800	2100	120	84	2500	2300	140	2600
Chlorophyll a (water) (µg/L)																
Dissolved Inorganic Carbon (mg/L)																
Dissolved Organic Carbon (mg/L)																
Dissolved Oxygen (mg/L)	7.9		1.1	10.2	5.5	5.5	5.2	3.9	3.7	4.1	4.6	6.7	4.6	5.5	5.6	3.8
E. coli (#/100mL)	510		84,000	2,600	1,600	550	32,000	110,000	1,200,000	240,000	160,000	1,300	5,700	600	580	34,000
pH																
Temperature (°C)	21.1		10.1	0.4	8.5	15.2	20.8	20.5	21.8	23.2	19.9	19.5	18.9	18.2	14	20.1
Nitrate + nitrite as N (mg/L)	0.05		3.4	2.5	3.6	1.7	5.1	2.8	2.4	0.62	1.6	1.4	0.96	1.6	1.8	1.1
Ortho Phosphate as P (mg/L)	1.3				4.1	2.5	4.6	0.54	1.1	1.1	0.75	0.25	1	1.1	0.51	1.8
Specific Conductance (µmhos/cm)	2020		3339	280	3646			800	2824	3169	632	810	6800	7450	1021	3968
Total Dissolved Solids (mg/L)					1980	960	3960	550	1720	4120	430	500	4700	4500	640	4950
Total Kjeldahl Nitrogen as N (mg/L)	2.3				6.2	2	6.1	4.7	9.1	5.7	8.1	0.71	4.6	4.1	1.2	4.6
Total Organic Carbon (mg/L)																
Total Phosphate as P (mg/L)	1.5		2.4	1.7	4.3	2.7	5.1	1.6	3.1	1.9	3.5	0.32	1.5	1.4	0.59	2.2
Total Suspended Solids (mg/L)					38	8	22	590	660	59	1250	27	49	41	21	76
Turbidity (NTU)	8.5		20	6.7	7.5	7.5	26.4	1000	823	64	0	15.8	40.3	31.6	16.2	61.4

Table B-3. (continued).

Date	9/29/05	3/7/06	4/4/06	4/22/06	5/4/06	5/11/06	5/18/06	5/25/06	6/1/06	6/8/06	6/15/06	6/22/06	6/29/06	7/6/06	7/20/06	8/3/06	8/17/06
Ammonia Nitrogen as N (mg/L)	0.29	4.9	0.05		0		0	3	0.66	2.6	0.08	0	0	0	0.28	0	0
Chloride(mg/L)	1900	1000	55	1000	42	35	39	1100	270	650	600	870	1000	38	350	54	45
Chlorophyll a (water) (µg/L)																	
Dissolved Inorganic Carbon (mg/L)																	
Dissolved Organic Carbon (mg/L)																	
Dissolved Oxygen (mg/L)	6.9	9.4	11.1		10.6	5.7	10.4	6.3	8.6	8.1	7.5	7.9	8.1	8.4	6.7	6.1	6
E. coli (#/100mL)	10,000	91	130		280	300	430	4,500	4,900	7,600	650	2,000	770	540	320,000	220	440
pH																	
Temperature (°C)	9.4	0.4	3.2		9.8	9.7	10.9	17.1	14.9	16.4	15.6	17.6	16.6	17.1	20.8	21.2	19.9
Nitrate + nitrite as N (mg/L)	2.7	3.5	8.9		9.2	6	5.1	7.9	13	8.4	10	8.4	5.9	4.9	2.9	4	2.9
Ortho Phosphate as P (mg/L)	1.7	2.5	0.16		0.14	0.08	0.1	4.8	1.1	2.3	2.5	3.2	2.6	0.23	1.3	0.47	0.31
Specific Conductance (µmhos/cm)	4259			4047	704	706	710	4037	1470	2713	2863	3468	3690	733	1507	811	744
Total Dissolved Solids (mg/L)	3650	2160	470		410	390	440	2260	370	1540	1650	1960	2130	470	910	510	440
Total Kjeldahl Nitrogen as N (mg/L)	0.3	8.5	0.6		0.6		0.5	4.9	1.7	4.7	1.2	1.6	1.5	0.4	4.6	0.6	0.5
Total Organic Carbon (mg/L)																	
Total Phosphate as P (mg/L)	0.88	2.8	0.24		0.19	0.14	0.13	4.7	1.3	2.7	3	3.6	2.7	0.31	2	0.51	0.37
Total Suspended Solids (mg/L)	22	13	21		21	16	9	13	13	29	14	16	8	5	190	6	2
Turbidity (NTU)	36.4		16.5		15.1	14.9	7.9	16.3	13.2	21.6	15.9	14	9.8	3.7	229	4.6	3.6

Table B-3. (continued).

Date	8/31/06	9/7/06	9/12/06	9/14/06	9/17/06	9/18/06	9/21/06	9/28/06	11/16/06
Ammonia Nitrogen as N (mg/L)	0	0		0	0.31	0.54	0.4	0	0
Chloride(mg/L)	760	78		53		1300	1500	53	600
Chlorophyll a (water) (µg/L)		14				33	19		
Dissolved Inorganic Carbon (mg/L)		69			64	65	77		
Dissolved Organic Carbon (mg/L)		3.8			14	11	11		
Dissolved Oxygen (mg/L)	8.7	12.1		10.3			11.5	10.8	10
E. coli (#/100mL)	2,200	460	27,000	5,600		11,100	830	250	240
pH		8.7					8.2		
Temperature (°C)	15.7	17.8		12.3			11.9	9.5	2.3
Nitrate + nitrite as N (mg/L)	1.8	1.2		4.8	2.2	2.2	2.7	3.5	28
Ortho Phosphate as P (mg/L)	0.83	0.24		0.16		2.2	2.3	0.19	4.8
Specific Conductance (µmhos/cm)	3053			803				808	1289
Total Dissolved Solids (mg/L)	1690	430		400		2570	2920	460	1600
Total Kjeldahl Nitrogen as N (mg/L)	1.7	0.6		0.3	4.9	3.6	2.8	0.5	1.3
Total Organic Carbon (mg/L)		5			30	16	14		
Total Phosphate as P (mg/L)	1	0.33		0.18	2.9	2.5	2.5	0.2	4.9
Total Suspended Solids (mg/L)	8	2.5		5		44.5	9	1	11
Turbidity (NTU)	6.2	1.6		4.4		61	15	2	13.4

Table B-4. Water quality data from 2006-2008 UHL/DNR sampling.

Date	7/13/06	7/27/06	8/10/06	8/24/06	11/2/06	12/7/06	1/11/07	2/8/07	3/8/07	3/22/07	4/5/07	4/19/07	4/30/07	5/2/07	5/7/07
Ammonia Nitrogen as N (mg/L)	< 0.05	0.26	< 0.05	< 0.05	< 0.05	1.1	0.14	0.3	0.14	< 0.05	< 0.05	< 0.05	0.08	< 0.05	< 0.05
Carbonaceous BOD (5 day) (mg/L)					5		1.9								
Chloride(mg/L)	1,100	250	48	2,100	950	1,800	540	1,000	810	170	99	340	350	320	370
Chlorophyll a (water) (µg/L)	32	88	5	170	19	170	6	1	6	3	3	15	18	10	11
Dissolved Inorganic Carbon (mg/L)	71	37	76	69	83	84	85	95	66	42	63	58	80	80	77
Dissolved Organic Carbon (mg/L)	9	8.7	3.5	15	5.7	12	4.4	7.7	5.4	5.8	2.8	2.2	5	4	4
Dissolved Oxygen (mg/L)	9.3	7.6	10	9.8	17.7	15.2	16.1	14.5	13.9	11.9	14.4	14.3	12	12	13.1
E. coli (#/100mL)	3,100	230,000	2,700	3,800	120	90	140	10	45	48,000	90	140	110	20	1,100
pH	8.8	8.2	8.6	8.8	8.6	8.1	8.4	8	8.2	8	8.1	8.4	8.4	8.2	8.8
Temperature (^{o}C)	23.9	24.5	22	22.9	2.7	0	2.5	0.3	2	5.8	3.2	9.4	14.9	13.3	13.8
Flow (cfs)						5	3	<1		35		6	5.2	1	4.3
Nitrate + nitrite as N (mg/L)	3.5	2	3.3	0.35	36	20	15	40	28	9.3	14	39	17	16	18
Ortho Phosphate as P (mg/L)	1.7	0.8	0.33	2.1	4.1	7.6	3.8	8	6.2	1.6	0.74	2.9	2.7	2.4	2.8
Total BOD (5 day) (mg/L)	4	14	1.9	14	1.9			4	<2	14	<2	<2	3	<2	<2
Total Dissolved Solids (mg/L)	2,300	820	450	3,870	2,320	3,600	1,300	2,500	1,800	570	520	920	1,000	980	1,100
Total Kjeldahl Nitrogen as N (mg/L)	2.1	3.9	0.6	4.9	0.2	3.3	1.1	1.4	1.7	2.7	0.6	1.1	1	1.1	1
Total Organic Carbon (mg/L)	11	26	4.6	19	7.9	22	5.2	13	7.1	19	2.9	4.4	5.2	4.1	4.2
Total Phosphate as P (mg/L)	1.9	1.9	0.36	2.7	5.5	6.5	3.7	7.3	6	2.1	0.76	3.1	2.9	2.6	2.8
Total Suspended Solids (mg/L)	8	490	6	48	7	29	8	7	8	180	11	9	19	12	6
Total Volatile Suspended Solids (mg/L)	4	60	2	28	3	21	4	5	3	29	2	3	5	3	2
Turbidity (NTU)	9.1	600	4.3	28	6	15	6	4.7	6.6	110	6.4	5.4	7.1	3.3	2.6

Table B-4. (continued)

Date	5/14/07	5/17/07	5/31/07	6/14/07	6/28/07	7/12/07	7/24/07	7/26/07	8/8/07	8/15/07	8/23/07	9/6/07	9/20/07	10/4/07	10/18/07
Ammonia Nitrogen as N (mg/L)	0.11	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	0.64	< 0.05	< 0.05	0.11	< 0.05	< 0.05	< 0.05	< 0.05	0.2
Carbonaceous BOD (5 day) (mg/L)															
Chloride(mg/L)	470	560	570	540	540	53	800	840	760	220	18	340	35	340	150
Chlorophyll a (water) (µg/L)	19	7	9	6	4	4	5	4	55	14	<1	16	7	5	12
Dissolved Inorganic Carbon (mg/L)	78	74	62	70	69	77	77	78	76	41	60	70	76	72	57
Dissolved Organic Carbon (mg/L)	5.5	5.2	7.7	5	4.7	3.6	5.7	5.1	8.4	7.9	1.9	4	3.2	4.5	6.8
Dissolved Oxygen (mg/L)	10.3	11.2	8.5	9.7	10.3	9.6	9.2	9	9.4		9.5	10.3	10.5	10	7.5
E. coli (#/100mL)	480	340	25,000	1,200	2,100	5,200	120,000	3,700	33,000	55,000	980	380	3,800	2,100	58,000
pH	8.5	8.2	8	8.5	8.3	8.6	8.5	8.3	8.6		8	8.4	8.3	8.2	7.9
Temperature (^{o}C)	18.3	14.2	18.9	21.5	20	20.2	21.6	23.9	23.1		19.1	20.4	15.8	15.4	15.3
Flow (cfs)	2.8	0.8	4	4	2	1	2.2	1.9	6		29	8	2	6	12
Nitrate + nitrite as N (mg/L)	16	25	17	25	22	5.6	33	31	16	9.5	8.9	21	4.4	19	8.1
Ortho Phosphate as P (mg/L)	3.6	4.4	3.4	4.1	3.9	1.3	6.6	8.9	3.2	1.8	0.17	2.2	0.42	2.8	1.4
Total BOD (5 day) (mg/L)	3	<2	<2	<2	<2	<2	4	<2	12	11	<2	<2	<2	<2	7
Total Dissolved Solids (mg/L)	1,300	1,500	1,400	1,400	1,400	500	1,900	2,000	1,700	750	380	1,000	450	1,000	580
Total Kjeldahl Nitrogen as N (mg/L)	1.3	1.4	1.3	0.8	0.8	0.6	1.7	1.1	1.5	3.3	0.7	0.8	0.6	0.9	1.7
Total Organic Carbon (mg/L)	6.1	5.6	8.1	7.3	5.3	5.3	8.9	7.2	11	33	5.1	4.2	3.6	5.1	9.2
Total Phosphate as P (mg/L)	3.5	4.5	3.6	3.8	3.9	1.3	6.7	2.4	3.9	3.6	0.59	2	0.4	2.8	1.6
Total Suspended Solids (mg/L)	7	4	15	29	6	2	11	7	28	670	45	3	3	5	69
Total Volatile Suspended Solids (mg/L)	2	2	3	5	1	1	3	3	13	74	5	2	1	2	13
Turbidity (NTU)	3.1	2.9	16	13	6	4.4	8.2	7.4	18	300	21	2.3	2.6	3.5	48

Table B-4. (continued)

Date	11/1/07	12/6/07	1/10/08	2/7/08	3/12/08	3/27/08	4/10/08	4/24/08	5/7/08	5/22/08	6/5/08	6/19/08
Ammonia Nitrogen as N (mg/L)	< 0.05	< 0.05	< 0.05	0.18	2	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	0.3	< 0.05
Carbonaceous BOD (5 day) (mg/L)												
Chloride(mg/L)	740	770	600	530	520	200	280	40	160	240	85	130
Chlorophyll a (water) (µg/L)	2	5	3	<1	2	2	6	41	10	19	30	2
Dissolved Inorganic Carbon (mg/L)	69	88	85	76	52	65	72	16	62	88	46	67
Dissolved Organic Carbon (mg/L)	4.3	4.1	4.2	4.9	15	3	2.9	8	4.2	4	8.2	2.6
Dissolved Oxygen (mg/L)	14.1	15.3	13.2	17.1	10.7	13.2	11.7	11	11.8	15.2	8.7	9.9
E. coli (#/100mL)	220	110	210	800	700	250	650	32,000	7,200	320	260,000	400
pH	8.2	7.7	8.2	7.8	8.2	8.5	8.8	8.3	8.5	8	8.5	8.6
Temperature (^{o}C)	8.1	0.1	3.1	0.5	3.1	4.3	4.7	10.9	14.2	13.2	16.8	14.9
Flow (cfs)	3		4	2	3	10	3	72	10	3	19	7
Nitrate + nitrite as N (mg/L)	28	36	26	21	19	9.6	14	4	8.8	16	8.4	13
Ortho Phosphate as P (mg/L)	4.6	7.3	6.3	4.8	4.1	1.2	2	0.43	1.2	2	0.84	1.1
Total BOD (5 day) (mg/L)	<2	<2	<2	4	14	<2	<2	11	<2	<2	10	<2
Total Dissolved Solids (mg/L)	1,400	1,900	1,600	1,400	1,300	680	880	270	610	840	470	620
Total Kjeldahl Nitrogen as N (mg/L)	1	1	0.8	1.1	4.7	0.7	0.8	6.1	1	1.1	3	0.4
Total Organic Carbon (mg/L)	6.1	5.2	4.5	5.7	16	4.1	4	50	4.9	4.7	24	3.2
Total Phosphate as P (mg/L)	4.6	6.9	4.9	4.5	4.4	1.3	2	2	1.3	2.1	1.5	1.2
Total Suspended Solids (mg/L)	4	2	5	3	13	17	24	1200	34	5	280	5
Total Volatile Suspended Solids (mg/L)	2	1	2	2	6	4	5	130	8	2	54	2
Turbidity (NTU)	3.7	2.5	4.7	4.5	13	11	13	590	24	3.3	190	3.7

Table B-5. Stressor co-occurrence and response considerations for candidate causes in Hecker Creek. *(*abbreviations: IR; Interquartile Range; NA, data indicator and/or stressor threshold not available; ?, uncertain or unknown; Qual., based upon qualitative evaluation only)*

Stressor Co-occurrence & Response						
Stressor	Indicator	Concentration or level at unimpaired sites in other waterbodies*	Concentration or level at impaired site(s) in the watershed	RASCAL and aerial photo assessment	Consistent with Stressor Co-occurrence	Consistent with Stressor Response
Altered Flow Regime (Conceptual Model 1)						
Increased max. flow	NA	NA	NA	NA	?	?
Increased frequency of low flows	NA	NA	NA	NA	?	?
Increased magnitude of low flows	Flow: Contribution area ratio	0.11-0.49 IR for statewide 1^{st} & 2nd order monitoring sites (n=100)	4.57 (n=9)	Sinkhole removes ~ 13-15 % of flow from stream	No	No
Altered daily or seasonal flow patterns	NA	NA	NA	NA	?	?
Altered Substrate (Conceptual Model 2)						
Increased suspended sediment (abrasive to soft tissue)	TSS (mg/L)	<u>Base flow</u> 6.75-24.25 IR for regional reference sites (n=14)	<u>Non-Event (Median)</u> 2005 54 (n=10) 2006 7 (n=14) 2007 9 (n=12)	Silt/mud is dominant substrate along 9.5% of channel	No	No
		<u>Event</u> 80-360 IR for statewide sites (n=757)	<u>Event (n=6)</u> Median= 845 468-1200 IR	NA	Yes	Yes
Decreased clarity (reduced feeding efficiency)	Turbidity (NTU)	<u>Base flow</u> 3.6-14.75 IR for regional reference sites (n=14)	<u>Non-Event (Median)</u> 2004 9.2 (n=11) 2005 38 (n=10) 2006 5.4 (n=14) 2007 7.8 (n=12)	NA	No	No
		<u>Event</u> 47-240 IR for statewide sites (n=604)	<u>Event (n=6)t</u> Median= 305 290-418 IR	NA	Yes	Yes
Decrease in benthic algae or macrophytes as a substrate for organisms	Periphyton Chl. A (ug/cm^2)	16.6 (7.9-19.9) median (IR) for 52b random sites (n=16)	44.5 (n=2)	NA	No	No
	Sediment Chl. A (ug/cm^2)	6.7 (3.6-11.6) median (IR) for 52b random sites (n=16)	17.5 (n=2)	NA	No	No
	% Total fines	12.5-55.2 IR (n=7) for regional reference sites	2000 14 (n=1) 2006 0 (n=1) 2007 15 (n=1)	NA	No	No
	% Silt	8.5-29.7 IR (n=7) for regional reference sites	2000 8 (n=1) 2006 0 (n=1) 2007 15 (n=1)	NA	No	No
	% Sand	4-18.5 IR (n=7) for regional reference sites	2000 0 (n=1) 2006 0 (n=1) 2007 0 (n=1)	NA	No	No

Stressor	Indicator	Concentration or level at unimpaired sites in other waterbodies*	Concentration or level at impaired site(s) in the watershed	RASCAL and aerial photo assessment	Consistent with Stressor Co-occurrence	Consistent with Stressor Response
Altered Substrate (Conceptual Model 2) (cont.)						
Increased deposited fine sediment	Sediment Deposition	RBP Qualitative Rating (poor >80% sediment deposition)		Silt/mud substrate on 9.5% of channel; 30.3% of cobble mostly embedded	?	?
	% Reach area as pool habitat	30.35-46.43 IR for regional reference sites (n=7)	2000 21.4 (n=1) 2006 8.9 (n=1) 2007 14.3 (n=1)	31.3% of channel length had no pools 45.4% had <1pool/250 ft	Yes	Yes
Embedded riffles	Embeddedness rating (coarse substrate area embedded by fine sediment)	1.93-2.43 IR for regional reference sites (n=7)	2000 1.67 (n=1) 2006 2.67 (n=1) 2007 3 (n=1)	NA	Yes	Yes
			Benthic Mac. Sampling embeddedness observations: 2000: <25% 2006: 25-50% 2007: 51-75%	42.1% dominated by cobble 30.3% of cobble mostly embedded	Yes	Yes
Altered Basal Food Source (Conceptual Model 3)						
Increased / altered primary producers	Seston Chl. A (ug/L)	6.5 (3.9-19.8) median (IR) for 52b random sites (n=16) 8.08 (2.7-9.1) median (IR) for 52b REMAP sites (n=30)	Median (IR) 2006 32 (16.5-60.5) (n=7) 2007 6 (4-14.5) (n=12)	NA	No	No
	Periphyton Chl. A (ug/cm^2)	16.6 (7.9-19.9) median (IR) for 52b random sites (n=16) 14.95 (6.6-19.6) median (IR) for 52b REMAP sites (n=30)	44.5 (n=2) 2000: non-filamentous algae on 25-50% of substrate 2006: filamentous algae on 51-75% of substrate 2007: filamentous algae on 25-50% of substrate	NA	Yes	?
	Sediment Chl. A (ug/cm^2)	6.7 (3.6-11.6) median (IR) for 52b random sites (n=16) 7.9 (2.7-10.8) median (IR) for 52b REMAP sites (n=30)	17.5 (n=2)	NA	Yes	?
	Respiration (g O_2/m^2/d)	6.0 (4.8-6.7) median (IR) for 52b random sites (n=13)	2007 5.27 May (n=13d)	NA	No	No
	Gross primary production (GPP) (g O_2/m^2/d)	3.5 (2.6-4.4) median (IR) for 52b random sites (n=13)	2007 4.52 May (n=13d)	NA	Yes	No
	Production-to-respiration ratio (P:R)	0.57 (0.47-0.99) median (IR) for 52b random sites (n=13)	2007 0.87 May (n=13d)	NA	No	No

Stressor	Indicator	Concentration or level at unimpaired sites in other waterbodies*	Concentration or level at impaired site(s) in the watershed	RASCAL and aerial photo assessment	Consistent with Stressor Co-occurrence	Consistent with Stressor Response
Altered Basal Food Source (Conceptual Model 3) (cont.)						
Decreased allochthonous food resources	Very Minimal Leaf Litter, Detritus, Small Woody Debris	NA		70.9% channel has <25% canopy coverage 59.2% <10% coverage	?	?
	Instream Cover – Small Brush – Avg. %	(1.75-2.75) IR for regional reference sites (n=5)	2006 8.25 (n=1) 2007 4 (n=1)	NA	No	No
	Avg. wood debris % occurrence – (old method)	(8.9-19.7) IR for regional reference sites (n=7)	2000 0 (n=1)	NA	Yes	?
	Instream Cover – Woody Debris – Avg. % - (new method)	(0.5-1.25) IR for regional reference sites (n=7)	2006 0 (n=1) 2007 0 (n=1)	20% of stream has trees on one side or other	Yes	?
Decreased Dissolved Oxygen (Conceptual Model 4)						
Decreased dissolved oxygen	Range of DO (mg/L) levels from daytime grab samples	8.65-9.63 IR for regional reference sites (n=14)	Non-Event 2004 9.1 (n=11) 2005 3.2 (n=10) 2006 6.1 (n=13) 2007 3 (n=10)	NA	No	No
	Minimum DO (mg/L) from daytime grab samples	6.8 minimum for regional reference sites (n=14)	2004 1.1 (n=11) 2005 3.7 (n=10) 2006 6 (n=13) 2007 7.5 (n=10)	NA	No	No
	Minimum DO (mg/L) from datalogger		2007 7.0 (May)	NA	No	No
	Meeting water quality standards designed to protect aquatic life	≥ 5.0 mg/L at least 16h/day	no violations	NA	No	No
		Minimum value ≤4.0 mg/L	10/28/04 1.1 6/30/05 3.9 7/21/05 3.7 9/22/05 3.8	NA	No	No
Increased Temperature (Conceptual Model 5)						
Increased temperature	Mean temp. (deg. C) from grab samples	13.88-18.73 IR for regional reference sites (n=14)	2004 17.8 (n=10) 2005 20.3 (n=7) 2006 23.3 (n=4) 2007 21.1 (n=6)	NA	No	No
	Maximum temp. (deg. C) from grab samples	19.9 maximum for regional reference sites (n=14)	2004 21.1 (n=10) 2005 23.2 (n=7) 2006 24.5 (n=4) 2007 23.9 (n=6)	NA	No	No
	Diurnal mean temp. (deg. C)	18.6 (16.8-23.1) median (IR) for 52b random sites (n=13)	Median (IR) 15.7 (13.45-18.22) (4/29-5/14/07)	NA	No	No
	Diurnal maximum temp. (deg. C)	22.7 (20.8-28.1) median (IR) for 52b random sites (n=13)	22.66 (4/29-5/14/07)	NA	No	No
	Diurnal minimum temp. (deg. C)	14.8 (12.3-19.5) median (IR) for 52b random sites (n=13)	10.47 (4/29-5/14/07)	70.9% of channel has <25% canopy coverage 59.2% of channel <10% coverage	No	No

Stressor	Indicator	Concentration or level at unimpaired sites in other waterbodies*	Concentration or level at impaired site(s) in the watershed	RASCAL and aerial photo assessment	Consistent with Stressor Co-occurrence	Consistent with Stressor Response
Increased Ammonia (Conceptual Model 6)						
Increased ammonia	Mean total ammonia	0.05-0.10 IR for regional reference sites (n=7)	2004 0.04 (n=10) 2005 0.32 (n=10) 2006 0.12 (n=15) 2007 0.10 (n=12)	NA	Yes	?
	Unionized ammonia exceeds WQ stds.	(Variable criterion depending on pH and temp.)	1 chronic violation (n=45) 0 acute (n=45)	NA	Yes	?
Physical Habitat Alteration (Conceptual Model 7)						
Decreased macro-habitat complexity	% (type) dominant channel bedform unit	IRs for regional references (n=7) 14-26.8 (Riffle) 26.8-57 (Run) 30.4-46.4 (Pool)	riffle/run/pool 2000 (n=1) (42.9/35.7/21.4) 2006 (n=1) (35.7/55.4/8.9) 2007 (n=1) (35.7/50/14.3)	29.4% (Riffle 49.6% (Run) 31.3% of channel length had no pools 45.4% had <1 pool per 250ft	Yes	Yes
	RBP - lacking variation in current velocity & depth	NA		49.6% of channel "run"; 76.7% had no pool or <1 pool per 250ft	Yes	No
	Width: Thalweg Depth Ratio	10.75-24.27 IR for regional reference sites (n=7)	2000 21.9 (n=1) 2006 24.4 (n=1) 2007 22.1 (n=1)	NA	No	No
	S.D. mean depth	0.65-0.76 IR for regional reference sites (n=7)	2000 0.27 (n=1) 2006 0.21 (n=1) 2007 0.21 (n=1)	NA	Yes	?
	% Instream cover (DNR method)	4-18 IR for regional reference sites (n=7)	2006 0 (n=1) 2007 0 (n=1)	2% channel poor habitat rating 76.7% had no pool or <1 pool per 250ft	Yes	Yes
Decreased micro-habitat complexity	Very Minimal Leaf Litter, Detritus, Small Woody Debris	see CM 3		70.9% channel has <25% canopy coverage 59.2% <10% coverage	?	?
	% Occurrence large woody debris (DNR method)	7.1-21.4 IR for regional reference sites (n=7)	2000 0 (n=1)	20% of stream has trees on at least one side;	Yes	?
	% Instream cover (DNR method)	4-18 IR for regional reference sites (n=7)	2006 0 (n=1) 2007 0 (n=1)	2% channel poor habitat rating 76.7% had no pool or <1 pool per 250ft	Yes	Yes
	Instream Cover – Small Brush – Avg. %	(1.75-2.75) IR for regional reference sites (n=5)	2006 8.25 (n=1) 2007 4 (n=1)	NA	No	No
	Avg. wood debris % occurrence – (old method)	(8.9-19.7) IR for regional reference sites (n=7)	2000 0 (n=1)	NA	Yes	?
	Instream Cover – Woody Debris – Avg. % - (new method)	(0.5-1.25) IR for regional reference sites (n=7)	2006 0 (n=1) 2007 0 (n=1)	LWD noted on in debris jams elsewhere in the stream	Yes	?

Stressor	Indicator	Concentration or level at unimpaired sites in other waterbodies*	Concentration or level at impaired site(s) in the watershed	RASCAL and aerial photo assessment	Consistent with Stressor Co-occurrence	Consistent with Stressor Response
Aquatic Life Depletion and Isolation (Conceptual Model 8)						
Disease	%DELT	0.05 for regional reference sites	2000=0 2006=0 2007= 2.9	NA	No	No
Chloride**	Mean chloride	EPA threshold values: chronic = 230mg/L acute= 860mg/L	2004 n=12 574.42 IR (36-915) 2005 n=10 1265.4 IR (125-2250) 2006 n=14 552.07 IR (53-1015) 2007 n=12 376.33 IR (125.75-595)	Exceedences all data 2004-2008 (n=97): Acute: > 860 mg/L = 24 Chronic (230): > 230 mg/L = 63	Yes	Yes
TDS	Mean TDS	325-375 IR for regional reference sites (n=7)	2005 n=10 2576 IR (572.5-4405) 2006 n=14 1302.9 IR (452.5-2148) 2007 n=12 1063.3 IR (560-1475)	NA	Yes	Yes
	Threshold value	EPA threshold value = 1000mg/L	43 exceedences all data (2005-2008) n=78:	NA	Yes	Yes

****** Values from draft Iowa WQ standard for Chloride using Hardness = 350 mg/L (measured in 2000) and Sulfate = 63 mg/L (state default value) would be: Acute = 706 mg/L and Chronic = 436 mg/L

Table B-6. FIBI metrics calculated from the 2000, 2006, and 2007 biological samples collected from the Hecker Creek watershed and the local comparison site.

	Hecker			comparison site		
Hecker	**2000**	**2006**	**2007**	**2006**	**2007**	**52b ref**
FIBI:	16	54	30	63	36	52
Native Spp:	3.00	13	8	10	8	12.5
NativeSppMetric1	2.72	10	7.26	5.663	4.53	5.9
Sucker Spp:	0	0	1	1	1	1.5
SuckerSppMetric2	0	0	4.64	2.896	2.896	3.7
Sensitive Spp:	1.00	3	2	3	2	2.5
SensitiveSppMetric3	2.65	7.95	5.3	4.959	3.306	4.1
BINV Spp:	1.00	4	2	3	2	2.5
BINVSppMetric4	2.52	10	5.04	4.72	3.147	4
% Top 3 Abundant:	97.37	76.226	65.71	65.6	82.02	76
PctTop3AbundMetric5	1.02	9.22	2.5	8.326	4.351	5.6
% Benthic Invert:	73.68	3.396	8.571	57.33	73.03	19.1
PctBINVMetric6	2.50	2.16	2.5	10	5	5.1
% Omnivore:	0.00	13.962	8.571	7.733	7.865	19.7
PctOmnivoreMetric7	2.50	10	2.5	10	5	8
% Top Carnivore:	0.00	0	0	2.667	1.124	0
PctTopCarnivoreMetric8	0.00	0	0	10	5	0
% Litho Spawner:	0.00	0.755	2.857	0	0	0.1
PctLithoSpawnerMetric9	0.00	0.95	2.5	0	0	0
Tolerance Index:	1.45	6.075	6.286	5.333	5	5.4
TolIndexMetric10	2.50	6.229	2.5	7.407	5	7.3
Adjusted CPUE:	6.85	30.435	3.448	49.77	12.31	52.8
AdjCPUEMetric11	0.69	3.043	0.345	4.977	1.231	5.3
% DELT:	0.00	0	2.857	0	0	0.05
DELTAdj	0.00	0	-2.5	0	0	
Reach Size:	540	644	609	641	650	
Fish Per 500 ft:	35	206	29	293	68	
Total Spp:	4.00	14	8	11	9	
Total Excluded Spp:	0.00	0	0	0	0	
Total Exotics Spp:	0.00	0	0	1	1	
Total LMB-BG:	1.00	1	0	0	0	
Major Drainage:	MSP	MSP	MSP	MSP	MSP	
Total Fish:	38.00	265	35	375	89	
Drainage Area:	4.58	4.58	4.58	11.465	11.465	
Log Drainage Area:	0.661	0.661	0.661	1.059	1.059	

Table B-7. BMIBI metrics calculated from the 2000, 2006, and 2007 biological samples collected from the Hecker Creek watershed and the local comparison site.

	Hecker			comparison site		
Hecker	**2000**	**2006**	**2007**	**2006**	**2007**	**52b ref**
BMIBI:	53.00	61.00	70.00	53.00	70	61
MH-Total Number of Taxa:	20.00	26.00	32.00	28.00	38	36
txtMetric1	7.59	9.87	10.00	8.00	10	7.3
SH-Total Number of Taxa:	9.00	9.00	11.67	8.67	10.67	13
txtMetric2	9.00	9.00	10.00	6.37	7.83	6
MH- Number of EPT Taxa:	2.00	10.00	9.00	9.00	13	11
txtMetric3	1.59	7.96	7.16	5.45	7.87	5.5
SH- Number of EPT Taxa:	5.33	5.00	7.33	3.67	4.33	6.8
txtMetric4	8.06	7.56	10.00	4.01	4.73	6.8
MH- Number of Sensitive Taxa:	1.00	2.00	4.00	3.00	4	5
txtMetric5	1.82	3.65	7.3	4.09	5.45	4.9
SH- % Ephemeroptera Taxa:	0.99	0.00	0.98	20.20	37.69	11
txtMetric6	0.13	0.00	0.13	2.58	4.82	1.4
SH- % EPT Taxa:	57.24	60.62	35.83	38.14	51.39	53.9
txtMetric7	5.99	6.35	3.75	3.99	5.38	5.6
SH- % Chironomidae Taxa:	13.61	9.06	11.78	39.13	9.76	24.1
txtMetric8	8.73	9.19	8.91	6.15	9.12	7.7
SH- % Scraper Organisms:	0.33	7.95	52.23	7.81	13.49	5.9
txtMetric9	0.07	1.78	10.00	1.75	3.02	1.3
SH- % 3 Dominant Taxa:	70.06	69.56	77.73	73.66	74.39	64.9
txtMetric10	10.00	10.00	8.66	6.89	6.7	6.3
SH- % Dominant FFG:	83.78	77.86	63.82	59.33	48.41	66.7
txtMetric11	2.70	3.69	6.03	6.78	8.6	5.6
SH- Modified Hilsenhoff Biotic Index:	4.94	5.76	6.37	4.84	3.97	5
txtMetric12	7.63	4.59	2.33	8.00	10	7.5
chkValidSample	TRUE	TRUE	TRUE	TRUE	TRUE	
Log Drainage Area:	0.661	0.661	0.661	10.59	1.05937	
Drainage Area:	4.58	4.58	4.58	11.46	11.4649	

Table B-8. Fish collected in Hecker Creek in 2000, 2006, and 2007.

sample date	**2000**	**2006**	**2007**
bluntnose minnow *Pimephales notatus*		37	
common shiner *Luxilus cornutus*		36	4
bigmouth shiner *Notropis dorsalis*	1	1	
creek chub *Semotilus atromaculatus*		30	14
southern redbelly dace *Phoxinus erythrogaster*		3	
central stone roller *Campostoma anomalum*		129	5
blacknose dace *Phoxinus cumberlandensis*	7	12	3
hornyhead chub *Nocomis biguttatus*		4	3
suckermouth minnow *Phenacobius mirabilis*		2	1
Johnny darter *Etheostoma nigrum*		1	
white sucker *Catostomus commersoni*			3
green sunfish *Lepomis cyanellus*		1	
longnose dace *Rhinichthys cataractae*	28	5	2
largemouth bass *Micropterus salmoides*	2	3	
fantail darter *Etheostoma flabellare*		1	
Total	**38**	**265**	**35**

Table B-9. Benthic macroinvertebrates collected in Hecker Creek in 2000, 2006, and 2007. For rapid benthic invertebrate sampling: U = uncommon, R = rare, C = common.

Phylum: Class	Order	Family	FinalID	2000	2000 rapid	2006	2007
Arthropoda: Insecta	Coleoptera	Dryopidae	Helichus striatus				1
		Dytiscidae	Agabus	1			
			Copelatus chevrolati chevrola	1			
			Copelatus glyphicus	1			
			Dytiscidae		R		
			Heterosternuta wickhami			2	1
			Hydrovatus pustulatus	1			
			Ilybius biguttulus			1	
			Laccophilus			2	
			Laccophilus fasciatus			2	
			Laccophilus maculosus			1	1
			Platambus semivittatus			2	
		Elmidae	Optioservus	1			
		Hydrophilidae	Hydrophilidae		R		
			Anacaena lutescens				3
			Laccobius reflexipenis				1
			Paracymus	2			
			Tropisternus	1			
			Tropisternus lateralis				1
	Diptera	Ceratopogonidae	Bezzia/Palpomyia			1	
		Chironomidae	Chironomidae	56	U	27	38
		Empididae	Hemerodromia			3	
		Limoniidae	Antocha				1
			Hexatoma			1	
		Simuliidae	Simuliidae			9	
			Simulium	110	C	70	9
		Tabanidae	Chrysops				2
		Tipulidae	Dicranota				1
			Tipula	1	R		2
	Ephemeroptera	Baetidae	Baetis flavistriga				3
			Baetis intercalaris	1			
			Baetis tricaudatus				1
			Callibaetis fluctuans			3	
		Caenidae	Caenis latipennis			12	1
		Leptohyphidae	Tricorythodes	2			

Table B-9. (Continued)

Phylum: Class	Order	Family	FinalID	2000	2000 rapid	2006	2007
Arthropoda: Insecta cont.	Hemiptera	Belostomatidae	Belostomatidae				3
			Belostoma flumineum			1	
		Gerridae	Aquarius				1
			Trepobates				1
		Saldidae	Saldidae	1	R		
	Lepidoptera	Crambidae	Crambus	1			
	Megaloptera	Sialidae	Sialis			1	
	Odonata	Aeshnidae	Aeshnidae			1	
			Boyeria vinosa				2
		Coenagrionidae	Coenagrionidae		R		1
			Coenagrion/Enallagma	3		5	
	Trichoptera	Brachycentridae	Brachycentrus occidentalis				4
		Helicopsychidae	Helicopsyche borealis				16
		Hydropsychidae	Hydropsychidae	6	U	10	3
			Ceratopsyche alhedra	65		2	
			Ceratopsyche bronta			12	18
			Ceratopsyche morosa	4		5	
			Ceratopsyche slossonae	16		19	6
			Cheumatopsyche	66		49	73
			Hydropsyche betteni	13		111	3
			Hydropsyche dicantha				17
			Hydropsyche placoda				1
		Hydroptilidae	Hydroptila			11	6
			Hydroptilidae			6	1
		Leptoceridae	Oecetis disjuncta				1
		Polycentropodidae	Polycentropus			1	
Arthropoda: Arachnida	Trombidiformes	Hydrachnidae	Hydracarina	1			
			Hydrachnida				1
Arthropoda : Crustacea	Amphipoda	Talitridae	Hyalella	9	U	6	17
	Decapoda	Cambaridae	Cambaridae				2
Annelida: Oligochaeta			Oligochaeta	3			4

Table B-9. (Continued)

Phylum: Class	Order	Family	FinalID	2000	2000 rapid	2006	2007
Annelida: Hirudinea	Arhynchobdellida	Erpobdellidae	Erpobdellidae		R		
			Erpobdella punctata punctata	2			
			Mooreobdella microstoma	1		3	1
	Rhynchobdellida	Glossiphoniidae	Glossiphoniidae		U		
			Glossiphonia complanata	1			5
			Helobdella stagnalis	5			1
			Helobdella triserialis			2	
Mollusca: Gastropoda	Basommatophora	Physidae	Physa			29	160
			Physidae	18	U		
Platyhelminthes: Turbellaria	Tricladida	Dugesiidae	Girardia			1	5

Table B-10. Instream habitat assessments for Hecker Creek and the local Yellow River watershed reference site compared to ecoregion 52b reference data.

		Hecker Creek			Local reference		Ecoregion 52b reference data	
		2000	2006	2007	2006	2007		
HabParamID	Hab LocID	Hab Value	Hab Value	Hab Value	Hab Value	Hab Value	25th percentile	75th percentile
Reach - Total Habitat Reach Length		486	594	594	594	594	468	810
Transect Depth - Average		0.37	0.32	0.36	0.73	0.78	0.73	1.35
Transect Depth - Standard Deviation		0.27	0.21	0.21	0.56	0.61	0.645	0.76
Stream Width - Average		13.6	13.8	13.75	13.9	14.08	16.58	40.375
Thalweg Depth - Average		0.622	0.5661	0.6232	1.1946	1.1679	1.4441	2.3025
Width - Thalweg Depth Ratio		21.9	24.4	22.1	11.6	12.1	10.75	24.267
Substrate - Percent Clay		6	0	0	0	0	0	7
Substrate - Percent Silt		8	0	15	22	19	8.5	29.667
Substrate - Percent Sand		0	0	0	0	2	4	18.5
Substrate - Percent Soil		0	0	0	0	0	0	0
Substrate - Percent Gravel		34	58	58	22	28	25.5	39
Substrate - Percent Cobble		34	30	8	40	44	26	36
Substrate - Percent Boulder		18	10	19	6	5	1.3333	7.5
Substrate - Percent Rip-Rap		0	0	0	2	2	0	0
Substrate - Percent Detritus/Muck		0	0	0	0	0	0	2
Substrate - Percent Wood		0	2	0	6	0	0	0
Substrate - Percent Bedrock		0	0	0	0	0	0	0.5
Substrate - Percent Other		0	0	0	2	0	0	1
Macrohabitat - Percent Riffle		42.9	35.7	35.7	14.3	32.1	14.05	26.767
Macrohabitat - Percent Run		35.7	55.4	50	35.7	19.6	26.8	57.15
Macrohabitat - Percent Pool		21.4	8.9	14.3	50	48.2	30.35	46.433
Reach - Percent Soft Sediment			0	14.3	17.9	7.1		
Streambank - Percent Bare	Left Bank	59	38.5	47	41.5	37.5	28.75	39.5
Streambank - Percent Bare	Right Bank	72	42.5	39.5	32	45	30.5	51.75
Streambank Angle - Percent Horizontal (0-15 degrees)	Left Bank	20	10	30	60	20	20	50
Streambank Angle - Percent Horizontal (0-15 degrees)	Right Bank	0	40	30	40	30	20	45
Streambank Angle - Percent Moderate (20-50 degrees)	Left Bank	60	90	50	20	70	40	60
Streambank Angle - Percent Moderate (20-50 degrees)	Right Bank	30	50	60	40	60	35	60
Streambank Angle - Percent Vertical (55-110 degrees)	Left Bank	20	0	20	20	10	10	15
Streambank Angle - Percent Vertical (55-110 degrees)	Right Bank	70	10	10	20	10	10	23.333
Streambank Angle - Percent Undercut (115-180 degrees)	Left Bank	0	0	0	0	0	0	0
Streambank Angle - Percent Undercut (115-180 degrees)	Right Bank	0	0	0	0	0	0	0
Canopy - Average Percent of Channel Shaded		91.62	78.02	79.28	70.54	73.06	26.94	39.46

Table B-10. (continued)

		Hecker Creek			Local reference		Ecoregion 52b reference data	
		2000	2006	2007	2006	2007		
HabParamID	Hab LocID	Hab Value	Hab Value	Hab Value	Hab Value	Hab Value	25th percentile	75th percentile
Canopy - Standard Deviation - Percent of Channel Shaded		13.09	28.55	25.98	32.04	30.3	26.853	34.115
Canopy - Transect Maximum Percent of Channel Shaded		100	100	100	98.2	99.1	56.76	79.583
Canopy - Transect Minimum Percent of Channel Shaded		61.26	32.43	45.05	29.73	21.62	2.7	9.31
Coarse Rock Embededness - Average		1.6667	2.6667	3	1.6	1.6667	1.9286	2.425
Instream Cover - Filamentous Algae - Average Percent			12.75	1	37.5	2	0.555	7.25
Instream Cover - Macrophytes - Average Percent			0	0	0	0	0	2.75
Instream Cover - Woody Debris - Average Percent		0	0	0	3	3	0.25	1.5
Instream Cover - Small Brush - Average Percent			8.25	4	8	5.5	1.25	3.25
Instream Cover - Trees/Roots - Average Percent			1	0.5	1.5	3.5	0.25	2.5
Instream Cover - Overhanging Vegetation - Average Percent			0	3	5.5	10.5	3.25	13.625
Instream Cover - Undercut Banks - Average Percent			0	1	3	3	0	2.5
Instream Cover - Boulders - Average Percent			9	23.25	11.75	2.5	1	8.75
Instream Cover - Artificial Structure - Average Percent			0	0	0.5	2.5	0	0
Instream Cover - Depth/Pool - Average Percent - IDNR Method			0	0	2.5	6.25	1	5.875
Fish Cover - Total Proportional Areal Cover - IDNR Method			31	32.75	73.25	38.75	19.125	34.18
Fish Cover - Total Proportional Areal Cover - EPA Method			18.25	31.75	33.25	30.5	8.25	28.125
Fish Cover - Natural Concealment Features			31	32.75	70.25	30	13.25	32.18
Fish Cover - Large Features Areal Cover - IDNR Method			19	48	31.5	17	4.5	19.5
Fish Cover - Large Features Areal Cover - EPA Method			10	24.75	19.75	14.5	3	11.75
Maximum Depth		1.3	1.2	1.5	3.2	3.4	3.8	5.5

Table B-11. Water quality data from grab samples collected during biosampling at Hecker Creek and the local Yellow River watershed comparison site in 2007.

Water quality parameter	Hecker Creek	Reference Site
NH3 nitrogen as N (mg/L)	0.64	< 0.05
Chloride (mg/L)	800	17
Chlorophyll a (µg/L)	5	1
Dissolved Inorganic Carbon (mg/L)	77	65
Dissolved Organic Carbon (mg/L)	5.7	1.1
Dissolved Oxygen (mg/L)	9.6	12.3
E. coli (# per 100mL)	120,000	200
Field pH	8.5	8.3
Field temperature (^{o}C)	21.6	15.8
Flow (cfs)	8	3.2
Nitrate+Nitrite nitrogen as N (mg/L)	33	8.5
Orthophosphate as P (mg/L)	6.6	0.03
Total Kjeldahl Nitrogen (mg/L)	1.7	0.2
Total Biological Oxygen Demand (mg/L)	1.9	< 2
Total Dissolved Solids (mg/L)	1900	370
Total organic Carbon (mg/L)	8.9	1.2
Total Phosphorus as P (mg/L)	6.7	0.03
Total Suspended Solids (mg/L)	11	< 1
Total Volatile Suspended Solids (mg/L)	3	< 1
Turbidity (NTU)	8.2	< 1

Table B-12. 2007 RASCAL in-stream assessment of Hecker Creek.

Flow at time of survey	*Stream Miles*	*% of Total*
Normal	4.47	100.0%
High	0.00	0.0%
Low	0.00	0.0%
No Flow	0.00	0.0%
Hydrologic Varaibility		
Dry Channel	0.00	0.0%
Pond	0.00	0.0%
Pool/Glide	0.94	21.0%
Riffle	1.31	29.4%
Run	2.22	49.6%
Substrate		
Bedrock	1.12	25.1%
Boulder	0.36	8.1%
Cobble	1.88	42.1%
Gravel	0.68	15.2%
Sand	0.00	0.0%
Silt/Mud	0.43	9.5%
Clay/Hard Pan	0.00	0.0%
Embeddedness		
Completely Exposed	0.26	5.9%
Partially Exposed	2.39	53.5%
Mostly Embedded	1.32	29.5%
Completely Embedded	0.04	0.8%
No Data/Does No Apply	0.46	10.2%
Pool Frequency		
None	1.40	31.3%
<1 Pool every 250'	2.03	45.4%
2-3 Pools every 250'	0.73	16.3%
> 3 Pools every 250'	0.29	6.5%
Riffle Frequency		
None	0.37	8.2%
<1 Riffle every 250'	0.99	22.1%
2-3 Riffle every 250	1.60	35.8%
>3 Riffle every 250'	1.51	33.8%
Losing Flow		
Yes	0.10	2.2%
No	4.37	97.8%

Left Riparian Zone Width	*Stream Miles*	*% of Total*
< 10 Feet	0.12	2.8%
10-30 Feet	1.01	22.6%
30-60 Feet	0.67	14.9%
> 60 Feet	2.64	59.1%
Right Riparian Zone Width		
< 10 Feet	0.28	6.3%
10-30 Feet	0.84	18.8%
30-60 Feet	0.67	15.0%
> 60 Feet	2.64	59.1%
Left Riparian Zone Cover		
Grass	0.29	6.6%
Trees	0.84	18.9%
Pasture	1.52	34.0%
CRP-Trees	1.11	24.8%
CRP-Grass	0.67	15.0%
Residential	0.00	0.0%
Commercial	0.00	0.0%
Right Riparian Zone Cover		
Grass	0.34	7.5%
Trees	0.87	19.5%
Pasture	1.37	30.7%
CRP-Trees	0.82	18.3%
CRP-Grass	1.04	23.3%
Residential	0.00	0.0%
Commercial	0.00	0.0%
Left Adjacent Land Cover		
Row Crop	2.68	60.1%
Trees	0.49	10.9%
Grass	0.00	0.0%
Pasture	0.96	21.5%
CRP	0.00	0.0%
Residential	0.00	0.0%
Commercial	0.00	0.0%
Open Feedlot	0.00	0.0%
Farmstead	0.09	2.0%
Cliff	0.00	0.0%
Other	0.21	4.8%

Table B-12. (continued).

Stream Habitat	*Stream Miles*	*% of Total*
Poor	0.09	2.0%
Average	3.87	86.6%
Excellent	0.51	11.3%
Bank Stability		
Stable	1.52	34.0%
Moderately Stable	1.78	39.8%
Moderately Unstable	0.47	10.5%
Unstable	0.66	14.7%
Artificially Stable	0.04	0.9%
Bank Height		
0 - 3'	1.63	36.6%
3 - 6'	1.99	44.4%
6 - 10'	0.74	16.6%
10 - 15'	0.08	1.7%
15' +	0.00	0.0%
Bank Erosion		
None	1.59	35.6%
Both Banks	0.11	2.5%
Alternate Banks	0.81	18.0%
Random	1.96	43.9%
Bank Material		
Rock/RipRap	0.00	0.0%
Soil/Silt	3.18	71.3%
Cobble/Gravel	0.00	0.0%
Sand	0.05	1.0%
Bank Vegetation		
None	0.38	8.4%
Overhanging Only	0.46	10.2%
Dislodged	0.05	1.2%
Partially Established	2.04	45.6%
Well Established	1.54	34.5%
Canopy Cover		
0-10%	2.65	59.2%
10-25%	0.52	11.7%
25-50%	0.46	10.3%
50-75%	0.59	13.3%
75-100%	0.25	5.5%

Right Adjacent Land Cover	*Stream Miles*	*% of Total*
Row Crop	2.02	45.2%
Trees	0.26	5.9%
Grass	0.36	8.2%
Pasture	0.35	7.8%
CRP	1.07	24.0%
Residential	0.00	0.0%
Commercial	0.00	0.0%
Open Feedlot	0.00	0.0%
Farmstead	0.31	6.8%
Cliff	0.00	0.0%
Other	0.06	1.5%
Right Livestock Access		
Yes	1.44	32.3%
No	3.02	67.7%
Left Livestock Access		
Yes	1.73	38.6%
No	2.74	61.4%
Channel Pattern		
Straight	0.59	13.3%
Meandering	3.69	82.5%
Braided	0.00	0.0%
Channel Condition		
Altered Channel	0.00	0.0%
Natural Channel	4.44	99.3%
Past Channel Alteration	0.00	0.0%
Recent Alteration	0.00	0.0%
Channel Vegetation		
None	0.60	13.4%
Isolated Pockets	3.48	77.8%
Well Established	0.39	8.8%
Sediment Deposition		
None	2.97	66.5%
Isolated Sediment Bar	1.44	32.2%
Unvegetated Point Bar	0.00	0.0%
Vegetated Point Bar	0.06	1.3%

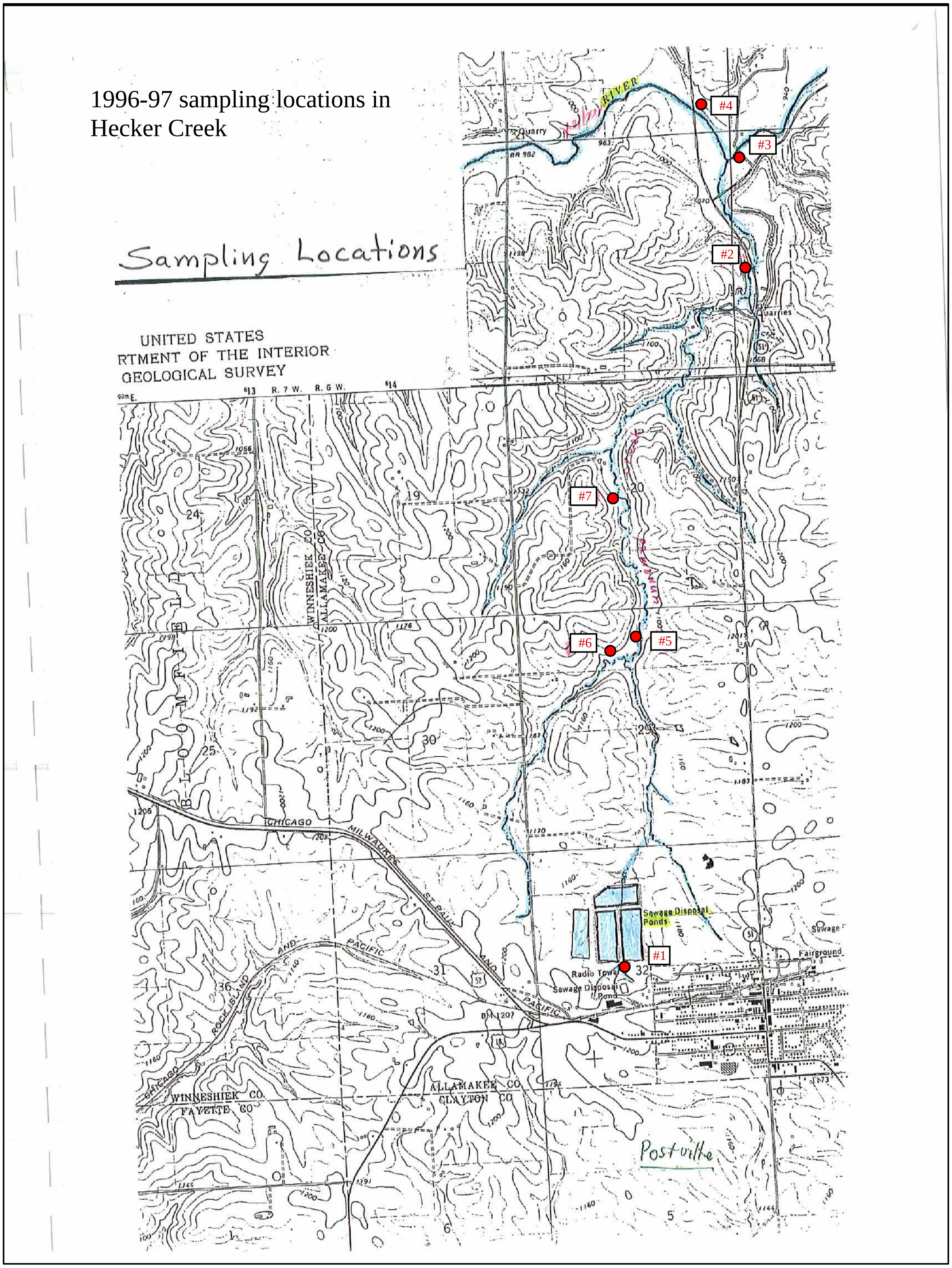


Figure B.1. Sampling locations of 1996-1997 Fox Engineering Associates, Inc. surveys.

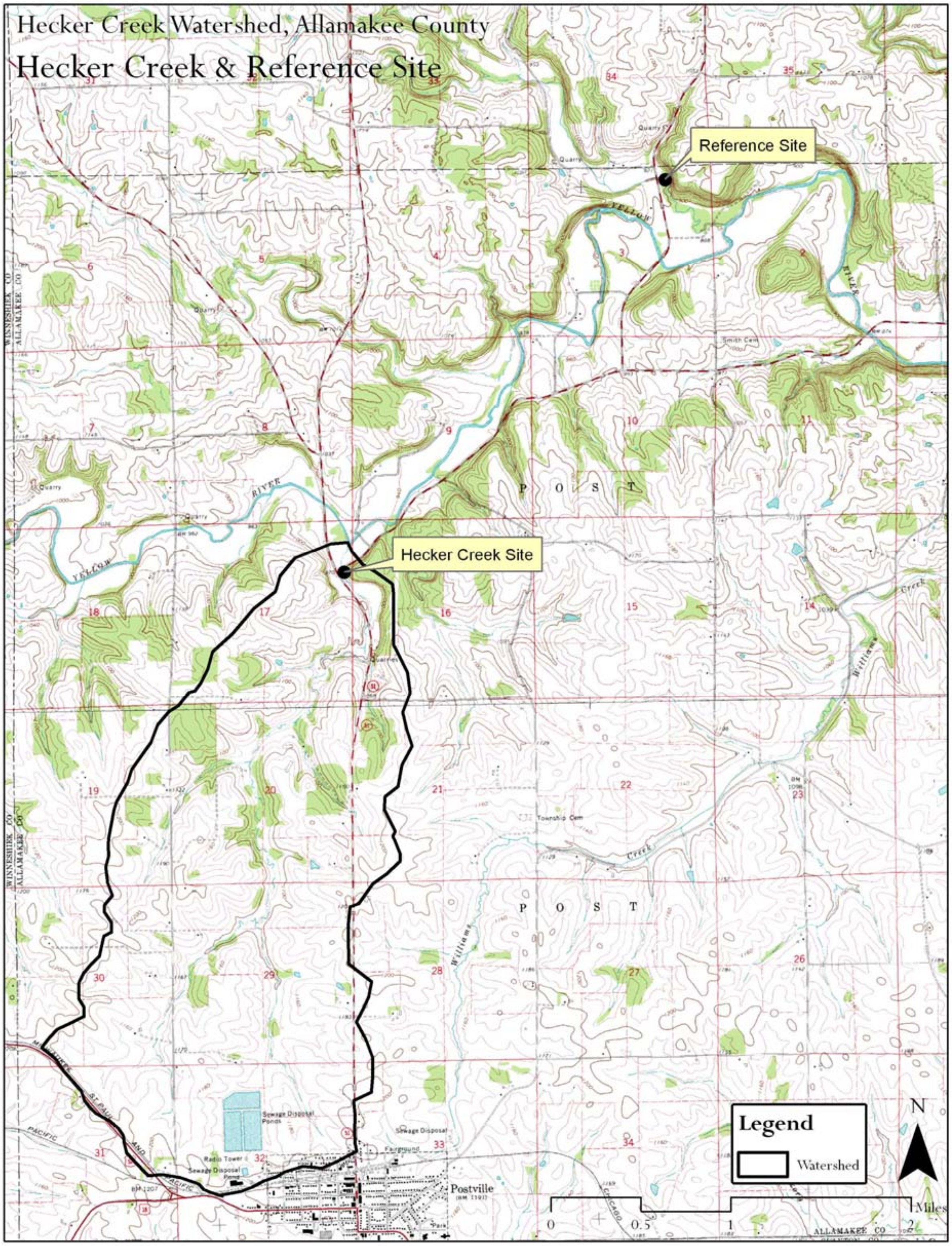


Figure B-2. Sampling locations in Hecker Creek and local comparison site in Yellow River watershed.

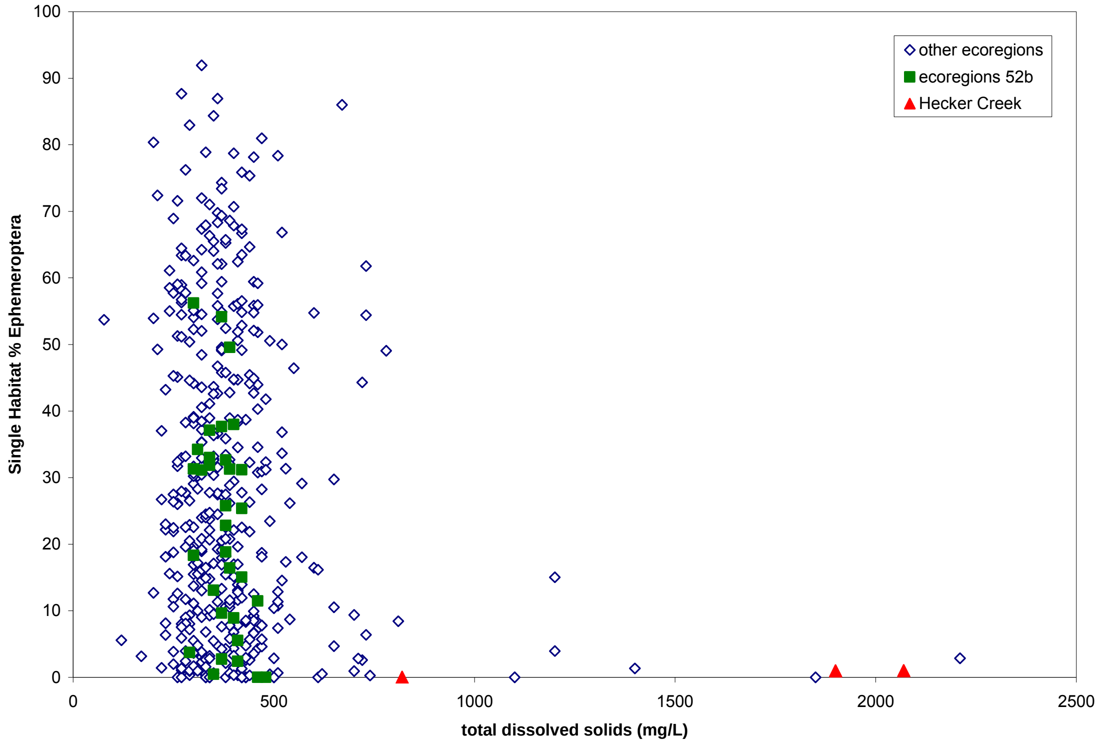


Figure B-3. Percent Ephemeroptera (single-habitat) and total dissolved solids.

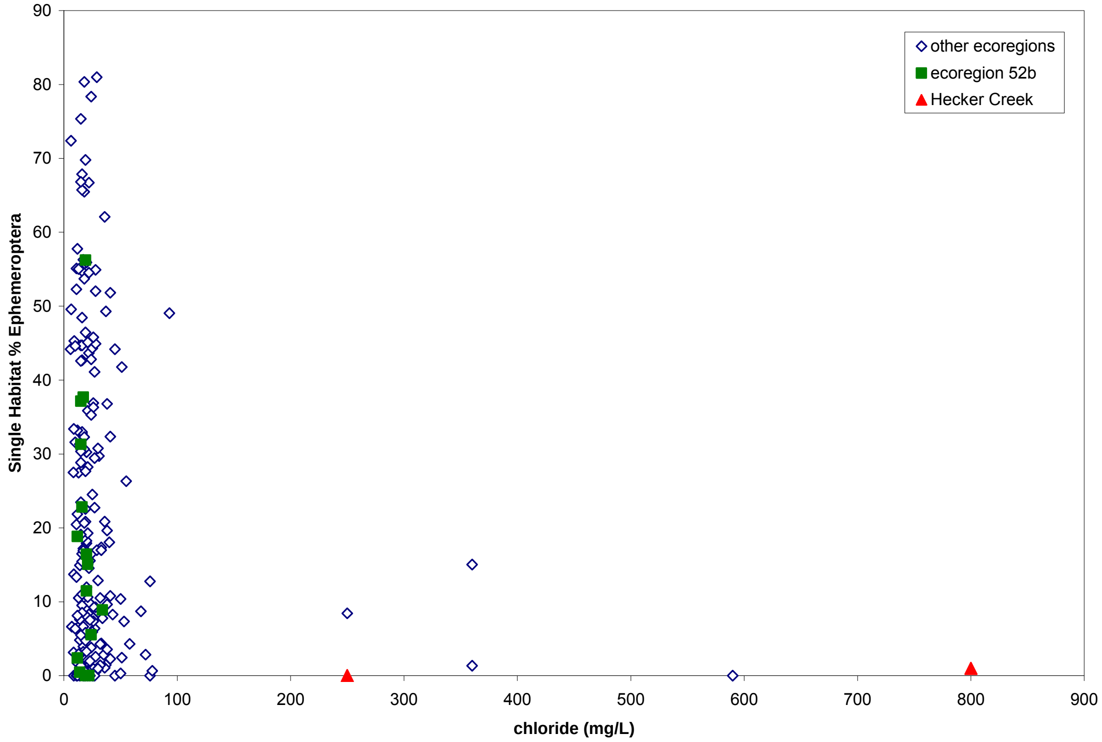


Figure B-4. Percent Ephemeroptera (single-habitat) and chloride.

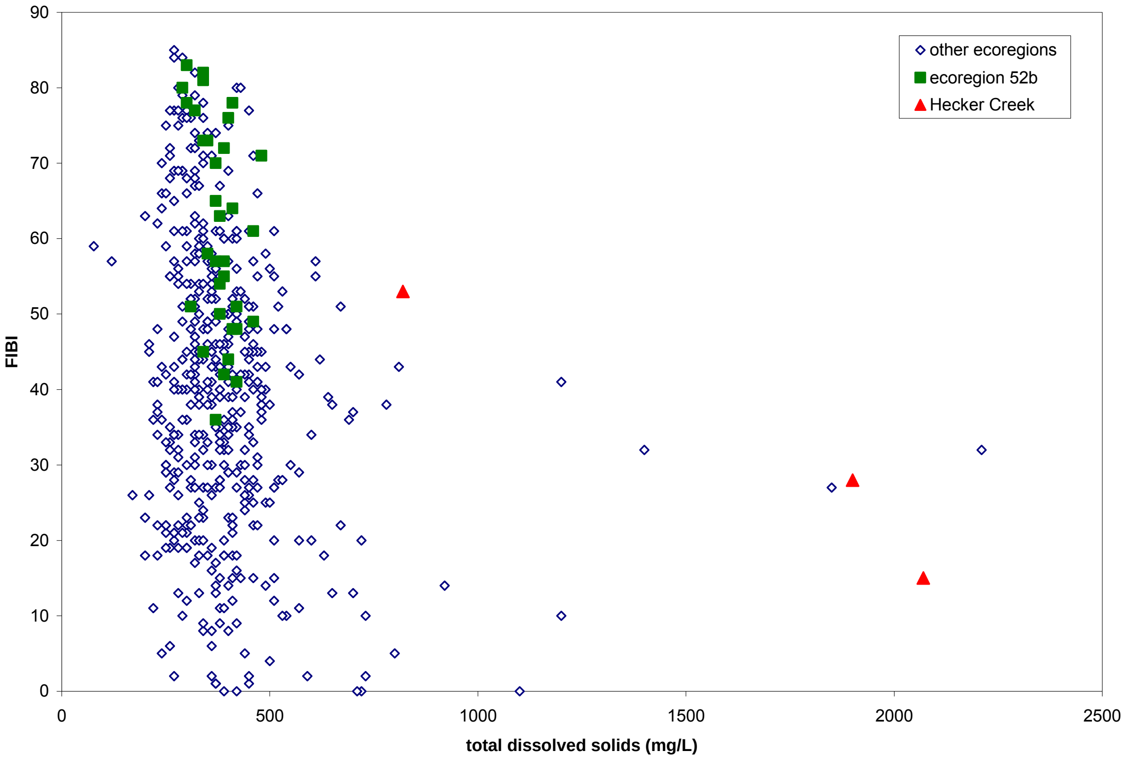


Figure B-5. Fish Index of Biotic Integrity (FIBI) and total dissolved solids.

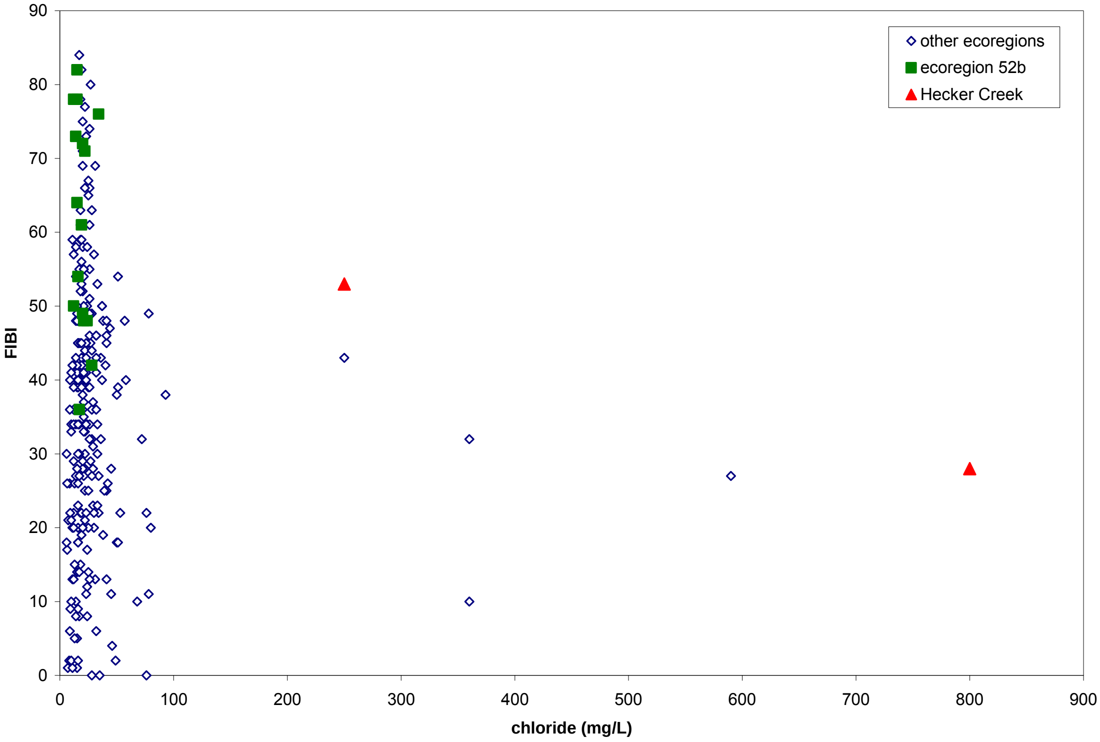


Figure B-6. Fish Index of Biotic Integrity (FIBI) and chloride.

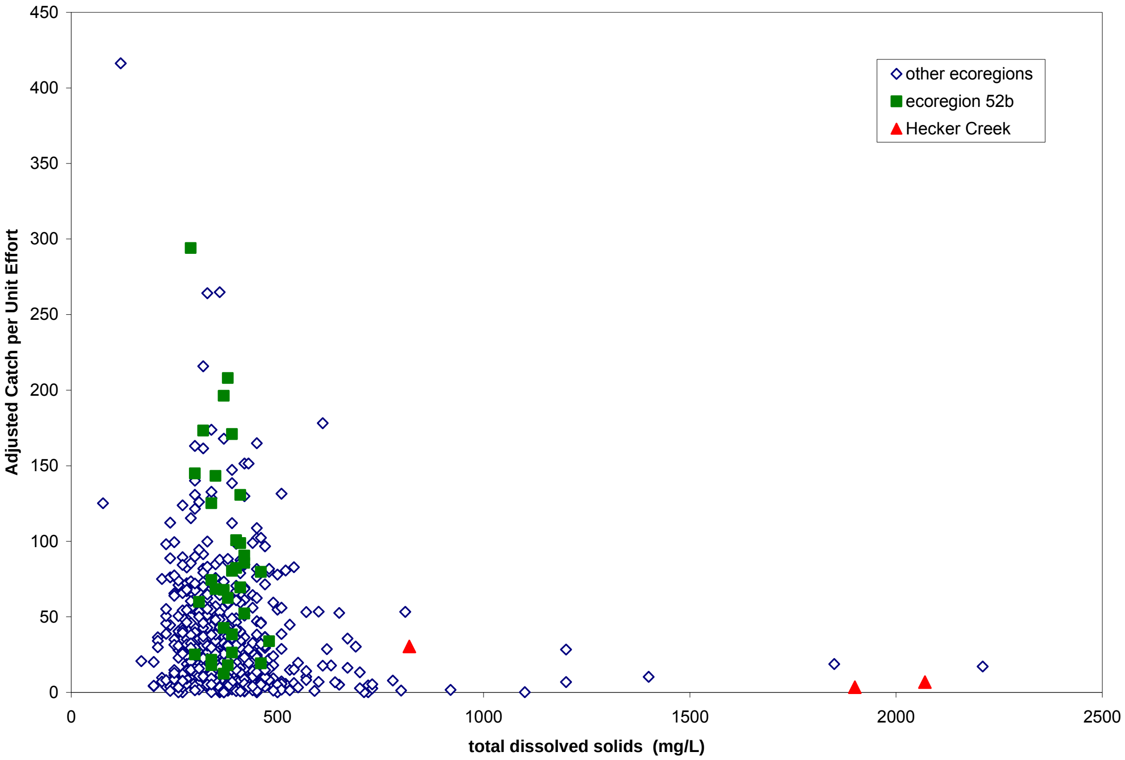


Figure B-7. Adjusted catch per unit effort and total dissolved solids.

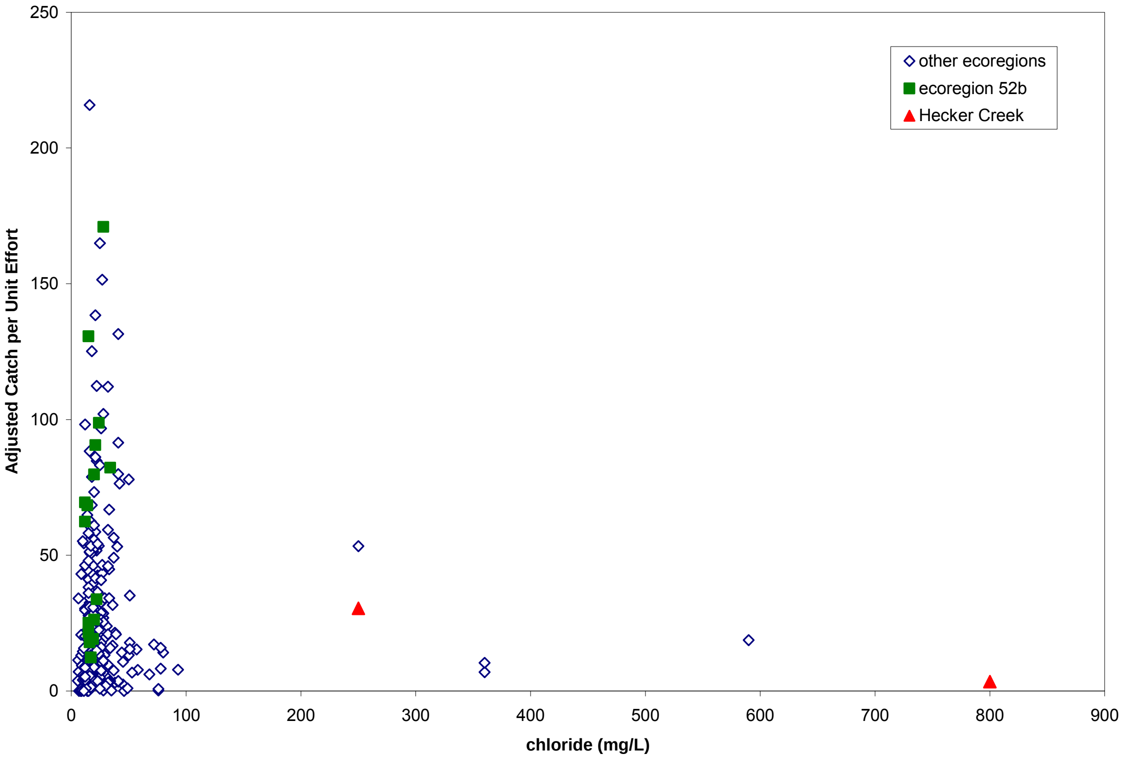


Figure B-8. Adjusted catch per unit effort and chloride.

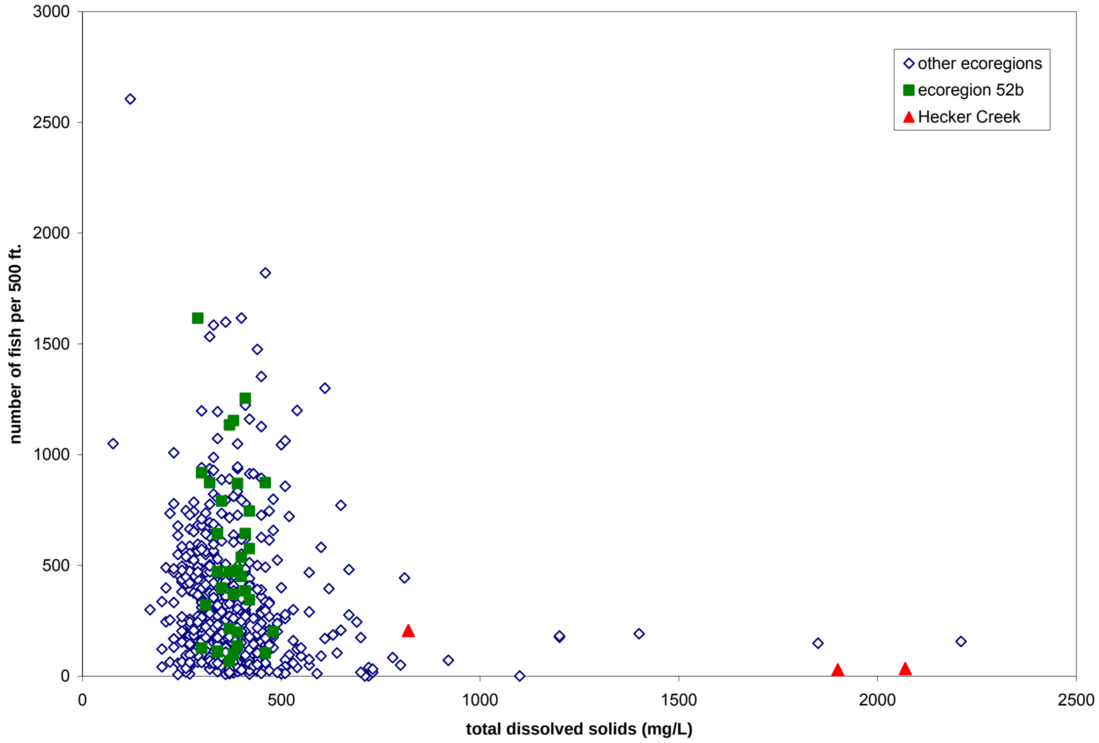


Figure B-9. Number of fish caught per 500 feet and total dissolved solids.

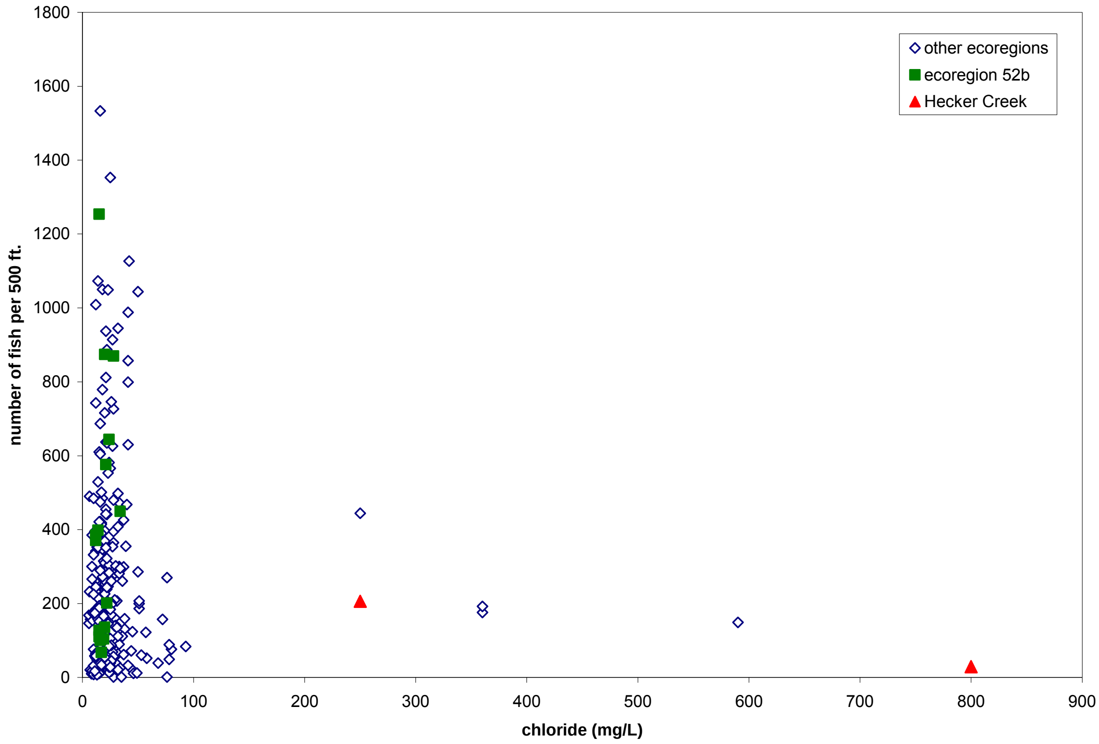


Figure B-10. Number of fish caught per 500 feet and chloride.

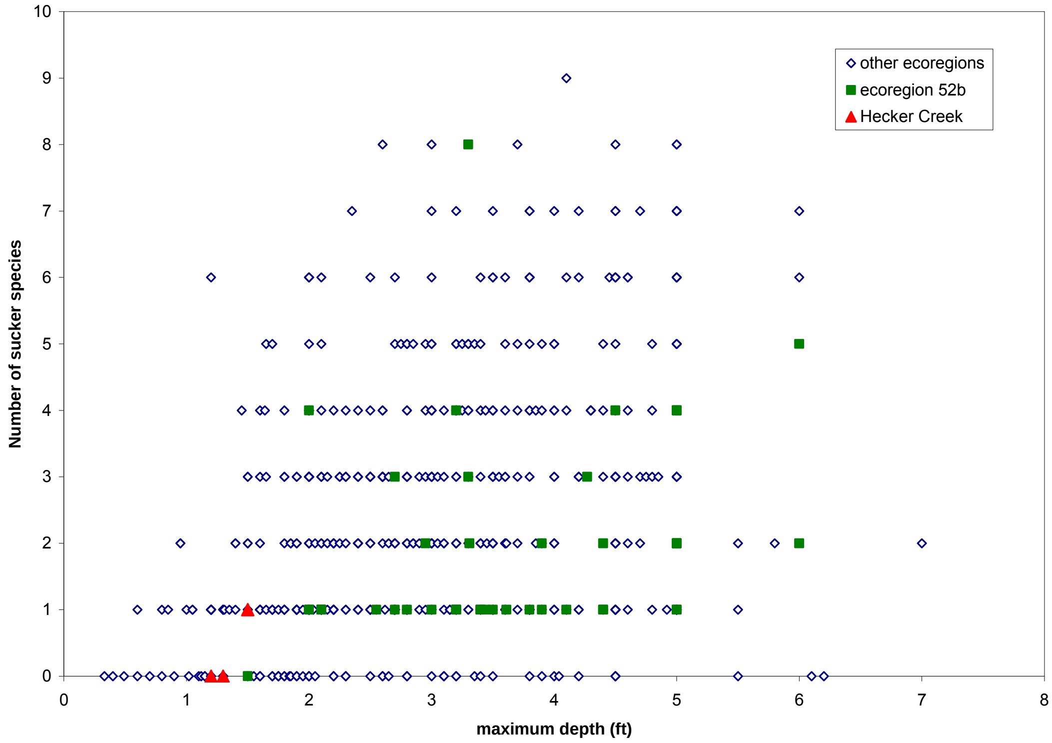


Figure B-11. Number of sucker species and maximum water depth.

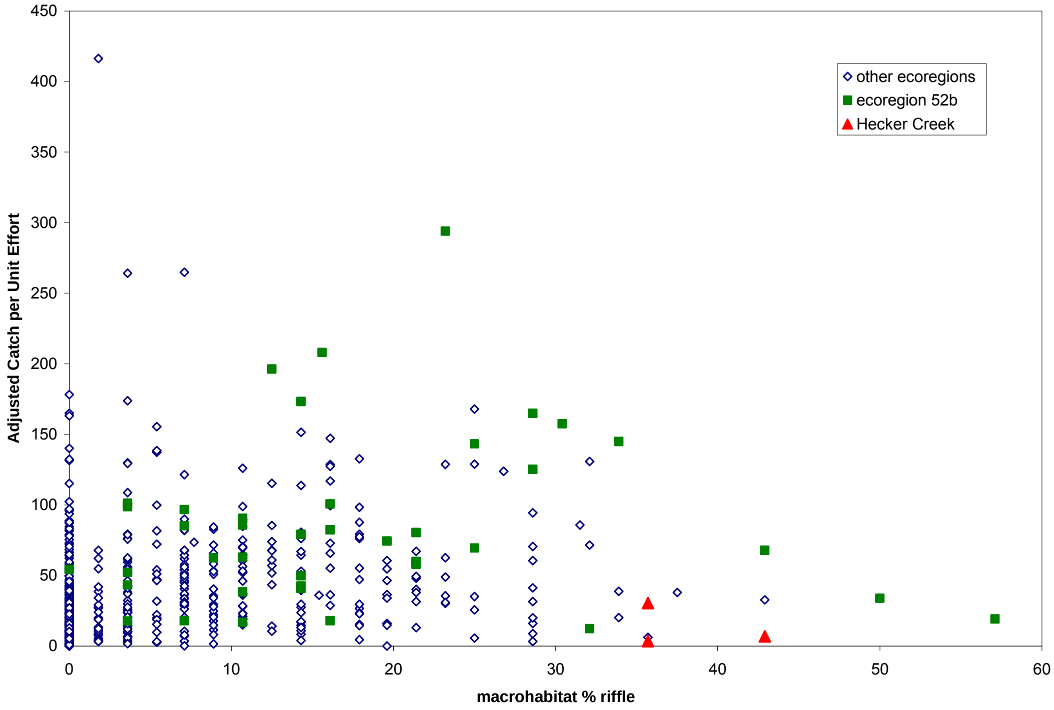


Figure B-12. Adjusted catch per unit effort and percent of the macrohabitat that is riffle.

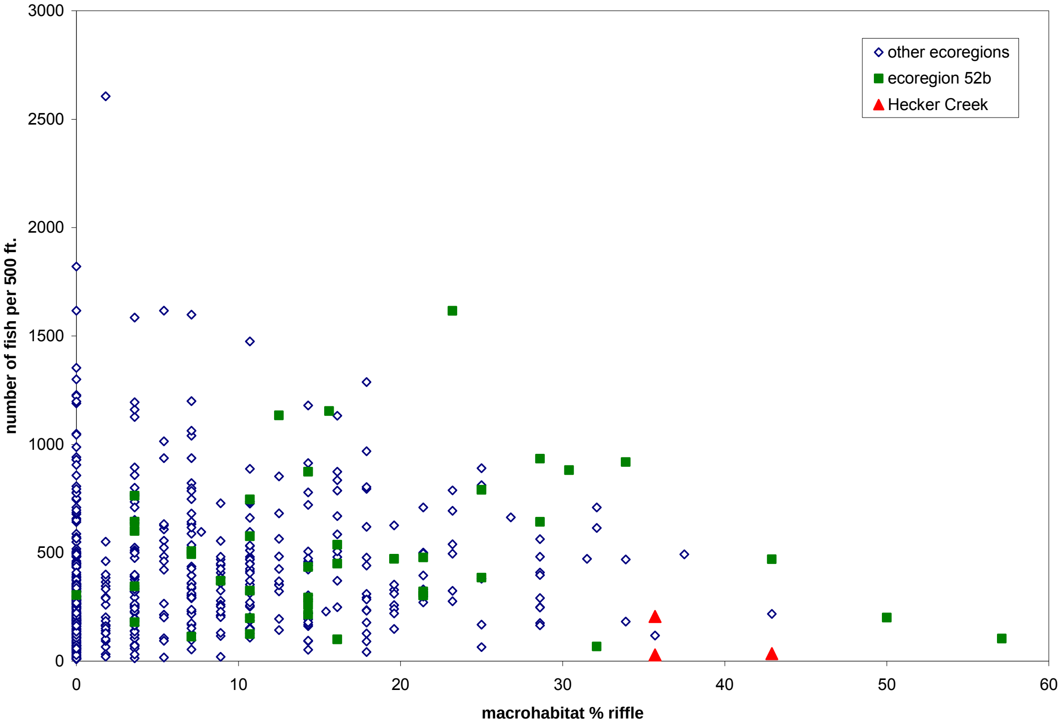
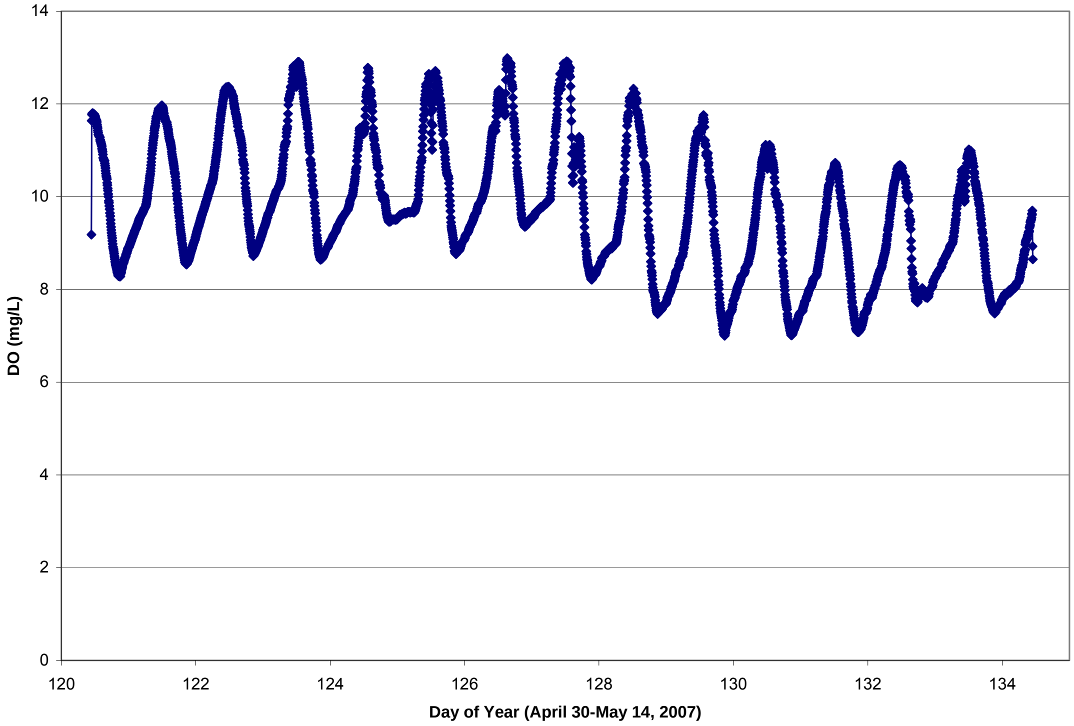


Figure B-13. Number of fish caught per 500 feet and percent of the macrohabitat that is riffle.



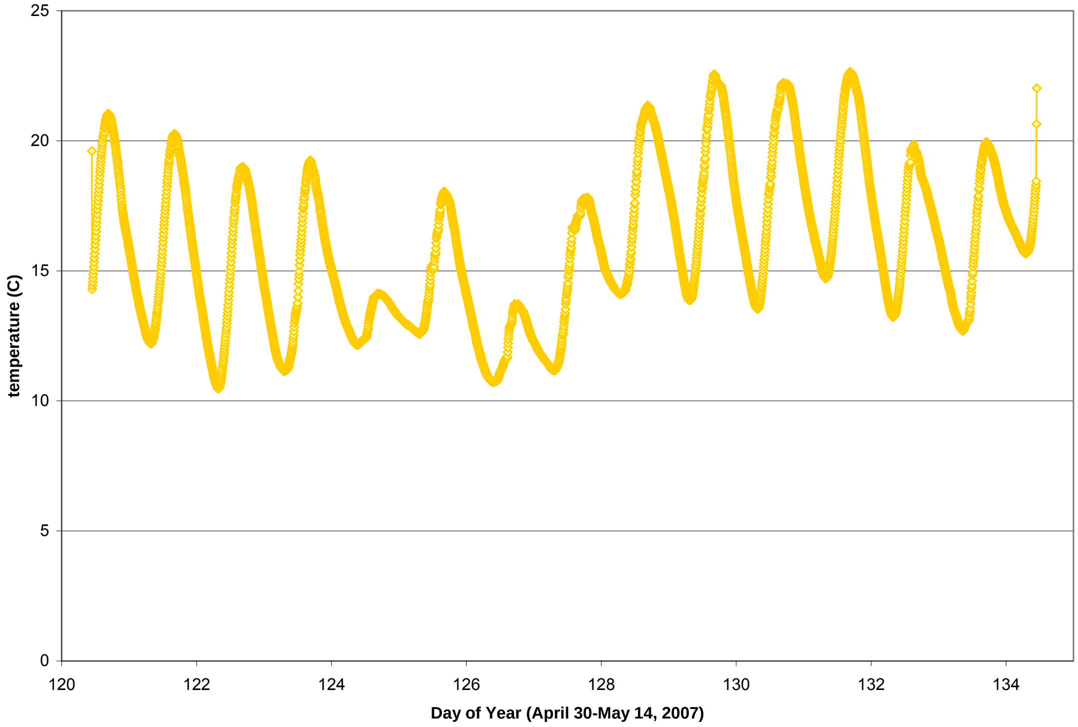


Figure B-14. Diurnal temperature and dissolved oxygen measurements in Hecker Creek for April 30-May 14, 2007.

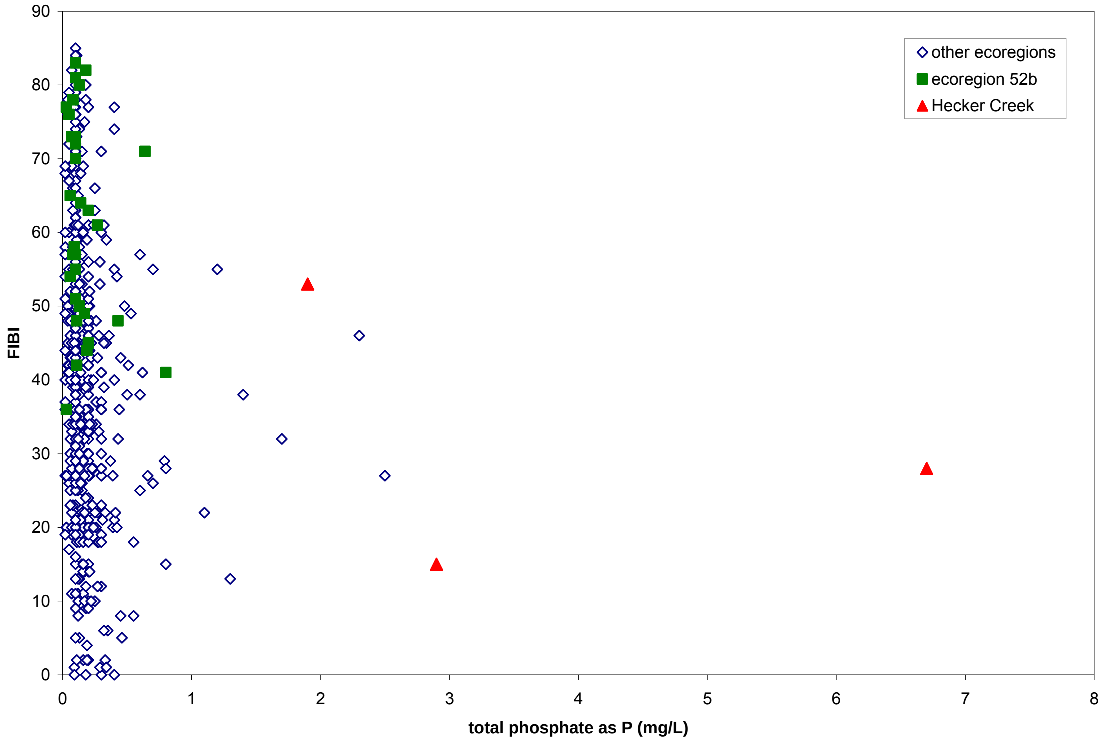


Figure B-15. Fish Index of Biotic Integrity (FIBI) and total phosphate.

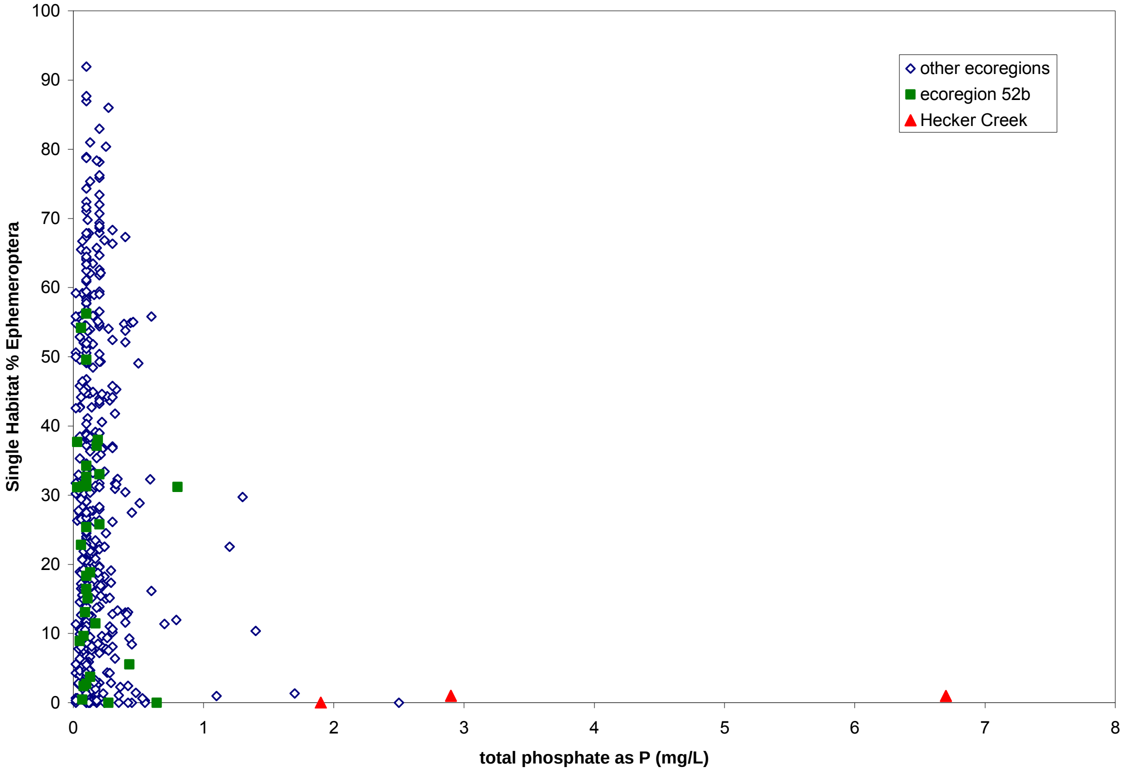


Figure B-16. Percent Ephemeroptera (single-habitat) and total phosphate.

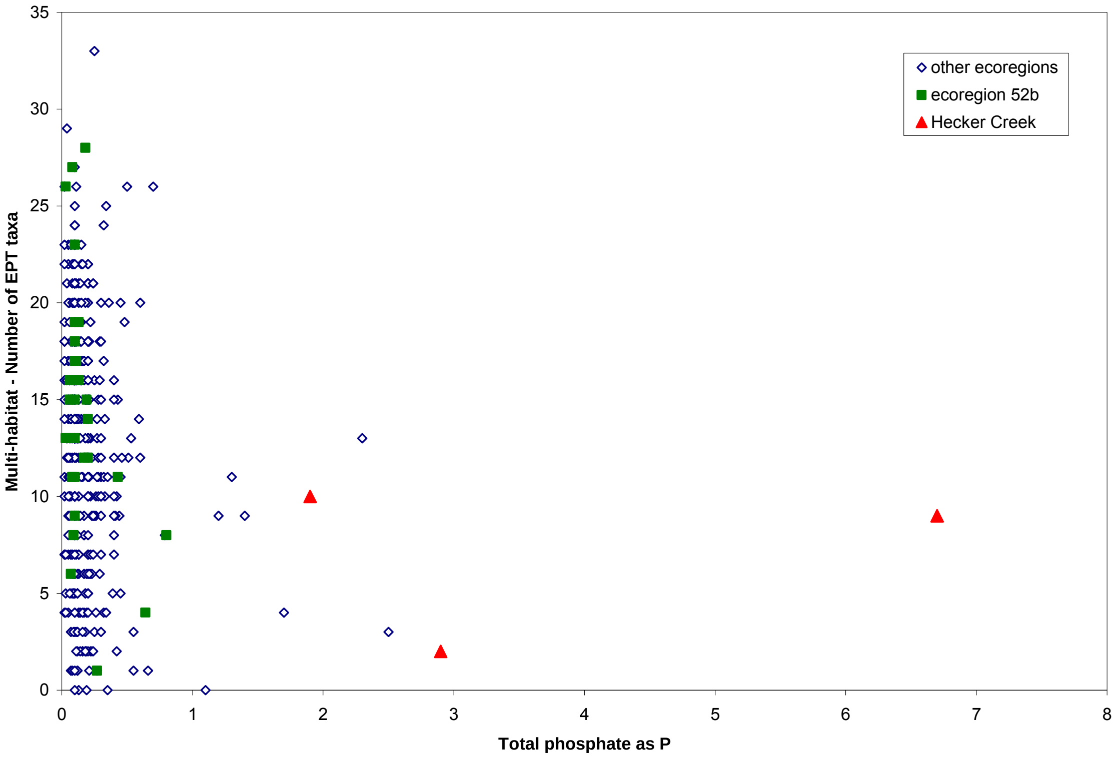


Figure B-17. Number of EPT taxa (multi-habitat) and total phosphate.

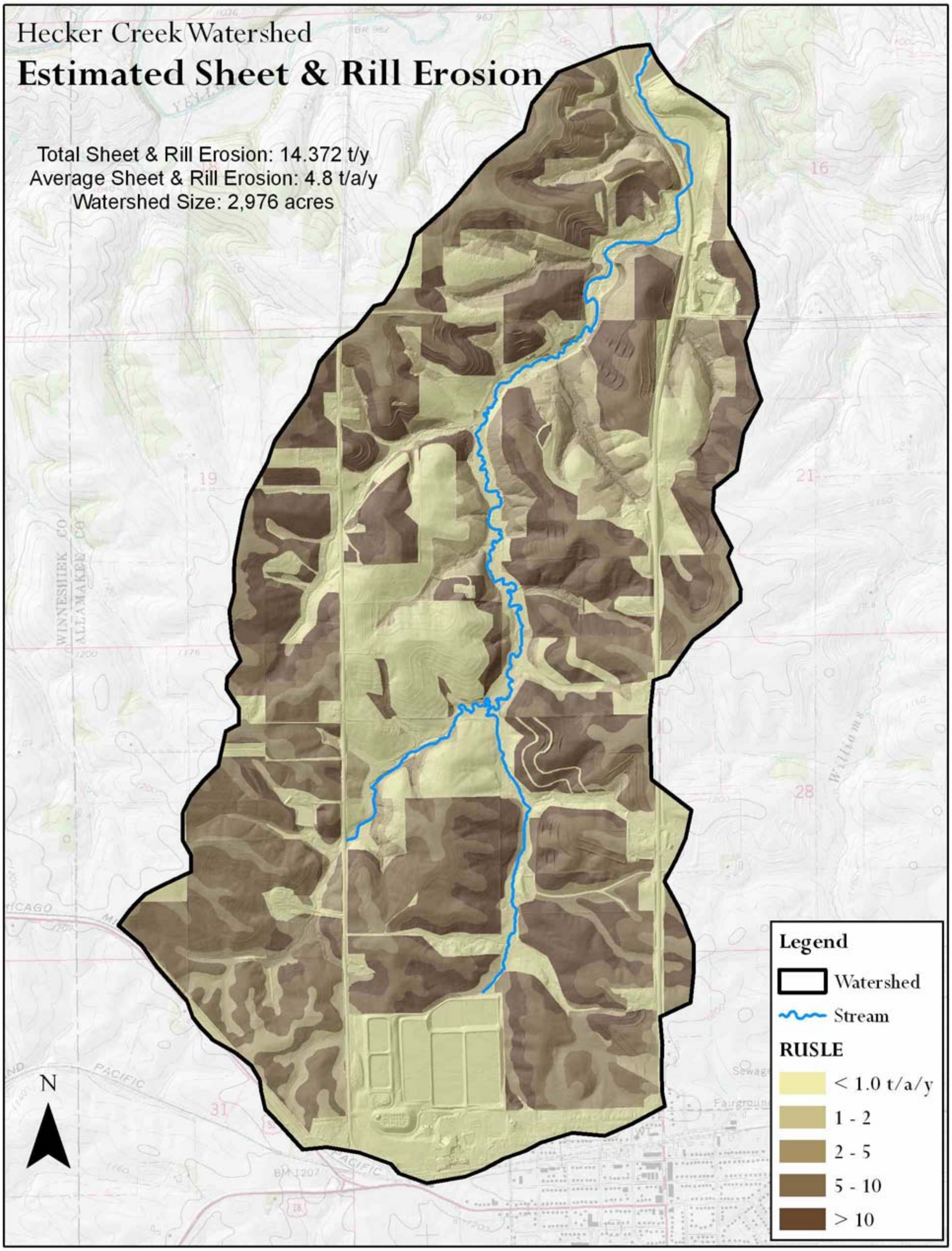


Figure B-18. RUSLE estimate of sheet and rill erosion in the Hecker Creek watershed based on 2007 watershed assessment.

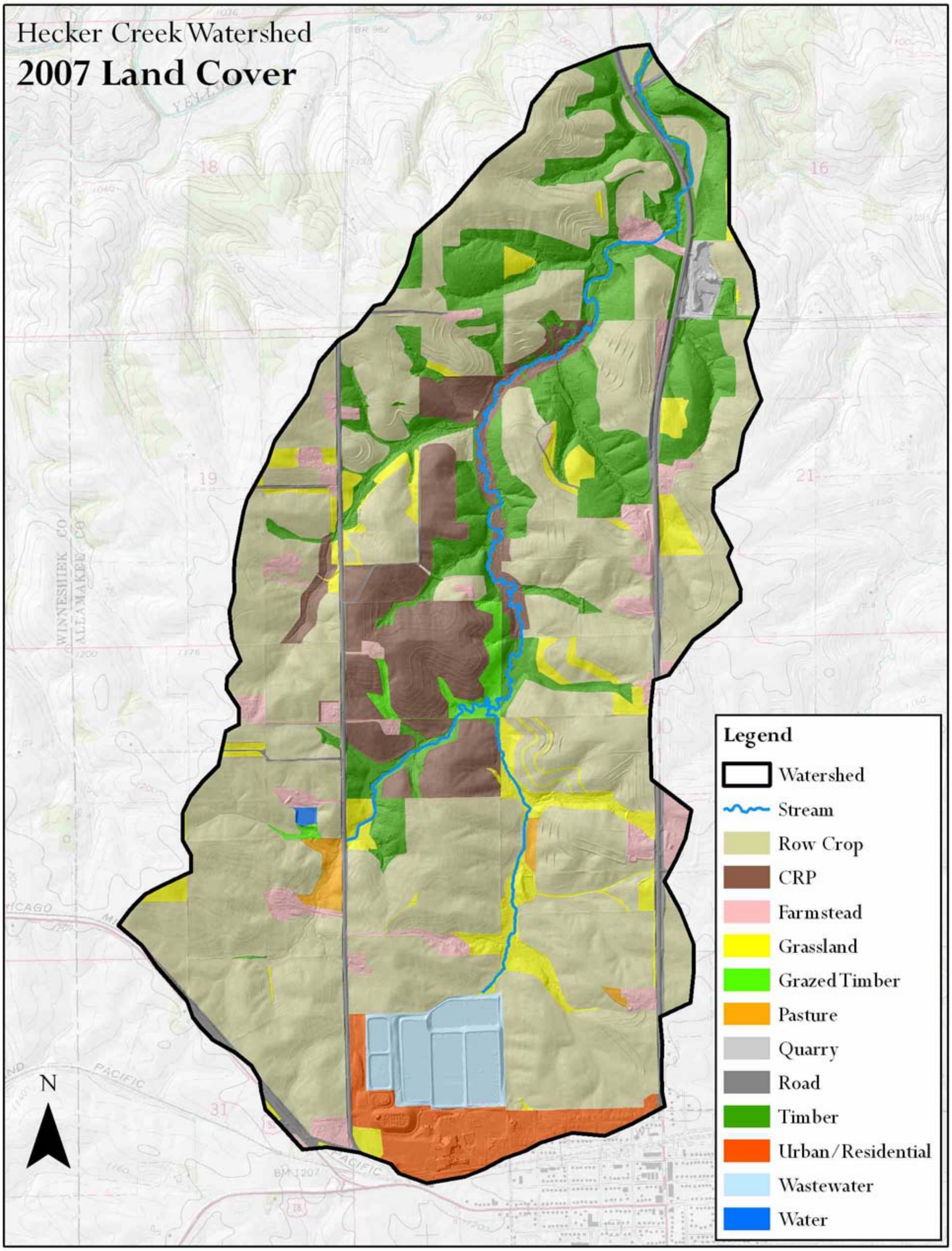


Figure B-19. Land use in the Hecker Creek watershed in 2007.

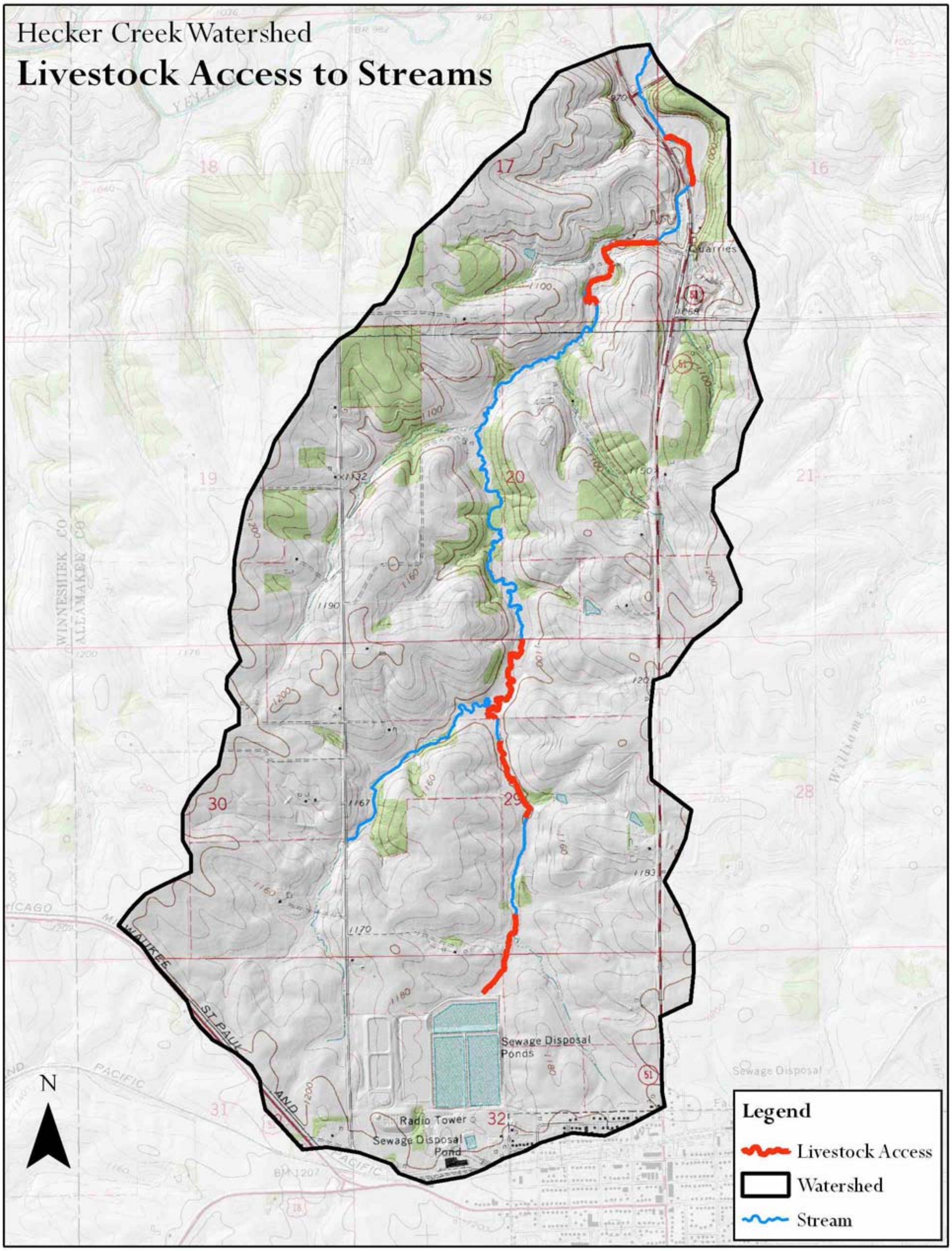


Figure B-20. Livestock access to stream in the Hecker Creek watershed in 2007.

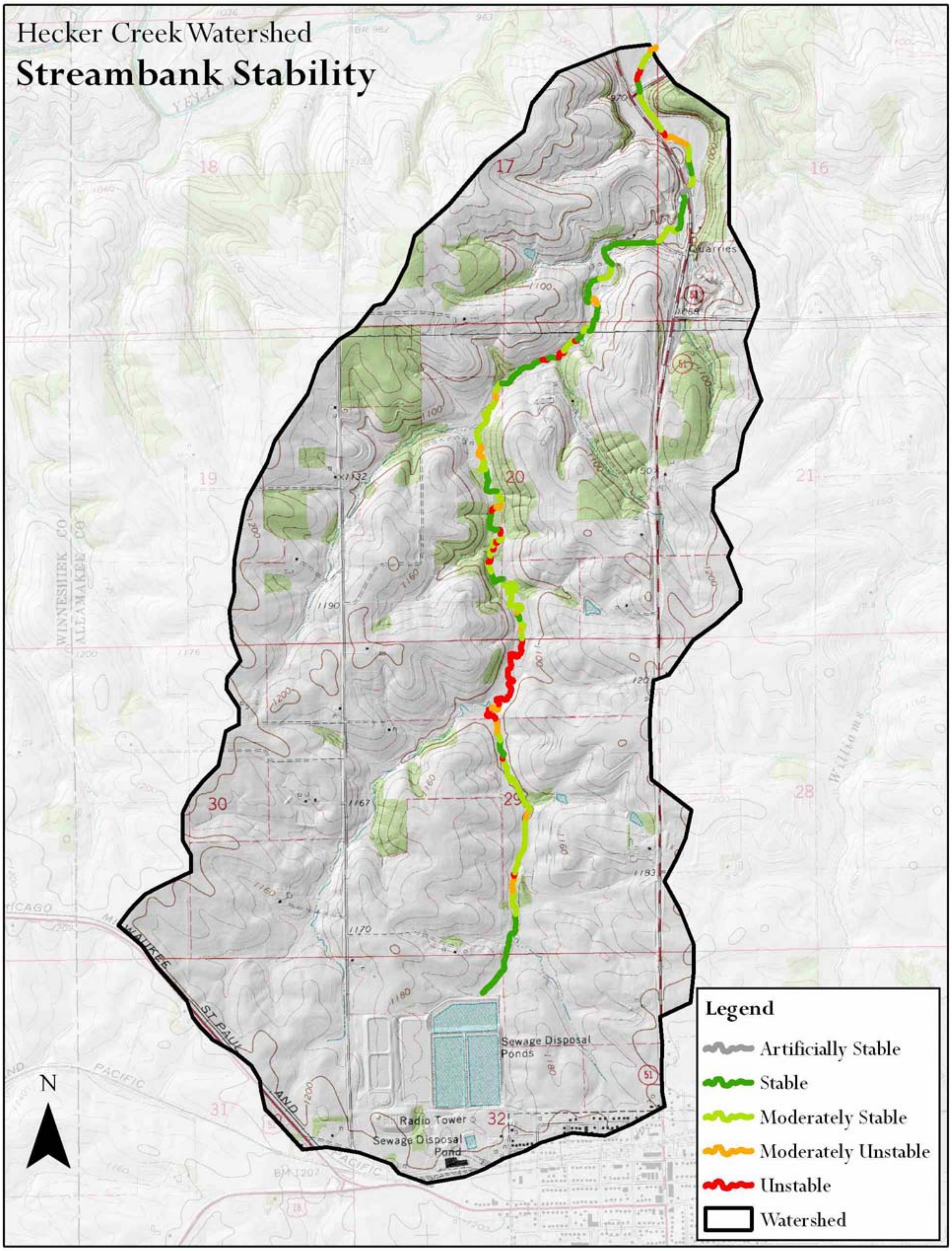


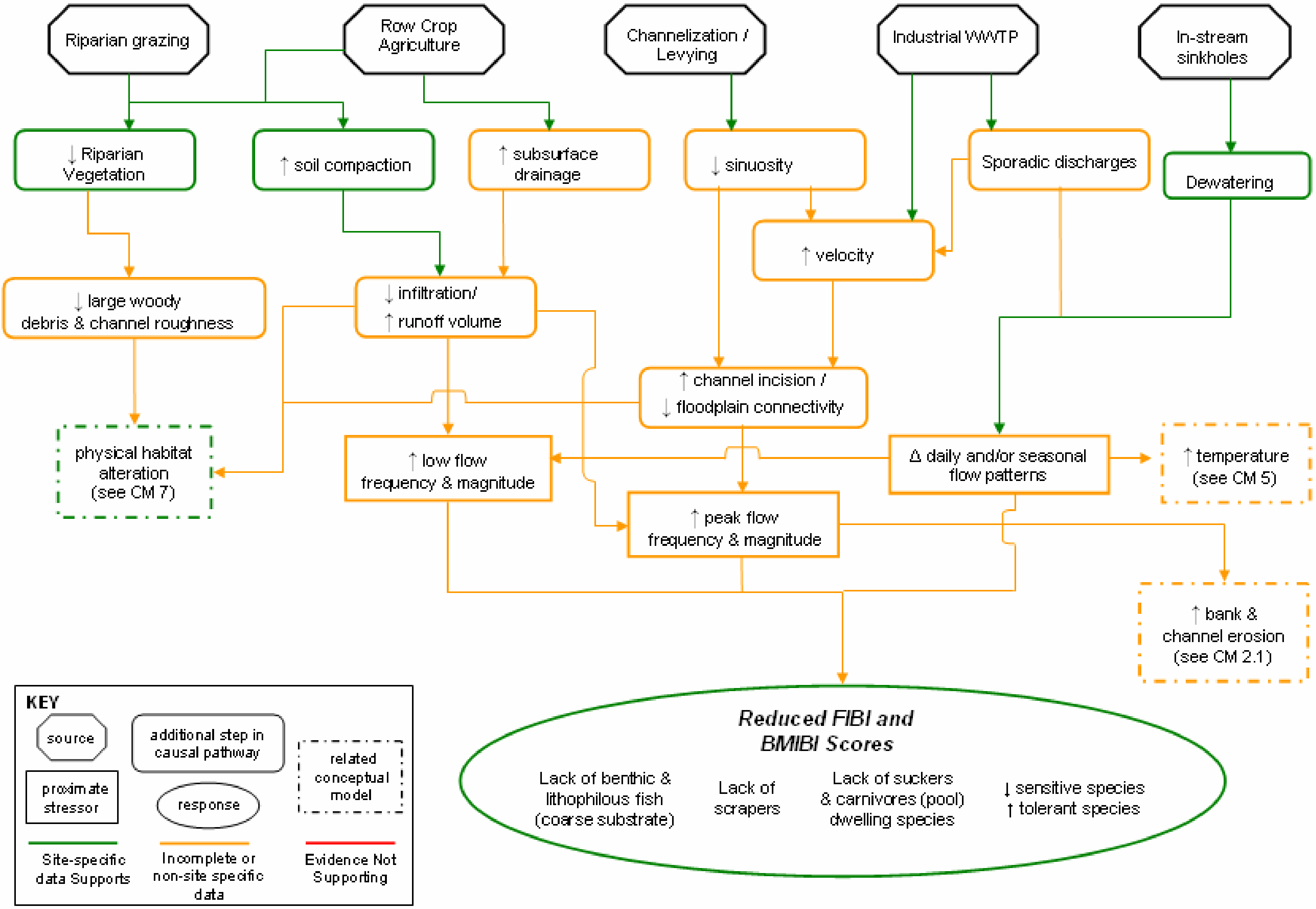
Figure B-21. Bank stability in the Hecker Creek watershed in 2007.

Appendix C

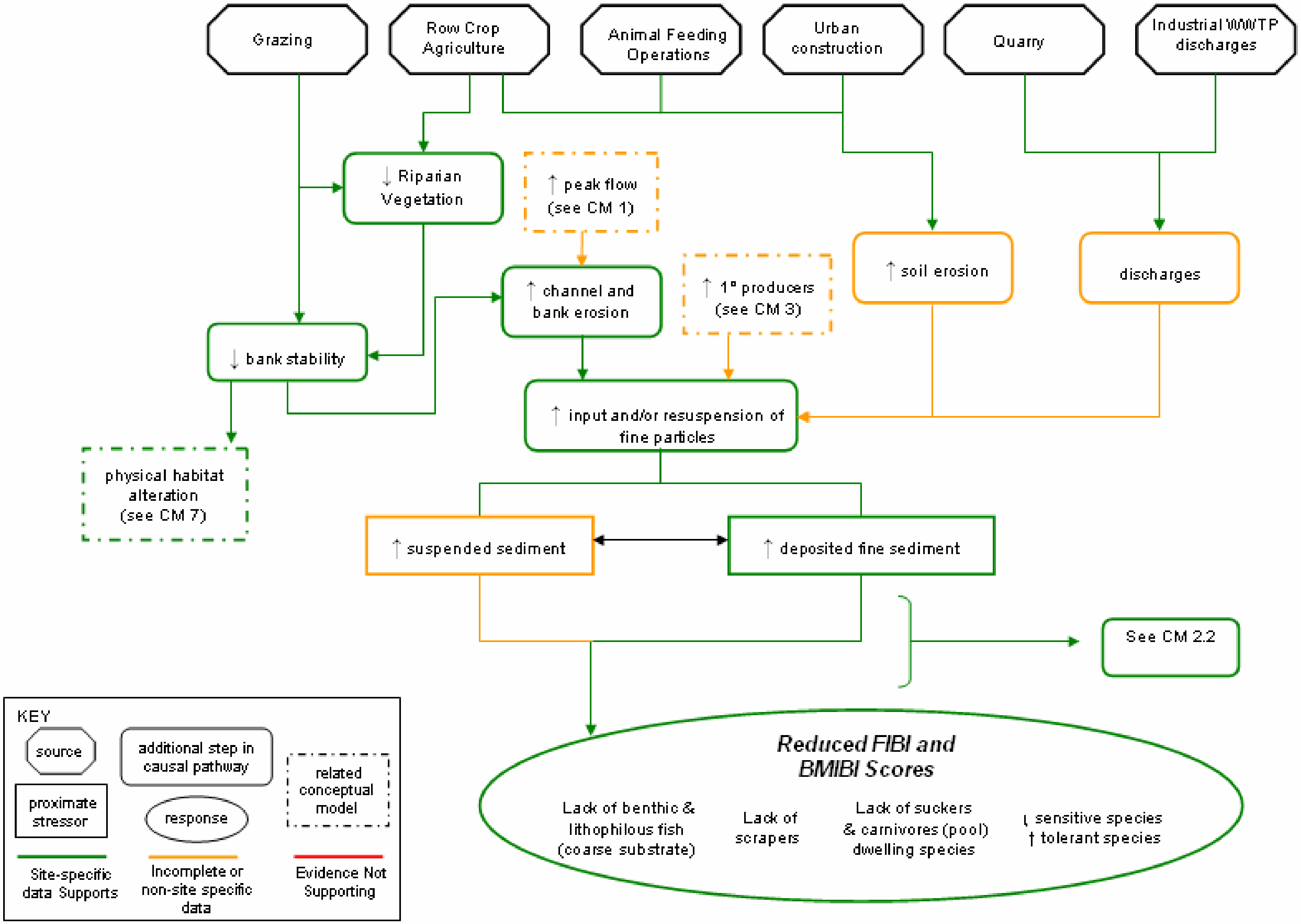
Conceptual Models of Plausible Causal Pathways

Conceptual Model 1:	Altered flow regime
Conceptual Model 2.1:	Suspended and Bedded Sediments (SABS)
Conceptual Model 2.2:	Suspended and Bedded Sediments (SABS)
Conceptual Model 3:	Altered basal food source
Conceptual Model 4:	Decreased dissolved oxygen
Conceptual Model 5:	Altered temperature
Conceptual Model 6:	Elevated ammonia
Conceptual Model 7:	Physical Habitat Alteration
Conceptual Model 8:	Aquatic Life Depletion and Isolation

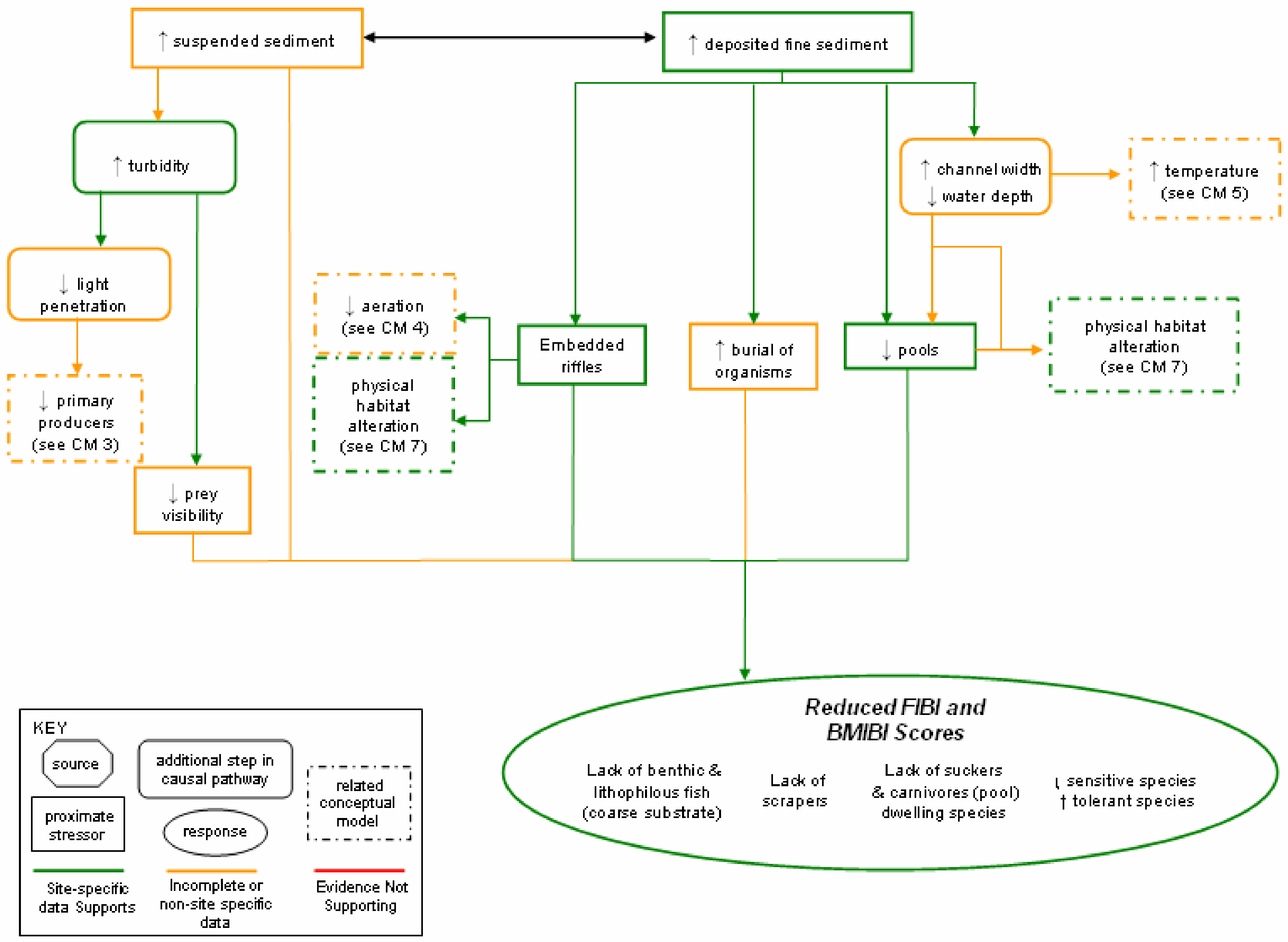
Conceptual Model 1 - Altered flow regime



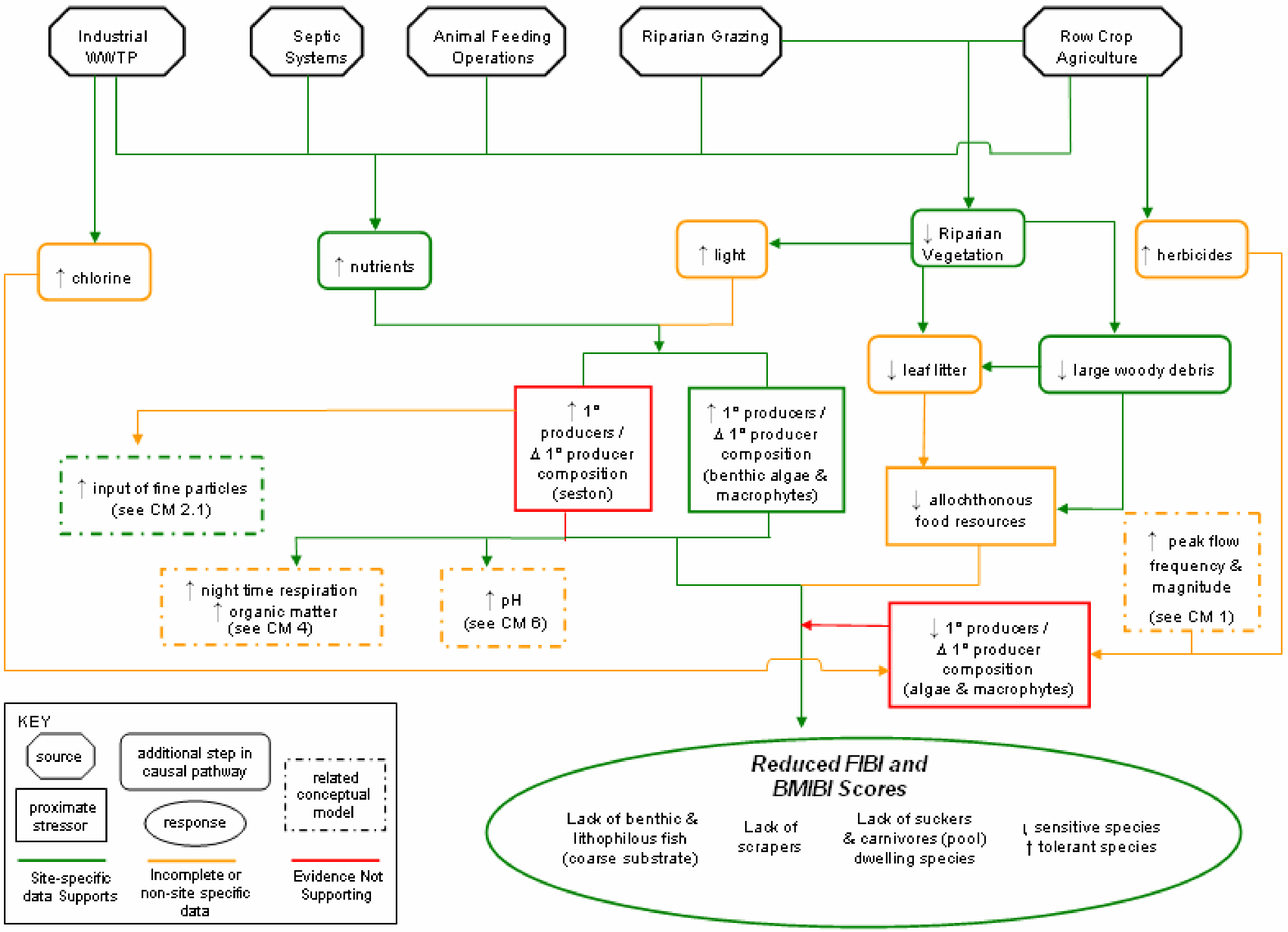
Conceptual Model 2.1 - Suspended and Bedded Sediments (SABS)



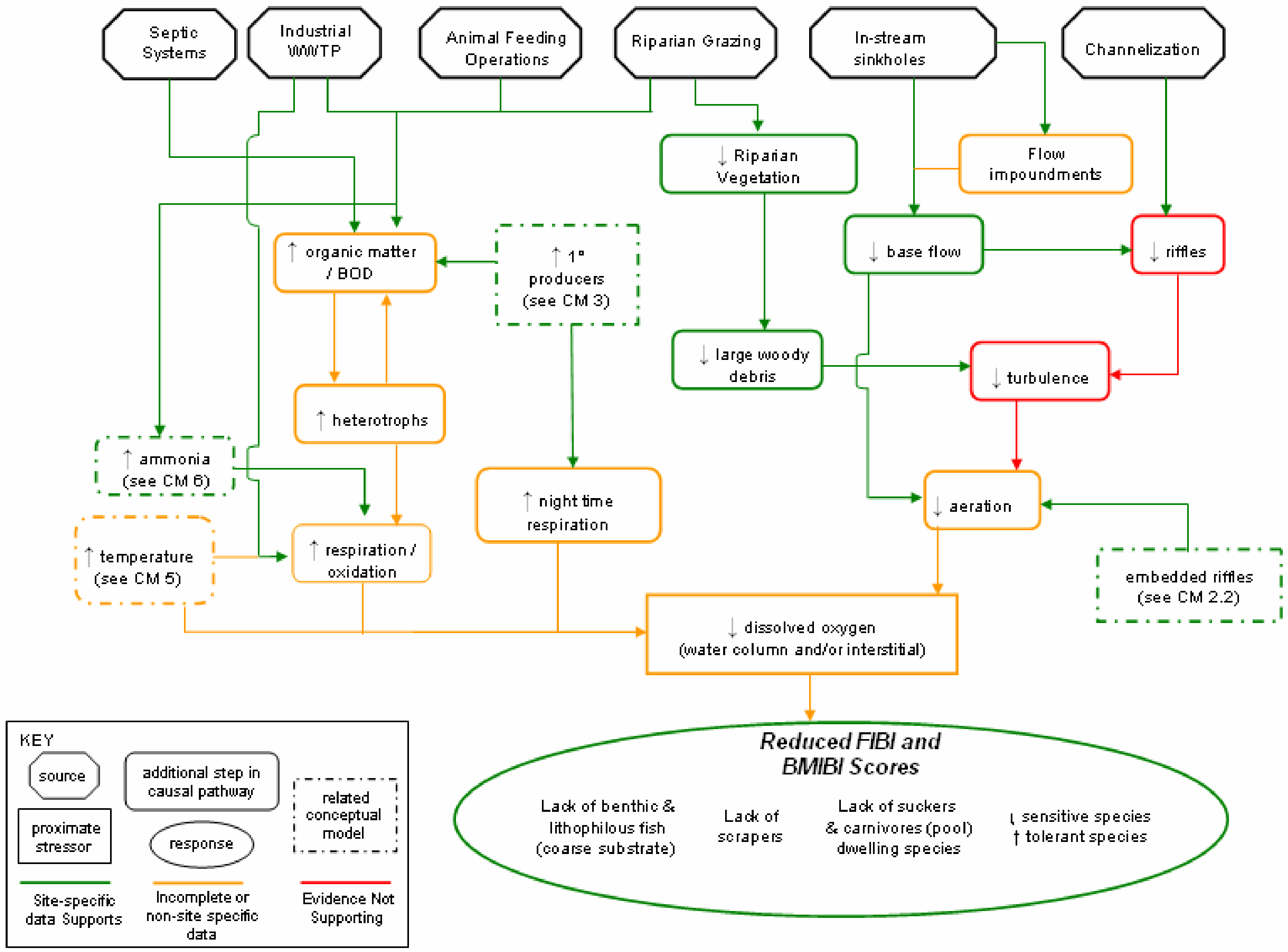
Conceptual Model 2.2 - Suspended and Bedded Sediments (SABS)



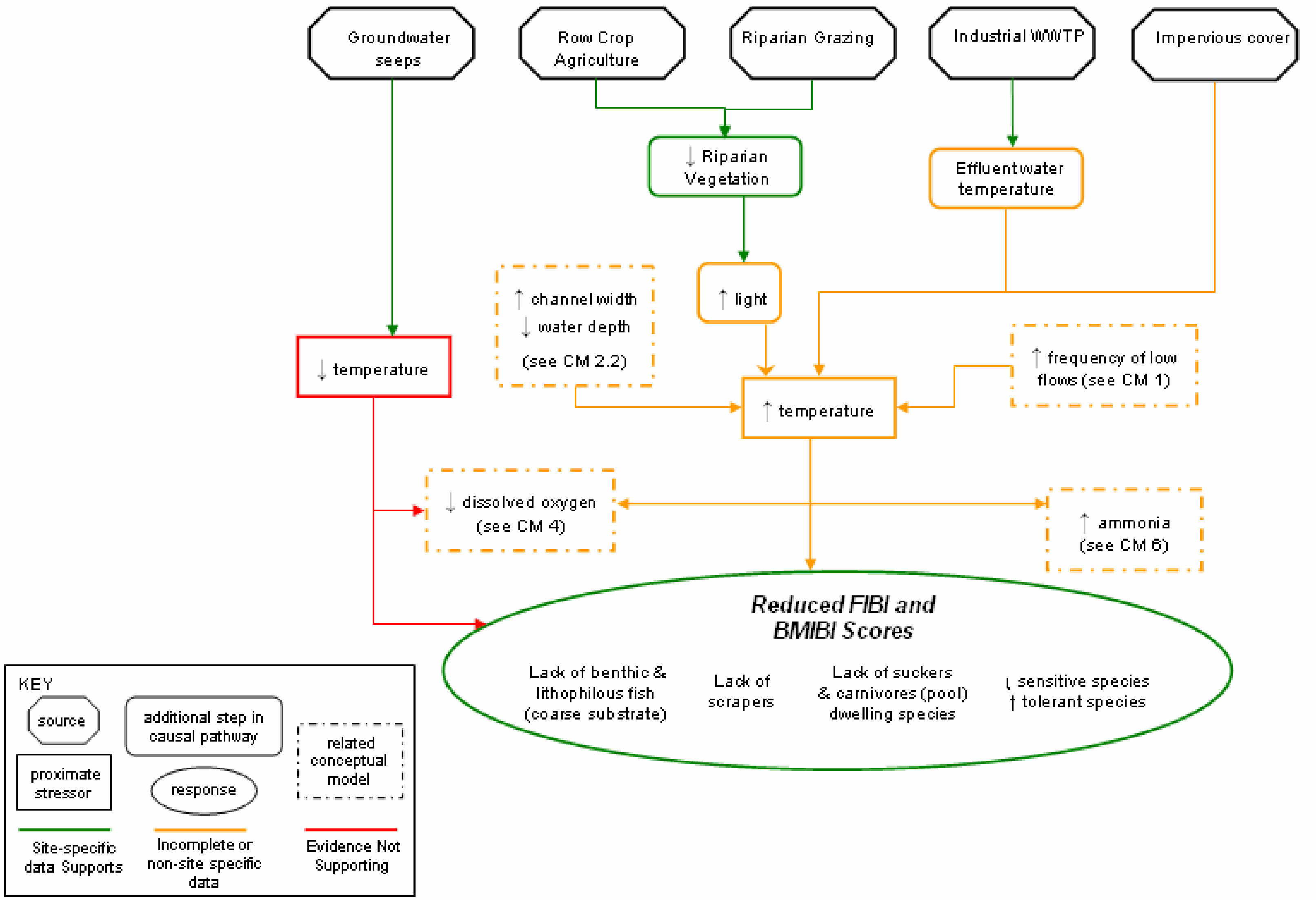
Conceptual Model 3 - Altered basal food source



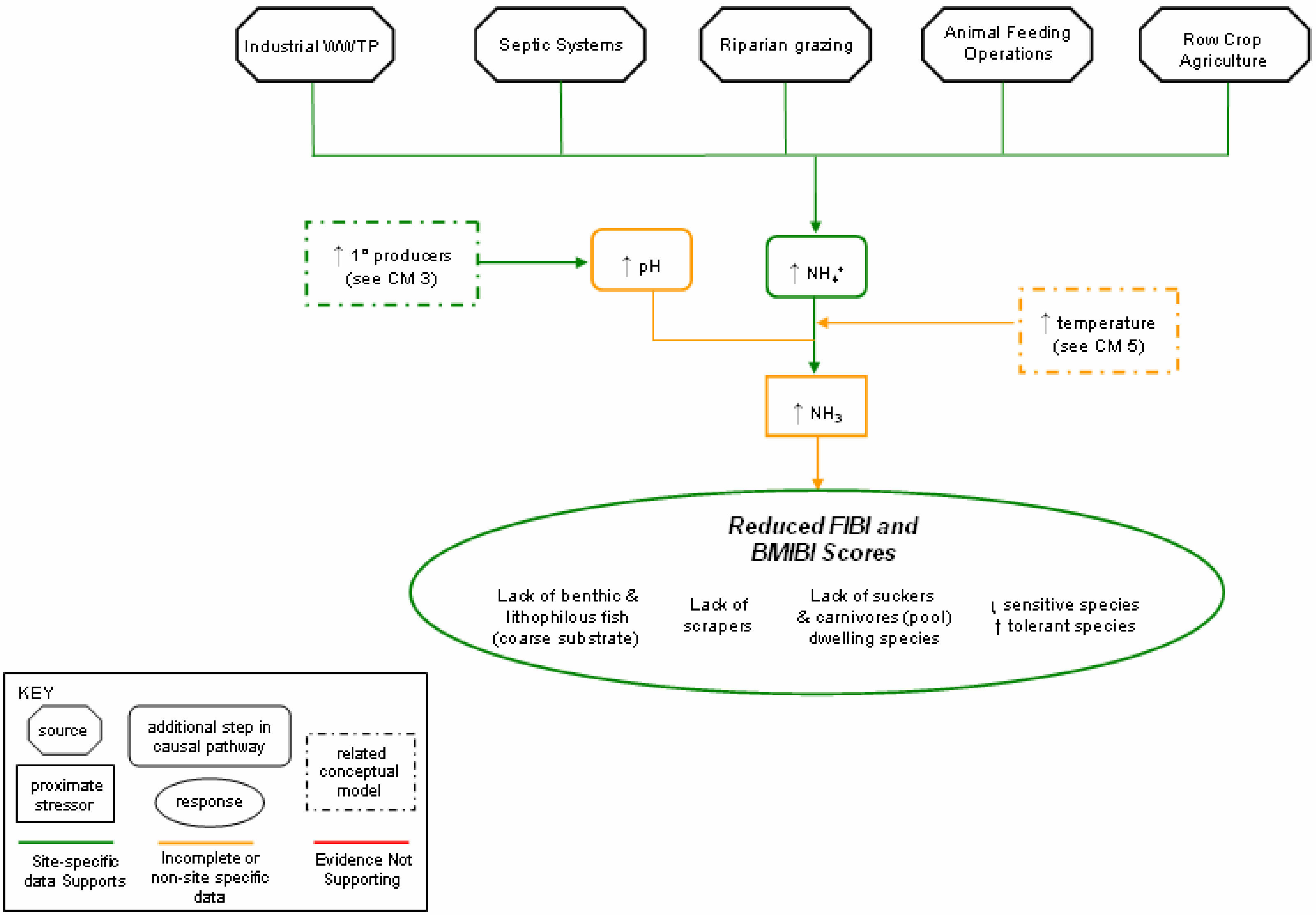
Conceptual Model 4 - Decreased dissolved oxygen



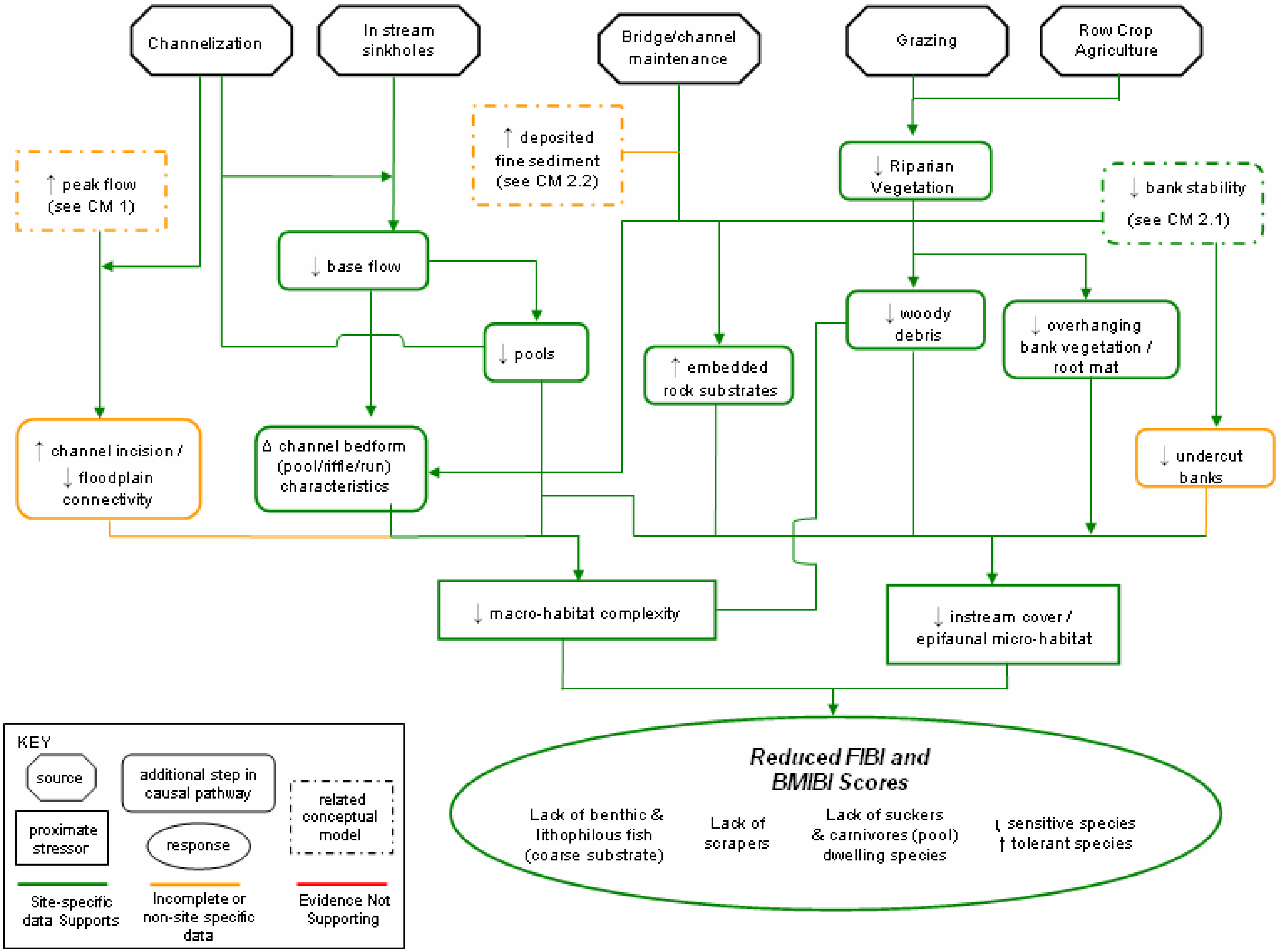
Conceptual Model 5 - Altered temperature



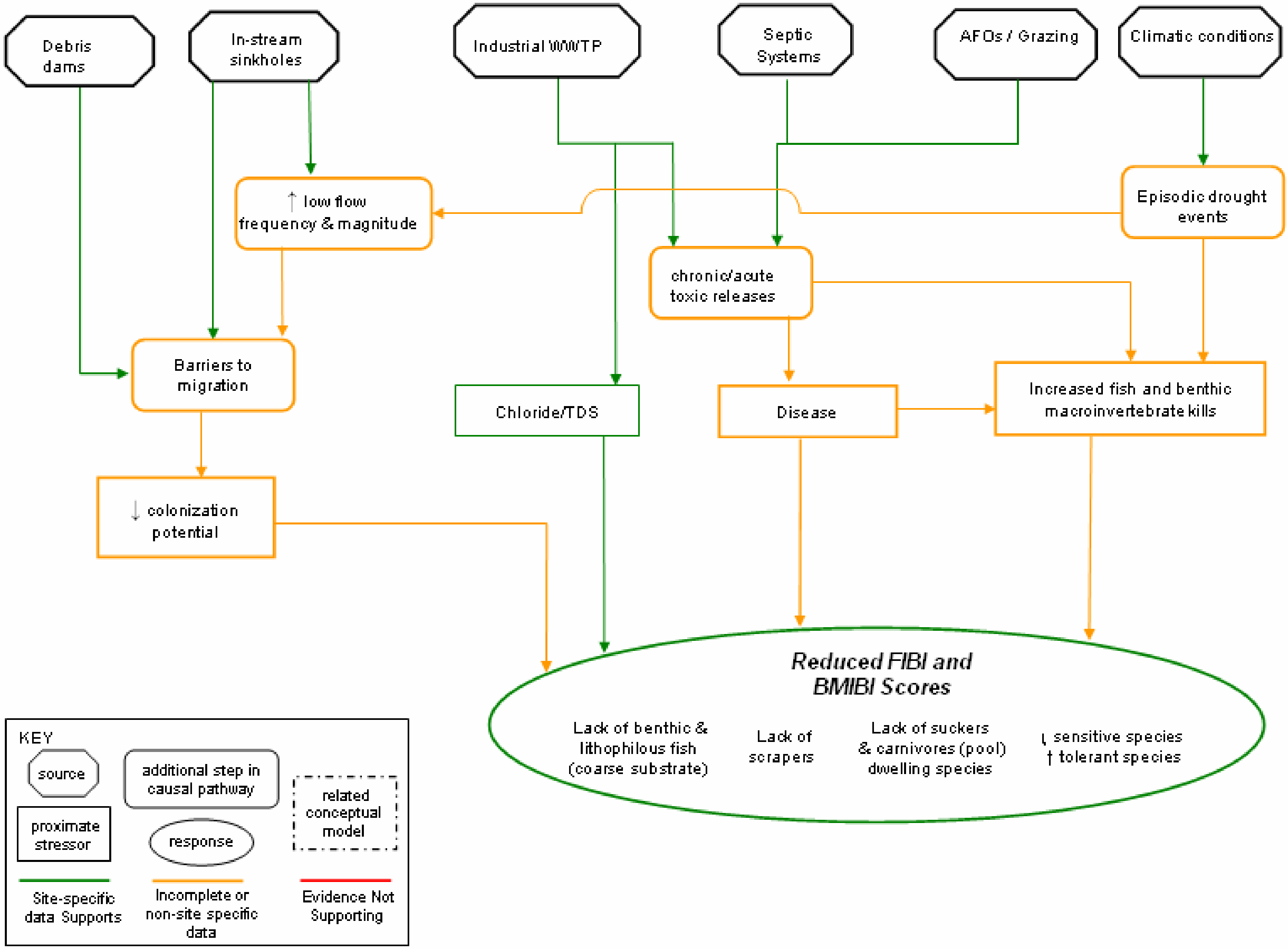
Conceptual Model 6 - Elevated ammonia



Conceptual Model 7 - Physical Habitat Alteration



Conceptual Model 8 - Aquatic Life Depletion and Isolation



Appendix D

Public Comments

Berckes, Jeff [DNR]

From: Dorothy Jarmes [jarmes@acrec.com]
Sent: Thursday, July 09, 2009 8:12 AM
To: Berckes, Jeff [DNR]
Subject: Fw: Article in Postville paper.

-------*Original Message*-------

From: Dorothy Jarmes
Date: 7/8/2009 2:46:17 PM
To: jeffberckes@dnr.iowa.gov
Subject: Article in Postville paper.

We were reading your article in the Postville paper and you do not know why there is no life in Hecker Creek. It is very simple fish and plant life can not live in salt. The problem is Agriprocessors.

Pleas E-mail me back. What do you think people have been complaining about it for years. It does not take a college degree to figure this out.

Jim and Dorothy Jarmes
jarmes@acrec.com

Berckes, Jeff [DNR]

From: Berckes, Jeff [DNR]
Sent: Thursday, July 09, 2009 2:12 PM
To: 'Dorothy Jarmes'
Subject: RE: Article in Postville paper.

Dorothy & Jim,

Thank you for your e-mail and your interest in Hecker Creek and the DNR's Stressor Identification. Your e-mail was a little unclear as to what you are requesting, so please reply if I do not completely address your concerns.

The press release, unfortunately, did not convey our intended message as clearly as I would have hoped. Hecker Creek is listed on the state's impaired waters list for "biological, cause unknown". When a waterbody is listed as a biological impairment, it is because sampling data from the area indicate the biological community was not performing up to expectations or due to a fish kill with unknown causes. The DNR then conducts a Stressor Identification on the stream to determine the causes of the impairment or fish kill. For Hecker Creek, the Stressor Identification determined that the aquatic life community does not meet expectations due to high levels of chloride (salt) and habitat alterations. To your point, Agriprocessors is identified in the document as the source of chloride contributions from their discharge, due to the kosher process using high levels of salt (aka sodium chloride). If you would like a preview of the document, it can be located on our webpage:

http://www.iowadnr.gov/water/watershed/tmdl/publicnotice.html

We are required by the Clean Water Act to investigate all impairments on the state's impaired waters list, and we choose to devote our efforts to waterbodies that have local interest. Hecker Creek and the Yellow River are important resources, and the local interest in the Hecker Creek impairment directed our efforts there. The presentation in Postville will explain the Stressor Identification and its results. I encourage you to attend the meeting if you are able to make it. Again, please let me know if you have any additional questions.

Thank you for your time,

~Jeff Berckes

"Empowering Iowans to Revitalize Rivers, Lakes, Streams, & Groundwater by Fostering Community Partnerships and Offering Technical Guidance"

Jeff Berckes, TMDL Program Coordinator
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Des Moines, IA 50319-0034
515-281-4791 (office) 515-281-8895 (fax)
jeff.berckes@dnr.iowa.gov

From: Dorothy Jarmes [mailto:jarmes@acrec.com]
Sent: Thursday, July 09, 2009 8:12 AM
To: Berckes, Jeff [DNR]

Berckes, Jeff [DNR]

From: Dorothy Jarmes [jarmes@acrec.com]
Sent: Thursday, July 09, 2009 4:45 PM
To: Berckes, Jeff [DNR]
Subject: RE: Article in Postville paper.

Yes I do have a question. What are you going to do about it? You know where it is coming from and who is responsible, so why do you not shut them down. Agriprocessors isn't good for the community and our water supply. And the new owners if they are new owners will be the same. As far as going to the meeting it will be more double talk. Years ago there was a committee that was trying to stop all the salt from going in to Hecker Creek, We run in to a wall of government barricades that could see nothing wrong. They did drill some wells to test the water, do not know how that turned out. I guess I do not understand why you say biological cause unknown? You do know but refuse to do any thing about it. There has been fines against Agriprocessors and either they do not pay them at all or the government reduces them to pennies on the dollar. I get so upset when there is articles in the papers that say Postville got just what it deserved because the people knew what was going on. Yes we did but tell me what you can do about it. The government will not listen !!!! I know for a fact that ICE were told on many occasions that we had a lot of illegals. Also as far as the water in Hecker Creek we tried to stop the dumping of salt.

Jim and Dorothy Jarmes

-------*Original Message*-------

From: Berckes, Jeff [DNR]
Date: 07/09/09 14:11:53
To: Dorothy Jarmes
Subject: RE: Article in Postville paper.

Dorothy & Jim,
Thank you for your e-mail and your interest in Hecker Creek and the DNR's Stressor Identification. Your e-mail was a little unclear as to what you are requesting, so please reply if I do not completely address your concerns.
The press release, unfortunately, did not convey our intended message as clearly as I would have hoped. Hecker Creek is listed on the state's impaired waters list for "biological, cause unknown". When a waterbody is listed as a biological impairment, it is because sampling data from the area indicate the biological community was not performing up to expectations or due to a fish kill with unknown causes. The DNR then conducts a Stressor Identification on the stream to determine the causes of the impairment or fish kill. For Hecker Creek, the Stressor Identification determined that the aquatic life community does not meet expectations due to high levels of chloride (salt) and habitat alterations. To your point, Agriprocessors is identified in the document as the source of chloride contributions from their discharge, due to the kosher process using high levels of salt (aka sodium chloride). If you would like a preview of the document, it can be located on our webpage:
http://www.iowadnr.gov/water/watershed/tmdl/publicnotice.html
We are required by the Clean Water Act to investigate all impairments on the state's impaired waters list, and we choose to devote our efforts to waterbodies that have local interest. Hecker Creek and the Yellow River are important resources, and the local interest in the Hecker Creek impairment directed our efforts there. The presentation in Postville will explain the Stressor Identification and its results. I encourage you to attend the meeting if you are able to make it. Again, please let me know if you have any additional questions.
Thank you for your time,
~Jeff Berckes

Berckes, Jeff [DNR]

From: Berckes, Jeff [DNR]
Sent: Monday, July 13, 2009 7:32 AM
To: 'Dorothy Jarmes'
Subject: RE: Article in Postville paper.

Jim and Dorothy,

The DNR is committed to the protection of Iowa's natural resources. In addition to the Stressor Identification the TMDL program completed on Hecker Creek, the following actions will help protect Hecker Creek.

Agriprocessors has current chloride limits that arose out of a lawsuit and were approved by the court. Since that time we have adopted new stream protection standards. Hecker Creek will receive increased protections in regard to chloride. We are also in the process of rulemaking to adopt a statewide chloride standard. You can submit comments on that standard through August 14th. The information to submit comments is in the attached article, below the article you originally commented on.

The Stressor Identification, the stream redesignation, and the adoption of a chloride standard will all necessitate a decrease in the discharge of chloride from the Agriprocessors facility. We are diligently working to get these new protections established but the rulemaking process is a lengthy one.

Thank you again for your comments. I hope that you are able to make it to the meeting next week.

~Jeff Berckes

"Empowering Iowans to Revitalize Rivers, Lakes, Streams, & Groundwater by Fostering Community Partnerships and Offering Technical Guidance"

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From: Dorothy Jarmes [mailto:jarmes@acrec.com]
Sent: Thursday, July 09, 2009 4:45 PM
To: Berckes, Jeff [DNR]
Subject: RE: Article in Postville paper.

Yes I do have a question. What are you going to do about it? You know where it is coming from and who is responsible, so why do you not shut them down. Agriprocessors isn't good for the community and our water supply. And the new owners if they are new owners will be the same. As far as going to the meeting it will be more double talk. Years ago there was a committee that was trying to stop all the salt from going in to Hecker Creek, We run in to a wall of government barricades that could see nothing wrong. They did drill some wells to test the water, do not know how that turned out. I guess I do not understand why you say biological cause unknown? You do know but refuse to do any thing about it. There has been fines against Agriprocessors and either they