Stressor Identification

for

Walnut Creek

Poweshiek County, Iowa

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Watershed Improvement Section
&
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2012

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Acknowledgements

The following IDNR staff prepared this document Jen Kurth, Jason Palmer, Lisa Fascher, Jackie Gautsch, Ken Krier, Brandon Harland, and Tom Wilton. Jamie Mootz provided data management support. Sampling data were collected and analyzed by staff of the State Hygienic Laboratory at the University of Iowa under cooperative agreements with the IDNR Ambient Water Monitoring and the TMDL programs. Financial support was provided by the State Environment First fund and various Federal Clean Water Act (Sections 104(b), 106, 319, 604(b)) program funds administered through Region VII, U.S. EPA, Kansas City, Kansas.

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Executive Summary

A Stressor Identification (SI) was completed for the upper segment of Walnut Creek (305(b) Segment: IA 02-IOW-0187_2) in Poweshiek County, Iowa. Walnut Creek is a tributary of the Iowa River. This waterbody is identified on Iowa's Section 305(b)/303(d) Integrated Report (IR) 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) may be required.

The first biological assessment of Walnut Creek occurred in the summer of 1999 as part of the Iowa Department of Natural Resources (IDNR) stream biocriteria project. The assessment uncovered evidence of biological impairment of the fish community. Biological sampling in 2008 confirmed the impairment still existed, and further sampling conducted in 2009 showed impairments in the fish community at multiple sites. Stream data and information about the watershed were reviewed to determine the cause(s) of impairment.

Despite existing data limitations, the evidence was sufficient to identify the following primary stressors, which are capable of causing biological impairment in the Walnut Creek watershed: increased peak flow frequency and magnitude, increase suspended and deposited fine sediments, decrease macro-habitat complexity, and decreased in-stream cover and epifaunal micro-habitat. The major stressors contributing to the impairment of Walnut Creek can all be linked to alterations in the watershed that have increased the speed with which water comes off the land and moves through the stream system. Extensive stream channelization has taken place in Walnut Creek. Channel straightening work had already occurred in the upper half of the watershed before the first aerial photos were taken in the 1930s. Since the 1930s, the stream length has been shortened by an additional 38.5 percent, with the majority of the work being done between the 1930s and 1950s. Stream channelization increases gradient, alters hydrology, affects sediment supply and processing dynamics, alters food web interactions, and results in a more homogeneous channel network, which eliminates quality in-stream habitat.

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) and/or implementation plans need to address the primary stressor(s) by focusing on all the ways these stressors, including their sources, lead to the biological impairment in this watershed. The identified stressors for Walnut Creek are all related to the channelization of the majority of the stream, and are not pollutants. Therefore a TMDL is not needed to address this impaired waterbody.

1. Introduction

This Stressor Identification (SI) for the upper segment of Walnut Creek [305(b) Segment IA 02-IOW-0187_2] was completed to determine the causes of the biological impairment including any pollutant for which a Total Maximum Daily Load (TMDL) is required. The SI includes a review of available data for the entire watershed of the upper segment of Walnut 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 type of stressor (e.g. channelization), the latter of which may not require a TMDL. However, regardless of whether or not the stressors are defined as a pollutant, a complete SI should identify all causal agents and pathways that are responsible for impairing the aquatic biological community.

1.1. Watershed Features

Walnut Creek is a warmwater stream located in northeastern Poweshiek County, Iowa, within the Iowa River basin. The watershed includes a total of 58,019 acres (90.65 square miles), is comprised of three Hydrologic Unit Code (HUC) 12s (Upper Walnut, Lower Walnut, and North Walnut) (Figure 1-1) and includes three impaired segments. To reduce the area to a size which can be more effectively monitored, it was decided to focus on the upper HUC 12 (070802080703) of Walnut Creek (Figure 1-2). The watershed is within the Rolling Loess Prairies-Western Corn Belt Plains ecoregion (47f) (Prior 1991; Griffith et al., 1994) (Appendix A, Figure A-1). This ecoregion is characterized by loess deposits on well drained plains and open low hills. Loess deposits in the region around Walnut Creek tend to be thinner than those found in the western portions of the ecoregion. The loess deposits near Walnut Creek are generally less than 25 feet in depth over clay loam till, Pennsylvanian and Cretaceous shale, sandstone and limestone. Although cropland agriculture is widespread, this region has more areas of woodland and pasture than some neighboring ecoregions.

The upper HUC 12 of the Walnut Creek watershed (hereafter known as Walnut Creek) includes a total of 26,227 acres (40.98 square miles) in northeastern Poweshiek County, from the headwaters (approximately five miles north of Grinnell) to the confluence with North Walnut Creek (approximately 2.6 miles northeast of Holiday Lake) (Figure 1-2). During baseflow conditions the channel of Walnut Creek extends for about 18 miles. The surface topography is characterized by a branching drainage pattern that directs streams and runoff east toward the Iowa River. Elevations range from approximately 1,000 feet above mean sea level at the headwaters to 800 feet above mean sea level at the confluence with North Walnut Creek (Figure 1-3).

An average basin slope (the average slope of the watershed) of 5.3 percent and a stream density of 1.52 (the ratio of stream miles to square miles of the basin) indicate that surface flows reach the stream quickly. Additionally, the watershed has a large number surface intake tiles from terraces (Figure 1-4) which impact surface water transport dynamics. The stream channel has also been extensively straightened. The upper half of the watershed was mostly straightened before the first aerial photos were taken in the 1930s. Since the 1930s, the stream length has been shortened by an additional 38.5 percent, with the majority of the work done between the 1930s and 1950s. Straightening increases stream gradient and creates a more homogeneous channel. 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 woody debris and habitat complexity, which were associated with reduced fish species diversity and abundance (Paragamian 1987; Heitke et al. 2006).

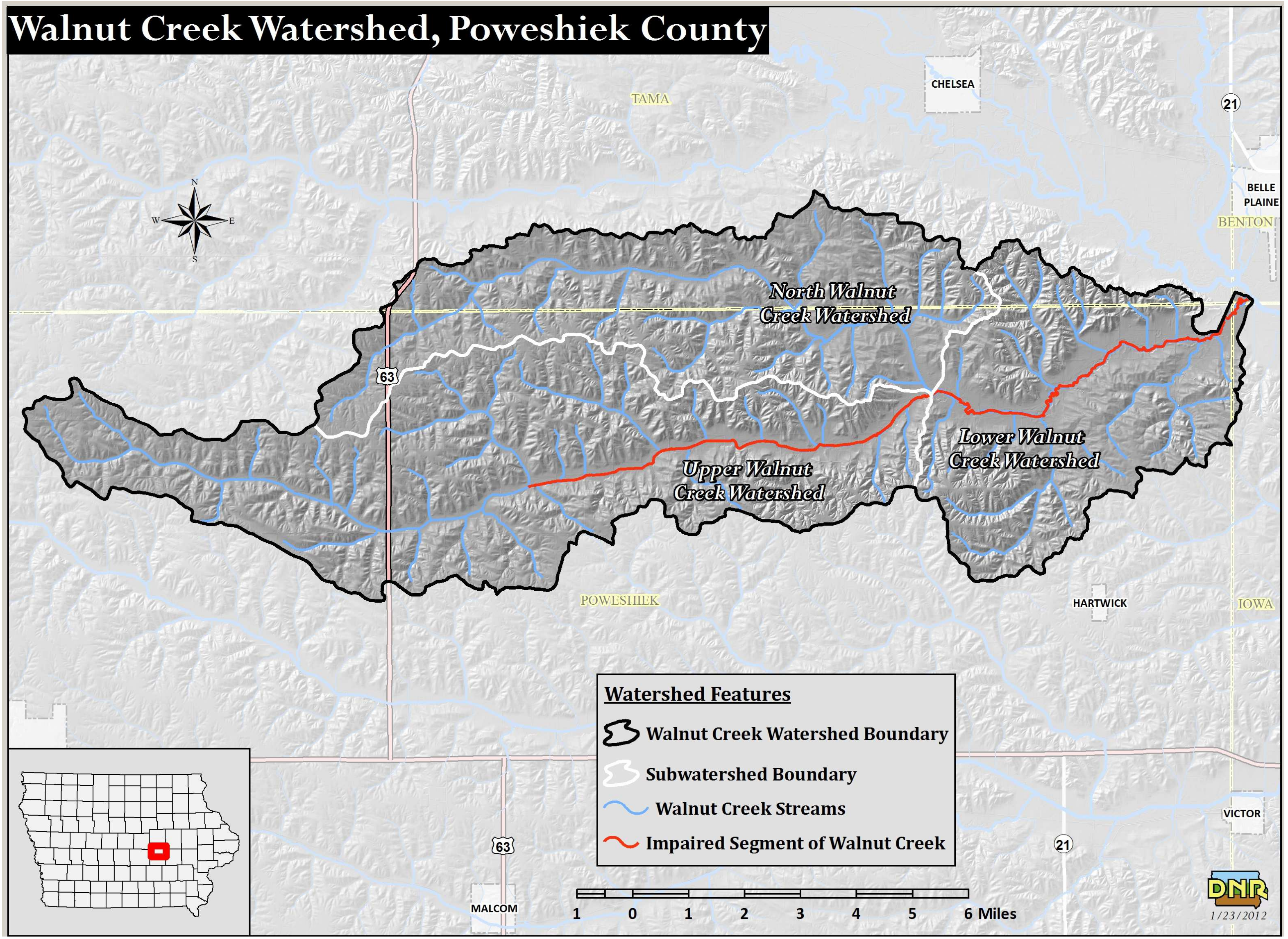

Figure 1-1. Entire Walnut Creek watershed with all three HUC-12s shown.

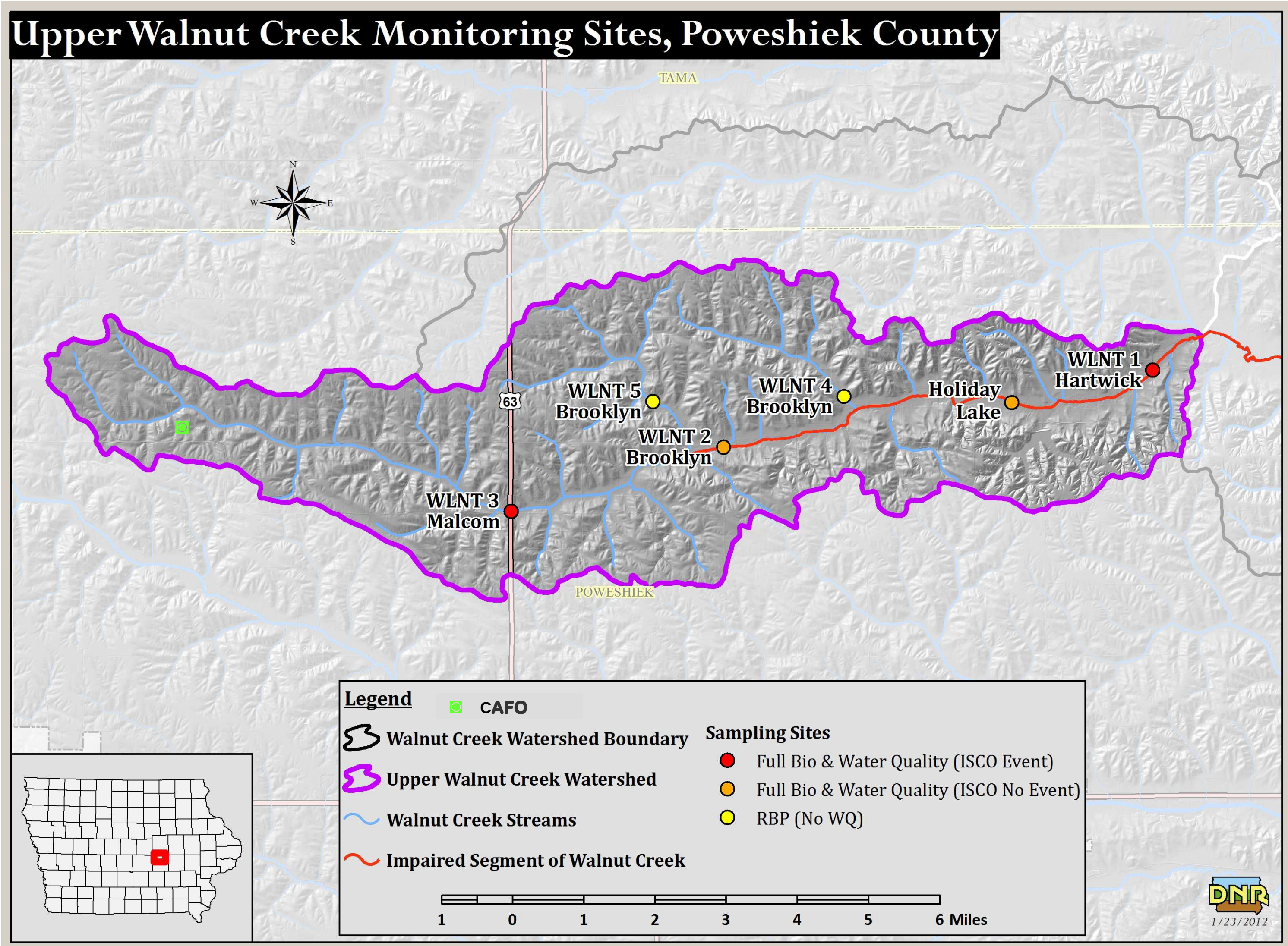

Figure 1-2. The Upper Walnut Creek watershed showing location of sampling sites, confined animal feeding operation (CAFO), and impaired segments in the watershed.

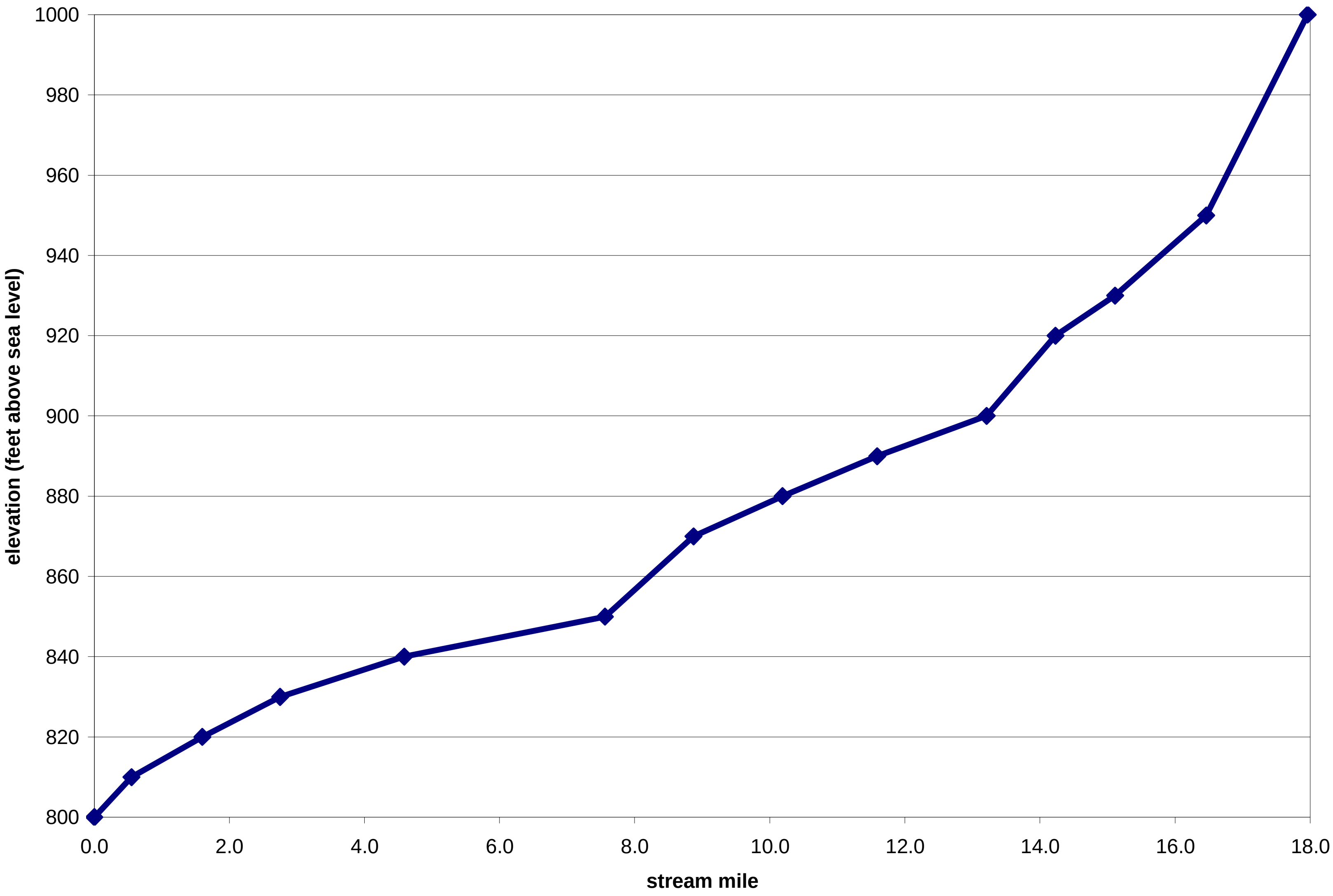

Figure 1-3. Walnut Creek stream gradient profile (mile zero represents confluence with North Walnut Creek).

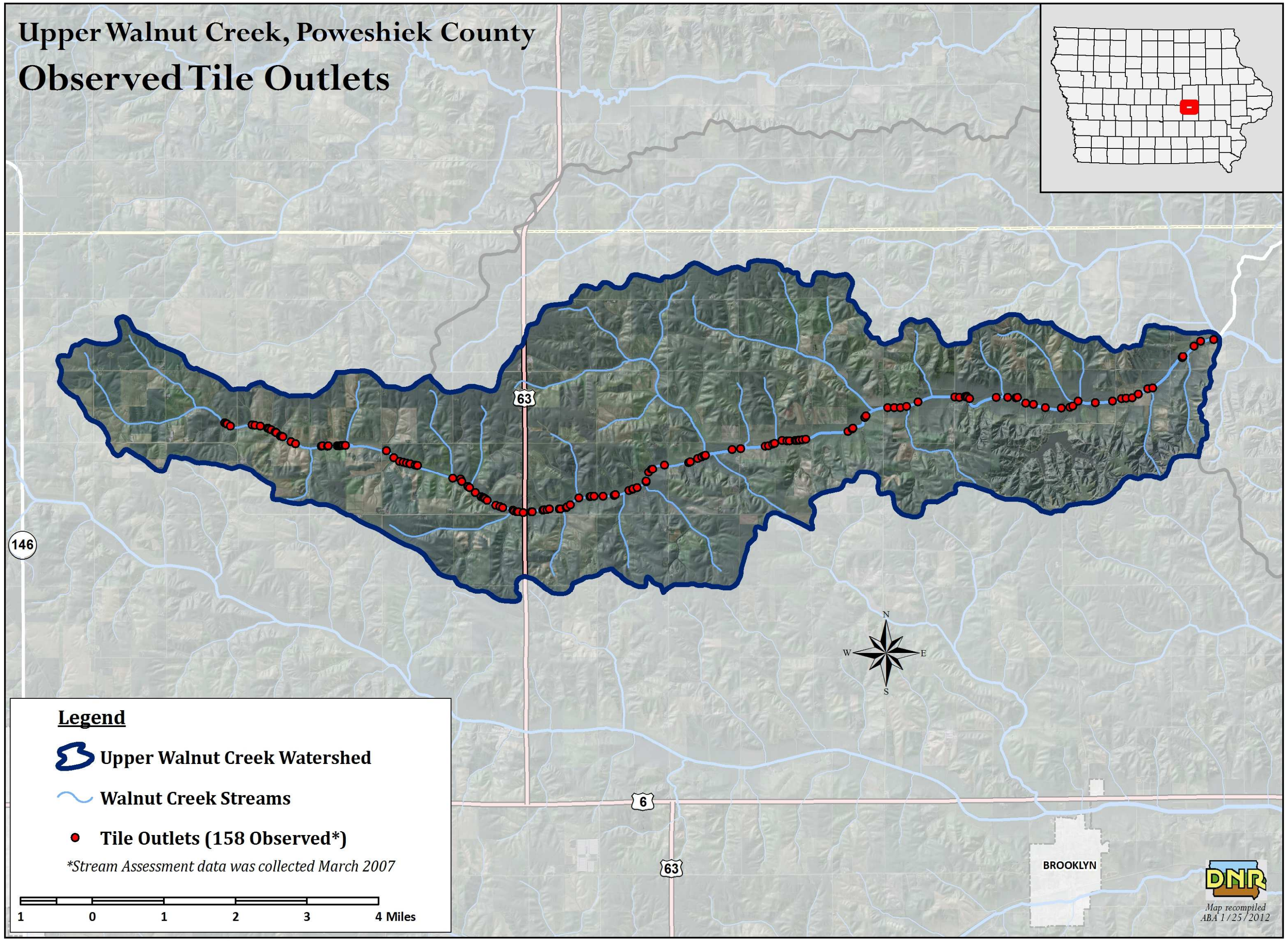

Figure 1-4. Tile outlets in the Walnut Creek watershed.

The geology of the Walnut Creek watershed is characterized by loess deposits on well drained plains and open low hills. The soils found in the Walnut Creek watershed are part of the Tama-Kilduff association, the Muscatine-Garwin association, and the Colo-Nodaway association. The Tama-Kilduff association consists mainly of gently sloping and moderately sloping soils on ridgetops and side slopes and are well-drained to moderately well-drained soils that formed in loess. The Muscatine-Garwin association consists mainly of soils on wide ridgetops and divides and is comprised of poorly-drained to somewhat poorly drained soils that formed in loess. The Colo-Nodaway association consists of nearly level soils on bottom lands, nearly all of which formed in alluvium and are poorly-drained to moderately well-drained soils.

Land use in the watershed is dominated by agriculture (Appendix B, Figure B-1). According to land use data from 2002, approximately 70 percent of the 26,227 acres in the watershed are devoted to row crop agriculture. There is one large confined animal feeding operation (CAFO) in the watershed with 2,490 hogs and a pit for manure storage (Figure 1-2). There are no permitted municipal or industrial point sources in the watershed.

1.2. Stream Flow and Water Quality

The Walnut Creek hydrograph from the 2009 monitoring season shows a large percentage of discharge from surface flow driven storm events. The maximum measured flow in Walnut Creek during the monitoring period was 1,691 cubic feet per second (cfs) on August 27, 2009 during a storm event at site WLNT1 when the Grinnell weather station recorded 4.18 inches of rain. The maximum average daily flow also occurred on that date at site WLNT1 (974 cfs), while the minimum average daily flow was 0.8 cfs on August 15, 2009 at site WLNT3 (Figure 1-5).

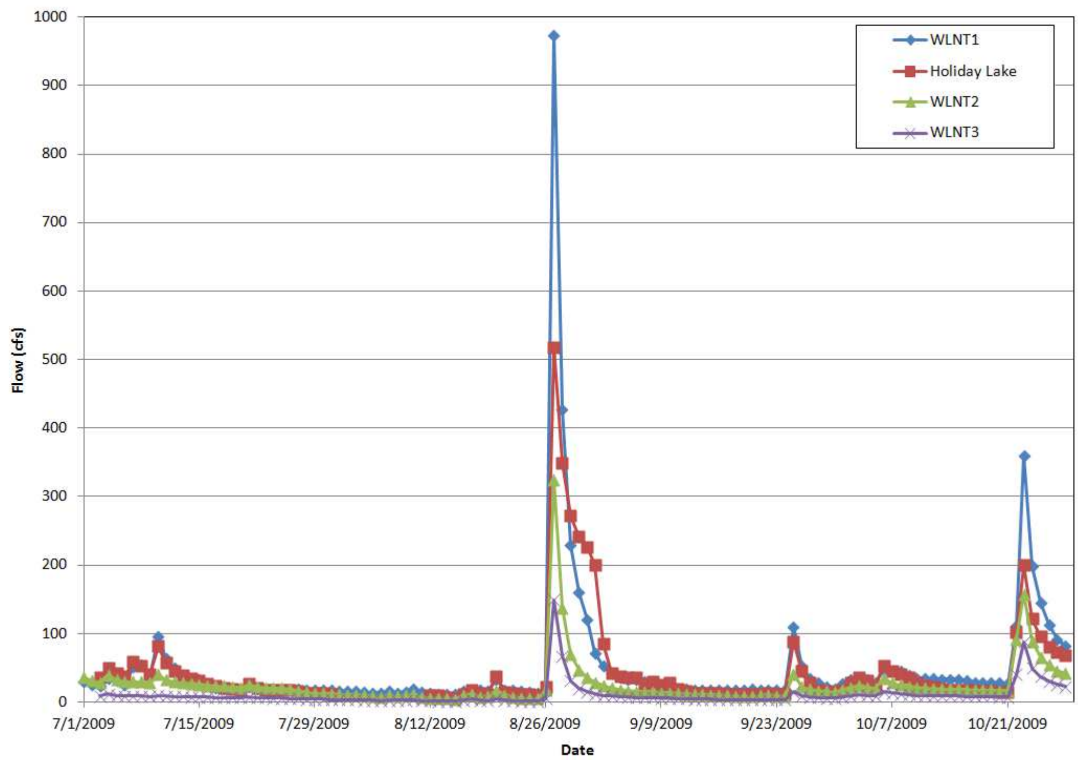

Figure 1-5. Walnut Creek average daily flows.

The nearest U.S. Geological Survey (USGS) stream flow gauge is on Walnut Creek approximate one mile downstream of the confluence with North Walnut Creek (Gauge No. 05452200). The average daily flows measured at the USGS gage show similar hydrographs compared to the average daily flows at WLNT1 (Figure 1-6).

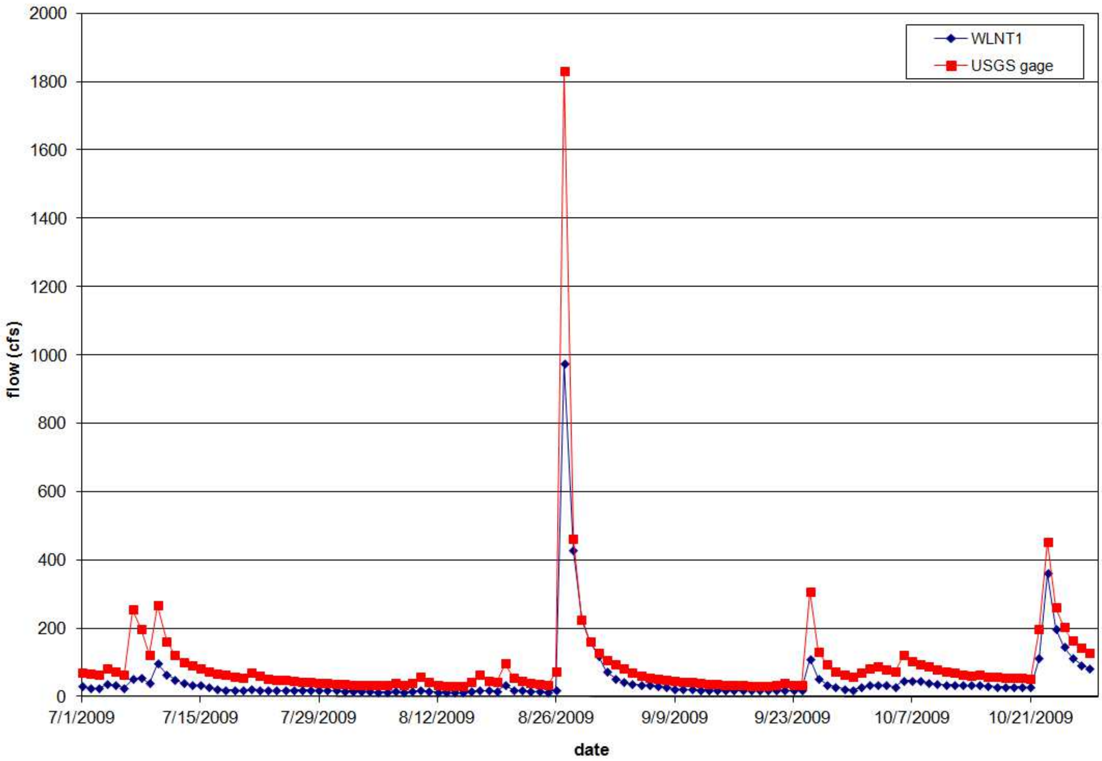

Figure 1-6. USGS stream flow gage average daily flows for Walnut Creek compared with average daily flows at WLNT1.

Water quality characteristics measured at Walnut Creek are generally indicative of intensive agricultural land uses (Appendix B; Table B-1 through B-3). Mean concentrations of nitrogen at the monitoring sites were at the upper end of the ecoregion reference stream site interquartile range, while mean concentrations of phosphorus and total suspended solids/turbidity in storm event samples were elevated compared to the state-wide sampling data (Table 1-1). Mean concentrations of ammonia and dissolved oxygen, however, met ecoregion expectations.

Table 1-1. Water quality measurements for Walnut Creek compared to ecoregion (bi-weekly grab sample) or statewide data (storm event sampling).

Parameter	WLNT1	WLNT3	Interquartile range	Data Source
Ammonia (mg/L)	< 0.5	< 0.5	0.5-0.6	Ecoregion
Dissolved oxygen (mg/L)	9.4	10.9	8.0-9.4	Ecoregion
Nitrogen (mg/L)	5.1	6.7	1.4-6.6	Ecoregion
Phosphorus (mg/L)	1.7	0.8	0.09-0.42	State-wide
Total Suspended Solids (mg/L)	1966.7	435.0	80-360	State-wide
Turbidity (NTU)	815.0	169.3	47-240	State-wide

1.3. Biological Impairment

Walnut Creek (305(b) segment: IA 02-IOW-0187_2) was first added to the Section 305(b)/303(d) (IR) impaired waters list in 2002, based on biological and habitat sampling conducted in 1999 as part of the Iowa Department of Natural Resources (IDNR) stream biocriteria monitoring. A series of biological metrics that reflect stream water quality and habitat integrity were calculated from sampling data collected at a site (Holiday Lake) approximately 3 miles upstream of the confluence with North Walnut Creek (Figure 1-1). 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 without backbones and are large enough to be seen without magnification. 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 various life stages of aquatic insects such as stonefly and mayfly nymphs.

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

Biological sampling from reference streams in Iowa's ecoregions has been used to derive biological impairment criteria (BICs) 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 BICs are the minimum threshold considered to support aquatic life use in ecoregion 47f (Table 1-1). 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 1999 FIBI score for Walnut Creek was 24 (poor) and the BMIBI score was 55 (fair). The aquatic life use was assessed as not supporting because the FIBI score did not attain the ecoregion BIC.

Biological and habitat sampling was repeated in 2008 and 2009 at the original site (Holiday Lake) and in 2009 at three new sites (Figure 1-1). Additional biological sampling using the Rapid Bioassessment Protocols (RBP) was done in 2009 at sites on two of the larger tributaries to Walnut Creek. Additionally, water chemistry data were collected at sites WLNT1, WLNT2, WLNT 3, and Holiday Lake (Figure 1-1) in 2009-2010 for the purpose of stressor identification. The BMIBI scores met the BICs at all sites in all years except for 2008 at Holiday Lake, but the FIBI scores failed at all sites in all years except WLNT1 in 2009, confirming the biological impairment first documented in 1999 (Table 1-1).

Table 1-2. Scores for indices of biological integrity for benthic macroinvertebrates and fish from biological sampling in 1999, 2008, and 2009 compared to ecoregion biological impairment criteria.

Site	WLNT1	Holiday Lake			WLNT2	WLNT3	BIC for ecoregion 47f
Year	2009	1999	2008	2009	2009	2009	
FIBI	54	24	31	26	29	23	36
BMIBI	63	55	40	57	62	53	51

The BMIBI and FIBI results are the primary evidence used to evaluate for aquatic life use impairment in the Walnut 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 Walnut Creek sampling (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). Benthic macroinvertebrates are generally doing well, but the bulk of the community was comprised of only a few taxa and there were increasing percentages of chironomids (midge larvae) going upstream in the watershed. Higher numbers of chironomids are generally indicative of increasing organic enrichment. The exception to this is the Holiday Lake site in 2008. However, looking at the stream discharge and stage data from the USGS gage there was a storm event in the watershed three days prior to the 2008 biological sampling which had high flows that could have scoured many of the benthic macroinvertebrates in the stream. Based on the FIBI metric analysis, it was determined that metrics of concern were as follows: low numbers of native fish species (except at lowest site), the top three most abundant species make up 2/3 to 3/4 of the assemblage, a lack of carnivores and lithophilous spawners (fish that need gravel/cobble substrates for spawning), extremely low numbers of sensitive fish species, low numbers of fish caught, and community composed primarily of species fairly tolerant of stream degradation.

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://www.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 most 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 (e.g. fertilizer application) with proximate stressors (e.g. low dissolved oxygen). From this perspective, an impairment cause can be viewed more broadly as encompassing the stressor itself (e.g. 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 (e.g. nutrients from 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, those candidate causes which were not evaluated due to a lack of data can be revisited should further monitoring produce such data. The results of the candidate cause rating process for the Walnut Creek watershed biological impairments are displayed in Table 2-1.

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

Candidate cause	Ranking
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	ND
● Cyanide	ND
● Oil / grease	ND
● PAHs	ND
● Pharmaceuticals	ND
● SOCs	ND
● Un-ionized ammonia	2
● Other	
Pesticides	
● Fungicides	ND
● Herbicides	ND
● Insecticides	ND
● Other	
Water Quality Characteristics	
● Chlorophyll a	2
● Dissolved oxygen	2
● Nutrients	
Nitrogen	1.5
Phosphorus	2
● pH	2
● Salinity / TDS / Chloride	3
● Turbidity / TSS	1.5
● Water temperature	2.5

Candidate cause	Ranking
Habitat Alterations	
● Bank erosion	1
● Channel incision/loss of flood plain connectivity	1
● Channel straightening	1
● Dewatering	3
● Excessive algae/macrophyte growth	2
● Flow impoundment	3
● Lack of woody debris/roughness/structure	1.5
● Physical barriers	2
● Riparian vegetation loss	1.5
● Sedimentation	1
Hydrologic Alterations	
● Flow diversion—sinkholes	3
● Flow regulations—dams	2.5
● Pumping (withdrawals)	3
● Subsurface tile drainage	2
● Urban stormwater outfalls	3
● Wetland loss	2.5
Exotic/Introduced Species and Other Biotic Factors	
● Competition	2
● Disease	3
● Endocrine disruption	3
● 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 Walnut 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 Walnut 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 Walnut Creek watershed with data collected for the IDNR stream biological assessment program. Walnut Creek sampling data and benchmarks reviewed for the stressor co-occurrence and stressor-response evidence considerations are summarized in Appendix B, Table B-4. In addition to water quality and stream habitat data, diurnal temperature and dissolved oxygen (DO) fluctuations were monitored in July 2009 for 14 days at WLNT1, WLNT2, and WLNT3 (Appendix B; Figures B-2 through B-4). There was also a datalogger deployment at the Holiday Lake site, but the battery failed approximately five days into the deployment (Appendix B; Figure B-5). 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, Walnut Creek stressor indicator data were compared with interquartile data ranges (25^{th} to 75^{th} percentile) for stream reference sites within the Rolling Loess Prairie ecoregion. In cases when reference data were not available, Walnut 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.

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, Walnut 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: *Spatial Co-occurrence, Biological Gradient, Plausible Effect Given Stressor-Response Relationship; Complete Causal Pathway and Consistency of Association*. All of these incorporated data from Walnut Creek along with ecoregion-specific or statewide sampling data. *Predictive Performance* and *Analogy* were not used because they were not applicable or no analogous stressor-response scenarios were identified. Other lines of evidence were selectively applied depending on the stressor and data/evidence. Rankings for each type of evidence consideration were then evaluated to reach a final rating for each potential proximate stressor (Table 4-1).

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

Proximate Stressor	Final Rating
Increased low flow frequency and magnitude	-
Increased peak flow frequency and magnitude	+
Change in daily/seasonal flow patterns	-
Increased suspended sediment	+
Increased deposited fine sediment	+
Decreased allochthonous food resources	-
Decreased primary producers (algae and macrophytes)	-
Increased/change in primary producer composition (sestonic algae)	-
Increased/change in primary producer composition (benthic algae/macrophytes)	-
Decreased primary producers (algae and macrophytes)	-
Decreased dissolved oxygen	-
Increased ammonia	-
Decreased macro-habitat complexity	+
Decreased instream cover/epifaunal micro-habitat	+
Decreased colonization potential	-
Disease	-
Increased kills (fish and benthic macroinvertebrates)	-
Competition	o

o = ambiguous or not enough evidence; + = supporting evidence; - = no 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: increased peak flow frequency and magnitude, decreased macro-habitat complexity, decreased in-stream cover and epifaunal micro-habitat, and increased suspended and deposited fine sediments. The supporting evidence for each primary cause (i.e., proximate stressor and associated causal pathways) is described below.

Increased peak flow frequency and magnitude:

Increases in stream flow velocities impact biota directly through increased hydraulic scour of benthic surfaces and indirectly through alteration of habitat. Organisms exposed to these shear forces may be dislodged and transported downstream, experience stresses that reduce reproduction and feeding efficiency, or may suffer from direct mortality. Increased in-stream velocities also have indirect impacts on stream biota. Large increases in stream velocity can scour periphyton, which mainly grows on the upper surfaces of benthic substrate, reducing food available for organisms. While changes in weather patterns can contribute to increased peak flows, the most common variables associated with increased peak velocities are alterations to the stream channel and changes to the watershed which increase runoff potential.

Channelization, the artificial straightening and dredging of streams, has been widely practiced in the United States. Streams are channelized to improve watershed drainage, increase agricultural production, and to provide flood control. Channelization usually involves clearing banks and channels of vegetation, removing large boulders and cobbles from the channels, and depositing the dredge spoils along the banks for levees. Energy, that would normally have been dissipated by the natural meandering of the stream channel or by spreading out into the floodplain, becomes focused on down-cutting the stream bottom, leading to incised channels that are even less connected to the flood plain.

The stream channel in Walnut Creek has been extensively straightened (Figure 4-1). The upper half of the watershed was mostly straightened before the first aerial photos were taken in the 1930s. Since the 1930s, the stream length has been shortened by an additional 38.5 percent, with the majority of the work being done between the 1930s and 1950s. Additionally, an average basin slope (the average slope of the watershed) of 5.3 percent and a stream density of 1.52 (the ratio of stream miles to square miles of the basin) indicate that surface flows reach the stream quickly.

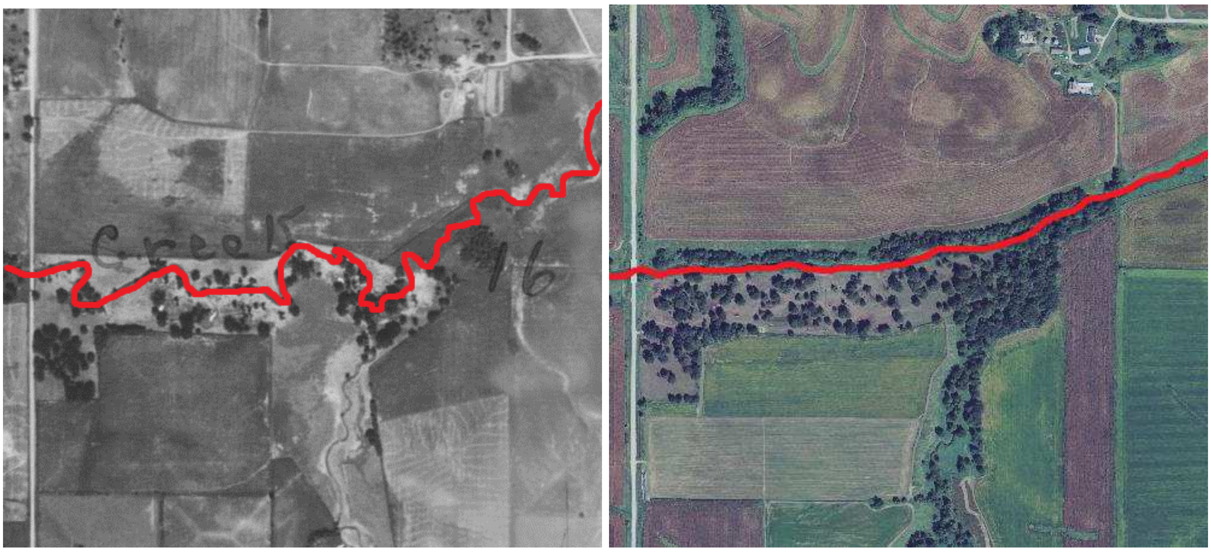

Figure 4-1. Aerial photography of a section of Walnut Creek in 1930 (left) and 2010 (right) showing channelization that has occurred in the watershed. Road shown at left of pictures is 150th St.

Additionally, the watershed has a large number of surface intake tiles from terraces (Figure 1-3) which impact surface water transport dynamics. All of this contributes to increases in peak flow frequencies and magnitudes. During storm events in the Walnut Creek watershed, runoff reaches the stream quickly, causing a rapid rise in the hydrograph (Figure 4-2) and an equally rapid fall after the storm has passed. With just over three inches of rain on August 26-27, 2009, the flow increase by an order of magnitude in just 8 hours at sites WLNT1 and WLNT3. Under more natural (less altered) conditions, the rise and fall in the hydrograph would be much more gradual.

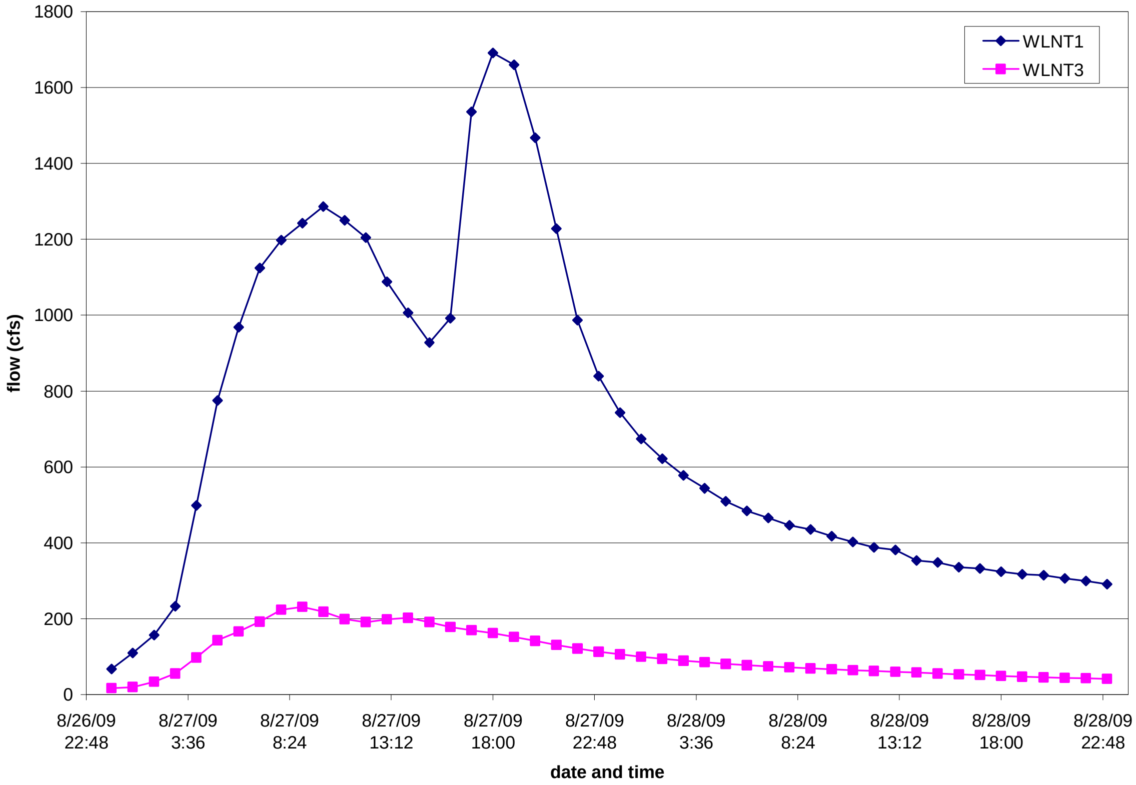

Figure 4-2. Hydrograph for storm event at sites WLNT1 and WLNT3.

<u>Habitat Alterations:</u>

Decreased macro-habitat complexity, in-stream cover, and epifaunal micro-habitat have been identified as primary stressors in Walnut Creek. These stressors are directly linked to increases in peak flow frequency and magnitude, and to the stream channelization activities in the watershed. In-stream cover is areas of shelter in a stream channel that provide aquatic organisms protection from predators or competitors and/or provide refuge from the force of the current. Epifaunal micro-habitat refers to the surfaces of a substrate, such as rocks, pilings, aquatic vegetation, or the stream bottom itself on which benthic macroinvertebrates may live.

Channel and floodplain modification and changes in discharge caused by changes in watershed land use may alter physical features of the stream network. This includes, peak discharge, lateral and longitudinal connectivity, sediment transport characteristics, and the retention and accumulation of woody debris and organic materials. 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 et al. 2006).

Increases in peak velocity will also result in changes in channel geomorphology. Typical reactions include channel incision (bed degradation) (Figure 4-3) followed by channel widening (stream bank sloughing/erosion) (Figure 4-4). These channel adjustments are a direct response to increased flow and are predictable and constant across landscapes (Lane, 1955; Simon, 1999). Large scale changes in channel form impact micro and macro habitat stability and availability, placing stress on resident biota. Additionally, at high flows, current velocity is increased as is bed shear stress and stress on biota. Incision isolates the channel from the floodplain, preventing fish from accessing preferred spawning and rearing habitats and from entering low-velocity refuges during periods of high discharge.

Figure 4-3. Deeply incised channel of Walnut Creek and eroding stream banks in 2007.

Figure 4-4. Row crop agriculture immediately adjacent to Walnut Creek with stream bank sloughing and erosion.

Alterations to a stream's natural hydrologic regime, such as channelization and/or artificial drainage, can cause an imbalance in the natural discharge-sediment load equilibrium of the stream and lead to bed and bank degradation (Lane, 1955) (Figure 4-4). This process leads to embedded coarse substrates, buried riffles, filled in pools, and ultimately results in an unstable, homogenous stream bottom with little variation in depth and habitat diversity (Figure 4-5).

Figure 4-5. Picture of Walnut Creek showing homogenous stream bottom with little depth variation and habitat diversity.

As pools fill in with sediment and eventually disappear, they no longer provide refuge at low flow, forcing fish to inhabit shallower areas with increasing temperatures and decreased dissolved oxygen (Smale and Rabeni 1995). Rowe et al. (2009) found a decrease in habitat diversity was associated with decreased fish diversity in Iowa wadeable streams. At the Holiday Lake site, the only site with multiple years of data, the channel riffle/run/pool composition changes dramatically over time with a marked decrease in pool habitat (Table 4-2).

Table 4-2. Change in channel bedform characteristics at Holiday Lake sampling site.

	1999	2008	2009
Percent riffle	0	0	0
Percent run	35.7	96.4	100
Percent pool	64.3	3.6	0

Sedimentation:

Sediment storage and transport are natural functions of stream ecosystems. In highly altered streams like Walnut Creek, however, excessive levels of deposited and suspended sediment can have detrimental effects on aquatic communities. In Walnut Creek, sedimentation issues are primarily linked to increases in peak flow frequency and magnitude, and to the stream channelization activities in the watershed.

Excessive sediment loads delivered from upland watershed sources via sheet, rill, and gully erosion can result in sediment deposition (siltation) in streams, causing a loss of aquatic habitat and reduced channel transport capacity. Excessive turbidity and siltation can be detrimental for sight-feeding fish, benthic-dwelling organisms, and basic aquatic life functions. It also reduces hatching success by limiting the amount of dissolved oxygen in fish spawning beds, trapping the fry in the sediment after hatching, or reducing the area of habitat suitable for development. The estimated pre-project sheet and rill erosion from upland areas in the Walnut Creek watershed is 122,334 tons per year (Appendix B, Figure B-6). The estimated pre-project sediment delivery is 23,224 tons per year (Appendix B, Figure B-7). There has been a project in the Walnut Creek watershed since 2008 whose primary focus has been reducing sediment delivery.

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 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.

There were not enough coarse substrates found in Walnut Creek to estimate embeddedness. This may be due to increased fine sediment inputs, but also because the stream system may not naturally have a large amount of coarse substrate. In the stream assessment conducted in 2007, the largest substrate particle size noted was gravel. Additionally, during the act of straightening, the stream channel was relocated, abandoning much of the original streambed. This would likely be where most of the available coarse material would likely been deposited over time in this watershed.

All sites had 100 percent soft substrates in the thalweg (deepest part of the stream), except for WLNT1 (92.9 percent), which was the only site with passing FIBI scores. Heitke et al. (2006) found a negative correlation between FIBI scores and reaches with fine substrates and unvegetated banks. Excessive fine substrates have been shown to specifically reduce the abundance of benthic invertivores, herbivores, and simple lithophilous spawners (Berkman and Rabeni 1987). Low numbers of benthic invertivores and a lack of simple lithophilous spawners at all sites except WLNT1 contributed greatly to the FIBI scores not meeting ecoregion expectations.

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 (6,800 mg/L) and turbidity (2,600 NTU) levels observed in Walnut Creek were sampled at site WLNT1 in summer 2009 during elevated flow conditions (storm event). The median event levels of TSS (1,967 mg/L) and turbidity (815 NTU) for Walnut Creek exceeded the 75^{th} percentile (TSS = 360 mg/L and turbidity = 240 NTU) of statewide sites that had storm event monitoring (Appendix B, Table B-5).

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 Rolling Loess Prairies ecoregion. This is largely because sand, which makes up a dominant share of the substrate in this system, does not remain suspended at low flows. Base flow TSS is usually a result of high levels of silt or clay in the system. These components of soil are easily flushed out and have few places to accumulate in a channelized system.

As previously described, Walnut Creek has seen a reduction in length of over 38% due to channelization just since the 1930's. Walnut Creek has a main channel sinuosity of 1.09, indicating that the stream is almost perfectly straight from end to end. Heavily channelized systems like this have highly altered sediment and storage characteristics. The absence of flow heterogeneity (riffles, pools, inside or outside bends) leads to a lack of substrate heterogeneity (silt, sand, gravel, cobble or boulders). In a meandering stream the changes in flow direction and current velocities associated with natural stream features provide areas for a systems sediment load to sort out. This sorting is reflected in natural areas of sediment deposition (point bars, sand and gravel bars and riffles) and erosion (undercut banks and pools).

A meandering stream system will work toward equilibrium in sorting and processing the type and amount of sediment entering the system. In Walnut Creek the absence of any meandering stream features impairs the streams ability to process sediment in a natural way. A reduction in sediment will not provide the stream with the dynamic sediment processing functions necessary to build and maintain habitat suitable for support of a functioning stream ecosystem. In lieu of broad scale remaindering of this system any sediment reduction efforts (successful or not) are unlikely to result in improvements to the aquatic community.

5. From SI to TMDL

Because the SI process was initiated pursuant to Iowa's Section 303(d) listings 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: Siltation (1100), Suspended Solids (2100), Turbidity (2500), Flow Alteration (1500), 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.

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, nor are the cumulative effects of multiple stressors occurring together.

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. 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.

5.2. Conclusions

Despite existing data limitations, the evidence was sufficient to identify the following primary stressors, which are capable of causing biological impairment in the Walnut Creek watershed: increased peak flow frequency and magnitude, decreased macro-habitat complexity, decreased in-stream cover and epifaunal micro-habitat, and increased suspended and deposited fine sediments.

The major stressors contributing to the impairment of Walnut Creek can all be linked to alterations in the watershed that have increased the speed with which water comes off the land and moves through the stream system—mainly the channelization of the majority of the stream. Depending upon the causal mechanism, primary stressors can be manifested as short-term acute impacts or long-term chronic impacts to aquatic biota. To restore the biological condition of the stream to un-impaired status, TMDL and/or implementation plans need to address each of the primary stressors and multiple causal pathways that occur in the watershed. The identified stressors are all related to the channelization of the majority of the stream, and are not pollutants. 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 Walnut 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 Walnut 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 Walnut 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 a monitoring plan as discussed 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 major stressors contributing to the impairment of Walnut Creek can all be linked to the alterations in the watershed that have increased the speed with which water comes off the land and moves through the stream system, mainly the channelization of the majority of the stream. Without habitat and stream channel improvements, the fish community in Walnut 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 Walnut Creek, each with different effectiveness and costs. No single BMP will be able to sufficiently improve the condition of Walnut 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 Walnut 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, and would maximize opportunities for future technical and funding assistance.

Stream channel reconstruction
The quickest and most effective way to improve stream habitat and stream ecosystem function would be to reconstruct the stream channel. This would involve re-meandering the stream channel, creating riffle-run-pool sequences that would provide the varying depths and velocities that are best for aquatic life, and restoring connection to the floodplain. 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, as will reconnection to the floodplain. 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 most proactive alternative in terms of restoring habitat, it is also the most expensive and would require major construction because this would need to be done to a large portion of the stream. Simply doing this on a small section of stream while ignoring the dynamics at play in the rest of the system would likely result in an expensive failure. The newly manufactured habitat would be inundated with sediment from upstream and the newly placed structures battered by high velocities from upstream channelization. An alternative BMP would be a series of riffle pool structures placed at designed intervals which would raise water levels in the system, making it more likely that high flows would access the flood plain.

Runoff detention basins
Detention basins are water control structures providing both retention and treatment of runoff. These BMPS protect against flooding and, if properly designed and constructed, can reduce downstream erosion by slowing peak velocity and volume of stream flow. A basin functions by allowing large flows of water to enter during storm events but limits the outflow. By capturing and retaining runoff during storm events, detention basins improve both storm water quantity and quality.

Cover crops and no-till agriculture
Cover crops and no till will increase soil permeability and infiltration limiting the amount of runoff reaching the stream.

Riparian vegetation buffers
A riparian buffer is a vegetated area (a "buffer strip") near a stream, which helps shade and partially protects a stream from the impact of adjacent land uses. It plays a key role in increasing water quality in associated streams, rivers, and lakes, thus providing environmental benefits. Riparian buffers act to slow surface runoff and reduce nutrients and other pollutants entering a waterbody. They also serve to provide habitat and wildlife corridors in primarily agricultural areas, and can be key in reducing erosion by providing stream bank stabilization. Installing 180 foot riparian buffers along the stream corridor throughout the watershed will help slow runoff and remove nutrients and sediment. Additionally, providing a wide buffer will allow the stream to re-meander on its own, thus regaining some of its previous functions without threatening other land uses or infrastructure. This option is both economically viable and highly effective because it is not subject to design and construction limitations of active stream restoration techniques.

7. Monitoring Plan

While a TMDL is not required to address the stressors identified for Walnut Creek, continued 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 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 Walnut Creek attaining its designated use. However, as the current watershed project is in the process of wrapping up, there are no plans for future water quality monitoring or biological or habitat sampling in the Walnut Creek watershed.

Future water quality monitoring in the Walnut 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.gov/InsideDNR/RegulatoryWater/WaterQualityStandards/Rules.aspx. 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 State Hygienic Lab (SHL) to ensure accuracy and consistency of methods.

7.1. Monitoring Plan for Future Watershed Projects

Any monitoring plan for Walnut Creek should involve water chemistry sampling, biological sampling, habitat sampling, and continuous sampling for dissolved oxygen, temperature, and flow (Table 7-1) at a minimum of two sites in Walnut Creek. Ideally, sampling would occur at the sites sampled for the preparation of the SI (Figure 1-2).

Table 7-1. Monitoring plan for Walnut Creek.

Component	Sample Frequency	Parameters/Details
Water chemistry sampling	Bi-weekly from March to October	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 July to September	Dissolved oxygen autosampler deployment according to IDNR protocols
Continuous stage or flow	15-60 minute intervals	Continuous flow or stage. will require manual flow measures (coincident with water chemistry sampling) to develop discharge rating curve for flow calculations.

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 Walnut Creek.

8.1. Public Meeting

May 13, 2009: met with Walnut Creek project coordinator and staff from State Hygienic Lab, and Iowa DNR regarding coordination of monitoring between Stressor Identification sampling and 319 sampling.

April 5, 2012: public meeting at Grinnell College to explain results of stressor identification for Walnut Creek. Approximately 25 people in attendance, including project coordinator, NRCS staff for Poweshiek County, local landowners, and Grinnell College faculty and students.

8.2. Written Comments

No written comments received.

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10. Appendices

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.

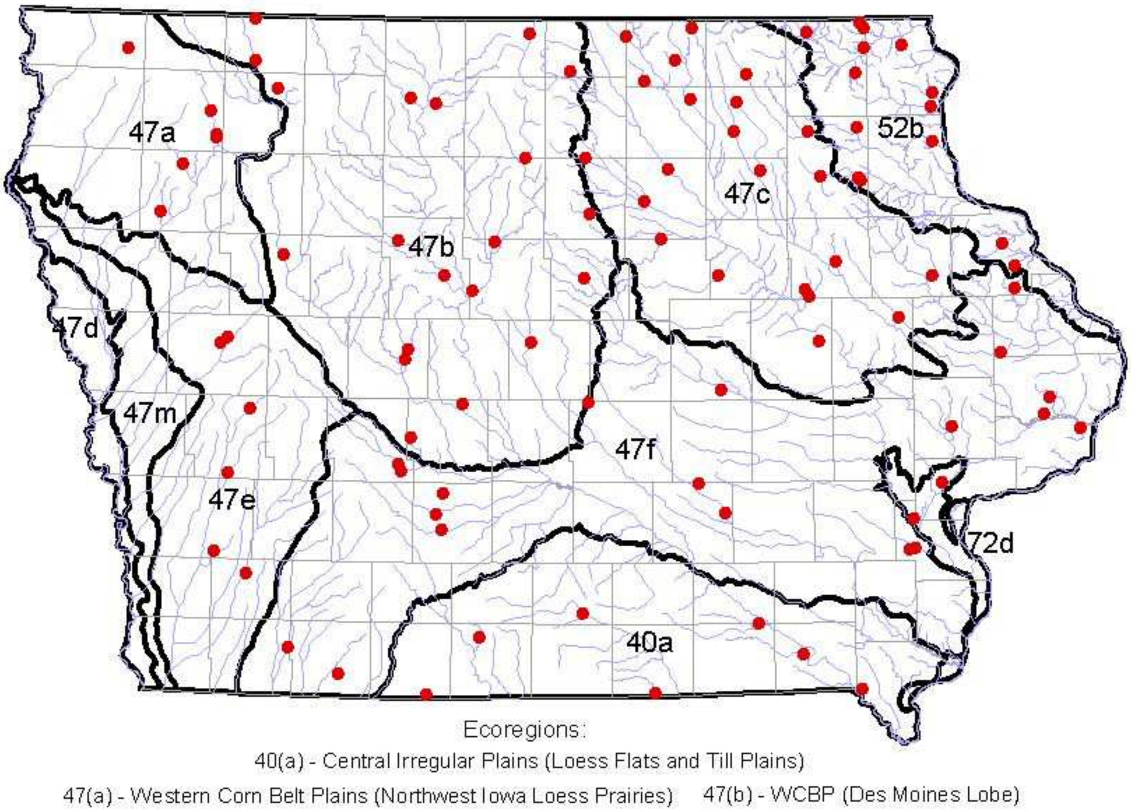


Figure A-1. Iowa ecoregions and wadeable stream reference sites.

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 fish to identify 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://www.iowadnr.gov/Environment/WaterQuality/WaterMonitoring/MonitoringPrograms/Biological.aspx (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 lithophilous 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 Walnut 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.

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 Silver 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 Walnut 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.

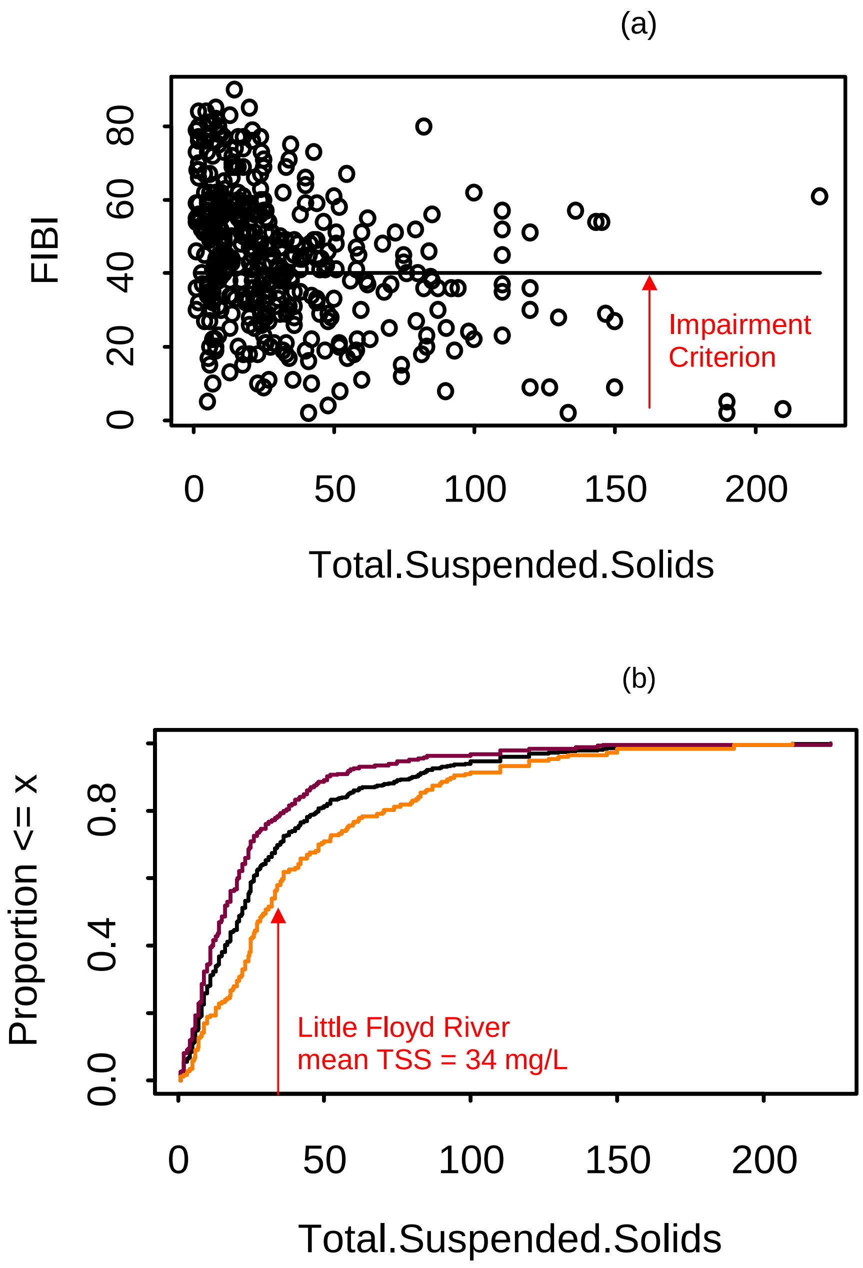
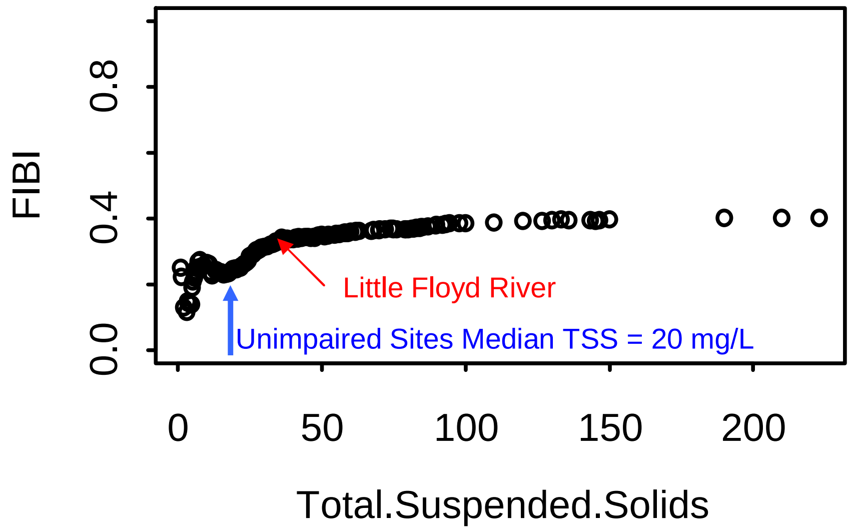


Figure A-2. Conditional Probability (CP) analysis using example data from the Little Floyd River, O'Brien County

(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.

(c)



(d)

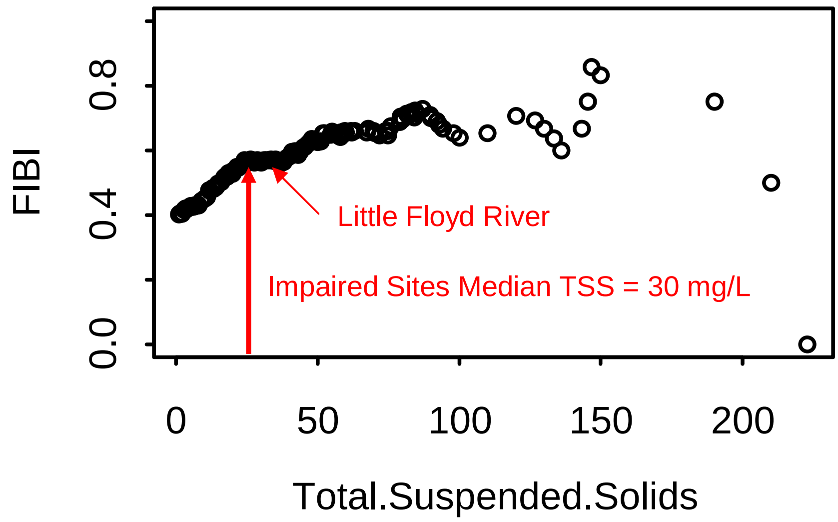


Figure A-2 continued. **(c)** Conditional Probability (CP) plot displaying the probability of observing an impairment (i.e., FIBI<40) when the observed stressor level is less than or equal to a specified level or criterion. For example the probability of impairment is approximately 0.25 for sites with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

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Appendix B—Data Summary

Table B-1. Water quality data from 1999 IDNR/UHL grab sampling during biological sampling at Holiday Lake Site.

Parameter	Unit of measure	9/20/99
Dissolved Oxygen	mg/L	12.6
Field pH	pH units	7.7
Field temperature	^{o}C	15
Flow rate	cfs	7.4

Table B-2. Water quality data from 2008 IDNR/UHL grab sampling during biological sampling at Holiday Lake Site.

Parameter	Units	9/16/08
Ammonia Nitrogen as N	mg/L	< 0.05
Chloride	mg/L	10
Chlorophyll a (water)	µg/L	2
Dissolved Inorganic Carbon	mg/L	52
Dissolved Organic Carbon	mg/L	1.6
Dissolved Oxygen	mg/L	9.7
E. coli	cfu/100 mL	1300
Field pH	pH units	8.1
Field temperature	^{o}C	12.9
Flow Rate	cfs	23
Nitrate + Nitrite Nitrogen	mg/L	6.3
Orthophosphate as P	mg/L	0.08
Total Kjeldahl Nitrogen	mg/L	0.4
Total Biochemical Oxygen Demand	mg/L	< 2
Total Dissolved Solids	mg/L	320
Total Organic Carbon	mg/L	2.6
Total Phosphate as P	mg/L	0.11
Total Suspended Solids	mg/L	26
Total Volatile Suspended Solids	mg/L	4
Turbidity	NTU	11

Table B-3. Water quality data from 2009-2010 IDNR/UHL sampling. Grey-shaded columns are from storm event samples. (ND = no data)

Parameter	Units	WLNT1												
		7/7/09	7/8/09	7/10/09	7/11/09	7/13/09	7/27/09	8/11/09	8/20/09	8/21/09	8/25/09	8/27/09	9/9/09	9/21/09
Ammonia Nitrogen as N	mg/L	0.08	0.16	0.26	<0.05	<0.05	<0.05	<0.05	0.05	0.12	<0.05	0.18	<0.05	<0.05
Carbonaceous BOD (5 day)	mg/L	6	< 2	6	3	< 2	< 2	< 2	5	3	< 2	4	< 2	< 2
Chloride	mg/L	5.8	8.7	4.8	8.7	11	9.2	9.9	7	10	6	4	10	10
Chlorophyll a (water)	µg/L	52	11	21	11	3	4	5	7	10	6	20	3	10
Dissolved Oxygen	mg/L	ND	9.1	ND	8.3	8.7	9.5	8.3	ND	9.2	8.4	8.2	10.3	9.2
E. coli	#/100 mL	>24,000	3,400	57,000	29,000	1,300	1,100	8,200	59,000	34,000	1,600	92,000	280	400
pH		ND	8	ND	8	8	8.3	8.2	ND	7.9	8.1	7.8	7.6	8.1
Temperature	^{o}C	ND	16.8	ND	21.4	18.1	19.2	19.3	ND	18.2	18.5	17.6	16.8	15.8
Flow	cfs	ND	39	ND	61	41	19	6	ND	22	12	1,200	22	14
Nitrate + nitrite as N	mg/L	2.2	4.8	1.4	4.9	6.2	6.1	4.3	1.7	3	3.6	1.9	5	4.7
Ortho Phosphate as P	mg/L	0.1	0.14	0.09	0.14	0.07	0.05	0.08	0.14	0.23	0.06	0.3	0.04	0.02
Sulfate	mg/L	8.6	15	7.6	15	18	18	18	13	16	19	17.6	19	20
Total Dissolved Solids	mg/L	160	270	180	270	300	310	320	240	270	300	210	300	310
Total Hardness	mg/L as $CaCO_3$	160	230	160	220	260	290	280	170	220	270	130	270	280
Total Kjeldahl Nitrogen as N	mg/L	11	2.7	12	2.3	0.4	0.2	0.4	4.8	2.2	0.6	4	0.3	0.4
Total Phosphate as P	mg/L	3.1	0.78	3.9	0.77	0.23	0.07	0.12	2.9	0.62	0.11	1.7	0.06	0.05
Total Suspended Solids	mg/L	4,100	780	6,800	880	57	20	32	1,600	340	43	2,100	9	5
Total Volatile Suspended Solids	mg/L	280	64	470	80	6	3	4	160	40	5	180	1	1
Turbidity	NTU	2,600	330	2,400	460	21	6.5	17	730	120	21	1,000	5.6	3.7

Table B-3 continued.

Parameter	Units	WLNT1						Holiday Lake						
		10/13/09	10/23/09	10/28/09	11/10/09	12/7/09	1/13/10	7/13/09	7/27/09	8/11/09	8/25/09	9/9/09	9/21/09	10/13/09
Ammonia Nitrogen as N	mg/L	<0.05	0.06	<0.05	0.06	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Carbonaceous BOD (5 day)	mg/L	< 2	6	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
Chloride	mg/L	9.5	8.7	9.4	8.7	8.8	8.8	9.6	9.1	9.4	10	9.8	10	9.2
Chlorophyll a (water)	µg/L	2	92	2	2	2	1	2	4	5	3	3	13	3
Dissolved Oxygen	mg/L	11.4	9.8	10.3	10.7	13.1	12.9	9.2	10	8.4	8.9	10.6	9.7	16.7
E. coli	#/100 mL	400	43,000	410	770	110	75	1,700	790	4,400	990	350	540	200
pH		7.9	7.5	8.1	8.1	8.3	7.9	8.1	8.3	8.2	8.3	8	8.1	8.4
Temperature	^{o}C	6.9	9.6	10.6	9.5	1..6	0.1	18	19.7	19.1	18	17	15.8	6.5
Flow	cfs	33	350	78	57	31	24	34	17	6	8.4	24	12	27
Nitrate + nitrite as N	mg/L	5.8	4.2	6.6	6.6	6.4	6	7.3	6.8	4.9	4.4	5.5	5	6.2
Ortho Phosphate as P	mg/L	0.04	0.23	0.06	0.05	< 0.02	0.02	0.06	0.04	0.07	0.05	0.03	0.02	0.04
Sulfate	mg/L	19	12	16	17	17	18	17	17	17	20	18	19	17
Total Dissolved Solids	mg/L	320	250	310	300	270	290	300	310	310	310	300	320	320
Total Hardness	mg/L as $CaCO_3$	300	220	270	280	260	270	270	280	280	280	280	300	290
Total Kjeldahl Nitrogen as N	mg/L	< 0.01	3.7	0.5	0.3	0.3	0.2	0.3	0.2	0.5	0.4	0.2	0.2	0.2
Total Phosphate as P	mg/L	0.09	1.5	0.13	0.11	0.06	0.08	0.11	0.06	0.1	0.09	0.06	0.06	0.06
Total Suspended Solids	mg/L	13	1,300	55	42	14	28	39	12	21	14	7	5	12
Total Volatile Suspended Solids	mg/L	2	92	6	4	2	3	4	2	3	2	1	1	2
Turbidity	NTU	6.2	330	29	20	4.3	9.2	13	4.9	9.8	7.4	4.6	3	4.6

Table B-3 continued.

Parameter	Units	Holiday Lake				WLNT2								
		10/28/09	11/10/09	12/7/09	1/13/10	7/13/09	7/27/09	8/11/09	8/25/09	9/9/09	9/21/09	10/13/09	10/28/09	11/10/09
Ammonia Nitrogen as N	mg/L	<0.05	<0.05	<0.05	0.11	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Carbonaceous BOD (5 day)	mg/L	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
Chloride	mg/L	8.8	8.9	8.6	9.2	9.4	9.1	9.5	10	9.7	10	9.3	9.2	8.8
Chlorophyll a (water)	µg/L	2	1	2	< 1	2	3	4	4	10	6	3	1	< 1
Dissolved Oxygen	mg/L	10.1	10.9	13.5	13	7.9	11.6	9	9.9	11.6	10.4	12.3	10.1	11
E. coli	#/100 mL	410	1,600	180	31	760	910	3,100	680	20,000	1,600	240	260	250
pH		8	8.2	8.3	8.1	8.2	8.4	8.3	8.4	8.1	8.2	8.5	8.1	8.1
Temperature	^{o}C	10.6	9.3	1.8	0.1	18.2	20.6	19.2	18.6	16.3	15.7	7.2	11.1	9.9
Flow	cfs	66	24	28	14	18	11	7	5	14	8.5	19	42	30
Nitrate + nitrite as N	mg/L	7.1	7.2	6.8	6.7	8.1	7.7	6	5	6.1	5.7	6.6	7.7	7.7
Ortho Phosphate as P	mg/L	0.06	0.05	0.02	0.09	0.06	0.05	0.08	0.06	0.03	0.04	0.04	0.06	0.05
Sulfate	mg/L	16	16	16	17	16	16	18	19	17	18	17	16	16
Total Dissolved Solids	mg/L	320	300	260	380	310	310	320	300	310	320	330	330	290
Total Hardness	mg/L as $CaCO_3$	310	320	270	280	280	290	280	290	280	290	280	310	290
Total Kjeldahl Nitrogen as N	mg/L	0.4	0.2	0.1	0.4	0.3	0.2	0.4	0.5	0.2	0.4	< 0.1	0.4	0.2
Total Phosphate as P	mg/L	0.12	0.06	0.05	0.16	0.09	0.06	0.1	0.08	0.07	0.05	0.08	0.1	0.07
Total Suspended Solids	mg/L	50	35	11	20	21	5	17	43	9	13	17	38	27
Total Volatile Suspended Solids	mg/L	5	4	1	3	3	1	3	5	2	2	3	4	3
Turbidity	NTU	33	16	3.7	8.4	10	3.2	10	8.3	5.3	6.9	7.6	17	10

Table B-3 continued.

Parameter	Units	WLNT2		WLNT3										
		12/7/09	1/13/10	7/13/09	7/27/09	8/11/09	8/25/09	8/27/09	8/28/09	9/9/09	9/21/09	9/25/09	9/26/09	10/13/09
Ammonia Nitrogen as N	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.1	<0.05	<0.05	<0.05	<0.05	<0.05
Carbonaceous BOD (5 day)	mg/L	< 2	< 2	< 2	< 2	< 2	< 2	< 2	5	< 2	< 2	6	2	< 2
Chloride	mg/L	8.6	8.5	11	11	12	13	12	7.3	12	12	11	11	11
Chlorophyll a (water)	µg/L	2	< 1	1	3	3	3	17	5	11	4	30	13	1
Dissolved Oxygen	mg/L	13.7	13.4	102	11.5	8.9	9.3	8.4	8.2	13.5	10.5	ND	9.2	12.7
E. coli	#/100 mL	600	2,200	750	480	2,100	360	130,000	24,000	620	1,400	140,000	140,000	170
pH		8	8.2	8.2	8.4	8.2	8.2	7	7.5	8.1	8.1	ND	7.9	8.3
Temperature	^{o}C	3.1	0.1	19.6	21.9	18.9	18.6	17.1	16.8	17.2	16	ND	14.6	8.2
Flow	cfs	19	9.7	7.8	5	7.7	7.7	220	63	6.1	3.2	ND	9	8.6
Nitrate + nitrite as N	mg/L	7.3	7.1	8.4	8	6.6	5.1	3	5	6.2	5.8	3.2	5.4	6.9
Ortho Phosphate as P	mg/L	0.02	0.04	0.06	0.05	0.08	0.07	0.35	0.25	0.03	0.04	0.26	0.24	0.05
Sulfate	mg/L	16	16	14	14	14	16	13	10	20	16	12	15	15
Total Dissolved Solids	mg/L	270	290	310	310	320	310	260	250	310	320	250	300	310
Total Hardness	mg/L as $CaCO_3$	290	280	280	290	280	280	190	190	280	300	240	290	280
Total Kjeldahl Nitrogen as N	mg/L	< 0.01	0.2	0.2	0.3	0.3	0.4	1.8	1.3	0.3	0.2	2.2	0.6	< 0.01
Total Phosphate as P	mg/L	0.05	0.08	0.07	0.06	0.1	0.1	0.77	0.49	0.0	0.07	0.9	0.44	0.08
Total Suspended Solids	mg/L	11	22	12	9	21	13	400	180	7	10	570	130	4
Total Volatile Suspended Solids	mg/L	2	2	2	2	3	2	48	19	1	2	56	15	1
Turbidity	NTU	4.4	7.9	5	4	11	10	220	110	4.1	5.6	270	66	2.6

Table B-3 continued.

Parameter	Units	WLNT3				
		10/23/09	10/28/09	11/10/09	12/7/09	1/13/10
Ammonia Nitrogen as N	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05
Carbonaceous BOD (5 day)	mg/L	5	< 2	< 2	< 2	< 2
Chloride	mg/L	11	1029	9.9	9.6	9.9
Chlorophyll a (water)	µg/L	44	1	< 1	< 1	< 1
Dissolved Oxygen	mg/L	9.2	9.9	10.8	13.3	13.3
E. coli	#/100 mL	37,000	310	180	41	31
pH		7.2	7.7	8	7.9	8.1
Temperature	^{o}C	9.8	11.4	10.3	3.8	1.8
Flow	cfs	92	22	21	8	6.1
Nitrate + nitrite as N	mg/L	5.8	7.9	8.1	7.8	7.4
Ortho Phosphate as P	mg/L	0.31	0.06	0.04	0.03	0.02
Sulfate	mg/L	12	14	14	13	14
Total Dissolved Solids	mg/L	260	320	310	270	280
Total Hardness	mg/L as $CaCO_3$	250	280	300	270	270
Total Kjeldahl Nitrogen as N	mg/L	7.2	0.3	0.1	0.2	0.1
Total Phosphate as P	mg/L	1.1	0.07	0.06	0.06	0.05
Total Suspended Solids	mg/L	830	20	21	7	5
Total Volatile Suspended Solids	mg/L	76	2	2	< 1	< 1
Turbidity	NTU	190	10	6.6	2	2.1

Table B-4. Stressor co-occurrence and response considerations for candidate causes in Walnut Creek, Iowa.

*(*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	Consistent with Stressor Occurrence	Consistent with Stressor Response
Altered Flow Regime (Conceptual Model 1)					
Increased max. flow	NA	NA	NA	NA	NA
Increased frequency of low flows	NA	NA	NA	NA	NA
Increased magnitude of low flows	Flow: Contribution area ratio	0.04-0.32 IR for statewide 3rd order monitoring sites (n=150)	WLNT1=0.525 (n=7) Holiday Lake=0.525 (n=7) WLNT2=0.487 (n=7)	yes	yes
		0.11-0.49 IR for statewide 1st & 2nd order monitoring sites (n=101)	WLNT3=0.563 (n=7)	yes	yes
Altered daily or seasonal flow patterns	NA	NA	NA	NA	NA
Altered Substrate (Conceptual Model 2)					
Increased suspended sediment (abrasive to soft tissue)	TSS (mg/L)	Base flow 17-36 IR for regional reference sites (n=19)	Non-event (Median) WLNT1 25.6 (n=7) Holiday Lake 15.7 (n=7) WLNT2 17.9 (n=7) WLNT3 10.9 (n=7)	no	no
		Event 80-360 IR for statewide sites (n=757)	Event WLNT1 1400 (n=12) WLNT3 450 (n=6)	yes	yes
Decreased clarity (reduced feeding efficiency)	Turbidity (ntu)	Base flow 10.1-24 IR for regional reference sites (n=19)	Non-event (Median) WLNT1 11.6 (n=7) Holiday Lake 6.8 (n=7) WLNT2 7.3 (n=7) WLNT3 6.8 (n=7)	no	no
		Event 47-240 IR for statewide sites (n=604)	Event WLNT1 495 (n=12) WLNT3 175 (n=6)	yes	yes
Decrease in benthic algae or macrophytes as a substrate for organisms	Periphyton Chl. A (µg/cm^2)	4.31 (2.51-7.64) median (IR) for 47f REMAP sites (n=28)	WLNT1= 1.05 (n=2) Holiday Lake= 0.5 (n=2) WLNT2= 0.45 (n=2) WLNT3= 0.6 (n=2)	yes	yes
	Sediment Chl. A (µg/cm^2)	3.44 (1.9-7.2) median (IR) for 47f REMAP sites (n=28)	WLNT1= 9.1 (n=2) Holiday Lake= 7.1 (n=2) WLNT2= 2.9 (n=2) WLNT3= 9.1 (n=2)	no	no
Increased deposited fine sediment	% soft sediments	38.43-94.68 IR for regional reference sites (n=10)	WLNT1 2009 = 92.86 Holiday Lake 2008 & 2009 = 100 WLNT2 2009 = 100 WLNT3 2009 = 100	yes	yes

Stressor	Indicator	Concentration or level at unimpaired sites in other waterbodies*	Concentration or level at impaired site(s) in the watershed	Consistent with Stressor Occurrence	Consistent with Stressor Response
Altered Substrate (Conceptual Model 2) continued					
Increased deposited fine sediment (continued)	% Silt	15-32 IR for regional reference sites (n=19)	WLNT1 2009 = 5 Holiday Lake 1999 = 47 2008 & 2009 = 4 WLNT2 2009 = 34 WLNT3 2009 = 30	no	no
	% Sand	19.5-58 IR for regional reference sites (n=19)	WLNT1 2009 = 84 Holiday Lake 1999 = 40 2008 = 79 2009 = 89 WLNT2 2009 = 53 WLNT3 2009 = 16	yes	yes
	% Reach area as pool habitat	19.5-58 IR for regional reference sites (n=19)	WLNT1 2009 = 3.55 Holiday Lake 1999 = 64.3 2008 = 3.6 2009 = 0 WLNT2 2009 = 51.8 WLNT3 2009 = 53.6	yes	yes
Loss of pool area & depth	Maximum depth (ft.)	2.9-4.1 IR for regional reference sites (n=19)	WLNT1 2009 = 2.9 Holiday Lake 1999 = 1.6 2008 = 3.2 2009 = 1.8 WLNT2 2009 = 2.8 WLNT3 2009 = 2.8	yes	yes
	Width: Thalweg Depth Ratio	16.91-30.65 IR for regional reference sites (n=19)	WLNT1 2009 = 22.16 Holiday Lake 1999 = 42.9 2008 = 18.2 2009 = 26.98 WLNT2 2009 = 15.62 WLNT3 2009 = 5.44	yes	yes
Embedded riffles	Embeddedness rating (% coarse substrate area embedded by fine sediment)	19.5-58 IR for regional reference sites (n=15)	Not enough riffle habitat to be evaluated for embeddedness at any of the sites in any year	NA	NA
Altered Basal Food Source (Conceptual Model 3)					
Increased / altered primary producers	Seston Chl. A (µg/L)	14.67 (6.75-40.38) median (IR) for 47f REMAP sites (n=28)	WLNT1= 4.7 (n=2) Holiday Lake= 4.7 (n=2) WLNT2= 4.6 (n=2) WLNT3= 3.7 (n=2)	no	no
	Periphyton Chl. A (µg/cm^2)	4.31 (2.51-7.64) median (IR) for 47f REMAP sites (n=28)	WLNT1= 1.05 (n=2) Holiday Lake= 0.5 (n=2) WLNT2= 0.45 (n=2) WLNT3= 0.6 (n=2)	no	no
	Sediment Chl. A (µg/cm^2)	3.44 (1.9-7.2) median (IR) for 47f REMAP sites (n=28)	WLNT1= 9.1 (n=2) Holiday Lake= 7.1 (n=2) WLNT2= 2.9 (n=2) WLNT3= 9.1 (n=2)	no	no

<table>
<tr><th>Stressor</th><th>Indicator</th><th>Concentration or level at unimpaired sites in other waterbodies*</th><th>Concentration or level at impaired site(s) in the watershed</th><th>Consistent with Stressor Occurrence</th><th>Consistent with Stressor Response</th></tr>
<tr><td colspan="6">Altered Basal Food Source (Conceptual Model 3) continued</td></tr>
<tr><td rowspan="3">Increased / altered primary producers (continued)</td><td>Respiration ($g\ O_2/m^2/d$)</td><td>5.81 (5.05-7.49) median (IR) for 47f REMAP sites (n=22)</td><td><u>July 2009</u>
WLNT1 2.01 (n=14d)
Holiday Lake 2.49 (n=5d)
WLNT2 3.13 (n=14d)
WLNT3 2.18 (n=14d)</td><td>no</td><td>no</td></tr>
<tr><td>Gross primary production (GPP) ($g\ O_2/m^2/d$)</td><td>3.89 (2.07-6.46) median (IR) for 47f REMAP sites (n=22)</td><td><u>July 2009</u>
WLNT1 1.24 (n=14d)
Holiday Lake 1.72 (n=5d)
WLNT2 3.83 (n=14d)
WLNT3 1.94 (n=14d)</td><td>no</td><td>no</td></tr>
<tr><td>Production-to-respiration ratio (P:R)</td><td>0.61 (0.34-0.99) median (IR) for 47f REMAP sites (n=22)</td><td><u>July 2009</u>
WLNT1 0.62 (n=14d)
Holiday Lake 0.69 (n=5d)
WLNT2 1.23 (n=14d)
WLNT3 0.89 (n=14d)</td><td>no</td><td>no</td></tr>
<tr><td rowspan="2">Decreased allochthonous food resources</td><td>Instream Cover – Small Brush – Avg. %</td><td>4.38-9.13 IR for regional reference sites (n=10)</td><td>WLNT1 2009 = 3
Holiday Lake 2008 & 2009 = 2
WLNT2 2009 = 9
WLNT3 2009 = 1.5</td><td>yes</td><td>yes</td></tr>
<tr><td>Instream Cover – Woody Debris – Avg. % - (new method)</td><td>1.13-7.69 IR for regional reference sites (n=10)</td><td>WLNT1 2009 = 1.5
Holiday Lake
2008 = 0
2009 = 1
WLNT2 2009 = 4
WLNT3 2009 = 0</td><td>yes</td><td>yes</td></tr>
<tr><td colspan="6">Decreased Dissolved Oxygen (Conceptual Model 4)</td></tr>
<tr><td rowspan="5">Decreased dissolved oxygen</td><td>DO (mg/L) levels from daytime grab samples</td><td>7.98-9.4 IR for regional reference sites (n=19)</td><td>WLNT1 = 9.4 (n=7)
Holiday Lake = 10.5 (n=7)
WLNT2 = 10.3 (n=7)
WLNT3 = 10.9 (n=7)</td><td>no</td><td>no</td></tr>
<tr><td>Minimum DO (mg/L) from daytime grab samples</td><td>6.95 minimum for regional reference sites (n=19)</td><td>WLNT1 = 8.3 (n=7)
Holiday Lake = 8.4 (n=7)
WLNT2 = 7.9 (n=7)
WLNT3 = 8.9 (n=7)</td><td>no</td><td>no</td></tr>
<tr><td>Minimum DO (mg/L) from datalogger</td><td></td><td><u>July 2009</u>
WLNT1 = 6.91
Holiday Lake = 7.99
WLNT2 = 7.42
WLNT3 = 7.07</td><td>no</td><td>no</td></tr>
<tr><td rowspan="2">Meeting water quality standards designed to protect aquatic life</td><td>$\geq$ 5.0 mg/L at least 16 h/day</td><td>No violations</td><td>no</td><td>no</td></tr>
<tr><td>Minimum value 4.0 mg/L</td><td>No violations</td><td>no</td><td>no</td></tr>
</table>

Stressor	Indicator	Concentration or level at unimpaired sites in other waterbodies*	Concentration or level at impaired site(s) in the watershed	Consistent with Stressor Occurrence	Consistent with Stressor Response
Physical Habitat Alteration (Conceptual Model 5)					
Decreased macro-habitat complexity	% (type) dominant channel bedform unit	IRs for regional reference sites (n=19) 1.8-15.2 riffle 31.25-57.15 run 30.35-58.95 pool	riffle/run/pool WLNT1 2009 3.55/92.9/3.55 Holiday Lake 1999 0/3.57/64.3 2008 0/96.4/3.6 2009 0/100/0 WLNT2 2009 3.6/44.6/51.8 WLNT3 2009 0/46.4/53.6	yes	yes
	Width: Thalweg Depth Ratio	16.91-30.65 IR for regional reference sites (n=19)	WLNT1 2009 = 22.16 Holiday Lake 1999 = 42.9 2008 = 18.2 2009 = 26.98 WLNT2 2009 = 15.62 WLNT3 2009 = 5.44	yes	yes
	S.D. mean depth	0.38-0.75 IR for regional reference sites (n=19)	WLNT1 2009 = 0.33 Holiday Lake 1999 = 0.12 2008 = 0.34 2009 = 0.19 WLNT2 2009 = 0.53 WLNT3 2009 = 0.5	no	no
Decreased micro-habitat complexity	% Instream cover (DNR method)	19.19-36.69 IR for regional reference sites (n=10)	WLNT1 2009 = 11 Holiday Lake 2008 = 4 2009 = 12 WLNT2 2009 = 31 WLNT3 2009 = 76.75	yes	yes
	Instream Cover – Small Brush – Avg. %	4.38-9.13 IR for regional reference sites (n=10)	WLNT1 2009 = 3 Holiday Lake 2008 & 2009 = 2 WLNT2 2009 = 9 WLNT3 2009 = 1.5	yes	yes
	Instream Cover – Woody Debris – Avg. % - (new method)	1.13-7.69 IR for regional reference sites (n=10)	WLNT1 2009 = 1.5 Holiday Lake 2008 = 0 2009 = 1 WLNT2 2009 = 4 WLNT3 2009 = 0	yes	yes
Aquatic Life Depletion and Isolation (Conceptual Model 6)					
Disease	%DELT	0.06 for regional reference sites	None found at any sites in all years	NA	NA

Table B-5. FIBI metrics calculated from the 1999, 2008, and 2009 biological samples collected from the Walnut Creek watershed compared with ecoregion reference site metrics. Items highlighted in red are outside of the ecoregion reference values.

Walnut Creek	WLNT1	Holiday Lake			WLNT2	WLNT3	47f
	2009	1999	2008	2009	2009	2009	reference
FIBI:	54	**24**	**31**	**26**	**29**	**23**	36
Native Spp:	20	14	15	**11**	**12**	**9**	14
NativeSppMetric1	7.49	5.443	5.831	**4.276**	**5.2**	**5.05**	5.83
Sucker Spp:	3	**0**	1	**0**	1	1	1
SuckerSppMetric2	5.74	**0**	1.988	**0**	2.22	2.87	2.95
Sensitive Spp:	2	0	0	1	0	0	0
SensitiveSppMetric3	2.19	0	0	1.135	0	0	0
BINV Spp:	6	3	3	4	**1**	**0**	2.5
BINVSppMetric4	6.24	3.241	3.24	4.32	**1.2**	**0**	4.17
% Top 3 Abundant:	39.51	**71.04**	**69.81**	**76.79**	**75**	**75**	71.15
PctTop3AbundMetric5	9.68	**4.813**	**5.017**	**3.857**	**4.63**	**6**	7.9
% Benthic Invert:	22.22	**2.715**	6.28	19.64	8.04	**0**	6.31
PctBINVMetric6	5.82	**0.738**	1.707	5	2.44	**0**	1.51
% Omnivore:	10.7	11.99	3.382	**1.785**	7.14	10	47.91
PctOmnivoreMetric7	9.15	8.978	10	**5**	10	7.5	8.37
% Top Carnivore:	**0**	**0**	**0**	**0**	**0**	**0**	0.06
PctTopCarnivoreMetric8	**0**	**0**	**0**	**0**	**0**	**0**	1.06
% Litho Spawner:	9.46	**0**	**0**	**0**	**0**	**0**	1.41
PctLithoSpawnerMetric9	4.92	**0**	**0**	**0**	**0**	**0**	0.57
Tolerance Index:	6.36	**8.699**	**7.476**	**7.545**	**7.2**	**7.95**	8.27
TolIndexMetric10	5.78	**2.065**	**4.007**	**3.897**	**4.44**	**3.25**	5.97
Adjusted CPUE:	**18.82**	**15.54**	27.21	**6.932**	20.66	**6.9**	20.49
AdjCPUEMetric11	**1.88**	**1.554**	2.721	**0.693**	2.07	**0.69**	2.05
% DELT:	0	0	0	0	0	0	0.06
DELTAdj	0	0	0	0	0	0	0
Reach Size (ft.):	920	740	768	779	908	595	792
Fish Per 500 ft:	**132**	299	270	**72**	**185**	**84**	194.5
Total Spp:	23	15	16	**11**	**12**	**9**	16.5
Total Excluded Spp:	1	0	0	0	0	0	0
Total Exotics Spp:	1	0	0	0	0	0	0.5
Total LMB-BG:	1	1	1	0	0	0	0.5
Major Drainage:	MSP	MSP	MSP	MSP	MSP	MSP	
Total Fish:	**243**	442	414	**112**	**336**	**100**	413
Drainage Area (mi^2):	40.03	34.9	34.9	34.9	24.2	11.7	
Log Drainage Area:	1.6023	1.54	1.54	1.54	1.3838	1.0681	
FIBI:	54	**24**	**31**	**26**	**29**	**23**	36
Native Spp:	20	14	15	**11**	**12**	**9**	14

Table B-6. BMIBI metrics calculated from the 1999, 2008, and 2009 biological samples collected from the Walnut Creek watershed compared to ecoregion reference site metrics. Items highlighted in red are outside of the ecoregion reference values.

Walnut Creek	WLNT1	Holiday Lake			WLNT2	WLNT3	47f
	2009	1999	2008	2009	2009	2009	reference
BMIBI:	63	55	**40**	57	62	53	51
MH-Total Number of Taxa:	39	28	**22**	28	34	27	28
txtMetric1	8.34	6.16	**4.84**	6.16	8.09	7.67	6.17
SH-Total Number of Taxa:	13	12.67	**9**	**9**	**7**	9	11
txtMetric2	7.01	7.04	**5**	**5**	**4.23**	6.57	5.73
MH- Number of EPT Taxa:	14	13	**6**	12	12	8	11
txtMetric3	6.39	6.1	**2.81**	5.63	6.08	4.82	4.82
SH- Number of EPT Taxa:	8.67	10	**5**	6.5	5	5	6.83
txtMetric4	6.88	8.18	**4.09**	5.31	4.46	5.43	5.52
MH- Number of Sensitive Taxa:	4	**1**	**1**	4	3	**1**	2.5
txtMetric5	4.05	**1.04**	**1.04**	4.17	3.39	**1.36**	2.28
SH- % Ephemeroptera Taxa:	23.19	18.24	**13.54**	19.17	29.62	19.8	17.81
txtMetric6	2.97	2.33	**1.73**	2.45	3.79	2.53	2.28
SH- % EPT Taxa:	75.64	74.29	49.87	77.88	76.1	53.61	52.74
txtMetric7	7.92	7.78	5.22	8.15	7.97	5.61	5.52
SH- % Chironomidae Taxa:	19.73	14.95	**34.95**	16.01	21.55	**32.57**	23.16
txtMetric8	8.11	8.59	**6.57**	8.49	7.93	**6.81**	9.63
SH- % Scraper Organisms:	16.07	**4.88**	**0.66**	16.05	28.21	17.16	6.48
txtMetric9	3.6	**1.09**	**0.15**	3.59	6.31	3.84	1.45
SH- % 3 Dominant Taxa:	**75.29**	58.51	**72.92**	**74.62**	**79.3**	**80.64**	74.3
txtMetric10	**4.47**	7.77	**5.07**	**4.75**	**4.28**	**5.03**	6.62
SH- % Dominant FFG:	53.38	55.77	64.71	56.48	45.99	51.31	70.66
txtMetric11	7.77	7.37	**5.88**	7.25	9	8.12	7.95
SH- Modified Hilsenhoff Biotic Index:	4.92	**6.17**	**5.65**	5.01	4.72	**5.52**	5.51
txtMetric12	7.7	**3.07**	**5**	7.37	8.44	**5.48**	7.28
chkValidSample	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	
Log Drainage Area:	1.60239	1.54	1.54	1.54	1.3838	1.0682	
Drainage Area (mi^2):	40.03	34.9	34.9	34.9	24.2	11.7	

Table B-7. Fish collected in Walnut Creek in 1999, 2008, and 2009.

Common name	Scientific name	WLNT1	Holiday Lake			WLNT2	WLNT3	WLNT4	WLNT5
		2009	1999	2008	2009	2009	2009	2009	2009
black bullhead	*Ameiurus melas*				1	2	1		
yellow bullhead	*Ameiurus natalis*		2	1	3				
suckermouth minnow	*Phenocobius mirabilis*	8						1	
brassy minnow	*Hybognathus hankinsoni*	12	26	103		39	8	4	28
sand shiner	*Notropis stramineus*	14	7	29		5			
central stoneroller	*Campostoma anomalum*	4	1			1	6		
golden shiner	*Notemigonus crysoleucas*	2							
creek chub	*Semotilus atromaculatus*	27	61	135	45	121	55	9	31
spotfin shiner	*Cyrpinella spilopterus*	43	8	28	6	5			
bluntnose minnow	*Pimephales natatus*	19	7	12	2	10	2		12
fathead minnow	*Pimephales promelas*			1			1		
common shiner	*Luxilus cornutus*	12	1	4	1	5	8	1	
bigmouth shiner	*Notropis dorsalis*	18	207	51	10	15		26	11
common carp	*Cyprinus carpio*	1							
hornyhead chub	*Nocomis biguttatus*	3							
western blacknose dace	*Rhinichthys atratulus*	26	44	12	25	92	12	47	38
johnny darter	*Etheostoma nigurm*	11	7	21	16	27		19	31
blackside darter	*Percina maculata*	1			1				
mud darter	*Etheostoma asprigene*	10	3	4	2				
fantail darter	*Etheostoma flabellare*	1						1	
qullback carpsucker	*Carpoides cyprinus*	3							
shorthead redhorse	*Moxostoma macrolepidotum*	15							
white sucker	*Catostomus commersoni*	1		1		14	7		
Moxostoma sp.		8							
largemouth bass	*Micropterus salmoides*	1	16						1
green sunfish	*Lepomis cyanellus*	3	6	6					
bluegill	*Lepomis macrochirus*			5					
orangespotted sunfish	*Lepomis humilus*			1					
gizzard shad	*Dorosoma cepedianum*		46						
Total number of fish collected		**243**	**442**	**414**	**112**	**336**	**100**	**108**	**152**

Table B-8. Benthic macroinvertebrates collected in Walnut Creek in 1999, 2008, and 2009. Rapid Bioassessment Protocol (RBP) abbreviations: A = abundant, C = common, U = uncommon, R = rare.

Phylum: Class	Order	Family	Final ID	WLNT1	Holiday Lake			WLNT2	WLNT3	WLNT4	WLNT5
				2009	1999	2008	2009	2009	2009	2009	2009
				Rull	Rull	Rull	Rull	Rull	Rull	RBP	RBP
Arthropoda: Insecta	Coleoptera	Dryopidae	Helichus striatus	2			1	1			
			Helichus lithophilous			1					
		Dytisicade	Acilius sylvanus					1		R	
			Agabus						2		
			Laccophilus maculosus	1							
			Neoporus undulatus	1							
		Elmidae	Macronychus glabratus			2					
		Hydrophilidae	Enochrus ochraceus	1						R	R
			Enochrus hamiltoni						1		
			Paracymus subcupreus					1	1		
		Haliplidae	Haliplus borealis	1				1		U	U
			Peltodytes tortulosus				1				
			Peltodytes edentulus	2				3	2		
	Diptera	Empididae	Empididae				1				
			Chelifera	1					1		
		Pediciidae	Pedicia	1							
		Tipulidae	Tipula	1		4				R	
		Culicidae	Anopheles	1						R	
		Simuliidae	Simulium	15		32	3	6	5	A	R
			Simuliidae			4					
		Muscidae	Limnophora						2		
		Ceratopogonidae	Probezzia	1							
			Atrichopogon			1					
		Ephydridae	Ephydridae						1		
		Chironomidae	Chironomidae	74	51	120	37	63	107	C	C
	Ephemeroptera	Baetidae	Baetis flavistriga	4		5		7	13	A	A
			Baetis brunneicolor	28			7	28	4		
			Baetis intercalaris	16	12	55	4	4	3		
			Plauditus	4		1	1	2	19		
			Fallceon quilleri		37		1				
			Paracleodes minutus			1					
			Paracleodes		1						
			Pseudocloeon dardanum	11	2		5	2			
			Pseudocloeon propinquum	14	4		10	15	28		
			Acentrella parvula	1	1						
		Baetisidae	Baetisca lacustris		2						
		Caenidae	Caenis punctata				1				
			Caenis		2						
		Isonychiidae	Isonychia	7			2				
		Leptohyphidae	Tricorythodes	21	5		7				
		Ephemeridae	Hexagenia limbata		6						

Table B-8. (continued)

Phylum: Class	Order	Family	Final ID	WLNT1 2009 Rull	Holiday Lake 1999 Rull	Holiday Lake 2008 Rull	Holiday Lake 2009 Rull	WLNT2 2009 Rull	WLNT3 2009 Rull	WLNT4 2009 RBP	WLNT5 2009 RBP
Arthropoda: Insecta (continued)	Ephemeroptera (continued)	Heptageniidae	Heptagenia pulla				1			A	A
			Heptagenia diabasia	122			153	147	95		
			Stenacron interpunctatum		4						
			Maccaffertium terminatum		18						
			Maccaffertium exiguum		1						
	Odonata	Aeshnidae	Boyeria vinosa	5	1	3	9	7		C	U
			Aeshna umbrosa	2			9	3	7		
		Coenagrionidae	Argia		7	1	1				
			Coenagrion/Enallagma					1			
		Calopterygidae	Hetaerina	4		1				R	U
			Calopteryx		4	1	1	3	1		
		Libellulidae	Erythemis simplicicollis								
		Lestidae	Archilestes	1							
		Limoniidae	Pilaria	1	1						
		Gomphidae	Gomphus		5						
			Stylurus notatus		1						
			Progomphus obscurus		2						
	Trichoptera	Hydropsychidae	Ceratopsyche morosa		17	2				C	C
			Ceratopsyche bronta	77	1	81	60	89	16		
			Cheumatopsyche	148	12	51	101	69	80		
			Hydropsyche betteni	1	96		1	2			
			Hydropsyche simulans	1	62						
			Hydropsychidae		17				8		
		Leptoceridae	Nectopsyche diarina	17			34	14		R	
		Hydroptilidae	Hydroptila	3		2		5	16	R	
			Hydroptilidae		1	3			5		
	Maegaloptera	Corydalidae	Corydalus		5						
	Hemiptera	Notonectidae	Notonecta					1	1		
		Bellostomatidae	Belostoma flumineum			2	1				
			Belostoma		1						
		Gerridae	Gerris buenoi	1			1	1		R	R
		Nepidae	Ranatra fusca			1					
			Ranatra		1						
		Hebridae	Hebridae		9						
		Corixidae	Sigara	1	1	1	2		1	U	C
			Trichocorixa	2		1		4			
			Corixidae						3		
		Pleidae	Neoplea	1				1			
Arthropoda: Crustacea	Amphipoda	Talitridae	Hyalella	6			3	7		R	
	Decapoda	Cambaridae	Cambaridae	1			2	3	3	U	C
			Orconectes			1					

Table B-8. (continued)

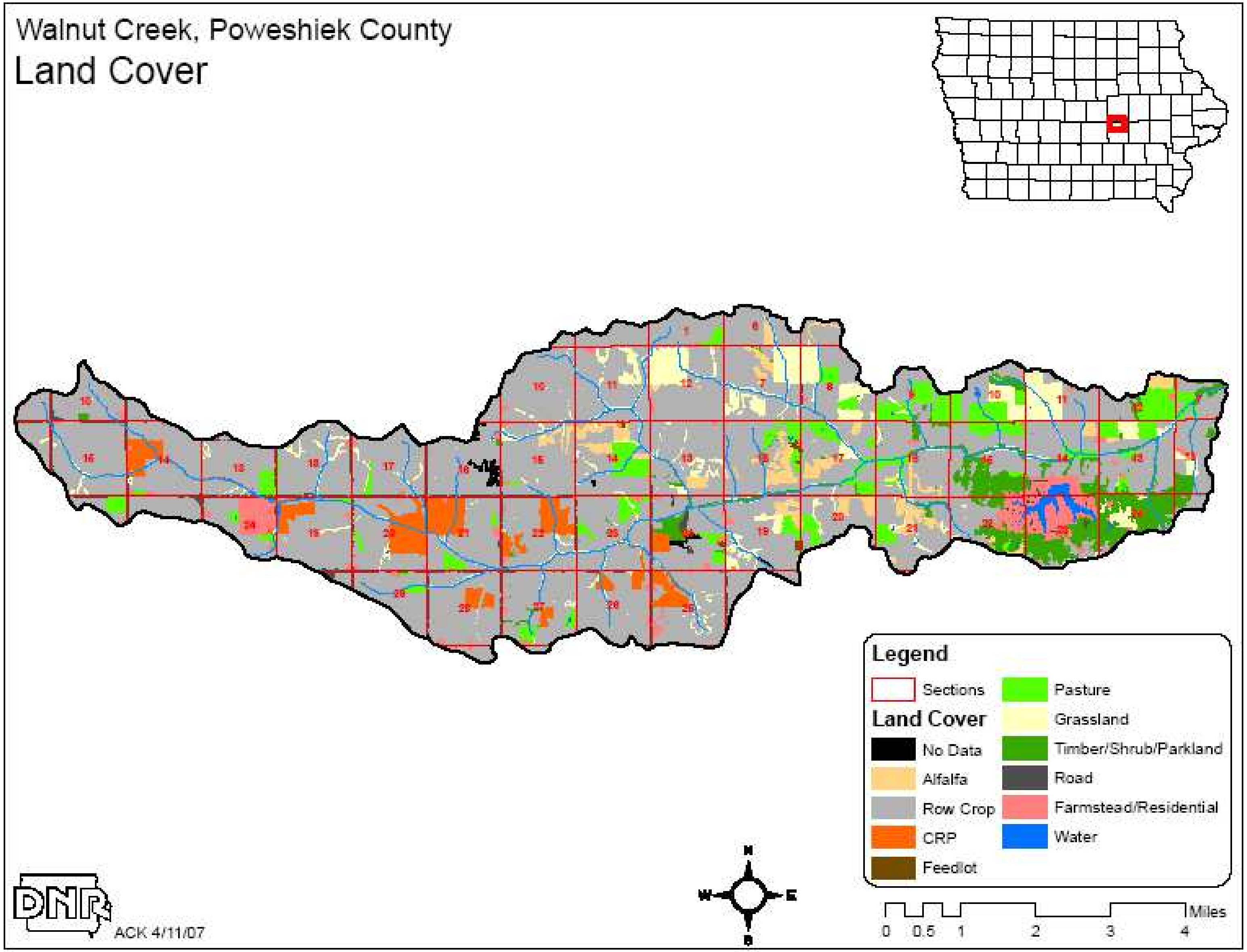
Phylum: Class	Order	Family	Final ID	WLNT1	Holiday Lake			WLNT2	WLNT3	WLNT4	WLNT5
				2009	1999	1999	1999	2009	2009	2009	2009
				Rull	Rull	Rull	Rull	Rull	Rull	RBP	RBP
Chelicerata: Arachnida	Acarina	Hydrachnida	Hydrachnida						3		
Annelida: Oligochaeta	Haplotaxida		Haplotaxida						1		
			Oligochaeta	6	35	9	13	4	36		
Annelida: Hirudinea	Arhynchobdellida	Erpobdellidae	Erpobdellidae				1		1	R	
			Erpobdella punctata	1				2	4		
			Erpobdella fervida						3		
			Erpobdella microstoma			1					
	Rhynchobdellida	Glossiphoniidae	Helobdella stagnalis					1			
			Placobdella picata	1							
			Placobdella parasitica	1							
			Placobdella ornata		1						
Mollusca: Gastropoda	Basommatophora	Physidae	Physa	2		4	2	7	12	C	C
		Lymnaeidae	Fossaria	12							
			Lymnaeidae					1			
Platyhelminthes: Turbellaria			Turbellaria		1						
	Tricladida	Dugesiidae	Girardia	1							

Table B-9. Instream habitat assessments for Walnut Creek compared to ecoregion reference data. Items highlighted in red denote values outside the ecoregion reference data interquartile range. Note that 1999 data at the Holiday Lake site used the Legacy method of assessment.

Habitat Parameter	Bank	WLNT1	Holiday Lake			WLNT2	WLNT3	47b reference data	
		2009	1999	2008	2009	2009	2009	25th percentile	75th percentile
Reach - Total Habitat Reach Length		891	594	729	729	810	540	675	793.5
Transect Depth - Average		0.73	0.26	0.92	0.6	0.95	1.16	0.48	1.08
Transect Depth - Standard Deviation		0.33	0.12	0.34	0.19	0.53	0.5	0.38	0.75
Stream Width - Average		27.26	19.3	25.64	25.63	23.28	9.63	20.22	50.56
Thalweg Depth - Average		1.23	0.45	1.412	0.95	1.49	1.77	0.94	1.9
Width - Thalweg Depth Ratio		22.16	42.9	18.2	26.98	15.62	5.44	16.91	30.65
Substrate - Percent Clay		2	**9**	**6**	2	2	**20**	0	4.5
Substrate - Percent Silt		5	**47**	4	4	**34**	30	15	32
Substrate - Percent Sand		**84**	40	**79**	**89**	53	16	19.5	58
Substrate - Percent Soil		**2**	0	0	0	**4**	**34**	0	1
Substrate - Percent Gravel		7	4	6	5	7	0	3	21
Substrate - Percent Cobble		0	0	0	0	0	0	0	26
Substrate - Percent Boulder		0	0	0	0	0	0	0	4
Substrate - Percent Rip-Rap		0	0	0	0	0	0	0	0
Substrate - Percent Detritus/Muck		0	0	**4**	0	0	0	0	1
Substrate - Percent Wood		0	0	**2**	0	0	0	0	1
Substrate - Percent Bedrock		0	0	0	0	0	0	0	1
Substrate - Percent Other		0	0	0	0	0	0	0	0
Macrohabitat - Percent Riffle		3.55	0	0	0	3.6	0	1.8	15.2
Macrohabitat - Percent Run		**92.9**	35.7	**96.4**	**100**	44.6	46.4	31.25	57.15
Macrohabitat - Percent Pool		**3.55**	**64.3**	3.6	0	51.8	53.6	30.35	58.95
Reach - Percent Soft Sediment		92.86		**100**	**100**	**100**	**100**	38.43	94.68
Streambank - Percent Bare	Left	**71**	**84.5**	**87.5**	**71**	**85**	42	46.4	70.25
Streambank - Percent Bare	Right	**83**	47	**84.5**	**80**	62.5	32		
Streambank Angle - Percent Horizontal (0-15 degrees)	Left	10	**60**	10	0	30	0	27.5	50
Streambank Angle - Percent Horizontal (0-15 degrees)	Right	30	20	10	10	0	0		
Streambank Angle - Percent Moderate (20-50 degrees)	Left	**60**	40	50	50	50	**60**	40	55
Streambank Angle - Percent Moderate (20-50 degrees)	Right	**60**	**80**	**70**	**80**	**60**	50		
Streambank Angle - Percent Vertical (55-110 degrees)	Left	**30**	0	**40**	**50**	**20**	**40**	7.5	17.5
Streambank Angle - Percent Vertical (55-110 degrees)	Right	10	0	**20**	10	**40**	**50**		
Streambank Angle - Percent Undercut (115-180 degrees)	Left	0	0	0	0	0	0	0	0
Streambank Angle - Percent Undercut (115-180 degrees)	Right	0	0	0	0	0	0		
Canopy - Average Percent of Channel Shaded		**22.97**	38.29	64.23	65.68	67.3	46.94	30.64	69.28

Table B-9. (continued)

Habitat Parameter	Bank	WLNT1	Holiday Lake			WLNT2	WLNT3	47b reference data	
		2009	1999	2008	2009	2009	2009	25th percentile	75th percentile
Canopy - Standard Deviation - Percent of Channel Shaded		32.06	35.82	32.2	30.31	29.97	42.17	24.52	30.92
Canopy - Transect Maximum Percent of Channel Shaded		48.65	89.19	91. 9	95.5	93.69	87.39	74.78	92.35
Canopy - Transect Minimum Percent of Channel Shaded		**0**	**1.8**	3.6	27.93	5.41	29.73	2.25	21.18
Instream Cover - Filamentous Algae - Average Percent		2		0	0	1	**54.25**	0	7.69
Instream Cover - Macrophytes - Average Percent		0		0	0	0	0	0	0
Instream Cover - Woody Debris - Average Percent		1.5		0	1	4	0	1.13	7.69
Instream Cover - Small Brush - Average Percent		3		2	2	9	1.5	4.38	9.13
Instream Cover - Trees/Roots - Average Percent		2		1	4.5	3	0.5	0	2.5
Instream Cover - Overhanging Vegetation - Average Percent		2		1	3	4	**19**	2.63	6.13
Instream Cover - Undercut Banks - Average Percent		0.5		0	1.5	2	1.5	0	2.38
Instream Cover - Boulders - Average Percent		0		0	0	0	0	0	3
Instream Cover - Artificial Structure - Average Percent		0		0	0	0	0	0	0.63
Instream Cover - Depth/Pool - Average Percent - IDNR Method		0		0	0	8	0	0	7.5
Fish Cover - Total Proportional Areal Cover - IDNR Method		11		4	12	31	**76.75**	19.19	36.69
Fish Cover - Total Proportional Areal Cover - EPA Method		9		4	12	22	22.5	16.19	27.13
Fish Cover - Natural Concealment Features		11		4	12	23	**76.75**	16.56	30.94
Fish Cover - Large Features Areal Cover - IDNR Method		**4**		**1**	7	17	**2**	7.38	16.88
Fish Cover - Large Features Areal Cover - EPA Method		**4**		**1**	7	9	**2**	6.38	13.06
Maximum Depth		**2.9**	**1.6**	3.2	**1.8**	**2.8**	**2.8**	2.9	4.1



B-1. Land use in the Walnut Creek watershed.

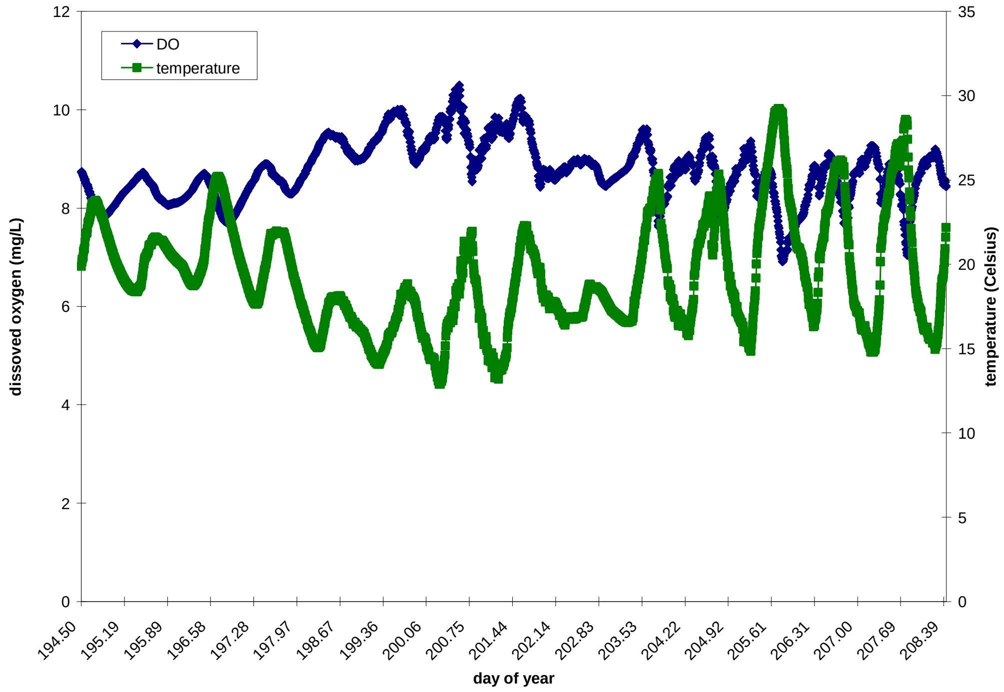


Figure B-2. Dissolved oxygen and temperature data from datalogger deployment at site WLNT1, July 13,-27, 2009.

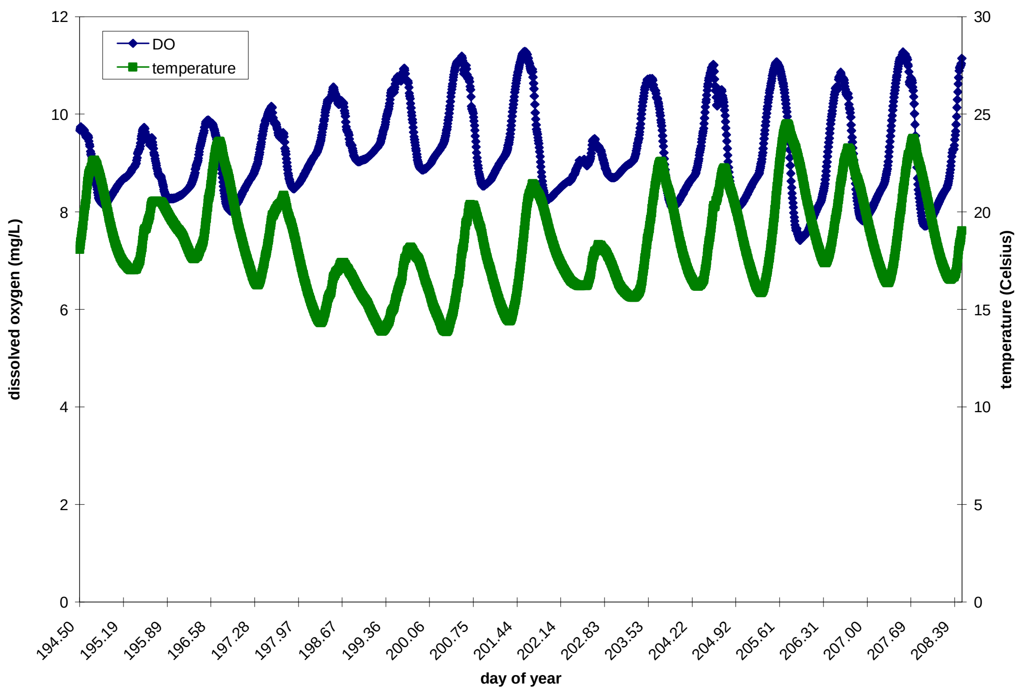


Figure B-3. Dissolved oxygen and temperature data from datalogger deployment at site WLNT2, July 13,-27, 2009.

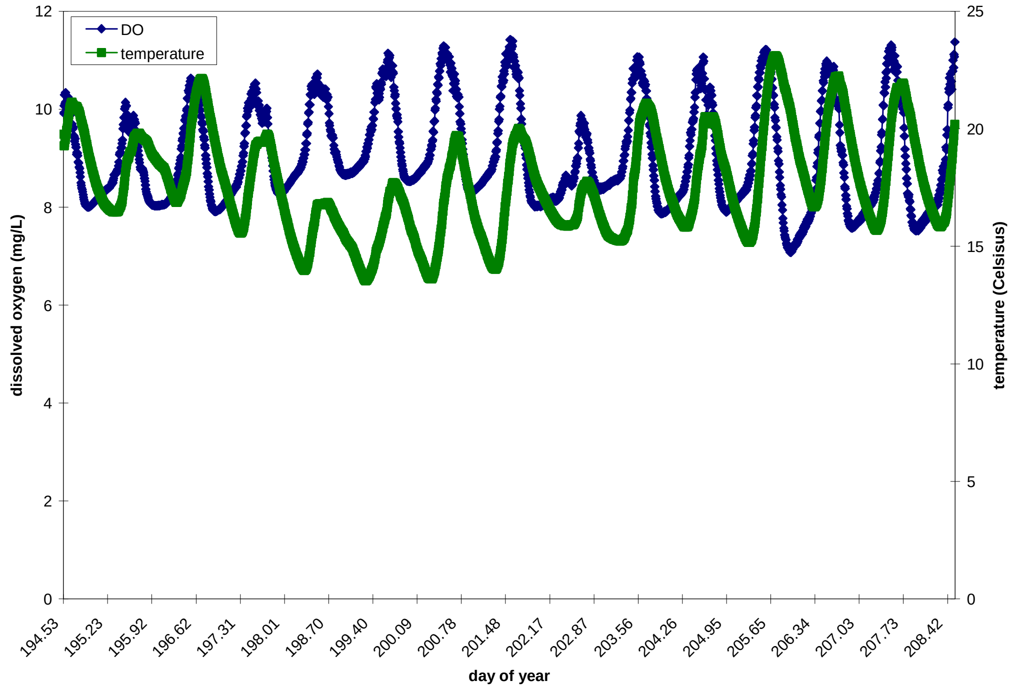


Figure B-4. Dissolved oxygen and temperature data from datalogger deployment at site WLNT3, July 13,-27, 2009.

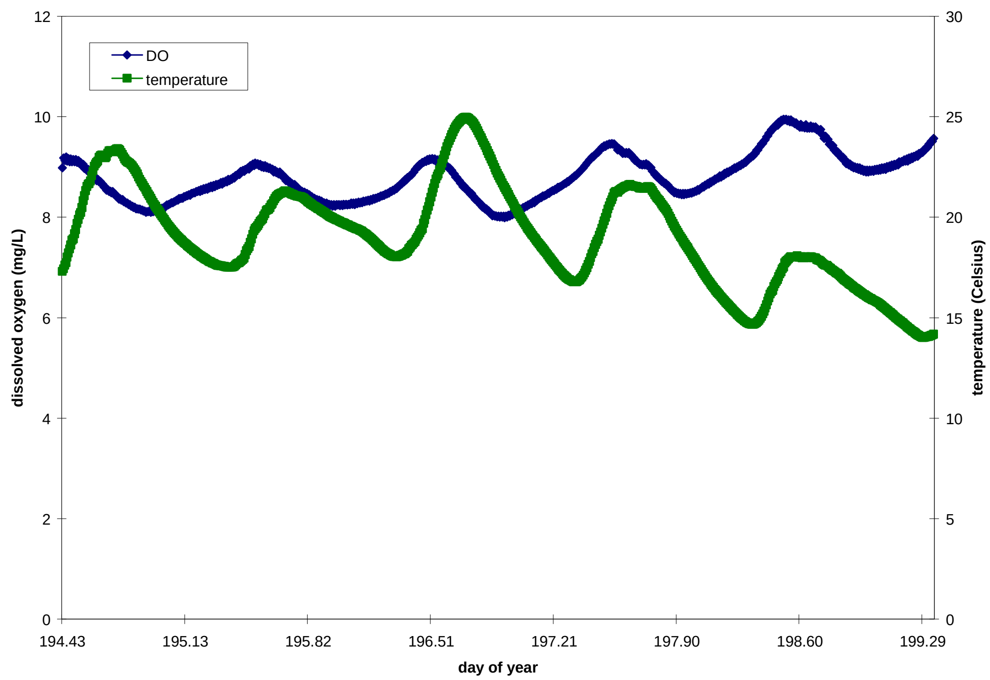


Figure B-5. Dissolved oxygen and temperature data from datalogger deployment at Holiday Lake site, July 13,-18, 2009. Note incomplete deployment—battery failed after five days.

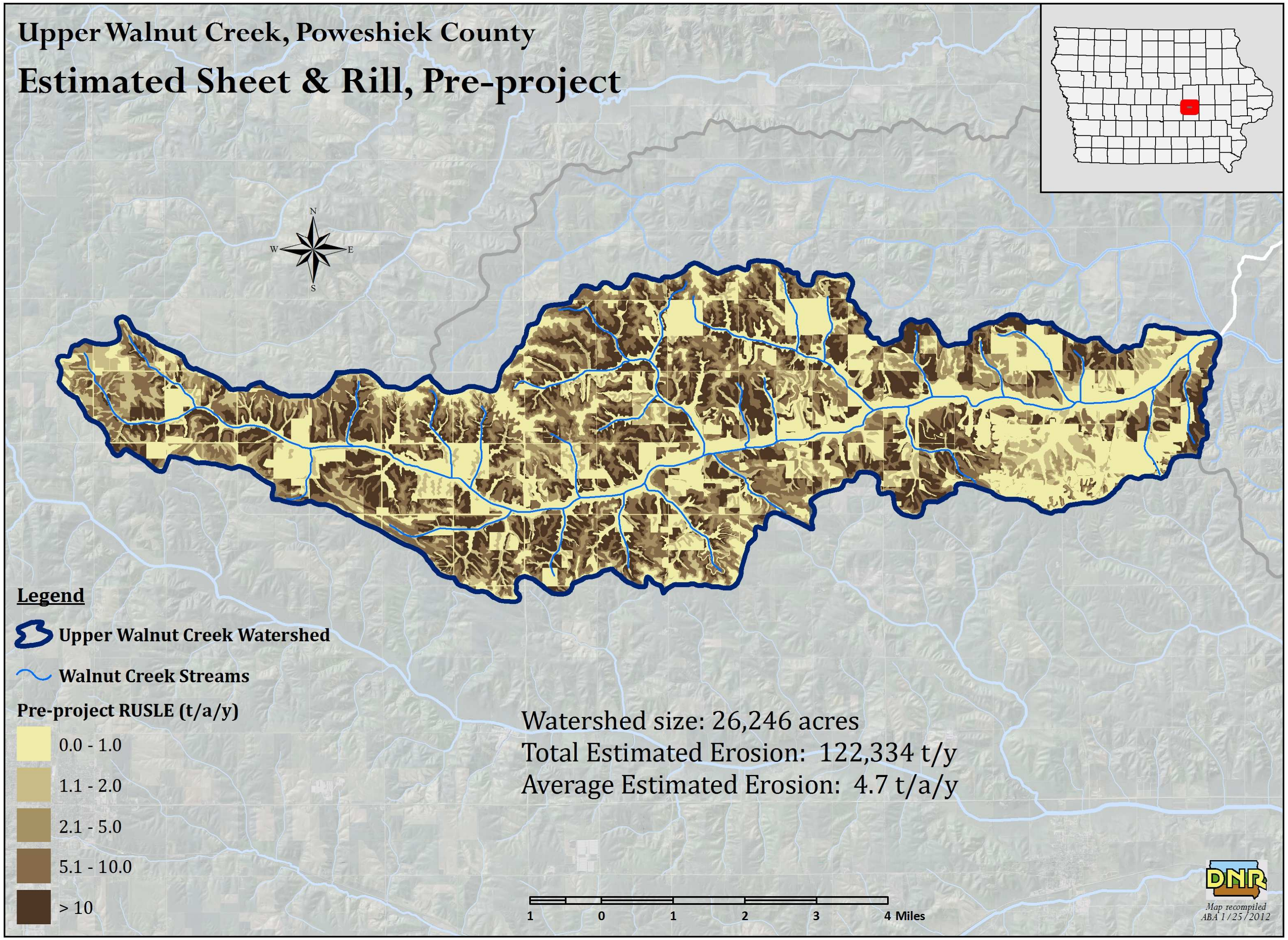


Figure B-6. RUSLE estimate of sheet and rill erosion in the Walnut Creek watershed.

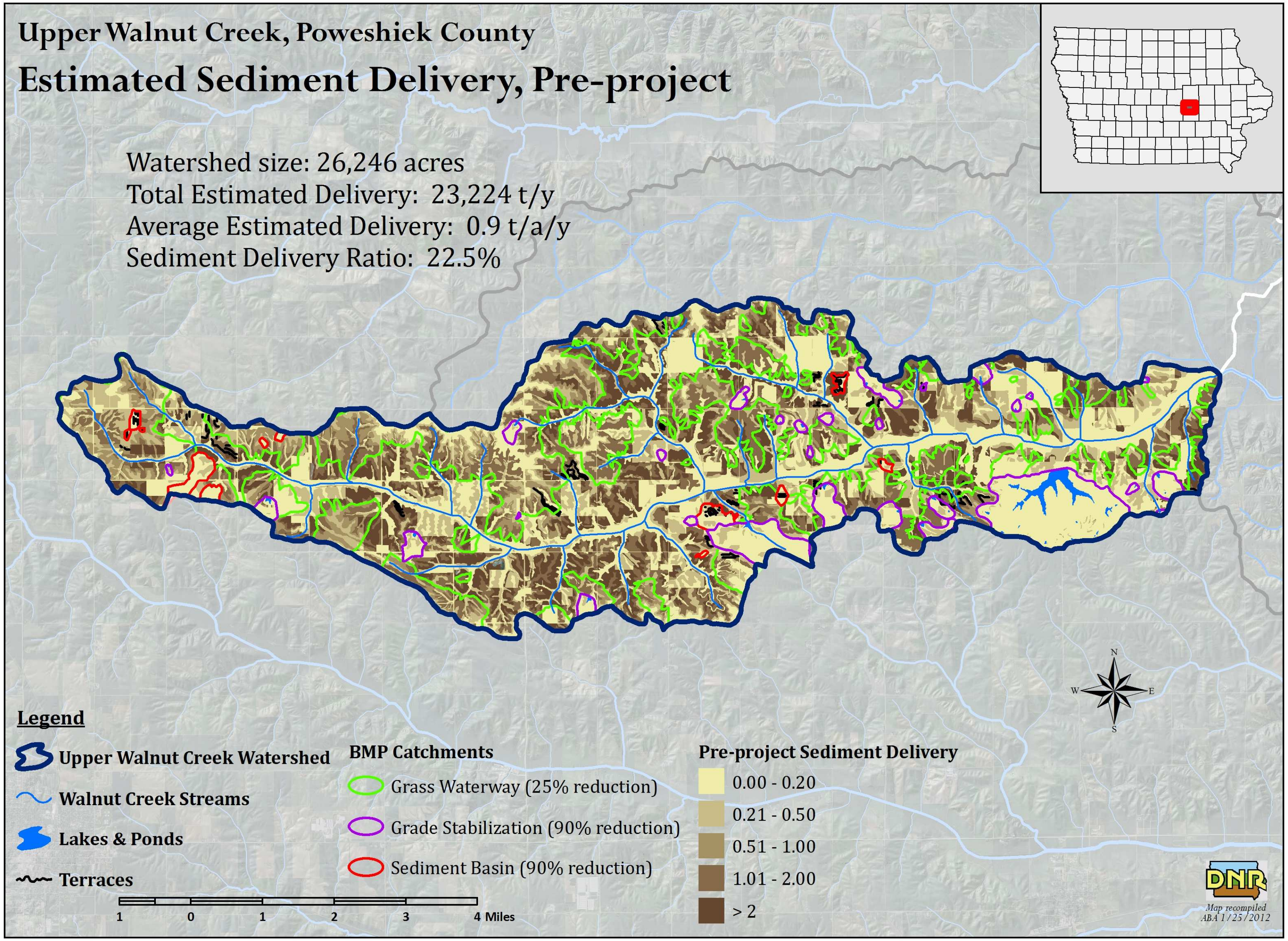
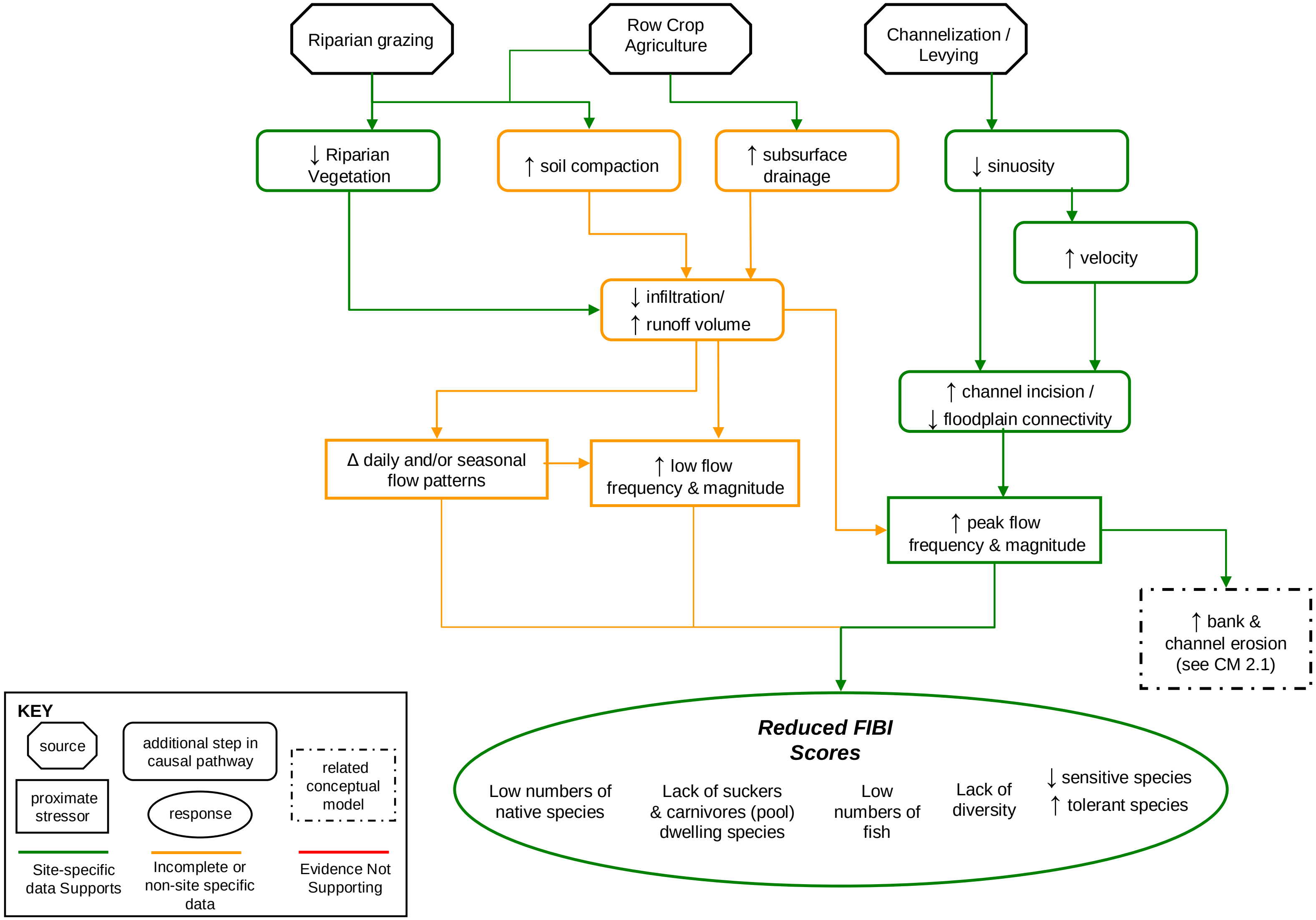


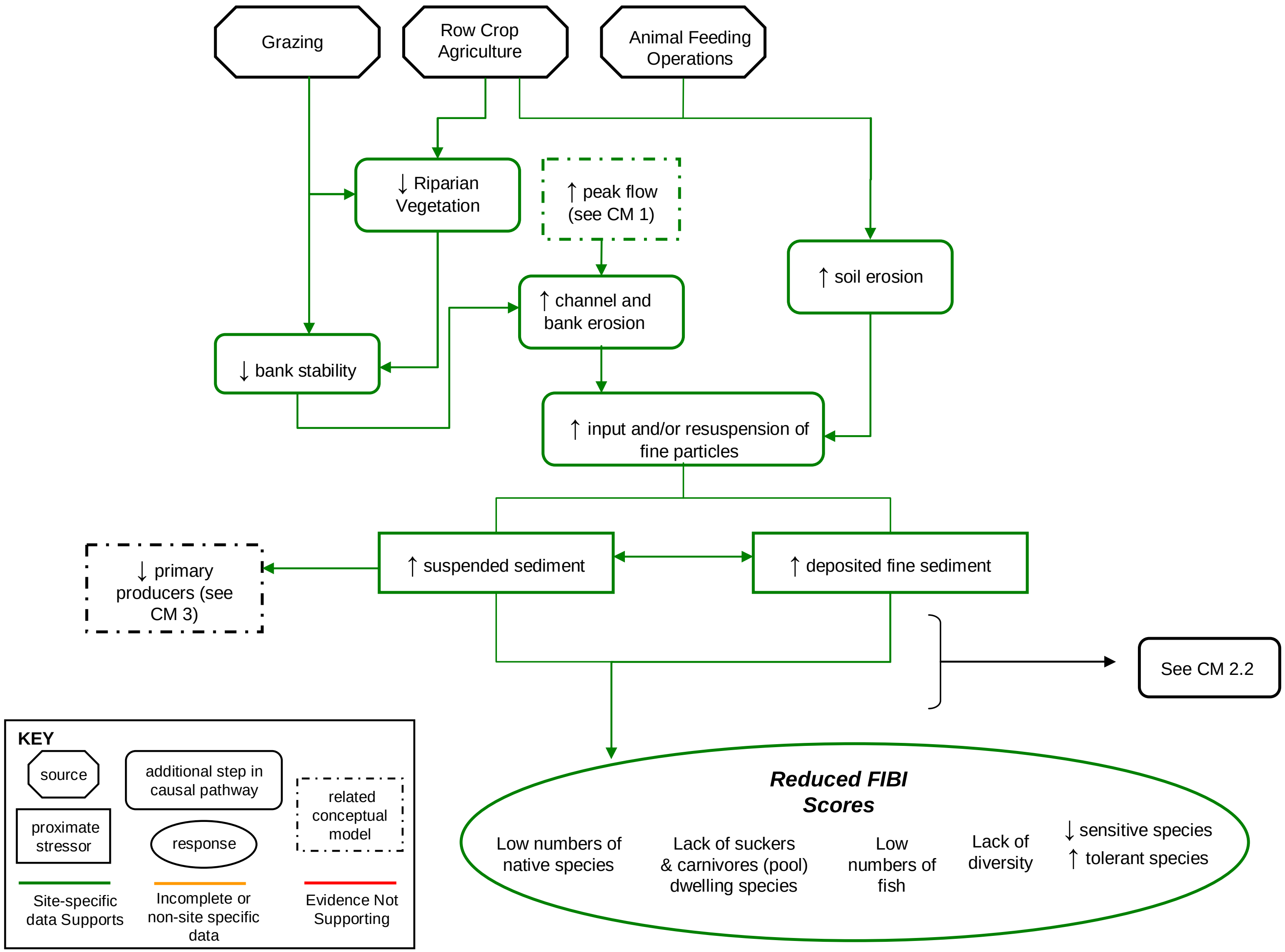
Figure B-7. Estimated sediment delivery in the Walnut Creek watershed.

Appendix C—Conceptual Models

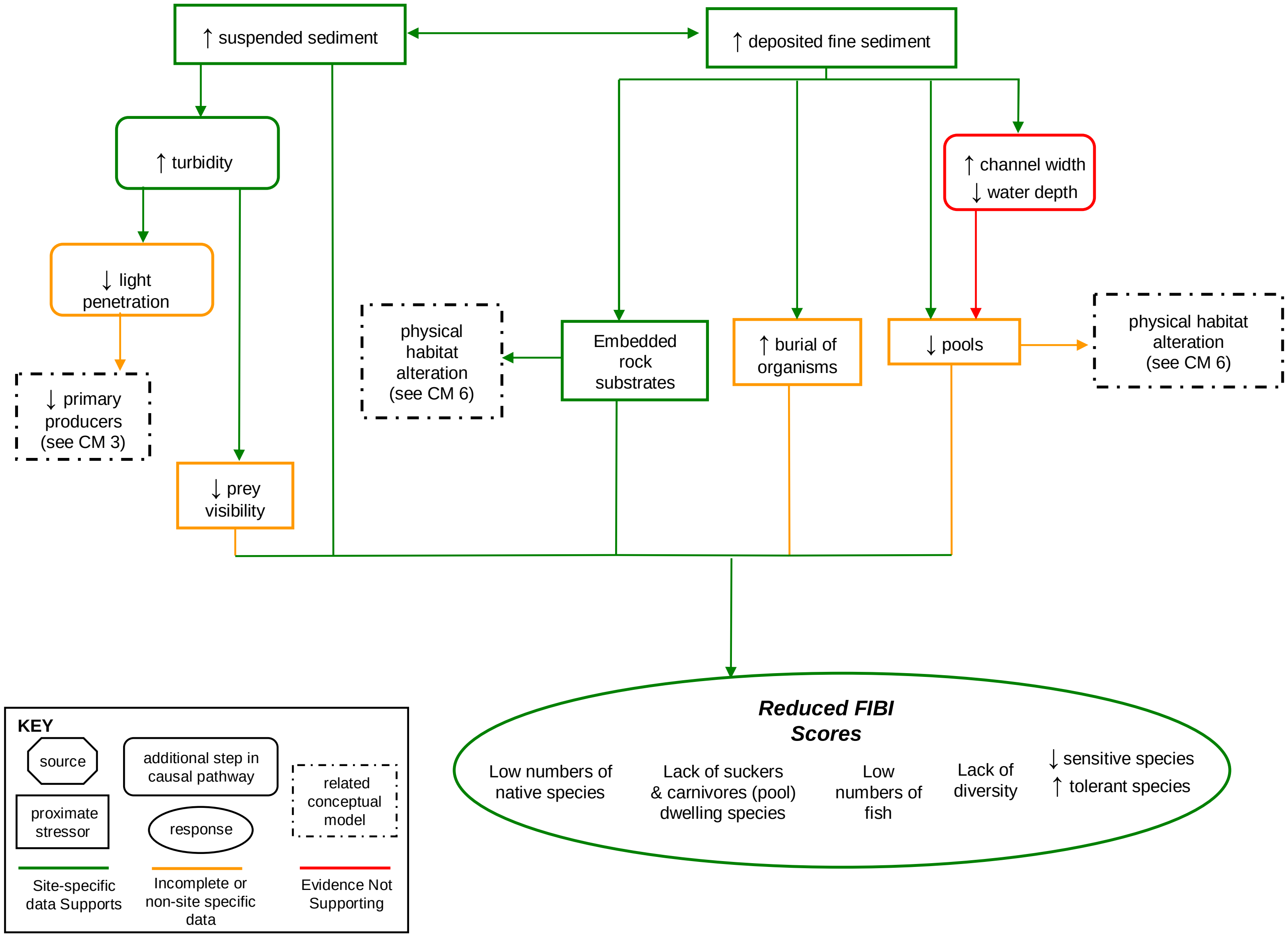
Conceptual Model 1 - Altered flow regime



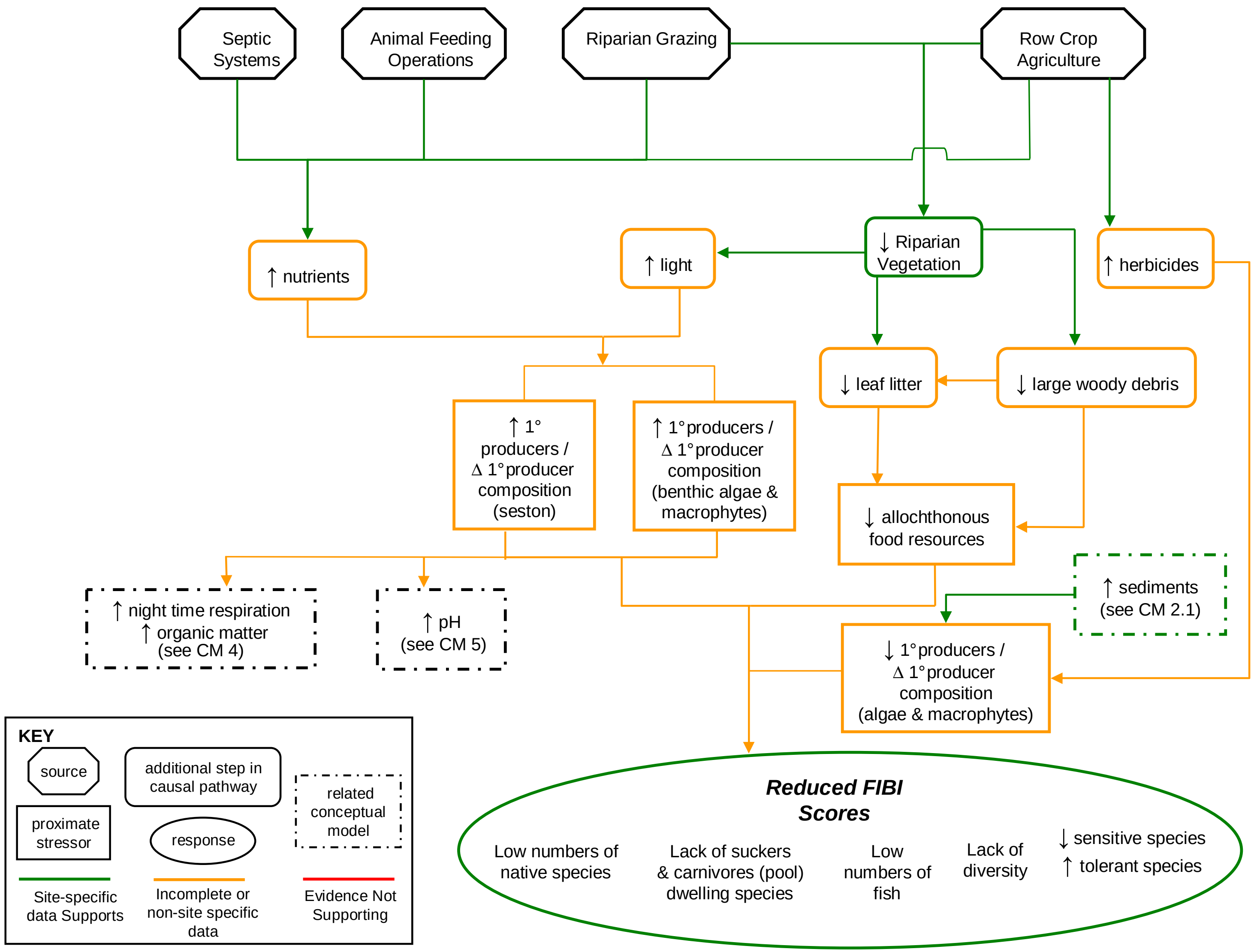
Conceptual Model 2.1 - Suspended and Bedded Sediments (SABS)



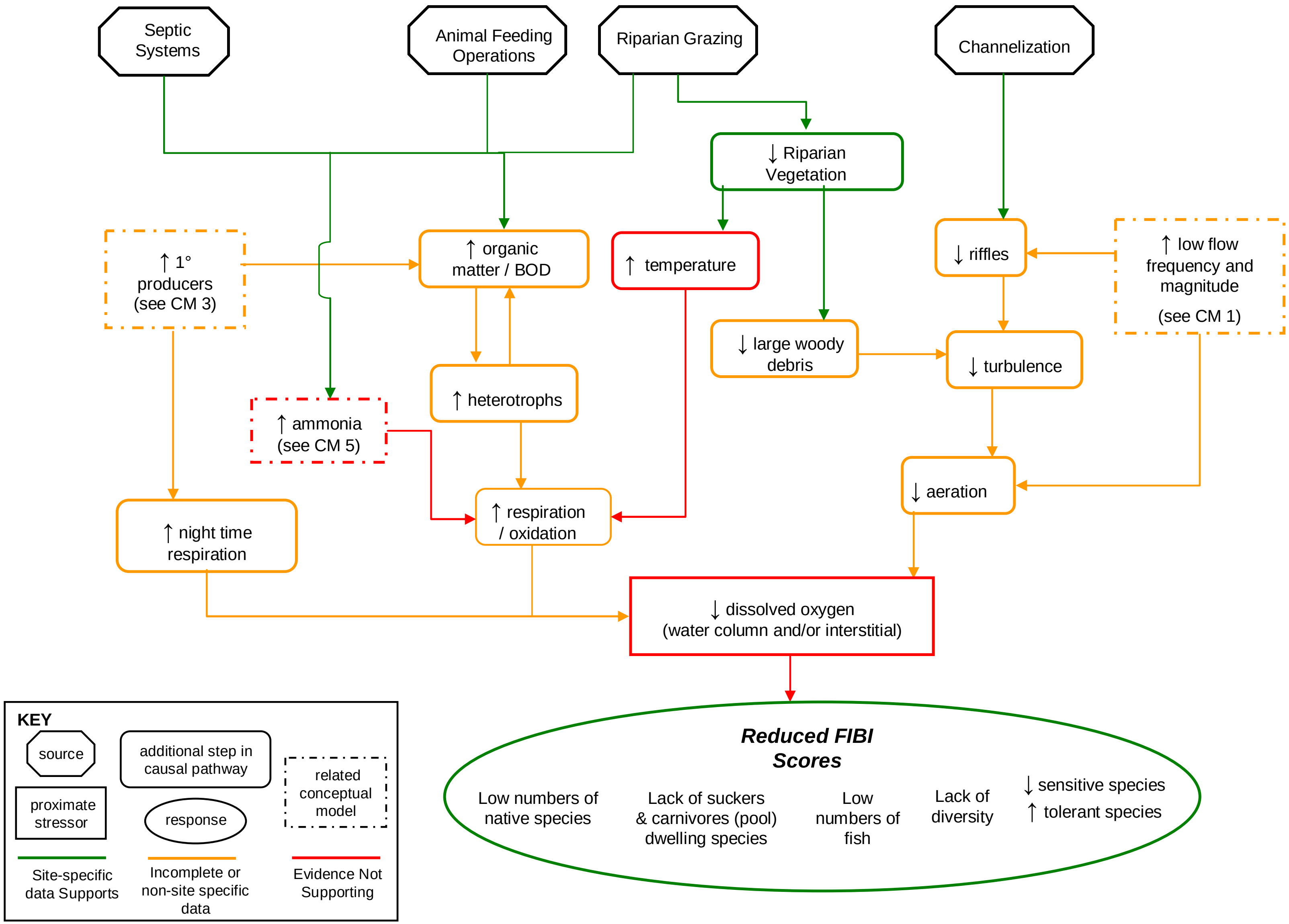
Conceptual Model 2.2 - Suspended and Bedded Sediments (SABS)



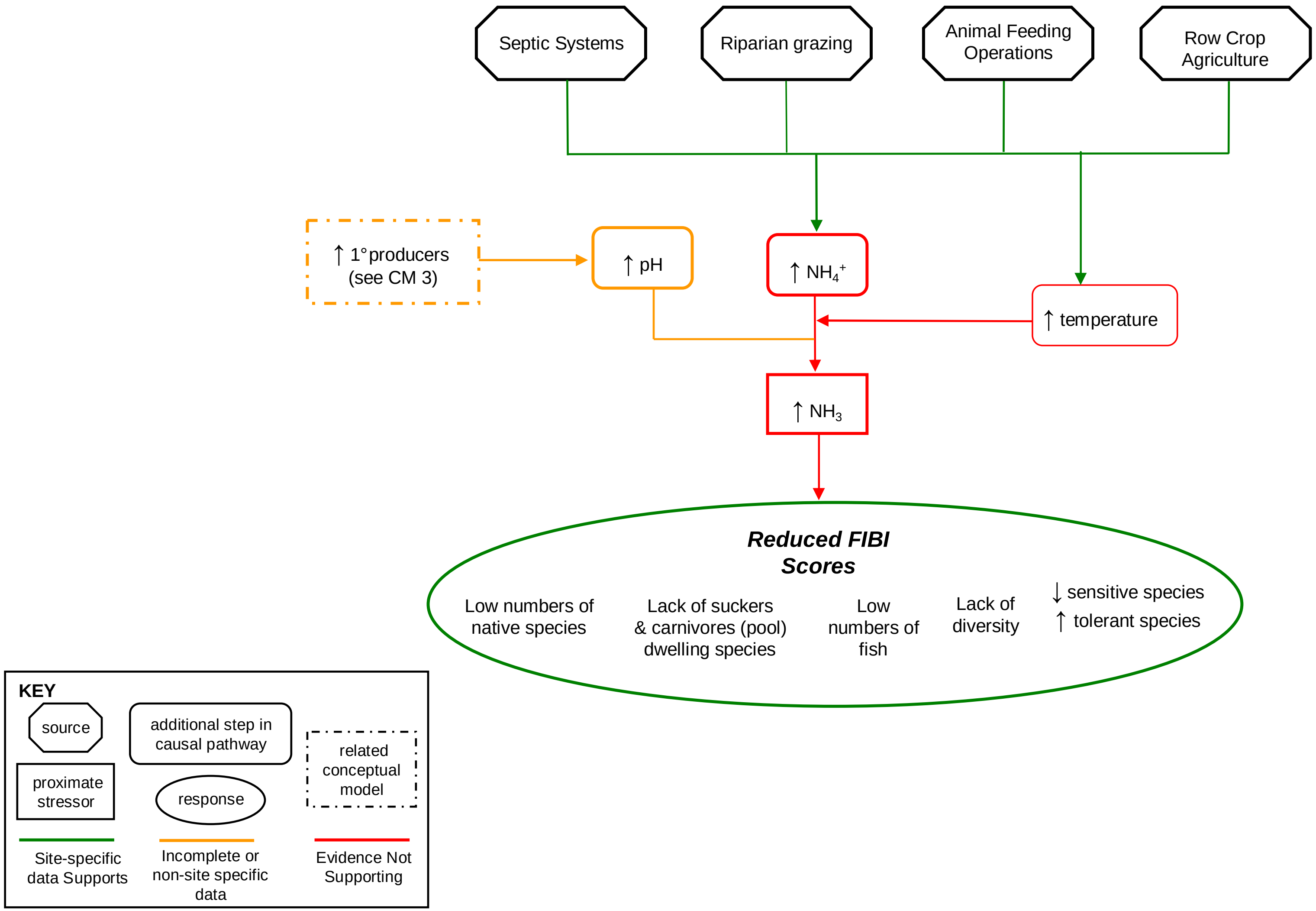
Conceptual Model 3 - Altered basal food source



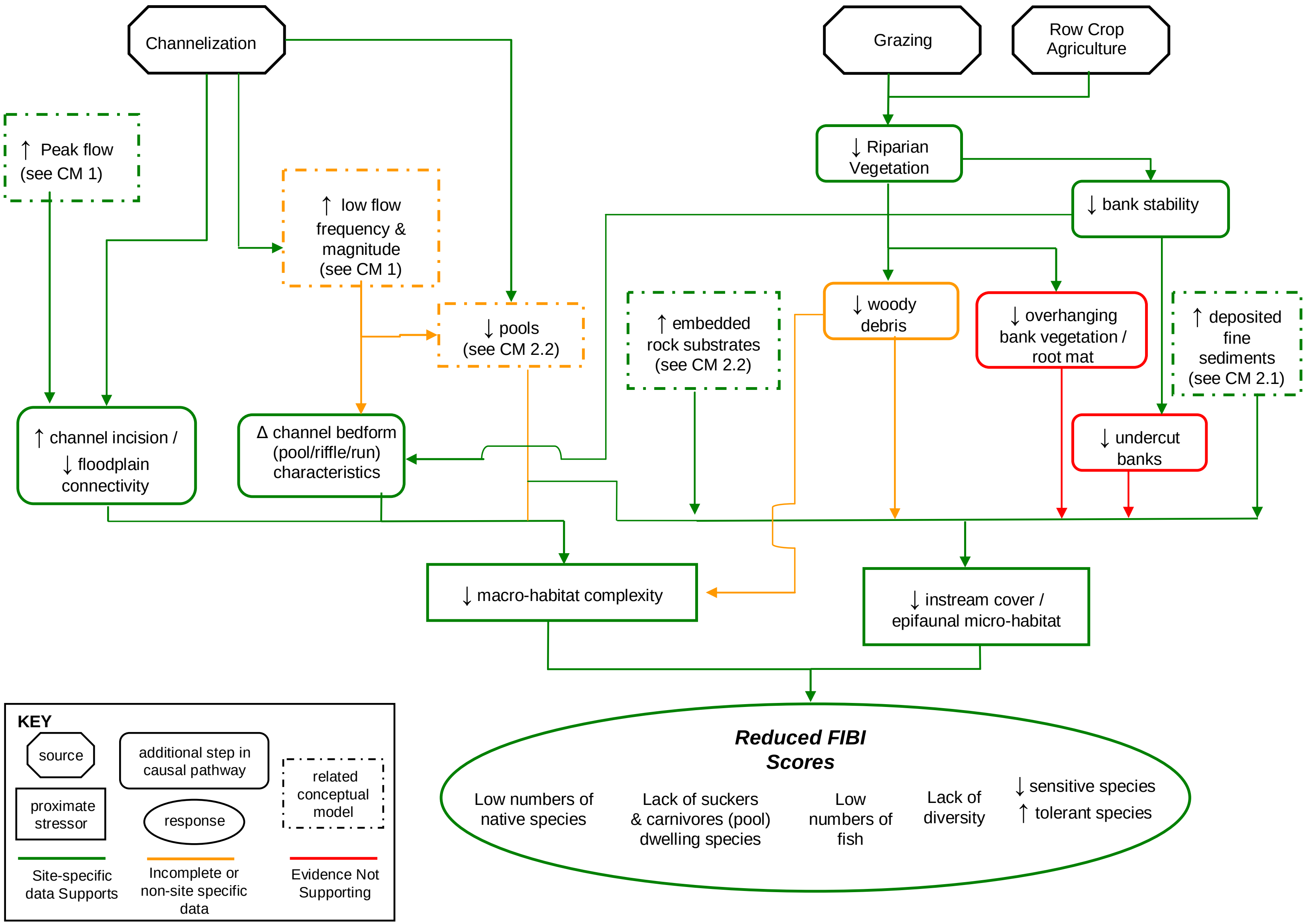
Conceptual Model 4 - Decreased dissolved oxygen



Conceptual Model 5 - Elevated ammonia



Conceptual Model 6 - Physical Habitat Alteration



Conceptual Model 7- Aquatic Life Depletion and Isolation