Stressor Identification
for

Dick Creek

Wayne County, Iowa

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Watershed Improvement Section
&
Watershed Monitoring and Assessment Section

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Executive Summary

A Stressor Identification (SI) was completed for Dick Creek (Segment IA 05-CHA-0067_0), located in Wayne County near the town of Corydon, Iowa. Dick Creek is a tributary of the South Fork Chariton River. This waterbody is identified on Iowa's Section 303(d) list of impaired waters as impaired for aquatic life use. 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.

Dick Creek was first placed on the impaired waters list in 2004 in response to fish sampling that was conducted by the Iowa Department of Natural Resources Fisheries staff in 1999 and 2001. Additional biological sampling and water quality monitoring occurred in early September of 2008 and in early August of 2009 in preparation for the development of this SI.

Data from the biological sampling in 2008 and 2009 showed that the fish community in Dick Creek was not meeting regional expectations for aquatic life uses. Data from the same sampling showed that the aquatic invertebrate community was meeting ecoregion expectations in the impaired segment of the stream. Data and information collected during the SI monitoring were assembled and a weight of evidence approach was used to evaluate candidate causes of impairment. The evidence review process considered data for proximate stressors including biological, chemical, or physical agents that directly impact stream biota, and additional data representing intermediary steps in causal pathways that connect stressor sources and biological effects.

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

- Low flow conditions/lack of habitat availability
- Depletion of dissolved oxygen

It is not recommended that the stream be a candidate for TMDL development as the manifestation of low dissolved oxygen conditions are driven primarily by seasonal low flow conditions within the system.

1. Introduction

A Stressor Identification (SI) for Dick Creek, 305(b) Segment No. IA 05-CHA-0067_0, was completed to determine the causes of 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 Dick 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 would not require a TMDL. However, regardless of whether or not the stressor is defined as a pollutant, a complete SI will identify all causal agents and pathways that are responsible for impairing the aquatic biological community.

1.1. Watershed Features

The Dick Creek watershed is located in south central Iowa, near the middle of the Southern Iowa Drift Plain landform region (**Figure 1-1**). This area of the state is characterized by steeply rolling hills and well connected drainage ways that cut deeply into the landscape.

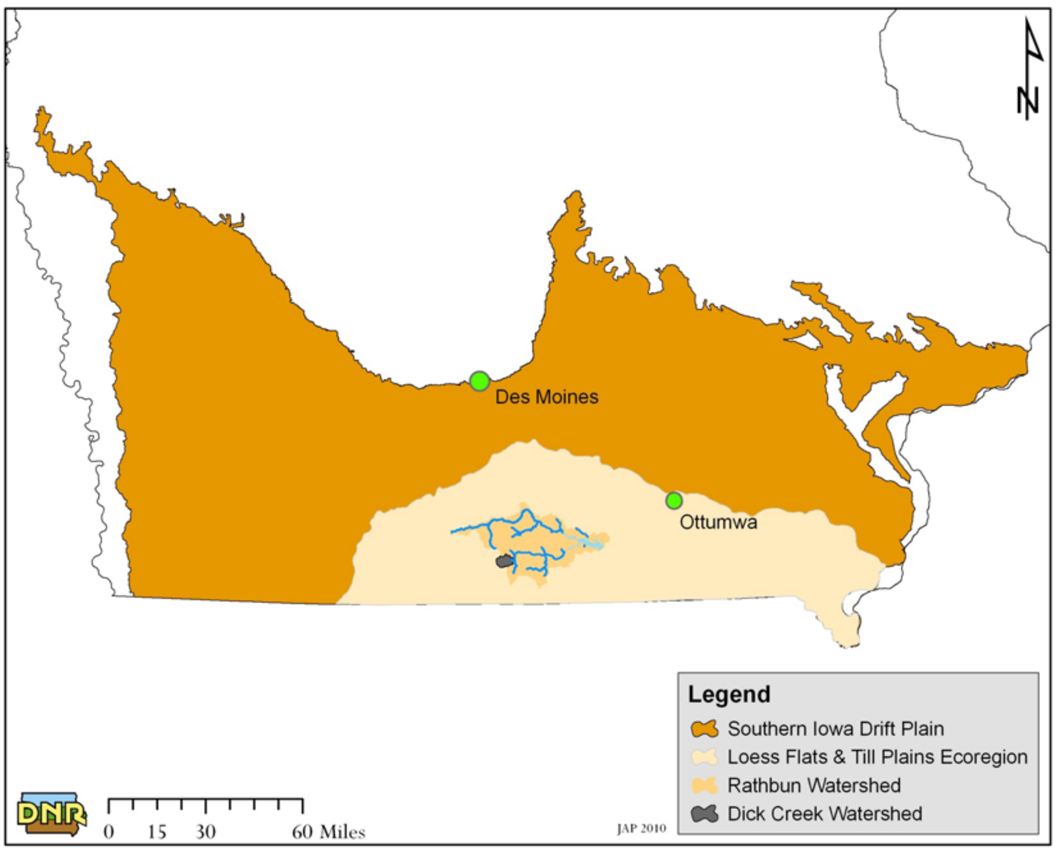

Figure 1-1 Loess Flats & Till Plains Ecoregion Map

The central portions of the Loess Flats and Till Plains Ecoregion have thinner layers of loess than the eastern and western boarders of the area (Prior, 1991). Over time the erosion of this loess layer has exposed a strongly eroded and weathered paleosol[1] that contains a thick

[1] A paleosol is a soil horizon from the geologic past, usually buried beneath more recent deposits or soil horizons

gumbotil[2] that is classified as very slowly permeable. This gumbotil is especially prevalent in Wayne County. All of the upland soils in the Dick Creek watershed formed either in (Clarinda series) or above (Seymour and Grundy series) this gumbotil layer.

The permeability ratings for soils above this gumbotil layer are 80 or 90. A permeability ranking of 80 means that the soil is capable of infiltrating 0.06-0.2 inches of precipitation per hour, whereas a ranking of 90 is equal to <0.06 in/hr of infiltration capacity. Fifty three percent of the land surface in the Dick Creek watershed has a permeability ranking of 90 (<0.06 in/hr) with an additional 18 percent in the 80 category. Only 29 percent of the watershed surface is capable of infiltrating more than 0.2 in/hr of precipitation. The bulk of this area is either in the alluvial valley or along the steep hill slopes (9-18% slope) where the landscape transitions from upland to valley position (**Figure 1-2**).

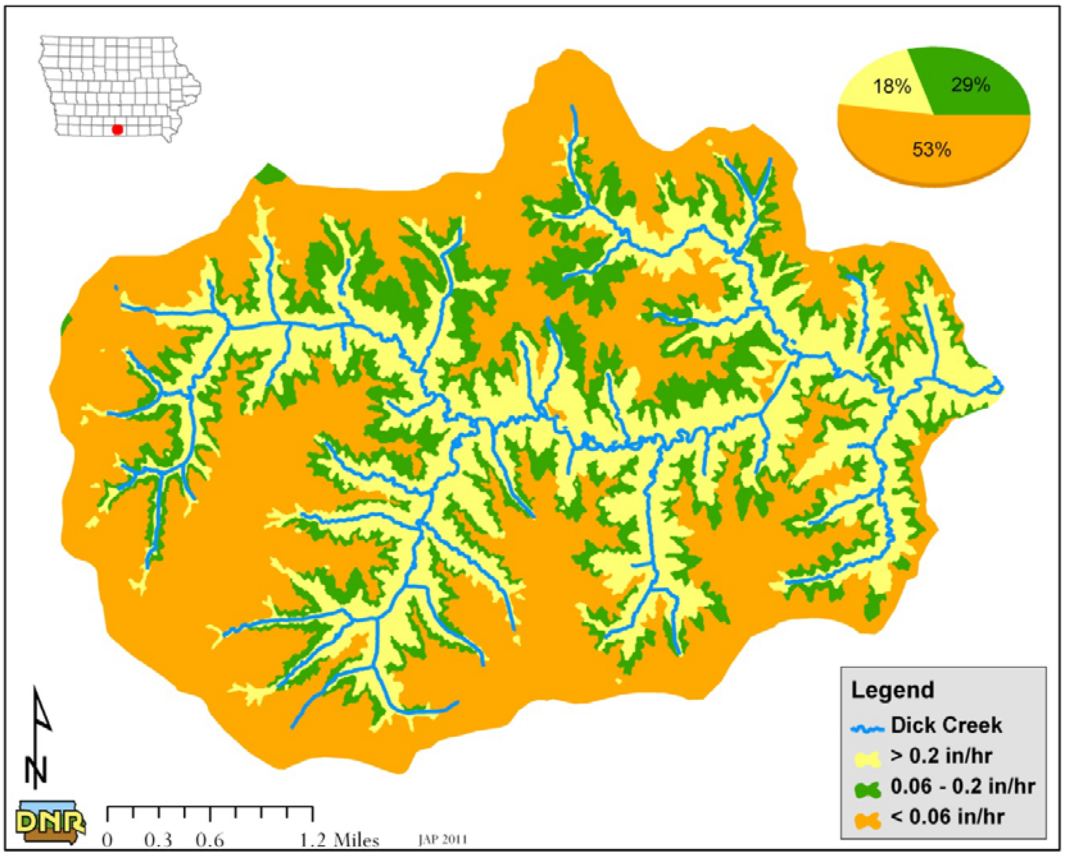

Figure 1-2 Dick Creek soil permeability rankings

The Dick Creek watershed, which is roughly 9,800 acres in size, contains about 4,100 acres of row-crop (42%), 4,400 acres of grazed and un-grazed grass land (45%) and roughly 900 acres of woodland (9%). The remaining acres are comprised of ponds, farmsteads and roads (**Appendix C, Figure C-3**). The watershed drops a total of 132 feet from an elevation of 1,115 ft in the west to an elevation of 983 feet at the confluence with the South Fork Chariton River. The stream itself drops a total of 93 feet from near Highway 65 in the south west end of the watershed to where it enters the South Fork Chariton River, 8.7 stream miles downstream,

[2] A gumbotil is a sticky clay formed through the weathering of glacial drift

resulting in a relief of 10.7 ft/mi or 0.2 percent. The bulk of this occurs gradually throughout the stream's length (**Figure 1-3**).

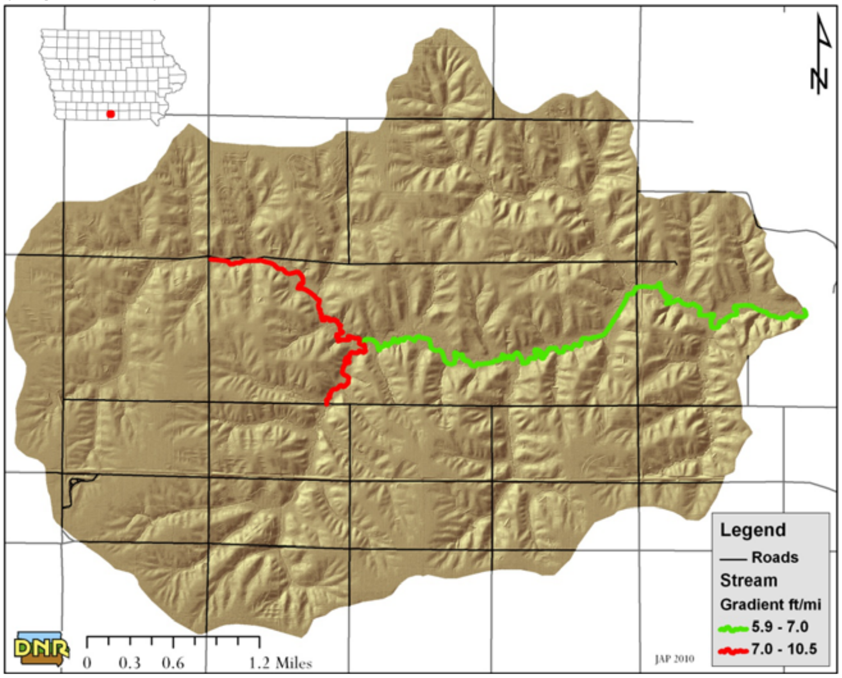

Figure 1-3 Relief map showing stream gradient in Dick Creek

The stream corridor in Dick Creek is morphologically active; a main channel sinuosity of 1.67 indicates that the stream is meandering in nature. Many oxbows (meander cutoffs), off channel chutes and tightly wound meander scrolls were observed through the stream corridor during a 2009 stream survey (**Figure 1-4**).

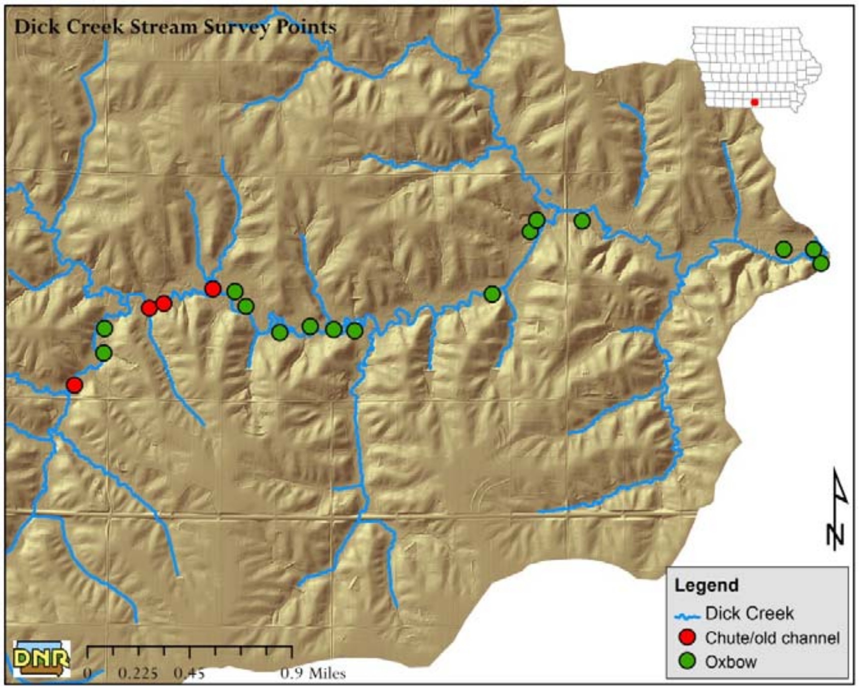

Figure 1-4 Map of geomorphic features identified during 2009 stream survey

1.2. Stream Flow and Water Quality

Water quality and stream discharge information was collected at two sites (Dick 1 and Dick 2) along Dick Creek in 2009 (**Figure 1-5**). Water quality samples were collected bi-weekly from July 2009 – October 2009 at Dick 1 and Dick 2 and then monthly for November 2009 – February 2010. Water quality samples were analyzed for the constituents found in **Table 1-1.** In addition to the scheduled sampling, storm event water collection was also conducted at Dick 1. This sampling was performed using an ISCO 6720 auto sampler set to trigger water collection upon a rise in stream stage. Continuous dissolved oxygen sampling was conducted at both sites from July 29th – August 9th using YSI water quality sondes outfitted with an optical dissolved oxygen probe.

Table 1-1 Water quality parameters from bi-weekly and event sampling

Ammonia nitrogen as N	Turbidity
Nitrite + nitrate nitrogen as N	Sulfate
Total Kjeldahl Nitrogen (TKN)	Hardness
Orthophosphate as P	Carbonaceous Biological Oxygen Demand (CBOD)
Total phosphate as P	Chloride
Total Dissolved Solids	Chlorophyll a
Total volatile suspended solids	E. Coli
Total Suspended Solids (TSS)	Field Measurements (Temperature, pH, Flow, and Dissolved oxygen)

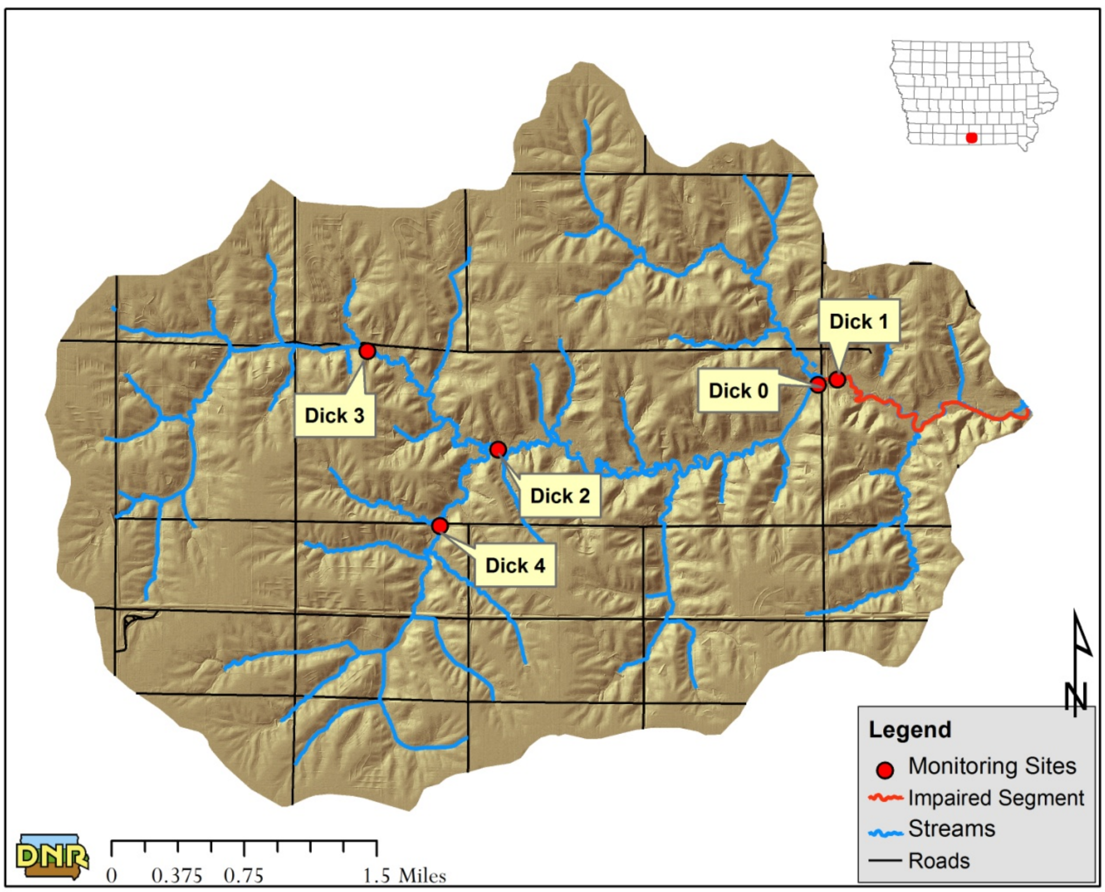

Figure 1-5 Map of monitoring locations in the Dick Creek Watershed

Continuous stream stage was collected at each site. Stage was collected at the Dick 1 site using the ISCO auto sampler while stage at Dick 2 was collected using an In-situ pressure transducer. Stream cross-sections were established at each site and stream flow was measured at both sites during water quality collection trips. These discrete measurements were used in conjunction with stream stage to create a stream stage/discharge curve which predicts stream flow at varying stream stages.

1.3. Biological Impairment

Dick Creek (IA 05-CHA-0067_0) was originally placed on Iowa's 303(d) (category 5) impaired waters list in 2004. The assessment of this segments aquatic life uses was based upon data collected in 1999 and 2001 as part of a DNR Fisheries stream sampling project (Chariton research station). Additional biological sampling was conducted at multiple sites in the watershed in 2008 and 2009 in support of this Stressor Identification (SI) project development (**Figure 1-5**).

All fish communities sampled in 2008 and 2009 at full bio sites failed the 40a ecoregion Fish Index of Biotic Integrity (FIBI) Biological Impairment Criterion (BIC) of 33. The results from Dick 0 in 2008 and Dick 1 and 2 in 2009 were very similar with FIBI scores of 26, 28, and 31 respectively. Of the three full biological sampling locations only the downstream most site (Dick 1) occurred on a stream reach that was classified as calibrated for use of the BIC. The other two sites were located further up in the watershed in an un-calibrated reach.

No single metric stood out as a major component of the low FIBI scores at the Dick Creek bio sites. In general there was an across the board slight depression of metric scores which pulled the FIBI score down (**Appendix B, Table B-5**). A trend seen at all sites was an overall low number of fish collected, resulting in low Catch Per Unit Effort (CPUE) values for each sample (**Table 1-2**).

The lack of top carnivore and sensitive species certainly contributed to the lower scores at Dick Creek sites. However, it should be noted that it is common in the 40a ecoregion to have streams that lack these groups of organisms (**Table 1-2**).

Table 1-2 Important fish data metrics from Dick Creek full biological sampling

Metric	Dick 1	Dick 0	Dick 2	40a 25th percentile
Total Fish	236	106	116	312
Fish per 500 ft	199	75	133	233
CPUE (score)	1.3	0.6	0.73	1.8
% top carnivore	0	0	0	0
# sensitive species	0	0	0	0
CPUE	1.3	0.6	0.73	37.54

The benthic macroinvertebrate sampling which took place at Dick 1 in 2009 included an artificial substrate collection and a Surber sample. The Surber was included due to heavy sedimentation of the artificial substrates and the availability of a riffle from which to collect the Surber sample. The Benthic Macroinvertebrate Index of Biotic Integrity (BMIBI) calculated with the artificial substrates scored a 24, which fell short of the 40a BIC of 41. The BMIBI that utilized the Surber sample scored a 46, passing the BIC.

The two sampling sites further up in the watershed (Dick 0 and Dick 2), while not in the calibrated range, did fail the BIC. The major components of the low BMIBI scores were the lack of Ephemeroptera (Mayflies), Plecoptera (Stoneflies), and Trichoptera (Caddisflies) (EPT) taxa as a component of the community, dominance of Chironomid taxa (midge larvae) and a large percentage of the community was comprised of a few taxa (**Table 1-3**).

Table 1-3 Important BMIBI metrics from Dick Creek full biological sampling

Metric	Dick 0	Dick 1	Dick 2	40a Ref
SH # EPT taxa	1.67	3.33	1.33	3.5 (25th)
% EPT taxa	11%	67.52%	5%	36% (25th)
% Chironomidae	88%	26.93%	94%	5.75% (25th)
% Dominant feeding group	99%	61.04%	100%	53% (25th)
% top 3 dominant	91%	88.98%	99%	68% (25th)

2. Stressor Identification Process

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

2.1. Candidate Causes and Theoretical Associations

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

Conceptual models (**Appendix D**) 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) is applied.

Final ratings are obtained by averaging the rankings from individual 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 revisited should the evidence analysis process fail to identify any likely causes from the primary list. Additionally, those candidate causes that were not evaluated due to a lack of data can be revisited should further monitoring produce such data. Results of the candidate cause rating process for the Dick Creek watershed biological impairments are displayed in Table 2-1.

Table 2-1 Dick Creek aquatic life use impairment candidate causes and probability rankings

Toxins (sediment and water)		**Habitat Alterations**	
Metals		● Bank erosion	1.7
● Arsenic	ND	● Channel incision/loss of flood plain connectivity	2
● Cadmium	ND	● Channel straightening	2.2
● Chromium	ND	● Dewatering	1.2
● Copper	ND	● Excessive algae/macrophyte growth	2
● Lead	ND	● Flow impoundment	2.8
● Mercury	ND	● Lack of woody debris/roughness/structure	2.8
● Selenium	ND	● Physical barriers	2.3
● Zinc	ND	● Riparian vegetation loss	3
● Other		● Sedimentation	1.5
Non-metals			
● Chlorine	ND	**Hydrologic Alterations**	
● Cyanide	ND	● Flow diversion—sinkholes	3
● Oil / grease	ND	● Flow regulations—dams	3
● PAHs	ND	● Pumping (withdrawals)	3
● Pharmaceuticals	ND	● Subsurface tile drainage	3
● SOCs	ND	● Urban stormwater outfalls	3
● Un-ionized ammonia	3	● Wetland loss	3
● Other			
Pesticides		**Exotic/Introduced Species and Other Biotic Factors**	
● Fungicides	ND	● Competition	3
● Herbicides	ND	● Disease	2.9
● Insecticides	ND	● Endocrine disruption	ND
● Other		● Harvest	3
		● Refugia depletion/isolations	2.4
Water Quality Characteristics		● Predation	ND
● Chlorophyll a	2		
● Dissolved oxygen	1		
● Nutrients			
Nitrogen	2		
Phosphorus	2		
● pH	2.4		
● Salinity / TDS / Chloride	3		
● Turbidity / TSS	1.7		
● Water temperature	2.4		

(1) high; (2) medium; (3) low; (ND) no data

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

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.

(U.S. EPA, May 2005: Handbook for characterizing causes. Eighth Edition)

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 Dick Creek watershed with data collected for the IDNR stream biological assessment program. Dick Creek sampling data and benchmarks reviewed for the stressor co-occurrence and stressor-response evidence considerations are summarized in Appendix C, Table C-1. Water quality and stream habitat data are summarized in **Appendix B, Tables B-1 through B-4**. Diurnal temperature and dissolved oxygen (DO) fluctuations were monitored from July 29, 2009 through August 9, 2009

(**Appendix C; Figure C-2).** These data were used to determine if violations of the DO standard (Iowa Administrative Code Ch. 61) 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, stressor indicator data and stream corridor assessment data from Dick Creek were compared with interquartile data ranges (IR: 25^{th} to 75^{th} percentile) for stream reference sites within the Loess Flats and Till Plains ecoregion (40a). In cases when reference data were not available, the 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 IR. Additionally, known associations between environmental conditions and biological responses, and data from published literature are 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 having 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 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, Dick Creek data were compared to interquartile data ranges from reference sites within the 40a ecoregion or data ranges for statewide random survey sites as well as information and correlative data from primary literature. The indicator data and other relevant information were evaluated qualitatively and/or quantitatively to evaluate the evidence supporting each hypothesized causal pathway. The results of this process are shown in the causal pathway conceptual model diagrams in Appendix D.

4. Strength of Evidence

The U.S. EPA (2005) handbook for characterizing causes served as the primary guidance document for evidence analysis and ranking. The main types of evidence consideration used in this SI are: *Plausible Effect Given Stressor-Response Relationship; Complete Causal Pathway and Consistency of Association*. Each of these considerations incorporates data from Dick Creek along with ecoregion-specific or statewide sampling data. The Dick Creek sampling data were not sufficient to perform the *Temporality and Spatial Co-occurrence* evidence considerations. *Analogy* was not used because no analogous stressor-response scenarios were identified. Other lines of evidence were selectively applied depending on the stressor and data/evidence. The final group rankings for the Dick Creek analysis of associations exercise can be found in **Table 4-1**. Final ranking scores are as follows: (+++) = strongest sufficient cause, (+) = Plausible but insufficient alone, (0) = other causes do not contradict, (-) = other causes stronger or candidate cause improbable, (---) = impairment confidently attributed to another cause.

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

Proximate stressor category (Conceptual model – Appendix D)	Final Ranking
Change in daily or seasonal flow patterns (CM 1)	0
Increase in low flow frequency or magnitude (CM 1)	+
Increase in peak flow frequency or magnitude (CM 1)	0
Increased suspended sediment (CM 2.1)	0
Increased deposited sediment (CM 2.1)	+
decrease in allochthonous food resources (CM 3)	-
decrease in primary producer composition (benthic and macrophytes) (CM 3)	-
increase in primary producer composition (seston) (CM 3)	0
increase in primary producer composition (benthic and macrophytes) (CM 3)	0
Decreased DO (CM 4)	+
Increased Temperature (CM 5)	-
Decrease in macro-habitat complexity (CM 7)	+
Decrease in in-stream cover/epifaunal micro-habitat (CM 7)	0
Barriers to migration and colonization (CM 8)	0

4.1. Primary Causes

The proximate stressors identified in the SI process (not ranked by order of importance) are: Low flow/habitat related impacts and low dissolved oxygen. The supporting evidence for each primary cause (i.e., proximate stressor and associated causal pathways) is described below.

Low Flow/Habitat related impacts

Dick Creek is a small third order stream that is on the lower edge of the calibrated range (10,300 – 156,000 acres) for using the warm water wadeable reference protocol (IDNR 2009; Wilton 2004). Only the lower 1.8 miles of the stream system falls within the IBI calibration range represented by wadeable reference sites. The other portions of Dick Creek were formally designated as general use, a classification that was used to represent a threshold where the warm water wadeable stream reference data is no longer applicable, as the watershed and stream conditions are no longer representative of those in the wadeable reference data set.

Reference sites within the 40a ecoregion have on average a 61,000 acre drainage area and a 25th and 75th percentile of 39,400 and 70,200 acres (respectively). At its mouth, Dick Creek drains 9,800 acres. The downstream most sampling site (Dick 1) is located at the upstream most end of the calibrated segment and has a drainage area of roughly 8,500 acres (**Figure 1-5**). The drainage area of the Dick Creek watershed is well below the "typical" range represented in the reference data set and is lower than that of the smallest 40a ecoregion reference site, Lick Creek, which has a drainage area of 10,400 acres.

Of the 54 third order streams in the 40a ecoregion classified as calibrated for the wadeable reference protocol Dick Creek has the fourth smallest watershed area. Given this information it is likely that the assessment conducted on Dick Creek is stretching the limits of the wadeable reference dataset.

In addition to having a small drainage area, the Dick Creek watershed also has a few unique geological characteristics that impact seasonal flow conditions. As discussed in Section 1.1, much of the Dick Creek watershed is covered in a paleosol soil with a very thick gumbotil layer, which acts as a water retardant layer on the surface of the landscape (aquatard). A breakdown of the percentages of the land surface impacted by reduced infiltration capacity in this watershed and other biological sampling sites in the 40a ecoregion show just how prominent this feature is (**Table 4-2**).

Table 4-2 Comparison of soil permeability ratings from 40a ecoregion

	<0.06 in/hr	0.06-0.2 in/hr	>0.2 in/hr
Dick Creek	**53%**	**18%**	**29%**
40a HUC 12 avg	**15%**	**40%**	**44%**
40a bio site avg	**19%**	**47%**	**34%**
40a bio site 25th	**10%**	**40%**	**29%**
40a bio site 75th	**27%**	**51%**	**46%**

Dick Creek's relative percentage of acres rated as having <0.06 in/hr infiltration capacity is more than three times higher than the HUC 12 average and is nearly double that of the 75th percentile of biological sampling sites. Only two other biological sampling sites in the ecoregion have a higher percentage rated as <0.06 in/hr, East Fork Medicine (60%) and Cooper Creek (55%).

This very large landscape feature has multiple impacts on the systems seasonal flow regime. With an infiltration capacity of <0.06 in/hr, only a very small percentage of a season's precipitation will be able to percolate into the subsoil horizon, decreasing the amount of subsurface flow available to the stream during baseflow conditions. These conditions may exacerbate the late season low-flow period making in-stream conditions particularly harsh for aquatic life.

In Iowa, nearly three quarters of a year's precipitation is received between April and September, most of which is delivered in short duration high intensity rainfall events. This, coupled with the high percentage of low permeability soils, provides a scenario where a large percentage of each rain event will be delivered to the stream system as storm event driven overland flow. Under these conditions, it is likely that winter snow pack and early season low intensity rain fall events have more impact on mid-summer flow conditions than the season's biggest rainfalls.

The large mid season storm events will provide little, if any, ground water recharge and any increase in stream flow will be very short lived, with flow conditions falling back to or below preevent levels in a short timeframe. An example of this scenario can be seen in **Figure 4-1** where roughly 6.5 inches of rain fell on the 27th of August, causing the stream rises nearly 10 feet over a few hours and then return back to its original stage in roughly 30 hours.

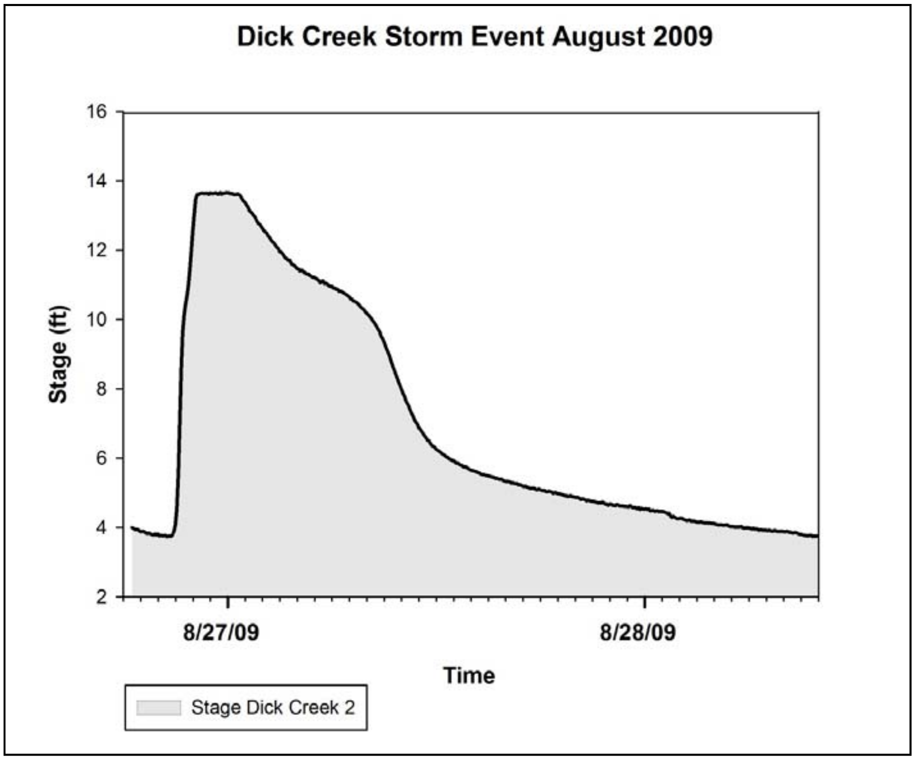

Figure 4-1 Dick Creek Storm Event at site Dick 2

The combination of a small drainage area and presence of an aquatard on the landscape surface likely exacerbate low flow during baseflow conditions. Maximum pool and average thalweg depth observed at each site fell below 25th percentile values from ecoregion reference site sampling (**Table 4-3).** This lack of pool depth/habitat has a direct physical impact on the fish community in Dick Creek. For instance, not a single sucker species (known to inhabit pool habitats) was collected at Dick 1 or 2 in the 2009 sampling season. This lack of depth may also limit the ability of organisms to move freely throughout the stream system, making it less likely that organisms will find refuge from extreme low flow or low dissolved oxygen conditions.

Table 4-3 Pool and Thalweg depth

	Dick 0	**Dick 1**	**Dick 2**	**40a 25th percentile**
Average Thalweg Depth	0.82 ft	0.74 ft	0.87 ft	0.99 ft
Maximum Depth	1.6 ft	1.8 ft	1.8 ft	2.78 ft

Another habitat related feature of the system which may be exacerbated during periods of low flow is the overall lack of coarse substrate and riffle habitat. Habitat data from sampling conducted at sites Dick 1 and 2 in 2009 indicated that gravel, boulders, and woody substrate were not present in the stream. Cobble was not present at Dick 2 and was only present in extremely small amounts at Dick 1. No riffle habitat was present at Dick 2, and Dick 1 had roughly five percent of its reach classified as riffle habitat (**Appendix Table B-4**). This overall lack of coarse material and riffle habitat present at each site may be, in-part, related to the low flow conditions observed onsite. As a stream loses flow, the area of the channel bottom which is covered by water shrinks substantially. This often results in only a trickle of flow passing over a very small percentage of the channel bottom; eliminating access to a substantial amount of channel bottom habitat.

Dissolved oxygen impacts

Temperature and flow are two important physical characteristics that influence stream ecosystem productivity. Temperature affects the growth and respiration of organisms and the productivity of ecosystems through its many influences on metabolic processes. Flow impacts the rate of growth, total accumulation of periphyton biomass and the stream's re-aeration capacity (Allen, 1995). Under most conditions oxygen is not typically a limiting factor to biological activities in streams. However, under conditions such as high temperatures and low flows oxygen can become a critical environmental variable.

As previously discussed, seasonal low flow conditions are of concern in the Dick Creek Watershed. This seasonal occurrence provides ideal conditions for low in-stream dissolved oxygen concentrations. These conditions were particularly evident during the continuous dissolved oxygen (DO) monitoring along Dick Creek, which took place from 7/29/2009 to 8/10/2009 (**Appendix Figure C-1 & C-2**). Stream gauging equipment installed at site Dick 1 recorded the minimum stage for the season on 8/13/2009.

Diurnal DO monitoring at Dick 1 and Dick 2 uncovered multiple violations of Iowa's DO water quality standards (**Table 4-4**). While DO levels were low at both monitoring sites, the depletion of DO appeared to be more severe at site Dick 1. As discussed below, the greater magnitude of fluctuation and extent of low dissolved oxygen levels at this site were associated with higher levels of algal photosynthetic production than at the Dick 2 site. During the eleven day deployment, DO levels dropped below 5 mg/l for longer than 8 hours on three separate occasions. Additionally, DO levels lower than the instantaneous standard of 4 mg/l occurred for a duration of more than two hours on four separate occasions.

Table 4-4 Break down of dissolved oxygen data

	Dick 1	Dick 2
WQ standard DO < 5 mg/l (8+ hrs)	3	1
WQ standard DO < 4 mg/l (2+ hrs)	4	0
Min DO	2.68	3.99
Max DO	17.16	14.28
Gross Primary Productivity (g O2 /m2/day)	15.67	2.11
Production/Respiration	1.13	0.48

The dips in nighttime DO levels observed at site Dick 1 were the result of high primary productivity and night time respiration. The diurnal swings observed at Dick 1 ranged from 2.8 to 16.5 mg/l in a single 24 hour period. These large diurnal swings in DO persisted through the deployment until the cycle was broken on the 8th of August by a runoff event (**Figure 4-2**).

Large diurnal swings in DO are commonly observed in systems that have high primary productivity. Further evidence of this production driven DO depletion is provided by stream metabolic rate estimates (**Table 4-4**) derived using a stream productivity calculator developed by the Central Plains Center for BioAssessment (**Anderson and Huggins 2003**). The calculator follows procedures developed by Odum (**1956**) whereby stream primary production is estimated from diurnal dissolved oxygen measurements. Gross Primary Production (GPP) values calculated from site Dick 1 averaged 15.67 (g O2 /m2/day) and Production/Respiration (P/R) ratios were 1.13. P/R ratios above 1 are not typically observed in free flowing streams (Dodds, 2006), which would suggest that the low flow conditions observed at this site were having a strong influence on in-stream DO conditions.

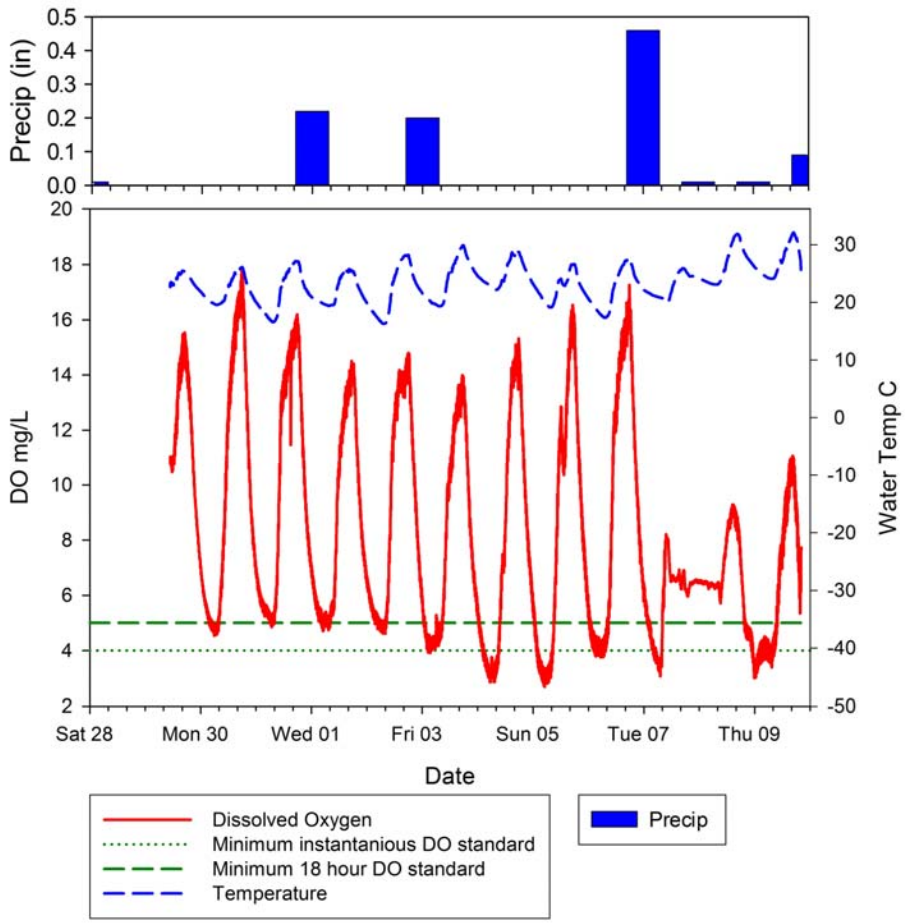

Figure 4-2 Dissolved oxygen and rainfall data from Dick 1

Average gross primary production (2.1 g O2/m2/day) and P/R (0.48) estimates for Dick 2 were lower than for Dick 1 and more similar to levels observed at sites within the ecoregion that were monitored during the 2002-2006 Regional Environmental Monitoring and Assessment Project (REMAP) stream survey (**Appendix Table C-1**). One explanation for this observed difference in primary productivity could be the difference in channel dimensions at Dick 1 and Dick2. Measurements taken at the time of sampling indicated that average stream depth was much shallower at Dick 1 than at Dick 2 (0.1 ft vs. 0.7 ft). This provides conditions that may allow greater light penetration and an increase in the growth of benthic algae.

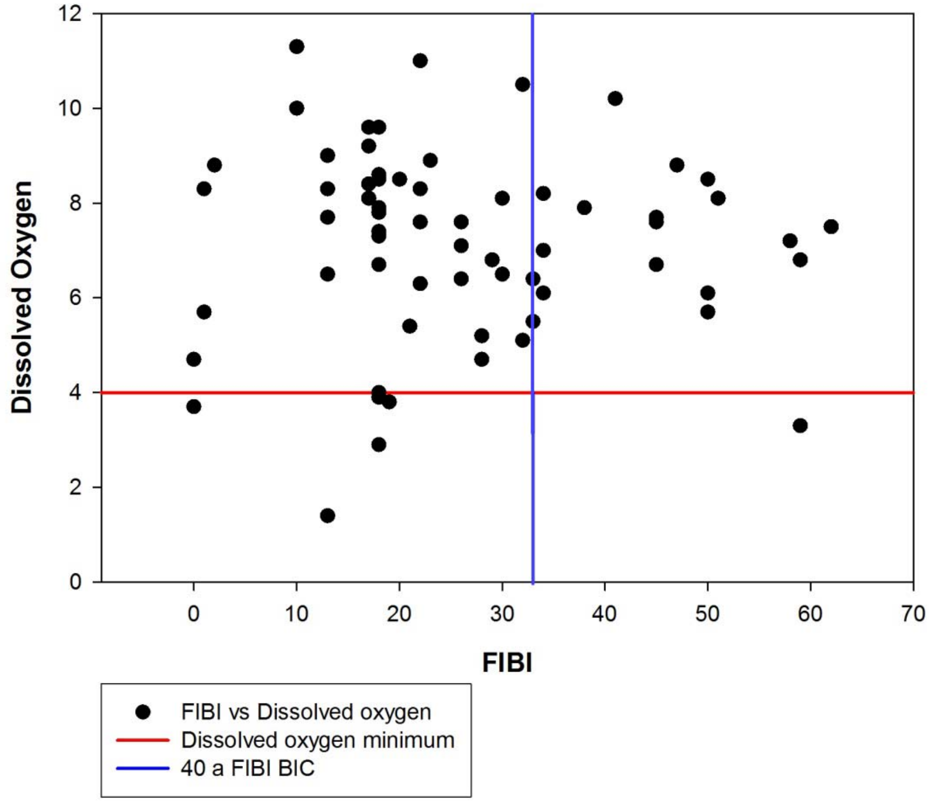

Figure 4-3 FIBI and dissolved oxygen data from all biological sampling in 40a ecoregion

The levels of DO observed in Dick Creek were certainly capable of stressing the aquatic life community. **Figure 4-3** (which displays FIBI scores and associated daytime dissolved oxygen values) shows that in all sampling conducted in the 40a ecoregion there was only one instance where a DO value of less than 4 mg/l corresponded with a FIBI score that passed the ecoregion BIC. While this is an important observation, it does need some qualification. Data used in this comparison represent single daytime grab samples taken during the biological sampling event. These data do not represent the lowest DO values recorded in the stream, which usually occurs just before dawn. By comparison, the lowest daytime grab recorded at sites Dick 1 and Dick 2 were 6.8 and 6.2 (mg/l) respectively.

Some uncertainty exists as to the primary cause of these low DO conditions. The median values for several measures of nutrient availability fall below or within the inner quartile range of ecoregion reference sites for the 40a ecoregion (**Table 4-5**). These data would suggest that excessive nutrient availability is not likely the driving mechanism for the low DO conditions. The low flow conditions observed in Dick Creek are more likely a significant factor given how major a driving force other factors like flow, habitat, and temperature can be in the manifestation of low DO conditions.

Table 4-5 Nutrient related water quality values from Dick Creek sampling

	Dick 1	Dick 2	40a 25th percentile	40a 75th percentile
Nitrate + Nitrite Nitrogen as N (mg/l)	0.3	0.5	0.09	0.34
Total Kjeldahl Nitrogen as N (mg/l)	0.7	0.6	0.61	1.15
Ortho Phosphate as P (mg/l)	0.02	0.03	NA	NA
Total Phosphate as P (mg/l)	0.08	0.1	0.07	0.16

A recent study conducted in Illinois (**Garvey, et al. 2007**) proposed that in stream systems there are a hierarchy of factors which control dissolved oxygen concentrations. This hierarchy suggests that the combined seasonal effects of temperature and flow is the most important controlling factor for in-stream DO concentrations followed by physical characteristics of the system, organic/nutrient enrichment, and then macro-organism composition. In this study over 50 percent of all DO fluctuation was explained by flow alone.

One important component of stream habitat, as it relates to DO, is the presence of directly connected areas of refuge from intermittent hypoxic conditions (**Garvey et al. 2007**). These areas of refuge allow for the survival of resident organisms and rapid re-colonization of habitat zones more readily impacted by depressed DO conditions. The biological impacts to the fish community observed at Dick 1 may be a result of the low dissolved oxygen conditions coupled with other low flow/habitat issues.

A lack of macro habitat complexity and low flows limit the direct connectivity of this segment of the stream system to areas of potential low DO refuge. As stream flow drops, segments of this system become either partially or fully disconnected pools. In these conditions, fish are unable to access potential areas of refuge, likely limiting the life cycle of individuals in the fish community. During periods of sustained low flow this lack of connected refuge also limits the re-colonization potential of certain segments in this system. Another potentially important feature of stream habitat that is lacking in Dick Creek is coarse substrate availability. The lack of gravel, cobble or boulders and the absence of riffles in much of this system, coupled with low flow conditions, likely limit the re-aeration potential of the stream

Sampling at the only area of riffle habitat identified in Dick Creek uncovered a benthic macroinvertebrate community that passed ecoregion expectations. A riffle sampled at Dick 1 using a Surber showed that, where favorable micro habitats exist, this system is capable of meeting ecoregion expectations. That being said, it must be pointed out that the 40a ecoregion has the lowest BIC of any ecoregion in Iowa (BMIBI 41) and only ranks in the fair condition category for the BMIBI. A fair ranking indicates that pollution sensitive bugs will be rare or absent from the community, suggesting that even least impacted reference sites located in this ecoregion will lack organisms sensitive to periods of low flow or low DO stress. This observation would suggest that intermittent periods of low dissolved oxygen during low flow conditions may be a common occurrence across this ecoregion.

Upon review of all available data it was the SI data review team consensus that the manifestation of low DO conditions in this system are primarily driven by a natural seasonal drop in flow. The small drainage area of this watershed coupled with the stream channel characteristics and geologic features described in Section 1 of this document highlight how and why this seasonal condition persists in Dick Creek.

4.2. Secondary stressor(s)

Sedimentation

Data collected during habitat sampling at Dick 1 and Dick 2 in 2009 indicated that the percentage of stream bottom sediments comprised of sand and/or clay were elevated compared with ecoregion reference site data (**Table 4-6**). Whereas silt, a common depositional substrate, was absent from Dick 1 and present in relatively low percentage in Dick 2.

Table 4-6 Soft sediment percentages from Dick 1 and 2 during the 2009 habitat sampling

	Dick 1	Dick 2	40a 75th percentile
Percent slay	38%	6.66%	10.5%
Percent sand	61%	64.4%	53%
Percent silt	0%	2.22%	23%

The relatively high percentage of stream bottom represented as clay and sand at site Dick 1 is in many ways indicative of the very low flow conditions present during habitat sampling. Clay, while classified as soft sediment, is not usually present in the form of a deposited material in stream systems. The presence of a clay bottom is typically an indication of channel scour. It is common to find exposed (scoured) clay bottoms in the thalweg (area of highest flow velocity and depth in a stream) of a channel that experiences frequent high flows. As flows become lower, the percentage of channel bottom covered with water gets smaller and smaller. The last areas covered by flowing water will be the thalweg of the channel. This area of concentrated flow becomes the dominant habitat available for organisms at extreme low flows and is devoid of larger materials which are scoured out during higher flows. This coarse substrate (gravel, cobble or boulders) may be present in the channel system but not be part of the lowest flow channel bottom.

On the whole, excessive sedimentation was not deemed to be a major component of the biological impairment present in this system. Follow up habitat sampling conducted during slightly higher flows may help identify what sediment related habitat features are a function of the stream’s flow condition vs stream bottom composition.

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: 1200.

Table 5-1 Candidate causes and cause codes used in the 305(b) 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.

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, either of which is capable of causing biological impairment in the Dick Creek watershed: Low DO (code 1200) and Seasonal low flow/Lack of habitat (990). Using a weight of evidence approach, it was the determination of the SI group that the low DO conditions observed in Dick Creek were primarily driven by seasonal low flow conditions. It is not recommended that this stream be a candidate for TMDL development as the manifestation of low DO conditions in this system are primarily driven by a seasonal drop in flow. The drainage area of this watershed coupled with the geologic features and stream channel characteristics described previously in this document, highlight how and why this seasonal condition persists in Dick Creek.

A recommendation from this study would be to follow up on the diurnal DO issues present in this watershed with additional sampling. In order to better characterize the mechanisms driving the DO conditions observed in this system, it would be prudent to collect diurnal DO and stream stage throughout an entire water year. This would allow for the comparison of wet and dry condition periods within this system.

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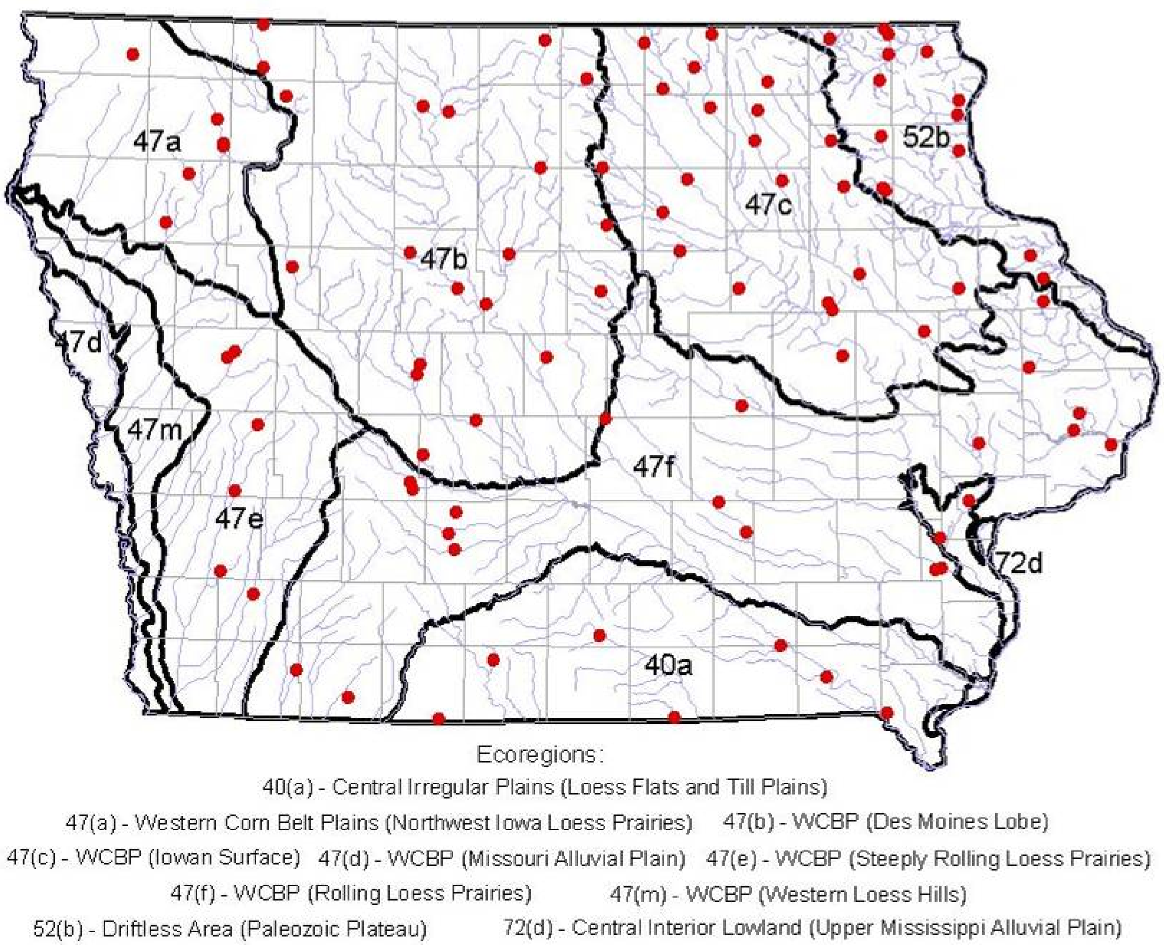
7. Appendices

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.



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

A.2. **Sampling Procedures**

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

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

Fish are sampled using direct current (DC) electrofishing gear. In shallow streams, one or more battery-powered backpack shockers are used, and a tote barge, generator-powered shocker is used in deeper, wadeable streams. Fish are collected in one pass through the sampling reach proceeding downstream to upstream. The number of individuals of each species is recorded, and individual fish are examined for external abnormalities, such as deformities, eroded fins, lesions, parasites, and tumors. Most fish are identified to species in the field; however, small or difficult 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://wqm.igsb.uiowa.edu/wqa/bioassess.html (Wilton 2004).

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

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

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

Appendix 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.

Appendix 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**

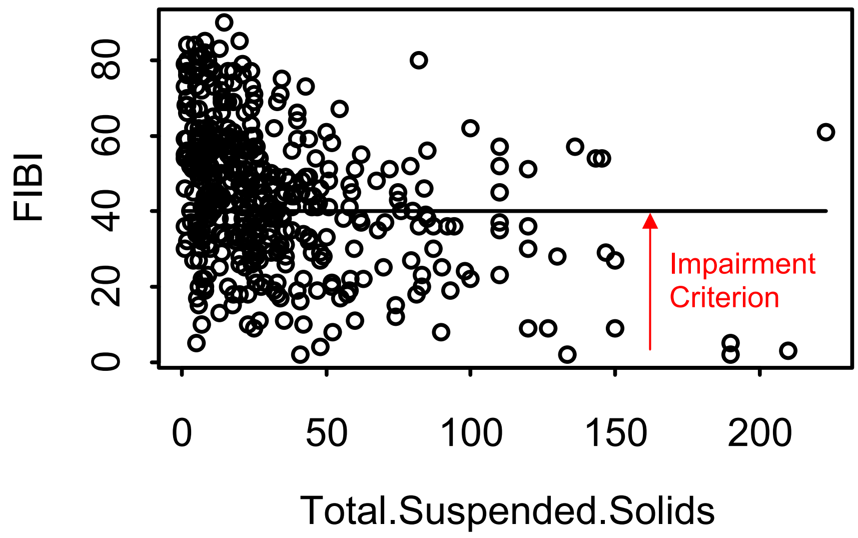
Graphical and quantitative analysis methods were used to examine the plausibility that various stressors occur at levels that are sufficient to impair the aquatic community of Dick Creek. The data analysis utilized biological and environmental indicator data collected primarily from wadeable streams during 1994-2003 as part of Iowa's stream biological assessment program. Scatter plots were created and visually examined to identify relationships between stressor indicators and biological response variables (i.e., benthic macroinvertebrate and fish IBIs). Regression coefficients were calculated to help identify stressor indicators that were significantly related with IBI levels. Examples of the scatter plot and simple regression analysis approach are displayed in Appendix B (Figures B-3 – B-13 and B-14 – B-19).

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]). While this technique was found to be useful previous SI projects it the type and quantity of data available for Dick Creek made this method less useful in this system. As such, CP was not used in the development of the Dick Creek SI.

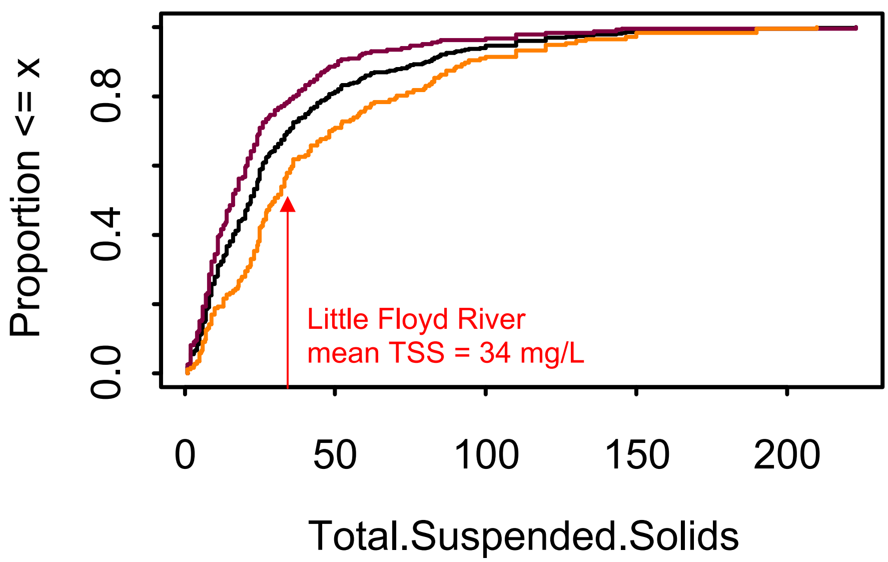
Essentially, the CP analysis method seeks to identify stressors that occur at levels associated with an increased probability of observing biological impairment. In the Little Floyd River example, biological impairment is defined as not achieving a BMIBI score or FIBI score that is greater than or equal 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).

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.

(a)

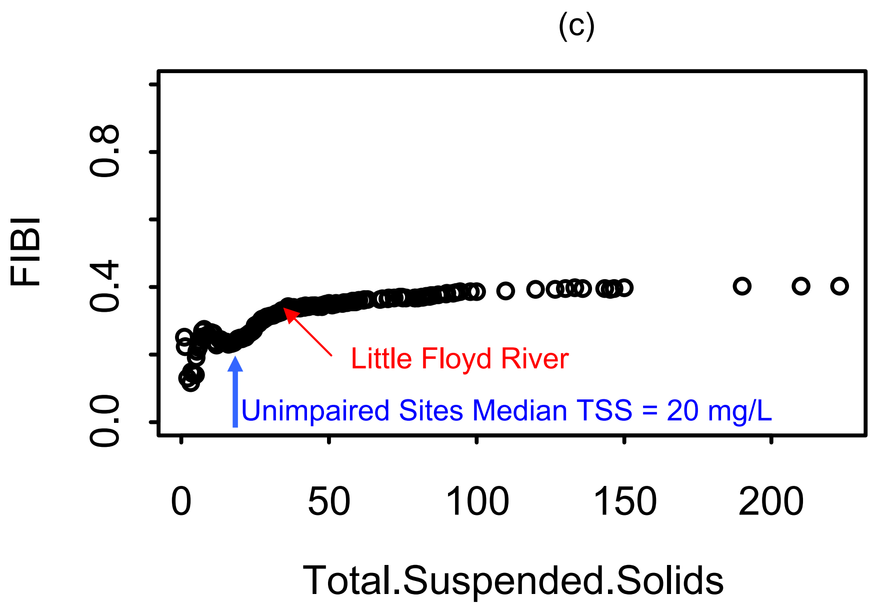


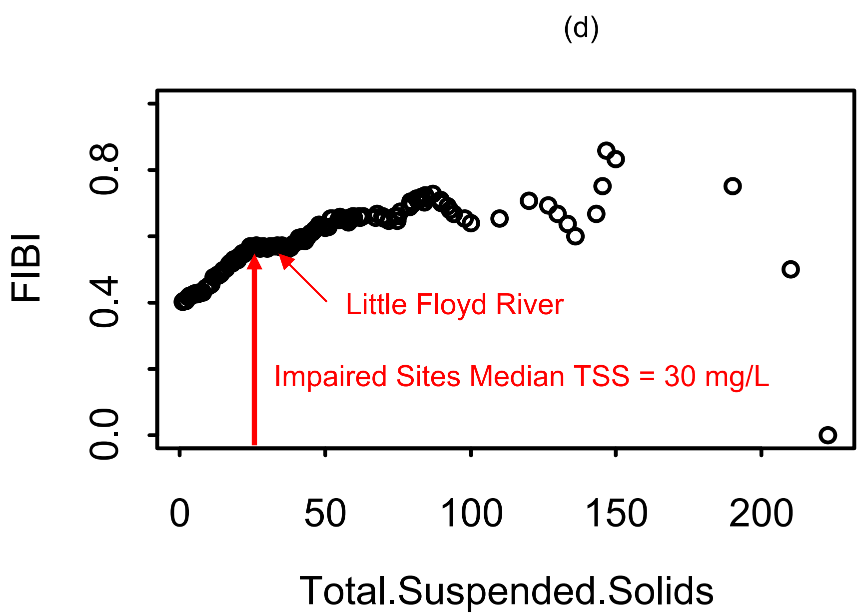
(b)



Appendix 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.





Appendix Figure A-3 Conditional Probability (CP) analysis using example data from the Little Floyd River, O'Brien County

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

A.5. **References**

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Appendix B Data Summary

Appendix Table B-1 Grab sample water quality at site Dick 1

Dick 1	9/11/2008	7/8/2009	7/21/2009	7/29/2009	8/12/2009	8/25/2009	9/10/2009	9/21/2009	10/5/2009	10/20/2009	11/5/2009	12/2/2009	1/5/2010	2/2/2010
Ammonia Nitrogen as N (mg/L)	0.12	0.025	0.06	0.35	0.24	0.025	0.025	0.025	0.025	0.025	0.05	0.025	0.14	0.18
Carbonaceous BOD (5 day) (mg/l)	1	1	1	3	1	1	1	1	1	1	1	1	1	1
Chloride (mg/l)	25	8.8	13	13	14	14	11	11	14	18	11	13	16	14
Chlorophyll A (ug/l)	5	6	3	25	10	4	3	3	1	3	0.5	2	0.5	0.5
E.coli (MPN/100ml)	1400	1600	930	3900	8200	480	1200	170	990	1300	620	280	86	97
Nitrate + Nitrite Nitrogen as N (mg/l)	1.1	0.77	0.025	0.025	1.5	0.08	0.05	0.05	0.22	0.05	0.46	0.38	0.89	0.79
Ortho Phosphate as P (mg/l)	0.11	0.05	0.02	0.02	0.12	0.04	0.01	0.01	0.06	0.04	0.02	0.01	0.02	0.01
Sulfate (mg/l)		23	29	28	27	28	27	29	28	37	33	36	43	35
Total Dissolved Solids (mg/l)	290	230	270	290	270	270	250	280	240	330	270	280	290	270
Total Hardness (mg/l)		170	220	220	160	200	210	230	190	260	240	230	270	210
Total Kjeldahl Nitrogen as N (mg/l)	1.2	0.7	0.7	2	2.2	0.8	0.7	0.7	0.7	0.6	0.8	0.3	0.5	0.3
Total Phosphate as P (mg/l)	0.24	0.17	0.08	0.11	0.31	0.1	0.07	0.05	0.16	0.08	0.08	0.08	0.05	0.07
Total Suspended Solids (mg/l)	22	18	11	23	55	7	8	6	10	6	8	5	6	6
Total Volatile Suspended Solids (mg/l)	6	3	2	5	10	1	2	2	2	2	2	1	2	2
Turbidity (NTU)	36	23	12	23	100	8.4	8.6	6.2	15	7.8	9.9	7.3	4.9	5.8
Temp	18.8	25.2	19.9	22.7	22.6	20.7	18.8	18.3	8.9	11.3	5.6	4.2	0	0
pH	7.6	7.8	7.7	8.2	7.4	7.9	7.7	7.6	7.7	7.9	7.3	7.8	7.5	7.5
DO	7.1	8.6	7.9	10.3	6.8	9.8	7.9	7.8	9.8	10.8	11.2	15.1	11.3	13.4
Flow	0.3	2.9	0.5	0.1	0.4	0.6	0.5	0.8	0.5	0.6	2.9	2.2	1.9	3.3

Appendix Table B-2 Grab sample water quality at site Dick 2

Dick 2	7/8/2009	7/21/2009	7/29/2009	8/12/2009	8/25/2009	9/10/2009	9/21/2009	10/5/2009	10/20/2009	11/5/2009	12/2/2009	1/5/2010	2/2/2010
Ammonia Nitrogen as N (mg/L)	0.025	0.07	0.025	0.08	0.025	0.025	0.025	0.06	0.025	0.06	0.025	0.18	0.19
Carbonaceous BOD (5 day) (mg/l)	1	1	1	1	1	1	2	1	1	1	1	1	1
Chloride (mg/l)	11	15	16	23	17	13	13	16	23	13	16	19	17
Chlorophyll A (ug/l)	9	5	4	5	1	5	2	5	2	0.5	1	1	1
E.coli (MPN/100ml)	2000	2500	440	1300	830	74	1000	2100	1100	700	1000	61	85
Nitrate + Nitrite Nitrogen as N (mg/l)	0.94	0.4	0.025	0.61	0.22	0.5	0.5	0.23	0.5	0.66	0.59	1.2	1
Ortho Phosphate as P (mg/l)	0.05	0.03	0.03	0.09	0.05	0.03	0.05	0.04	0.04	0.02	0.01	0.01	0.01
Sulfate (mg/l)	24	27	25	33	28	27	24	25	36	32	36	42	34
Total Dissolved Solids (mg/l)	250	290	280	280	290	270	280	250	330	260	280	310	270
Total Hardness (mg/l)	170	270	230	200	220	220	230	190	270	230	230	260	200
Total Kjeldahl Nitrogen as N (mg/l)	0.8	0.6	0.8	1.5	1	0.5	0.8	0.5	0.6	0.8	0.3	0.6	0.5
Total Phosphate as P (mg/l)	0.18	0.09	0.1	0.16	0.1	0.1	0.1	0.12	0.07	0.08	0.07	0.04	0.06
Total Suspended Solids (mg/l)	30	11	21	24	9	6	7	10	4	10	5	4	8
Total Volatile Suspended Solids (mg/l)	6	3	4	5	2	2	3	3	2	2	1	1	2
Turbidity (NTU)	40	11	12	40	11	5.9	7.7	17	6.9	14	8.5	4	6.7
Temp	22.9	19.1	21.7	25.4	20.6	19.5	17.7	9.2	11.2	6.9	4.5	0	0
pH	7.6	7.8	7.9	7.7	7.7	7.8	7.7	7.8	7.8	7.3	7.8	7.5	7.7
DO	7.6	7.8	9.4	7.8	10.6	10.5	6.2	9.7	9.4	10.8	13.4	13.1	12.7
Flow	1.4	0.5	0.4	0.4	0.2	0.2	0.3	0.3	0.3	1.2	1.2	0.5	1.5

Appendix Table B-3 Storm event water quality from site Dick 1

Dick 1	8/16/2009	8/16/2009	8/20/2009	8/27/2009	10/1/2009	10/1/2009
Event composite	pre-peak	post-peak	pre-peak	event grab sample	pre-peak	post-peak
Ammonia Nitrogen as N (mg/L)	0.025	0.06	0.025	0.025	0.08	0.025
Carbonaceous BOD (5 day) (mg/l)	5	3	4	3	11	6
Chloride (mg/l)	9.4	8.4	7.8	2.9	5.8	8.7
Chlorophyll A (ug/l)	36	12	7	5	33	10
E.coli (MPN/100ml)	29,000	7,700	10,000	16,000	46,000	110,000
Nitrate + Nitrite Nitrogen as N (mg/l)	0.16	0.54	0.33	0.17	0.34	0.53
Ortho Phosphate as P (mg/l)	0.08	0.15	0.14	0.21	0.11	0.21
Sulfate (mg/l)	19	12	17	4.8	13	15
Total Dissolved Solids (mg/l)	180	200	210	160	130	200
Total Hardness (mg/l)	130	90	130	70	100	110
Total Kjeldahl Nitrogen as N (mg/l)	4.4	3.2	2.8	1.6	6.5	2
Total Phosphate as P (mg/l)	1.2	0.77	0.64	0.5	2	0.77
Total Suspended Solids (mg/l)	2,000	620	610	330	3,400	550
Total Volatile Suspended Solids (mg/l)	170	72	72	32	320	68
Turbidity (NTU)	960	460	400	210	2,000	350

Appendix Table B-4 Chlorophyll a data from sites Dick 1 and 2

		Dick 1 7/29/2009	Dick 1 8/12/2009	Dick 1 7/29/2009	Dick 1 8/12/2009
Chlorophyll A	**periphyton**	2.3	1.2	2.8	1.2
Filter Volume (ml)	**periphyton**	15	20	10	20
Sample Volume (ml)	**periphyton**	90	232	87	92
Chlorophyll A	**sediment**	14	1.2	NA	3.1
Filter Volume (ml)	**sediment**	5	10	NA	10
Sample Volume (ml)	**sediment**	157	82	NA	122

Appendix Table B-5 Habitat data

Habitat parameter	Dick 0	Dick 1	Dick 2
Reach - Total Habitat Reach Length	594.00	594.00	594
Transect Depth - Average	0.45	0.51	0.58
Transect Depth - Standard Deviation	0.25	0.28	0.33
Stream Width - Average	7.13	11.96	9.46
Thalweg Depth - Average	0.82	0.74	0.87
Width - Thalweg Depth Ratio	8.70	16.16	10.87
Substrate - Percent Clay	39.00	38.00	6.66
Substrate - Percent Silt	24.00	0.00	2.22
Substrate - Percent Sand	18.00	61.00	64.44
Substrate - Percent Soil	0.00	0.00	4.44
Substrate - Percent Gravel	7.00	0.00	0
Substrate - Percent Cobble	0.00	1.00	0
Substrate - Percent Boulder	0.00	0.00	0
Substrate - Percent Rip-Rap	0.00	0.00	0
Substrate - Percent Detritus/Muck	7.00	0.00	22.22
Substrate - Percent Wood	5.00	0.00	0
Substrate - Percent Bedrock	0.00	0.00	0
Substrate - Percent Other	0.00	0.00	0
Macrohabitat - Percent Riffle	0.00	5.40	0
Macrohabitat - Percent Run	50.00	33.90	20
Macrohabitat - Percent Pool	50.00	60.70	80
Reach - Percent Soft Sediment	100.00	85.71	96
Mean streambank % bare	86.00	90.00	86.40
Mean Streambank Angle - Percent Horizontal (0-15 degrees)	20.00	35.00	55.50
Mean Streambank Angle - Percent Moderate (20-50 degrees)	55.00	45.00	33.50
Mean Streambank Angle - Percent Vertical (55-110 degrees)	25.00	20.00	11.00
Mean Streambank Angle - Percent Undercut (115-180 degrees)	0.00	0.00	0.00
Canopy - Average Percent of Channel Shaded	67.39	65.77	74.87
Canopy - Standard Deviation - Percent of Channel Shaded	26.44	30.10	26.28
Canopy - Transect Maximum Percent of Channel Shaded	100.00	99.10	99.1
Canopy - Transect Minimum Percent of Channel Shaded	23.42	12.61	22.52
Coarse Rock Embededness - Average	na	na	na
Instream Cover - Filamentous Algae - Average Percent	0.00	0.00	0
Instream Cover - Macrophytes - Average Percent	3.00	0.00	0
Instream Cover - Woody Debris - Average Percent	5.50	0.00	0.62
Instream Cover - Small Brush - Average Percent	5.50	2.50	0.62
Instream Cover - Trees/Roots - Average Percent	0.50	7.00	3.12
Instream Cover - Overhanging Vegetation - Average Percent	2.50	0.50	3.75
Instream Cover - Undercut Banks - Average Percent	0.00	2.50	0
Instream Cover - Boulders - Average Percent	0.00	0.00	0
Instream Cover - Artificial Structure - Average Percent	0.00	0.50	0
Instream Cover - Depth/Pool - Average Percent - IDNR Method	0.00	0.00	0
Fish Cover - Total Proportional Areal Cover - IDNR Method	17.00	13.00	8.13
Fish Cover - Total Proportional Areal Cover - EPA Method	14.00	13.00	8.13
Fish Cover - Natural Concealment Features	17.00	12.50	8.13
Fish Cover - Large Features Areal Cover - IDNR Method	6.00	10.00	3.75
Fish Cover - Large Features Areal Cover - EPA Method	6.00	10.00	3.75
Maximum Depth	1.60	1.80	1.8

Appendix Table B-6 Fish data from biological sampling

Fish	Dick 0	Dick 1	Dick 2
FIBI:	26.00	28.00	31.00
Native Spp:	12.00	11.00	11.00
NativeSppMetric1	6.44	5.82	7.40
Sucker Spp:	1.00	0.00	0.00
SuckerSppMetric2	2.75	0.00	0.00
Sensitive Spp:	0.00	0.00	0.00
SensitiveSppMetric3	0.00	0.00	0.00
BINV Spp:	2.00	3.00	2.00
BINVSppMetric4	2.98	4.41	3.74
% Top 3 Abundant:	54.72	75.85	61.21
PctTop3AbundMetric5	5.00	5.46	10.00
% Benthic Invert:	6.60	14.83	6.03
PctBINVMetric6	2.48	5.49	2.84
% Omnivore:	13.21	57.20	48.28
PctOmnivoreMetric7	5.00	3.53	5.55
% Top Carnivore:	0.00	0.00	0.00
PctTopCarnivoreMetric8	0.00	0.00	0.00
% Litho Spawner:	0.00	2.54	1.72
PctLithoSpawnerMetric9	0.00	1.87	1.61
Tolerance Index:	8.02	8.37	8.62
TolIndexMetric10	3.14	2.59	2.19
Adjusted CPUE:	5.95	12.96	7.34
AdjCPUEMetric11	0.60	1.30	0.73
% DELT:	1.89	0.00	0.00
DELTAdj	0.00	0.00	0.00
Fish Per 500 ft:	75.00	199.00	133.00
Total Spp:	14.00	11.00	12.00
Total Excluded Spp:	0.00	0.00	0.00
Total Exotics Spp:	0.00	0.00	0.00
Total LMB-BG:	2.00	0.00	1.00
Major Drainage:	MSP	MSP	MSP
Total Fish:	106.00	236.00	116.00
Drainage Area:	13.10	13.60	7.80
Log Drainage Area:	1.12	1.13	0.89

Appendix Table B-7 Benthicmacroinvertebrate data from biological sampling

	Dick 0	Dick 1 art sub	Dick 1 surber	Dick 2
BMIBI:	26	26	46	20
MH-Total Number of Taxa:	31	29	29	27
txtMetric1	8.55	7.92	7.92	8.61
SH-Total Number of Taxa:	3.67	5.33	6.67	3.67
txtMetric2	2.59	3.73	4.67	3.03
MH- Number of EPT Taxa:	9	9	9	4
txtMetric3	5.26	5.22	5.22	2.69
SH- Number of EPT Taxa:	1.67	2.33	3.33	1.33
txtMetric4	1.75	2.42	3.46	1.65
MH- Number of Sensitive Taxa:	1	2	2	1
txtMetric5	1.31	2.6	2.6	1.53
SH- % Ephemeroptera Taxa:	10.84	12.24	11.14	5.36
txtMetric6	1.39	1.57	1.42	0.69
SH- % EPT Taxa:	11.45	12.86	67.52	5.36
txtMetric7	1.2	1.35	7.07	0.56
SH- % Chironomidae Taxa:	87.53	85.25	26.93	93.57
txtMetric8	1.26	1.49	7.38	0.65
SH- % Scraper Organisms:	8.34	0.31	0.57	0.88
txtMetric9	1.87	0.07	0.13	0.2
SH- % 3 Dominant Taxa:	98.02	97.5	88.98	98.93
txtMetric10	0.49	0.62	2.72	0.32
SH- % Dominant FFG:	90.73	97.5	61.04	98.87
txtMetric11	1.54	0.42	6.49	0.19
SH- Modified Hilsenhoff Biotic Index:	5.89	6.12	5.38	6.06
txtMetric12	4.11	3.26	6	3.48
Log Drainage Area:	1.1172	1.1335	1.1335	0.892
Drainage Area:	13.1	13.6	13.6	7.8

Appendix C Additional Tables and Figures

Appendix Table C-1 Stressor co-occurrence and response considerations for candidate causes in Dick Creek.

Abbreviations: IR; Interquartile Range; NA, data indicator and/or stressor threshold not available; ?, uncertain or unknown; Qual., based upon qualitative evaluation only.

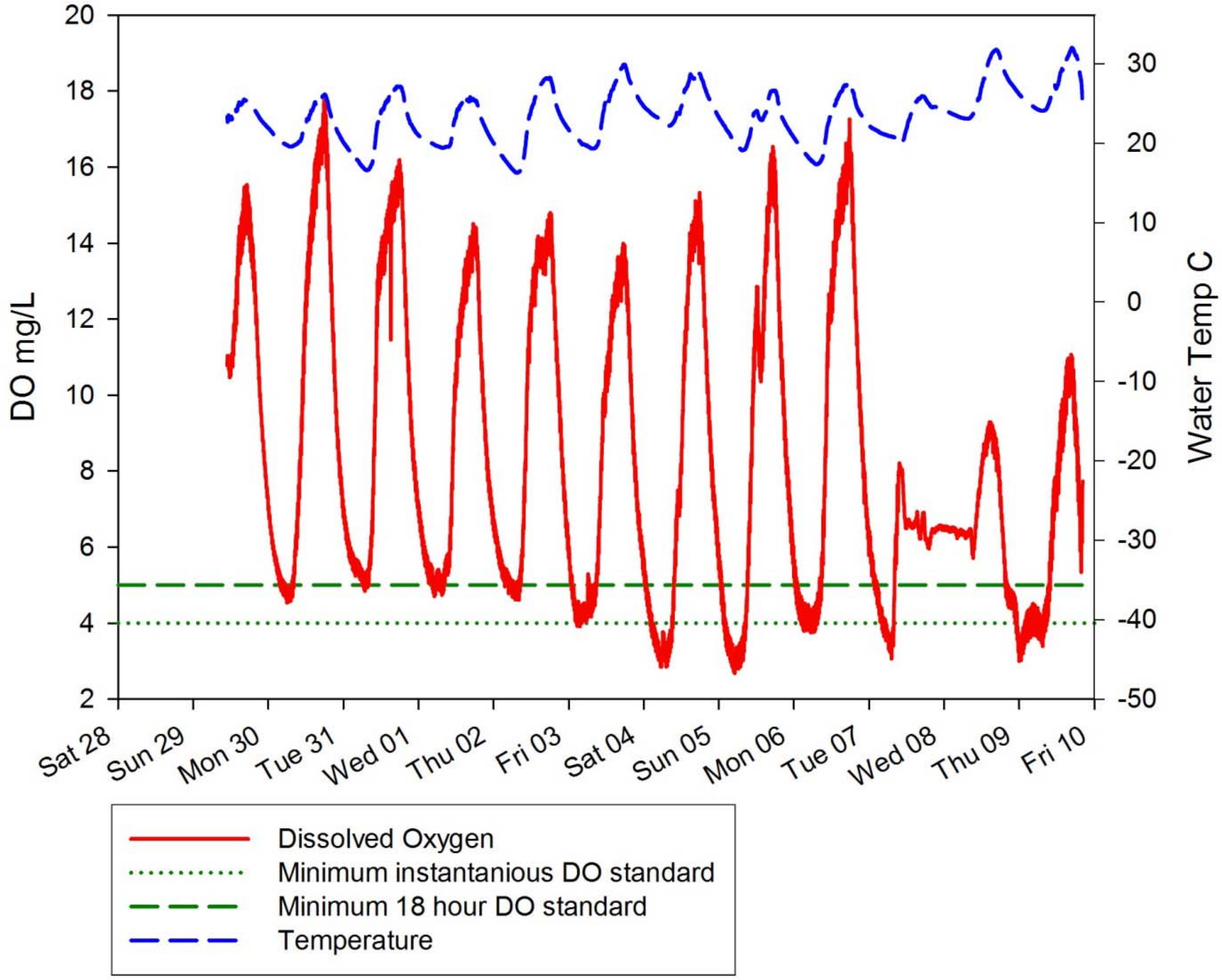
Stressor Co-occurrence & Response					
Stressor	Indicator	Concentration or level at unimpaired sites in other waterbodies*	Concentration or level at impaired site(s) in the watershed	Consistent with Stressor Occurrence	Consistent with Stressor Response
Altered Flow Regime (Conceptual Model 1)					
Increased 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	0.00-0.05 IR for all 40a ecoregion monitoring sites (n=65)	Dick 1 = 0.118 (n=11) Dick 2 = 0.051 (N=13)	?	?
Altered daily or seasonal flow patterns	NA	NA	NA	NA	NA
Increased temperature	Median temp. (deg. C) from grab samples	18.2-24 IR for regional reference sites (n=7)	Non-Event (Median) Dick 1= 19.35 (n=10) Dick 2= 19.5 (n=9)	No	No
	Maximum temp. (deg. C) from grab samples	24.4 maximum for regional reference sites (n=7)	Non-Event (Median) Dick 1=25.2 (n=10) Dick 2=25.4 (n=9)	No	No
Altered Substrate (Conceptual Model 2)					
Increased suspended sediment	TSS (mg/L)	Base flow 11.25-45.13 IR for regional reference sites (n=6)	Non-Event (Median) Dick 1=10.5 (n=10) Dick 2=10 (n=9)	No	No
		Event 80-360 IR for statewide sites (n=757)	Dick 1 Median= 615 565-1,655 IR	Yes	?
Decreased clarity (reduced feeding efficiency)	Turbidity (ntu)	Base flow 12.05-35.05 IR for regional reference sites (n=6)	Non-Event (Median) Dick 1=23 (n=10) Dick 2=11 (n=9)	No	No
		Event 47-240 IR for statewide sites (n=604)	Dick 1 Median= 430 362.5-835 IR	Yes	?

Stressor Co-occurrence & Response (continued)					
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)					
Decrease in benthic algae or macrophytes as a substrate for organisms	Periphyton Chl. A (µg/cm^2)	1.95 (1.04-3.65) median (IR) for 40a REMAP sites (n=28) 4.95 (2.25-10.63) median (IR) for statewide REMAP sites for 2nd order streams (n=61)	Dick 1 1.75(n=2)	No	No
	Sediment Chl. A (µg/cm^2)	2.03 (1.16-4.2) median (IR) for 40a REMAP sites (n=28) 2.55 (1.15-6.74) median (IR) for statewide REMAP sites for 2nd order streams (n=61)	Dick 1 7.6(n=2)	Yes	No
Increased deposited fine sediment	% soft sediment	30.35-91.1 IR for regional reference sites (n=7)	Dick 0 100 Dick 1 85.7 Dick 2 96	Yes	No
	% Silt	5-23 IR for regional reference sites (n=7)	Dick 0 24 Dick 1 0 Dick 2 2.22	No	No
	% Sand	37-53 IR for regional reference sites (n=7)	Dick 0 18 Dick 1 61 Dick 2 64.4	No	No
	% Reach area as pool habitat	39.25-69.65 IR for regional reference sites (n=7)	Dick 0 50 Dick 1 60.7 Dick 2 80	No	No
Loss of pool area & depth	Maximum depth (ft.)	2.78-4.35 IR for regional reference sites (n=7)	Dick 0 1.6 Dick 1 1.8 Dick 2 1.8	Yes	Yes
	Width: Thalweg Depth Ratio	16.1-30.05 IR for regional reference sites (n=7)	Dick 0 8.7 Dick 1 16.16 Dick 2 10.87	Yes	Yes
Embedded riffles	Embeddedness rating	2-3 IR for regional reference sites (n=7)	NA	NA	NA

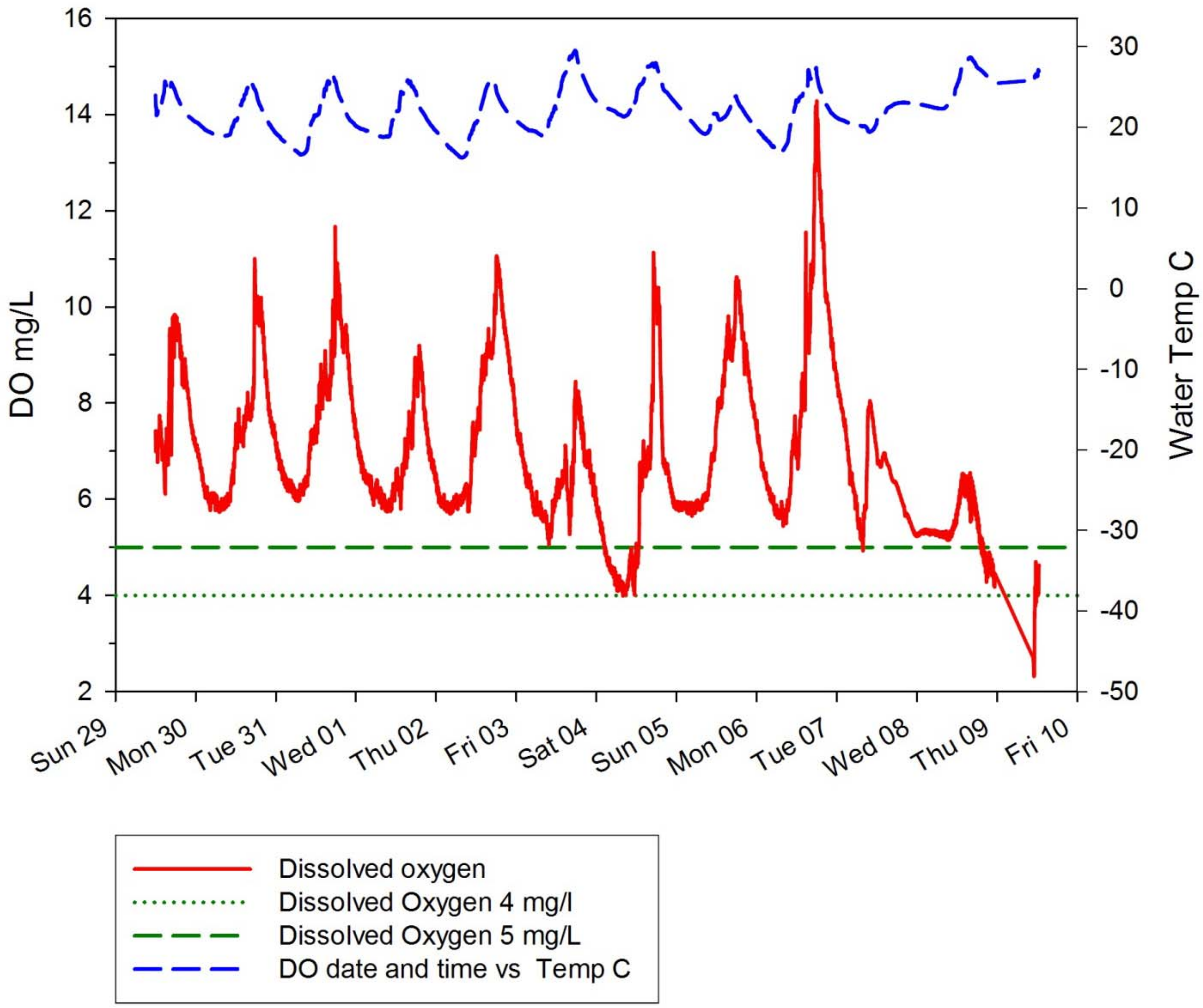
Stressor Co-occurrence & Response (continued)					
Stressor	Indicator	Concentration or level at unimpaired sites in other waterbodies*	Concentration or level at impaired site(s) in the watershed	Consistent with Stressor Occurrence	Consistent with Stressor Response
Altered Basal Food Source (Conceptual Model 3)					
Increased / altered primary producers	Seston Chl. A (µg/L)	13 (6.38-48.06) median (IR) for 40a REMAP sites (n=30) 4.75 (2.63-8.5) median (IR) for statewide REMAP sites for 2nd order streams (n=61)	Non-Event (Median) Dick 1=3.5 (n=10) Dick 2=5 (n=9)	No	No
	Periphyton Chl. A ($\mu g/cm^2$)	1.95 (1.04-3.65) median (IR) for 40a REMAP sites (n=28) 4.95 (2.25-10.63) median (IR) for statewide REMAP sites for 2nd order streams (n=61)	Dick 1 1.75(n=2)	No	No
	Sediment Chl. A ($\mu g/cm^2$)	2.03 (1.16-4.2) median (IR) for 40a REMAP sites (n=28) 2.55 (1.15-6.74) median (IR) for statewide REMAP sites for 2nd order streams (n=61)	Dick 1 7.6(n=2)	Yes	?
	Respiration (g $O_2/m^2/d$)	10.29 (6.35-12.76) for 40a REMAP < 50 mi drainage area (n=12)	Dick 1 13.9 Dick 2 4.37	Yes	?
	Gross primary production (GPP) (g $O_2/m^2/d$)	2.0 (0.71-4.15) for 40a REMAP < 50 mi drainage area (n=12)	Dick 1 15.67 Dick 2 2.11	Yes	Yes
	Production-to-respiration ratio (P:R)	0.23 (0.06-0.34) for 40a REMAP < 50 mi drainage area (n=12)	Dick 1 1.13 Dick 2 0.48	Yes	Yes

Stressor Co-occurrence & Response (continued)					
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 Basal Food Source (Conceptual Model 3 continued)					
Decreased allochthonous food resources	Instream Cover – Small Brush – Avg. %	(2.5-7.38) IR for regional reference sites (n=5)	Dick 0 5.5 Dick 1 2.5 Dick 2 0.62	No	No
	Instream Cover – Woody Debris – Avg. % - (new method)	(0.75-10) IR for regional reference sites (n=5)	Dick 0 5.5 Dick 1 0 Dick 2 0.62	Yes	?
Decreased Dissolved Oxygen (Conceptual Model 4)					
Decreased dissolved oxygen	Range of DO (mg/L) levels from daytime grab samples	7.2-8.3 IR for regional reference sites (n=7)	Dick 1= 7.83 - 9.8 (n=10) Dick 2= 7.8 - 9.7 (n=9)	No	No
	Minimum DO (mg/L) from daytime grab samples	6.1 minimum for regional reference sites (n=7)	Dick 1=6.8 (n=10) Dick 2=6.2 (n=9)	No	No
	Minimum DO (mg/L) from datalogger		Aug 2009 (n=12d) Dick 1= 2.68 Dick 2= 3.99	Yes	Yes
	Meeting water quality standards designed to protect aquatic life	< 5.0 mg/L at least 8h/day	Aug 2009 (n=12d) Dick 1= No Dick 2= No	Yes	Yes
		Minimum value ≤4.0 mg/L	Aug 2009 (n=12d) Dick 1= No Dick 2= No	Yes	Yes
Physical Habitat Alteration (Conceptual Model 5)					
Decreased macro-habitat complexity	% (type) dominant channel bedform unit	IRs for regional references (n=21) 2.7-19.65 (Riffle) 15.5-53.55 (Run) 39.25-69.65 (Pool)	riffle/run/pool Dick 0 (0/50/50) Dick 1 (5.4/33.9/60.7) Dick 2 (0/20/80)	Yes	?
	Width: Thalweg Depth Ratio	16.1-30.05 IR for regional reference sites (n=7)	Dick 0 8.7 Dick 1 16.16 Dick 2 10.87	Yes	Yes
	S.D. Transect depth	0.44-0.7 IR for regional reference sites (n=7)	Dick 0 0.25 Dick 1 0.28 Dick 2 0.33	Yes	Yes

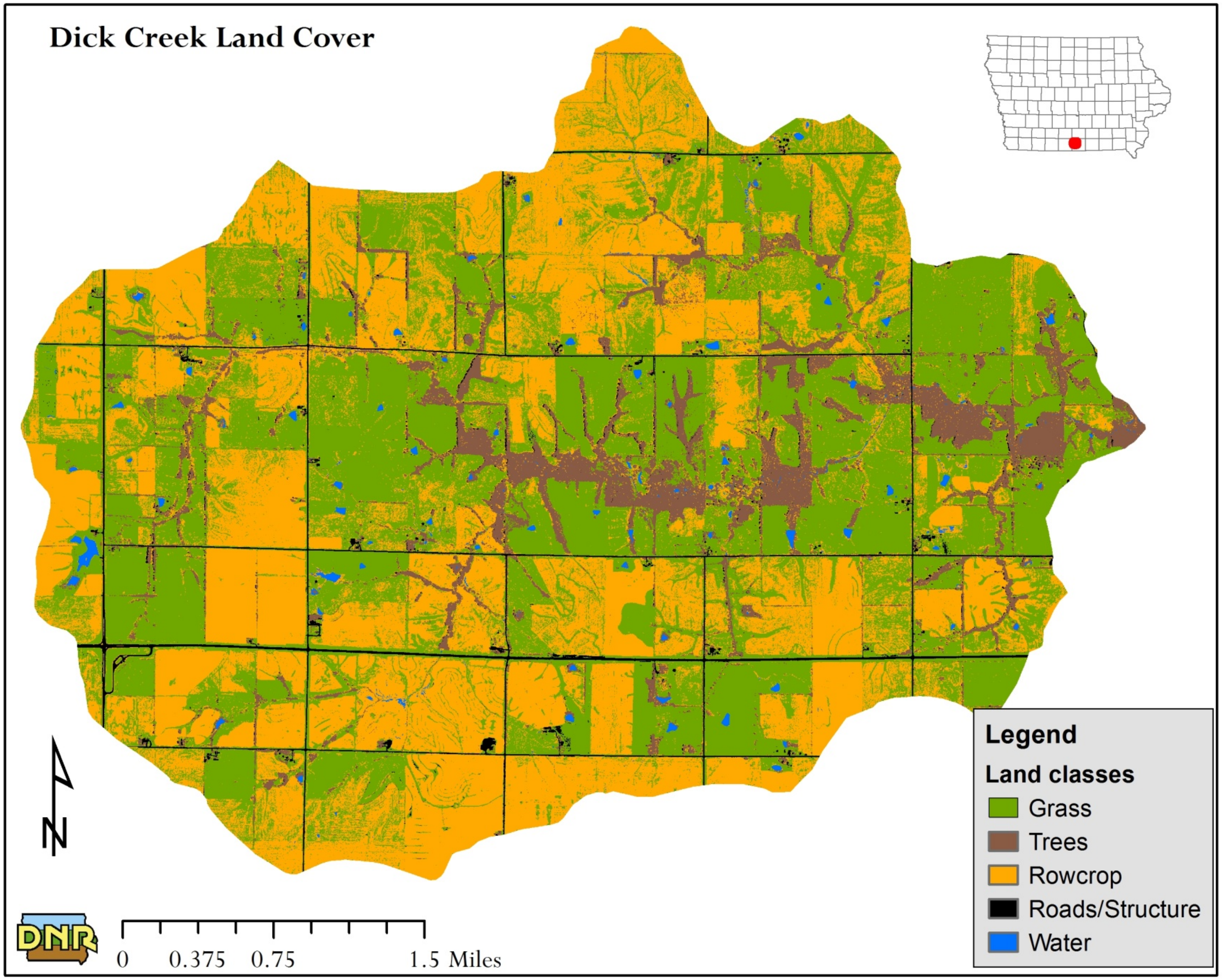
Stressor Co-occurrence & Response (continued)					
Stressor	Indicator	Concentration or level at unimpaired sites in other waterbodies*	Concentration or level at impaired site(s) in the watershed	Consistent with Stressor Occurrence	Consistent with Stressor Response
Physical Habitat Alteration (Conceptual Model 5 continued)					
Decreased micro-habitat complexity	% Instream fish cover (DNR method)	12.25-25.88 IR for regional reference sites (n=5)	Dick 0 17 Dick 1 13 Dick 2 8.13	No	No
	Instream Cover – Small Brush – Avg. %	(2.5-7.38) IR for regional reference sites (n=5)	Dick 0 5.5 Dick 1 2.5 Dick 2 0.62	No	No
	Instream Cover – Woody Debris – Avg. % - (new method)	(0.75-10) IR for regional reference sites (n=5)	Dick 0 5.5 Dick 1 0 Dick 2 0.62	Yes	?
Aquatic Life Depletion and Isolation (Conceptual Model 6)					
Disease	%DELT	0.08 – 0.55 (IR) for regional reference sites	Dick 0 1.89 Dick 1 0 Dick 2 0	Yes	?



Appendix Figure C-1 Dissolved oxygen graph from Dick1 monitoring site

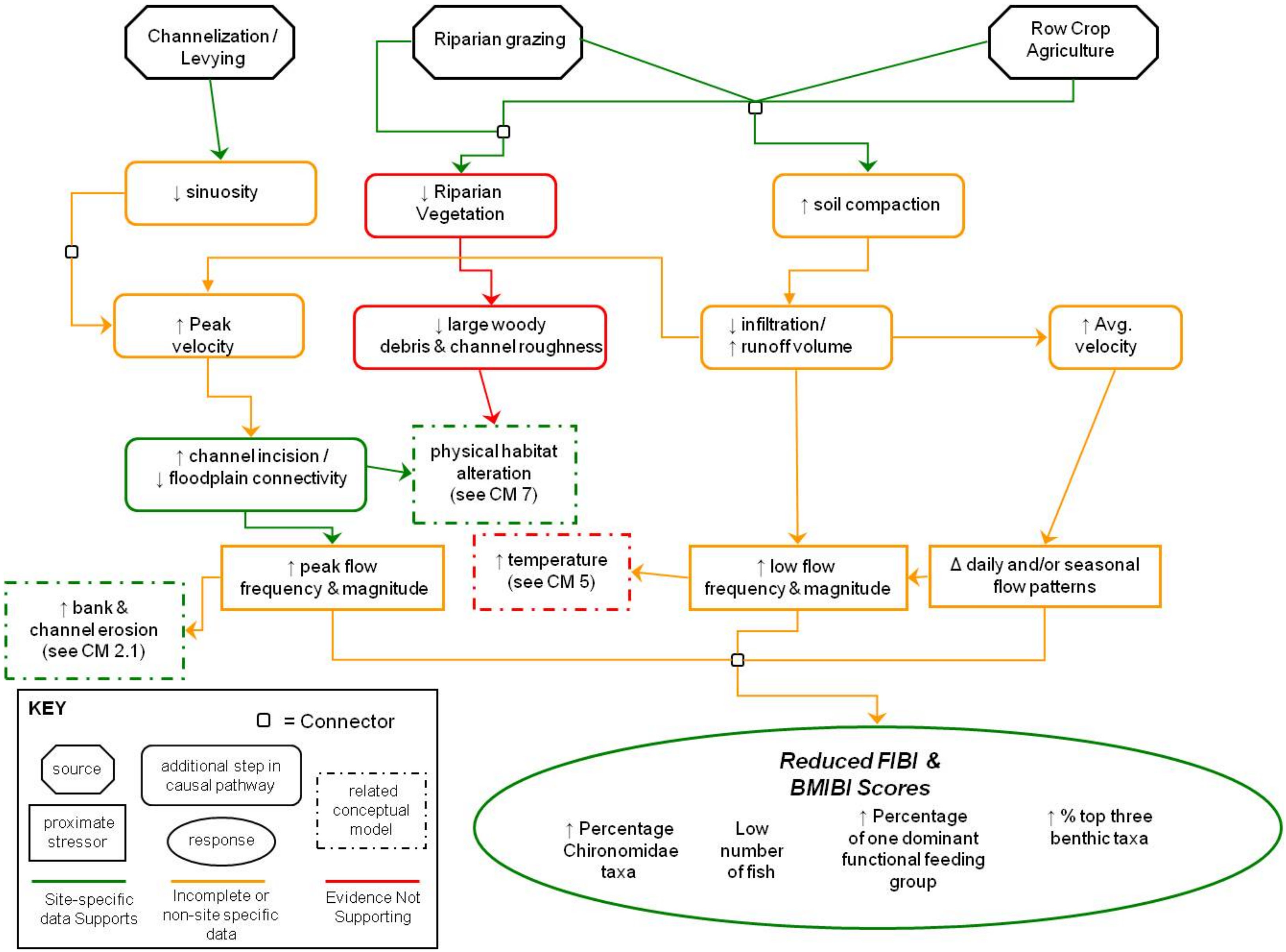


Appendix Figure C-2 Dissolved oxygen graph from Dick 2 monitoring site

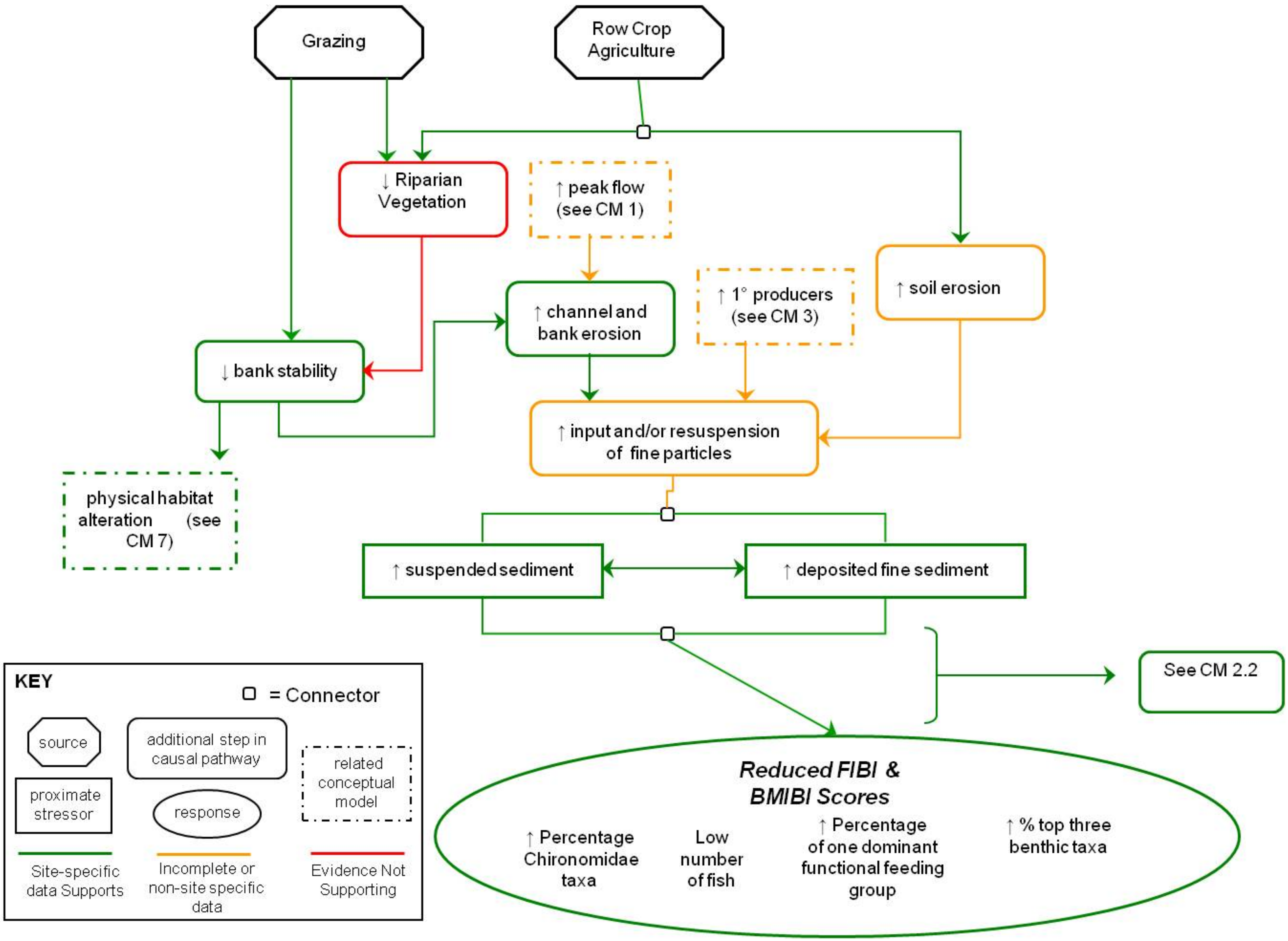


Appendix Figure C-3 Dick Creek land cover map

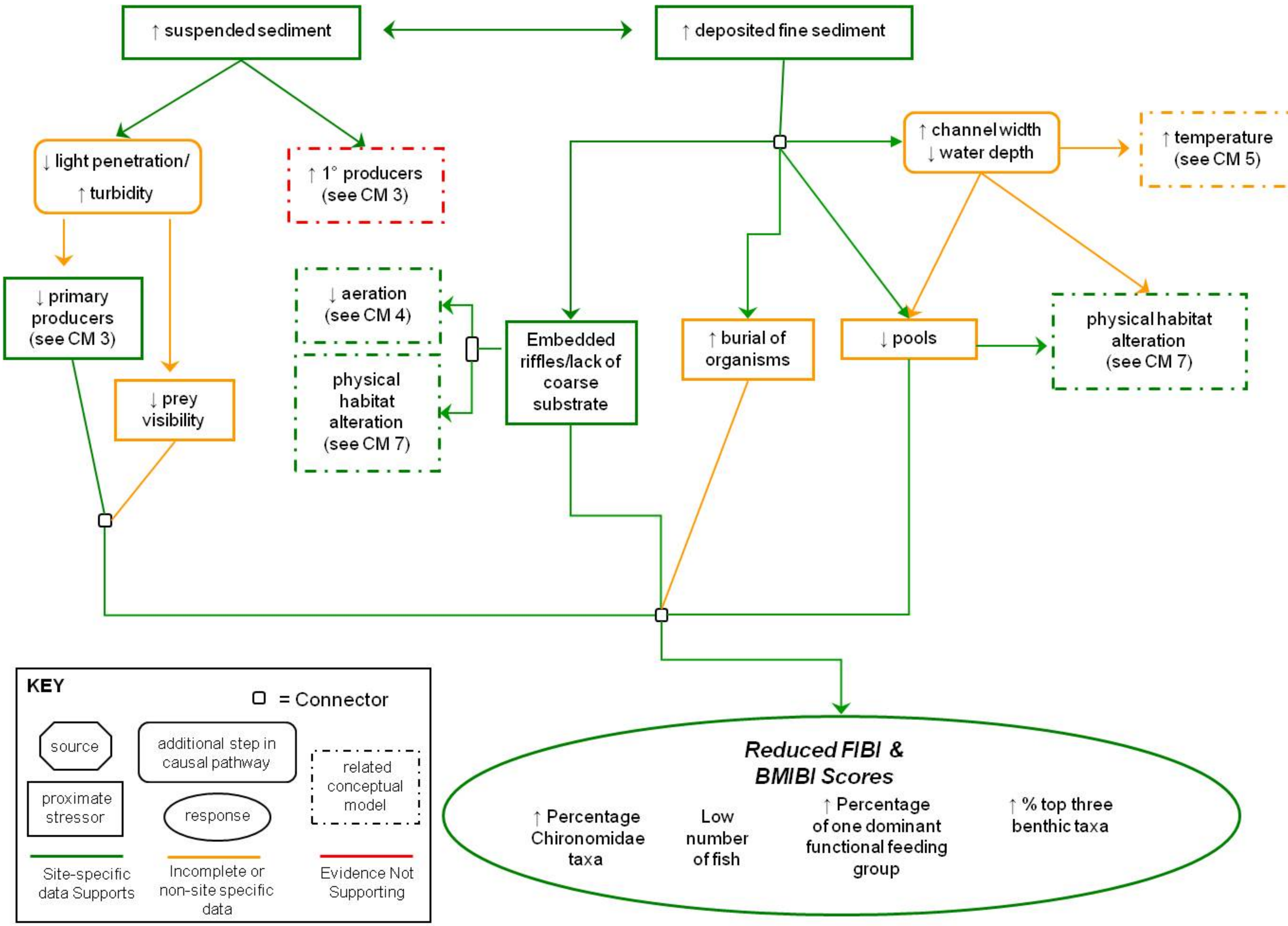
Appendix D Conceptual Models of Plausible Causal Pathways



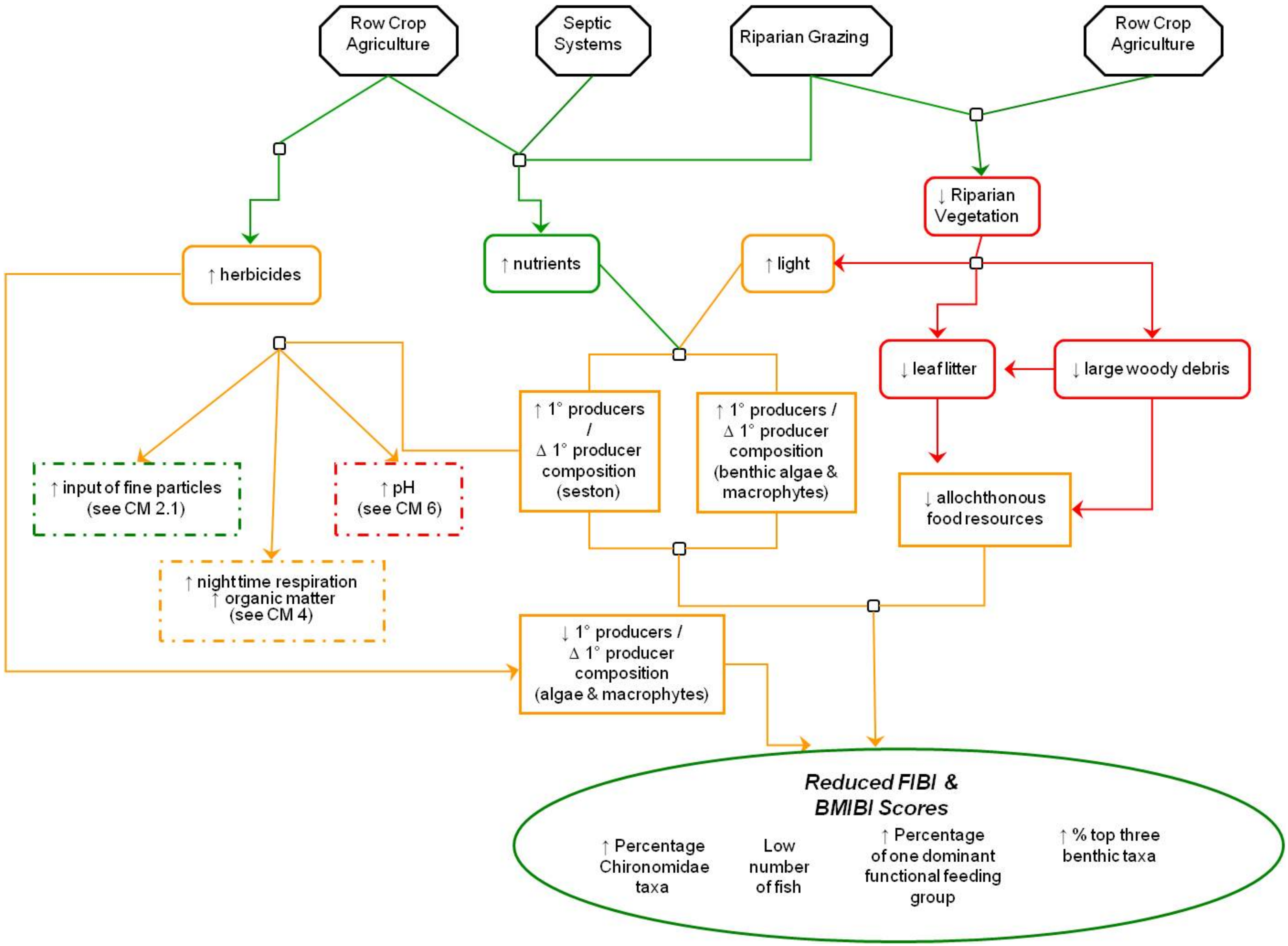
Appendix Figure D-1 Conceptual model 1- Altered flow regime



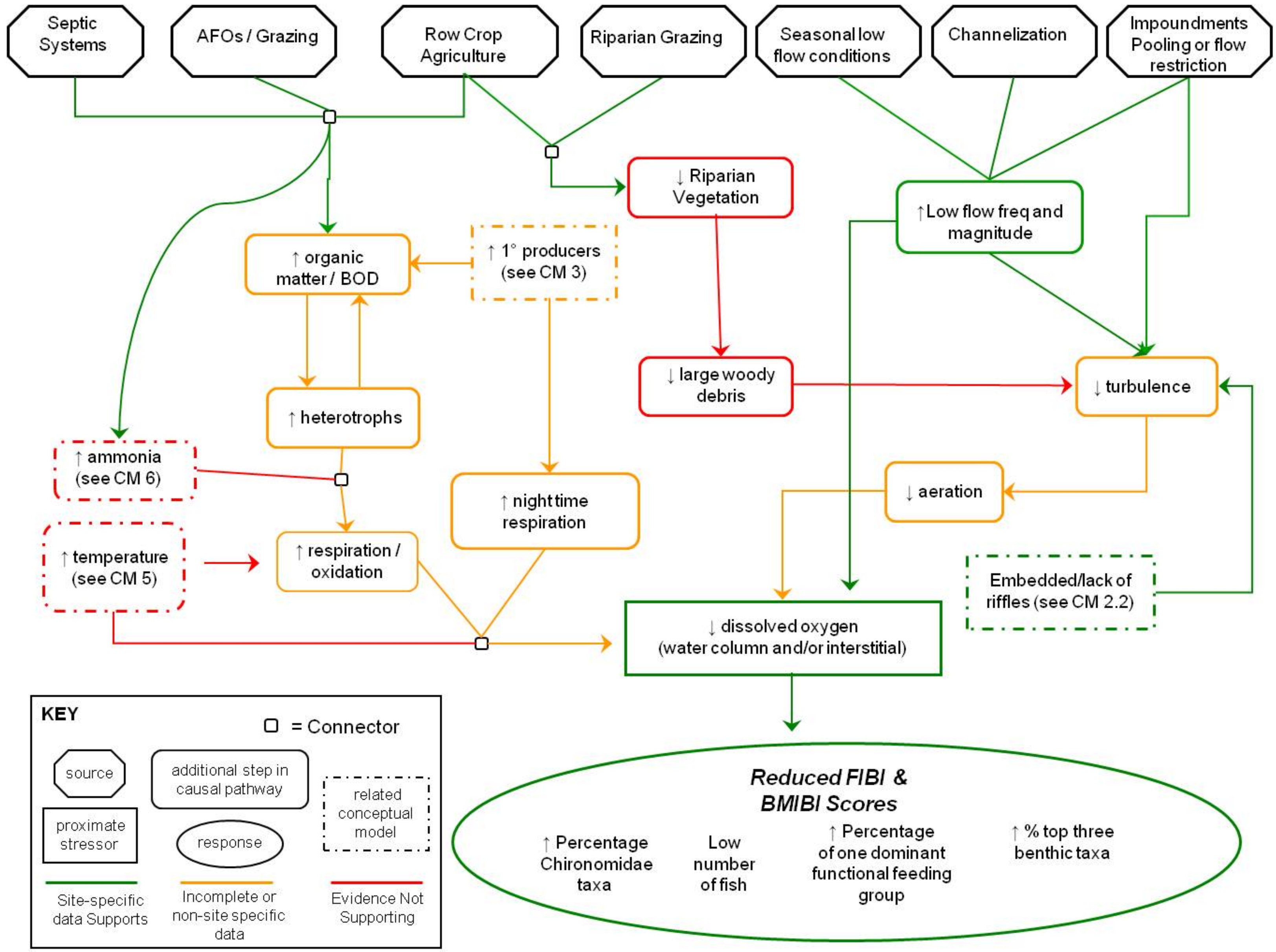
Appendix Figure D-2 Conceptual model 2.1- Suspended and bedded sediments



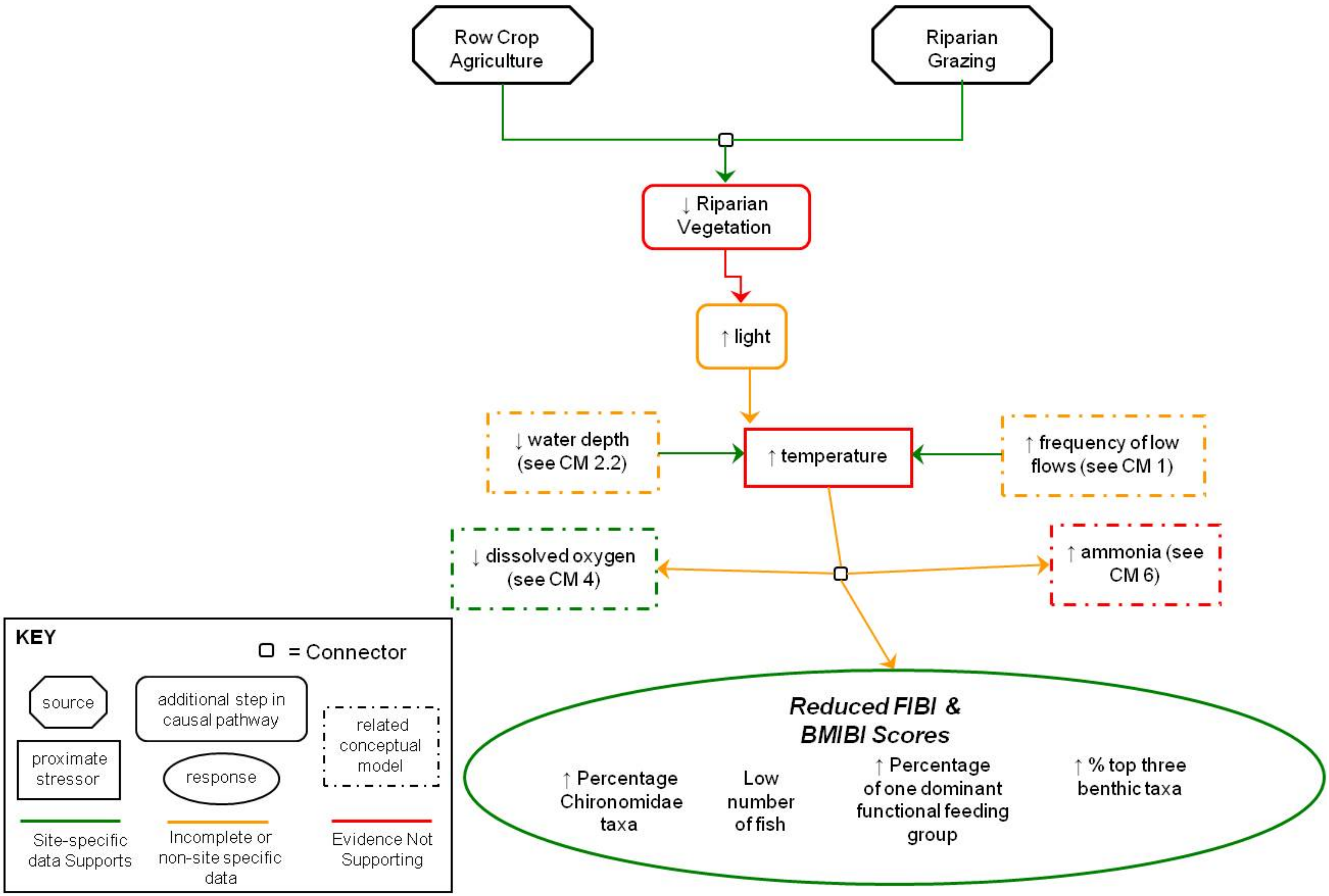
Appendix Figure D-3 Conceptual model 2.2 – Suspended and bedded sediments



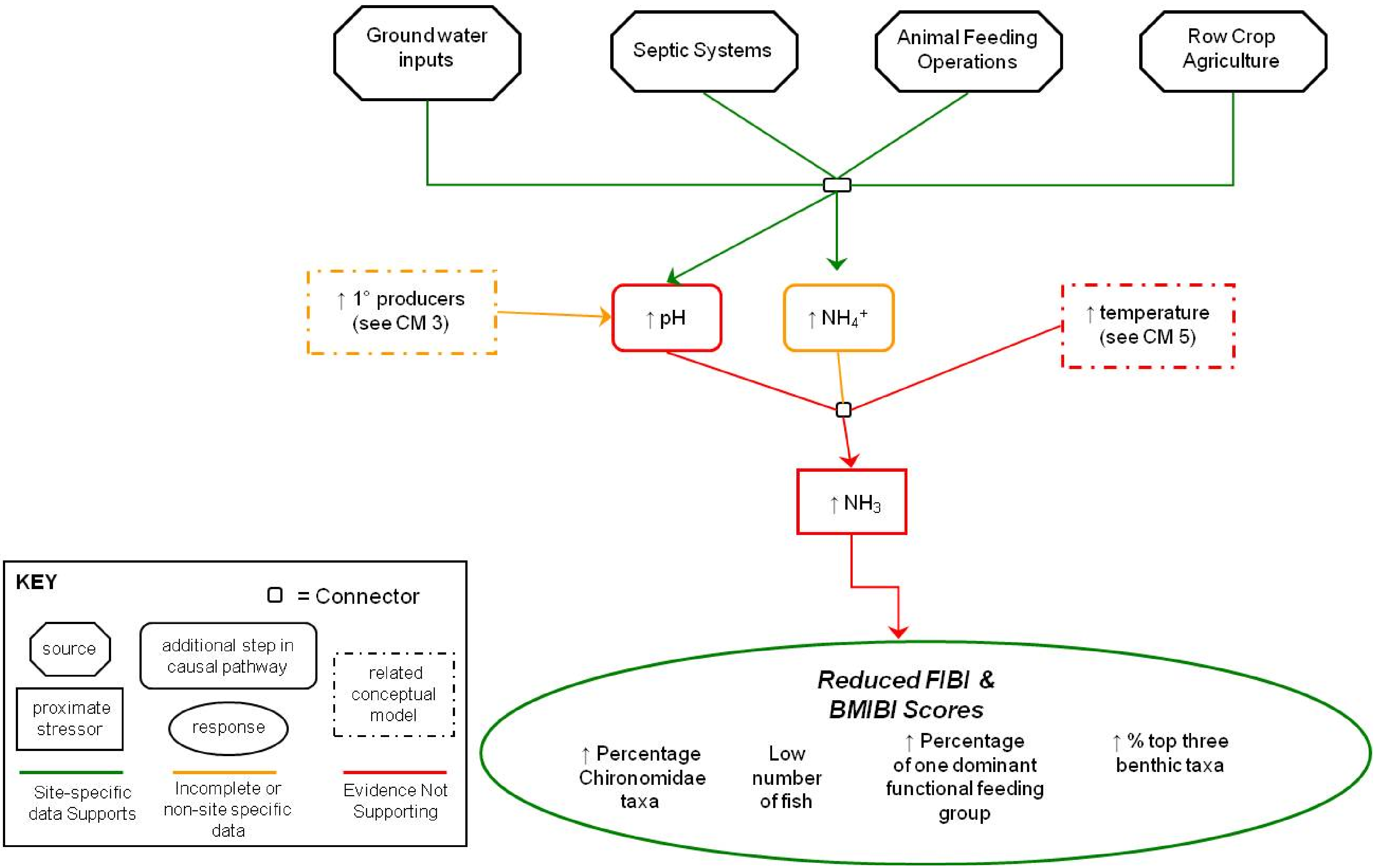
Appendix Figure D-4 Conceptual model 3 – Altered basal food source



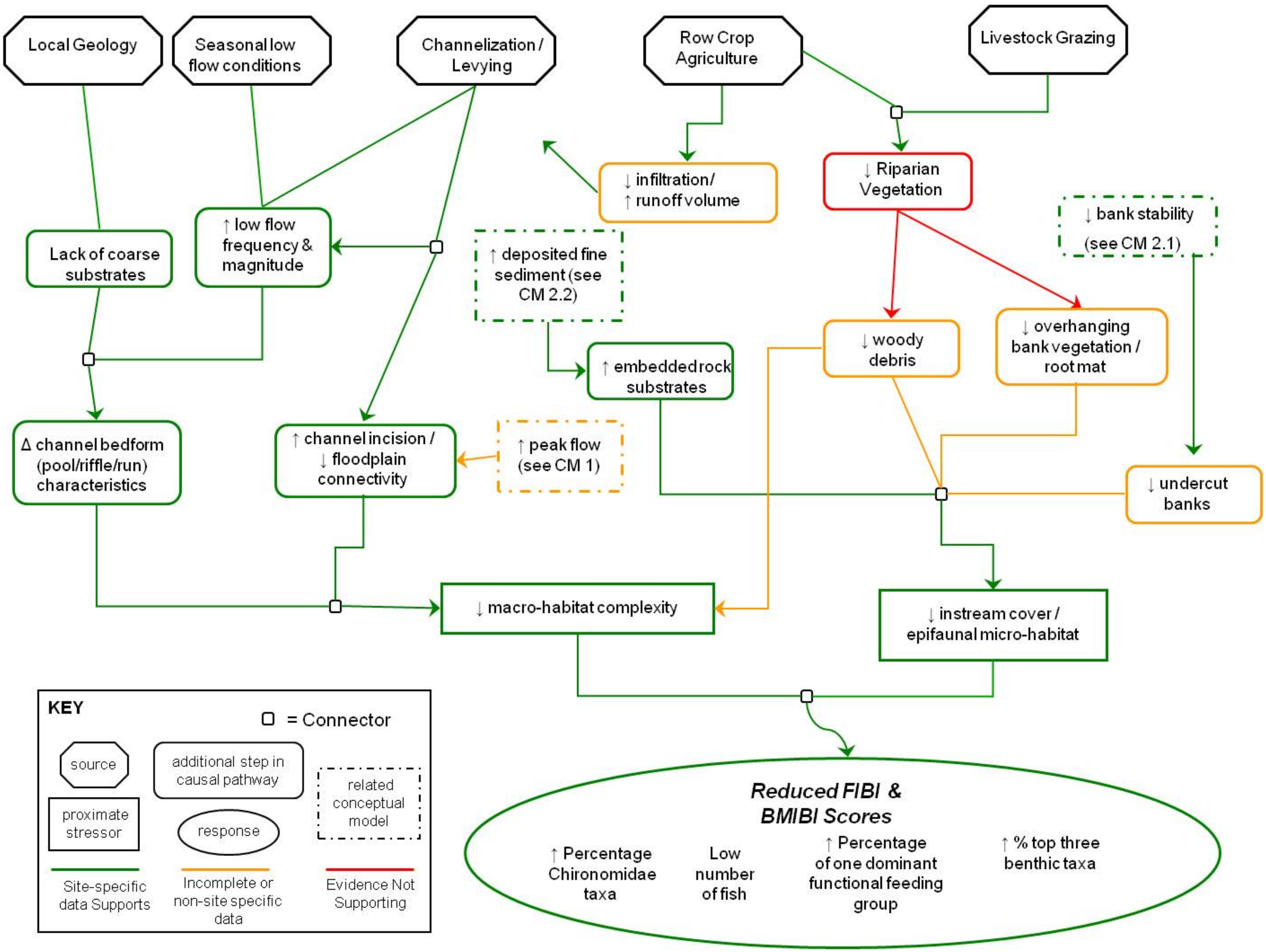
Appendix Figure D-5 Conceptual model 4 – Decreased dissolved oxygen



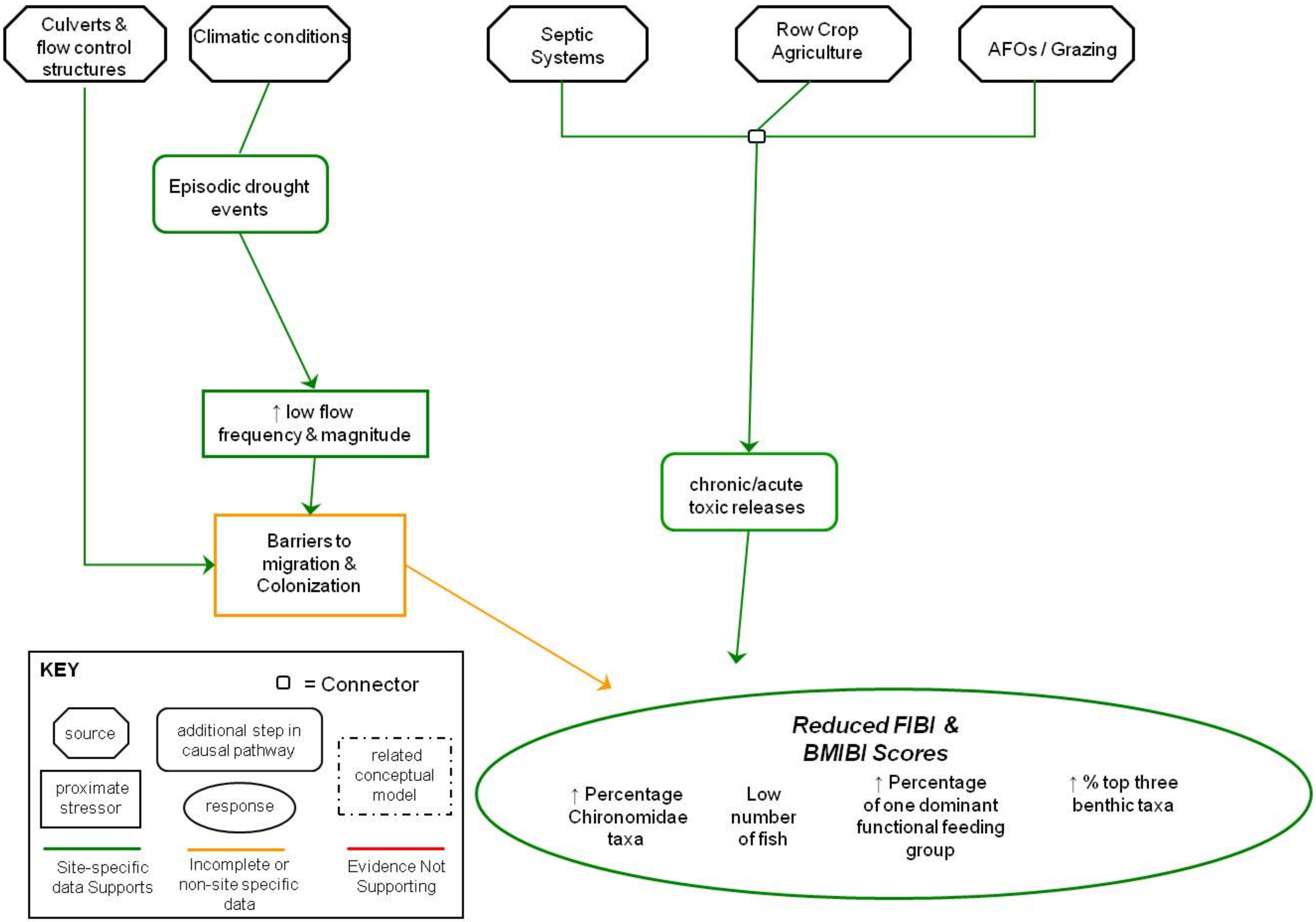
Appendix Figure D-6 Conceptual model 5 – Altered temperature regime



Appendix Figure D-7 Conceptual model 6 – Elevated ammonia



Appendix Figure D-8 Conceptual model 7 - Physical habitat alteration



Appendix Figure D-9 Conceptual model 8 – Aquatic life depletion and isolation