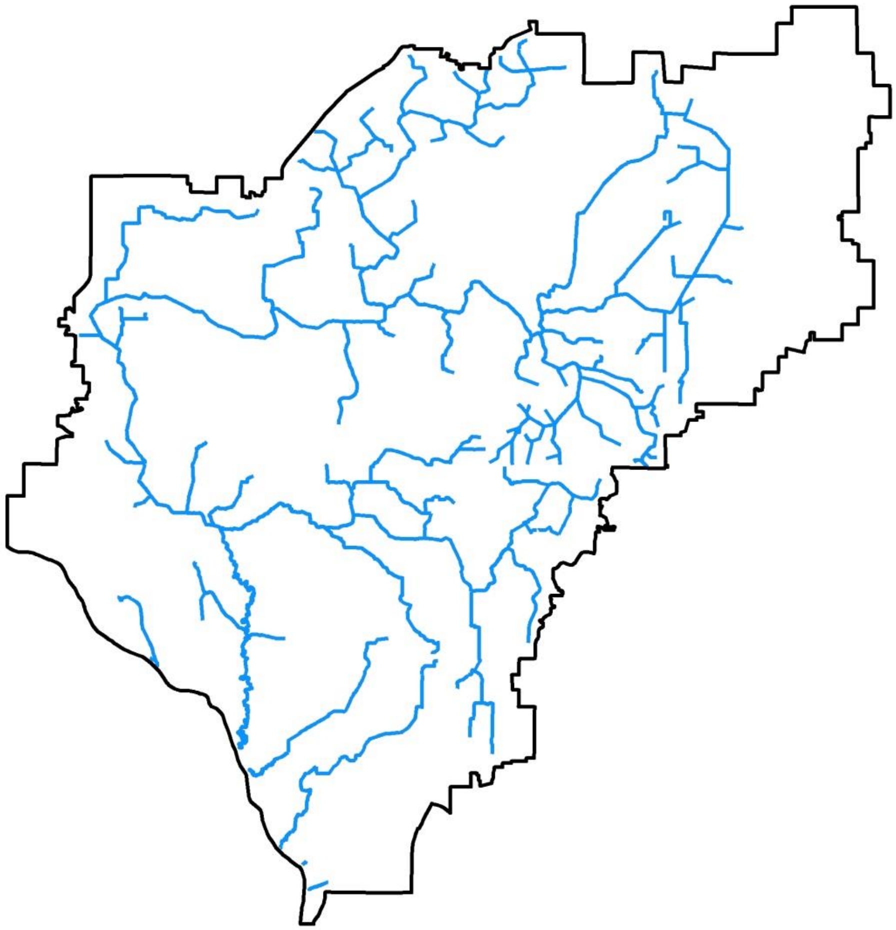
Coon Creek Watershed District

Biotic Stressor Identification Report



Prepared by:

Coon Creek Watershed District
12301 Central Ave NE, Blaine, MN 55434

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ABBREVIATIONS

ACD	Anoka Conservation District
BMP	Best Management Practice
CAC	Citizen Advisory Committee
CADDIS	Causal Analysis/Diagnosis Decision Information System
CCWD	Coon Creek Watershed District
CFU	Colony Forming Units
DELT	Deformities, Eroded fins, Lesions or Tumors
DNR	Department of Natural Resources
DO	Dissolved Oxygen
DBS	Deposited and Bedded Sediments
ECS	Ecological Classification System
EPT	Ephemeroptera, Plecoptera, Trichoptera
FBI	Family Biotic Index
F-IBI	Fish Index of Biological Integrity
FASL	Feet above Sea Level
GIS	Geographic Information Systems
IBI	Index of Biological Integrity
M-IBI	Macroinvertebrate Index of Biological Integrity
MNDNR	Minnesota Department of Natural Resources
MPCA	Minnesota Pollution Control Agency
MPN	Most Probable Number
MSHA	Minnesota Stream Habitat Assessment
PLS	Public Land Surveys
SI	Stressor Identification
STORET	STOrage and RETrieval Systems
TAC	Technical Advisory Committee
TALU	Tiered Aquatic Life Uses
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
TSS	Total Suspended Solids
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
UMRB	Upper Mississippi River Basin
WRAPS	Watershed Restoration and Protection Strategy
WMA	Wildlife Management Area

Executive Summary

This Stressor Identification report evaluates stressors that are the likely cause(s) of aquatic life and aquatic recreation impairments for the Coon Creek Watershed District in Anoka County, Minnesota. This report covers four impaired reaches: Coon Creek, Sand Creek, Pleasure Creek, and Springbrook Creek. This report details steps taken using the United States Environmental Protection Agency's and Minnesota Pollution Control Agency's (MPCAs) Stressor Identification guidance as well as the US EPA's Causal Analysis/Diagnosis Decision Information System (CADDIS). CADDIS is a methodology for conducting a stepwise analysis of candidate causes of impairment. CADDIS characterizes the potential relationships between candidate causes and stressors and identifies the probable stressors based on the strength of evidence from available data.

In 2006, Coon Creek (reach 07010206-530), Sand Creek (reach 07010206-558), Pleasure Creek (reach 07010206-594), and Springbrook Creek (reach 07010206-557) were added to Minnesota's 303(d) List of Impaired Waters for aquatic life impairment. The MPCA has developed an Index of Biotic Integrity (IBI) to evaluate the biological health of streams in the state. Currently, an IBI has been developed for two biological communities: fish (F-IBI) and macroinvertebrates (M-IBI). Coon Creek, Sand Creek, Pleasure Creek, and Springbrook Creek, are all listed as impaired based on M-IBI standards. Coon Creek and Sand Creek are also in violation of F-IBI standards, but since both of these streams are more than 50% channelized, the fisheries impairment has been deferred until the state's Tiered Aquatic Life Uses (TALU) program is in place. Coon Creek, Pleasure Creek, and Springbrook Creek, have also been added to the 2014 303(d) List of Impaired Waters for contact recreation due to elevated *Escherichia Coli* (*E. coli*) concentrations.

Portions of CCWD have been monitored for macroinvertebrates and fish since 2000 by both the MPCA and ACD. The most recent data (within 10 years) was analyzed to determine the integrity of listed impairments, however, on stream reaches where recent data was limited, monitoring data from year 2000 was used despite being outside the 10-year window.

Potential candidate causes that were ruled out based on examination of existing data include nitrates, pH, temperature, and un-ionized ammonia. Candidate causes that could not be ruled out were examined in more detail to determine possible linkages to identified impairments. The remaining causes were dissolved oxygen, excess sediment, excess phosphorus, altered habitat, altered hydrology, and chlorides. Specific stressors creating similar effects were aggregated as recommended in CADDIS methodology to simplify the CADDIS process.

Evidence was strongest for excess phosphorus and altered habitat as widespread stressors, followed by excess sediment, and altered hydrology (flashy flows). Dissolved oxygen had strong evidence, but was isolated to Coon Creek headwaters and is likely the result of natural sources. Altered habitat was an expected stressor since impaired reaches are designed and maintained as stormwater conveyance channels. Efficient stormwater conveyance requires channel maintenance; a practice contrary to the creation of adequate habitat. Therefore, implementation activities should focus on the control of stormwater flows which will lead in reductions of phosphorus, sediment, and hydrology (flashiness).

1.0 Introduction

1.1 Overview of Watershed Impairments

Coon Creek (AUID# 07010206-530) was first placed on the 2006 State of Minnesota's 303(d) list of impaired waters for impairment of “aquatic life” as measured by aquatic macroinvertebrate index of biological integrity (M-IBI). Sand Creek (AUID# 07010206-558), Pleasure Creek (AUID# 07010206-594), and Springbrook Creek (AUID# 07010206-557) were also added to the list in 2006 for impairment of “aquatic life” based on the same M-IBI assessment. In 2010 and 2011, the MPCA also monitored Coon Creek for bacteria as part of the Upper Mississippi River Bacteria TMDL project. The assessment process for the draft 2014 303(d) list determined that Coon Creek, Pleasure Creek, and Springbrook Creek are all exceeding the state’s *Escherichia coli* (*E. coli*) water quality standard and added them to the impaired waters list. Sampling of fish assemblages on Sand Creek and Coon Creek also show an impaired fish community, however since both of these streams are more than 50% channelized, the listing will be deferred until the State’s Tiered Aquatic Life Uses (TALU) program is in place. An overview of all watershed impairments are summarized below (Table 1) and also illustrated in Figure 1.

Table 1. Summary of stream reaches with impairment listings in the Coon Creek Watershed.

Waterbody Name	Reach Description	AUID##	Year Listed	Affected use	Impairment
Coon Creek	Unnamed Cr. to Mississippi R.	07010206-530	2006	Aquatic life	Macroinvertebrate bioassessments
Unnamed Ditch *Pleasure Creek*	Headwaters to Mississippi R.	07010206-594	2006	Aquatic life	Macroinvertebrate bioassessments
Sand Creek	Unnamed Cr. to Coon Cr.	07010206-558	2006	Aquatic life	Macroinvertebrate bioassessments
County Ditch 17 *Springbrook Creek*	Headwaters to Mississippi R.	07010206-557	2006	Aquatic life	Macroinvertebrate bioassessments
Coon Creek	Unnamed Cr. to Mississippi R.	07070206-530	Draft 2014	Aquatic recreation	Escherichia coli
Unnamed Ditch *Pleasure Creek*	Headwaters to Mississippi R.	07010206-594	Draft 2014	Aquatic recreation	Escherichia coli
County Ditch 17 *Springbrook Creek*	Headwaters to Mississippi R.	07010206-557	Draft 2014	Aquatic recreation	Escherichia coli
Coon Creek	Unnamed Cr. to Mississippi R.	07070206-530	Deferred	Aquatic Life	Fish bioassessment
Sand Creek	Unnamed Cr. to Coon Cr.	07010206-558	Deferred	Aquatic Life	Fish bioassessment

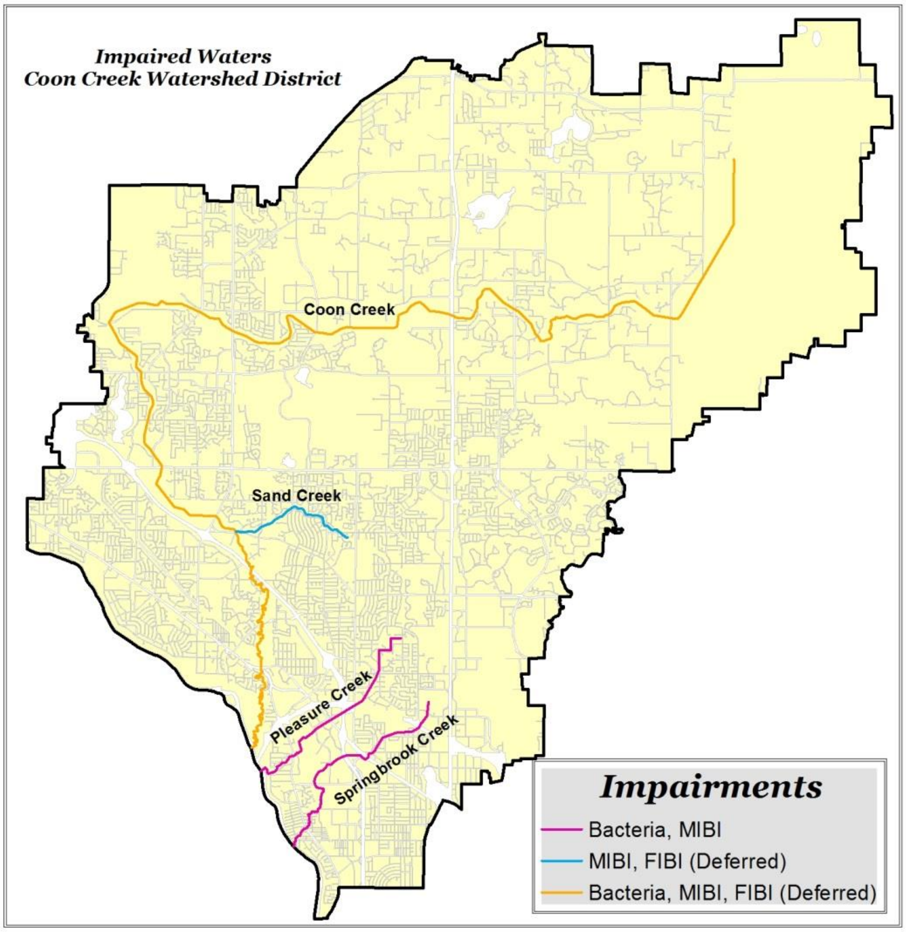

Figure 1. Impaired reaches within CCWD.

1.2 Organizational framework of Stressor Identification process

The Stressor Identification (SI) process is a reactive measure prompted by an assessment of biological monitoring data not meeting the expected community composition for a given stream classification. This SI report was prepared using both the US EPA and MPCA **Stressor Identification document** and the **US EPA's Causal Analysis/Diagnosis Decision Information System** (CADDIS). CADDIS is a methodology for conducting a stepwise analysis of candidate causes of impairment (Figure 2). CADDIS characterizes the potential relationships between candidate causes and stressors, and then identifies the probable stressors based on evidence from available data. This process draws upon a broad array of disciplines including aquatic ecology, hydrology, geomorphology, geology, chemistry, and land use analysis. Strength of Evidence (SOE) analysis is included in the SI process to substantiate or refute the case for selected candidate stressors.

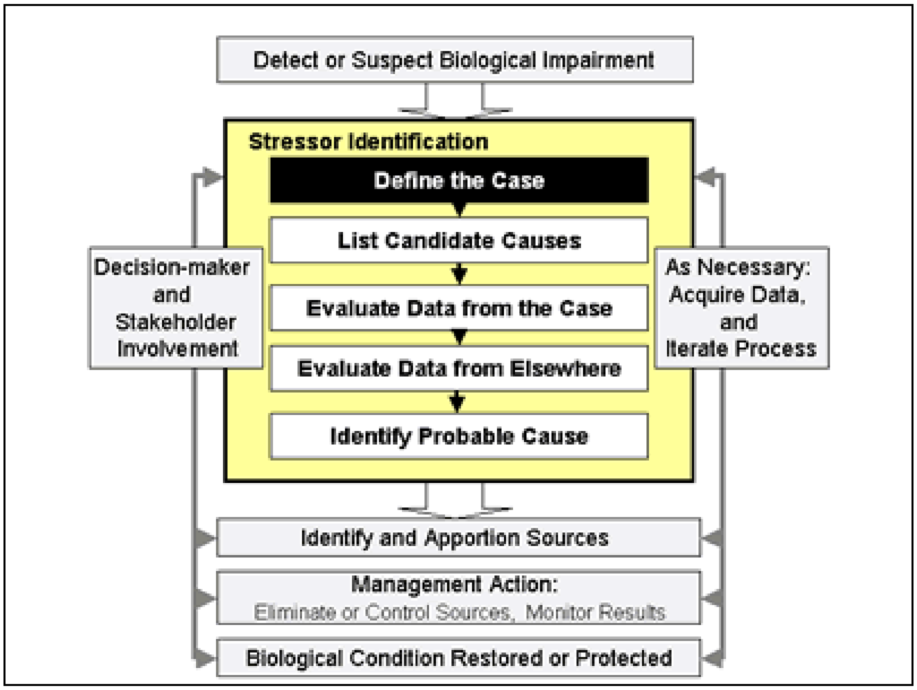

Figure 2. Conceptual model of SI framework (EPA CADDIS, 2012).

2.0 Watershed Description

2.1 Physical Setting

The CCWD is a 107 square mile drainage area located in central Anoka County, in east central Minnesota. While there may be consistent chemical and physical stressors across the entire watershed, it is difficult to accurately evaluate potential biological stressors without further stratifying the drainage area into smaller subwatersheds. For this report, CCWD was separated into four subwatersheds, each based on hydrologic boundaries of impaired reaches. The names and locations of the four subwatersheds are shown in Figure 3 below.

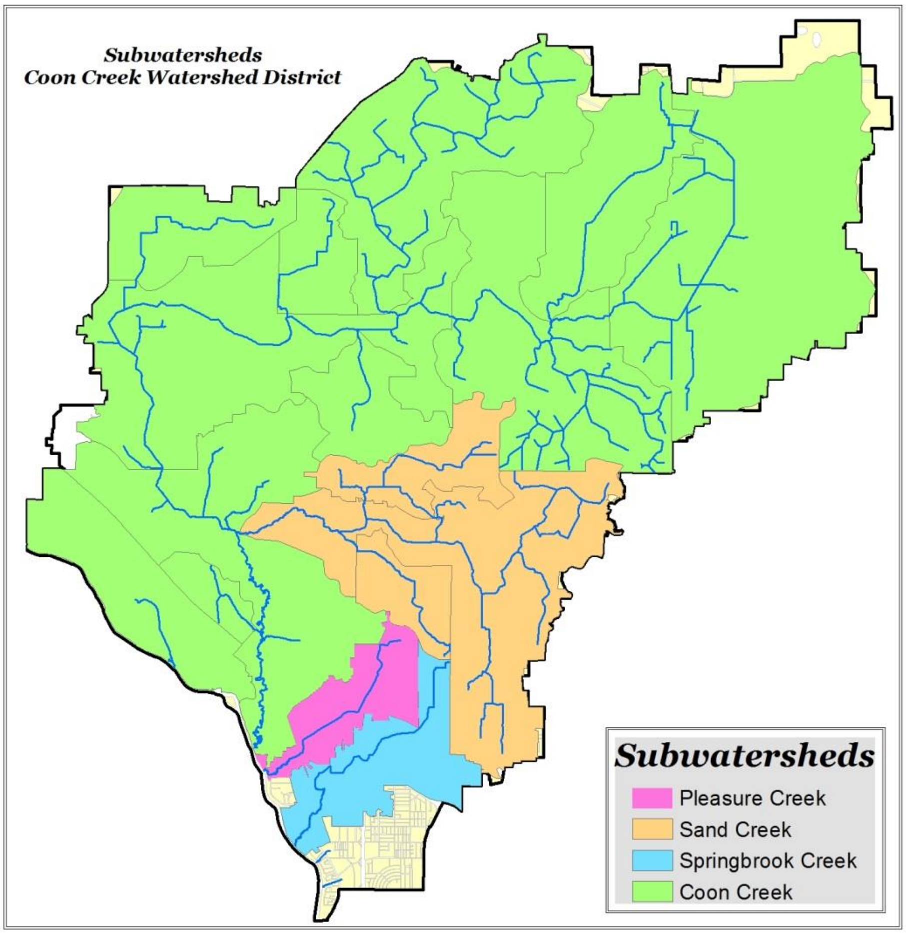

Figure 3. Name and location of CCWD subwatersheds.

2.2 Ecological Setting

The US EPA defines ecoregions for Minnesota based on areas of relative homogeneity for land use, soils, landforms, and potential natural vegetation. The Coon Creek watershed is located within the North Central Hardwood Forest ecoregion. This ecoregion is defined as an area of transition between forested areas to the north and east and agricultural areas to the south and west. The terrain varies from rolling hills to smaller plains. Upland areas are forested by hardwoods and conifers while the plains include livestock pastures, hay fields and row crops such as potatoes, beans, peas, and corn.

The Minnesota Department of Natural Resources and the U.S. Forest Service have also developed an Ecological Classification System (ECS) to aid in ecological mapping and landscape classification. The ECS follows the National Hierarchical Framework of Ecological Units (ECOMAP 1993). The ECS is a method to identify, describe, and map progressively smaller units of land with varying capabilities to support natural resources. The system integrates climate, geology, topography, soils, hydrology, and vegetation data. The benefits of this classification system are it allows resource managers the ability to consider ecological patterns at various scales and to identify areas with similar management issues and opportunities. The seven levels of classification and mapping for Minnesota are shown below (Table 2) along with CCWD's designation.

Table 2. ECOMAP classification system.

Province	Eastern Broadleaf Forest
Section	Minnesota and NE Iowa Morainal
Subsection	Anoka Sand Plain
Land Type Association	Anoka Lake Plain
Land Types	Glacial Lake Hugo Lake Plain
	Glacial Lake Fridley Lake Plain
	Mississippi Sand Plain
Land Type Phase	N/A

2.3 Land Use

The CCWD is comprised of varying land uses but is generally described as having an almost entirely developed southern portion while maintaining a more rural, agricultural northern portion. More specific land uses are tabled below (Table 3) with Figure 4 providing a visual breakdown.

Table 3. 2010 land use breakdown

LAND USE	Area (acres)	Percent
Single Family Residential	21,413	31.5%
Open/Vacant	19,054	28.0%
Parks/Recreation	10,909	16.1%
Agricultural	4,965	7.3%
Multi-family Residential	2,337	3.4%
Commercial	2,249	3.3%
Water	1,686	2.5%
Industrial	1,623	2.4%
Public/Semi-Public	1,535	2.3%
Major Highways	1,426	2.1%
Airport	627	0.9%
Railway	92	0.2%
Total	67,916	100%

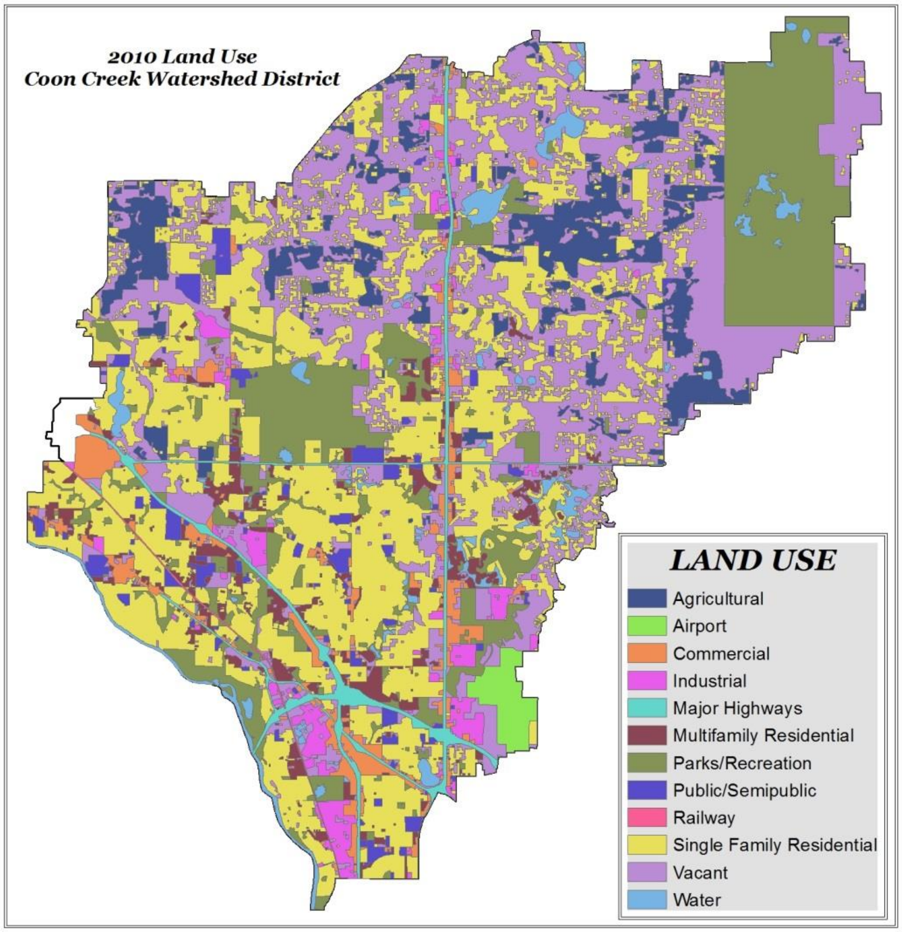

Figure 4. Land Use Breakdown in 2010.

2.4 Soil Formations

The soils of the 107 square mile Coon Creek Watershed District developed from glacial outwash and organic deposits (USDA 1977). It is located on the Anoka Sand Plain which is a sand outwash plain formed by the retreat of the Superior Lobe, of the Grantsburg Sub-Lobe, of the late Wisconsin glaciers. Soils are derived primarily from fine sands and are mostly droughty, upland soils (Psamments). However, there are organic soils (Hemists) in depressions and valleys along with poorly drained prairie soils (Aquolls) along the Mississippi River (Cummins and Grigal 1981).

On a finer scale, the watershed's landscape occurs in three geomorphic land types that contain distinctive landforms and patterns. The three land types are Glacial Lake Hugo, Glacial Lake Fridley, and the Mississippi River Terrace (Figure 5).

Glacial Lake Hugo

This is the largest land type in the watershed, covering approximately 37,000 acres (57 sq. mi.) This equates to about 54% of the total watershed area. The Glacial Lake Hugo Plain is an undulating sand plain comprised of rolling dunes and small flats in the upland, and low-lying depressions and flats. The elevation ranges from 930 feet above sea level (FASL) to 840 FASL with an average slope of roughly 0.95%. Soils on this plain are excessively drained, somewhat poorly drained, or very poorly drained, and dominated by Zimmerman fine sands (45%), Isanti fine sands (15%), and Lino fine sands (10%).

Glacial Lake Fridley Plain

Approximately 22,042 acres (34 sq. mi.) are classified as Glacial Lake Fridley Plain. This land type covers roughly 32% of the total watershed area and is characterized by large, level areas that were, or still are, bogs with small island-like features rising roughly 0-15 feet above the general surrounding land level. Elevations for this land type range from 920 FASL to 890 FASL with an average slope of 0.7%. This is the flattest portion of the watershed. Soils in this plain are very poorly drained and formed of organic material and fine sands which are also poorly drained. Rifle peat and muck account for 60% of the soils in this land type followed by 20% Isanti fine sand.

Mississippi River Terrace

The Mississippi River Terrace defines most of the western boundary of the watershed. The Coon Creek portion of the Mississippi River Terrace is approximately 8,736 acres (13.7 sq. mi.), which comprises roughly 13% of the total watershed area. This land type is described as nearly level, to a gently sloping outwash plain, which is dissected by drainage ways that historically led to the Mississippi River. This plain has an average slope of 1.4% but greater variability is seen due to large depressions that have steeper slopes adjacent to them. Elevation ranges from 890 FASL to 810 FASL occur in the Mississippi River Terrace. Soils in this portion of the plain tend to be excessively drained and sandy throughout.

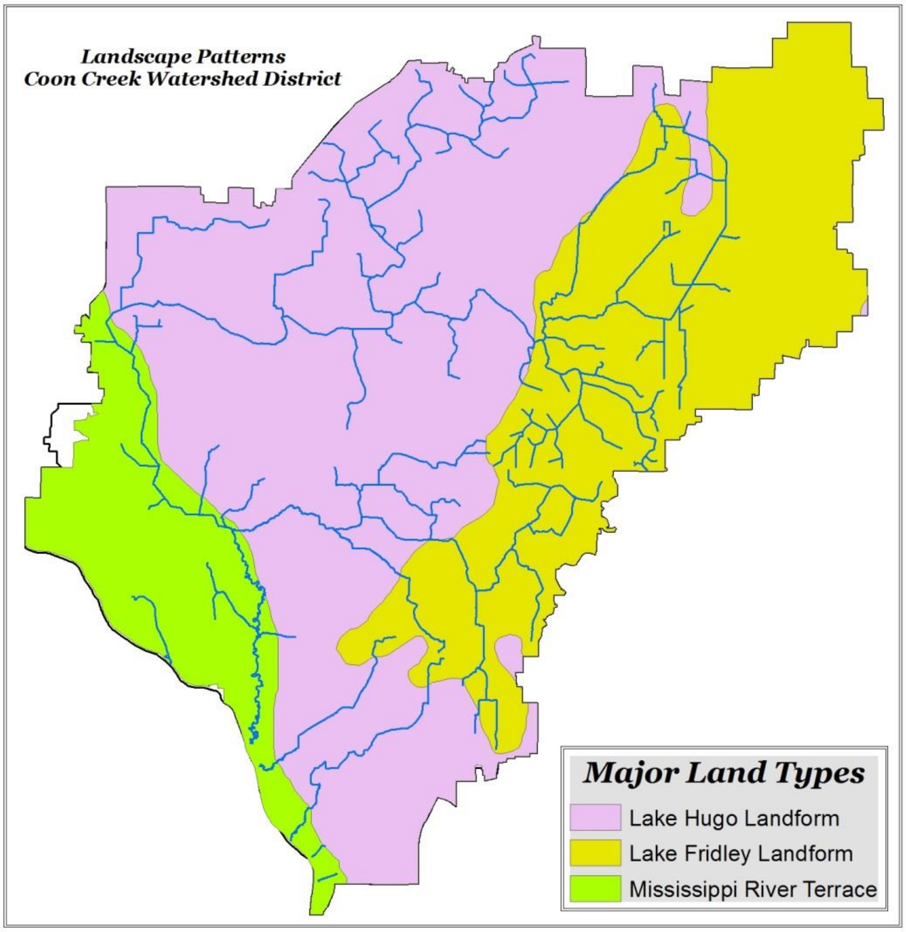

Figure 5. Major Landscape Patterns of CCWD.

2.5 Historic Conditions

Three historic periods can be distinguished based upon land cover change in the watersheds of the four streams examined in this study. These periods were identified through use of Public Land Surveys (PLS), oral history accounts, and examination of aerial photos. The first of these periods is defined as the pre-European Settlement era, prior to the 1850's. Land cover in the pre-European era was mostly dominated by oak savannah intermixed with tamarack bogs and sedge meadows. Deciduous forest and wet prairie were the only other land cover types utilizing more than 5% of the total watershed area (Figure 6).

While there are no detailed maps of CCWD showing pre-European settlement stream morphology, generalizations can be made from PLS sketches. Public land surveys from 1847-1855 suggest Coon Creek was a highly meandering stream along most of its reaches. Evidence that Coon Creek was a highly meandering stream is also prevalent when soils and topography are examined. Soils in this area are mostly comprised of highly erodible fine sands which favor sinuous channels. Topography in the area has minimal change evidenced by an average stream slope of less than 1.0% through most of the district with the exception being along the Mississippi river terrace. Lower portions of the system do have a slightly larger variation but still exhibit a modest average stream slope of 1.4%. Erodible soils, in combination with low stream gradient, create conditions favorable for a naturally meandering system.

The second period of land cover change was dominated by the introduction and intensification of agricultural practices, beginning in the late 1800's and continuing into the early to mid-20th century. This period is defined by the intensification of agriculture and progressive drainage of the land. To facilitate agriculture on poorly drained land and sub-par soils, the state passed Chapter 108 under state statute in 1883 allowing county commissioners to authorize the construction of ditches or water courses within the county, including the drainage of shallow, grassy, meandered lakes under four feet in depth. Drainage law set forth a process allowing landowners the right to petition for drainage projects; those who benefitted from the drainage were assessed to pay for it. From 1891-1918, a total of 13 ditches were dug in the drainage area of Coon Creek. Ditches dug for agricultural drainage were often laterals stemming from the main channel of Coon Creek. In addition to agricultural drainage ditch construction, large portions of natural streams were channelized to more quickly transport water off the land.

The third and final period of historic change for CCWD occurred during the mid to late 1900's. By the late 1940-50's, flooding became an issue affecting both agriculture upstream areas and downstream areas in Coon Rapids, where rapid housing growth occurred post-World War II. With continued suburban growth, the drainage system that mainly served as an agricultural tool began to function as a storm sewer system in the 1960-80's. Portions of the Pleasure and Springbrook Creek watersheds were encased entirely in pipes to quickly move water downstream. Today, agricultural use is diminishing while housing has expanded northward and public demand for water quality and aesthetics have become dominant issues.

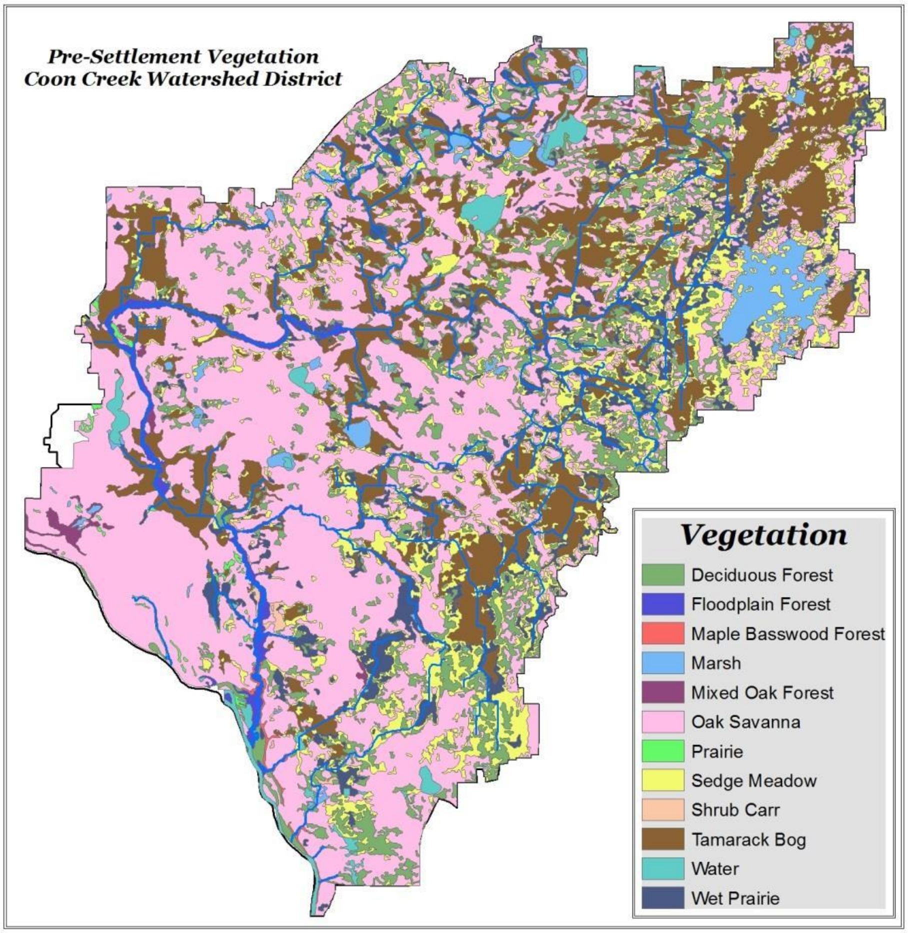

Figure 6. Pre-settlement vegetation.

3.0 Stream Descriptions

Coon Creek, Sand Creek, Pleasure Creek, and Springbrook Creek all serve as an integral part of the stormwater drainage system for portions of the seven cities within the watershed. These streams have been mostly channelized, dredged, or straightened, and function mainly to convey stormwater from the watershed to the Mississippi River.

Coon Creek

Of the 107 square miles encompassing the area of this study, approximately 78.3 square miles are drained by the Coon Creek subwatershed. This subwatershed includes portions of the cities of Andover, Blaine, Columbus, Coon Rapids, and Ham Lake. The main stem of Coon Creek begins as a series of channelized streams in a large wetland complex known as the Carlos Avery Wildlife Management Area (WMA). Coon Creek flows generally south - southwest to its confluence with the Mississippi River just south of the Coon Rapids Dam. The main channel of Coon Creek is approximately 26.7 miles long and drops roughly 90 feet from its headwaters to mouth. Nearly half of the total drop occurs within 5 miles of the creek's outlet into the Mississippi River. Land use shifts from predominately forest and wetland in the headwaters to dense, urban residential use near the outlet. A breakdown of land use in this watershed has vacant space comprising 31.8% of the watershed. Below vacant space came single family residential housing (29.8%), parks/recreation (17.6%), and agriculture use at 10%.

Sand Creek

At 15.8 square miles, the Sand Creek subwatershed unit is roughly 20% smaller than the Coon Creek subwatershed unit. The Sand Creek subwatershed is covered mostly by the rapidly developing City of Blaine along with the eastern edge of Coon Rapids. Land use in this drainage area is dominated by three main classifications, single family residential (37.9%), vacant space (20.1%), and parks/recreation (10.7%). No other land use type accounts for more than 10% of the total subwatershed area. The Sand Creek subwatershed drains to Sand Creek before eventually emptying to Coon Creek. Sand Creek has an approximately 8.3 mile long main channel that flows northerly, before turning west to its confluence with Coon Creek in Coon Rapids. Sand Creek has a total elevation change of roughly 50 feet over the entire main channel.

Pleasure Creek and Springbrook Creek

Both Pleasure Creek and Springbrook Creek have much smaller subwatersheds than those mentioned above. Pleasure Creek drains only 2.7 square miles accounting for roughly 2.5% of the total drainage area for CCWD. Springbrook Creek is slightly larger at 4.13 square miles but is still small when compared to the Coon Creek and Sand Creek subwatersheds. Land use in both of these systems in densely urbanized and almost completely developed. In Pleasure Creek, 62.8% of the subwatershed is broken down between residential (49.3%), and major highways (13.5%). Springbrook Creek subwatershed is similarly developed with 40% residential and 13.9% commercial. These subwatersheds were nearly fully built-out prior to modern stormwater regulation creating additional challenges when trying to achieve today's water quality objectives.

4.0 Aquatic Life Impairment Basis

Biological health was determined through the use of a multi-metric approach referred to as an Index of Biological Integrity (IBI). These indices make use of numerous attributes to measure species diversity and abundance, composition, feeding characteristics, and reproductive strategies. Typically, IBI's will use 8-12 attributes (also known as metrics) to draw conclusions about the biological assemblage present, which provides insight into the health of the stream they were sampled from. Each recorded metric has a predictable change in the face of human disturbance; this helps to determine sources and severity of disturbance. IBI's have been developed separately for fisheries (F-IBI) and macroinvertebrates (M-IBI), as well as separate thresholds based on stream classifications.

The MPCA classifies streams based on drainage area, gradient, and geographic locations in order to better assess Minnesota's aquatic biological communities. Each classification has an expected community composition for both fish and macroinvertebrates. Table 4 lists all biological monitoring stations found in the Coon Creek Watershed District, along with corresponding fish/macroinvertebrate classifications as assigned by the MPCA. Figure 7 shows the geographical location of the listed biological monitoring sites.

Table 4. Biological monitoring stations in CCWD. NS=Not Sampled.

Station ID	Location Description	Fish Class	Invert Class	Subwatershed
10UM003	Vale St. NW, Coon Rapids	5	6	Coon Creek
00UM064	111th Ave, Coon Rapids	5	5	Coon Creek
10UM021	149th Ave, Ham Lake	6	6	Coon Creek
10UM018	Andover Blvd, Andover	6	6	Coon Creek
10UM017	Hanson Blvd, Coon Rapids	5	6	Coon Creek
10UM020	Naples St NE, Ham Lake	7	6	Coon Creek
00UM059	Hwy 65, Ham Lake	7	6	Coon Creek
00UM065	Olive St., Blaine	6	5	Sand Creek
00UM062	East River Rd, Coon Rapids	6	5	Pleasure Creek
00UM061	Riverview Terrace Rd, Fridley	6	5	Springbrook Creek
00UM086	County Rd 10, Blaine	6	NS	Springbrook Creek

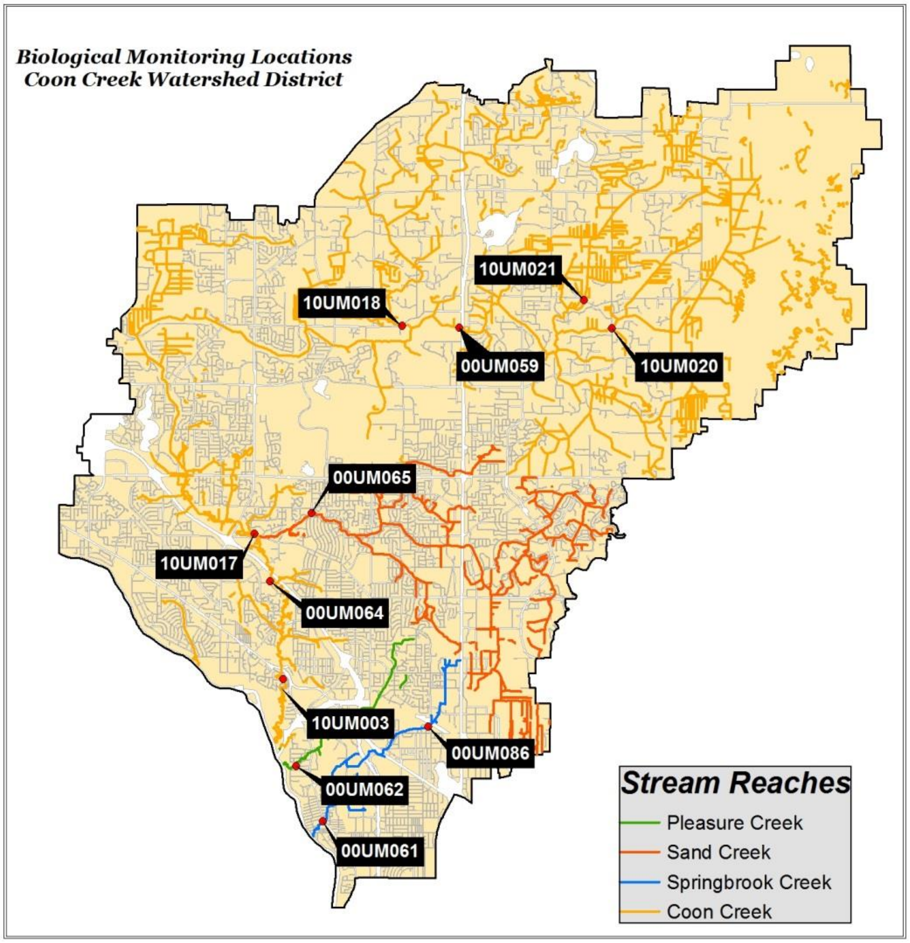

Figure 7. Map of MPCA biological monitoring locations.

4.1 Coon Creek

Coon Creek (AUID# 07070206-530) has five separate classifications used to assess biological health, three for fish, and two for invertebrates. Fish classifications for Coon Creek are Northern Streams, Northern Headwaters, and Low Gradient, while macroinvertebrate assessments are classified as either Southern Forest Streams (Glide/Pool Habitats), or Southern Streams (Run/Riffle Habitats).

A survey of the fish community in Coon Creek was conducted by MPCA at five locations, however only one of these locations (ID 10UM003) was considered to be currently assessable by MPCA standards. Fish species collected at site 10UM003 are indicative of a stressed, warm water fishery. Complete sampling data is detailed in Appendix A and computed metric scoring is detailed in Appendix B for all stream reaches. A total of 27 species were sampled at this site scoring below only 9 other sites in the entire UMRB with a Northern Streams classification. Despite having above average diversity for the UMRB, species evenness begins to show evidence of a stressed community. Species composition was dominated by four species leaving the other 23 species with few individuals. Common Shiner (*Luxilus cornutus*), Green Sunfish (*Lepomis cyanellus*), Sand Shiner (*Notropis stramineus*), and White Sucker (*Catostomus commersonii*) dominated the fish community at this site. These species are generally considered to be pollution tolerant and typical of degraded urban streams. The dominance by few species is also typical of degraded urban streams. Outside of the dominant species, strong numbers of bigmouth shiner (*Hybobsis dorsalis*) and fathead minnow (*Pimephales promelas*) were also collected. These species have been observed to actually show a preference for turbid waters prone to siltation (Becker 1983). An evaluation of the remaining Coon Creek sites show a predominance of short lived, generalist species. The dominance by generalist species and lack of long lived species in combination with few intolerant species supports the listing of Coon Creek as biologically impaired water.

Coon Creek macroinvertebrate assemblages are also indicative of stream degradation. Two sites are meeting the M-IBI threshold for their given stream designation but the overall picture for Coon Creek is symptomatic of a stressed system. EPT taxa are widely known to be highly sensitive to various forms of disturbance. The number of EPT taxa in Coon Creek is well below the average of Upper Mississippi River Basin (UMRB) sites with healthy invertebrate assemblages. In addition to the low number of EPT taxa, a low number of EPT individuals are also represented (Appendix B). Both of these metrics do however improve downstream suggesting a possible improvement in stream condition.

4.2 Sand Creek

Biological sampling in Sand Creek has all been at one site, station 00UM065. Fish sampling has a total of four sampling events and results are indicative of not only degraded conditions but also deteriorating conditions (Appendix B). Species richness (number of taxa collected) has declined by approximately 50% from 2000 to 2010. Also, the total number of individuals has shown the same trend, declining from 290 specimens in 2000 to only 43 in 2010. Of the total number of fish captured, White Sucker (*Catostomus commersonii)* were dominant, followed by, Johnny Darter (*Etheostoma nigrum*), Blacknose Dace (*Rhinichthys atratulus*), and Fathead Minnow (*Pimephales promelas*). These species are all tolerant of disturbed conditions (Becker 1983). The average F-IBI score for these four sampling events aligns very closely with the average of all impaired sites in the UMRB, scoring 18.25 and 17.25 respectively. One sample on Sand Creek indicates a severe impairment with only two taxa sampled and a total of eight individuals. Listing of Sand Creek for impaired fisheries has been deferred until the development of Tiered Aquatic Life Uses (TALU) standards are in place. TALU will provide revised standards for streams with modified use such as those functioning primarily as stormwater conveyance channels.

Macroinvertebrate sampling consists of only two samples, one sample from 2000 and the other from 2010. These samples also show potentially deteriorating conditions with M-IBI scores of 34 and 17 respectively (Appendix B). Both of these samples have a higher than expected number of Hydropsychidae species and individuals when compared to other streams of the UMRB with Southern Streams classification. An increase in the Hydropsychidae metric is predicted with the presence of increased stream disturbance, especially from excess nutrients. Tolerant taxa were also dominant, accounting for 68% of all taxa sampled. The abundance of tolerant taxa paired with the complete absence of intolerant taxa is a pattern representative other impaired sites in the UMRB. The number of long lived species was comparable to other streams of the UMRB but the number of long lived individuals was much lower than expected. The lack of long lived individuals provides further evidence that stream degradation is occurring.

4.3 Pleasure Creek

Pleasure Creek fish sampling has been limited to one sampling event in 2000 at station 00UM062. Sampling results show a slightly higher than average number of taxa and individuals compared to other low gradient sites of the UMRB. Metric scores can be found in Appendix B of this report. MPCA data indicates station 00UM062 is “non-assessable” due to its proximity to a larger body of water (Mississippi River). The designation of “non-assessable” status was justifiable as Gizzard Shad (*Dorosoma cepedianum*), a known large river species, were sampled in Pleasure Creek. Since sampling was performed on a “non-assessable” reach, Pleasure Creek is not currently listed as impaired for fish assemblages.

Macroinvertebrate assemblages for Pleasure Creek were assessed through one sample, also collected in 2000 at site 00UM062. This sampling effort resulted in an M-IBI score of 29 which is below the Southern Streams class threshold of 35.9. EPT percentage metric scores suggest good stream condition however; further insight can be gained when looking at the distribution of families within this metric. The percentage of Ephemeroptera and Plecoptera are very low at 0.9% and 0% respectively, indicative of poor stream condition. Trichoptera percentage is much higher at 42.9% which upfront can suggest sufficient stream condition but this is not the case. Dominance by Hydropsychidae, a family belonging to the Trichoptera order, is a mark of disturbed stream condition as discussed in the previous section. In Pleasure Creek, 22.7% of all Trichoptera belong to the Hydropsychidae family, higher than the average of 16.4% for streams in the UMRB that meet the M-IBI threshold. There are also a greater proportion of macroinvertebrates who collect their food by filtering from the water column rather than physically gathering their food. This indicates a high amount of organic matter is present in the water column which makes filter feeding a more efficient strategy. The combination of fish and macroinvertebrate IBI scores indicates Pleasure Creek is a degraded stream.

4.4 Springbrook Creek

The fish community of Springbrook Creek is difficult to evaluate for two reasons: 1) sampling conducted by MPCA was done on a “non-assessable” site due to its proximity to a large body of water; 2) two sampling events show a wide disparity in results making it difficult to determine the severity of the impairment. Fish sampling shows 12 species totaling 494 individuals in the first sample, while the second sample shows 4 species tallying only 38 individuals. These samples were conducted in 2000 and only 14 days apart so it is difficult to interpret such a large difference in the number of individuals. Fish sampling in Springbrook Creek was dominated by Creek Chub (*Semotilus atromaculatus*), Hybrid Sunfish, and Brook Stickleback (*Culaea inconstans*). Of these species, Creek Chub was most abundant. Creek Chub are known to be tolerant of considerable pollution (Becker 1983). Of the individuals sampled, 92% were considered tolerant providing a strong likelihood degraded conditions exist. There was also a strong representation of planktivorous fish indicating a significant amount of organic matter available, much like Pleasure Creek. It should again be noted; the sampling of fish assemblages was conducted on a non-assessable reach, and is currently not impaired for fish assemblages.

Macroinvertebrate assemblages were sampled at an assessable site and the data suggests an unhealthy assemblage. Small percentages (0.3%) of intolerant macroinvertebrates were found which correlates well with the 92% of fish sampled that were considered tolerant. An examination of feeding strategies showed 44% of macroinvertebrates collected their food by filtering it from the water column. This was considerably higher than the average of streams in the UMRB meeting M-IBI thresholds. The proportion of macroinvertebrates who feed via filtration mirrors the number of planktivorous fish, suggesting abundant organic material in the stream. A high amount of organics can be driven by excess phosphorus; this theory is examined in section 8.3 of this report.

5.0 Aquatic Recreation Impairment Basis

5.1 *Escherichia Coli* (*E. coli*) Background

A near infinite number of bacteria, viruses, and microorganisms exist in our environment. Most are beneficial but roughly 10 percent are considered harmful (MPCA 2008). The harmful varieties are known as "pathogens," and if ingested by humans can pose significant health risks.

Fecal coliform is one variety of bacteria categorized as a pathogen because of its potential health risk to humans. *Escherichia coli* (*E. coli*), a bacterium found in the feces of warm blooded animals, are a sub-group of bacteria used as a surrogate to fecal coliform to evaluate the safety of recreational and drinking waters. The MPCA sets *E. coli* standards for aquatic recreation (swimming, wading, etc.) and designates "impairement" if 10% of measurements in a calendar month are >1260 colony forming units per 100 milliliters of water (cfu/100mL) or if the geometric mean of five samples taken within 30 days is greater than 126 cfu/100mL from April through October. These standards are often referred to as "chronic" and "acute" standards respectively. In regards to the State of Minnesota *E. coli* standard for contact with water, Coon Creek, Springbrook Creek, and Pleasure Creek are in exceedance resulting in their addition to the Draft 2014 Impaired Waters List.

5.2 *Escherichia Coli* (*E. coli*) Data

E. coli were monitored in 2013 across CCWD including all four impaired stream reaches as well as CD 58 and CD11 tributaries (Figure 8). In addition to 2013 monitoring, Coon, Pleasure, and Springbrook Creeks have earlier monitoring of varying effort. Coon Creek was monitored in 2010 and 2011 as part of the Upper Mississippi River Bacteria TMDL project. Pleasure Creek has additional sampling data from 2006-2009 and Springbrook Creek has *E. coli* samples dating back to 2006.

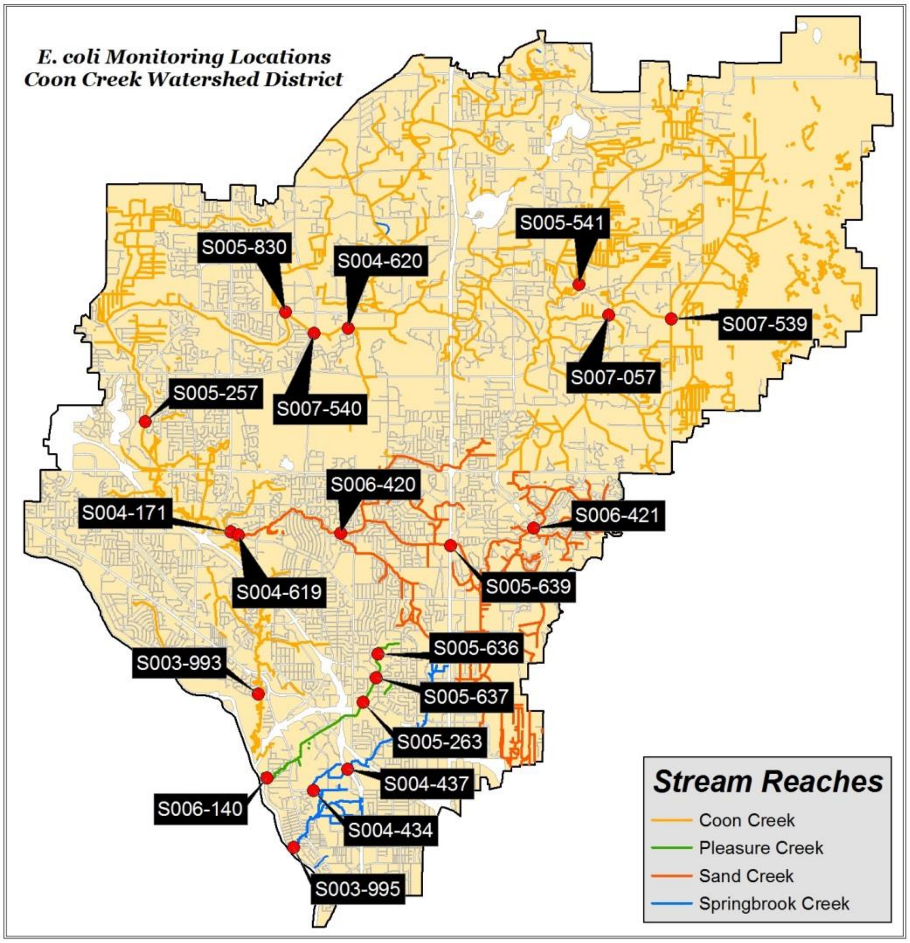

Figure 8. Locations of *E. coli* monitoring conducted in 2013 (site S003-993 was also monitored in 2010 and 2011).

Coon Creek

The Coon Creek System (Coon Creek, CD58, and CD11) has had a total of 107 bacteria samples documented. *E. coli* levels found throughout Coon Creek are quite high. A total of seven samples reached the upper limit of laboratory test range (>2420 cfu/100mL). Five of seven monitored months have a geometric mean exceeding 126 cfu/100mL indicating acute impairment (Table **5**). The chronic standard of 1260 cfu/100mL was exceeded 12 times which is more than the 10% exceedance threshold for chronic impairment. Coon Creek is in clear violation of *E. coli* standards and justly listed for non-support of aquatic recreation.

Table 5. *E. coli* sampling for Coon Creek system. Red numbers indicate violation of standards for aquatic recreation.

Sample Month	Total Samples (N)	#>1260 cfu/100mL	% samples>1260 cfu/100mL	Monthly Geometric Mean (cfu/100mL)
April	7	0	0%	33
May	9	0	0%	468
June	23	7	30%	384
July	32	0	0%	112
August	8	0	0%	324
September	12	2	17%	267
October	16	3	19%	449
Totals	107	12	11%	-

E. coli levels have a drastic variation when comparing base flow samples to storm flows. On average, storm flows are contributing 10 times more *E. coli* than base flows. Table 5 (above) highlights the effect of storm versus base flows during the month of July. July *E. coli* levels are expected to be at or near their highest levels due to increased stream temperature, long periods of intense sunlight, and generally low flow. However in 2013, the month of July actually met standards likely due to lack of storm event sampling. This suggests that *E. coli* levels could potentially meet state standards if storm flows are better controlled.

Sand Creek

Sand Creek *E. coli* monitoring if far less robust than Coon Creek but does give reason for concern. A total of 32 samples were recorded in 2013. The months of April and August did not have any *E. coli* samples documented. Regardless, it is apparent that Sand Creek is in violation of the acute and chronic standards (Table 6). Geometric means for all months where data was recorded are in violation of the acute standard. The month of October has an extremely high geomean but this number is not representative of typical conditions since all events were recorded during a single storm event. Sand Creek also shows a significant increase in bacteria levels during storm events, although not as drastic as Coon Creek. Storm flow *E. coli* monitoring shows 3.5 times the average *E. coli* level of base flows. It should be noted the variation between storm and base flows would be increased with elimination of a base flow sample of 2282 cfu/100mL recorded on July 18, 2013. This reading is much higher than any other base flow sample and may be due to laboratory error or an isolated event at or near the monitoring location. Samples taken at this site two weeks prior and then again two weeks after did not detect similar *E. coli* levels (150 cfu/100mL, 133.4 cfu/100mL) making laboratory error the more likely scenario.

Table 6. *E. coli* monitoring for the Sand Creek system. Red numbers indicate violations of standards for aquatic recreation.

Sample Month	Total Samples (N)	#>1260 cfu/100mL	% samples>1260 cfu/100mL	Monthly Geometric Mean (cfu/100mL)
April	-	-	-	-
May	4	0	0%	142
June	8	3	38%	480
July	12	1	8%	130
August	-	-	-	-
September	4	1	25%	250
October	4	4	100%	1903
Totals	32	9	28%	-

Pleasure Creek

Pleasure Creek is also impaired by excessive *E. coli* based on exceedances of both criteria. Available data clearly documents exceedances of the "impaired" criteria and across all sampling sites. Sampling on upstream sites has been conducted less frequently but *E. coli* levels nearing upper limits of laboratory test ranges have still been documented. This indicates that *E. coli* is an issue throughout the entire stream reach and is not simply an exceedance based on downstream degradation. Acute *E. coli* standards were violated in six out of seven sampled months providing evidence that impairment isn't due to an isolated event. The occurrence rate and magnitude of exceedance indicates a consistent source is present in the Pleasure Creek Watershed (Table 7). As with Coon and Sand Creeks, storm flows are a significant factor contributing roughly four times the *E. coli* amount as base flows.

Table 7. *E. coli* sampling for Pleasure Creek. Red numbers indicate violation of standards for aquatic recreation.

Sample Month	Total Samples (N)	#>1260 cfu/100mL	% samples>1260 cfu/100mL	Monthly Geometric Mean (cfu/100mL)
April	4	0	0%	29
May	6	3	50%	759
June	10	2	20%	581
July	5	0	0%	138
August	10	2	20%	290
September	3	0	0%	180
October	3	1	33%	591
Totals	41	8	20%	-

Springbrook Creek

Springbrook Creek is in violation of both acute and chronic standards although not as severely as Sand Creek and Pleasure Creek (Table 8). Springbrook Creek narrowly violates the chronic standard with 13% of samples exceeding 1260 cfu/100mL, similar to Coon Creek. The acute standard was exceeded six out of seven months over a three year monitoring period. The magnitude of exceedances match those of other CCWD impaired reaches with storm samples occasionally reaching laboratory limits of 2420 cfu/100mL. The difference between storm flow and base flow E coli level on this reach was substantial. Storm flows accounted for 12 times the number of colony forming units than did base flows magnifying the importance of controlling storm runoff and high flows.

Table 8. *E. coli* sampling for Springbrook. Red numbers indicate violation of standards for aquatic recreation.

Sample Month	Total Samples (N)	#>1260 cfu/100mL	% samples>1260 cfu/100mL	Monthly Geometric Mean (cfu/100mL)
April	6	0	0%	37
May	8	0	0%	180
June	13	4	31%	355
July	15	0	0%	139
August	5	0	0%	214
September	9	0	0%	433
October	8	4	50%	404
Totals	64	8	13%	-

5.3 Potential Sources

Source identification for fecal bacteria can be a difficult task due to the wide array of potential sources, pathways, and their interactions with each other. MPCA launched the Upper Mississippi River Bacteria TMDL project in March 2008 and identified potential sources of *E. coli* bacteria across the entire UMRB (MPCA, 2014). Table 9 summarizes the most common sources and pathways of contamination identified in this study.

Table 9. Common sources of fecal bacteria identified in MPCA UMRB Bacteria TMDL.

Source	Common Pathways
Humans	Wastewater Treatment Facilities and Collection Systems
	Land Application of Bio-solids
	Illicit discharges from unsewered communities
	Land Application of septage
Pets	Dogs
	Cats
Livestock	Animal Feeding Operations (Feedlots)
	Livestock Not Requiring Registration
	Land Application of Manure
	Grazing
Wildlife	Deer
	Raccoons
	Ducks
	Geese
*Land Cover (Impervious/Pervious) is a critical factor in the fate and transport of sources listed above.	

With respect to CCWD, specific sources can be eliminated based on knowledge of existing land use. Livestock operations are few and relatively small in CCWD with most agricultural land dedicated to sod farming. The lack of livestock makes feedlot operations, land application of manure, and grazed pastures, unlikely *E. coli* sources. Municipal wastewater treatment facilities are non-existent in CCWD therefore effluent from these facilities as a source is also unlikely.

Microbial source tracking was performed as part of the UMRB Bacteria TMDL project for Pleasure Creek and Springbrook Creek. Microbial source tracking identifies bacteria specific to certain hosts providing strong evidence toward possible sources. The UMRB Bacteria TMDL project analyzed primers specific to cattle, pigs, and humans. The “human” category also contained primers for pets such as cats and dogs, but since the primer was more reactive to humans, all three of these sources were categorized as one.

Microbial tracking on Pleasure and Springbrook Creek identified human (human/cat/dog) sources as the major contributors of *E. coli* contamination. Interestingly, cattle were also identified as a significant contributor on Springbrook Creek which was not anticipated due to the urban setting. The primer used for cattle identification (Cow M3) has 100% specificity which indicates no false positives should exist (Shanks et al. 2010). Despite the claim of 100% specificity, cattle as a major contributing source seem unlikely. At the time of writing, it is unknown why cattle specific *E. coli* were detected in Springbrook Creek. The Upper Mississippi River Bacteria TMDL report hypothesizes improperly processed compost may be a source of cattle specific bacteria in urbanized settings but no further work was found to support this theory (Plevan et al., 2013). Even if this was a potential source, it is unlikely to be present in amounts large enough to be a dominant contributor of *E. coli*.

It is not surprising human (humans/cats/dogs) source of *E. coli* were detected in Pleasure and Springbrook Creek given the degree of urbanization on the surrounding landscape. Researchers have positively correlated microbial densities with watershed factors such as land use, density of housing, population, development, percent impervious area, and domestic animal density (Struck *et al*., 2006). Selvakumar and Borst (2006) found microorganism concentrations from high-density residential areas were higher than those associated with low-density residential and landscaped commercial areas. It is likely urban runoff containing *E. coli* from numerous sources is being "flushed" from the landscape during precipitation events. Urban stormwater "flush" is contributing to the large disparity in *E. coli* concentrations during base and high flow events (Figure 9). If sources such as leaky/failing septic systems or illicit discharges were the main sources, it would be expected to observe much higher *E. coli* concentrations during base flow events when dilution is reduced.

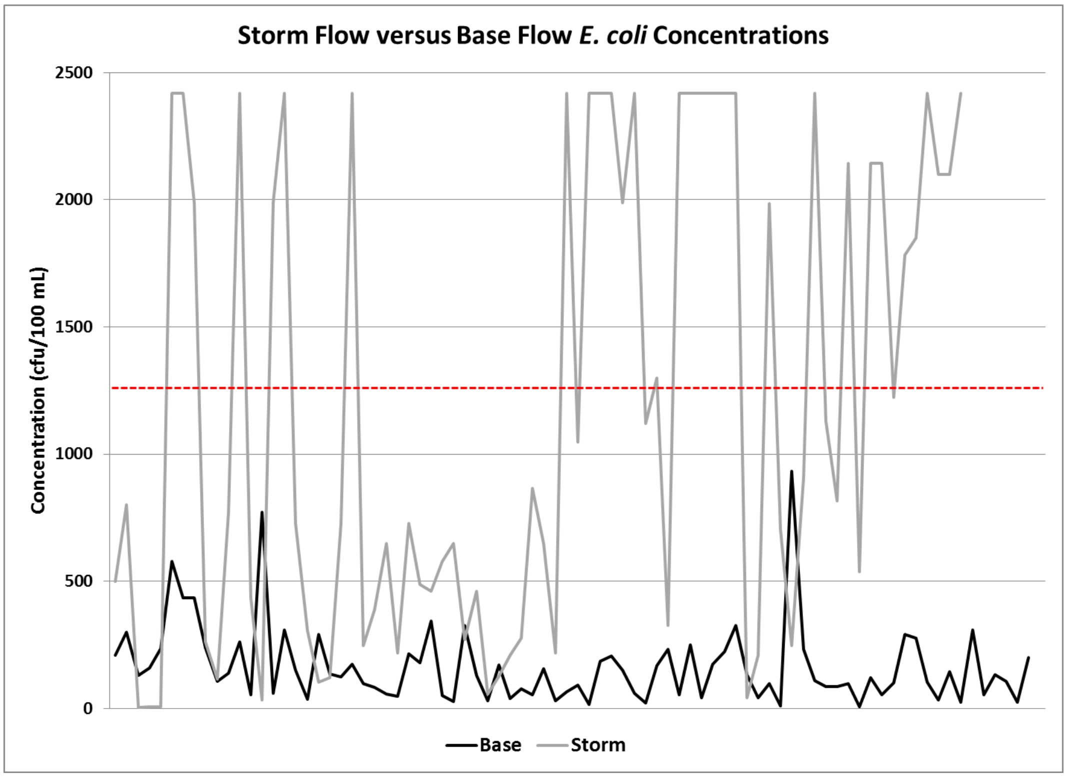

Figure 9. Storm flow vs base flow *E. coli* concentrations. Figure is not stream specific nor temporal. Horizontal red line indicates Acute standard of 1260 cfu/100mL. Upper limit of Y-axis is lab limit of 2420 cfu/100mL.

Urban stormwater alone cannot be the sole source of elevated *E. coli* in CCWD since rural areas also experience high *E. coli* concentrations. This is exemplified in the upper reaches of Coon Creek where the percent impervious and housing density drops significantly when compared to Pleasure and Springbrook Creek. Unfortunately, microbial source tracking was not available for the headwaters of Coon Creek so the following potential sources are only speculative.

Waterfowl congregations are considered a potential contributing source but to what degree are not fully known. Large populations of waterfowl are common across CCWD, especially during spring and fall migrations. CCWD contains the Carlos Avery WMA and expansive agricultural sod fields. These areas (Carlos Avery WMA and sod fields) are located in the headwaters of Coon Creek creating a direct spatial connection between observed exceedances and the source. These areas provide excellent waterfowl feeding areas in addition to resting areas during migration (Figure 10).

Figure 10. Waterfowl congregations in CCWD.

Historically, *E. coli* were viewed solely as an indicator of sewage contamination which in many cases it was. Today, a better understanding of *E. coli* exists and indicates that some *E. coli* strains are able to survive in the environment; outside the gut of warm blooded animals. Often times, *E. coli* can exist in counterintuitive areas such as naturally forested areas. Recognizing the ability of *E. coli* to survive in the environment has led to the identification of "naturalized" strains that are able to survive in soil and stream sediments. Transport of naturalized *E. coli* strains from soil to water or the re-suspension of sediment borne *E. coli* during high flows have been documented as potential pathways for contamination (Jamieson et al., 2005). This theory fits well to conditions present in Coon Creek, especially the headwaters. Hydrology monitoring provides evidence that high flows and elevated TSS are common throughout Coon Creek during storm events. It has been previously shown that run-off from soil may contribute up to 19% of *E. coli* detected in some waterways (Ishii et al., 2006). Adjacent to many headwater reaches are sod fields that present favorable conditions for sediment runoff immediately following harvest. It is likely that some proportion of the *E. coli* concentration sampled in CCWD is from natural strains further complicating management of *E. coli*.

Based on evidence above, it is likely CCWD has multiple sources contributing to overall concentrations; some natural and some un-natural. In addition to multiple sources of *E. coli*, interacting factors such as temperature, stream flow, nutrients, sediment, etc. can exacerbate the issue making its management very challenging. Microbial source tracking is helpful to isolate exact cause but can also confound things when seemingly inaccurate sources are identified as with the case of bovine detection on Springbrook Creek. Addressing the issue of elevated *E. coli* should be part of an effort to improve overall water quality by addressing inter-linked stressors such as nutrients, suspended sediments, and increased flow.

6.0 Stressor ID List

6.1 Preliminary List of Potential Stressors

The process of stressor identification is centered on US EPA's guidance document - **CADDIS**. CADDIS characterizes the potential relationships between stressors and candidate causes, and identifies the causes of greatest significance based on the strength of evidence from available data. Completion of the CADDIS process does not result in a finished Total Maximum Daily Load (TMDL). The product of CADDIS is a stressor(s) for which a TMDL load allocation can be developed. For example, the CADDIS process may help to isolate excess sediment as the cause of the biological impairment but further work must be done to develop the allowable loadings and allocations needed to correct the impairment.

The first step in the CADDIS process was the development of a preliminary list of stressors. The compilation of all potential stressors is a key step to the CADDIS process and sets the platform on which the stressor identification process builds. A preliminary stressor list is meant to be a comprehensive compilation of any potential stressors which may be leading to current impairments, in this case – fisheries, macroinvertebrates, and Escherichia coli impairment.

Developing a list of preliminary stressors requires the balancing of a tradeoff between too many or too few stressors. Too many preliminary stressors leads to a time consuming, expensive, and burdensome CADDIS process while a narrow list of stressors risks overlooking the true cause of impairment.

Table 10 is a list of preliminary stressors developed by CCWD, the Technical Advisory Committee (TAC), and Citizen Advisory Committee (CAC). The candidate causes are grouped by process: physical, chemical, and biological. This list establishes potential causes of biological impairment as well as the bacteria impairment.

Table 10. Preliminary stressor identification.

Physical	Chemical	Biological
Flow Regime	Chlorides	Vegetation
Channelization	Dissolved Oxygen	Algal growth
Ditch Maintenance	Nutrients	Invasive species
Impervious Cover	Nitrates	Predation
Suspended Solids	Toxics (Un-ionized Ammonia)	Self-reproduction
Sediment Load		
Precipitation		
Riparian Buffer		
Temperature		
Flood Control		
Natural Geology		
Illicit Discharges		
Stormwater Ponds		
Water Control Structures		
Exposed Soils		
Organics (Clippings, leaves)		
Wastewater		
Altered Habitat		
Pet/Animal waste		
Toxics		

6.2 Refinement of Stressor ID List

The stressor identification (SI) process recommends the elimination of very unlikely and/or low priority stressors to prevent the SI process from becoming too unwieldy. By using professional judgment, technical staff and stakeholders eliminated preliminary stressors unlikely contributing to CCWD impairments. Some specific stressors were also combined to create a more general stressor such as the combination of "TSS" and "Turbidity" into "Sediment". The end result of this task was a list of candidate causes that can be analyzed more efficiently using CADDIS methodology (Table 11).

Table 11. Condensed preliminary stressor list.

Candidate Causes		AFFECTED IMPAIRMENTS		
Candidate Causes	**Process**	**Invert**	**Fish**	**Bacteria**
Nitrates	Chemical	X	X	-
Altered Hydrology	Physical	X	X	-
Altered Habitat	Physical	X	X	-
Chlorides	Chemical	X	X	-
Toxics (Unionized Ammonia)	Chemical	X	X	-
Dissolved Oxygen	Physical	X	X	-
pH	Chemical	X	X	-
Wastewater	Chemical	-	-	X
Excess Sediment	Physical	X	X	X
Nutrients (TP)	Chemical	X	X	X
Temperature	Physical	X	X	-

7.0 Candidate Causes Ruled Out

This section examines the possible candidate causes of biological impairment for CCWD. All candidate causes from Table 11 (above) were either eliminated or strengthened based on the evidence in the following sections. Candidate stressors that were eliminated are discussed first, followed by those causes which could not be ruled out.

7.1 Eliminated Cause #1 – Nitrates

Nitrogen is a naturally occurring element and a critical nutrient in the life cycle of plants. However, elevated concentrations of nitrate, a byproduct produced by oxidation of nitrogen, poses significant health risks to a number of organisms, including fish, macroinvertebrates, and even humans (Camargo *et al*., 2005). Nitrate toxicity arises via conversion of red blood cells into a form incapable of uptaking oxygen molecules. Conversion of cells from a healthy state to oxygen incompetent red blood cells leads to a condition known as methemoglobinemia, which limits the amount of oxygen an organism can absorb (Grabda *et al*., 1974). The literature reports macroinvertebrates, especially certain species of caddisfly, were shown to have the lowest acute toxicity values for nitrate (Camargo and Ward, 1995). Overall, macroinvertebrates were most sensitive to nitrates, followed by amphibians, and eventually fish which showed the highest nitrate tolerance of aquatic organisms.

Currently, the state of Minnesota has a draft standard for nitrates in place but at the time of writing the standard has not been adopted. The proposed nitrate standard for Class 2B waters advises an acute standard (maximum value) of 41 mg/L for a 1-day duration and a chronic maximum standard of 4.9 mg/L for a 4-day duration (MPCA, 2010).

Nitrate sampling in CCWD is limited to Coon Creek and Springbrook Creek. However, sampling conducted on Coon Creek was below its confluence with Sand Creek therefore data from this location was used to provide a broad assessment of nitrates in Sand Creek as well. It was assumed that if nitrate levels in Sand Creek were of significant levels, Coon Creek monitoring would detect increased levels of nitrate even though dilution from one stream reach to another is likely. A total of 78 samples were collected: 10 from Coon Creek; and 68 from Springbrook Creek. Nitrate levels on Coon and Springbrook Creek were low relative to draft acute and chronic standards (Figure 11). Of all 78 samples, the highest nitrate concentration was 1.9 mg/L at site S004-437. This is a mere 5% of the acute standard and 38% of the chronic standard. It is unlikely that nitrates play a role in the biological impairments for CCWD based on concentrations well below draft state standards and therefore ruled out as a candidate cause.

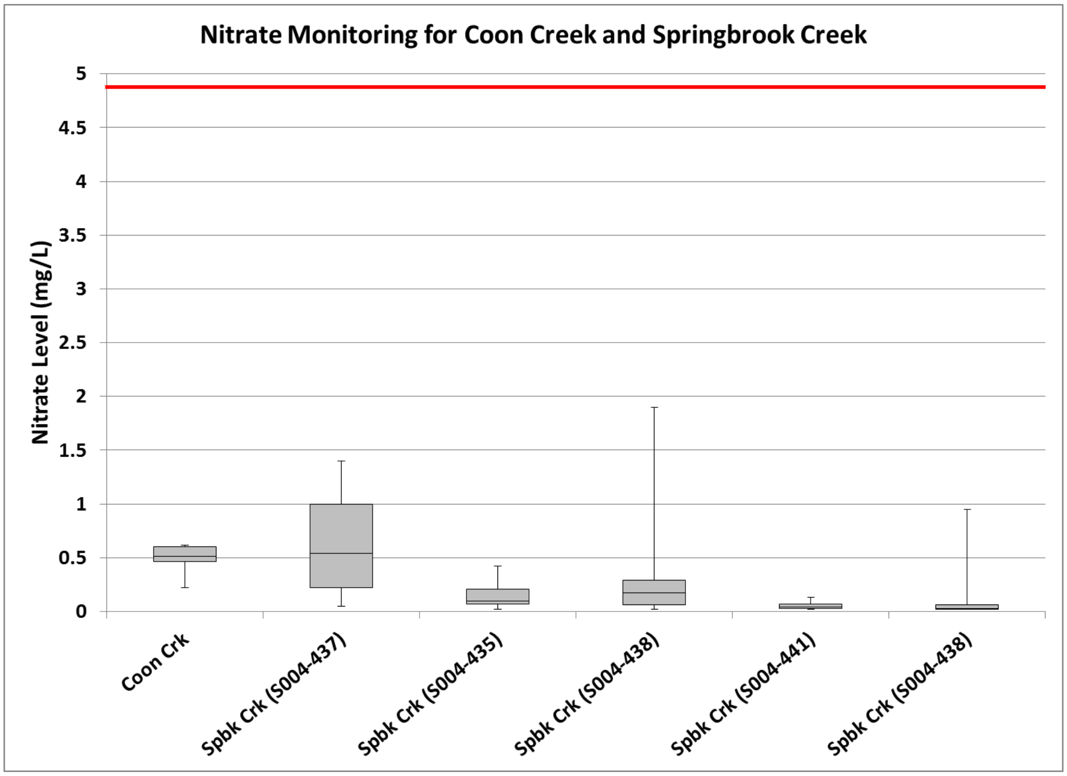

Figure 11. Nitrate levels on Coon Creek and Springbrook Creek. Box plots show median (middle line), 25th and 75th percentile (boxes), and max/min readings (lines). Acute draft standard is 41 mg/L and chronic standard is 4.9 mg/L (indicated by red line).

7.2 Eliminated Cause #2 - pH

As part of yearly water quality monitoring, pH has been routinely sampled across CCWD since 2005. The MPCA water quality standard states pH must stay inside the range of 6.5 to 9.0. A total of 441 samples have been taken across CCWD and all but one sample (pH 6.24) have been within acceptable ranges (Figure 12).

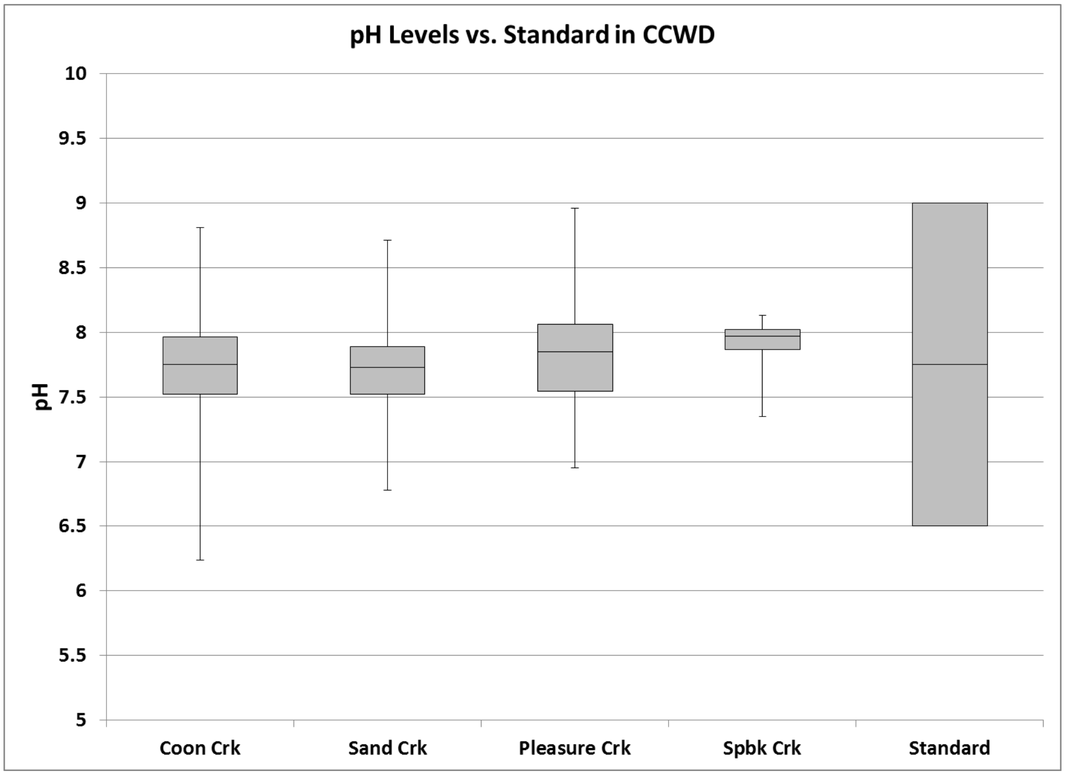

Figure 12. pH levels in impaired reaches for CCWD. Box plots show median (middle line), 25th and 75th percentile (boxes), and max/min readings (lines).

Measured pH levels are lower during storm events which is not surprising since dilution of surface water is expected from rainfall which has a lower pH (Table 12). An average of all sites results in a pH level toward the lower end of the acceptable range but still fully capable of supporting aquatic life. Due to the low frequency (0.002 %) of samples outside ranges necessary for sustaining aquatic life, pH was eliminated as a candidate cause.

Table 12. Summary of pH monitoring in CCWD.

Stream Reach	N	Storms	Baseflow	All	Samples <or>Standard
Coon Creek	224	7.52	7.90	7.75	1
Sand Creek	154	7.63	7.80	7.72	0
Springbrook Creek	8	7.76	8.0	7.88	0
Pleasure Creek	55	7.71	7.92	7.82	0

7.3 Eliminated Cause #3 - Temperature

Coon, Sand, Pleasure, and Springbrook Creeks are all classified as warm water systems. Fish and macroinvertebrate assemblages suited for warm water systems are generally more tolerant of temperature variation than cold-water species. A study of 31 common warm water piscivores showed maximum temperature tolerances ranging from 30.1° C to 36.0° C (Eaton *et al*., 1995). Figure 13 below displays temperature ranges recorded across CCWD streams in 2013; a typical range of temperatures found in warm water streams (Allan 1995). In mid-summer, when temperatures are at their highest, stream temperatures generally ranged from 20° - 25° C. As expected, the months of June and July provided the highest temperature readings with 16 samples topping 25° C. Sand Creek had the highest recorded temperature at 29° C but even this value is within the suitable range for most warm water species. Average temperature between streams varied little, showing only a modest variation of 4° C.

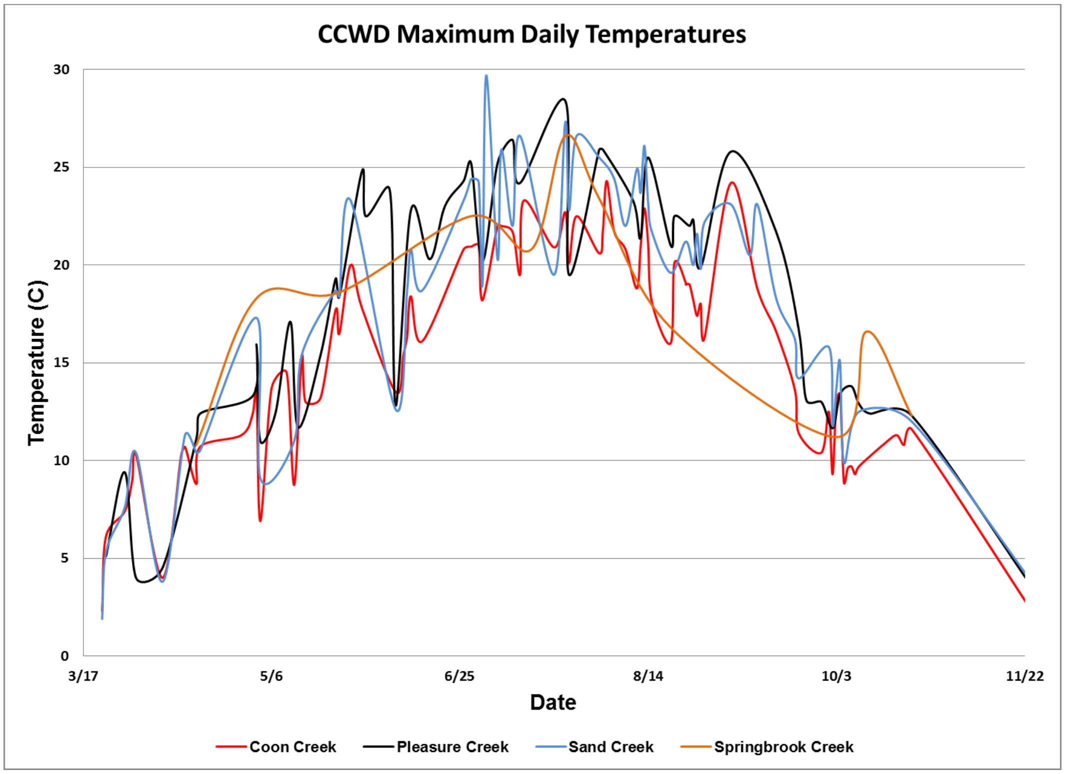

Figure 13. Annual stream temperature for impaired stream reaches in CCWD.

Temperature was eliminated as a candidate cause for biological impairment because maximum daily stream temperatures do not exceed the temperature ranges typical of warm water streams. A maximum reported temperature of 28.6° C recorded in Sand Creek is within temperature ranges suitable for warm water species typically found in Minnesota.

7.4 Eliminated Cause #4 – Un-Ionized Ammonia

Total ammonia is a commonly measured parameter to assess water quality. Total ammonia is the sum of ammonia in the un-ionized form (NH_3) and the ionized form (NH_4^+). Although ammonia does occur naturally through processes such as animal excretions and plant decomposition, excess ammonia can enter surface waters through unnatural pathways such as domestic, industrial, or agricultural pollution (primarily through fertilizers). Excess ammonia can become toxic to aquatic life if levels become too high, so control of unnatural sources is critical. The toxicity of ammonia is dependent on two factors; 1) pH, and 2) temperature. Increased pH and increased temperature favor the unionized form (NH_3) of ammonia which is far more toxic than (NH_4^+).

Increased (NH_3) can lead to fish kills, but more common problems associated with elevated concentrations are reduced fish growth, gill condition, organ weights, and hematocrit (Milne *et* *al.*, 2000). It has also been reported that un-ionized ammonia generated in sediment may be toxic to benthic or surface water biota (Lapota *et al.*, 2000).

The State of Minnesota has set un-ionized ammonia standards at 0.04 mg/L. Un-ionized ammonia can be calculated from the following equation; $f = 1/(10^{(pka-pH)} + 1) \times 100$ (Emerson *et al.,* 1975). In order to use this equation, pH, water temperature, and total ammonia (NH_3+NH_4^+) must all be recorded simultaneously. A total of 21 CCWD samples were sufficient to calculate un-ionized ammonia concentrations. These samples were collected from 10 different sites accounting for three of four biologically impaired reaches; Coon Creek, Pleasure Creek, and Springbrook Creek. County Ditch 58, a non-impaired reach, was also sampled.

Coon Creek had the highest sampling frequency accounting for 17 of the 21 total samples. NH_3 concentrations ranged from 0.000 mg/L up to 0.006 mg/L, which is well below the standard maximum concentration of 0.04 mg/L (Figure 14). The same pattern was true for all other sampled reaches as well. Pleasure Creek NH_3 concentrations were 0.003 mg/L at the outfall to the Mississippi River, and Springbrook Creek showed concentrations of 0.001 mg/L at both its outfall to the Mississippi River and an upstream sampling site near Hwy 10.

County Ditch 58, a stream reach showing full support of aquatic life, had an NH_3 concentration of 0.002 mg/L. Comparison of this value to stream reaches in CCWD which are in non-support of aquatic life, shows a similar NH_3 concentration. It would be expected that if un-ionized ammonia was the root cause of biological impairment, County Ditch 58 would also have an unhealthy aquatic community since NH_3 concentrations are similar to non-supporting reaches. NH_3 levels are far lower than state standards and fully supporting stream reaches in CCWD present similar levels of NH_3 as non-supporting reaches. Based on this evidence, un-ionized ammonia was ruled out as a candidate stressor.

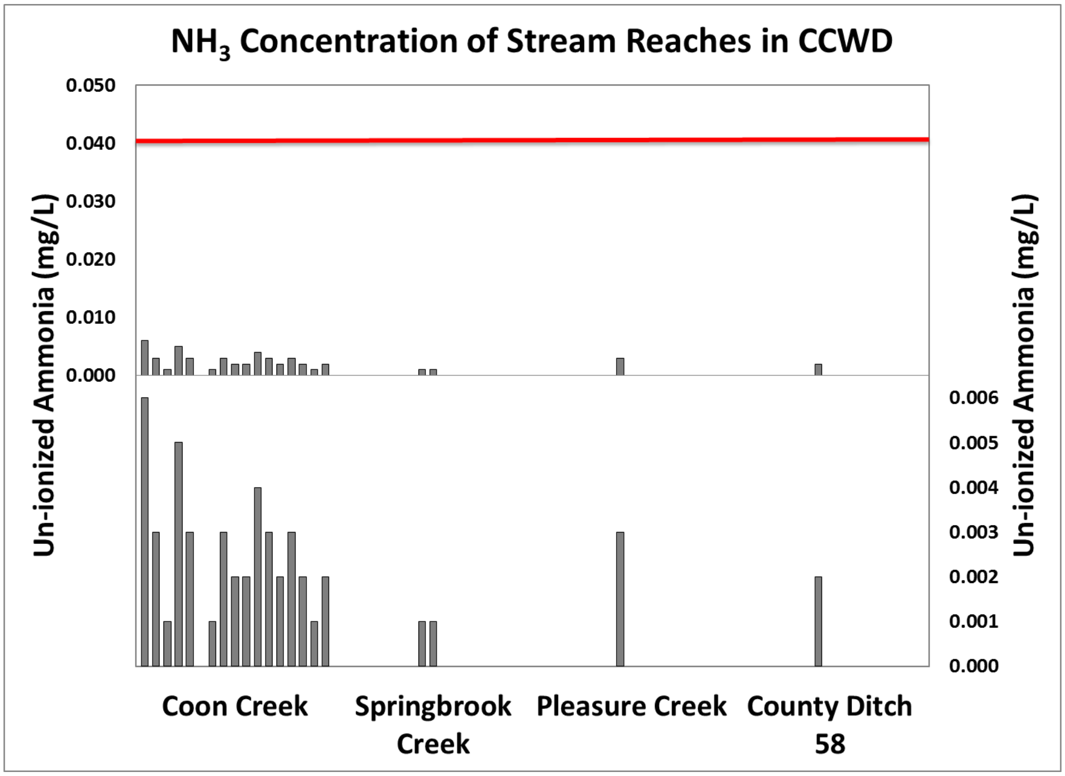

Figure 14. Un-ionized ammonia concentration in CCWD. Top panel shows concentrations in relation to standard (red line). Bottom panel shows same readings on smaller scale for comparison between reaches.

8.0 Candidate Causes Not Ruled Out

8.1 Candidate Cause #1 – Dissolved Oxygen

Living aquatic organisms require oxygen to sustain life. For aquatic life, oxygen is present through molecules of gas dissolved in the water. A measurement of Dissolved Oxygen (DO) levels provides insight into the potential for a water body to support aquatic life. Low DO or high daily fluctuations of DO can have negative effects on many species of fish and macroinvertebrates (Davis 1975; Nebeker *et al.* 1991).

The MN state standard for DO concentration has recently been revised and new stipulations have been drafted. The excerpt below is from the Guidance Manual for Assessing the Quality of Minnesota Surface Waters (MPCA, 2009):

> *"Under revised assessment criteria beginning with the 2010 assessment cycle, the DO standard must be met at least 90 percent of the time during both the 5-month period of May through September and the 7-month period of October through April. Accordingly, no more than 10 percent of DO measurements can violate the standard in either of the two periods.*
>
> *Further, measurements taken after 9:00 in the morning during the 5-month period of May through September are no longer considered to represent daily minimums, and thus measurements of >5 DO later in the day are no longer considered to be indications that a stream is meeting the standard.*
>
> *A stream is considered impaired if, 1) more than 10 percent of the "suitable" (taken before 9:00 AM) May through September measurements, or more than 10 percent of the total May through September measurements, or more than 10 percent of the October through April measurements violate the standard, and 2) there are at least three violations."*

Small fluctuations of DO are common and occur on a daily basis due to the demands and availability of DO. The uptake of DO from the water column occurs through various processes such as respiration, decomposition, etc. DO availability is at its highest late in the day due to the release of oxygen into the water column throughout the day via photosynthesis. After daylight hours, photosynthesis is halted due to the lack of light available to plants. During this period of low light, oxygen demand from aquatic organisms still exists, thus causing a decline in overall DO levels. This results in DO levels being lowest during early morning hours and the reasoning for requiring DO samples to be taken before 9:00 AM. This rise and fall of DO levels is referred to as the "diurnal cycle". Diurnal fluctuations of more than 3.5 mg/L per day can present problems to many aquatic organisms (MPCA, 2013).

A drop in DO levels can have a number of negative effects on aquatic life. Low DO levels often result in a loss of species richness and diversity (Carpenter *et al.* 1998; Correll 1998). In addition to fewer species, low DO can shift the community structure toward more tolerant species. For example, most species of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) will decrease in numbers or become completely absent in sites experiencing low DO (Marcy, 2007). These species will be replaced by increases in Diptera (flies), Hemiptera (true bugs), and beetles (Coleoptera) including a number of less desirable forms of aquatic life which can include Oligochaeta (aquatic worms), Chironomidae (midges), Culicidae (mosquitoes), and Psychodidae (moth flies). These shifts can result in losses of sensitive, carnivorous, and insectivorous species and increase in tolerant and generalist species (Miltner and Tankin, 1998). Many species of fish simply avoid habitats where dissolved oxygen concentrations are below 5 mg/L (Raleigh *et al*., 1986).

Sources and Pathways of Low Dissolved Oxygen

The DO regime of a stream is driven by a combination of natural and anthropogenic factors. The natural setting and background characteristics of a watershed can greatly influence the dissolved oxygen demand of a water body (i.e. soils, hydrology, climate, biological productivity). Agricultural and urban land-uses, impoundments (dams), and point-source discharges are just a few examples of anthropogenic (human) factors that can alter DO concentrations in a given water body. A conceptual model for low dissolved oxygen as a candidate cause is shown in Appendix C.

Water Quality Data – Dissolved Oxygen

Sand Creek and Springbrook Creek are meeting the DO standard on more than 90% of samples providing evidence that low DO is not the primary factor leading to biological impairment along these reaches (Table 13). The biological impairment on Pleasure Creek is also not likely affected by low DO despite occasional DO exceedances on Pleasure Creek. Analysis of pre-9 AM samples for Pleasure Creek indicated 4 samples were below the required 5 mg/L standard however, these samples were taken at the outlet of a large network of stormwater ponds located in the headwaters of the creek. DO concentrations recovered at the next downstream monitoring site and continued to increase before reaching the stream outfall where biological sampling occurred. The lack of spatial/temporal co-occurrence refutes dissolved oxygen as a candidate cause of impairment for Pleasure Creek. The same cannot be said for Coon Creek, but only in the headwaters of the system. Figure 15 shows a series of synoptic longitudinal DO surveys conducted throughout the length of Coon Creek in 2013. A synoptic monitoring approach attempts to gather data across a large spatial scale and minimal temporal scale. In terms of DO, the objective was to sample a large number of sites from upstream to downstream under comparable ambient conditions. Longitudinal sampling was conducted on eight separate days across seven sites on Coon Creek. Location descriptions for station identification numbers can be found in Table 14. Monitoring data suggests that the headwaters of Coon Creek often experiences DO levels below the 5 mg/L minimum standard.

Table 13. DO sampling data for impaired stream reaches in CCWD.

Stream Reach	Time Period	N	N<5mg/L	%< 5mg/L	N pre 9AM	N<5mg/L	%< 5mg/L
Coon Creek	May -Sept	217	25	11.5%	16	7	44%
	Oct - April	66	0	0.0%	2	0	0.0%
Sand Creek	May -Sept	147	5	3.4%	3	0	0.0%
	Oct - April	38	1	2.6%	3	0	0.0%
Pleasure Creek	May – Sept	49	4	8.2%	11	4	36%
	Oct - April	16	0	0.0%	2	0	0.0%
Springbrook Creek	May – Sept	28	1	0.4%	0	0	n/a
	Oct - April	7	0	0.0%	0	0	n/a

Table 14. Location descriptions for station ID numbers. Stations are listed on upstream to downstream orientation.

Station ID	Location Description
S007-539	Coon Creek at Lexington Avenue, Ham Lake
S007-057	Coon Creek at Naples St., Ham Lake
S004-620	Coon Creek downstream of CD 58, north from 142nd Ave. NW, Andover
S007-540	Coon Creek at Prairie Rd., Andover
S005-257	Coon Creek at 131st Ave. NW., Coon Rapids
S004-171	Coon Creek downstream of Hanson Blvd., Coon Rapids
S003-993	Coon Creek at Vale St., Coon Rapids

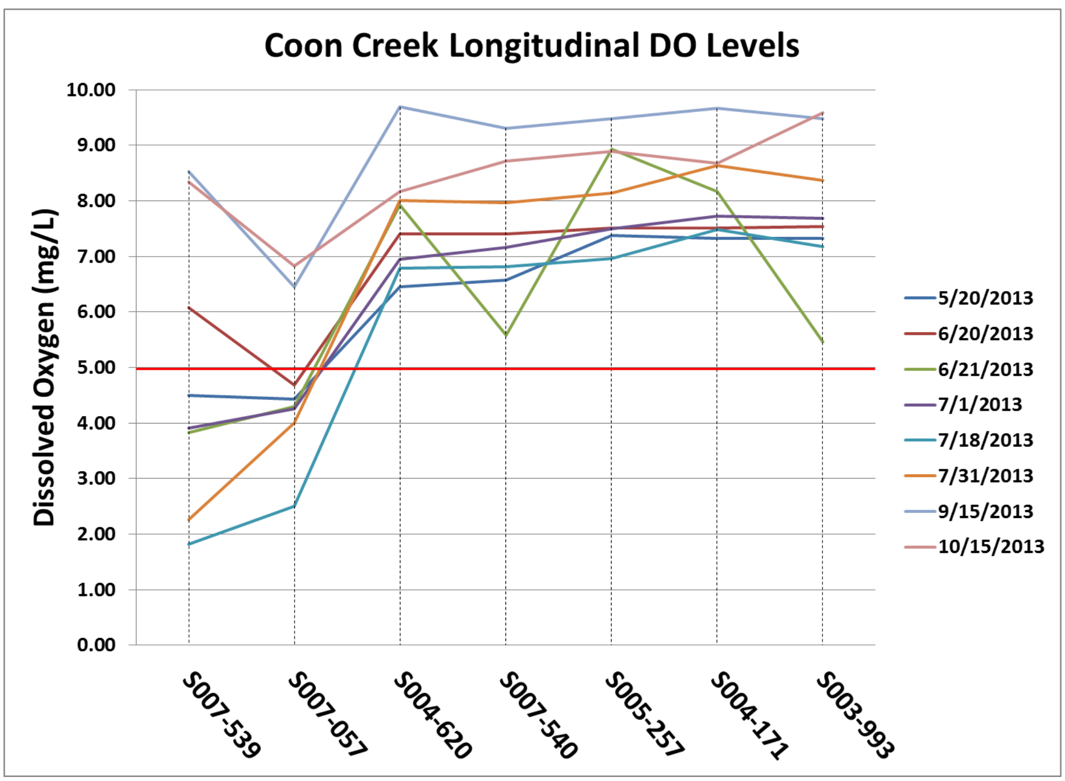

Figure 15. Longitudinal display of DO levels from headwaters to outfall. Red line indicates 5 mg/L minimum standard.

The low DO levels observed in Coon Creek headwaters are of particular interest due to headwater connections to the Carlos Avery WMA. This WMA contains approximately 15,000 acres of naturally occurring wetland. Naturally occurring wetlands are known to possess low DO concentrations which can be detected in downstream monitoring locations. Monitoring site S007-539 is located on County Ditch 44 and directly connected to the Carlos Avery WMA. Site S007-057 is also directly connected and in close proximity to upstream site S007-0539. These two sites closest to Carlos Avery WMA account for all of Coon Creek's DO violations. DO concentrations increase away from this large wetland complex establishing an effect gradient for spatially linked sites.

Causal Analysis – Biological Response to Low Dissolved Oxygen

Fish sampling was analyzed from stations 10UM020 and 10UM021. Both of these stations are in Coon Creek headwaters in close proximity to where low DO data was recorded. The four most common fish species sampled at these stations were Fathead Minnow (*Pimephales promelas*), Central Mudminnow (*Umbra limi*), Northern Redbelly Dace (*Phoxinus eos*), and Brook Stickleback (*Culaea inconstans*). Complete monitoring data can be found in Appendix A. These four species have been well documented to be highly tolerant of low DO and often found where other fish cannot survive (Kramer, 1987; Mathews and Styron, 1980; Nelson and Paetz, 1992). These species have a preference for wetlands, small ponds, bogs, and small streams which exhibit low flow and adequate vegetation (Becker, 1983).

In addition to highly tolerant species, other DO sensitive metrics such as number of serial spawning fish and number of sensitive species follow predicted responses to low DO (Figure 16). The number of serial spawning fish in Coon Creek Headwaters was well above non impaired UMRB sites while sensitive species were few, as expected. For comparison, Sand Creek displayed a much lower number of serial spawning fish as expected since DO profiles in Sand Creek are sufficient.

Fish abundance analysis further strengthens the case for DO as a candidate cause. Site 10UM020 had only 112 individuals sampled, roughly 75% fewer fish than the median number of individuals for non-impaired UMRB sites. Zero of these 112 individuals were considered to be intolerant or long lived species. Although fish abundance could be responsive to a variety of stressors, it is likely that the sustained low DO conditions observed in headwater reaches contributes to the lack of intolerant and long lived species. Fish abundance in Coon Creek increases outside headwater reaches as does the DO profile. This spatial/temporal co-occurrence provides strong evidence DO is limiting fish assemblages in headwater reaches of Coon Creek.

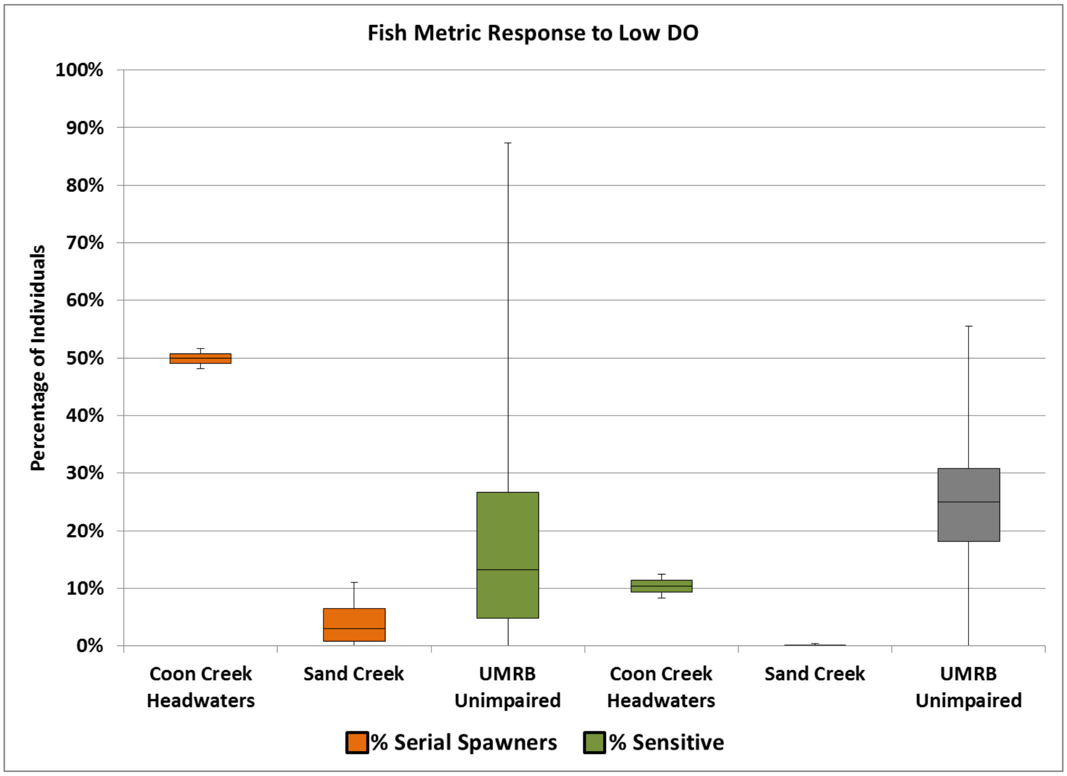

Figure 16. % serial spawning fish and % sensitive individuals compared to non-impaired UMRB sites.

Macroinvertebrate populations are also affected by low DO. Figure 17 shows the percentage of individuals belonging to EPT taxa from impaired CCWD reaches. The percentage of EPT individuals is a good indicator of DO levels since EPT taxa are highly sensitive to low DO. The percentage of EPT individuals in Coon Creek headwaters is low and aligned with impaired sites in the UMRB. The percentage of EPT individuals increases away from the headwaters of Coon Creek as does DO concentration.

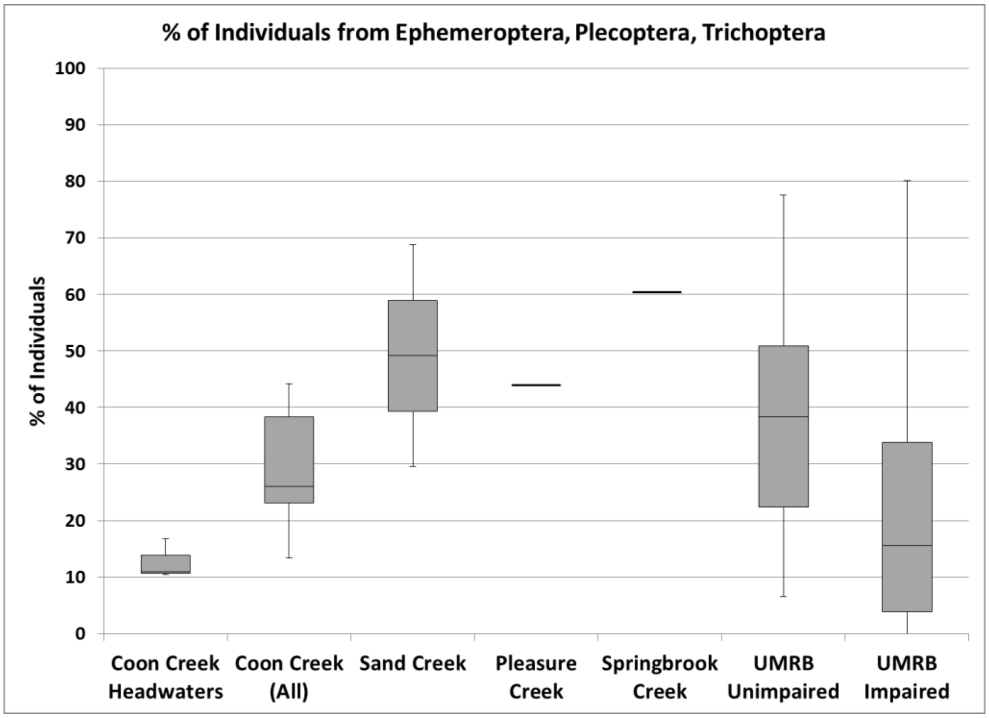

Figure 17. Percentage of EPT individuals for CCWD. Box plots show median (middle line), 25th and 75th percentile (boxes), and max/min readings (lines).

Strength of Evidence Summary for Dissolved Oxygen

Analysis of DO and biological data suggest that headwaters of Coon Creek do not possess the DO profile necessary to support healthy fish and macroinvertebrate communities. Natural soil characteristics along with the geographic setting of the creek are two factors limiting DO concentrations. Coon Creek headwaters flow through hemist soils which are rich in organic material. Over time, the organic material in these soils naturally decomposes and in the process, consumes oxygen; a concept known as sediment oxygen demand. Increased sediment oxygen demand depletes the amount of oxygen available to fish and macroinvertebrates, especially during early morning periods. These same organic soils can also release phosphorus into the water column only exacerbating the low DO regime due to increased algal productivity and vegetation growth. TP introduction to surface waters is accelerated through soil erosion. Sod farming is common to the area and can result in large tracts of exposed land following sod harvest. If storm events occur during this time, an opportunity exists for soil erosion to occur. Sediment concentrations and phosphorus both spike during storm events exhibiting the inter-relatedness of these parameters.

Increased sediment oxygen demand is a common characteristic of large wetland complexes due to the reasons highlighted above. Monitoring stations in Coon Creek headwaters are located immediately downstream of the Carlos Avery WMA, a 15,000 acre wetland. It is plausible low DO concentrations typical for this wetland, were detected during supplementary data collection efforts. Strength of evidence for DO is shown below (Table **15**). Information on strength of evidence scoring is provided in Appendix D.

Table 15. Weight of evidence table for Dissolved Oxygen.

Strength of Evidence Table – Dissolved Oxygen				
	Scores for Impaired Reaches			
Types of Evidence	Coon Creek	Sand Creek	Pleasure Creek	Springbrook Creek
Spatial/Temporal co-occurrence	+	+	+	+
Evidence of exposure, biological mechanism	++	0	0	0
Causal pathway	++	+	+	+
Field evidence of stress response	++	0	0	0
Field experiments/manipulation of exposure	++	+	+	+
Laboratory analysis of site media	NE	NE	NE	NE
Temporal sequence	0	0	0	0
Verified or tested predictions	++	+	+	+
Symptoms	++	+	+	+
Mechanistically plausible cause	++	0	0	0
Stressor-response in other field studies	++	0	0	0
Stressor-response in other lab studies	++	0	0	0
Stressor-response in ecological models	NE	NE	NE	NE
Manipulation experiments at other sites	NE	NE	NE	NE
Analogous stressors	NE	NE	NE	NE
Consistency of evidence	++	+	+	+
Explanatory power of evidence	++	0	0	0

8.2 Candidate Cause #2 –Excess Sediment

In a 2003 EPA study, increases in suspended sediment and turbidity within aquatic ecosystems were identified as one of the greatest causes of water quality and biological impairment in the United States (USEPA, 2003). Sediment transport is a natural function of a healthy stream but an imbalance in this function can have detrimental effects on aquatic life. Excess sediment can affect aquatic life via two major pathways; 1) direct, physical effects, such as gill abrasion, organism drift, burial of fish eggs and macroinvertebrates, and 2) indirect effects like reduction in visibility, reduced algal/macrophyte growth, and increased nutrient transport. (USEPA, 1977; USEPA, 2010).

Suspended sediment consists of fine sediment particles that are suspended in the water column, much like the name suggests. Suspension of fines is a function of multiple factors (i.e. particle size, stream gradient, sinuosity, stream flow, etc.). Suspended sediment can deposit (becoming bedded sediment) when any of the aforementioned factors change in such a way that prevents continued suspension. Typical scenarios for deposition of sediment are decreased stream flow or decreased stream gradient. The distinction between TSS and bedded sediment is often a function of particle size. TSS is generally comprised of finer sediments than bedded sediment however this can be affected by higher flows which have the ability to "lift up" larger particles than baseflow conditions.

In 2010, MPCA released draft TSS standards for public comment (Markus, 2010). The new TSS criteria are separated by geographic region and stream characteristics (e.g. cold water, warm water). CCWD falls under the "Central Region" and the corresponding draft TSS standard for this region has been set at 30 mg/L. This concentration is not to be exceeded in more than 10 percent of samples within a 10-year data window. Deposited and bedded sediment does not have a state standard at the time of writing but is often positively correlated with elevated TSS concentrations.

Sources and Pathways of Excess Sediment

The conceptual model for sediment as a candidate causes for impairment is shown in Appendix C. There are many potential sources and causal pathways for excess sediment in the CCWD, mostly associated with land cover changes and stream alteration. Agricultural uses and construction activity can leave exposed soils which are vulnerable to sediment loss, especially during intense rainfall events. Excess sediment can also arise from a variety of other sources such as channelization, inadequate buffer strips, and increases in impervious surfaces due to urbanization. These factors, individually or in combination, are likely increasing TSS concentrations in CCWD.

Water Quality Data – Excess Sediment

TSS levels exceeding the state standard have been consistently observed in CCWD. Stream outfalls, or discharges, are considered a strong predictor of upstream conditions, and also the reason biomonitoring is usually conducted near these locations. TSS concentrations are higher at outfalls compared to upstream monitoring sites for all CCWD impaired reaches. Outfall TSS concentrations greater than 10 times the standard have occurred since 2005. Figure 18 shows individual TSS readings for each stream reach. Coon Creek has the highest frequency of exceedance (30.6%) followed by Pleasure Creek (20.7%), Sand Creek (12.5%), and Springbrook Creek (6.7%). All streams have more than 10% of samples exceeding 30 mg/L except Springbrook Creek. Of the samples exceeding the 30 mg/L standard, 94% of them occur during storm flows. High outfall TSS concentrations indicate degrading conditions when moving upstream to downstream. Each impaired stream reach has a biomonitoring site located at its outfall which provides an accurate picture of water quality conditions in relation to biotic impact.

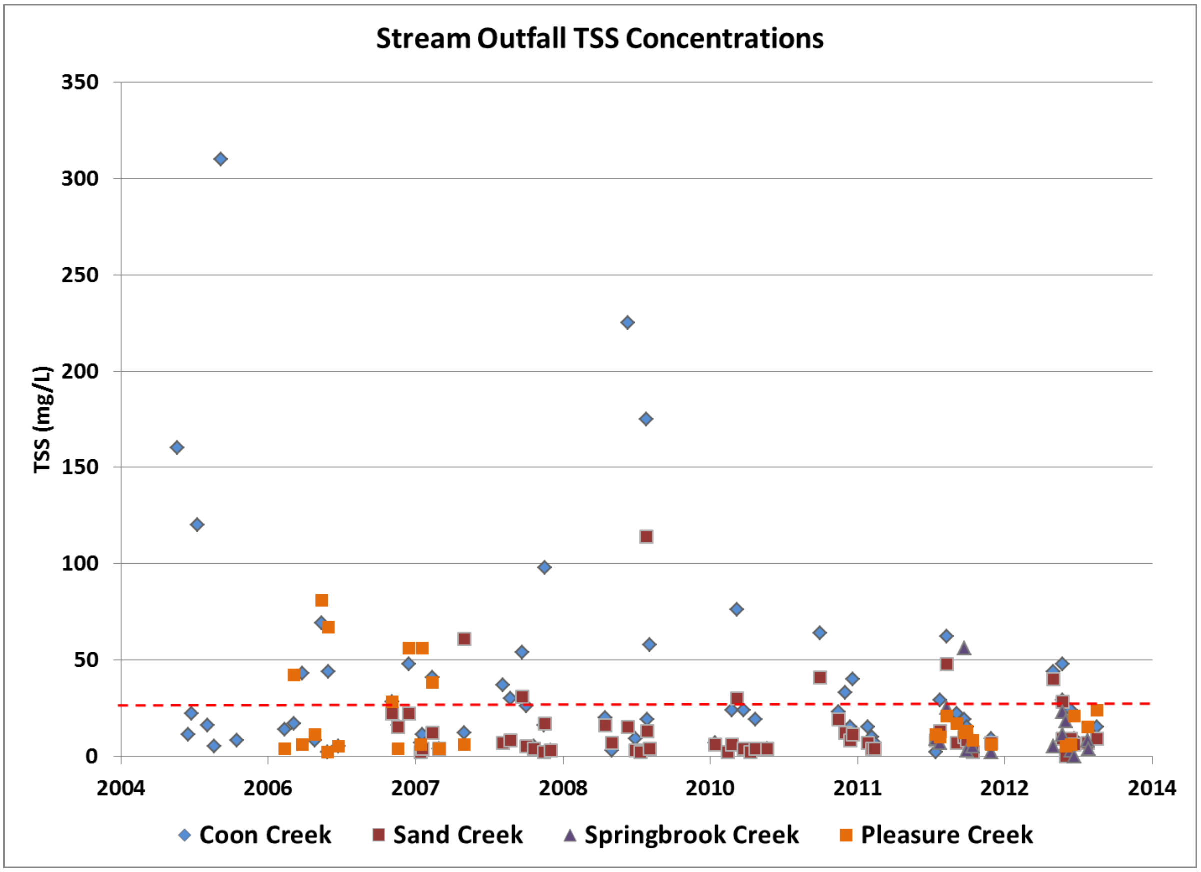

Figure 18. TSS sampling data at outfalls of impaired stream reaches in CCWD. Red line represents draft 30 mg/L standard.

Causal Analysis – Biological Response to Excess Sediment

Based on overall IBI scores alone, it is difficult to isolate the potential effects of elevated TSS from other potential causes. Analysis of TSS sensitive species or biological metrics that are sensitive to elevated TSS concentrations can provide insight into the role excess sediment is playing in biotic impairment. Table 16 is a compilation of observed biological metrics and predicted responses to suspended sediment for macroinvertebrates and fish (Markus, 2010).

Table 16. Biologic metrics sensitive to TSS.

Biota Impacted	Effect
macroinvertebrates	↓ filter feeders (esp. Hydropsychidae) (x)
macroinvertebrates	↓ species diversity (x)
macroinvertebrates	↓ grazer/scrapers taxa
macroinvertebrates	↑ chironomidae density
macroinvertebrates	↓ Ephemeroptera, Trichcoptera
Fish	↓ abundance / feeding efficiency / growth smallmouth bass

Fish assemblages throughout Coon and Sand Creek indicate degraded conditions. The percentage of intolerant individuals is a good overall indicator of stream degradation. Intolerant species are sensitive to environmental degradation and often the first species to disappear following disturbance. Intolerant fish are completely absent from Sand Creek monitoring and nearly non-existent in Coon Creek with less than 1% of individuals considered "intolerant".

TSS often affects fish species reliant on visual cues for feeding due to decreased visibility in turbid waters (Vinyard and O'brien, 1976). Common taxonomic families reliant on visual feeding cues are Salmonidae (salmon and trout), Cyprinidae (minnows), and Centrarchidae (sunfish). On the contrary, species such as suckers and catfish are relatively unaffected by increased TSS because they rely heavily on olfactory cues for feeding rather than visual cues. Metric scores are shown below for reaches with pending fish impairments inside CCWD (Figure 19, Figure 20). These impaired reaches are classified differently for fish assemblages thus using slightly different metrics for assessment. Northern Headwaters (class 6) and Low Gradient (class 7) classifications each use the metric "Minnows-TolPct". This metric calculates the percentage of fish sampled that are cyprinids (excluding tolerants); a species found to be reliant on visual feeding cues in an aforementioned study. Both reaches are scoring poorly in this metric, indicative of a fish community stressed by elevated TSS concentrations. This supports the theory that sediment is impacting fish assemblages.

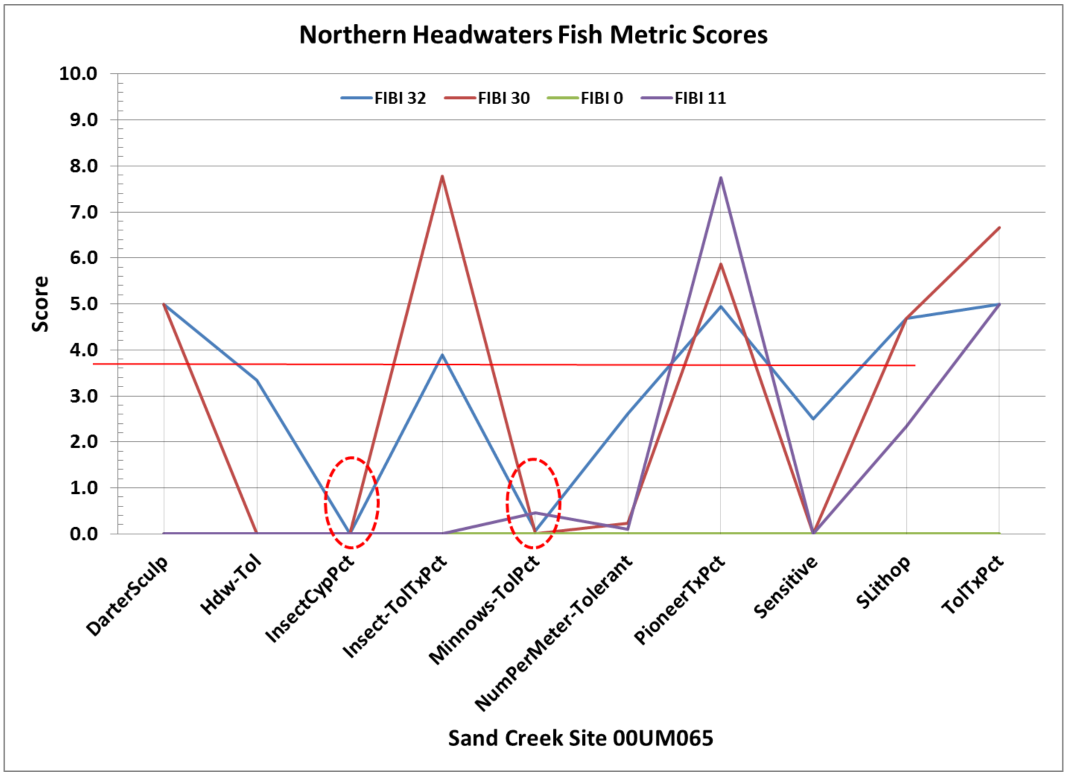

Figure 19. F-IBI metric scores. Horizontal red line is average score needed to meet IBI threshold. Red dashed circles highlight metrics assessing cyprinids.

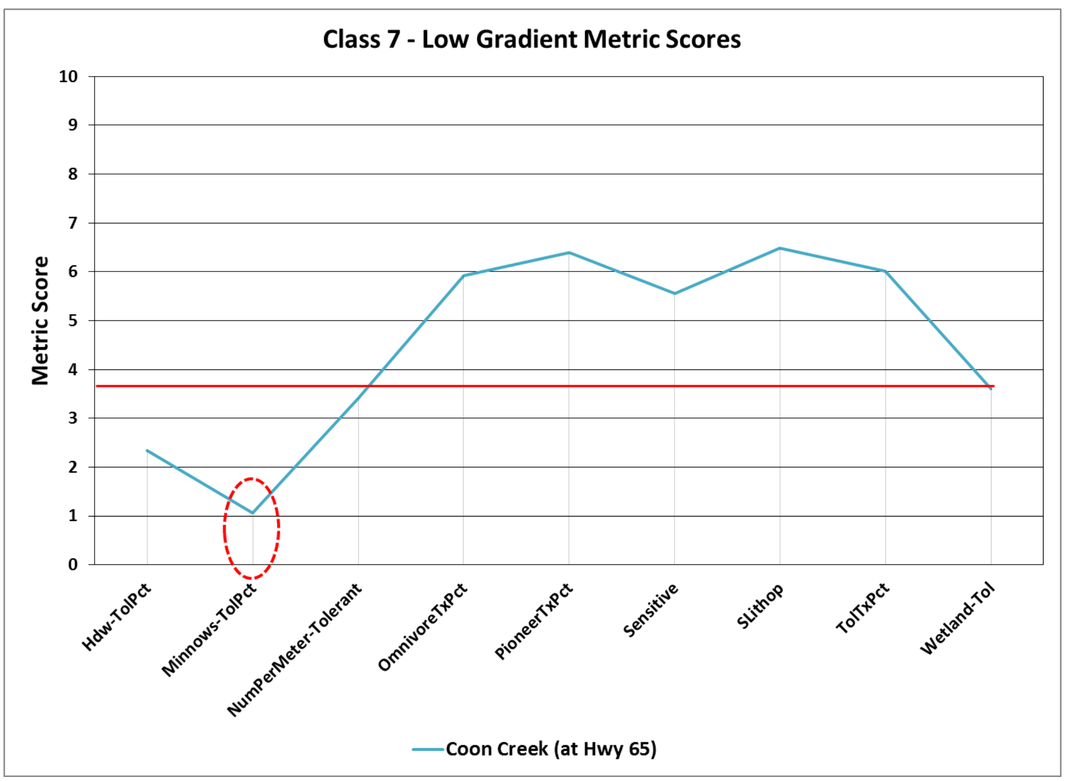

Figure 20. F-IBI metric scores. Horizontal red line is average score needed to meet IBI threshold. Red dashed circle highlights metric assessing cyprinids.

An examination of lower Coon Creek (Sites 10UM017, 00UM064, 10UM003) further substantiates TSS as a candidate cause of biological impairment. Raw fish data (Figure 21) shows very few numbers of cyprinids and centrarchids (visual feeders) relative to sucker species (olfactory feeders). The disparity between these feeding strategies suggests that visual feeding species may not be as efficient as species feeding via olfactory cues at this site. This community shift is likely a biological response to the frequency of high suspended sediment concentrations as this site has the highest TSS concentrations in all of CCWD.

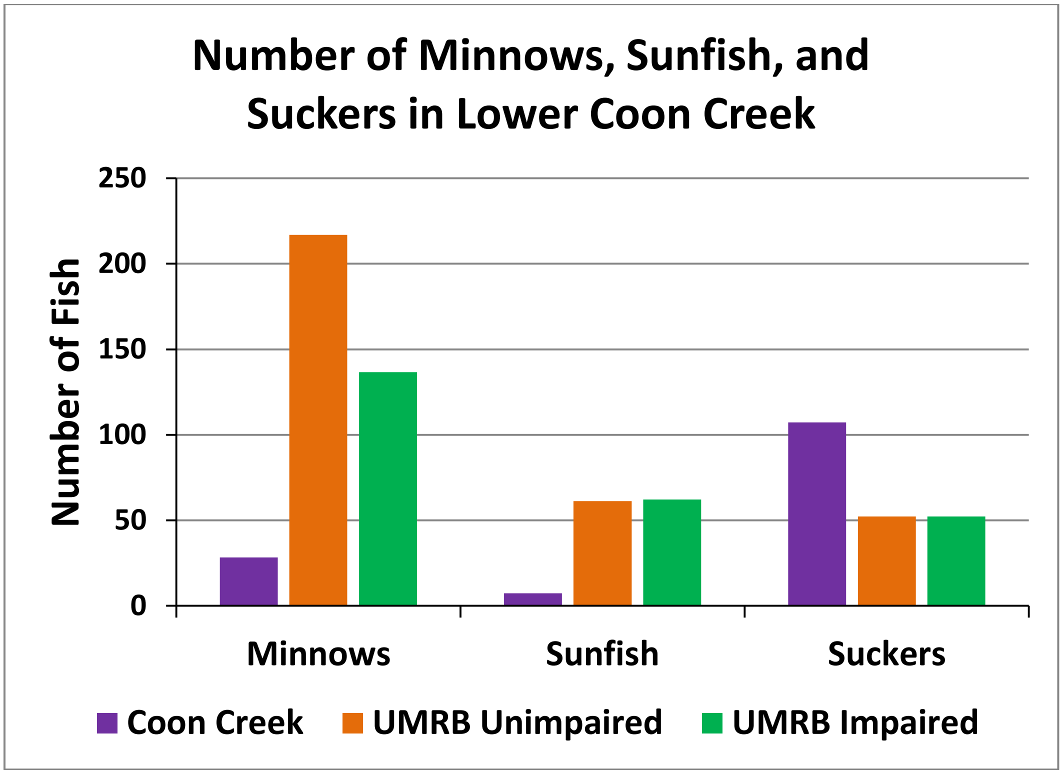

Figure 21. Numbers of minnows, sunfish, and suckers in Lower Coon Creek. All other UMRB sites also displayed for comparative purposes.

Analysis of macroinvertebrate functional feeding groups also supports the theory of excess sediment as a candidate cause. Macroinvertebrate filter feeding is typically done in one of two ways: 1) by using physical adaptations such as antennae, or 2) by constructing a net which filters material from the water and then gathering the filtered material from the net (Chirhart, 2003). When sediment concentrations reach problematic levels, filtering the water column no longer becomes an efficient feeding strategy because nets are often clogged or destroyed by sediment. Adaptations such as antennae can also become overloaded with inedible debris. When excess sediment is problematic, there is often a shift in community structure toward species that physically gather food rather than filter it. Figure 22 below shows the abundance of these two functional feeding groups at biologic monitoring stations throughout CCWD. All Coon Creek and Sand Creek monitoring sites have a higher percentage of gatherers than filterers as expected with excess sediment. Pleasure and Springbrook Creek have a more evenly aligned ratio of filterers and gatherers, with a slight advantage actually going toward filterers. The more evenly aligned ratio of filterers and gatherers is expected in Springbrook Creek since

TSS concentrations are acceptable in this reach. However, the ratio does not follow the expected response for Pleasure Creek; a stream exhibiting a 20.7% TSS exceedance rate. It is possible the unexpected representation of filterers in Pleasure Creek is the result of shorter exposure times to elevated TSS concentrations. Increased urbanization in this subwatershed reduces the time of concentrations (TOC) relative to Coon Creek and Sand Creek. A shorter TOC results in a short burst of TSS rather than the more prolonged release observed in Coon and Sand Creeks.

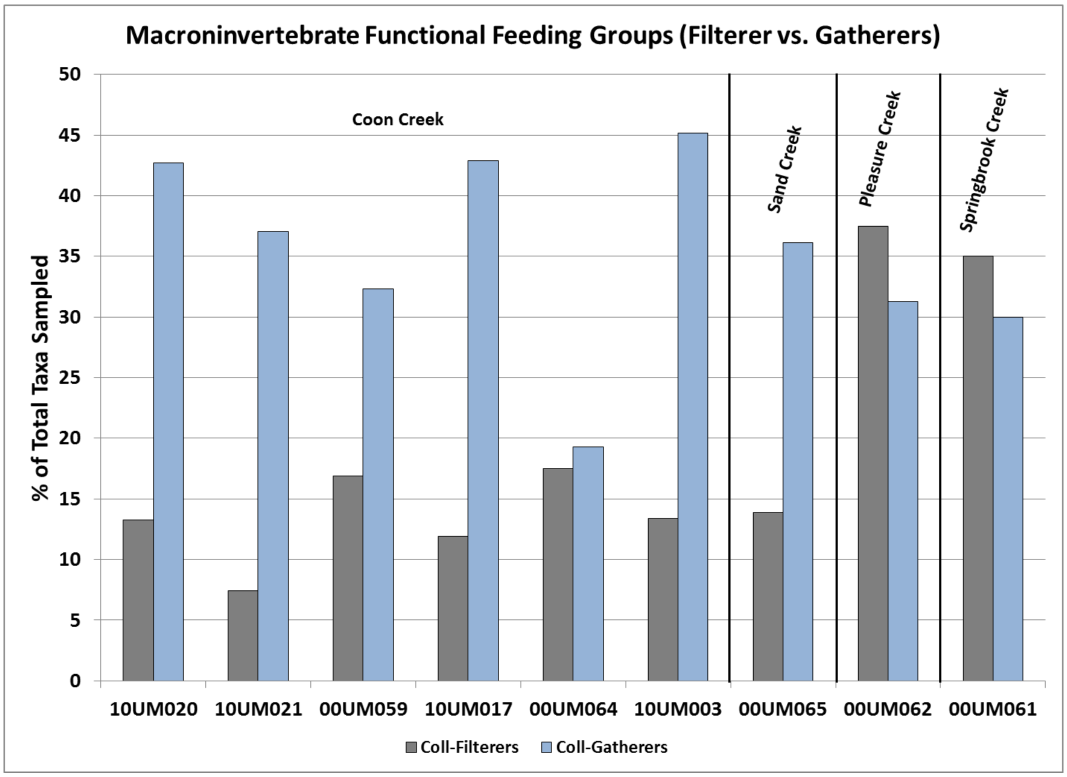

Figure 22. Comparison of functional feeding groups; Collector-Filterer and Collector-Gatherer.

Species with gills (i.e., mayflies) are documented to be particularly sensitive to suspended sediment, exhibiting a negative relationship (USEPA, 2012). The percentage of Ephemeroptera (i.e., mayflies) across impaired reaches of CCWD follows the predicted response to excess suspended sediment concentrations (Figure 23). Only one site, Springbrook Creek, had a percentage of Ephemeroptera individuals comparable to non-impaired UMRB sites. The increased representation of Ephemeroptera individuals in this reach is plausible since Springbrook had the lowest frequency of TSS exceedance as well as the lowest mean TSS concentration. This evidence strengthens the case for TSS as a candidate cause for impairment across Coon, Sand, and Pleasure Creek.

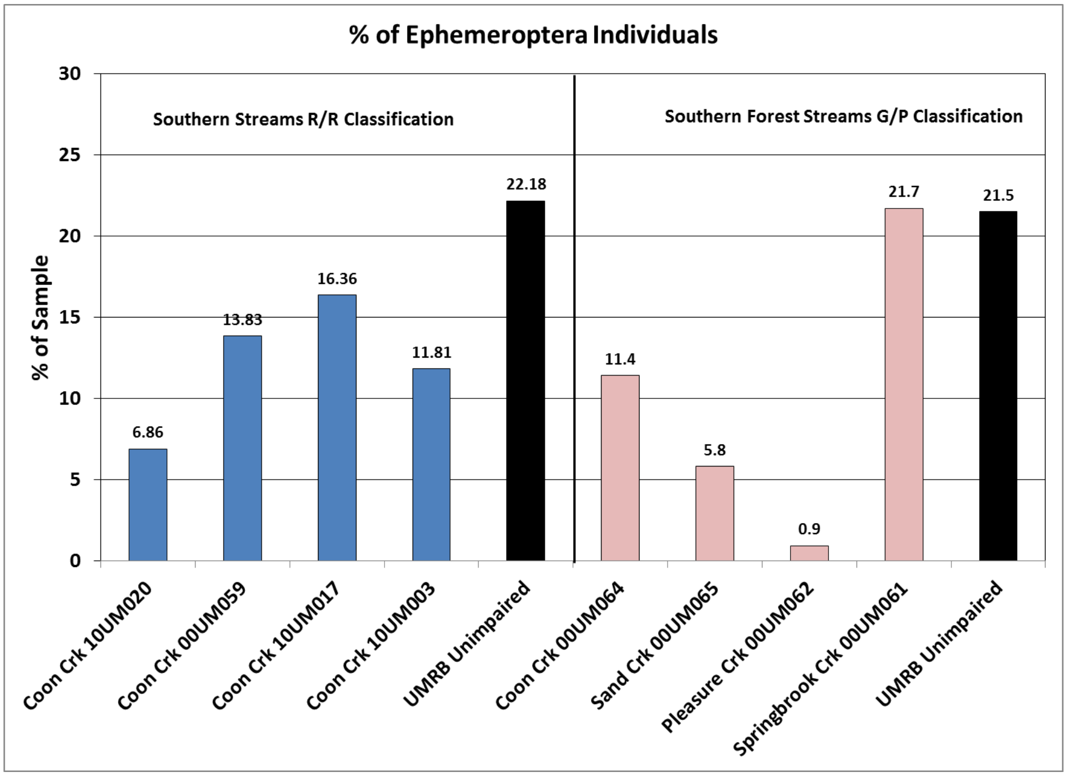

Figure 23. % Individuals belonging to Family Ephemeroptera.

The final macroinvertebrate metric analyzed was "ScraperPct". Scraper macroinvertebrates are species that feed on algae and other microorganisms attached to fixed substrates such as rocks and wood. Excess sedimentation can smother this food source or abrade it from the substrates where it grows, resulting in a decline of scraper macroinvertebrates. Figure 24 shows the percentage of scraper individuals compared to the mean values for streams in the UMRB with healthy macroinvertebrate assemblages. All impaired stream reaches in CCWD score consistently lower than unimpaired UMRB sites. The relatively low representation of scraper macroinvertebrates aligns with the predicted response to excess sediment.

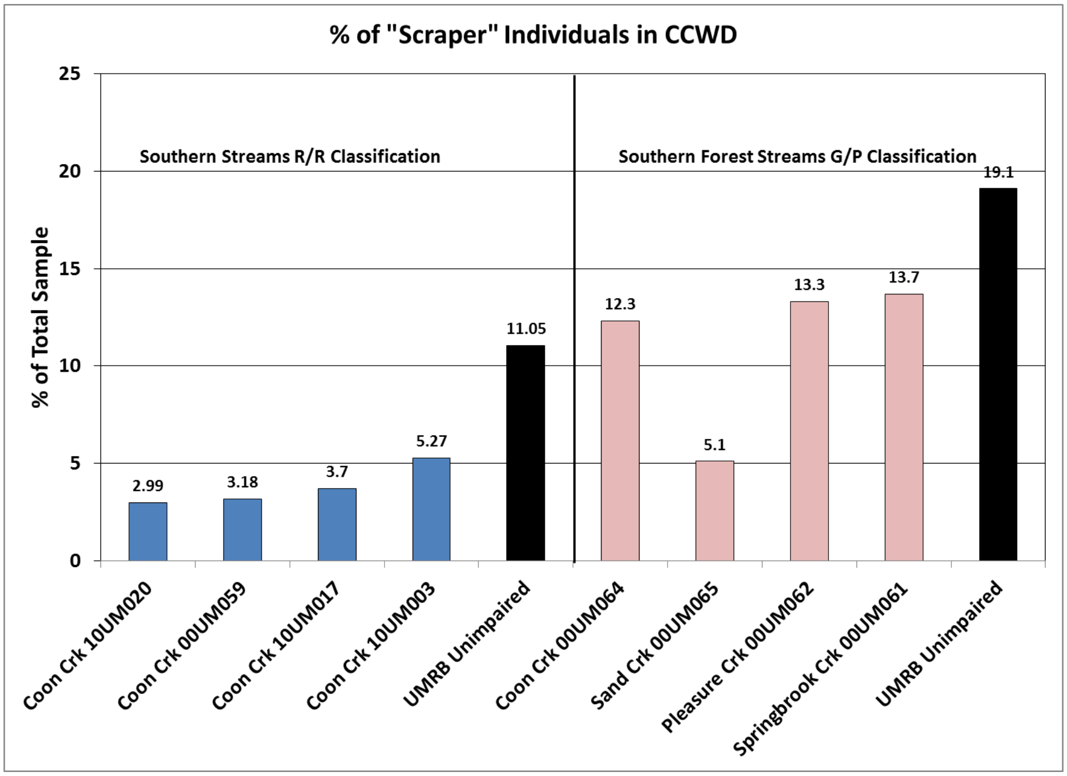

Figure 24. Percentage of individuals from "scraper" metric compared to mean values of sites in UMRB with health macroinvertebrate assemblages.

Strength of Evidence Summary for Excess Sediment

Based on analysis of existing water quality data and biological indicators, there is enough evidence to list excess suspended sediment as cause of aquatic life impairment. TSS concentrations exceeding the 30 mg/L state standard have been regularly documented (>10% of samples) in three of four impaired reaches. Suspended sediment is clearly impacting fishery assemblages in Coon and Sand Creeks. The effect of suspended sediment on macroinvertebrate assemblages is strong on all reaches except Springbrook Creek. The biological impacts of suspended sediment are most severe in Coon Creek, not coincidentally where TSS exceedances are most frequent. Strength of evidence for excess sediment is shown below (Table 17). For information on scoring, please see Appendix D.

Table 17. Weight of evidence table for excess sediment.

Strength of Evidence Table – Excess Sediment				
	Scores for Impaired Reaches			
Types of Evidence	Coon Creek	Sand Creek	Pleasure Creek	Springbrook Creek
Spatial/Temporal co-occurrence	+	+	+	0
Evidence of exposure, biological mechanism	++	++	++	++
Causal pathway	+	+	+	+
Field evidence of stress response	++	+	+	0
Field experiments/manipulation of exposure	0	0	0	0
Laboratory analysis of site media	0	0	0	0
Temporal sequence	0	0	0	0
Verified or tested predictions	+	+	+	0
Symptoms	+	+	+	+
Mechanistically plausible cause	+	+	+	+
Stressor-response in other field studies	+	+	+	+
Stressor-response in other lab studies	NE	NE	NE	NE
Stressor-response in ecological models	NE	NE	NE	NE
Manipulation experiments at other sites	NE	NE	NE	NE
Analogous stressors	NE	NE	NE	NE
Consistency of evidence	+	+	+	0
Explanatory power of evidence	++	++	0	0

8.3 Candidate Cause #3 – Excess Phosphorus

Phosphorus is an essential nutrient for all aquatic life making it a critical component of a healthy ecosystem. However, elevated phosphorus concentrations can induce an imbalance in biologic assemblages resulting in unhealthy community composition. In most cases, high phosphorus concentrations are not proximate stressors for aquatic life. However, elevated phosphorus can have indirect adverse effects on aquatic communities via increased primary production, and growth and accumulation of plant/algal biomass (Dodds and Welch, 2000). Increases in primary production and plant and algal biomass can have direct impact of the physical and chemical characteristics of a stream. Physical characteristics, such as habitat, can be hindered by the increased accumulation of plant and algal growth. The most common chemical parameter affected by elevated phosphorus concentrations is dissolved oxygen levels, a candidate cause already identified as a concern in the upper reaches of Coon Creek.

Sources and Pathways of Excess Phosphorus

In the CCWD, the most probable sources and pathways for phosphorus are naturally nutrient rich soils, and stormwater generated in urbanized areas. All potential sources and pathways for excess phosphorus in the CCWD are shown in Appendix C.

Water Quality Data – Excess Phosphorus

The State of Minnesota has released a draft river eutrophication criterion that provides a standard for total phosphorus. The proposed standard is set at 0.100 mg/L. The background and methods for developing this new standard can be found at: http://www.pca.state.mn.us/index.php/view-document.html?gid=14947.

Many, if not most, streams in the region exceed the draft 0.100 mg/L standard, and impaired reaches in CCWD are no different. Water quality data collected in CCWD impaired reaches confirms phosphorus concentrations are frequently exceeding 0.100 mg/L. Table 18 lists median values as well as the number of samples over the 0.100 mg/L draft standard. Sand Creek has the lowest median concentration of all reaches but still experiences an exceedance frequency of 17%. Other stream reaches had higher exceedance frequencies. Springbrook Creek violated the standard in 70% of samples, followed by Coon Creek with 63%, and Pleasure Creek with 26%. The frequency of exceedance becomes even more eye-catching when storm events are examined. Coon Creek and Springbrook Creek approached an 80% exceedance frequency calculating at 79% and 75% respectively. A max reading of 0.672 mg/L was recorded in Coon Creek along with several samples in excess of 0.500 mg/L, five times the standard.

Table 18. Median total phosphorus concentrations for impaired CCWD stream reaches.

Stream Reach	N	Median (Storms)	Median (Baseflow)	All	Samples>0.100 mg/L
Coon Creek	247	0.206	0.106	0.156	156
Sand Creek	184	0.084	0.063	0.074	32
Springbrook Creek	40	0.124	0.114	0.119	28
Pleasure Creek	53	0.095	0.067	0.083	14

Excessive phosphorus is leading to increased plant and algal growth in upper reaches of CCWD, specifically on County Ditches 11 and 44. County Ditch 11 is a headwater lateral to the main stem of Coon Creek and where the lowest DO and highest TP concentrations were recorded. County Ditch 44 is the main headwater stem of Coon Creek extending to the Carlos Avery WMA. Both channels are symptomatic of excess phosphorus evidenced by the large blooms of duckweed (Figure 25). Increased plant growth can lead to an increase in dissolved oxygen demand during periods of low light and plant decomposition. Increased DO demand results in wide daily DO flux as well as sustained periods of low DO concentration, both harmful to fish and macroinvertebrates (see section 8.1).

Figure 25. County Ditch 11 (left) and 44 (right). Note duckweed blooms; likely a result of low flow and excess phosphorus.

Low DO levels have already been identified earlier in this report as a primary stressor for the headwaters of Coon Creek. In 2013, the headwaters of Coon Creek experienced a maximum phosphorus concentration of 0.563 mg/L during a June 21st storm event. This spike in total phosphorus triggered a drop in DO concentrations down to 2.16 mg/L, well below the 5 mg/L standard. By plotting DO and TP concentrations relative to one another, a negative correlation exists (r= -0.35, p=0.055 Figure 26). Outside of Coon Creek headwaters, DO concentrations are generally sufficient even though excess TP is still observed. The effects of excess phosphorus in lower Coon Creek and other impaired CCWD reaches are likely masked by increased stream gradient resulting in constantly flowing water. Coon Creek headwaters, where low DO is observed, have the lowest stream gradient in all of CCWD and also rank toward the lower quartile of all UMRB reaches. The exceptionally low gradient in the upper reaches of Coon Creek minimizes flow velocity. Minimal flow reduces aeration caused by riffles, waterfalls, and/or impoundments and also allows phosphorus loading to build before eventual flushing downstream.

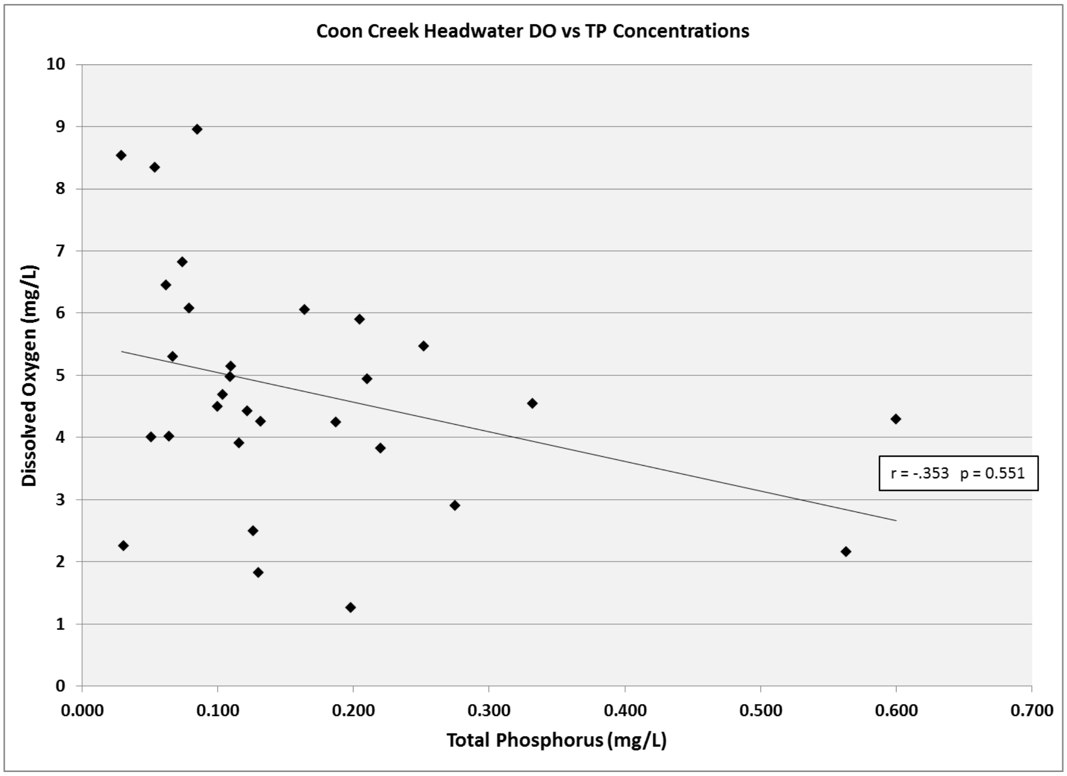

Figure 26. Correlation between TP and DO concentrations for headwaters of Coon Creek.

Causal Analysis – Biological Response to High Phosphorus

As cited earlier in this report, excess phosphorous alone is not a direct detriment to aquatic life. It is often ancillary effects such as low DO that negatively impact biotic assemblages. Those effects are detailed in an earlier section of this report (section 8.1).

Outside of reaches experiencing low DO concentrations, biological responses to excess phosphorus are still observed in the fish community. Eutrophication, caused by excess nutrients such as phosphorus, can shift fish assemblages toward species that feed primarily on particulate organic material (Miranda, 2008). Biologic metric "DetPlnkPct" measures the percentage of planktivorous or detritivorous fish present in a sampled reach. A high percentage of this feeding guild does not always result in biotic impairment but can provide evidence of a community shift toward species more tolerant of nutrient rich streams. In stream reaches where excess phosphorus is present, an increased percentage of planktivores and detritivores are expected. A strong representation of these feeding guilds is present in CCWD waters with impaired fish assemblages (Figure 27). The increased representation of these feeding guilds in impaired reaches supports the case for excess phosphorous as a candidate stressor.

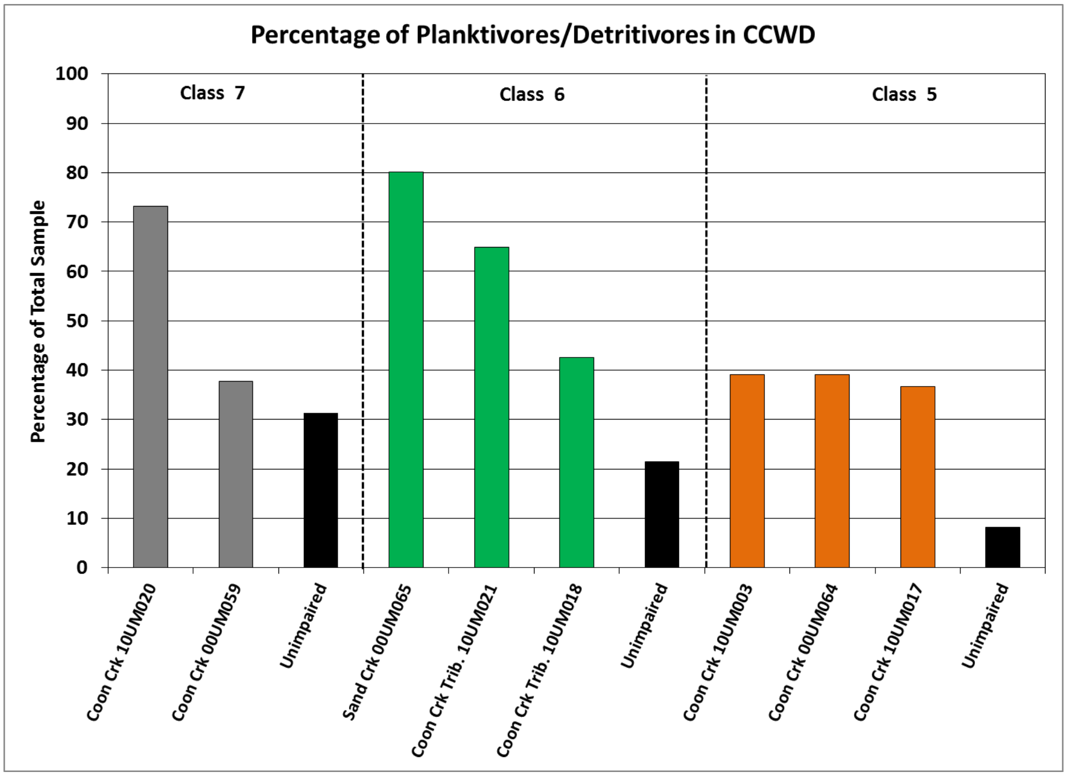

Figure 27. Planktivorous and detritivorous fish representation in reaches with pending fish impairments.

Miltner and Rankin (1998) concluded the number of sensitive fish species was significantly higher in streams with TP concentrations below 0.120 mg/L. Work conducted by MCPA indicated that when TP concentrations reached .100 mg/L, the number of sensitive fish species accounted for only 10% of the total sampling catch (MPCA, 2013). As shown in Table 18 (pg.58), TP concentrations found in CCWD frequently exceed this threshold. The percentage of sensitive individuals sampled in Coon and Sand Creek aligns well with results presented in both of these studies. Stream reaches with deferred fish impairments had poor representations of sensitive fish (Table 19).

Table 19. Percent of sensitive individuals sampled.

Impaired Reach	# Sensitive Individuals	Total Catch	% of Sensitive Individual in Total Catch
Coon Creek	117	1706	6.8%
Sand Creek	1	290	0.003%

Figure 28 compares the number of sensitive fish species sampled in CCWD to non-impaired UMRB sites. As evidenced by both Table 19 and Figure 28, all impaired reaches are lacking adequate representation of sensitive individuals, strengthening the case for excess TP as a candidate cause.

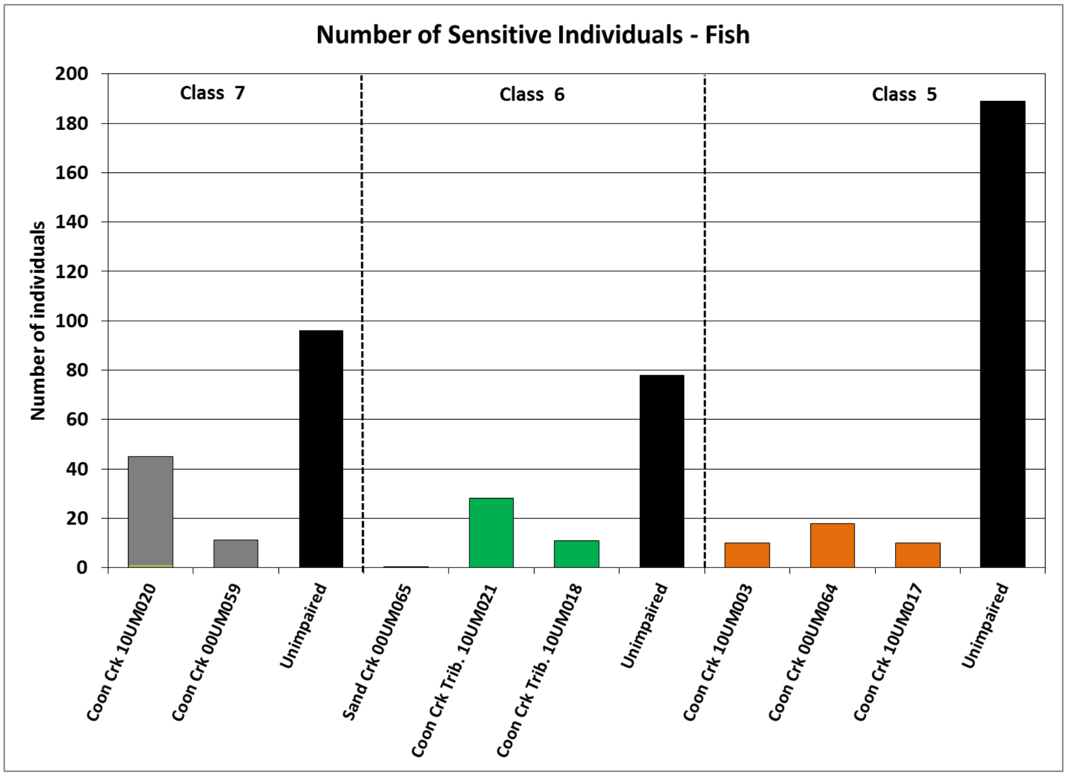

Figure 28. Number of sensitive individuals in reaches with pending fish impairments.

Macroinvertebrate assemblages can also provide valuable information regarding excess nutrients in streams. In MPCA's effort to develop river nutrient criteria, it was determined that the number of macroinvertebrate taxa exhibited a strong negative correlation with TP concentrations (MPCA, 2013). The total number of macroinvertebrate taxa in CCWD impaired reaches falls below the median of non-impaired UMRB sites at most monitoring stations and often below the 25th percentile (Figure 29).

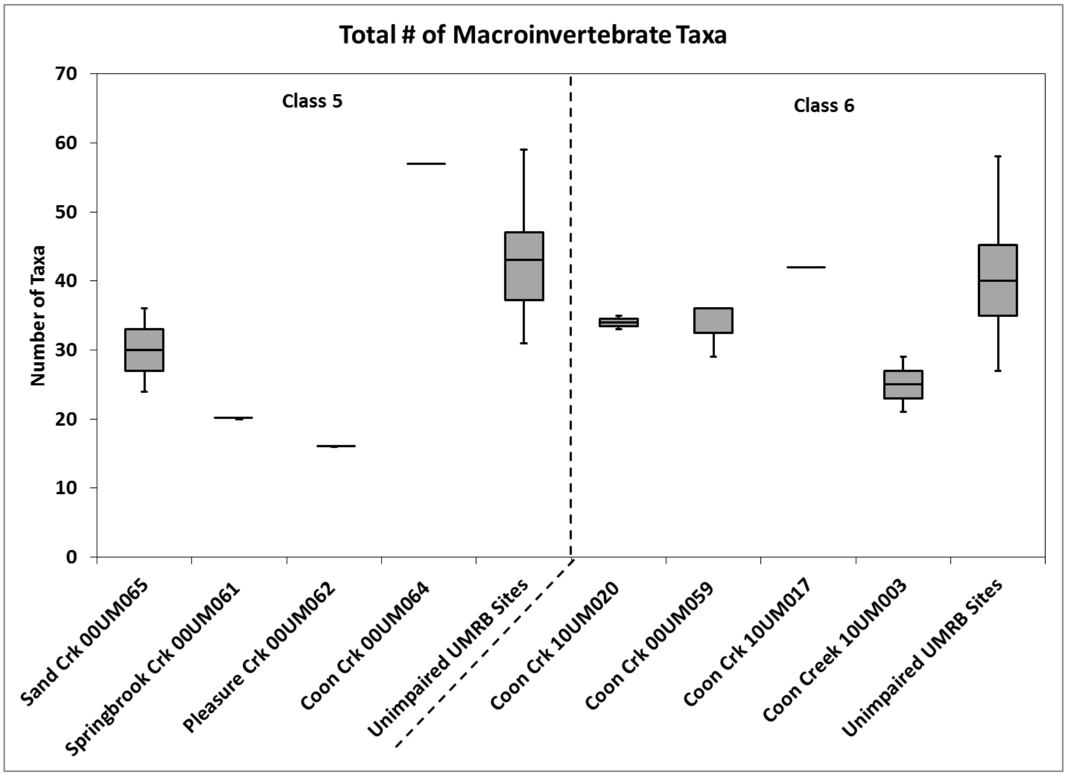

Figure 29. Number of macroinvertebrate taxa in CCWD impaired reaches.

Excessive nutrients can also result in species composition shifts away from functional assemblages of intolerant species towards less desirable assemblages of tolerant species (Hilsenhoff, 1988). The disparity between tolerant and intolerant taxa is greater in CCWD than non-impaired UMRB sites (Figure 30). Tolerant taxa are higher across all sites in CCWD than non-impaired UMRB sites. Intolerant taxa sampled follow the predicted response for degraded streams, scoring lower than non-impaired UMRB sites in all but one location. Site 10UM003, located at the downstream end of Coon Creek, scored higher than non-impaired UMRB sites, however the number of intolerant individuals was low.

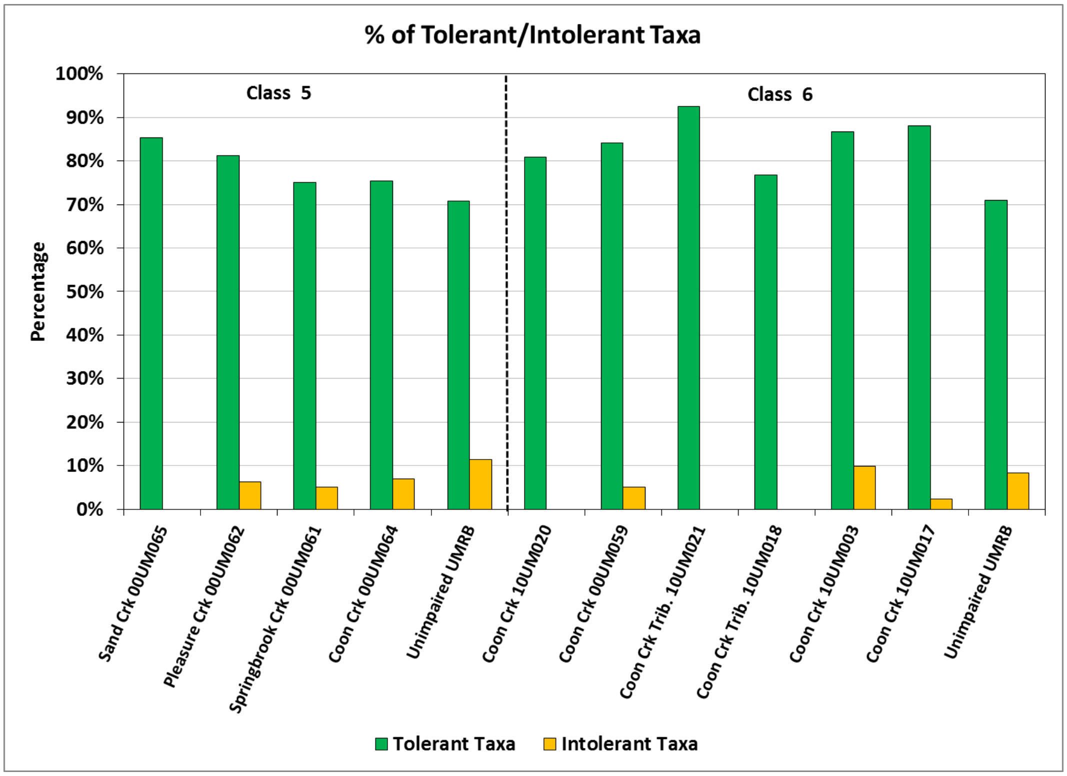

Figure 30. Intolerant/Tolerant taxa in CCWD.

Strength of Evidence Summary for High Phosphorus

Based on phosphorus concentrations in excess of state standards, insufficient DO concentrations in Coon Creek headwaters, the prevalence of planktivorous and detritivorous fish, low percentages of sensitive fish, low numbers of macroinvertebrate taxa, and shift from intolerant to tolerant macroinvertebrates, there is enough evidence to list excess phosphorus as a limiting factor to aquatic life. Strength of evidence for excess phosphorus is shown below (Table 20). For information on scoring, please see Appendix D.

Table 20. Weight of evidence table for excess phosphorus.

Strength of Evidence Table – Excess Phosphorus				
Types of Evidence	Scores for Impaired Reaches			
	Coon Creek	Sand Creek	Pleasure Creek	Springbrook Creek
Spatial/Temporal co-occurrence	+	+	+	+
Evidence of exposure, biological mechanism	++	++	++	++
Causal pathway	++	++	++	++
Field evidence of stress response	+	0	0	+
Field experiments/manipulation of exposure	0	0	0	0
Laboratory analysis of site media	0	0	0	0
Temporal sequence	0	0	0	0
Verified or tested predictions	+	+	+	+
Symptoms	+	+	+	+
Mechanistically plausible cause	+	+	+	+
Stressor-response in other field studies	+	+	+	+
Stressor-response in other lab studies	NE	NE	NE	NE
Stressor-response in ecological models	NE	NE	NE	NE
Manipulation experiments at other sites	NE	NE	NE	NE
Analogous stressors	NE	NE	NE	NE
Consistency of evidence	+	+	+	+
Explanatory power of evidence	++	++	++	++

8.4 Candidate Cause #4 –Altered Habitat

Habitat is a broad term encompassing all aspects of the physical, chemical, and biological conditions needed to support living organisms. More simplistically, habitat describes the place where an organism lives or occurs. This section deals only with the physical attributes of habitat. It is worth mentioning that physical habitat is often interrelated with other stressors (e.g., sediment, flow, DO) which are all addressed separately in this report. An example of the interaction between physical habitat and other stressors would be the ability of adequate refuge habitat to minimize impact of high flows on biota. In streams, habitat can include the rocks and sediments present in or near the stream; plants growing or attached to debris in the stream; or, organic material that falls into the stream such as logs, twigs, leaves, etc. Habitat can also include elements of stream structure (e.g., riffles, runs, pools) or other stream formations outside the primary flow channel. These areas outside the primary flow channel serve as refuge during high flow events.

Numerous studies have concluded that the impacts of channelization on habitat and the associated biotic community have generally been negative (Carrol *et al.* 1977; Hortle and Lake, 1983; Sullivan *et al.* 2004). Species richness is often positively correlated with the availability of diverse habitats (Meffe *et al.* 1997). Lau *et al*. determined that channelized streams had poorer quality habitat primarily due to loss of heterogeneity (2006). Habitat diversity is necessary to support hearty assemblages of fish and macroinvertebrates since each species has a preferred set of habitat requirements. Generalist species can tolerate a large range of habitat conditions while other species known as specialists, require very specific habitats. A simplified example of habitat diversity is a stream bottom composed of sand, gravel, and cobble. A combination of these substrate types will allow for more diverse aquatic assemblages than a stream composed entirely of one substrate material.

Shifts in biotic assemblages can result from decreased habitat diversity or a reduction in habitat quality. Assemblage shifts occur via behavior alteration, increased mortality, or decreased reproductive success (Griffith *et al.*, 2010).

Numerous stream habitat assessment indices are available. Commonly accepted methods include, the Ohio Qualitative Habitat Evaluation Index (Ohio QHEI), EPA Rapid Bioassessment Protocol, and the Minnesota Stream Habitat Assessment Protocol (MSHA). A review of these methods suggests habitat conditions are usually measured by the number of different habitat types present, the quality of those habitats, the amount of that habitat available, and the amount of in stream cover.

Habitat is highly variable across the CCWD and is considered a critical component in assessing biological communities. A high degree of channel alteration and land use change has occurred in CCWD which makes the evaluation of habitat conditions prudent.

Sources and Pathways of Altered Habitat

The causes for lack of habitat in the CCWD are modeled in Appendix C. As discussed above, channelization has a significant impact on both the quality and diversity of stream habitat. The ability of the CCWD system to serve as a stormwater conveyance system is dependent on constructed channels with minimal obstructions (i.e. tree snags, root wads, etc.) Major land use changes such as urbanization are also likely affecting habitat connectivity through degradation of riparian zones. In urbanized areas, removal of riparian habitat is common to increase aesthetic value of property along streams.

Habitat Data – Altered Habitat

During biological monitoring, MPCA measured existing habitat conditions using the MSHA protocol. The MSHA is useful in describing the aspects of habitat needed to obtain an optimal biological community. MSHA methods are slightly modified from the Ohio QHEI to more adequately assess important characteristics influencing Minnesota Streams. The MSHA score is comprised of numerous scoring components including land use, riparian zone, instream zone (substrate, embeddedness, cover types and amounts) and channel morphology (depth variability, sinuosity, stability, channel development, velocity). All of these component scores are summed for a total possible score of 100 points. Narrative ratings of good, fair, or poor are assigned based on summed totals (Table 21).

Table 21. Criteria determining MSHA narrative rating.

Rating	Criteria	Threshold
Poor	MSHA score below the median of the most-disturbed sites	MSHA<45
Fair	MSHA score between the median of the least-disturbed sites and the median of the most-disturbed sites	45<MSHA<66
Good	MSHA score above the median of the least-disturbed sites	MSHA>66

Table 22 provides results of the MSHA surveys conducted during fish sampling visits in CCWD. Where multiple visits occurred at the same station, the scores from each visit have been averaged. The bottom row is the average of all CCWD sites. The abundance of fair to poor habitat supports altered habitat as a candidate cause for impairment.

Table 22. Habitat scores for biological monitoring locations.

Visits	Site ID	Stream	Land Use (0-5)	Riparian (0-15)	Substrate (0-27)	Cover (0-17)	Channel Morphology (0-36)	MSHA Score (0-100)	MSHA Rating
1	10UM021	Coon Creek Trib. (CD11)	2.3	8	9.0	13	4	36.3	Poor
1	10UM020	Coon Creek	2.5	11.0	9.0	16.0	11.0	49.5	Fair
3	00UM059	Coon Creek	2.0	9.5	11.0	9.0	13.0	44.5	Poor
1	10UM018	Coon Creek Trib. (CD58)	3.5	10.0	12.8	12.0	17.0	55.3	Fair
1	10UM017	Coon Creek	2.0	6.5	14.0	7.0	19.0	48.5	Fair
1	00UM064	Coon Creek	1.0	11.5	17.1	9.0	23.0	61.6	Fair
1	10UM003	Coon Creek	4.2	14.5	18.0	13.0	26.0	75.8	Good
4	00UM065	Sand Creek	2.0	8.8	14.2	7.5	15.5	48.0	Fair
1	00UM062	Pleasure Creek	0.5	12.5	18.1	9.0	19.0	59.1	Fair
1	00UM061	Springbrook Creek	1.5	12.0	18.7	12	18	62.2	Fair
1	00UM086	Springbrook Creek	1.0	10.5	17.3	6.0	15.0	49.8	Fair
-	CCWD	ALL	2.0	10.0	14.0	9.6	15.8	51.5	Fair

The contribution of each habitat component relative to the overall MSHA score is displayed on page 69 along with an ideal contribution. The ideal contribution was determined by entering maximum scores for each habitat component. The relative contribution of each habitat component is important since more weight is put on morphology and substrate scores. Examination of single habitat components compared to the maximum score provides insight into which habitat component is most limiting to aquatic assemblages. Land use and channel morphology scored poorly across CCWD, averaging roughly 50% of the maximum score. Lack of channel morphology was identified as the most significant contributor to the marginal habitat scores across CCWD.

Site 10UM003 was the highest scoring site in CCWD in terms of habitat and also the only site considered to achieve a good habitat classification. This site is located near the outfall of Coon Creek but more importantly on a reach that has not underwent channelization, further strengthening the case that habitat scores are significantly limited by channelization. In upstream reaches of Coon Creek, channel morphology and substrate scored poorly providing small contributions to overall score (Figure 31 pg. 69). This area is laden with heavily channelized agricultural ditches inundated with sand and silt substrates. MSHA data confirms that no coarse substrate was observed in upstream reaches representative of a channelized stream. In-stream cover accounted for the largest portion of the overall score, likely due to an abundance of channel vegetation. Continuing downstream, channel morphology scores improve along with substrate diversity. Improving substrate scores are likely due to increased stream gradient allowing for a flushing of fine sediments rather than deposition. Habitat diversity begins to even out when moving downstream reaching a near ideal distribution near the outfall, not coincidentally where site 10UM003 is located.

Sand Creek cannot be analyzed from upstream to downstream since MSHA data only exists at one site (00UM065). However, conclusions can be drawn regarding habitat conditions present on Sand Creek when comparing to the ideal. All habitat categories are contributing a relatively equal percentage of distribution meaning that no habitat type is more or less dominant than the other (Figure 32 pg. 69). Despite having an optimal distribution of habitat, an overall MSHA rating of Fair suggests habitat quality may be the larger issue. Contrary to Coon Creek where channel morphology was identified as having the most impact, it may be wise to focus on improving the quality of habitat across all categories for Sand Creek, rather than singling out one component specifically.

Pleasure Creek and Springbrook Creek show similar habitat distribution to one another; not surprising given their close proximity and similar land uses (Figure 33, Figure 34 Pg. 70). In both of these reaches, land use is limiting overall habitat scores. These stream reaches have the highest degree of urbanization throughout all of CCWD so it is not appalling surrounding land use scores poorly for these streams. MSHA data also designates both of these reaches as having low channel stability which is defined as "a high degree of bedload and severely eroding banks. A homogenous stream bed characterized by shifting sand substrates has low stability."

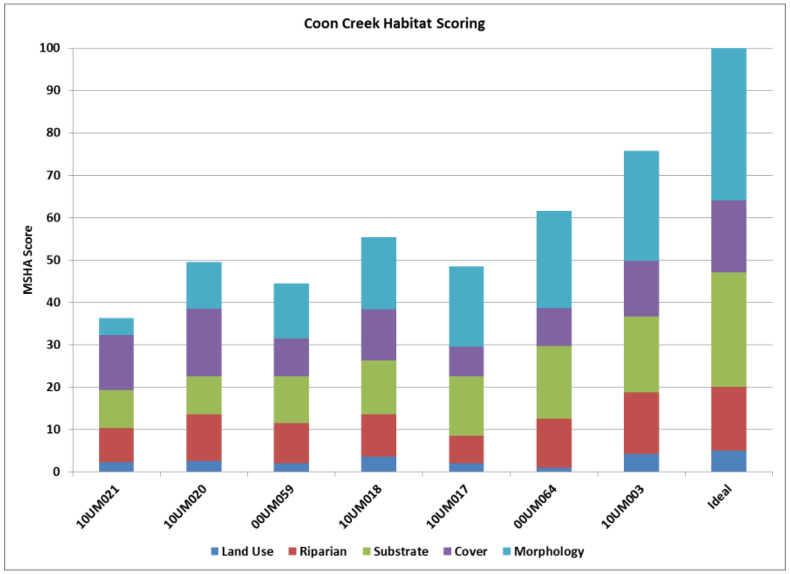

Figure 31. Habitat scores for biomonitoring sites located on Coon Creek (listed upstream to downstream).

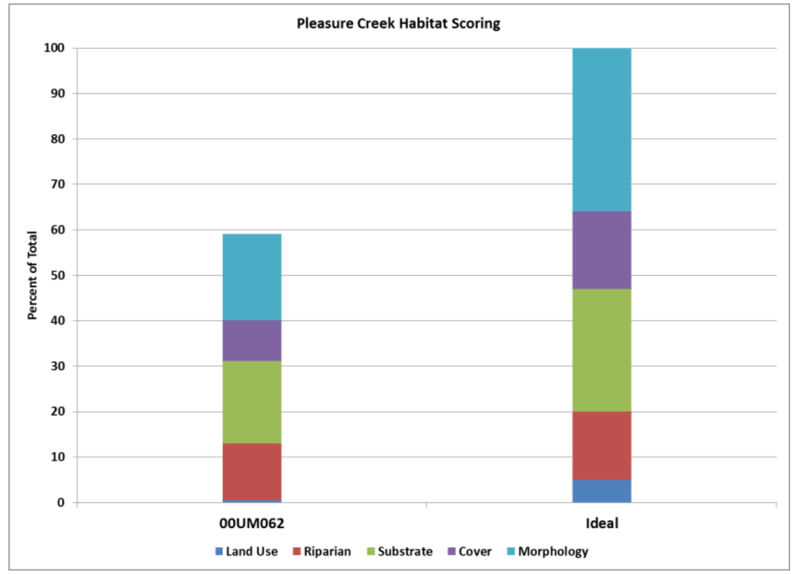

Figure 33. Habitat scores for biomonitoring site on Pleasure Creek.

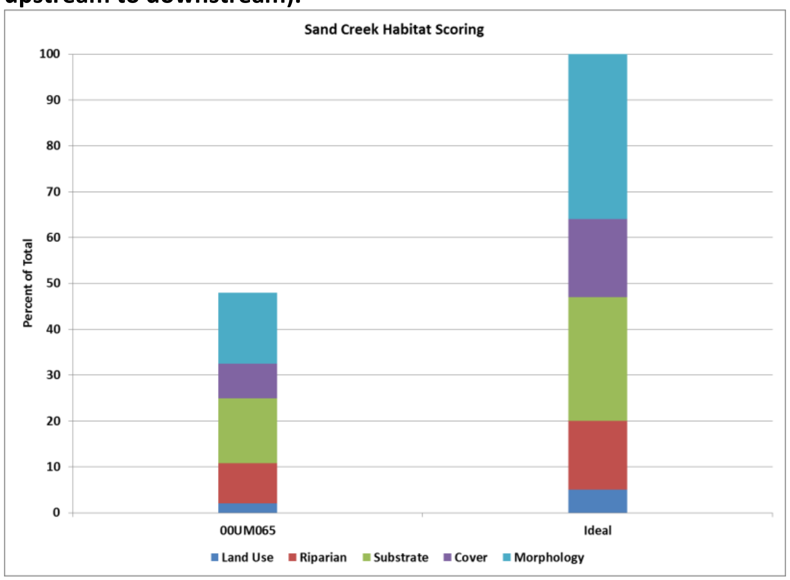

Figure 32. Habitat scores for biomonitoring site on Sand Creek.

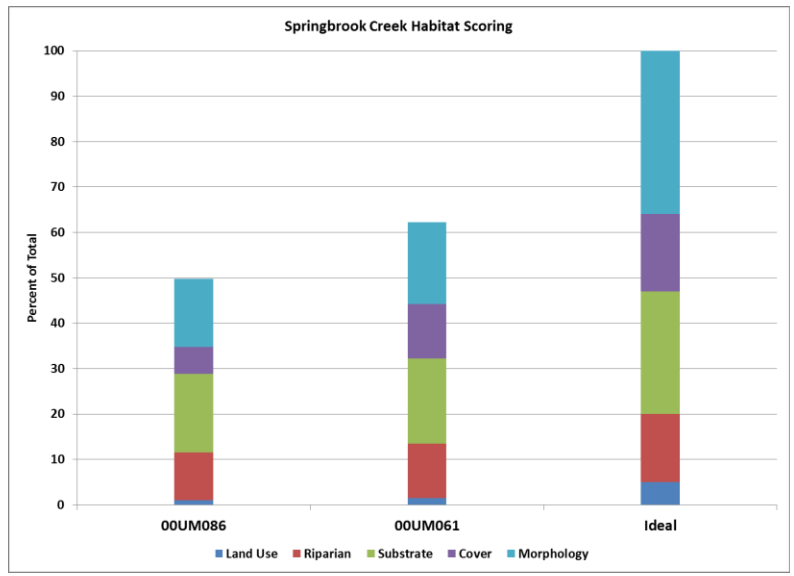

Figure 34. Habitat scores for biomonitoring sites on Springbrook Creek (listed upstream to downstream)

CCWD contains approximately 300 miles of public and private ditch system. Only 7.9 miles of the ditch system are considered “natural” or unchannelized. The remaining 292.1 miles of ditch are considered channelized (Figure 35). Stream reaches with a “High” degree of channelization are non-natural constructed ditches. “Moderate” channelization represents streams that naturally existed but have been altered (i.e., dredged, straightened, armored), and “Low” channelization depicts stream reaches that exist in their unaltered natural state.

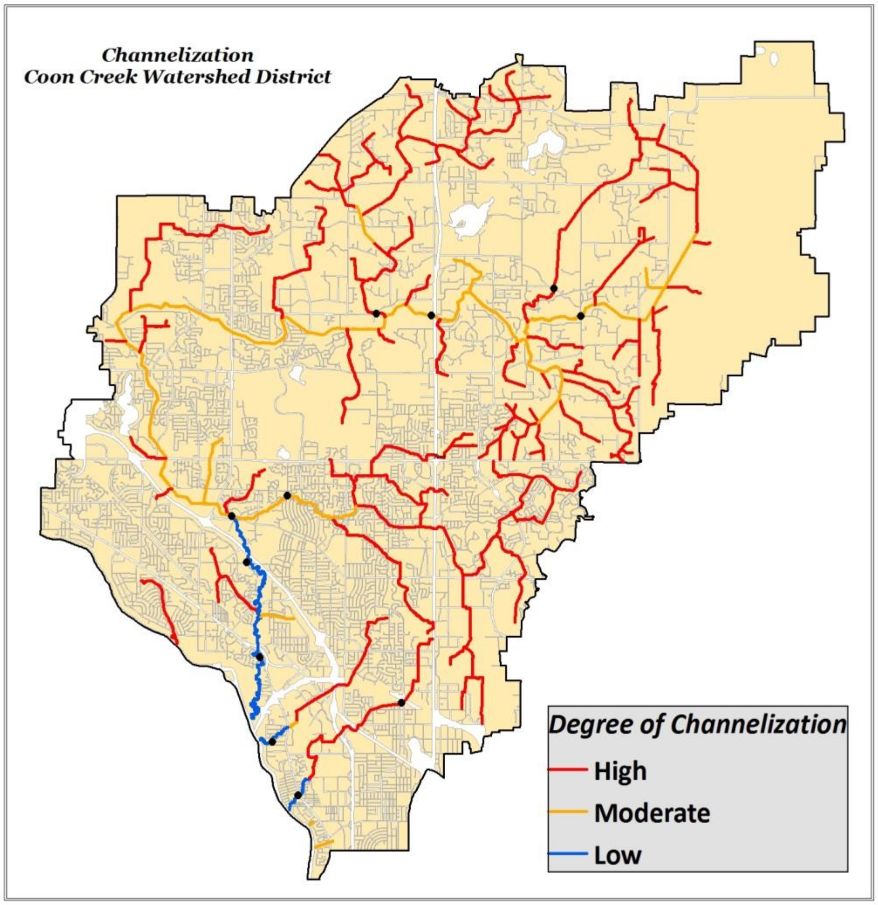

Figure 35. Degree of channelization found in the public ditch system of CCWD. Only the lower portions of Coon Creek, Pleasure Creek, and Springbrook Creek, exist in their natural state. Black dots represent MPCA biological monitoring stations.

A study conducted by Knight *et al.*, correlated channelization to profound changes in the physical and geomorphological characteristics of streams (2012). Major changes to studied streams included an over-widening of the stream leading to lack of depth variability, blockages due to excess sediment, and pool infilling; all conditions found in CCWD (Figure 36). Channelization affects in-stream habitat such as riffle-pool sequences, snags, meanders, and changes in streambed composition. Trees and native vegetation are commonly removed or altered to a degree which destabilizes the banks, reduces shading, and increases inputs of sediment, nutrients, and other pollutants from the watershed which can alter water chemistry.

Figure 36. Two stream reaches in CCWD exhibiting lack of depth variability and excess sedimentation resulting from channelization.

Sand Creek reach exhibiting poor depth variability and poor sinuosity.

Coon Creek reach displaying lack of depth variability and excess sedimentation evidenced by mid-stream sand bar formation.

To deal with increased sedimentation, channel maintenance is routinely conducted to maintain design flood capacity. Channel maintenance, often referred to as "dredging", removes sediment from the stream bed, places it on the upper banks, and re-slope stream banks back to preferred geometry. This activity temporarily restores channel capacity and efficiency back to "as-built" design specifications. A drawback of this activity is the removal of channel vegetation (both in stream and along banks) and stream straightening which have both been shown to decrease aquatic habitat, water quality, and channel stability (Beeson and Doyle, 1995). Figure 37 (below) shows a channel in the process of being dredged. As evidenced by the photo, dredging operations are quite destructive; making it is easy to see how this practice can alter habitat, and ultimately aquatic life.

Figure 37. Channel in the process of being dredged.

Pearson correlation analysis relating stream sinuosity (a measure of channelization) and overall habitat scores for CCWD was strong (*r*=0.846 *p*<0.05), demonstrating that channelization is directly affecting overall habitat scores (Figure 38).

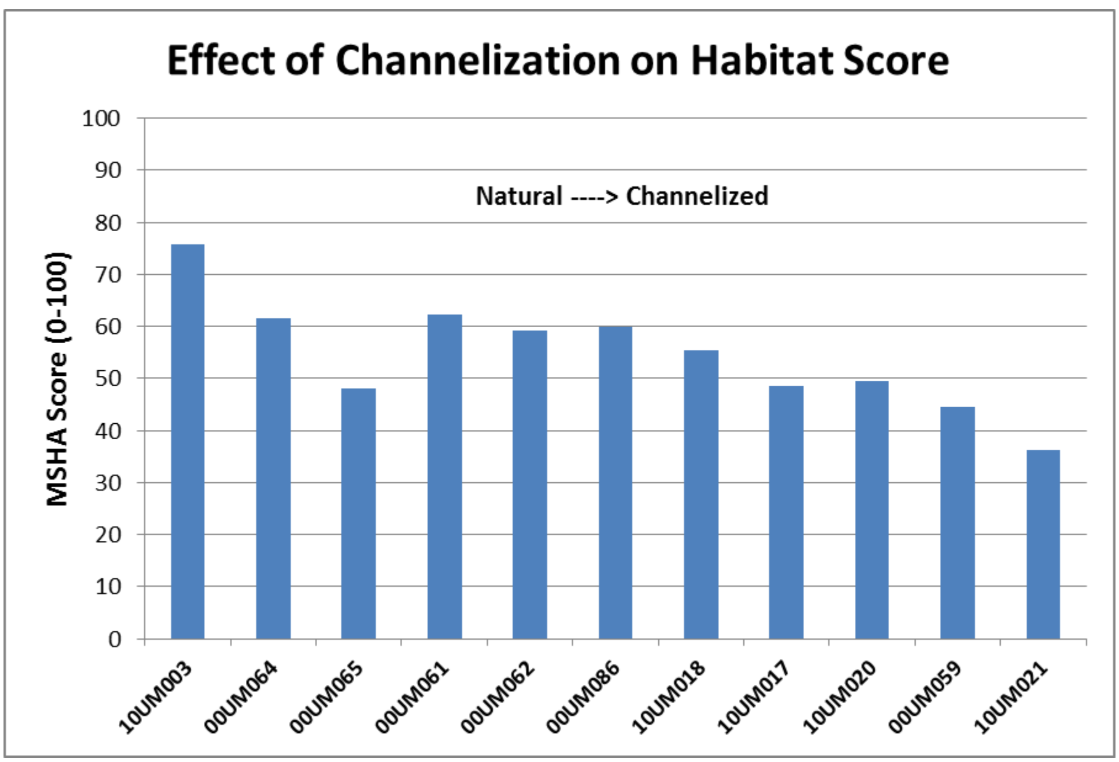

Figure 38. Correlation between MSHA habitat scores and degree of channelization.

Causal Analysis – Biological Response to Altered Habitat

Specific biological effects of altered habitat are difficult to determine since altered habitat is often intertwined with other potential stressors (e.g., sediment, flow, temperature, dissolved oxygen) (USEPA, 2012). MSHA scores were plotted relative to IBI scores for all monitored stations for both fish and macroinvertebrates (Figure 39, Figure 40). Both fish and macroinvertebrates had a positive correlation with habitat but both correlations were weak. It is plausible these correlations were weakened by effects from interacting stressors as discussed earlier. It is difficult to eliminate compounding factors during sampling. For example, it would be expected for aquatic assemblages to meet IBI standards at site 10UM003 since habitat scored well at this site. However, measured IBI scores are below threshold at this location, likely due to poor water quality which is not via habitat sampling.

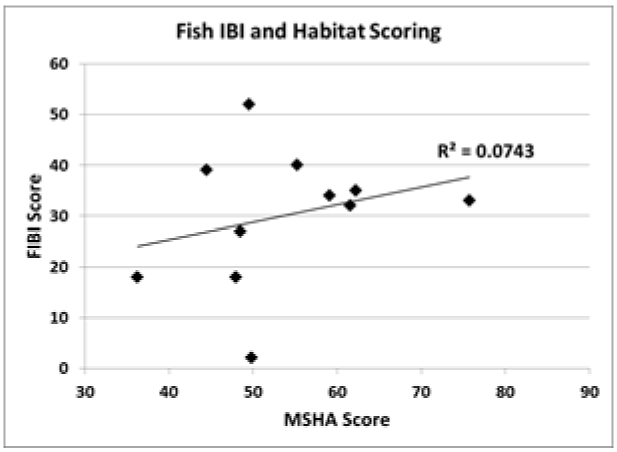

Figure 39. Fish IBI against habitat correlation.

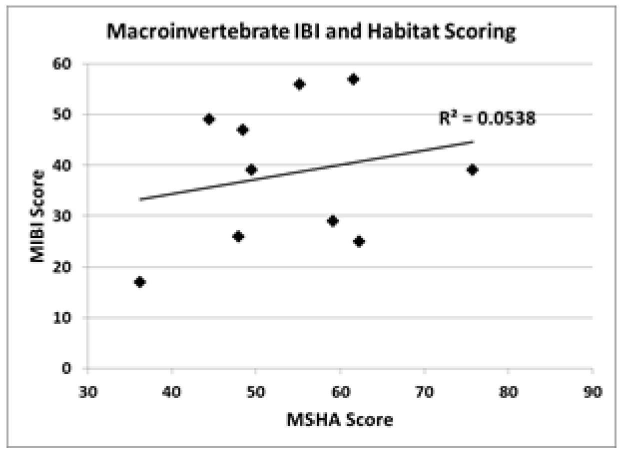

Figure 40. Macroinvertebrate IBI against habitat correlation.

Fish metrics with stressor response to poor habitat include tolerant taxa (increase), benthic insectivores (decrease), simple lithophilic spawners (decrease), and darter/sculpin/round-bodied suckers (negative). Each of these metrics was plotted against habitat scores for monitoring stations in Coon and Sand Creek (Figure 41-Figure 44). All metrics followed predicted response, with benthic insectivores and tolerant taxa showing significant response when statistically challenged (p=0.01, p=0.02 respectively). Correlations between habitat and simple lithophilic spawners and darter/sculpin/round bodied suckers did not prove significant when challenged. Despite the lack of significance in 2 of the 4 habitat sensitive metrics, this is strong evidence for habitat as a candidate cause for fish assemblage impairment. These metrics do have sensitivities to other water quality parameters which may be weakening the statistical significance of the latter two metrics.

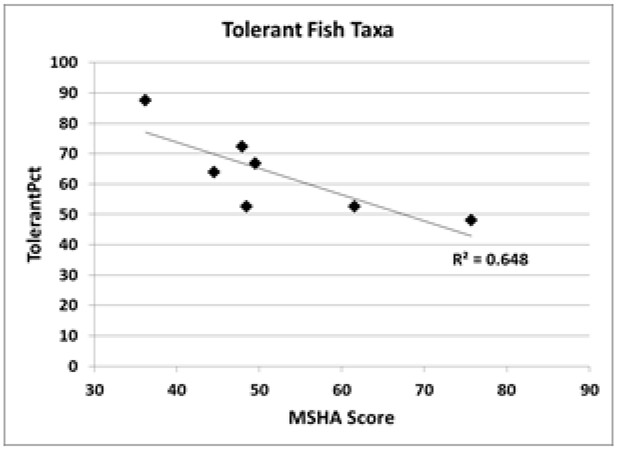

Figure 41. Percentage of tolerant fish taxa.

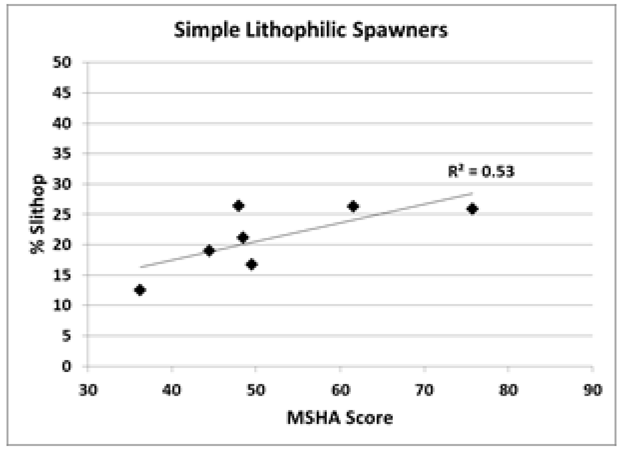

Figure 42. Percentage of simple lithophilic spawning fish.

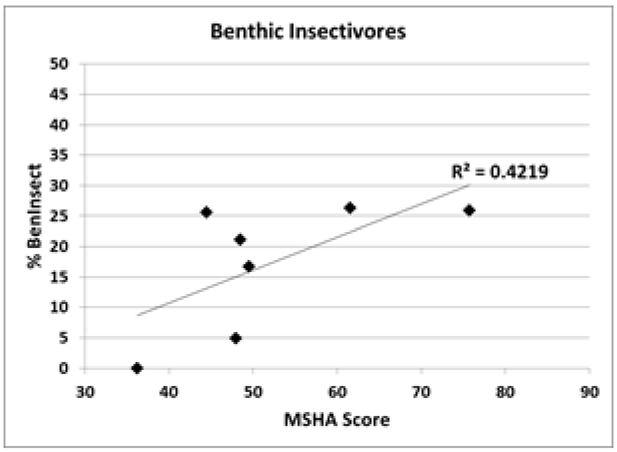

Figure 43. Percentage of benthic insectivore taxa.

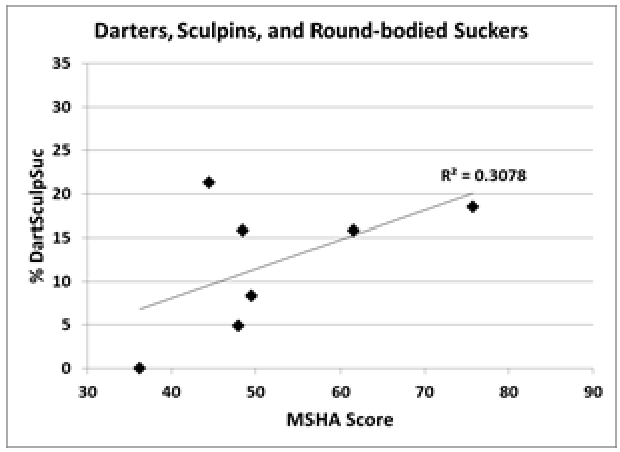

Figure 44. Percentage of darters, sculpins, and round-bodied suckers.

Macroinvertebrate assemblages provide a slightly clearer picture of the role altered habitat is playing in macroinvertebrate impairments. Macroinvertebrate metrics “TolerantPct” and “ClingerPct” are generally accepted to provide a good measure of stream degradation due to habitat condition. Both of these metrics were plotted against MSHA scores and both followed the predicted response to poor habitat in CCWD (Figure 45, Figure 46). The percentage of tolerant individuals increased with degrading habitat ($r=-0.874$, $p=0.01$) while clingers decreased ($r=0.481$, $p>.05$). Macroinvertebrates do not possess the ability to move from areas with degraded habitat to the same degree as fish, therefore macroinvertebrate communities are more susceptible to habitat degradation and perhaps a better overall indicator.

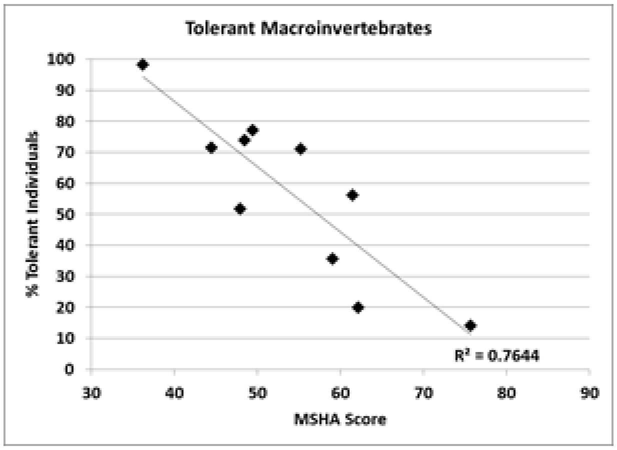

Figure 45. % Tolerant individuals against MSHA score.

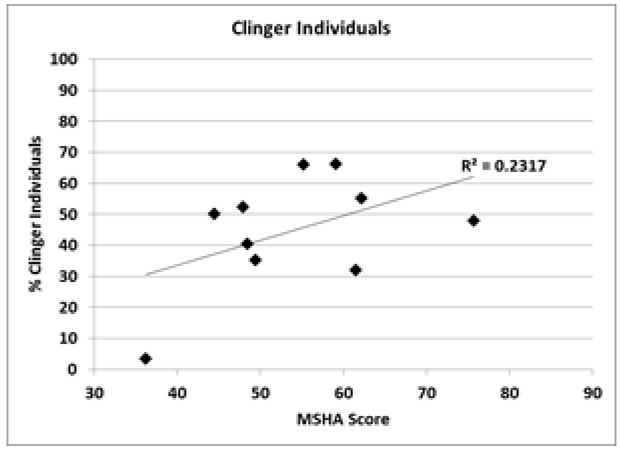

Figure 46. % Clinger individuals against MSHA score.

Strength of Evidence Summary for Altered Habitat

MSHA data concludes that habitat conditions are sub-par at best across much of CCWD. Most sites scoring Fair or Poor are limited by poor channel morphology, lack of substrate, and surrounding land use. Altered habitat appears to be contributing to impaired fish assemblages in Coon and Sand Creek. Macroinvertebrate IBI scores also show a positive relationship when plotted against habitat scores for reaches with macroinvertebrate impairments. Individual metrics with sensitivity to habitat alteration also follow predicted responses. For this reason, habitat alteration was identified as a candidate cause of biological impairment. The lack of adequate habitat and corresponding biologic assemblages is not surprising since many of the impaired streams in CCWD act as stormwater conveyance ditches. Impaired reaches have undergone a high degree of alteration to increase their efficiency for stormwater transport. Strength of evidence for altered habitat is shown below (Table **23**). For information on scoring, please see Appendix D.

Table 23. Weight of evidence table for altered habitat as a candidate cause.

Strength of Evidence Table – Altered Habitat				
	Scores for Impaired Reaches			
Types of Evidence	Coon Creek	Sand Creek	Pleasure Creek	Springbrook Creek
Spatial/Temporal co-occurrence	+	+	+	+
Evidence of exposure, biological mechanism	++	++	++	++
Causal pathway	+	+	+	+
Field evidence of stress response	++	++	+	+
Field experiments/manipulation of exposure	++	++	++	++
Laboratory analysis of site media	0	0	0	0
Temporal sequence	+	+	+	+
Verified or tested predictions	+	+	+	+
Symptoms	+	+	+	+
Mechanistically plausible cause	+	+	+	+
Stressor-response in other field studies	NE	NE	NE	NE
Stressor-response in other lab studies	NE	NE	NE	NE
Stressor-response in ecological models	NE	NE	NE	NE
Manipulation experiments at other sites	NE	NE	NE	NE
Analogous stressors	NE	NE	NE	NE
Consistency of evidence	+	+	+	+
Explanatory power of evidence	++	++	++	++

8.5 Candidate Cause #5 –Altered Hydrology

The hydrologic regime of a stream is driven by a combination of natural and anthropogenic (human) factors. Natural factors affecting hydrologic regime are the characteristics of the watershed (i.e. topography, soils, climate). Alteration of any of these factors has direct impact of the hydrologic regime of a stream. The characteristics of a given watershed were created by the earth's natural process with zero human input.

Human impacts are often considered the greatest threat to stream condition, both in terms of water quality and quantity. Urbanization and channelization are two anthropogenic factors common across Minnesota landscapes. Unfortunately, both of these factors have the ability to alter stream flows and directly impacting biologic assemblages. Both of these practices also contribute to additional stressors such as bank destabilization and increased scouring to the increased shear stress created by high velocity flows. For this reason, altered hydrology (specifically increased flashiness) is commonly associated with other stressors such as poor habitat conditions and excess TSS.

Channelization - Channelized ditches are a common feature in the Minnesota landscape, especially in areas of the state where agriculture is or once was prevalent. It is reported that anywhere from 20,000 to 27,000 miles of public drainage ditch or channelized streams are present in the state of Minnesota (BWSR, 2006). In the CCWD alone, there are roughly 139 miles of public drainage ditch and another 161 miles of private drainage networks. These drainage networks were designed and constructed for two reasons; 1) drain saturated soils to allow for agriculture, 2) serve as a stormwater conveyance system.

It is well understood that channelized systems are not optimal for fish and macroinvertebrate assemblages. A Midwest study conducted in 1996 showed that channelized sections of streams had lower quality fish assemblages than natural streams based on fish IBI results due to increased generalist, tolerant species (Lau *et al.*, 2006). In addition, macroinvertebrate assemblages showed lower diversity, lower abundance, and increased drift in channelized reaches compared to natural streams (Edwards *et al.*, 1984). Numerous studies have confirmed that microhabitats (runs, riffles, and pools) in a stream are directly impacted by channel form and each will support distinct biotic communities (Gorman and Karr, 1978; Beisel *et al.*, 1998; Taylor, 2000).

Urbanization - Urbanization has greatly impacted the hydrologic regime of streams across CCWD. Approximately 40.7% of CCWD is urbanized as defined by commercial, industrial, multi or single family residential land use. Urban streams are often affected by multiple co-occurring stressors at once, a scenario referred to as the urban stream syndrome (USEPA, 2010). Hydrologic symptoms generally associated with urban stream syndrome are increased frequencies of overland and erosive flows, increased magnitude of stormflow, increased flashiness, and reduced time of concentrations. Stream flashiness was identified in a 2010 study as the most commonly associated stressor with increased urbanization (Cuffney, 2010).

A 2003 study conducted by the US Geologic Survey evaluated the effects of urbanization on 30 Wisconsin streams. It was concluded the quality of macroinvertebrate and fish assemblages were negatively correlated with urban land use (USGS, 2003).

Sources and Pathways of Altered Hydrology

A conceptual model for altered hydrology as a candidate cause is shown in Appendix C. The most plausible sources for altered hydrology in the Coon Creek Watershed include increased impervious surface due to urbanization, agricultural drainage, and channelization of streams.

Water Quality Data – Altered Hydrology

Hydrology monitoring has been conducted on all impaired reaches in CCWD, with varying periods of record. Sand Creek has the longest period of record dating back to 2001 followed by Coon Creek which began in 2005. Pleasure and Springbrook Creeks only have two years of monitoring (2012, 2013) so long term trend analysis on these reaches is not feasible but monitoring can still be helpful to determine recent stream fluctuations.

Coon Creek and Springbrook Creek are considered the flashiest of all four major subwatersheds in CCWD. Coon Creek has experienced stage increases of more than four feet (4.03 ft, 4.08 ft, and 4.14 ft) and Springbrook Creek has neared this mark with a maximum increase of 3.81 feet. In both of these systems, water levels rise dramatically in response to precipitation before eventually returning to base flows (Figure 48, Figure 49). Springbrook Creek and lower Coon Creek are highly urbanized and much of this development was constructed prior to stormwater regulation. As a result, sharp increases in flow shortly after precipitation are expected. Coon Creek headwaters, near Naples Street, have experienced stage increases nearing 3.5 feet despite having far less urban development than lower Coon Creek. However, the numerous agricultural ditches in this portion of the creek are highly efficient and quickly remove water from the landscape and deliver it the main channel of Coon Creek. This leads to similar "flashiness" as lower reaches despite the more rural land uses.

Sand Creek is less "flashy" than both Coon and Springbrook Creeks but is exhibiting flow alteration. In most years, Sand Creek shows a modest stage increase of up to two feet, even during large precipitation events. This is most likely due to the expansive network of stormwater ponds located on the upper most reach of Sand Creek and its laterals. The outfall of Sand Creek can experience sudden hydrologic changes immediately following a storm common of a channelized urbanized stream. For example, a 2.07 inch precipitation event on June 21st, 2013 resulted in a 1.16 foot stage increase in a mere 2 hours. A visualization of the sharp increases in stream stage can be seen in (Figure 50). Flashy flows in Sand Creek also multiply the already flashy flows of Coon Creek since Sand Creek is a main tributary to Coon Creek.

Pleasure Creek is the most stable system in all of CCWD. Variations in stream stage rarely exceed one foot, even during large storms (Figure 51). Pleasure Creek has a similar degree of channelization and surrounding land use as Springbrook Creek so it would be easy to assume the hydrographs should be similar. A closer look at the two streams shows one major difference. Pleasure Creek flows through two different networks of stormwater ponds (Figure

47). The first network of ponds is in the upper portion of the watershed and the second is located northeast of East River Road toward the lower third of the system. Both of these pond networks provide significant storage and rate control for stormwater. Without the stormwater pond network on Pleasure Creek, hydrologic "flashiness" would be likely resemble Springbrook Creek since channel morphology and land use characteristics are very similar.

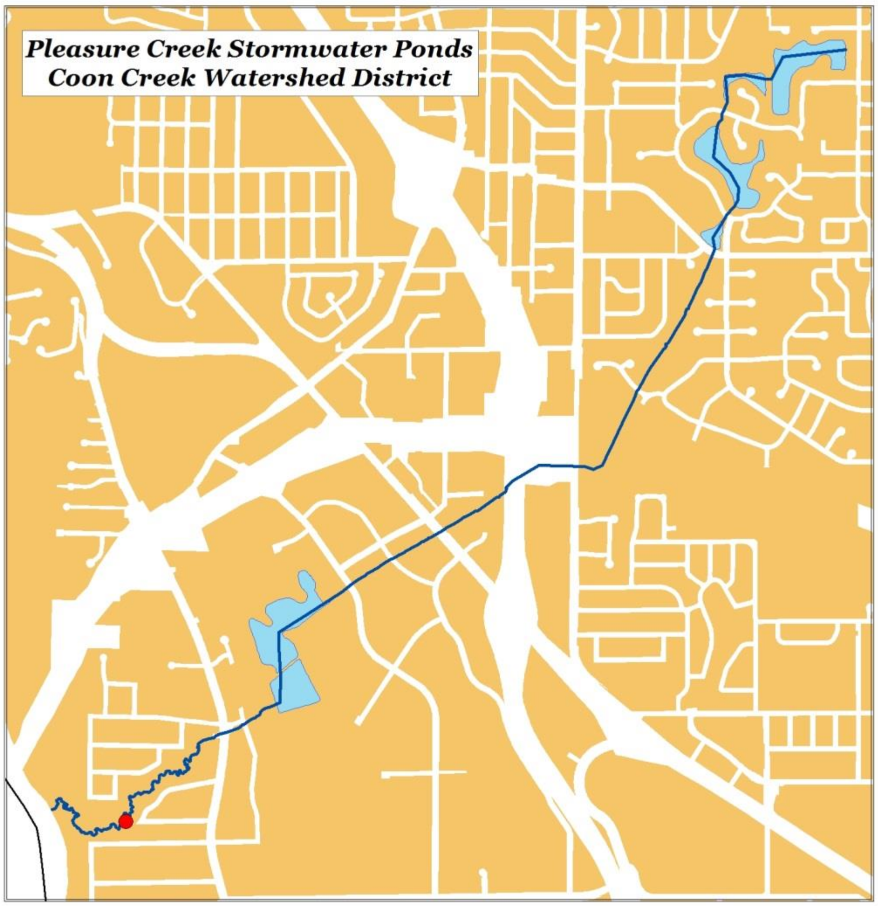

Figure 47. Locations of major stormwater ponds along Pleasure Creek. Red dot locates biological monitoring station 00UM062 and location where hydrograph data was collected

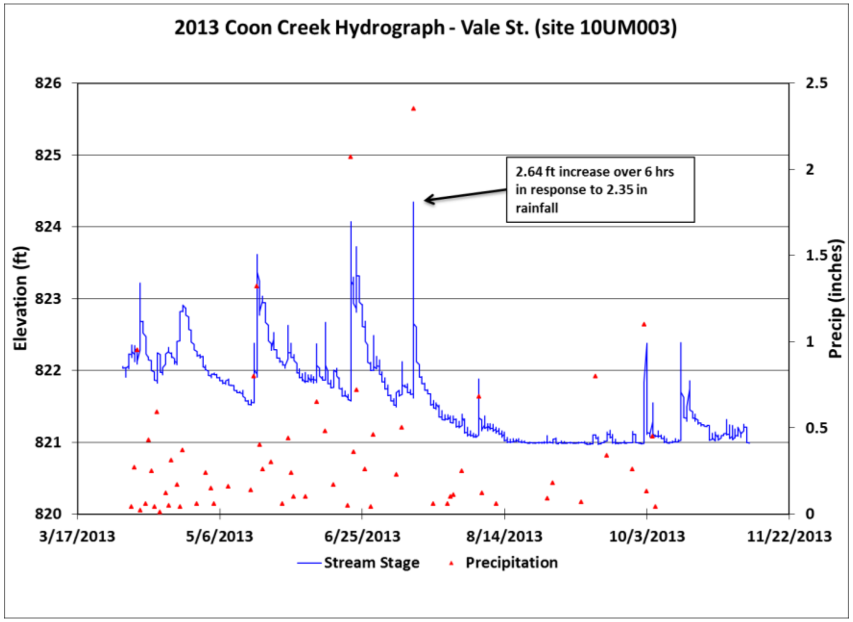

Figure 48. 2013 Hydrograph for Coon Creek at monitoring site 10UM003.

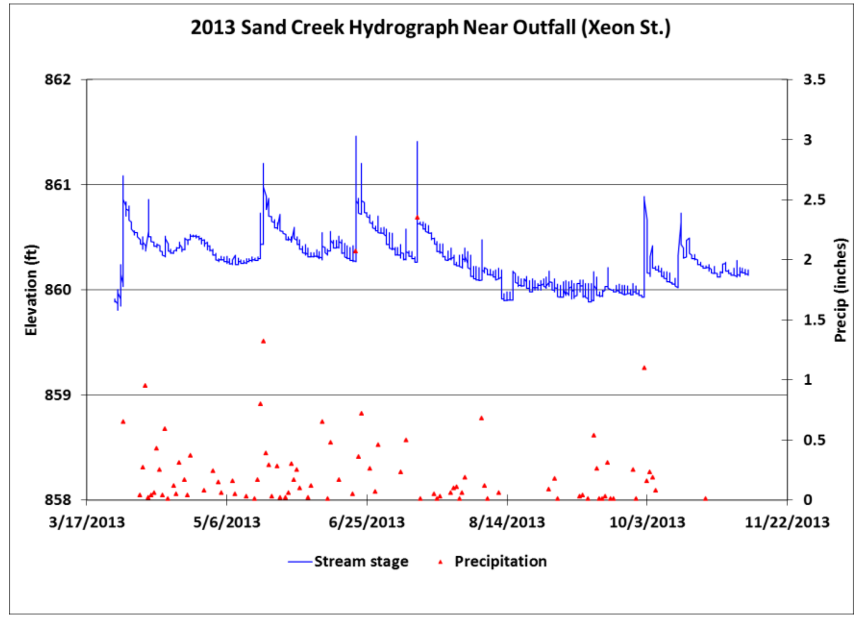

Figure 50. 2013 Sand Creek Hydrograph near monitoring site 00UM065.

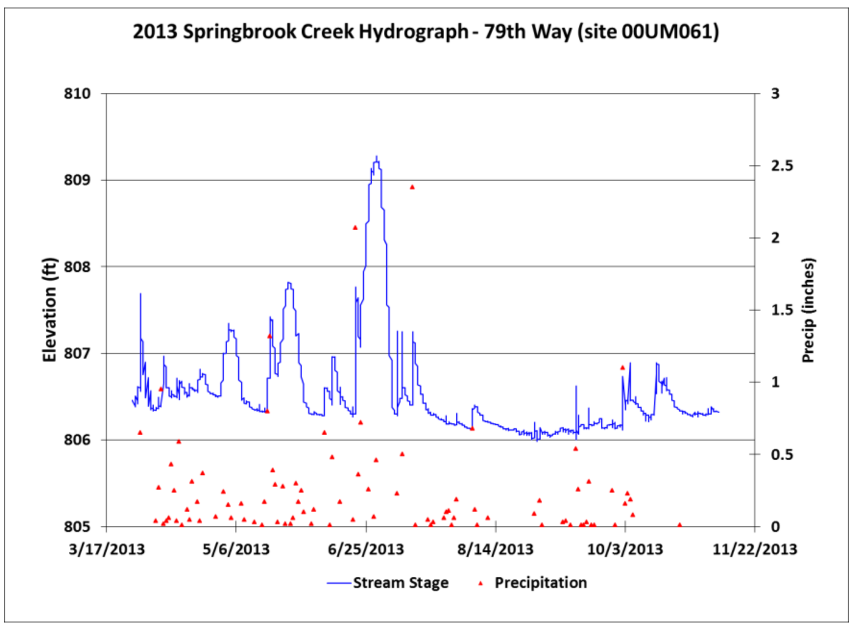

Figure 49. 2013 Springbrook Creek Hydrograph at monitoring site 00UM061.

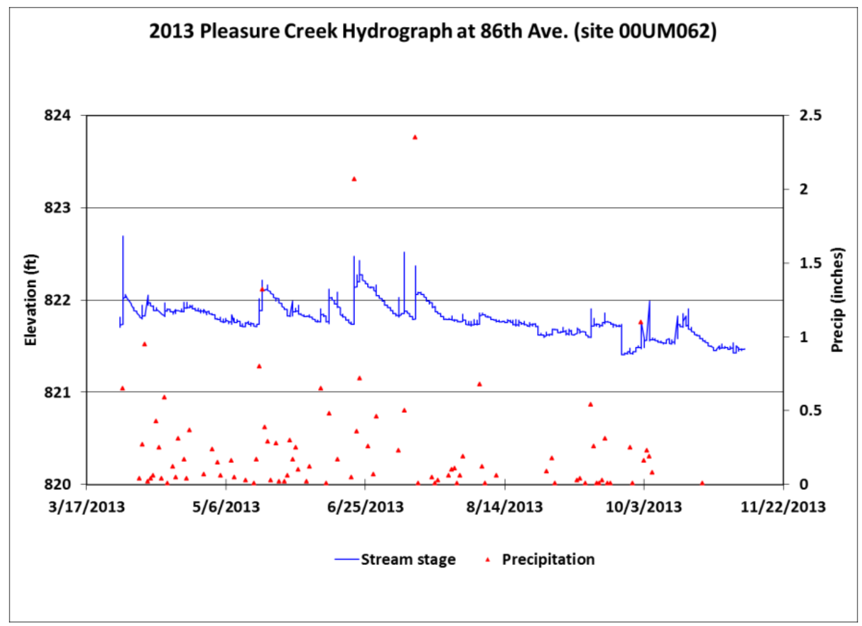

Figure 51. Pleasure Creek Hydrograph at monitoring site 00UM062.

The trapezoidal design of channelized ditches allows for efficient transport of water (Figure 52). The ability of these trapezoidal channels to contain and quickly transport high flows is what makes them an attractive design for flood protection. Unfortunately, this design often results in high peak velocities and flashiness as demonstrated by the hydrographs shown above.

Figure 52. Geometry of constructed agricultural ditches across CCWD.

Causal Analysis – Biological Response to Altered Hydrology

High flows can cause the physical dislodgement of fish and macroinvertebrates if they are unable to seek refuge in tributaries or refuges outside of the main stream channel. Stream flashiness can be particularly detrimental to biological assemblages because even if refuge is available, sudden increases in velocity reduce the period of time organisms have to seek out these habitats.

Increased stream velocity can also increase the mobilization of sediment, woody debris, and plant material. The mobilization of these materials can dislodge organisms. When the interval between high velocity events becomes more frequent, species that do not manage well under those conditions will be reduced or eliminated, leading to altered populations and decreased species richness. Those species remaining are often those with shorter life strategies who can complete their reproductive cycle within the confines of the recurrence interval of high flows.

The composition of fish communities in Coon Creek suggests frequent high flows have indeed altered populations. Lower Coon Creek, the flashiest portion of the district, is home to high numbers of generalist species with short life cycles and considered tolerant of stream degradation (Figure 53). A study conducted by Poff and Allan in 1995 concluded that generalist and tolerant species are dominant in streams exhibiting variable flow compared to streams with more stable hydrology.

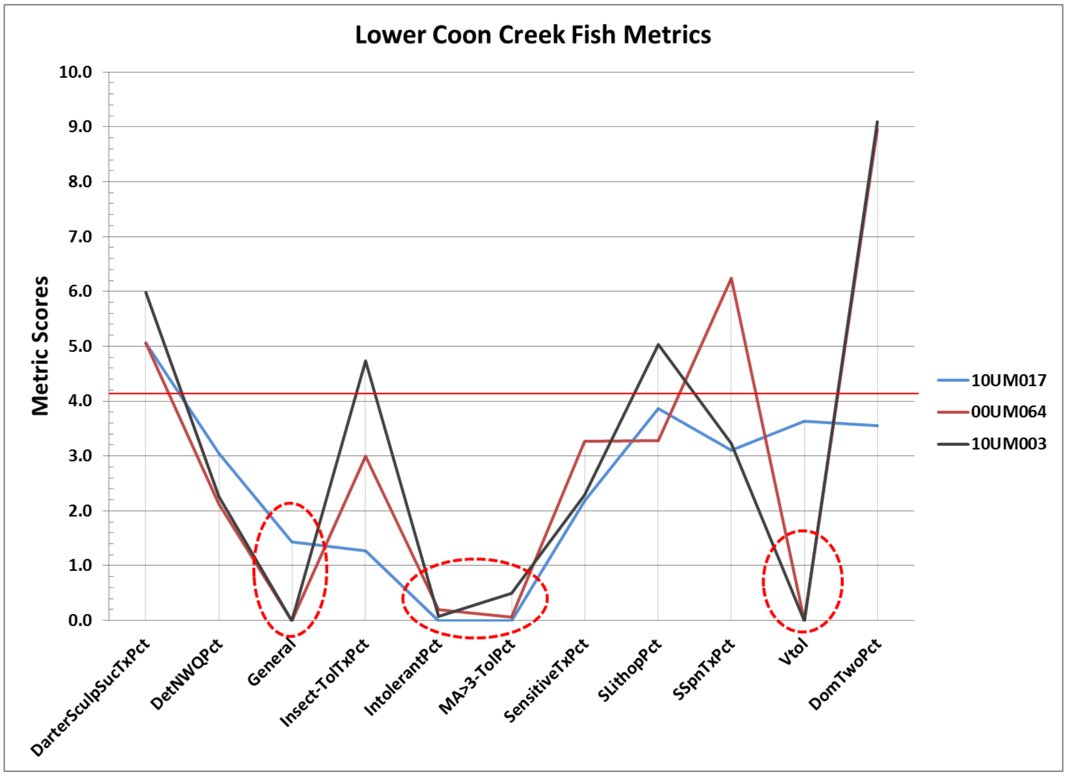

Figure 53. Biologic metric scores for lower Coon Creek. Metrics "General", "IntolerantPct", "MA>3-TolPct", and "Vtol" score poorly indicative of stress related to high flows.

Large representations of generalist and tolerant species are not limited to Coon Creek. The dominance of these groups is found in fish assemblages of Sand Creek as well; the second stream with a deferred fish impairment. The percentage of generalist fish species accounted for over 80% of all fish sampled which is nearly double the median of all non-impaired UMRB sites. Tolerant species accounted for 88% of the total sample, roughly 1.5 times non-impaired UMRB median values (Figure 54).

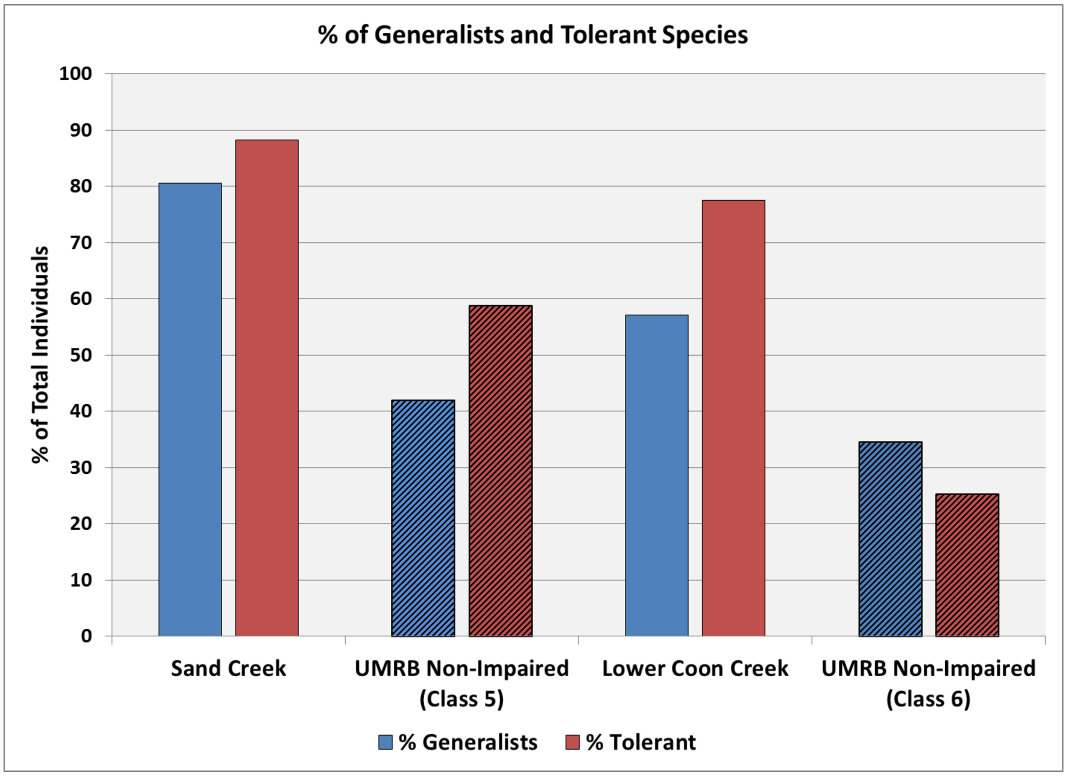

Figure 54. % of generalist and tolerant species in stream reaches with pending fish impairments.

Behavioral traits of macroinvertebrates can also provide insight into hydrologic conditions. Behavioral traits are habits exhibited by macroinvertebrates in relation to their surroundings (Merrit *el al*., 1996). Most macroinvertebrates are assigned to one of five categories, called behavioral classifications (Table 24). Analysis of the proportion of one classification to another can provide clues toward conditions macroinvertebrates are experiencing. For example, in still standing or slow moving water, a disproportionate number of "swimmer" and "burrower" macroinvertebrates would be expected. The reasoning for the shift is the lower physiological expense for swimmers at these sites and the increased sediment deposition for burrowers, which prefer soft bottom substrate. Figure 55 shows the proportions of these five behavioral classifications in impaired CCWD reaches. All but two sites show a stronger representation of clinging macroinvertebrates than non-impaired UMRB sites. Site 10UM003, the furthest downstream monitoring site on Coon Creek, is where hydrology is most variable. This site is dominated by clinging and sprawling macroinvertebrates, two classifications well adapted to manage high flows. There is also a very small representation of swimming macroinvertebrates, a classification not well suited for fluctuating flows. Without refuge, swimmer macroinvertebrates are extremely susceptible to washout when flow increases occur.

Pleasure Creek, a stream with stages rarely fluctuating more than one foot, exhibits a large number of clinging and sprawling invertebrates. This is not the expected response of the macroinvertebrate community since high flows are not an issue as indicated by the stream hydrograph. However, only two habitat types were sampled at this site; 1) riffles, run, rocks, and 2) snags, woody debris, and root wads. Both of these habitat types are highly favorable to clinging invertebrates so this likely accounted for the higher than expected numbers of this behavioral classification rather than biological response to altered hydrology. All other stream reaches in CCWD had a more equal distribution of habitat types sampled such as undercut banks, overhanging vegetation, and aquatic macrophytes.

Table 24. Macroinvertebrate behavioral classifications.

Habit	Definition
Burrowers	Live in fine sediments on stream bottom, particularly depositional areas
Climbers	Dwell on live aquatic plants or decaying organic detritus
Clingers	Maintain a relatively fixed position on firm substrates in current often through use of morphological or physiological adaptations (i.e., suckers, tarsal claws, dorsoventral flattening)
Sprawlers	Reside on surfaces of leaves or on top of find sediments
Swimmers	Adapted for movement in open water column through fish-like movements

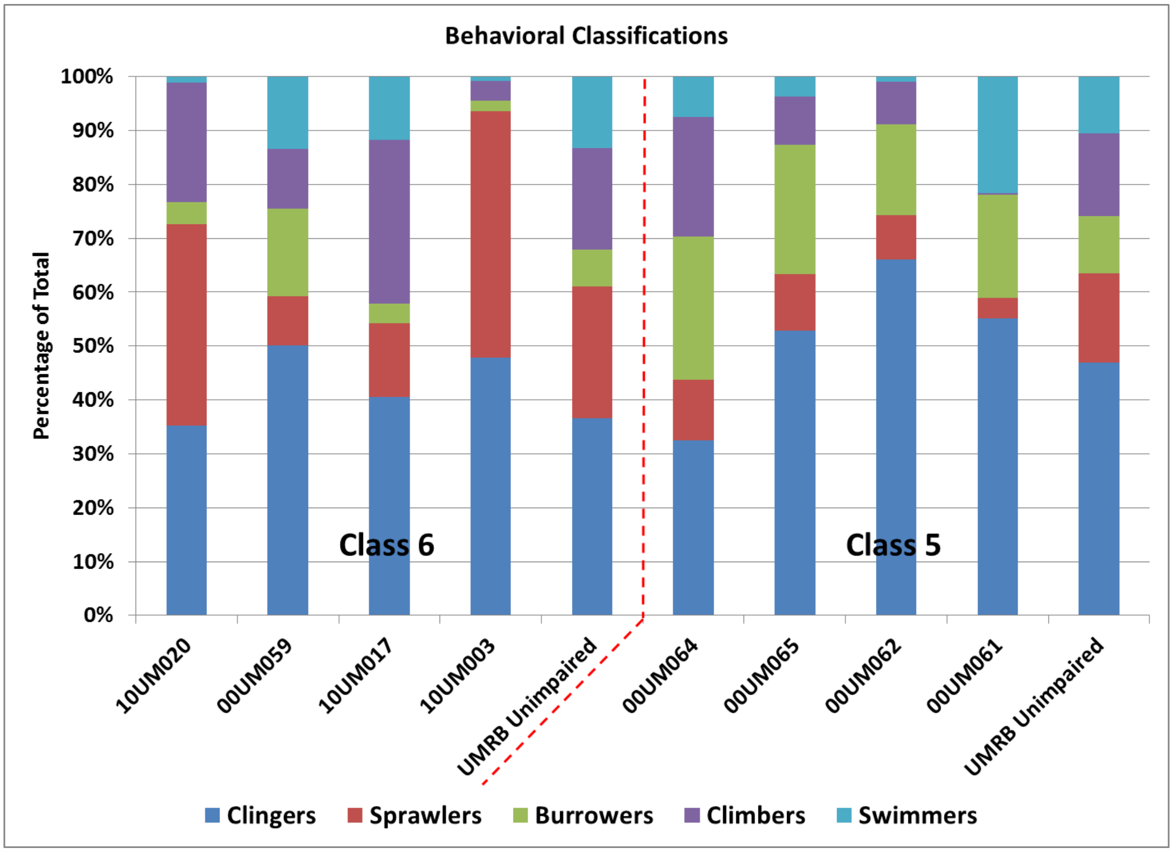

Figure 55. Proportion of each habit classification compared to unimpaired UMRB sites. Red line separates class 6 from class 5 classification.

Strength of Evidence Summary for Altered Hydrology

Urbanization and stream channelization are common across the landscape of CCWD and the effect on biological assemblages is apparent. Lack of long lived species in conjunction with an abundance of tolerant and generalist fish is evidence that variable flows have induced biological response in fish assemblages of Coon and Sand Creek. The abundance of clinger macroinvertebrates and weak representation of free swimming macroinvertebrates suggests that high flows are impacting macroinvertebrate assemblages as well. Stream hydrographs suggest Coon, Sand, and Springbrook Creek are all flashy systems. Pleasure Creek does not exhibit the same stage increases in response to storm events eliminating the co-occurrence of candidate cause and observed effect for this reach. Strength of evidence for channelization is shown below (Table 25). For information on scoring, please see Appendix D.

Table 25. Weight of evidence for channelization as a candidate stressor.

Strength of Evidence Table – Altered Hydrology				
	Scores for Impaired Reaches			
Types of Evidence	Coon Creek	Sand Creek	Pleasure Creek	Springbrook Creek
Spatial/Temporal co-occurrence	+	+	-	+
Evidence of exposure, biological mechanism	+	+	- -	+
Causal pathway	+	+	0	+
Field evidence of stress response	+	+	0	+
Field experiments/manipulation of exposure	0	0	0	0
Laboratory analysis of site media	0	0	0	0
Temporal sequence	0	0	0	0
Verified or tested predictions	+	+	0	+
Symptoms	+	+	+	+
Mechanistically plausible cause	+	+	+	+
Stressor-response in other field studies	++	++	++	++
Stressor-response in other lab studies	NE	NE	NE	NE
Stressor-response in ecological models	+	+	0	+
Manipulation experiments at other sites	NE	NE	NE	NE
Analogous stressors	NE	NE	NE	NE
Consistency of evidence	+	+	0	+
Explanatory power of evidence	++	++	0	++

8.6 Candidate Cause #6 - Chlorides

Numerous studies have been conducted in an attempt to quantify the tolerable salinity ranges for numerous species of fish. Evens and Frick (2001) summarized a number of studies investigating salinity tolerance for fish and concluded that observed mortality began when long term exposure (greater than 7 days) to chloride concentrations reached 1,000 mg/L. A study conducted by Crowther and Hynes (1977) examining the salinity tolerance of macroinvertebrates showed similar ranges of tolerance compared to fish. Crowther and Hynes concluded that the addition of road salts (a common source of chlorides) to experimentally modified streams did not promote organism drift, behavioral changes, or cause mortality until concentrations reached 1,000 mg/L. Even at a concentration of 1000 mg/L, the increase in organism drift was only observed in one of eight taxa studied. These studies suggest an acute standard of 860 mg/L is conservative and well suited to prevent significant harm to aquatic life.

Sources and Pathways of Chlorides

Various sources of pollutants can increase chloride concentrations (i.e., industrial sources, wastewater, and urban runoff). In urbanized watersheds, such as Pleasure and Springbrook Creek, de-icing practices are thought to be a significant contributor of increased chloride concentrations. Miles of local, county, and state highways exist in the Pleasure and Springbrook Creek subwatersheds create a clear spatial connection for chloride introduction to surface waters.

Water Quality Data – Chlorides

The chloride standard for the state of Minnesota is separated into an acute and chronic standard. The acute standard of 860 mg/L for greater than one hour and the chronic standard of 230 mg/L for a four day average are based on fish toxicity levels. A stream is considered impaired if the acute standard is exceeded once or more in a consecutive three year period. The chronic standard has a threshold of two or more exceedances in a consecutive three year period.

An examination of chloride concentrations in surface waters of CCWD indicates concentrations fall below state standards but have exceeded 230 mg/L on occasion (Table 26). A total of 387 samples have been collected on biologically impaired reaches and only 5 samples (1.3%) have exceeded the chronic level of 230 mg/L. The stream reach with the highest chloride concentration is Springbrook Creek. Springbrook Creek exceeded the chronic standard on two occasions in 2012 (245 mg/L, 253 mg/L). Despite exceeding 230 mg/L, it is unknown if this concentration was sustained over a four day average as required for impairment determination. Overall, exceedances are not blatant and considered short term exposure, which has been shown to have a negligible effect on biological assemblages (Blasius and Merritt 2002). The acute standard of 860 mg/L has not been exceeded as evidenced by a maximum reading of 279 mg/L in all of CCWD. Long term trends of chloride levels in CCWD are difficult to assess for Springbrook and Pleasure Creeks (Figure 56). Springbrook Creek only has one year of sampling data so analysis of a long term trend is unattainable. Pleasure Creek has a more robust data set but does not have sampling from 2010 and 2011 making trend analysis imprecise.

Table 26. Chlorides summary for biologically impaired reaches.

Stream Reach	Year	N	Mean	Median	Max	# samples >230 mg/L	MN Standard
Coon Creek	2005-2012	191	47	46	102	0	Acute 860 mg/l Chronic 230 mg/L
Sand Creek	2007-2012	144	67	66	279	1	
Springbrook Creek	2012	12	172	191	253	2	
Pleasure Creek	2006, 2007, 2008, 2009, 2012	48	120	125	262	2 (not within consecutive 3 yr period)	

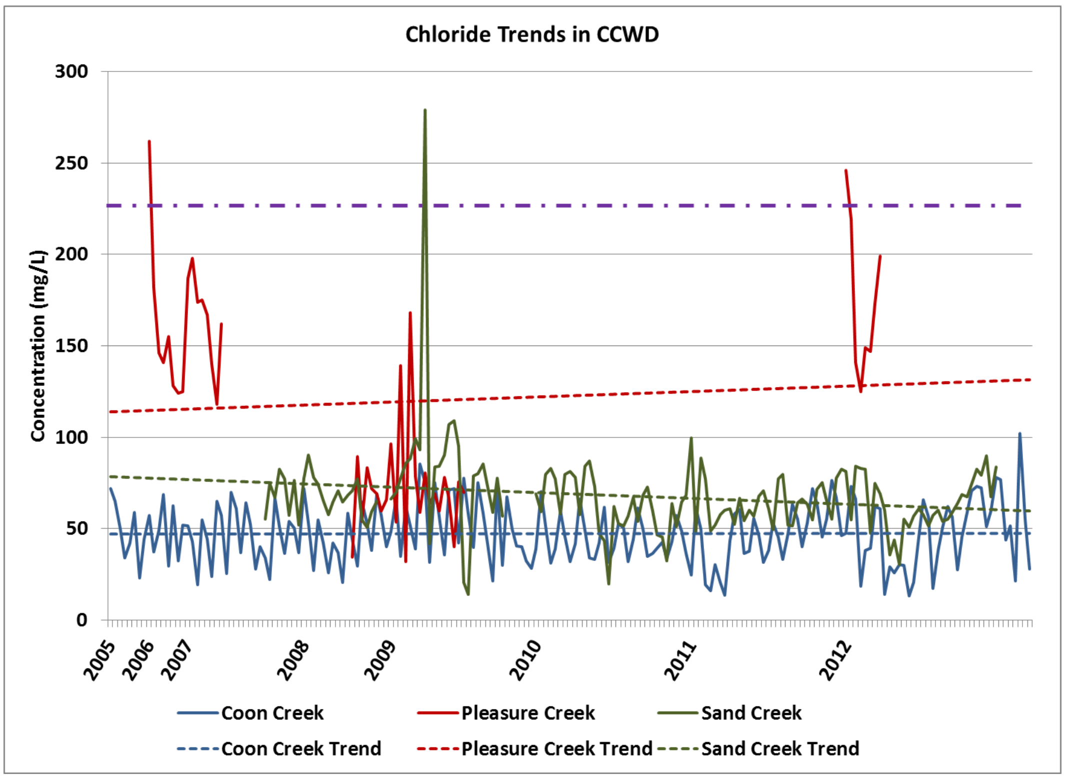

Figure 56. Long term chloride concentrations for Coon Creek, Sand Creek, and Pleasure Creek. Dashed colored lines show chloride trend for each stream reach. Dashed purple line indicates chronic standard of 230 mg/L

Mean chloride concentration for Pleasure and Springbrook Creeks were higher than Coon and Sand Creeks, most likely due to the more urbanized land use. The eight year trend for chlorides in Coon Creek is relatively unchanged since monitoring began in 2005. Sand Creek is showing an overall decrease in chloride concentrations but also exhibits slightly higher average concentration than Coon Creek.

Causal Analysis – Biological Response to Chlorides

Since Springbrook Creek experiences chloride concentrations higher than any other reach in CCWD, biological impacts resulting from excess chloride would first be observed in this reach. Literature on salinity tolerance for specific species of fish and macroinvertebrates is limited, especially at concentrations observed in Springbrook Creek. As mentioned above, most biological responses aren't observed until concentrations reach 1,000 mg/L (Crowther and Hynes. 1977). Ephemeroptera are considered to be sensitive to many forms of degradation, including salinity. A study conducted by Dunlop *et al*. (2007) found Ephemeroptera to be the most saline sensitive order of macroinvertebrates. MPCA data shows 21.7% of all macroinvertebrates sampled in Springbrook Creek belong to the Order Ephemeroptera. This aligns closely with other non-impaired streams in the UMRB (21.5% Ephemeroptera). If chlorides were indeed impacting biological assemblages, it would be expected to see a much smaller representation of salinity sensitive macroinvertebrates such as Ephemeroptera.

Based on the evidence above, it is inconclusive if chlorides are a candidate cause for biological impairment. Water quality data shows exceedances of the chronic limit have occurred however the biologic assemblages do not show evidence of stressor response. Much of the chloride data for CCWD falls between the months of May and October. Research suggests chloride concentrations increase outside this monitoring period due to the increased use of road de-icing salts during winter months (Thomas et al. 2007). Expansion of water quality monitoring efforts into winter months would provide a better picture of the chloride concentrations in Springbrook Creek. It is recommended that CCWD subscribe to expanded winter monitoring in upcoming monitoring efforts.

Strength of Evidence Summary for Chlorides

Urbanization and corresponding road de-icing practices are common across the landscape of CCWD, specifically in the Pleasure and Springbrook Creek subwatersheds. Water quality exceedances above 230 mg/L are observed but these instances are rare. Biological assemblages do not show clear effects linked to excessive chlorides. The percentage of macroinvertebrates belonging to the saline sensitive Ephemeroptera Order aligned with other non-impaired streams in the UMRB. Time of exposure is an important factor when analyzing the biological effects of chloride. It is possible the exceedances observed in Springbrook Creek are brief and occur infrequently enough that chlorides are not limiting biotic assemblages. Strength of evidence for chlorides is shown below (Table 27). For information on scoring, please see Appendix D.

Table 27. Weight of evidence for chlorides as a candidate cause.

Strength of Evidence Table – Chlorides				
	Scores for Impaired Reaches			
Types of Evidence	Coon Creek	Sand Creek	Pleasure Creek	Springbrook Creek
Spatial/Temporal co-occurrence	0	0	- - -	- - -
Evidence of exposure, biological mechanism	- -	- -	+	+
Causal pathway	+	+	+	+
Field evidence of stress response	0	0	0	0
Field experiments/manipulation of exposure	0	0	0	0
Laboratory analysis of site media	NE	NE	NE	NE
Temporal sequence	0	0	0	0
Verified or tested predictions	0	0	0	0
Symptoms	0	0	- - -	- - -
Mechanistically plausible cause	0	0	0	0
Stressor-response in other field studies	0	0	0	0
Stressor-response in other lab studies	NE	NE	NE	NE
Stressor-response in ecological models	+	+	+	+
Manipulation experiments at other sites	NE	NE	NE	NE
Analogous stressors	NE	NE	NE	NE
Consistency of evidence	+	+	+	+
Explanatory power of evidence	++	++	++	++

9.0 Summary and Recommendations

The Coon Creek Watershed District has four different stream reaches with macroinvertebrate impairments: Coon Creek, Sand Creek, Pleasure Creek, and Springbrook Creek. In addition, Coon Creek and Sand Creek have impairments for fish assemblages but those have been deferred until the upcoming release of TALU. Also, CCWD has been added to the Draft 2014 Impaired Waters List for violation of aquatic recreation standards due to elevated *E. coli* concentrations on Coon Creek, Pleasure Creek, and Springbrook Creek. Multiple causes for the various impairments were found on all stream reaches.

Dissolved oxygen was a clear stressor in upper reaches of Coon Creek as evidenced by frequent water quality samples experiencing concentrations below 5 mg/L. IBI scores for macroinvertebrates were below impairment thresholds at all headwater sites. Macroinvertebrate communities lacked EPT taxa, a metric considered sensitive to low dissolved oxygen. Fish IBI scores indicated impairment in one of two samples. The sample that suggested a healthy fish community was slightly misleading since overall scores were driven up by a high percentage of headwater and minnow species. These metrics are driven by species that prefer quiescent pools with abundant cover but are metrics with minimal response to low dissolved oxygen. Fish assemblages sampled in adjacent reaches were dominated by species considered tolerant of low dissolved oxygen. Dissolved oxygen levels rebounded further downstream likely due to increased distance from Carlos Avery WMA. Where DO levels rebound, a higher number of EPT taxa were found strengthening the co-occurrence between low DO and observed biological impairments. Factors causing low DO in Coon Creek headwaters were excess phosphorus from nutrient rich soils and the proximity to the Carlos Avery WMA.

Excess sediment was the second identified stressor in CCWD. Sediment can present issues when increased suspended sediment and/or increased bedded sediment are present. High, erosive flows resulting from channelization and urbanization can cause increased sediment loads and hamper both fish and macroinvertebrate assemblages. In Coon and Sand Creek, the lack of visual feeding fish (i.e., minnows, sunfish), suggested that excess suspended sediment was problematic to this feeding guild. Excess sediment creates turbid conditions which hinders the ability of these families to see their prey. In response, fish assemblages will often shift toward species who feed via sensory or olfactory indicators (i.e., catfish, suckers). In lower Coon Creek where TSS levels were at their highest, olfactory feeding fish were dominant over sight feeding fish providing evidence that suspended sediment was altering biological assemblages. Sources of sediment in CCWD are urban stormwater, in-stream sediment agitation, bank erosion, and soil erosion stemming from construction and agricultural activities.

Phosphorus was also identified as a candidate cause for biological impairment. High concentrations of phosphorus have been recorded district wide although its greatest impact was observed in Coon Creek headwaters. Phosphorus itself is not toxic to aquatic life but can contribute to excessive vegetation growth resulting in low dissolved oxygen levels. Dense macrophytes and duckweed blooms have been documented along upper reaches of Coon Creek, a direct result of excess phosphorus. The biological response to low DO as a result of excess phosphorus was detailed above. Throughout the rest of the district, biological response to excess phosphorus was observed. A measure of planktivorous and detritivorous feeding guilds (fish) showed higher percentages across Coon and Sand Creek compared to median values of other non-impaired UMRB sites. Planktivores and detritivores are species of fish which feed on organic matter in the water column. Excess phosphorus is often indicative of a large amount of organic matter available. Increased organic matter allows for increased numbers of planktivores and detritivores. An increase in planktivores and detritivores does not indicate impairment however does show biological response to excess phosphorus. High phosphorus levels in CCWD are driven by hemist soils rich in nutrients, urban stormwater, and soil erosion containing sediment bound phosphorus.

Alteration of habitat was another cause of impairment in CCWD. MSHA habitat scores fell predominantly in the fair to fair-poor category across CCWD. Lower Coon Creek achieved a good standing in terms of overall MSHA but previously mentioned stressors likely impacted biological assemblages in that area. In general, fish assemblages showed a positive correlation with habitat across all monitoring sites. Tolerant fish, benthic insectivores, serial spawning species, and number of darter/sculpin/round bodied suckers in Coon and Sand Creek all responded as expected to habitat degradation. Macroinvertebrate metrics "Tolerant" and "ClingerPct" also responded as predicted in impaired reaches. Despite the observed biological effects of altered habitat, water quality is inducing more stress response than habitat. This is evident in lower Coon Creek, where habitat scored well. If habitat was the most significant detriment to bioligcal assemblages, it would be expected to see strong IBI scores at this site with adequate habitat. IBI scores did not show much change compared to other impaired reaches of CCWD highlighting the negative effects of poor water quality. Addressing the issue of altered habitat is difficult since the impaired reaches in CCWD act as stormwater conveyance channels. These are not typical "streams" as envisioned by most. Rather, these are channelized and highly altered constructed conveyance ditches. The publication of TALU standards have not occurred at the time of writing. TALU standards will provide information for the expected biological assemblage of stormwater conveyance channels relative to natural streams.

Altered hydrology was an identified stressor to the fish and macroinvertebrate communities within the CCWD. Urbanized landscapes and channelized streams are common throughout CCWD. Both of these practices lead to increased peak flows. A common biological response to high flows is a shift in community composition from long lived species toward species with shorter life strategies. Reaches with pending fish impairments had very few long lived species compared to other UMRB sites. The Coon and Sand Creek fish communities were dominated by tolerant and generalist species, a shift commonly found in streams with highly variable flow. Macroinvertebrate assemblages also showed biological response to increased flows as a result of urbanization and channelization. A disproportionate number of clinger taxa and sprawler taxa were observed compared to free swimming macroinvertebrates. This suggested that communities have shifted toward species reliant on fixed substrate or those with body adaptations allowing them to tolerate flashy flows.

Chlorides were analyzed as a potential cause and results were inconclusive. Exceedances of state chloride standards do occur but they are rare and narrowly violate numerical thresholds. Studies presented indicated that biological effects are generally not observed until concentrations approach 1,000 mg/L, hence the acute standard of 860 mg/L. Recorded water quality data does not indicate concentrations reach this level but winter monitoring has not been conducted. This is important since chloride concentrations are expected to peak during winter and late spring snowmelt events. Springbrook Creek has the highest chloride concentration of all impaired reaches in CCWD; therefore it would be expected for biological effects to arise here first. Analysis of Ephemeroptera, a saline sensitive mayfly, showed populations similar to non-impaired UMRB sites. To better evaluate chloride concentrations in CCWD, chloride monitoring should be expanded to include winter months.

Impaired stream reaches in CCWD are impacted by some combination of the aforementioned candidate causes. Of the identified stressors, evidence was strongest for excess phosphorus and altered habitat as the most widespread, followed by excess sediment, and altered hydrology (Table 28). The identification of altered habitat as a primary stressor came as little surprise since the CCWD is a heavily channelized network of stormwater conveyance channels. Maintaining these channels for efficient transport of water is an important component of the District’s flood control strategy. Unfortunately, maintenance for efficient transport of water is not conducive to promoting quality habitat. Furthermore, evidence suggests impaired biotic assemblages do occur in areas of CCWD with sufficient habitat making the case that water quality is more detrimental than habitat quality. Therefore, implementation activities should focus on controlling excess phosphorus, excess sediment, and altered hydrology before addressing habitat. More specifically, control of excess phosphorus and excess sediment during storm flows will be beneficial to the biological health of the Coon Creek system.

Table 28. Primary stressors to aquatic life in biologically impaired reaches in the Coon Creek Watershed District. (●)=primary stressor, (○)=not a stressor, and (/)=inconclusive evidence.

HUC-8 Subwatershed	AUID (Last 3)	Stream	Reach Description	Biological Impairment	Primary Stressor					
					Dissolved Oxygen	Excess Sediment	Phosphorus	Altered Habitat	Altered Hydrology	Chlorides
07010206 Mississippi River-Twin Cities	530	Coon Creek	Unnamed Cr. to Mississippi R.	Macroinvertebrates	●	●	●	●	●	/
				Fish (Deferred)	●	●	●	●	●	/
	594	Unnamed Ditch *Pleasure Creek*	Headwaters to Mississippi R.	Macroinvertebrates	○	●	●	●	○	/
	558	Sand Creek	Unnamed Cr. to Coon Cr.	Macroinvertebrates	○	●	●	●	●	/
				Fish (Deferred)	○	●	●	●	●	/
	557	County Ditch 17 Springbrook Creek	Headwaters to Mississippi R.	Macroinvertebrates	○	/	●	●	●	/

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APPENDIX A

Fish and Macroinvertebrate Sampling Data (listed by station)

Biological Station Information 10UM003

Stream Name:	COON CREEK
Waterbody Name:	Coon Creek
Data Steward Org:	MPCA
Station ID:	10UM003
Hydrologic Unit Code (HUC):	07010206
Assessment Unit:	07010206-530
Period of Record:	2010 through 2010
Drainage Area (square miles)	91.60
Lat/Lon	45.14457,-93.29646
Land Use	Agricultural 7.7% Forest 21.8% Range 17.9 % Urban 34.5 % Water 1.1 % Wetland 16.9 % Other 0.0 %

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Site Index of Biological Integrity	
Category	IBI/Rating
Visit Year	2010 (2nd visit)
Fish IBI	No Visit
Fish Rating	
Invertebrate IBI	28

Year 2010 Data	
Site Index of Biological Integrity	
Category	IBI/Rating
Visit Year	2010
Fish IBI	33
Fish Rating	
Invertebrate IBI	49

Year 2010 Data			
Fish species found at this site			
Species	Count	Min Length (mm)	Max Length (mm)
Bigmouth Buffalo	1	335	335
Bigmouth Shiner	24	49	72
Black Bullhead	2	110	226
Blacknose Dace	1	56	56
Blackside Darter	19	65	94
Bluegill	1	57	57
Bluntnose Minnow	2	45	46
Brook Stickleback	2	29	39
Central Mudminnow	3	68	78
Channel Catfish	1	460	460
Common Carp	5	521	598
Common Shiner	42	46	169
Creek Chub	19	65	135
Fathead Minnow	24	38	67
Freshwater Drum	1	407	407
Green Sunfish	30	47	110
Hornyhead Chub	7	47	55
Iowa Darter	2	33	61
Johnny Darter	2	33	61
Largemouth Bass	3	37	335
Longnose Dace	1	80	80
Northern Pike	3	259	425
Sand Shiner	35	39	78
Shorthead Redhorse	1	471	471
Silver Redhorse	2	558	579
Spotfin Shiner	1	89	89
White Sucker	37	60	349

Year 2010 Data
Invertebrates that were found at this site
Amphipods
Biting Midges
Black Flies
Broad-Winged Damselflies
Caecidotea
Circular-Seamed Flies
Darners
Flatworms
Maccaffertium
Marsh Beetles
Mayflies
Midges
Net-Spinning Caddisflies
Orconectes
Riffle Beetles
Spring Stoneflies
Water Scavenger Beetles
Water Striders

Year 2010 (2nd Visit) Data
Invertebrates that were found at this site
Amphipods
Biting Midges
Black Flies
Broad-Winged Damselflies
Caecidotea
Circular-Seamed Flies
Darners
Flatworms
Maccaffertium
Marsh Beetles
Mayflies
Midges
Net-Spinning Caddisflies
Orconectes
Riffle Beetles
Spring Stoneflies
Water Scavenger Beetles
Water Striders

Year 2010 Data	
Fish attributes that were found at this site	
Attribute	Count
DELT (abnormalities)	2
Darter species	3
Exotic species	1
Fish per 100 m	67.4
Game fish species	5
Gravel spawning species	7
Piscivore species	3
Pollution intolerant species	1
Special concern species	0
Total species	27

Year 2010 Data

Attributes regarding the invertebrates that were found at this site	
EPT Taxa	4
Ephemeroptera Taxa	2
Hilsenhoffs Biotic Index (HBI)	4.3
Intolerant Families	1
Percent Pollution Tolerant	1.9
Percent Chironomidae	7.1
Percent Diptera	9.3
Percent Dominant Taxa	39.8
Percent Dominant Two Taxa	70.8
Percent Filterers	32
Percent Gatherer	59.6
Percent Hydropsychidae	31.1
Percent Scraper	6.5
Plecoptera Families	1
Total Families	18
Trichoptera Families	1

Year 2010 (2nd Visit) Data	
Attributes regarding the invertebrates that were found at this site	
EPT Taxa	4
Ephemeroptera Taxa	3
Hilsenhoffs Biotic Index (HBI)	4.2
Intolerant Families	0
Percent Pollution Tolerant	.3
Percent Chironomidae	5.7
Percent Diptera	7.6
Percent Dominant Taxa	44.5
Percent Dominant Two Taxa	76
Percent Filterers	32.2
Percent Gatherer	61.5
Percent Hydropsychidae	31.5
Percent Scraper	4.7
Plecoptera Families	0
Total Families	12
Trichoptera Families	1

Biological Station Information 00UM064

Stream Name:	COON CREEK
Waterbody Name:	Coon Creek
Data Steward Org:	MPCA
Station ID:	00UM064
Hydrologic Unit Code (HUC):	07010206
Assessment Unit:	07010206-530
Period of Record:	2000 through 2000
Drainage Area (square miles)	87.29
Lat/Lon	45.17203817,-93.30095797
Land Use	Agricultural 8.1% Forest 22.4% Range 18.7 % Urban 32.1 % Water 1.2 % Wetland 17.7 % Other 0.0 %

Year 2000 Data	
Site Index of Biological Integrity	
Visit Year	2000
Fish IBI	32
Fish Rating	
Invertebrate IBI	57
Invertebrate Rating	

Year 2000 Data			
Fish species found at this site			
Species	Count	Min Length (mm)	Max Length (mm)
Bigmouth Shiner	31	51	80
Black Bullhead	4	119	146
Black Crappie	11	87	104
Blacknose Dace	11	30	80
Blackside Darter	3	46	75
Bluegill	1	101	101
Central Mudminnow	16	32	88
Common Carp	10	420	600
Common Shiner	14	64	112
Creek Chub	17	34	43
Fathead Minnow	80	36	61
Green Sunfish	83	45	109
Hybrid Sunfish	5	55	106
Iowa Darter	14	30	47
Johnny Darter	45	25	59
Longnose Dace	3	33	103
Pumpkinseed	1	54	54
Smallmouth Bass	1	395	395
White Sucker	77	33	385

Year 2000 Data
Invertebrates that were found at this site
Amphipods
Balloon Flies
Biting Midges
Black Flies
Branchiobdellida
Broad-Winged Damselflies
Crane Flies
Darners
Decapoda
Electric Light Bugs
Finger-Net Caddisflies
Fingernail Clam
Flatworms
Gastropods
Grass Moths
Long-Horn Caddisflies
Marsh Beetles
Marsh Flies
Mayflies
Midges
Mosquitoes
Narrow-Winged Damselflies
Net-Spinning Caddisflies
Northern Caddisflies
Predaceous Diving Beetles
Riffle Beetles
Snout Beetles
Thienemannimyia Gr.
Water Boatman
Water Scavenger Beetles
Water Scorpions

Year 2000 Data	
Fish attributes that were found at this site	
Attribute	Count
DELT (abnormalities)	3
Darter species	3
Exotic species	1
Fish per 100 m	165.5
Game fish species	5
Gravel spawning species	5
Piscivore species	2
Pollution intolerant species	2
Special concern species	0
Total species	19

Year 2000 Data	
Attributes regarding the invertebrates that were found at this site	
EPT Taxa	7
Ephemeroptera Taxa	3
Hilsenhoffs Biotic Index (HBI)	4.9
Intolerant Families	1
Percent Pollution Tolerant	5.2
Percent Chironomidae	42.8
Percent Diptera	48
Percent Dominant Taxa	42.8
Percent Dominant Two Taxa	59.8
Percent Filterers	13.7
Percent Gatherer	55
Percent Hydropsychidae	11.4
Percent Scraper	18.5
Plecoptera Families	0
Total Families	27
Trichoptera Families	4

Biological Station Information 10UM017

Stream Name:	COON CREEK
Waterbody Name:	Coon Creek
Data Steward Org:	MPCA
Station ID:	10UM017
Hydrologic Unit Code (HUC):	07010206
Assessment Unit:	07010206-530
Period of Record:	2010 through 2010
Drainage Area (square miles)	68.93
Lat/Lon	45.18473,-93.31044
Land Use	Agricultural 8.9% Forest 25.4% Range 19.6 % Urban 24.0 % Water 1.3 % Wetland 20.8 % Other 0.0 %

Year 2010 Data	
Site Index of Biological Integrity	
Visit Year	2010
Fish IBI	27
Fish Rating	
Invertebrate IBI	47
Invertebrate Rating	

Year 2010 Data

Fish species found at this site

Species	Count	Min Length (mm)	Max Length (mm)
Bigmouth Shiner	283	36	82
Black Crappie	1	103	103
Blacknose Dace	21	42	75
Blackside Darter	1	68	68
Bluntnose Minnow	10	40	85
Brassy Minnow	2	71	74
Brook Stickleback	21	25	61
Central Mudminnow	27	69	107
Common Shiner	12	41	106
Creek Chub	30	65	180
Fathead Minnow	59	43	60
Golden Shiner	1	67	67
Hornyhead Chub	4	86	115
Hybrid Sunfish	37	48	135
Johnny Darter	84	49	76
Largemouth Bass	1	137	137
Mottled Sculpin	6	55	93
Pumpkinseed	2	62	62
White Sucker	204	67	263

Year 2010 Data
Invertebrates that were found at this site
Amphipods
Black Flies
Broad-Winged Damselflies
Caecidotea
Circular-Seamed Flies
Electric Light Bugs
Gastropods
Long-Horn Caddisflies
Maccaffertium
Mayflies
Micro-Caddisflies
Midges
Moth Flies
Narrow-Winged Damselflies
Net-Spinning Caddisflies
Oligochaeta
Orconectes
Pleid Water Bugs
Riffle Beetles
Water Striders

Year 2010 Data	
Attributes regarding the invertebrates that were found at this site	
EPT Taxa	6
Ephemeroptera Taxa	3
Hilsenhoffs Biotic Index (HBI)	6
Intolerant Families	0
Percent Pollution Tolerant	8.4
Percent Chironomidae	55.5
Percent Diptera	61.1
Percent Dominant Taxa	55.5
Percent Dominant Two Taxa	70.4
Percent Filterers	13.1
Percent Gatherer	78.2
Percent Hydropsychidae	8.4
Percent Scraper	1.6
Plecoptera Families	0
Total Families	18
Trichoptera Families	3

Year 2010 Data	
Fish attributes that were found at this site	
Attribute	Count
DELT (abnormalities)	2
Darter species	2
Exotic species	0
Fish per 100 m	287.9
Game fish species	3
Gravel spawning species	4
Piscivore species	2
Pollution intolerant species	0
Special concern species	0
Total species	19

Biological Station Information 10UM018

Stream Name:	COUNTY DITCH 58
Waterbody Name:	County Ditch 58
Data Steward Org:	MPCA
Station ID:	10UM018
Hydrologic Unit Code (HUC):	07010206
Assessment Unit:	07010206-636
Period of Record:	2010 through 2010
Drainage Area (square miles)	10.64
Lat/Lon	45.23368,-93.25418
Land Use	Agricultural 7.0% Forest 29.4% Range 23.5 % Urban 22.0 % Water 2.3 % Wetland 15.9 % Other 0.0 %

Year 2010 Data	
Site Index of Biological Integrity	
Visit Year	2010
Fish IBI	40
Fish Rating	
Invertebrate IBI	56
Invertebrate Rating	

Year 2010 Data			
Fish species found at this site			
Species	Count	Min Length (mm)	Max Length (mm)
Bigmouth Shiner	4	50	80
Blacknose Dace	6	75	98
Brassy Minnow	4	64	71
Brook Stickleback	23	25	55
Central Mudminnow	25	36	120
Common Carp	1	53	53
Creek Chub	4	29	127
Fathead Minnow	25	27	66
Green Sunfish	1	61	61
Johnny Darter	50	28	64
Mottled Sculpin	6	75	99
Northern Redbelly Dace	5	28	33
White Sucker	13	42	149

Year 2010 Data
Invertebrates that were found at this site
Amphipods
Balloon Flies
Beetles
Biting Midges
Black Flies
Broad-Winged Damselflies
Chiggers
Circular-Seamed Flies
Darners
Gastropods
Mayflies
Micro-Caddisflies
Midges
Net-Spinning Caddisflies
Predaceous Diving Beetles
Riffle Beetles
Water Boatman

Year 2010 Data	
Attributes regarding the invertebrates that were found at this site	
EPT Taxa	5
Ephemeroptera Taxa	3
Hilsenhoffs Biotic Index (HBI)	6
Intolerant Families	1
Percent Pollution Tolerant	1.9
Percent Chironomidae	55.8
Percent Diptera	63.5
Percent Dominant Taxa	55.8
Percent Dominant Two Taxa	66.3
Percent Filterers	17
Percent Gatherer	76.3
Percent Hydropsychidae	10.3
Percent Scraper	2.9
Plecoptera Families	0
Total Families	19
Trichoptera Families	2

Year 2010 Data	
Fish attributes that were found at this site	
Attribute	Count
DELT (abnormalities)	1
Darter species	1
Exotic species	1
Fish per 100 m	111.3
Game fish species	1
Gravel spawning species	2
Piscivore species	0
Pollution intolerant species	0
Special concern species	0
Total species	13

Biological Station Information 00UM059

Stream Name:	COON CREEK
Waterbody Name:	Coon Creek
Data Steward Org:	MPCA
Station ID:	00UM059
Hydrologic Unit Code (HUC):	07010206
Assessment Unit:	07010206-530
Period of Record:	2000 through 2010
Drainage Area (square miles)	35.78
Lat/Lon	45.23318,-93.23622
Land Use	Agricultural 6.5% Forest 29.3% Range 23.3 % Urban 9.3 % Water 1.1 % Wetland 30.5 % Other 0.0 %

Year 2010 Data	
Site Index of Biological Integrity	
Visit Year	2010
Fish IBI	36
Fish Rating	
Invertebrate IBI	48
Invertebrate Rating	

Year 2000 (2nd Visit) Data	
Site Index of Biological Integrity	
Visit Year	2000 (2nd visit)
Fish IBI	37
Fish Rating	
Invertebrate IBI	46
Invertebrate Rating	

Year 2000 Data	
Site Index of Biological Integrity	
Visit Year	2000
Fish IBI	44
Fish Rating	
Invertebrate IBI	53
Invertebrate Rating	

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Water Temperature °C	17°
Conductivity µmhos/cm	465
Field Turbidity NTU	8.35
Dissolved Oxygen mg/L	6
PH	7.95
Flow m3/sec	.07044
Nitrogen mg/L	0.3
Total Phosphorus mg/L	0.095
Total Suspended Solids mg/L	8
Ammonia mg/L	0.1
Fish Rating	

Year 2010 Data			
Fish species found at this site			
Species	Count	Min Length (mm)	Max Length (mm)
Blacknose Dace	1	75	75
Brook Stickleback	34	27	52
Central Mudminnow	5	37	115
Fathead Minnow	7	29	48
Johnny Darter	18	41	64
Mottled Sculpin	4	30	80
Northern Redbelly Dace	13	29	39
White Sucker	11	123	382

Year 2000 (2nd Visit) Data

Fish species found at this site			
Species	Count	Min Length (mm)	Max Length (mm)
Bigmouth Shiner	1	80	80
Black Bullhead	14	79	100
Black Crappie	9	89	102
Blacknose Dace	5	71	93
Brassy Minnow	7	71	84
Brook Stickleback	1	36	36
Central Mudminnow	13	56	93
Common Carp	4	69	105
Fathead Minnow	10	55	67
Green Sunfish	4	58	71
Hybrid Sunfish	1	81	81
Iowa Darter	8	41	44
Johnny Darter	78	38	70
Mottled Sculpin	5	32	41

Year 2000 Data			
Fish species found at this site			
Species	Count	Min Length (mm)	Max Length (mm)
Bigmouth Shiner	7	55	81
Black Bullhead	19	80	114
Black Crappie	102	92	112
Blacknose Dace	4	59	73
Brook Stickleback	1	38	38
Central Mudminnow	24	54	90
Common Carp	26	50	543
Common Shiner	1	122	122
Fathead Minnow	57	46	72
Green Sunfish	4	58	95
Hybrid Sunfish	2	75	100
Iowa Darter	2	34	40
Johnny Darter	67	30	61
Mottled Sculpin	2	30	71
White Sucker	16	150	278
Yellow Perch	3	86	104

Year 2010 Data
Invertebrates that were found at this site
Amphipods
Balloon Flies
Black Flies
Circular-Seamed Flies
Dixid Midges
Electric Light Bugs
Face Flies
Gastropods
Grass Moths
Large Caddisflies
Mayflies
Midges
Mosquitoes
Narrow-Winged Damselflies
Net-Spinning Caddisflies
Northern Caddisflies
Oligochaeta
Pleid Water Bugs
Predaceous Diving Beetles
Riffle Beetles
Snout Beetles
Thienemannimyia Gr.
Water Scavenger Beetles
Water Scorpions

Year 2000 (2nd Visit) Data
Invertebrates that were found at this site
Amphipods
Balloon Flies
Black Flies
Circular-Seamed Flies
Dixid Midges
Electric Light Bugs
Face Flies
Gastropods
Grass Moths
Large Caddisflies
Mayflies
Midges
Mosquitoes
Narrow-Winged Damselflies
Net-Spinning Caddisflies
Northern Caddisflies
Oligochaeta
Pleid Water Bugs
Predaceous Diving Beetles
Riffle Beetles
Snout Beetles
Thienemannimyia Gr.
Water Scavenger Beetles
Water Scorpions

Year 2000 Data
Invertebrates that were found at this site
Amphipods
Balloon Flies
Black Flies
Circular-Seamed Flies
Dixid Midges
Electric Light Bugs
Face Flies
Gastropods
Grass Moths
Large Caddisflies
Mayflies
Midges
Mosquitoes
Narrow-Winged Damselflies
Net-Spinning Caddisflies
Northern Caddisflies
Oligochaeta
Pleid Water Bugs
Predaceous Diving Beetles
Riffle Beetles
Snout Beetles
Thienemannimyia Gr.
Water Scavenger Beetles
Water Scorpions

Year 2000 Data	
Fish attributes that were found at this site	
Attribute	Count
DELT (abnormalities)	2
Darter species	2
Exotic species	1
Fish per 100 m	181.2
Game fish species	3
Gravel spawning species	3
Piscivore species	1
Pollution intolerant species	0
Special concern species	0
Total species	16

Year 2000 (2nd Visit) Data	
Fish attributes that were found at this site	
Attribute	Count
DELT (abnormalities)	3
Darter species	2
Exotic species	1
Fish per 100 m	90.4
Game fish species	2
Gravel spawning species	2
Piscivore species	1
Pollution intolerant species	0
Special concern species	0
Total species	15

Year 2010 Data	
Fish attributes that were found at this site	
Attribute	Count
DELT (abnormalities)	3
Darter species	1
Exotic species	0
Fish per 100 m	58.9
Game fish species	0
Gravel spawning species	2
Piscivore species	0
Pollution intolerant species	0
Special concern species	0
Total species	8

Year 2000 Data	
Attributes regarding the invertebrates that were found at this site	
EPT Taxa	4
Ephemeroptera Taxa	2
Hilsenhoffs Biotic Index (HBI)	5.1
Intolerant Families	1
Percent Pollution Tolerant	1.2
Percent Chironomidae	21.9
Percent Diptera	51.2
Percent Dominant Taxa	27.8
Percent Dominant Two Taxa	52.8
Percent Filterers	30.2
Percent Gatherer	60.2
Percent Hydropsychidae	5.2
Percent Scraper	2.2
Plecoptera Families	0
Total Families	22
Trichoptera Families	2

Year 2000 (2^{nd} Visit) Data	
Attributes regarding the invertebrates that were found at this site	
EPT Taxa	5
Ephemeroptera Taxa	2
Hilsenhoffs Biotic Index (HBI)	5.8
Intolerant Families	0
Percent Pollution Tolerant	.7
Percent Chironomidae	31.1
Percent Diptera	79.9
Percent Dominant Taxa	47.4
Percent Dominant Two Taxa	78.5
Percent Filterers	51.9
Percent Gatherer	41.6
Percent Hydropsychidae	4.4
Percent Scraper	2
Plecoptera Families	0
Total Families	16
Trichoptera Families	3

Year 2010 Data	
Attributes regarding the invertebrates that were found at this site	
EPT Taxa	4
Ephemeroptera Taxa	3
Hilsenhoffs Biotic Index (HBI)	5.9
Intolerant Families	0
Percent Pollution Tolerant	2
Percent Chironomidae	64.5
Percent Diptera	66.1
Percent Dominant Taxa	64.5
Percent Dominant Two Taxa	80.9
Percent Filterers	16.4
Percent Gatherer	72
Percent Hydropsychidae	16.4
Percent Scraper	5.3
Plecoptera Families	0
Total Families	16
Trichoptera Families	1

Biological Station Information 10UM021

Stream Name:	COUNTY DITCH 11
Waterbody Name:	County Ditch 11
Data Steward Org:	MPCA
Station ID:	10UM021
Hydrologic Unit Code (HUC):	07010206
Assessment Unit:	07010206-756
Period of Record:	2010 through 2010
Drainage Area (square miles)	3.98
Lat/Lon	45.23885,-93.19304
Land Use	Agricultural 6.5% Forest 31.2% Range 47.2 % Urban 8.5 % Water 0.0 % Wetland 6.6 % Other 0.0 %

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Site Index of Biological Integrity	
Visit Year	2010
Fish IBI	18
Fish Rating	
Invertebrate IBI	17
Invertebrate Rating	

Year 2010 Data			
Fish species found at this site			
Species	Count	Min Length (mm)	Max Length (mm)
Black Bullhead	5	84	155
Brook Stickleback	31	25	43
Central Mudminnow	113	39	125
Common Carp	3	43	74
Fathead Minnow	147	40	72
Green Sunfish	1	70	70
Northern Redbelly Dace	28	36	72
White Sucker	11	130	176

Year 2010 Data
Invertebrates that were found at this site
Amphipods
Caecidotea
Chiggers
Crawling Water Beetles
Darners
Fingernail Clam
Gastropods
Hirudinea
Mayflies
Midges
Narrow-Winged Damselflies
Oligochaeta
Water Boatman

Year 2010 Data	
Fish attributes that were found at this site	
Attribute	Count
DELT (abnormalities)	0
Darter species	0
Exotic species	1
Fish per 100 m	242.1
Game fish species	1
Gravel spawning species	1
Piscivore species	0
Pollution intolerant species	0
Special concern species	0
Total species	8

Year 2010 Data	
Attributes regarding the invertebrates that were found at this site	
EPT Taxa	2
Ephemeroptera Taxa	2
Hilsenhoffs Biotic Index (HBI)	6.4
Intolerant Families	0
Percent Pollution Tolerant	45.9
Percent Chironomidae	14.5
Percent Diptera	14.5
Percent Dominant Taxa	21.6
Percent Dominant Two Taxa	38.2
Percent Filterers	4.7
Percent Gatherer	55.1
Percent Hydropsychidae	0
Percent Scraper	29.4
Plecoptera Families	0
Total Families	12
Trichoptera Families	0

Biological Station Information 10UM020

Stream Name:	COON CREEK
Waterbody Name:	Coon Creek
Data Steward Org:	MPCA
Station ID:	10UM020
Hydrologic Unit Code (HUC):	07010206
Assessment Unit:	07010206-530
Period of Record:	2010 through 2010
Drainage Area (square miles)	20.00
Lat/Lon	45.23351,-93.18253
Land Use	Agricultural 5.9% Forest 26.1% Range 18.0 % Urban 4.0 % Water 0.6 % Wetland 45.3 % Other 0.0 %

Year 2010 Data	
Site Index of Biological Integrity	
Visit Year	2010
Fish IBI	52
Fish Rating	
Invertebrate IBI	35
Invertebrate Rating	

Year 2010 (2nd Visit) Data	
Site Index of Biological Integrity	
Visit Year	2010 (2nd visit)
Fish IBI	No Visit
Fish Rating	
Invertebrate IBI	42
Invertebrate Rating	

Year 2010 Data

Fish species found at this site

Species	Count	Min Length (mm)	Max Length (mm)
Bigmouth Shiner	3	52	82
Black Bullhead	1	146	146
Brassy Minnow	1	65	65
Brook Stickleback	21	25	50
Central Mudminnow	12	57	105
Common Shiner	1	72	72
Creek Chub	11	26	141
Fathead Minnow	5	42	69
Golden Shiner	1	82	82
Johnny Darter	1	59	59
Northern Redbelly Dace	45	25	60
White Sucker	10	127	296

Year 2010 Data
Invertebrates that were found at this site
Amphipods
Beetles
Circular-Seamed Flies
Fingernail Clam
Gastropods
Large Caddisflies
Long-Horn Caddisflies
Mayflies
Midges
Narrow-Winged Damselflies
Net-Spinning Caddisflies
Oligochaeta
Riffle Beetles

Year 2010 (2nd Visit) Data
Invertebrates that were found at this site
Amphipods
Beetles
Circular-Seamed Flies
Fingernail Clam
Gastropods
Large Caddisflies
Long-Horn Caddisflies
Mayflies
Midges
Narrow-Winged Damselflies
Net-Spinning Caddisflies
Oligochaeta
Riffle Beetles

Year 2010 Data	
Fish attributes that were found at this site	
Attribute	Count
DELT (abnormalities)	0
Darter species	1
Exotic species	0
Fish per 100 m	74.7
Game fish species	0
Gravel spawning species	2
Piscivore species	0
Pollution intolerant species	0
Special concern species	0
Total species	12

Year 2010 Data	
Attributes regarding the invertebrates that were found at this site	
EPT Taxa	5
Ephemeroptera Taxa	2
Hilsenhoffs Biotic Index (HBI)	5.7
Intolerant Families	0
Percent Pollution Tolerant	1.6
Percent Chironomidae	65.2
Percent Diptera	66.1
Percent Dominant Taxa	65.2
Percent Dominant Two Taxa	78.3
Percent Filterers	7.7
Percent Gatherer	89.8
Percent Hydropsychidae	7
Percent Scraper	.3
Plecoptera Families	0
Total Families	13
Trichoptera Families	3

Year 2010 (2nd Visit) Data	
Attributes regarding the invertebrates that were found at this site	
EPT Taxa	5
Ephemeroptera Taxa	2
Hilsenhoffs Biotic Index (HBI)	6
Intolerant Families	0
Percent Pollution Tolerant	1.6
Percent Chironomidae	73.4
Percent Diptera	74.7
Percent Dominant Taxa	73.4
Percent Dominant Two Taxa	83.5
Percent Filterers	5.1
Percent Gatherer	90.2
Percent Hydropsychidae	5.1
Percent Scraper	1.6
Plecoptera Families	0
Total Families	17
Trichoptera Families	3

Biological Station Information 00UM065

Stream Name:	SAND CREEK
Waterbody Name:	Sand Creek
Data Steward Org:	MPCA
Station ID:	00UM065
Hydrologic Unit Code (HUC):	07010206
Assessment Unit:	07010206-558
Period of Record:	2000 through 2010
Drainage Area (square miles)	15.12
Lat/Lon	45.18845,-93.28514
Land Use	Agricultural 5.1% Forest 9.9% Range 18.3 % Urban 60.2 % Water 0.8 % Wetland 5.7 % Other 0.0 %

Year 2010 Data	
Site Index of Biological Integrity	
Visit Year	2010
Fish IBI	0
Fish Rating	
Invertebrate IBI	17
Invertebrate Rating	

Year 2010 (2nd Visit) Data	
Site Index of Biological Integrity	
Visit Year	2010 (2nd visit)
Fish IBI	11
Fish Rating	
Invertebrate IBI	No Visit
Invertebrate Rating	

Year 2005 Data

Site Index of Biological Integrity	
Visit Year	2005
Fish IBI	30
Fish Rating	
Invertebrate IBI	No Visit
Invertebrate Rating	

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Site Index of Biological Integrity	
Visit Year	2000
Fish IBI	32
Fish Rating	
Invertebrate IBI	34
Invertebrate Rating	

Year 2010 Data			
Fish species found at this site			
Species	Count	Min Length (mm)	Max Length (mm)
Brook Stickleback	2	60	61
White Sucker	6	96	125

Year 2010 (2nd Visit) Data			
Fish species found at this site			
Species	Count	Min Length (mm)	Max Length (mm)
Black Bullhead	1	77	77
Brook Stickleback	1	50	50
Fathead Minnow	1	67	67
Golden Shiner	1	78	78
Largemouth Bass	2	52	57
White Sucker	37	63	292
Fathead Minnow	10	55	67
Green Sunfish	4	58	71
Hybrid Sunfish	1	81	81
Iowa Darter	8	41	44
Johnny Darter	78	38	70
Mottled Sculpin	5	32	41

Year 2005 Data			
Fish species found at this site			
Species	Count	Min Length (mm)	Max Length (mm)
Black Bullhead	1	170	170
Blacknose Dace	8	80	102
Bluegill	1	92	92
Brook Stickleback	2	58	58
Green Sunfish	2	55	73
Johnny Darter	3	25	69
Largemouth Bass	3	73	76
Pumpkinseed	1	109	109
White Sucker	68	29	266

Year 2000 Data			
Fish species found at this site			
Species	Count	Min Length (mm)	Max Length (mm)
Black Bullhead	3	94	165
Black Crappie	1	102	102
Blacknose Dace	41	62	94
Brassy Minnow	5	41	72
Brook Stickleback	4	41	43
Central Mudminnow	2	45	89
Fathead Minnow	30	55	73
Green Sunfish	6	54	108
Johnny Darter	58	25	60
Northern Redbelly Dace	1	57	57
Pumpkinseed	30	43	90
White Sucker	109	44	265

Year 2000 Data
Invertebrates that were found at this site
Amphipods
Asellus
Balloon Flies
Black Flies
Broad-Winged Damselflies
Crane Flies
Decapoda
Electric Light Bugs
Gastropods
Marsh Beetles
Mayflies
Midges
Narrow-Winged Damselflies
Net-Spinning Caddisflies
Oligochaeta
Pleid Water Bugs
Predaceous Diving Beetles
Riffle Beetles
Thienemannimyia Gr.
Water Scavenger Beetles

Year 2010 Data
Invertebrates that were found at this site
Amphipods
Asellus
Balloon Flies
Black Flies
Broad-Winged Damselflies
Crane Flies
Decapoda
Electric Light Bugs
Gastropods
Marsh Beetles
Mayflies
Midges
Narrow-Winged Damselflies
Net-Spinning Caddisflies
Oligochaeta
Pleid Water Bugs
Predaceous Diving Beetles
Riffle Beetles
Thienemannimyia Gr.
Water Scavenger Beetles

Year 2000 Data	
Fish attributes that were found at this site	
Attribute	Count
DELT (abnormalities)	0
Darter species	1
Exotic species	0
Fish per 100 m	152.6
Game fish species	3
Gravel spawning species	2
Piscivore species	1
Pollution intolerant species	0
Special concern species	0
Total species	12

Year 2005 Data	
Fish attributes that were found at this site	
Attribute	Count
DELT (abnormalities)	0
Darter species	1
Exotic species	0
Fish per 100 m	45.4
Game fish species	4
Gravel spawning species	2
Piscivore species	1
Pollution intolerant species	0
Special concern species	0
Total species	9

Year 2010 Data	
Fish attributes that were found at this site	
Attribute	Count
DELT (abnormalities)	0
Darter species	0
Exotic species	0
Fish per 100 m	5.1
Game fish species	0
Gravel spawning species	1
Piscivore species	0
Pollution intolerant species	0
Special concern species	0
Total species	2

Year 2010 (2nd Visit) Data	
Fish attributes that were found at this site	
Attribute	Count
DELT (abnormalities)	1
Darter species	0
Exotic species	0
Fish per 100 m	27.2
Game fish species	1
Gravel spawning species	1
Piscivore species	1
Pollution intolerant species	0
Special concern species	0
Total species	6

Year 2000 Data	
Attributes regarding the invertebrates that were found at this site	
EPT Taxa	4
Ephemeroptera Taxa	3
Hilsenhoffs Biotic Index (HBI)	4.8
Intolerant Families	0
Percent Pollution Tolerant	5.5
Percent Chironomidae	45.8
Percent Diptera	49.8
Percent Dominant Taxa	45.8
Percent Dominant Two Taxa	73.5
Percent Filterers	28
Percent Gatherer	55.6
Percent Hydropsychidae	27.6
Percent Scraper	10.5
Plecoptera Families	0
Total Families	19
Trichoptera Families	1

Year 2010 Data	
Attributes regarding the invertebrates that were found at this site	
EPT Taxa	2
Ephemeroptera Taxa	1
Hilsenhoffs Biotic Index (HBI)	4.5
Intolerant Families	0
Percent Pollution Tolerant	1.6
Percent Chironomidae	12.7
Percent Diptera	13.6
Percent Dominant Taxa	64.3
Percent Dominant Two Taxa	77.3
Percent Filterers	64.9
Percent Gatherer	31.2
Percent Hydropsychidae	64.3
Percent Scraper	1.9
Plecoptera Families	0
Total Families	13
Trichoptera Families	1

Biological Station Information 00UM062

Stream Name:	TRIB. TO MISSISSIPPI RIVER
Waterbody Name:	Trib. to Mississippi River
Data Steward Org:	MPCA
Station ID:	00UM062
Hydrologic Unit Code (HUC):	07010206
Assessment Unit:	07010206-594
Period of Record:	2000 through 2000
Drainage Area (square miles)	2.73
Lat/Lon	45.13062814,-93.28787069
Land Use	Agricultural 0.1% Forest 4.1% Range 0.6 % Urban 91.2 % Water 2.0 % Wetland 2.0 % Other 0.0 %

Year 2000 Data	
Site Index of Biological Integrity	
Visit Year	2000
Fish IBI	34
Fish Rating	
Invertebrate IBI	29
Invertebrate Rating	

Year 2000 Data			
Fish species found at this site			
Species	Count	Min Length (mm)	Max Length (mm)
Black Crappie	3	92	134
Blackside Darter	7	54	64
Bluntnose Minnow	1	66	66
Brassy Minnow	3	58	66
Common Carp	2	635	635
Common Shiner	18	79	120
Creek Chub	267	45	225
Emerald Shiner	2	67	69
Fathead Minnow	45	38	53
Gizzard Shad	7	87	113
Green Sunfish	2	25	36
Largemouth Bass	2	48	50
Orangespotted Sunfish	1	69	69
Smallmouth Bass	12	59	88
White Sucker	88	60	205

Year 2000 Data
Invertebrates that were found at this site
Balloon Flies
Black Flies
Crane Flies
Finger-Net Caddisflies
Fingernail Clam
Flatworms
Mayflies
Midges
Net-Spinning Caddisflies
Oligochaeta
Riffle Beetles

Year 2000 Data	
Fish attributes that were found at this site	
Attribute	Count
DELT (abnormalities)	0
Darter species	1
Exotic species	1
Fish per 100 m	296.8
Game fish species	4
Gravel spawning species	4
Piscivore species	3
Pollution intolerant species	1
Special concern species	0
Total species	15

Year 2000 Data	
Attributes regarding the invertebrates that were found at this site	
EPT Taxa	3
Ephemeroptera Taxa	1
Hilsenhoffs Biotic Index (HBI)	4.2
Intolerant Families	0
Percent Pollution Tolerant	.3
Percent Chironomidae	24.3
Percent Diptera	34.9
Percent Dominant Taxa	25.7
Percent Dominant Two Taxa	50
Percent Filterers	59.2
Percent Gatherer	40.4
Percent Hydropsychidae	25.7
Percent Scraper	0
Plecoptera Families	0
Total Families	8
Trichoptera Families	2

Biological Station Information 00UM061

Stream Name:	TRIB. TO MISSISSIPPI RIVER
Waterbody Name:	Trib. to Mississippi River
Data Steward Org:	MPCA
Station ID:	00UM061
Hydrologic Unit Code (HUC):	07010206
Assessment Unit:	07010206-557
Period of Record:	2000 through 2000
Drainage Area (square miles)	4.78
Lat/Lon	45.11255134,-93.284805
Land Use	Agricultural 0.1% Forest 8.9% Range 0.4 % Urban 85.3 % Water 2.6 % Wetland 2.8 % Other 0.0 %

Year 2000 Data	
Site Index of Biological Integrity	
Visit Year	2000
Fish IBI	35
Fish Rating	
Invertebrate IBI	25
Invertebrate Rating	

Year 2000 Data			
Fish species found at this site			
Species	Count	Min Length (mm)	Max Length (mm)
Black Bullhead	3	121	132
Blacknose Dace	7	32	103
Blackside Darter	2	55	56
Creek Chub	180	39	190
Fathead Minnow	25	35	67
Golden Shiner	3	76	94
Green Sunfish	67	38	97
Hornyhead Chub	3	62	101
Hybrid Sunfish	174	32	105
Johnny Darter	1	53	53
Largemouth Bass	1	49	49
White Sucker	28	47	172

Year 2000 Data
Invertebrates that were found at this site
Amphipods
Asellus
Balloon Flies
Black Flies
Crane Flies
Finger-Net Caddisflies
Fingernail Clam
Flatworms
Mayflies
Midges
Narrow-Winged Damselflies
Net-Spinning Caddisflies
Oligochaeta
Riffle Beetles

Year 2000 Data	
Fish attributes that were found at this site	
Attribute	Count
DELT (abnormalities)	3
Darter species	2
Exotic species	0
Fish per 100 m	306.8
Game fish species	2
Gravel spawning species	3
Piscivore species	1
Pollution intolerant species	0
Special concern species	0
Total species	12

Year 2000 Data	
Attributes regarding the invertebrates that were found at this site	
EPT Taxa	3
Ephemeroptera Taxa	1
Hilsenhoffs Biotic Index (HBI)	4.3
Intolerant Families	0
Percent Pollution Tolerant	2.1
Percent Chironomidae	17.8
Percent Diptera	21.2
Percent Dominant Taxa	22.4
Percent Dominant Two Taxa	42.6
Percent Filterers	44.2
Percent Gatherer	54.9
Percent Hydropsychidae	19.6
Percent Scraper	0
Plecoptera Families	0
Total Families	11
Trichoptera Families	2

APPENDIX B

Minnesota Pollution Control Agency Fish and Macroinvertebrate Metric Scores

Macroinvertebrate Metric Scores

Classification	Class 6 - Southern Forest Streams (Glide/Pool Habitat)									Class 5 – Southern Streams (Run/Riffle Habitat)				
Stream Reach	Coon Cr.	Coon Cr.	Coon Cr.	Coon Cr.	Coon Cr.	Coon Cr.	Coon Cr.	Coon Cr.	D58	Coon Cr.	Sand Cr.	Sand Cr.	Sprbk Cr.	Pleas. Cr.
Station ID	10UM003 (2010)	10UM003 (2010)	10UM017 (2010)	00UM059 (2010)	00UM059 (2000)	00UM059 (2000)	10UM020 (2010)	10UM020 (2010)	10UM018 (2010)	00UM064 (2000)	00UM065 (2000)	00UM065 (2010)	00UM061 (2000)	00UM062 (2000)
PredatorCh	0.0	0.7	2.9	4.3	3.6	2.9	2.9	2.9	4.3	9.2	3.1	0.8	0	0
DomFiveCHPct	1.6	3.5	8.6	6.1	5.1	2.9	6.4	5.1	8.1	7.6	4.8	0.0	0	3.7
HBI_MN	6.4	7.3	3.3	5.2	7.0	7.8	3.6	5.3	6.7	3.5	4.2	2.4	8	8
ClingerCh	5.3	6.7	6.7	7.3	5.3	4.0	6.0	4.0	8.0	-	-	-	-	-
Coll-FiltererPct	8.5	8.6	5.7	10.0	10.0	10.0	7.4	3.3	10.0	-	-	-	-	-
Intolerant2Ch	0.0	7.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	-	-
POET	2.9	5.0	5.0	5.0	4.3	3.6	2.9	2.9	5.0	-	-	-	-	-
TaxaCountAllChir	0.6	3.0	6.8	5.0	5.0	3.0	4.7	4.1	7.1	-	-	-	-	-
TrichopChTxPct	2.9	6.3	5.8	5.1	8.5	10.0	5.2	5.3	5.7	-	-	-	-	-
TrichwoHydroPct	0.0	0.0	1.9	0.0	3.7	2.0	2.7	2.0	1.1	-	-	-	-	-
ClimberCh	-	-	-	-	-	-	-	-	-	10.0	6.8	4.6	0	0
ClingerChTxPct	-	-	-	-	-	-	-	-	-	2.4	4.1	1.9	5.8	9.2
InsectTxPct	-	-	-	-	-	-	-	-	-	6.5	3.2	0.0	1	3.5
Odonata	-	-	-	-	-	-	-	-	-	9.0	6.1	6.1	3.9	0
Plecoptera	-	-	-	-	-	-	-	-	-	0.0	0.0	0.0	0	0
Trichoptera	-	-	-	-	-	-	-	-	-	5.0	0.0	0.0	2	2
Tol2ChTxPct	-	-	-	-	-	-	-	-	-	3.9	2.2	1.3	4	2.7
M-IBI Total Score	28	49	47	48	53	46	42	35	56	57	34	17	25	29
M-IBI Threshold	46.8	46.8	46.8	46.8	46.8	46.8	46.8	46.8	46.8	35.9	35.9	35.9	35.9	35.9
+/- to Threshold	19	-2	0.2	-1	-6	1	5	12	-9	-21	1	19	11	7

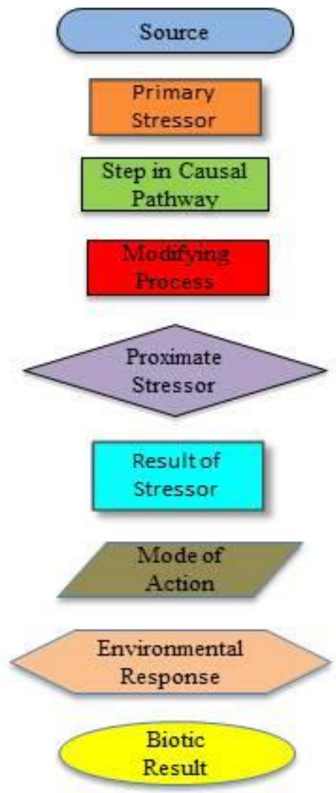
Fish Metric Scores															
Classification	**Class 5 - Northern Streams**			**Class 7 - Low Gradient**				**Class 6 - Northern Headwaters**							
Stream	Coon Cr.	Coon Cr.	Coon Cr.	Coon Cr.	Coon Cr.	Coon Cr.	Coon Cr.	D58	Sprbk Cr.	Pleas. Cr.	Sprbk Cr.	Sand Cr.	Sand Cr.	Sand Cr.	Sand Cr.
Station ID	10UM017 (2010)	10UM003 (2010)	00UM064 (2000)	00UM059 (2010)	00UM059 (2000)	00UM059 (2000)	10UM020 (2010)	10UM018 (2010)	00UM061 (2000)	00UM062 (2000)	00UM086 (2000)	00UM065 (2000)	00UM065 (2005)	00UM065 (2010)	00UM065 (2010)
DarterSculpSucTXPct	5.1	6.0	5.1	-	-	-	-	-	-	-	-	-	-	-	-
DetNWQPct	3.0	2.3	2.1	-	-	-	-	-	-	-	-	-	-	-	-
General	1.4	0.0	0.0	-	-	-	-	-	-	-	-	-	-	-	-
Insect-TolTXPct	1.3	4.7	3.0	-	-	-	-	3.6	5.8	3.1	0.0	3.9	7.8	0.0	0.0
IntolerantPct	0.0	0.1	0.2	-	-	-	-	-	-	-	-	-	-	-	-
MA>3-TolPct	0.0	0.5	0.1	-	-	-	-	-	-	-	-	-	-	-	-
SensitiveTXPct	2.2	2.3	3.3	-	-	-	-	-	-	-	-	-	-	-	-
SLithopPct	3.9	5.0	3.3	-	-	-	-	-	-	-	-	-	-	-	-
SSpnTXPct	3.1	3.2	6.2	-	-	-	-	-	-	-	-	-	-	-	-
Vtol	3.6	0.0	0.0	-	-	-	-	-	-	-	-	-	-	-	-
DomTwoPct	3.5	9.1	9.0	-	-	-	-	-	-	-	-	-	-	-	-
FishDELTPct	0.0	0.0	0.0	-5.0	-5.0	-5.0	0.0	0.0	0.0	0.0	-10.0	0.0	0.0	0.0	-5.0
TolTxPct	-	-	-	6.2	5.6	6.2	5.6	3.5	6.2	7.0	3.7	5.0	6.7	0.0	5.0
SLithop	-	-	-	8.3	5.6	5.6	5.6	4.7	7.0	9.4	0.0	4.7	4.7	0.0	2.3
Minnows-TolPct	-	-	-	0.1	0.1	3.0	8.9	0.6	0.2	0.8	2.6	0.1	0.0	0.0	0.5
NumPerMeter-Tolerant	-	-	-	5.6	3.3	1.3	1.9	2.2	0.3	1.8	0.2	2.6	0.2	0.0	0.1
PioneerTxPct	-	-	-	6.9	6.7	5.6	5.6	3.0	2.1	4.4	0.0	4.9	5.9	0.0	7.7
Sensitive	-	-	-	5.6	5.6	5.6	2.8	5.0	2.5	2.5	2.5	2.5	0.0	0.0	0.0
Wetland-Tol	-	-	-	5.4	2.7	2.7	5.4	-	-	-	-	-	-	-	-
OmnivoreTXPct	-	-	-	5.6	6.7	5.6	5.6	-	-	-	-	-	-	-	-
Hdw-TolPct	-	-	-	0.2	1.0	5.8	10.0	-	-	-	-	-	-	-	-
InsectCypPct	-	-	-	-	-	-	-	1.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Hdw-Tol	-	-	-	-	-	-	-	6.7	0.0	0.0	3.3	3.3	0.0	0.0	0.0
DarterSculp	-	-	-	-	-	-	-	10.0	10.0	5.0	0.0	5.0	5.0	0.0	0.0
Total Fish IBI Score	27	33	32	36	44	37	52	40	35	34	2	32	30	0	11
F-IBI Threshold	50	50	50	40	40	40	40	40	40	40	40	40	40	40	40

Upper/Lower CI	59/41	59/41	59/42	50/30	50/30	50/30	50/30	56/24	56/24	56/25	56/25	56/25	56/25	56/25	56/25

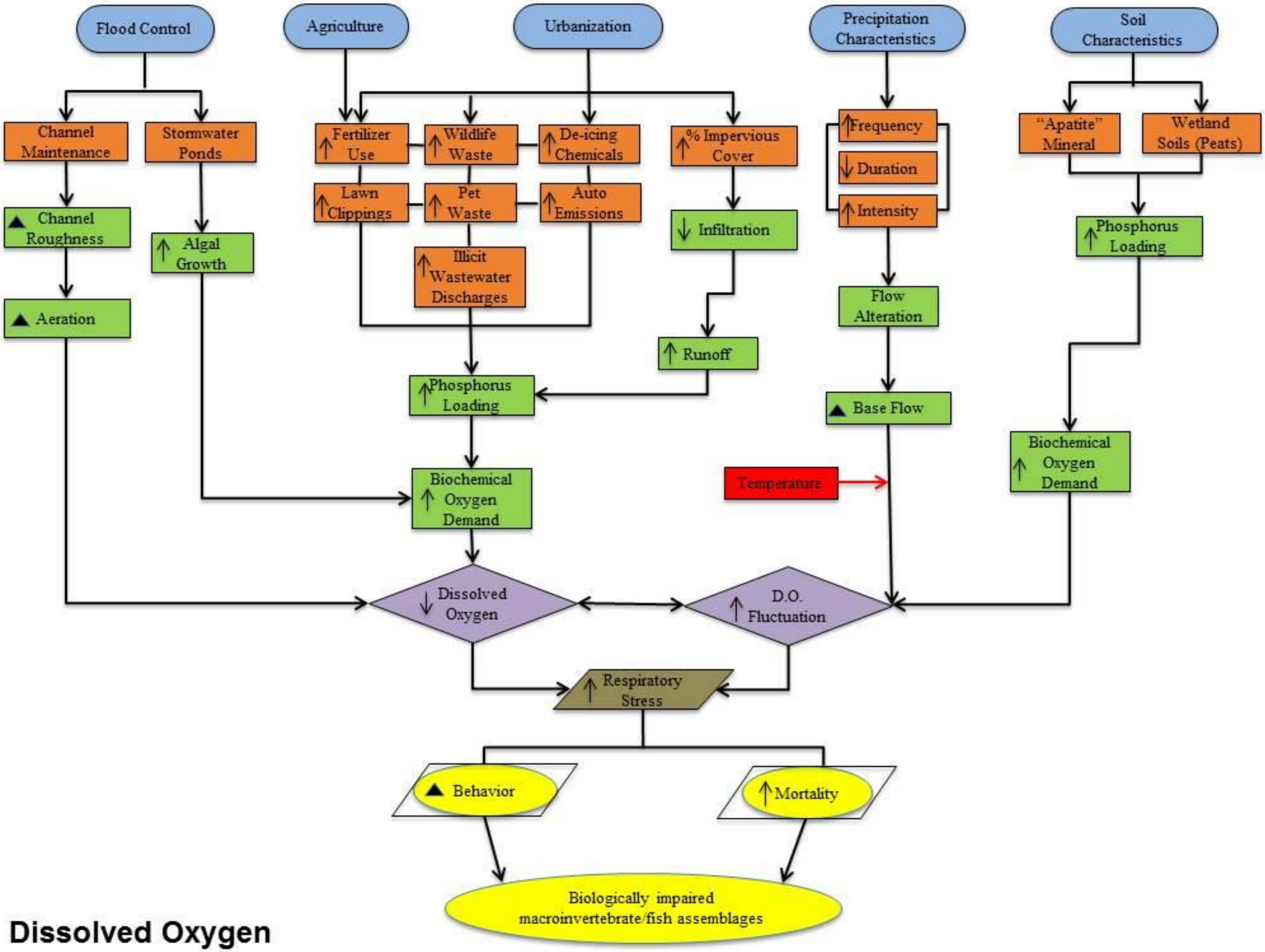
APPENDIX C

Conceptual Diagrams for Candidate Causes

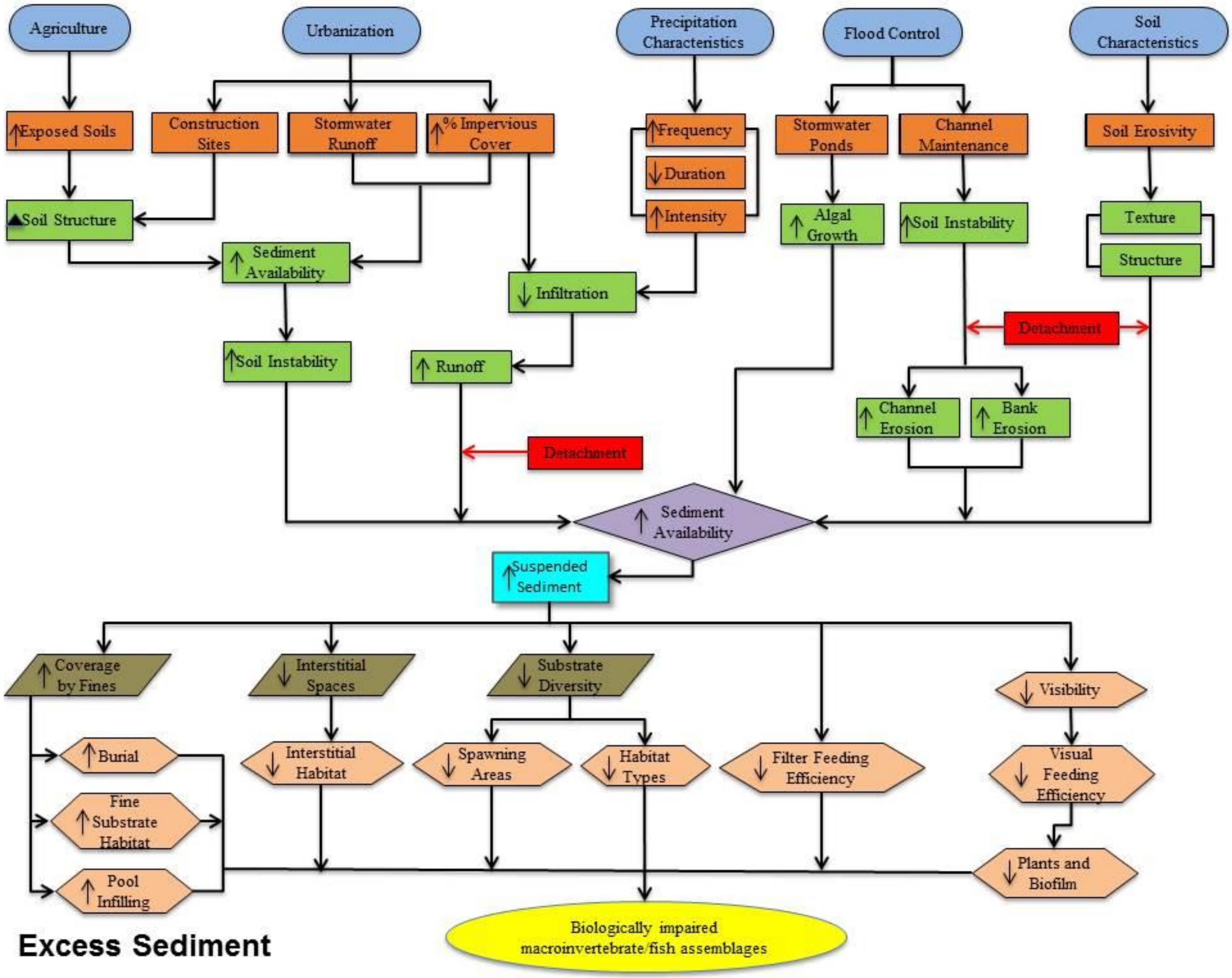
LEGEND



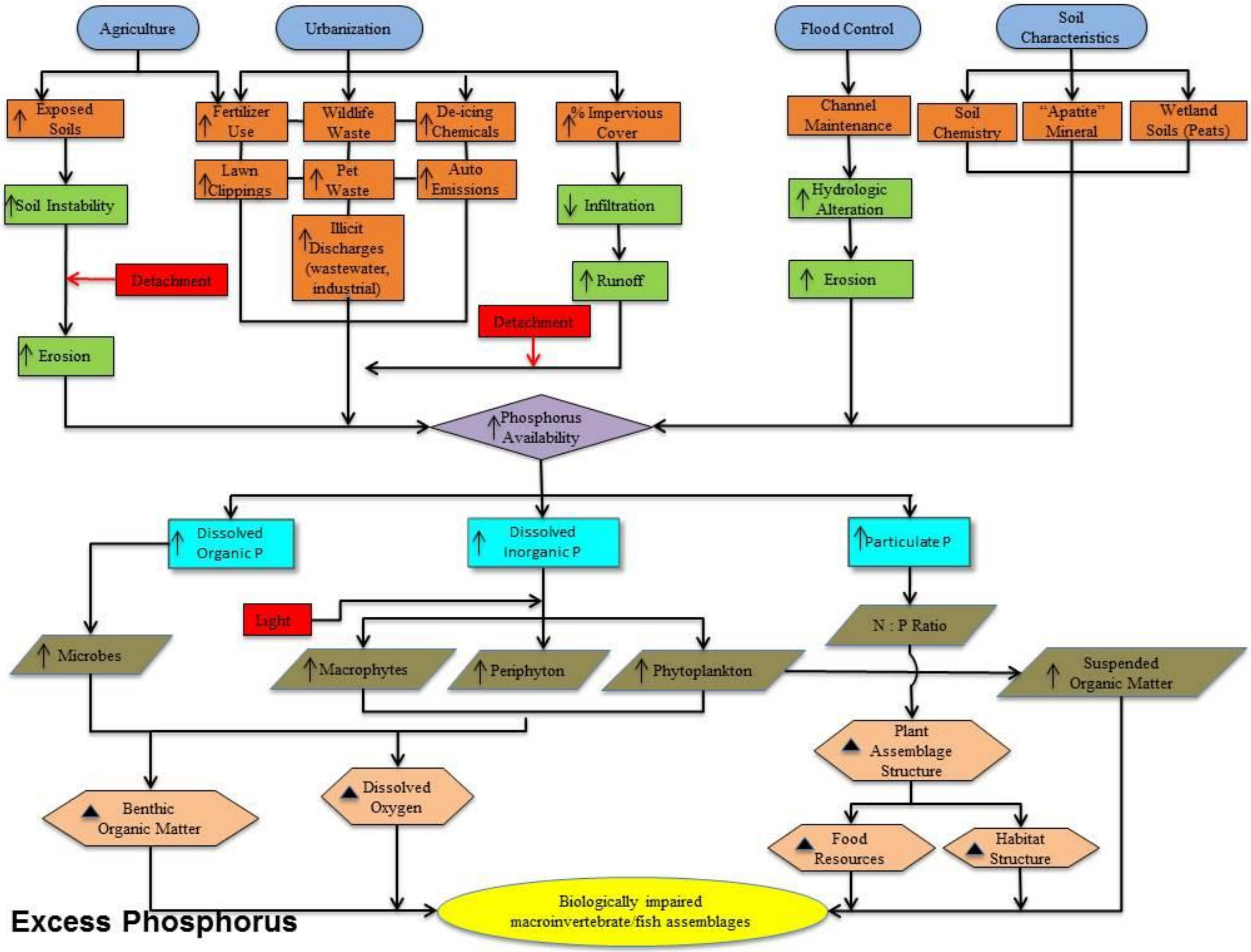
Source
Primary Stressor
Step in Causal Pathway
Modifying Process
Proximate Stressor
Result of Stressor
Mode of Action
Environmental Response
Biotic Result



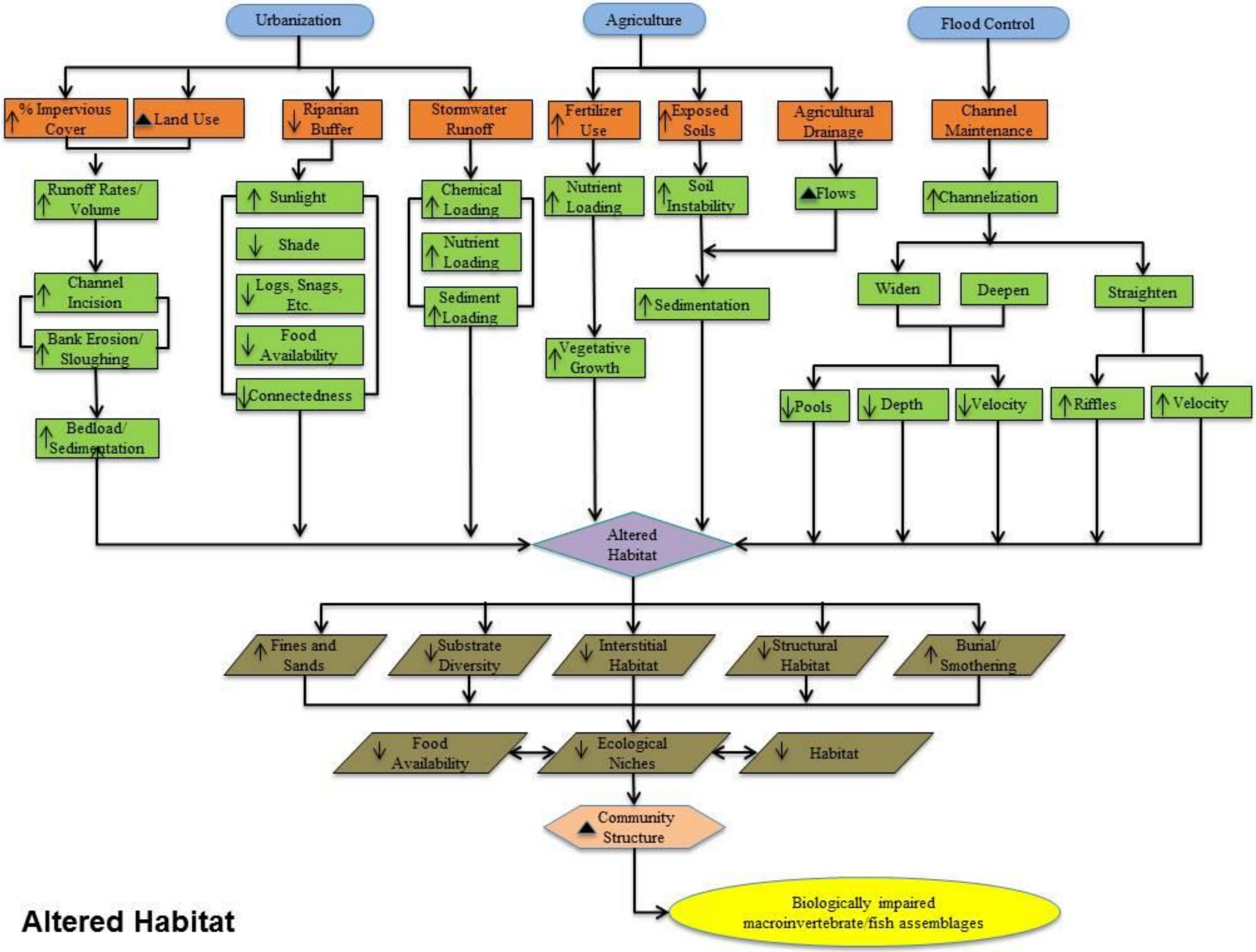
Dissolved Oxygen



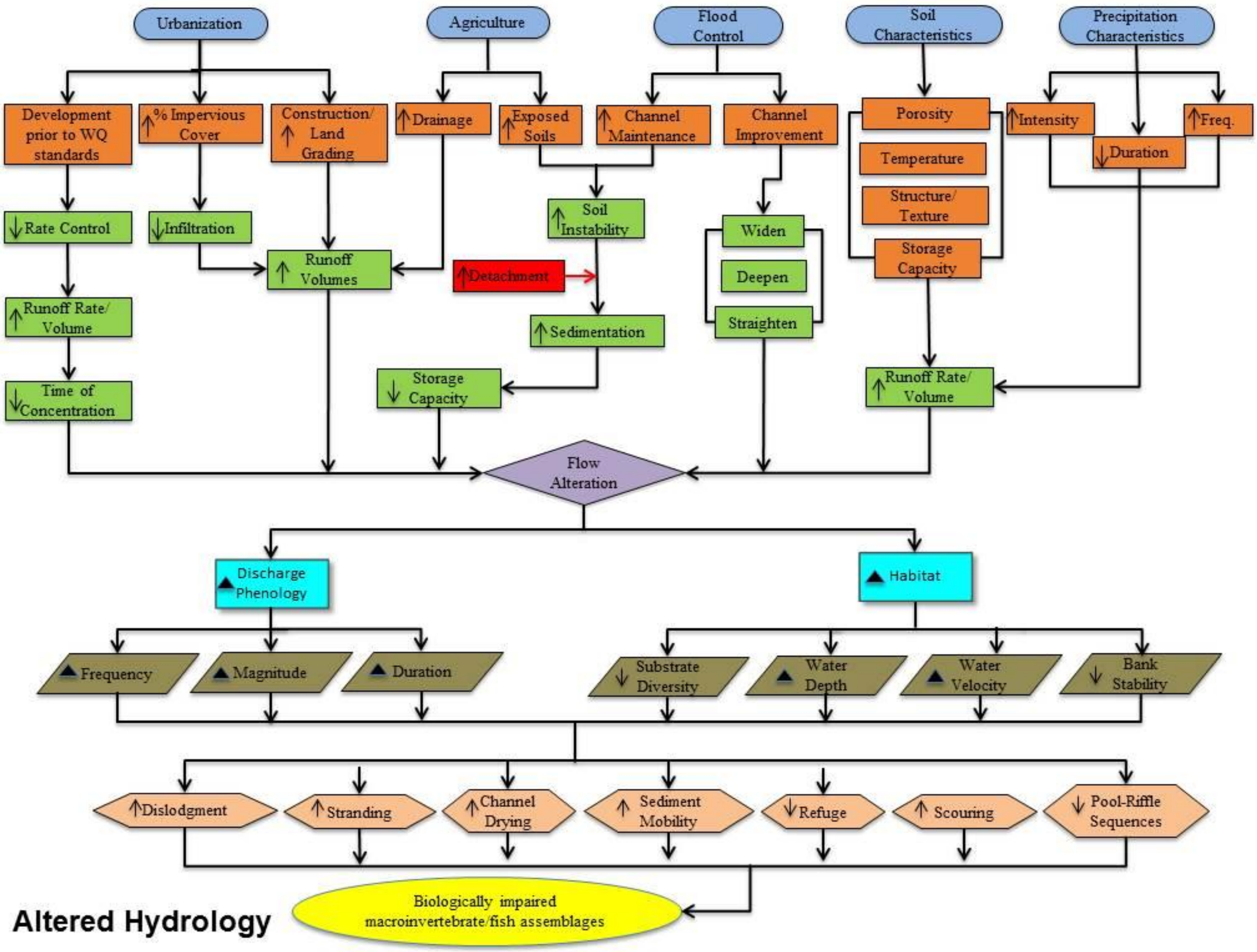
Excess Sediment



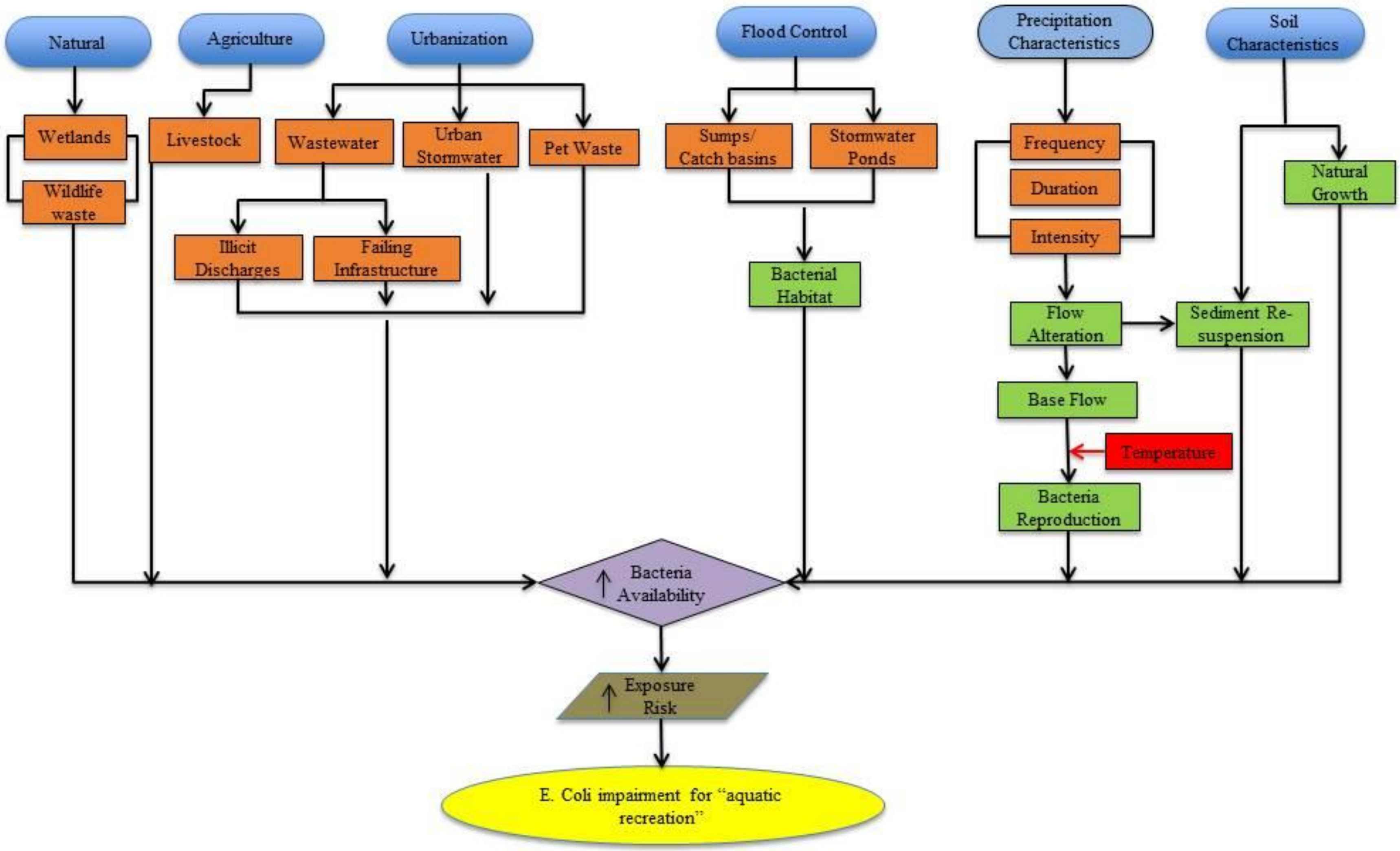
Excess Phosphorus



Altered Habitat



Altered Hydrology



Bacteria (E. coli)

APPENDIX D

Scoring methodology for strength of evidence tables

System used for scoring types of evidence.

Type of Evidence	Finding	Interpretation	Score
Types of Evidence that Use Data from the Case			
Spatial/Temporal Co-occurrence	The effect occurs where or when the candidate cause occurs, **OR** the effect does not occur where or when the candidate cause does not occur.	This finding *somewhat supports* the case for the candidate cause, but is not strongly supportive because the association could be coincidental.	+
	It is uncertain whether the candidate cause and the effect co-occur.	This finding *neither supports nor weakens* the case for the candidate cause, because the evidence is ambiguous.	0
	The effect does not occur where or when the candidate cause occurs, **OR** the effect occurs where or when the candidate cause does not occur.	This finding *convincingly weakens* the case for the candidate cause, because causes must co-occur with their effects.	- - -
	The effect does not occur where and when the candidate cause occurs, **OR** the effect occurs where or when the candidate cause does not occur, and the evidence is indisputable.	This finding *refutes* the case for the candidate cause, because causes must co-occur with their effects.	R
Temporal Sequence	The candidate cause occurred prior to the effect.	This finding *somewhat supports* the case for the candidate cause, but is not strongly supportive because the association could be coincidental.	+
	The temporal relationship between the candidate cause and the effect is uncertain.	This finding *neither supports nor weakens* the case for the candidate cause, because the evidence is ambiguous.	0
	The candidate cause occurs after the effect.	This finding *convincingly weakens* the case for the candidate cause, because causes cannot precede effects (note that this should be evaluated with caution when multiple sufficient causes are present).	- - -
	The candidate cause occurs after the effect, and the evidence is indisputable.	This finding *refutes* the case for the candidate cause, because effects cannot precede causes.	R
Stressor-Response Relationship from the Field	A strong effect gradient is observed relative to exposure to the candidate cause, at spatially linked sites, and the gradient is in the expected direction.	This finding *strongly supports* the case for the candidate cause, but is not convincing due to potential confounding.	+ +
	A weak effect gradient is observed relative to exposure to the candidate cause, at spatially linked sites, **OR** a strong effect gradient is observed relative to exposure to the candidate cause, at non-spatially linked sites, and the gradient is in the expected direction.	This finding *somewhat supports* the case for the candidate cause, but is not strongly supportive due to potential confounding or random error.	+
	An uncertain effect gradient is observed relative to exposure to the candidate cause.	This finding *neither supports nor weakens* the case for the candidate cause, because the evidence is ambiguous.	0

Type of Evidence	Finding	Interpretation	Score
	An inconsistent effect gradient is observed relative to exposure to the candidate cause, at spatially linked sites, **OR** a strong effect gradient is observed relative to exposure to the candidate cause, at non-spatially linked sites, but the gradient is not in the expected direction.	This finding *somewhat weakens* the case for the candidate cause, but is not strongly weakening due to potential confounding or random error.	-
	A strong effect gradient is observed relative to exposure to the candidate cause, at spatially linked sites, but the relationship is not in the expected direction.	This finding *strongly weakens* the case for the candidate cause, but is not convincing due to potential confounding.	- -
Causal Pathway	Data show that all steps in at least one causal pathway are present.	This finding *strongly supports* the case for the candidate cause, because it is improbable that all steps occurred by chance; it is not convincing because these steps may not be sufficient to generate sufficient levels of the cause.	+ +
	Data show that some steps in at least one causal pathway are present.	This finding *somewhat supports* the case for the candidate cause.	+
	Data show that the presence of all steps in the causal pathway is uncertain.	This finding *neither supports nor weakens* the case for the candidate cause.	0
	Data show that there is at least one missing step in each causal pathway.	This finding *somewhat weakens* the case for the candidate cause, but is not strongly weakening because it may be due to temporal variability, problems in sampling or analysis, or unidentified alternative pathways.	-
	Data show, with a high degree of certainty, that there is at least one missing step in each causal pathway.	This finding *convincingly weakens* the case for the candidate cause, assuming critical steps in each pathway are known, and are not found at the impaired site after a well-designed, well-performed, and sensitive study.	- - -
Evidence of Exposure or Biological Mechanism	Data show that exposure or the biological mechanism is clear and consistently present.	This finding *strongly supports* the case for the candidate cause, but is not convincing because it does not establish that the level of exposure or mechanistic action was sufficient to cause the effect.	+ +
	Data show that exposure or the biological mechanism is weak or inconsistently present.	This finding *somewhat supports* the case for the candidate cause.	+
	Data show that exposure or the biological mechanism is uncertain.	This finding *neither supports nor weakens* the case for the candidate cause.	0
	Data show that exposure or the biological mechanism is absent.	This finding *strongly weakens* the case for the candidate cause, but is not convincing because the exposure or the mechanism may have been missed.	- -

Type of Evidence	Finding	Interpretation	Score
	Data show that exposure or the biological mechanism is absent, and the evidence is indisputable.	This finding *refutes* the case for the candidate cause.	R
Manipulation of Exposure	The effect is eliminated or reduced when exposure to the candidate cause is eliminated or reduced, **OR** the effect starts or increases when exposure to the candidate cause starts or increases.	This finding *convincingly supports* the case for the candidate cause, but it may be given a lower score if it could have resulted from other factors (e.g., removal of more than one agent or other unintended effects of the manipulation).	+ + +
	Changes in the effect after manipulation of the candidate cause are ambiguous.	This finding *neither supports nor weakens* the case for the candidate cause.	0
	The effect is not eliminated or reduced when exposure to the candidate cause is eliminated or reduced, **OR** the effect does not start or increase when exposure to the candidate cause starts or increases.	This finding *convincingly weakens* the case for the candidate cause, because such manipulations can avoid confounding. However, effects may continue if there are impediments to recolonization or if another sufficient cause is present.	- - -
	The effect is not eliminated or reduced when exposure to the candidate cause is eliminated or reduced, **OR** the effect does not start or increase when exposure to the candidate cause starts or increases, and the evidence is indisputable.	This finding *refutes* the case for the candidate cause, given that data are based on a well-designed and well-performed study.	R
Laboratory Tests of Site Media	Laboratory tests with site media show clear biological effects that are closely related to the observed impairment.	This finding *convincingly supports* the case for the candidate cause.	+ + +
	Laboratory tests with site media show ambiguous effects, **OR** clear effects that are not closely related to the observed impairment.	This finding *somewhat supports* the case for the candidate cause.	+
	Laboratory tests with site media show uncertain effects.	This finding *neither supports nor weakens* the case for the candidate cause.	0
	Laboratory tests with site media show no toxic effects that can be related to the observed impairment.	This finding *somewhat weakens* the case for the candidate cause, but is not strongly weakening, because test species, responses or conditions may be inappropriate relative to field conditions.	-
Verified Predictions	Specific or multiple predictions of other effects of the candidate cause are confirmed.	This finding *convincingly supports* the case for the candidate cause, because predictions confirm a mechanistic understanding of the causal relationship, and verification of a predicted association is stronger evidence than associations explained after the fact.	+ + +
	A general prediction of other effects of the candidate cause is confirmed.	This finding *somewhat supports* the case for the candidate cause, but is not strongly supportive because another cause may be responsible.	+

Type of Evidence	Finding	Interpretation	Score
	It is unclear whether predictions of other effects of the candidate cause are confirmed.	This finding *neither supports nor weakens* the case for the candidate cause.	0
	A prediction of other effects of the candidate cause fails to be confirmed.	This finding *somewhat weakens* the case for the candidate cause, but is not strongly weakening, because other factors may mask or interfere with the predicted effect.	-
	Multiple predictions of other effects of the candidate cause fail to be confirmed.	This finding *convincingly weakens* the case for the candidate cause.	- - -
	Specific predictions of other effects of the candidate cause fail to be confirmed, and the evidence is indisputable.	This finding *refutes* the case for the candidate cause.	R
Symptoms	Symptoms or species occurrences observed at the site are diagnostic of the candidate cause.	This finding is sufficient to *diagnose* the candidate cause as the cause of the impairment, even without the support of other types of evidence.	D
	Symptoms or species occurrences observed at the site include some but not all of a diagnostic set, **OR** symptoms or species occurrences observed at the site characterize the candidate cause and a few others.	This finding *somewhat supports* the case for the candidate cause, but is not strongly supportive because symptoms or species are indicative of multiple possible causes.	+
	Symptoms or species occurrences observed at the site are ambiguous or occur with many causes.	This finding *neither supports nor weakens* the case for the candidate cause.	0
	Symptoms or species occurrences observed at the site are contrary to the candidate cause.	This finding *convincingly weakens* the case for the candidate cause.	- - -
	Symptoms or species occurrences observed at the site are indisputably contrary to the candidate cause.	This finding *refutes* the case for the candidate cause.	R
Types of Evidence that Use Data from Elsewhere			
Mechanistically Plausible Cause	A plausible mechanism exists.	This finding *somewhat supports* the case for the candidate cause, but is not strongly supportive because levels of the agent may not be sufficient to cause the observed effect.	+
	No mechanism is known.	This finding *neither supports nor weakens* the case for the candidate cause.	0
	The candidate cause is mechanistically implausible.	This finding strongly weakens the case for the candidate cause, but is not convincing because the mechanism could be unknown.	- -

Type of Evidence	Finding	Interpretation	Score
Relationships from Laboratory Studies	The observed relationship between exposure and effects in the case agrees quantitatively with stressor-response relationships in controlled laboratory experiments.	This finding *strongly supports* the case for the candidate cause, but is not convincing because the correspondence could be coincidental due to confounding or differences in organisms or conditions between the case and the laboratory.	+ +
	The observed relationship between exposure and effects in the case agrees qualitatively with stressor-response relationships in controlled laboratory experiments.	This finding *somewhat supports* the case for the candidate cause, but is not strongly supportive because the correspondence is only qualitative, and the degree of correspondence could be coincidental due to confounding or differences in organisms or conditions between the case and the laboratory.	+
	The agreement between the observed relationship between exposure and effects in the case and stressor-response relationships in controlled laboratory experiments is ambiguous.	This finding *neither supports nor weakens* the case for the candidate cause.	0
	The observed relationship between exposure and effects in the case does not agree with stressor-response relationships in controlled laboratory experiments.	This finding *somewhat weakens* the case for the candidate cause, but is not strongly weakening because there may be differences in organisms or conditions between the case and the laboratory.	-
	The observed relationship between exposure and effects in the case does not even qualitatively agree with stressor-response relationships in controlled laboratory experiments, or the quantitative differences are very large.	This finding *strongly weakens* the case for the candidate cause, but is not convincing because there may be substantial and consistent differences in organisms or conditions between the case and the laboratory.	- -
Stressor-Response Relationships from Other Field Studies	The stressor-response relationship in the case agrees quantitatively with stressor-response relationships from other field studies.	This finding *strongly supports* the case for the candidate cause, but is not convincing because the correspondence could be coincidental due to confounding or differences in organisms or conditions between the case and elsewhere.	+ +
	The stressor-response relationship in the case agrees qualitatively with stressor -response relationships from other field studies.	This finding *somewhat supports* the case for the candidate cause, but is not strongly supportive because the correspondence is only qualitative, and the degree of correspondence could be coincidental due to confounding or differences in organisms or conditions between the case and elsewhere.	+
	The agreement between the stressor-response relationship in the case and stressor-response relationships from other field studies is ambiguous.	This finding *neither supports nor weakens* the case for the candidate cause.	0

Type of Evidence	Finding	Interpretation	Score
	The stressor-response relationship in the case does not agree with stressor-response relationships from other field studies.	This finding *somewhat weakens* the case for the candidate cause, but is not strongly weakening because there may be differences in organisms or conditions between the case and elsewhere.	-
	There are large quantitative differences or clear qualitative differences between the stressor-response relationship in the case and the stressor-response relationships from other field studies.	This finding *strongly weakens* the case for the candidate cause, but is not convincing because there may be substantial and consistent differences in organisms or conditions between the case and elsewhere.	- -
Stressor-Response Relationships from Ecological Simulation Models	The observed relationship between exposure and effects in the case agrees with the results of a simulation model.	This finding *somewhat supports* the case for the candidate cause, but is not strongly supportive because models may be adjusted to simulate the effects.	+
	The results of simulation modeling are ambiguous.	This finding *neither supports nor weakens* the case for the candidate cause.	0
	The observed relationship between exposure and effects in the case does not agree with the results of simulation modeling.	This finding *somewhat weakens* the case for the candidate cause, but is not strongly weakening, because it may be due to lack of correspondence between the model and site conditions.	-
Manipulation of Exposure at Other Sites	At other sites, the effect is consistently eliminated or reduced when exposure to the candidate cause is eliminated or reduced, **OR** the effect is consistently starts or increases when exposure to the candidate cause starts or increases.	This finding *convincingly supports* the case for the candidate cause, because consistent results of manipulations at many sites are unlikely to be due to chance or irrelevant to the site being investigated.	+ + +
	At other sites, the effect is eliminated or reduced at most sites when exposure to the candidate cause is eliminated or reduced, **OR** the effect starts or increases at most sites when exposure to the cause starts or increases.	This finding *somewhat supports* the case for the candidate cause, but is not strongly supportive because consistent results of manipulation at one or a few sites may be coincidental or irrelevant to the site being investigated.	+
	Changes in the effect after manipulation of the candidate cause are ambiguous.	This finding *neither supports nor weakens* the case for the candidate cause.	0
	At other sites, the effect is not consistently eliminated or reduced when exposure to the cause is eliminated or reduced, **OR** the effect does not consistently start or increase when exposure to the cause starts or increases.	This finding *strongly weakens* the case for the candidate cause, but is not convincing because failure to eliminate or induce effects at one or a few sites may be due to poorly conducted studies, or results may be irrelevant due to differences among sites.	- -
Analogous Stressors	Many similar agents at other sites consistently cause effects similar to the impairment.	This finding *strongly supports* the case for the candidate cause, but is not convincing because of potential differences among the agents or in conditions among the sites.	+ +

Type of Evidence	Finding	Interpretation	Score
	One or a few similar agents at other sites cause effects similar to the impairment.	This finding *somewhat supports* the case for the candidate cause, but is not strongly supportive because of potential differences among the agents or in conditions among the sites.	+
	One or a few similar agents at other sites do not cause effects similar to the impairment.	This finding *somewhat weakens* the case for the candidate cause, but is not strongly weakening because of potential differences among the agents or in conditions among the sites.	-
	Many similar agents at other sites do not cause effects similar to the impairment.	This finding *strongly weakens* the case for the candidate cause, but is not convincing because of potential differences among the agents or in conditions among the sites.	- -
Evaluating Multiple Lines of Evidence			
Consistency of Evidence	All available types of evidence support the case for the candidate cause.	This finding *convincingly supports* the case for the candidate cause.	+ + +
	All available types of evidence weaken the case for the candidate cause.	This finding *convincingly weakens* the candidate cause.	- - -
	All available types of evidence support the case for the candidate cause, but few types are available.	This finding *somewhat supports* the case for the candidate cause, but is not strongly supportive because coincidence and errors may be responsible.	+
	All available types of evidence weaken the case for the candidate cause, but few types are available.	This finding *somewhat weakens* the case for the candidate cause, but is not strongly weakening because coincidence and errors may be responsible.	-
	The evidence is ambiguous or inadequate.	This finding *neither supports nor weakens* the case for the candidate cause.	0
	Some available types of evidence support and some weaken the case for the candidate cause.	This finding *somewhat weakens* the case for the candidate cause, but is not convincing because a few inconsistencies may be explained.	-
Explanation of Evidence	There is a credible explanation for any negative inconsistencies or ambiguities in an otherwise positive body of evidence that could make the body of evidence consistently supporting.	This finding can save the case for a candidate cause that is weakened by inconsistent evidence; however, without evidence to support the explanation, the cause is barely strengthened.	+ +
	There is no explanation for the inconsistencies or ambiguities in the evidence.	This finding neither strengthens nor weakens the case for a candidate cause.	0
	There is a credible explanation for any positive inconsistencies or ambiguities in an otherwise negative body of evidence that could make the body of evidence consistently weakening.	This finding further weakens an inconsistent case; however, without evidence to support the explanation, the cause is barely weakened.	-