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Biota TMDL Protocols and Submittal Requirements

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<u>*** ATTENTION!*****\</u>**

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Introduction

Purpose

The purpose of this document is to provide guidance on the submission requirements for Biota Total Maximum Daily Load (TMDL) studies by the Minnesota Pollution Control Agency (MPCA) and the United States Environmental Protection Agency (EPA). The intended audience is MPCA staff and management, as well as technical staff of local organizations and consulting firms responsible for developing TMDLs.

While several technical references are provided, the guidance is based on the assumption that the reader has a general knowledge of watershed science, including monitoring and assessment techniques, modeling tools, restoration practices, and the relationships between physical and chemical stream features and aquatic life. This guidance is designed to bridge the gap between general watershed programs, such as Minnesota's Clean Water Partnership and Section 319 programs, and the unique requirements of TMDLs.

While this guidance is intended to build a common understanding of TMDLs, it will not meet every project need. Each TMDL project tends to have its own unique set of issues and challenges. The MPCA will provide the assistance and oversight needed to address these issues on a case by case basis.

Biota Protocol Organization

SECTION I

This section provides background information on the TMDL process, the need for protocol development, and a brief overview of some of the concepts and tools that will be used throughout the biota TMDL protocol. Section I will also provide some historical background on the use of biological data in assessing use attainment status for the streams and rivers of Minnesota. Most of the material in Section I will be a review for those familiar with TMDL requirements and the biological assessment techniques used in Minnesota.

SECTION II

Section II focuses on the Stressor Identification (SI) process and the data required to complete this task. The SI process is a tool developed by EPA for identifying the cause(s) of biological or other impairments in a waterbody. This section will assist the project leader trough the various steps used to identify the most probable stressor(s) in your study watershed. The Stressor Identification process and the Causal Analysis / Diagnosis Decision Information System (CADDIS) developed by the EPA will serve as the framework for this section of the protocol, however, additional steps and tools have been included by MPCA staff with experience in completing SI investigations and biological TMDLs. This section is organized in a step-by-step format and includes worksheets and periodic checklists to guide the user through the SI process. **Completion of the steps outlined in section II should result in the identification of a stressor, or several stressors for which the TMDL needs to address.**

SECTION III

This section will provide guidance for developing a TMDL and Implementation plan for biotic impairments. The federal requirements and Minnesota protocol for TMDL studies will be presented with a specific focus on some of the components unique to biological TMDLs.

SECTION I:
Protocol Intro / TMDL Process Overview

1.1 TMDL Overview

The TMDL process offers an excellent opportunity to identify and restore water quality and aquatic life in streams, rivers, and lakes, as well as enhance the involvement of watershed residents and stakeholders in water quality issues. Other potential benefits of the TMDL process include:

- Encourages the development of a consistent framework for conducting water quality studies
- Defines existing impairments and pollution sources, quantifies source reductions, and sets comprehensive restoration strategies to meet water quality standards
- Provides a framework for assessing future impacts to water quality
- Accelerates the schedule at which impaired waters are addressed through more effective coordination of existing and future resources among local entities, state, and federal environmental agencies
- Provides a basis for revising local regulations (e.g., zoning and sub-division) and developing performance-based standards for future development
- Facilitates the incorporation of TMDL schedules and implementation activities into local government water plans.

What is a TMDL?

A TMDL or Total Maximum Daily Load (TMDL) is a calculation of the maximum amount of a pollutant that a water body can receive and still meet water quality standards, and an allocation of that amount to the pollutant's sources. Section 303(d) of the Clean Water Act (CWA) and its implementing regulations (40 C.F.R. § 130.7) require states to identify waters that do not or will not meet applicable water quality standards and to establish TMDLs for pollutants that are causing non-attainment of water quality standards.

The allowable daily load, or TMDL, can be calculated using the formula below:

$$TMDL = sumWLAs + sumLAs + MOS + RC^*$$

sumWLAs
The Wasteload Allocation (WLA) variable represents the total pollutant allocations associated with existing or future point sources. Common point sources that could influence aquatic life include discharges from wastewater treatment plants and MS4 permitted communities.

sumLAs

The Load Allocation (LA) variable represents the total pollutant loading from non-point sources within the watershed, including natural background conditions. Common non-point sources in Minnesota include sediment and excess nutrients.

MOS

The Margin of Safety (MOS) variable accounts for any uncertainties about the relationship between pollutant loads and receiving water quality (EPA nutrient protocol). This includes seasonal variation

RC

The Reserve Capacity (RC) variable accounts for future pollutant loading resulting from growth. The MPCA requires RC to be *considered* in all TMDL projects. The final report must clearly describe the rationale used for setting the RC. Where appropriate, the inclusion of an RC allocation is encouraged, but not all TMDLs will need to incorporate this variable.

A TMDL study includes the identification of pollutant sources as specifically as possible, and determines or estimates how much each source must reduce its contribution in order to meet the maximum allowable pollutant load. The sum of all contributions must be less than the maximum daily load.

What is the process for completing TMDLs?

As noted above, the Clean Water Act Section 303, establishes water quality standards and TMDL programs. Section 303(d) of the CWA requires states to publish, every two years, an updated list of streams and lakes that are not meeting their designated uses because of excess pollutants or habitat degradation.

The list, known as the 303(d) list, is based on violations of water quality standards and is organized by drainage basin. States must establish priority rankings for waters on the lists and develop TMDLs for listed waters. Minnesota's 303(d) list can be found on the MPCA Web site at: *http://www.pca.state.mn.us/water/tmdl/index.html* The *2006 Guidance Manual for Assessing the Quality of Minnesota's Surface Waters for Determination of Impairment: 305(b) Report and 303(d) List* explains MPCA's process for assessing water bodies for the 305(b) report and the 303(d) impaired waters list. The guidance manual is also on the MPCA Web site at: *http://www.pca.state.mn.us/publications/manuals/tmdl-guidancemanual04.pdf*

The Clean Water Act requires a completed TMDL for each water identified on a state's Impaired Waters list. Lakes or river reaches with multiple impairments require multiple TMDLs. States have the primary responsibility for developing TMDLs and submitting them to EPA for review and approval. If EPA disapproves a TMDL, EPA is required to establish the TMDL.

The TMDL Process

Assess the state's waters
↓
List those that do not meet standards
↓
Identify sources and reductions needed (TMDL Study)
↓
Implement restoration activities (Implementation Plan)
↓
Evaluate water quality

The process for completing a TMDL study is complex and varies significantly from project to project. Some of the many variables that determine scope of a project include:

- Number of pollutant sources
- Type of pollutant and size of the watershed

- Amount of existing data
- Relationship of one impairment to others that may exist in the same or nearby water bodies
- Extent of stakeholder involvement
- Availability of necessary resources.

Public participation is critical throughout the TMDL process, and Minnesota expects advisory groups to be involved from the earliest stages of the project. At a minimum, the EPA requires that the public must be given an opportunity to review and comment on TMDLs before they are formally submitted to EPA for approval. Every TMDL is formally public noticed in Minnesota with a minimum 30-day comment period.

After a TMDL is approved by the EPA, a detailed implementation plan is finalized to meet the TMDL's pollutant load allocation and achieve the needed pollutant reductions or habitat improvements to achieve the biota standard. Depending on the severity and scale of the impairment, restoration may require 10-20 years or longer and millions of dollars. Further information on MPCA's TMDL implementation policy can be found at: *http://intranet.pca.state.mn.us/policies/programpolicies/i-wq2-031.pdf* The reader is also encouraged to refer to EPA's 1991 guidance document: *"Guidance for Water Quality- based Decisions: The TMDL Process"* at *http://www.epa.gov/OWOW/tmdl/decisions/* for a more complete description of the federal program.

Who is responsible for doing TMDLs?

The MPCA is responsible for completing and submitting TMDLs to the EPA. However, stakeholders and local governments play a critical role in the development and implementation of TMDLs. Locally-driven projects are more likely to succeed in achieving water quality goals because local communities often best understand the sources of water quality problems and are better able to find effective solutions to those problems. Their work to develop and implement TMDLs is essential for the successful restoration and maintenance of our rivers, streams, lakes, and the aquatic life and recreational resources they support.

For nearly two decades, the MPCA has contracted with counties, watershed districts, soil and water conservation districts, and other local organizations to restore lakes and streams impacted by non-point source pollution. This watershed work has been completed through the agency's Clean Water Partnership and Clean Water Act Section 319 programs. Many local government agencies have gained considerable expertise in watershed work and stakeholder involvement due to this experience. Building off of this success, the MPCA will provide grant contracts to qualified local governments and watershed organizations to develop and manage approximately two-thirds of future TMDL projects. The MPCA will direct the remaining projects. The contracts cover staffing, equipment, lab costs, and other project expenses. The MPCA also provides oversight, technical assistance, and training to ensure regulatory and scientific requirements are met. The MPCA submits final TMDLs for EPA approval.

For additional information on TMDL grant requirements, see MPCA's TMDL workplan guidance at: *http://www.pca.state.mn.us/publications/wq-iw1-01.pdf*

1.2 Biocriteria Development and Use in Minnesota

The MPCA uses Indices of Biological Integrity based on fish and macroinvertebrate communities to assess the health of rivers and streams. The basis for using the health of the biological community for assessment is the narrative water quality standards in Minnesota Rules Chapter 7050 (*https://www.revisor.leg.state.mn.us/rules/?id=7050*).

The aquatic life use support assessment methodology described in the MPCA's Guidance Manual for Assessing the Quality of Minnesota Surface Waters (*http://www.pca.state.mn.us/publications/wq-iw1-04.pdf*) fully supports this narrative standard and protects the biological integrity of rivers and streams by:

- Measuring attainment directly through sampling of the aquatic biota
- Controlling biological and sampling variability through regionalization, classification and strict adherence to sampling protocol
- Establishing impairment thresholds based on data collected from reference (minimally impacted) waters of the same class, and
- Incorporating a confidence limit (based on the repeatability of the IBI) to account for variability within the aquatic community due to natural spatial and temporal differences and sampling or method errors.

Index of Biological Integrity and Reference Conditions

The MPCA uses an index of biological integrity (IBI) as an initial biological impairment determinant for rivers and streams. The IBI is one of the most common and widely accepted analytical tools used to measure the integrity of aquatic communities. The IBI relies on multiple attributes of the aquatic community, called "metrics", to evaluate a complex biological system. Each metric is based upon a structural (e.g., species composition) or functional (e.g., feeding habits) aspect of the aquatic community that demonstrates a predictable response to human disturbance. The IBI incorporates professional judgment in a systematic and sound manner, but sets quantitative criteria that enable determination of a continuum between very poor and excellent biotic condition. Since the metrics are differentially sensitive to various perturbations (e.g. siltation, toxic chemicals, etc.) as well as various degrees or levels of change within the range of integrity, conditions at a site can be determined with considerable accuracy.

For the IBI to be effective in detecting disturbances due to human influence, it is necessary to identify and partition the factors that contribute to natural variability. On a regional scale, differences in climate, topography, geology and other geophysical characteristics influence aquatic communities. On a reach scale, factors such as stream size and temperature may influence aquatic communities. To account for the variability resulting from these natural differences, it is necessary to classify waterbodies into distinct groups (e.g. small warm water streams, coldwater streams, and large rivers) and develop different IBIs or set different scoring criteria for each stream class.

The MPCA uses a regional reference site approach to develop and calibrate the IBI (Hughes 1995, EPA 1996). The selected reference sites represent a specified waterbody class. Properly defined reference conditions provide a benchmark for comparison to measure the degree of water quality impairment. The term “reference” applies to sites that are least impacted by human influence for a given waterbody class. Reference sites are not necessarily pristine, and in fact rarely are. Many reference sites reflect some degree of impairment caused by centuries of settlement and land use practices.

In Minnesota, the first regions to undergo IBI development were the Minnesota River Basin (Bailey *et al*. 1992) and the Red River Basin (Niemela *et al*. 1998). The indices developed for these basins are based on the original, 60 point scoring system used by Karr (1981). A narrative description of the fish communities, ranging from excellent to very poor, is used as a means to interpret the scores. IBI scores showing an “excellent”, “good”, or “fair” fish community are considered supporting of their aquatic life use.

Figure 1: MPCA staff collecting fish community data

Monitoring and assessment methods have evolved as the biological monitoring program has gained experience and acquired more data from streams and rivers statewide. Beginning in the St. Croix River Basin (Niemela and Feist, 2000, Chirhart, 2002) and the Upper Mississippi River Basin (Niemela and Feist, 2002, Genet and Chirhart 2003), the MPCA began developing IBI's for stream fish and invertebrate communities based on a zero to 100 point scoring system. Impairment thresholds are now determined based on the range of IBI scores measured at the reference sites within each stream class. The lowest IBI score in the range of scores measured at reference sites is an appropriate threshold limit for biogeographically similar areas of the state because reference streams within similar regions and class are likely to exhibit similar departures from pre-settlement conditions.

The MPCA’s Biological Monitoring Program has been collecting data by major river basin over the last 15 years. MPCA biologists are now conducting a statewide analysis of fish and macroinvertebrate community data to provide a consistent and refined approach to biological criteria development for riverine surface waters statewide. All currently available IBI documents can be found at: *http://www.pca.state.mn.us/water/biomonitoring/index.html*

Data Requirements and Determination of Impaired Condition

Biological data are used to assess stream reaches for impaired biological condition for the 305(b)/303(d) integrated report, following the Consolidated Assessment and Listing Methodology (CALM). The period of record for assessment is the most recent decade of available data. An assessment can be based on a single biological monitoring event. Table 1 shows the relationship between IBI scores and use support categories based on impairment thresholds defined by the narrative description of the fish community or by the range of IBI scores at reference sites. Sites with IBI scores above the threshold are considered to be **fully**

supporting of aquatic life. Sites with IBI scores below the threshold are considered **non-supporting** of aquatic life. A **partial support** status may be assigned to a stream segment if multiple samples taken at sites within the assessment unit provide discrepant information. Reaches that are non-supporting or partially supporting of their aquatic life uses are identified as candidates for the 303(d) list.

Table 1: Summary of Data requirements and IBI thresholds for assessment of fish communities

Impairment Assessment For	Period of Record	Minimum No. of Data Points	Use Support or Listing Category Based on IBI Score		
IBI Thresholds → (Old method, Red and Minnesota Rivers)			Excellent, Good or Fair	Multiple sites in a stream segment give discrepant results	Poor or Very Poor
IBI Thresholds → (New method; e.g., St. Croix River)			IBI ≥ impairment threshold*		IBI < impairment threshold*
305(b) Report	Most recent 10 years	na	Fully Supporting	Partially Supporting	Not Supporting
303(d) List (TMDL)	Most recent 10 years	na	Not Listed	Listed**	Listed

* Impairment threshold based on IBI scores from regional reference sites. Thresholds are dependent on region, stream size, and stream classification.
** Following review by professional judgment team

Following the initial biological assessment a final determination of impairment for 303(d) listing is based on an assessment of all available information. This includes habitat quality, available water chemistry data, and biological condition of nearby upstream and downstream segments, local land use information, and other watershed data. The MPCA will present this information to the professional judgment group for the basin in which the reach is located to help make final determinations on use support for 303(d) listing.

1.3 Understanding Impaired Biota

The composition of aquatic communities found in streams and rivers is determined by the interaction of numerous physical, chemical, and biological processes. As a result, biological impairments can be driven by natural or unnatural changes to one or many components of these systems. Biological impairments differ from some traditional water quality impairments in that the impaired biotic communities are indicators of disturbance rather than causes of disturbance. The IBI score is a biologically based reflection of water quality and physical habitat conditions and does not provide the numerical, load-based, water quality information needed for completing a TMDL. An additional effort is required to determine the pollutants or stressors causing the degraded biological assemblage and the parameter(s) for which the TMDL will be completed.

One of the most challenging aspects of biotic TMDL development is identifying the dominant stressors and developing load allocations for them. Biological impairments are commonly caused by stressors that are not considered conventional pollutants within our water quality rules. These include stressors such as degraded habitat or altered hydrology. While it is possible to develop WLA and LA for some non-conventional pollutants, stressors for which loads cannot be determined require flexibility and innovation. Ohio currently completes TMDL reports using Qualitative Habitat Evaluation Index (QHEI) scores as the target.

As the biological monitoring program develops and more biological TMDLs are initiated, we anticipate developing TMDLs using the strategy that best fits the nature of the impairment and still meets TMDL goals and EPA requirements. We encourage our partners to pursue new, innovative approaches for stressor ID and TMDL development. The overall strategy for stressor identification and TMDL development should be discussed as an initial step in these projects. In many cases, additional data collection will be required to provide further insight into the nature of the impairment. We anticipate that the direction of many projects will change once additional information is gathered, and new diagnostic tools are made available.

Completing biological impairment TMDLs is a new and challenging undertaking for the MPCA and its partners. Aquatic organisms are generally responsive to improvements in physical and chemical habitat conditions and can re-populate areas quickly. Dr. Joe Magner, senior research scientist for the MPCA, often repeats the line “If you build it, they will come” from the movie *Field of Dreams,* when speaking of the potential success of stream restoration projects, and the associated repopulation of healthy fish and macroinvertebrate communities. If we work to build healthy watersheds and stream corridors, there is a strong likelihood that we will be able to restore biological integrity as well.

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SECTION II:
Stressor Identification / CADDIS

2.0 Introduction

The US EPA has developed the Stressor Identification (SI) process for identifying any type of stressor or combination of stressors that cause biological impairment. The Stressor Identification is intended to lead water resource managers through a formal and rigorous process that:

- **Identifies stressors causing biological impairment in aquatic ecosystems**
- **Provides a structure for organizing the scientific evidence supporting the conclusions**

The Stressor Identification process (SI) is prompted by biological assessment data indicating that a biological impairment has occurred. The general SI process entails critically reviewing available information, forming possible stressor scenarios that might explain the impairment, analyzing those scenarios, and producing conclusions about which stressor or stressors are causing the impairment. The accuracy of the identification depends on the quality of data and other information used in the SI process. In some cases, additional data collection may be necessary to accurately identify the stressor(s).

The process of stressor identification draws upon a broad variety of disciplines and is most effective when the SI investigators seek input from professionals in aquatic ecology, biology, geology, geomorphology, statistics, chemistry, environmental risk assessment, and toxicology. Sophisticated knowledge in certain fields may increase the tools available to investigators (e.g., physiological responses to certain stressors), but the SI process also can be used by investigators with very general tools (e.g., fish population estimates). Results of general measures, however, may not be as precise as when more specialized measures are used.

Completion of the Stressor Identification process does not result in a finished TMDL. The product of the SI process is the identification the stressor(s) for which the TMDL load allocation will be developed. In other words, the SI process may help investigators nail down excess fine sediment as the cause of biological impairment, but a separate effort is then required to determine the WLA, LA, RC and MOS needed to promote the recovery of the impaired biota. In some cases, the reason for the biological impairment will be fairly obvious, but the Stressor Identification process should still be completed in order to increase confidence in the case and the defensibility of the TMDL.

EPA has developed an internet-based tool to help investigators complete the Stressor Identification process. The Causal Analysis / Diagnosis Decision Information System (CADDIS), offers a step-by-step application of Stressor ID that helps investigators conduct causal evaluations of aquatic ecosystems. Section II of this protocol is based on the CADDIS framework, and will guide the user through CADDIS to identify the most probable causes of impairment.

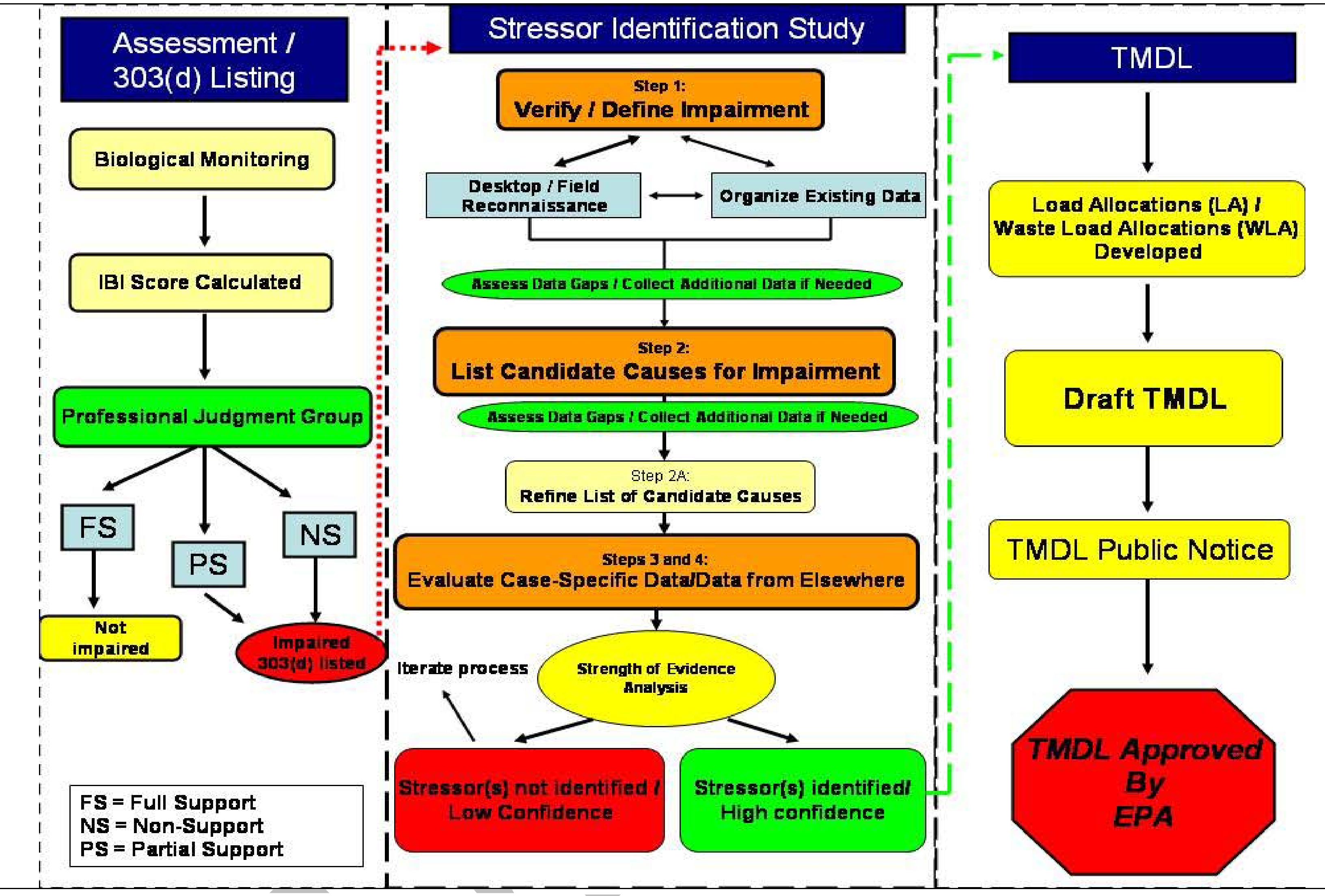

Figure 2: Conceptual model of biological assessment, stressor identification process, and TMDL development. Stakeholder involvement should be included throughout the process as well.

2.1 CADDIS STEP 1: Verify and Define Impairment

The most successful TMDL studies are those with considerable buy-in from local government, stakeholders, and technical experts. In order to maximize buy-in from these partners, there must be confidence that the impairment is properly defined and represents a true impaired condition that can be addressed through the TMDL process.

The first step in the Stressor Identification (SI) analysis is to verify the biological impairment. Verifying the impairment involves the organization and review of historical data, natural background information, and other data that will form the basis of the investigation. This initial step should be approached as a preliminary screening process to address some of the questions and comments that often surface during the early stages of TMDL projects. Verification of the impairment will assure that the MPCA project manager, technical staff, project team, and key stakeholders are all in agreement on the terms of the impaired condition and upcoming TMDL study.

A biologically impaired stream reach does not automatically indicate anthropogenic disturbance within the watershed. Further investigation is needed to determine whether or not the impairment is the result of a disturbance that can be addressed through the TMDL process. Several regions of Minnesota contain stream and river systems with natural background conditions that are less suitable for aquatic life. For example, many streams that originate from or flow through wetland dominated landscapes are often naturally low in dissolved oxygen concentration. This natural condition often limits the diversity of life that can inhabit these streams. Impairments resulting solely from natural background conditions should be considered for de-listing due to natural background conditions. For more information on the delisting of impaired waters, refer to the MPCA guidance presentation *Setting the Course for Improved Water Quality - Listing and Delisting Waters* which can be found at *http://www.pca.state.mn.us/publications/wq-iw3-53.pdf* or section "X" of MPCA's Guidance Manual for Assessing the Quality of Minnesota Surface Waters (*http://www.pca.state.mn.us/publications/wq-iw1-04.pdf*).

Confidence Level in the 303(d) Listing

The impairment listing should be discussed in detail with the project team, MPCA/DNR staff, and possibly even a select group of stakeholders before the TMDL study is initiated. Any uncertainties about whether or not the impairment listing is accurate or deserving of TMDL consideration should be addressed before substantial resources are dedicated to the study. Any issues regarding the 303(d) listing should be brought to the attention of the MPCA TMDL project manager that is assigned to the TMDL. If there are objections or disagreements with the listing and investigators feel it should be dropped, changed, or verified with further data collection, a solution should be developed with coordination from the MPCA project manager and technical staff. In some cases, MPCA staff can provide resources or guidance for additional data collection that will better define the impairment and provide data for stressor identification.

Natural Background Conditions

A screening of natural background conditions in the watershed should be conducted prior to initiating the TMDL/Stressor ID study. The screening should document any natural processes that could potentially limit the quality or availability of aquatic habitat and reduce biological expectations. MPCA has previously de-listed impaired waters due to naturally low dissolved oxygen concentrations (see Hardwood Creek TMDL). Typically, these conditions result from localized groundwater inputs or wetland influence. Minnesota rule 7050.0170 covers waters of the state with natural background conditions that may inhibit certain uses. In section X, subpart C of the MPCA's *Guidance Manual for Assessing the Quality of Minnesota Surface Water* (September 2007), impairments due to natural causes are discussed briefly:

> *"A third pathway for removing a waterbody from the impaired waters list is to determine that there are essentially no anthropogenic sources contributing to the impairment. Thus, the sources of the impairment are all natural. According to US EPA's Consolidated Assessment and Listing Methodology, these waters are impaired but no TMDL pollution reduction study plan is required."*

If natural background conditions are believed to be a factor in the impaired condition, additional monitoring may be required to make the case.

Figure 3: Mission Creek (St. Croix Basin) is naturally low in Dissolved Oxygen concentration due to significant wetland influence. The picture above is biological monitoring station 06SC104.

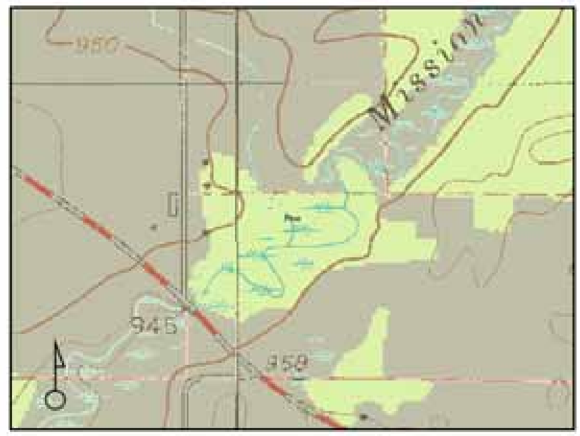

Figure 4: Topographic map of monitoring site showing wetland complex surrounding 06SC104. Extensive diurnal and longitudinal DO monitoring indicated DO concentrations well below the standard of 5 mg/L at all hours.

The pre-TMDL screening of the watershed is not intended to provide loopholes for de-listing or aid in circumventing the TMDL process. Rather, its purpose is to account for the complexity of stream habitats and the natural variability of aquatic resources in our state. Minnesota is an exceptionally diverse state in terms of aquatic and terrestrial ecosystems, and the TMDL process must take that into account.

If natural background conditions are suspected to be prominent stressors, support your case with historical data, or by developing a monitoring plan to collect supporting information. In the case of Mission Creek, shown figures 3 and 4, a monitoring plan was established to conduct intensive water chemistry and diurnal/longitudinal monitoring for dissolved oxygen. Water chemistry and flow monitoring indicated wetland flushing under high flow and prominent wetland signatures under baseflow conditions. Diurnal flux of dissolved oxygen concentrations was very minimal, which indicated the low DO conditions were not the result of increased photosynthetic activity due to nutrient enrichment and primary production/decomposition. Thus, the biologically impaired reaches of Mission Creek are being considered for de-listing due to natural background conditions in the watershed.

Geographic Scope and Stream Reach Addition/Removal

Minnesota currently lists streams as biologically impaired based on Assessment Unit Identification (AUIDs). AUIDs are stream reaches typically determined by significant breakpoints in stream networks (large lakes, major tributaries, coldwater/warmwater fishery designations, etc.). Before initiating the TMDL study, it is important to identify the AUIDs included in the 303(d) listing and understand the use designations assigned to each of them. It may prove valuable to look for additional stream reaches or significant tributaries for impaired conditions that can be grouped within the same Stressor ID and TMDL study. When possible, it's advantageous to address them together if they are within a common watershed of reasonable scale and/or they are likely to exhibit common stressors to aquatic life.

Although AUIDs serve as the basis for 303(d) listings, it is valuable to characterize the impaired stream reaches based on a set of key factors such as land-use, channel morphology, existing habitat conditions, and restoration potential. Watershed reconnaissance methods, which will be covered in detail in the next section of the protocol, can help in accomplishing this type of stream reach characterization. Stratifying the stream by these characteristics facilitates site selection for new monitoring stations and helps screen for potential stressors and their sources.

2.2 Define Impairment

After verifying the impaired condition and characterizing the impaired stream reaches, provide a description of the impairment that prompted the stressor ID and TMDL study. The impairments should be described in terms their nature, magnitude, frequency, and duration.

The nature of the impairment refers to the parameters for which the reach is impaired. Briefly discuss the designated use classes of the impaired reach and the standards that are used to assess them. Use class designations for Minnesota waters can be found in Minnesota Rule 7050.0470. When defining the impairment, be sure to list any violations of water quality standards or "flags" for parameters that appear problematic but have insufficient supporting data for listing. Be sure to reference the Index of Biotic Integrity (IBI) threshold used to list the stream reach, or document the narrative standard used if applicable (i.e. lack of coldwater assemblage).

The "magnitude" of impairment refers to the degree by which the state standard in question was violated. Minnesota operates on the basis of "independent applicability," meaning that a single impaired biological site along a stream reach can result in a TMDL listing, even if every other site on that reach is in compliance with the standard. The magnitude of impairment should be defined by comparing the IBI scores (or other biological data) to the applicable standard. Temporal information should also be provided for the impairment (i.e. dates of assessment and TMDL listing).

"Frequency" and "duration" are terms that are more applicable to water quality impairments such as turbidity or low dissolved oxygen. Most biological impairments tend to be longer in duration and do not oscillate from impaired to unimpaired on short time scales. This is especially true for those impairments driven by watershed-wide, non-point source stressors that cause long-term physical habitat degradation. Frequency and duration of the impairment may apply to impairments where stressors are the result of point-source discharges, or seasonal variations of stream conditions.

Example*:* *(Description of the impairment (Little Scioto River, Ohio, USA)*

2.3 Using IBI Metrics and Habitat Data

Disaggregating the Index of Biotic Integrity into its component metrics is helpful for identifying stressors and the distinctive mechanisms or exposure pathways affecting aquatic biota. This task should be completed early in the Stressor ID/TMDL study to better your understanding of the impaired condition. This section will cover some of the common attributes (or metrics) used in IBI scoring and how they can be used to infer relationships between various stressors and biological response. Many metrics respond to a multitude of stressors and their cumulative effects and therefore may not be diagnostic of any one stressor.

The following metrics represent a selection of possible biological attributes to evaluate. Take time to look through existing biological data and associated stressor information and pay attention to metrics scores that have been demonstrated to show a response to known stressors. After completing this step, you should be able to describe the impairment with greater detail, and the stressor identification study will be more focused on the mechanisms most likely responsible for a low IBI score or degraded biological assemblage.

Species Richness and Composition

Total number of native fish species:

The species richness metric (excludes hybrid and exotic species) is common to almost every IBI developed in streams throughout the country. For warm or cool water streams and rivers, it is well documented that species richness declines as environmental degradation increases (Karr et al. 1986; Leonard and Orth 1986). Therefore, the number of native fish species metric is expected to give an indication of environmental quality throughout the range of IBI scores, from exceptional to poor. However, because it is responsive across the range of disturbance and to a multitude of stressors, it is not particularly diagnostic of any one stressor.

Number of darter species:

Darter species are generally found in higher quality streams throughout Minnesota and many are considered sensitive to environmental degradation. Darters are small benthic species that are typically found in riffle and run habitats. Most are benthic invertivores and simple lithophilic spawners, and therefore rely on undisturbed benthic habitats (i.e. clean, course substrates) in order to feed and reproduce. Loss of channel complexity (i.e. riffle, run, pool sequences) from channelization and siltation of coarse substrates (embeddedness) will cause these species to decline.

Number of Ephemeroptera, Plecoptera, and Tricoptera (EPT) Taxa:

Macroinvertebrates in the orders Ephemeroptera (mayflies), Tricoptera (Caddisflies), and Plecoptera (Stoneflies), are known to be excellent indicators or overall environmental disturbance. The EPT taxa inhabit a wide variety of habitats, ranging from fast flowing riffles, to sparsely vegetated pools, and slow moving wetland type reaches. Because of their ability to exploit a variety of habitats, their diversity is a good indicator of habitat quality. Sometimes the order Odonata (dragonflies) is added to this metric to make it more useful in slow moving, wetland type systems where stoneflies are less likely to thrive.

Percent Dominant 2 Taxa:

The relative abundance of the two most dominant taxa tends to increase in degraded streams. Healthy aquatic ecosystems tend to have diverse invertebrate communities with an even distribution of taxonomic groups. An uneven distribution of organisms or a population dominated by one or a few taxa, can be indicative of disturbance.

Trophic Composition and Reproductive Function

Percent of individuals that are simple lithophilic spawners:

Successful reproduction is critical to the survival of any organism. The spawning strategies of some fish species have been shown to be affected by habitat quality (Berkman and Rabeni 1987). Simple lithophilic spawners are fish species that broadcast their eggs over clean course substrates and do not build a nest or provide parental care (Balon 1975). After broadcasting their eggs, the eggs are allowed to develop in the interstitial spaces between gravel and cobble substrates. Fish that exhibit this spawning behavior appear to be the most environmentally sensitive of the spawning guilds. These species are particularly sensitive to habitat degradation caused by excessive sedimentation (Berkman and Rabeni 1987). Often times the necessary habitat is not available at the time of spawning or the eggs are smothered by sediment.

Percent of individuals that are omnivores:

Omnivorous fish species are those that have the physiological ability (usually indicated by the presence of a long coiled gut and dark peritoneum) to digest both plant and animal matter (Karr et al. 1986). Because omnivores are flexible in regard to the food they eat, they generally do better than specialized foragers in conditions where the food supply has been disrupted or degraded. Their dominance within a fish community indicates an unstable food base and can be indicative of increased nutrient loading (McCormick et al. 2001; Thoma and Simon 2003).

Number of filterer taxa:

The number of filterer taxa represents the number of different macroinvertebrate taxa that collect their food by filtering it out of the water column. The filtering is typically done one of two ways: 1) by using physical adaptation such as a filamentous antennal structure or 2) by constructing a net which filters the water and gathering filtered material from the net. A high number of filterers indicate an abundance of particulate matter in suspension.

Abundance and Condition

Percent of individuals with deformities, eroded fins, lesions, or tumors (DELT anomalies):

The percent of individuals with DELT anomalies metric has been used to identify sites that have been severely degraded. In other parts of the Midwest DELT anomalies have been associated with environmental degradation primarily due to industrial pollutants (Sanders et al. 1999). The highest incidence of DELT anomalies in fish often occur downstream from dischargers of industrial and municipal wastewater, and areas subjected to the intermittent stresses from combined sewers and urban runoff (Ohio EPA 1987). DELT anomalies are not prevalent in fish from most Minnesota surface waters; however, it is important to retain the metric to identify streams that are severely degraded and to provide evidence of a causal pathway where chemical pollutants may be a likely stressor.

Tolerance Measures

Number of Intolerant Taxa:

Number of Intolerant Taxa is a direct measure of taxa richness of those organisms receiving a score of two or lower in the Hilsenhoff Biotic Index (HBI) (Hilsenhoff 1987). The HBI was developed as a tool to monitor the effects of organic enrichment on the aquatic invertebrate community. An organism with a high score has been defined by Hilsenhoff to be tolerant of organic pollution. An organism with a low score is considered sensitive to organic pollution. The presence of moderate numbers of intolerant taxa is an indicator of good aquatic health.

Percent Tolerant Taxa:
This metric looks at relative abundance of tolerant taxa. Tolerant taxa are those that receive a rating of eight or higher in the HBI. Tolerant invertebrates are often found to thrive in areas known to have low dissolved oxygen, high turbidity, or heavy siltation. Unlike intolerant taxa, tolerant organisms occur at all sites but tend to dominate in relative abundance as conditions are degraded (Fore et al. 1996).

Habitat Measures

Number of Clinger Taxa:
Clinger taxa are organisms that have morphological adaptations that allow them to thrive by attaching to the substrata in fast flowing water. Clinger taxa include flat bodied organisms such as stoneflies and Heptageniid mayflies; organisms that attach themselves to rocks and plants, such as blackflies and craneflies; netspinning caddisflies that attach themselves to stationary substrates; and casebuilding caddisflies (Rossano 1995, Merritt and Cummins 1996). A diverse group of clinger taxa indicate that substrate has not become embedded or covered by fine organic or inorganic material. A lack of clinger taxa can indicate siltation or substrate embeddedness that generally is the result of erosion.

2.4 Define the Objectives of the Stressor ID Investigation

The objectives describe the management context within which the results of the investigation will be used. These objectives may be limited or broad. In most cases, the primary objective is to evaluate which cause, among several potential candidate causes, is most likely responsible for an observed effect. The investigation's purpose influences the range of candidate causes that will be considered. For this reason, defining the investigation's objectives has ramifications for the final outcome and the practical use of the entire causal assessment effort. It also determines the extent and types of data that will be analyzed, and influences the geographic area and time frame under consideration (*example objectives statement*).

2.5 CADDIS STEP 1 WRAP-UP

At the conclusion of CADDIS Step 1, you should have completed the following:

Section 2.0 (CADDIS Step #1) - Verify and Define Impaired Condition
☐ **The details of the impairment should be verified and generally agreed upon among the managers, stakeholders, and technical staff involved. (section 2.1)** ☐ **Natural or unnatural (i.e. dams, irreversible channelization) background conditions that could be causing the impairment should be discussed and documented (section 2.1)** ☐ **The stream reaches included in the listing should be identified and described in terms of beneficial use criteria and assessment unit identification (AUID). If the project managers have any interest in adding, removing, or changing the stream reaches included in the study, that should be addressed in this stage of the project if possible (section 2.1)** ☐ **The impairment should be described in terms of its spatial extent, magnitude, and nature (section 2.2)** ☐ **The Index of Biotic Integrity (IBI) scores should be further evaluated. The metric scores and biological assemblages found in the stream should be analyzed to glean information on potential stressors in the watershed. (section 2.3)**

**** EPA CADDIS *example products from Step 1* ****

3.0 Reconnaissance for Stressor Identification

Completion of CADDIS step 1 results in an executive summary of the impaired condition, watershed characteristics, and geographic scope of the study. Step 2 of the Stressor ID / CADDIS process will present various tools and techniques that can be used to further assess watershed processes and biological integrity for the purpose of identifying candidate causes for the impaired condition. Upon completing this step, you will have compiled adequate information to develop a list of candidate causes and identify major data gaps that need to be filled in order to verify or refute them.

Watershed information should be collected early on in the Stressor Identification process and used throughout the investigation to support claims and guide data collection efforts. This section will identify important watershed data sets, analysis tools, and reconnaissance methods that will be useful in Stressor ID and TMDL studies. The most effective method for watershed recon and data collection will vary depending on the geographic scope of the impairment and the level of familiarity with the impaired stream and its watershed.

The degree to which watershed data will be used in actual TMDL development will vary depending on the nature of the impairment, the dominant stressors involved, and the pathways of those stressors. Stressors resulting from watershed-wide disturbances (i.e. impervious surface coverage, widespread deforestation) will rely more heavily on high quality watershed data for modeling purposes. Impairments that are driven by localized stressors (perched culverts, localized habitat degradation, point-source discharge), will utilize site-specific data and consequently rely less on comprehensive watershed data. Regardless of its use in the TMDL equation, an understanding of watershed characteristics and processes are critical for the elimination or diagnosis of candidate causes for impairment.

3.1 Level I: DESKTOP RECONNAISSANCE

The first level of stream and watershed reconnaissance can be performed without leaving the office. The "desktop reconnaissance" stresses the use of GIS coverages, aerial photos, topographic maps, historical data and other resources to generate an overview of key watershed characteristics and processes. The data compiled during the desktop reconnaissance will serve as the foundation for the Stressor ID and TMDL studies by helping investigators organize and analyze existing data, as well as identify data gaps that need to be filled. The following tools should be considered during the planning and reconnaissance phase of the stressor identification and TMDL study.

The following sections are not necessarily presented in chronological order or by priority. Each of the following data sets will be valuable to stressor ID projects and TMDL studies. These data should be gathered in the preliminary stages of these studies to provide managers, stakeholders, and technical staff with the resources for a successful project.

High Resolution Aerial Photography

Aerial flyovers are available to facilitate stressor identification and biotic TMDL development. The optimal time to conduct these aerial flyovers is in the spring after snowmelt and prior to tree canopy cover. Late fall can also offer good conditions for aerial photography. Stream systems with little or no canopy cover, like some of the streams in western Minnesota, can be photographed in mid-summer months. The lack of leaf cover in the spring creates an opportunity to collect detailed aerial images of the stream channel, banks, and riparian corridor. These images allow for detailed evaluation of channel conditions and processes that may be affecting aquatic habitat.

Obtaining high quality aerial photos should be one of the first considerations for all biological TMDL projects. These photos are valuable for desktop reconnaissance work and for planning the fieldwork components of the project. They also serve as powerful visual aids during stakeholder presentations, and can be used as supporting evidence for stressor verification and TMDL development.

Historic Aerial Photography

Historical aerial or land based photography can provide valuable information to the stressor ID and TMDL study. These photos can provide documentation of changes in land-use, stream channel stability, stream impoundments, etc. Historical photos may help define the temporal scale for the potential stressor sources within the watershed. The information gathered from aerial photos can also aid in setting realistic and obtainable goals for the TMDL study and implantation measures.

Historic aerial photos area available for some counties through the Minnesota DNR data deli and MPCA GIS database (see Table 2). Other sources for aerial imagery include the *Minnesota Land Management Information Center* (LMIC) and the *University of Minnesota's John R. Borchert Map Library*.

Minnesota Department of Natural Resources (DNR) Watershed Assessment Tool

The DNR is in the process of developing a Watershed Assessment Tool (WAT) to aid with watershed level natural resource management. This tool can be used for informing watershed-based monitoring and TMDL projects. The tool is based on the five major components of river systems discussed earlier in this protocol; hydrology, biology, water quality, geomorphology, and connectivity. The purpose of the tool is to educate citizens and water quality professionals about the linkages between these five components and their importance for protecting and restoring Minnesota's water resources.

The first section of the WAT explains the five components of river systems in detail. This section includes numerous high quality graphics that further explain the importance of each component. Links are provided for GIS data layers related to each component. There are also map books available for each major watershed that display data layers and summary information by watershed. These sections of the WAT provide a great overview of the important components to consider when putting together or reviewing a monitoring plan for stressor ID and TMDL development.

The second section of the WAT is the watershed assessment mapping tool. This tool displays, summarizes, and compares GIS natural resource data by major watershed boundary. The data layers available through the WAT can be used during the early phases of stressor ID projects to identify major geological, ecological, and political factors in the watershed. There are data distribution and summary tables for each major watershed in Minnesota. Most of the available data layers are related to the five major components of river systems. Plotting these layers on a watershed map within the WAT provides a general picture of watershed health. The data available through the WAT can provide supporting data for causal analysis, aid in the planning of monitoring efforts, and provide stakeholders with user-friendly watershed data.

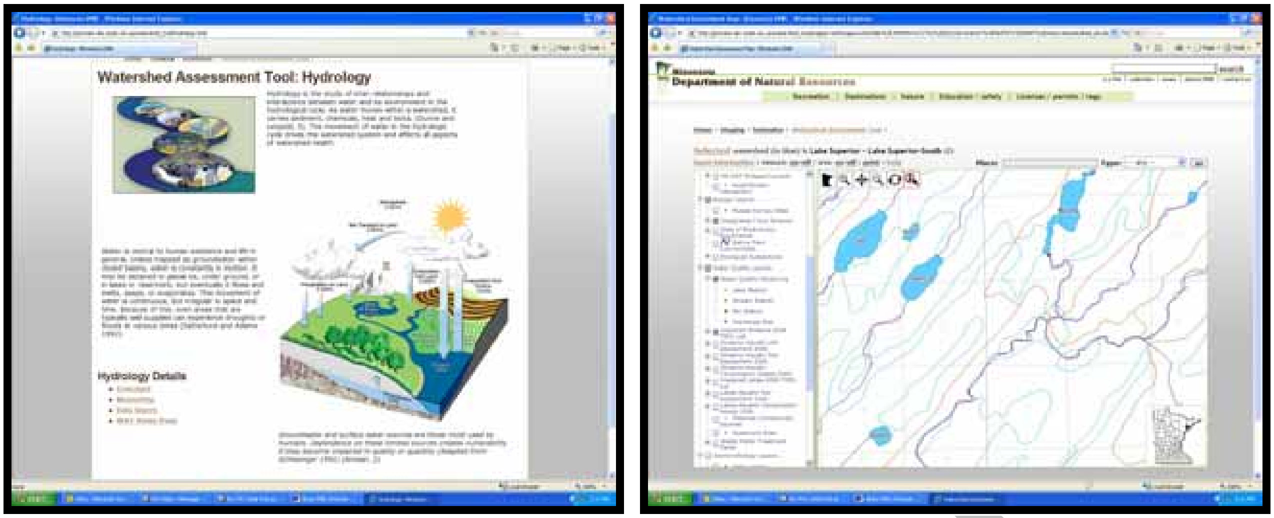

Figure 5: Screenshots from DNRs Watershed Assessment Tool (WAT)

The current version of DNRs WAT is Phase One of the tool. Future versions will provide analysis and ranking of watershed health using key data layers, and eventually allow for the examination of trends in watershed state and condition. The WAT is available at the following link (*http://www.dnr.state.mn.us/watershed_tool/index.html*).

GIS data layers provide key information and modeling tools for many impaired waters studies. These data are especially valuable for acquiring information on the natural background conditions of the watershed, identifying potential pollutant sources and pathways, and model development for TMDL load allocation scenarios. This section provides some information on common GIS layers used in stressor identification studies and where to obtain them. The intent of this list is to highlight the data layers that would be the most useful for biological TMDLs in Minnesota. Table 2 is not a complete list of available data layers, and it should be noted that many more spatial data layers are available to suit your project needs. Some of the layers listed below can be found on MPCA's local network. Others will need to be downloaded from public websites. If you are interested in one or more of the datasets on the following page but do not have access to the MPCA's GIS database, contact one of the MPCA's GIS contacts:

Thomas Pearson, MPCA - St. Paul Office (thomas.pearson@pca.state.mn.us)
Nels Rasmussen, MPCA - Rochester Office (nels.rasmussen@pca.state.mn.us)
Pete Knutsen, MPCA - Brainerd Office (pete.knutson@pca.state.mn.us)

Also, be sure to check with county offices and other local partners to find out what GIS layers and aerial imagery is available for the study area. Many counties are investing in LIDAR imagery and geologic studies that can aid in stressor ID and TMDL studies.

Table 2: Key GIS layers for conducting stream and watershed reconnaissance to define the impaired condition and identify potential stressors to aquatic life.

Parameter	Specific Details	Scale	Location
Soils and Geology	SSURGO: Soil Survey Geographic database from the Natural Resources Conservation Service (NRCS)	1:12,000 to 1:63,360	V:\soils\ssurgo
	STATSGO: State Soil Geographic database from NRCS	1:250,000	V:\soils\statsgo
	Surficial geology		X:\Agency_Files\Water\GIS\data\minnesota\geology\quatgeo
Current Land use and Land cover	State-wide land use / land cover data for 2000		X:\Agency_Files\Water\GIS\data\minnesota\landcover\landcover_mn_2000
	State-wide impervious data layer for 2000		X:\Agency_Files\Water\GIS\data\minnesota\impervious\impervious_mn_2000
	State-wide impervious data layer for 1990		X:\Agency_Files\Water\GIS\data\minnesota\impervious\impervious_mn_1990
Pre-settlement Vegetation	Spatial data layer of pre-settlement vegetation		X:\Agency_Files\Water\GIS\data\minnesota\landcover\presettle_veg
Topography	30-meter NED DEM data layer for Minnesota		V:\elevation\national_elevation_dataset\ned30\mn_ned
	10-meter NED DEM data layer for Minnesota		V:\elevation\national_elevation_dataset\ned10\ned10
	A hillshade created using a 30-meter DEM with a five-meter vertical exaggeration		X:\Agency_Files\Water\GIS\data\minnesota\dem\mn_hill_ned5
	Most up-to-date coverage for NED		http://seamless.usgs.gov/website/seamless/viewer.htm
Hydrography	National Hydrography Dataset (NHD)	1:100,000	U:\nhdrl\ 100KNHD_linearrch.lyr (rivers) 100KNHD_wb.lyr (lakes)
	National Hydrography Dataset (NHD)	1:24,000	U:\nhd_24kic\Data\NHDinSDE\ nhd_flowline (rivers) nhd_waterbody (lakes)
Aerial Photography	Best source for imagery data layers in Minnesota is the imagery server at Minnesota Land Management Information Center (LMIC)		http://www.lmic.state.mn.us/chouse/wms_image_server_description.html
	Additional imagery datasets (Farm Services Agency (FSA) and the National Agriculture Imagery Program (NAIP)		V:\images
Point sources, Feedlots, Impervious surface	Registered Feedlots		V:\pca\feedlots.lyr
	Impervious Surfaces		X:\Agency_Files\Water\GIS\data\minnesota\impervious
	Discharges to Surface Water (Point-Source)		V:\pca\delta_water_quality_stations.lyr
Additional Data Layers	Minnesota PCA		U:\ and V:\ drives
	Minnesota DNR		http://deli.dnr.state.mn.us/
	Minnesota DNR Watershed Assessment Tool		http://preview.dnr.state.mn.us/watershed_tool/index.html
	Minnesota Land Management Information Center		http://www.lmic.state.mn.us/chouse/metalong.html

Watersheds and Sub-Catchments

The DNR offers GIS watershed layers delineated to major drainage basin, major watershed, and minor watershed. These layers are easily obtainable and are useful for plotting land-use data, monitoring sites, and also provide solid graphic aids for stakeholders and technical team members. The following GIS layers have also proven to be valuable in Stressor Identification and TMDL studies.

(1) NRCS 8 and 11-digit HUC Watersheds
The NRCS 8 and 11-digit HUC watersheds provide the framework for the MPCA's intensive watershed monitoring effort that began in 2006. The impetus for this effort was the need for a more systematic, comprehensive monitoring approach for the assessing biological integrity of the state's watersheds. The adoption of this monitoring framework has led to a watershed approach that is used for biological assessment, identification of impaired waters, and TMDL development.

The NRCS 8 and 11-digit HUCs can be used as the watershed scale for Stressor ID and TMDL development. Currently, MPCA staff is in the process of developing several stressor identification studies and TMDLs on the 11-digit HUC scale. The MPCA advocates developing watershed TMDLs for impaired biota, as long as the scale provides adequate resolution for the identification of stressors and their stressors. Consider using the 8 and 11-digit HUC watersheds to expand the scope of the investigation if there are other impaired streams within close proximity. If additional biological data is required to determine the extent of the impairment within the watershed, contact the MPCA project manager to discuss options for additional monitoring.

(2) NHDPlus Sub-Catchment Watershed Layers
The National Hydrography Dataset (NHD) 100k sub-catchments are available though the MPCA's GIS database. If you have access to this database, these layers can be found on the network at U:\nhd_plus_100k\. The NHD sub-catchments are derived from an integrated suite of application-ready geospatial data products, incorporating many of the best features of the NHD, the National Elevation Dataset (NED), and the National Watershed Boundary Dataset (WBD).

MPCA staff are using NHDPlus sub-catchments to complete the Watershed Assessment of River Stability and Sediment Supply (WARSSS) process for the Ann River watershed near Mora, MN. The NHD sub-catchment layer has provided a workable scale to investigate sediment sources and pathways within the 46,000 acre watershed.

Identify Points of Interest

After compiling GIS layers, topographic maps, aerial photos, and other desktop data, we recommend dedicating some time to identifying "points of interest" within the study area. The points of interest may be high/low risk land-use, changes in stream type or habitat type, natural features, or other characteristics that may be influencing conditions within the watershed. The points of interest should be documented and described so they can be field verified later in the data collection process. Field verification is discussed further in section 3.7 of this protocol.

Points of interest are best identified using current or historical aerial photos, GIS, Google Earth, or a combination of all of these resources. MPCA staff typically use Google Earth (http://earth.google.com/) to conduct a "fly over" of the study area before initiating data collection efforts. Google Earth offers aerial imagery in a user-friendly format. This free software program provides an excellent tool for learning more about the watershed and identifying points of interest that warrant further investigation.

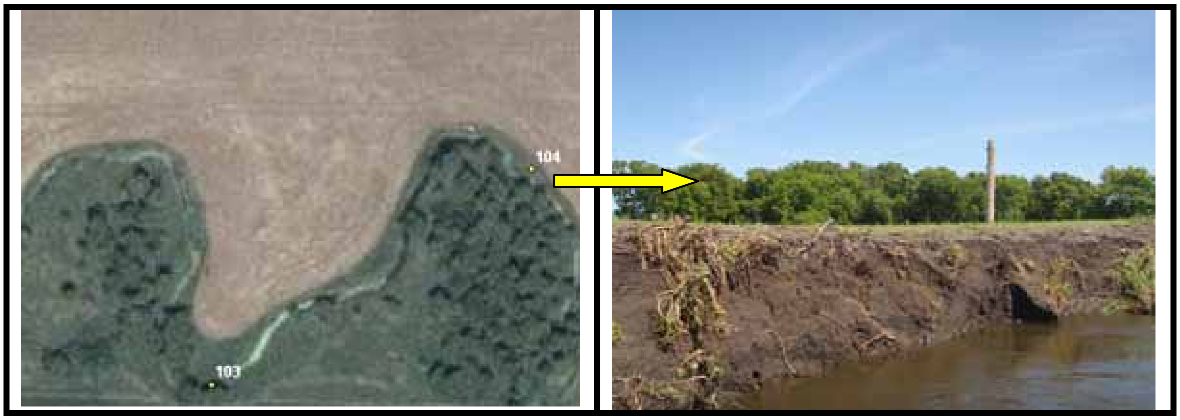

Figure 6: MPCA staff are currently conducting pre-TMDL / Stressor ID monitoring in the Drywood Creek watershed in western Minnesota. During a pre-monitoring "fly-over" using Google Earth and aerial photos, MPCA staff identified points of interest like the one depicted in the photo above (left). From the photo, it was noted that row crops were being cultivated right up to the stream bank. A field visit to this site provided (right) verification of these practices, and also evidence that weed killers were being applied right up to the stream.

The example above is just one type of feature worth documenting during initial photo reconnaissance work. Identifying points of interest prior to field activities using these desktop tools can significantly improve the efficiency of field visits, and will also provide the context for making more sense out of your field observations. Identifying points of interest via maps and aerial photos is a quick way to make the fieldwork portion of the project more manageable and focused on potential impacts to aquatic life.

3.7 Level II: Field Reconnaissance

Geographic Information Systems (GIS) and topographic maps are useful planning tools, but there is no substitute for field observations. For example, a land-use GIS dataset may identify a piece of land as pasture, but it will not provide any information as to how that pasture is managed, or the impact that that pasture may have on the stream. Aerial photos can sometimes be used to identify areas of streambank erosion, but bank angles, height, soil composition and other details are difficult to determine unless you are in the field collecting those measurements. A few solid days of field reconnaissance can provide valuable background information to better understand the dynamics of the watershed and potential stressor sources.

The next phase of reconnaissance involves some level of fieldwork in order to verify and expand on the information collected during the previous step. After completing the field reconnaissance work, you should have a fairly comprehensive understanding of the key watershed processes and pathways that shape the physical and chemical characteristics of the aquatic habitat within the study watershed. Field visit locations should include the areas of interest identified through the desktop reconnaissance. The following sections present some important watershed features and concepts to consider when performing the field reconnaissance visits.

Objectives of Stream and Watershed Reconnaissance

Objective #1: Document Physical Integrity of Stream Channel / Riparian Conditions

The physical integrity of the stream channel and riparian corridor often dictates the quality of habitat available to aquatic life. Stream channel stability is driven by four major variables -

sediment discharge, sediment particle size, streamflow, and stream slope (Lane, 1955). These variables can change significantly within a watershed depending on stream order, local geology, land use, and other natural and anthropogenic influences. It is important to assess the physical integrity of the impaired watershed, and attempt to understand the connections of these physical variables to biological integrity.

A wide variety of data collection methods exist for assessing physical integrity of stream channels, ranging from highly rigorous and quantitative to rapid and qualitative. Most of these methods focus key components of stream channel stability, riparian quality, and in-stream habitat quality. The methods used during the initial watershed reconnaissance should be more rapid and qualitative, as the objective is to collect data on a larger spatial scale in order to make general assessments of physical integrity. The qualitative data collected throughout the study watershed will facilitate the selection of specific study reaches to return to for more rigorous data collection, if such data is deemed necessary.

The methods in table 3 can be incorporated into the stream reconnaissance effort for documenting physical integrity, channel stability, and riparian conditions. If done at enough sites within the study watershed, the results can provide a rapid, watershed-wide analysis of channel condition and corresponding habitat quality. These methods are especially valuable if little is known about the physical condition of the stream corridor. If the physical integrity and channel evolution processes are already well-known within the watershed, it may be worthwhile to move on to more rigorous assessment methods, such as those described in section 4.5

Table 3: Rapid Assessment methods for physical integrity/riparian quality of stream channels and corridors

Methods for Rapidly Assessing Physical Integrity of Stream Channel and Riparian Quality	
Rapid Geomorphic Assessment (RGA)	**Klimetz, L., and Simon, A., 2008. Characterization of "Reference" Suspended-Sediment Transport Rates for Level III Ecoregions of Minnesota. *USDA-ARS National Laboratory Technical Report* No. 63.**
Pfankuch Stability Index	Pfankuch, D. J. 1975. Stream Reach Inventory and Channel Stability Evaluation. USDA Forest Service, R1-75-002, U.S. Government Printing Office #696-260-200, Washington, D.C.: 26 pp.
Rosgen Recon Level Assessment (RLA)	**http://www.epa.gov/warsss/** **http://www.wildlandhydrology.com/**
Minnesota Stream Habitat Assessment	http://www.pca.state.mn.us/publications/wq-bsm3-02.pdf
NRCS Stream Visual Assessment Protocol	http://www.nrcs.usda.gov/technical/ECS/aquatic/svapfnl.pdf
MADRAS (Ditch Assessment)	Contact Joe Magner at MPCA, St. Paul Office

Assessments of channel stability, riparian condition, and physical habitat should be conducted within reaches that exhibit different features, both naturally and due to anthropogenic influence. These features include changes in stream gradient, substrate particle size or composition, bank height/angle/composition, width to depth ratio, channel and valley geometry, and in-stream habitat features such as pool and riffle quality. Documenting the various channel types and habitat conditions throughout the study area will define the existing conditions and may help in identifying stressors related to physical stream characteristics and processes. Table 4 presents some of the areas that MPCA staff typically collects data to assess channel stability and physical habitat.

Table 4: Recommended areas for assessing channel stability/riparian quality

Recommended Locations for Assessing Channel Stability	
· **Biological Monitoring Stations**	· **Upstream/Downstream of major tributaries**
· **Changes in local land-use**	· **Upstream downstream of stream impoundments, diversions, reservoirs**
· **Change in riparian condition or type**	· **Impacted areas (areas of known incision (down-cutting) or stream bed aggradation)**
· **Change in local geology/topography**	· **Minimally disturbed sites (i.e. river form and fluvial processes in tact)**

Objective #2: Document Hydrologic Features / Pathways

Hydrologic features such as tributaries, wetlands, connected lakes or reservoirs, and groundwater seeps or springs should be identified, characterized, and evaluated for potential influences on the conditions of the study stream. An efficient method for assessing the water chemistry and hydrological characteristics of these features is to take a water quality monitoring device (such as YSI or Hydrolab) and obtain a set of measurements from these areas under different flow conditions. MPCA staff typically tries to collect water samples and field parameters at key hydrological locations under three flow conditions - first flush of spring snowmelt, summer low flow (baseflow), and during a May/June or fall rain event. The water chemistry parameters used are listed in the table below. It is not necessary to sample every wetland inlet/outlet, field tile outfall, groundwater seep, etcetera; the objective is to obtain representative samples from water sources, conduits, and sinks. Data collection at these locations during distinct points of the hydrograph will make it easier to select parameters and monitoring locations for further monitoring.

Table 5: Watershed reconnaissance of hydrological pathways/processes

General Reconnaissance Approach for Watershed Processes/Pathways	
Equipment	1. Water monitoring device (YSI, Hydrolab, Hach) **Key parameters:** *Temperature, Specific Conductivity, pH, Dissolved Oxygen, Turbidity, ORP* 2. Digital Camera/GPS (Document monitoring sites)
Sampling Events	1. Spring Snowmelt - "First Flush" 2. Baseflow (summer) 3. Rain Event (summer/fall)
Monitoring Locations	1. Source water areas (headwaters streams, wetlands, lakes, etc.) 2. Road/Drainage Ditches 3. Field tile outfalls (Agricultural Watersheds) 4. Stormwater Outfalls 5. Wetlands that outlet to stream, or flow-through wetlands 6. Groundwater upwellings / seeps 7. Longitudinal sites along main stem of impaired stream

Analyzing water samples for geochemical parameters and stable isotopes is an effective method for documenting the hydrological pathways and processes within a watershed, such as groundwater/surface water interactions. For additional information on this technique, refer to Appendix (currently under development).

Objective #3: Document Impacted Areas / Reference Reaches/Potential Stressor Sources
In most cases, the initial review of aerial photos, GIS layers, and topographic maps will result in a set of locations that will need to be further investigated in the field. These areas may consist of potential stressor sources (i.e. gravel pits, wastewater treatment facilities, areas of severe bank erosion, etc.), impacted areas, or potential reference reaches. Be sure to document these locations with field notes, photographs, and GPS the location if necessary.

MPCA staff has conducted several stream surveys to document these features within impaired watersheds. The points of interest tend to vary depending on they type of watershed the impaired stream is in (i.e. urban, agricultural, forested). The table below covers some points of interest that should be documented if they exist in the study area. In some cases, it may be more valuable to develop more generalized descriptions of these features. For example, in a watershed with extensive erosion processes, it is more valuable to document areas where certain types of erosion are dominating (i.e. bank, bluff, streambed) and locate a selection of these areas to return to for further analysis.

Table 6: General list of stream features to document during stream reconnaissance. There may be other features of interest depending on the nature of the impairment and study watershed.

Examples of features to document during watershed reconnaissance	
Erosional features	**Streambanks/streambed erosion, gullies, sheet and rill, bluffs, ravines**
Stream Impediments/Diversions	**Dams, perched or undersized culverts, natural barriers**
Stormwater Features	**Outfalls, ponds, BMPs, etc.**
Land-use	**Gravel pits, parking lots in stream corridor, livestock pasture, cattle crossings, etc.**
Point Sources of Pollution	**NPDES permitted dischargers, feedlots, Superfund sites**
Reference Reaches	**Areas of favorable land-use, exceptional habitat, minimally disturbed areas**

Figures 7 and 8 on the following pages are examples of a stream reach characterization project completed for the Miller Creek TMDL study. Miller Creek is an urban trout stream in Duluth, Minnesota. The Miller Creek watershed is extremely variable in terms of land-use, hydrology, and fluvial geomorphology. Some of this variation in stream type is due to natural characteristics of the watershed. The characterization of Miller Creek's stream reaches has proved valuable for establishing TMDL goals, locations for new monitoring sites, and in the evaluation of reach-specific stressors. It has also served as a valuable educational tool for the public.

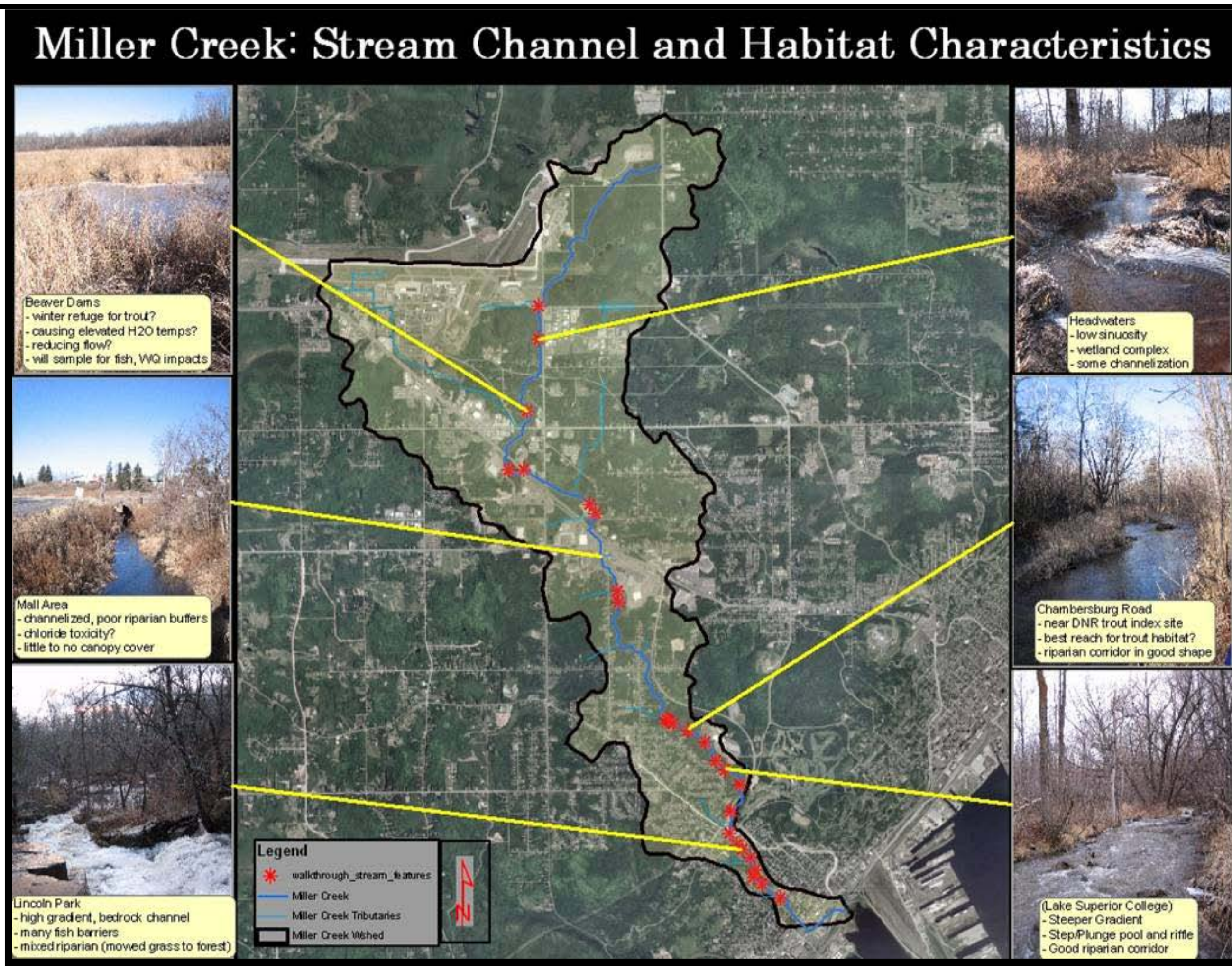

Figure 7: Miller Creek stream reach characterization. The impaired AUID stretches from the headwaters to the outlet into the St. Louis River. The Miller Creek TMDL project team has conducted watershed reconnaissance to divide the stream into seven reaches based on land-use, stream morphology, and restoration potential. Breaking the stream into reaches facilitated analysis of localized stressors, pollution sources and pathways, and provided a framework for additional data collection.

Miller Creek Example: Continued

<u>Lake Superior College (LSC) - Skyline Avenue (Similar Reach #5; RM 1.6 - 3.0)</u>
· Stream gradient increases and channel becomes mostly bedrock/cobble/boulder
· Riparian area in tact with many large deciduous trees

The Skyline Avenue-Lake Superior College (LSC) reach of Miller Creek is a transition zone for the stream. It is a mix of moderately sloped channels and bedrock waterfalls. The falls and other high gradient features are far less prominent here than in the Lincoln Park section. Increased amounts of impervious surfaces and the resulting stormwater outflows to Miller Creek were found to increase channel instability and sediment loading in several places along Skyline Avenue, US Highway 53, and below LSC campus. Several stormwater control structures were observed in non-compliance in this reach.

The stream reaches within LSC campus have a high quality riparian corridor and provide good habitat for trout. There are several stormwater gullies entering the stream in this area that will require maintenance or installation of improved BMPs. Currently, the dominant in-stream habitat consists of large boulders, shallow step pools and plunge pools, large woody cover, and some undercut banks. Like other reaches of the creek, deep pools are scarce through this reach which could stress brook trout populations during summer low flow and overwintering periods.

Currently, there are no data available to determine the status of the brook trout population within this reach. The DNR plans to establish a site within the LSC reach and begin sampling in the summer of 2007 with one or two years of follow-up sampling.

Channel just west of Enger Golf Course. The culvert just upstream of this bend may have been undersized in the past. The channel has downcut a new path (right) and abandoned the more gradual bend of the natural channel (left).

One of several stormwater gullies from LSC campus.

Most of this reach has a high quality riparian corridor and good in-stream habitat. The lack of deep pools may be the factor limiting trout abundance and growth.

Figure 8: Example of stream reach photos taken on Miller Creek during initial reconnaissance.

Fish Stations: None; *A site near RM 2.5 will be sampled by DNR during 2007 field season*
Temperature Stations: *proposed stations @ RM 1.6; RM 2.3; and RM 3.0*

Possible Stressors	Restoration/Implementation Goals
· Increased Temperature / overwintering	· Address gully erosion, failing erosion controls
· Altered flow regime	· Channel restoration near Enger Golf Course
· Chloride toxicity	· Improve baseflow, reduce stormflow
	· Preserve / enhance riparian corridor

Objective #4: Identify Areas for Further Monitoring
The data collected during the desktop and field reconnaissance efforts should be used to inform the site selection process for additional monitoring. Upon completion of the reconnaissance objectives listed in the sections 3 and 4, the chemical, physical, and biological characteristics of the watershed should be better understood. Additional monitoring should be conducted at sites that will document these characteristics and their relationships to the biological impairment.

3.8 Stressor ID Reconnaissance Summary

Section 3.0 -- Desktop and Field Reconnaissance
Desktop Reconnaissance:
☐ The collection of high-resolution aerial photography should be considered for the project. Is it feasible given the scale of the project? Historic aerial photos should be considered for documenting land-use history, changes in stream geomorphology, etc. (Section 3.2 and 3.3)
☐ Find your watershed on the DNR's Watershed Assessment Tool. Use the tool to evaluate the watershed for road crossings and other potential stream connectivity issues, local geology and soil composition, potential contaminant sources, water appropriation permits, etc. (Section 3.3)
☐ Obtain and plot applicable GIS layers for the project. Establish watershed sub-catchments within the project area to help identify potential stressor sources and pathways (Section 3.4)
☐ Develop project map using all available GIS layers, aerial photos, and other spatial information. Use this map to plan monitoring activities and field reconnaissance efforts that will be further explained in the next section. Existing and proposed monitoring stations should be included on this map.
Field Reconnaissance:
☐ Document physical integrity of the stream channel and riparian conditions. See table X.x for a list of some of the available methodologies. The goal of this assessment should be a general characterization of the stream reaches that will be addressed during the investigation. (Section 3.7)
☐ Document hydrological features and pathways within the watershed. Collect reconnaissance data at hydrologically significant locations under different flow regimes (snowmelt, baseflow, storm events). Refer to table X.x for more information (Section 3.7)
☐ Documented impacted areas and potential reference reaches. Within the study area there will likely be areas of varying degrees of habitat degradation. Identify potential stressor sources such as stream impoundments, point source discharges, areas of severe bank erosion, cattle pastures, etc. (Section 3.7)
☐ Identify areas for future biological, water chemistry, flow, and physical monitoring. These sites should be located in reaches that will provide the evidence needed to evaluate the relationships between potential stressors and biological assemblages.

4.0 Organize Data / Data Gaps Analysis (DGA)

This step of the protocol discusses the benefits of a data gaps analysis (DGA) to set the stage for the remainder of the Stressor ID investigation. At this stage of the project, the impaired condition should be better understood in terms of nature, magnitude, and geographic scope. In addition, the existing data should be organized and monitoring locations inventoried and mapped. As a result, any gaps in the data set needed to further investigate the impaired condition should be easier to identify.

The main purpose of the DGA is to assess the quantity and quality of data available for the major physical, chemical, and biological factors of river systems. The sections below discuss these major components and the level of data suggested for Stressor ID analysis. It is important to remember that there are no minimum data requirements for completing a Stressor ID study. The importance of certain parameters will also vary depending on the geographic region of the impaired reach or watershed. As such, the following are simply recommendations for data collection efforts. A quality data set that considers the key physical, chemical, and biological drivers of watershed systems will facilitate the development of a thorough and defensible Stressor Identification analysis.

4.1 Flow Monitoring Data

Restoring stream function requires some knowledge of flow characteristics in the watershed. At a minimum, it is helpful to know whether the impaired stream and tributaries are intermittent, perennial, or ephemeral, along with the flow contributions from baseflow and storm flow. It is also important to learn about the hydrology of the stream; how important is snowmelt, groundwater, rainfall, or a combination of these pathways? These are all general pieces of hydrological information that should be better understood before planning flow monitoring efforts for stressor identification and TMDL projects.

Adequate flow data is also important for verifying the bankfull discharge values. The bankfull stage corresponds to the discharge at which channel maintenance is the most effective. This discharge typically has a recurrence interval of about 1.5 years as determined using a flood frequency analysis (Dunne and Leopold, 1978.) Identification of bankfull stage is a critical task in stream classification, modeling, and in designing stream restoration projects. Morphological features that indicate the bankfull stage can be difficult to determine in the field if the stream channel is incised, which is often the case in many Minnesota watersheds. Flow data collected at a gauging site can provide guidance for identifying bankfull stage in the field. A better option for identifying bankfull stage in the field may be the use of regional hydraulic geometry curves if developed for your region (Magner and Brooks, 2007; and Magner and Steffen, 2000). For more information on the definition of bankfull and its importance in watershed science, refer to the following EPA website (*http://www.epa.gov/warsss/sedsource/bankfull.htm*).

Continuous stage recorders

It is helpful to have a minimum of one continuous flow gauging station within the study watershed. This station should be installed to collect water level readings at a time interval that is directly related to the hydrological characteristics of the stream. For example, if the stream is set in an urbanized environment with a high level of impervious surface, a recording interval of 15 minutes may be needed to capture the rapidly changing hydrograph from storm runoff events. If the stream is situated in a watershed that has some wetland storage, and a landscape that promotes infiltration, a recording interval of 30-60 minutes may be adequate to capture the entire runoff hydrograph. Continuous flow data is critical for computing sediment and nutrient loads, along with calculating mean velocities over a range of stream stages. When setting up a station for recording continuous stream stage and discharge measurements, we suggest seeking the assistance of a trained hydrographer.

Site selection is important when determining where to install a continuous stage recorders. The main problems encountered during site selection are associated with sites that have poor downstream controls. Controls are features in the stream that cause river stage to respond in a predictable manner during a wide range of discharges. Examples of good controls can be riffles, channel shape, or culverts. It is important to choose locations that do not have backwater/backflow, eddy effects, or rapidly changing channel characteristics.

Stage versus Discharge Relationships

Paired measurements of stream stage and discharge should be made over a wide range of flows during the study period. These relationships are then plotted to develop a rating curve for that particular site, which can be used to estimate flow based on stream stage at the gauging station. Development of rating curves along with gauging station establishment can be found in USGS publication TWRI-A10 and TWRI-A13. A minimum of monthly paired stage-discharge measurements should be made at the gauging location during the open water season. A cross sectional survey of the gauged location should be made and tied into the elevation for the stage recorder. At long interval gauging stations, bed movement can be calculated through an annual cross sectional survey that is tied to a permanent monument.

4.2 WATER CHEMISTRY

Three critical factors to consider in the development of a water chemistry monitoring plan for biological TMDLs are parameter selection, sampling time and frequency, and site location. The level of effort for each project will vary depending on the characteristics of the watershed, and the likelihood that water chemistry parameter is a direct or indirect stressor to aquatic life.

Water chemistry monitoring frequencies and locations should be established with specific goals in mind. Targeted monitoring should be conducted if existing data or professional judgment has identified parameters in the watershed that are likely to be stressors. First and foremost, water chemistry monitoring should be conducted at sites that allow for analysis of biological response to water chemistry. Locations of targeted monitoring sites may also bracket potential stressor sources or watershed processes that are thought to be causing condition of concern (i.e. wetlands causing low dissolved oxygen.) If the source of the stressor is a point-source, the monitoring stations should be set up in a manner that will clearly show the impact the discharges are having on different reaches of the waterbody. This may involve monitoring locations immediately upstream and downstream of the point-source, and several additional stations at specific increments downstream to determine the extent of the impacted area.

Table 7 provides a list of important water quality parameters to consider when designing a stressor ID or TMDL study. Keep in mind that the stressor identification process is essentially a process of elimination, and as such, it is advantageous to operate with a broad focus in the early stages. As the process moves forward, the number of parameters monitored should be reduced as the list of candidate stressors is refined. Table 7 provides a general list of stream parameters commonly included in Stressor Identification studies. The list is not tailored to any specific region of the Minnesota or specific watershed land-uses. Be sure to discuss the relevance of each parameter to the project before the monitoring plan is finalized.

Table 7: Collection of important water chemistry parameters for Stressor ID development.

Parameter	Sampling time / frequency	Site Selection
Dissolved Oxygen ** For more information on parameters/methods associated with Dissolved Oxygen monitoring, see MPCA DO protocol	· Target critical months for low DO (July - Sept), or mid-winter if concerned about low DO conditions under ice · To improve the defensibility of your case for low DO under certain flow/temperature regimes, consider collecting diurnal DO during various flows and weather periods. · **Diurnal monitoring strongly recommended** · If diurnal monitoring is not possible, point measurements should be taken during critical times (i.e. at or before sunrise and late evening hours) · Longitudinal DO surveys recommended. Longitudinal surveys should be conducted during late afternoon evening (high point of diurnal swing) and early morning before sunrise (low point of diurnal swing).	· Co-locate with biological monitoring stations · Upstream/Downstream of wetland complexes, point source dischargers, any feature that could cause fluxuation in DO concetration (*i.e. dam, stream diversion, lake/reservoir, stream gradient change, etc.*)
Biochemical Oxygen Demand (BOD) **Sediment Oxygen Demand (SOD)** (if low dissolved oxygen conditions expected)	· See Dissolved Oxygen TMDL Protocol	
pH	· Take measurments during routine WQ sampling	
Conductivity	· Take measurments during routine WQ sampling · If urban watershed with chloride concerns, continuous conductivity data collection is recommended	
Temperature	· Warmwater/coolwater stream -- take measurements during routine WQ sampling · If coldwater stream with temperature concerns, continuous monitoring is recommended at multiple locations in the stream	
ORP	· Take measurments during routine WQ sampling if ORP probe is available	
TP, Ortho-P	· Snowmelt / Baseflow / Stormflow samples	
NO2+NO3, TKN, NH4*	· Snowmelt / Baseflow / Stormflow samples	
TSS, VSS	· Snowmelt / Baseflow / Stormflow samples	
Turbidity	· Snowmelt / Baseflow / Stormflow samples	
Chloride (Urban watersheds, Point Source Discharges)	· Snowmelt / Baseflow / Stormflow samples	
Pesticides (Ag watersheds)	· Check with Minnesota Department of Agriculture for existing data	
Metals (urban watersheds)	· Check with Metropolitan Council for existing data	· Targeted monitoring at pour points of minor watersheds, suspected sources/sinks, and biological monitoring stations

* Used to calculate un-ionized ammonia (NH_3) along with pH and temperature

For additional information on important water chemistry parameters for stream studies, refer to chapter 2, section C of the USDA guidance document titled *Stream Corridor Restoration: Principles, Processes, and Practices*. This guidance document can be found at the following link: *http://www.nrcs.usda.gov/technical/stream_restoration/*

4.3 Geochemical and Stable Isotope Monitoring

Appendix Currently Under Development

4.4 Physical Habitat/Stream Corridor Condition

All MPCA biological monitoring data will be accompanied by qualitative or quantitative physical habitat data. The qualitative habitat assessment methods used by MPCA are heavily based on the Qualitative Habitat Evaluation Index (QHEI) methodology that was developed in Ohio. The QHEI method is currently used by many other state and federal agencies to assess in-stream habitat, stream channel condition, and riparian quality. The Minnesota version of the QHEI is called the Minnesota Stream Habitat Evaluation (MSHA) and can be found through the links in table 8.

The MPCA's quantitative habitat data has proven useful for identifying key stressors in impaired watersheds. The Groundhouse River stressor identification and TMDL project relied heavily on MPCA's quantitative habitat information to support the case for excess fine sediment (embedded substrate) as the leading candidate cause for biological impairment. If quantitative habitat data is not available for the biological monitoring sites within your project area, consider collecting it using the guidance provided through the link in table 8. Quantitative habitat data is often superior to qualitative data for comparing the quality of different habitat types between stations. Quantitative data will also help to build a more defensible case if a specific habitat variable is a leading candidate cause for impairment.

Table 8: Habitat evaluation methods typically used in biological assessment, stressor identification, and TMDL development

MPCA Quantitative Habitat Assessment	***http://www.pca.state.mn.us/publications/wq-bsm3-01.pdf***
Minnesota Stream Habitat Evaluation - MPCA (MSHA)	***http://www.pca.state.mn.us/publications/wq-bsm3-02.pdf***
Qualitative Habitat Evaluation Index - Ohio (QHEI)	***http://www.epa.state.oh.us/dsw/documents/QHEIManualJune2006.pdf*** ***http://www.epa.state.oh.us/dsw/documents/QHEIFieldSheet061606.pdf***
EPA Rapid Bioassessment Protocol	***http://www.epa.gov/owow/monitoring/rbp/wp61pdf/ch_05.pdf*** ***http://www.epa.gov/owow/monitoring/rbp/wp61pdf/app_a.pdf***
NRCS Stream Visual Assessment Protocol	***http://www.nrcs.usda.gov/technical/ECS/aquatic/svapfnl.pdf***

Other methods of habitat data collection can be considered for the purposes of stressor identification and TMDL development. If there is a specific habitat parameter that is important to the study but not covered by MPCA habitat methods, there are numerous other methods that can be applied. Habitat data is supplementary to the biological data. The biological data will ultimately provide the criteria for whether or not a stream is listed as impaired. Habitat parameters can serve an important role in TMDL development as surrogate measures for certain parameters without statewide criteria (i.e. substrate embeddedness, riparian conditions, etc.). MPCA is currently in the process of developing surrogate measures from the qualitative and quantitative habitat data collected over the lifetime of the biological monitoring program.

4.5 Suspended and Bedded Sediment (SABS) / Fluvial Geomorphology

Imbalance in loading of suspended and bedded sediment (SABS) to aquatic systems is now considered one of the greatest causes of water quality and biological impairments (Berry et al., 2003). As of 1998, approximately 40% of assessed river miles in the United States had problems arising from sediment stress (US EPA, 2000). The sources of sediment loading to streams and their effects on aquatic life are driven by a complex set of natural and anthropogenic processes in the watershed and stream channel. The impact of SABS on aquatic life has been studied intensively due to its importance within State and Federal programs charged with the assessment, protection, and restoration of water resources. For more information on the specific biological effects of SABS in aquatic systems, refer to the EPA publications that can be found through the following link:
http://www.epa.gov/waterscience/criteria/sediment/

Undoubtedly, many of the biological impairments in Minnesota streams and rivers will be the result of stressors related to sediment imbalance. Despite the impact of SABS to Minnesota's water resources and its ramifications for the impaired waters program, no water quality standard currently exists to directly address suspended or bedded sediments. Minnesota currently uses a turbidity standard as its main water quality criterion to assess the impacts of suspended sediment. Through statistical analysis of existing data, relationships have been developed between total suspended solids (TSS) and turbidity, which allows for the two to be interchanged when analyzing water quality data and setting targets for TMDL load and wasteload allocations (see MPCA Turbidity TMDL Protocol).

Figure 9: Two underwater pictures from the Ann River, near Mora, Minnesota. The photo on the left is from a less disturbed site in the upper reaches of the river. Notice the clean, coarse substrate available for aquatic life. The photo on the right is from a reach in the lower watershed that is impacted by depositional sediment. Coarse substrate at this location is embedded under several inches of fine material.

There are fewer tools available for tying the potential impacts of bedded sediment to existing water quality standards. United States Environmental Protection Agency (EPA) has recently started dialogue with the States to develop a water quality criteria strategy for the next decade. Through this dialogue, the need for new and improved water quality criteria for SABS, or methodologies for deriving SABS criteria on a regional or site-specific basis, was identified as one of the highest priorities for the EPA water quality criteria program (EPA, 2003). EPA put together a draft publication titled "Developing Water Quality Criteria for Suspended and Bedded Sediments (SABS): Potential Approaches" in August of 2003. This document stresses the need for water quality criteria to address SABS and provides some potential approaches for developing these criteria using existing State protocols, and several new methods.

Looking ahead, the MPCA and other environmental agencies in Minnesota will need to join the movement initiated by EPA to develop criteria for SABS that can be applied in the impaired waters program. In the meantime, the MPCA and other entities working on impaired biota projects will have to rely on the best available methods and guidelines to assess the impact of SABS as a potential stressor in biotic impairments. The following material and well the appendices referenced below provide some of the methods MPCA and its partners have been using to assess the impacts of SABS to aquatic life.

Suspended Sediments as a Stressor

There is not currently a water quality standard for suspended sediments in Minnesota streams and rivers. As a result, critical values for total suspended solids and volatile suspended solids are typically based on eco-region values or scientific literature. Comparing the TSS values in your study stream to the eco-region averages provides a quick, but coarse method of assessing TSS as a stressor. The eco-region TSS values for 1970-1992 can be found in McCollor and Heiskery (1993).

Duration, magnitude, and frequency are important measures to consider when assessing the potential impacts of suspended sediment to biota. Load duration curves (LDC) have been used to examine the concentrations of TSS and other parameters under various flow regimes. The use of these curves provides a more complete picture of the relationships between flow regime and suspended sediments (Figure 10). Newcombe and McDonald (1991) and Newcombe and Jensen (1996) make the case for collecting and analyzing suspended sediment data for duration of exposure and concentration. These articles also provide an extensive set of data tables documenting the effects of SABS on fish. For an extensive summary of journal articles associated with this topic, refer to Berry et al (2003). For technical information on load duration curves and the application of that method to TMDLs, see Cleland (2002).

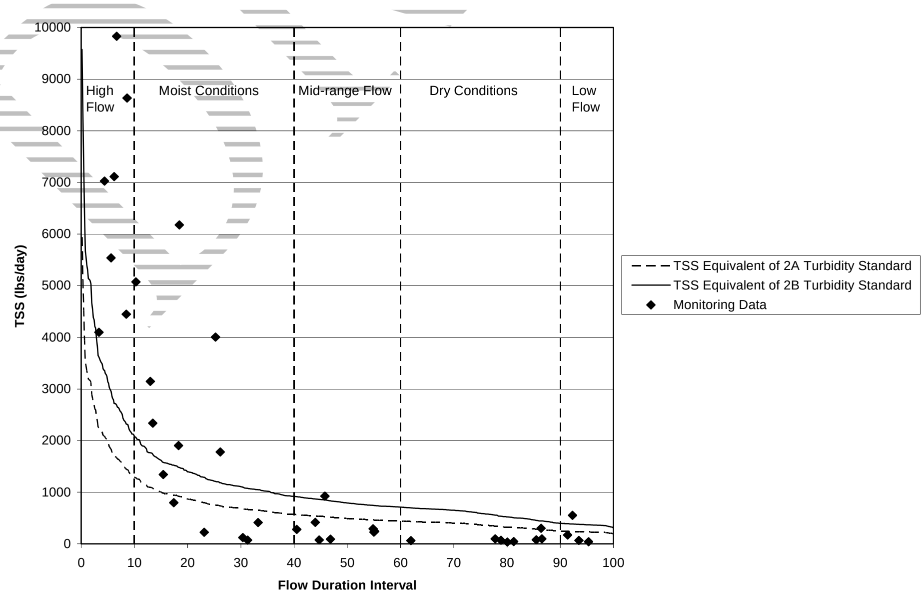

Figure 10: Load duration monitoring curves for Browns Creek, Washington County, Minnesota.
The LDC depicted in figure 10 indicates that Browns Creek, a coldwater trout stream, experiences high levels of TSS mostly during "moist conditions," or high flows on the

hydrograph. LDCs are a valuable tool for gaining a better understanding of watershed processes and "pollutant" loading from non-point sources and point-sources. However, there are some significant limitations when applying these curves to examine stressor potential. The most apparent is the inability of LDCs to address duration, assuming that the parameters being evaluated are collected as grab samples representing an episodic point on the hydrograph.

Deposited and Bedded Sediment (DBS)

Deposited and bedded sediments (DBS) are mineral and organic particles that settle out of the water column and collect on the bed of a water body, or that travel primarily by rolling along a stream bed rather than moving in the water column. It includes surficial and deeper deposits and bedded layers within the depths used by organisms (US EPA CADDIS, 2005).

Other terms commonly used to describe DBS include: bedded sediment, clean sediment, bedload, fines, deposits, soils, and eroded materials. The organic components include organic solids such as soil organic matter, algal cells, particulate detritus, and anthropogenic materials such as organic flocs. Changes in the composition, distribution, or quantity of deposited and bedded sediment can alter the behavior, health, or survival of biota by altering benthic habitat quality or availability. For more information on the biotic effects of DBS, refer to Berry et al. (2003).

There are numerous methods of assessing whether or not DBS may be a stressor to aquatic life. Minnesota does not have a water quality standard based on DBS as some other states do, however, monitoring for DBS has been critical to almost every biological TMDL initiated in the state. The following approaches can be used to potential for DBS as a stressor:

(1) MPCA Habitat Data

Quantitative or qualitative habitat data collected by MPCA at biological monitoring stations includes measurements of DBS. These include dominant substrate type, percentage of substrate embedded by fine material, and depth of fine material. These parameters can be compared across monitoring sites and inferences can be made between the DBS data and the biological assemblages present at the site. See figures 18 and 19 for an example of how these data were used to assess DBS for the Groundhouse River Fish impairment in central Minnesota.

(2) Channel Morphology

MPCA staff and contractors have used measurements of channel morphology to assess DBS as a stressor. Although there are several methods for collecting these data, the majority of the data collection has been conducted using the methods outlined in *Applied River Morphology* (Rosgen, 1996). Data collection at Level II or Level III of this methodology includes morphological features directly or indirectly responsible for the presence or absense of DBS in excess amounts.

(3) Pebble Counts

Pebble counts are useful for characterizing stream channel materials, and can provide valuable information to determine sediment transport, channel hydraulics, streambed monitoring for aggrading or downcutting, and stream classification. MPCA staff collects pebble count data following the original methods developed in Wolman (1954). Verry (2005) provides a great overview of the Wolman methods and the value of pebble counts in stream studies.

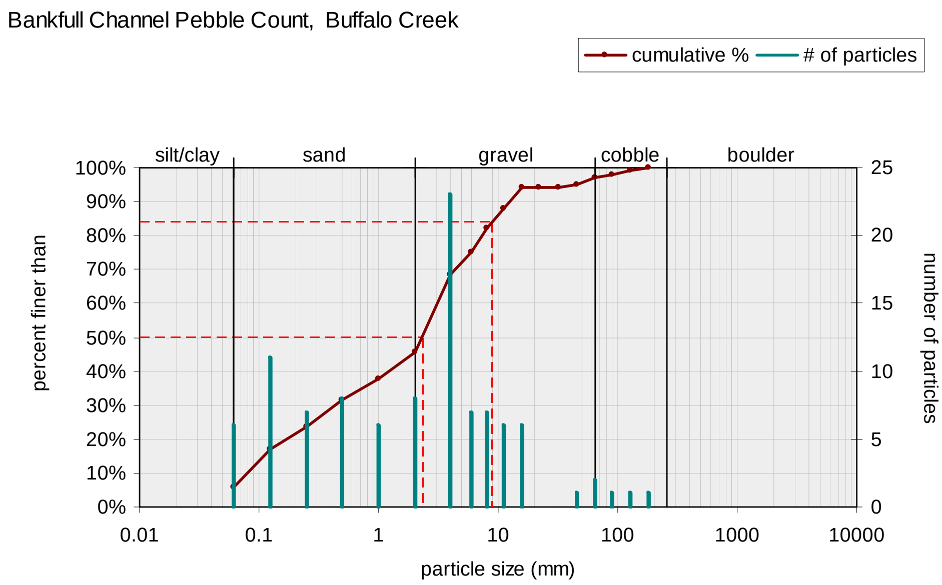

Figure 11: Bankfull channel pebble count from Buffalo Creek, near Glencoe Minnesota

4.6 Stream and Watershed Connectivity

Watershed connectivity is defined as the maintenance of lateral, longitudinal, and vertical pathways for biological, hydrological, and physical processes (Annear, 2004). The most simplistic example of stream connectivity may be the free flow of water downstream in a river and the passage of fish upstream. The construction of a high dam across a stream is a vivid and obvious illustration of fragmentation or the loss of connectivity. Other impediments to stream connectivity can be more subtle, such as a perched road culvert or a physical change to an important tributary for fish migration or spawning. Stream connectivity issues can be also the result of natural features in the watershed, such as impassable waterfalls or intermittent streams.

Stream connectivity assessments should be conducted in all stressor ID and TMDL investigations. The connectivity of a stream often drives the components of the watershed that are traditionally monitored – water quality, physical habitat, geomorphology, and biology. An impediment to stream connectivity, such as the perched culvert shown in figure 12, can have dramatic effects on a local fish or invertebrate population by blocking migrations and isolating certain species above or below the culvert. As an initial effort to evaluate the connectivity within the watershed, take a look at the data available through the watershed assessment tool (WAT) developed by DNR (link). At a minimum, the road crossings (culverts), known impoundments, diversions, or other obstructions in the watershed should be identified and evaluated for fish passage and hydrologic connectivity.

Figure 12: Perched culvert on the left prevents fish passage upstream. The culvert on the right is sized and placed properly, maintaining the connectivity of the stream. (photos: USFWS Region 3)

For additional information on the concept of stream and watershed connectivity, refer to the Minnesota DNR's watershed assessment tool (ext. link). For more information on fish-friendly culvert design, placements, and maintenance, refer to this publication prepared by the Fish and Wildlife Service Midwest fisheries office called *Planning, Design, and Construction of Fish-Friendly Stream Crossings* (USFWS, 2008).

4.7 BIOLOGICAL DATA

In Minnesota, stream reaches can be listed as biologically impaired based on a relatively small data set. In fact, there are many 303(d) listings for impaired biota that are based on a single assessment point. As a result, some stressor identification studies will begin with a significant paucity of biological data. Additional biological sampling is strongly encouraged in this situation in order to further define the nature and extent of the impairment. It is possible for stressor identification studies to be completed with limited biological data, but ideally, the biological data set should offer adequate spatial and temporal coverage of the impaired stream reach or watershed.

The establishment of additional of biological monitoring stations should be done under guidance from the project managers and technical advisory committee. There are several methodologies for selecting locations for new monitoring sites, and it is important that new sites are established in line with project goals and data collection objectives. The following guidance for site selection was taken from the *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish,* Second Edition (Barbour et al, 1999).

STATION SITING

Site selection for assessment and monitoring can either be "targeted", i.e., relevant to special studies that focus on potential problems, or "probabilistic", which provides information on the overall status or condition of the watershed, basin, or region. In a probabilistic or random sampling regime, stream characteristics may be highly dissimilar among the sites, but will provide a more accurate assessment of biological condition throughout the area than a targeted design. Selecting sites randomly provides an unbiased assessment of the condition of the waterbody at a scale above the individual site or stream. Studies for 305(b) status and trends assessments are best done with a probabilistic design.

To meaningfully evaluate biological condition in a targeted design, sampling locations must be similar enough to have similar biological expectations, which, in turn, provides a basis for comparison of impairment. If the goal of an assessment is to evaluate the effects of water chemistry degradation, comparable physical habitat should be sampled at all stations, otherwise, the differences in the biology attributable to a degraded habitat will be difficult to separate from those resulting from chemical pollution water quality degradation. Availability of appropriate habitat at each sampling location can be established during preliminary reconnaissance. In evaluations where several stations on a waterbody will be compared, the station with the greatest habitat constraints (in terms of productive habitat availability) should be noted. The station with the least number of productive habitats available will often determine the type of habitat to be sampled at all sample stations.

For bioassessment activities where the concern is non-chemical stressors, e.g., the effects of habitat degradation or flow alteration, or cumulative impacts, a different approach to station selection is used. Physical habitat differences between sites can be substantial for two reasons: (1) one or a set of sites is more degraded (physically) than another; or (2) is unique for the stream class or region due to the essential natural structure resulting from geological characteristics. Because of these situations, the more critical part of the site selection process comes from the recognition of the habitat features that are representative of the region or stream class. In basin-wide or watershed studies, sample locations should not be avoided due to habitat degradation or to physical features that are well-represented in the stream class.

Stressor identification and TMDL projects can benefit from "probabilistic" or "targeted" sampling. If there is limited biological data available at the onset of the project, a probabilistic design may provide an unbiased approach to further the assessment of the impaired stream reach or watershed. The majority of biological monitoring completed for stressor identification will be targeted sampling directed at problem areas or reference reaches within the study watershed. Targeting these areas is the most effective way to develop stressor-response relationships that will be required to diagnose and refute candidate causes for impairment. The reconnaissance methods discussed in section 3 are effective tools for identifying potential locations for targeted sampling.

Targeted sampling can introduce bias to a stressor identification study if the sampling locations are not adequately thought out. An impaired watershed may have several types of disturbances operating, which could introduce multiple, independent stressors to a stream at different locations. A targeted sampling approach must establish monitoring sites that address each potential stressor in order generate unbiased results.

Comparing Biological Data

Comparing biological and other data between monitoring stations is an effective method for identifying potential stressors in a watershed. However, some caution should be used when using this approach in Stressor Identification. In an ideal study, all of the biological data is collected within the same monitoring year, or even within the same week or month. Comparing data that was collected within a short temporal range will minimize the effects of variables that are intrinsically linked to biological monitoring, such as climatic conditions, species migrations, and reproduction/re-colonization. The MPCA's biological sampling protocol reduces the effects of these variables by sampling during established seasonal index periods and conditions that are representative of the stream being assessed (i.e. avoiding extreme low/high flows)

It is still useful to compare biological data between monitoring stations with different sampling years. The MPCA biological data should be considered representative of the conditions at that location unless best professional judgment determines otherwise. The MPCA uses a 10-year window for assessment data. As a result, any data collected more than 10 years from the present day cannot be used for assessment purposes. However, data outside of the 10-year assessment window can still be used for stressor identification and TMDL purposes. The older data can provide useful background information and can be compared to newer data as part of the stressor analysis and site to site comparisons.

Beyond Fish and Macroinvertebrates

Fish and macroinvertebrate assemblages are the focus of most biological assessment in Minnesota. However, MPCA staff and other agencies are conducting other types of biological monitoring including aquatic vegetation, mussels, and other organisms that utilize riverine habitats. Applying these other biological measures to your project provides a more comprehensive assessment, and may offer critical pieces of information that would not be obtained with conventional fish and macroinvertebrate collection. MPCA has used aquatic plants as another form of biological assessment in low-gradient, wetland dominated stream reaches. Appendix A provides an example case-study of an aquatic plant survey being used as an additional IBI metric to fish and macroinvertebrates. In this specific case, the results of the aquatic plant survey indicated a healthy riverine wetland system, whereas the fish and macroinvertebrate scores indicated impairment.

Biological Data from Other Sources

The biological data used for surface water assessments and IBI development has been predominantly collected by MPCA staff, but also includes data collected by the Minnesota DNR and USGS. The MPCA's biological database serves as the data source for 303(d) listings and de-listings, and operates on strict QA/QC guidelines. Currently, biological data collected by citizen monitoring groups and educational institutions are not used for assessments of streams, rivers, and lakes. However, data from these sources can be used as supplemental information in stressor identification studies and during TMDL implementation as an effectiveness monitoring tool.

4.8 Meteorological and Climate Information

Weather conditions can be a driving factor for many potential stressors to aquatic life. Precipitation, air temperature, and catastrophic climactic events can have dramatic effects on the life cycles and overall abundance of certain aquatic organisms. Historical meteorological data for Minnesota is available online from the Climatology Working Group at: *http://climate.umn.edu/*.

4.9 Summary

Section 4.0 -- Data Gaps Analysis (DGA)

Hydrology

☐ Document hydrological pathways and processes for the impaired reach and watershed, including:
- Historic/current flow regime (intermittent/perennial; flashy hydrology vs. watershed storage)
- Document the water sources and pathways that drive the local hydrology (i.e. groundwater, rainfall and snowmelt)
- Approximate bankfull discharge and recurrence interval
- Alterations to the natural hydrology of the watershed from land-uses or climatic events

☐ Plan flow monitoring approach for the project. Consider:
- Continuous stream gauging station and development of rating curves (Section 4.1)
- Obtain and analyze historic flow records

Water Chemistry

☐ Organize and evaluate existing water chemistry data, including grab samples, continuous monitoring data, watershed reconnaissance data (Section 4.2)

☐ Decide on the objectives for additional water chemistry monitoring (Section 4.2)
- Targeted or probabilistic design?
- Select monitoring locations and decide on parameters, frequency, timing, and type (baseflow, rain event etc.)
- Establish locations and protocol for continuous monitoring of temperature, conductivity, dissolved oxygen.

☐ Consider using geochemistry tracing techniques to better understand hydrological pathways/processes within the watershed (Section 4.3)

Physical Habitat

☐ Organize existing habitat data for the impaired reach and reference areas
- MPCA quantitative or qualitative habitat data (Section 4.4)
- Collect MPCA quantitative habitat data at all biological monitoring stations

☐ Collect additional habitat data if necessary
- MPCA quantitative habitat data or other methods depending on project needs (Section 4.4)

Fluvial Geomorphology

☐ Determine objectives for geomorphological data collection
- Watershed vs. Stream reach scale
- Rapid/Qualitative vs. Quantitative
- Rosgen/EPA WARSSS (Section 4.5)

Stream and Watershed Connectivity

☐ Plan and implement an assessment strategy for watershed connectivity.
- Barriers to fish migration (perched undersized culverts, dams, waterfalls, intermittent streams)
- Use DNR's Watershed Assessment Tool to assess watershed connectivity in the study area (Section 4.6)
- Evaluate biological data set upstream and downstream of suspected barriers to determine effects

Biology

☐ Organize existing biological data
- Adequate spatial and temporal coverage? Coverage of various habitat types, disturbance gradients, etc.?
- Evaluate existing biological data for trends/relationships with the location of candidate causes for impairments

☐ Identify locations for further biological assessment, if necessary.
- Probabilistic or targeted monitoring?

5.0 CADDIS STEP # 2: LIST CANDIDATE CAUSES

Introduction

The goal of this step is to develop a list of candidate causes, or stressors, which may be responsible for the observed biological effects. Listing these candidate causes further refines the scope of the causal analysis, and provides a framework for assembling available data and determining what data are lacking for the causal analysis.

5.1 Develop List of Candidate Causes for Impairment

There is no formal procedure for developing the list of candidate causes, but most Stressor Identification projects have developed the list through brainstorming sessions with the managers, stakeholders, and technical staff. Listing candidate causes requires balancing two issues. If you include every potential stressor the causal analysis will be burdensome, but being overly selective in this step may eliminate the true cause.

The initial list of candidate causes should include all stressors that could be causing the biological impairment. These stressors may be chemical (e.g., elevated concentrations of metals or ammonia), physical (e.g., increased sediment or water temperature), and/or biological (e.g., increased abundance of an invasive species). A candidate cause may be a proximate stressor - the agent that organisms contact or with which they co-occur (e.g., low dissolved oxygen concentrations). Alternatively, a candidate cause may include more detailed information about how that proximate stressor produces a response (e.g., low levels of dissolved oxygen asphyxiating fish), or more details of the precursors of the proximate stressor (e.g., increased nutrients leading to increased algal biomass, resulting in low dissolved oxygen once the algae die). More detail is better if it helps identify ways of distinguishing among various candidate causes.

The candidate cause list can be based on many things, including existing data from monitoring sites (including information on possible sources), existing knowledge of biological processes or mechanisms, anecdotal evidence, or stakeholder input. The quality and scope of the existing data set will likely influence the nature of the list of candidate causes. Projects with a wealth of existing data covering the biological, physical, chemical, and land-use components of the watershed should be able to confidently develop a list candidate causes early in the process. In these cases, the list of candidate causes could be short, with each item on the list supported by the existing data set. On the other hand, projects with limited data will likely have more items on the list of candidate causes, and will need to collect additional data or perform additional analysis to winnow it down.

Because biological effects usually involve processes at multiple spatial and temporal scales, the listing of candidate causes should involve explicit consideration of the scales at which each candidate cause operates. The maps created in Step 1 should be used to develop connections between candidate causes and the potential sources and pathways of physical, chemical, and biological stressors.

Table 9: Tips for *including* Candidate Causes

Do:	Explanation
• **Include candidate causes that are suggested by a manager or stakeholder.**	They may be right, and if they are wrong they will need to be convinced
• **Include things that are common causes of the observed biological effect in your state or region.**	Do not forget the usual suspects. At first, this will be based on professional experience, but later common causes may be identified by analysis of regional data or prior causal analyses.
• **If you think it is possible but are uncertain, include it.**	It is better to include a possible cause than to impart bias to the assessment.
• **Think about what may be uncommon or unique about the impaired site.**	Compare habitat, WQ, and other data between impaired and unimpaired sites.
• **Think about the natural history of the impaired organisms.**	If the biological impairment is specific, such as absence of certain species of fish while other species thrive, becoming familiar with their natural history and reproduction may lead you to consider causes unique to the impairment.
• **Pay attention to the type and magnitude of observed effects.**	Some streams may have many apparent stressors, but in most cases, there will be a subset of them that have the most significant impact.

Table 10: Tips for *excluding* Candidate Causes

Do:	Explanation
• **Exclude things that can be confidently eliminated without quantitative analysis and without controversy.**	Evidence that can clearly and easily exclude stressors should be used, but with great caution.
• **Exclude constituents of natural background water chemistry or habitat, even if they interact with an anthropogenic cause.**	For example, if low pH and metals are suspected to be interacting to cause effects, but low pH occurs throughout the watershed because of natural factors, then only the metals need be treated as a candidate cause. It is important to distinguish causes from the environmental context in which they operate.

Do Not:	Explanation
• **Do not exclude a stressor based on its concentration in or absence from grab samples.**	You may be sampling at the wrong time of day or the wrong place or the stressor may occur episodically.
• **Do not exclude a stressor for lack of data.**	If a candidate causes is reasonable but no data exists to support including or excluding it from the list, include it until additional data can be collected.
• **Do not exclude a stressor because no source is known or because other steps in the causal chain seem to be missing.**	An unknown source may be present and the exposure may result from another pathway or may result from an intermittent process.
• **Do not exclude a stressor because it cannot be managed.**	Limiting the list to candidate causes that your organization can address runs the risk of eliminating an important cause and exaggerating the importance of minor but readily remediated contributors to the impairment. It also precludes the possibility that creative options might be found for remediating causes that are not part of the a priori set of options.

5.2 Common Candidate Causes of Biological Impairments

The EPA has compiled a list of candidate causes that are often linked with biological impairments. The majority of biological impairments in Minnesota will be the result of one or more of the candidate causes on the list below. This list provides an overview of common stressors - it is not a comprehensive list, and it should not limit the scope of your stressor identification study. The listed causes are generic (e.g., nutrients or invasive non-native species) whereas the candidate causes in a Stressor ID should be specific (e.g., total phosphorous or zebra mussels). The initial list is refined by moving through the process of drawing a map, gathering information, constructing a conceptual model, and engaging stakeholders.

The Common Candidate Causes section of CADDIS provides some suggestions on what to look for when deciding whether to include a cause on your list. Information is currently available for the parameters below. Some of these common stressors will act together to cause effects or may reflect different steps along a causal pathway. For example, flow alteration may result in reduced base flow which can increase the deposition of fine sediment or cause low dissolved oxygen conditions. Hyperlinks and web addresses are provided for each parameter.

- Metals (http://cfpub.epa.gov/caddis/candidate.cfm?section=133&step=24&parent_section=132)
- Sediments (http://cfpub.epa.gov/caddis/candidate.cfm?section=134&step=24&parent_section=132)
- Nutrients (http://cfpub.epa.gov/caddis/candidate.cfm?section=135&step=24&parent_section=132)
- Low DO (http://cfpub.epa.gov/caddis/candidate.cfm?section=136&step=24&parent_section=132)
- Temperature (http://cfpub.epa.gov/caddis/candidate.cfm?section=137&step=24&parent_section=132)
- Ionic Strength (http://cfpub.epa.gov/caddis/candidate.cfm?section=138&step=24&parent_section=132)
- Flow Alteration (http://cfpub.epa.gov/caddis/candidate.cfm?section=139&step=24&parent_section=132)
- Toxics (http://cfpub.epa.gov/caddis/candidate.cfm?section=140&step=24&parent_section=132)

5.3 Gather and Map Potential Sources

Common candidate causes for impairment such as low dissolved oxygen, excess fine sediment, and turbidity are all endpoints for various watershed processes and/or introduced disturbance within the watershed. In order to complete a TMDL for the key stressors, their sources and causal pathways must be well understood and clearly defined. After the list of candidate causes is developed, the focus should shift to identifying the sources and key processes that produce the potential stressors.

Information on point and non-point sources near the waterbody can help identify the sources and pathways behind potential stressors. Point sources, such as drainage pipes, outfalls, and ditches, are easily identified as sources. Constituents of the effluent or the effluent as a whole can be listed as candidate causes. The location of other sources, especially those of the non-point variety, may be more difficult to pinpoint. For example, sheet and rill erosion from agricultural fields may be widespread across the entire watershed and the impacts may be difficult to track to specific sub-watershed or stream reach. In these situations, consider using maps, aerial photos, and GIS applications to identify risk areas and build the case for the causal pathway.

5.4 Assess Data Gaps and Plan Monitoring Efforts

Each candidate cause should be evaluated in terms of its connection to the impairment, the data available to make the case, and the additional data that needs to be collected to strengthen the case. Available data for each candidate cause should be assessed for quantity, quality, and whether or not the methods used were adequate for stressor identification analysis. For example, if low DO conditions are identified as a candidate cause for impairment, the project team should discuss the DO data in terms of the number of measurements taken, the quality of those measurements, and whether or not the data available is adequate to establish linkages between low DO concentrations and impaired biota. Data of adequate quality and quantity is critical for establishing a defensible list of final candidate causes.

If data gaps are identified for one or more candidate causes on the list, a data collection strategy should be developed that will lead to further investigation of those candidate causes. Identifying data gaps and working to fill them assures that adequate resources are allocated to each parameter on the list of candidate causes. The collection of additional data to fill data gaps can lead to the elimination of the marginal candidate causes, which will free up project resources to focus on the parameters of highest concern.

5.5 Develop Conceptual Models

After the list of candidate causes is finalized, the next step is to develop conceptual models to link the cause with the effects. Conceptual models depict the sources and pathways of potential stressors in the watershed. These models provide an effective way to communicate hypotheses and assumptions about how and why effects are occurring. In addition, conceptual models can also show where different causes may interact and where additional data collection may be required.

Conceptual models will vary in complexity depending on the mechanisms and ecological processes involved. A generalized model may show land uses in the watershed that generate in-stream stressors impacting valued resources. For instance, if fish communities appear to be impacted by moderate levels of sediment in a stream, it is important to show that the effect could have occurred via several possible pathways, or a combination of pathways. Be sure to include all of the reasonable pathways in the conceptual model initially, and then cross out pathways when existing data or professional judgment indicates that they are improbable. Do not assume that one pathway is dominant until all others have been evaluated. Careful consideration of each pathway will result in a more defensible case for the candidate cause.

The EPA's CADDIS tool provides a library of conceptual models for some common stressors to aquatic life. These generic conceptual models depict some of the common sources and causal pathways associated with these stressors. All of them are available in Microsoft Powerpoint format, which allows for easy editing to fit the specifics of your case.

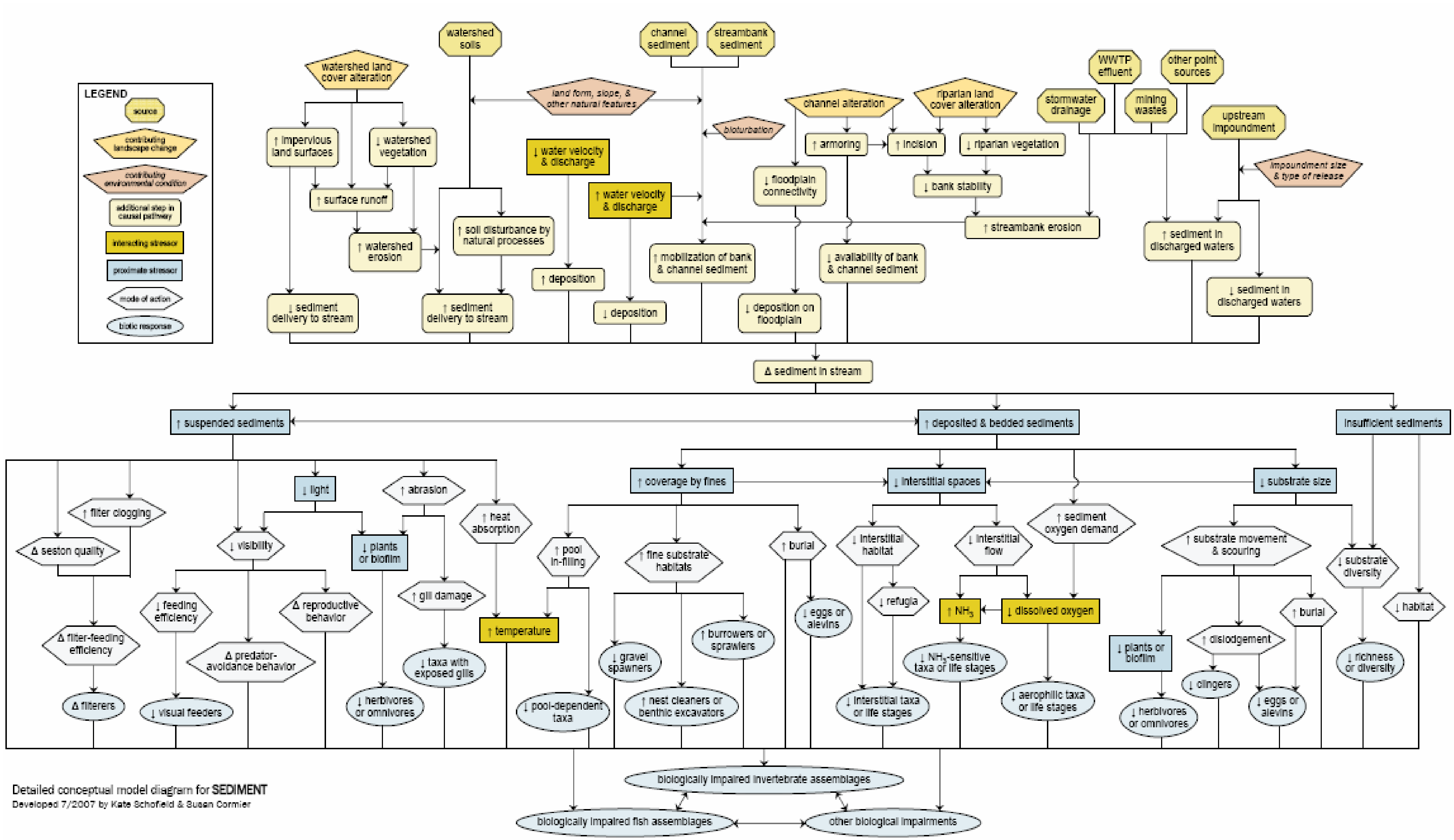

Figure 13: Example of conceptual model for a clean sediment stressor (EPA CADDIS, 2

EPA Conceptual Model Library
http://cfpub.epa.gov/caddis/info_sources.cfm?section=181&step=0&parent_section=29

5.6 Groundhouse River Conceptual Model Example

*** The material for the following case study was taken from Screening Level Causal Analysis and Assessment of an Impaired Reach of the Groundhouse River, Minnesota (Lane and Cormier, 2004).*

Conceptual models for three candidate causes were developed for the Groundhouse River stressor identification study. The three candidate causes evaluated were (1) *loss of habitat associated with unstable or unsuitable geological substrates*; (2) *low dissolved oxygen or altered food source associated with excessive nutrient loading*, and (3) *chronic and acute toxicity*. These candidate causes remained after the larger list of candidate causes was reduced after additional data collection, further analysis of existing data, and input from stakeholders and technical staff.

Figure 14 depicts the conceptual model that was developed for candidate cause #1, loss of habitat associated with unstable or unsuitable geological substrates. The impaired reach of the Groundhouse River exhibited a general lack of fish diversity. The number of simple and lithophilic spawning taxa was especially low. These fish require clean gravel habitat for spawning purposes. Reconnaissance and monitoring visits to this area of the stream indicated that the substrate was dominated by fine sands and silt, and much of the coarse substrate was embedded by this excess sediment. As a result, unstable or unsuitable substrate was identified as a candidate cause, and a conceptual model was developed to explore the sources and pathways involved.

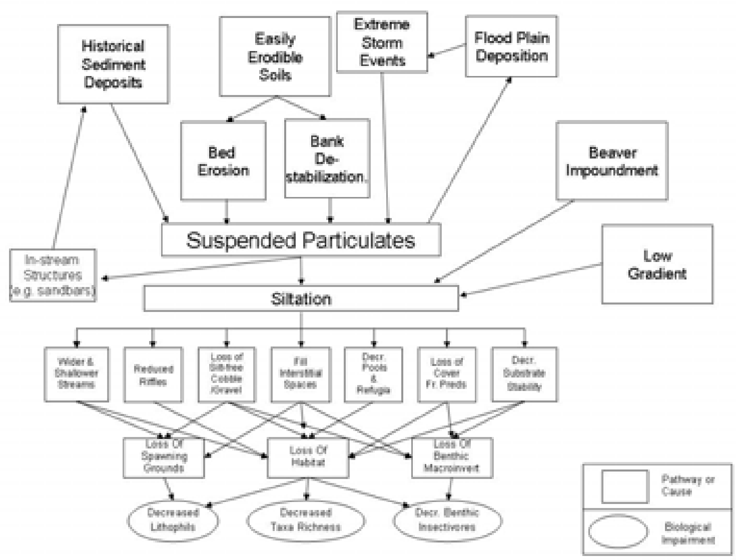

Figure 14: Conceptual model from Lane and Cormier, 2004. Natural features and characteristics of stream systems related to sedimentation. Those systems already predisposed to sedimentation may be additionally vulnerable to anthropogenic inputs.

Explanation of the Conceptual Model

Loss of breeding, feeding, or refugia habitat associated with unstable or unsuitable geological substrates is a common disturbance in stream systems. It often occurs due to excess silt and sediments entering the stream, settling, and covering/filling cobbles and gravel substrates and interstitial spaces, decreasing pool depth, and potential burial of larger coarse woody debris. In addition, excessive sediments can affect stream aquatic use conditions by eliminating stable, coarse substrates that provide shelter during high flow events, thereby potentially affecting fry of larger fish, smaller fish, and the macroinvertebrate food resource. Sediment sources within the stream include materials eroded from banks and scoured off the stream bed. Potential exterior sources of silt and sediments include gravel and mining operations, farming activities, road ways and urban runoff, and the extensive dirt and gravel road system in the drainage area. Naturally occurring stream features and landscape characteristics may also affect stream sediment conditions, potentially altering the occurrence of suitable gravel substrates. Beaver dams and low gradients, may both decrease flow, causing particulates to settle. Also, aquatic systems with naturally elevated particulate levels may be more susceptible to the effects of anthropogenic sediment loading.

End of Case Example

5.7 Engage Stakeholders

Stakeholder input is an important component in developing the list of candidate causes for impairment. In many cases, the resource professionals working on the project may be located outside the watershed, and must rely on stakeholders for key information on land-use activities and historic information pertaining to the watershed. The importance of including stakeholders in this part of the Stressor Identification process extends beyond their role as a key information source. Actively pursuing stakeholder input also promotes buy-in from local groups, which is important for public relations and implementation purposes.

Engaging stakeholders in the stressor ID and TMDL process is not a trivial task. Advice on engaging stakeholders can be found in Watershed Academy's Getting In Step Guide. A fairly comprehensive list of Public Involvement Techniques EXIT Disclaimer can be found on the EPA sponsored website SMARTe EXIT Disclaimer .

The project maps and conceptual models of candidate stressors can stimulate productive and informative stakeholder discussions. Questions may include the following:

- What have we missed? Is there additional information that should be considered in the investigation?
- Are there potential causes that should be added to the list for us to analyze?

5.8 Refine or Finalize the List of Candidate Causes

The final task of step #2 in the CADDIS process is to finalize the list of candidate causes. At this point, the list of candidate causes should have been shared with the stakeholders and technical advisory committee (TAC). Any comments from stakeholders or the TAC should be incorporated as necessary. The list of candidate causes should be evaluated for strength of data to support or eliminate candidate causes. This section will describe some key points to consider when deciding on the final set of candidate causes that will be further evaluated with more rigorous analysis tools later in the process. Four general rationales are used, listed below in rough order of decreasing level of confidence for either excluding or deferring analysis of a potential cause.

(1) Evidence that the cause is absent based on high quality stressor measurements — In most cases, this evaluation is equivalent to analysis and evaluation of spatial and temporal co-occurrence. That is, although the cause *could* occur, data indicate that it *has not* occurred at the site. For example, if continuous data loggers indicate that DO concentrations at the impaired location are not lower than those in a reference location during the preceding year, low DO can be removed from consideration as a candidate cause. The degree of quality needed to defend omission from the analysis will vary with the stressor and the level of confidence desired.

In general, long term (e.g., a year or more) temporally continuous and spatially extensive data is needed for a high level of confidence in omitting a potential cause. Since the data are available and must be analyzed in order to omit the potential cause, we suggest that you include these less likely candidate causes in the strength-of-evidence analysis (section 6.5).

(2) Evidence of an impossible cause or mechanism — Indisputable evidence that a cause would not occur at the site (e.g. low dissolved oxygen in a cataract or very turbulent stream) or that the biological effect is never caused by the agent (e.g., over-harvesting causing liver cancer in fish). This type of information is sufficient to omit a potential cause from the list of candidate causes. When available, evidence that demonstrates a candidate cause is impossible is discussed in the *Common Candidate Causes* section.

(3) No evidence that the cause is present — A lack of the observations that usually accompany a biological effect due to a particular cause. We provide check lists of factors that suggest that a potential cause be listed (see *Common Candidate Causes*). If these sources, site evidence or biological effects are absent, then the cause is either unlikely or you are lacking information. For example, if the watershed of an impaired stream is undisturbed forest, if sediment accumulation is not observed at the impaired site and if known sediment-sensitive species are present, then sediment may be omitted from the list of candidate causes. Using “absence of evidence” as a reason to omit a potential cause from the analysis is risky. Use it with great caution, because it could be that the relevant evidence is present but just has not yet been observed. For example, you may have observations from the autumn, but the exposures may occur in the winter.

(4) Insufficient data and evidence — No data are available or available data are untrustworthy for evaluating the potential cause. In these situations, you may decide to defer analysis until data become available or until analysis is not needed because a probable cause was identified, remediated, and the biological condition improved. By deferring a potential candidate cause rather than excluding it, you demonstrate scientific awareness and lack of bias.

5.9 CADDIS Step #2 Wrap-Up

At the conclusion of step #2 of the CADDIS process, you should have the following products completed:

Section 5.0 -- List Candidate Causes for Impairment
☐ **Develop list of Candidate Causes.** The list should be thoroughly reviewed by stakeholders and technical staff before moving on to Step #3. Candidate causes that are less likely should be removed if the data or professional knowledge is adequate to do so. When removing a candidate cause, be sure to document the rationale for doing so. (section 5)
☐ **Update maps and GIS to document location of stressor sources/pathways.** The maps created in step #1 of CADDIS should be updated to display the areas where the candidate causes for impairment are observed. If possible, also indicate known or potential source areas for the candidate causes. This task is more easily completed for point sources, but non-point sources can also be prioritized based on potential risk (i.e. erosion prone areas, nutrient rich soils, etc.).
☐ **Develop Conceptual Models of Candidate Causes.** Conceptual models should be developed for each candidate cause on the list. These models will assist with the identification of stressor sources and causal pathways. (Section 5.5)
☐ **Conduct stakeholder meeting to discuss candidate causes.** At some point during step #2, a stakeholder meeting should take place to discuss candidate causes and receive stakeholder input on them.

DRAFT

6.0 CADDIS STEP #3: Evaluate Data from the Case

In step #3 of CADDIS, the data and other evidence gathered for the case will be used to evaluate the strength of evidence for each candidate cause. The Stressor ID process relies on a variety of evidence types and analysis methods to accomplish this task. This section explains the types of evidence used in stressor ID studies and how to organize your data for strength of evidence analysis. The main objective of Step # 3 is to assemble and analyze data from the case at hand, with three goals in mind:

(1) Develop consistent and credible evidence that allows for the elimination of very improbable causes, or to use symptoms to refute or diagnose a cause

(2) Begin building the body of evidence for those candidate causes that cannot be eliminated or diagnosed. These lines of evidence will be used in Step 5 to identify the most probable causes

(3) Assign scores to candidate causes based on the available data

The analyses conducted during this step combine measures of the biological response (e.g., trout abundance or invertebrate taxonomic richness) with direct measures of proximate stressors (e.g., turbidity or percent embeddedness values). They may also include measures of other steps linking sources, candidate causes, and biological effects. For example, if low levels of dissolved oxygen (DO) constitute the candidate cause, data from the case may include actual dissolved oxygen measurements at the impaired and reference sites; evidence that organisms intolerant of low DO have declined at the impaired site; and/or measurements of increased organic matter (one potential step in the causal pathway) at the impaired site.

Key Questions to consider for Step 3:

- **Do the candidate cause and the effect occur in the same location?**
- **Is there a complete series of events linking the source to the causal agent?**
- **Does the magnitude of the effect increase with the magnitude of exposure to the causal agent?**

6.1 Data Sources

The data used for stressor identification may be collected specifically for the case or you may have data from elsewhere that was collected for other purposes. Data generated by models can also be a vital component of a causal analysis when sufficient data to support or refute relationships between stressors and biological impairments is not otherwise available. This section covers analysis techniques using only case-specific data. Guidance for using data from elsewhere is presented in section 7.0 of this protocol.

Data from the Case

Data from the case includes data collected within the impaired reach, and one or more reference locations within the study area if such areas exist. At a minimum, you will have the data used to classify the reach as impaired. Additional data should have been collected during steps 1-3 of this protocol to further define the impairment and explore the relationships between candidate stressors and the impaired biological communities. The iterative nature of the SI process allows for additional data collection at any time to enhance the data set available for analyzing these relationships.

6.2 Assembling the Data

Biological TMDLs and Stressor Identification projects can be very data intensive. At this stage of the project, you likely have data covering the hydrology, biology, geology, land-use, climate, water chemistry, and other important factors of the study watershed. In order to evaluate data from the case for stressor-response relationships, you will need to organize the existing data into a format that clearly shows the specific measurements available for the key parameters and how each of them relate to the list of candidate causes.

Begin by taking inventory of the available data associated with each listed candidate cause. For example, if bedded sediment was identified as a candidate cause, list all of the data sources available to analyze the relationship between bedded sediment and biological response. These data may include reach or cross section pebble counts, measures of substrate embeddedness, percent fine substrate, and other related measurements. Organize these data into a format that allows for comparisons between monitoring locations. It is especially important to organize this information in a manner that allows for clear comparison of the impaired locations and unimpaired locations. The EPA stressor ID guidance recommends developing tables for each candidate cause to accomplish this task.

The Groundhouse River stressor ID (Lane and Cormier, 2004) used tables to organize data and examine the causal pathways identified for each candidate cause. The two columns on the left side of figure 15 represent the candidate causes that were identified from the first two steps of the Stressor ID process and the available data associated with each of them. After the parameters associated with each candidate cause are identified, it becomes easier to compare them across the monitoring sites in the study watershed. In the case of the Groundhouse River table below, site #3 was impaired for fish IBI and site #2 was not impaired. The table was set up to compare the relevant data for site #3 against site #2. It clearly shows the important parameters associated with each candidate cause and the results for the two sampling locations.

Complete Exposure Pathway				
Candidate Cause	Parameter	Concentration or level at upstream site 2	Conc. or level at downstream site 3 (Standard Deviation)	Consistent with pathway?[b]
1. Loss of Habitat Associated with Unstable or Unsuitable Geologic Substrates	% Riffles	14.5	6.7 (2.9)	Yes
	Gradient (m/km)	1.89	0.8 (0.00)	Yes
	Bed Shear (KPa)	2000	400 [a]	Yes
	Bank Shear (KPa)	470	150 [a]	Yes
	Collapsed Banks?	No	Yes	Yes
	Bank Erosion (m/m)	1.00 / 5	0.08 / 5	If source from site No, if upstream source, Yes
2.1. Excess Nutrients and Low Dissolved Oxygen	D.O. (mg/L)	8.40	8.73 (0.11)	No
	P (mg/L)	0.08	0.08 (0.02)	No
	NO_2+NO_3+N (mg/L)	0.05	0.07 (0.00)	Yes
	Gradient (m/km)	1.89	0.8 (0.00)	Yes
	% Riffles	14.5	6.7 (2.9)	Yes
	TSS (mg/L)	2.40	1.85 (0.78)	No
	Temp. (°C)	26.80	21.40 (0.01)	No
2.2. Excess Nutrients and Altered Food Resources	Turbidity (NTU)	2.90	3.42 (1.72)	Yes
	Algal Growth	Unknown	Present only at POTW outflow [a]	No
	P (mg/L)	0.08	0.08 (0.02)	No
	NO_2+NO_3-N (mg/L)	0.05	0.07 (0.00)	Yes
	TSS (mg/L)	2.40	1.85 (0.78)	No
	D.O. (mg/L)	8.40	8.73 (0.11)	No
3. Chronic or Acute Toxicity	Insufficient Data Available			

[a] Data collected in 2003; site 2 was sampled in 1996
[b] Is the difference in the parameter between sites 2 and 3 consistent with greater strength of the exposure pathway at site 3?
[c] Calculated following Minnesota Rule 7050.0222 (Specific Standards of Quality and Purity for Class 2 Waters of the State; Aquatic Life and Recreation)

Figure 15: Table of candidate causes and associated parameters for biological monitoring stations in the Groundhouse River. From Lane and Cormier, 2004.

6.3 Analyzing Case-Specific Data

As shown in the Groundhouse River example above, this step of the stressor identification relies heavily on drawing comparisons between impaired locations and "unimpaired" or "reference" conditions. These comparisons can involve quantitative biological, chemical, and physical measurements, or they can be more observational or qualitative in nature. The objective is to compare parameters associated with the remaining candidate causes across the applicable geographic scope. The results of these comparisons should help in building the body of evidence for or against candidate causes.

The stressor identification process is most effective when it can draw primarily from case-specific data. In the case of the Groundhouse River example, the impaired reach (site #3) was compared to an unimpaired reach upstream of the impaired area (site #2). In most of the stressor identification examples provided by the EPA and MPCA, the reference condition used is represented by an unimpaired site upstream or downstream from the impaired location on the same waterbody. This approach is effective if the impairment is localized and there are suitable reference reaches available. If the impairment is more widespread throughout the watershed, it may be difficult or impossible to locate a reference reach within the study area for comparative analysis. In these situations, the stressor ID and TMDL may need to pull information from elsewhere. For more information on using data sources outside of the study watershed, refer to section 7 of this protocol.

For certain parameters, there are established guidelines or standards available with which data from the case can be compared. The majority of these guidelines and standards are associated with water quality or biological parameters. Two commonly used sources for water quality guidelines and standards are described below:

(1) Eco-Region Values from Minimally Impacted Streams

The conditions at impaired sites can be compared against regional expectations or water quality criteria. These sources of information should be used as supplementary evidence for or against a candidate cause, but using them to refute or diagnose a candidate cause should be done with great caution.

The state of Minnesota is comprised of numerous eco-regions that are based on geology, hydrology, native vegetation, and other natural features of the landscape (Omerik, 1987). All of the variables considered in the development of eco-regions influence the characteristics of the streams and rivers within them. In many cases, streams within the same eco-region will exhibit similar physical, chemical, and biological characteristics. These streams are also likely to respond similarly to introduced disturbances in the watershed. If enough streams within an eco-region have been studied over an adequate temporal and spatial scale, you may be able to make inferences on the condition of the impaired water as it relates to similar water bodies in the eco-region.

The ecoregion scale has been widely used for evaluating various water quality components as potential stressors to aquatic life. Ohio EPA used eco-regions in a technical bulletin that addressed the associations between nutrients, habitat, and aquatic biota in Ohio streams and rivers (Rankin et al, 1999). The complete report can be found at the following link *(http://www.epa.state.oh.us/dsw/documents/assoc_load.pdf)*. The MPCA has used eco-region boundaries to define the water quality characteristics of minimally impacted streams within Minnesota's seven ecoregions (McCollor and Heiskery, 1993). The MPCA report, entitled Selected Water Quality Characteristics of Minimally Impacted Streams from Minnesota's Seven Ecoregions can be found at through this hyperlink *(http://www.pca.state.mn.us/publications/tdr-g1-03.pdf)*.

If used correctly, ecoregion data can provide a baseline for water quality, habitat, and biological parameters. If the conditions of the study streams vary considerably from the eco-region averages, it may provide support for a candidate cause. This may be especially valuable for parameters that do not have water quality standards in place (i.e. nutrients, TSS, etc.). In order for the case to be valid, the parameter would have to be at a concentration or magnitude proven to have biological effects. Consider TSS concentrations as an example. If TSS concentrations for a given stream are considerably higher than eco-region averages, it may emerge as a logical candidate cause for impairment.

(2) Water Quality Criteria

Many of Minnesota's water quality criteria were established to protect aquatic life in streams, lakes, and wetlands. The criteria for dissolved oxygen, turbidity, pH, and other conventional parameters are based on scientific literature or field studies based on the biological response to changes in these water chemistry parameters. Violations of water quality criteria can serve as signals for potential stressors, especially if monitoring results indicate significant violations of water quality standards in terms of frequency, magnitude, and/or duration.

Violations of water chemistry standards alone should not result in the outright diagnosis of a given parameter as a candidate cause. However, comparing chemistry data to WQ standards and across study sites can provide a valuable screening assessment and can provide the impetus for additional monitoring of those parameters. To view Minnesota's water quality standards, follow the link below.

Minnesota's Water Quality Rules (Chapter 7050)
http://www.pca.state.mn.us/water/standards/index.html#rules

6.4 Types of Case-Specific Evidence

The Stressor Identification process is designed to work with many types of evidence. The more types of evidence that support a candidate cause for impairment, the stronger the case for it being the true cause of impairment. The types of evidence presented in this section are some of the more commonly used forms in ecological and water resource management studies. The evidence generated by analyzing associations among data from the case will likely fall into one of the types listed in table 11.

Throughout this section you will notice tables with scoring criteria for strength of evidence analysis. These tables should be referenced while completing strength of evidence analysis for each of the candidate causes. Strength of evidence analysis (SOE) will be used to evaluate each remaining candidate causes using the types of evidence presented in this section. SOE is explained in further detail in section 6.5.

It is not necessary to analyze the candidate causes using each one of these evidence types, but as stated previously, a candidate cause supported or refuted by multiple lines of evidence will make for a stronger case. Table 11 summarizes the evidence types and provides a brief conceptual overview of each type. Be sure to consider each type of evidence in your analysis of candidate causes. If no data is available for a specific type of evidence, decide whether or not it is crucial to the case.

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Table 11: Types of evidence that use data from the case. Additional information for each type of evidence can be acquired by following the hyperlinks in the "types of evidence" column.

Type of Evidence	Concept
Spatial/Temporal Co-occurrence	The biological effect is observed where and when the causal agent is observed and is not observed in the absence of the agent.
Evidence of Exposure or Biological Mechanism	Measurements of the biota show that relevant exposure has occurred or that other biological processes linking the causal agent with the effect have occurred.
Causal Pathway	Precursors of a causal agent (components of the causal pathway) provide supplementary or surrogate evidence that the biological effect and causal agent are likely to have co-occurred.
Stressor-Response Relationships from the Field	The intensity or frequency of biological effects at the site increases with increasing levels of exposure to the causal agent or decrease with decreasing levels.
Manipulation of Exposure	Field experiments or management actions that decrease or increase exposure to a causal agent decrease or increase the biological effect.
Laboratory Tests of Site Media	Laboratory tests of site media can provide evidence of toxicity, and Toxicity Identification Evaluation (TIE) methods can provide evidence of specific toxic chemicals, chemical classes, or non-chemical agents.
Temporal Sequence	The cause must precede the biological effect.
Verified Prediction	Knowledge of the causal agent's mode of action permits prediction of unobserved effects that can be subsequently confirmed.
Symptoms	Biological measurements (often at lower levels of biological organization than the effect) can be characteristic of one or a few specific causal agents. A set of symptoms may be diagnostic of a particular cause if they are unique to that cause.

(1) Spatial/Temporal Co-Occurrence

Evaluating data for spatial and temporal co-occurrence is one of the primary lines of evidence used in Stressor Identification studies. For this type of evidence, the biological effect must be observed where and when the cause is observed, and must not be observed where and when the cause is absent.

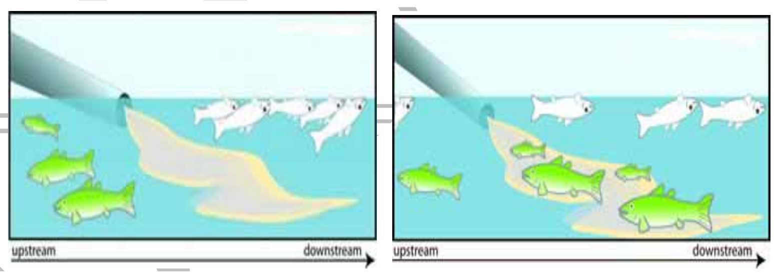

Figure 16 : Left: Spatial/Temporal Co-occurrence with Upstream/Downstream Comparisons, Supports. The impairment (dead fish) occurs downstream of the source of the causal agent (effluent) but not upstream. (*General explanation of symbols*) **Right:** Spatial/Temporal Co-occurrence with Upstream/Downstream Comparisons, Refutes. The impairment (dead fish) occurs both upstream and downstream of the source of the causal agent (effluent). (CADDIS, 2005)

The use of spatial co-occurrence evidence relies on a data set that is adequate for drawing spatial connections between the candidate cause and biological effect. In many cases, this is accomplished by comparing biological, physical, and chemical conditions between higher quality sites and degraded sites.

Additional Examples of Spatial/Temporal Co-occurrence

Consider increased suspended solid concentrations as a candidate cause of reduced aquatic invertebrate abundance. What findings support or weaken the case for increased suspended solids as the cause, based on spatial/temporal co-occurrence?

- **Supporting evidence (spatial co-occurrence)** - Suspended solid concentrations are higher at the impaired site(s) than at unimpaired reference sites.
- **Supporting evidence (temporal co-occurrence)** - Suspended solid concentrations are episodic, and insect abundance decreases during periods with high suspended solids.
- **Weakening evidence (spatial co-occurrence)** - Suspended solid concentrations at the impaired site(s) are similar to those at unimpaired reference sites, or are greater at unimpaired reference sites than at the impaired site(s).
- **Weakening evidence (temporal co-occurrence)** - Suspended solid concentrations are episodic, and insect abundance increases or remains unchanged during periods with high suspended solids.

Scoring Spatial and Temporal Co-Occurrence Data

The evidence for or against the candidate cause should be scored based on the nature and strength of spatial co-occurrence relationships. Scoring the evidence using a strength of evidence (SOE) approach will facilitate the task of identifying the strongest and weakest evidence for this candidate cause and others. The Stressor Identification guidance recommends scoring the evidence using a set of symbols to represent the nature and strength of the relationship between candidate stressors and biological effects. Table 12 summarizes the symbols used and how to interpret them when analyzing evidence of spatial and temporal occurrence. More information on SOE analysis can be found in section 6.5.

Table 12: Scoring method for evaluating the nature and strength of spatial co-occurrence relationships. See the Groundhouse River case-study for an example of this scoring method using actual data from a Stressor Identification study.

Finding	Interpretation	Score
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

(2) Stressor-Response Relationships from the Field

Stressor-response evidence from the field is based on the classic requirement of toxicology that effects must be shown to increase with dose. This principle is also applicable to stressors other than chemical contaminants. As with other types of evidence from the case, the most compelling evidence is based on data collected during the same time period, from a set of spatially contiguous sites in which all other candidate causes remain constant. However, the relationship may be derived from a set of sites that are located in the same vicinity, but are not spatially contiguous.

Field stressor-response relationships are commonly analyzed with correlation or regression techniques. The direction (i.e., negative or positive sign) of the correlation or regression coefficient is first evaluated to determine whether it is consistent with the causal hypothesis. For example, a positive correlation between dissolved oxygen levels and mayfly taxonomic richness would support the hypothesis that low levels of dissolved oxygen cause impairment. Strong correlations and steep slopes increase confidence that the relationship is real. However, statistical tests of these relationships should be interpreted cautiously as these tests are very sensitive to sample size.

The "stressor" part of the relationship may involve measuring the candidate causal agent (i.e. embedded substrate), or an appropriate surrogate. For example, nutrient concentrations sometimes are used as surrogates for algal growth, and stressor-response relationships showing increased impairment with increased nutrient concentrations may be used to support increased algal growth as a candidate cause. However, it is important to realize that one measure may be a surrogate for more than one stressor (e.g., nutrient concentrations also may be used as surrogates for low dissolved oxygen). Stressor-response relationships also can be based upon indicators of exposure to a stressor, such as DELT counts (DELT = **D**eformities, **E**roded fins, **L**esions, **T**umors). DELT is one of the metrics calculated in the development of fish index of biotic integrity (IBI) scores (see section 2.3).

Stressor-response evidence that ***Supports*** **a candidate cause:**

- Data showing that the effect decreases as the magnitude or duration of exposure to the candidate cause decreases
- Data showing that the effect increases as the magnitude or duration of exposure to the candidate cause increases

Stressor-response evidence that ***Weakens*** **a candidate cause:**

- Data showing that the effect increases as the magnitude or duration of exposure to the candidate cause decreases
- Data showing that the effect decreases as the magnitude or duration of exposure to the candidate cause increases
- Data showing that there is no change in the effect as the magnitude or duration of exposure to the candidate cause changes

Confounding Variables

Analyses of stressor-response relationships from the field are often complicated because multiple stressors frequently occur together. For this reason, stressor-response relationships from the field should not be used alone to evaluate a case. Exploring correlations among an entire suite of stressor variables can provide useful insights, and multivariate techniques such as principal components analysis (PCA) can be used to divide stressors into groups that increase or decrease together. However, none of these techniques can eliminate the possibility that an unmeasured stressor may be the true cause of the correlation.

Confounding arises when you can't separate out the effects of variables that are correlated. For example, say the biological response variable you are investigating is low EPT richness, and two of your candidate causes are excess fine sediments and phosphorus. You know that these two variables are often linked, but you only have data for sediments. You run a correlation between EPT and fine sediments, and it is significant. However, you cannot conclude from this information that fine sediments alone are responsible. The correlation between EPT richness and sediments could be either (1) reflecting a true relationship between EPT richness and sediments OR (2) reflecting a true relationship between EPT richness and phosphorus, with fine sediments is just serving as indicator of phosphorus OR (3) both sediments and phosphorus impact EPT, and you are attributing the impacts of both stressors to sediments.

Scoring Stressor-Response Data

The scoring approach for the stressor-response evidence is similar to the criteria used for spatial co-occurrence. The main difference is that stressor-response data cannot be used to refute a candidate cause due to the potential for confounding of variables.

Table 13: Scoring method for evaluating the nature and strength of spatial co-occurrence relationships. See the Groundhouse River case-study for an example of this scoring method using actual data from a Stressor Identification study.

Finding	Interpretation	Score
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 conclusive 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**
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.**	- -

(3) Complete Exposure Pathway

Complete exposure pathway is the physical path a stressor takes from the source to the community or organisms it is impacting. Taking a closer look at intermediate steps in these pathways can provide evidence for or against a candidate cause. This type of evidence is particularly valuable in complementing data sets for a candidate cause with few direct measurements.

As an example, consider low concentrations of dissolved oxygen as a candidate cause of decreased fish abundance. One of several causal pathways by which dissolved oxygen concentrations can be reduced is via an increase in nutrients leading to an accumulation of algal biomass. When these algae eventually die, bacteria, fungi and protozoans can increase and rapidly consume the available oxygen.

Given this causal pathway, what findings support or weaken the case for low levels of dissolved oxygen as the cause?

- ***Supporting evidence*** - *Monitoring data show that sites with low fish abundance have higher nutrient concentrations or greater algal biomass than sites with high fish abundance.*
- ***Weakening evidence*** - *Monitoring data show that nutrient concentrations and algal growth measures are not higher at sites with reduced fish abundance, relative to unimpaired sites.*

In summary, the data relevant to the hypothesized steps linking a candidate cause to potential sources can be used to assess the likelihood that that agent is present. These steps in the causal pathway serve as surrogates for the proximate stressor when data on the stressor itself are unavailable or as supplementary sources of information when stressor data is available. Multiple causal pathways may lead to a candidate cause, and evidence supporting the steps in even one pathway can be enough to bolster the case for a candidate cause. The conceptual models developed in section 5.5 of this protocol should be used to evaluate the pathways associated with each candidate cause.

It is important to keep in mind that candidate causes cannot be completely refuted using causal pathway evidence. Although some pathways may be eliminated, there are always potential unknown sources or pathways that may result in the candidate cause.

Scoring Complete Exposure Pathway Data

The scoring criteria for this type of evidence is based on the completeness of the pathways and the quality of the data available to support or refute them. See table 14 for a description and interpretation of these scoring criteria.

Table 14: Scoring method for evaluating evidence of a complete exposure pathway. See the Groundhouse River case-study for an example of this scoring method using actual data from a Stressor Identification study.

Finding	Interpretation	Score
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**	- -

(4) Temporal Sequence

Temporal sequence evidence is based on the fact that the candidate cause for impairment must precede the effect. In order to evaluate the case for temporal sequence, adequate data must be available before and after the effect occurs. Adequate data does not necessarily mean rigorous, quantitative data - anecdotal evidence, notes, or pictures can also be used to document temporal sequence of the effects that are believed to be causing the impaired condition.

Convincing evidence of temporal sequence is relatively uncommon for several reasons. First of all, this type of evidence usually depends upon data collected over relatively long time scales, often before an observed impairment suggests when and where data should be collected. Only measurements of the candidate causal agent (i.e., the proximate stressor) should be used to evaluate temporal sequence: surrogates or measurements of other steps in the causal pathway are considered under other types of evidence. In addition, temporal sequence evidence can be difficult to apply in cases where non-point source pollution is the driver. The effects of non-point pollution tend to aggregate over time, and the exact point at which biotic effects take place is difficult to pin down. Immediate impacts to a stream via channelization, the addition of a point-source pollution source, or construction of a dam are easier to trace back to causing a detectable shift in the biological assemblage.

Consider reduced water flow as a candidate cause of low benthic macroinvertebrate species richness. What findings support or weaken the case for reduced water flow as the cause, based on temporal sequence?

Supporting evidence - Monitoring data show a diverse macroinvertebrate community, but after water is diverted for irrigation species richness of the community declines. This sequence of events supports the case for reduced water flow as a cause, since the biological effect occurred only after water flow was diminished.

Weakening evidence - Monitoring data show an impaired macroinvertebrate community, and after water is diverted for irrigation the community is unchanged. This lack of a cause-effect temporal sequence weakens the case for reduced water flow as a cause, and suggests that the biological community was impaired by some factor other than reduced water flow.

Scoring the Evidence

Only the time order of the candidate cause and the observed effect is evaluated under temporal sequence. The magnitude of change is evaluated later in Step #5 of CADDIS.

Table 15: Scoring method for evaluating evidence of temporal sequence. See the Groundhouse River case-study for an example of this scoring method using actual data from a Stressor Identification study.

Finding	Interpretation	Score
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**	-
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**

(5) Evidence of Exposure or Biological Mechanism

Evidence of exposure or biological mechanism are measurements of the biota that show relative exposure to the candidate cause has occurred, or that other biological mechanisms linking the cause to the effect have occurred. Some stressors will inflict behavioral, physical, and or physiological changes in organisms that are visible or otherwise detectable using various field or lab techniques. Many of these effects have been well documented through field or laboratory studies.

Some of the measurements or observations which may provide evidence of exposure or mechanism include:

- **Body burden measurements of toxic substances or parasites (DELT)**
  - **D**eformities
  - **E**roded fins
  - **L**esions
  - **T**umors
- **Biomarkers of exposure, such as cytochrome P450 levels**
- **Behavioral observations (i.e. avoidance or behaviors such as convulsive swimming**

As an example, consider increases in an invasive predator as a candidate cause of decreased native fish abundance. What findings support or weaken the case for increased invasive predators as the cause, based on evidence of exposure or mechanism?

Supporting evidence - Examination of the invader's gut contents shows that many of the invasive individuals have native fishes in their stomachs.

Weakening evidence - Examination of the invader's gut contents shows that no native fishes are found in the invader's stomachs.

Data relevant to evaluating exposure or a particular mechanism are analyzed by comparing measurements from impaired versus unimpaired sites. Whereas spatial/temporal co-occurrence deals only with measures of the candidate causal agent, or proximate stressor, evidence of exposure or mechanism explicitly considers surrogate measures or measures of other steps in the causal pathway. In other words, whereas spatial co-occurrence evidence would compare concentrations of dissolved oxygen in the water column between two sites, evidence of exposure would look for behavioral changes in the organisms (i.e. fish gulping at the water surface). Mere spatial/temporal co-occurrence does not establish the implications or effects of the exposure.

Scoring the Evidence

Table 16: Scoring method for evaluating evidence of exposure or biological mechanism. See the Groundhouse River case-study for an example of this scoring method using actual data from a Stressor Identification study.

Finding	Interpretation	Score
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**	**- -**
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**

(6) Symptoms

The presence or absence of characteristics that occur only in response to a particular stressor can be used to diagnose that stressor as the cause. Confidence in this type of evidence is increased when a larger number of characteristic symptoms are observed, or when the observed symptoms are highly specific to a few potential causes. Non-specific effects are more difficult to diagnose, so this type of evidence is more helpful when impairments are defined as specifically as possible (e.g., as decreases in specific insect taxa of concern, rather than as decreases in total insect abundance).

What "Symptoms" evidence would support or weaken the case for a candidate cause?
Supports….

- Data showing that a unique set of characteristics caused by a candidate cause (e.g., symptoms within the organism, the presence of indicator species) are present at the impaired site

Weakens….

- Data showing that one or more characteristics usually caused by a candidate cause are not present at the impaired site
- Data showing that one or more characteristics at the impaired site that are not those caused by the candidate cause are present at the impaired site

Although the term "symptoms" is familiar to most people from its use in medicine, the concept can be extended to other levels of biological organization. Symptoms evidence can be applied to many of the individual metrics within the IBI. For example, when effects are defined at the assemblage level (e.g., decreased numbers of mayfly taxa or decrease in simple lithophilic spawning fish) the abundances of specific taxa can be analyzed as symptoms in support of particular candidate causes.

Table 17: Scoring method for evaluating evidence of symptoms.

Finding	Interpretation	Score
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**

6.5 Scoring the Evidence

Strength of Evidence (SOE) Analysis

The SOE analysis organizes information relevant to each candidate cause so that it can be easily compared and communicated. When there are many candidate causes or when evidence is ambiguous, strength of evidence analysis is more useful than elimination of alternatives because it identifies the alternative that is best supported by the evidence. Even when a cause has been identified by a process of elimination or diagnosis, it is often desirable to complete the strength of evidence analysis in order to organize all of the evidence for the decision makers and stakeholders.

After the data is organized and evaluated for the various types of evidence, the strength and consistency of the evidence for candidate cause should be scored for comparative purposes. The scores for the various types of evidence will become particularly valuable in Step #5 of CADDIS, when the most probable cause(s) for impairment will be identified. The scoring system for all of the evidence types used in stressor identification is available in through the following link (*summary table of scores*). The rationale for each score is provided in the column entitled "interpretation". The sign of the score is based on whether the type of evidence supports the candidate (+), weakens the candidate (-) or has no impact (0).

The number of plusses and minuses increases with the degree to which the evidence either supports or weakens the case for a candidate cause. Evidence can score up to three plusses (+++) or three minuses (---). However, the maximum number recommended for a particular type of evidence depends on the likelihood that an association might be observed because of chance rather than because of the true cause. Therefore, the highest scores are given to the types of evidence:

- That use data from the case
- That are based on more than one association
- That closely link the proximate cause and the effect

If the available data cannot be analyzed in way that can be used to evaluate a type of evidence, it is scored as "no evidence" (NE). If other candidate causes in the analysis do have this type of evidence, we recommend including the NE to help compare the relative strength of the evidence across candidate causes. However, if no candidate causes can be evaluated for a particular type evidence, do not include the row of NEs in your summary scoring table. Sometimes it doesn't make sense to score one type of evidence, because of the results of another. For example, it wouldn't make sense to evaluate a stressor-response relationship in the field if the effect and stressor do not spatially co-occur. In these situations, we recommend using "not applicable" (NA).

There are two other types of scores that should be used with caution. Refute (R) is used for indisputable evidence that disproves that the candidate cause is responsible for the specific effects. Diagnose (D) is used when a set of symptoms for a particular causal agent or class of agents is, by definition, sufficient evidence of causation, even without the support of other types of evidence. When using R and D as scores in the strength of evidence table, be prepared to defend your case with data or observations that are adequate in quantity and quality. Do not refute or diagnose a candidate cause without careful consideration of the evidence and all possible associations.

Once you have all the scores, compile them in a summary worksheet (*example scoring table*). The Groundhouse River case study presented in section 6.6 contains example scoring tables. The scoring tables will be used in Section 8 of this protocol to identify the probable cause. The following sections present the various types of case-specific evidence that you should consider in your SOE analysis for the remaining candidate causes.

6.6 CASE STUDY - Groundhouse River TMDL

***** The material for the following case study was taken from Screening Level Causal Analysis and Assessment of an Impaired Reach of the Groundhouse River, Minnesota (Lane and Cormier, 2004).***

The Groundhouse River stressor identification project used spatial co-occurrence, stressor-response evidence, and causal pathway analysis to examine the relationships between candidate causes and biological response in the watershed. This case study will highlight the use of these types of evidence to evaluate fine bedded sediment as a stressor to aquatic life in the Groundhouse River.

The nature of the Groundhouse impairment and available data were ideal for spatial co-occurrence analysis. The fish impairment was limited to one reach of the river, while the remaining reaches achieved the fish IBI criteria established for the stream. In all, there were seven biological monitoring stations along the mainstem of the Groundhouse River. The abundance of monitoring locations along with the localized nature of the impaired condition set the stage for an effective analysis using several types of evidence.

The first step in this analysis was to identify and organize the existing data related to fine bedded sediment. The two main sources of this data were the quantitative habitat data collected by the MPCA during the biological sampling, and geomorphic surveys that were completed using the Rosgen level II methods. Parameters such as % fines, depth of fines, % embedded substrate, and the D50 (median particle size) are just a few examples of the data pulled from these monitoring efforts. As recommended by the Stressor Identification guidance, the Groundhouse team assembled the relevant data in table format to begin the analysis of available evidence. Figure 17 shows the parameters that were used to compare sediment data between the impaired site (#3) and an unimpaired site (#2) located just upstream of the impaired area.

Spatial Co-occurrence			
Candidate Cause	**Parameter**	**Conc. or level at upstream site 2**	**Conc. or level at downstream site 3 (Standard Deviation)**
1. Loss of Habitat Associated with Unstable or Unsuitable Geologic Substrates	D50 (mm)	22	1[a]
	% Fines	17.3	58.7 (17.7)
	Depth of Fines (cm)	5.60	7.99 (0.86)
	% Embed.	39.0	51.2 (8.8)
	% Boulder	3.5	0 (0)
	% Coarse Substrate	82.7	40.4 (16.3)
	% Cover	10.8	8.65 (1.90)

Figure 17: Spatial co-occurrence analysis of fine bedded sediment as a candidate cause for impairment in the Groundhouse River. Site 2 is unimpaired and site 3 is the impaired reach.

The available evidence supported spatial co-occurrence of fine bedded sediment and biological impairment in the Groundhouse River. Values for percent fines, percent embeddedness, and percent coarse substrate were noticeably different between the impaired and unimpaired sites. Looking at the data, the investigators were confident in claiming that the impairment occurs at the same spatial location as the candidate cause. As a result, the candidate cause of fine bedded sediment was retained for further analysis using other lines of evidence.

"Stressor-Response Evidence from the Field" was also incorporated into the Groundhouse River stressor identification process. This evidence string was used to evaluate fine bedded sediment as a candidate cause. As bedded sediment and substrate embeddedness increase in streams, the fish and invertebrate species that require clean gravel substrates for spawning and feeding are often reduced or completely absent from the assemblage (Berkman, 1987).

The authors of the Groundhouse River stressor identification report explored this biological response across the seven monitoring stations in the watershed. After breaking down the IBI scores into metrics, it became clear that the impaired site had reduced numbers of the species that depend on clean, coarse substrate in certain life stages. When graphed out across all of the monitoring sites in the watershed, the predicted response became clearly associated with the stream reaches most impacted by silty or embedded substrates. As shown in figures 18 and 19, the stressor-response evidence from Groundhouse River monitoring stations supported fine bedded sediment as a candidate cause for impairment.

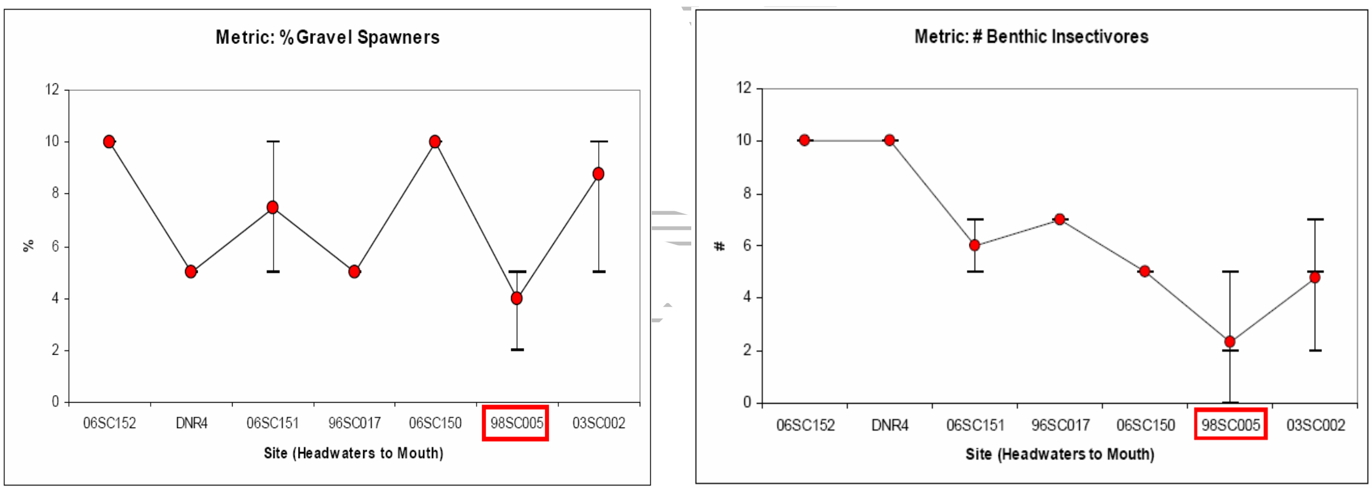

Figure 18: Graphs from the Groundhouse River Stressor Identification study showing a numbers of species at each site that are sensitive to excess bedded sediment. 98SC005 is the impaired site. (Tetra Tech, 2007)

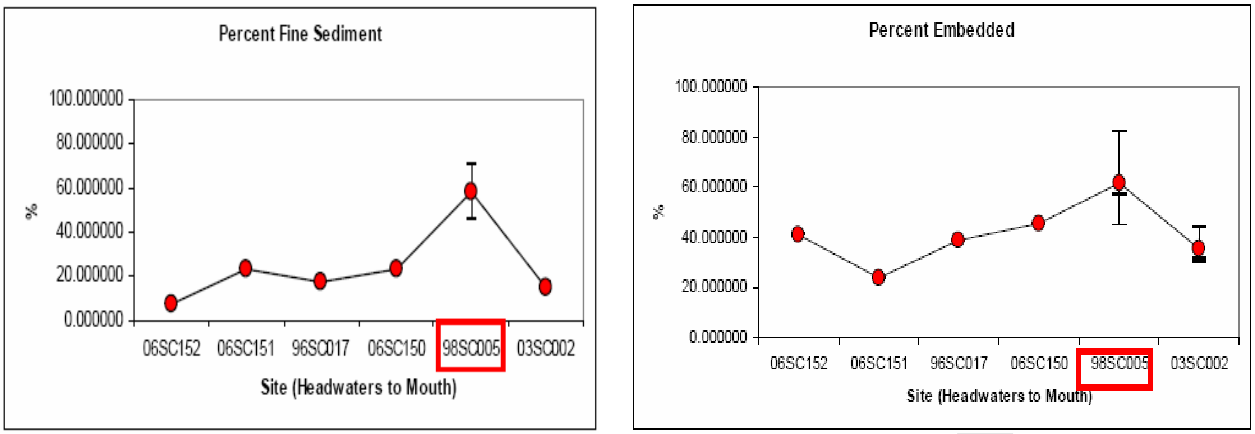

Figure 19: Graphs from the Groundhouse River Stressor Identification displaying measures of fine sediment and embeddedness across the monitoring sites. Note the high percentages of fines and embeddedness at the impaired location, 98SC005. (Tetra Tech, 2007).

Finally, an analysis of the causal pathways associated with fine bedded sediment was evaluated for consistency. When the conceptual model for this candidate cause was developed, all logical sources and pathways for the candidate were included (figure 20). Each causal pathway in the conceptual model was evaluated for plausibility based on data or other observations from the impaired reach and other study reaches. In the case of the Groundhouse, there were numerous potential sources and pathways for the candidate cause of fine bedded sediment. The authors of the Groundhouse River stressor Identification organized the parameters associated with fine bedded sediment into a table and analyzed the available evidence for completeness of the pathways. Most, if not all of the data show consistency with the pathways identified in the conceptual model (figure 21).

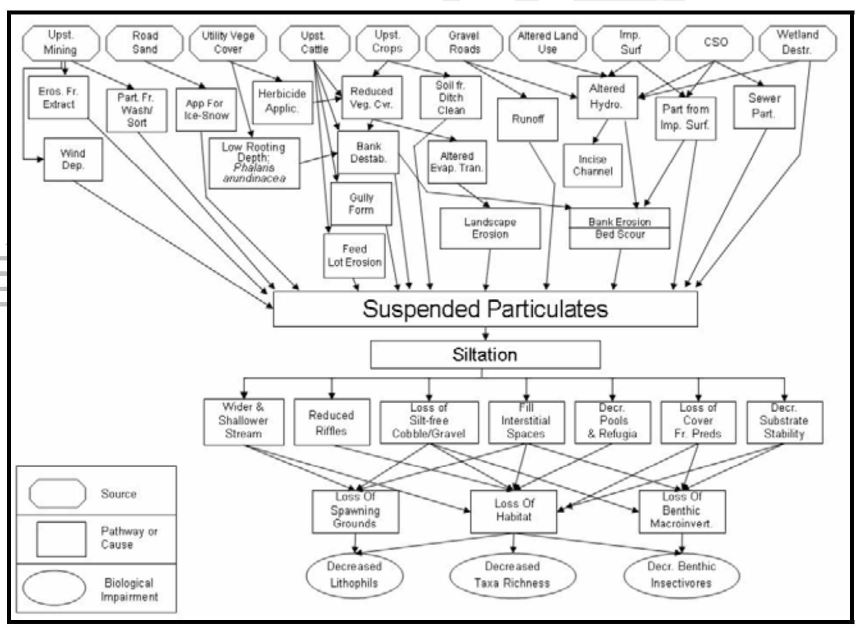

Figure 20: Conceptual model for candidate cause # 1 - Loss of habitat associated with unstable or unsuitable geologic substrates. (Lane and Cormier, 2004)

By taking a closer look at the causes and pathways in the conceptual model, investigators may be able to generate more evidence for or against a candidate cause. Pathways or causes supported at every step with hard evidence such as monitoring data, pictures, and field notes will emerge as stronger candidates for causing the impaired condition. The table below summarizes some of the key causes and pathways that were analyzed for complete exposure pathway in the Groundhouse River stressor identification. As evidenced by the table, most of the pathways leading to the candidate cause were supported with data from the case.

Complete Exposure Pathway				
Candidate Cause	**Parameter**	**Concentration or level at upstream site 2**	**Conc. or level at downstream site 3 (Standard Deviation)**	**Consistent with pathway?**[b]
1. Loss of Habitat Associated with Unstable or Unsuitable Geologic Substrates	% Riffles	14.5	6.7 (2.9)	Yes
	Gradient (m/km)	1.89	0.8 (0.00)	Yes
	Bed Shear (KPa)	2000	400[a]	Yes
	Bank Shear (KPa)	470	150[a]	Yes
	Collapsed Banks?	No	Yes	Yes
	Bank Erosion (m/m)	1.00 / 5	0.08 / 5	If source from site No, if upstream source, Yes

Figure 21: Analysis of complete exposure pathway for fine bedded sediment as a candidate cause for impairment in the Groundhouse River (Lane and Cormier, 2004).

Strength of Evidence Example

The Groundhouse River stressor ID used strength of evidence analysis to identify the candidate causes with the strongest relationships to the observed impairment. Table 21 shows consistency of association, spatial co-occurrence, and stressor response, but the strength of those associations were not displayed. The text and tables in this section provide examples of the strength of evidence analysis performed for the candidate cause of excess fine (bedded) sediment in the Groundhouse River watershed.

The Groundhouse River stressor ID compared case-specific data across numerous lines of evidence. The main evidence types used in this study were spatial co-occurrence, complete exposure pathway, plausible mechanism, plausible stressor-response, consistency of evidence, and coherence of evidence. Each of the three candidate causes were evaluated using these lines of evidence and available data. The strength of evidence analysis performed provided the necessary documentation to identify the candidate causes that warranted further analysis in later stages of the SI process.

Candidate Cause #1: Loss of Habitat Associated with Unstable or Unsuitable Geological Substrates			
	Evidence	Evidence	Score
Case-Specific Considerations			
Spatial Co-Occurrence	Compared with upstream site: Lower D50, greater % and depth of fines, greater % embeddedness, less % boulders, less % coarse material, less % cover	Compatible	+
Complete Exposure Pathway	Compared with upstream site: Fewer riffles, lower gradient, lower bed shear strength, lower bank shear strength, collapsed banks evident; lower D50, greater depth and percent fines, greater embeddedness, and fewer boulders and coarse gravel	Compatible	+
	Compared with upstream site: Lower measured bank erosion and TSS at site 3 than at site 2	Source Uncertain	-
Considerations Based on Other Situations or Biological Knowledge			
Plausible Mechanism	**Reproduction:** Caux et al. (1997) and Rowe et al. (2003) noted changes in salmonid community composition associated with increased turbidity, such as cascading trophic effects affecting fish community composition, high mortality of eggs from decreased gas exchange, and physiological and behavioral changes in juvenile and adult fish. A high percentage of fine sediments is also inversely related to the size (and ultimately survival) of embryos and fry (U.S. EPA 1998). **Prey Availability:** Fine sediments also disrupted trophic interactions, due to smothering, scour, and lack of habitat (Caux et al. 1997). Highly embedded substrates, low abundance of boulders and gravel affect fish through decreased intergravel flow (decreasing prey abundance) and decreased cover (Rowe et al. 2003).	Plausible	+

SOE Table 1. (Continued).

Candidate Cause #1: Loss of Habitat Associated with Unstable or Unsuitable Geological Substrates			
	Evidence	Evidence	Score
Considerations Based on Other Situations or Biological Knowledge			
Plausible Stressor-Response	Caux et al. (1997) recommend substrate not exceed 10% fine material (<2 mm) for Canadian salmonids. U.S. EPA (1998) set in-stream numeric criteria for percent fines (<6.5 mm) of <30% for viable salmonid fry emergence. The D50 (Knopp 1993) values of at least =37 mm and ideally =69 mm are ideal targets for mean particle size diameter for western mountain streams. Site 3 had almost 60% fines (vs. 15% for site 2), greater than 50% embedded substrates, and a D50 value of 1 mm.	Consistent for count of taxa	+
Considerations Based on Multiple Lines of Evidence			
Consistency of Evidence	Scores for candidate cause are nearly all consistent.	Mostly Consistent	+
Coherence of Evidence	Low bank erosion at site 3 may be a function of a low gradient and wider and more accessible floodplain, thus lower banks. Source of silt may be upstream.	Credible Explanation	+

Figure 22: Strength of evidence tables from the Groundhouse River stressor ID. The tables below were used to evaluate candidate cause # 1 - Loss of Habitat Associated with Unstable or Unsuitable Geological Substrates (Lane and Cormier, 2004). Most of the evidence for candidate cause # 1 scored a (+), indicating that the available data supported unstable or unsuitable stream substrate as a potential cause of biotic impairment. The strength of association may have been higher if additional data was available to strengthen the case. For information on the scoring system for strength of evidence analysis, refer to the *summary table of scores* on the EPA's CADDIS website.

Each candidate cause for the Groundhouse River impairment was evaluated using tables similar to the one above. The final results for all candidate causes are summarized in table 18. The table shows strong and consistent relationships between candidate cause #1 and biological impairment, however, it is also obvious from the table below that additional data would have helped improve the defensibility of the strength of evidence. Scores for the consistency and coherence of evidence are shown in the table below, but these will be evaluated later in section 8 of the protocol.

Table 18: Summary of strength of evidence scores for three candidate causes for impairment in the Groundhouse River (Lane and Cormier, 2004).

Parameter	Candidate Cause 1 (Sediments)	Candidate Cause 2.1. (Low DO)	Candidate Cause 2.2. (Altered Food Resource)	Candidate Cause 3 (Acute or Chronic Toxicity)[a]
Spatial Co-Occurrence	+	0	---	+
Complete Exposure	0	0	+	NE[a]
Plausible Mechanism	+	+	+	+
Plausible Stressor Resp.	+	-	0	NE
Consistency of Evidence	+	-	-	NE
Coherence of Evidence	+	0	0	0

[a] Unmeasured chemicals not considered
[b] NE = No Evidence

SUMMARY

The Groundhouse River case study provided some examples of how data from the case can be evaluated based on several lines of evidence. In this particular case, evidence of spatial co-occurrence, stressor-response, and complete exposure pathway were found to support the candidate cause of fine bedded sediment. This case study clearly shows the benefit of collecting biological and physical habitat data in enough locations to compare conditions between impaired and unimpaired locations and throughout the entire watershed. In the case of the Groundhouse, the seven monitoring stations provided a good basis for spatial comparisons of key data sets. Important chemical and physical habitat parameters were available to evaluate the candidate causes, and the predicted biological response was verified by multiple lines of evidence generated from the monitoring data.

End of Case Study

IMPORTANT NOTE: Keep in mind that the purpose of CADDIS step #3 is not to diagnose or refute candidate causes. If there is enough evidence to do so, then that option can be explored. The main objective of this step is to organize evidence from the case in a manner that allows for comparisons and strength of evidence analysis. In CADDIS step #4, you will continue this process by introducing data from other studies or scientific literature to support the case in favor of or against candidate causes. In CADDIS step #5, the strength of evidence analysis and other evidence will be evaluated and a probable cause will be identified.

6.7 CADDIS Step #3 Summary

Section 6.0 -- Evaluate Data from the Case
☐ A summarization of the supporting data, analyses, and scoring rationale for each type of evidence that was evaluated. For case-specific data, there should be scoring for the following types of evidence: · Spatial and Temporal Co-Occurrence · Complete Exposure Pathway · Plausible Mechanism · Temporality · Plausible Stressor-Response · Symptoms ☐ A set of tables containing strength of evidence scores for each candidate cause evaluated ☐ A list of the causes that you either eliminated or diagnosed. This list is formed by first scrutinizing the negative results, which are more likely to be decisive and may have been strong enough to refute a candidate cause. You should also carefully review evidence of symptoms that were strong enough to score a "D" (for diagnosed) or "R" (for refuted), to make certain those symptoms are sufficiently characteristic of a candidate cause to support the conclusion.

7.0 CADDIS STEP #4 - Evaluate Data from Elsewhere

Introduction

In Step 3, you examined and scored data from the case, eliminating candidate causes from further consideration where possible, and diagnosing causes using symptoms when possible. The candidate causes that remain are evaluated further in this step by incorporating data from scientific literature or other studies conducted independently from the case. The evidence developed from this information completes the body of evidence used to identify the most probable causes of the impaired condition.

Virtually everything that is known about an impaired aquatic ecosystem and the candidate causes of the impairment may be useful for inferring causality. In this step, the investigation is widened by seeking data from outside of the immediate case and analyzing it to generate causal evidence. That evidence is combined with evidence from the case (CADDIS Step 3), and all the evidence is evaluated and summarized in tables for strength-of-evidence analysis (CADDIS Step 5).

Questions that frequently can be addressed using Data from Elsewhere:

- **Is it plausible that the candidate cause resulted in the observed biological effect given stressor-response relationships derived in the laboratory?**
- **Is it plausible that the candidate cause resulted in the observed biological effect given stressor-response relationships derived from other field studies?**
- **Is the pathway linking the candidate cause to the observed effect mechanistically plausible?**

Questions that less frequently can be addressed:

- **Are there other cases in which the biological effect responded to manipulation of the candidate cause?**
- **Is it plausible that the candidate cause resulted in the observed biological effect given stressor-response relationships derived from simulation models?**
- **Do analogous stressors cause similar effects?**

7.1 Potential External Data Sources

(1) Existing Stressor Identification or TMDL Studies

TMDLs for impaired biota are a relatively new undertaking for the state of Minnesota. However, there are several stressor identification studies and TMDL projects completed or near completion. It can be assumed that a significant number of biological impairments in the state will be due to similar stressor scenarios (i.e. fine bedded sediment, low dissolved oxygen concentration, flow alterations, temperature regime). The use of data sets, stressor identification, models, and analysis techniques from existing TMDLs is encouraged to the extent practicable. Contact the MPCA project manager or technical staff assigned to your project for additional information on past or current stressor ID or TMDL projects that may be of use.

(2) Reference Sites

Reference reaches are commonly used to investigate the departure of a river reach or watershed from the natural background condition. Barbour et al. (1996) describe two types of reference conditions typically used in biological studies: site-specific and regional reference. Site-specific reference reaches are usually from the same waterbody and are located upstream or outside of the sphere of influence of the disturbance. Site-specific reference sites should be considered part of the data set from the case, and thus should be considered in the previous section. Regional reference conditions, on the other hand, consist of measurements from a population of relatively unimpaired sites within a relatively homogeneous region and habitat type, and therefore are somewhat less site-specific (Barbour, 1999). The biological criteria established by the MPCA for specific drainages in Minnesota are based on regional reference conditions (see section 1.2). In short, the reference condition establishes the basis for making comparisons and for detecting use impairment; it should be applicable to an individual waterbody, such as a stream reach, but also similar on a regional scale (Gibson et al. 1996).

There are some important limitations to keep in mind when using reference conditions in impaired waters studies. Hughes (1995) points out three problems with site-specific reference conditions: (1) lack of broad study design makes extrapolating results from reference sites on a broad scale; (2) site specific reference conditions typically allow limited variance estimates due to limited number of sites; (3) site-specific reference sites involve a substantial assessment effort in order to use them at a state or nationwide scale. These shortcomings are important to keep in mind, but they should not discourage the use of reference conditions in TMDL studies.

Site-specific reference conditions offer some advantages over regional or eco-region reference sites. If selected properly, the physical and chemical habitat found at site-specific reference sites are often similar to the expected conditions of the impacted area, which reduces any variation in biological response due to habitat conditions. When feasible, reference sites should bracket the suspected stressor sources and impacted areas, with sampling stations at points of increasing distance from the impact sources (Barbour, 1999).

Site-specific or regional reference reaches will need to be selected and verified by the managers and technical staff involved with the project. In significantly altered watersheds, such as urbanized systems or areas with significant ditching, suitable reference reaches may be difficult or impossible to locate. In these situations, historical data or simple ecological models may be necessary to establish reference conditions (Barbour, 1999). See chapter 3 in Gibson et al. (1996) for more detail. This document can be found at the following hyperlink (*ext link*).

The MPCA biological database contains data for streams flagged as "minimally impacted" for certain regions of the state. These streams were used to develop the biocriteria currently used to assess streams and rivers for fish and macroinvertebrate index of biotic integrity. This database of minimally impacted streams may provide stream reaches to investigate as potential reference sites. Keep in mind that there are natural differences within drainage basins and eco-regions, and that a minimally impacted reach near the impaired area may not be suitable for comparison. The database provides a quick reference for biological monitoring locations within a given drainage area that support healthy biological assemblages. Gathering background information and performing field reconnaissance are necessary steps to identify them as suitable reference reaches. For more information on the MPCA's biological database and potential reference reaches, contact the project manager or MPCA technical staff involved with your project.

7.2 Assembling Data from Elsewhere

Among the most commonly available and useful types of evidence from other cases and studies are stressor-response relationships developed in the laboratory or other field investigations. Although stressor-response relationships for chemical stressors are most common, the same concepts can be applied to other agents, such as suspended or bedded sediment, flow, and temperature regime. The common candidate causes section of CADDIS (*ext link*) describes available reviews of stressor-response relationships for metals, nutrients, temperature, dissolved oxygen, and sediments.

Evaluating the quality of data that have been collected and developed by others presents its own challenges. Although the collection and analysis procedures may have already been set and completed, you still have the responsibility of evaluating whether the data are sufficient quality to support the current causal analysis prior to analyzing associations. For additional guidance on data quality, refer to the data quality section of CADDIS (*ext link*).

7.3 Types of Evidence that Use Data from Elsewhere

The types of evidence that use data from elsewhere are conceptually described in the table 19. Links are provided to the EPA CADDIS website for more detailed descriptions and analytical advice. Use these types of evidence to evaluate your candidate causes if it will strengthen or weaken your case for them. Do not feel obligated to use these types of evidence if the case-specific evidence is adequate for diagnosing or refuting candidate causes.

Table 19: Types of evidence that can be used to evaluate data from elsewhere.

Type of Evidence	Definition
Stressor-Response Relationships from Other Field Studies	The causal agent in the case is at levels that are associated with similar biological effects in other field studies
Stressor-Response Relationships from Laboratory Studies	The causal agent in the case is at levels that are associated with related effects in laboratory studies. The laboratory studies may test chemicals, materials, or contaminated media from sites contaminated by the same chemical, mixture or other agent as the case. If the effects or conditions in the laboratory and field are dissimilar, extrapolation models may improve the correspondence
Stressor-Response Relationships from Ecological Simulation Models	The causal agent in the case is at levels that are associated with similar effects in mathematical models that simulate ecological processes
Manipulation of Exposure at Other Sites	At similarly affected sites, field experiments or management actions that alter exposure to a causal agent also alter the biological effects
Analogous Stressors	Evidence that agents that are similar to the candidate causal agent in the case cause effects similar to the effect observed in the case is supportive of that candidate causal agent as the cause

7.4 Analyzing and Evaluating Data from Elsewhere

Data from elsewhere should be analyzed in terms of associations that might support or weaken candidate causes. The types of evidence generated from these associations are described in table 19. Data compiled from the literature or from regional surveys usually require some type of analyses to produce stressor-response relationships or other associations used for causal analysis. The Analyzing Data section of CADDIS describes methods you can use to analyze data from laboratory or field studies to derive stressor-response relationships.

The associations drawn upon from elsewhere are evaluated by considering the degree to which they support or weaken the case for a candidate cause. We recommend scoring the evidence using the same system used that was used to score the case-specific data. The evaluation of case-specific data and data from elsewhere can be presented in the same table. Data from elsewhere should be referenced within the table and a brief statement should be provided concerning the applicability of the data to the actual case. The Groundhouse River stressor identification process incorporated data from elsewhere and effectively used the external data to support the case for a candidate cause. See figure 22 in section 6.4 for an example. The *Little Scioto River case study* from Ohio offers another example of how to use data from other sources to support or weaken a case for a candidate cause.

7.5 CADDIS Step #4 Summary

At the completion of this section, you should have all of the evidence for the stressor identification organized and scored based on strength of evidence. This includes data from the case and that from relevant studies or scientific literature. This information will be the basis for the next and final step of the stressor identification process in which you will identify the most probable cause of impairment.

Section 7.0 -- Evaluate Data from Elsewhere
☐ At the completion of this section, you should have all of the evidence for the stressor identification organized and scored based on strength of evidence. This includes data from the case and that from applicable studies or scientific literature. This information will be the basis for the next, and final step of the stressor identification process in which you will identify the most probable cause of impairment.

8.0 CADDIS STEP #5: Identify Probable Cause

Introduction

Identifying the most probable cause is the last step in the Stressor Identification process. Using the evidence organized in the previous sections, you will distinguish the most probable candidate cause(s) from those with less support from the data or other observations. The rationale for identifying one cause relative to the others needs to be clear, reasonable, and convincing in order for stakeholders and managers to buy into the final TMDL and implementation projects.

This step of the protocol is divided into two tasks to make the process of determining a probable cause more manageable. In the first task, the evidence gathered for each candidate cause is reviewed, candidate causes are sorted into categories, and the most compelling lines of evidence are noted. In the second task, the strength of evidence for each candidate cause is compared across all candidate causes. The final product is the identification of the candidate cause or causes for the biological impairment, and a description of the evidence that led to the decision.

In ideal cases, a probable cause for impairment is identified, and the information is effectively communicated to managers and stakeholders. In some situations, no cause is identified or the confidence in conclusions is too low to support moving forward with the development of a TMDL and implementation plan. Even if the results of the first stressor identification run are inconclusive, it will likely result in specific recommendations for the collection of additional information that will enable a cause to be identified.

Completion of this section should result in the following products:

- **An evaluation of the consistency and credibility of the case based on SOE scores**
- **A classification of each candidate cause as refuted, diagnosed, probable, unlikely or uncertain**
- **A discussion of the reasons for the final conclusions including the most compelling lines of evidence**
- **A report summarizing the stressor identification effort**

8.1 Weighing Evidence for Each Candidate Cause

(1) Evaluate Consistency and Coherence of Evidence

When a candidate cause is consistently supported or weakened by many types of evidence, the confidence in the argument for or against the cause increases. It is unlikely to find eight different types of evidence all supporting a cause by chance. In contrast, consistent support for a cause by only one or two types of evidence could easily occur by chance alone. Sometimes there is a reasonable explanation for why a type of evidence does not agree with the rest of the evidence. So, if inconsistent evidence can be explained by a mechanistic, conceptual, or mathematical model, then the confidence in the argument for a candidate cause increases.

	Candidate Causes		
Types of Evidence	NH_3	CU	TSS
Co-occurrence	+	-	+
Causal Pathway	+	-	-
Manipulation	+	-	+
Stressor-Response	+	-	-

Figure 23: A candidate cause is strongly supported if all available types of evidence are consistently supportive (NH_3). It is greatly weakened if all available types of evidence are consistently weakening (Cu). It is also weakened if some types of evidence support and others weaken the candidate cause (TSS).

Two types of evidence are used within the SI process to evaluate the consistency and coherence of the case - consistency of evidence and reasonable explanation. These types of evidence should be applied to SOE analysis completed for each candidate cause. Table 20 describes the two approaches used in the SI process to evaluate consistency and credibility of evidence.

Table 20: Types of evidence used to evaluate the consistency and credibility of the evidence for a specific candidate cause.

Type of Evidence	The Concept
Consistency of evidence	The degree to which types of evidence in a strength-of-evidence analysis are in agreement in either supporting or weakening the case for a candidate cause.
Reasonable Explanation of Evidence	The final consideration in a strength-of-evidence analysis. If the results of a strength-of-evidence analysis are not consistent, a mechanistic, conceptual, or mathematical model reasonably may explain the apparent inconsistencies. This concept is called coherence in the Stressor Identification guidance document.

Evaluate the consistency and coherence of evidence by bringing together the strength of evidence (SOE) tables produced in sections 6 and 7 of the protocol. Evaluate each specific effect individually. Although this makes for a complicated summary, it is important to complete because different candidate causes may be eliciting different effects. **Resist the temptation to add up the scores.** Adding the scores erroneously implies that each type of evidence is equally important. Consider a candidate cause with two types of evidence, each with a score of +, giving a sum of ++ (1+1=2), and another with three types of evidence with scores of +++, ++ and - - - (3+2-3=2). Both sum to 2, but the triple negative score may be strong enough to refute the candidate cause. Instead, use the scoring tables to identify the most compelling pieces of evidence and to develop an overall sense of the case for each candidate cause.

Table 21 displays the scoring criteria for evaluating consistency of evidence. After assembling all the scored types of evidence for each candidate cause, observe if all types of evidence are supporting, weakening, or a mixture of points that support and weaken the case for the candidate cause. Ambiguous evidence (scores of 0) are not included. Based on this assessment, score the body of evidence for that candidate.

Table 21: Scoring criteria for evaluating consistency of evidence for a candidate cause.

Finding	Interpretation	Score
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.	-

Table 22 presents the scoring criteria for evaluating whether or not there is a reasonable explanation for the observed effects. Generally the explanations depend on the expertise and judgment of the scientists who are conducting the assessment. It is a relatively weak type of evidence, because assessors often can suggest explanations after the fact. However, thinking about possible explanations can lead to the collection of new information that could increase confidence in iterative assessments of the impairment.

Table 22: Scoring criteria for evaluating reasonable explanation of evidence

Finding	Interpretation	Score
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.	-

For a detailed discussion on the recommended approach for evaluating consistency and coherence of the evidence, click on the links below.

- *Consistency of Evidence* (EPA - CADDIS)
- *Explanation of the Evidence* (EPA - CADDIS)

Example worksheets for consistency of evidence: *Little Scioto River, Ohio, USA*

(2) Summarize Compelling Evidence

After scoring the body of evidence for consistency, make a preliminary evaluation of the potential for the candidate cause to have led to each specific effect. The most compelling case for a candidate cause will likely be supported by the five characteristics of causal relationships (table 23). Record the most compelling evidence for or against each candidate cause. This evidence will be used to support your case when presenting it to stakeholders and decision-makers.

Although there are fifteen types of evidence, they can be usefully thought of as potentially supporting the five characteristics of causal relationships listed in table 23. Confidence in a cause is increased if the supporting evidence addresses all five characteristics. Bear in mind, however, that it is not necessary that you be able to demonstrate all five characteristics to satisfy the decision-makers and stakeholders involved in the case.

Table 23: The five characteristics of causal relationships used in the Stressor ID process

Characteristics of Causal Relationship	Principle
Co-occurrence	An effect consistently occurs where and when its cause occurs and does not occur in the absence of its cause.
Sufficiency	The intensity or frequency of a cause is adequate to produce the observed magnitude of effect.
Temporality	A cause precedes its effects
Manipulation	Changing the cause changes the effect
Coherence	The relationships between a cause and effect are consistent with scientific knowledge and theory; and the evidence is consistent.

If strength of evidence analysis was completed for these relationships in steps 3 and 4, take one final look at the scores to verify that they are final. Again, the five causal relationships discussed above are the most powerful in terms of relating a candidate cause to the impairment, so be sure all evidence is documented and scoring is done with great scrutiny.

(3) Summarize Strength of Evidence for Candidate Causes

In this step, strength of evidence (SOE) scores are used to categorize the status of each remaining candidate cause. Drawing upon all of the SOE scores for each candidate cause, a general determination should be made regarding the status of each of them. Use the guidelines in the table 24 to formulate a general statement about the probability that the individual cause is responsible for the impairment. This can be done in table format, or in discussion format as it was for the Groundhouse River stressor ID (Lane and Cormier, 2004).

Table 24: Status categorization for strength of evidence analysis

Situation	Status
Cause refuted by indisputable evidence	**Refuted**
Cause of impairment identified by diagnostic symptoms	**Diagnosed**
Cause of impairment refuted by diagnostic symptoms	**Refuted**
All evidence supports the case for the cause, evidence for three or four characteristics of causal relationships	**Probable**
All evidence weakens the case for the cause, evidence against three or four characteristics of causal relationships	**Unlikely**
All evidence supports the case for the cause, evidence for only one or two characteristics of causal relationships	**Probable with low confidence**
All evidence weakens the case for the cause, evidence against one or two characteristics of causal relationships	**Unlikely with low confidence**
Some evidence supports and some weakens the case for the cause	**Unlikely with low confidence**
Insufficient evidence to make a determination	**Additional information required**

8.2 Task #2 -- Identify Probable Causes

At this point, all of the evidence should be organized and summarized, and a final determination of probable causes for the impairment should be made. The final decision should be supported by the tables, graphs, and/or text that were prepared for the previous steps in the process. In the discussion of the results, be sure to include any data or information that could improve confidence in the diagnosis.

8.3 Typical Outcomes and Suggestions

Scenario # 1	**One candidate cause is diagnosed or probable; other candidate causes are refuted or unlikely**

This is the ideal outcome of the stressor identification process. Document your findings and proceed to TMDL development for the stressor.

Scenario # 2	**You have compelling evidence that different specific effects were caused by different causal agents; other causal agents are refuted or unlikely**

Document your conclusions and rationale. Revisit how each specific effect is related to the impairment that originally triggered the investigation. You may be able focus management action on the causal agent(s) that will provide the biggest gains in improving condition. Revisit the conceptual models to see if the different causal agents can be traced back to a common source.

Scenario # 3	**You have sparse evidence across all candidate causes**

If the evidence for all the candidate causes is too sparse to confidently identify a probable cause, you may still be able to identify the candidate cause that has the strongest support relative to the others. To do this, consider what you know about ecology in general and about this particular ecosystem, the impairment, and the candidate causes. All the evidence is important, as noted previously. However, the likelihood that the magnitude, intensity and duration of exposure were sufficient to cause the effect weigh heavily here. If one candidate cause emerges as having the strongest support, it may make sense to identify it and indicate uncertainty about the others. Consider the consequences of not identifying the cause with the strongest support: if not identified, it may be that no action will be taken at all. A thoughtful adaptive management approach can provide additional evidence for causal analysis while also improving some conditions at the site.

Scenario # 4	You have uneven evidence across candidate causes

If you have a strong case for one candidate cause, but the other candidate causes are uncertain because there are fewer data and less evidence to evaluate, then there may be bias in data collection, either from the site or from the literature. You must remain objective and question assumptions, biases, and motives at every opportunity. If the lack of data is from the field, look for data sets collected by other groups or agencies. You might also want to recommend changes to your monitoring program. If the lack of data is from the literature, consult other case studies and invest the time now to develop a useful literature summary so that you can strengthen future case studies.

Scenario # 5	You have insufficient evidence across all candidate causes

If, after considering all of the evidence, none of candidate causes provide a satisfactory explanation for the effects, you have several options for iterating the process or collecting additional information.

- Consider the specific biological effect again. Errors in the biological survey or assessment may have resulted in mischaracterization of the effect. Defining the biological effect more specifically, or defining more than one effect, makes it easier to find relevant evidence.
- There may be other possible candidate causes that have not yet been considered. Re-examine your conceptual models. Consult experts outside your specialty. Talk to stakeholders and local people.
- Consider if jointly acting events cause the effect. For example, excessive high algal biomass plus three consecutive cloudy days might result in unusually low levels of dissolved oxygen. Multiple causes are discussed further below.
- Perhaps the data have not properly captured episodic events. Try to narrow the geographic scope of the assessment to make it easier to find potential sources. Investigate the types of sources and land-use activities to better characterize the possibility of episodic events.
- If all else fails and you are unable to isolate a probable cause, identify the cause or causes that are most likely by using best professional judgment and indicate what new data would strengthen a determination of the probable cause. Consult with decision-makers to determine if additional data collection is warranted.

Scenario # 6	Evidence suggests that multiple causes are operating

It is not uncommon for the evidence to point to two or more causes for the impaired condition. If multiple causes seem to be operating, it may be appropriate to consider whether the impairment was properly defined in *Step 1*. It is also entirely reasonable to have two causes for impairment that are affecting aquatic life independently from one another. Be sure to evaluate each cause carefully, making sure that they are not an intermediate pathway for another cause (i.e. excess nutrients and low dissolved oxygen - low DO is cause, excess nutrients is a step in the pathway).

- The apparent multiple causes may actually be individual causes of multiple effects. Consider partitioning the impairment if, for example one cause is inducing tumors in fish and another is reducing benthic insect abundance.
- The apparent multiple causes may actually be operating in different areas of the aquatic system. Consider partitioning the impairment spatially.

It may be appropriate to consider whether the candidate causes were properly defined or whether they should have been combined as described in *Listing Multiple Stressors as Candidate Causes*.

Otherwise, report that the impairment apparently has multiple causes and consider recommending a remedial strategy, such as:

- Remediate a dominant and potentially sufficient cause. An apparently dominant cause may be sufficient alone to induce the impairment and its actions may be masking the more subtle effects of other causes.
- Remediate a necessary cause. If one cause is necessary for occurrence of the impairment, then remediating only the one cause is adequate.
- Remediate a feasible cause. If it is not clear how multiple causes interact, perform the easiest remediation and monitor the results.
- Remediate all causes. In some cases, it is feasible to remediate all of the multiple causes.

Scenario # 7	You have insufficient data to diagnose or identify a probable cause

Although the stressor identification process does not have minimum data requirements, it is difficult to reach conclusions without a well-rounded data set. It will also be more challenging to convince managers and stakeholders to invest time and resources into a TMDL project when there is no support for or against possible stressors.

The most logical option is to recommend the collection of additional data. Typically, working through the stressor identification informs further data collection efforts by identifying data gaps for analysis of candidate causes.

8.4 Documenting the Conclusions

The ultimate objective of the stressor ID process is to identify the probable causes for impairment and provide the justification for selecting it or them over the other candidate causes. For examples of this step, see the *Little Scioto River case-study* from Ohio or the Groundhouse River study from Minnesota. Reflect back on the reason for the causal analysis and provide the level of information that will help inform decision making (*The Role of Stressor Identification in Various Water Management Programs*).

8.5 Communicating the Results

The best strategy for communicating results depends on your audience and how costly or contentious the recommended action is. In most cases, the results should be presented in a report that includes the following:

(1) The reason for the causal analysis

(2) A list of the candidate causes and the information supporting their selection

(3) The source of the data used in the analysis

(4) Tables of the evidence derived from the data

(5) Conceptual models of the causal pathways

(6) The key evidence that strengthen the probable cause and weakens the other candidate causes

(7) Determination of the probable cause or causes

(8) Qualitative assessment of the overall confidence of the entire case

(9) Next steps or other recommendations

The overall confidence in the case is measured qualitatively, because so many different types of information are used to determine a probable cause. When writing the causal assessment, include a list of the major sources of uncertainty and their possible influence on your determination of the cause of the specific effects. This is not meant to add uncertainty to the stressor ID results. Rather, it provides those involved with the project a chance to reflect on any uncertainties, which can then be addressed in later stages of the project or future monitoring efforts.

If your confidence in the final result is low, consider iterating the process (*options for iteration*). If the cause is not sufficiently certain for the decision maker, there may be other sources of data, other ways to evaluate existing data, or the impairment may need to be approached from another angle.

If confidence in the identified stressor(s) is high, start identifying sources, implementing corrective actions, and monitoring the results. If the cause is confidently identified, then the next steps may include allocating the contributions of different sources of the cause, developing and implementing management options, and monitoring the effectiveness of actions. These important activities are all part of the TMDL process that will be discussed in the next portion of the Biota TMDL protocol.

8.6 CADDIS Step #5 Summary

Section 8.0 -- Identify Probable Cause for Impairment
☐ Probable cause(s) for impairment should be identified. The rationale for selecting the cause(s) over others should be explained in detail and supported by the SOE tables or other graphics. If no stressor is identified or there is not adequate evidence to reduce the number of candidate causes for impairment, iterate the stressor ID process to collect the necessary data (Section 8.4).
☐ Results of the Stressor Identification process should be communicated to stakeholders, managers, and other interested parties. (Section 8.6)
☐ Proceed to TMDL Development if stressor is identified with confidence

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Section III:
Biota TMDL Submittal Requirements

DRAFT

9.0 Introduction

For an approvable TMDL, the final report must meet both federal requirements and state protocols. Each major component of a TMDL is described in this section and includes:

- Federal requirements, which are used by the EPA as a basis for reviewing and approving TMDLs; and
- Minnesota's protocols as required by the MPCA.

In addition, "MPCA's Checklist" *(X:\Agency_Files\Water\Impaired Waters\Public Participation\TMDL Review Checklist.doc)* for reviewing the adequacy of draft TMDLs prior to submittal to EPA should also be consulted to ensure the report is complete.

EPA Guidelines for Reviewing TMDLs Under Existing Regulations Issued in 1992 (*http://epa.gov/owow/tmdl/guidance/final52002.html*)

Section 303(d) of the Clean Water Act (CWA) and EPA's implementing regulations at 40 C.F.R. Part 130 describe the statutory and regulatory requirements for approvable TMDLs. Additional information is generally necessary for EPA to determine if a submitted TMDL fulfills the legal requirements for approval under Section 303(d) and EPA regulations, and should be included in the final submittal. Use of the verb "**must**" below denotes information that is required to be submitted because it relates to elements of the TMDL required by the CWA and by regulation. Use of the term *"should"* below denotes information that is generally necessary for EPA to determine if a submitted TMDL is approvable. These TMDL review guidelines are not themselves regulations. They are an attempt to summarize and provide guidance on current statutory and regulatory requirements relating to TMDLs. Any differences between these guidelines and EPA's TMDL regulations should be resolved in favor of the regulations themselves.

9.1 Identification of Waterbody, Pollutant of Concern, Pollutant Sources, and Priority Ranking

Federal Requirements:
The TMDL submittal should identify the waterbody as it appears on the State's/Tribe's 303(d) list. The waterbody should be identified/geo-referenced using the National Hydrography Dataset (NHD), and the TMDL should clearly identify the pollutant for which the TMDL is being established. In addition, the TMDL should identify the priority ranking of the waterbody and specify the link between the pollutant of concern and the water quality standard.

The TMDL submittal should include an identification of the point and non-point sources linked to the pollutant of concern, including location of the source(s) and the quantity of the loading, e.g., lbs/per day. The TMDL should generally provide the identification numbers of the NPDES permits within the waterbody. Where it is possible to separate natural background conditions from non-point sources, the TMDL should include a description of the natural background. This information is necessary for EPA's review of the load and wasteload allocations, which are required by regulation.

The TMDL submittal should also contain a description of any important assumptions made in developing the TMDL, such as:

(1)The spatial extent of the watershed in which the impaired waterbody is located;

(2) The assumed distribution of land use in the watershed (e.g., urban, forested, agriculture);

(3) Population characteristics, wildlife resources, and other relevant information affecting the characterization of the pollutant of concern and its allocation to sources;

(4) Current and future growth trends, if taken into consideration in preparing the TMDL (e.g., the TMDL could include the design capacity of a wastewater treatment facility); and

(5) An explanation and analytical basis for expressing the TMDL through surrogate measures, if applicable. Surrogate measures are parameters such as percent fines and turbidity for sediment impairments; chlorophyl a and phosphorus loadings for excess algae; length of riparian buffer; or number of acres of best management practices.

Minnesota biota TMDLs:

· See Minnesota's Checklist for background information needed in addition to the federal requirements.

· The TMDLs should incorporate key findings of the Stressor Identification report in order to support the linkages between the pollutant of concern and biological effect. The TMDL report should discuss the expected changes in the biological assemblage if TMDL goals are met and key pollutant loads are reduced.

9.2 Description of the Applicable Biological and Water Quality Standards

Federal Requirements:
The TMDL submittal must include a description of the applicable State/Tribal water quality standard, including the designated use(s) of the waterbody, the applicable numeric or narrative water quality criterion, and the anti-degradation policy. (40 C.F.R. §130.7(c)(1)). EPA needs this information to review the loading capacity determination, and load and wasteload allocations, which are required by regulation.

The TMDL submittal must identify appropriate water quality or biological target(s). These are the narrative or numeric criteria used to measure whether or not the applicable water quality standard for a designated use is attained. Generally, the "pollutant" of concern and the numeric or narrative water quality target are, respectively, the chemical or physical disturbance causing the biological impairment and the water quality or biological standard. The TMDL expresses the relationship between any necessary reduction of the pollutant of concern and the attainment of the numeric or narrative standard. Occasionally, the pollutant of concern is different from the pollutant that is the subject of the numeric water quality target (e.g., when the pollutant of concern is phosphorus and the numeric water quality target is expressed as Dissolved Oxygen (DO) criteria). In such cases, the TMDL submittal should explain the linkage between the pollutant of concern and the chosen numeric water quality target.

Minnesota biota TMDLs:
Minnesota's biological criteria are based on narrative water quality standards. The standards are based on the prevention of "material alteration of the species composition, material degradation of the stream beds, and the prevention or hindrance of the propagation and migration of fish and other biota normally present" (Minnesota Rule 7050.0150 Subp. 6). A detailed description of the factors used for determination of use impairment can be found in Subp. 6 of *Minnesota Rule 7050.0150*

9.3 Loading Capacity - Linking Water Quality, Physical Habitat, and Pollutant Sources

Federal Requirements:
A TMDL must identify the loading capacity of a waterbody for the applicable pollutant. EPA regulations define loading capacity as the greatest amount of a pollutant that a water can receive without violating water quality standards (40 C.F.R. §130.2(f)).

The pollutant loadings may be expressed as either mass-per-time, toxicity or other appropriate measure (40 C.F.R. §130.2(i)). The TMDL must be expressed in terms of a daily load, but may additionally be expressed in terms other than a daily load, e.g., an annual load. The submittal should explain why it is appropriate to express the TMDL in the terms and units of measurement chosen. The TMDL submittal should describe the method used to establish the cause-and-effect relationship between the numeric target and the identified pollutant sources. In many instances, this method will be a water quality model.

The TMDL submittal should contain documentation supporting the TMDL analysis, including the basis for any assumptions; a discussion of strengths and weaknesses in the analytical process; and results from any water quality modeling. EPA needs this information to review the loading capacity determination, and load and wasteload allocations, which are required by regulation.

TMDLs must take into account critical conditions for steam flow, loading, and water quality parameters as part of the analysis of loading capacity. (40 C.F.R. §130.7(c)(1)). TMDLs should define applicable critical conditions and describe their approach to estimating both point and non-point source loadings under such critical conditions. In particular, the TMDL should discuss the approach used to compute and allocate non-point source loadings, e.g., meteorological conditions and land use distribution.

Minnesota biota TMDLs:
As described in EPA guidance, a TMDL identifies the assimilative or loading capacity of a waterbody for a particular pollutant. EPA regulations define loading capacity as the greatest amount of loading that a waterbody can receive without violating water quality standards (40 C.F.R. § 130.2(f)). For impaired waterbodies, the loading capacity will define the overall pollutant reductions that are necessary to attain water quality standards or achieve designated use for recreation, fisheries, drinking water supplies, aesthetics, and wildlife. A biological impairment is a response parameter and not a pollutant loading parameter. This requires that the loading capacity be defined in the balanced allocation as a combination of all the contributing stressor parameters being allocated. It would simplify the TMDL if only one parameter allocation can be reduced to attain the water quality numeric limits, but if several of the stressor parameters are in need of reduction then loading capacity of each must be described. The loadings are required to be expressed as mass-per-time (pounds per day), toxicity, or some other appropriate measure (40 C.F.R. § 130.2(i)).

To date, the biological TMDLs developed in Minnesota have all calculated a mass-per-time load reduction for key stressors. The MPCA advocates completing TMDLs using this approach, however, we are open to exploring new methods for TMDL development including habitat-based TMDLs. Ohio EPA has been developing TMDLs based on Qualitative Habitat Evaluation Index (QHEI) scores. Minnesota state agencies are in the process of analyzing statewide biological, habitat, and water chemistry data. These analyses are critical for developing the tools needed to complete habitat-based TMDLs for biological impairments.

As the term implies, TMDLs are typically expressed as total maximum daily loads. For example, it is appropriate and justifiable to express a TMDL in relationship to flow in terms of allowable loadings at the 7Q10 and increments higher as needed to balance all the sources of stress as they are introduced into the system under various flow regimes. The TMDL submittal must identify the waterbody's loading capacity for the applicable pollutant and describe the rationale used to establish the cause-and-effect relationships between the numeric target and designated uses of the impaired waterbody. In most instances, this method will be a water quality model or flow/load duration curves. Supporting documentation for the TMDL analysis also must be contained in the submittal, including the basis for assumptions, strengths and weaknesses in the analytical process, results from water quality modeling, etc.

Critical Condition
TMDLs **must** take into account critical conditions for stream flow, and water quality parameter concentrations and loading, as part of the analysis of loading capacity (40 C.F.R. §130.7(c)(1).

Seasonal factors, such as leaf canopy protection or the rate of human soil disturbance activities can affect the critical conditions and the TMDL. Likewise, different sources may dominate the stressor parameter loading under different flow regimes. Dominance of non-point runoff related sources may significantly drop off during dry weather periods when point sources become a more significant portion of the loading. TMDLs should define applicable critical conditions that consider these source and delivery factors and the timing of when the beneficial use is impaired. TMDLs should describe their approach to estimating both point and non-point source loadings under such critical conditions. In particular, the TMDL should discuss the approach used to compute and allocate non-point source loadings, e.g., meteorological conditions and land use distribution.

9.4 Load Allocations (LAs)

Federal Requirements:
EPA regulations require that a TMDL include LAs, which identify the portion of the loading capacity attributed to existing and future non-point sources and to natural background. Load allocations may range from reasonably accurate estimates to gross allotments (40 C.F.R. §130.2(g). Where possible, load allocations should be described separately for natural background and non-point sources.

Minnesota biota TMDLs:
The load allocation (LA) is all those sources of pollutant loading not associated with a point source – non-NPDES or non-septic system. These sources include atmospheric deposition, natural land use such as limited use forests, grasslands, and wetlands and watershed runoff from managed land such as row cropped fields, silver culture, roads and non-MS4 communities.

Natural background load is a portion of the watershed loading, and should be defined as precisely as possible. The LA should be as source specific as the data allows. "Source specific" should be considered a relative term, and as such, could result in a LA broken down by watershed sub-basin, land-use activity (agriculture), land-use sub-activity (row crop agriculture) or by individual sources (a particular row crop field). TMDLs with source specific load allocations will result in implementation recommendations with a greater level of focus.

The location of sources in the watershed may need to be evaluated for its loading potential at the point of LA calculation. Load impact reductions from source location considerations (fate and transport) needs to be documented to justify reduction allowances for loads entering surface waters. This consideration may apply to both the WLA and LA.

9.5 Wasteload Allocations (WLAs)

Federal Requirements:

EPA regulations require that a TMDL include WLAs, which identify the portion of the loading capacity allocated to individual existing and future point source(s) (40 C.F.R. §130.2(h), 40 C.F.R. §130.2(i)). In some cases, WLAs may cover more than one discharger, e.g., if the source is contained within a general permit.

The individual WLAs may take the form of uniform percentage reductions or individual mass based limitations for dischargers where it can be shown that this solution meets WQSs and does not result in localized impairments. These individual WLAs may be adjusted during the NPDES permitting process. If the WLAs are adjusted, the individual effluent limits for each permit issued to a discharger on the impaired water must be consistent with the assumptions and requirements of the adjusted WLAs in the TMDL. If the WLAs are not adjusted, effluent limits contained in the permit must be consistent with the individual WLAs specified in the TMDL.

If a draft permit allows a higher load for a discharger than the corresponding individual WLA in the TMDL, the State/Tribe must demonstrate that the total WLA in the TMDL will be achieved through reductions in the remaining individual WLAs, and that localized impairments will not result. All permitees should be notified of any deviations from the initial individual WLAs contained in the TMDL. EPA does not require the establishment of a new TMDL to reflect these revised allocations as long as the total WLA, as expressed in the TMDL, remains the same or decreases, and there is no reallocation between the total WLA and the total LA.

Minnesota biota TMDLs:
In addition to the technical aspects of determining pollutant load allocations outlined below, the process may also involve intensive stakeholder and policy-making efforts.

WLA Sources

All sources that are covered by a National Pollutant Discharge Elimination System (NPDES) permit plus certain septic systems are to be considered in the WLA. These sources, for the purpose of the TMDL should be referred to as point sources.

Point Sources include:

- Public Owned Treatment Works (POTWs) and other Wastewater Treatment Facility (WWTF) permittees with discrete discharges and explicit numeric discharge limits need to be included in the waste load allocation.

- NPDES Stormwater permits (including for those communities designated as Municipal Separate Storm Sewer System (MS4s)), construction activities, and industrial activities are to be part of the WLA.

- Straight-Pipe Septic Systems: Straight-pipe septic systems are <u>illegal and un-permitted</u>, and as such are assigned a zero wasteload allocation.

- Livestock facilities that have been issued NPDES permits are assigned a zero wasteload allocation. This is consistent with the conditions of the permits, which allow no pollutant discharge from the livestock housing facilities and associated site. Discharge of pollutants from fields where manure has been land applied may occur at times. Such discharges are covered under the load allocation portion of the

TMDLs, provided the manure is applied in accordance with manure management provisions of the permit.

- It is important to note that all relevant NPDES permits in an impaired reach watershed need to be listed individually in the TMDL document. To the extent possible and practical, individual wasteload allocations should be established for these NPDES dischargers, including MS4s (see below – estimating WLA loads.

- The location of sources in the watershed may need to be evaluated for their water quality impact at the point of LA calculation. For example, while phosphorus entering surface waters is generally transported downstream, there may be specific instances where phosphorus load retention upstream of an impairment should be taken into account. In order to justify any allocation allowances based on source location, clear support and documentation is necessary. This consideration may apply to both the WLA and LA.

- Pollutant trading can be included as a means to meet a TMDL allocation. However, the details of trading can be determined in the TMDL implementation plan. Trading may further the need for geographic consideration of loads.

Water Quality Based Effluent Limits
The TMDL will set water quality based effluent limits for all point sources. For wastewater facilities, the water quality based effluent limits will be discharge concentration permit limits. Attainment is needed at or above low flow conditions as defined by (7Q10). For MS4s, the water quality based effluent limits can be in the form of Best Management Practice (BMPs) requirements.

Estimating WLA Loads and Allocations

Wastewater point sources:
For POTWs and industrial wastewater facilities, either the facility should be contacted directly or the MPCA should be contacted for the discharge monitoring reports (DMRs) for that facility. These can be used to define the current WWTF phosphorus loading to the waterbody, which will serve as a basis for the allocations.

MS4 Stormwater:
If estimates of current loads from regulated MS4s will be determined in the TMDL, each MS4 should be contacted for pertinent information. Guidance issued in 2002 from EPA (*"Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm Water Sources and NPDES Permit Requirements Based on Those WLAs"* (November 22, 2002); *http://www.epa.gov/npdes/pubs/final-wwtmdl.pdf*) will be useful in determining your approach. MPCA policy for setting WLAs for permitted stormwater may also be helpful (*http://www.pca.state.mn.us/publications/wq-strm7-01.pdf*).

The WLA should, when possible, be expressed as a mass loading rather than a percent reduction. If the WLA is expressed as a percent reduction, the TMDL should clarify the baseline conditions from which the reductions will be applied.

EPA notes that it may be reasonable to express NPDES-regulated storm water discharges from multiple point sources as a single categorical wasteload allocation when data and information are insufficient to assign each source or storm water outfall individual WLAs. More specifically, the Wasteload Allocation in the TMDL can be expressed as either a 1) single number for all NPDES-regulated stormwater discharges, or 2) when information allows, as different WLAs for different categories, such as all MS4s separated out from construction stormwater, and treated either in aggregate or as individual MS4s (City A vs. City B).

In keeping with this guidance, the MPCA believes that most wasteload allocations for MS4s will be made in the aggregate by categorical sector (e.g. a 33 percent reduction for the MS4 sector) because of the insufficient quantity and quality of existing data on MS4 stormwater impacts. However, if enough data exists, it is strongly encouraged that an individual WLA can be set for each MS4 discharger.

An example of these two options are:

1. Sector-wide allocation: A TMDL could find that all regulated MS4 sources together can contribute a total of 300 lbs. of phosphorus and the WLA is set at 300 lbs. for MS4 stormwater. All MS4s would be evaluated together to achieve the WLA.

2. Individual allocation
   If a city-by-city WLA approach for MS4s is preferred, the MPCA proposes that the WLA be divided among MS4s. There are several methods for dividing the WLA among cities and these are described in MPCA's Implementation Plan guidance for permitted MS4 stormwater (*http://www.pca.state.mn.us/water/stormwater/impairedwaters.html*).

Construction Stormwater:

Minnesota's Construction General Permit requires permittees to implement specific BMPs when construction projects occur within one mile of an impaired water or when a TMDL prescribes specific BMPs for construction stormwater.

Construction stormwater must be given a WLA when the impairment is for biota (fish, macroinvertebrate, or plant). When the TMDL contains a categorical WLA for MS4 stormwater, the WLA for construction stormwater may be included with the MS4 WLA. When the WLA for MS4s are individual or there is no MS4 WLA, the WLA for construction stormwater may be estimated using one of several techniques. The most common method will be an area-based estimate in which construction stormwater receives a WLA proportional to the area of the watershed that is under a construction permit. A five year average is typically used for the area-based estimate. Construction stormwater should be given a single WLA (i.e. not different WLAs for different construction projects). The TMDL should contain language indicating that construction stormwater that is in compliance with the general permit is considered to meet TMDL requirements (see MPCA policy for setting WLAs at *http://www.pca.state.mn.us/water/stormwater/impairedwaters.html*)

Industrial Stormwater: In Development - COMING SOON

NPDES Permit Compliance Schedules and Water Quality Trading Discussions in the TMDL report.

The Federal Code of Regulations (40 CFR) lays out the expectations for the TMDL activities and for the National Pollutant Discharge Elimination System (NPDES) permits for each type of permitted discharger. Since the TMDL activities are only one method to set the water quality based effluent limits for NPDES permits, two compliance schedule expectations are considered normal:

1. That the NPDES permit will respond individually to meet the effluent requirements; and

2. That the compliance schedule for meeting the requirements will be within one permit cycle.

Therefore it is important for the TMDL project teams to include members from other programs when wastewater facility permitting, feedlot permitting, and/or stormwater permitting issues exist in the watershed of interest. There are opportunities in the permit programs that allow more flexibility than items 1 and 2 above indicate if taken in their strictest interpretation.

Wastewater Facility Permits

There is an expectation for all wastewater NPDES permits to meet the water quality based effluent limits (TMDL allocation) in the first five year permit cycle. There can be exceptions to this process when justified. It is important to note that the exception is rare and not to be considered typical. An example of a justification is when the TMDL activities are in a timeline that is out of sequence with other impaired water TMDL activities which deal with the same parameter, but *may* require more restrictive limits or longer seasonal application of the limits.

The other expectation is that the wastewater NPDES facility will comply with the allocation as an individual. Two emerging program activities are pollutant trading and watershed permitting. The first, pollutant trading, is when entities located inside the same watershed for a given impairment work together to cumulatively reduce the stressor parameter(s). The pollutant trade can benefit dischargers by using either the benefits of economy of scale, or by limiting the upgrades or installations of BMPs to those that are the least expensive and “trading” the activities of the most expensive for an equivalent reduction or a net decrease.

The second option, a watershed permit, is where all NPDES activities are sequenced and considered on a cumulative basis in a watershed. In this process a cumulative problem can be solved by sequencing all the NPDES permits to implement similar reductions across a given timeframe. This has the potential to accelerate implementation schedules and also provides a better opportunity to set expectations for reductions at an equitable level. It is important that if any of these alternatives are used in the TMDL negotiations and final implementation goals, they be discussed briefly in the TMDL report to provide guidance on the expectations for the compliance schedules and/or the use of more flexible alternatives other than each facility upgrading its technology to comply.

Stormwater Permits

TMDL WLAs for regulated MS4s should reflect the timing required to implement BMPs. In general, it should be assumed that multiple permit schedules will be needed to meet TMDL reduction targets and the regulated MS4 needs to make progress in each permit cycle to meet a WLA. Progress indicators include establishing a stormwater program, doing good housekeeping, addressing retrofits and new development, prevention and education, and structural BMPs.

If the TMDL study or TMDL Implementation Plan has enough data to set reduction milestone timelines and goals, then the SWPPP for each permit cycle can reference the TMDL or Implementation Plan and the milestones to justify its compliance with the TMDL. Other options are also possible:

1) Phased TMDLs: For instances where the TMDL study has significant uncertainty about stormwater loadings and management practices to effectively address that loading, an EPA memorandum dated August 2, 2006 entitled *Clarification Regarding "Phased" Total Maximum Daily Loads* *http://www.epa.gov/owow/tmdl/tmdl_clarification_letter.pdf* outlines acceptable methods to discuss "phased" approaches in the TMDL study.

   As noted in this document, "phased TMDLs be limited to TMDLs that for scheduling reasons need be established despite significant data uncertainty and where the State expects the loading capacity and allocation scheme will be revised in the near future as additional information is collected." The document cites examples of situations where this may apply, including lake nutrient TMDLs where there are uncertain loadings from major land uses and/or limited knowledge of in-lake processes. As with any TMDL, each phase must be established to attain and maintain the applicable water quality standard and would require re-approval by EPA if the loading capacity, wasteload or load allocations are revised.

   For stormwater TMDLs using a phased approach, collection of missing data needed to assess loading or management practices would be required through SWPPPs. This should be clearly discussed in the TMDL report.

9.6 Margin of Safety (MOS)

Federal Requirements:
The statute and regulations require that a TMDL include a margin of safety (MOS) to account for any lack of knowledge concerning the relationship between load and wasteload allocations and water quality (CWA §303(d)(1)(C), 40 C.F.R. §130.7(c)(1)). EPA's 1991 TMDL Guidance explains that the MOS may be implicit, i.e., incorporated into the TMDL through conservative assumptions in the analysis, or explicit, i.e., expressed in the TMDL as loadings set aside for the MOS. If the MOS is implicit, the conservative assumptions in the analysis that account for the MOS must be described. If the MOS is explicit, the loading set aside for the MOS must be identified.

Protocol for Minnesota biota TMDLs:
The rationale for selecting the MOS and its adequacy must be included in the TMDL submittal. As indicated in the federal requirement, an explicit MOS would include setting a portion of the loading capacity aside as the MOS (i.e., not allocated to any source). Examples of an implicit margin of safety include the use of conservative assumptions in selecting a numeric water quality target and predicting the performance of best management practices. A related implicit MOS is the use of conservative design criteria for the sizing of best management practices.

The purpose of the MOS component of the TMDL equation is to provide additional assurance that the projected load estimation process will be adequate for achieving numeric or narrative water quality standards. As such, MOS encompasses two primary factors affecting these outcomes: variability and uncertainty. "Variability" refers to the fluctuations in measured values for a given parameter across flow regimes, up and down the reaches (spatially) and as well as by temporal factors - such as within year (seasonal) and year-to-year changes (induced by climatic conditions and biological response). "Uncertainty" refers to prediction error resulting from limits in the data and predictive models. Walker (2001 & 2003) has provided detailed discussions of these subjects and the reader is directed to these articles for more detail on the topic. The MOS should not encompass future growth or allocations addressed through the reserve capacity. It is encouraged that these aspects of assimilation capacity should be dealt with as a separate allocation explicitly stated as a part of the formal TMDL process.

In instances where there is a scarcity of data, the TMDL components need to be estimated with greater uncertainties and hence, a higher MOS. As more data is collected, estimates of variability and uncertainty can be reduced thereby allowing a smaller MOS component – and greater allocations to the other components balancing the TMDL equation. In short, if there are limited data available, a model based portrayal may have to suffice until more monitoring is conducted. Alternatives to explicit Margin of Safety expressions include: conservative water quality criteria/standards, conservative reduction goals, conservative modeling assumptions, conservative effluent limits/ discharge permits, conservative BMP designs, and/or conservative growth projections. In these cases, the MOS is included in the other terms of the TMDL equation and is not explicitly quantified, either in terms of load or the corresponding risk that the goals will be achieved (Walker, 2001). Hence, the risk of making improper management decisions can become larger.

Uncertainty Estimates

Uncertainty analyses should be included in TMDL allocations. In summary on these topics Walker (2003) cautions against setting an unrealistically high confidence level and/or compliance rates as TMDL goals. A high MOS could hinder progress of restoration by increasing costs, reducing credibility, and stimulating controversy. Rather, he suggests an incremental or adaptive approach to achieving the desired compliance rate and confidence level through successive TMDLs as may be appropriate, as recommended by the National Research Council (2001). This will often be the case in TMDLs where a majority of the loading which needs be reduced to achieve the TMDL, arises from unregulated non-point source runoff, or as Walker (2003) states, "a phased approach is applicable where the load allocation is not immediately achievable (with or without an MOS) because of limits in control technology." In any case, the TMDL equation must be written such that the TMDL is met by the allocations.

9.7 Reserve Capacity *(allocation for future growth)*

Federal Requirements:
Implied under LA and WLA requirements as the "portion of the loading capacity attributed to existing and future sources"

Minnesota biota TMDLs:
Reserve Capacity is that portion of the TMDL that accommodates future loads. The MPCA's policy on reserve capacity is that it be considered by all TMDL projects and the final report should clearly describe the rationale for a decision regarding this issue.

An allocation for reserve capacity in the TMDL can be ascribed singly to the WLA the LA or both; e.g. new and expanding WWTFs and/or expected land use changes. In the case of MS4s, it is preferred to accommodate future growth in the WLA based on larger municipal boundaries or expansion area designations, if appropriate. It is preferred that non-permitted MS4s likely to require permit coverage in the future be included in the WLA rather than the Reserve Capacity. If growth is not accommodated in the WLA or if a reserve capacity is not included, either no new future loads are anticipated or allowed, or increased loads must be accommodated by pollutant trading. If future loads are to be accommodated by trading only, a discussion of a viable trading program and the implications to new loads should be included. A typical 20-year planning "window" for consideration of reserve capacity is recommended.

The TMDL report should provide the basis for the amount of reserve capacity, guidelines for making reserve capacity available to new loads, and the means to replenishing reserve capacity when it has been depleted. Replenishing reserve capacity can be accomplished through the following options:

WWTF sources

- Concentration adjustments – reallocation based on reduced concentration effluent limits at the given design flow;
- Flow adjustments – reallocation based on reduced flow at the given concentration; or
- Mass adjustments – reallocation based on reduced mass-based effluent limit

Nonpoint sources and MS4s

- Additional BMP implementation
- Reducing watershed loads
- Reducing margin of safety through greater understanding of load response conditions

It is anticipated that reserve capacity issues will largely be a policy discussion that will require input from all affected parties and consideration of future loads in the watershed. Policy considerations of awarding reserve capacity to new loads should be based on an equitable and consistent set of criteria.

Federal, state, county and city census and planning documents provide valuable data for population trends and predictions and can be used when estimating the reserve capacity allocation. In the Twin City Metro Area, the Metropolitan Council provides similar reports and has historic aerial photographs that can be used for observing impervious surface changes when redevelopment is of the infilling or higher density kind.

The awarding of reserve capacity should be fully documented so that any future reallocation can consider past allocation changes. Additionally, reserve capacity balances must be documented at all times. This should include detailed documentation of all loads that have been transferred between the WLA, LA and the RC.

9.8 Seasonal Variation

Federal Requirements:
The statute and regulations require that a TMDL be established with consideration of seasonal variations. The TMDL must describe the method chosen for including seasonal variations. (CWA §303(d)(1)(C), 40 C.F.R. §130.7(c)(1)).

9.9 Reasonable Assurances

Federal Requirements:
When a TMDL is developed for waters impaired by point sources only, the issuance of a National Pollutant Discharge Elimination System (NPDES) permit(s) provides the reasonable assurance that the wasteload allocations contained in the TMDL will be achieved. This is because 40 C.F.R. 122.44(d)(1)(vii)(B) requires that effluent limits in permits be consistent with "the assumptions and requirements of any available wasteload allocation" in an approved TMDL.

When a TMDL is developed for waters impaired by both point and non-point sources, EPA's 1991 TMDL Guidance suggests that the TMDL provide reasonable assurances that non-point source control measures will achieve expected load reductions. This information is necessary for EPA to determine that the TMDL, including the load and wasteload allocations, has been established at a level necessary to achieve water quality and/or biological standards. EPA's August 1997 TMDL Guidance also directs EPA Regions to work with States to achieve TMDL load allocations in waters impaired only by non-point sources.

Protocol for Minnesota TMDLs:
In general, reasonable assurances include descriptions of the regulatory and non-regulatory efforts at the state and local levels that will likely result in reductions from the load allocation portion of the TMDL. Reasonable Assurances also include the identification of potential or likely funding sources that will enable reductions from the load allocation.

The following list of scenarios describes when to include Reasonable Assurances in the TMDL submittal:

- **Non-point source only TMDLs (Load Allocation only):**
  Although EPA does not require reasonable assurances in this type of TMDL, the MPCA requires a description of reasonable assurances for non-point only TMDLs. Reasonable assurances in these types of TMDLs allow the MPCA to evaluate the potential options available to enable reductions from non-point sources.

- **TMDLs with offsets in the Waste Load Allocation from the Load Allocation:**
  EPA requires reasonable assurances in this situation in order to approve the TMDL. This is clarified in the 1991 EPA guidance document, *Guidance for Water Quality-Based Decisions: The TMDL Process*. The guidance addresses waters impaired by both point and non-point sources, where the wasteload allocation to point sources is not as strict because

of non-point source loading reductions. In such cases, some additional provisions in the TMDL, such as a schedule and description of the implementation mechanisms for non-point source control measures, are needed to provide reasonable assurance that they will produce the expected load reductions. Such additional provisions are needed in this type of TMDL to assure compliance with the federal regulations at 40 CFR 130.2(i), which require that in order for wasteload allocations to be made less stringent, more stringent load allocations must be "practicable."

- **TMDLs without offsets in the Waste Load Allocation from the Load Allocation:** Although EPA does not require reasonable assurances in this type of TMDL, the MPCA requires a description of reasonable assurances. Reasonable assurances in these types of TMDLs allow the MPCA to evaluate the potential options available to enable reductions from non-point sources.

- **TMDLs with wastewater permittees in the Waste Load Allocation:** Reasonable assurances are not required for wastewater permittees because federal regulations require compliance with the Waste Load Allocation in the TMDL.

- **TMDLs with MS4 stormwater permittees in the Waste Load Allocation:** NPDES permit requirements must be consistent with the assumptions and requirements of available WLAs. See 122.44(d)(1)(vii)(B). Since permits for required and discretionary MS4 do not contain numeric limits, the MPCA requires an MS4 to provide reasonable assurances in the following manner:

  > "If a USEPA-approved **TMDL(s)** has been developed, you must review the adequacy of your Storm Water Pollution Prevention Program to meet the **TMDL's Waste Load Allocation** set for storm water sources. If the **Storm Water Pollution Prevention Program** is not meeting the applicable requirements, schedules, and objectives of the **TMDL**, you must modify your **Storm Water Pollution Prevention Program**, as appropriate, within 18 months after the TMDL is approved."

  This permit language should be cited in the reasonable assurance section of the TMDL. In addition, note that the implementation plan, likely to be finalized one year following EPA approval of the TMDL, will identify specific BMP opportunities that may achieve their load reduction and their adoption schedule. The individual SWPPPs would be modified accordingly following the recommendations of the implementation plan.

- **TMDLs with construction stormwater permittees in the Waste Load Allocation:** NPDES permit requirements must be consistent with the assumptions and requirements of available WLAs. (See CWA section 122.44(d)(1)(vii)(B).) Since permits for construction stormwater do not contain numeric limits, the MPCA requires a construction stormwater permittee to provide reasonable assurances by citing the TMDL compliance requirements of provisions in the NPDES Construction Stormwater Permit (Part I.B.7, Part III.A.4.d, and Part III.A.7). According to Part I.B.7 of the General Permit:

  > "*Discharges to waters identified as impaired pursuant to section 303 (d) of the federal Clean Water Act (33 U.S.C. § 303(d)) where the identified pollutant(s) or stressor(s) are phosphorus (nutrient eutrophication biological indicators), turbidity, dissolved oxygen, or biotic impairment (fish bioassessment, aquatic plant bioassessment and aquatic macroinvertebrate*

bioassessment), and with or without a U.S. Environmental Protection Agency (USEPA) approved Total Maximum Daily Load (TMDL) for any of these identified pollutant(s) or stressor(s), unless the applicable requirements of Part III.A.9 are met."

As with MS4s, the permit language above should be cited in the reasonable assurance section of the TMDL.

References:

EPA's 1991 document, *Guidance for Water Quality-Based Decisions: The TMDL Process* (EPA 440/4-91-001) *http://www.epa.gov/OWOW/tmdl/decisions/*

MS4 permit requirements: *http://www.pca.state.mn.us/water/stormwater/stormwater-ms4.html#requirements*

Construction stormwater permit requirements: *http://www.pca.state.mn.us/water/stormwater/stormwater-c.html#forms*

9.10 Implementation

Federal Requirements:
EPA policy encourages Regions to work in partnership with States/Tribes to achieve non-point source load allocations through implementation measures such as BMPs, stream restoration projects, or other methods. In addition, EPA policy recognizes that other relevant watershed management processes may be used in the TMDL process. EPA is not required to and does not approve TMDL implementation plans.

Protocol for Minnesota biota TMDLs
Projects must include in the written TMDL submitted to MPCA the broad implementation strategies to be refined and finalized after the TMDL is approved. Projects are required to submit a separate, more detailed implementation plan document to MPCA within one year of the TMDL's approval by EPA.

The Minnesota Clean Water Legacy Act requires a range of implementation costs to be included in the TMDL. It is recommended that a range of probable costs be included in the discussion by land use type. For instance, large watershed scale TMDLs may have significant implementation cost ranges due to the large number of measures needed, even though they are implementing the least expensive measure on a unit cost basis. The factors that contribute to or control the cost estimate ranges should be broadly outlined in the narrative.

For further information on implementation plan requirements, review MPCA's TMDL work plan guidance at *http://www.pca.state.mn.us/publications/wq-iw1-01.pdf* and the MPCA policy on implementation plans at *http://intranet.pca.state.mn.us/policies/programpolicies/i-wq2-031.pdf* .

The biota TMDL implementation plan section should identify broad strategies, activity areas, and mechanisms for achieving loading reductions related to the TMDL. The implementation plan section should also specify:

- How the public will be involved,
- What mechanisms such as financial assistance, ordinances etc., exist or are proposed for development,

- How progress will be monitored with WQ/biological/habitat monitoring, BMP tracking etc.
- How control activities or reference reaches will be sited
- What planning tools or processes will be used to achieve non-point source reductions
- What planning tools, processes, ordinances are in-place or will be proposed to control point sources
- What educational and cooperative efforts among stakeholders, landowners, and agencies exist or a proposed for development.
- What time period each sector will be given for adoption goals, retrofitting and implementation of structural measures.

For MS4s, this section of the TMDL should provide a high level overview of activities that will be refined in the implementation plan. Providing this information will help enhance reasonable assurance, including:

- The current BMPs that are planned (to be refined during implementation planning and SWPPP development);
- The current schedule (i.e., how many permit cycles) for putting BMPs in place; and
- Expected range of potential reductions, based on literature, which can be achieved for each category of BMP (e.g., citizen education program, stormwater ponds, alum treatment, etc.).

Additional information on MS4 requirements and implementation options can be found at *http://www.pca.state.mn.us/water/stormwater/impairedwaters.html*.

9.11 Monitoring Plan to Track TMDL Effectiveness

Federal Requirements:
EPA's 1991 document, Guidance for Water Quality-Based Decisions: The TMDL Process (EPA 440/4-91-001). *http://www.epa.gov/OWOW/tmdl/decisions/* recommends developing a monitoring plan to track the effectiveness of a TMDL. A monitoring plan is particularly when the TMDL involves both point and non-point sources reductions. The monitoring plan should describe the additional data to be collected to determine if the load reductions provided for in the TMDL are being achieved and leading to attainment of water quality standards.

Protocol for Minnesota biota TMDLs:
A biota TMDL monitoring plan provides an opportunity to evaluate many components of watershed health. Many of Minnesota's watersheds have active associations that routinely collect water quality data and information. The monitoring plan for the TMDL should outline how collaborative monitoring efforts could be used to better define pollutant sources, evaluate the effectiveness of controls, and ultimately assess the adequacy of the TMDL.

Effectiveness Monitoring
Effectiveness monitoring is a defensible way to track the progress of the TMDL and implementation actions. If conducted properly, effectiveness monitoring should provide measures of progress across temporal and spatial scales and various implementation practices. For example, the monitoring plan may compare various types of stream restoration projects in the watershed (i.e. channel re-construction vs. riparian tree planting) and the changes in

biological assemblage or surrogates (i.e. habitat measures) over time. The results of an effectiveness monitoring effort are important to share with stakeholders, managers, and technical staff involved with the project.

Effectiveness monitoring requires a substantial baseline data set to which post-TMDL/implementation monitoring data can be compared. The monitoring conducted for the initial assessment, stressor identification, and TMDL studies will likely account for a significant portion of the baseline data. However, do not assume that these data are sufficient for a defensible effectiveness monitoring plan. The completion of the TMDL study and implementation plan may change the management objectives within the study watershed, and therefore, additional data may be needed to adequately monitor the effectiveness of future management.

Tips for Planning Effectiveness Monitoring Projects

The following guidance is slightly modified from part 654 of the NRCS National Engineering Handbook on Stream Restoration. Some of the material has been modified to better fit a monitoring plan to evaluate the effectiveness of a watershed-based restoration.

(1) Project Planning

Step #1 **- Define the goals, objectives, and scale of the monitoring effort**
The primary goal of a post-TMDL monitoring plan should be to evaluate the effectiveness of the TMDL allocations and implementation measures. A clear, concise statement of project goals, objectives, and project scale will increase buy-in from stakeholders, managers, and funding sources.

Step #2 **- Choose performance criteria**
Performance criteria are standards to evaluate to what extent the project is achieving desired or designed outcomes. The performance criteria identify in quantitative terms (defined metrics) or qualitative terms (absence/presence) the results or outcomes of project operation.

Link performance criteria to goals — Goals and objectives for the project should articulate the specific outcomes and results that are expected and intended from the project. The hydrologic, geotechnical, and ecological needs and opportunities identified in planning should have resulted in clear statements for project performance. Performance criteria are meant to assess progress toward the goals. If the goals and objectives are not clear enough for identifying performance criteria, then clarification, interpretation, or explanation of the goals and objectives must be done. The effort to understand or clarify goals will allow establishment of performance criteria that are closely aligned with stated goals.

Develop the criteria — The primary reason for a monitoring plan is to assess progress and to indicate the steps required to fix a system or component of the system that is not successful (FISRWG 1998). To that end, the performance criteria and monitoring parameters should be developed as indicators of success. Performance criteria are usually developed through an iterative process that involves listing measures of performance relative to goals and then refining them to develop the most efficient and relevant set of criteria (FISRWG 1998). Criteria are usually specified as levels of outputs (hydraulic capacities, ranges, minimums, maximums, or threshold measurements).

Examples of performance criteria for biological TMDLs may include overall IBI score, a desired change in individual metric scores (i.e. increase in intolerant fish species), water quality standards, habitat measures, or geomorphic parameters. The performance criteria should be related to the overall objective of the TMDL, which is to restore physical, chemical, and biological integrity to the impaired watershed.

Monitoring performance criteria **—** Performance criteria for the monitoring plan establish the acceptable or desired levels for the parameters being monitored. The performance criteria are based on comparison of the parameter's measurement to the agreed on performance criteria. The monitoring parameters identified are measured in the field and compared to performance criteria.

Identify reference sites **—** The biological, hydrologic, geomorphic, habitat conditions at the reference site represent the conditions that are the goals of the project. By examining the conditions at the reference site, the study team can ascertain the level of success that is possible from the project. Pre- and post construction evaluations can measure the change or impact from the project, but the level of success can be judged only relative to reference systems (FISRWG 1998).

In impaired waters studies, reference sites may not exist within the watershed or surrounding watersheds. In these cases, it may be necessary to expand the search for a reference condition to other areas with similar natural background conditions, or design a stream restoration project that represents the desired condition for the impaired reach. The Hardwood Creek TMDL (near Hugo, MN) used a series of completed stream restoration projects as the reference reaches for TMDL development and establishment of performance criteria.

Step #3 **-- Choose maintenance and monitoring parameters and methods**
The purpose of monitoring is to ensure the project performs the hydrologic, geomorphic, and habitat functions that are the basis of goals and objectives and project design. Table 25 provides some parameters and methods for assessment of these variables.

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Table 25: A list of parameters for evaluating effectiveness of implementation measures

General objectives	Potential evaluation tools and criteria
Channel capacity and stability	Channel cross sections
	Flood stage surveys
	Width-to-depth ratio
	Rates of bank of bed erosion
	Longitudinal profile
	Aerial photography interpretation
Improve aquatic habitat	Water depths
	Water velocities
	Percent overhang, cover, shading
	Pool/riffle composition
	Stream temperature
	Bed-material composition
	Population assessments for fish, invertebrates, macrophytes
Improve riparian habitat	Percent vegetative cover
	Species diversity
	Size distribution
	Age class distribution
	Plantings survival
	Reproductive vigor
	Wildlife use
	Aerial photography
Improve water quality	Temperature
	pH
	Dissolved oxygen
	Conductivity
	Nitrogen
	Phosphorous
	Herbicides/pesticides
	Turbidity/opacity
	Suspended/floating matter
	Trash loading
	Odor
Recreation and community involvement	Visual resource improvement based on landscape control point surveys
	Recreational use surveys
	Community participation in management

***Step #4* -- Determine the level of effort and duration**

The level of effort needed for effectiveness monitoring is determined by the goals, objectives, and performance criteria identified in step #3 and the end use of the monitoring data. Monitoring efforts to determine whether state water quality standards are met requires a high level of effort in terms of frequency, duration, and parameters measured.

***Frequency* —** The frequency of monitoring will depend on the parameters being measured and the overall objectives of the monitoring plan. Water chemistry parameters will likely require a higher frequency of monitoring in order to evaluate the response to seasonal variation and different flow regimes. Biological, geomorphological, and physical habitat monitoring will most likely be sampled less frequently, but should also be considered for seasonal variation.

***Duration* —** Monitoring should extend long enough to provide assurances of sustainability for the project and whether or not the system has met performance criteria. Monitoring data should be collected for a duration that allows for trend analysis which enables adaptive management decisions to be made.

Timing **—** Timing of monitoring activities is a critical consideration for any effectiveness monitoring project. Biological monitoring activities to evaluate IBI or individual metrics should be carried out during MPCA's index periods (*MPCA protocols*).

Sensitivity **—** The sensitivity of the parameter to change will also determine the level of effort and duration needed to detect a change. Depending on the antecedent conditions, biological assemblages can improve rapidly if habitat is restored and there are adequate opportunities for in-migration and natural reproduction.

9.12 Public Participation

Federal Requirements:
EPA policy is that there should be full and meaningful public participation in the TMDL development process. The TMDL regulations require that each State/Tribe must subject draft TMDLs to public review, consistent with its own continuing planning process (40 C.F.R. §130.7(c)(1)(ii)). In guidance, EPA has explained that final TMDLs submitted to EPA for review and approval should describe the State's/Tribe's public participation process, including a summary of significant comments and the State's/Tribe's responses to those comments. When EPA establishes a TMDL, EPA regulations require EPA to publish a notice seeking public comment (40 C.F.R. §130.7(d)(2)).

Provision of inadequate public participation may be a basis for disapproving a TMDL. If EPA determines that a State/Tribe has not provided adequate public participation, EPA may defer its approval action until adequate public participation has been provided for, either by the State/Tribe or by EPA.

Protocol for Minnesota biota TMDLs:
An active stakeholder and public participation process is required throughout the development of every TMDL. This includes input on the development of the project workplan to the approval of final pollutant load allocations and public notice process. The ultimate success of the project is in large part dependent upon the effectiveness of this process. Development of practical, pragmatic solutions with input and buy-in from stakeholders is fundamental. It is critical that the stakeholders affected by any given TMDL project share a common understanding of the problem and what is needed to solve it.

Public participation is also required through the 2006 Clean Water Legacy Act which requires the MPCA to seek "broad and early public and stakeholder participation in scoping the activities necessary to develop a TMDL, including the scientific models, methods, and approaches to be used in TMDL development, and to implement restoration…"

Based on the recommendations of a broad-based group of stakeholders ("The G16") advising the MPCA on TMDLs, the MPCA has piloted an intensive public participation process through its Lake Pepin TMDL. The results of this process will be critical to determining guidance for other TMDL projects. This will include development of a stakeholder advisory group which will provide recommendations on a project throughout the process. The stakeholder advisory group can also receive advice on technical issues from a technical/science advisory group, comprised of experts from academia and other institutions. More information on this structure and process can be found by referring to a fact sheet on the Lake Pepin project:
http://www.pca.state.mn.us/publications/wq-iw9-01f.pdf

Probably the most critical phase of a stakeholder advisory group process is in developing and making recommendations for source reductions and pollutant load allocations (load allocations, wasteload allocations, margin of safety, and reserve capacity). Federal regulations specify only that the total allocations (point source and nonpoint source, margin of safety) prescribed by a given TMDL must satisfy water quality standards for that water's designated use. The specific method for allocating pollutant loads among sources is a policy issue that must be determined by states according to their own priorities and judgment.

Additional information on the allocation process and options can be found at these EPA websites: *http://www.epa.gov/waterscience/models/allocation/def.htm*; and *http://www.epa.gov/waterscience/models/allocation/19schemes.htm*

Local government (contractors) will have a primary role throughout the public participation process. In general, local government should be prepared to be engaged in these public participation activities:

- Help identify stakeholders that can represent diverse public and private interests in affected watersheds on the Stakeholder Advisory Group for the project.
- Conduct public outreach and education activities at key points throughout the project and prepare a report or section of the draft TMDL that describes those activities.
- Coordinate with the MPCA as needed to assist in the formal public notice process for the draft TMDL, including:
    - Help organize a public meeting(s) for the draft TMDL and compile comments from the public.
    - Help respond to comments, as needed, on the draft TMDL from technical staff, citizens and other interested parties, and EPA.
    - Submit public outreach materials along with the draft TMDL or final report, such as charts, graphs, modeling runs, fact sheets, presentation materials, maps, etc.

Following the allocation process and the final development of a draft, the public notice process can begin. These steps will be led by the MPCA, coordinating with the local government contractor. Most activities will be conducted by the project manager, basin coordinator, public information officer, or impaired waters coordinator, as appropriate. The MPCA has developed guidance on specific steps that are required during the public notice process and MPCA project managers may access the latest version of this guidance on the agency's X Drive.

In general, here are the basic steps to the public notice process:

1. MPCA public information staff and project manager prepare public notice package, to include Draft TMDL, Fact Sheet, Public Notice and Press Release.

2. Public Notice
   - The draft TMDL must be on public notice for a minimum of 30 days.
   - The public notice must be published in the *State Register*.
   - The notice must be published on the MPCA Web site.
   - The notice should also be mailed or e-mailed to a list of interested parties for the project, and must be mailed to a statewide list of interested parties maintained by the impaired waters program coordinator.

- Public meetings during the public notice phase will be determined based on the level of public participation and outreach during other phases of the project.

3. Public comments: All written public comments must be provided to EPA with the submission of the TMDL. Responses can either be summarized for all comments received or for each letter received. Copies of each comment letter must also be submitted.

4. Final MPCA approvals (either by the Commissioner or the Citizens Board).

5. The TMDL is submitted to EPA for final approval. In accordance with the 2006 Clean Water Legacy Act (114D.25), the final TMDL is submitted to EPA no sooner than 30-days following the conclusion of the public notice period.

Ultimately, a successful public participation process will help ensure that the TMDL is sent to EPA on schedule and has the stakeholder support needed to launch effective implementation.

References:
2004 Impaired Waters Legislative Report: Impaired Waters Stakeholder Process: Policy Framework: *http://www.pca.state.mn.us/publications/reports/lrwq-iw-1sy04.pdf*

9.13 Submittal Letter

Federal Requirements:
A submittal letter should be included with the TMDL submittal, and should specify whether the TMDL is being submitted for a technical review or final review and approval. Each final TMDL submitted to EPA should be accompanied by a submittal letter that explicitly states that the submittal is a final TMDL submitted under Section 303(d) of the Clean Water Act for EPA review and approval. This clearly establishes the State's intent to submit, and EPA's duty to review, the TMDL under the statute. The submittal letter, whether for technical review or final review and approval, should contain such identifying information as the name and location of the waterbody, and the pollutant(s) of concern.

Protocol for Minnesota biota TMDLs:
The submittal letter is written by the MPCA and signed by the Commissioner. In addition, the final TMDL report, and any other documents that are a necessary part of the TMDL submittal are ultimately approved by the Commissioner.

In accordance with Minn. Stat. Sec. 114D.25, MPCA will submit the TMDL to the U.S. Environmental Protection Agency for review and final approval after a 30-days waiting period upon agency approval. This delay and notice will be facilitated by the TMDL coordinator position at the MPCA.

9.14 Administrative Record

Federal Requirements:
While not a necessary part of the submittal to EPA, the State should also prepare an administrative record containing documents that support the establishment of the TMDL and calculations/allocations in the TMDL. Components of the record should include all materials relied upon by the State to develop and support the calculations/allocations in the TMDL, including any data, analyses, or scientific/technical references that were used, records of

correspondence with stakeholders and EPA, responses to public comments, and other supporting materials. This record is needed to facilitate public and/or EPA review of the TMDL.

Protocol for Minnesota biota TMDLs:
The MPCA project manager and administrative staff will gather and file all necessary documents for the administrative record.

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APPENDIX A

MISSION CREEK AQUATIC VEGETATION/WETLAND ASSESSMENT

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October 9, 2008

PURPOSE
The areas of Mission Creek where dense vegetation occurs in the channel were assessed to determine their potential wetland properties and condition.

METHODS
Vegetated areas of Mission Creek were observed at 8 bridge crossing that have been previously sampled for water chemistry and, on some reaches, aquatic biology on 9/11/2008. At each site the general vegetation pattern of the channel were noted and plant species lists were developed.

WETLAND DEFINITION AND CLASSIFICATION
Wetlands are defined both ecologically and legally based on 3 components: the presence of 1) hydric soils, 2) surface or subsurface hydrology, and 3) hydrophytic vegetation (US ACOE 1987, MN BWSR 2004, Mitsch and Gooselink 2000). In typical wetland determinations for regulatory jurisdiction under both federal and state law, indicators for all 3 components must be present for the area in question to be considered a wetland.

Over the years a number of wetland classifications have been developed to better regulate and manage wetlands. The following classification systems are used in MN under various capacities:

1) *"Circular 39"*: The US Fish and Wildlife Service (US FWS) originally developed Circular 39 to better manage wetlands for waterfowl production (Shaw and Fredine 1956). The system breaks wetlands into general types based on hydrology and predominant vegetation. There are 8 Circular 39 wetland types in MN. While Circular 39 has generally fallen out of favor, it is the primary classification in the state's Wetland Conservation Act (WCA) which regulates wetland drain and fill activities and DNR's Public Waters regulations for wetlands.
2) *"Cowardin"*: In preparation for a mapping effort of the nation's wetlands called the National Wetland Inventory (NWI) the US FWS created the *Classification of Wetlands and Deeepwater Habitats* (Cowardin et al. 1979) which now commonly goes by the name of the lead author. Unlike Circular 39, Cowardin is hierarchical and provides a much more detailed system to more accurately describe the actual wetland spectrum occurring on the ground. Cowardin (and systems derived from Cowardin) continues to be the leading wetland classification system for management and regulation. While NWI is often criticized as being outdated and often inaccurate due to aerial photography limitations at the time it remains a valuable resource for wetland and water managers.
3) *"Eggers and Reed"*: The US Army Corps of Engineers put forward *Wetland Plants and Plant Communities of Minnesota and Wisconsin* (Eggers and Reed 1997) as a further

refinement of local wetland classes to better enable wetland "functions and values" assessment. It corrects some distinct plant community types that get lumped together under both Circular 39 and Cowardin that do not receive proper protection or management considerations under regulatory programs that only follow those systems. Eggers and Reed is included here because it is the primary classification used in the MN Routine Assessment Method (MnRAM) for assessing wetland functions and values under WCA; it is the anticipated classification to be used for the Rapid Floristic Quality Assessment method currently under development (*see WETLAND CONDITION ASSESSMENT*); and BWSR is considering replacing Circular 39 in WCA with it.

WETLAND CLASSIFICATION OF MISSION CREEK

Mission Creek is a low gradient stream that often flows through, and is fed by, adjacent wetland complexes. These conditions generate many areas within the channel that meet the definition of a wetland (Table 1). Thus, while Mission Creek is clearly a stream, in reaches where these conditions exist it is ecologically behaving as a wetland. Over the course of our field visits four general channel types were observed. Channel type descriptions and corresponding wetland classifications are provided in Table 2.

Table 1. Wetland indicators occuring in Mission Creek.

Wetland Component	Observed Indicator
Hydric Soils	Muck Presence (indicator A8; NRCS 2003). Organic muck that is generated only under hydric-anaerobic conditions is present.
Hydrology	Perennial flowing surface water is present.
Hydrophytic Vegetation	All species observed in the channel have Obligate (99% occurance in wetlands) National Wetland Indicator status (Reed 1988).

Type A Mission Creek channels are deep marshes that are dominated by what are called non-persistent emergent species. Non-persistent emergents typically exist in 6 inches to 3 feet of standing water and typically don't begin to emerge from the water's surface until the middle of the growing season. Their tissues decompose rapidly following senescence (i.e., the leaf and stem litter does not persist); thus, during spring and early summer deep marshes dominated by non-persistent emergents appear as open water habitats. There are two dominant non-persistent emergents in Mission Creek: *Zizania palustris* (Wild Rice) and *Sagittaria rigida* (Sessile-fruited arrowhead). Both species prefer soft silty/mucky substrates and *Z. palustris* in particular prefers slowly flowing water. Both conditions exist in Type A channels of Mission Creek. In addition to the two dominant species a variety of emergent, floating leaved (i.e., leaves float horizontally on the water's surface), and submergent (i.e., stems and leaves exist primarily below the water's surface) species are present in Type A channels (Table 3)

Table 2. General channel types and corresponding wetland types of Mission Creek.

Channel Type	Description	Circular 39	Cowardin	Eggers & Reed
A	Very low gradient, no or short banks bordering on marsh/wet meadow complexes, with emergent vegetation (i.e., plants emerging from the water) covering > 70% of channel	Type 4-Deep Marsh	Riverine Lower Perennial Emergent-Nonpersistent (R2EM2)	Deep Marsh
B	Low gradient, banks present, may be boredered by wetland or upland, emergent vegatation restricted to small patches on inside bends, submerged and floating leaved aquatic vegetation typically > 50% cover	Type 5-Shallow Open Water	Riverine Lower Perennial Aquatic Bed (R2AB)	Shallow, Open Water
C	Impoundment, flow drastically reduced and channel is pooled, banks not present, pool borderd by marsh submerged and floating leaved aquatic vegetation typicallly > 50% cover	Type 5-Shallow Open Water	Riverine Lower Perennial Aquatic Bed (R2AB)	Shallow, Open Water
D	Moderate gradient, banks present, sandy bottom, Flow is enough to prevent vegetation from establishing	NA	Riverine Lower Perennial Unconsolidated Bottom (R2UB)	NA

Type B and C channels are both considered shallow open water wetlands that are dominated by submergent and floating leaved species. Differences exist, however, in stream conditions which results in differences in community composition and structure between the two types. Type B channels have more current and the dominant aquatic vegetation is rooted. Vegetation can also be patchy, where flows are great enough to exclude vegetation establishment. Emergent vegetation (if present) typically is limited to small patches at inside curves where flows are less intense. Type C channels, on the other hand, are influenced by impoundments where flows are extremely low and the stream begins to pool. Vegetation can be very dense and substrates consist of deep muck. Free floating leaved species such as *Lemna minor* (Lesser duckweed) and *Wolfia columbiana* (Watermeal) which may be present at low amounts in the other channel types, can become dominant in the stagnate water and virtually cap the water surface shading out submergent species and blocking oxygen and heat exchange.

Type D channels have enough flow to prevent vegetation from establishing. Without vegetation these channels no longer meet the wetland definition and are better classed as a type of deepwater habitat.

NWI lumps the majority of Mission Creek with surrounding wetland polygons. In other words, NWI did not map the majority of Mission Creek as separate polygons but instead considered the Creek to be a part of the surrounding matrix. Most likely this was due to lower resolution aerial photography available at the time of mapping and a minimum mapping unit greater than the size of the creek. There is a stretch of Mission Creek with a Type C channel from County Rd 133 south to the large manmade impoundment that is mapped under the Cowardin classification as Riverine Lower Perennial Unconsolidated Bottom (R2UB). As indicated in Table 2 for Type C channels, the Cowardin class should be more appropriately classified as Aquatic Bed (as opposed to Unconsolidated Bottom) because of the presence of aquatic vegetation.

Table 3. Species lists, plant functional guilds, C-values, metric tallys, and reference based benchmarks for Type A-C channels.

Type A-Deep Marsh

Scientific Name	Common Name	Guild[†]	C-value
Ceratophyllum demersum	Common coontail	SA	2
Lemna minor	Lesser duckweed	FA	5
Potamogeton nodosus	American pondweed	FA	6
Riccia fluitans[‡]	Slender riccia	FA	NA
Sagittaria rigida	Sessile-fruited arrowhead	NE	7
Schoenoplectus tabernaemontani	Soft stem bulrush	PE	4
Sparganium eurycarpum	Giant bur reed	PE	5
Spirodela polyrrhiza	Greater duckweed	FA	5
Stuckenia pectinatus	Sago pondweed	SA	3
Zizania palustris	Wild rice	NE	8

Species Richness	9
Mean C	5.00
Reference Mean-C Benchmark	3.50

Type B-Shallow Open Water (with current)

Scientific Name	Common Name	Guild	C-value
Ceratophyllum demersum	Common coontail	SA	2
Elodea canadensis	Canadian elodea	SA	4
Lemna minor	Lesser duckweed	FA	5
Nuphar lutea ssp. variegata	Yellow pond lily	FA	6
Nymphaea odorata	American white waterlily	FA	6
Potamogeton nodosus	American pondweed	FA	6
Potamogeton zosteriformis	Flat-stemmed pondweed	SA	6
Spirodela polyrrhiza	Greater duckweed	SA	5
Stuckenia pectinatus	Sago pondweed	SA	3

Species Richness	9
Mean C	4.78
Reference Mean-C Benchmark	4.10

Type C-Shallow Open Water (impoundment)

Scientific Name	Common Name	Guild	C-value
Ceratophyllum demersum	Common coontail	SA	2
Lemna minor	Lesser duckweed	FA	5
Potamogeton foliosus ssp. foliosus	Leafy pondweed	SA	6
Potamogeton zosteriformis	Flat-stemmed pondweed	SA	6
Wolffia columbiana	Columbian watermeal	SA	5

Species Richness	5
Mean C	4.80
Reference Mean-C Benchmark	4.10

[†]Guilds: FA = Floating leaved aquatic SA = Submerged aquatic NE = Non-persistent emergent PE = Persistent emergent

[‡]*R. fluitans* is a nonvascular species and is not assigned a C-value

WETLAND CONDITION ASSESSMENT

Since 1995 the Biological Monitoring Unit at the MPCA has worked to characterize wetland community responses across a gradient of human stressors with the purpose of assessing wetland condition (http://www.pca.state.mn.us/water/biomonitoring/bio-wetlands-plants.html). We recently completed the initial development of a wetland condition assessment technique called the Floristic Quality Assessment (FQA; Milburn et al. 2007). FQA is based on plants and their individual affinity with unaltered habitats which is captured by a measure called the Coefficient of Conservatism (*C*). *C* is a numerical rating from 0-10 of how conservative each plant species is to unaltered habitats based on expert opinion from local botanical experts. FQA metrics (such as Mean-*C* or the Floristic Quality Index) have been repeatedly found to be responsive indicators of wetland condition. Milburn et al. (2007) includes *C*-value assignments for MN's entire wetland flora. The MPCA is currently developing sampling methods and scientifically based performance criteria for a Rapid FQA.

One of the goals for this assessment was to assess the condition of the wetland vegetation occuring in Mission Creek using FQA. Mean-*C* was the primary metric used because different sampling effort and methodology has little or no effect on it (Bourdaghs et al. 2006). While there are no formally established performance criteria to make high confidence assessments from Mean-*C* at this time, results can be compared to existing reference data (i.e., data from least anthropogenically impacted sites) to make an initial assessment of wetland condition in Mission Creek. Data from DNR's MN County Biological Survey (MCBS) was used to compute an initial Mean-*C* reference benchmark for deep marsh communities (i.e., Type A channels). MCBS collects data from intact natural plant communities in the state which can be considered as reference. To create the benchmark, Mean-*C* was calculated from data from 40 Deep Marsh MCBS sites. The 5th percentile of the distribution was then picked as the benchmark. The Shallow Water benchmark was calculated from 29 depressional wetland sites that the MPCA has sampled. The 5th percentile represents the lower end of the reference distribution. Sites that score above the benchmark are considered in a natural condition and sites that score below are considered impacted or degraded. Mean-*C* was then computed from the species lists for each of the vegetated channel types and scores were compared to the appropriate benchmark (Table 3).

Mean-*C* for all of the wetland channel types (A-C) scored above their respective reference benchmarks (Table 3). In addition, all of the plant species recorded in Mission Creek are natives. This suggests that these wetland areas are in a natural condition or are high quality.

The Type A channels that are dominated by *Z. palustris* may in particular be considered high quality, because it is very sensitive to sedimentation. *Z. palustris* is an annual species, meaning that each plant sprouts from seed each year. If the seed bed becomes buried by sediment, *Z. palustris* has difficultly sprouting and the population can quickly disappear. It also is a very valuable food species for waterfowl as well as a culturally and commercially important food source for the people of MN.

The Type B and C channels are both considered Shallow Open Water plant communities but have a primary difference, water flow. Given that factor, the reference benchmark calculated from depressional wetlands is appropriate for Type C channels but perhaps not for Type B. Again, all species recorded in the Type B channels are native and expected members of a natural Shallow Open Water plant community. Type B channels also had greater species richness compared to Type C, which was probably due to the greater range in abiotic conditions in the higher flow environment (i.e., areas higher and lower flow in the channel).

Type C channels clearly had Mean-*C* over the benchmark; however, there were areas where small floating aquatic species (*L. minor* and *W. columbiana*) were very dense. These small floating aquatic species are not rooted in the soil and thus get their nutrients from the water column. High abundance of theses species can be an indicator of nutrient enrichment. At this time the abundance of the small floating aquatics is not great enough to exclude all other plant species but it may warrant future monitoring.

In summary, the vegetated areas of Mission Creek can be defined as wetlands and they are in a natural condition as measured by the vegetation community. Areas that are dominated by *Z. palustris* have increased significance due to wildlife, commercial, and cultural benefits.

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